New Zealand Journal of Botany

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

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To cite this article: D. C. Mildenhall & L. J. Brown (1987) An early Holocene occurrence of the mangrove Avicennia marina in Poverty Bay, North Island, New Zealand: Its climatic and geological implications, New Zealand Journal of Botany, 25:2, 281-294, DOI: 10.1080/0028825X.1987.10410075

To link to this article: http://dx.doi.org/10.1080/0028825X.1987.10410075

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New Zealand Journal of Botany, 1987, Vol. 25: 281-294
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An early Holocene occurrence of the mangrove *Avicennia marina* in Poverty Bay, North Island, New Zealand: its climatic and geological implications

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Abstract Pollen evidence indicates that the mangrove *Avicennia marina* var. *resinifera* (Forst. f.) Bakh. (Avicenniaceae) once occurred in Poverty Bay, and its presence is used as evidence for warm climate following the last glaciation. Radiocarbon dates indicate a maximum time of 9840 ± 190 years B. P. (NZ 6309B)* for this warm climate event, coinciding with the Holocene climatic optimum. The mangrove is currently found *c.* 1° further north in the Bay of Plenty.

The climatic implications of the pollen data when considered with macrofaunal determinations, sediment lithologies, depositional environments, and radiocarbon dates show that the early postglacial in Poverty Bay was a time of complex depositional and erosional conditions associated with the postglacial rise in sealevel, local tectonic activity, and the concomitant change in coastal geomorphology.

A full description of the pollen of extant *Avicennia marina* var. *resinifera* is presented.

Keywords *Avicennia marina* var. *resinifera*; Avicenniaceae; pollen analysis; pollen morphology; Quaternary; postglacial; paleoclimate; paleoenvironments; sea level; climatic optimum; coastal geomorphology; radiocarbon dates; Poverty Bay; East Cape

INTRODUCTION

Test wells drilled on the Poverty Bay flats (also known as the Gisborne plain), Fig. 1, 2, as part of the groundwater investigation programme of the East Cape Catchment and Regional Water Board, have provided core barrel and bailer samples of sediment and organic material (shell, wood, and peat). These have been studied for lithological description, paleoecology, and radiocarbon age.

During pollen-analytical studies of postglacial peats and other carbonaceous sediments a relatively large number of pollen grains of *Avicennia marina* var. *resinifera* (Forst. f.) Bakh. were identified in sample Y18/f227* from 30 m below ground surface in a test well (Y18/w8)† at Awapuni, Poverty Bay flats (Fig. 2, 3). The pollen grains (9% of the total pollen count) occur only in one sample and in spite of intensive searching no other specimens were found at any other locality in the area or in any other samples at the original sample site.

The presence of *Avicennia marina* var. *resinifera* in the Poverty Bay area at about 9840 years B.P. provides further evidence of warmer and wetter conditions in New Zealand than present (McGlone et al. 1984). Its present distribution has become restricted during the Holocene climatic optimum (see Pittock & Salinger 1983) and provides evidence from its existence, contrary to the views expressed by Molloy (1969), that the weather and climate about 10 000 years ago was essentially the same as that of the present day.

ECOLOGY AND PRESENT AND FOSSIL DISTRIBUTION OF *Avicennia marina* var. *resinifera*.

Avicennia marina var. *resinifera* (Avicenniaceae) is a small tree usually 8 m tall, but can be 15 m (Salmon 1980). It is reduced to shrub form at the southern extremities of its New Zealand range in Raglan Harbour, and around Opotiki and Ohiwa harbours in the west and east of North Island, New Zealand, respectively (Fig. 1). Morton & Miller

*New Zealand Radiocarbon Dating Laboratory sample number with age based on the new half life uncorrected for secular effects, as are all other radiocarbon ages in the text of this paper. See Table 1.

Received 23 May 1986; accepted 11 September 1986

*New Zealand Fossil Record File number based on the metric (NZMS 260) system.

† Number assigned to well by the East Cape Regional Water Board when the record is filed within the specific NZMS 260 (1:50 000) sheet (Y18).

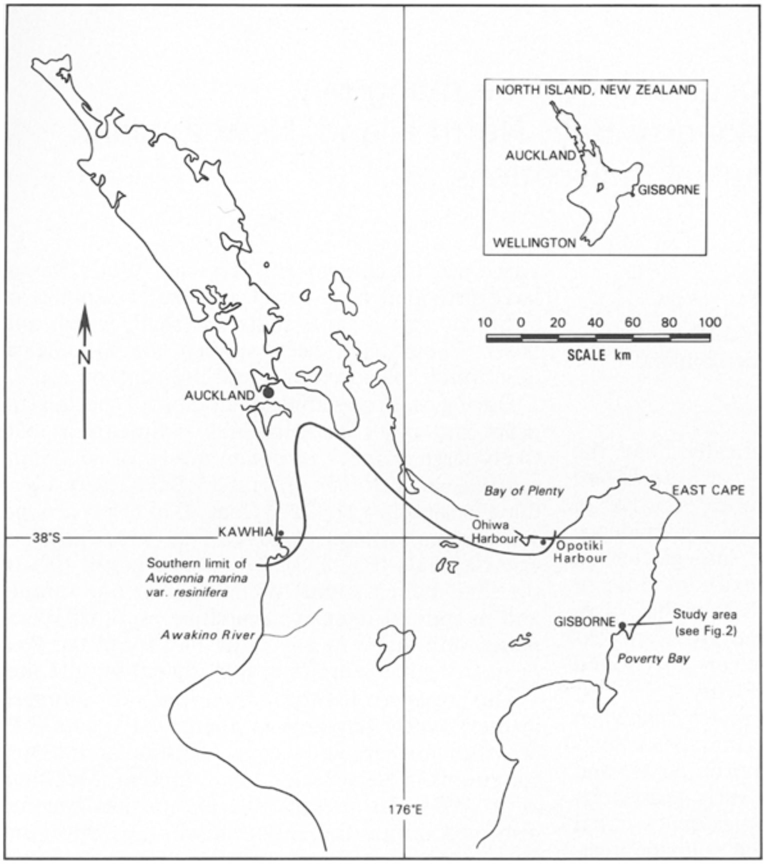


Fig. 1 Locality diagram showing the present distribution of *Avicennia marina* var. *resinifera*, and the Poverty Bay flats study area.

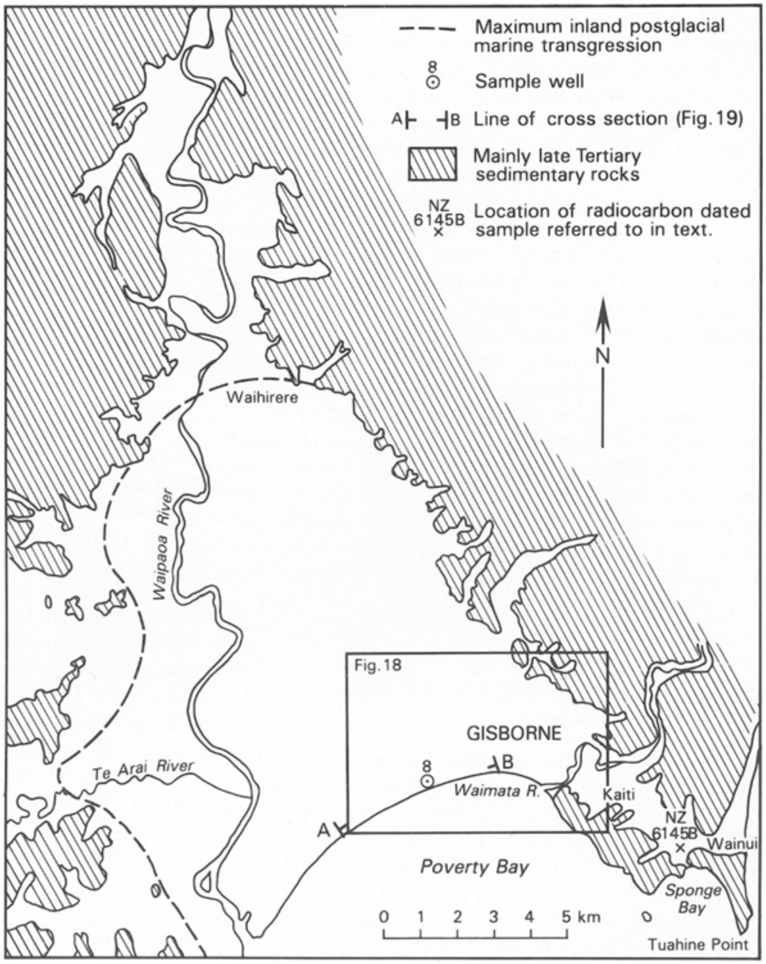
(1968) and Salmon (1980) state that *Avicennia* occurs in Kawhia Harbour but Godley (1975) states definitely that it does not occur there. The southernmost New Zealand mangrove plant occurs as a solitary small shrub near the mouth of the Awakino River (H. W. Wellman pers. comm.). This tree is separated from other known mangroves by at least 130 km and is unlikely to form the basis of a viable population. Even so it is still about 15′ further north than the southernmost mangroves in Australia (P. J. Garnock-Jones pers. comm.). The variety is endemic and the only member of the family to occur in New Zealand. Some botanists suspect the New Zealand *Avicennia* to be either a different species, or a different variety of the widespread Australian and Pacific species. In this paper, the New Zealand specimens of *A. marina* are regarded as variety *resinifera* in the absence of consensus. Because of its significance in the marine food chain and its growth habit and ecology it has been extensively studied (for example, see Chapman & Ronaldson 1958; Morton & Miller 1968; Küchler 1972; Chapman 1976, 1977).

The mangrove ("manawa" in Maori) grows on coastal shallow-water mudflats, swamps, tidal estuaries, and lagoons to form mangrove swamps. Mangrove distribution is controlled by temperature, not reaching much beyond the winter isotherm of 0°C (Morton & Miller 1968). Its southern limit is also determined by frosts, although it can withstand frosts of −2°C each winter (Walter *in* Chapman, 1977) but cannot survive freezing to −3°C (Sakai & Wardle 1978).

It can withstand a high degree of salinity as its aerating roots (pneumatophores) are periodically immersed in seawater. It is intolerant to conditions with permanent standing water or sluggish drainage, and does not thrive on open coasts, coasts subject to erosion, or on or near rocky cliffs.

A. marina has an unusual dispersal mechanism compared with non-mangroves, in that it produces viviparous seedlings that develop on the tree before dropping to float until they become stranded. They then rapidly root. The flowers of mangrove are small, clustered, and inconspicuous but make up for this by fragrance which attracts large numbers

Fig. 2 Poverty Bay flats showing localities mentioned in the text.



of bees (Küchler 1972). The flowering season is irregular but generally flowers are open from March to June. Pollen production of the New Zealand variety is likely to be similar to *A. marina* in Australia with strong pollen production but highly localised dispersal (Grindrod 1985). Since the flowers are insect pollinated it could be expected that *Avicennia* pollen is under-represented in the fossil record, as appears to be the case in the late Quaternary in New Zealand and elsewhere (Muller 1964). However, Macphail & McQueen (1983) regard *Avicennia* pollen as well- to over-represented in Quaternary and Recent deposits, but do not give reasons for their conclusion.

Outside of New Zealand *A. marina* occurs in the Philippines, Indonesia, India, East Africa, and Australia. Neither it, nor any other mangrove occurs, or has occurred, on Chatham Islands, contrary to a suggestion by Walter (1971), and to illustrations in Plaziat et al. (1983), Plaziat *in* Por & Dor (1984), and Risk & Rhodes (1985). The mangrove-associated molluscan mudflat fauna does occur on Chatham Islands but this fauna is not restricted to mangal situations.

In New Zealand *Avicennia* pollen has not been recorded, outside of its present ecological range, from sediments older than those deposited at the end of the last glaciation (about 14 000 years ago). Pollen grains of *Avicennia* from sediments in the Firth of Thames of last glaciation age have been recorded (D. T. Pocknall pers. comm.).

No fossil leaves or fruits have been recorded, but wood, thought to be of *Avicennia*, has been reported from Miocene sediment in Kaipara Harbour (Sutherland 1985).

Fossil pollen resembling *Avicennia* have been reported from the middle to late Eocene of Western Australia (Churchill 1973), from the lower Miocene of the Marshall Islands (Leopold 1969), from the upper Miocene of northwest Borneo (Muller 1964; Anderson & Muller 1975), and from the Pliocene of Guyana (Wymstra 1971). *Avicennia* cf. *marina* pollen has also been recorded by Bessedik & Cabrera (1985) from France and Spain, in an area corresponding to the maximum Miocene transgression in the northwest Mediterranean. There is, as yet, no geological evidence to support the paleobiogeographic outline proposed by Chapman *in* Por & Dor (1984) for the Pacific area; this depicted New Zealand, lacking mangrove pollen, separate from Australia, which has fossil mangrove pollen. The record of fruits and pollen of *Avicennia* from the Eocene London Clay (Montford 1970) are regarded as unproven. With the number of records of *Avicennia* pollen in pre-Quaternary sediments outside of New Zealand, it is surprising that it has not been recorded from New Zealand, particularly since Miocene wood possibly occurs. Late Tertiary climate and environments of deposition were ideal for *Avicennia* to exist (Hornibrook 1978) and there is a good palynological record.

POLLEN MORPHOLOGY OF *Avicennia marina* var. *resinifera*

Pollen grains of the various species of *Avicennia* are quite similar. The pollen grains of *A. marina, A. resinifera,* and/or *A. marina* var. *resinifera* have been described by Leopold (1969), Huang (1972), Mukherjee & Chanda (1973), Saxena (1981), and others, but here a fuller description of pollen from herberium material is given. The fossil material all falls into the range of the modern New Zealand *A. marina* var. *resinifera.* Format and terminology follows that of Faegri & Iversen (1964).

Avicennia marina var. *resinifera* (Forst. f.) Bakh. — Monad, isopolar, prolate to prolate-spheroidal, rarely almost oblate; amb sub-circular to sub-triangular, tricolporate, colpi long, distinct, gaping, margins straight, tapering from 7 μm at equator to a fine point near poles, small apocolpial area 6–7 μm across; colpus membrane psilate to very faintly flecked; ora circular to oval, large, thin-walled, often distorted, 7–8 μm across, often lolongate or lalongate in appearance; exine 2.5–3.0 μm in polar area and mesocolpia, sexine twice thickness of nexine but decreases in thickness towards colpi: sexine reticulate, surface undulating in sectional view, muri thick, underlain by single columellae, heads of columellae rounded, fused, up to 1.5 μm in diameter but most *c.* 1.0–0.5 μm, lumina irregular, rounded, polygonal to elongated, up to 2.5 μm long but usually less than 1.5 μm, generally largest in polar areas, smaller on mesocolpia and along colpi, floor of lumina psilate; aperture membranes broken down or lost in fossil specimens obscuring nature of ora. See Fig. 4–17.

Dimensions — equatorial diameter 21(26)36 μm (herbarium), 19(24)30 μm (fossil); polar diameter 28(34)39 μm (herbarium), 23(27)34 μm (fossil); 25 specimens of each measured. The microscope used was a Zeiss Photomicroscope III, serial number 4693518 on which all photomicrographs were taken.

The pollen is distinct from all others in the present day New Zealand flora because of its flared colpi, simplibaculate reticulate exine, and large ora.

GEOLOGY OF POVERTY BAY

Test well (Y18/w8) is located at the meat processing plant of Advanced Meat Limited, Pacific Street, Awapuni, on the western boundary of Gisborne city (Fig. 2). The well site is about 4 m above present mean sealevel at grid reference Y18/442691*. Strata penetrated by the well, and the sheet fossil numbers assigned to the samples examined for radiocarbon dating, macropaleontology, and palynology (all palynology samples come from cores) are shown in Fig. 3. The single occurrence of mangrove pollen (Y18/f227 at a depth of 26 m below present day sealevel) is probably related to the postglacial geological processes in Poverty Bay. Studies on sediment and organic material from various test wells have established that extremely complex, local depositional and environmental conditions, associated with the postglacial rise in sealevel, influenced the sediment deposition (Brown 1984).

The Poverty Bay flats comprise the coastal floodplain of the Waipaoa River inland from Gisborne (Fig. 2) at the Poverty Bay coast. An area of about 18 000 hectares of plain has been formed by the infilling of a wide triangular-shaped river valley with predominantly river silt, during the Quaternary.

The "basement rocks" underlying the Poverty Bay flats are Tertiary-age bedded mudstone, siltstone, and sandstone, as exposed in the wave cut platform off Kaiti Beach. Undulations (erosion surfaces) and dislocations (faulting) occur on the basement surface. A "seismic noise" survey of Gisborne city (Hatherton & Orr 1971) and a few test wells which have penetrated to basement were used to produce Fig. 18 showing approximate 50 m and 100 m (below mean sea level) contours of the basement beneath Gisborne city. A "channel" underlies the area bounded by the Taruheru Stream in the

*Grid reference for sheet Y18 based on the national thousand metre grid of the 1:50 000 topographical map series NZMS 260.

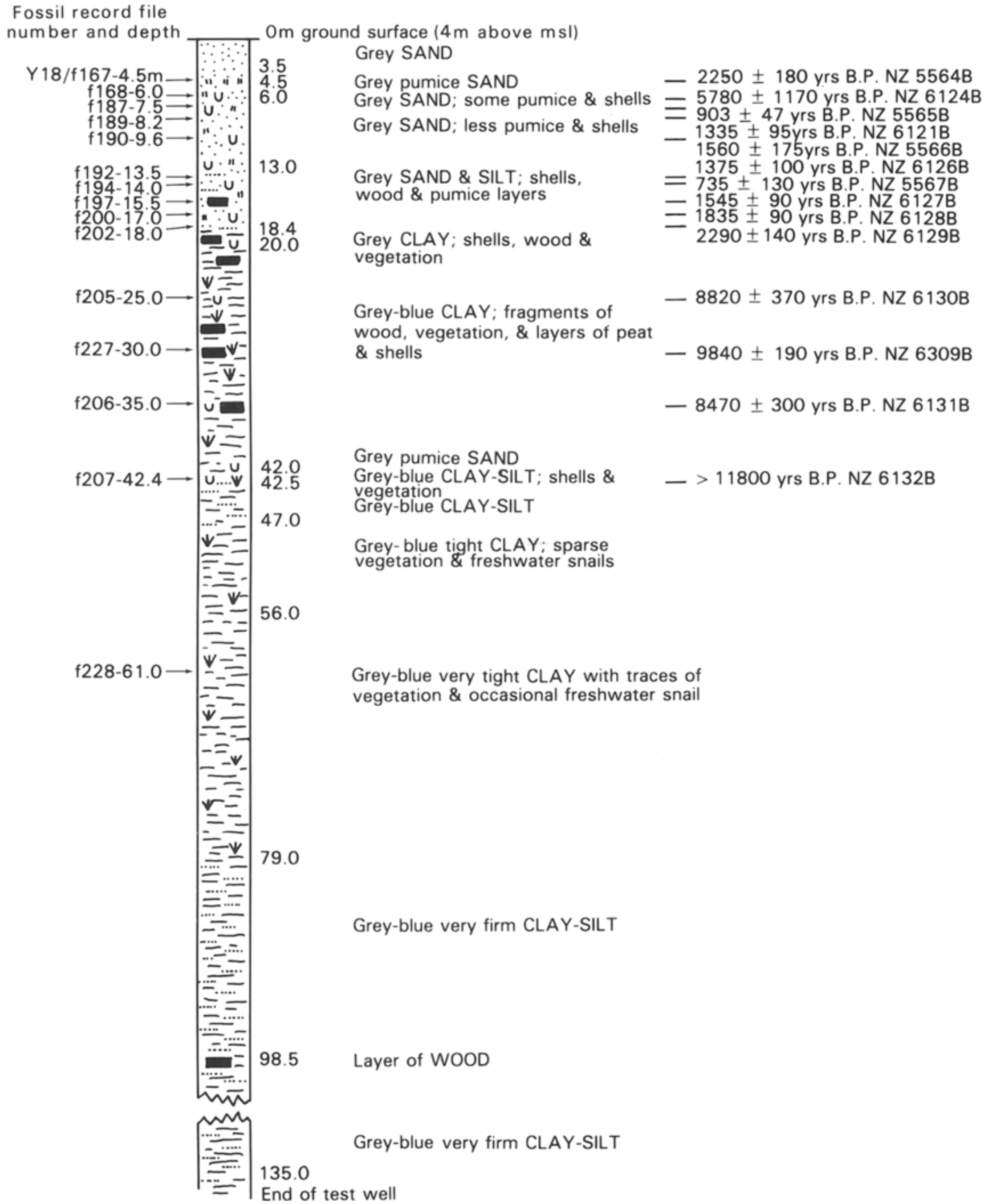


Fig. 3 Lithologic column for test well Y18/w8, Awapuni, Gisborne. Radiocarbon ages given in years before present (see also Table 1), calculated in terms of new half life (5730 ± 40 years) and uncorrected for secular effects.

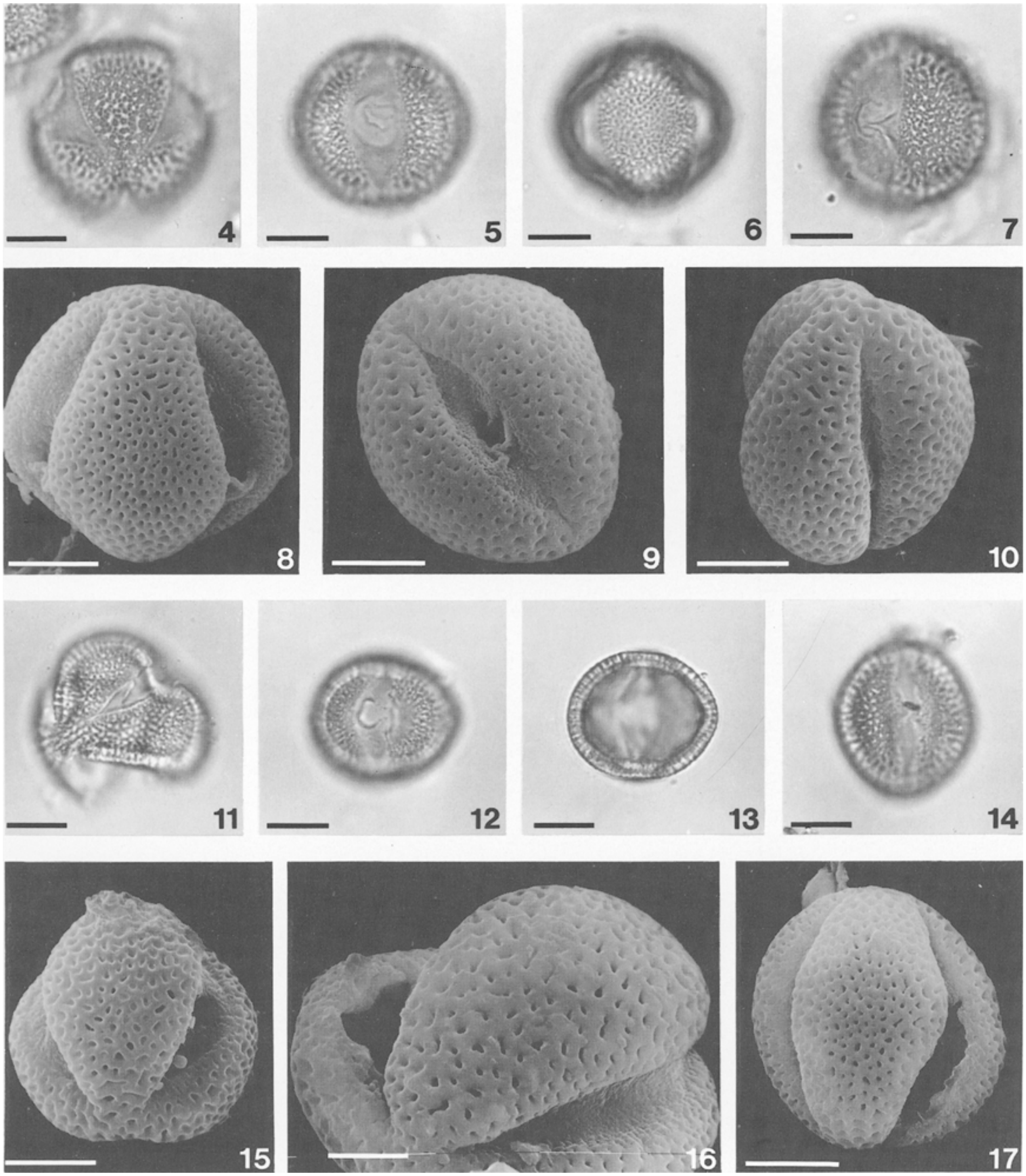


Fig. 4–17 Light micrographs (Fig. 4–7; 11–14) and scanning electron micrographs (Fig. 8–10; 15–17) of modern (Fig. 4–10) and fossil (Fig. 11–17) specimens of *Avicennia marina* var. *resinifera*. Scale bar = 10 μm except for Fig. 16 where the scale bar = 5 μm. Modern pollen – Fig. 4 sub-polar view showing reticulation formed by rounded heads of the columellae; Fig. 5–7 same specimen in equatorial view showing firstly, apertural area with gaping colpus, circular os and psilate membrane and secondly, the reticulate mesocolpial area, and finally, a sectional view illustrating the three dimensional aspect; Fig. 8–10 sub-equatorial and equatorial views illustrating the reticulate sexine and nature of the apertural area; Fig. 11–17 from Slide L11062 illustrating the same aspects as in Fig. 4–10; Fig. 11 from single mount slide SM1402; Fig. 12, 13 are the same specimen (SM1403); Fig. 14 from Slide L11062/2 co-ordinates 14.0 × 106.8.

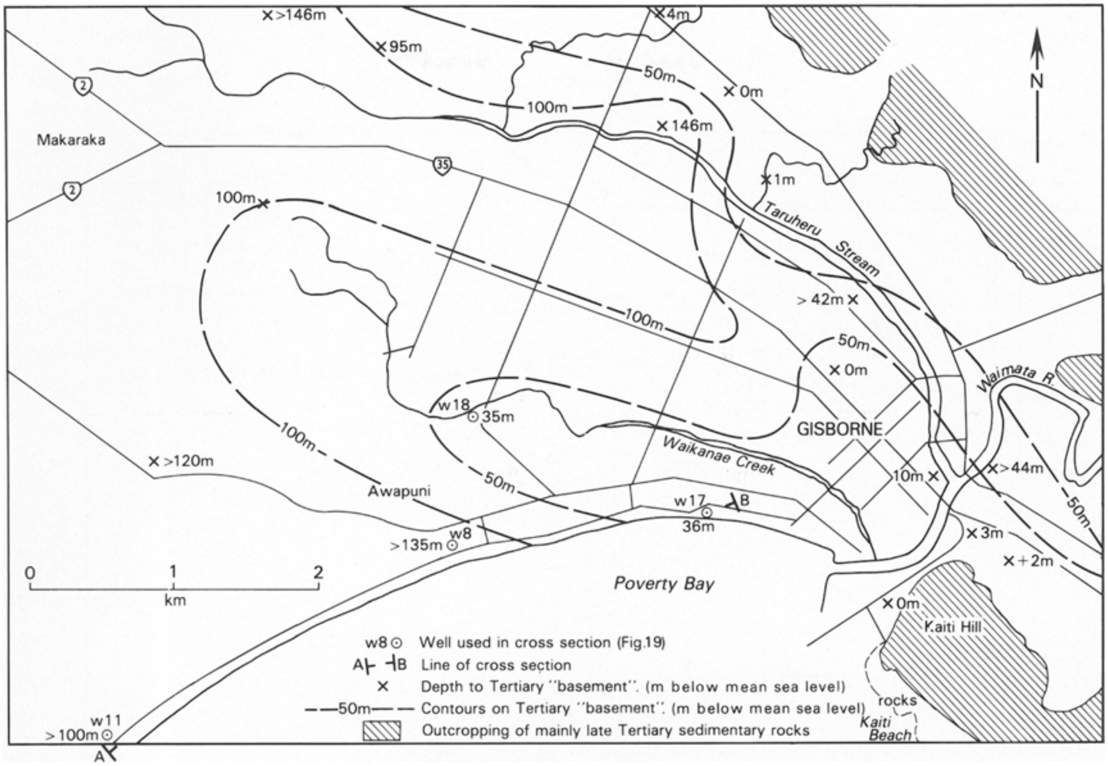


Fig. 18 Contours on surface of "Tertiary basement" beneath Gisborne city.

north and Waikanae Creek in the south and a "shelf" underlies the area of Gisborne between Waikanae Creek and the present coast. These features of the basement topography influenced depositional environments during early postglacial time when the mangrove swamps were established.

Towards the end of the last (Otira) glaciation at 18 000 years B. P., sealevel was 120 m below that of the present day and about 30 km offshore from Poverty Bay. About 14 000 years ago the climate became warmer, glaciers receded, ice caps melted, and sealevel rose. Rising postglacial sealevel reached the present Poverty Bay coast about 10 000 years ago and by about 6000 years ago sealevel had risen to the present level and extended over the Poverty Bay flats as far inland as Waihirere (Fig. 2). During the following 6000 years of relatively stable sealevel the coast prograded to produce the present Poverty Bay flats.

At the end of the last glaciation the reduction in erodable material, brought about by forest regeneration at high altitudes in the catchment, and changes in river profile and course length, imposed by rising sealevel, resulted in downcutting and reworking of Quaternary alluvium and marine deposits of the Waipaoa valley and floodplain, and the underlying and adjacent Tertiary mudstone, siltstone, and sandstone. Superimposed on these processes was the effect of postglacial tectonic activity which produced uplift along the northeast margin of the Poverty Bay flats. River response to this uplift has been intense reworking and infilling on the Poverty Bay flats, mainly by the Waipaoa River, but also from the Waimata River in the vicinity of Gisborne city.

ENVIRONMENT GEOLOGY OF POVERTY BAY FOSSIL LOCALITIES

Macrofaunal and palynological determinations show the abundance of reworked fossils in many samples, and inversion of radiocarbon dates with depth is common (see Fig. 3).

All pollen samples contain fine organic debris and recycled ?Miocene spores and pollen. Even the charcoal in sample Y18/f227 could have been recycled, and the sediments themselves may have been reworked during postglacial time. The radiocarbon age of subsurface samples containing wood and shell

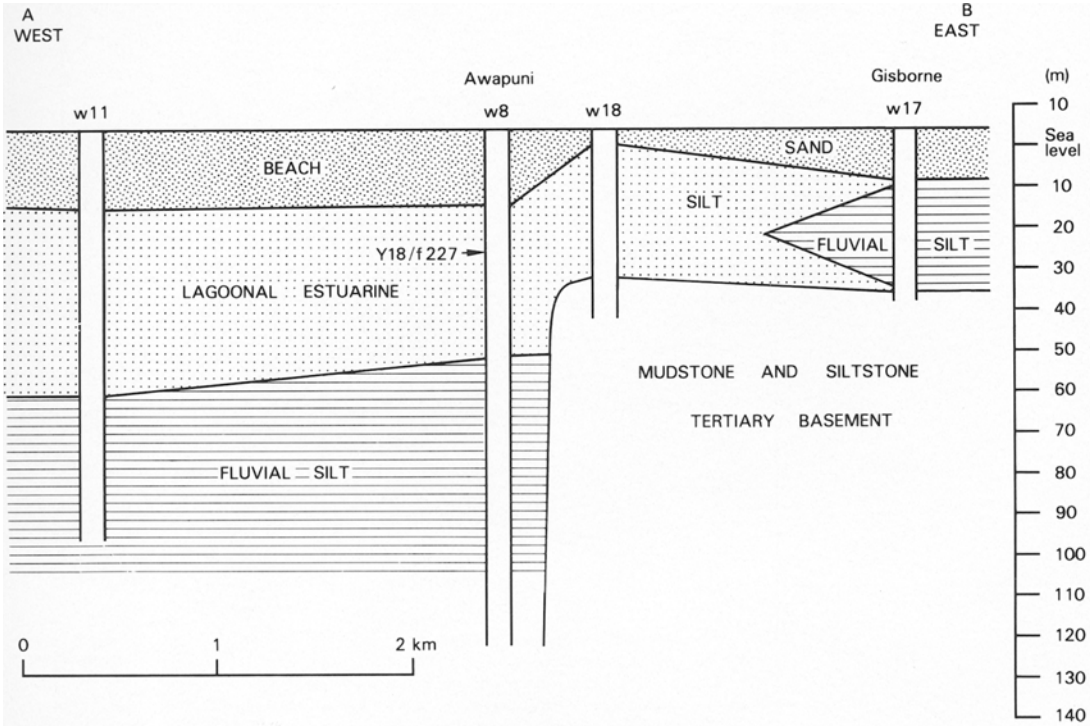


Fig. 19 Cross-section compiled from well log data, eastern Poverty Bay.

fragments may be significantly older than the age of burial, if reworked older material is mixed with the *in situ* material. This would explain the inconsistencies of decreasing radiocarbon dates with depth.

Fig. 19 is a cross-section summarising the subsurface postglacial geology, compiled by correlating logs of strata penetrated by four wells located along or adjacent to the Poverty Bay coast. Well Y18/w8 (Fig. 18, 19) penetrated 36 m of early postglacial grey-blue silt and clay containing occasional shells, layers of peat, and fragments of wood from 20 m to 56 m below ground surface. Above 20 m, late postglacial beach sand occurs. The radiocarbon age (NZ 6309B) of 9840 $\pm$ 190 years B. P. from the peat layer at 30 m, in which *Avicennia marina* was identified, is the oldest age associated with a postglacial marine environment so far obtained from the Poverty Bay flats. However, reworked older organic material (mainly charcoal) may affect the radiocarbon age so that it is a maximum age rather than the actual age of the accumulation and burial of the peat sample with the mangrove pollen. A shell sample (Y18/f207) from a depth of 38 m in the well gave an indefinite age of $>$11 800 years B. P. (NZ 6132B), while peat associated with the shell sample yielded a palynoflora suggesting postglacial conditions with a warm humid climate, cut off from the influence of saline water (see below, Palynology and paleoecology). The sparse shells present in strata from 38 m to 52 m below ground in the well are an estuarine fauna with *Austrovenus stutchburyi* dominant (A. G. Beu pers. comm.).

Fig. 18, 19 illustrate the proximity of well Y18/w8 to a shelf in the Tertiary "basement". The peat layer containing *Avicennia marina* pollen and also other coastal taxa, and dinoflagellate cysts, accumulated at the same time as the rising sea swamped this land surface and an extensive sheltered shallow water area extended over the area now underlying Gisborne city. Well Y18/w17, located about 2 km east of Y18/w8, penetrated a thin layer of lagoonal–estuarine strata immediately overlying Tertiary strata, and overlain by 28 m of swamp and fluvial material derived from both the Waipaoa and Waimata River catchments (Fig. 19). Palynological studies of 9 samples collected from the swamp/fluvial deposits penetrated by this well indicate that a coastal freshwater raupo/burr-reed pond with marginally marine or brackish water, succeeded a freshwater Cyperaceae-fringed pond.

About 6000 years ago, when the sea had risen to the present level, and swamp, estuarine, lagoonal, and beach environments extended inland as far as

Table 1 Details of radiocarbon dates referred to in this paper. NZA = old age; NZB = new age; NZC = age based on new half-life + secular correction. For stratigraphic position of dated samples from test well Y18/w8 see Fig. 3, for other sample see text.

Locality*	C_{14} numbers	Radiocarbon age	Material
f167	NZ5564A	2190 ± 180 y. B. P.	Shell
	NZ5564B	2250 ± 180 y. B. P.	
f168	NZ6124A	5620 ± 1140 y. B. P.	Shell
	NZ6124B	5780 ± 1170 y. B. P.	
f187	NZ5565A	877 ± 45 y. B. P.	Shell
	NZ5565B	903 ± 47 y. B. P.	
f189	NZ6125A	1295 ± 95 y. B. P.	Shell
	NZ6125B	1335 ± 95 y. B. P.	
f190	NZ5566A	1515 ± 170 y. B. P.	Shell
	NZ5566B	1560 ± 175 y. B. P.	
f192	NZ6126A	1335 ± 95 y. B. P.	Shell
	NZ6126B	1375 ± 100 y. B. P.	
f194	NZ5567A	715 ± 125 y. B. P.	Shell
	NZ5567B	735 ± 130 y. B. P.	
f197	NZ6127A	1500 ± 85 y. B. P.	Shell
	NZ6127B	1545 ± 90 y. B. P.	
f200	NZ6128A	1780 ± 90 y. B. P.	Shell
	NZ6128B	1835 ± 90 y. B. P.	
f202	NZ6129A	2220 ± 140 y. B. P.	Shell
	NZ6129B	2290 ± 140 y. B. P.	
f205	NZ6130A	8560 ± 360 y. B. P.	Shell
	NZ6130B	8820 ± 370 y. B. P.	
f206	NZ6131A	8230 ± 290 y. B. P.	Shell
	NZ6131B	8470 ± 300 y. B. P.	
f207	NZ6132A	>11500 y. B. P.	Shell
	NZ6132B	>11800 y. B. P.	
f217	NZ6145A	6250 ± 100 y. B. P.	Shell
(g.r.	NZ6145B	6430 ± 110 y. B. P.	
502663)	NZ6145C	7110 ± 110 y. B. P.	
f227	NZ6309A	9560 ± 180 y. B. P.	Peat
	NZ6309B	9840 ± 190 y. B. P.	

* Fossil record number from sheet Y18, grid reference Y18/442691 except as indicated. Dates uncorrected for secular effect except Y18/f217.

Waihirere (Fig. 2), Kaiti Hill and Tuahine Point were islands and much of the area now occupied by Gisborne city would have been below sea level. About 6000 years ago tectonic uplift raised the sea floor at least 6 m above sealevel — an estuarine fauna collected from a drain excavation inland of Sponge Bay at about 6 m above present day mean sealevel has been radiocarbon dated at 6430 ± 110 years B. P. (NZ 6145B) (Table 1). This uplift joined Kaiti Hill and Tuahine Point to the mainland, and the Waimata River course, mouth and lagoon were confined to the area west of Kaiti. The Waimata River (and also the Waipaoa River) adjusted to tectonic uplift by downcutting into the uplifted strata. This process continued until about 4000 years ago when progradational marine deposits, derived from material transported by the rivers into Poverty Bay, began to accumulate on the eroded surface of the postglacial marine transgressional deposits. Sample Y18/f168, radiocarbon dated at 5780 ± 1170 years B. P. (NZ 6124B), from a depth of 6 m in well Y18/w8, is an example of reworking and redistribution of postglacial marine material. Progradational marine and associated deposits accumulated unconformably on top of the older postglacial transgressional marine deposits, and the present day beach ridges and swales were formed (Pullar & Warren 1968).

Table 2 Pollen and spores identified from testwell Y18/w8, Awapuni, Gisborne.

Fossil record number	Y18/f227	Y18/f207	Y18/f228
Metres below surface	30	42.2	61
Slide number	L11602	L11373	L11132
Species			
Lycopodophyta; Bryophyta:			
Anthocerotales			X
Cingulatisporites bifurcatus (Couper)	X		
*?*Perotriletes*	1		
Sphagnum			X
Lycopodium billardieri group	X	X	X
L. deuterodensum	X		
L. fastigiatum	1		1
L. scariosum			X
L. volubile	X		
Pteridophyta:			
**Ceratosporites*			1
Cyathea	105	10	79
*?*Cyathidites subtilis* Partridge	1		
Dicksonia squarrosa	5	X	2
**Dictyophyllidites arcuatus* Pocknall & Mildenhall		X	
Gleichenia circinata	X		X
Histiopteris incisa	1	?	1
Hymenophyllaceae	X		X
Hymenophyllum	X		
Hypolepis cf. *tenuifolia*			1
Ophioglossum coriaceum			X
Paesia scaberula	X		1
Phymatodes diversifolium	X		X
Polypodiaceae	X	X	2
**Polypodiisporites*		X	
**P. inangahuensis* (Couper)			X
**P. irregularis* Pocknall & Mildenhall	1		
**P. radiatus* Pocknall & Mildenhall	X		
Pteris comans	X		1
unidentified monolete spores	14	2	31
Gymnospermae:			
Dacrydium bidwillii/biforme group	X		4
D. cupressinum	11	18	7
Dacrycarpus dacrydioides	1	5	1
Libocedrus		1	
**Microcachryidites antarcticus* Cookson			X
**Phyllocladidites mawsonii* (Cookson)	X		
Phyllocladus	1	X	30
Podocarpus	50	100	47
P. ferrugineus		X	
P. spicatus	X	X	X
P. totara	X	X	X
Angiospermae : dicotyledonous			
Araliaceae	X	X	
Ascarina lucida	X	X	1
Avicennia marina	8		
*?*Beaupreaidites*			X
?*Callitriche*		X	
Compositae (Tubuliflorae)	1	1	2
Coprosma	1	6	47
Cruciferae	X		
Dodonaea viscosa	1	8	X

Elytranthe			X
Epacridaceae	1		X
Epilobium			X
Eugenia maire		3	
Griselinia littoralis		3	
Gunnera	X		
**Haloragacidites harrisii* (Couper)	X		X
?*Hebe*		2	
Hoheria			1
Knightia excelsa			X
Leptospermum		9	
Loranthus micranthus	X	1	
Metrosideros		8	
Muehlenbeckia	X		
Myriophyllum	X		X
Myrsine		?	
**Nothofagidites cranwellae* (Couper)	1		1
**N. matauraensis* (Couper)	X		
Nothofagus fusca group	1	9	21
N. menziesii	X	1	1
Plagianthus	1	1	11
**Proteacidites*	1		
Pseudowintera	X		1
*?*Rhoipites alveolatus* (Couper)	X		
?*Salicornia australis*	X		
Sapotaceoidaepollenites latizonatus (McIntyre)		X	
Stellaria			X
Tetrapathaea tetrandra		X	
unidentified pollen	7	5	2
Angiospermae: monocotyledonous			
Cyperaceae	1	1	20
Gramineae	1		2
Palmae		X	
Phormium tenax			1
Restionaceae	X	2	
Sparganium	X		
Typha	X	32	
Chlorophyceae:			
Pediastrum		X	
Total count	217	228	320

X Present but not located during count
* Recycled
? = Uncertain identification

PALYNOLOGY AND PALEOECOLOGY

Of the six samples examined for pollen analysis from test well Y18/w8 (Fig. 2), three produced spore/pollen assemblages that could be used to determine paleoenvironment. The taxa identified are listed in Table 2.

Reworked spores and pollen

Many of the palynomorphs in this sequence that appear to be *in situ* are badly preserved, either as a result of reworking, transportation to the deposition site by water, or oxidation. However, the pollen grains of *Avicennia* are all well preserved and are unlikely to have been recycled. Also *Avicennia* has not been recorded in Tertiary sediments in New Zealand.

Some of the recycled taxa include dinoflagellates, ?*Cyathidites subtilis* Partridge (Miocene), *Dictyophyllidites arcuatus* Pocknall & Mildenhall (Miocene), *Phyllocladidites mawsonii* (Cookson) (Cretaceous-Miocene), *Microcachryidites antarcticus* Cookson (Late Cretaceous-Miocene), *Nothofagidites matauraensis* (Couper) (mainly early Tertiary), *N. cranwellae* (Couper) (mainly late Tertiary), *Haloragacidites harrisii* (Couper) (mainly Tertiary), *Sapotaceoidaepollenites latizonatus* (McIntyre) (Eocene-Miocene), and *Proteacidites* species. Age data are from Couper (1960) and Pocknall & Mildenhall (1984). Overall these recycled taxa suggest a Miocene source.

In situ palynology

The deepest and oldest sample (Table 2), from 61 m (Y18/f228), is dominated by *Podocarpus* (mainly *P. spicatus*, and *P. totara*), *Phyllocladus*, and *Coprosma* and represents a late last-glaciation coastal flora. Cyperaceae, *Nothofagus fusca* group, *Dacrydium cupressinum, Plagianthus*, and *Dacrydium bidwillii/biforme* group are other common pollen types. Tree pollen only forms 56% of the total pollen count and herbaceous pollen 11%. In spite of the relative scarcity of tree pollen and the overall last-glaciation aspect to the assemblage, *Ascarina lucida* and *Dodonaea viscosa*, two frost tender plants, are present. Conditions must have been warm and humid for these taxa to survive, and mild conditions may have existed through the last glaciation in the Gisborne area (McGlone et al. 1984). Dinoflagellates are present, indicating a marine influence in the immediate environment.

The next sample, from 42.4 m (Y18/f207), is dominated by *Podocarpus spicatus*, plus other species, with *Dacrydium cupressinum, Nothofagus fusca* group, *Coprosma*, Myrtaceae, *Dodonaea viscosa*, and *Typha* less frequent. The assemblage represents deposition from a coastal podocarp forest into a raupo swamp. Tree pollen forms 62% of the total count but local pollen, of Myrtaceae and *Typha* in particular, are well-represented and distort the regional pattern. The sample represents the early postglacial when conditions were warm and humid. No dinoflagellates were identified, and the presence of a freshwater alga *Pediastrum* indicates that the swamp must have been cut off from the influence of saline water at this time.

The last sample, from 30 m (Y18/f227), is dominated by pollen of *Podocarpus* (*P. totara* and *P. spicatus* in particular), with rarer amounts of pollen from *Dacrydium cupressinum* and *Avicennia marina* var. *resinifera*, and abundant spores of *Cyathea*. Charcoal in this sample indicates the possibility of fires inland from the site of deposition. Dinoflagellates are present, indicating a marine or brackish water environment of deposition. Because the mangrove is an insect pollinated plant with highly localised dispersal, the abundance of *Avicennia* pollen indicates that the mangrove must have been growing on or close to the site of deposition. The assemblage represents deposition from a coastal podocarp forest into an estuarine or lagoonal mudflat environment. Climatic conditions were warm and humid.

Paleoecology

The presence of *Avicennia* at this locality makes it possible to estimate the temperature during the early part of the postglacial for the Poverty Bay area. On the east coast of North Island *Avicennia* grows today near Opotiki Harbour (Fig. 1), where it is restricted by winter frosts. It could conceivably exist at East Cape, which is further north than Ohiwa and Opotiki Harbours, except that its way is barred by rocky coastal cliffs and otherwise unsuitable environments. During the early postglacial the average winter temperature was higher and frosts less prevalent, and the coastal platform was exposed to allow *Avicennia* to round East Cape. At Opotiki, a weather station 6 m above mean sea-level records an average of 25.4 days of ground frost per year and an average minimum annual air temperature of −1.9°C (NZ Meteorological Service 1983). At Gisborne Airport, 4 m above mean sea-level, a weather station records an average of 40.7 days of ground frost per year and an average minimum annual air temperature of −1.9°C. In winter, the average minimum monthly air temperature varies between −0.4°C and −1.2°C at Opotiki, and −0.4°C and −1.1°C at Gisborne, with lowest recorded temperatures of −4.2°C and −3.4°C respectively (NZ Meteorological Service 1983). These figures suggest that *Avicennia* could grow in Gisborne, at the present day, at least as well as it does at Opotiki. The only difference is that more frosts occur in Gisborne which could kill *Avicennia* in the winter if regularly below −2°C (Chapman & Ronaldson 1958; Sakai & Wardle 1978). The number of winter ground and air frosts must have been considerably less (implying that skies would have been less clear) and the average winter temperature and humidity higher, during the time *Avicennia* grew there.

Temperatures may have been at least 1°C higher, that is, equivalent to those at Auckland where *Avicennia* is actively reproducing. The winter average minimum monthly air temperature range there is 1.1°C to 3.1°C (NZ Meteorological Service 1983). The summer temperatures need not have been any higher.

In spite of the doubts raised above about the reliability of the radiocarbon dates the Holocene southward migration of *Avicennia* must coincide with the climatic optimum of 8000 ± 1000 years B.P. (Pittock & Salinger 1983) and provides evidence for the concept denied by Molloy (1969). Unfortunately with only one locality containing *Avicennia* pollen, the exact relationship in Poverty Bay that *Avicennia* has with the duration of the climatic optimum is unknown.

DISCUSSION AND CONCLUSIONS

At Poverty Bay, extensive shallow-water, marginal marine lagoons, estuaries, and swamps were present at about 10 000 years B.P., especially once the rising sea had "swamped" the Tertiary age shore platform at the eastern end of the bay adjacent to the present Waimata River mouth (Fig. 18). Enough time elapsed for *Avicennia marina* to establish there.

Although the early postglacial climate was sufficiently warm and humid to allow *Avicennia* to flourish on mudflats that would have bordered a coastal platform from Bay of Plenty around East Cape and south to Poverty Bay (Fig. 1), the areal extent of the mangrove swamps is unknown, as only one sample containing abundant *Avicennia* pollen has so far been identified from the area. This may be for a number of reasons or combinations of reasons. *Avicennia* may have only occurred there for a short period of time due to changing climatic and geographic conditions. Pollen preservation may not be good enough at other localities, especially with river flooding imposing wet then dry conditions, in which grains could be oxidised. Also pollen may have been concentrated only locally and not dispersed well enough to appear in assemblages outside of the immediate vicinity of the parent plants. Tectonic uplift and subsequent reworking and erosion by rivers, and possibly also the sea, may have removed much of the early postglacial strata from Poverty Bay flats, including the strata associated with the mangrove swamps. The mangrove swamps could have been established offshore from the present day coast, and as such are only present in the onshore sample as a result of unusual transportation and preservation conditions. Alternatively, the mangrove swamps may have been at, or near, their landward distribution limit and offshore of the present day coast during the time of deposition of the other samples collected.

The current New Zealand distribution of *Avicennia* compared with that of the past indicates that frosts were probably less frequent and air temperatures higher during the early Holocene climatic optimum than at the present day. The past distribution of *Avicennia* was also affected by sealevel changes. Rising sealevel prior to 6000 years B.P. created areas suitable for mangrove to flourish and migrate around East Cape. Once it arrived, it should have stayed unless a rapid shift in coastline eliminating tidal mudflats, coupled with deteriorating more frosty climatic conditions, prevented it from surviving in the Poverty Bay area. Woodroffe et al. (1985) report that southward migration of *Avicennia* in northern Australia was caused by an interaction of sealevel changes and sedimentation, with temperature and rainfall not important. However, this change was recorded as occurring for approximately 1000 years, starting between 6500 and 7000 years B.P., which is well after the migration had occurred in New Zealand, and presumably after mangrove had retreated back to at least its present distribution.

With the growth habitat of *Avicennia* many sites must exist where fossil pollen and wood occur. Such horizons will be important sealevel, tectonic, and salinity/temperature indicators, and should, in the north of North Island, be studied in conjunction with current coastal Quaternary sedimentological and tectonic studies.

ACKNOWLEDGMENTS

We would like to acknowledge the help of Messrs A. Armstrong and B. W. Turnpenny (East Cape Catchment and Regional Water Board), R. J. Allnatt (welldriller – Gisborne) and V. M. Williams (NZ Geological Survey) in logging wells, collecting samples, and providing logistic assistance. Dr H. S. Jansen and Mr R. C. McGill, Radiocarbon Dating Laboratory, Institute of Nuclear Sciences, DSIR, Gracefield provided the radiocarbon dates. Dr. A. G. Beu (NZ Geological Survey) identified and provided paleoenvironmental information for macrofaunal samples. Pollen samples were processed by Y. M. Crosbie while C. D. Clowes, B. Burt, W. St George, J. I. Raine, J. G. Gregory, D. W. Heron, P. Matthews, and R. Morrison all assisted towards completion of the paper. Special thanks to Dr M. S. McGlone (Botany Division, DSIR) who refereed an earlier version of this paper and supplied additional data.

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