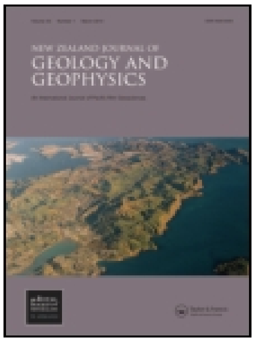

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Quaternary geology of the North Kaipara Barrier, Northland, New Zealand

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with an Appendix

Quaternary palynology: North Kaipara Barrier

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Abstract North Kaipara Barrier is formed by sediments, mainly estuarine and dune sands of the Kaihu Group, deposited in a major cycle of transgression (subsidence) and regression (uplift) during the Quaternary. Hautawan, Okehuan and younger lignites along with terrace surfaces at 105 m, 67 m, 40 m, 24 m, 8 m and 4–2 m a.s.l., which can be correlated with dated surfaces elsewhere in the North Island, provide chronologic control. Five units, the Hautawan **Dargaville Formation**, Nukumaruan–Castlecliffian **Rototuna Formation**, Castlecliffian–Hawera **Pareotaunga Formation**, Hawera South Head Formation, and the Hawera Shelly Beach Formation, are present. The barrier has changed little since the end of Okehuan time when the major existing valleys were cut in Rototuna sediments. Upper Pleistocene terrace surfaces are locally preserved within these valleys. Undifferentiated Hawera and Holocene deposits are also present on the barrier.

Keywords Quaternary; Pleistocene; Holocene; Kaihu Group; North Kaipara Barrier; Hautawan; Okehuan; palynology; terraces; stratigraphy; sea levels; South Head Formation; Shelly Beach Formation; new stratigraphic names; Dargaville Formation; Rototuna Formation; Pareotaunga Formation

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INTRODUCTION

This study is taken from an unpublished M.Sc. thesis (Richardson 1975) where analyses and data are documented.

The North Kaipara Barrier described by Schofield (1970) has an average width of 7 km and stretches 85 km southeasterly from Manganui Bluff to the Kaipara North Head (Fig. 1). Quaternary eolian and marine sands up to 220 m above sea level (P9/064453*, Muarangi) and to 95 m below sea level (Richardson 1975) are the predominant sediments forming the barrier. Six terrace levels best developed at 105 m, 67 m, 40 m, 24 m, 8 m, and 4–2 m above sea level are present (see Fig. 3). Brothers (1954) has described a similar northwesterly trending barrier immediately to the south. Other work in the area includes that of Maxwell (1897), Mulgan (1903), Ferrar (1934), Thompson (1961), and Schofield (1970).

STRATIGRAPHY

Ferrar (1934) mapped the barrier grouping all the sediments as Kaihu "Series" ranging from Lower Pleistocene to Recent in age. Brothers (1954) described four formations forming the Kaihu Group on South Kaipara Barrier. Chappell (1964) proposed the following definition: "The Kaihu Group includes all poorly to moderately consolidated sediments and intercalated volcanic rocks which overlie well lithified rocks in the West Northland–Southwest Auckland region. Deposits of the Kaihu Group are separated from underlying rocks which are of Altonian age or older, by a major unconformity". Included in Kaihu Group are complexly interdigitated terrestrial, littoral, and shallow marine sediments, together with lava flows, volcanic ash horizons, and recent sediments (Chappell 1964). With the exception of a few small outcrops of older rocks, all the sediments of the North Kaipara Barrier are included in the Kaihu Group.

Two of Brothers's (1954) units, the South Head and Shelly Beach Formations, have been recognised in the area; the Waioneke Formation, however, was not identified. Kaihu Formation (Brothers

*Grid references are based on the national 1000 m grid of the 1:50 000 topographic map series NZMS 260.

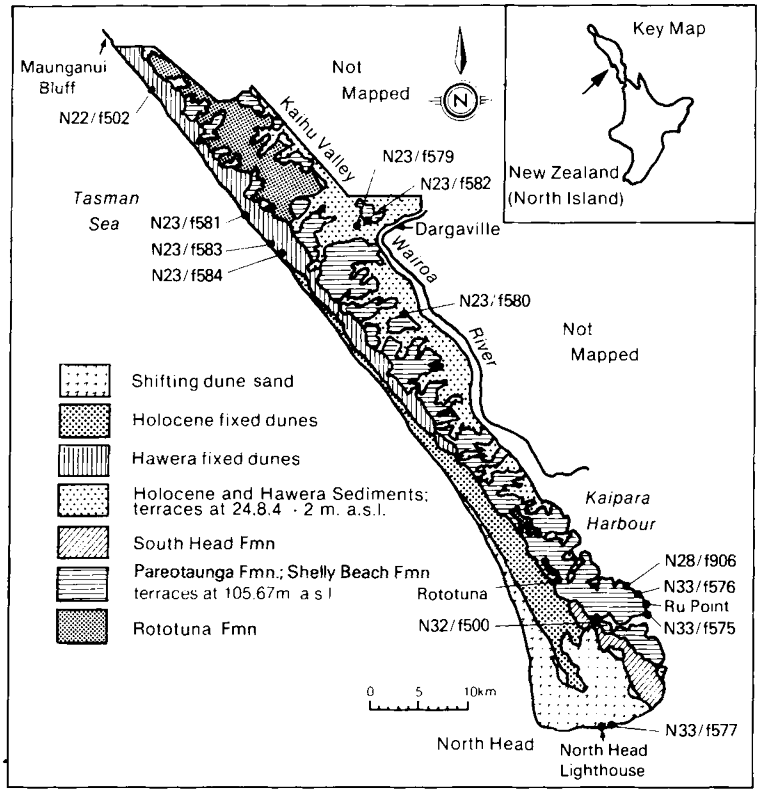

Fig. 1 Generalised geological and locality map of the North Kaipara Barrier. All fossil localities are given in terms of the pre-metric New Zealand Fossil Record file based on the 1:63 360 topographical map series (NZMS 1). For metric conversions for these samples see text and Table 2 (Appendix 1).

1954; Chappell 1964, 1970) is here replaced by three new lithologically and paleontologically distinct formations (Fig. 2), the **Dargaville, Rototuna,** and **Pareotaunga Formations.** At least one and possibly three reversals in the general "Kaihu" transgression was noted by Chappell (1964, 1970) and he suggested (1975) a closer study of this formation would be useful.

Chappell (1975) proposed a correlation of terrace surfaces along the west coast of the North Island and the Bay of Plenty that can be integrated with terraces of North Kaipara (Fig. 3).

DARGAVILLE FORMATION (new)

The name is taken from the town of Dargaville which is partly built on sediments of this formation which replaces in part the Kaihu Formation of Brothers (1954) and is a correlative of Kear's (1957) Ohuka Formation and Fleming's (1953) Okiwa Group (Fig. 2). The formation in its type locality is exposed in roadcuts along Hokianga Road, Kaihu Valley (Fig. 1). Altonian and older rocks unconformably underlie the formation; in places (undifferentiated) Quaternary sandstones unconformably overlie it.

The formation is typically very fine grained (with the exception of basal conglomerates), poorly sorted, and very positively (fine) skewed. The clay-silt content in the sands usually exceeds 20%, much of it of secondary origin. The sands also have a low heavy mineral content ($< 0.5\%$) despite common yellow-brown iron staining. The lack of heavy minerals may indicate the West Auckland Sand Facies (Schofield 1970) was not in existence in Hautawan time, or that the Dargaville Formation received little or no west coast sediments, or removal of heavy minerals was accomplished by weathering and leaching. The second possibility is somewhat unlikely at this early stage of the North Kaipara Barrier's history because of a probable coastal situation. The last possibility is more likely if the original heavy mineral content of the sands was also low.

Dark-brown biotite in these sediments is not generally found in younger formations. Local Lower Miocene rocks which commonly contain dark-brown biotite (Fortune 1968) are a likely source for much of the Dargaville Formation sediments.

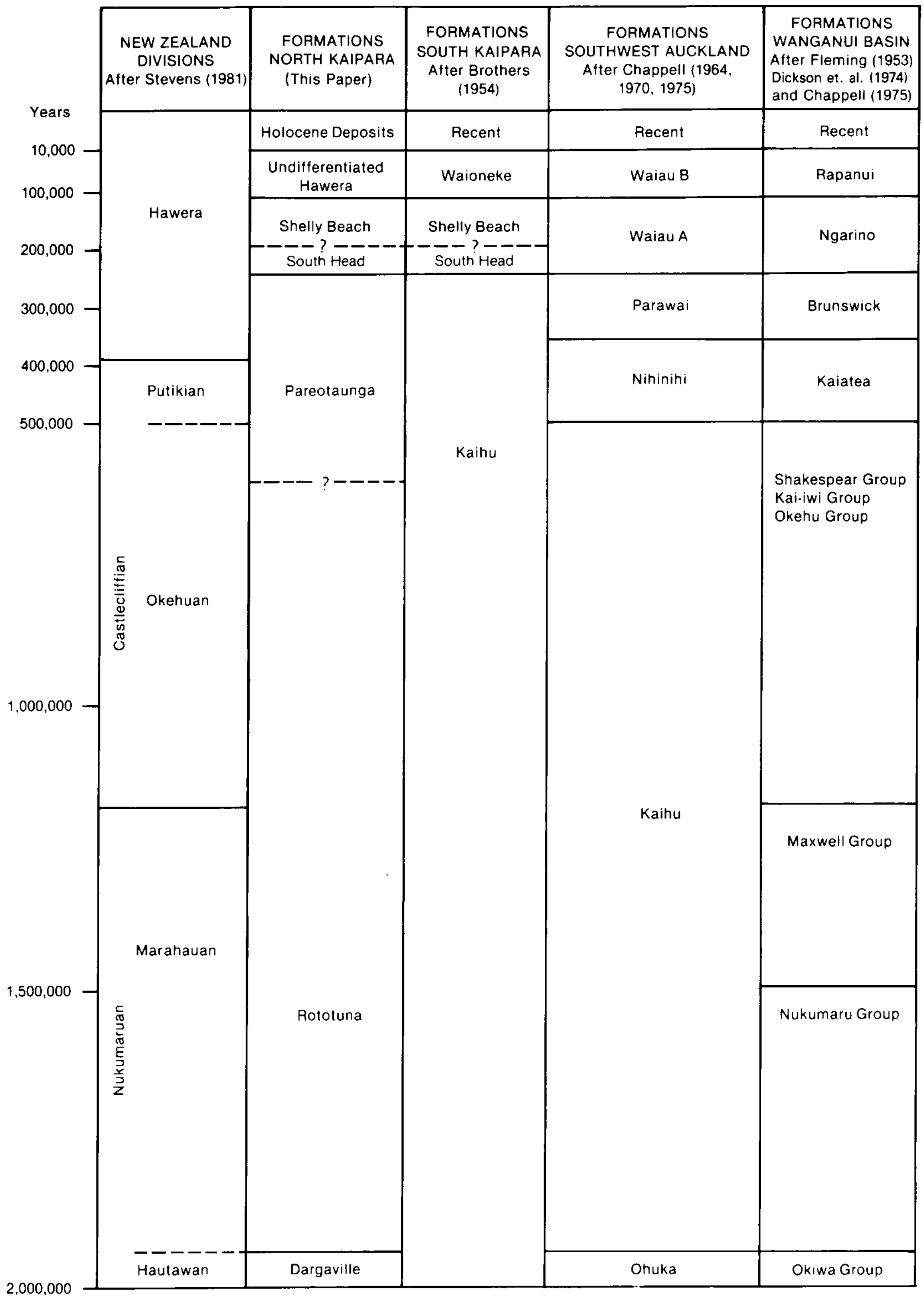

Fig. 2 Correlation of North Kaipara Formations with other west coast sediments.

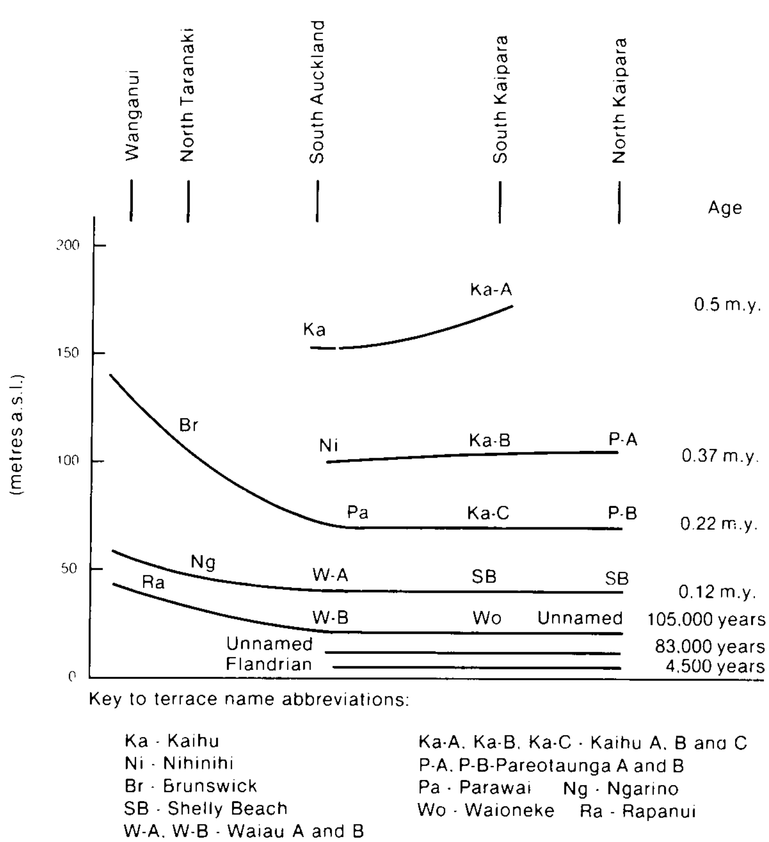

Fig. 3 Terrace associations, Wanganui to North Kaipara (after Chappell 1975).

Two lignites, P7/f9579 (N23/f579)* and P7/f9582 (N23/f582) from the formation have been dated palynologically as Hautawan by D. C. Mildenhall (Appendix 1). From the palynology he envisages a coastal river valley with savannah woodland in the drier areas (fixed dunes) and forest on the floor of the valley. The description is not unlike that for the area at present. Mud at site P7/f9582 has a similar clay–silt ratio to that of the modern Wairoa River sediment. Mildenhall (1975a) believes the early Hautawan represents a period of dry and/or windy conditions the same as or slightly cooler than the present day.

From the base upwards, the formation consists of: (1) coarse conglomerate (about 2 m); (2) clay or fine sand with chert pebbles, claystone pebbles, and other rock fragments (up to 20 m); (3) fine dune sands (about 7 m); (4) lignite at 20 m a.s.l. (up to 6 m); (5) horizontally bedded, alternating clay and fine sands (13 m); and (6) horizontally bedded fine muddy sand (12 m). The total thickness of the formation is at least 50 m and ranges from below sea level to 46 m above sea level.

It appears that the Hautawan lignites were deposited when relative sea level was perhaps a little less than 20 m above present and was rising (transgression) to at least 46 m above sea level. This transgression could have been the initial phase of the general Kaihu transgression of Brothers (1954) and Chappell (1970).

The highest sea level recorded in the Kaipara area is 170 m (Brothers 1954) which is a correlative of the 500 000 year old 155 m stand of Chappell (1975). Average subsidence (transgression) can be calculated assuming that absolute sea levels at about 2 000 000 and 500 000 years B.P. were nearly the same. Thus, average subsidence in this transgression was (170−20)/1500 = 0.1 mm/year, about 1 m in 10 000 years.

Trace levels at 40, 24, and 8 m a.s.l. were cut into Dargaville sediments in Hawera time and are not related to deposition of the formation.

*Fossil locality number recorded in the New Zealand Fossil Record File based on the 1:50 000 topographical map series (NZMS 260); the relevant fossil record number based on the 1:63 360 topographical map series (NZMS 1) is given in brackets.

ROTOTUNA FORMATION (new)

The name is taken from the Rototuna area where a 105 m terrace cuts into subdued dune forms. The formation replaces in part the Kaihu Formation of Brothers (1954) and is a correlative of Chappell's (1970) Kaihu Formation and Fleming's (1953) Nukumaru, Maxwell, Okehu, and Lower Kai-iwi Groups (Fig. 2). It is assumed (no sections seen) that the formation conformably overlies Dargaville Formation and unconformably underlies Pareotaunga Formation. At Ru Point (Q9/144464), Shelly Beach Formation unconformably overlies the formation. It is estimated (Fig. 2) that the Rototuna sediments represent over one million years of deposition during which the barrier grew southward (alongshore) and vertically.

The formation is distributed over the full length of the barrier (Fig. 1). Near the North Head lighthouse (Q9/131342) there is about 63 m of Rototuna Formation, indicating that the North Barrier extended farther south at the end of Rototuna deposition. At that location, 4 m of lignite containing an ash bed, cap the Rototuna Formation. Mildenhall (Appendix 1) believes the base of the lignite Q9/f9577 (N33/f577) is Castlecliffian or younger.

Old subdued dunes up to 165 m a.s.l. form the bulk of the sediment, and some marine sands can be seen along the southeast coast where the formation also passes below sea level. The fine grained (average median size Md = 0.21 mm) yellow-brown dune sands are highly weathered, particularly above 105 m where little erosion has taken place. They are commonly structureless and appear to have a high secondary clay content. Heavy mineral content ranges from 5% near the west coast to less than 0.1% at the east coast. It is likely the West Auckland Sand Facies (Schofield 1970) was in place during this time and that the harbour was becoming a closed system as Schofield suggested.

A peat P7/f7580 (N23/f580) and a lignite Q9/f7906 (N28/f906) within the formation are younger than Hautawan but no younger than Okehuan (D. C. Mildenhall, Appendix 1; Mildenhall 1975b). Mildenhall believes these lignites were deposited in a coastal environment similar to that described for the Hautawan samples but with full forest conditions (dominated by beeches and podocarps) existing close to the sites. The lignite Q9/f7906 is extremely woody and supports the value of 82% tree pollen derived by Mildenhall. Pollen of both warm and cool associated plants were found in the samples. The presence of wood of *Libocedrus bidwillii* (R. N. Patel pers. comm.) in Q9/f7906 supports a cooler than present climate. In the same lignite, abundant gum is present although no *Agathis* pollen or leaf material was seen.

It appears the lignites were formed during a major regression in Okehuan time as both sites are only 15 m a.s.l. and it is likely that sea level was at least as low as at present. An Okehuan regression during the general Kaihu transgression was alluded to by Chappell (1975). During the low stand, the barrier was at least as large as at present and the major modern valleys were cut. In Nebraska, the Kansan Stage may have lasted from 1.2 m.y. to perhaps as late as 0.6 m.y. (Boellstorff & Te Punga 1977). If the Kansan and Okehuan Stages are correlative, the valleys would have been eroded during a glacial stage 600 000 years long. Much of the upper Rototuna dune sands may have been deposited during the early phases of this regression when large areas of the shelf would have been exposed.

Well-preserved terraces at 105 m and 67 m are cut in many places in Rototuna sediments. Brothers's (1954) 170 m terrace was not identified and Rototuna sediments are found only to 165 m a.s.l. The subdued appearance of the dune forms may thus be related to washing during the transgressional high stand which may have occurred 500 000 years B.P. (Chappell 1975).

PAREOTAUNGA FORMATION (new)

The name is taken from the Pareotaunga Point (first point south of Ru Point, Fig. 1) where the formation crops out. The formation replaces in part the Kaihu Formation of Brothers (1954) and is a correlative of Chappell's (1964) Upper Kaihu, Nihinihi, and Parawai Formations. In the Wanganui Basin, the Upper Kai-iwi, Shakespeare, Kaiatea, and Brunswick units of Fleming (1953) are likely correlatives (Fig. 2).

The white to light buff, fine-grained (Md = 0.18 mm) estuarine and (minor) dune sands are characterised by striking differential weathering (Fig. 4). The sands have less clay content than the Dargaville and Rototuna Formations and it is thought to be mainly primary (Richardson 1975). Heavy mineral content does not exceed 2.5%, indicating that little west coast material is incorporated in the sediments. Most of the sand is probably reworked from the Rototuna Formation. Pareotaunga sands are also more quartzitic than those of the Rototuna Formation, and this may indicate weathering and reworking (Schofield 1970).

The sands are generally crossbedded, but horizontal stratification is common and often seen below terrace surfaces (105 m terrace, P8/835780). The best exposed and thickest Pareotaunga sequences are in the southeastern part of the barrier adjacent to the 105 m and 67 m terrace surfaces. Pareotaunga sediments occur along the length

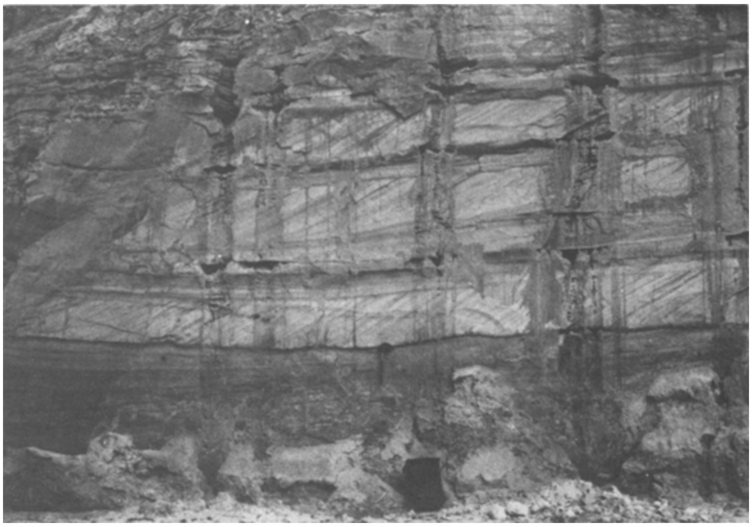

Fig. 4 Crossbedded Pareotaunga Formation near Waikere Creek (Q9/150426) displaying differential weathering.

of the barrier (Fig. 1) and some dip into valleys formed during the Okehuan regression (P8/039525).

Pareotaunga sediments are believed to have been deposited during the major Kaihu transgression to 170 m above present sea level, about 500 000 years B.P., and during other high stands at 370 000 (105 m) and 220 000 (67 m) years B.P. (Chappell 1975; Fig. 3). At least one regression or stillstand during the overall transgression is recorded in the sequences. A lignite, Q9/f9575 (N33/f575), at 10 m a.s.l., lies on estuarine sands and is buried by 60 m of estuarine sands. Mildenhall (Appendix 1) found a rich palynoflora with an assemblage that represented a coastal swamp surrounded by a lowland forest. The climate was not unlike that at present although possibly wetter. No age-significant fossils were present, but Mildenhall believes the lignite to be no older than Castlecliffian. From its stratigraphic position, we believe that the lignite occurs very low in the Pareotaunga Formation. Several other thin lignite beds occur in this unit, possibly indicating other stillstands or regressions of unknown magnitude.

Pareotaunga sedimentation ended with a major regression after the +67 m stand.

SOUTH HEAD FORMATION (Brothers 1954)

This formation was described by Brothers (1954) from the South Kaipara Barrier with its reference area at South Head. The unit is correlative in part to the Waiau A (Chappell 1964) and the Ngarino Formations (Dickson et al. 1974; Fig. 2).

A 15 km long, 4 km wide band of lobate transverse dunes aligned with respect to a southwest wind (similar to that of today) is easily mapped in the eastern North Head–Pouto area (Fig. 1). Brothers (1954) recognised the formation in the cliffs north of Pouto on the North Barrier. Near Tauhara Creek (Q9/163402), South Head Formation sits unconformably on Pareotaunga Formation and beneath Shelly Beach Formation, while at Pouto it passes below sea level.

The formation is made up of crossbedded brown, or reddish-brown, deeply weathered, fine-grained (Md = 0.16 mm) dune sands. The sands appear to have a high secondary clay component and high heavy mineral content, the latter ranging from 14.5% to 5%. The high heavy mineral content may indicate that the Kaipara Harbour mouth was in a similar position to that at present, because examination of modern beach sands along the Kaipara Barrier coasts shows that heavy mineral content decreases away from the harbour entrance (Schofield 1970; Yock 1973; Richardson 1975).

South Head deposition began during the regression following the +67 m (220 000 year B.P.; Fig. 3) stand. During this regressional period, valleys were enlarged along the barrier. The sea-level curve of Chappell (1974) and Bloom et al. (1974) shows a major regressional period between 220 000 and 160 000 years B.P., with a small transgression at 180 000 years B.P., and a possible transgression at 200 000 years. Assuming Chappell's (1975) uplift rate of 0.3 mm/year for the North Kaipara area, local relative sea levels during the minima would have been about −55 m at 205 000 years, −69 m at 190 000 years, and −118 m at 160 000 years B.P. Schofield (1975) postulated that in correlating a sea-level fluctuation with coastal progradation, it is not the maximum fall of sea level during a fluctuation that is important, but the net fall between sea-level maxima. The net local (adjusted) fall between the 220 000 year maximum and the 180 000 year maximum would have been about 50 m, while there was a net 30 m rise in sea level between 180 000 and 125 000 years B.P. Schofield (1975) also demonstrated that dune building during the Holocene responded rapidly to sea-level fluctuations. This seems likely to have been so also at earlier times, so the bulk of the South Head Formation was probably deposited during the regressional phase 220 000–190 000 years B.P. (Fig. 2).

SHELLY BEACH FORMATION (Brothers 1954)

Horizontally bedded estuarine sands and clays below a 40 m terrace at Shelly Beach (South Barrier), named Shelly Beach Formation by Brothers (1954), can be seen in different areas to sit unconformably on his Kaihu Formation or South Head Formation, in many places containing sandstone pebbles of those formations. The Waiau A (Chappell 1964) and the Ngarino Formations (Dickson et al. 1974) are in part likely correlatives (Fig. 2).

Shelly Beach Formation has been recognised along the eastern side of the North Kaipara Barrier. Its sediments are not extensive but can usually be found wherever the 40 m (120 000 year B.P., Chappell 1975) terrace occurs, and particularly near headlands where the potential for erosion of older sediments is greatest. At Tauhara Creek (Q9/163399) it can be seen unconformably overlying both South Head and Pareotaunga Formations and containing boulders of the latter.

The yellow fine-grained (Md = 0.24 mm) Shelly Beach sands appear to be of mainly estuarine and dune origin and are impoverished in clay and heavy minerals as is the Pareotaunga Formation. Most of the sand is thought to be slightly reworked Pareotaunga and Rototuna Formation sediments.

Undifferentiated Kaihu Group sediments

Some sediments on the North Kaipara Barrier have little or no lithologically distinctive characteristics, are difficult to date, and are commonly very local in distribution. Sediments related to the unnamed 24 m and 8 m terraces of the barrier are examples.

Other sediments such as the late Pleistocene dune sands can be separated as a group from Holocene dune sands and South Head Formation on geomorphic evidence but are not sufficiently well known to erect new units. A correlative of the Te Akeake Sands Member (Pain 1976) eventually will be delineated along the west coast in the northern half of the barrier. Holocene dune sands appear to have buried Hawera dunes near North Head.

Sediments exposed over 70 km of the west coast appear to be mainly dune sands of similar mineralogy separated by numerous lignites and paleosols at all levels from below sea level to about +75 m. These sediments are likely to be facies equivalents of Rototuna and younger sediments, but mixing along the west coast has masked definitive characteristics.

Lignite beds are well exposed near sea level, particularly where they extend below mean sea level. Some individual beds can be traced for over 3 km (O7/650004–660992) but most pinch out in a few tens of metres into what appears to be old soils (often marked by an iron pan). Beds are up to 9 m thick (P7/741879, Fig. 5) but most are 1–5 m thick.

The lowermost of three lignites, P7/f9583 (N23/f583), exposed in a cliff section near Baylys

Fig. 5 A 9 m thick lignite forming the lower portion of the coastal cliff at Keiwaikare Valley (P7/741879); sample P7/f9581 (N23/f581) was taken from the lower right.

Beach (P7/771837), contains seeds of an apparently extinct plant (C. J. Burrows pers. comm.) and may be early Pleistocene in age. Palynologic study of other lignite beds, O7/f9502 (N22/f502), P7/f9581 (N23/f581), and Q9/f9577 (N33/f577), indicates a Castlecliffian or younger age and a climate similar to the present (Mildenhall, Appendix 1). A pollen assemblage from the base of a 9 m thick lignite bed, P7/f9581, at sea level, Keiwaikare Valley (P7/741879), is similar to that of another Q9/f8500 (N32/f500), at 10 m a.s.l. in Pareotaunga Formation sediments 55 km to the southeast. The Pareotaunga Formation is late Pleistocene (Fig. 2). Since a 67 m terrace is cut in sands above P7/f9581, that lignite must be older than 220 000 years (Fig. 3).

Other lignites along the coast may be much younger, particularly those near the top of the cliffs. However, height above sea level cannot be used to assess relative ages because lignites can form at any altitude and are more readily preserved in valley cuts and interdune areas. Onshore prevailing winds and available fine sands are responsible for burial and preservation of the numerous lignite beds along the coast. Close sampling for palynology and dating of (rare) ash layers will be needed to establish a stratigraphy.

Holocene deposits

Silty clays and estuarine sands forming swampy terraces 2–4 m a.s.l. are common in the eastern part of the barrier, while drifting and fixed fine-grained dune sands are found in the southwestern part (Fig. 1). The dune sands are unweathered and characteristically have more than 5% heavy mineral content (Schofield 1970; Richardson 1975). Both terraces and dune sediments are related to the Holocene transgression which reached a local maximum of +2.1 m, 4425 years ago (Schofield 1975).

Five distinct dune belts of Holocene age were described by Schofield for the South Kaipara Barrier. On the North Barrier it seems that a similar, but somewhat more complicated, zonation exists, as the southeasternmost dunes are still active (Fig. 1).

HOLOCENE RADIOCARBON DATES

At Ureti Stream (O7/654998), on the west coast, a slab of cemented rock (60 × 35 × 5 cm, Fig. 6) was collected from the modern storm strand. It is assumed that the slab was ripped off the sea floor and tossed on the beach by wave action. One side was slightly abraded indicating some erosion before being dislodged. The other (lower) side, showing no erosion, indicates that the slab has been dislodged very recently and has undergone little transport. Kear & Bowen (1970) and Ricketts (1981) have discussed the origin of similar cemented rocks from Northland.

The shells, which appear to have been *in situ*, include abundant *Austrovenus stutchburyi* (Wood), *Zearcopagia disculus* (Deshayes), *Mactra (Cyclomactra) ovata* (Gray), *Zeacumantus lutulentus* (Kiener), *Chemnitzia*, Patellidae, and *Ammonia beccarii* (Linné). This association is essentially that found on present-day east coast (harbour) tidal flats. It is likely that the rock records a lagoonal environment of deposition. Shell and matrix material have been dated at 10 100 ± 200 years B.P. (matrix—NZ3906B) and 8610 ± 140 years B.P. (shells—NZ3907B). The late T. Grant-Taylor (pers. comm.) cautioned that the high $\delta^{13}C$ values of −35.9‰ matrix and −7.1‰ shells may indicate problems with the dates, but he regarded a Postglacial age as reasonable. The $\delta^{13}C$ value for the shells may indicate some adhering matrix material, while the $\delta^{13}C$ value for the matrix may indicate a terrestrial source for the carbon in the carbonate cement.

If the shell date of 8610 ± 140 years B.P. is accurate, the shells were deposited during one of the stillstands in the Holocene transgression when sea level was about 22 m below present (Gibb 1979).

At Treasure Bay (Q9/139468), north of Ru Point, wood from a lignite bed, Q9/f9576 (N33/f576), 1–2 m below sea level and 25 m offshore, produced a date of 7050 ± 90 years B.P. (NZ3871C; corrected for secular effect). The lignite appears to have been buried by estuarine sediments when Holocene sea level first approached the present level.

Palynologic study indicates that the lignite formed in a coastal swamp surrounded by kauri forest (Mildenhall, Appendix 1). Mildenhall found that Cyperaceae (65%) and *Agathis australis* (13%) were dominant and *Libocedrus*, probably *L. plumosa*, a common lowland forest element, was present. Leaves of *Agathis australis* and a 1 m diameter stump of *Leptospermum*, probably a very large kanuka (*L. ericoides*), were identified (R. N. Patel pers. comm.).

CONCLUSIONS

1. All the sediments forming the North Kaipara Barrier belong to the Kaihu Group and range from Hautawan to Recent in age.
2. The Dargaville Formation of Hautawan age was deposited in an estuarine situation during a transgressional period with relative sea level near that of the present. Climate was probably dry and/or windy, while temperatures were the same as, or slightly cooler than, today's.

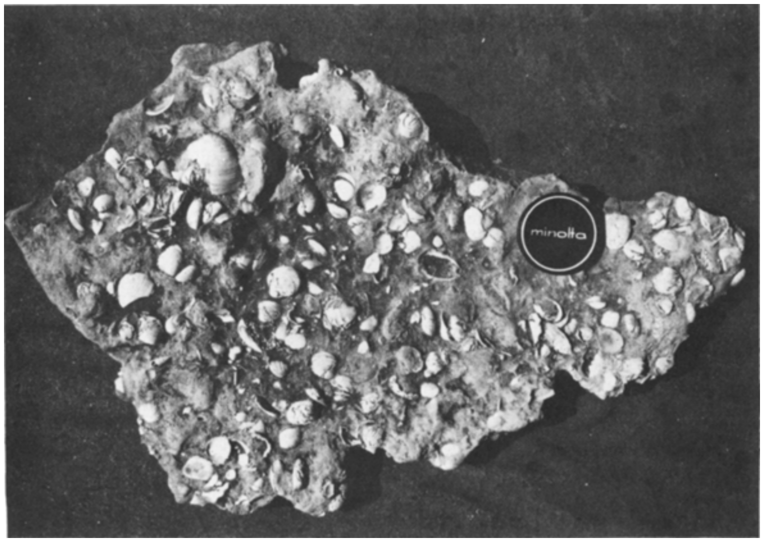

Fig. 6 Upper surface of carbonate-cemented shelly slab 07/f9500 (N22/f500) dated at 10 100 ± 200 years B.P. (NZ3906B, matrix) and 8610 ± 140 years B.P. (NZ3907B, shells) (scale: lens cap is 50 mm diam.).

3. Rototuna Formation, which forms the bulk of the barrier's sediments, was deposited during a period of over one million years. In Okehuan time, at least one major regression occurred and the existing major valleys were cut. The barrier has changed little since late Okehuan time.

4. Pareotaunga Formation sediments are related to sea-level stillstands during the general Kaihu transgression at 170 m (500 000 years), 105 m (370 000 years), and 67 m (220 000 years B.P.) during the late Pleistocene regression (uplift).

5. Dune sands forming the bulk of the South Head Formation were probably deposited during the regressional period 220 000–190 000 years B.P. The harbour entrance at that time was in the modern position, and coastal sediment transport and provenance were the same as at present.

6. Shelly Beach Formation is not extensively distributed on the North Barrier but is associated with a 40 m terrace.

7. More work is needed to characterise and differentiate younger Hawera sediments and to fully understand climatic and vegetational changes from the record of peat deposits.

8. Holocene sea levels did not reach present levels until after 7000 years B.P.

9. A high Holocene sea-level stand at 2–4 m a.s.l. is in evidence, and dunes related to the regression to present sea level are common in the southwestern area of the barrier.

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APPENDIX 1

Quaternary palynology: North Kaipara Barrier

D. C. MILDENHALL

INTRODUCTION

Fourteen spot samples from lignites interbedded with dune sands, situated along the west coast of Northland, New Zealand, from about Maunganui Bluff south to Kaipara Harbour, produced a rich and varied palynoflora (Table 1). The geology of North Kaipara Barrier is described in the associated paper.

Origins

The lignites have at least two different origins. Some are formed in small basins of internal drainage and as pockets trapped within migrating dune sands. These lignites are relatively thin seams of little lateral extent. Pollen from these deposits tend to reflect the local swamp vegetation to the virtual exclusion of the regional pollen species which would tend to give a more accurate idea of paleoclimate. A second type of lignite, of much greater lateral extent, forms in river valleys and estuaries. These lignites, which are up to 9 m thick, can be traced for several kilometres along the west coast. Their thicknesses can be quite variable, appearing to grade into old soils mantling some of the dunes. These lignites tend to have a higher proportion of regional pollen types (i.e., the palynofloras have a much larger number of species, and swamp pollen types are less abundant). Large forest trees, including kauri and beeches, grew on or very close to these sites of deposition and their fossil remains (leaves, fruits, wood) are preserved in what appears to be a forest floor litter. Samples from these lignites give us a much better basis for determining paleoclimate, paleoecology, and age. These lignites also tend to contain marine dinoflagellates indicating a definite coastal swamp and/or estuarine environment.

PALYNOLOGY

All pollen and spores identified are listed in Table 1 and all relevant locality data are listed in Table 2. Some key fossils are illustrated (Fig. 7–15). The ages of samples containing key taxa are based on data presented in Fig. 16. The original fossil record forms are held in the master file at Auckland District Office of New Zealand Geological Survey (Otara). Each sample will be discussed separately, as follows, with L numbers representing the slide catalogue of the Palynology Section, New Zealand Geological Survey, Lower Hutt. The fossil locality numbers are those recorded in the New Zealand Fossil Record File based on the 1:50 000 topographical map series (NZMS 260). The relevant fossil record number based on the 1:63 360 topographical map series (NZMS 1) is given in brackets.

O7/f9502 (N22/f502)—L6936

This sample is dominated by *Dacrydium cupressinum* (37%) and *Podocarpus* (19%) with abundant Restionaceae (29%) growing on site and swamping the regional pollen rain. Kauri (*Agathis australis*) macroplant fossils occur at this locality, but the pollen of kauri is relatively rare (3%), presumably because it does not preserve well. A warm temperate, moist, coastal forest is indicated by the pollen, but the local environment is that of an acid peat swamp.

The age must be Castlecliffian or younger on the lack of extinct taxa. An undated tephra immediately overlies this sample.

P7/f9579 (N23/f579)—L6869

This sample is dominated by Myrtaceae pollen (29%) representing *Leptospermum, Metrosideros, Eugenia,* and *Eucalyptus.* Other abundant pollen types are *Phyllocladus* (14%), *Nothofagus menziesii* (12%), *N. "fusca"* group (?*N. truncata*) (7%), *Dacrydium cupressinum* (5%), and *Podocarpus* (5%). Leaves of *D. cupressinum* (Braggins pers. comm.) and seeds of *P. spicatus* (Burrows pers. comm.) have been identified. The presence of *Polycolpites reticulatus* Couper, a monad of *Acaciapollenites, Nothofagidites cranwellae* (Couper) (Fig. 10, 11) and *Proteacidites minimus* Couper (Fig. 13, 14) indicates an age no younger than Hautawan; the presence of *Toronia (Persoonia) toru* suggests an age no older than Hautawan; its present distribution is between latitudes 35°S and 38°S in the lowland or montane shrubland and forest. Full forest conditions existed close to the site of deposition. The presence of large numbers of *Nothofagus menziesii* pollen suggests either cooler conditions or deteriorating soil conditions. It is found south of about Tauranga where a relict stand exists. In North Island it is not common below an altitude of 600 m (Wardle 1967). It is common in Hautawan samples and occurs, also with abundant Myrtaceae, in the Ohuka Carbonaceous Sandstone (Mildenhall 1975a) of Hautawan age. This sample equates well with those from the Ohuka Carbonaceous Sandstone and may well represent a wind-induced(?), open savannah-like coastal environment, but with moister forest conditions nearby to produce pollen from taxa like *Dacrydium cupressinum* and *Dacrycarpus dacrydioides.* Dinoflagellates occur in the sample indicating an estuarine environment, possibly a coastal river valley with savannah in the drier areas (fixed dunes) and forest on the floor of the valley. Leaves of broadleaf plants occur in the lignite, including *Beilschmiedia taraire* indicated by J. E. Braggins, University of Auckland.

P7/f9581 (N23/f581)—L6871

This sample is dominated by *Nothofagus "fusca"* group beech (64%) and *Dacrydium cupressinum* (21%). Leaves of *Dacrydium cupressinum, Podocarpus totara, Agathis, Cyathodes,* and *Nothofagus truncata*; wood of *Dacrydium colensoi, Agathis,* and Myrtaceae; and seeds of *Elaeocarpus dentatus, Eleocharis sphacelata,* and *D. cupressinum* have been identified (Burrows pers. comm.; Braggins pers. comm.). Tree pollen forms 91% of the total pollen, and the assemblage is indicative of a moist, warm temperate forest. No extinct taxa occur, and the age is probably Castlecliffian or younger.

Table 1 List of palynomorphs found in Hautawan–Holocene lignites of North Kaipara Barrier, Northland, New Zealand. For Cruciferae read *Nestegis*.

SPECIES	07/f 9502	P7/f 9579	P7/f 9581	P7/f 9582	P7/f 9587	P8/f 7580	P8/f 9533	P9/f 7536	P9/f 7537	Q9/f 7906	Q9/f 8500	Q9/f 9575	Q9/f 9576	Q9/f 9577
Sheet fossil number → Slide Number L	6936	6896	6871	6872	6944	6870	6873	6945	6946	6874	6875	6876	6877	6947
Bryophyta:														
Cingulatisporites bifurcatus		x				1								
Rudolphisporis rudolphi						x								
Sphagnum						x		1	x					2
Lycopodophyta:														
Lycopodium billardieri group	x	x		x		x			x			x		
L. deuterodensum		x				1				1				
L. fastigiatum group								1						
L. laterale	20													
L. volubile									x					
Pteridophyta:														
Asplenium		x												
Blechnum		x											1	
Cyathea	5	26	37	16	5	1	x	12	21	1	5	59	5	14
C. dealbata	x	x	x	x	x			x	x			x		x
C. medullaris		x	x	x								x		
C. smithii	x	x	x		x			x	x					x
Dicksonia squarrosa		1		x	x	x	1	1	x	2		5		
Gleichenia circinata	30	1		66	x	.200	5	x	1	68	3	1	1	
Grammitis				1				x						x
Histiopteris incisa		1		x								3		
Hymenophyllum		x		1	x					x				
H. sanguinolentum										x				
Hypolepis		x										x	9	
H. tenuifolia												2	x	
Lindsaea linearis			x			x				x				
Lygodium articulatum		x		1		x								
Paesia scaberula		1		?		1								
*Peromonolites problematicus				?										
Phymatodes diversifolium		3		4		x		x	1	1		x		
*Polypodiisporites n.sp.				3		x				3		x		
Psilotaceae						x								
Pteridium aquilinium			x											
Pyrrosia serpens		x												
unidentified monolete spores	5	25	1	5	3	x	2	4	5	1	7	41	28	1
unidentified trilete spores				x										
Gymnospermae:														
Agathis australis	8				x			3	5				40	
Dacrycarpus dacrydioides	1	5	2	x	3			12	2	x		x		1
Dacrydium bidwillii/biforme	15	6		3	2	26	32	19	6	23	1	9	5	6
D. cupressinum	100	22	66	1	3	11	37	100	60	13	2	12	9	47
Libocedrus plumosa								7	1			x	2	3
Phyllocladus	12	64		x	3	78	100	24	9	100	3	1	7	
Podocarpus	58	x	x	x	x	x	4	104	100	x	x	x	x	51
P. ferrugineus	x	8	14	x	x	12	4	x	x	1		4	5	x
P. hallii												x		
†P. spicatus													3	x
P. totara	x	15			12	33	3	x	x,	8	2	14	5	x
Angiospermae; dicotylous														
*Acaciapollenites myriosporites		2		2		x								
Araliaceae		1		2	4	x	x	2	4	1		6		1
Ascarina lucida	1	14		1		x	x			1		x	x	
Balanophoraceae								x		x				
*Beaupreaidites elegansiformis				x						?				
Callitriche		x		x	x			x	x	x		12		81±
Chenopodiaceae	x				x	x		x	1			x		
Colobanthus												x		
Compositae (Tubuliflorae)	1	2			1	5		1	3	x		x		
Coprosma	2	6	3	24	3	2		3	4	x	1	10	1	
Coriaria		1												
*Cranwellia striata				x										
Cruciferae		21	3	3	3	1	2	3	2	2		x	x	x
*?Cupanieidites										x				
Cyathodes fasciculata		x			x	x			x	x		x	2	
Dactylanthus taylori								x						
Dodonaea viscosa		4		1		2	x					x	x	
Dracophyllum group	x	x	4	2	3	29	5	3	2	6	1	2		
Dysoxylum spectabile					2									
Elaeocarpaceae						2								
Elytranthe colensoi			x	1	1			x		x				
Epacris	1	x		2						?		x		
Epilobium												x		
*Eucalyptus		x		x										
Eugenia maire		1		x		2						2		
?Euphrasia												x		
Fuchsia		x												
Gaultheria		x												
?Geniostoma ligustrifolium		?												
Gentiana		x												

Grislinia								2				4		
Gunnera				x	x		1?							
**Haloragacidites harrisii*				1		x		x		?			x	
Haloragis		1				x						x		x
H. micrantha												x		
Hebe		14		1		x	1	1				9		
Hoheria		x				x								
Hydrocotyle	x			x	x			1	1			4	1	
H. novaezelandiae					3									
Ixerba brexioides		1							1				x	
Knightia excelsa		5	x			x	2	x	3	x		x	x	2
?Laurelia novaezelandiae												1		
Leptospermum	1	28	x	32	x	3	13	x	x	10		21	6	x
L. ericoides					32			1	1					
L. scoparium			3					45	26	x		x		35
Leucopogon								x		x				
Lophomyrtus		1		x								x		
Loranthus micranthus		x				x	1					1		
Melicytus		x			2		4			x				
Metrosideros		100	9	68	1	2	10	42	54	1		76	2	100
M. robusta		x		x				x	x			x		x
Muehlenbeckia		1						x						1
Myosotis						1	1					x		
Myriophyllum			1					x						
Myrsine	3	6	2	5		1	3	8	5	2	1	x	8	2
**Nothofagidites cranwellae*		x		1										
Nothofagus fusca group	1	31	200	50	7	7	7	55	4	78	45	6	x	6
N. menziesii		53		17	27	5	2	3		3		1		
N. truncata		?	x											
Papilionaceae										x				
Plagianthus	1						1	1	x	x				1
**Polycolpites reticulatus*		x		1										
**Proteacidites franktonensis*				1										
**P. minimus*		x					?					?		
Pseudopanax				3					x			1		4
Pseudowintera	x	x	·3	3				1	1?			x	x	
Quintinia (?serrata)		x			100	2	10	x	x	x				
Ranunculaceae		x		x								1?		
Rosaceae				x										
Rubus		x												
Salicornia australis									?					
**Sparsipollis papillatus*				x										
Toronia (Persoonia) toru		x	x	x		x	1	1	x	x			1	
Tupeia antarctica		x	x	2	2	2						1		
Umbelliferae	1			2	3		1	x	x			x	x	x
Weinmannia								1						2
unidentified pollen	3	7		6	1		2			1		15	1	
Angiospermae; monocotylous:														
Arthropodium		2		x		1								
A. cirratum				1										
Astelia	1	1		1	x	1		x				1	1	x
A. nervosa					2									
Cordyline								x						
Cyperaceae	4	6	x	41	12	3	4	11	6	8	5	100	200	1
Dianella nigra													1	
Freycinetia	1	1		2		1	3					x		
Gramineae	1	3		x				1		x		1	x	
Liliaceae				3			1			x		?		
**Liliacidites*				x										
Phormium cookianum												1		
P. tenax				6	x				x	x		3	2	
Potamogeton		3												
Restionaceae	89	10	1	x		55	32	4		17	7	5	3	
Calorophus	x					x	x							
Leptocarpus	x					x	x							
Rhopalostylis sapida							x							
Sparganium	3			3				x				6	2	x
Typha orientalis		x										3		
Dinophyceae:		x									x			
Chlorophyceae:														
Botryococcus									x					
Total count	368	504	349	389	240	489	295	478	329	352	83	444	351	361
Percentage tree pollen %	63	46	91	18	25	60	66	71	62	82	78	14	25	33
shrub pollen %	4	43	8	67	65	18	19	24	35	8	4	46	7	43
herb pollen %	33	11	2	13	10	21	15	4	3	10	18	40	67	24

(tree pollen = beech + gymnosperms)

x = present.
? = uncertain identification.
† = *Podocarpus spicatus* is almost certainly more abundant than the table suggests; it is probably included in the the *P. totara* count.
± = see text.

Sheet and fossil record no.	Slide no.	Grid reference	Locality (abbreviated)
O7/f9502	L6936	66179911	¾ km S of Ureti Stream
P7/f9579	L6869	84848633	¾ km SE of intersection State Highway 12 and Scottys Camp Rd
P7/f9581	L6871	74188791	Coast, 6½ km NW of Baylys Beach
P7/f9582	L6872	86978710	1½ km NW of Dargaville
P7/f9587	L6944	77909650	1¼ km NW of Mamaranui
P8/f7580	L6870	91227582	Redhill Rd, 1½ km NW of Te Kopuru
P8/f9533	L6873	96936395	1½ km W of Tikinui
P9/f7536	L6945	05274844	Near Lake Rototuna
P9/f7537	L6946	05274844	Near Lake Rototuna
Q9/f7906	L6874	13204749	1½ km SE of Beacon Point
Q9/f8500	L6875	10084392	3 km NW of Lake Humuhumu
Q9/f9575	L6876	14614543	Toetoe Point
Q9/f9576	L6877	13924683	½ km NW of Ru Point
Q9/f9577	L6947	13203422	1 km E of old lighthouse

Table 2 Locality data for all samples mentioned in Appendix 1. Grid references and fossil record numbers are based on the national thousand-metre grid of the 1:50 000 topographical map series (NZMS 260).

P7/f9582 (N23/f582)—L6872

This sample is very similar to P7/f9579 being dominated by Myrtaceae (34%; including *Metrosideros, Leptospermum, Eucalyptus*, and *Lophomyrtus*) and "*fusca*" beech (17%). Other prominent pollen types are *Nothofagus menziesii* (6%), *Coprosma* (8%), and Cyperaceae (14%). A number of extinct taxa occur—*Acaciapollenites myriosporites* (Cookson) (Fig. 8), *Beaupreaidites elegansiformis* Cookson (Fig. 9), *Proteacidites franktonensis* Couper (Fig. 15), *Nothofagidites cranwellae, Cranwellia striata* (Couper), *Haloragacidites harrisii* (Couper), *Polycolpites reticulatus* (Fig. 12), *Sparsipollis papillatus* Mildenhall & Crosbie, and *Polypodiisporites* n. sp.—which together indicate an age no younger than Hautawan. *Toronia toru* is known to appear towards the top of the Hautawan in the north and south Auckland area (author's records). The paleoenvironment is the same as P7/f9579, namely, a coastal river valley floor with swamps and moist forest and savannah-like vegetation on the drier dunes above the forest. Coastal plants are common—*Ascarina lucida, Dodonaea viscosa, Arthropodium*, and probably *Acacia*—as are swamp taxa including *Dacrydium colensoi* (wood, Patel pers. comm.), *Phormium tenax* (including seeds, Burrows pers. comm.), *Sparganium*, Restionaceae, Cyperaceae, and *Gleichenia circinata*. Pollen deposition was into an acid peat swamp. *Acacia* is abundant on the slides and indicates an open environment (Mildenhall 1972). Leaves of *Beilschmiedia taraire* have been identified from this locality (Braggins pers. comm.).

P7/f9587 (N23/f587)—L6944

This sample is unusual in that the most abundant palynomorph is *Quintinia* (cf. *serrata*) at 43%. *Nothofagus menziesii* (12%), *Leptospermum ericoides* (14%), *Podocarpus* (5%), and Cyperaceae (5%) are common. This sample is from a buried soil formed under a broadleaf forest, which suggests warm temperate conditions, although *N. menziesii* is abundant suggesting ameliorating climate or poor soil conditions. No extinct taxa occur and the age is probably younger than Castlecliffian. *Nothofagus truncata* leaves have been identified from this locality (Braggins pers. comm.).

P7/f7580 (N23/f580)—L6870

This sample is dominated by *Gleichenia circinata* spores (41% of the total pollen and spore count) which, together with Restionaceae (19% of the pollen count only), are local palynomorphs growing on the site of deposition which was an acid peat swamp. Apart from Restionaceae, the dominant pollen types are *Phyllocladus* (27%), *Podocarpus* (16%), *Dacrydium bidwillii* type (9%), *D. cupressinum* (4%), and *Dracophyllum* group (10%). *Polypodiisporites* n. sp. and *Acaciapollenites myriosporites* are the only extinct taxa. This implies, on negative evidence, an age younger than Hautawan but no younger than Okehuan. The immediate environment was wet (hornworts, sedges, rushes, etc., common) with podocarp forest in the immediate vicinity. The dominance of *Phyllocladus* could indicate cool temperate conditions, or simply a forest margin situation.

P8/f9533 (N27/f533)—L6873

This sample is similar to P7/f7580 in being dominated by *Phyllocladus* (35%). Restionaceae (11%), *Dacrydium cupressinum* (13%), *D. bidwillii* group (11%), Myrtaceae (8%), *Podocarpus* (4%), and *Quintinia* (3%) are common. The environment is that of an acid swamp surrounded by a podocarp forest and may be indicative of cool temperate conditions. *Proteacidites minimus* Couper (?*Knightia excelsa*) is the only extinct taxon present. Gum, presumably of kauri, and kauri wood (Patel pers. comm.) is present in the sample but no kauri pollen was located; however, pollen recovery from this sample was poor. Age is uncertain, but probably younger than Hautawan.

P9/f536-7 (N27/f536-7)—L6945, L6946

These two samples, a metre apart, are dominated by *Podocarpus* (23%, 33%), *Dacrydium cupressinum* (22%, 20%), Myrtaceae (19%, 27%), *Nothofagus* spp. (13%, 1%), and *Phyllocladus* (5%, 3%). Kauri pollen occurs in both samples. A warm, moist, temperate environment existed, and the pollen rain is from a broadleaf–podocarp forest. Swamp taxa are rare because the samples were obtained from gyttya lake sediments. No extinct taxa occur except

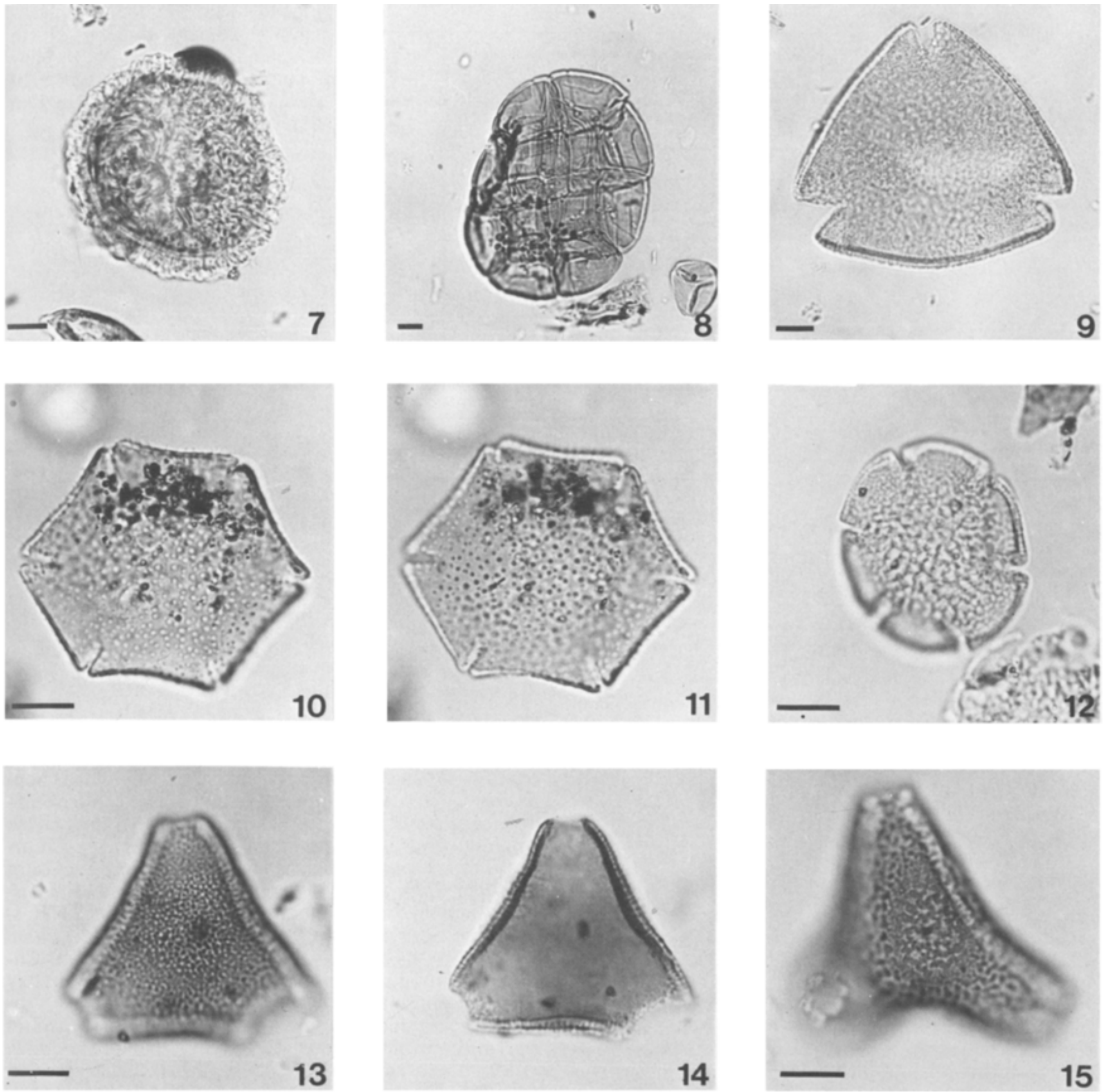

Fig. 7–15 Zeiss photomicrographs of some key pollen from Quaternary sediments, North Kaipara Barrier. Photomicrographs taken on Zeiss Universal Photomicroscopes 838 and 2868. Co-ordinates of all specimens illustrated, which are from strew mounts, are given from photomicroscope 838. Localities can be determined by reference to Tables 1 and 2 via the L number (strew slide number). **7** *Dacrydium cupressinum.* L6872/1, co-ordinates 1001/085 (England Finder reading J29), size 60 µm. **8** *Acaciapollenites myriosporites* (Cookson) Mildenhall. L6872/1, co-ordinates 1011/193 (England Finder reading U30/2), size 90 µm. Note *Leptospermum* bottom right-hand corner. **9** *Beaupreaidites elegansiformis* Cookson. L6872/1, co-ordinates 1032/220 (England Finder reading X32/2), size 72 µm. **10–11** *Nothofagidites cranwellae* (Couper) Fasola. L6869/1, co-ordinates 992/110 (England Finder reading L28/4), size 47 µm. **12** *Polycolpites reticulatus* Couper. L6872/1, co-ordinates 1063/222 (England Finder reading X36), size 34 µm. **13–14** *Proteacidites minimus* Couper (?*Knightia excelsa*). L6869/2, co-ordinates 994/100 (England Finder reading K29/3), size 39 µm. Compare this with fig. 11 in Mildenhall & Suggate (1981) from late Miocene sediments. **15** *Proteacidites franktonensis* Couper. L6872/1, co-ordinates 1057/179 (England Finder reading S35/3), size 47 µm. All specimens are slightly overexpanded giving high size measurements. Bar scale = 20 µm.

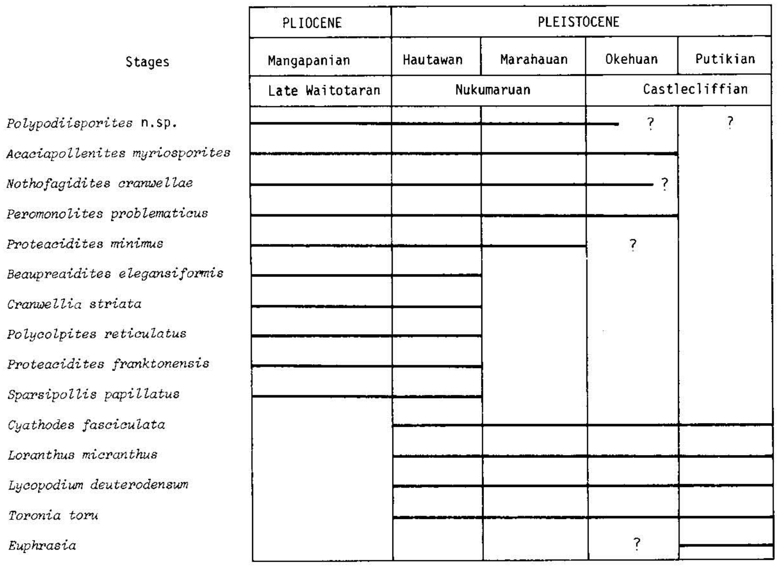

Fig. 16 Key taxa found in Hautawan–Putikian lignites of North Kaipara Barrier and their New Zealand time ranges. Some of these key taxa are illustrated in Fig. 7–15.

Haloragacidites harrisii in f7536 which may represent long-distance transport of *Casuarina* from Australia. No indication of age is possible other than on negative evidence of a lack of extinct taxa, suggesting a Castlecliffian or younger age.

Q9/f7906 (N28/f906)—L6874

This sample is dominated by *Phyllocladus* (36%) and *Nothofagus "fusca"* group beech (28%) and as such is similar to samples P7/f7580 and P8/f9533. Other common pollen types are *Dacrydium bidwillii* group (8%), *D. cupressinum* (5%), Restionaceae (6%), and Myrtaceae (4%). Full podocarp forest conditions existed close to the deposition site which was an acid, woody peat swamp. Conditions were temperate, the dominance of *Phyllocladus* either being local forest margin or an indication of cooler conditions. The presence of wood of *Libocedrus bidwillii* (Patel pers. comm.) supports a cool climate hypothesis. Extinct taxa present include *Polypodiisporites* n. sp., ?*Haloragacidites harrisii*, ?*Cupanieidites*, and ?*Beaupreaidites elegansiformis* and, combined with a lack of other extinct taxa, would suggest an age of Nukumaruan–Castlecliffian, but if the uncertain identifications are correct then the age could be Hautawan.

Q9/f8500 (N32/f500)—L6875

The sample contains plenty of organic material but few pollen grains. The dominant type is *Nothofagus "fusca"* group beech (66%) but there are too few grains to date the sample or to aid in determining the paleoenvironment. The presence of dinoflagellates indicates coastal estuarine conditions. The sample appears very similar to P7/f9581.

Q9/f9575 (N33/f575)—L6876

This sample is dominated by Cyperaceae (30%), Myrtaceae (30%), and podocarps (12%). The assemblage represents a coastal swamp surrounded by a broadleaf–podocarp forest, probably dominated by *Metrosideros* (?pohutukawa), *Dacrydium cupressinum*, and *Podocarpus*. The coastal situation is indicated by the presence of taxa like *Colobanthus, Myosotis, Epilobium*, and *Ascarina lucida*; the swamp situation by *Phormium tenax*, Restionaceae, *Sparganium*, Cyperaceae, *Haloragis micrantha, Laurelia novae-zelandiae, Hydrocotyle*, and others. Climate conditions were probably not unlike the present day — moist and temperate to warm temperate.

No age-significant fossils occur although *Proteacidites minimus* and *Polypodiisporites* n. sp. were identified. *P. minimus* can easily be confused with *Knightia excelsa*, and *Polypodiisporites* occurs into the middle Pleistocene. Age cannot be older than Castlecliffian.

Q9/f9576 (N33/f576)—L6877

This sample is dominated by Cyperaceae (65%), podocarps (9%), and *Agathis australis* (13%). Kauri leaves, and tree stumps of *Leptospermum*, are prominent at the same locality. All three pollen types originated from on-site taxa, so little idea of the regional vegetation can be seen. The assemblage represents a coastal swamp (with Cyperaceae, Restionaceae, *Sparganium, Phormium tenax, Hydrocotyle*, etc.) with kauri and *Leptospermum* on drier areas, including the fixed dunes, around the swamp where they were periodically drowned by a rising water table and/or migrating dunes. The species of *Libocedrus* present is almost certainly *L. plumosa*, a common lowland forest element in the north of North Island. The lack of extinct taxa and radiometric date of 7050 ± 90 (NZ3871C) dates the locality as Holocene, and the presence of kauri indicates a paleoclimate not much different from the present warm temperate conditions. The presence of *Haloragacidites harrisii* (*Casuarina*) is not significant as it is commonly found in Quaternary sediments, presumably as trans-Tasman long distance dispersal.

Q9/f9577 (N33/f577)—L6947

This sample is relatively poor in species and contains *Dacrydium cupressinum* (14%), *Podocarpus* (15%), *Metrosideros* (29%), *Leptospermum* (10%), and *Nestegis* (24%). This latter pollen type (a small, relatively thin walled, spherical, reticulate tricolpate grain) includes thicker walled Cruciferae and porate *Sparganium* in the count as well since it was easier to lump them in together than to try and identify some of the individual grains. Most grains are *Nestegis*. The lignite bed from which this sample was taken contains wood, presumably podocarp and/or Myrtaceae, and podocarp fruits (seeds of *Podocarpus spicatus* and *P. ferrugineus* occur — Burrows pers. comm.). A *Metrosideros* (pohutukawa?)/podocarp forest existed on and close to the deposition site. Conditions were moist and similar to the present day. No extinct taxa were found and the age must therefore be Castlecliffian or younger. An undated tephra immediately overlies this sample.

COMPARISON WITH OTHER LOCALITIES

Samples collected in the South Auckland area from the Ohuka Carbonaceous Sandstone (Mildenhall 1975a) contain assemblages very similar to those from localities P7/f9579 and P7/f9582 in that they are dominated by Myrtaceae pollen and contain extinct plants in common, namely *Acaciapollenites myriosporites, Beaupreaidites elegansiformis, Proteacidites minimus, Eucalyptus, Nothofagidites cranwellae, Cranwellia striata*, and *Haloragacidites harrisii*. The radiometric date of slightly less than 1.7 m.y. would place both sets of samples in the Hautawan above the Pliocene/Pleistocene boundary (Boellstorff & Te Punga 1977).

In the Frankton drillholes (Couper & Harris 1960) similar assemblages are found in what was identified as Hautawan. Here the sediments are probably the equivalent of the lower part of the Puketoka Formation of Kear & Schofield (1978) or possibly the upper part of the Whangamarino Formation. Also, identical Myrtaceae-dominant assemblages with similar extinct taxa are known to occur at Oruarangi Point below or overlapping the presumed palynologically determined Pliocene/Pleistocene boundary, and at Ohinewai, approximately 18 km north of Huntly.

From these comparisons it is clear that localities P7/f9579 and P7/f9582 are of Hautawan age or possibly earliest Marahauan. All other samples are younger than Hautawan and are not possible to date although ages of Castlecliffian or younger have been assumed. No attempt can be made to correlate these samples with those further south because the relative lack of extinct taxa, the fact that they are spot samples, and the dominance of local on-site taxa over the regional pollen rain make comparisons of little use. The presence of *Polypodiisporites* n. sp., whose upper range is not accurately known, but is younger than Nukumaruan (Pocknall & Mildenhall 1984), in samples P8/f7580, Q9/f7906, and Q9/f9575, does suggest a possible Castlecliffian age for these samples.

For more accurate palynological dating, detailed work on sections is required to assess the range of extinct taxa, the first appearance of modern taxa, and the significance of vegetational changes in the Northland area. These sections would have to be tied to a well-dated tephra or tephras.

CONCLUSIONS

Lignites west of the Kaihu and Wairoa Rivers are at least as old as earliest Pleistocene. While some dune sands beneath these lignites and below sea level could well be as old as latest Pliocene, most dune sands and lignites are Castlecliffian and younger.

Several environments of deposition are represented in the lignites, paleosols, and lacustrine sediments: (1) coastal swamps, dammed by dunes; (2) estuarine swamps and valley peat swamps; and (3) inland lakes dammed by dunes.

Climatic conditions can only be guessed at since a good regional pollen rain and good sequences are required to determine trends. The lack of tree pollen in a sample does not necessarily imply cooler conditions; it may be purely a local effect of heavy pollen production by on-site herbaceous and shrubby plants. The presence of a large number of *Nothofagus menziesii* pollen may reflect cooler conditions because silver beech is not known north of Tauranga at the present day, as suggested by Couper & McQueen (1954) for a sample of similar age (Hautawan) at Ohuka. Similarly, samples with abundant *Phyllocladus* and wood of *Libocedrus bidwillii* could also be symptomatic of cool conditions, but all samples containing these two pollen dominants also have taxa consistent with warm coastal, frost-free, temperate climates. Local edaphic conditions or wind must be the controlling climatic factor in the dune sands.

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