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Mid-Conference Field Trip

15 February 2006

Te Aupouri Peninsula Field Guide

Geomorphology & Evolution of Te Aupouri Peninsula and Karikari Peninsula

A Summary

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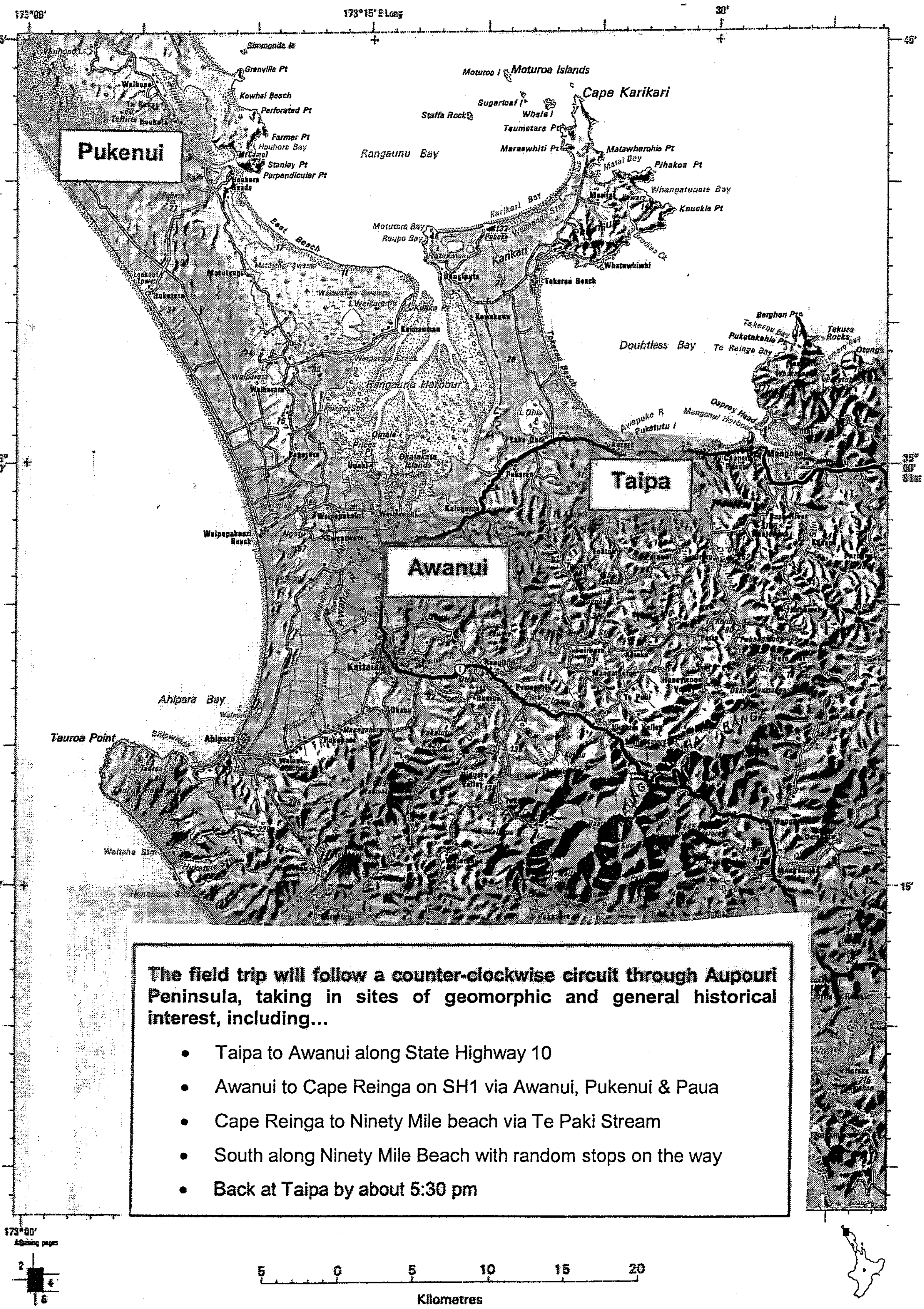
Contents

Disclosure Statement

This field guide was originally prepared as a teaching resource for postgraduate students at the University of Auckland. It contains unpublished data and interpretations collated by the authors from colleagues, students and other sources. Please do not cite this work without prior consultation with the second author, Dr Scott Nichol (School of Geography & Environmental Science, The University of Auckland s.nichol@auckland.ac.nz).

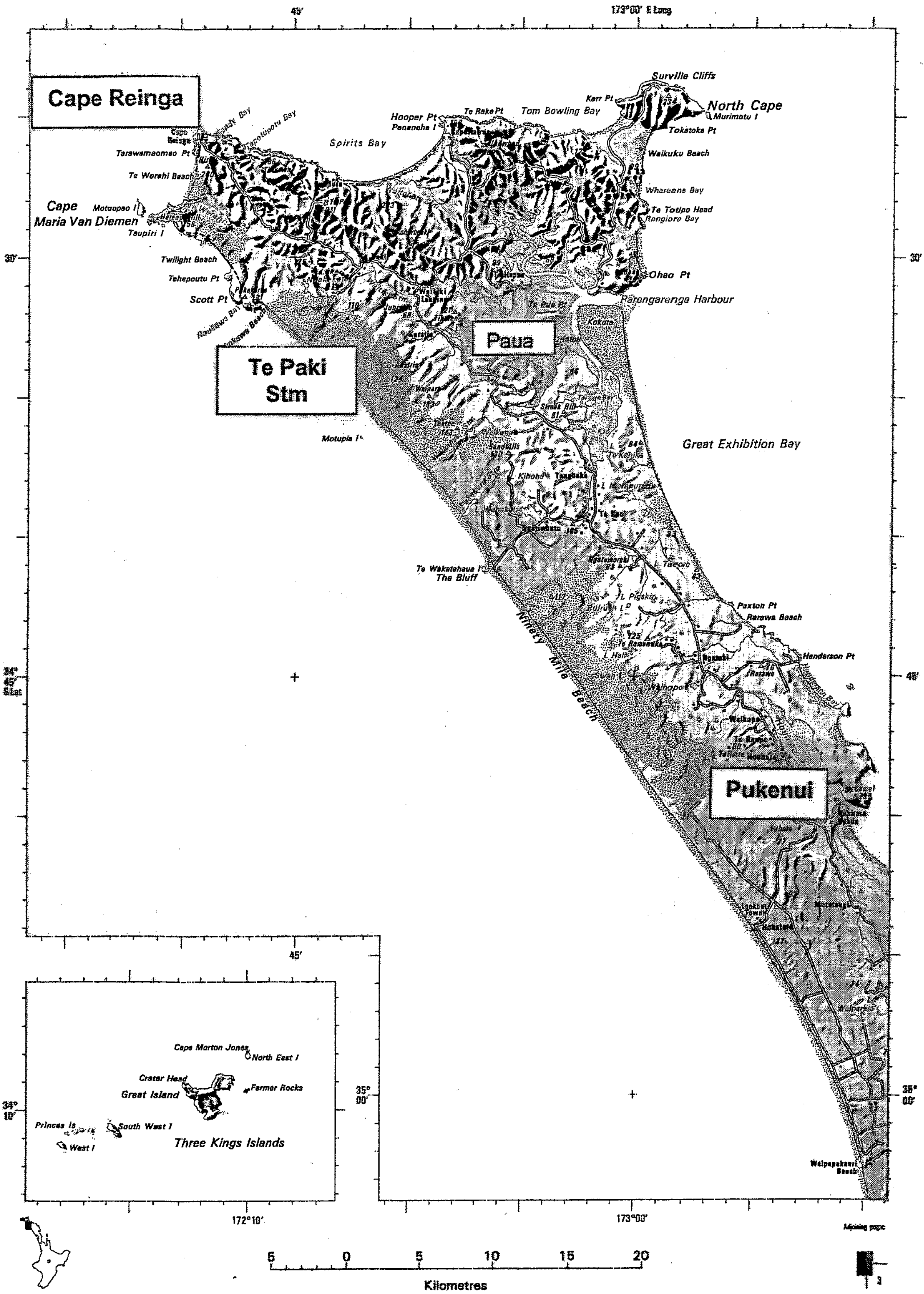
Thank you.

Route Maps



The field trip will follow a counter-clockwise circuit through Aupouri Peninsula, taking in sites of geomorphic and general historical interest, including...

- Taipa to Awanui along State Highway 10
- Awanui to Cape Reinga on SH1 via Awanui, Pukenui & Paua
- Cape Reinga to Ninety Mile beach via Te Paki Stream
- South along Ninety Mile Beach with random stops on the way
- Back at Taipa by about 5:30 pm


Cape Reinga
Te Paki Stm
Paua
Pukenui
Cape Maria Van Diemen
Spirits Bay
Tom Bowling Bay
Surville Cliffs
North Cape
Great Exhibition Bay
Parengarenga Harbour
Ohao Pt
Scott Pt
Twilight Beach
Tehepoutu Pt
Te Werahi Beach
Motupia I
Te Wakatehaua I
The Bluff
Ninety Mile Beach
Paxton Pt
Rarawa Beach
Henderson Pt
Hooper Pt
Te Rake Pt
Kerr Pt
Tokatoka Pt
Waikuku Beach
Whareana Bay
Te Totipo Head
Rangiora Bay
Cape Morton Jones
North East I
Crater Head
Great Island
Farmer Rocks
Princes Is
South West I
West I
Three Kings Islands
172°10'
173°00'
173°00' E Long
45'
30'
34° 45' S Lat
35° 00'
34° 10'
Kilometres
5 0 5 10 15 20

Section One: Introduction to the Field Area

The Study Area - Where on Earth are we?

The Northland Peninsula is the northernmost extension of North Island and mainland New Zealand. It reaches into the temperate southwest Pacific Ocean to a latitude of just over 34° south on a latitude close to Sydney. There are a whole set of unique factors and conditions associated with this location on the globe. We are standing on the northern extreme of what has been described as an oceanic sub-continent, a place with a climate and history, both natural and cultural.

Northwards lies *Te Aupouri*, in Maori, or in English, the Aupouri Peninsula. Ninety Mile Beach sweeps towards *Te Rerengawairua,* Cape Reinga, along the western flank of the Peninsular. To the east is the smaller Karikari Peninsula, separated by an elongate zone of alluvium leading into the saucer-shaped Rangaunu Harbour. Beyond the lands end are the sub-tropics, a region dominated by oceanic processes, and somewhere beyond that most of the rest of the world.

Oceanic Circulation - Conveyor Belts and Giant Whirlpools

The influence of the ocean on both land and sea of the far north is an example *par excellence* of New Zealand's maritime location. The general surface circulation of the south-western Pacific Ocean shows a westward inflow of water from the central South Pacific to the Coral Sea (Fig.1). Some very warm Coral Sea water is advected southwards down the east coast of Australia in a complex succession of fast moving eddies labelled the East Australian Current (Church, 1987). Flow retroflects away from the Australian coast centred at 33-34° south with the conjunction of warm Coral Sea water and cold Tasman Sea water. Driving the Tasman Current; a permanent meandering zonal flow crossing the Tasman Sea (Andrews, Lawrence and Nillson, 1980). The East Auckland Current is largely derived from warm Tasman Sea water bending around North Cape. The current passes down the north-east coast of North Island before pushing away from the coast in the vicinity of East Cape (Brodie, 1960). In contrast, advection of sub-tropical water from north of North Island down the north-west coast is generally weaker than for the north-east coast and currents more variable (Stanton, 1973).

Oceanic currents rarely flow at steady speeds and in the constant directions which the generalised, small scale models of mean current imply. There may also be some direct entry of tropical water from the north-east of North Island (Heath, 1985). For example, Rochford (1973) monitored direct flow of low-salinity tropical water to the north of New Zealand from the region between Vanuatu and Fiji during February 1970. Eddies and counter-currents off the north-east coast can also develop rapidly in response to local weather changes (Anon, 1987). As yet we know very little about the significance of these secondary current patterns.

Climate - The Winterless North?

The far north's weather is predominantly delivered by either south-west or north-east winds associated with an eastward procession of anticyclones and intervening troughs across the Tasman Sea (de Lisle and Kerr, 1964). South-westerlies dominate but

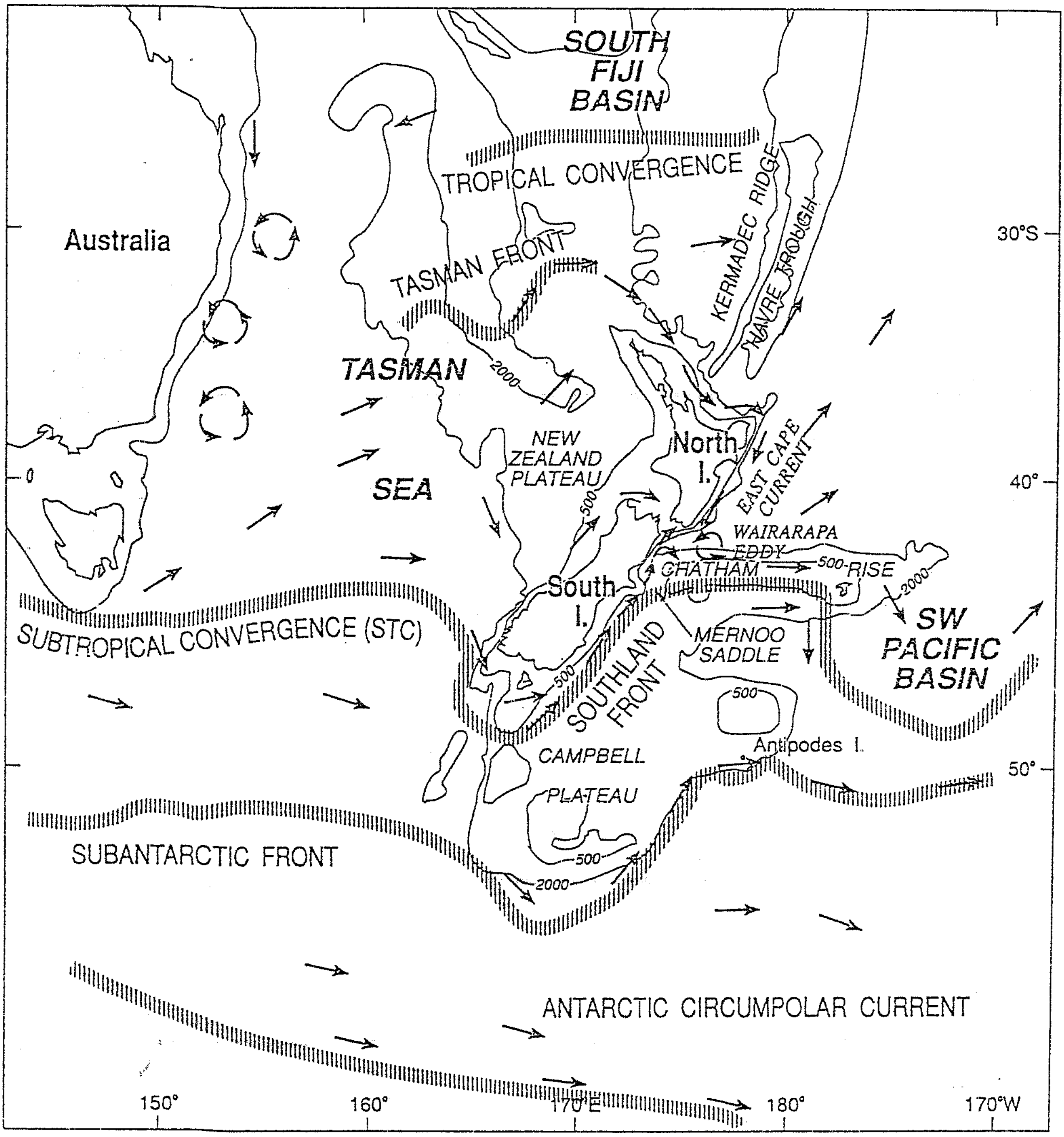


Figure 1. Oceanographic features of the south-west Pacific.
Source: Bradford-Grieve *et al.* (1991)

during the months December to April these are often equalled or exceeded in frequency by wind from the easterly quarter. North-easterly storms of tropical or sub-tropical origin typically occur once or twice a year during the summer (Cornforth, 1980). Resultant wave energy on the east coast is greatest during the months January to April (Evans and Ballantine, 1986). However, the climate is characterised by instability and significant storms may occur in any season.

The far north is mild, humid and rather windy, owing to its low latitude, low elevation and extensive surrounding ocean. Check out these statistics from the New Zealand Meterological Service (Moir *et al.*, 1986):

> Mean annual temperatures: *15.5 - 16° C*
>
> Sunshine hours: *exceeding 2120/yr*
> (both very high for any New Zealand region)
>
> Rainfall: *1083mm/yr at North Cape and 1429 mm/yr at Kaitaia*
> (low to moderate for New Zealand)

Rainfall is strongly related to altitude in maritime climates so the dunelands and coastal fringes are probably drier than both North Cape and Kaitaia. Winters are wetter than summers but frosts are rare.

Is this the winterless north? It depends on whether you hale from Dunedin or Suva.

Section Two: Pre-Quaternary Geology

Paleo-Islands - The Archaic Archepeligo

Imagine we are standing on the Ahipara plateau looking north. If we cast our minds back, say 2 million years, what would we be looking at? The geological time scale (Fig. 2) can be used to slot these periods into context.

Evidence suggests that during the Pliocene (5 million to 1.63 million yrs BP) the far north beyond Ahipara consisted of an archipelago. At the same time the sea flowed where the Auckland Isthmus now lies, from the Manukau to the Hauraki Gulf. The separation of these islands has been correlated with the location of species of the land snail *Rhytida*. Different species developed in the areas considered to be the Aupouri Island, Karikari Island, Northland Island, and the North Island south of Auckland. Similar patterns are found in the stag beetles *Lisottes*. These areas were thought to have been separated by straits during the Pliocene and some of the interglacial ages of the Pleistocene (Powell, 1949; Climo, 1975).

The far north islands date back to the mid-Cretaceous (about 100 million years ago) and consisted of a chain stretching from the Three Kings to Ahipara. Figure 3a depicts the lay of the land during the Pliocene. The remnants of these islands can be identified in turn (after Millener, 1981).

North Cape Block

The largest island was the North Cape Block or *massif* (meaning an isolated mountain area) which stretches 70 km east to west and 7 km north to south. It is mainly volcanic lavas erupted on the seabed (Whangakea Group) which has been slowly uplifted. Near North Cape a basic intrusive rock is present. Younger sedimentary rocks, of similar age to the Waitemata sand/mud-stones of Auckland are present on the northern side of Parengarenga Harbour and fringing other parts of the harbour.

Mt Camel

Mt Camel (210 m) is part of the tombolo forming the eastern margin of Hohoura Harbour which links a chain of four upstanding blocks of volcanic and sedimentary rock. These too are undersea volcanic and sedimentary rock types around 100 million years old. The volcanic rock has resisted erosion and now forms prominent features, similar to those at the northern end of Karikari Peninsula.

Karikari Peninsula Block

This block of volcanic and sedimentary rock has the same origin as Mount Camel and the Three Kings Islands. They consist of lavas and keratophyres interleaved with greywackes.

As far as we know there are no sediments from the Pliocene period. In fact everything else you can see: the dunes, the beaches and the harbours are *coastal* (!!) in origin and probably date from the Quaternary period.

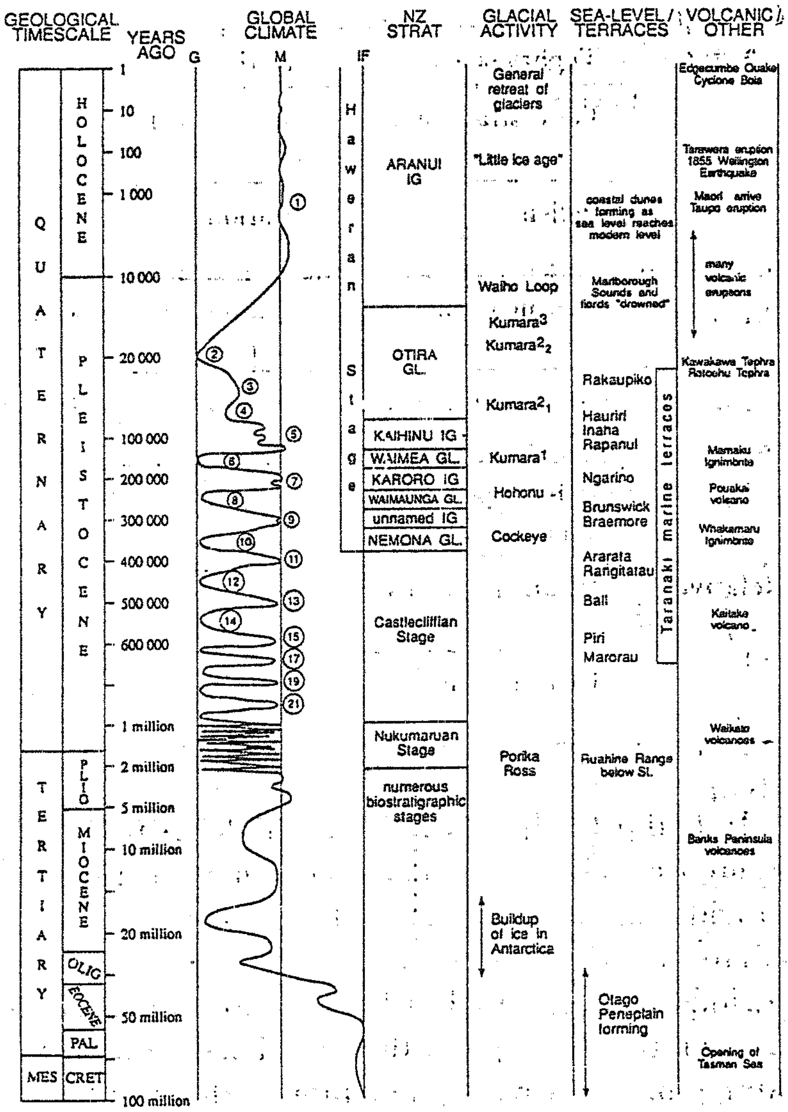
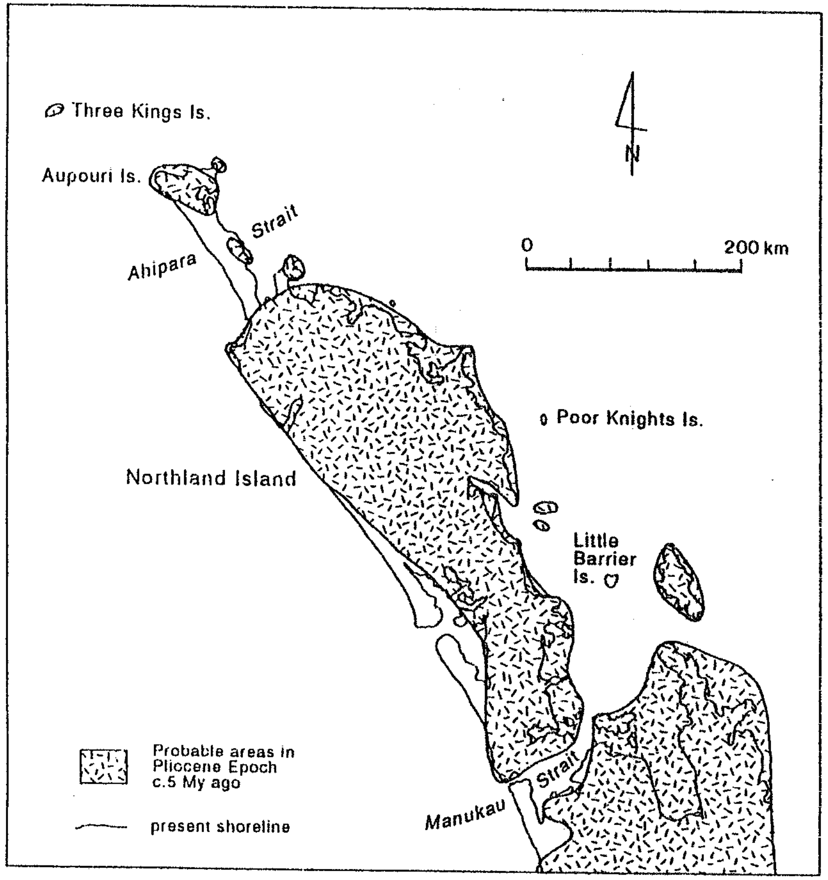


Figure 2. An outline chronology of New Zealand Landform Development.
Source: Pillans *et al.* (1992)

A. Pliocene Shoreline.



B. Sand accumulation since the Pliocene.

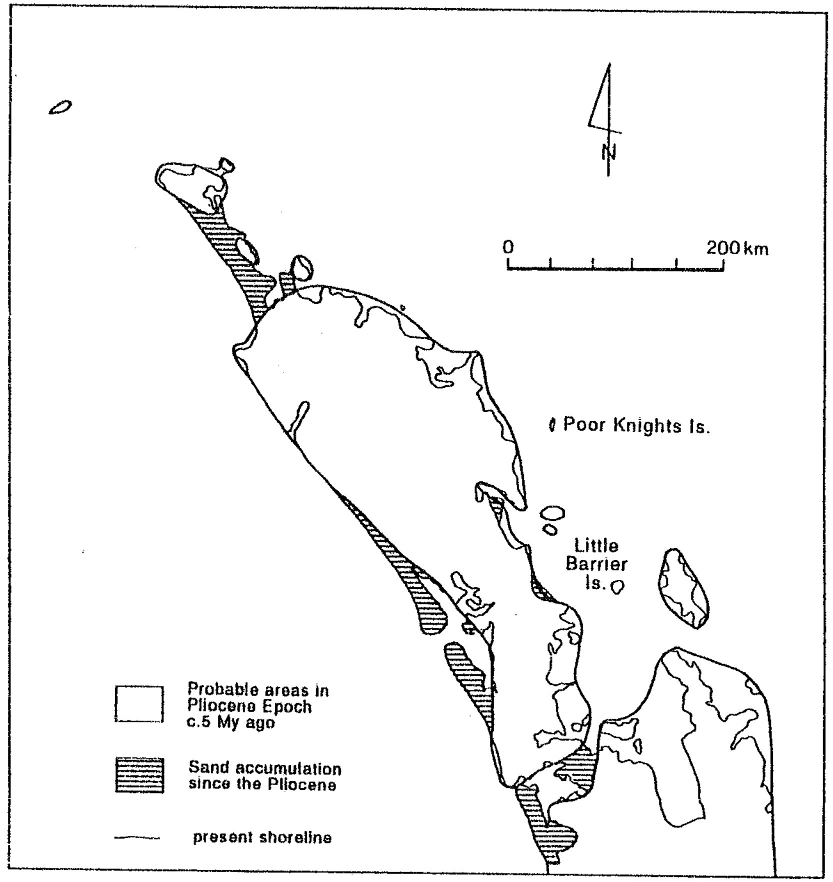


Figure 3. Development of the Northland shoreline over the last 5 million years.
Source: Ballance and Williams (1992)

Large Scale, Long Term Sediment Transport - Rivers of Sand

As illustrated in Figure 3b the formation of the coastal systems that linked the archipelago to the rest of North Island was part of larger scale, widespread sedimentation along the Northland coast during the Quaternary period. These sands occur in three principle areas: two form the outer barriers of the Manukau and Kaipara Harbours with the third being the Aupouri-Karikari compound tombolo. Where did the sand come from? The essence of any discussion on sediment transport should address; 1) the *provenance* (sediment source), 2) sediment pathways, and, 3) the modes and mechanisms of transport and deposition.

Origin of Sand on the West Coast

Schofield (1970) identified the *West Auckland Sand Facies* as a sand body possessing a *remarkably consistent* mineralogical content from the South Kaipara Barrier to Te Aupouri. He noted an increase in mechanically resistant minerals with distance northwards (potash feldspar) which led to the conclusion that sand in the northern regions may have been transported greater distances than that to the south.

Stewart *et al.* (1986) discovered that quartz from the west coast beaches had an ^{18}O (oxygen isotope) value consistent with a high temperature and similar to the Ohinewai Tephra formation of the central North Island. They speculated that quartz sand was deposited by the Waikato River and then driven northwards by longshore drift.

This interpretation of the origin of quartz sand is unlikely to explain the provenance of all sediment bound up in the West Auckland Sand Facies. Schofield (1970) had commented that west coast energy conditions were strong enough to rapidly mix several facies into one. Within the older formations of the west coast sand barriers are highly quartzose dune and estuarine sands almost identical to the Parengarenga Sand Facies (discussed in the next section). The provenance of sand formations at Aupouri have never been comprehensively studied. But an intensive study of South Auckland sand formations, south of the West Auckland Sand Facies has been undertaken. The West Auckland sands are thought to have passed through this area on their journey north.

Recently Stokes and Nelson (1991) identified four broad sequential changes in the sand mineralogy of coastal deposits in South Auckland. An initial Late Pliocene, mainly silicic volcanic minerals were superseded in the Early Pleistocene by predominantly Mesozoic basement minerals. Then, during the early part of the Late Pleistocene, a mixed andesitic volcanic and basement mineralogy became prominent. In the late Quaternary the andesitic mineralogy dominated.

Changes in mineral composition were attributed by Stokes and Nelson to changes in the predominant source of supply. The initial supply of silicic volcanic material from inferred late phases of the Coromandel Volcanic Zone in the late Pliocene. During the initiation of the Taupo Volcanic Zone in the early Pleistocene, horst and graben topography developed in the South Auckland region and uplifted basement rocks provided most of the sediment for South Auckland formations. This contrasts with the conventional understanding that the Taupo Volcanic Zone itself supplied all the North Island west coast sand (eg: Hamill and Ballance, 1985). Nevertheless longshore dispersal of Taupo Volcanic Zone sediment in the direction of the Aupouri Peninsula would have continued periodically when the paleo-Waikato River discharged into the Tasman Sea rather than the Hauraki Gulf. Andesitic minerals in the late Pleistocene and Holocene sediments were derived from Egmont Volcanics further down the west coast.

So how do the sequential changes of provenance in west coast coastal sands in south Auckland affect our understanding of large-scale long-term sediment transport in our study area? The concept of silicic sand deposits being derived from the Coromandel Volcanic Zone provides a possible time and origin for those highly quartzose deposits which are encountered in sand deposits of Te Aupouri Peninsula. If this is generally true then silicic sands are the oldest of the sands in the far north.

How much of the west coast-derived sand at Te Aupouri came from erosion of basement sediment, the Taupo Volcanic Zone or other sources such as the Egmont Volcanics? The homogeneity and the extent of the West Auckland Sand Facies is a poor indicator of possible multiple provenances of sediment. Some of the mineralogical signature of any possible source would be diluted and altered by mechanical abrasion of less resistant minerals as the river of sand flowed northwards. The only way to unravel the evolutionary history of the facies would be to systematically study the mineralogy and provenance of sequential dune formations all the way up the west coast of Northland. South Auckland aside, this has yet to be done.

<u>Origin of Sand Populating the East Coast</u>

Schofield (1970) defined the *Parengarenga Sand Facies* as a population of sediment confined to the east coast between Parengarenga Harbour and Doubtless Bay. Sediments with similar characteristics are also found in more ancient coastal deposits in localities on the Kaipara Harbour (and places like Kai-iwi Lakes north of Dargaville). The sand is characterised by its high quartz content with silica in excess of 95 %. Chromite in the sand, Schofield suggested, was derived locally. He thought that the bulk of the sand was derived from podzol soils while a minor amount might be derived from nearby keratophyres, ultra-mafics from the North Cape Block. These conclusions were based on the sand facies being adjacent to areas of mature sandy podzol soils. Also that grains were highly angular and had not been transported a long way. However Schofield considered that the bulk of material was not sorted to the extent required to separate quartz from other sand minerals if all the sediment was derived from the nearby North Cape Block.

Batt and Fortune (1973) disagreed with Schofield. They argued that an area of c.750 km^2 with a quartz layer 15 cm thick would be need to be eroded just to supply enough sand for Kokota Spit alone. Another possible source was proposed by Ricketts (1975). He analyzed sand mineralogy in detail and considered the bulk of the sand to have been derived from the ignimbrites, rhyolites and dacites of the Taupo Volcanic Zone. Ricketts thought that initially, transport of sediment would have been down a paleo-Waikato River. The sand was subsequently transported alongshore and northwards.

Thus two partial hypotheses on the origin of the Parengarenga Facies were up for grabs. Both had some problems. Schofield's *pedogenic* (soil formed) local origin theory was contradicted by the presence of secondary minerals from volcanic sources and had the problem of the volume needed to supply enough sand to develop the facies. Ricketts' central North island origin theory did not account for the local mineral (chromite) input which was detected, nor did it explain the angularity of many sand grains.

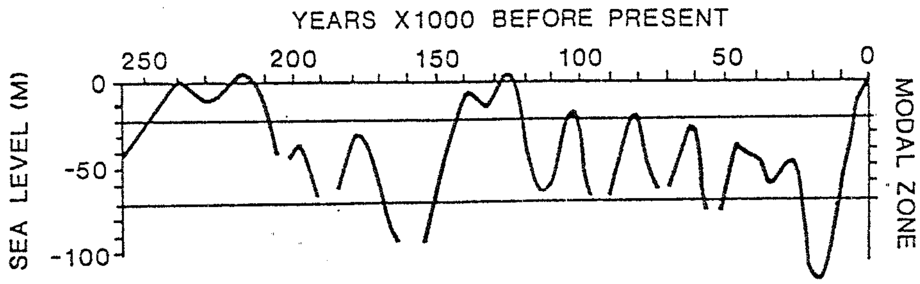
Stewart *et al.* (1986) looked at whether quartz in a number of North Island soils was pedogenic in origin and examining selected materials which may have been a regional source of aeolian quartz. Beach sands from Waimamaku (on the west coast) and Rarawa (on the east coast) were sampled as potential sources for aeolian quartz in adjoining soils (Thus beaches were viewed as a source for soils and not the other way round as Schofield did). In addition they examined three podzols to determine if the highly quartzose elluviated horizon in each was the result of pedogenic quartz formation in the soil or a result of concentration by soil podzolisation. They also undertook oxygen isotope analysis of the samples. This method discloses whether the quartz was formed under low or high temperature conditions.

Analysis of the beach sands indicated a greater component of low temperature quartz on the east coast sample compared to the west coast sample. By comparing the oxygen isotope values of the high temperature west coast sample and locally derived quartz from weathered Mesozoic greywacke, Stewart *et al.* proposed a local component of 45 % for the Rarawa Beach sand. This finding concurred with Ricketts (1979) who suggested that the east coast beaches had multiple sources and a probable local component in the order of 40 %.

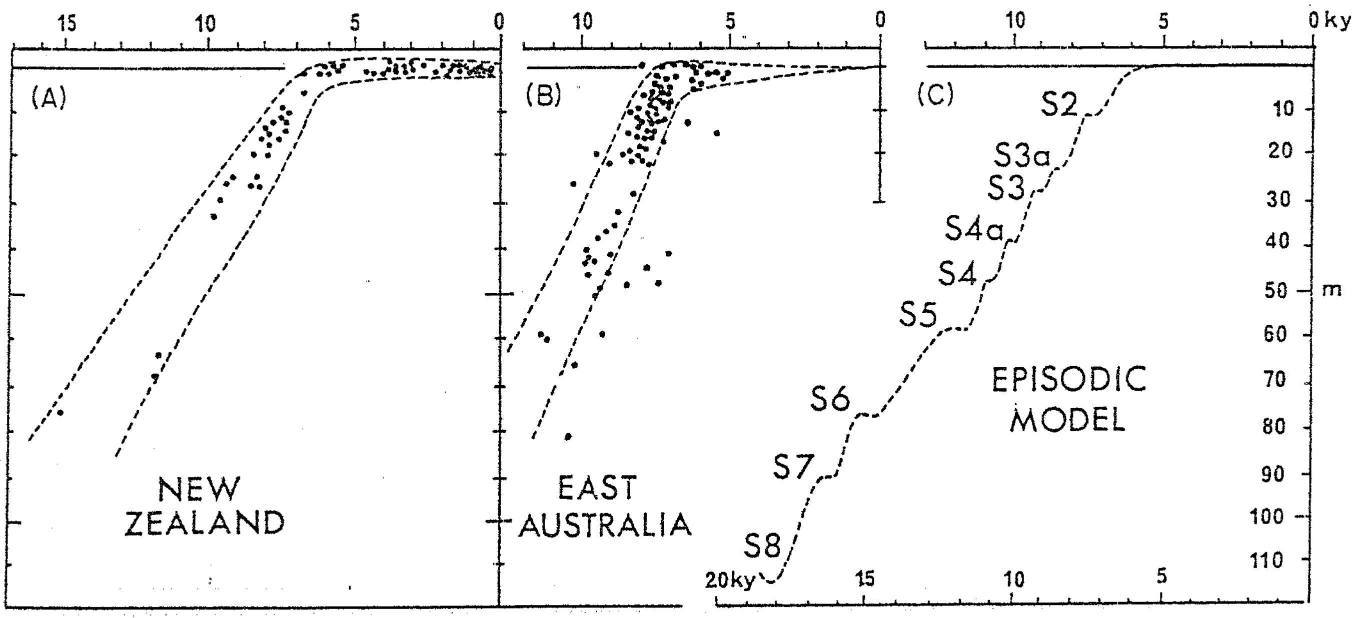
No evidence of pedogenic quartz formation was found in the soils examined. Quartz in the elluviated horizon of the podzols resulted from residual concentration rather than quartz crystallisation. Schofield's pedogenic hypothesis was thus disproved.

Stewart *et al.* decided that the Parengarenga Facies had a multiple provenance. Rounded quartz was derived from local sedimentary rocks and had been mechanically abraded and deposited during the Quaternary. But the mass of silica sands were traced to Quaternary rhyolitic tephras. Whether these were derived from the Taupo- or Coromandel Volcanic Zones has not yet been investigated.

Since the paper of Stewart *et al.* (1986) the local versus imported ratio of the Parengarenga Sand Facies seems well defined. We know that the sand has been retransported by fluvial and marine processes. However the sediment pathways and their timing are still hazy. We still do not know how far has the sand been carried by marine processes. Was it deposited locally or nearer the central North Island? Did the sand migrate up the west coast or the east and did it pass through the old Ahipara Strait or around the north of North Cape? How old is the east coast sand? Older than the west coast sand and if so how much older? These are but a few of the many unanswered questions lying around us.



A. Late Quaternary sea level curve based on coral terraces,



B. (A and B) Radio carbon data and sea-level envelopes for eastern Australia and New Zealand, showing envelopes of sea-level change. (C) Summary regional sea-level curve, with probable shoreline pauses, based on the model of episodic transgression. Curves based on data for eastern South Island, New Zealand (after Gibb, 1986; Herzer, 1981 and Carter *et al.*, 1985) and eastern Australia (after Belperio, 1979; Grindrod & Rhodes, 1984; Pye & Rhodes, 1985; Thom & Roy, 1985).

Figure 4: Late Quaternary and Holocene sea-levels for Australasia
Sources: Chappell (1974); Carter *et al.*, (1986)

Paleo-Sea-Level - Absolutely Eustatic

The credible Huon Peninsula record from Papua New Guinea (Chappell, 1974, 1983) chronicles eight major oscillations in sea-level over the last 250,000 years (Fig 4a). Of these only two sea-level highs, at 240,000-215,000 and 125,000-120,000 yrs BP, reached the datum of present sea-level (PSL). The latter of these, the *Last Interglacial* (or *oxygen isotope stage 5e*) is thought to have been 4-6 m higher than present (Chappell, 1983). Just which elevation these sea-levels attained on other coasts is a matter of ongoing debate and some conjecture. Gibb (1986) purported a Last Interglacial bench near 3.0 ± 0.3 m above its modern analogue at stable sites around New Zealand. Two further sea-level highs, at 80,000 and 105,000 years BP, peaked within -10 m and -20 m of PSL.

During the Holocene an episodic sea-level rise, the *Holocene Marine Transgression*, began 18,000 years ago, 110 m below PSL (Carter *et al.*, 1986). This rise reached the present sea-level datum around 6,500 yrs BP and is believed to have oscillated less than ±1.0 m up to the present day, a period known as the *Holocene Stillstand* (Gibb, 1986) (see Fig. 4b).

The inference from this discussion of paleo-sea-levels is that they have a major bearing on the evolution of Te Aupouri and Karikari Tombolos. They do. Notwithstanding this, coastal deposition is most closely related to a surplus in the sediment flux. It is a point of debate which mechanisms will produce this surplus in any particular system but it is possible for both regressing and transgressing sea-levels to trigger the release of sand from the offshore shelf. During a lowering sea-level, sediment is fed from the shelf within the falling wave base. On low angle, high energy coasts (such as the west coast of northern North Island) this may result in sustaining sand supply to the shore over several thousand years (Roy *et al.*,1980; Bird and Jones, 1988). Sea-level rise activates large volumes of sediment, some of which accumulates as coastal dunes. Under these conditions dune instability may result from either coastal erosion or coastal deposition as dunes are overwhelmed by an increasing sand flux (Psuty, 1986, Orme, 1988).

Ages of at least some of Australian and New Zealand parabolic and transgressive dunefields indicate that they were activated prior to the Holocene Stillstand whilst sea-level was still rising (Pye and Bowman, 1984; Shepherd, 1987). But coastal dune building may not be synchronous with sea-level fluctuations of any sort. Many if not most barrier systems comprising strandline plains formed in Australasia soon after the sea-level stillstand commenced 6,500 yrs BP (Thom, 1984; Gibb and Aburn, 1986; Osborne, 1992). Presumably such progradation was a response to stationary sea-level conditions creating a surplus in coastal sediments.

With such a remarkably wide array of dune types found in the study area there is a marvellous opportunity to investigate whether phases of dune formation are contemporaneous between the different morphologies and to establish their relationship to paleo-sea-levels.

In summary, Section 3 noted how sand was transported to the study area from the south. With a sediment surplus, oscillations in sea-level provided an opportunity for sand from the shelf to be delivered to the shoreline and transported inland by aeolian transport. The landforms which have developed on unconsolidated Quaternary sediments record successive marine, aeolian and fluvial processes operating on the margins of the landmass and culminating in net accretion during the Quaternary.

The last point to be made in this discussion is an important one. It is: the sea-level curves of both the Late Quaternary and the Holocene (Figs. 4a, 4b) show that most deposition, be it from stationary, rising or falling sea-levels, occurred well below PSL. At the present moment with sea-level at an extreme high position, the active process bandwidth has abandoned most of this material. It now forms the core of the tombolos upon or against which dune sand has periodically been overlain. If the relative position of the land and sea has remained stable then most of the tombolo has been either reworked or lies in deposits now buried or submerged offshore. Due to our temporal location we can only investigate those deposits which were lain down at sea-level highs or those shifted above the PSL datum by wind transport or uplift.

Marine Terraces and Uplift Rates - Fact or Science Fiction?

Chappell (1975) postulated that North Island has undergone *epeirogenic* uplift (uplift that is uniform on individual stretches of coast, but different from stretch to stretch). Despite undergoing large-scale uplift, actual tectonic deformation within the Northland region is believed to be absent from the Quaternary (Brothers, 1954). Thus uplift is thought to be regionally uniform. Within this context, marine terraces along the west coast of Auckland and Northland have been measured with the objective of estimating the regional uplift rate (Table 1).

Marine terraces are planar surfaces which have been relocated beyond the reach of shoreline processes. Terraces may contain further *surfaces* which are stratigraphically, rather than physiographically defined. It was Brothers (1954) who first proposed that these terraces represented prolonged phases of sea-level stillstand during interglacial highs. Along the west coast of Auckland terraces comprise thick, transgressive aeolian, intertidal and shallow marine sequences and are mantled by several phases of dune deposition (Chappell, 1974).

It is generally accepted that there has been uniform uplift of Northland as the Pacific Plate moves beneath the Australian Plate on which Northland is situated (Barter, 1976). More contentious is the rate of uplift. For instance, Pillans' (1986) Late Quaternary uplift map for the North Island largely ignores the Northland record, citing the paucity of data in the area. Elevations from different "flights" of terraces are quite varied - producing a wide range of estimations for the rate of uplift (Table 1). In fact only 24 % of the first 110 m above PSL does not have a terrace of some sort somewhere along the west coast of Auckland and Northland! It appears that terraces may have been forcibly correlated between sites.

Even within the Aupouri Peninsula there is ample variability in uplift rates between locations. Leach (1966) obtained a rate of 0.30 mm/yr from terraces at North Cape. Ricketts (1975) uplift rate near Parengarenga is 0.35 mm/yr. Goldie (1975) derived the same figure from landforms near Houhora. Hicks'(1975) rate from Herekino Harbour, south of Ahipara is just 0.21 mm/yr. Estimations of uplift of the Kaipara barriers further down the west coast are back up to 0.30 mm/yr (Richardson, 1975). Although these calculations may all seem to be fairly close, the consequences of projecting different rates back over 1.8 million years are radically different!

Marine terraces are notoriously difficult to interpret, indeed, numerous workers have warned against terrace correlation. Firstly, the terrace surfaces may not be marine in origin. To be certain there needs to be evidence of fossil cliffs, marine fossils, or marine sediments. Carbonates are rarely present in sands pre-dating the Holocene. Porous, sandy substrates are poor preservers of fossil evidence and the humid climate of Te Aupouri would assist in the breakdown of carbonate material. Determining an accurate terrace level is further complicated by the covering of what may be terrace surfaces by transgressive aeolian deposits. Elevations taken from dune-mantled marine-cut surfaces over-estimate the rate of uplift. Such errors are common in the study area and may account for much of the variation in elevation between locations (see Goldie, 1975, 27-31; Ricketts, 1975, 134).

A related complication stems from the fact that similar looking depositional sequences can occur more than once. Nor does the altitude at which any two deposits lie always differentiate them from one another. If a terrace has cut into older Quaternary beds and no evidence of this cut is preserved (ie: shell, pebble layer) then the young terrace may be indistinguishable from the older basal deposit.

Despite the potential for error these studies preferred to accept these surfaces as marine terraces for the want of alternative methods. Goldie's (1975) terrace correlation, for example, was not only forced by a lack of fossils but also the dearth of tephra horizons such as found further south. Most of the terrace studies were undertaken before the widespread adoption of luminescent dating techniques which would have provided an alternative means of aging Quaternary surfaces. These have the added advantage of sampling facies boundaries rather than measuring physiographic surfaces.

The final points in this (largely sceptical) perspective on the accuracy of terraces and uplift rates draw again on the elevation of surfaces attributed to past sea-level highs. As stated earlier global eustatic sea-level in the Last Interglacial is thought to have been 4-6 m above present (Harmon *et al*, 1981; Chappell, 1983). Northland coastal deposits attributed to this period are all within this range of elevation, often lower (Gibb, 1986), suggesting either zero uplift or even tectonic downdrop! A simple calculation using uplift rates in the order of 0.35 mm/year places Last Interglacial deposits about 4.3 m above the level in which they are found.

Lastly, Pillans (1986) notes that with uplift rates above 0.20 mm/yr, shore platforms and other testimony of lower sea-level stillstands at 80,000 and 105,000 yrs BP should have been raised above their modern analogue, beyond the reach of the present band of active processes. There is no evidence of this occurring in the Northland region.

This general discussion indicates that the wide margins of error in establishing the morphometry of marine terrace surfaces has led to an over-estimation of uplift rates in Te Aupouri - a contention helped by the relative pattern and elevations of old sea-level surfaces in the region. Perhaps the whole topic deserves another look.

Awhitu Peninsula	Auckland Area	South Kaipara Peninsula	North Kaipara Peninsula	Aupouri - Karikari Peninsula	North Cape Area
165-180	150-180	167		167-183	116-182 (possibly 2 surfaces)
90-105	90-107	107	105	88-110	
60-70	60-75	67	67	60-74	76
35-45	27-36	31-41	40	39-51	30-40
18-24	15-24	14-23		15-31	17
8-10	6	5-8		6.5-11	7
2-4	3-4		4	4.5-6.7	
	1-2			1.5-4.8	

Source: Soons and Selby, 1992

Table 1. Correlated Marine Terrace Heights, Northland and Auckland (Height in Metres).

Section Five: Evolution of the Tombolos

Coastal Landforms - Sand Through the Hourglass

Southern Te Aupouri Peninsula

Coastal geomorphological investigation of both the southern Te Aupouri and Karikari Peninsulas was undertaken by Hicks (1975, 1983). He recognised seven dune types in the area on the bases of morphology, the extent of erosion, soil profile characteristics and evidence of vegetative cover (Fig 5). Five episodes of dune advance were identified, separated by phases of stability during which vegetation colonised the dunes. Most of the sediment came from the west coast and transgressed north-eastwards across older surfaces, driven by the prevailing wind. The depositional patterns of southern Aupouri and Karikari will be discussed in turn.

West Coast Foredunes

Looking towards Tauroa (Reef) Point from the Ahipara Plateau one can see long, lobate sand tongues which reach from old marine terraces and parabolic dunes to the south-west, up the high headland of the point and then spill downslope to Ahipara Bay. Hicks (1975) called these sand sheets *Reef Point drift dunes*. The vertical distance they rise and fall is a great example of the power of aeolian transport on a windward coast.

Further to the north, Ninety Mile Beach, apart from the sheltered 3 km north of Ahipara, lacks foredune strandplains. While Hicks attributes this paucity to the destruction of foredunes by devegetation it is possible that on such a high energy coast they never existed in linear form. It is plain, however, that in the recent past aeolian sand transport has outstripped the ability of vegetation to hold down dune sand. Inland from the beach lies a 0.5-3.0 km wide *coastal deflation zone* (Fig.5).

Until exotic afforestation of this area commenced in 1963, sand from this deflation zone lacked vegetation cover and fed active transverse dunes along most of the peninsular. Outcrops of old soil-bearing surfaces in the deflation zone are evidence of past dune cover but the nature and age of these old dunes is unknown. Another unanswered question of the Ninety Mile Beach area is whether the shoreline has *retrograded* (moved its position inland) during recent phases of sediment transport. There is little or no surficial evidence of this at Te Aupouri but the shoreline at both Awhitu and North Kaipara peninsulas has clearly cut deep into old aeolian landforms (Richardson, 1975; McDonald, 1986).

It should be noted that the present foredune along Ninety Mile Beach is artificial, having been planted with marram grass and maintained by the New Zealand Forest Service and presumably subsequent owners of the exotic forests inland. More discussion of the effects of this planting is presented in Section 8 which focuses on biogeography.

Te Aupouri Transverse Dunes

Inland from and nourished by the coastal deflation zone are massive, aligned *transverse dune ridges* (Figs. 5 and 6; Table 2). Prior to the planting of exotics these were slowly marching inland along the entire western length of the peninsula. Now a

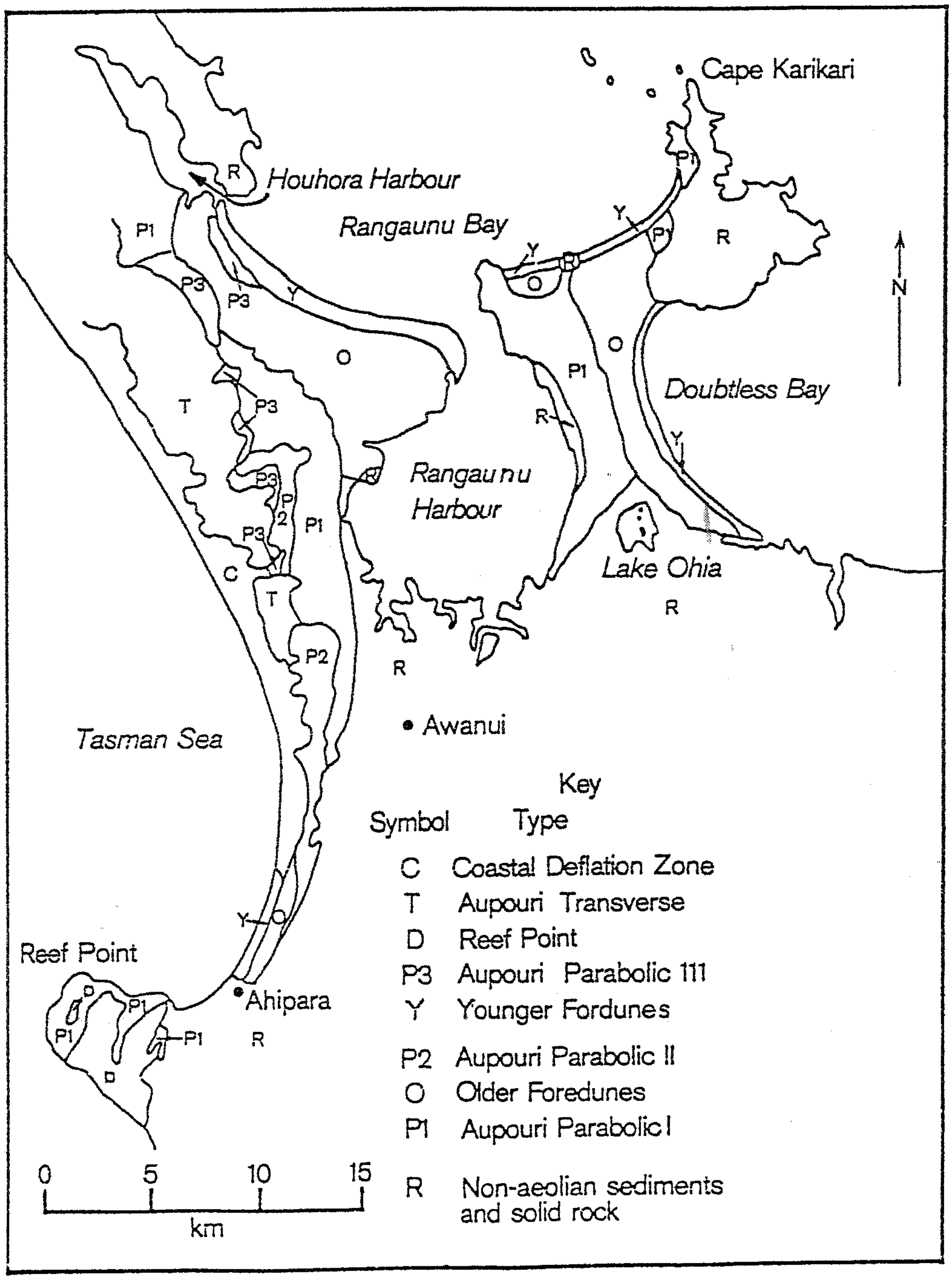


Figure 5. Dune classification of the southern Te Aupouri and Karikari Peninsulas.

Source: Hicks (1977)

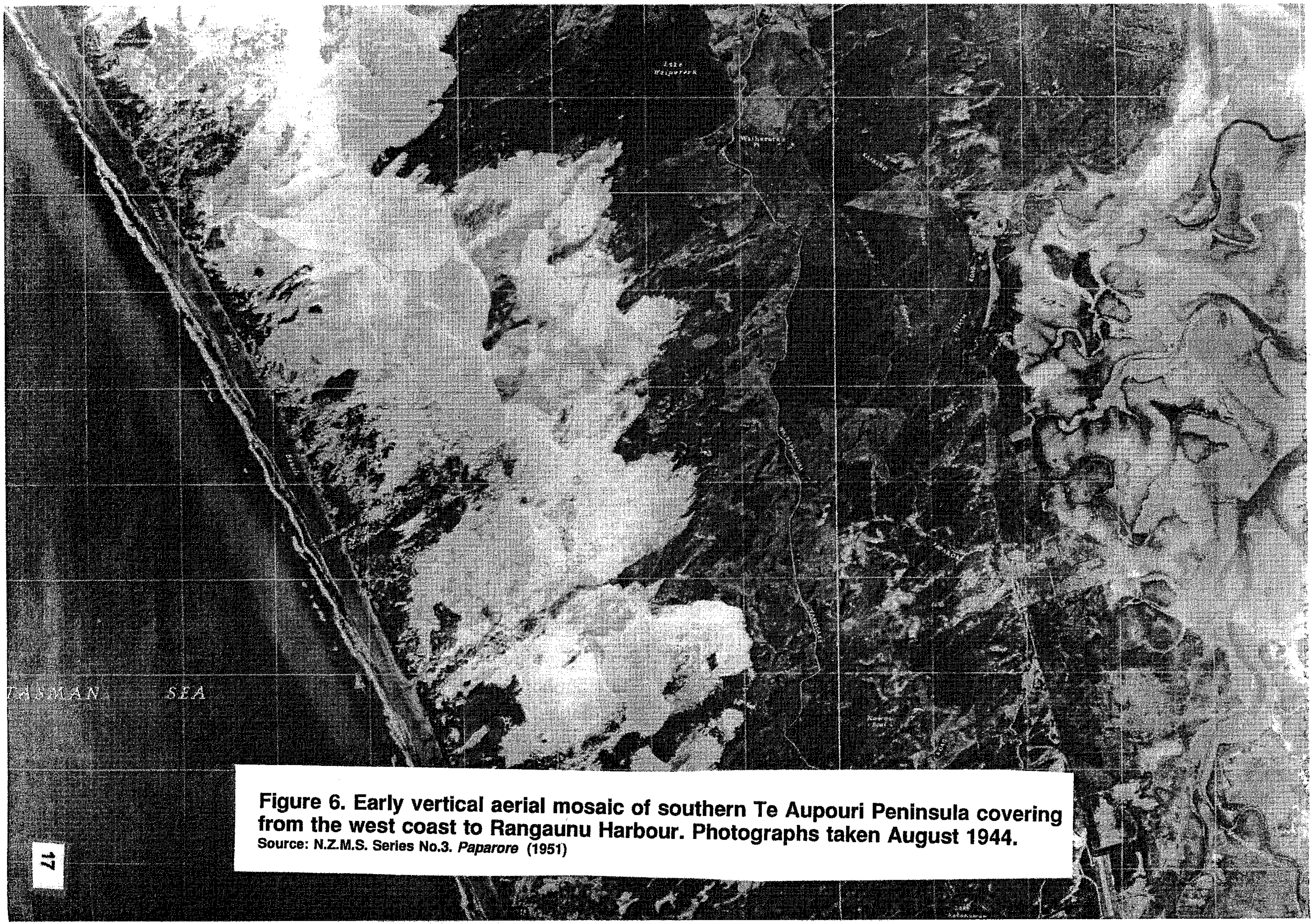


Figure 6. Early vertical aerial mosaic of southern Te Aupouri Peninsula covering from the west coast to Rangaunu Harbour. Photographs taken August 1944.
Source: N.Z.M.S. Series No.3. *Paparore* (1951)

2,000 ha dune reserve in the Te Paki area at the northern end of Ninety Mile Beach is the only extensive area of freely moving sand. In their natural state the transverse ridges were unweathered, unvegetated and unstable. Hicks (1983) noted that their crests recorded an *aklé* pattern. Although transverse dunes appear enormous with elevations reaching 50-100 m above PSL, Hicks (1975) points out that the dunes have, with distance from the west coast, advanced over a rising land surface and the height difference between crests and hollows is more like 30 m.

Dune hollows within the transverse complex are close to the water table and are composed of weathered, consolidate dune sand. Outcrops similar to those in the coastal deflation zone are commonly exposed in these swales indicating that old dunes also underlie the transverse dunes.

Hicks (1983) writes:
the transverse dune advance has been occasioned by almost complete destruction of vegetation on the foredunes (possibly also on unconsolidated parabolic dunes derived from them) by fires of either natural or Polynesian origin prior to European settlement.

This contention is broad enough and well supported enough by geomorphological evidence to be generally accepted. Nevertheless the timing of the initiation of dune instability and the relative contribution of various agents of fire have not been identified. We still do not know with any certainty how old these dunes are or even what caused them.

Type 3 Parabolic Dunes

Further inland from the transverse dune ridges are isolated areas of low, irregular parabolic relief, termed *type 3 parabolic dunes* by Hicks (1983) (Figs. 5 and 6; Table 2). This distribution suggests that the parabolic dunes have been partially overwhelmed by the larger transverse dunes. The parabolic dunes are only slightly weathered and still unconsolidated, with sharp ridges with frequent blowouts. Natural scrub grows on the ridges but terracettes have formed where they have been grassed and stock has been run. Dune hollows are mostly above the water table and although they contain wetland vegetation assemblages there is little or no peat accumulation.

Hicks found similar soil and vegetation types on both type 3 parabolic dunes and remnants of Holocene foredunes near Ahipara. As a result he propounded a similar age for the two dune areas. If coastal progradation followed sea level stillstand 6,500 yrs BP then type 3 parabolics were probably derived from an early episode of wind erosion near the shoreline soon after. The zone of transgressive dunes which separate the parabolic 3 dunes from the coast must have been generated since then.

With both parabolic and transgressive dunes derived from Holocene phases of dune instability, how is it that they have such manifested themselves in such different relief? The answer lies in the *morphogenesis* (development of the form) of the two dune types. While parabolic dunes form when the movement of sand is partially impeded by the succession of vegetation, transverse dunes develop when the movement of sand totally overwhelms existing vegetation and topography. Hicks (1975) ascribes this process to burning; either natural or anthropogenic. If the burning was solely natural why was there not more than one episode of transverse dune development over the long span of time recorded in the geomorphology? Perhaps instability from past natural burning episodes has produced parabolic and not transverse dune forms. It seems fairly certain that the impact of people in prolonging dune instability has had a central role in the shift to a transverse dune type.

Type 2 Parabolic Dunes

Continuing this traverse of the southern Aupouri, a further parabolic variety, the *type 2 parabolic dune* (Hicks, 1983), is encountered (Figs. 5 and 6; Table 2). These are rounded parabolas, up to 50 m in elevation. Dune sands have become consolidated and weathered to several metres. The dunes are subject to moderate wind erosion where the surface is devegetated. Drainage networks have not yet developed. Type 2 parabolic dunes were once vegetated by native forest as evidenced by massive stumps found on the ground or preserved in widespread peat deposits. Egg cup podzols (discussed in Section 8) are also common on the flanks or crests of dunes. Hicks (1983) credits an interstadial age to these dunes similar to the older parallel foredunes near Ahipara from which they trail landward as well as similar foredunes on the Karikari Peninsula. A better guess of their age may place them in the Last Interglacial, 125,000 years ago with parabolic dune development occurring soon after.

Type 1 Parabolic Dunes

The third variety of parabolic relief, the *type 1 parabolic dune* (Hicks, 1983), exhibits low (under 30 m), elongate parabolas further to the east of the other parabolic types (Figs. 5 and 6; Table 2). It is distinguished by highly developed podzolic soils, ranging from thin iron pans to indurated sandstone hard pans up to 0.5 m thick and overlain by up to 0.1 m of bleached silica sand. The surface is subject to severe soil loss by wind or sheet wash down the hard pan. Dune ridges are breached by surface stream networks and truncated by sapping at the edge of swamps. Dune hollows have grown outwards and relief has lowered. Low cliffs fronted by dissected, podzolised foredunes truncate the advance along its eastern margin. An *in situ* (in growth position) tree stump has been dated to an age in excess of 40,000 yrs BP. Finding an age of this dune type is even more speculative than for type 2 parabolic dunes. It is transparently much older. Does it date to the Penultimate Interglacial 215,000 years ago?

East Beach Younger Foredunes

Along Rangaunu Bay between Houhora and Rangaunu Harbours is a sequence of parallel dunes originating from the Parengarenga Facies and classified by Hicks (1975) as *younger foredunes* (Figs. 5 and 7; Table 2). This is the widest zone of unconsolidated foredunes on the Aupouri and Karikari Peninsulas, demonstrating an abundant supply of sand during the period of their progradation. The crests of East Beach foredunes are prone to severe wind erosion and are punctuated by multiple blow-outs. Hicks (1975) found that immediately south of Houhora Heads these have become mobile parabolic dunes (but does not say whether these are moving to the west or the east). He provides these unconsolidated dunes with the same post-Holocene stillstand age as the west coast foredunes near Ahipara and similar foredunes on the Karikari Peninsular.

East Beach Older Foredunes

Located between the Holocene foredunes of East Beach and the parabolic dunefields lies a sequence of parallel consolidated foredunes, classified by Hicks (1975) as *older*

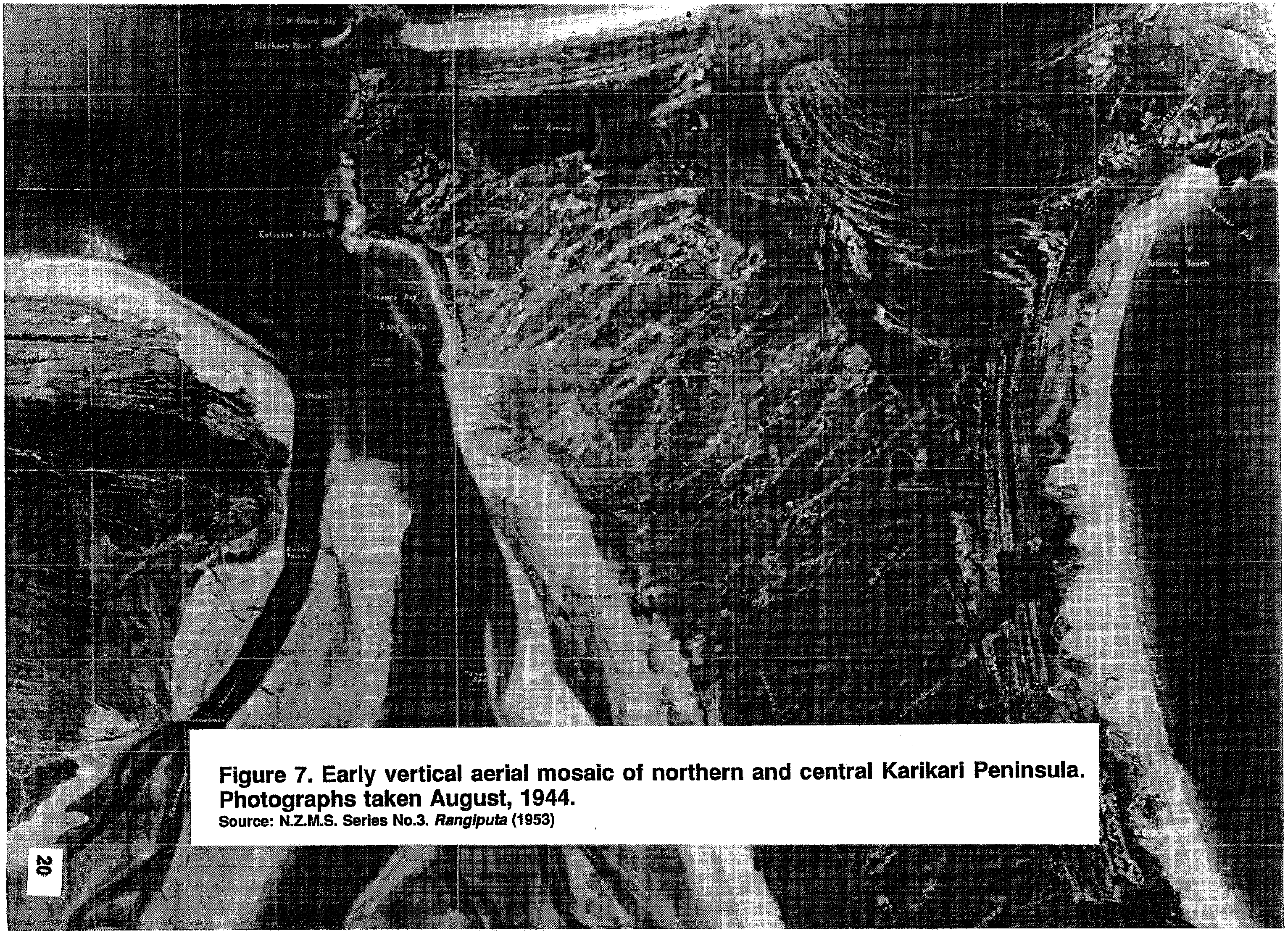


Figure 7. Early vertical aerial mosaic of northern and central Karikari Peninsula. Photographs taken August, 1944.
Source: N.Z.M.S. Series No.3. *Rangiputa* (1953)

foredunes (Figs. 5 and 7; Table 2). The ridges are either partially or totally buried by peat which has accumulated in the dune swales and overtopped the lower dunes. The ridges are analogous in their position to the modern unconsolidated foredunes, but interestingly, unlike the younger features, are composed of sand believed to come from the west coast and not the east!

An hypothesis for this seeming anomaly in the sedimentation pattern is suggested here. It can be inferred that the sand found in the older East Beach dunes came primarily from the erosion of type 1 parabolic dunes that once reached across the Aupouri tombolo as far as the Karikari peninsula. Northern Rangaunu Harbour was excavated out of these parabolic dunes by the well developed, northward flowing drainage network of the much older (pre-Quaternary) high-relief catchments of the Northland hinterland. The older foredunes of East Beach must have developed when this sediment became available for coastal deposition. The degree of maturity of these features places this episode in the Last Interglacial, 125,000 yrs BP.

Karikari Younger Foredunes

A curved sequence of *younger foredunes* (Hicks, 1975) extend along the length of Puheke, Karikari and Tokerau Beaches (Figs. 5 and 7; Table 2). Hummocky foredunes form a 100-200 m wide belt behind Puheke and Karikari Beaches. By comparison the younger Tokerau foredunes are highly irregular in form. This irregularity seems to be a consequence of considerable sand movement within the foredune belt after devegetation. While Puheke and Karikari sands belong to the Parengarenga Facies, Tokerau Beach has a much higher component of mafic minerals derived from the volcanic tip of the Karikari Peninsula.

Karikari Older Foredunes

Landward of the younger foredune sequence lie *older foredunes* (Hicks, 1975) separated by tracts of peat swamp (Figs. 5 and 7; Table 2). The landward limit of the older foredune belts is defined by the margin of the parabolic dunefields. As at East Beach these are low, parallel and partially buried sand ridges. Older dunes at Karikari and Puheke Beaches are poorly preserved due to peat development, marine erosion and burial by mobile dunes.

Older foredunes at Tokerau Beach can be traced to the northwest of the contemporary Tokerau Beach where they are intersected by older Karikari foredunes. It is evident that prior to the convergence of the two foredune sequences a strait linked Doubtless and Rangaunu Bays. As the respective foredune belts prograded, they bisected to form a tombolo. During this process the Karikari dunes deflected the tidal current towards the western end of the Tokerau dunes which were truncated. Progradation continued, joining the two dune sequences and then working to infill the two discrete embayments (Hicks, 1975).

Karikari Parabolic Dunes

The western half of Karikari Peninsula and outlying areas behind Karikari Beach are entirely comprised of *type 1 parabolic dunes* (Hicks, 1983) of a west coast origin (Figs. 5 and 7; Table 2). They demonstrate low, elongate and regular parabolic morphology, reflecting the lengthy distance they have travelled. The parabola apices are frequently breached by active or dry stream channels. The dunes are consolidated with advanced podsolation comparable to similar dunes on Te Aupouri Peninsular. These dunes are subject to severe surface soil loss, by wind or sheet wash, down to the hardpan. Swales have expanded outwards and contain peat deposits and evidence of former forest cover.

Pre-parabolic Surface (the primary dune surface)
Unconformably underneath and beyond the eastern limits of the type 1 parabolics and lapping onto volcanic rocks is a low relief surface named by Hicks (1983) the *pre-parabolic surface* (of course parabolas are not a recent invention!). While dune ridges are unrecognisable, remnants may exist in the form of low, rounded hummocks. Sections of the surface expose indurated aeolian and waterlaid sandstones, with seams and lenses of lignite. The soil profile shows extreme podzolisation. Low areas are characterised by well developed gullies and broad peat swamps where drainage is impeded. Hicks (1983) attributes this surface to several episodes of dune advance interspersed with stable intervals which occurred during the early late Pleistocene.

Dune Type	Morphology	Mineralogy	Soil	Vegetation	Dissection
TE AUPOURI TRANSVERSE	Transverse, akle	West Coast Facies	Sand	None (before 1963)	Undissected, no surface drainage
TYPE 3 PARABOLIC	Aligned, irregular parabolas	West Coast Facies	Sand	*Leptospermum /Kunzea* Scrub	Few breaches or surface streams
TYPE 2 PARABOLIC	Aligned, irregular parabolas	West Coast Facies	Mature Podsol	Formerly mixed Kauri forest and sandy peat swamp	Few breaches or surface streams
TYPE 1 PARABOLIC	Irregular and regular parabolas	West Coast Facies	Very Mature Podsol	Formerly mixed Kauri forest and peat swamp	Surface stream networks
YOUNGER FOREDUNES	Parallel foredune ridges	Parengarenga Facies	Sand	*Leptospermum /Kunzea* and coastal scrub	Closely spaced ridges, few streams
OLDER FOREDUNES	Parallel foredune ridges	Parengarenga Facies	Mature Podsol	Formerly mixed Kauri forest and swamp	Widely spaced ridges dissected by streams

Source: Adapted from Hicks (1975)

Table 2. Characteristics of Southern Aupouri and Karikari Peninsula Dunes

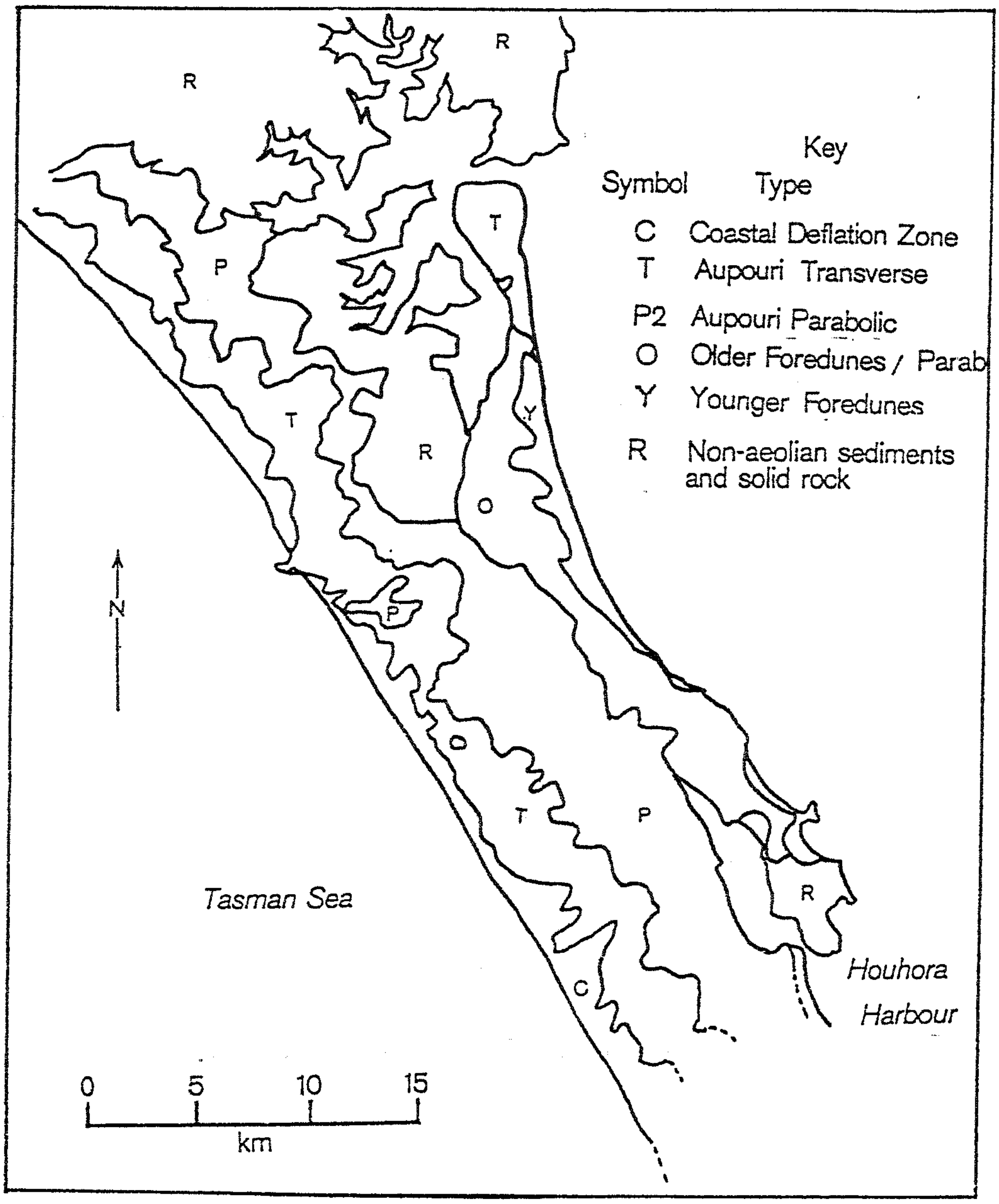


Figure 8. Preliminary dune classification of the northern Te Aupouri Tombolo.

Northern Te Aupouri - West Coast
No one has tackled in a geomorphological sense the western portion of the northern Aupouri tombolo. The obvious starting point would be to extend Hicks' landform classification further north along the peninsula. On the face of it this can be done with some success (Fig. 8). The western coastal deflation zone and transverse dune type extend the length of Ninety Mile Beach and beyond Scott Point to Twilight Beach (Fig. 9). North of Te Paki Stream transverse dunes attain their maximum elevation and abut pre-Quaternary lithology. Clearly, surficial expression of the parabolic dune units are absent from this area, but are found as far north as Lake Wahakura near the southern end of Parengarenga Harbour and discontinuously inland from the western harbour margins. Whether all three parabolic types are present or not is not known without further investigation of morphology, soils, erosion and vegetation. Nevertheless it can be concluded that the surficial sequence of Quaternary dune types is neither as complete or as old as in the south.

Northern Te Aupouri - East Coast
The Quaternary geology of coastal deposits on the eastern side of Te Aupouri Peninsula has been studied by Goldie (1975) and Ricketts (1975) and by a number of others at Kokota, Parengarenga Harbour. Goldie worked on the tombolo enclosing Houhora Harbour whereas Ricketts investigated the southern Parengarenga Harbour - Te Kao district.

Goldie's work was the less significant and his contribution is largely dealt with in the preceding section on terraces and uplift. Goldie did identify types of both eastern and western set parabolic dunes which fit into Hicks' classification. Eastern set parabolic dunes appear analogous to dunes on the northern end of East Beach immediately to the south. Western set parabolics are found within 2 km of the east coast at Henderson Bay. Based on morphological and soil classification criteria, both type 2 and 3 parabolic dunes are represented (after Hicks, 1983). Type 2 parabolics reach the vicinity of the present main arterial route north and occurrences of type 3 parabolics are confined to the eastern side of the road (Fig. 10). Many stumps and logs - evidence of former forest cover - have been excavated from beneath the present vegetative cover of *Leptospermum/Kunzea* and wetlands.

Ricketts (1975) interpretation of Kokota, the sand spit at Parengarenga, is incorporated into the next section. The residual of his study area can be subdivided on the basis of morphology into three major physiographic regions.

Between Wairahi Stream and Paxton Point is an old stabilised eastern set dunefield bounded and partially inundated on its landward margin by west coast dunes. One could speculate that this dunefield could be placed with Hicks' (1983) type 2 parabolic and older foredunes types if it were not unconformably overlain by a parabolic dune complex up to 30 m thick, which exhibits deep podzolisation. Consequently the dunefield may have originated in an earlier phase. A similar area immediately to the north exhibits greater elevation and less extensive exposures. This area is distinguished by old fluvial and pond deposits indicated by peat and concave-up silt deposits.

The second physiographic region consists of large zones of active transverse and parabolic dunes are found along the east coast. South of Waiharara stream, parabolic dunes are aligned broadly parallel to the present eastern shoreline in concord with Goldie's and Hicks' typing of similar features to the south. The dune type classification can be extended north of Waiharara Stream in spite of somewhat variant morphology. Dunes here are more irregularly distributed, reflecting the greater elevation and relief of that area. All are within 1.5 km from the coast. Destabilisation is common including morphological evidence of coalescence between dunes, local bulges and blowouts.

The third region occurs inland from the northern zone of Pleistocene dunes, between Te Kao and Lakes Morehurehu and Te Kahika. It is an expanse of flat-topped hills that Ricketts (1975) interprets as an old marine terrace resting on Cretaceous and Tertiary basement lithics. Coastally-derived sediments of this surface were regarded by Ricketts as the oldest in the area.

In summary then, it is feasible to extend Hicks (1983) classification further north on Te Aupouri Peninsula. A preliminary attempt at this, employing morphological, geological and soil classification criteria, literative interpretation and limited fieldwork is portrayed in Figure 8. However its validity needs to be checked by in-depth fieldwork.

Previous discourse linking the evolutionary chronology of Te Aupouri and Karikari Peninsulas to marine terraces has been largely neglected in this discussion. In actual fact an history of coastal evolution remains unaccomplished. The geomorphological approach of Hicks (1975, 1983) utilising morphology, topographic dissection, vegetation and soil profile criteria is a good starting place. Any definitive study would also include a reinterpretation of surfaces attributed to marine erosion. Progress in scientific methodology now allows any new work to proceed in the context of advances in facies modelling and to be framed in a chronology derived from a wide array of new dating techniques.

The Evolution of Kokota - Dating with Destiny

Introduction

The white silica sand of Kokota barrier-spit is undoubtedly the most striking feature of Parengarenga Harbour. The bulk of surficial sands comprising the spit are unconsolidated deposits of the Parengarenga Facies. These sand reserves are extensive, estimated at 118.9 x 10^6 tonnes (Batt and Fortune, 1983). The spit extends south to north, 6 km from its proximal to distal ends, is 0.75 km wide in the south and 3 km wide in the north (Fig. 10).

Kokota is a flat sand plain, surrounded by a semi-continuous ring of partially vegetated dunes, and supporting a number of large free-moving dunes of transverse or barchan types. Three contemporary beach environments are represented: ocean; harbour entrance; and, harbour-inlet beach (Adam, 1984). There is an analogous transition from swell wave-dominated beach processes, to tidal-dominated processes, to tidal-dominated and fetch wave processes with distance into the harbour.

Beneath the aeolian veneer of the spit interior, three beach facies, akin to the

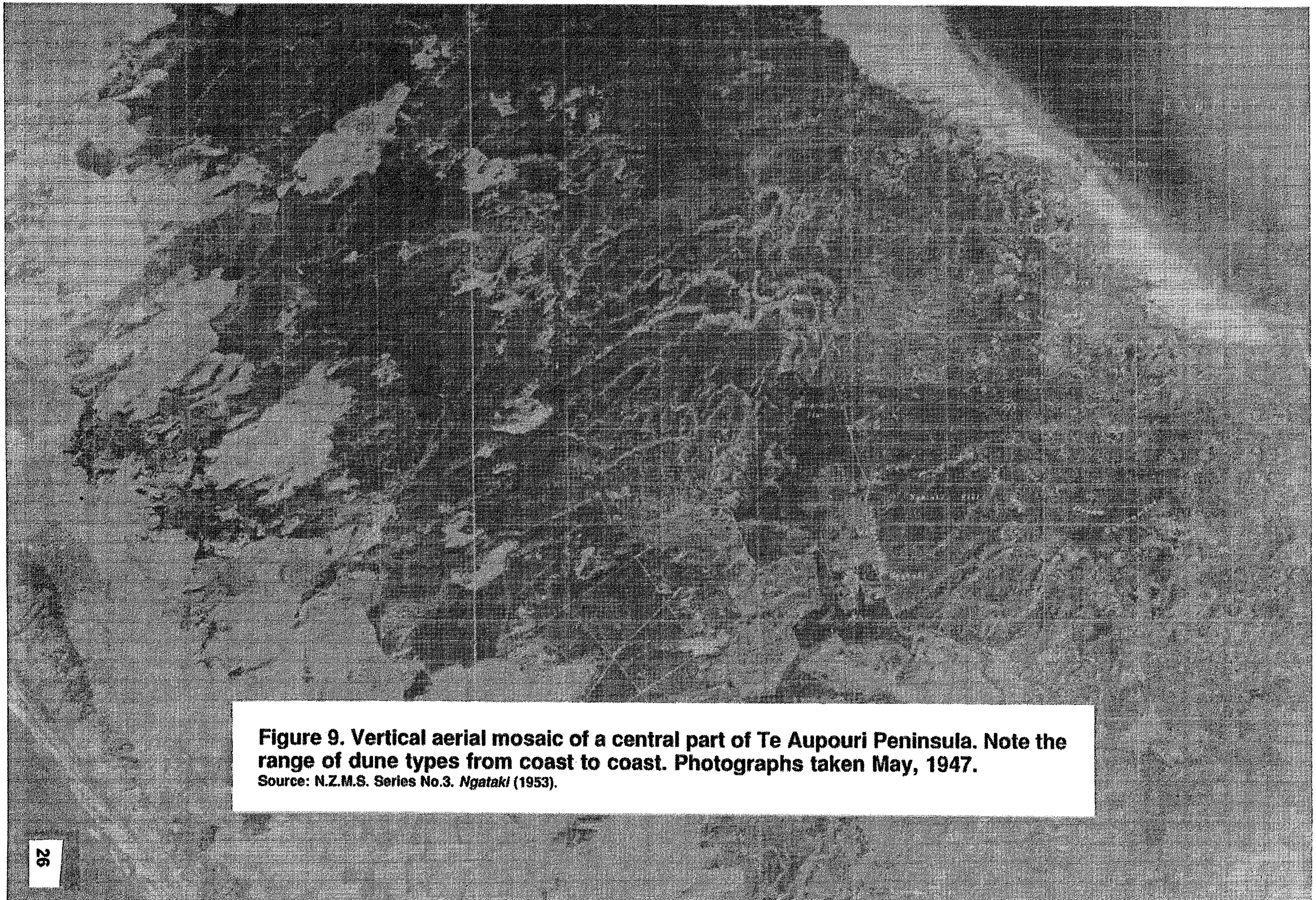


Figure 9. Vertical aerial mosaic of a central part of Te Aupouri Peninsula. Note the range of dune types from coast to coast. Photographs taken May, 1947.
Source: N.Z.M.S. Series No.3. *Ngataki* (1953).

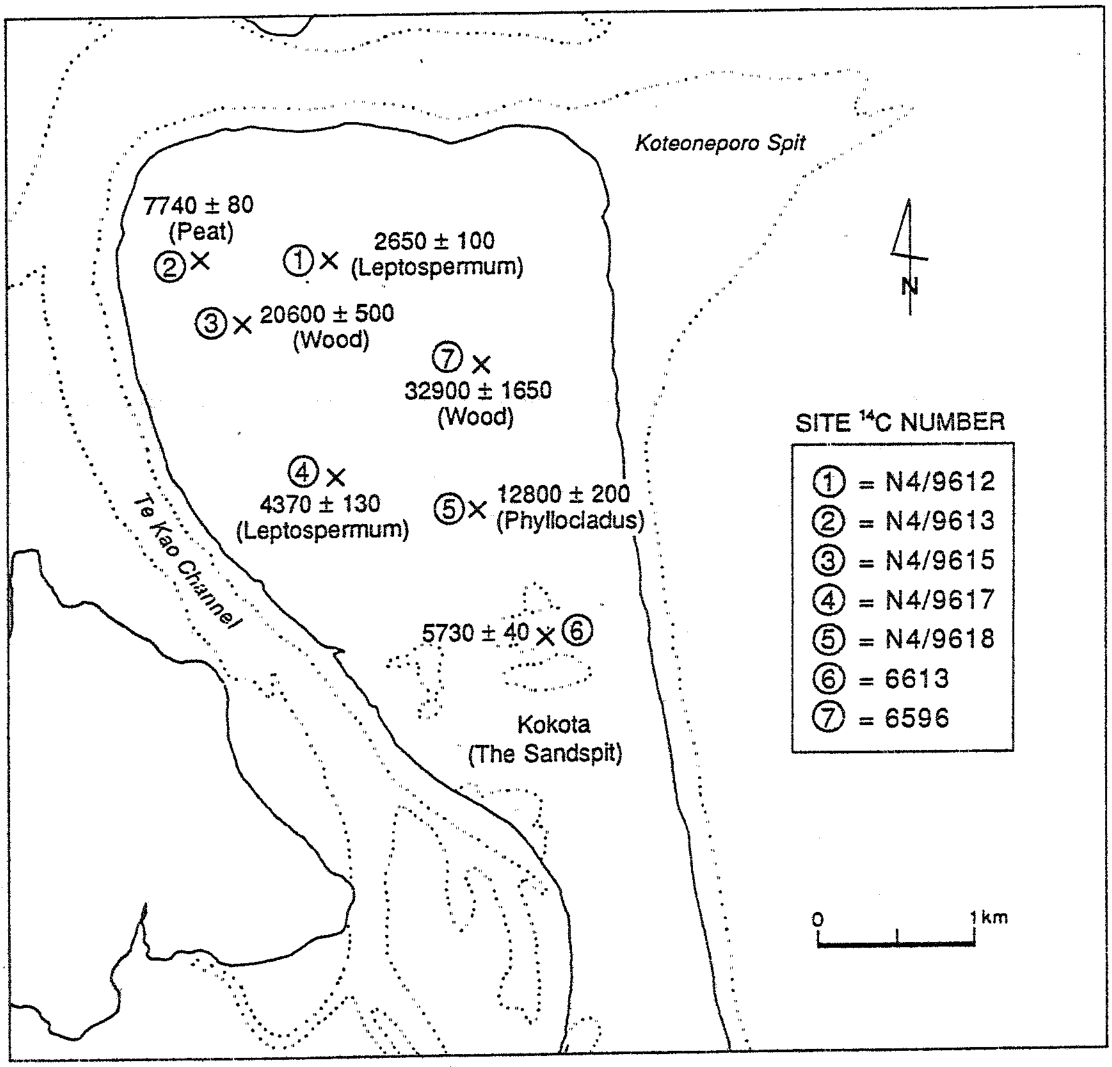


Figure 10: Location of ^{14}C dates, Kokota.

contemporary beach environments have been identified along with a recurve-shaped offshore bar facies (Batt and Fortune, 1973). These facies have not been dated. This is unfortunate as their elevation correlates closely with present-day analogues and along with their freshly preserved nature suggests that they relate to the Holocene development of the barrier-spit.

Aeolian sands also overly a sandstone terrace which may have provided a core for the formation of the present barrier-spit. The western edge of this terrace is well-defined, and in the interior, areas of the terrace surface are exposed (Murray-Brown, 1984). It is 6-8 m above PSL. The terrace is 2 m higher than the surrounding sand flat on its western side but the eastern boundary is masked by drifting sand.

<u>Dates and Interpretations</u>

There is much dead organic material, both on and off the terrace. A number of radiocarbon (^{14}C) dates have been performed on samples from this material (Fig. 10). Thermoluminescence (TL) dates have also been undertaken on layers within the terrace surface. The details of all these dates, both ^{14}C and TL, are compiled in Table 3. To clarify the sequence of deposition, the ages, materials and substrates of dated materials have been stacked chronologically in Fig. 11.

What can be gleaned from these dates? Working in time backwards from the present, the first observation that we can make is that the most recent dates are on *Leptospermum scoparium* (manuka) growing in peaty sand, over 2,500 years ago. Lack of sub-fossil vegetation subsequent to this period indicates that a dune destabilisation phase may have been initiated around that time. Maybe the largely unvegetated dunal vista that we see today dates from that period. Another observation is that the youngest-aged ^{14}C sample is situated near the distal end of the spit (Fig. 10). Hence the spit had largely formed by 2,500 yrs BP.

We can reconstruct the type of environment that existed before 2,500 yrs BP from the string of five ^{14}C dates reaching back to 7,740 yrs BP (Table 3, Fig. 11). These indicate that coastal scrub cover and a high peat-forming water-table prevailed in this interval. The wide range of ages suggests more than one phase of plant mortality, perhaps due to localised instances of dune instability (Interestingly this pattern contrasts with the rest of Te Aupouri Peninsula as presented in Section 8).

The time interval of coastal scrub cover on Kokota largely overlaps with the Holocene stillstand. While the two youngest dates are from surfaces exposed in the sand flat above unconsolidated sands (2,580 ± 70 yrs BP, 3,990 ± 80 yrs BP), the next oldest date (5,730 ± 40 yrs BP) is derived from wood above sandstone at a level below the exposed terrace. The oldest of these dates (7,740 ± 80) is taken from peat overlying the sandstone terrace deposit.

It is difficult to ascertain from such a limited data base, but one could hypothesise that the distribution of mid-late Holocene ^{14}C dates implies the spread of coastal scrub to new environments on Kokota. Thus the oldest of these dates is found on the terraced remnant of the Late Pleistocene surface which was not inundated by the present stillstand sea-level. However as sea-level rose in the Mid Holocene it moved the beach face inland and this terrace may have been buried by transgressive dunes.

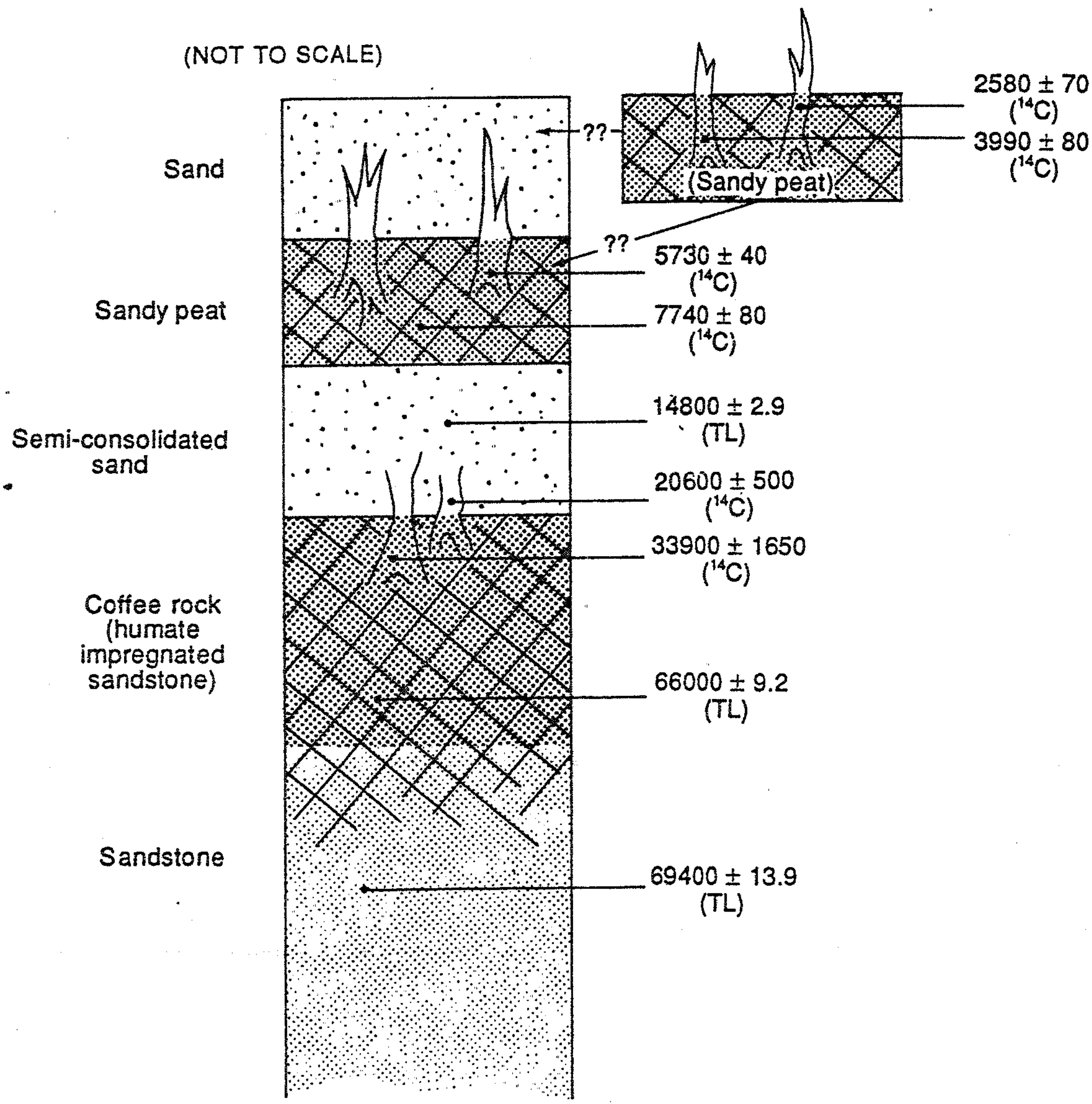


Figure 11. A stacked chronology of dating estimations and associated substrates for Kokota.

Wood dated at 5,730 yrs BP overlies a lower level of Late Pleistocene sandstone which was probably eroded at the culmination of the Holocene Marine Transgression out of the same consolidated material as comprises the terrace. This area must have been revegetated early in the stillstand period before being inundated by moving sand.

The two youngest dates represent vegetation occupying aeolian deposits on top of an assumed Mid-Holocene beach facies. They represent a different stratigraphic context from the other two dates which overlie Late Pleistocene sediment. Consequently an ambiguous interpretation of the stratigraphic location of these younger dates is represented in Fig. 11. Either there was a continuous spread of vegetation and sandy peat substrates throughout the Mid Holocene, or there was an effective lag of perhaps 1,500-2,000 years after stillstand commenced. This delay would have been caused by a sequence of; 1) progradation of the spit, 2) mantling in dunes, and 3) establishment of pioneer vegetation, before 4) the eventual development of the coastal scrub sampled for ^{14}C dating. Just which interpretation is correct could be tested by producing time-lines of the Holocene evolution of the barrier spit using ^{14}C dates of the beach facies beneath the barrier-spit.

Earlier dates from samples ranging in age from 12,800 ± 200 yrs BP to 33,900 ± 1,650 yrs BP, portray mixed conifer-podocarp forest growing in the area throughout the last stages of the Pleistocene and the first of the Holocene (Table 3). Tree stumps (*Agathis, Podocarpus, Phyllocladus*) are confined to locations atop of the sandstone terrace and below the peat and *Leptospermum* layers which yeilded Mid-Holocene ^{14}C ages. Thus, we can state with some certainty that there was a switch from full forest in the Pleistocene to coastal scrub in the Holocene and this occurred well before the culmination of the Holocene marine transgression. Was the transformation triggered by the climate change that stimulated the marine transgression rather than the direct effects of sea-level rise? Alternatively, did sand influxes and rising water-tables affect the forest so early on in the Holocene? Or is there another factor that we have not considered?

We can speculate that an ancestral Parengarenga embayment probably existed from the onset of Te Aupouri Tombolo growth but the evolution of the Kokota barrier-spit is almost certainly a Late Quaternary development. TL dating was employed to assist with the task of determining the age of this development (McLean *pers comm*, 1992). Unlike many ^{14}C dates, TL dates sample the substrate directly. The TL estimations on Kokota were selected with the idea in mind of placing the depositional facies comprising and overlying the sandstone terrace into a chronological framework. Contacts of old beach and dune facies are recorded in excellent exposures within the terrace scarp, located several metres above their present analogues.

It could have been assumed that a Last Interglacial age would be rendered from the samples taken from above and below the contact of beach and dune strata. Surprisingly, ages of 66,000 ± 9.2 yrs BP (humate impregnated sandstone; aeolian facies) and 69,400 ± 13.9 yrs BP (sandstone; beach facies) were returned (Table 3, Fig.8). If these are to be believed then a sea-level high has been recorded at approximately 60,000-70,000 yrs BP. Such a phenomenon is not recorded elsewhere although it is not out of the question that a Late Pleistocene interstadial has been recorded (see Fig. 5a). If this is true then a history of rapid uplift has been chronicled (see Section 4) and Last Interglacial deposits are absent on Kokota. Alternatively these TL dates may have been contaminated by submersion in the water-table and may be assumed to be minimum dates.

Sample No.	Data source	Grid Ref.	Material	Layer	Age
NO2/f9612 [1]	Ricketts	N4/461386; interdune flats, northern end of spit	Wood; *Leptospermum scoparium*	*In situ* within surficial peaty sand, thin crust of flaky peat present	2,580 ± 70 (^{14}C, new $T_{1/2}$)
NO2/f9613 [2]	Ricketts	N4/452386; peat capped terrace	Peat	Peaty layer overlaying coffee rock terrace	7,740 ± 80 (^{14}C, new $T_{1/2}$)
NO2/f9615 [3]	Ricketts	N4/456381; peat capped terrace	Wood	Peaty layer overlaying coffee rock terrace	20,600 ± 500 (^{14}C, new $T_{1/2}$)
NO2/f9617 [4]	Ricketts	N4/462370; interdune flats, immediately west of Pleistocene terrace	Wood; *Leptospermum scoparium*	*In situ* within peaty sand	3,990 ± 80 (^{14}C, new $T_{1/2}$)
NO2/f9618 [5]	Ricketts	N4/472368; peat capped terrace	Wood; *Phyllocladus* bark	*In situ*, partly buried by peat containing fossil *Leptospermum* and sedges	12,800 ± 200 (^{14}C, new $T_{1/2}$)
NO2/f065 (NZ 6613) [6]	Hosking	N4/477359; interdune flats, centre of spit, north of Pleistocene scarp	Wood; species not stated	*In situ*, in clean sand with roots in humate impregnated sandstone (coffee rock)	5,730 ± 40 (^{14}C, new $T_{1/2}$)
NO2/f066 (NZ 6596) [7]	Hosking	N4/472378; interdune flats, between two large dunes, on coffee rock terrace	Wood; *Agathis australis*	*In situ*, within coffee rock deflation surface above orange sandstone	33,900 ± 1650 (^{14}C, new $T_{1/2}$)
?? [8]	McLean	Coffee rock terrace	Substrate	Consolidated sand above coffee rock layer	14,800 ± 2.9 (TL)
?? [9]	McLean	Coffee rock terrace	Substrate	Base of coffee rock layer	66,000 ± 9.2 (TL)
?? [10]	McLean	Coffee rock terrace	Substrate	Sandstone beneath coffee rock layer	69,400 ± 13.9 (TL)

Source: compiled

Table 3. Dating estimations for Kokota Spit, Parengarenga

The third TL date, sampled from semi-consolidated sand overlying the sandstone terrace, rendered an age of 14,800 ± 2.9 (Table 2, Fig. 11). An unstable phase near 15,000 yrs BP does indicate that fresh sand was moving at that time, tending to

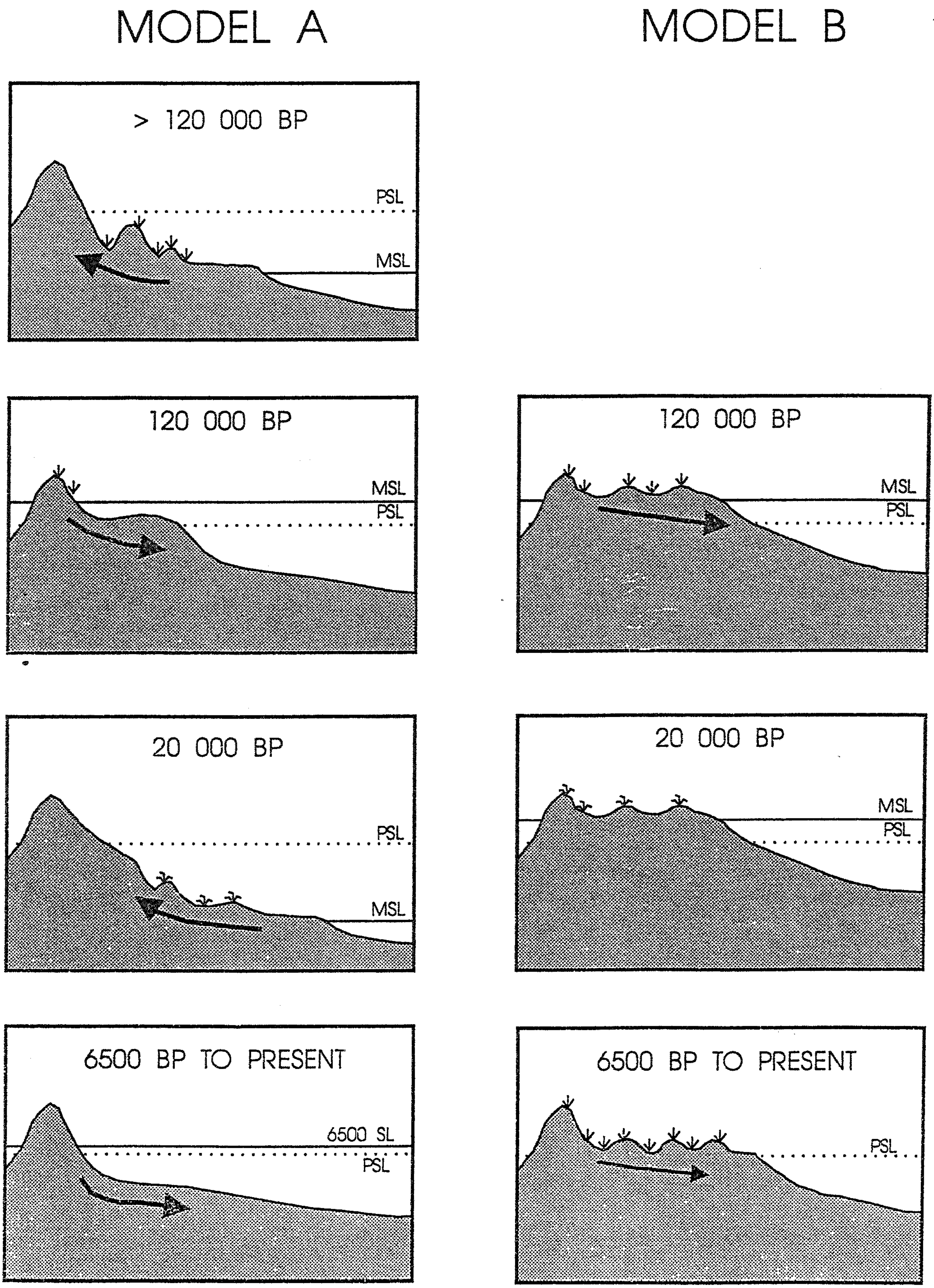


Figure 12. Alternative models for the accumulation of sand on Kokota. Arrows depict the net direction of sediment movement.

support the theory of dune transgression affecting the area whilst sea-level was still well below PSL and rising.

Evolutionary Models

This discussion on the Quaternary evolution of Kokota represents *work in progress* (ie: not to be quoted or used out of a teaching context). As part of this ongoing project McLean (*pers. comm.*, 1992) has presented two elementary models of coastal evolution which may explain sequential deposition at this location. These are outlined below and illustrated in Fig. 12 for the purpose of generating thought and discussion. Just which models, or elements thereof, are authentic depends on the accuracy of the paleo-environmental interpretations and ages presented above.

Further dating of marine deposits beneath the barrier-spit and sandstone substrates tied in with better data of the elevation and structure of various deposits is required. When this is done Kokota may prove its potential to be one of the better Late Quaternary coastal sites in New Zealand.

Model A

1. Before the Last Interglacial sea-level high: *low sea-level dune buildup.*
2. During the last Interglacial: *partial destruction of dunes.*
3. During Last Glacial (c.20,000 yrs BP): *build up of dunes at low sea-level.*
4. In the Present Interglacial: *partial destruction at sea-level during stillstand.*

Model B

1. During the Last Interglacial: *deposition of dunes; beach/dune boundary position portrayed by structural exposures in sandstone.*
2. During the Last Glacial: *coastal processes abandoned the area, coastal zone operates at lower sea-levels.*
3. In the Present Interglacial: *dune-building phase following Holocene stillstand formed the current barrier-spit.*

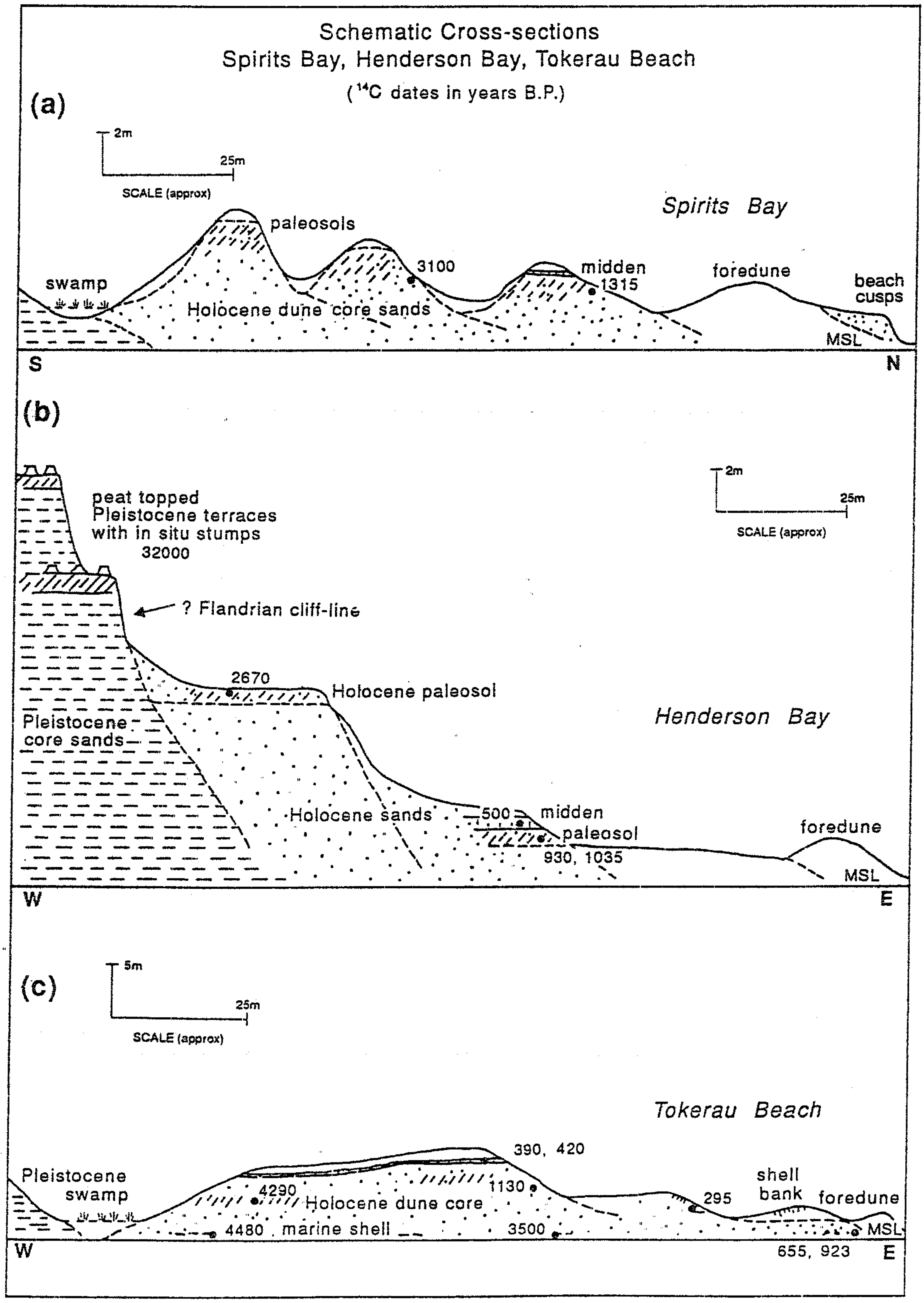


Figure 13.
Source: Millener (1981)

Section Six: Smaller Beaches and Embayments

Introduction - Life's a Beach

This section addresses some of the beaches encountered around Te Aupouri and Karikari Peninsulas. Its purpose is primarily descriptive and centres on providing contextual information for field teaching. Two time-scales are of relevance: the term of Holocene (in place of Quaternary) beach/dune evolution; and, the *real-time* scale of active beach/dune process and sedimentation.

Rip Curls or Beach Breaks

Twilight Beach (Te Paengarehia)

This exposed, high-energy 4 km long beach is bounded by outcrops of Whangakea Volcanics at Scott Point and Herangi. There are two dune systems; one bordering the beach, and an inland transverse dune system which has inundated a Pleistocene parabolic dune complex (Partridge, 1992). These drifting dunes, up to 70 m above PSL, are in the course of moving to the northeast and encroaching onto the wetlands and farmland behind the fixed dune complex. Outcrops of the older parabolic complex are often capped by iron pans and have been deeply eroded behind the beach/dune system. Midden deposits have been instrumental in protecting older dune remnants from erosion. Faunal and archaeological lag deposits are frequently found resting upon iron pans exposed by aeolian deflation (Millener, 1981, Taylor, 1984).

Spirits Bay (Piwhane)

This isolated north-facing 8 km long beach is parenthesised by dramatic headlands of Wangakea Volcanics up to 300 m high. Streams drain into the sea at both ends of the beach from lagoons and wetlands enveloped between Holocene and Tertiary sediments (Millener, 1981). Dunes are vegetated, tending higher halfway along the beach and composed of yellowish sand with a high component of shell grit (Partridge, 1992). The schematic cross-section of the dune/beach complex (Fig. 13a) depicts a mid-late Holocene barrier which have undergone periodic phases of stability and instability since its deposition. Some instability may have been initiated by Polynesian habitation as evidenced by frequent midden deposits.

Spirits Bay is distinctive for its highly carbonate beach sands and well-preserved *beach cusps* (small-scale rhythmic features on the foreshore). Variation in cusp morphology depends on grain size, beach slope and tidal range. The cusps at Spirits Bay are remarkable for their carbonate sedimentary structure which is unstudied in the beach morphology literature! On reflective beaches, such as Spirits Bay, cusps are associated with *gravity* (or *subharmonic*) edge waves; resonant waves trapped by reflected and incident waves against the edge of the beach. The trapped wave field organises into a series of discrete nodes. Although not easy to observe, edge waves have a maximum elevation at the shoreline and this is visible as peaks in the run up spectra. The period of gravity edge waves is two times the period of the incident wave (Carter, 1988).

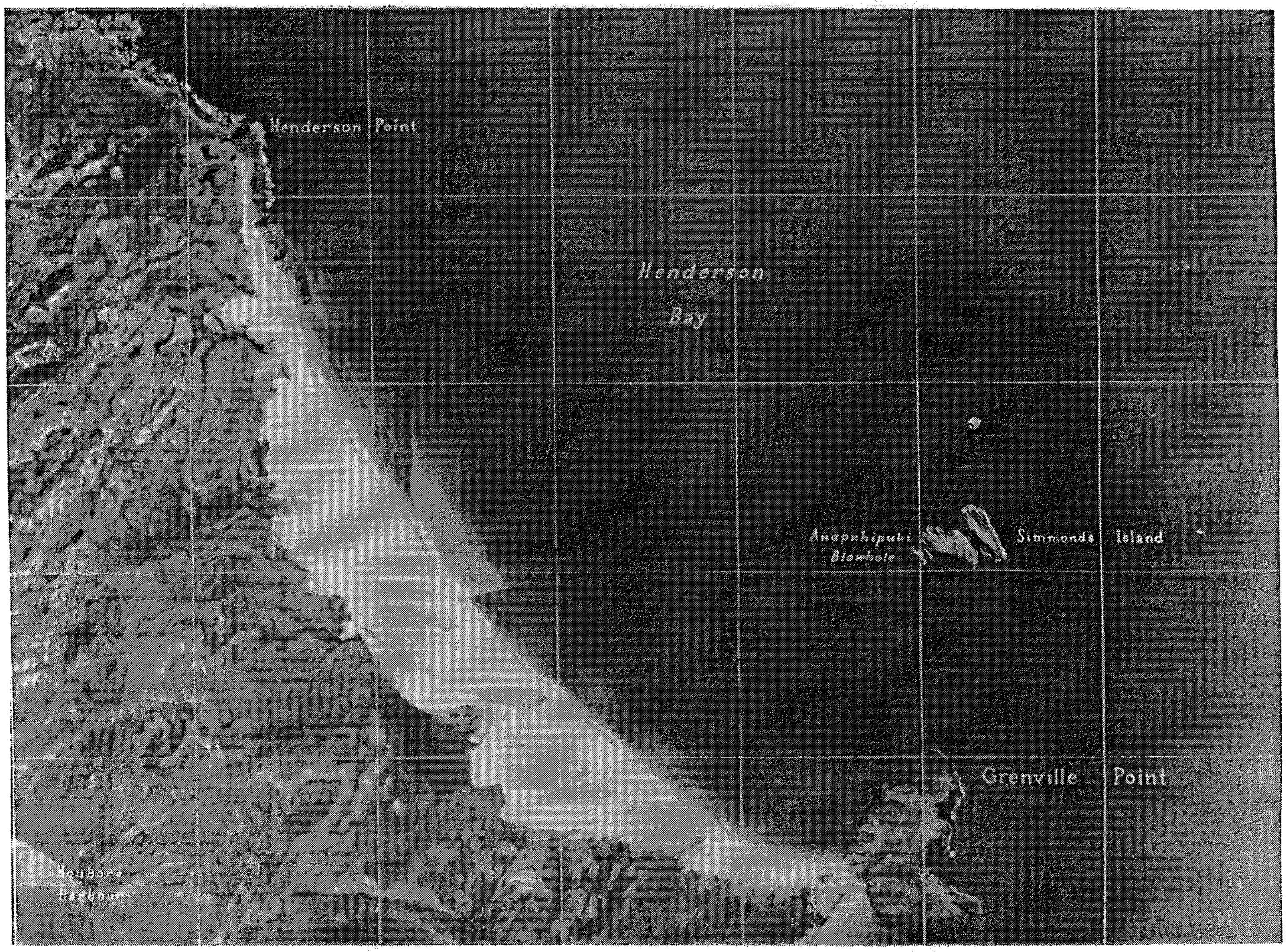


Figure 14. Vertical aerial photograph of Henderson Bay. Taken May 1947, prior to the planting of marram grass.
Source: N.Z.M.S. Series No. 3. *Grenville* (1953)

Spirits Bay Edge Waves,
Some Things to Look For...

Sediment
What is the sediment pattern?
How is the sediment laid down?
Where is sediment moving the most?
Is there relationship between cusp spacing and location on the beach?

Swash
How does swash flow around the cusps?
Which features are depositional or erosional?
Is there a difference in permeability between horns and bays?

Waves
Can edge waves be seen by eye?
Can we calculate the period of edge waves?

Henderson Bay

Henderson Bay is a 4.3 km long, gently curving sandy beach with rocky headlands at either end. It is part of a tombolo forming the eastern margin of Houhora Harbour which links four blocks of volcanic and sedimentary rock. Fig. 13b shows the beach backed by a 6 m high transverse dune field, breached in places by small drainage systems. The Holocene dunes are resting against a cliff-line excavated from the extensive Pleistocene dune system studied by Goldie (1975). Pleistocene deposits behind Henderson Bay have planar surfaces which have been interpreted as marine cut terraces at heights of 2-4 m, 6-8 m, 19-29 m, 40 m and 60 m. Remnants of Holocene dunes also mantle these higher terraces. A diverse and extensive assemblage of subfossil avain and reptilian remains have been collected from these dune remnants. Midden shell has been ^{14}C dated at 500 ± 70 yrs BP, while faunal remains in paleosols rendered ages ranging from 930 ± 60 yrs BP to 2,840 ± 50 yrs BP, well before human habitation (Millener, 1981). The morphology of the Henderson Bay dune field has been modified since the extensive planting of marram grass in 1976 (Fig. 14).

Tokerau Beach

Sweeping 10 km along the eastern side of Karikari Peninsula, Tokerau Beach is largely sheltered by the configuration of Doubtless Bay. The beach is backed by a belt of aeolian sand dunes and marine-deposited shell ridges up to 500 m wide, the younger Tokerau foredunes classified by Hicks (1975, 1983) (Figs. 7, 13c). The dunebelt is broadest at the south where it terminates as a spit across the Awapoko River estuary. Dunes consist largely of subparallel lines of hummocks separated by meandering hollows. Lags of sea-rafted pumice occur around the base of dune hummocks and less commonly in shell-ridge exposures (Osborne *et al.*, 1991) An extensive zone of largely unvegetated hummocks is found for some 2 km north of D. Urlich Road. Marine shell beneath the dune system has been dated to 4,480 ± 60 yrs BP confirming a Holocene Stillstand age for the system while Polynesian use of the dune area dates back at least 420 ± 40 yrs BP.

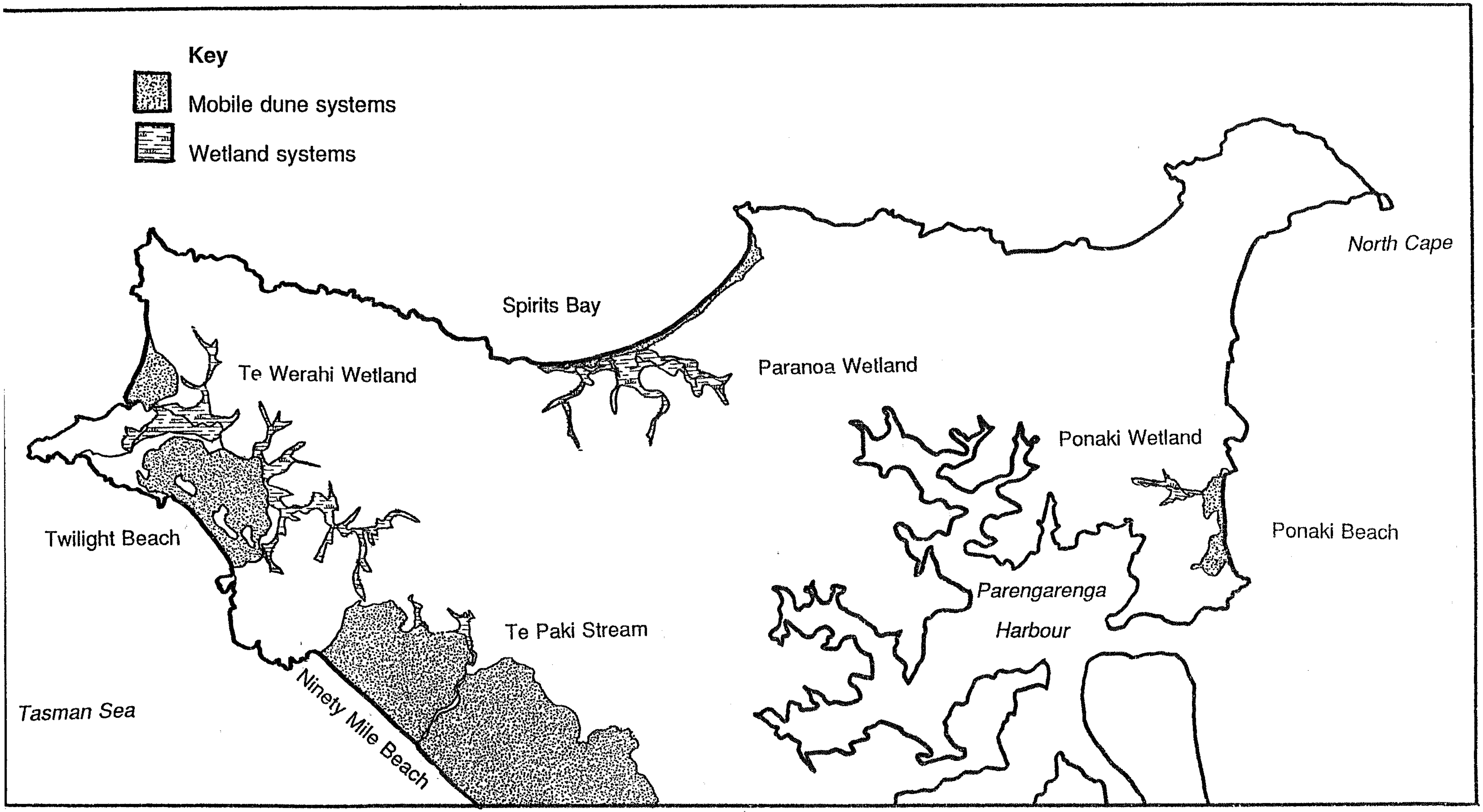


Figure 15. Location of four wetland and related dune systems in the Te Paki area.

Section Seven:
The role of Wetlands in Coastal Systems

Features from the Black Lagoons

Valley floor wetlands are commonly created by sand barriers forming across stream exits. It has been considered that such systems usually evolve in response to periods of coastal progradation and sediment transport associated with a stable sea-level (Thom and Chappell, 1975). Yet, little attention has been given to the association between coastal wetlands and dunes systems. It is the contention here that often one can justify viewing this interaction holistically. By incorporating the physical properties of both landform types, a more rigorous interpretation of morphodynamics can be achieved. As can be seen in this section, both evolution and process are interlinked in the wetland and dune systems of the far north.

Four wetlands are examined. All are located in the Te Paki Reserve on the North Cape Geological Block. The are: Te Werahi and Te Paki on the west coast, Paranoa behind Spirits Bay, and Ponaki on the east coast (Fig. 15).

Wetland Systems - Quick Sand or Slow Sand?

Te Werahi Wetland

A complex wetland system is located behind the advancing transverse dunes of Twilight Beach and the hardrock outcrop of Cape Maria van Dieman. The 422 ha wetland is fed by a large catchment (3,365 ha) and drains onto Te Werahi Beach (Fig. 16a). Te Werahi wetland has three tiers separated by narrow, braided sandy streams. The water level of each tier is efficiently controlled at each constriction by sills comprising sand transferred from the adjacent dune system. The top tier of the wetland is occupied by a *Typha angustifolia* (raupo) dominated floating mat vegetation complex.

Sediment cores of the benthic substrate were sampled by Enright *et al.*(1988). These revealed unconsolidated organics overlying sand. Four ^{14}C dates at the base of the organic layer ranged from 2,150 ± 100 yrs BP to 3,710 ± 80 yrs BP. Thus far evidence suggests that the age of the wetland corresponds with the advance of the adjacent transverse dunefield and passing of forest cover. Nevertheless Enright *et al.* (1988) believed the wetland probably originated in response to coastal progradation with the advent of the Holocene Stillstand but may have expanded with the activation of the coastal dune complex through deforestation (see Section 8). A multi-disciplinary team of scientists (McLean *et al.*, 1985) considered the wetland was resilient to disturbance in that large influxes of sand from adjacent dunes could be absorbed by the depth of the system.

Paranoa Wetland

Paranoa is one of three separate valley-floor swamps that combine to form a 200 ha wetland at the western end of Spirits Bay. A sand barrier impedes access to the sea. Interestingly the wetland has a minimal surface slope with a narrow channel meanders through the upper and middle reaches. This may be a relict feature of a past system as flow in the channel is minimal and consequently flushing of the wetland is very inefficient (McLean *et al.*,1985).

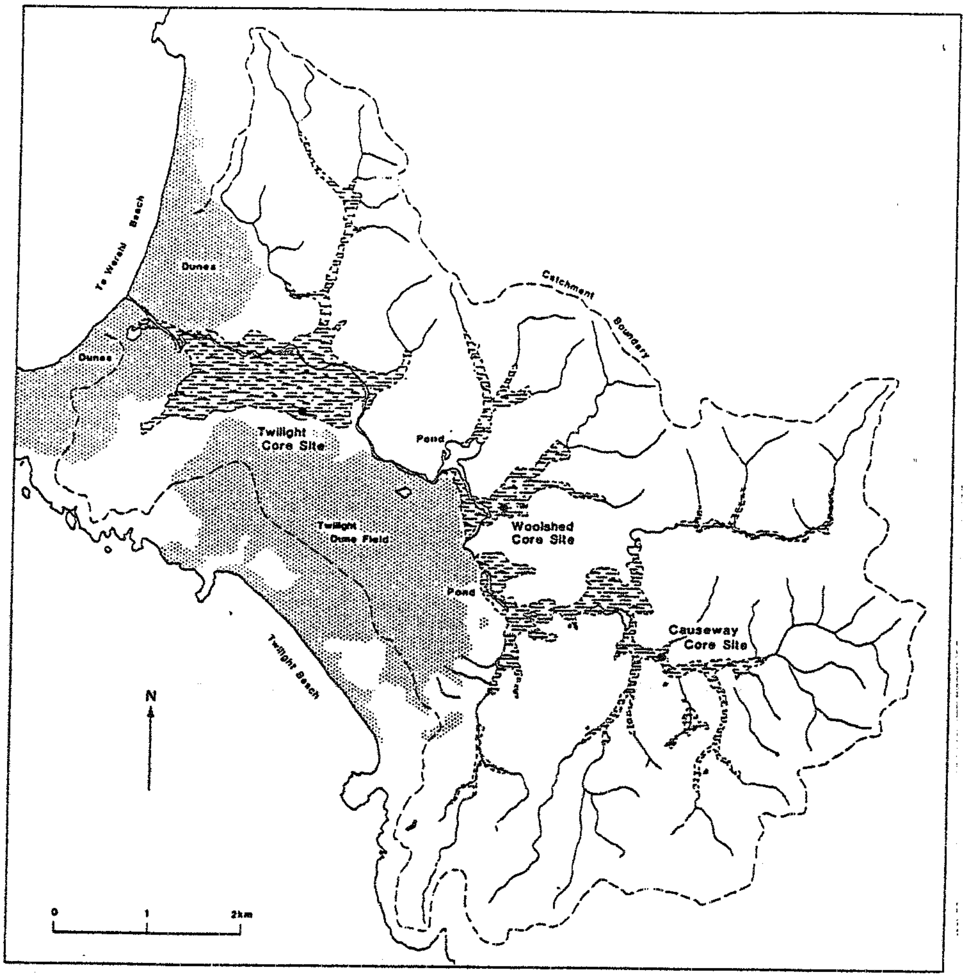


Figure 16A. The Te Werahi wetland and dune system.
Source: Enright *et al.* (1988)

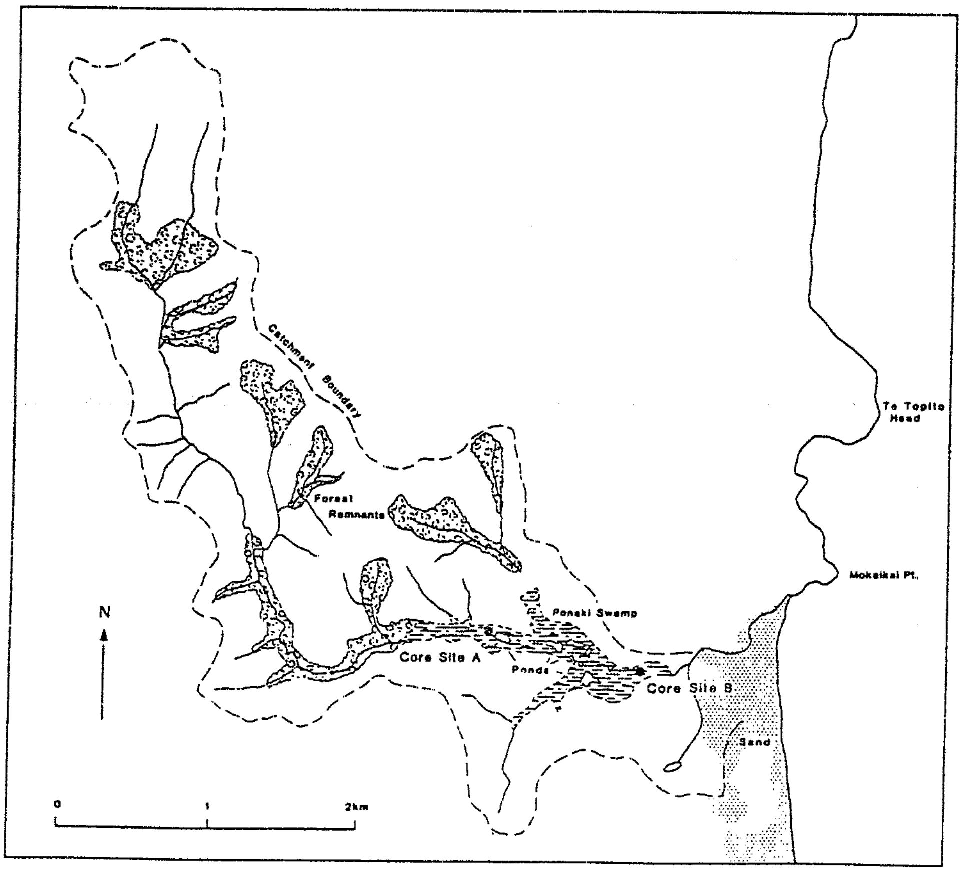


Figure 16B. The Ponaki wetland and dune system.
Source: Enright *et al.* (1988)

The Paranoa system is considerably older than Te Wehari wetland. Core dates of 5,920 ± 100 yrs BP at 1.55 m and 17,850 ± 1000 yrs BP at 3.2 m. These ages also indicate that the accumulation rate of both mineral and organic sediments in the system has been very slow, around 1 cm every 70 years (McLean *et al.*, 1985). Cores also revealed *Leptocarpus scirpus* (a brackish rush) pollen began at about 6000 yrs BP in upper swamp. This pattern is consistent with much greater incursion of salt water than at present.

It appears that the wetland is a mature, largely relict feature that would be very sensitive to complete infilling consequent to the development of surrounding land (McLean *et al.*, 1985). During the culmination of the Holocene Marine Transgression the valley may have been drowned and functioned as an estuary. Present-day sediment exchange between wetland and coastal dune processes is slight. The dunebelt is evidently acting as a barrier to incursions into the wetland from the sea, both by filtering saline intrusion and by preventing physical sedimentation of marine-sourced sands.

Ponaki Wetland

Located on the east coast north of Parengarenga Harbour, the Ponaki wetland is a small system (46 ha) with a catchment of 775 ha. It occupies a 1.5 km long narrow and steep-sided valley (Fig. 16b). Drainage is partially blocked by an active transverse dune which includes material reworked from consolidated dune sands. Vegetation is similar to Te Werahi and the two wetlands appear to have the same gross geomorphological characteristics.

Two cores were sampled, one each from the middle and lower parts of the the swamp (Enright *et al.*, 1988). Sediments comprised a layer of semi-consolidated organics overlying charcoal-bearing muds which was interdigitated with sand in the lower swamp. Sand has obviously drifted across from the unstable coastal dunes from time to time. The ^{14}C age of charcoal and other organics taken from the most-landward core base was 239 ± 55 yrs BP.

The stratigraphy and age of Ponaki core sediments indicates recent wetland development representing a major phase of pre-European burning. Although like Te Werahi, Ponaki is a drowned valley system comprising valley floor wetland and transgressive barrier subsystems, this wetland did not exist before 200-300 yrs BP and probably owes its origin to the destabilizing effects of fire on coastal and catchment vegetation and soils. Removal of coastal vegetation eroded both unconsolidated and consolidated dunal material. These sands were redeposited in the lower reaches of the valley, impeding discharge and so producing a wetland over the valley floor (Enright *et al.*, 1988) .

Te Paki Stream

On the west coast, near the northern end of Ninety Mile Beach, the Te Paki system represents a further sub-type of drowned valley morphology in which wetland is virtually absent. Its setting closely resembles Te Werahi which drains the adjoining catchment to the north. Both have developed behind a large transverse dune system which has overwhelmed a Pleistocene parabolic dune complex.

Major differences in morphology at Te Paki apparently result from a higher influx of dune sand. With the steady encroachment of transverse dunes into the valley floor, drainage of the catchment has become constricted. The two tributaries of the Te Paki Stream demonstrate the consequences of the valley acting as a sediment sink for dunal sand. In the first instance the sand influx exceeds the ability of the draining stream to transfer sediment away from the advancing slip face. Consequently the drainage channel behind the transverse dunes has been ponded, rerouted or variously forced to seep beneath the advancing dunes or infilled dune flats. This process is ongoing and may result in the formation of a fully enclosed dune lake. The second tributary demonstrates a more advanced stage of infilling where all drainage is directed into ground-water seepage and, cut off from fresh inputs of sand, Lake Ngakeketa has formed in the upper catchment.

In the vicinity of the rest area at Te Paki Stream, sediment transfer downstream is more effective and balances sediment inputs from the dune. Sand delivered into the stream by inflow, rotational slumping, or precipitation processes on the slipface is flushed downstream. The effectiveness of this sediment transfer is evidenced by the contrasting unvegetated mobile dunes seaward of the stream and the stable well-vegetated dunes immediately inland from the stream.

This discussion of Te Paki is largely extemporaneous. Research of this system using the methodology of Masters (1983) or similar would prove an interesting exercise. The combination of far north dune and wetland components utilising a comparative systems approach could also be developed much further than it has here or in previous studies (ie: McLean *et al.*, 1985; Enright *et al.*, 1988).

Section Eight: Biogeography

Vegging Out

Not only is the role of vegetation in stabilising and moulding sand deposits fundamental to dune geomorphology but vegetation also interacts in other ways with sandy landforms. For instance vegetative cover is strongly reflected in soil development and maturation rates. *Macro-faunal sub-fossils* (old bits of plants) provide datable material which are especially valuable in recording phases of dune instability and the levels of old surfaces. *Palynology* (pollen analysis) provides important information about past species assemblages which can be employed to draw inferences about paleo-climates and correlated with sea-level records. As painful as it might seem we need to grasp something of the plant biogeography of Aupouri to comprehend its geomorphic evolution.

Present Vegetation - Pine Trees and Pot?

At present farming and forestry are the primary land uses of the Aupouri Peninsular. Most of the Aupouri Peninsular is now planted with exotic conifers (predominantly *Pinus radiata*) and grasses. Most importantly natural forest is missing apart from isolated patches of *Dacrycarpus dacrydioides* (kahikatea) swamp forest in the south and small stands of *Metrosideros excelsia* (pohutukawa) and *Dysoxylum spectabile* (Dick, 1950).

In the remaining area, four *natural* vegetation/landform assemblages can be identified (Newnham, 1990):

**Present-Day Natural Vegetation Assemblages,
Te Aupouri Tombolo**

Unstable dunes
occupied by pioneer sand binders and coastal scrub.

Stable dunes
supporting scrub dominated by *Leptospermum scoparium* (manuka) and *Kunzea ericoides* (kanuka).

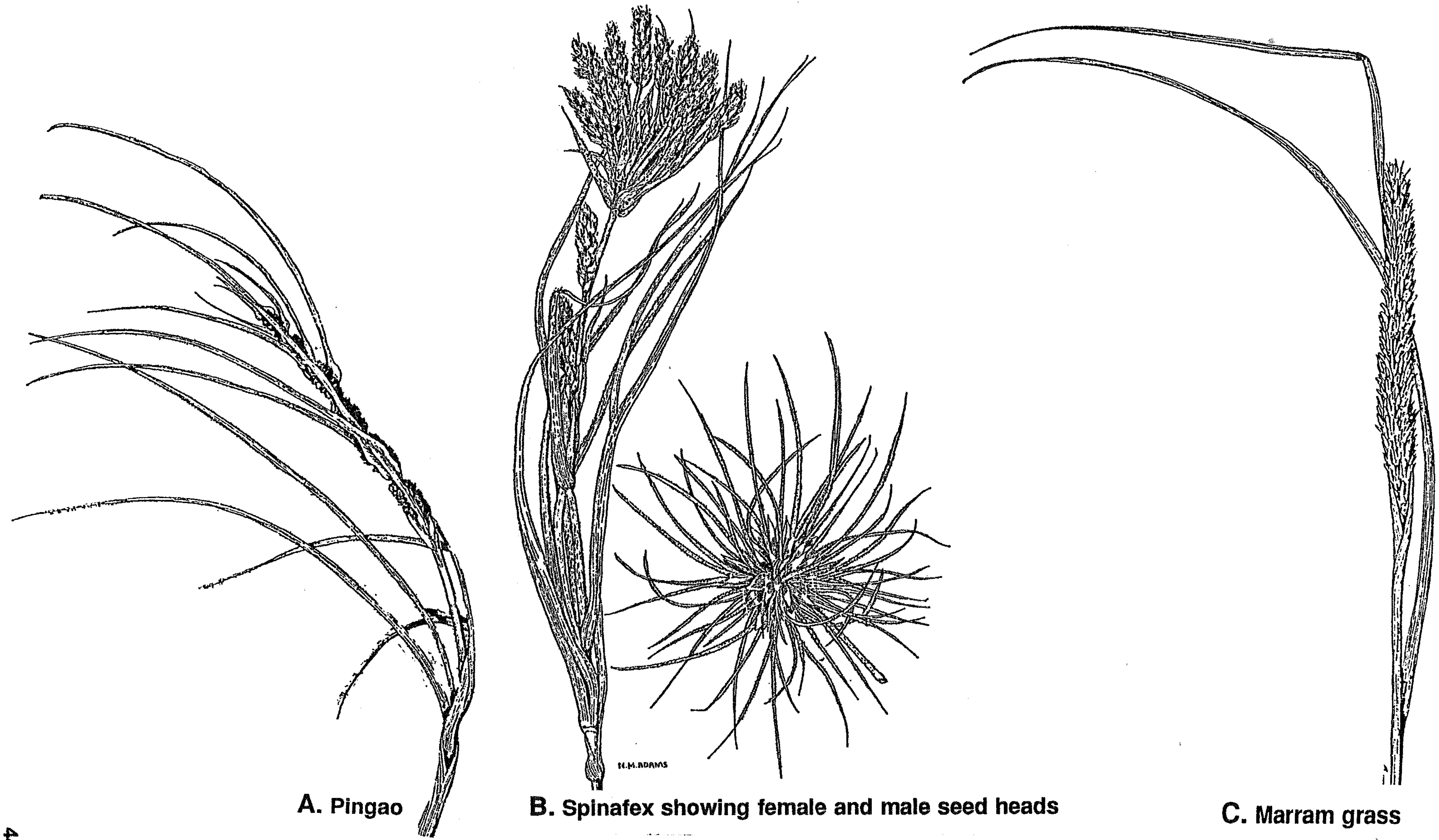
Peat swamps
deep and free of sand, containing *Typha angustifolia* (bullrush).

Sandy peat swamps
shallower and occupied by sedge swamp communities with *Schoenus* species and *Cladium teretifolium* prominent.

Plants of Unstable Dunes - Thing of the Wild Frontier

A summary of the distribution of sand dune and beach vegetation in the far north is provided by Partridge (1992). The most important species from a geomorphological perspective are the sand binders which contribute to the formation of dunes. In New Zealand these are pingao, marram grass and spinafex. Pingao and Marram are *rhizoferous*, that is they grow from *rhizomes* (roots) whereas Spinafex is *stoloniferous* ie: grow from *stolons* (runners).

Figure 17. Pioneer sand-binding vegetation of New Zealand.
Source: Moore and Adams (1963)



Pingao, *Desmoschoenus spiralis* (or bundle rush spiral)
This species has a buried rhizome sheathed in old leaf bases (Fig 17a). The growing point seeks out light and grows by rapid lengthening of the stem while its broad leaf base protects the growing point. It is endemic to New Zealand and the Chatham Islands and is distinguished by its seasonally orange and yellow foliage. Because of this pingao is prized as a *taonga* (resource) for Maori weaving and natural foredunes are regarded as *wahi taonga mahi a ringa* (treasured resource sites for crafts).

Spinifex, *Spinifex hirsutus* (translated as shaggy spine bearing).
Another indigenous species but with a distribution that includes Australia, spinifex is identifiable from its "tumbleweed" mobile seed head (Fig. 17b). The plant sends out strong runners on the surface to bind dunes and capture sand by causing a drop in wind velocity and consequent deposition of aeolian transported sand.

Marram Grass, *Ammophila areanaria* (meaning to love sand)
This exotic from Europe is the most vigorous of sand colonisers. It prefers pure sand. Although very competitive on unvegetated surfaces, marram does not survive long after dune stabilised and will die soon after the establishment of secondary colonising species. It can be identified by its leaves which are less silvery than spinifex and the absence of runners on the dune surface (Fig. 17c).

It is a point of great consequence that marram is a much more aggressive dune builder than native dune grasses. Accordingly dunes stabilised by marram often exhibit steeper slopes and greater elevations. This ability to trap sand can interrupt sediment exchange between beach and dune by creating an impervious barrier between the two. The morphology of a marram-built dune is usually distinctive from pingao- or spinafex built dunes both of the present and the past.

Hesp and Thom (1990) report a pattern common to Ninety Mile Beach and the Manuwatu that occurs where well-developed foredunes have been established within marram. Whilst the seaward slopes are fed by beach sand and are healthy and stable, the landward slopes are poorly vegetated and highly unstable. Sand from the landward slopes is eroded and transported inland. Hesp and Thom (1990) detect a deficiency of intermediate vegetation colonisers available to colonise the landward foredune slopes. They speculate that a hiatus in vegetational succession may result in dune instability.

Paleo-vegetation - Fire in the Forest

The Pollen Record
Pollen sites in the far north (Newnham, 1990; Ogden *et al.*, 1993a; McLean *et al.*, 1985; Enright *et al.*, 1988) all occur where pollen has been preserved in accumulations of peat. These provide the recorded changes in vegetation and climate since the glacial maximum around 40,000 yrs BP denoted in Table 4.

Pleistocene Dune Soils and the Kauri
A *podzol* is a soil characterised by strong leaching often formed in a wet, temperate climate under forest. There are more than 120 000 ha of kauri podzol in Northland. The close relationship between vegetation and soil is best illustrated in sandy parent

materials. At its best the *albic* (infertile) horizon is pure white, deep, and shaped like an egg cup. This is the world famous *egg cup podzol!* This type of soil horizon is associated with the growth of a single tree. The pattern may be caused by *polyphenolic compounds* (powerful organic acids) in the leaf/litter leachates, or just the concentration of canopy intercepted rainfall which flows down the tree trunk and into the soil at its base over a period of hundreds of years. Then again some scientists are sceptical that the egg cup podsol exists at all! What do you think?

Death of the Pleistocene Kauri forest.

The extent of sub-fossil kauri in Northland and the huge area of kauri podsols that no longer support kauri forest needs some sort of explanation. There are copious unpublished radiocarbon dates from kauri, unidentified wood, and peat from the far north of New Zealand in the range 40,000 to 20,000 yrs BP (Ogden *et al.*, 1993b). What caused this change in forest cover? Perhaps the kauri fell victim to fire or disease. But it might also be that the podsolisation process, which produces heavily leached soils and thick impervious iron pans, might have killed the kauri off as well. Renewed bog growth in association with an interstadial may have been the agent of this mortality (Ogden *et al.*, 1993b). Local rises in the water table would have preserved the dead material in a sub-fossil state. As a species that prefers well drained soils, the increasingly boggy podzols would have not suited kauri at all. So ironically the kauri forest might have helped to kill itself off! The legacy of this once extensive vegetative cover is recorded in the soil characteristics of consolidated dunes, the deeply leached podsols and the pans that are often exposed as an erosional surface.

The Holocene Forest

Subsequent to the *hiatus* (break) in bog development of the late last glacial (Table 4), the pollen record indicates a resurgence of warm temperature conifer-angiosperm forest in the Holocene which probably persisted through the bulk of the Holocene epoch. However, historical accounts show patchy evidence from early european pioneers that dunal scrub communities were more extensive than at present at the time of early european settlement. Dieffenbach (1843) found the burnt remains of large Kauri and concluded that this species had recently been extensive in the area. Vegetation on the North Cape Block is largely fire-induced *Leptospermum/Kunzea* heathlands with small refugium of forest cover (McLean *et al.*, 1985). The profiles of dune soils also suggest a former forest cover (Hicks, 1975; Millener, 1981). Thus it seems that once extensive native forests had disappeared by the time of european colonisation. Furthermore there is little doubt that the present natural vegetation pattern is a result of fire. But when did these fires occur and were they caused by human or natural agents?

Late Holocene Deforestation and Dune Destabilisation

Pollen analysis at Paranoa wetland behind Spirits Bay (Enright *et al.*, 1988) strongly demonstrates a late Holocene transition from forest to heathland. Mixed kauri forest species dwindled after 3,000-2,800 yrs BP and were replaced by heathland species. Firing events were recorded at 2,600 and 2,150 yrs BP.

On the west coast near Twilight Beach, Fleming and Powell (1974) obtained a date

of 2,100 yrs BP from the shell of a forest dwelling flax-snail (*Placostylus ambagiosus*) found in eroding dunes. Powell (1979) remarks:
"At some localities the fossils are to be found at any one time in thousands as bleached but well preserved shells scattered on the coastal sand dunes. These tell an interesting story of former forested conditions where now only drifting sand prevails."

There is an increase in charcoal abundance between 2,600 and 2,100 yrs BP in cores taken from the adjacent Te Werahi wetland and the slow advance of transgressive dunes into the wetland appears to have been underway 2,000 years ago.Pre-dating human occupation, the increase in charcoal may have been due to natural fire.

In the south of Te Aupouri Peninsula, Hicks (1975) derived dates which suggest that kauri survived on the Parabolic 2 dunes until at least 1,860 yrs BP before being inundated by the advance of Parabolic 3 dunes. Closer examination reveals that loss of forest and the development of Parabolic 3 dunes was probably well underway 2,000-1,500 years ago (Enright and Osborne, 1988).

Based on the compiled evidence it seems that a phase of dune destabilisation began 3,000 - 2,000 years ago. With natural fires recorded in disparate areas of the peninsula over this period it appears that the denudation of unconsolidated sand initiated a phase of transgressive dune building. From this evidence the role of human occupation in destabilisation dunes before about 800 years ago has not really been proven. After that time, the impact may have been quite significant. Please read on!

Last Glacial maximum (40,000 - 20,000 BP)	Cooler, wetter or cloudier weather, mixed kauri forest.
Late Last Glacial (20,000 - 14,000 BP)	Erosion of peats by burning events. The dry late glacial climate may have led to higher evapotranspiration rates leaving vegetation susceptible to fire.
Early Holocene (14,000 - 4,000 BP)	Podocarp-angiosperm forest, maximum of tree pollen data indicative of the warmest and wettest climate, swamp forest and peat swamp communities expanded, reduced evapotranspiration, rising sea-levels, or local hydrological change. Time of maximum forest expansion.

Source: Newnham, 1990

Table 4. Vegetation change in the far north for the period 40,000 to 4,000 years BP.

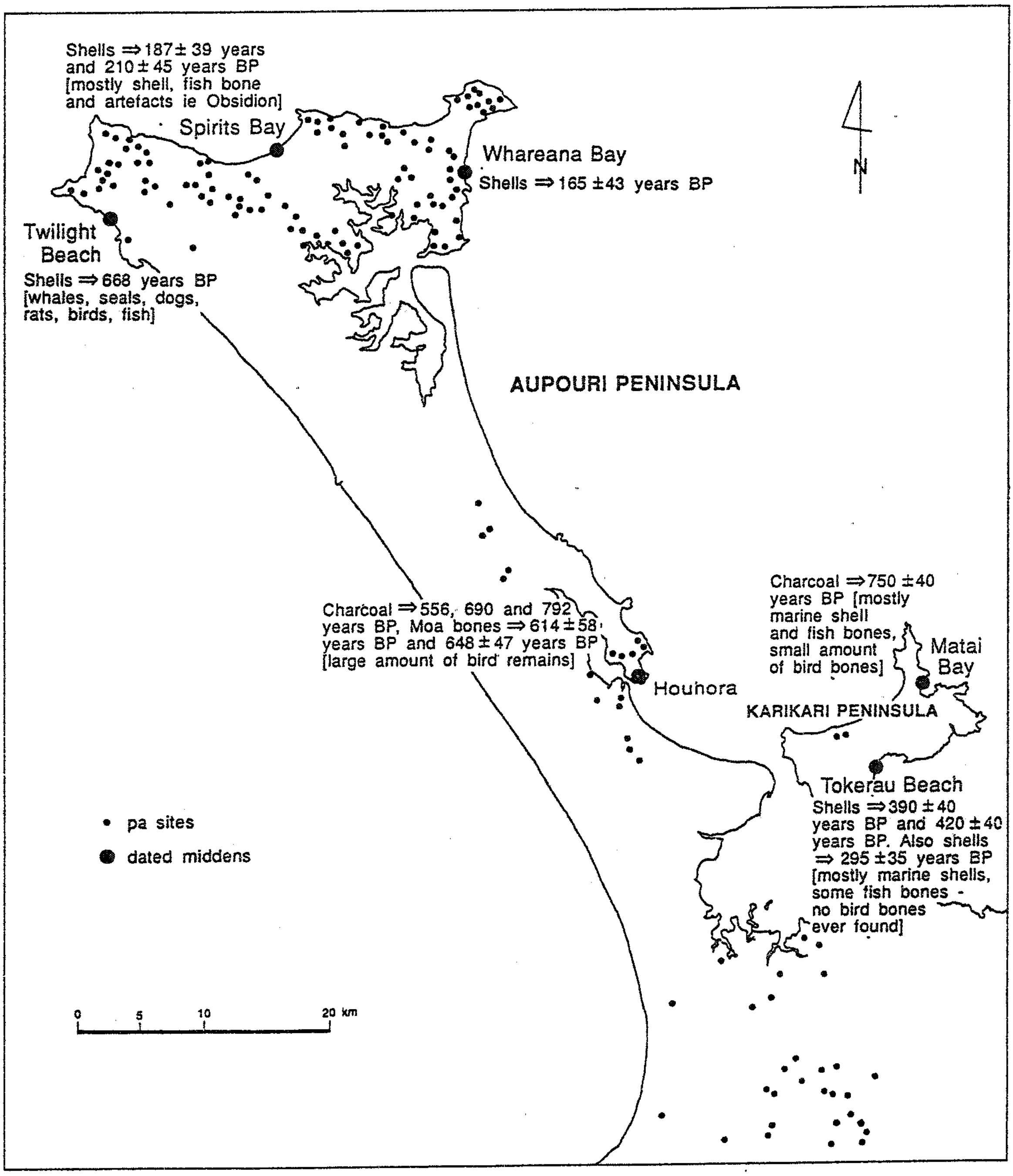


Figure 18. Pa sites and middens of Te Aupouri and Karikari Peninsulas.
Source: Millener (1981); Coster (1988)

Section Nine: Human Occupation, Deforestation and Coastal Destabilisation

Folk Tales

Introduction

It can be argued that few countries have such a brief history of human occupancy nor such little human disturbance of natural coastal areas as New Zealand. But just how extensive has coastal disturbance been in this short time?

Although consensus on the first settlement of New Zealand is *truly ragged* (Sutton, 1987), it is generally believed that colonisation began within the last 1,200 years (Davidson, 1984). None of the ^{14}C-dated sites on Te Aupouri Peninsula provide clear evidence of settlement earlier than 1,000 yrs BP. The most extensive work done in the far north is by Coster (1989) who assembled an archaeological chronology for the area. Coster's study is highly relevant to geomorphologists as his interpretation tapped geomorphological, palynological and paleoenvironmental sources as well as archaeological ones. Employing data from over 400 sites and 20 ^{14}C-dates, Coster proposed three phases of human habitation for Te Aupouri Peninsula. The distribution and characteristics of archaeological sites in the study area are depicted in Figure 18.

Early Phase - 1000 to 500 yrs BP

Excavations at Twilight Beach and Mt Camel (Houhora) suggest that occupation at these earliest archaic sites occurred between 600-700 yrs BP. It is at this early stage of settlement that the initial impact on coastal forest and dunes of human occupation should be evident. Coster considered that early settlement was primarily coastal with fishing and hunting of sea-mammals predominant aspects of subsistence (Taylor, 1984). The repercussions of this settlement pattern were; 1) degradation of the coastal zone, 2) firing of the forest, and 3) a decline in the bird population due to human impact, loss of habitat and predation by Polynesian rats and dogs. Although archaic artifacts are quite common, little trace of early occupation sites remain due to the severe erosion of devegetated coastal dunes.

Coster's interpretation of the role and timing of first occupation may not be a definitive one. Two alternative versions are presented by Millener (1981) and Sutton (1987). Millener considered that human occupation only accelerated deforestation and dune destabilisation which had already begun. Localised, pre-Polynesian destruction of coastal forest is noted from Cape Maria van Dieman (1,595 ± 70 yrs BP), Tom Bowling Bay 1,610 ± 65 yrs BP, with later occurrences at Waikuku Beach (1,020 ± 35 yrs BP) and Henderson Bay (950 ± 60 yrs BP). The two earliest of these dates were ascribed by Millener to natural firing and the latter two to human influence. On the other hand Sutton attempted to argue for human influence before 1,000 yrs BP and under-rates the likely role of natural localised fires (Enright and Osborne, 1988).

Middle Phase - 500 to 300 yrs BP

Coster considered that at some stage the Polynesian population largely abandoned coastal sites in favour of the unstable but forested Holocene dune belt. This zone contained usable soils for agriculture. Coster interprets ^{14}C evidence as suggesting that abruptly, after only about 200 years, these too were abandoned. It was supposed this was due to the deterioration of soils, possibly resulting in the formation of the coastal deflation zone and transverse dune sheet along the west coast. If correct, then the widespread transverse dune movement is quite recent, remarkably rapid and unrelated to natural phases of instability. However, this shift may not have been prompted by environmental degradation but by the adaption of defensive settlement patterns. The actual timing and distribution of transgressive dune phases remains a persistent enigma.

Late Phase - 300 yrs BP to Present

Coster considered that c.300 yrs BP, people relocated to stable volcanic soils around Hohoura and the North Cape Block to continue agricultural practises. Intermittent seasonal exploitation of fish and shellfish continued through into the post-European era. Exploitation of kauri gum drew numbers of European people into the area in the period from 1890 to 1914. While the most significant recent development is the reforestation of the peninsula with over 30,000 ha of exotic conifers since the 1960s.

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