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B.G. McFadgen*

Four depositional episodes based on sand deposits and the soils on them are proposed for Holocene coastal sand dunes on Chatham Island: Te Onean Depositional Episode (*c.* 5,000 to 2,200 years BP), Okawan Depositional Episode (*c.* 2,200 to 450 years BP), Kekerionean Depositional Episode (*c.* 450 to 150 years BP) and Waitangian Depositional Episode (*c.* 150 years BP to present day). Each depositional episode has two phases: an unstable phase with a high rate of deposition and no soil formation, followed by a stable phase with a low rate of deposition and soil formation. The Okawan, Kekerionean, and Waitangian episodes closely match late Holocene depositional episodes on the New Zealand mainland. The earliest human occupation remains (Moriori) are in Kekerionean sands and the inferred date for Moriori settlement of Chatham Island is between 400 and 450 years BP. Bones of Hooker's sea lion are found in Te Onean and Okawan deposits. The most recent bones are in Kekerionean middens and it is inferred that Hooker's sea lion was driven from the Chatham Islands by human predation. The depositional episodes appear to be unrelated to sea level changes, tectonic activity, or cultural influence. It is suggested that they may be related to coastal erosion initiated by storms.

Keywords: Archaeology, climate, Moriori, sand dunes, soils, sea lions

INTRODUCTION

Chatham Island (44° S, 176° 30′W) is the largest of a group of 10 islands, and lies some 900 km east of Banks Peninsula, New Zealand (Fig.1). These islands, at time of European contact, were occupied by the Moriori, a Polynesian people who lived mainly by hunting and gathering sea foods (Richards, 1972; Sutton, 1979, 1990; Smith, 1977). How long the Moriori had occupied the islands is uncertain. Estimates of first settlement range from *c.* 1,000 years BP (Sutton, 1980) to *c.* 450 years BP. Published radiocarbon dates (Sutton, 1976, 1977; Dodson and Kirk, 1978), however, support the more recent date.

Holocene sand dunes form a nearly continuous belt around the north and east coasts from Waitangi West Beach to Owenga. The prehistoric Moriori left extensive remains of their occupation in the dunes (Smith and Wernham, 1976). In 1985, severe storms eroded many kilometres of dunes along the north and east coasts, continuing an ongoing process. As a result of the 1985 storms, many sections with middens, sea-rafted pumices, and old soils were exposed (Fig. 1). The erosion was most severe at Maunganui Beach, Taupeka, and from Te Awa Patiki to Owenga, all of which face east or northeast. In some places the Holocene dune belt has now been entirely removed.

The dune sand is very shelly and, consequently, there has been remarkable preservation both of Moriori middens and of naturally-deposited animal bones, including many from Hooker's sea lion (*Phocarctos hookeri*) (Gibson and Cawthorn, unpublished). The middens range from scattered shells to deposits over a metre thick and extending for several tens of

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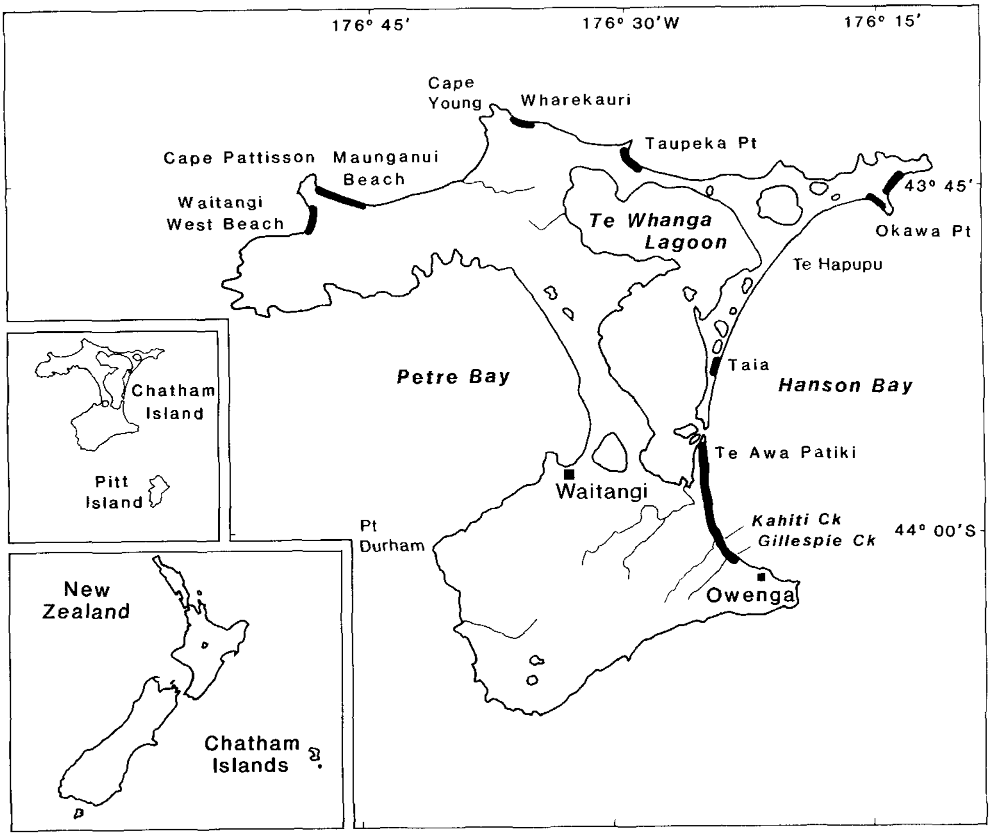

Fig. 1 – Map of Chatham Island showing localities mentioned in text. Sections discussed in text indicated by thick lines. Settlements of Waitangi and Owenga shown as squares.

metres. Their additional content of fish, bird and sea mammal bones, charcoal and stone flakes distinguishes them from natural shell deposits thrown up into the dunes by wave action.

The Hooker's sea lion bones are in the sections, and in wind-eroded dune hollows. Little is known about the history of Hooker's sea lion on Chatham Islands. Except for a few bones from Moriori middens (Smith, 1977; Smith and Wernham, 1976), they appear to have been previously unrecorded (Crawley, 1990). The presence of the sea lion bones in the dunes adds to our knowledge of the natural distribution of Hooker's sea lion and the effects of human presence on them.

The length and distribution of the exposed sections provided a rare opportunity to record Holocene dune stratigraphy on Chatham Island. Ground soils (soils on the present day ground surface), buried soils, and sea-rafted pumice proved most useful for correlating the sections.

The ground soils are useful for correlation because they have different degrees of profile development depending on their age. They show four stages of profile development which is assumed to indicate approximately the age of the sands below. Ground soils with similar profile development are generally in belts roughly parallel with the present coast, and older soils are inland of younger soils.

The exposed sections are a stratigraphic record to which the occupation remains and sea lion bones are tied and, if the buried soils and sea-rafted pumice are accepted as time planes, then a date can be established for the human settlement of Chatham Island.

This paper describes a stratigraphic sequence of dune sands, based on soils and sea-rafted pumice. Data were collected during fieldwork between 1986 and 1991. Four depositional episodes comprising sand dune accumulation and soil formation are proposed, with each episode being dated by radiocarbon. Problems encountered with some of the dated material, and their resolutions, are discussed.

The depositional episodes are described at sites in clockwise order from Waitangi West Beach to Owenga (Fig. 1). Correlation of the episodes with chronostratigraphic units in coastal sand dunes on the New Zealand mainland is proposed. This correlation is based on sea-rafted pumices and on dates adopted for the episodes and for the units. Factors responsible for the episodes are briefly considered.

The age and distribution of Hooker's sea lion bones is discussed and an explanation is proposed for their apparent absence at the time of European contact. A section on the human settlement of Chatham Islands focusses not on where the first settlers came from, but on when they arrived.

Sand dunes and soils

The sand dunes appear to have accumulated in four successive depositional episodes named here in order of decreasing age: Te Onean (5,000–2,200 years BP), Okawan (2,200–450 years BP), Kekerionean (450–150 years BP), and Waitangian (150–0 years BP). In this paper the distinction is maintained between the names of the depositional episodes, which end with "an", and soil names adopted by Wright (1959).

The dune sand is supplied principally from marine erosion. Composition of the coastal dunes is likened to that of pre-Holocene Wharekauri Sand (Hay, Mutch and Watters, 1970) which is widespread over central and northern Chatham Island, and Te Onean dunes are probably formed from Wharekauri and earlier sand eroded during the post-glacial sea level rise. There are no large rivers to supply additional sediment and the principal source of sand for subsequent dune-building episodes appears to be wave-eroded sections. The quantity of free sand available for dune-building has thus probably diminished with time, as sand has become locked up in stable dunes.

The depositional episodes are recognised in sand dunes from Waitangi West Beach at the northwest corner of Chatham Island to Owenga at the south east corner. Some episodes are not recognisable at some places, possibly because their deposits have been buried by later sands, and are therefore not visible, have subsequently eroded, or never formed. Sand dunes on the west coast between Waitangi and Waitangi West Beach were not examined.

Soils on Te Onean sands are well-developed podzols (Appendix 1) and include Te One soils (Wright, 1959). Soils on Okawan sands are poorly-developed podzols (Appendix 1). Soils on Kekerionean sand include Kekerione soils (Wright, 1959) and all soils are well-defined topsoils over loose sands which may be stained by soil forming processes (Appendix 1). Waitangian sand is either unstable, or only recently stabilised under marram grass.

At some places, older soils have been buried by younger sand dunes and ground soils can be traced to buried soils in the eroded sections. Buried soils are recognised by their organic content, structure and, usually, their dark colour (Appendix 1). The buried soils indicate times of stability between episodes of sand accumulation. Following McFadgen (1985), times of sand accumulation are called *unstable phases*, times of soil formation, *stable phases*. The phases are considered synchronous for most of the island, but it should be noted that the evidence in support of synchroneity is not as extensive as in similar deposits on the New Zealand mainland (McFadgen, 1985).

Stratigraphic boundaries in the sections are the tops of the three buried soils (Fig. 2). The beginning of each depositional episode is inferred from calibrated radiocarbon dates. Only one item of European origin was found in the sections – a sheep bone (*Ovis aries*) below

Waitangian sand – and the bone is used tentatively to provide a maximum date for the onset of the Waitangian Depositional Episode.

Once stabilised, dunes and soils appear to have remained intact except for erosion by wave action. Wind erosion of stable dunes appears to be a modern phenomena related to stock damage. Although stones were present, none of the sections examined exhibited any stone lines or lag deposits which might be interpreted as evidence for wind erosion.

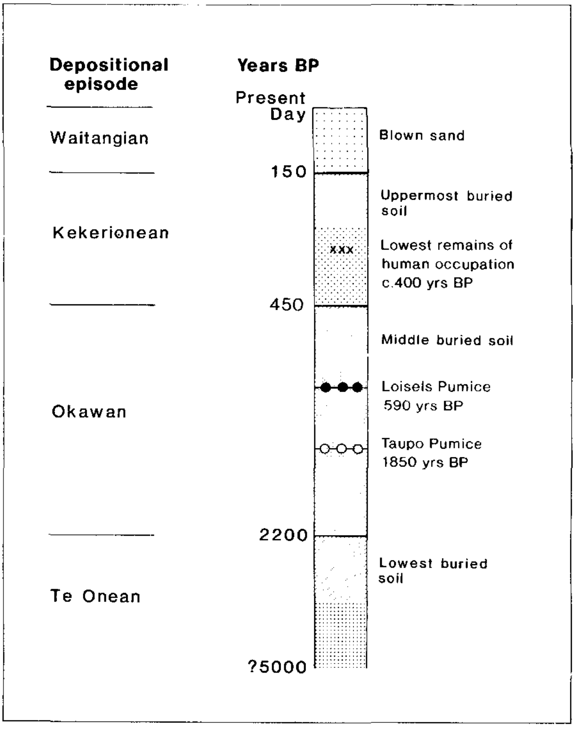

Fig. 2 – Idealised section through sand dunes showing late Holocene soils and the Loisels and Taupo pumices. Inferred ages in calendar years ago.

Sea-rafted pumices

The sea-rafted pumices are Taupo Pumice (Healy, Vucetich and Pullar, 1964) and Loisels Pumice (Wellman, 1962) but only Taupo Pumice was abundant enough to be useful for direct dating.

Sea-rafted pumice disperses rapidly and is washed up on beaches soon after eruption (Coombs and Landis, 1966). Primary sea-rafted Taupo Pumice is assumed here to be the same age as the Taupo Pumice eruption (*c.* 1,850 years BP; Froggatt, 1990). The Taupo Pumice eruption is closely dated by radiocarbon from samples killed by airfall tephra. Loisels Pumice is from an unknown source and its first appearance on New Zealand beaches is now dated by radiocarbon to *c.* 590 years BP (Appendix 2).

The use of the pumice for correlation and dating is criticised by Osborne, Enright & Parnell (1991) because no distinction is made between primary and secondary sea-rafted deposits. Identification as primary sea-rafted is always uncertain, however, because all sea-rafted pumice deposits are subject to possible reworking. Any recognisable pumice deposit is worth considering for correlation and dating purposes because even secondary deposits provide a maximum age for the deposits above them.

Osborne, Enright and Parnell (1991) proposed an age of *c.* 1,000 years for Loisels Pumice. However, their proposed age is based on an unreliable sample (Appendix 2). The best date currently available, found using maximum and minimum dates from the sections in which the pumice is found, and using the most up-to-date radiocarbon calibration data (Stuiver and Reimer, 1993; Stuiver and Braziunas, 1993; McFadgen and Manning, 1990), is *c.* 590 years BP (Appendix 2).

Sand deposits and soils are best correlated with the depositional episodes by matching the buried soils, and sea-rafted pumice with an ideal sequence (Fig. 2). Where the pumice and/or buried soils are absent, radiocarbon dates, and degree of soil profile development of ground soils, are used for correlation.

Radiocarbon dating

Midden shells are used to date sand dunes which post-date human settlement. They are

Table 1 – Radiocarbon dates used to define ages of Depositional Episodes. Maximum dates for the beginning of events indicated >; minimum dates <. Tu = Te Onean unstable phase, Ts = Te Onean stable phase, &c.

Lab no.	Conventional Radiocarbon Age (Years BP 1950)	Calibrated Age Range (95% confidence Interval in years BP (1950))	∂C13 (ppm)	Material dated	Locality and provenance of sample	Significance
WK1012	1,660 ± 50	1,320–1,130	+2.7	Tuatua shells	Maunganui Beach west, Okawan buried soil	<Os,>Ku
WK1160	2,730 ± 70	2,680–2,320	–20.8	Seal coprolite	Te Awa Patiki, Te Onean buried soil	<Ts,>Ou
WK1161	750 ± 75	510–280	–22.4	Seal coprolite	Gillespie Creek, Okawan buried soil	<Os,>Ku
WK1162	920 ± 60	630–460	–21.9	Seal coprolite	Maunganui Beach west, Okawan buried soil	<Os,>Ku
WK1163	1,340 ± 90	1,090–710	–22.0	Seal coprolite	Maunganui Beach east, Okawan buried soil and sand just below the soil	<Ou,>Ku
WK1164	820 ± 65	550–320	–22.3	Seal coprolite	Okawa, Kekerionean sand	>Ks
WK1165	2,290 ± 70	2,100–1,750	–21.7	Seal coprolite	Okawa Point north, sand below Okawan and Te Onean ground soils	>Os
WK1166	990 ± 60	670–500	–20.7	Seal coprolite	Waitangi West, Okawan buried soil	<Os,>Ku
WK1538	13,850 ± 110	16,460–15,780	+1.4	Tuatua shells	Te Awa Patiki, below Te Onean sand	>Tu
NZ7293	3,890 ± 70	4,070–3,690	+0.5	Tuatua shells	Gillespie Creek, Kekerionean sand	>Ks
NZ7295	715 ± 60	480–280	+1.6	Tuatua shells	Gillespie Creek, shell midden in Kekerionean buried soil	<Ks,>Wu
NZ7458	2,670 ± 45	2,540–2,280	+1.8	Tuatua shells	Te Awa Patiki, Te Onean buried soil	>Ou
NZ7475	775 ± 30	490–360	+1.9	Tuatua shells	Te Awa Patiki, shell midden on Okawan buried soil	<Os,>Wu
NZ7476	910 ± 250	930–0	–25.3	Seal coprolite	Maunganui Beach west, Okawan buried soil	<Os,>Ku
NZ7491	3,070 ± 40	2,950–2,760	+1.7	Tuatua shells	Maunganui Beach west, sand below Te Onean ground soil	>Ts
NZ7492	780 ± 38	500–340	+1.8	Tuatua shells	Maunganui Beach west, shell midden in Kekerionean buried soil	<Ks,>Wu

considered reliable because their date of death (collection) is likely to be close to when the midden was formed. Prehuman deposits are dated using marine shells and coprolites, probably from seals. There was no charcoal in the prehuman deposits. Shells of lagoon species, whether occurring naturally or in a midden, are considered unreliable because of probable contamination by old carbon from limestone rocks.

Where dates on stratigraphically contemporary marine shells and coprolites differ, the shell dates are older. The shells were isolated tuatua valves found in sand which was once some distance from the beach. Isolated tuatua shells can be found on the dunes today, a hundred or more metres from the beach, and have possibly been dropped by sea birds, or thrown into the air by waves and caught by the wind during storms. The ages of the shells on many of the present day dunes are not known. Evidence suggests that on some dunes the shells could be quite old. Shells on the beach at Te Awa Patiki, for example, have been washed from an old shoreline buried beneath sand dunes possibly 5,000 years old. Such reworked shells dropped or thrown on to the dunes in the past would adequately explain the older shell dates, which at best are only maximum dates for the deposits stratigraphically above them.

The coprolites are probably seal. Seal bones are frequently found in the dunes. Some coprolites were round and more or less complete, but most were in pieces and needed to be carefully picked out of the sections. Their fragmentation suggests some reworking of sand before the sand became stable, but the pieces were very fragile and would have broken down and entirely disappeared if they had been substantially reworked.

Coprolites are mainly gut bacteria, with a small amount of undigested cellulose and muscle fibre from foods (L. Holloway, *pers. comm.* 1991), and seal coprolites also contain fish bones. The $\partial C13$ of the coprolites was low (–20.8 to –25.3,Table 1) and comparable with fish flesh (Rafter *et al.*, 1972). The time taken for food to pass through a seal is less than 24 hours (King, 1983) and the life span of the bacteria is probably as short (L. Holloway, *pers. comm.* 1991). Even if a seal had only recently arrived from the sub-Antarctic, a journey which would take at least a fortnight, its coprolites should be in equilibrium with the radiocarbon activity of the sea around Chatham Islands. The sub-Antarctic ocean has less radiocarbon than sub-tropical seas (Stuiver and Braziunas, 1993), and if the coprolites included a residue of radiocarbon from the sub-Antarctic, their true age would be younger than reported here.

The type of date a sample gives depends on its stratigraphic position relative to the event to be dated, and on the likely size of its inbuilt and storage ages (McFadgen, 1982). Due to the possibility of a long storage age (McFadgen, 1982), naturally-deposited marine shells do not give minimum dates for stratigraphically older deposits. Only coprolites and midden shells give minimum dates. Coprolites, midden shells, and naturally-deposited marine shells all give maximum dates for stratigraphically younger deposits.

Coprolites from a buried topsoil are assumed to have been deposited shortly before the soil was buried. Were they much older, they would have been destroyed by scavengers or decay.

Radiocarbon dates in this paper (Tables 1, 3 and 4) are calibrated as follows. Southern hemisphere terrestrial calibrations are based on a compilation of 20 year tree ring data by Stuiver and Reimer (1993) with an offset of 40 radiocarbon years as recommended by Vogel, Fuls and Visser (1993). New Zealand marine calibrations are based on the carbon cycle model calibration curve of Stuiver and Braziunas (1993), with geographic offset delta-R set to -30 ± 15 as recommended by McFadgen and Manning (1990).

RECOGNITION OF DEPOSITIONAL EPISODES AROUND CHATHAM ISLAND COAST

Waitangi West Beach

At Waitangi West Beach, on the western side of Cape Pattisson, aeolian sands form a belt up

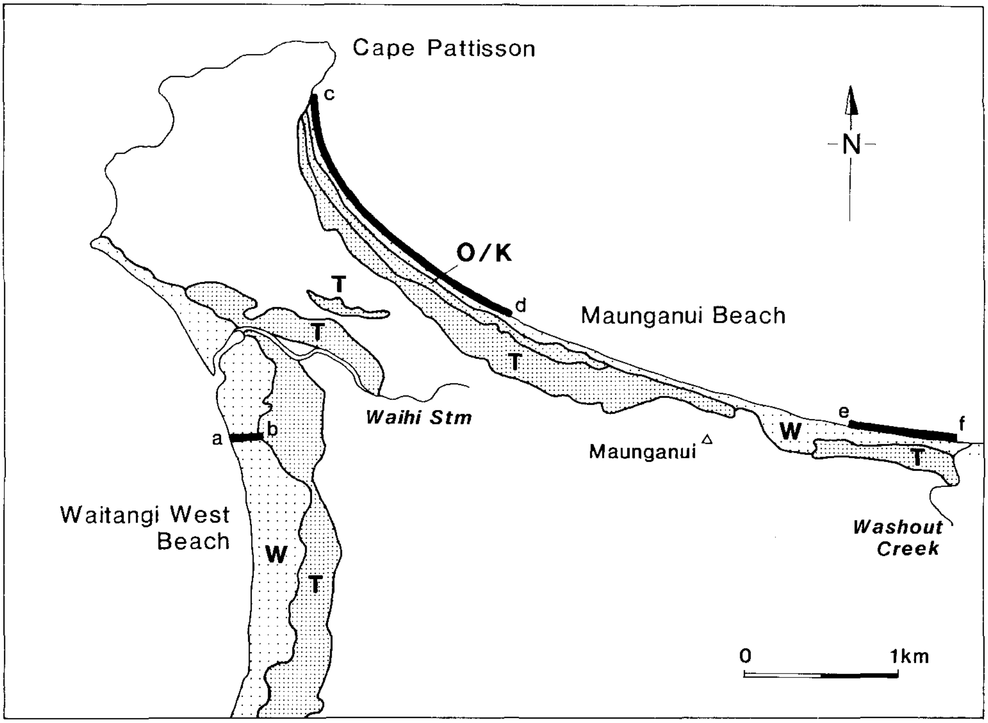

Fig. 3 – Sketch map of Cape Pattisson area traced from air photographs. Dune sands T = Te Onean; O = Okawan; K = Kekerionean; W = Waitangian. a-b, c-d, e-f = section drawings Fig.4.

to 1 km wide (Fig. 3). The sands are badly wind-eroded for up to 300 m inland from high water mark, and two buried soils are exposed at many places. Stabilised dunes inland of the eroded sands carry a well-developed podzol (Te One loamy sand; Wright, 1959).

Loisels Pumice is on the ground surface 60 m behind the present foredune. It is less than a metre above high water mark (Fig. 4A) and forms a band some 30 m wide which can be traced through the dunes for more than a kilometre. Pumice pieces are rarely more than 10 cm in diameter.

Taupo Pumice forms a stranded shoreline ridge some 4 m wide and 0.7 m thick, 160 m inland of, and 3.5 m above, high water mark (Fig. 4A). The ridge was traced through the dunes for about 1 km. Pumice lumps are up to 0.8 m long, but most are generally less than 25 cm in diameter. The ridge is overlain by sand which contains the buried soils.

A generalised cross-section perpendicular to the coast (a-b, Fig. 4A) is described in Appendix 3 (Section 1).

The Okawan and Kekerionean buried soils are slightly peaty sands, the Kekerionean a little more so than the Okawan. They are separated by windblown sand along their seawards margin and merge inland (Fig. 4A). The Okawan buried soil extends closer to the coast than the Kekerionean buried soil, and overlies the Taupo Pumice ridge. Neither soil extends as far as the Loisels Pumice.

The Okawan buried soil contains bones of birds, fish, and sea mammals; tuatua shells; stones; and fragments of seal coprolites. No shell middens nor other signs of human activity were seen in the soil. Seal coprolites from the buried soil are between 670 and 500 years BP (WK1166, Table 1).

The Kekerionean buried soil contains shells, stones, bones and coprolite fragments and, in

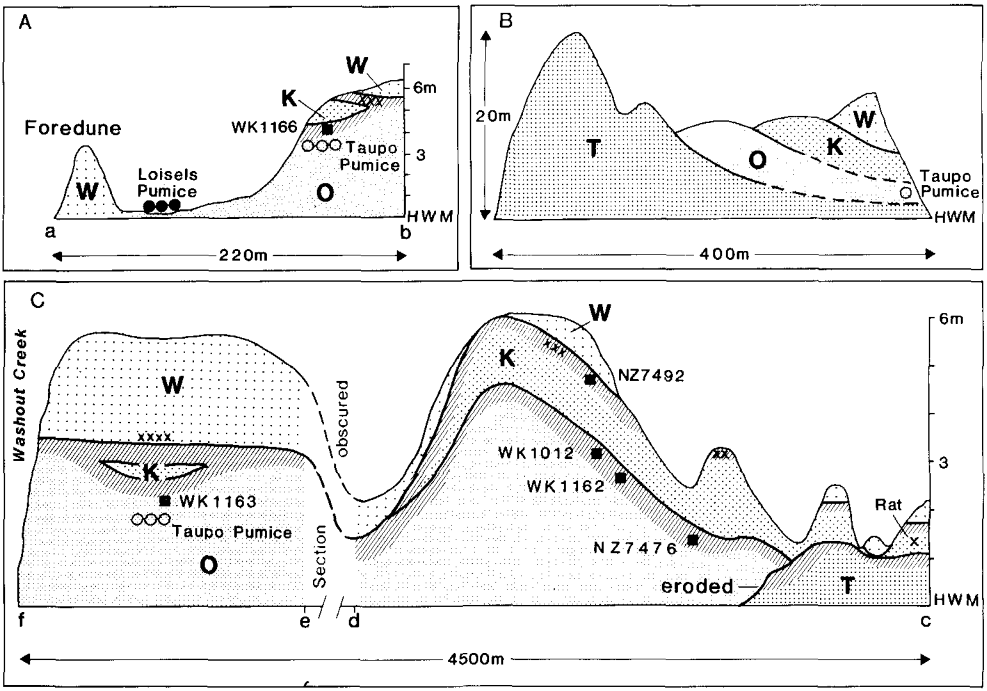

Fig. 4 – Section drawings for Fig 3. A: Generalised section at Waitangi West Beach based on sections exposed by natural erosion along line a-b (Fig.3). Symbols as in Fig.3. Soils shown hatched. Black square marks position of radiocarbon sample: WK1166 = 670–500yrs BP. B: Diagrammatic section across sand dunes at Maunganui Beach based on dug holes and sections exposed by natural erosion. Dotted lines = inferred correlation. Symbols as in Fig.3. C: Longitudinal section of sea-eroded sand c-d, e-f at Maunganui Beach (Fig.3). Vertical exaggeration = x45. Symbols as in Fig.3. "xxx" = midden layers. Soils shown hatched. Black squares mark positions of radiocarbon samples: WK1012 = 1,320–1,130yrs BP; WK1162 = 630–460yrs BP; WK1163 = 1,090–710yrs BP; NZ7492 = 500–340yrs BP; NZ7476 = 930–0yrs BP. Dotted lines = inferred correlation.

its upper part, shell middens with abundant tuatua shells and fish bones. Bones of the rat, which would have arrived with the earliest settlers, were at the same level as the middens, but none were seen in the lower part of the soil, nor in the Okawan soil.

Maunganui Beach

Maunganui Beach, between Cape Pattisson and Washout Creek, is 1.5 km from Waitangi West Beach (Fig. 3). Dunes form a belt of overlapping sands of different ages up to 400 m wide which is being eroded by the sea (Fig. 4B).

Te Onean dunes are up to 20 m high (Fig. 4B) and carry a well-developed podzol (Te One loamy sand; Wright, 1959) (Appendix 1). The soil is badly wind-eroded in places and, on its deflated surface, are large numbers of well-rounded gravels and stones, a few shells, and the bones of fish, birds, and seals. A near-complete skeleton of a Hooker's sea lion was dug out of sand below the Te Onean ground soil. Tuatua shells from near the bones are 2,950–2,760 years BP (NZ7491, Table 1).

Okawan and Kekerionean dunes are a narrow belt up to 100 m wide, between the Te Onean dunes and the present foredune, northwest of Maunganui hill (Fig. 3). The dunes are two low transverse ridges up to 8 m high, which are being buried by new sand advancing from the coast (Fig. 4B). Soil profiles on the ridges vary, probably a result of past blowouts, and it is difficult to characterise them. The most developed soil seen on the Okawan (inland) ridge was a weak podzol, with occasional "egg cup" podzols about 1 m across showing a well-formed iron pan below a leached horizon. The most developed soil seen on the Kekerionean (seawards) ridge was a topsoil on loose, unweathered sand which, in turn, buried an earlier similar topsoil.

Waitangian sand is an unstable, active foredune which is gradually moving inland over Kekerionean groundsoil.

Sea erosion has exposed a section nearly three kilometres long, and up to 8 m high (c-d, e-f, Figs 3 and 4C). The three buried soils (Fig. 2) are all present (Appendix 1; Section 2 (Appendix 3)). Loisels Pumice is only found as drift pumice mixed with loose sand, seaweed and driftwood. Taupo Pumice is below the Okawan buried soil between Maunganui hill and Washout Creek and consists of well-rounded lumps, up to 20 cm in diameter, and about 2 m above present high water mark. The pumice was not extensive and may have been reworked.

The Te Onean buried soil is only visible at the northern end of the section. It is about a metre above present high water mark and has a moderate to heavy iron-stained subsoil. The buried soil ends abruptly against Okawan sand (Fig. 4C) and appears to have been eroded by the sea before being buried by Okawan sand.

The Okawan buried soil is more or less continuous north west of Maunganui hill. At places it splits in two, separated by up to 30 cm of sand. Towards the southeastern end of the section it merges with the Kekerionean buried soil. The Okawan buried soil, and the sand just above and below it, contain occasional bones (seal, bird, and fish); occasional landsnails and seashells; and, more commonly, water worn stones and gravels, and fragmented and whole coprolites. There is no charcoal, no burnt stones or other evidence of human activity.

The Kekerionean buried soil has a similar content to the Okawan buried soil, plus shell midden deposits. The shell middens are layers, up to 30 cm thick, of shells, charcoal, burnt stones, lenses of fishbones, and seal bones. None of the occupation extends to the base of the soil, although in sand at the north end of the section a rat skeleton was found just below the soil (Fig. 4C).

Seal coprolites from within and just below the Okawan buried soil are between 1,090 and 710 years BP (WK1163, Table 1). Tuatua shells from the Okawan buried soil are between 1,320 and 1,130 years old (WK1012, Table 1), and seal coprolites, between 930 and 0 years BP (NZ7476, WK1162, Table 1). *Tuatua shells from a midden in the Kekerionean buried soil are* between 500 and 340 years BP (NZ7492, Table 1).

Wharekauri

At Wharekauri, east of Cape Young, there is a belt of stable dunes up to 300 m wide (Fig. 5). The foredune, up to 100 m wide, is Waitangian sand recently stabilised with marram grass. Kekerionean sand is a low ridge parallel to the foredune and has a well-defined topsoil over a colour subsoil (Kerekione sand; Wright, 1959) (Appendix 1). Okawan and Te Onean dunes are absent. Loisels Pumice is in the swale behind the foredune but was not found in section, and there is no Taupo Pumice.

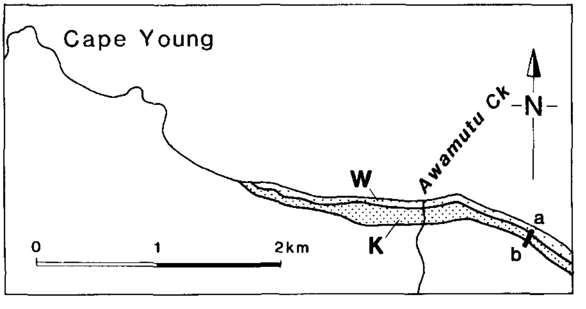

Fig. 5 – Sketch map of Wharekauri traced from air photographs. Symbols as in Fig.3. a-b = Section 3 (Appendix 3).

Waitangian sand overlies the seaward edge of the Kekerionean sand. A section in the left bank of a small stream (a-b, Fig. 5; Section 3 (Appendix 3)) shows midden debris in but not below the buried Kekerionean topsoil.

Taupeka

From Taupeka Point south for 2 km, there is a belt of dunes about 300 m wide (Fig. 6). Te Onean dunes carry a moderately developed podzol (Te One loamy sand; Wright, 1959). Waitangian sand, only recently stabilised with marram grass, overlaps the sand plain in front of the Te Onean dunes. Just south of Taupeka Point, the sea has eroded a 200 m long section (a-b, Fig. 6; Appendix 3 (Section 4)) exposing Taupo and Loisels pumice layers, a buried soil, and the remains of Moriori and post-European contact Maori occupation.

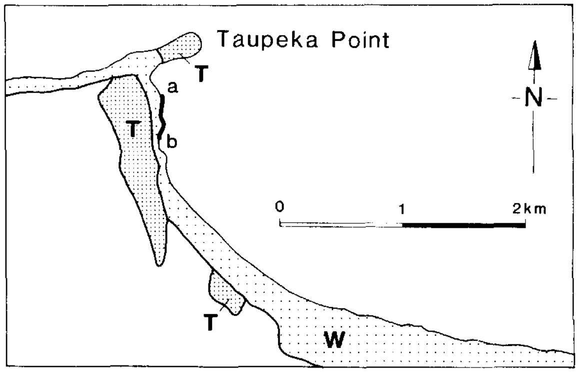

Fig. 6 – Sketch map of Taupeka Point traced from air photographs. Symbols as in Fig.3. a-b = Section 4 (Appendix 3).

Taupo Pumice, only in a moderate amount with pieces up to 30 cm diameter, is probably not a primary sea-rafted deposit.

Loisels Pumice is throughout the buried topsoil in lenses up to a metre long and 2 cm thick. Using the pumice layers, the soil is correlated with the Okawan buried soil, although the absence of the Kekerionean buried soil makes the correlation uncertain.

Taupeka Point was a site of Moriori settlement and, later, of Maori settlement (Richards, 1972; Simmons, 1964). The area in the vicinity of the section (a-b, Fig. 6) contains a major concentration of archaeological sites (Sutton, 1984). Occupation remains in the section comprised shell midden, charcoal, and fireplaces, all within the buried soil. Human bones were eroding out of the section from below the buried soil, but these were from holes that had been cut from the buried soil into the dirty white sand below. Apart from the bones there was no sign of human occupation below the buried soil.

A small reverse triangular cross-sectioned adze and a piece of clay tobacco pipe were picked up from the sand at the base of the section. Other early East Polynesian adze types and European items have been picked up by the owner (Mr J.Hough) and are in his possession.

Okawa Point North

North of Okawa Point is a belt of stable and unstable dune ridges up to 0.5 km wide and 5 km long, roughly parallel to the present coast (Fig.7). Soils on the stable dunes have been mapped as Te One loamy sand (Wright, 1959). Examination during this study showed three stages of soil profile development, each confined to a distinct ridge or ridges.

Northeast of Titore Creek (Fig.7) the coastal dunes are unstable Waitangian sand and, behind them, are up to three ridges of Kekerionean sand. Kekerionean ground soil is a well-defined topsoil with a subsoil defined by colour (Appendix 1).

A section through the Waitangian and Kekerionean sands (a-b, Fig.7; Section 5 (Appendix 3)) is exposed in a small stream 0.5 km northeast of Titore Creek (Fig.7 inset). The Kekerionean soil is younger than both Taupo and Loisels pumices both of which occurred as isolated lumps. Seal coprolites below the soil are between 550 and 320 years BP (WK1164, Table 1). The oldest cultural remain is the shell midden in the buried Kekerionean topsoil.

The Kekerionean and Waitangian sands were traced southwest along the coast in a wave-cut section to Titore Creek. The Kekerionean buried soil is generally between one and two metres above high water mark, and the sand beneath it contains Taupo Pumice and seal coprolites.

Southwest of Titore Creek the coastal dunes are Waitangian sand. Behind them, in sequence of distance inland, are a wind-eroded ridge which shows no ground soil at all, a ridge of Okawan sand, and a ridge of Te Onean sand.

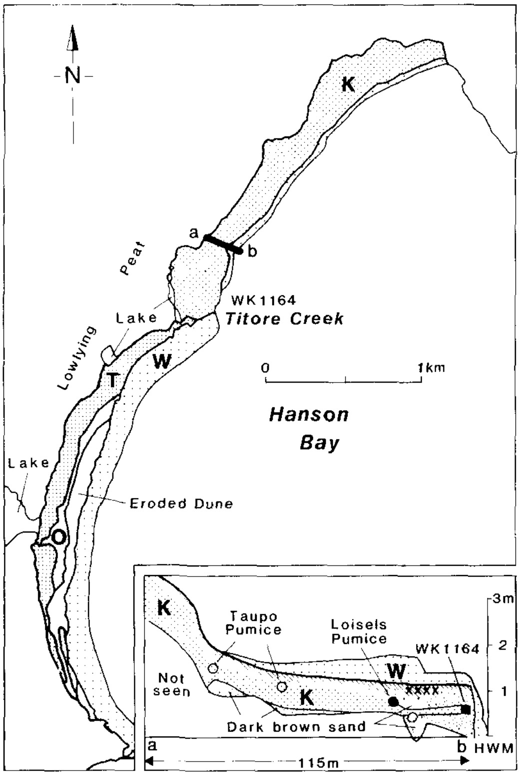

Fig. 7 – Sketch map of coast north of Okawa Point traced from air photographs. Symbols for Fig. 7 and inset as in Figs 3 and 4. WK1164 = 550–320yrs BP. a-b = section (inset) and Section 5 (Appendix 3).

The Okawan ground soil is a weak podzol (Appendix 1). Okawan sand contains rounded pebbles, bones of birds and seals, and seal coprolites, which wind erosion has concentrated on the bottoms of extensive deflation hollows.

The Te Onean ground soil is a well-formed podzol (Appendix 1). Where wind erosion and stock have broken through the soil, there are extensive deflation hollows covered with small well-rounded pebbles, bones of seals and birds, and seal coprolites. In the sides of many hollows, between 0.5 m and 1.0 m from the ground surface, is a dull-brown slightly coherent sand, generally less than 20 cm thick containing bird bones. The dull-brown sand has a weakly developed structure, and is probably a former, shortlived stable dune surface.

Seal coprolites collected *in situ* from the Te Onean and Okawan sands were insufficient for dating the sands separately. A combined sample is between 2,100 and 1,750 years BP (WK1165, Table 1). About 90% of the sample was from Okawan sand, the remainder from Te Onean sand. The date is a maximum for formation of the Okawan ground soil.

Okawa Point West

On the west side of Okawa Point is a 0.5 m thick wave-cut section, more than a hundred metres long (a-b, Fig. 8). The section has a single buried soil in sand, overlain by a thin scatter of paua shell midden. Just below the buried soil, at present storm beach level and extending for about a third of the section length, is a well-defined layer of Loisels Pumice. The buried soil is correlated with the Okawan buried soil, but only tentatively because of the absence of the Kekerionean buried soil.

About 4 km northwest of section a-b, coastal Waitangian dunes partly cover older dunes with a weak podzol ground soil mapped as Kekerione sand (Wright, 1959). From the degree of ground soil development, the older dunes are either

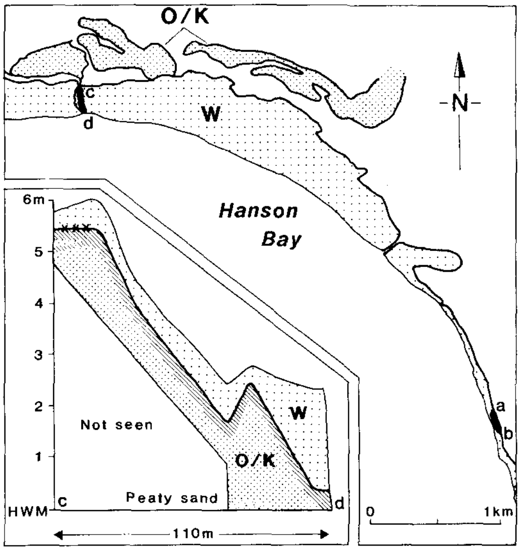

Fig. 8 – Sketch map of coast west of Okawa Point traced from air photographs. Symbols for Fig. 8 and inset as in Figs 3 and 4. a-b = section described in text. c-d = section (inset) and Section 6 (Appendix 3).

Okawan or Kekerionean. A cross-section through these dunes (c-d, Fig. 8 inset; Section 6 (Appendix 3)) is exposed in the north bank of a small stream. No pumice was seen, and the dunes, therefore, could not be related to the Loisels Pumice in section a-b. The oldest evidence for human occupation is a shell midden on the soil buried by the Waitangian dunes.

Seal and bird bones are common in deflation hollows in the dunes, but shell middens contain only fish and bird bone.

Lake Taia

Immediately west and south of Lake Taia, an old shoreline of Te Whanga lagoon can be traced for about 2 km (Fig. 9A). The old shoreline is a sand ridge, steep on the lagoon side with a gentle back slope towards the sea (Fig. 9B). The height of the ridge crest above the present lagoon shoreline ridge crest, measured by spirit levelling, is about 1 m.

In the edges of hollows formed by wind and stock erosion, sections of the old ridge show a moderately well-developed soil on shelly sand (Appendix 1; Section 7 (Appendix 3)), overlying a well-defined pumice layer.

The shelly sand is bedded and contains whole shells of lagoon species: cockles (*Austrovenus stutchburyi*), pipis (*Paphies Paphies australis*), and *Macomona liliana*.

The pumice layer is well-defined for 6 m across the ridge crest. Pieces are generally well-rounded, less than 3 cm in diameter, strong, with small elongated vesicles and mineral inclusions. They are heavily iron-stained. After boiling in hydrochloric acid to remove the staining, the pumice is greyish with distinctive pale grey bands. It is probably Loisels Pumice, based on age, appearance and chemistry (P. Froggatt *pers. comm.* 1991).

Pieces of Taupo Pumice up to 20 cm in diameter were found in the hollows, but no Taupo Pumice was found in a stratigraphic context.

The occurrence of the two pumices indicates that the ridge is Okawan in age and was the lagoon's shoreline possibly from before the Taupo Pumice eruption 1,850 years BP until after the Loisels Pumice 590 years BP.

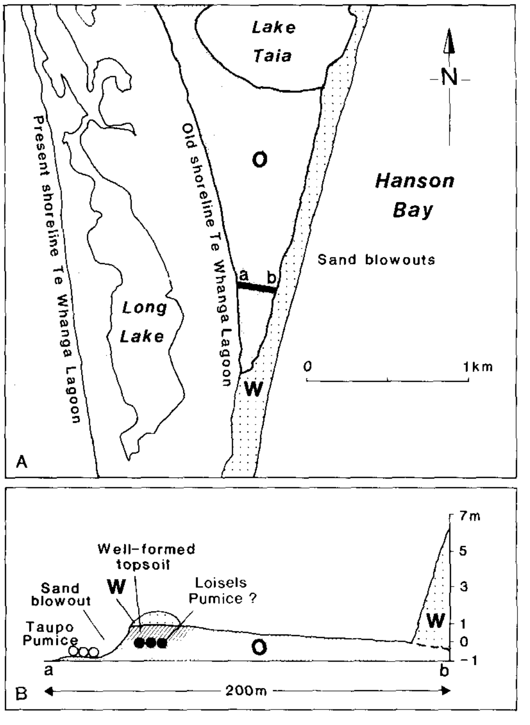

Fig. 9 – A: Sketch map of vicinity of Lake Taia traced from air photographs. Symbols as in Figs 3 and 4. Note that the Okawan sand seaward of the old lagoon shore is not aeolian. a-b = section (Fig.9B) and Section 7 (Appendix 3). B: Section a-b. Symbols as in Figs 3 and 4. Note Taupo Pumice in bottom of blowout. Datum = crest of ridge along present shore of Te Whanga Lagoon.

There are many shell middens on the ridge (Smith and Wernham, 1976). Examination of the edges of the hollows and adjacent ground surface showed that all middens in the vicinity of the hollows are on Okawan soil.

Further south, the ridge gets progressively closer to the sea until approximately 2 km south of Lake Taia, the sea is only 200 m away, and the ridge is buried by Waitangian sand (Fig. 9A).

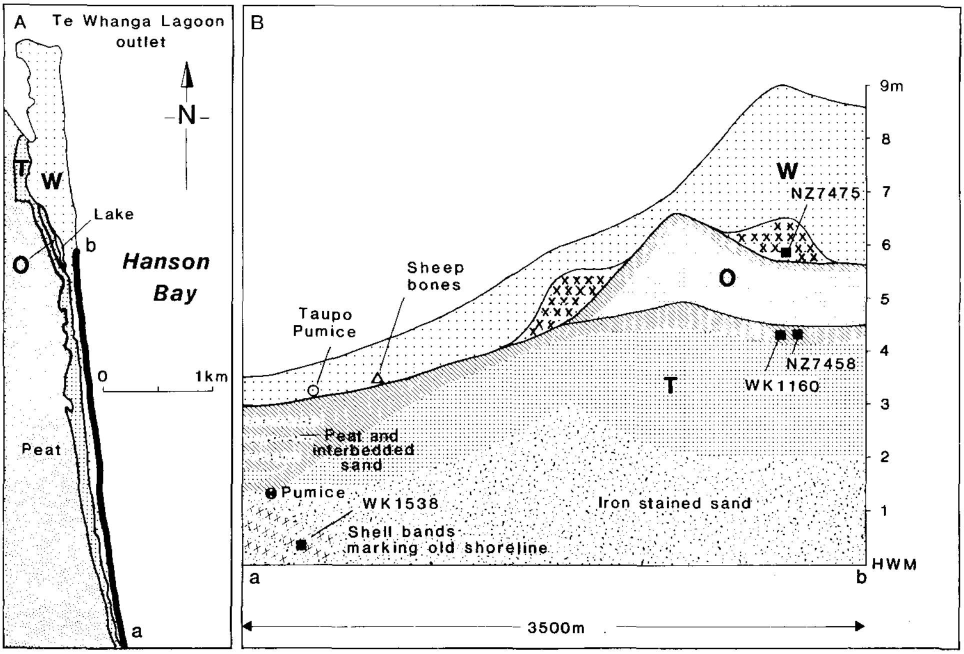

Fig. 10 – A: Sketch map of the coast at Te Awa Patiki, south of Te Whanga Lagoon outlet traced from air photographs. Symbols as in Fig.3. a-b = section (Fig. 10B) and Section 8 (Appendix 3). B: Section a-b (Fig. 10A). Vertical exaggeration = ×330. Symbols as in Figs 3 and 4. Note that shell bands marking old shoreline are natural shell deposits not shell midden. WK1538 = 16,460–15,780 yrs BP; WK1160 = 2,680–2,320yrs BP; NZ7458 = 2,540–2,280yrs BP; NZ7475 = 490–360yrs BP.

Te Awa Patiki to Gillespie Creek

The coast from Te Awa Patiki is dealt with in three parts: Te Awa Patiki, which is from 2 km to 6 km south of the outlet of Te Whanga lagoon; the coast from 6 km south of the outlet to just north of Gillespie Creek; and Gillespie Creek, from just north of the creek to 0.5 km south.

Te Awa Patiki

The coastal dune belt south of the Te Whanga Lagoon outlet is 500 m wide at the northern end, but is generally less than 200 m wide. Te Onean dunes interfinger with peat and carry a well-developed podzol (Te One loamy sand; Wright, 1959). The seaward edge of the Te Onean dunes is overlain by Waitangian sand and there is a narrow strip of Okawan sand around the inland edge of a small seasonal lake (Fig.10A).

At high water mark is a near-continuous section some 3.5 km long (a-b, Fig.10A), cutting obliquely across a 9 m high transverse foredune (Fig.10B). Section a-b (Fig. 10B, Section 8 (Appendix 3)) is thus a cross-section of the foredune and shows the Te Onean and Okawan buried soils. No deposits of Kekerionean age were seen.

Thin bands of shells in black iron-cemented sand at the base of the section (Fig.10B) are at high water mark. They are similar to layers of shells and sand at high water mark on the present beach and are probably an old shoreline. Their stratigraphic position is below Te Onean sand and their expected age is *c.* 5,000 years BP. However, tuatua shells (*Paphies Mesodesma subtriangulatum*) from the black sand have a radiocarbon date of 13,850 ± 110 years BP (16,460–15,780 years BP WK1538, Table 1).

Sea level 13,850 radiocarbon years BP was between 56 m and 75 m below present day sea level (Carter *et al.*, 1986) and rose to about its present level by 6,500 years BP (Gibb, 1986).

To bring the shell bands to their present height would require an average uplift rate between 4 and 5.5 mm/year. This rate is high, and inconsistent with the heights of raised marine benches described by Hay, Mutch and Watters (1970). The shells have probably been reworked from earlier offshore deposits.

The shells are being eroded from the black sand and mixed with shells on the present beach. Storms have thrown shells onto low-lying parts of the foredune 2–3 m above the beach. The storm-tossed shell deposits differ from middens in that they do not, as a rule, contain bones, stone flakes, or charcoal, and, if they were to be radiocarbon-dated, the shells would give spuriously old dates.

One piece of pumice, similar to Taupo Pumice, was partly embedded in the black sand. A piece of reworked Taupo Pumice was on top of the Te Onean buried soil. No other pumice was seen.

The two buried soils and the Okawan sand between them contain occasional tuatua shells (*Paphies Mesodesma subtriangulatum*), pieces of seal coprolite, and rounded pebbles. Sheep bones (*Ovis aries*) were found on the Te Onean buried soil under Waitangian sand (Fig. 10B). Shells from the Te Onean buried soil are between 2,540 and 2,280 years BP (NZ7458, Table 1), and seal coprolites between 2,680 and 2,320 years BP (WK1160, Table 1). The similar ages of the dates from shells and coprolites suggests a negligible inbuilt age for the shells in this case. However, the shells are still interpreted as giving a maximum age. Shells from midden on the Okawan buried soil are between 490 and 360 years BP (NZ7475, Table 1).

Shell middens are common on the Okawan buried soil. The largest in section was 40 m long and 1 m thick for half its length. The middens contain the bones of fish, birds and seals, and the shells are nearly all tuatua.

From Te Awa Patiki to Gillespie Creek

From Te Awa Patiki to Gillespie Creek (Fig. 1) the dune belt is about 200 m wide. The foredune, Waitangian sand, overlaps onto Te Onean sand which carries a well developed podzol (Te One loamy sand over peat; Wright, 1959). The sea has eroded a more or less continuous section for about 5 km. For most of the 5 km, Waitangian sand overlies the Te Onean buried soil. There is an upper buried soil at some places which is probably Okawan, but this is unconfirmed.

Taupo Pumice is common at the mouth of Kahiti Creek (Fig. 1), but could not be stratigraphically related to the section. Loisels Pumice was seen only at the mouth of Gillespie Creek.

Shell middens are common in the dunes. The middens exposed in the section are all on top of the single buried soil or, where there are two soils, on top of the upper buried soil.

Gillespie Creek

From Gillespie Creek south is a 0.5 km long section (Fig. 11A and B; Section 9 (Appendix 3)), exposed by stream and wave action. On the northwest side of Gillespie Creek, Okawan ground soil overlies sand containing Loisels and Taupo pumices (Fig. 11B).

On the southeast side, the Okawan and Kekerionean soils are both buried (Fig. 11B). The Okawan soil is paler than the Kekerionean soil, but both contain bones of fish, bird and seals, seal coprolites, rounded pebbles and occasional tuatua shells. Within the Kekerionean soil are shell middens and localised lenses of sand which are probably the result of human disturbance. Loisels Pumice is not extensive, but forms a well-defined lens in the Okawan sand.

Seal coprolites in the Okawan buried soil are between 510 and 280 years BP (WK1161, Table 1). Tuatua shells in Kekerionean sand, immediately above the Okawan soil, are between 4,070 and 3,690 years BP (NZ7293, Table 1). The shell date does not agree with either the stratigraphy or the coprolite date, and the shells have probably been reworked.

Tuatua shells from a midden in the lower part of the Kekerionean buried soil are between 480 and 280 years BP (NZ7295, Table 1).

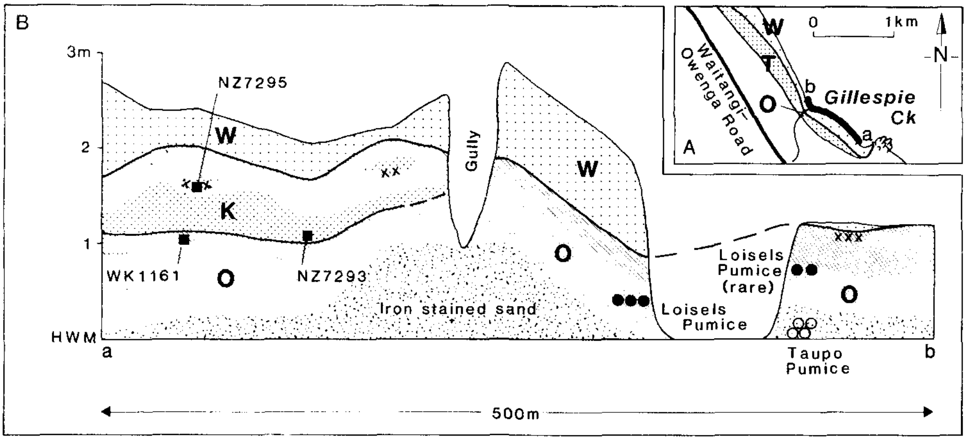

Fig. 11 – A: Sketch map of coast at Gillespie Creek. Symbols as in Fig.3. a-b = section (Fig. 11B) and Section 9 (Appendix 3). B: Section a-b (Fig. 11A). Vertical exaggeration = ×55. Symbols as in Figs 3 and 4. WK1161 = 510–280yrs BP; NZ7293 = 4,070–3,690yrs BP; NZ7295 = 480–280yrs BP.

DATING THE DEPOSITIONAL EPISODES

Interpreted ages for the sand deposits on the west, north and east coasts of Chatham Island are given in Figs 12 and 13. Te Onean, Okawan and Kekerionean sands and soils, and Waitangian sand, are present on each of the three coasts.

The age range for the start of each depositional phase is determined by bracketing (McFadgen, 1982). Dates (Table 1) are classified as maximum, minimum, or close depending on their inbuilt age and stratigraphic relationship to the event dated (McFadgen, 1982). Dated tuatua shells (NZ7293) from Kekerionean sand at Gillespie Creek are considerably older than coprolites from the Okawan soil below and the shells have probably been reworked. The tuatua date is regarded only as a maximum for subsequent deposits. Dated tuatua shells (WK1538) from the black sand at the foot of the Te Awa Patiki section have probably been reworked from older, offshore deposits. They provide only a very old maximum age for deposits stratigraphically above them.

Data for determining the age range for the start of each phase (Fig. 13) include radiocarbon dates, sea-rafted pumice layers, and European-introduced remains. The onset of a stable or of an unstable phase is taken as midway between the youngest maximum age, and the oldest minimum age.

No such data were available for determining the start of the Te Onean unstable phase. An onset date has been inferred through correlation of a post-glacial marine bench on Chatham Island with stranded post-glacial shorelines on the West Wellington coast and on Enderby Island, all of which are understood to be the result of the post-glacial sea level maxima. The Te Onean dunes (Hay, Mutch and Watters (1970) "Older dunes") overlie a post-glacial marine bench which sits 1.5 m above present sea level (Hay, Mutch and Watters, 1970). On Enderby Island the stranded post-glacial shoreline, 2–3 m above the present day beach ridge, overlies wood with an age of *c.* 5,600 years BP (McFadgen and Yaldwyn, 1984), while the post-glacial sea level maximum on the West Wellington coast is dated to about 5,000 years BP (Fleming, 1972). It is therefore inferred that the Te Onean unstable phase started sometime around 5,000 years BP. The date for the start of Te Onean sand accumulation could be up to 1,000 years in error either way.

Te Onean soil formation and burial could be up to 300 years in error, events younger than the Te Onean, up to 100 years.

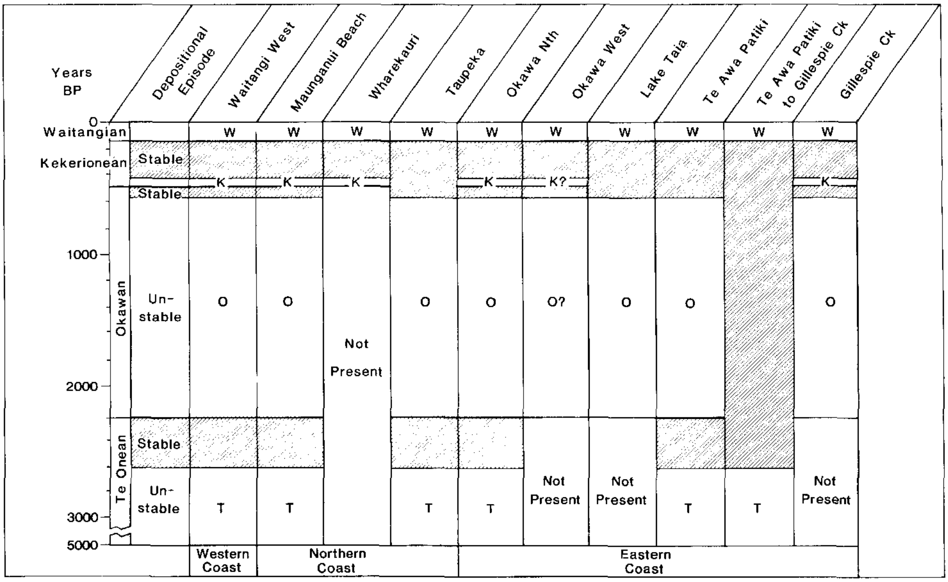

Fig. 12 – Adopted ages for late Holocene sand deposits of Chatham Island. T = Te Onean, O = Okawan, K = Kekerionean, W = Waitangian.

Adopted ages in calendar years for stratigraphic events are:

Stratigraphic event	Years BP	Years AD/BC
Kekerionean soil buried	150	1800 AD
Kekerionean soil begins to form	400	1550 AD
Okawan soil buried	450	1500 AD
Okawan soil begins to form	550	1400 AD
Te Onean soil buried	2,200	250 BC
Te Onean soil begins to form	2,640	690 BC
Te Onean sand begins to accumulate	5,000	3050 BC

CORRELATION OF DEPOSITIONAL EPISODES WITH NEW ZEALAND MAINLAND

McFadgen (1985) describes three chronostratigraphic units in late Holocene coastal sand dune deposits on the New Zealand mainland. Each unit represents a depositional episode similar to that described here. Correlation between three of the depositional episodes proposed in this paper and the three chronostratigraphic units is based on the Taupo Pumice, Loisels Pumice, and the adopted dates for the episodes and the mainland units (Table 2). Deposition and soil formation post-dating Taupo Pumice on Chatham Island correlates well with that on the New Zealand mainland. The Tamatean unstable phase was a continuation of the deposition which began before the Taupo Pumice and deposits immediately preceding the Taupo Pumice on the mainland are probably equivalent to the immediate pre-Taupo Okawan deposits. Correlations, with adopted dates, are given in Table 2.

For the earlier deposits, I propose a tentative correlation between the Te Onean Depositional Episode and the Foxton Dune Building Phase (Cowie, 1963) in the Manawatu district. The Foxton Dune Building Phase was estimated to be 4,000 to 2,000 years BP (Cowie, 1963). Shepherd (1987) suggests that the Foxton dunes began to accumulate at the end of the post-glacial sea level rise 6,000–5,500 years BP, which is roughly the same as the inferred time the Te Onean dunes began to accumulate.

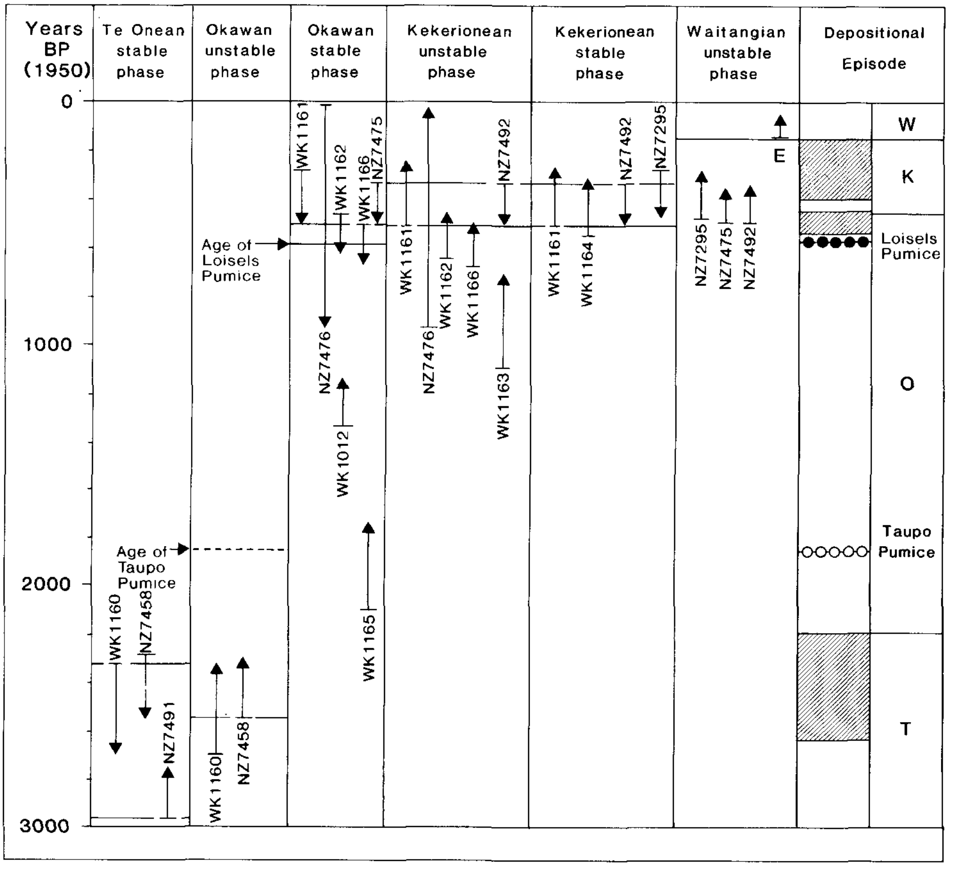

Fig. 13 – Calendar age ranges for key stratigraphic events: beginning of Te Onean stable phase, Okawan unstable phase, *etc.* Included are all radiocarbon dates listed in Table 1 except NZ7293 and WK1538. Both exceptions are on samples thought to have been reworked, and both give maximum dates older than 3,000 years. Arrow heads indicate two kinds of dates: upward-pointing = maximum dates; downward-pointing = minimum dates. Arrow length equals 95% confidence interval. Bones of European-introduced animals (E) used to indicate a maximum age of 150 years.

Table 2 – Correlation of Chatham Island Depositional Episodes (this paper) with Chronostratigraphic Units on the New Zealand mainland (McFadgen, 1985). (Adopted dates for the New Zealand mainland recalculated using 1993 radiocarbon calibration data.)

Depositional Episode (Chatham Island)	Adopted Dates (Years BP)	Chronozone (NZ mainland)	Adopted Dates (Years BP)
Waitangian		Hoatan	
unstable phase	150–0	unstable phase	150–0
Kekerionean		Ohuan	
stable phase	400–150	stable phase	440–150
unstable phase	450–400	unstable phase	450–440
Okawan (post-Taupo Pumice)		Tamatean	
stable phase	550–450	stable phase	570–450
unstable phase	1,850–550	unstable phase	1,850–570

The end of the Foxton Dune Building Phase is dated by Shepherd (1987) as several hundred years after the end of the Te Onean Depositional Episode. At two sections near the Manawatu River, 'Foxton' sand buries peat and trees with dates ranging from 2,270 to 1,595 years BP (Shepherd, 1987). The sand is interpreted by Shepherd (1987) as a final advance of Foxton dunes after dunes closer to the coast had become stable. If Shepherd's (1987) interpretation of his sections is correct, then my correlation is not supported. I suggest, however, that his 'Foxton' sand is derived from erosion of formerly stable dunes, similar to the erosion of Motuiti dunes during the Waitarere Dune Building Phase (Cowie, 1963), and that it represents the onset of a new unstable phase.

CAUSES OF DEPOSITIONAL EPISODES ON CHATHAM ISLAND

The age correlation between the depositional episodes on Chatham Island and the three mainland chronostratigraphic units is remarkably close, even though Chatham Islands are some 900 km east of the New Zealand mainland and different processes appear to have been responsible for their formation. The mainland episodes are explained principally by changes in erosion rates in river systems (McFadgen, 1985). On Chatham Island there are no rivers large enough to provide the sediment. River sediment yield cannot therefore be used to explain the episodes on Chatham Island.

There is no correlation of the depositional episodes with tectonic uplift. Shoreline features of post-glacial age which might possibly have been uplifted and stranded by earthquakes include a 3 m (10 foot) and the 1.5 m (5 foot) raised marine benches (Hay, Mutch and Watters, 1970), as well as the stranded Taupo Pumice shoreline at Waitangi West Beach. Both marine benches, however, pre-date Te Onean dunes (Hay, Mutch and Watters, 1970). Although Taupo Pumice is found at various heights around Chatham Island, the deposit at Waitangi West Beach is the only well-defined shoreline. Its location on the exposed west coast leads to the supposition that it was driven to its present height by westerly storms.

If the argument advanced in this paper is correct, then humans arrived on Chatham Island too late for burning and clearing of vegetation to be invoked as an explanation. The Chatham Island data thus support the conclusion of McFadgen (1985) that depositional episodes are unrelated to human activity. On both the New Zealand mainland and Chatham Island, human settlement occurred during an unstable phase and was followed shortly after by the stabilisation of coastal dunes and formation of soils.

McGlone (unpublished) has suggested a model of recurring disturbance at various times by various events to explain McFadgen's (1985) stratigraphic and chronological evidence on the mainland. However, both on Chatham Island and on the mainland, soils appear to have begun forming about 550 years BP after more than a millenium of sand accumulation, a time scale too long to fit McGlone's hypothesis.

The Chatham Island evidence suggests that the episodes on at least some parts of the coast may be related to coastal erosion initiated by storms. Sand, eroded from the sections by wave action, is currently blowing inland onto older stable dunes. Some sand is removed by the sea and, through longshore drift, is possibly contributing to new foredunes at, for example, Wharekauri and Te Hapupu (Fig. 1). These same processes, reworking pre-existing bodies of sand, may account for the formation of the earlier deposits.

An increase in coastal erosion around both main islands of New Zealand since the mid-1950s is related to a parallel increase in tropical and extra-tropical cyclonic storms (Grant, 1981). It is possible that the storms are more frequent during warm periods than cold (Lamb, 1972; Grant, 1981). Correlation of unstable and stable phases with times of high and low temperatures respectively is poor (McFadgen, 1985), but severe storms have a large random component which could account for the lack of correlation (Reid, unpublished).

HOOKER'S SEA LION

Rounded pebbles are sparsely scattered throughout the buried soils, and are common as lag gravels on the surface of eroded Te Onean dunes where they are often found along with the bones of sea mammals. The pebbles range in size up to 10 cm and are identified here as sea lion gastroliths (*cf.* Fleming, 1951).

Bones collected from the eroded Chatham Island dunes were identified as Hooker's sea lion (*Phocarctos hookeri*) by Drs Alan Baker (National Museum of New Zealand) and Martin Cawthorn (Department of Conservation). They were most common at West Waitangi Beach, Maunganui Beach, and near Okawa Point, and were also found along the Te Awa Patiki coast. The bones are from both adults and juveniles, and include both males and females (Gibson and Cawthorn, unpublished).

The oldest identified bones are from a skeleton found beneath Te Onean ground soil near the top of a high dune at Cape Pattisson. Tuatua shells from alongside the bones have a radiocarbon date of 2,950–2,760 years BP (NZ7491, Table 1) which is interpreted as a maximum date for the bones. Stratigraphically younger bones were found on eroded Okawan dunes, and the youngest bones are from a Moriori midden on the Kekerionean buried soil at Maunganui Beach.

Hooker's sea lion bones from two individuals have previously been recorded from a Moriori midden near Point Durham on Chatham Island (Smith, 1977), while other bones have been reported from a midden just south of Lake Taia (Smith and Wernham, 1976). Sea lion bones have been collected at two places on Pitt Island: by the author at Waipaua and by Dr P.R. Millener (National Museum of New Zealand) at Tupuangi (Gibson and Cawthorn, unpublished). In each case the bones appeared to have eroded out of Moriori middens.

Hooker's sea lion today inhabits the sub-antarctic islands of New Zealand (Crawley, 1990), and males range north to about 41 degrees latitude (M. Cawthorn, *pers. comm.* 1992). In prehistoric times their range extended to the northern North Island (Smith, 1989), but apart from Smith's (1977) and Smith and Wernham's (1976) midden finds, they do not appear to have been recorded previously from the Chatham Islands (Crawley, 1990). The bones from the dunes and the middens discussed above indicate the former widespread distribution of Hooker's sea lion on the Chatham Islands.

The apparent disappearance of Hooker's sea lion from Chatham Island by the time of European contact parallels their disappearance from much of the New Zealand mainland during the prehistoric period (Smith, 1989). The coincidence of human settlement and the disappearance of Hooker's sea lion indicates that the animal may have been driven from Chatham Island by human predation.

MORIORI SETTLEMENT OF CHATHAM ISLAND

Cultural remains are common in the Kekerionean buried soils and are found in Kekerionean sand. They are also found in the Okawan ground soils, and in Okawan buried soils only where these soils are not buried by Kekerionean sand, but by Waitangian sand. Cultural remains are not found in Okawan sand. I therefore conclude that Chatham Island was first settled by humans during the Kekerionean unstable phase, between about 450 and 400 years BP.

An earlier settlement date of *c.* 1,000 years BP was proposed by Sutton (1980). In support of the earlier date he cited artifacts found on the Chatham Islands which are matched in early New Zealand Archaic assemblages. Neither existing radiocarbon dates nor the results of this study support Sutton's early settlement date. The corollary, that "early" Archaic artifacts persisted on the New Zealand mainland until 450–400 years BP, agrees with Davidson (1984) who showed that some early types continued in use on the mainland until after 1400 AD. As the artifacts persisted in use on the mainland until quite late in the prehistoric sequence, there is no need to invoke an early settlement date for Chatham Island. It is quite plausible that even 450–400 years BP the earliest Chatham Island settlers would have brought Archaic artifacts with them.

There are 19 existing radiocarbon dates (Sutton, 1976, 1977; Dodson and Kirk, 1978; Table 3). With one exception, all the dates are less than 450 years BP. The exception is a date on cockle shells from a limestone cave on the Te Whanga lagoon shore (NZ882, Table 3) which has a 95% calibrated age range of 920 to 690 years BP. The possibility that the shells

Table 3 – Unpublished radiocarbon dates from archaeological sites

Lab No.	Conventional Radiocarbon Age (years BP(1950))	Calibrated Age Range (95% Confidence Interval in years BP (1950))	∂C13 (ppm)	Material Dated and Provenance of sample
NZ554	265 ± 58	430–370 (8%) 330–0 (87%)	–25.0	Site 74, Maunganui Beach west. Charcoal from burnt post, 20 cm deep in a single layer midden and working floor. "Late" style adzes and a shark tooth necklace found on the floor.
NZ555	95 ± 58	270–190 (26%) 140–10 (68%)	–25.0	Site 49, Lake Waikuia. Charred wood from oven in single layer site with middens. Carved trees nearby.
NZ556	99 ± 47	260–210 (22%) 140–20 (72%)	–25.0	Site 4, Taia. Charcoal from oven among shell mounds. Carved trees nearby.
NZ557	283 ± 61	460–80 (84%) 30–0 (12%)	–25.0	Site 19, Te Ana a Moe. Leaves from rat nest in a fire-place in a limestone cave with carvings on walls. Sample overlain by European debris, and overlying 1.5 m of deposits containing remains of extinct birds.
NZ882	1,249 ± 61	920–690 (95%)	–1.2	Site 19, Te Ana a Moe. Shells (cockle) from limestone cave. "Earliest" date for human occupation.
NZ7849	735 ± 35	460–310 (95%)	–0.9	Site 570, Pitt Island, shells (limpets, catseyes, turban shells) from eroding midden.

NZ554–882 are courtesy of D.R. Simmons, *pers. comm.*, site numbers as listed in Simmons (1964). NZ7849 from collection made by author.

incorporated old carbon from the limestone while they were growing makes the date a maximum only. In addition, although the deposits dated by the cockles were originally identified as cultural, they are now thought to be natural (D.R.Simmons, *pers comm.* 1991).

The Pitt Island date (NZ7849, Table 3) is from a site at the mouth of the Waipaua Stream and indicates occupation of the site sometime between 460 and 310 years BP. The site is one of a series along the northeast and southeast coasts of Pitt Island from which artifacts similar to early types on the New Zealand mainland have been collected. As well as the artifacts, the sites contained pieces of obsidian which appear to be from Mayor Island in the Bay of Plenty. The combination of early artifact types and obsidian indicates that the sites were probably occupied early in the prehistoric sequence of the Chatham Islands (Sutton, 1980, 1982). Although no natural obsidian source has been found on the Chatham Islands, obsidian, as well as metamorphosed argillite (both from mainland New Zealand) are occasionally also found on Chatham Islands sites (Sutton and Campbell, 1981; Leach *et al.*, 1986).

A settlement date of between 450 and 400 years BP is in accordance with the estimated Moriori population of *c.* 2,000 people (Richards, 1972) at the time of European contact in 1791 AD. If the population doubled every 50 years or so (*cf.* Houghton, 1980), this estimated population could have been reached if the first settlers arrived about 1500 AD.

Unlike other Polynesian islands, which were settled by sailing upwind against the prevailing ocean currents (Irwin, 1989), the Chatham Islands are generally down-wind and down-current from the settlers' homeland, so drift voyages to the Chatham Islands, whether accidental or on purpose, would have been possible. Ocean currents flow eastwards towards Chatham Islands (Heath, 1985), and a west to northwest airstream flows over Chatham

Islands for about a third of the time (Thompson, 1983). Kauri logs, presumably from the New Zealand mainland, have washed up on the north shore of Chatham Island (Simmons, 1962), and notes in bottles from the Cook Strait area have been picked up on the north shore of Chatham Island within months of being written (M. Peirce, *pers. comm.* 1987). Computer simulated drift voyages show that there is a reasonably good chance of a departure from New Zealand ending up on the Chatham Islands (Leach *et al.*, 1986).

That Chatham Islands were not settled earlier than 450 to 400 years BP is probably due to New Zealand's large size. Given this, the crew of a canoe accidentally blown offshore would have had little trouble finding the right direction to return. For the first few hundred years, New Zealand, with its extensive land mass and varied resources, would have been sparsely populated and an attractive place to live, and there was probably little reason for its inhabitants to leave in search of other islands.

However, in the New Zealand mainland archaeological record of 500 to 400 years BP there are signs of stress, *ie*, a changing environment and declining food resources (Davidson, 1984). About this time, the first fortifications appeared (Davidson, 1984). Armed conflict, probably brought about by population pressure and a demand for land, became prevalent. For the first time in 400 or 500 years, there would have been good reasons for people to leave New Zealand in search of other places to live. It was about this time that the ancestors of the Moriori arrived in the Chatham Islands.

CONCLUSIONS

1. Dune sand accumulated during four Holocene depositional episodes: the first from about 5,000 years BP to about 2,200 years BP, the second from about 2,200 years BP to about 450 years BP. The third began about 450 years BP, shortly before the Polynesian (Moriori) settlement of Chatham Island. The fourth depositional episode began about 150 years BP, at about the time of European contact, and still continues.
2. Dune building and soil forming episodes on Chatham Island correlate well with similar events on the New Zealand mainland. Unlike the mainland, the Chatham Island episodes are unrelated to river sediment yield, but like the mainland, human influence was negligible. The Chatham Island episodes may be related to coastal erosion initiated by storms.
3. The date of human settlement of Chatham Island was probably between 450 and 400 years BP.
4. Hooker's sea lion disappeared from Chatham Island after Moriori settlement, possibly driven away by human predation.

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APPENDIX 1

SOIL PROFILE DESCRIPTIONS

Depth (cm)	Horizon Designation	Description
TE ONEAN SAND DUNE AT MAUNGANUI BEACH WEST (GR 274761)		
0–23	A	greyish yellow (2.5Y7/2), slightly peaty sand, loose, soft, few stones, few roots, irregular distinct boundary.
23–39	uA1	black (2.5Y2/1), slightly loamy sand with many brownish-grey grains evident, soft, weakly developed medium granular structure, few round and sub-round gravel and stones up to 10 cm across, many roots, indistinct boundary.
39–52	uA2	brownish grey (7.5YR5/1) sand, loose, few roots, distinct boundary.
52–56	uB21	dark brown (7.5YR3/4) sand, slightly hard to hard, moderately developed fine "blocky" (with rounded corners) structure, disintegrating to single grain, few roots, indistinct boundary.
56–63	uB22	brown (7.5YR4/4) sand with few fine distinct dull brown mottles, soft, weakly developed fine blocky and single grain structure, few roots, indistinct boundary.
63–77	uB23	dull brown (7.5YR5/4) sand with few fine distinct brown mottles, soft, single grain, diffuse boundary.
77–100+	C	dull yellow orange (10YR7/3) sand, soft, single grain.
THROUGH DUNES EXPOSED BY COASTAL EROSION AT MAUNGANUI BEACH WEST (GR 260770)		
Waitangian Depositional Episode		
0–100	–	greyish yellow (2.5Y7/2) sand with dirty greyish yellow patches and many fine distinct brownish black mottles up to 10 cm above lower boundary, soft and loose, many marram grass roots, distinct irregular boundary.
Kekerionean Depositional Episode		
100–120	1uA	brownish black (7.5YR3/2) very slightly peaty sand, weakly developed very fine to fine nut structure with single grain, few roots, few small rounded gravels; with occasional shell fragments, bird and fish bones and coprolite fragments; shell middens; distinct irregular boundary.
120–170	C	light grey (2.5Y8/2) sand with many fine distinct brownish black mottles within 10 cm of upper boundary, soft, loose, distinct irregular boundary.
Okawan Depositional Episode		
170–190	2uA	brownish black (7.5YR3/2) very slightly peaty sand, weakly developed very fine to fine blocky and nut structure with single grain, few roots, few small gravels; with shells, fish and bird bones, coprolite fragments; distinct irregular boundary.
190–700+	C	greyish yellow (2.5Y7/2) sand, soft and loose.
KEKERIONEAN SAND DUNE AT WHAREKAURI (GR 429826)		
0–25	A	brownish black (7.5YR2/2) sand, slightly hard to soft, weakly developed fine and very fine blocky structure with some single grain, few roots, with occasional rounded gravels and stones, rare charcoal and coprolite fragments, distinct boundary.
25–45	(B)	dull brown (7.5YR5/3) sand, soft to loose, single grain, few roots, with occasional rounded stones and gravel, rare coprolite fragments, diffuse boundary.
45–70+	C	dull brown (7.5YR6/3) sand, soft to loose, single grain, no roots, with rare rounded gravels and stones.
KEKERIONEAN SAND DUNE AT OKAWA (GR 720787)		
0–20	A	brownish black (10YR3/2) sand, single grain and weakly developed fine and medium granular structure, very friable, indistinct boundary.
20–22	(B)	dark brown (7.5YR3/4) sand, single grain with weakly developed rare granular peds hanging on roots, loose, indistinct boundary.
22–100+	C	dull yellow orange (10YR7/2) sand, single grain, loose, roots to 50 cm.

TE ONEAN SAND DUNE AT OKAWA (GR 705785).

0–5	A1	dark reddish brown (5YR3/2) loamy sand, soft to slightly hard, moderately developed fine nut structure, many roots, indistinct boundary.
5–15	A2	brownish grey (5YR4/1) sand with few fine distinct dark reddish brown mottles, loose to soft, single grain to weakly developed fine nut structure, many roots, indistinct boundary.
15–22	B21	dark reddish brown (5YR3/3) sand with few fine and medium distinct brown and grey mottles, soft to slightly hard, moderately developed very fine and fine blocky structure, many roots, distinct irregular boundary.
22–30	B22	brown (7.5YR4/4) sand with many fine distinct dark reddish brown and brownish grey mottles, loose, single grain and weakly developed fine granular structure, many roots, indistinct boundary.
30–54	C	dull orange (7.5YR7/4) sand with few fine distinct dark reddish brown mottles in the top half of the horizon, loose, single grain with a little very weakly developed very fine nut structure, few roots, distinct to indistinct boundary.
54–70	1uA?	dull brown (7.5YR5/4) sand, soft to slightly hard, single grain and weakly developed fine blocky structure, indistinct boundary.
70+	C	dull orange (7.5YR7/4) sand, loose to soft, some very weakly developed very fine nut structure but mostly single grain.

OKAWAN SAND DUNE AT OKAWA (GR 706785).

0–8	A1	brownish black (7.5YR2/2) loamy sand, weakly developed medium to fine crumb structure, soft, many roots, indistinct boundary with a few stones on boundary.
8–20	A2	greyish brown (7.5YR4/2) sand with few fine distinct dark reddish brown and brownish black mottles, single grain with some weakly developed medium crumb structure, loose, few roots, distinct boundary.
20–30	B21	dark reddish brown (5YR3/3) sand with few fine distinct dull yellow orange mottles, single grain and weakly developed fine and very fine blocky structure, soft to loose, few roots, distinct boundary.
30–32	B22	brown (7.5YR4/4) sand with few fine distinct dark reddish brown mottles, single grain, loose, few roots, distinct boundary.
32–100+	C	dull yellow orange (10YR6/3) sand, single grain, loose, few roots.

OLD LAGOON SHORE AT TAIA (GR 573632)

0–20	–	brownish grey (7.5YR4/1–5/1) sand, loose, single grain with rare medium granular peds, many roots, indistinct boundary
20–40	uA	brownish black (7.5YR3/1) peaty sand with brownish grey mottles, very friable, moderately developed fine to medium granular structure with single grain, with roots, indistinct boundary
40–65	B21	brownish black (7.5YR3/1) sand, very friable, weakly developed fine granular structure with single grain, rare roots, diffuse boundary
65–80	B22	very dark brown (7.5YR2/3) sand, very friable, single grain, no roots, indistinct boundary
80–105	B23	brown (7.5YR4/4) sand, very friable, single grain, no roots, 3 cm thick band of pumice lumps between 90 and 93 cm, diffuse boundary
105–140+	C	dull yellow orange (10YR6/3) sand, single grain, no roots.

APPENDIX 2

Dating Loisels Pumice

The most reliable samples for dating sea-rafted Loisels Pumice are those with a negligible inbuilt age (McFadgen, 1982). Midden shells are potentially the best for minimum dates because they were originally collected live for food. Shoreline shells, on the other hand, are suitable for maximum dates, but will normally give poor minimum dates because of their unknown and possibly large inbuilt age. Shells on the present Te Awa Patiki beach, described earlier in this report, have a storage age (McFadgen, 1982) of thousands of years. Few broken shells may indicate only a little reworking (*cf.* Osborne, Enright and Parnell, 1991), but unless bivalves still in position of articulation are found, the reworking may have occurred after an unknown and possibly long period of storage. For this reason, I

Table 4 – Radiocarbon dates used to define the age of sea-rafted Loisels Pumice. For details of sample significance, locality and stratigraphy, see McFadgen (1982).

Lab. No.	Conventional Radiocarbon Age (years BP (1950))	Calibrated Age Range (95% Confidence Interval in years BP (1950))	∂C13	Material Dated
NZ354	689+/-40	660–550 (95%)	–25.0	Charcoal
NZ631	525+/-44	550–460 (94%) 620–610 (1%)	–25.0	Charcoal
NZ632	1,008+/-60	680–510 (95%)	1.22	Shells
NZ651	1,111+/-41	1,060–930 (95%)	–24.8	Wood
NZ1296	761+/-44	490–320 (95%)	1.12	Shells
NZ1297	832+/-44	540–410 (95%)	1.12	Shells

consider the minimum date of *c.* 1,000 years for Loisels Pumice at Tokerau Beach (Osborne, Enright and Parnell, 1991) to be unreliable.

The best age estimate for Loisels Pumice is obtained by bracketing samples from many sections (McFadgen, 1982). Any deposit with a maximum date appreciably younger than reliable minimum dates from other sections may be secondary. Loisels Pumice at Matai Bay, originally dated by Wellman (1962) and redated by Osborne, Enright and Parnell (1991), now has a maximum date younger than minimum dates from other sections. Small pieces of pumice found by Osborne, Enright and Parnell (1991) below the main pumice layer confirm the deposit as secondary. There is no indication from radiocarbon dates that the other deposits dated by McFadgen (1982) or Osborne, Enright and Parnell (1991) are secondary. The best current estimate for the arrival of Loisels Pumice is the age range 660–510 calendar years BP based on the dates used by McFadgen (1982) (Table 4). The dates are recalibrated according to Stuiver and Reimer (1993) and Stuiver and Braziunas (1993) using a delta-R for shell samples of -30 ± 15 (McFadgen and Manning, 1990).

APPENDIX 3

GENERALISED SECTION DESCRIPTIONS

Measurements are generally for the best exposures and are a guide to the relative thickness of deposits.

thickness (metres)

SECTION 1: Waitangi West Beach, 200 m north of track between homestead and beach, and 200 m from high water mark (GR 251757)

Waitangian Depositional Episode

Light brown windblown sand 0.40

Kekerionean Depositional Episode

Brownish black buried topsoil with shell midden charcoal, and burnt stones, fragmented and whole fish and bird bone, and coprolites 0.40

Light brown windblown sand 0.20

Okawan Depositional Episode

Brown buried topsoil with fragmented and whole fish and bird bones and coprolite fragments (WK1166: 670–500 yr BP) 0.30

Light brown windblown sand .... 0.60+

SECTION 2: Coast between Cape Pattisson and Washout Creek (GR 260770)

Waitangian Depositional Episode

Grey windblown sand up to 2. 50

Kekerionean Depositional Episode

Brownish black slightly peaty sand (buried topsoil) with shells; bones of birds, fish and seals;

few small rounded gravels; coprolites; shell middens with charcoal and burnt stones; (NZ7492: 500–340 yrs BP) 0. 20
Light grey windblown sand up to 0. 90

Okawan Depositional Episode
Brownish black slightly peaty sand (buried topsoil) with shells; bones of birds, fish and seals; few small rounded gravels; coprolites; (NZ7476: 930–0 yrs BP; WK1012:1,320–1,130 yrs BP; WK1162:630–460 yrs BP) 0. 20
Grey windblown sand, with Taupo Pumice; (WK1163: 1,090–710 yrs BP); up to 7. 00

Te Onean Depositional Episode
Brown sand (buried topsoil) 0. 20
Clean white sand 0. 10
Iron pan 0. 02
Orange brown iron-stained sand to high water mark .... 0. 80 +

SECTION 3: *Wharekauri, in west bank of small creek at coast (GR 443821)*

Waitangian Depositional Episode
Blown sand, up to 1. 50

Kekerionean Depositional Episode
Grey sand (buried topsoil) with fireplace, charcoal, burnt stones, flaked chert, shell fragments, scattered bones 0. 20
Blown sand .... 1. 00+

SECTION 4: Coast 500 m south of Taupeka Point (GR 501805)

Waitangian Depositional Episode
Loose, white blown sand 0. 25

Okawan Depositional Episode
Grey brown sand (buried topsoil) with occupation remains, bird bones, stones, Loisels Pumice 0. 15
Pale brown blown sand with the bones of pilot whales 0. 15
Dirty white blown sand with Taupo Pumice and seal bones .... 0. 60 +

SECTION 5: Okawa Beach, north bank of stream (GR 714780).

Waitangian Depositional Episode
Windblown sand, pinching out upstream 0. 65

Kekerionean Depositional Episode
Peaty sandy topsoil with shell midden in upper part 0. 35
Grey windblown sand, thickening upstream, Taupo and Loisels pumices; (WK1164: 550–320 yrs BP) 0. 75
Dark brown and black sand, 1 piece Taupo Pumice .... 0. 60 +

SECTION 6: Okawa Point West, north bank of stream (GR 690765)

Waitangian Depositional Episode
Grey wind blown sand 0. 80

Okawan/Kekerionean Depositional Episode
Grey black buried topsoil, with shell midden on upper surface 0. 30
Brown wind blown sand 1.10
Dark brown peaty sand with wood and gravels at stream level .... 0. 40+

SECTION 7: Taia, exposed in edge of sand blowout (GR 573632)
Waitangian Depositional Episode
Grey, very friable blown sand 0. 20
Okawan Depositional Episode
Brownish black peaty sand (buried topsoil)
with 2 cm thick shell midden layer in top 0.20
brownish black sand 0. 25
dark brown iron-stained sand 0.15
Brown iron-stained sand with lenses of
coarse shell sand and shell fragments 0. 10
Brown iron-stained sand as above with
Loisels (?) pumice 0. 03
Brown iron-stained sand as above 0. 12
Fine to coarse shelly sand 1. 10
Whole and fragmented shells .... 0. 10 +

SECTION 8: Coast at Te Awa Patiki, south of Te Whanga lagoon outlet (GR 566563)
Waitangian Depositional Episode
Blown sand 2.50
Okawan Depositional Episode
Shell middens (up to 40 m long) (NZ7475: 490–360 yrs BP) 0.80
Sandy topsoil with shells, bones of seal,
bird and fish, coprolites, and
occasional stones 0.20
Blown sand 0.30
Te Onean Depositional Episode
Sandy topsoil with shells, bird bones, fish and seal bones, coprolites, and occasional
rounded gravels (NZ7458:2,540–2,280 yrs BP;WK1,160:2,680–2,320 yrs BP) 0.30
Blown sand 2. 20
Dark brown sand, iron cemented, with thin bands of shells in black sand at the
southern end of the section (WK1538:16,460–15,780 yrs BP) .... 2. 00 +

SECTION 9: Gillespie Creek, Owenga (GR 589482)
Waitangian Depositional Episode
Loose light brown windblown sand 0. 40
Kekerionean Depositional Episode
Black sand (buried topsoil) with shell midden,
burnt stones, and charcoal (NZ7295:490–270 yrs BP). 0. 40
Light brown sand with rare tuatua shells near base,
no charcoal (NZ7293:4,070–3,690 yrs BP) 0. 25
Okawan Depositional Episode
Medium brown sand, slightly coherent (buried topsoil),
with occasional bird bones (WK1161:510–280 yrs BP) 0. 10
Light brown windblown sand with
Loisels Pumice near top 0. 60
Olive and yellow orange iron-stained sand
with Taupo Pumice .... 0. 30 +