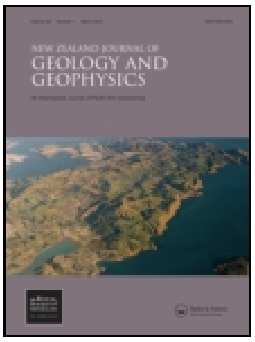

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Holocene sand dunes on Enderby Island, Auckland Islands

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Abstract On Enderby Island, Holocene sand dunes are separated into lower and upper deposits by layers of peat and silt. The lower deposits contain roughly equal proportions of shell fragments and basalt grains; the upper deposits are almost entirely shell fragments. The dunes overlie lagoon muds which probably accumulated behind an old stranded beach ridge at a time when sea level was some 2 m higher than today. Radiocarbon dating gives an age for the lower deposits of between 5700 and 2800 years B.P., and for the upper deposits of less than 2800 years B.P. The dunes are thought to have begun accumulating when the sea breached a gap between Enderby Island and Rose Island.

Keywords Holocene; sand dunes; radiocarbon dating; Enderby Island; Auckland Islands; beach ridges; sea levels

INTRODUCTION

Enderby Island is a small, low-lying island some 4.5 km long, 2.5 km wide, and up to 43 m high, situated at the northern end of the Auckland Islands (Fig. 1). Along the north and west coasts, vertical cliffs rise to more than 30 m, but along the south and east coasts, the cliffs are lower and there are sandy beaches. Sand dunes on the south coast of Enderby Island (Fig. 1, 2) are the only dunes in the Auckland Islands (New Zealand Pilot 1971). They are composed mainly of shell fragments and cover some 20 ha.

The island was once part of a Pliocene basalt dome, now largely eroded by the westerly seas of the "roaring forties". Glacial sediments are present on the island, and postglacial deposits include peat, which blankets almost the entire island, stranded beach ridges, and the sand dunes (Fleming et al. 1976).

The island is uninhabited and its only mammals are mice, rabbits, and cattle introduced last century, and sealions and seals (Taylor 1971).

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SANDY BAY DUNES

The sand dunes are north and east of Sandy Bay (Fig. 1) and are highest and most extensive in the northeastern corner of the bay which is the part most exposed to the prevailing winds. The prevailing winds are from the westerly quarter (De Lisle 1965), but Sandy Bay is comparatively sheltered from the northwest, and the highest dunes are where sand would be blown up the beach by west and southwest winds. A low transverse foredune ridge (1: Fig. 2, 3), about 4 m high, extends around the north of the bay just inland of high water mark; but in the northeast corner there is no transverse ridge, blowouts have occurred, and sand has moved inland in a roughly ENE direction for more than 0.5 km, leaving a longitudinal ridge (2: Fig. 2, 3) 8–12 m high, extending inland between 2 streams, and a large blowout with a horseshoe-shaped ridge (3: Fig. 2, 3) 8–25 m high.

About half of the dune area is stable and covered with a close-cropped sward induced by rabbits and cattle. If it were not for the combined erosive effect of the rabbits and wind, the entire dune area would probably be stable. Wind erosion of the southwest end of dune ridge 3 has left the surface of the sand covered with a lag gravel of rounded pebbles identified as sealion gastroliths (Fleming 1951).

Sections through the dune ridges show 2 distinct sand deposits (Fig. 4): a "lower" sand composed of shell fragments and basalt grains in more or less equal amounts, and an "upper" sand composed almost entirely of shell fragments and very few basalt grains. Both sands are well sorted and finer than intertidal beach sand (Fig. 5), which is composed almost entirely of shell fragments. The 2 deposits are separated by peat and silt (Fig. 4) and in dune ridge 3, overlie a 2 m thick lagoon deposit of mud resting on glacial till of the Enderby Formation (Fleming et al. 1976) at about present high water level. The base of the lagoon deposit is silty sand

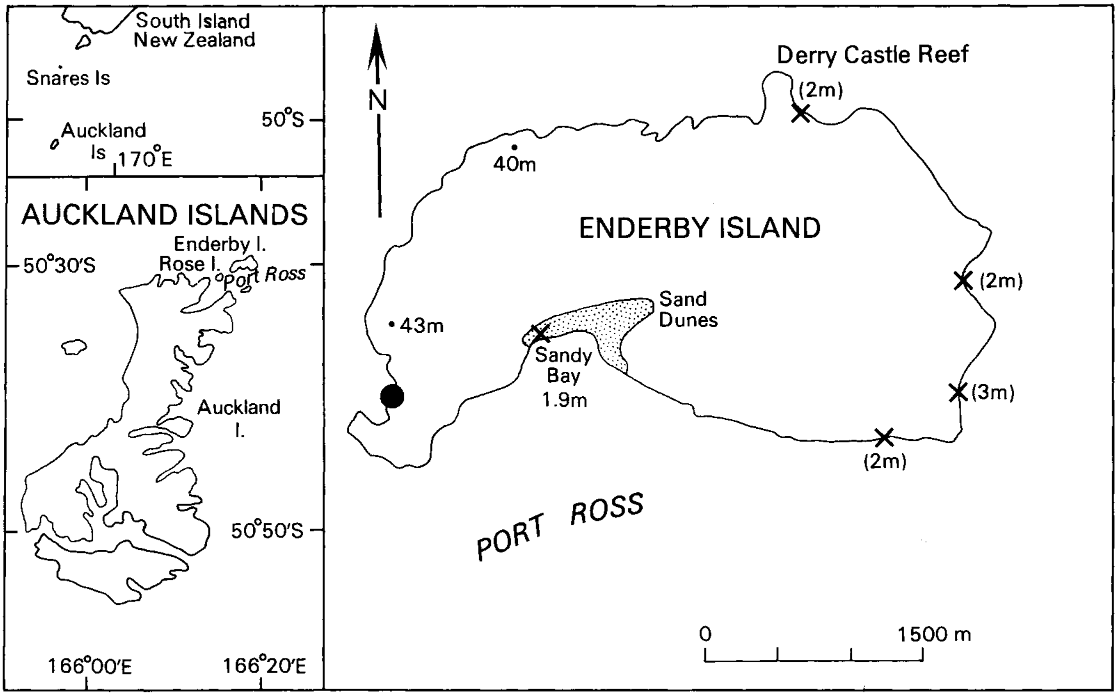

Fig. 1 Sketch map of Enderby Island showing the location of sand dunes and stranded beach ridges (crosses). Beach ridge emergence heights (m) in brackets. Height of Sandy Bay stranded beach ridge is above highest level of seaweed and driftwood. ● = growing beach ridge 25 m above sea level. *Insets*: locality maps.

composed of shell fragments with no observable basalt grains.

Within the upper sand deposit are lenses of sealion gastroliths and a series of brown "peaty" layers which contain many royal albatross bones (Yaldwyn 1975). The brown layers are little more than organically discoloured sand. They are interpreted as representing short intermittent periods of stability between phases of sand accumulation. Fish bones, presumably food remains, and skeletons of sealions and birds other than the albatrosses, were found on and in the brown layers, and it is possible that some of the organic discolouration may be from the decay of animal remains. Neither the brown layers nor the albatross bones were seen in the lower sand, but too few exposures were seen to be sure that they were in fact absent.

About 99% of the grains in each deposit are smaller than 0.5 mm (1 ϕ) and both the basalt and shell grains are rounded and abraded. Amongst the shell fragments are microscopic marine gastropods and bivalves and forams (Appendix 1). The shells are indicative of a low, intertidal, sheltered environment with algae, rocks, and nearby sand and gravel (B. A. Marshall pers. comm.). The forams are subtidal species which live on the sea bottom in sheltered water to depths of c. 20 m (J. D. Collen pers. comm.). Neither the shells nor forams indicate a marine environment in the vicinity of Sandy Bay greatly different from that of today.

Land snails recovered from the upper sand deposit and from the sand at the bottom of the lagoon mud (Appendix 1), live under tussock (F. M. Climo pers. comm.) and suggest a tussock vegetation on or in the vicinity of the dunes. Fire and introduced mammals have virtually eliminated tussock grassland on the island today (Taylor 1971).

Brachiopod beaks (*Neothyris lenticularis*), considerably larger than the shell fragments, were seen among the dunes. The brachiopods occur naturally in the vicinity of the Auckland Islands (Foster 1974), but their occurrence up on the sand dunes is unusual, and, like the erratic pebbles found in peat on Snares Island (Fleming 1951), they are probably sealion gastroliths.

It is inferred from the sequence of basalt-rich sand followed by calcareous sand in dune ridges 2 and 3 that the 3 dune ridges formed concurrently. The layers of peat and silt between the 2 sand deposits indicate a hiatus in sand accumulation, during which time a change occurred in the source of the sand.

Fig. 2 View of Sandy Bay dunes looking eastwards along beach. Dune ridges numbered 1, 2, and 3. Note: (1) the dark-coloured surface of dune ridge 3, caused by accumulation of sealion gastroliths after wind erosion, and (2) Hooker's Sealions on beach. *(Photo: Ecology Division, DSIR)*

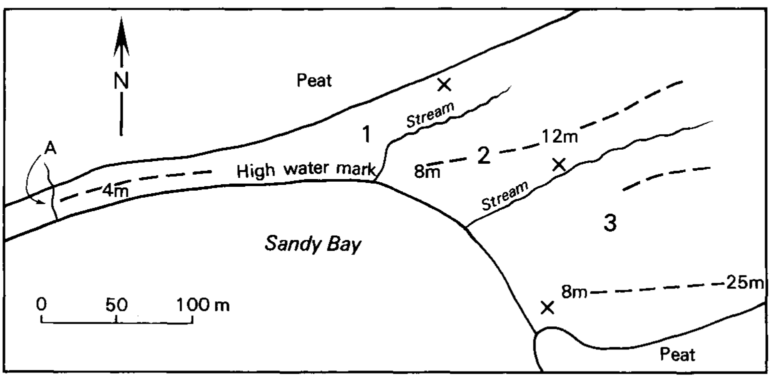

Fig. 3 Sketch map of dune ridges (1, 2, 3) in Sandy Bay. Ridge crests shown by broken lines. Boundaries between dunes 1 and 2, and 2 and 3, marked by streams. Dune heights shown in metres. Crosses = sections shown in Fig. 4. A = stranded beach ridge exposed in stream bank.

CORRELATION OF DUNES WITH POSTGLACIAL BEACH

At the western end of dune ridge 1, an old stranded beach ridge is exposed in a stream bank which cuts across the dune (Fig. 3). It is composed almost entirely of stones, unlike the present storm beach which is almost entirely sand, and its height above the highest level of seaweed and driftwood is about 1.9 m.

A stranded beach ridge was seen at several places on the comparatively sheltered, south, east, and north coasts of Enderby Island (Fig. 1). Except for that in the bay east of Derry Castle Reef, which is being actively eroded (Fleming et al. 1976), all are intact grass-covered ridges of sand and boulders immediately behind the growing beach ridge. At each place the growing beach ridge is composed of boulders. Because the Auckland Islands region is apparently sinking (Summerhayes 1967), a tectonic

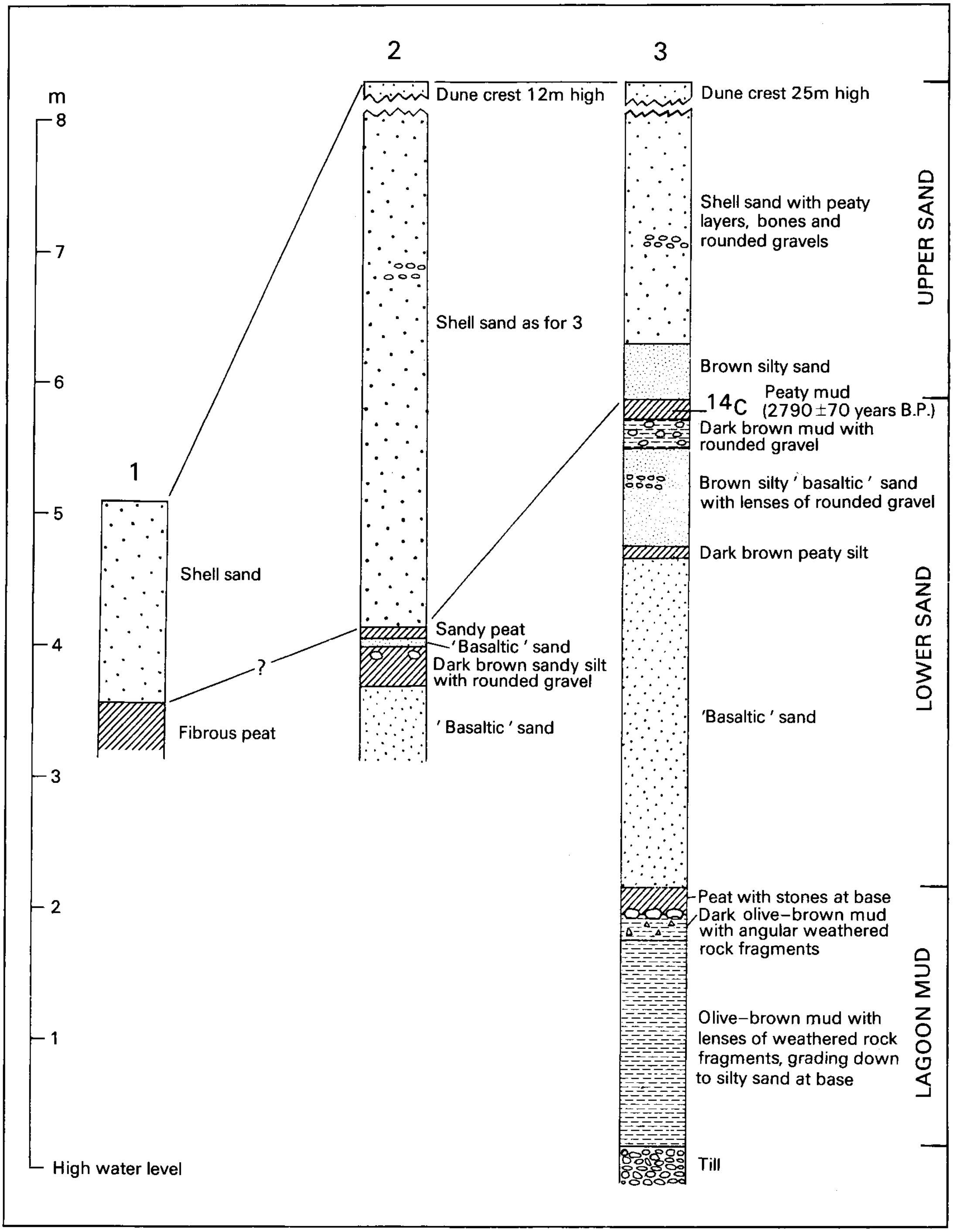

Fig. 4 Sections through dune ridges 1, 2, and 3. Note radiocarbon-dated peat in section 3 (NZ5302A: 2790 ± 70 years B.P.).

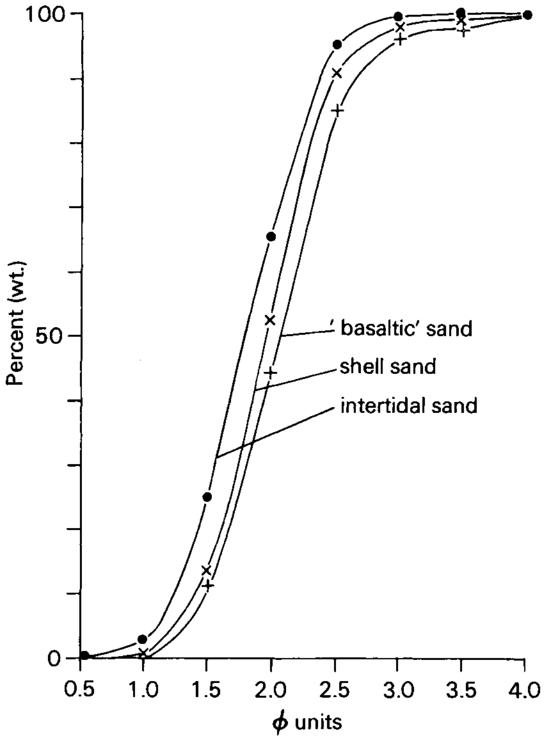

Fig. 5 Size frequency distribution of the basaltic and shell sands compared with intertidal sand from Sandy Bay. (1 ϕ unit = $-\log_2$ diameter in mm.) Percentages were determined by dry sieving.

origin is unlikely, and the beach ridge may have been stranded either by readjustment of the earth's surface in response to changing surface loads since the last ice age (Clark 1980), or by a eustatic fall in sea level. The beach ridge emergence height (i.e., height above a similar feature forming today — Wellman 1971) is about 2–3 m (Fig. 1).

It is inferred, from the close correspondence between the emergence heights of the beach ridge and the height of the lagoon mud in Sandy Bay, that the lagoon deposit accumulated behind the beach ridge at the time the beach ridge was forming.

DATING OF SAND DUNES

A maximum age for the formation of the stranded beach ridge and therefore for the Sandy Bay lagoon deposits and sand dunes is given by radiocarbon-dated sticks of wood from peat beneath the beach ridge in the bay east of Derry Castle Reef (Fleming et al. 1976). The wood has a date (NZ3983A) of 5600 $\pm$ 70 years B.P. (C. A. Fleming pers. comm.).

A minimum age for the lower sand deposit and a maximum age for the upper sand deposit is given by a radiocarbon date for peaty mud between the 2 deposits in dune ridge 3 (Fig. 4). The peat has an age (NZ5302A) of 2790 $\pm$ 70 years B.P.

DUNE ORIGIN

The apparent absence of basalt grains from the silty shell sand at the bottom of the lagoon muds strongly suggests that the appearance of the basalt grains in the lower sand deposit is in some way connected with the origin of the dunes.

The most likely source of the shell fragments is the seabed of Port Ross. Shell occurs as a bottom deposit (British Admiralty 1952) but appears to be absent from the seabed in the approaches to Sandy Bay (Fig. 6). Strong tidal streams flow through the gap between Enderby Island and Rose Island (New Zealand Pilot 1971) and probably account for this absence. Scouring is indicated by seabed contours on the Port Ross side of the gap which show a pocket 17 fathoms (31 m) deep (Fig. 6).

The gap between the islands is about 300 m wide and is flanked by rocks less than 2 m below low water level. Waves driven by southwesterly winds have enormous power, which may be judged from the occurrence of a growing beach ridge (Fig. 7) at the top of a 25 m high cliff on the southwest corner of Enderby Island (Fig. 1). The beach ridge, which is at the end of a narrow cove, is 4 m high and composed of basalt slabs each weighing about 0.5 t, broken from the tops of basalt columns at the cliff edge and driven 30 m inland by wind and wave action. Considering such power, we suggest the gap between Enderby and Rose Islands may not be very old, and the sand dunes may be a result of the sea breaching the gap, subsequent scouring of shell deposits on the Port Ross sea bottom, and their transport to Sandy Bay by the strong tidal stream and southeasterly swell generated by occasional southerly storms.

Such an explanation would account for the basalt grains in the lower sand deposit as the residue of the eroded basalt from between the islands, but it does not account for the hiatus in sand accumulation, nor for the near absence of basalt grains in the upper sand deposit. The upper sand deposit, however, may be related to the breaching of the gap on the southwest side of Rose Island sometime later; the near absence of basalt grains being due, perhaps, to weaker sea currents or a longer transport distance to Sandy Bay. Alternatively, the upper sand may be related to the sea level change which stranded the beach ridge.

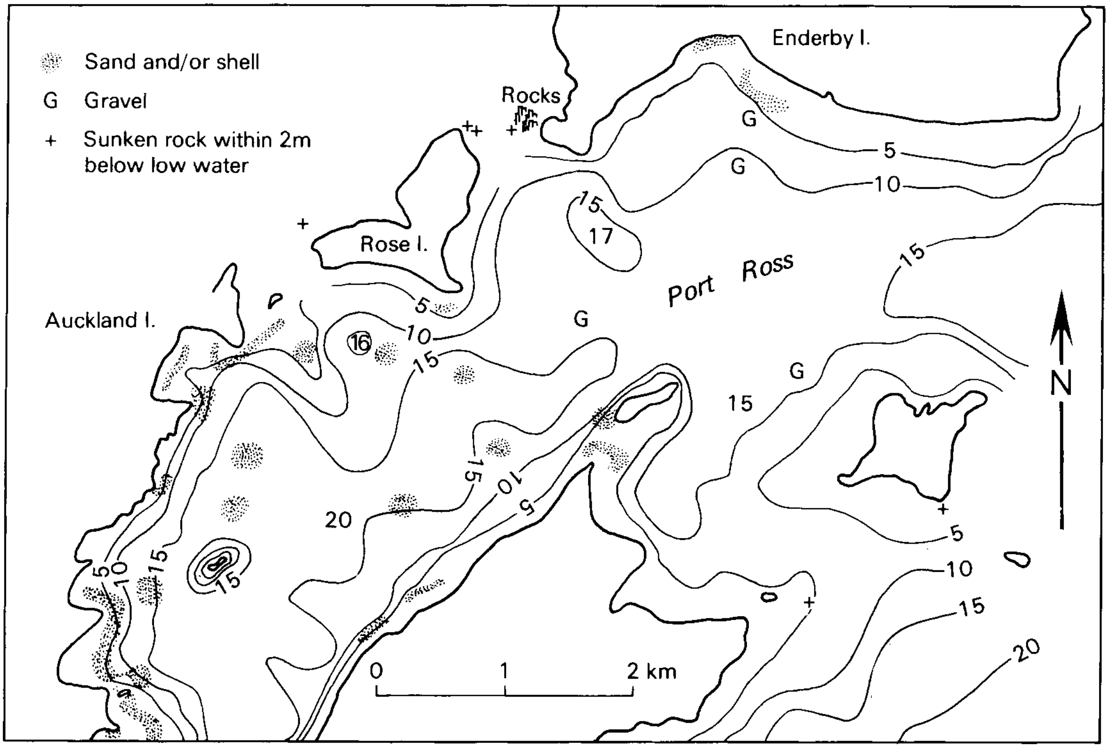

Fig. 6 Sketch map of part of Port Ross showing seabed contours and the recorded location of sandy and/or shelly bottom deposits. Contour interval = 5 fathoms (1 fathom = approx. 1.8 m). Note: (1) the absence of sandy and/or shelly bottom deposits in the approaches to Sandy Bay, and (2) the deep pockets southeast of the gaps between Enderby, Rose, and Auckland Islands. Data from British Admiralty (1952).

Fig. 7 Growing beach ridge at the top of a 25 m cliff on the southwest corner of Enderby Island. Note height of beach ridge compared with person (P).

CONCLUSIONS

1. The sand dunes began accumulating between 5700 and 2800 years ago.
2. The calcareous sand deposit is less than 2800 years old.
3. It is suggested that the sand dunes began accumulating as a result of sea bottom scour after the sea breached the gap between Enderby and Rose Islands.

ACKNOWLEDGMENTS

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APPENDIX 1

Shells and forams identified from sand deposits, Enderby Island.

SAND AT BOTTOM OF LAGOON MUD

Land snails
- *"Paralaoma"* n. sp. (Endemic to Auckland Is.)
- *Ptychodon (Alsolemia) benhami*

Marine shells
- *Gaimardia trapesina flemingi* (juveniles)
- *Benthocardiella striatula*
- *Tawera bollonsi* (juveniles)
- *Liotella polypleura*
- *Sinezona laevigata*
- *Eatoniella* spp. (juveniles, 2 species)

LOWER SAND DEPOSIT

Marine shells
- *Perrierina (Legrandina) aucklandica*
- *Eatoniella* sp.
- Trochidae (genus and species indet.)

Foraminifera
- *Pileolina* sp.
- *Quinqueloculina* cf. *lamarkiana*
- *Cibicides* sp.

UPPER SAND DEPOSIT

Land snails
- *"Paralaoma"* n. sp. (Endemic to Auckland Is.)

Marine shells
- *Tawera bollonsi*
- *Eatoniella* sp.
- *Eatoniella (Dardanula) roseola*
- *Pisinna minor*
- Limpets (juveniles) indet.

Foraminifera
- *Notorotalia ?depressa*
- *Notorotalia ?aucklandica*
- *Pileolina* sp.
- *Elphidium* sp.
- *Quinqueloculina* cf. *miles*