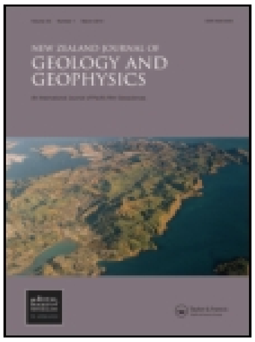

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The origin of the Koputaroa dunes, Horowhenua, New Zealand

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Abstract The Koputaroa Dune Phase was active in an area near Levin, Horowhenua County, during late Pleistocene time. The dune sand was considered previously to have been blown from braided river beds during the Otira Glaciation. Analysis of the heavy mineral content and roundness of Koputaroa Phase dune sand, modern fluvial sand, and Holocene coastal dune sand has indicated that some, at least, of the Koputaroa Phase dune sand may have been derived from a marine rather than a fluviatile source.

Keywords dunes; late Pleistocene; heavy minerals; grains; roundness; Horowhenua; Koputaroa

INTRODUCTION

A late Pleistocene episode of eolian activity, termed the Koputaroa Phase by Cowie (1963), was responsible for the formation of parabolic sand dunes near Koputaroa and Levin, Horowhenua County. The soil which developed upon the dunes was distinguished by Gibbs (1957) and has been described by Cowie (1968). Peat containing pollen indicative of a cool climate is interbedded within one Koputaroa Phase dune and has been dated at 35 000 ± 1700 years B.P. (Fleming 1972). However, at least two dunes contain an interbedded horizon of Aokautere Ash (= Oruanui Ash, c. 20 000 years B.P.), and other dunes overlie aggradational gravels with an estimated age of 18 000–23 000 years B.P. (Fleming 1972).

Cowie (1963) considered that the dune sand was unlikely to have a coastal origin because sea level would have been much lower than at present when the dunes were forming. He suggested that "it was more likely they were related to the braided courses of rivers draining periglacial areas" which "would explain their limited extent". Fleming (1972) also stated that Koputaroa Phase dunes are derived "not from beaches but from glacial river beds" and that "such glacial-stage dunesands seem to have accumulated when streams began to incise below an aggraded terrace, lowering the water-table".

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ANALYSES

Research carried out during the period 1976–81 has indicated that at least some of the Koputaroa Phase dunes are likely to be coastal in origin. This has been determined by comparison of the heavy mineral content and rounding of three categories of sand: (1) Koputaroa Phase dune sand; (2) sand derived from local rivers; and (3) sand from Holocene coastal dunes. Nine samples of Koputaroa Phase dune sand were collected from four separate localities in the Levin–Koputaroa area (Fig. 1). In two of the localities, samples were taken from both above and below the interbedded Aokautere Ash. River sand was obtained from the bed of the Manawatu River (5 samples), Ohau River (3 samples) and Rangitikei River (1 sample). Holocene dune sand of known coastal origin was obtained from the Foxton–Waitarere area.

Heavy mineral content

The heavy mineral content of 10 g subsamples was determined using tetrabromoethane ($C_2H_2Br_4$, specific gravity of 2.96) following the method of Allman & Lawrence (1972). A standard size fraction was not used because the samples possessed broadly similar size distributions with a mean size of about 2.5ϕ (0.177 mm). The results are given in Table 1.

There is a wide range of values for samples within each of the three categories, which is to be expected of beds deposited in moderate to high energy environments. Nevertheless, whereas the Holocene coastal dunes and Koputaroa Phase dunes exhibit a similar range of values, the river sand contains significantly less heavy minerals with only one sample exceeding 0.5%.

In the Horowhenua district, the mineralogy of samples of beach sand, Holocene dune sand, and the Otaki Sandstone has been determined by Oliver (1948); Claridge (1977) analysed some Holocene and Koputaroa Phase dune sands, and Gibb (1977) carried out a more detailed analysis of the magnetic fraction of the beach sand. The heavy mineral fraction of all samples consisted primarily of grains of hornblende, hypersthene, and augite. These minerals were considered to have originated in the Taranaki and Central Volcanic regions to the north, where they occur in abundance, to have been transported to the coast by rivers, and carried southwards into the Horowhenua district by the dominant littoral drift. The varying proportions of individual heavy minerals apparent at different sites

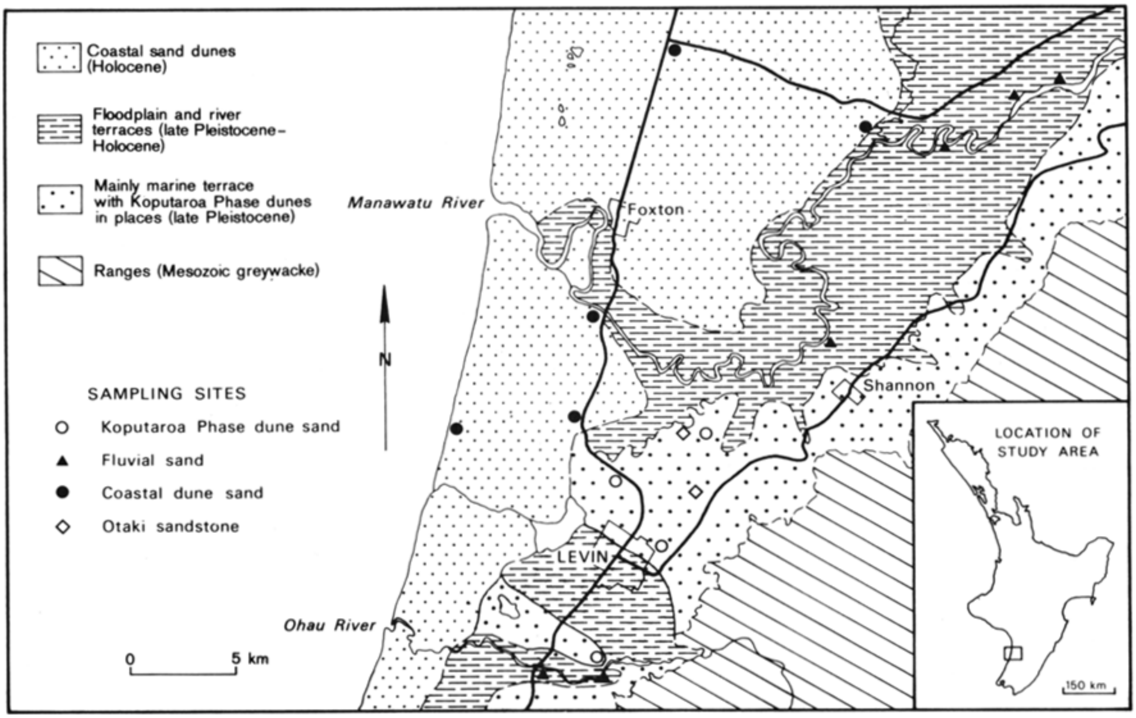

Fig. 1 Geomorphology of the southern Manawatu–northern Horowhenua district. This map shows the location of the samples depicted in Fig. 2.

Table 1 Heavy mineral content of sand samples.

	Number of samples	Mean heavy mineral content	Standard deviation	Range of values
Koputaroa Phase dune sand	9	7.0%	3.1	2.0–12.2%
Fluvial sand	9	0.4%	0.6	trace–2.0%
Holocene coastal dune sand	7	6.0%	3.4	3.1–13.7%

Table 2 Mean Powers's roundness of sand samples.

	Number of samples	Mean Powers's roundness	Standard deviation	Range of values
Koputaroa Phase dune sand	20	0.40	0.06	0.31–0.55
Fluvial sand	23	0.28	0.05	0.16–0.39
Holocene coastal dune sand	16	0.35	0.04	0.30–0.42

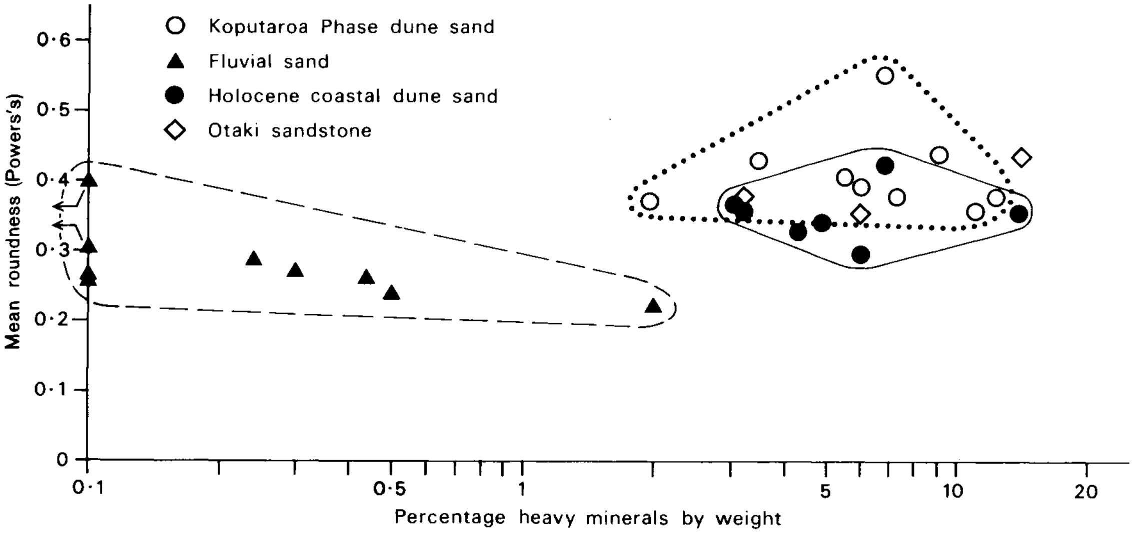

Fig. 2 Bivariate distribution of heavy mineral content and mean roundness. Note that these two variables enable fluvial sand to be distinguished from the other categories.

are likely to reflect the differing late Quaternary eruptive histories of the two main source areas, which are characterised by contrasting heavy mineral suites.

The load carried by rivers which flow in the vicinity of the Koputaroa Phase dunes consists of quartzofeldspathic sediment derived primarily from the Mesozoic greywacke rocks which form the axial ranges. The paucity of heavy minerals in the fluvial sediment can be related to the low heavy mineral content of the greywacke rocks (Reed 1957). At the time the Koputaroa Phase dunes were forming, the nearby rivers may have been transporting a higher proportion of heavy minerals owing to a greater fallout of tephra in their catchments. However, this possibility is not supported by an analysis of the fluvial sediment underlying the late Pleistocene Ashhurst Terrace of the Manawatu River which indicates only a trace of heavy minerals. Furthermore, the heavy minerals within the Koputaroa Phase dune sand appear to be far more rounded than those in fluvial samples.

Roundness

Grain roundness was assessed by means of Powers's (1953) visual method. Sand grains were examined under a binocular microscope, and by reference to a visual chart each grain was allocated to one of six classes ranging from 0.14 (very angular) to 0.84 (very round). Grains of uniform size were examined (the 0.25–0.35 mm fraction), slides were coded to avoid possible observer bias, only quartz and feldspar grains were considered, and grains were sampled systematically by means of an eyepiece graticule. At least 50 grains from each sample were assessed for roundness by each of a number of observers, and a mean value was obtained for each sample. Each observer assessed the roundness of grains from every category so as to minimise any possible error resulting from differences between observers when class means for each category were compared.

Mean roundness values were obtained for 59 samples, including the 25 samples which had been analysed for their heavy mineral content. The results are given in Table 2.

These values indicate that river sand is less rounded than Holocene coastal dune sand, and Koputaroa Phase dune sand is the most rounded of the three categories. Whereas fluvial transport is ineffective in rounding quartz and feldspar grains, marine transport in the coastal zone is considered to be more effective in rounding sand-sized particles, and eolian environments are most conducive to grain rounding (Blatt et al. 1972).

RESULTS

The bivariate distribution of heavy mineral content and average roundness for the 25 samples which had been analysed for both values is plotted on a scattergram (Fig. 2). The graph indicates that the river sand can be distinguished from both the Koputaroa Phase dune sand and the Holocene coastal dune sand. In the absence of a mechanism capable of significantly increasing the heavy mineral content of river sand during eolian transport, it seems unlikely that the Koputaroa Phase dunes could have been derived from river sand. The alternative hypothesis, that the Koputaroa Phase sand is coastal in origin, is strongly supported by the almost identical range of distribution of heavy mineral content and roundness for both categories of dune sand.

DISCUSSION

Whereas a coastal origin for the Koputaroa Phase dunes is suggested by the evidence presented above, the reservations expressed by Cowie (1963) remain: some if not all of the dunes were active during the last stadial of the Otira Glaciation when the shoreline was probably located more than 30 km to the west. Three possible modes of origin for the dunes are outlined below.

1. The Koputaroa Phase dunes may have resulted from remobilisation of the sandy marine beds underlying the Tokomaru Marine Terrace and its continuation to the west. These sands have been termed the Otaki Sandstone by Oliver (1948). The roundness and heavy mineral content of three samples of Otaki Sandstone are comparable with those of the Koputaroa and Holocene dunes (Fig. 2). However, the lithification of many Otaki Sandstone beds and their thick loess cover (Cowie 1964; Cowie & Milne 1973) are likely to have inhibited remobilisation of the sand.
2. The Koputaroa Phase dunes may have been generated during the last stadial and have migrated inland from the former coastline to their present position. Assuming an adequate sand supply and a sea level 100 m below present, at typical migration rates of 10–30 m/year, it would have taken 1000–3000 years for the dunes to reach their present position. This would suggest that some of the dunes were generated about 21 000–23 000 years ago during a period of marine regression (Bloom et al. 1974).

   Fifteen kilometres to the north, Foxton Phase dunes (Cowie 1963) have migrated at least 16 km inland during Holocene time and were stabilised 1600–1800 years ago. It is unlikely that, during the last stadial of the Otira Glaciation, the prevailing westerly winds would have been any less vigorous than at present, and dune migration over a distance of 30 km or more could have occurred.
3. The dunes may have resulted from the mobilisation of transgressive and/or regressive sands deposited upon the inner continental shelf during relatively higher sea levels associated with interstadials of the Otira Glaciation when sea levels repeatedly rose to less than 45 m below the present level (Bloom et al. 1974). Such marine sands would have been deposited only 15–20 km west of the present Koputaroa Phase dunes and may have undergone repeated reworking during a number of interstadials, the last of which peaked approximately 28 000 years ago. Such sands, being unconsolidated and by virtue of their younger age possessing only a thin loess cover, would have been readily mobilised following any breaching of the vegetation cover and may have migrated eastwards to form the Koputaroa Phase dunes.

The writer favours the third possible mode of origin for the Koputaroa Phase dunes. However, a combination of the mechanisms outlined above is not necessarily precluded because the greater degree of roundness of the Koputaroa Phase dune sand compared to the Holocene coastal dune sand indicates a considerable degree of reworking of the grains in a marine and/or eolian environment prior to their final stabilisation.

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