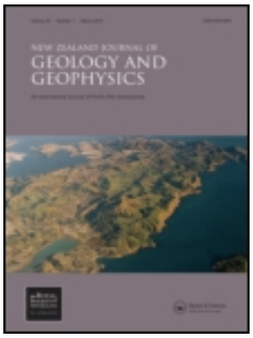

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COASTAL SANDS OF NORTHLAND AND AUCKLAND

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ABSTRACT

Eight types of sand facies are recognised. The Waikato River and the marine Hauraki (A) sand facies are derived from a rhyolitic provenance and are characterised by included pumice. Hauraki (B) Sand Facies is a coastal derivative of Hauraki (A), in which rock fragments and mafic minerals are decreased and pumice has disappeared. Its predominantly andesine feldspar content has increased to between 50% and 75%. The Parengarenga Sand Facies is high in silica, 95%+, and is derived from podsols. The Bay of Islands and Orewa sand facies are localised where there is little coastal progradation. The former has a high proportion of both shell and rock fragments whereas the latter with 70% quartz is derived by erosion of Waitemata sandstones. The West Auckland Sand Facies has been formed by mixing of the Parengarenga, Orewa, Bay of Islands, and Waikato River facies by strong west coast currents. At Muriwai it is also mixed with the Egmont Blacksand Facies.

The region of greatest east-coast progradation lies between Marsden Point and Tokatu Point, where almost all the sand is derived from the sea floor, and where progradational rates are a function of sea-level fluctuations. Progradation along the west coast, since at least the Pliocene, has built the very large Manukau, South Kaipara, and North Kaipara barriers and Aupouri Tombolo. Despite periods of erosion during the periods of rising sea level, they owe a continued preservation to an overall drop in sea level of several hundred feet during the Quaternary—a falling sea level being one that favours progradation by supplying sand from the sea floor. The south-eastward directed North Kaipara Barrier and smaller barriers to the north, and the north-westward directed South Kaipara and Manukau barriers have been built by the opposing oceanic West Auckland and Westland Currents that converge opposite the Kaipara Harbour entrance.

INTRODUCTION

The rapid expansion of secondary industries in the Auckland region has brought the realisation that some sands are more suitable than others for certain purposes. It has created a rapidly increasing demand, especially in the building industry, so that more and more sand may be taken from the sea which could eventually lead to coastal erosion if this demand exceeds the natural rate of replenishment.

Coastal research is required to evaluate the situation and this description of the local coastal sands forms a basis for further more detailed research in the future. However, the prime reason for this investigation has been the economic assessment of the sands available (Schofield, in press) and hence the use of A.F.S. clay (p. 773) contents in this report and the use of the settling tube method for determining grain sizes (p. 768).

Mineralogical Analysis

Determination of minerals has been limited to six main groupings; quartz, potash feldspar, soda-calc feldspar, mafic minerals, residue (consisting mainly of rock fragments), and shell fragments.

Of the six categories, shell has been determined as a percentage of the whole, whereas the percentages given for the other five have been calculated on a shell-free basis. There are two reasons for this approach. Firstly, as shell can also be stained, it can make the counting of stained feldspar crystals difficult and thus it is best leached out before the sample is treated for feldspar determination (*see below*). Secondly, it is not an important item in coastal research, and would present only a masking effect if the content of the other categories were not given on a shell-free basis.

The method employed for determination of potash and soda-calc feldspars follows that described by Hayes and Klugman (1959) except that (a) a micro-split was not employed, (b) slides prepared with a mountant were allowed to dry and when required were reactivated with a solvent (xylol) which has the advantages of being quick drying and stopping fine sand grains from being completely buried in the mountant, (c) fume treatment with hydrofluoric acid was for half of the slide only and was normally for 20 min. in the moderately warm and humid Auckland climate, and (d) as well as using sodium cobaltinitrite to stain potash feldspar yellow, red ink was used to stain the soda-calc feldspar pink. When using Depex as a mountant, care had to be taken to make a generous coating on the slide or grains were dislodged during the feldspar staining process, or, worse still, the hydrofluoric acid fumes penetrated beneath the skin of the mountant so that large areas were destroyed during subsequent washings.

The sample chosen usually consisted of the median grain size and although a micro-split was not used to reduce this to 1,000 grains, statistical analyses of the results (Schofield, 1967a) show that its non-employment has made little or no difference. In almost all cases more than 400 grains were counted.

Grain-size Analysis

A settling tube containing water at a known temperature and a clear glass volumetric measuring tube attached to the base was used for grading analyses. Its construction, method of use, and graphs for converting time-of-settling to grain size for different temperatures are given by Emery (1938). This method has the advantages of speed—six to eight samples can be completed in an hour including the calculations required for cumulative grading curves. So far as the use of grain-size analyses in coastal research is concerned, it gives more natural results than sieve analyses, because the association of minerals with the same hydraulic equivalents in nature (e.g., small heavy mafic minerals being equated with slightly larger, lighter quartz) is retained in the settling tube, whereas sieving dissociates such minerals. Nevertheless, during the present survey, the mafic mineral content has generally been small, and as feldspar and quartz have the same hydraulic properties this effect of hydraulic equivalence has made little difference. Thus when comparisons with sieve analyses were made by quartering samples

and passing two of the quarters through sieves and the other two through the settling tube, the scatter of results for both methods was the same. The scatter for median grain sizes ranged from 0·025 and 0·05 mm depending on whether the sample was fine or moderately coarse.

Other advantages consist of the ease with which the median grain size can be sampled and the number of recordings that can be taken as the sand settles. The latter is important when reproducing the results in the form of a cumulative grading curve.

The settling tube has disadvantages in that it is restricted to a grain size range between 1 mm and 0·05 mm, but this range covers most sands. The results for the coarse and fine tails are not as accurate as those obtained during sieving so that some of the more sophisticated parameters derived from grain-size analysis such as kurtosis cannot be employed. However, for much coastal research and for almost all industrial purposes, the settling tube method of grain-size analysis has much to recommend it.

PART 1—DISTRIBUTION

The region covered by this sand survey includes all of Northland, the Coromandel Peninsula, and some of the South Auckland area. It is equivalent to the area covered by New Zealand Geological Survey Maps 1 : 250,000, numbers 1 (Kear and Hay, 1961), 2A and 2B (Thompson, 1961a and 1961b) and 3 (Schofield, 1967b).

For the convenience of description, later discussion, and reference between this paper and the publication on industrial usage of the sand deposits (Schofield, in press) this region has been divided into eight areas (Fig. 1). These are: (1) Waikato and Manukau, (2) Kaipara South, (3) Kaipara North to Hokianga Harbour, (4) Kaitaia to North Cape, (5) Bay of Islands, (6) Whangarei Harbour to Tokatu Point, (7) Auckland and Hauraki Gulf, (8) Coromandel Peninsula.

Area 1—Waikato and Manukau (Fig. 2)

Waikato River

Grain size, sorting, and angularity: The highly angular Waikato River sand, its median size ranging from 0·5 to 1·1 mm (Table 1), is the consistently coarsest sand known within the Northland–Auckland region. As is typical of stream deposits, sorting is moderately good but not as excellent as that developed in dunes and beach deposits (*see* cumulative grading curves in Figs. 3A, 3C, and 3D).

Along the coast at the mouth of the river the median grain size ranges from 0·15 to 0·36 mm.

Mineralogy: The range of values for quartz and feldspar in the sands found in the Waikato River and along the coast at its mouth is about the same for both environments. There are, however, significant differences in other constituents within these two environments (Table 1). Whereas the 1% to 9% of mafic minerals within the river are low compared with 11%

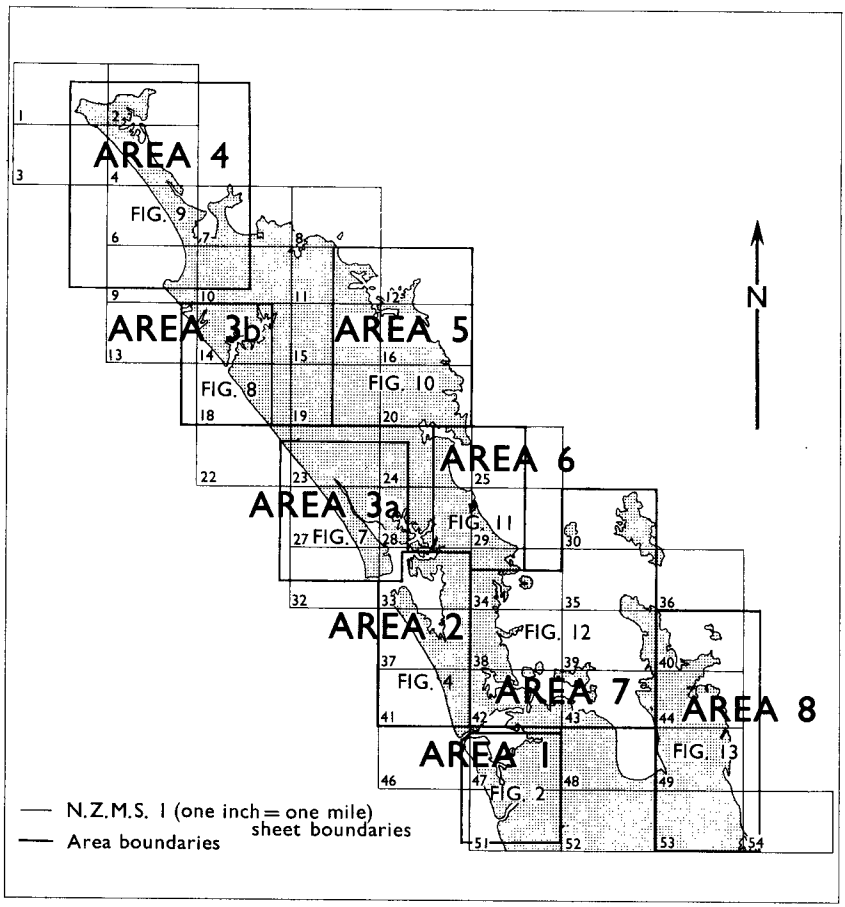

FIG. 1—Division of Northland–Auckland region into areas which tend to be separate units so far as type(s) of sand are concerned. For details of areas see the figures as marked on the respective areas.

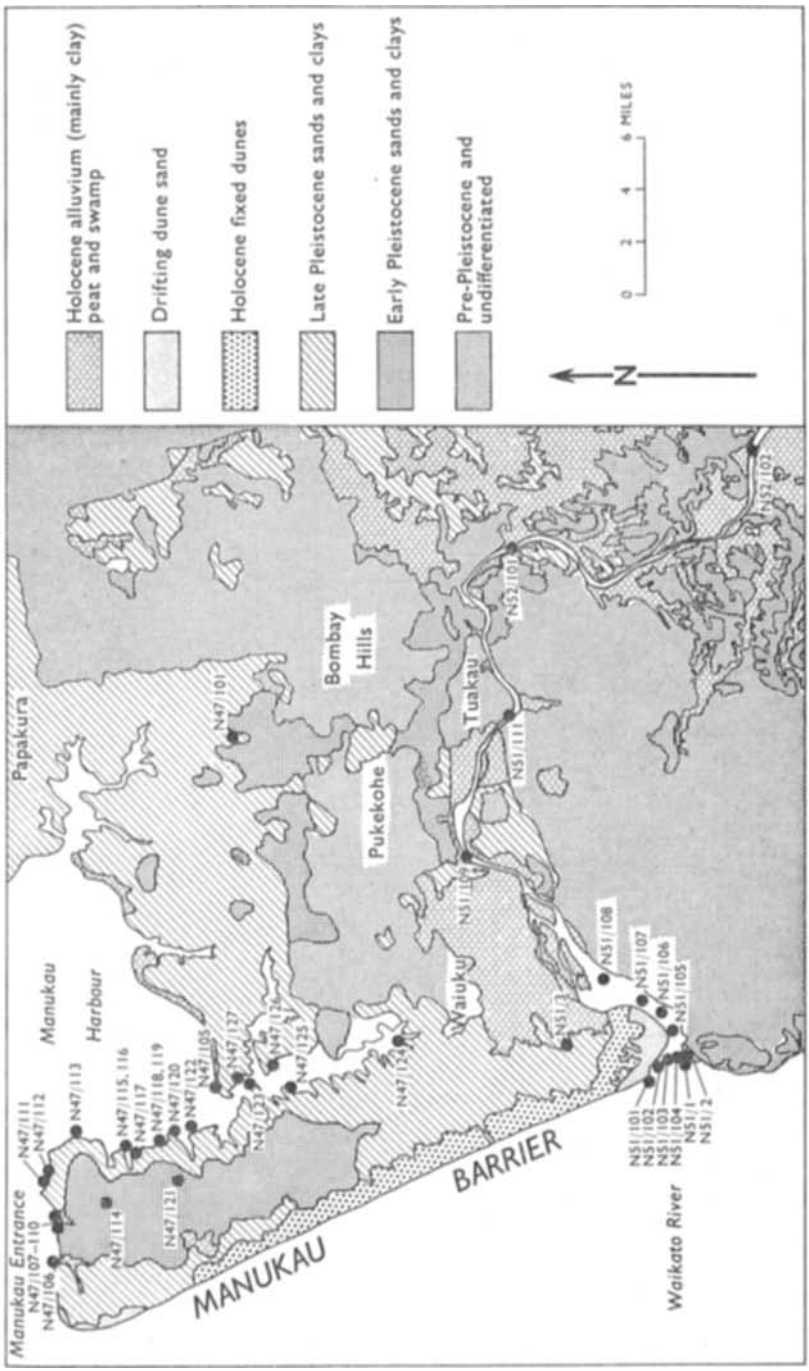

FIG. 2—Quaternary geology and sample positions in Area 1—Waikato and Manukau.

TABLE 1—Waikato River (in Downstream Order) and Coastal Sand* (Fig. 2)

Sample	Median (mm)	% on shell-free basis					Pumice	Shell	Grid Ref.‡	Type of Sample
		Qtz	Feldspar K†	Feldspar Na†	Mafics	Residue†				
N52/102a	0·60	21·5	1·7	34·7	3·0	38·8	17	nil	639901(61)	River sand
N52/101a	0·71	19·2	2·2	44·5	3·5	30·5	5	nil	572063(61)	
N51/111a	1·1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		461064(64)	
N51/109c	0·58	18·6	1·3	39·0	7·1	34·0	8	nil	366082(64)	
N51/108b	0·58	17·0	1·9	44·5	3·8	32·7	2	nil	290005(64)	
N51/107a	0·65	14·9	1·5	34·4	1·2	46·8	13	nil	273980(64)	
N51/106b	0·70	19·6	2·4	26·5	5·4	46·2	16	nil	266964(64)	
N51/105b	0·50	16·8	1·7	47·0	6·5	27·9	0·5	nil	251958(64)	
N51/103a	0·50	19·8	0·4	24·3	7·5	48·2	3	5·0	234961(64)	
N51/102b	0·50	23·0	1·0	29·5	8·8	37·5	4	1·0	226972(64)	
N51/101	0·32	12·9	1·8	28·6	57·0	0·0	0	nil	220980(64)	Coast
N51/104	0·36	20·0	2·8	48·3	11·3	17·6	0	<1·0	233953(64)	
N51/1	0·15	26·5	—	26·0§	31·5	16·0	0	nil	—	
N51/2	0·15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	236940(64)	

* Full details of locality, collector, analyst, and other remarks are given in Schofield (in press).
† K = potash feldspars Na = soda-calc feldspars Residue = mainly rock fragments including pumice.
‡ Grid references refer to the national thousand-yard grid shown on the 1:63,360 topographical map series (NZMS 1). Sheet numbers (e.g., N52) are given as part of the sample numbers in column 1 and the year of the edition used is shown in brackets after each grid reference.
§ K + Na.

to 57% at the coast, the reverse is true for "residue" which consists mainly of rhyolitic rock fragments, and ranges from 28% to 48% in the river compared with the coastal 0 to 18%. Of the "residue" in the river 0·5% to 17% consists of pumice which appears to be absent along the coast.

Manukau Barrier

A coastal barrier, here named the Manukau Barrier, commences north of the Waikato River mouth, and extends north-westwards for a distance of 25 miles to the entrance of Manukau Harbour (Fig. 2). It widens from an average of 2·5 miles in the south to more than 5 miles in the north, its highest point being 934 ft above sea level near its northern extremity. Geologically it consists of a complex of mainly coastal sediments in the west, and probably mainly fluviatile sediments in the east—a complex resulting from alternating depositional and erosional periods brought about by sea-level fluctuations of several hundred feet above and below the present. Although pumice is known, it is rare compared with the pumiceous nature of Quaternary sediments east of the Manukau Barrier.

The great bulk of the Manukau Barrier consists of sand containing large reserves of titano-magnetite to be used for manufacture of iron and steel. These have been investigated by Kear (1965).

Beach Sands of the Manukau Barrier

Grain size, sorting, and angularity: The well sorted, sub-angular to sub-rounded beach sands (Table 2, Fig. 2) are consistently coarse grained along the harbour beaches of the Manukau Barrier (median grain sizes (0·29 to 0·54 mm). The sands along the southern shores of Manukau Entrance are finer, having median grain sizes of 0·13 to 0·2 mm. This is probably due to their higher mafic mineral content, the smaller but heavier mafic minerals being hydraulic equivalents of the coarser quartz and feldspar grains.

Mineralogy. Mineralogically the beach sands along the Manukau Entrance differ markedly from sands along the harbour shore of the Manukau Barrier. The former have a range of 64% to 100% mafic minerals, whereas the latter contain only 0 to 11% (Table 2). The inner beaches consist instead of mainly feldspar and quartz both ranging from about 30% to 65%, there being no definite distributional pattern in the feldspar/quartz ratios.

Weathered Quaternary Sands

Samples of weathered Quaternary sands (Table 2, Fig. 2) were obtained from the northern part of the Manukau Barrier.

Clay content: Because of their extremely weathered nature and because of the reconnaissance nature of the present survey, it is not possible to assess how much of the 10%–40% A.F.S. clay content* is primary, as the result of original deposition; secondary, as the result of weathering; or derived, as the result of illuviation from an overlying ash cover.

*The A.F.S. (American Foundryman's Society) clay content is a parameter used in describing foundry sands and consists of particles less than 20 microns in diameter.

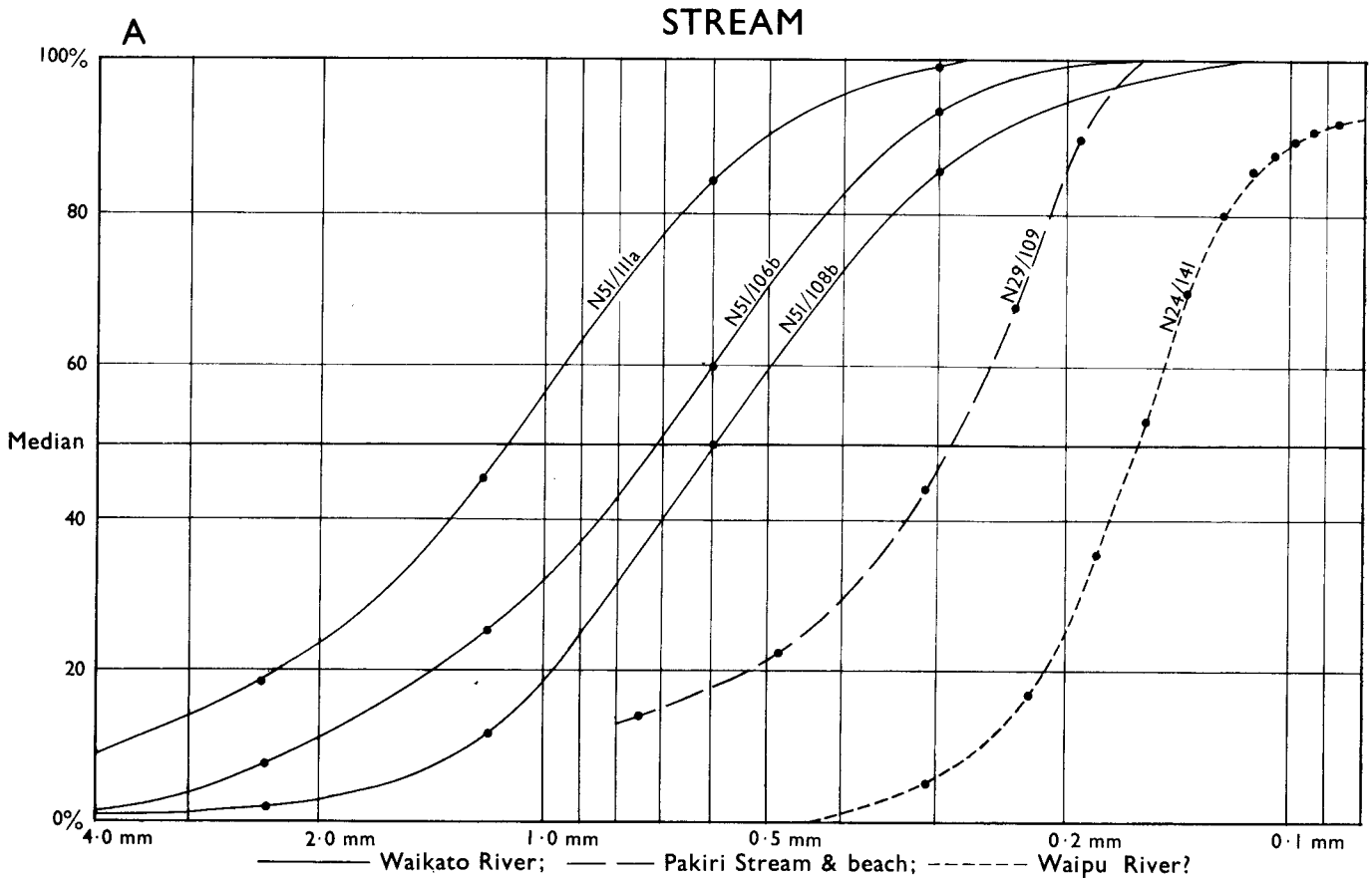

FIG. 3A (*for caption, see p. 779*).

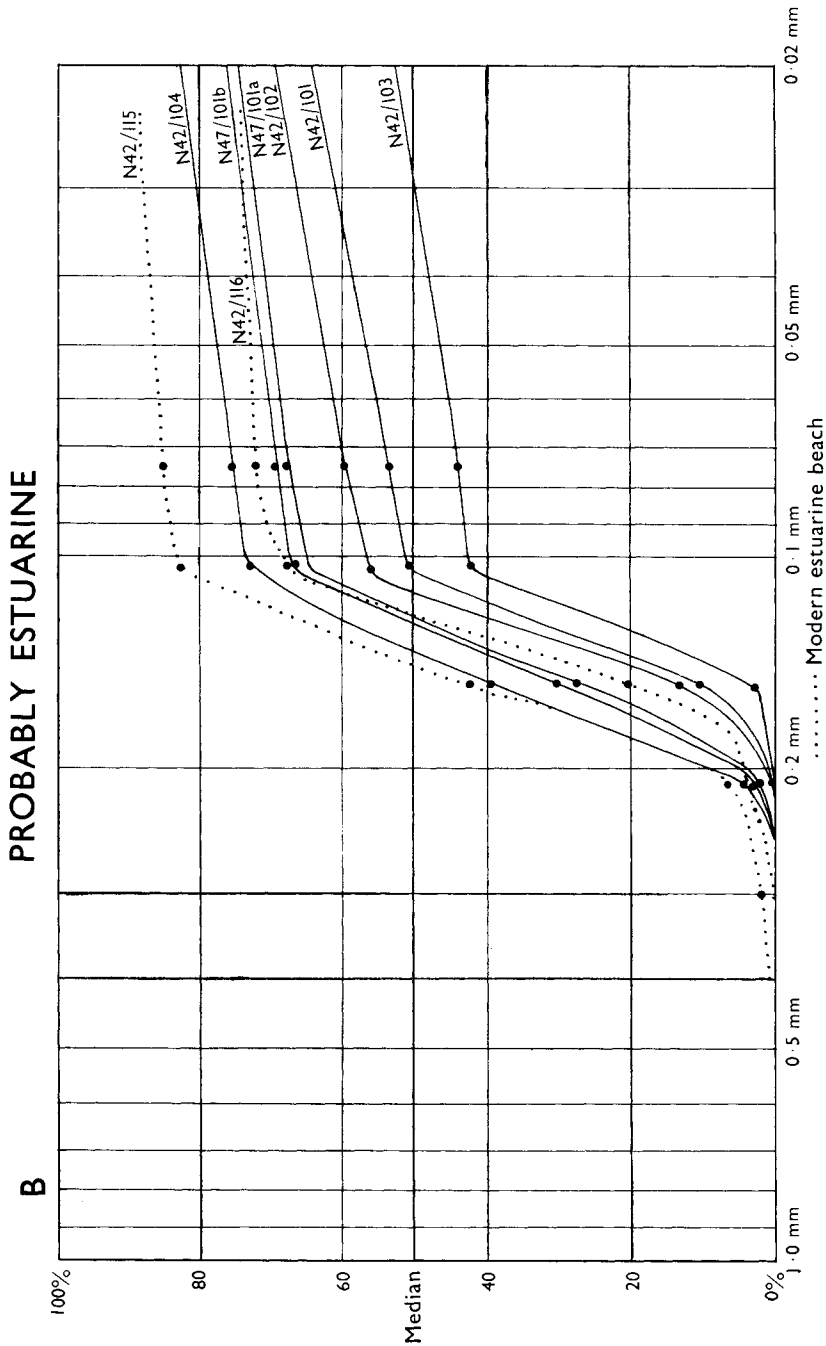

FIG. 3B (*for caption, see p. 779*).

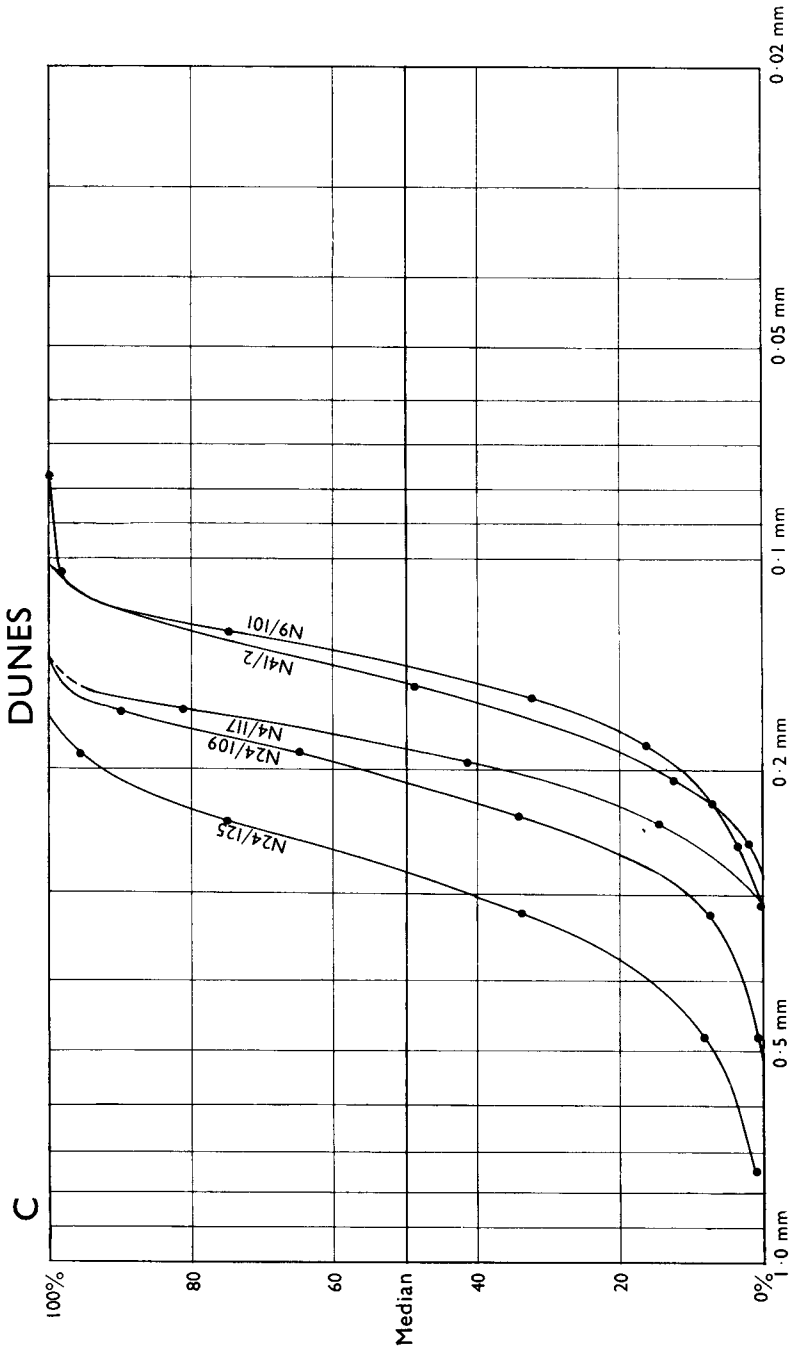

FIG. 3C (*for caption, see p. 779*)

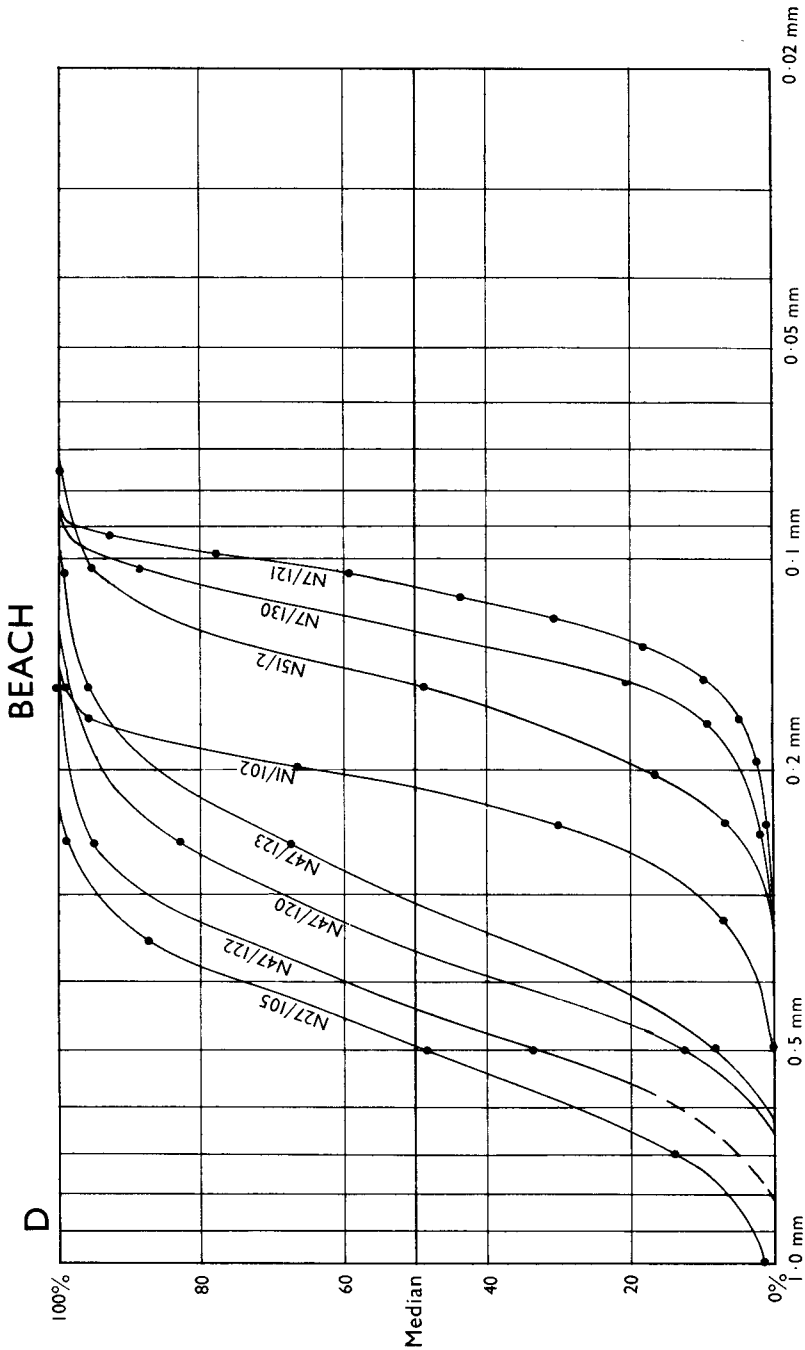

FIG. 3D (*for caption, see p. 779*).

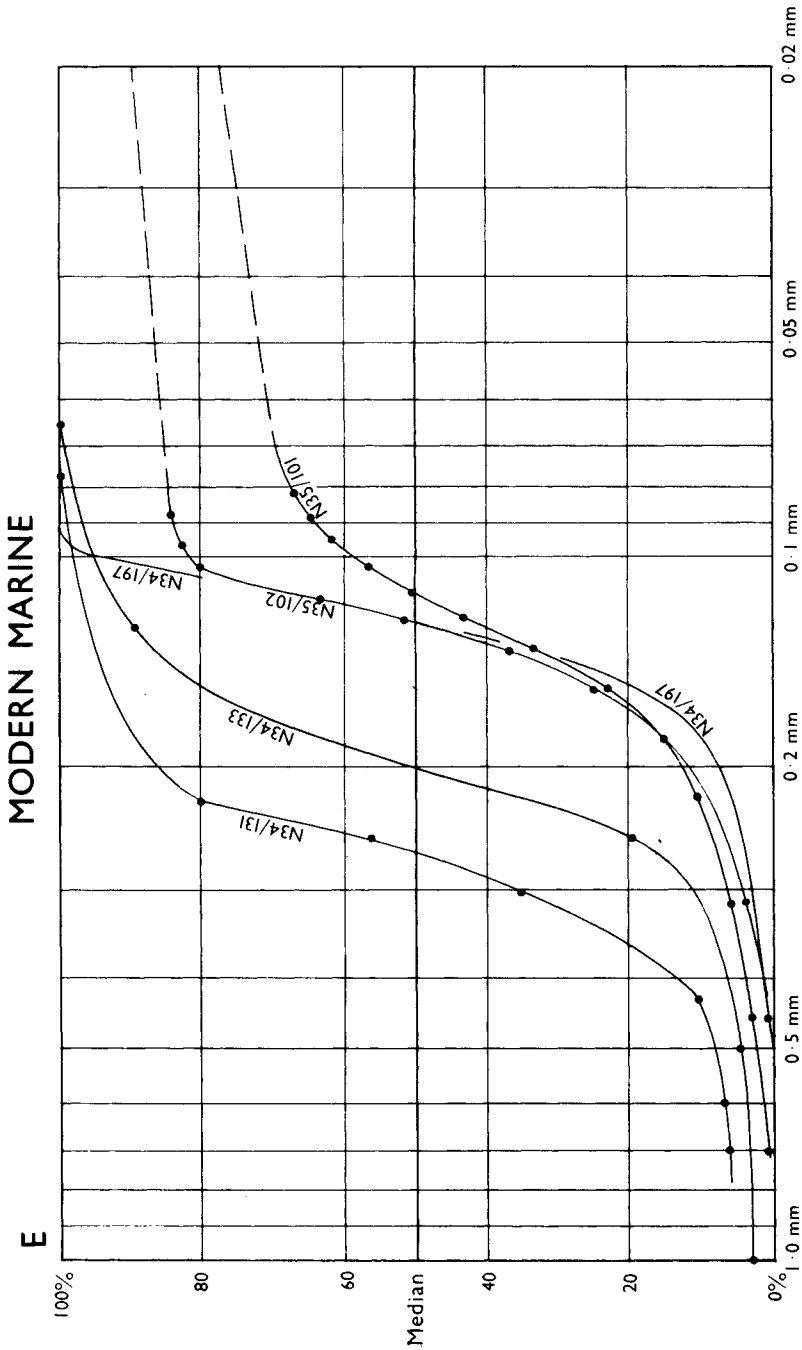

FIG. 3E (*for caption, see p. 779*).

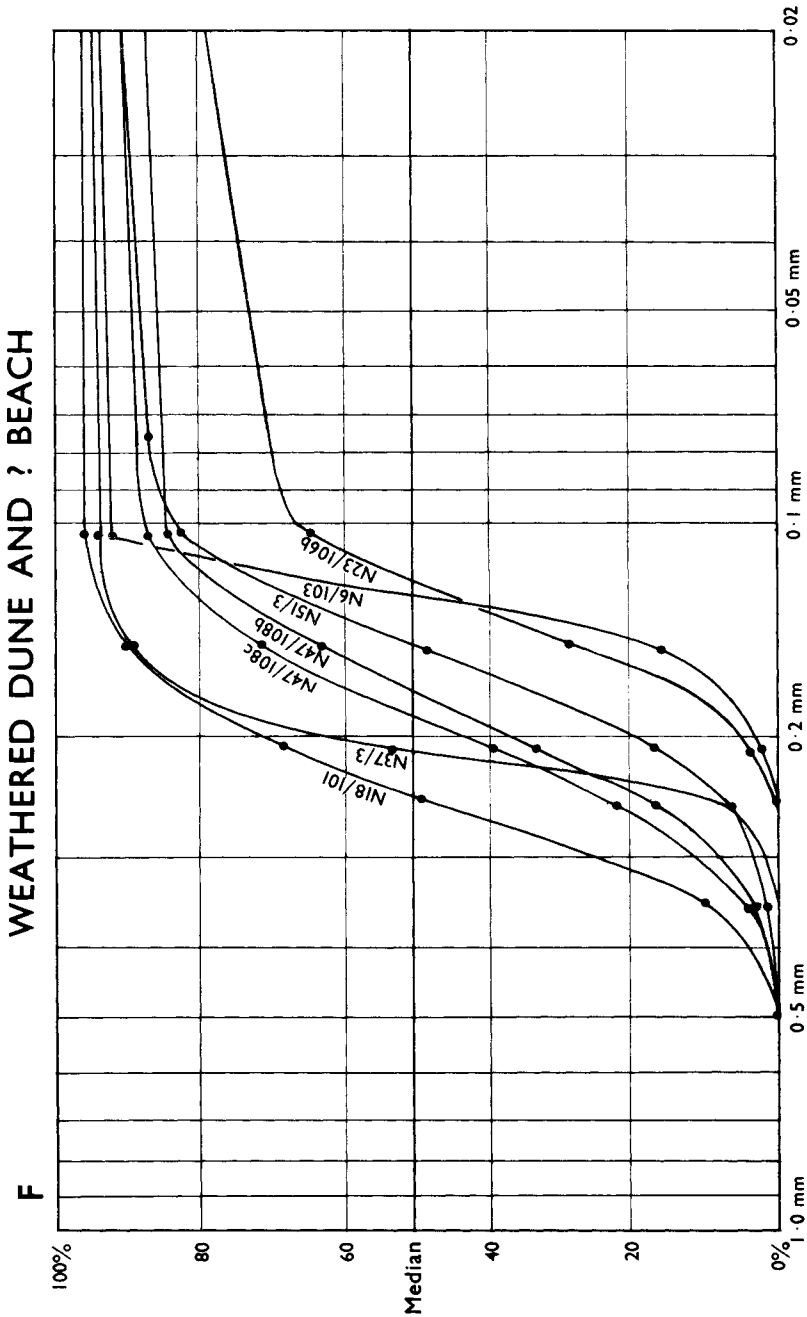

FIG. 3—Examples of cumulative grading curves for sands from different environments: A stream, B probably estuarine, C dune, D beach, E modern marine, F weathered dune and ?beach.

TABLE 2—Sands of Manukau Barrier* (Fig. 2)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na†	Mafics	Residue	Shell	F/Q‡	A.F.S. Clay	Grid Ref.§	Type of Sample
N47/106	0·13	7·2	0·5	0·9	88·7	2·6	nil	0·2	nil	108365(64)	Beaches, Manukau Entrance
N47/109	0·13	nil	nil	nil	100·0	nil	nil	—	nil	132363(64)	
N47/110	0·20	18·3	0·8	11·4	64·3	5·2	nil	0·7	nil	135365(64)	
N47/111	0·16	7·1	0·6	4·7	85·9	1·7	nil	0·7	nil	156373(64)	
N47/112	0·35	39·3	0·6	48·6	8·9	2·6	<1·0	1·3	nil	163369(64)	Harbour beaches
N47/113	0·48	37·6	0·0	55·7	5·1	1·6	<1·0	1·4	nil	188353(64)	
N47/116	0·40	46·5	0·0	45·0	4·7	3·8	nil	1·0	nil	180322(64)	
N47/117	0·41	47·6	0·0	40·7	10·8	0·9	<1·0	0·9	nil	174315(64)	
N47/118	0·38	42·3	0·0	50·4	4·1	3·2	nil	1·2	nil	179296(64)	
N47/119	0·30	62·0	0·4	30·0	3·8	3·8	<1·0	0·5	nil	182292(64)	
N47/120	0·36	58·0	0·0	39·5	0·2	2·3	nil	0·7	nil	187289(64)	
N47/122	0·43	41·2	0·5	54·6	1·0	3·7	nil	1·3	nil	190276(64)	
N47/123	0·31	55·4	0·0	38·3	1·9	4·4	nil	0·7	nil	221238(64)	
N47/124	0·45	26·5	0·0	66·2	3·3	4·0	<1·0	2·5	nil	247139(64)	
N47/125	0·54	49·1	0·4	40·0	0·0	10·5	nil	0·8	nil	215210(64)	
N47/126	0·48	43·4	0·0	49·0	0·0	7·6	<1·0	1·1	nil	236223(64)	
N47/105	0·29	22·5	1·0	72·0	2·9	1·7	<1·0	3·2	nil	218259(64)	
N47/107	0·24	55·1	3·3	31·6	4·6	5·4	nil	0·6	27	123366(64)	Weathered sand
N47/108a	0·20	51·8	4·7	28·5	8·1	6·9	nil	0·6	10	123366(64)	
N47/108b	0·17	60·3	5·5	19·8	10·7	3·7	nil	0·4	12	123366(64)	
N47/114	0·12	85·1	6·7	1·3	4·4	2·5	nil	0·1	34	140333(64)	
N47/115	0·14	81·4	1·8	0·9	1·6	14·3	nil	0·0	40	180322(64)	
N47/121	0·19	49·0	0·4	38·0	9·4	3·2	n.d.	0·8	28	155283(64)	
N47/127	0·27	35·4	1·2	51·8	5·1	6·5	nil	1·5	30	226242(64)	
N47/101a	0·12	98·0	1·5	0·0	0·0	0·0	nil	—	25	448252(64)	Pleistocene ? Estuarine
N47/101b	0·12	98·5	1·5	0·0	0·0	0·0	nil	—	12	448252(64)	

* See footnote to Table 1.
† K and Na respectively potash and soda-calc feldspars.
‡ F/Q = ratio of total feldspar to quartz.
§ See note to Table 1.

Grain size, sorting, and angularity: The median grain sizes range from 0·12 to 0·27 mm. Whereas N47/108a and 108b are subangular to subrounded, and their sand fraction has the well sorted nature of a dune (e.g., cumulative grading curves, Fig. 3C) the sand fraction of N47/107, 114, 115, 121, and 127 is more angular and more closely resembles the poorer sorted stream gradings (Fig. 3A).

Mineralogy: The mafic mineral content of 2% to 11% is similar to that of beach sands along the harbour shores of the Manukau Barrier, but with the exception of N47/127, the quartz content of 49% to 85% is generally higher and the feldspar content of 3% to 38% is lower than their counterparts within the modern harbour beaches. This is most likely due to the higher resistance of quartz to weathering, some of the feldspar being altered to secondary clay.

Area 2—Kaipara South (Figs. 4, 5, and 6)

North of Muriwai the straight coast continues as a 30-mile long by 5-mile wide complex barrier, here named the South Kaipara Barrier, that was built at the same time and in the same manner as the Manukau Barrier (q.v.). North Kaipara Barrier (*see* Area 3 below) appears to have reached its maximum southern extension by early or mid Quaternary times, whereas the South Kaipara Barrier has continued to grow northwards a further 3 to 4 miles during the Late Pleistocene as is shown by the extent of Late Pleistocene dunes, and by an additional mile during the Holocene (Fig. 4). This need not mean that Kaipara Entrance will be narrowed any further because the erosion at the southern end of the North Kaipara Barrier could be a sympathetic shift within the coastal regime.

Beach and Holocene Dune Sand

Except near its southern end, sand from along the beach and modern foredune on the open coast of the South Kaipara Barrier has a fairly consistent quartz content of 50% to 62% (Fig. 5 and Table 3) whereas the total feldspar content shows a consistent drop from an average of 44% at 10 miles north of Muriwai, to an average of 18% at the very northern end of the barrier. The use of feldspar/quartz (F/Q) ratios overcomes the masking effect of the high mafic mineral content at the southern end of the South Kaipara Barrier (Table 3) and it can be seen that the relative increase in feldspar continues south-eastwards towards Muriwai. The reduction in total feldspar northwards along the open coast may be due to the relative ease by which feldspar is broken during transport, compared with the tougher quartz, or it may be due to mixing with more quartzitic sand coming from Kaipara Harbour. There is a similar relative increase in potassium feldspar which is also tougher than the soda-calc feldspar (Pettijohn, 1957). This is shown by the Na/K ratios for beach samples N37/108, 117, 120, 122, and 124 (Table 3) but not by the modern foredunes (N37/110, 118, 121, 123, and 125) which show a reversal of this trend. Although the F/Q ratios continue to drop all the way to the northernmost end of the South Kaipara Barrier, there is a sudden reversal in the Na/K values for the northernmost 4·5 miles (N33/105, 107, and

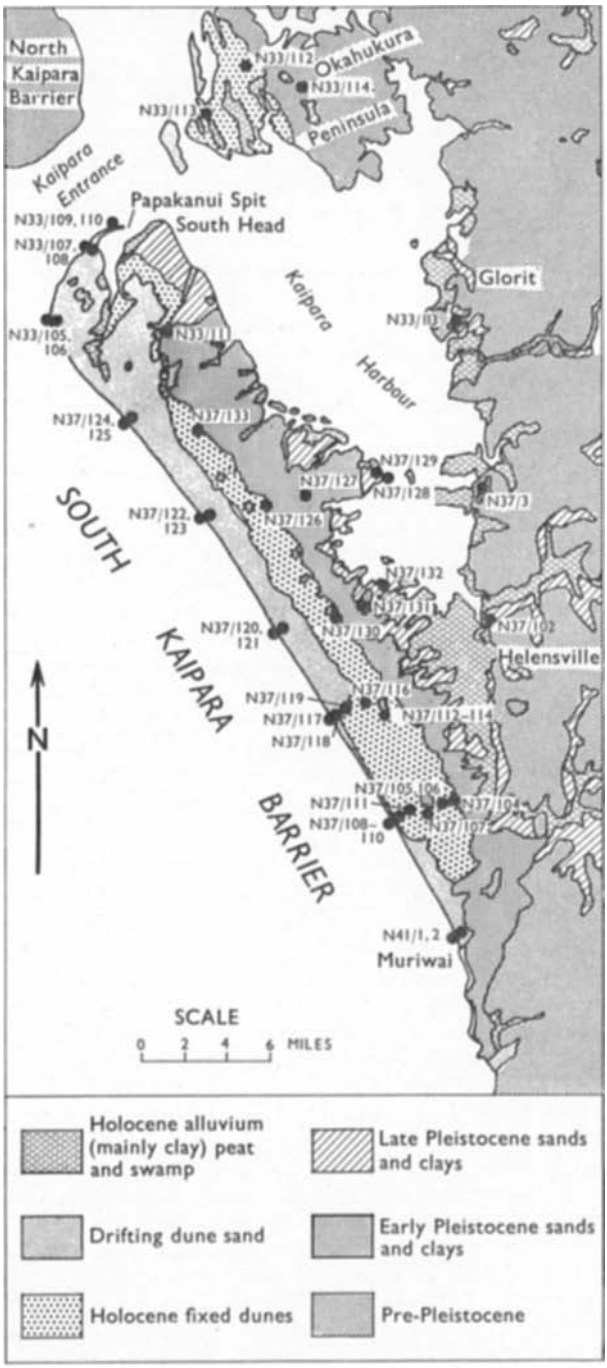

FIG. 4—Quaternary geology and sample positions in Area 2—Kaipara South.

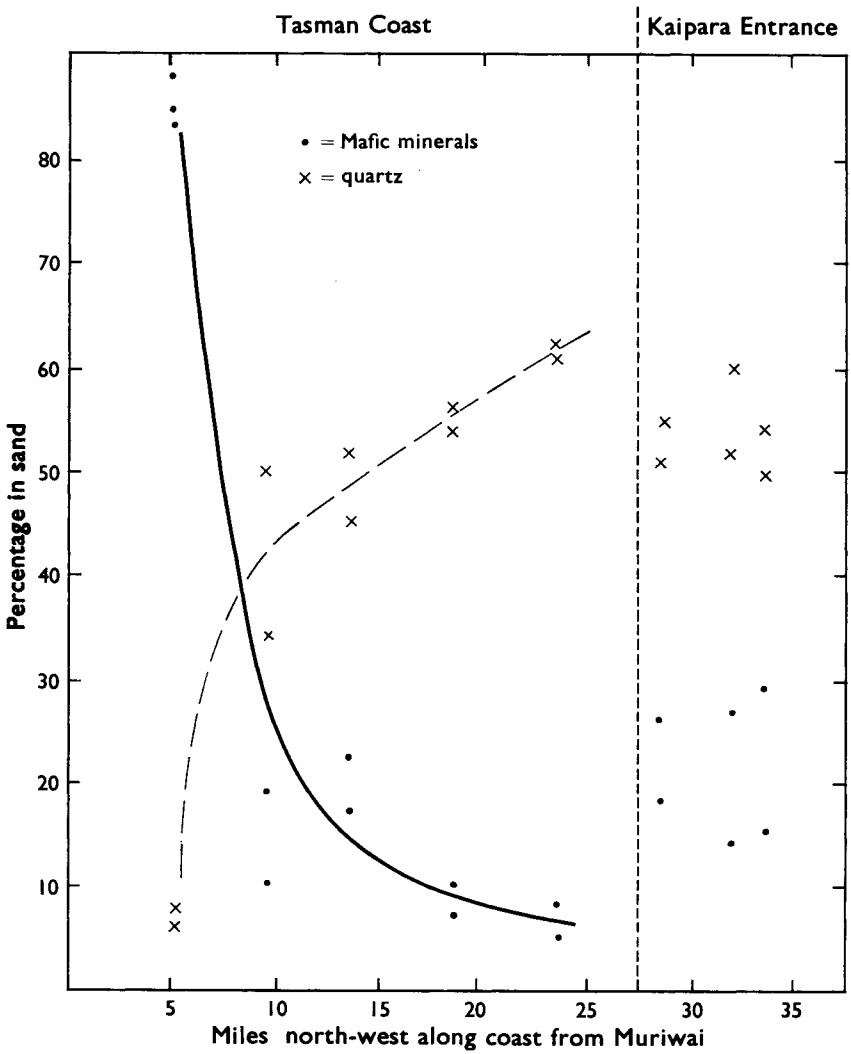

FIG. 5—Quartz and mafic-mineral trends along the coast of the South Kaipara Barrier.

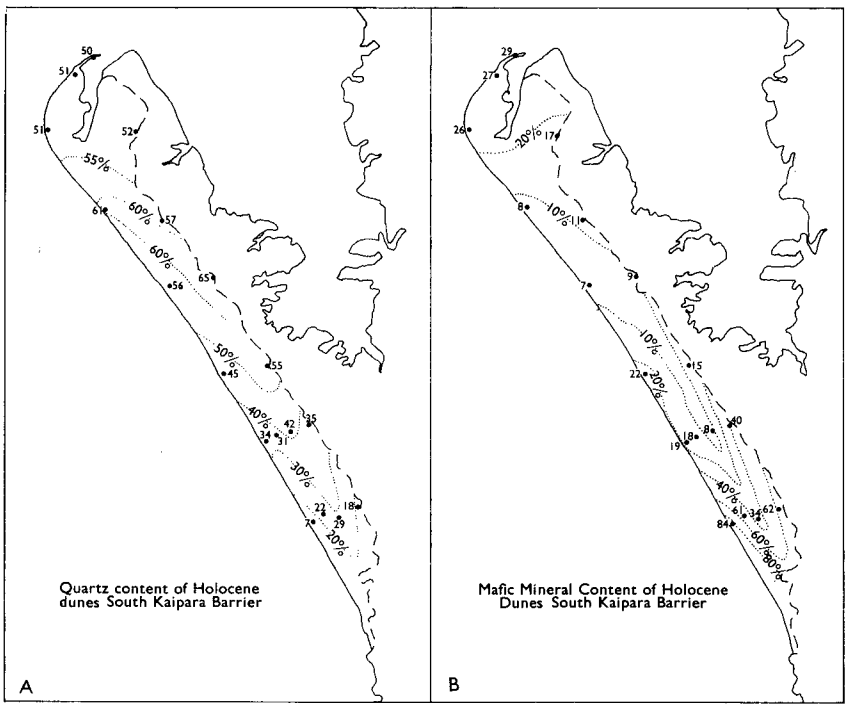

FIG. 6—Quartz and mafic-mineral contents in post-glacial dunes of the South Kaipara Barrier.

109, Table 3 and Fig. 4). There is also a sudden increase in the Na/K values in the modern foredunes. These changes coincide with the swing of the west coast into Kaipara Entrance. It also coincides with a significant increase in mafic minerals (Fig. 5). The relative decrease in potassium and the absolute increase in mafic silicate minerals suggest a local increase in the supply of fresh sand.

Along this same coast, in all but one of the seven localities sampled (N33/105–110; N37/117, 118, 120–125) the foredune sands have a higher mafic mineral content than the beach but this could be due to a temporary condition of the beach.

Dunes built in Holocene times extend a little over 2 miles inland from the west coast of the South Kaipara Barrier, and although they have an incipient soil cover, they have not been weathered sufficiently to produce any alteration in the mineral content. They, together with the modern foredunes, show a remarkably consistent pattern of quartz distribution (Fig. 6A), the main trend being an increase from 20% quartz in the south to more than 60% in the north. Conversely the pattern of mafic mineral distribution (Fig. 6B) shows a main trend from an average 60% content in the south to something less than 10% in the north.

Only one modern beach sand has been collected from within the harbour at Shelly Beach (N37/128) and, as expected, the quartz content is relatively high at 76% and the mafic minerals low at 3%.

Grain size: The median grain size of the furthest inland and southern third of the post-glacial dunes ranges between 0·14 and 0·19 mm. Half way along the South Kaipara Barrier the modern foredune (N37/121) has a median of 0·21 mm and north-westwards along the west coast it tends to coarsen, being a maximum of 0·28 mm at the end of the open coast (N33/106). The modern beach tends to be slightly coarser than the modern foredune, ranging from an average of 0·18 mm (N37/108, 109) in the south to 0·33 mm (N33/107) in the north.

Angularity: There is little variation in the angularity of the modern sand deposits, all being within the range of angular to sub-angular.

Weathered Sands

Clay content: The A.F.S. clay content of weathered samples collected from the South Kaipara Barrier ranges from 9% to 57%. The clay content in the more quartzitic sands, east of the harbour (N33/103; N37/3, 4, 5, and 102) is less, ranging from 5% to 36%.

Mineral content: Insufficient weathered samples have been collected to show any change in quartz content with age as is shown for the North Kaipara Barrier (p. 791). Except for N37/131, which has an exceptionally low silica content of 38%, the quartz range of 52% to 91% is comparable with that of weathered sands of the North Kaipara Barrier. Similarly, in both areas, the weathered sands tend to have a higher quartz content than the modern, unweathered sands. This is no doubt due to the resistance of quartz to weathering. Furthermore, as within the northern part of Kaipara Harbour, the quartz content is increased still further in samples that lie east of the harbour. Thus the quartz content in the sand fraction for N33/114, 103, N37/3, 4, 5, and 102 ranges from 82% to 100%, four having the maximum amount. Sample N37/4, with 82% quartz, is of further interest in that the remainder of the sand fraction consists of well rounded spinels, the mafic minerals most resistant to breakdown.

Grain size: Most of the weathered sands have the same median grain size range as for the unweathered dunes, namely, 0·14 to 0·19 mm. There are, however, three with medians between 0·10 and 0·12 (N37/5, 130, and 131) and one with a median of 0·21 (N37/3).

Angularity: The weathered sands within the South Kaipara Barrier remain angular to sub-angular but the highly quartzitic sands east of the Kaipara Harbour tend to be sub-rounded (N33/103, N37/4 and 3); with N37/5 being angular, probably because of its fine median of 0·11 mm; and N37/102 being angular to sub-angular. The latter is the only sand east of the harbour that has feldspar preserved and is perhaps more closely allied to the sands within the South Kaipara Barrier, despite its high quartz content of 96%.

TABLE 3—Kaipara South (Arranged from North to South in Each Section)* (Fig. 4)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na†	Mafics	Residue	Shell	F/Q‡	Na/K	Grid Ref.§	Type of Sample
N37/128	0·20	75·8	0·0	19·4	3·1	1·7	1·0	0·3	—	904943(44)	Harbour beach
N33/109	0·27	54·4	1·6	15·5	24·0	4·5	nil	0·3	9·7	723111(43)	Coastal beach (high tide)
N33/107	0·33	60·3	2·1	18·5	14·2	4·9	nil	0·3	8·8	707097(43)	
N33/105	0·30	54·6	2·8	22·8	17·6	2·2	nil	0·5	8·1	682052(43)	
N37/124	0·22	61·8	6·8	21·6	5·0	4·8	1·0	0·5	3·2	729985(44)	
N37/122	0·24	53·6	4·5	27·6	10·1	4·2	1·0	0·6	6·1	784917(44)	
N37/120	0·22	51·7	2·1	23·2	17·5	5·5	1·0	0·5	11·0	831843(44)	
N37/117	0·18	50·0	4·5	36·0	10·0	0·0	nil	0·8	8·0	868782(44)	
N37/108	0·16	8·0	0·6	6·5	85·0	0·0	nil	0·9	11·0	907716(44)	
N37/109	0·20	4·0	0·0	8·5	87·5	0·0	nil	2·1	—	907716(44)	
N33/110	0·22	50·2	1·5	16·6	28·9	2·8	nil	0·4	11·0	723111(43)	Modern foredune
N33/108	0·26	51·5	0·6	16·6	27·0	4·3	nil	0·3	27·5	798096(43)	
N33/106	0·28	50·8	1·7	19·4	25·8	2·3	nil	0·4	11·4	684052(43)	
N37/125	0·21	61·1	3·4	24·2	8·3	3·0	nil	0·5	7·1	732986(44)	
N37/123	0·22	56·3	5·2	26·8	6·5	5·2	1·0	0·6	5·1	785918(44)	
N37/121	0·21	45·1	2·8	25·1	21·8	5·2	nil	0·6	9·0	834845(44)	
N37/118	0·15	33·5	8·0	39·0	19·0	0·0	nil	1·4	4·9	868782(44)	
N37/110	0·19	7·0	2·0	7·5	84·0	0·0	nil	1·4	3·7	907716(44)	
N33/112	0·18	61·0	n.d.	13·0‖	14·0	11·0	nil	0·2	—	815220(43)	Holocene dunes (non-weathered)
N33/113	0·19	62·0	n.d.	8·0‖	15·0	15·0	nil	0·1	—	793191(43)	
N33/111	0·18	52·5	n.d.	20·0‖	17·0	10·0	nil	0·4	—	756040(43)	
N37/133	0·18	57·0	n.d.	17·0‖	11·0	15·0	nil	0·3	—	782874(44)	
N37/126	0·18	65·2	0·0	21·0	9·3	4·5	nil	0·3	—	827928(44)	
N37/115	0·16	35·0	3·0	22·5	40·0	0·0	nil	0·7	7·5	908795(44)	
N37/116	0·14	42·5	4·5	45·0	8·0	0·0	nil	1·2	10·0	891788(44)	
N37/119	0·17	31·0	5·2	41·0	18·2	4·5	nil	1·5	7·9	880783(44)	
N37/103	0·15	21·0	2·0	12·0	64·0	0·0	nil	0·7	6·0	951727(44)	
N37/104	0·15	18·1	0·7	15·7	63·0	2·0	nil	0·9	22·4	951727(44)	
N37/111	0·17	21·6	3·0	12·4	61·0	1·6	nil	0·7	4·1	923722(44)	
N37/107	0·17	28·6	3·6	33·6	33·6	0·5	nil	1·3	9·3	934721(44)	

								A.F.S. Clay		
N37/129	0·15	91·5	0·0	4·9	3·6	0·0	nil	24·08	903944(44)	Weathered dunes of South Kaipara Barrier
N37/127	0·16	76·8	0·0	22·3	0·9	—	nil	31·50	852933(44)	
N37/132	<0·01	69·4	1·5	25·4	3·7	0·0	nil	56·51	901868(44)	
N37/131	0·10	37·6	n.d.	58·8‖	0·0	3·6	nil	42·66	889859(44)	
N37/130	0·12	52·5	n.d.	15·8‖	27·8	3·9	nil	19·10	871851(44)	
N37/112	0·15	58·1	9·2	30·8	1·1	0·7	nil	10·00¶	904784(44)	
N37/113	0·17	71·0	4·5	23·0	0·8	0·0	nil	8·50¶	904784(44)	
N37/114	0·16	56·0	12·0	31·0	1·0	0·0	nil	10·40¶	904784(44)	
N37/105	0·16	65·3	7·9	21·8	1·0	4·0	nil	19·00¶	942725(44)	
N37/106	0·14	74·0	5·0	20·0	0·4	0·0	nil	19·50¶	942725(44)	
N33/114	0·20	100·0	0·0	0·0	trace	0·0	nil	12·60	849207(43)	Pre-Holocene of eastern harbour coast
N33/103	0·19	100·0	0·0	0·0	0·0	0·0	nil	n.d.	953047(43)	
N37/3	0·21	100·0	0·0	0·0	0·0	0·0	nil	5·21	975935(44)	
N37/4	0·15	82·0	0·0	0·0	18·0	0·0	nil	15·00	Kakanui	
N37/102	0·15	96·5	n.d.	3·5‖	0·0	0·0	nil	7·76	971849(44)	
N37/5	0·11	100·0	0·0	0·0	0·0	0·0	nil	35·60	Helensville	

* See footnote to Table 1.
† K and Na = potash and soda-calc feldspar.
‡ F/Q = ratio of total feldspar to quartz.
§ See note to Table 1. To update grid for use on maps published since 1949, subtract 2 from the above eastings and 3 from the above northings.
‖ Includes potash feldspar.
¶ Approximate only.

Area 3—Kaipara North Head to Hokianga Harbour (Figs. 7 and 8)

Coastal sedimentation and cliff erosion within the Tangihua Volcanics and Waipoua Basalt have straightened the west coast for its full length. The pattern of coastal sedimentation—(a) prominent dunes limited to northern sides of the Herekino and Hokianga Harbours (Fig. 8), and (b) post-glacial progradation at only the southern end of North Kaipara Barrier (Fig. 7)—demonstrates that effective coastal drift has been south-eastwards towards Kaipara Entrance. This drift has built a coastal barrier, 50 miles long by 5 miles wide, from Maunganui Bluff to Kaipara Entrance separating the Wairoa River from the Tasman Sea. The barrier, here named the North Kaipara Barrier, is a complex similar in origin to the Manukau Barrier (*see* Area 1).

Modern Beach and Dune Sand

The beach sands with median grain sizes ranging from 0·19 to 0·29 mm (Table 4) are slightly coarser than the dune sands (0·16 to 0·23 mm). The sand grains are sub-angular with a few well rounded grains confined to the coarsest grades.

Quartz, and total feldspar range from 38% to 60%, and 26% to 52% respectively. Mafic mineral content is almost always below 10% but falls between 2% and 32%.

Insufficient samples have been collected to establish more than the most generalised of mineral trends (Table 4). These show increasing quartz relative to total feldspar (F/Q ratios, Table 4), and increasing potassium feldspar relative to soda-calc feldspars (Na/K ratios, Table 4) in a direction south-eastwards along the open coast. The highest potassium feldspar is 9·2% for N27/118 at the south-east end of the beach. Both these trends may be due to the greater resistance of quartz and potassium feldspar to breakdown during transport and/or to mixing with more quartzitic sands derived from Kaipara Harbour.

Weathered Sands and Sand Plus Clay

Clay content: Some of the samples included in this section have been little weathered but all contain clay either as a result of weathering (secondary clay) or as a result of original or primary clay deposition. The latter deposits are all horizontally bedded and although no estuarine shells have been discovered, are most likely estuarine sediments. The primary nature of the clay in Late Pleistocene deposits found below the 45 ft and lower terraces can be easily recognised because of its unoxidised nature, but the proportion of clay due to weathering or primary nature in older higher level deposits, remains uncertain.

Mineral content: The average quartz content of the unweathered coastal sands between Maunganui Bluff and Kaipara Harbour is 52%, and contrasts with that of 96% for the sand fraction of the innermost harbour sands (N23/110 and N27/114; Table 4). This significant increase may be due to derivation from the local hinterland, but insufficient petrological analyses have been made of the Cretaceo–Tertiary sediments to be certain

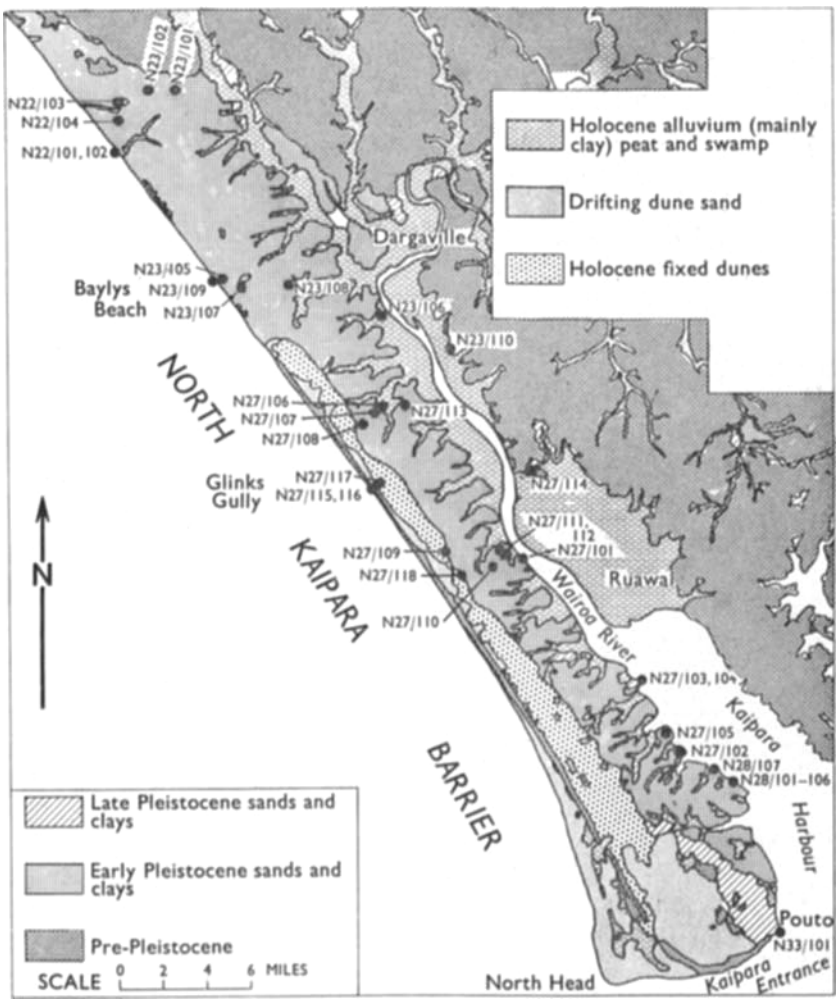

FIG. 7—Quaternary geology and sample positions in Area 3 (a)—Kaipara North Head.

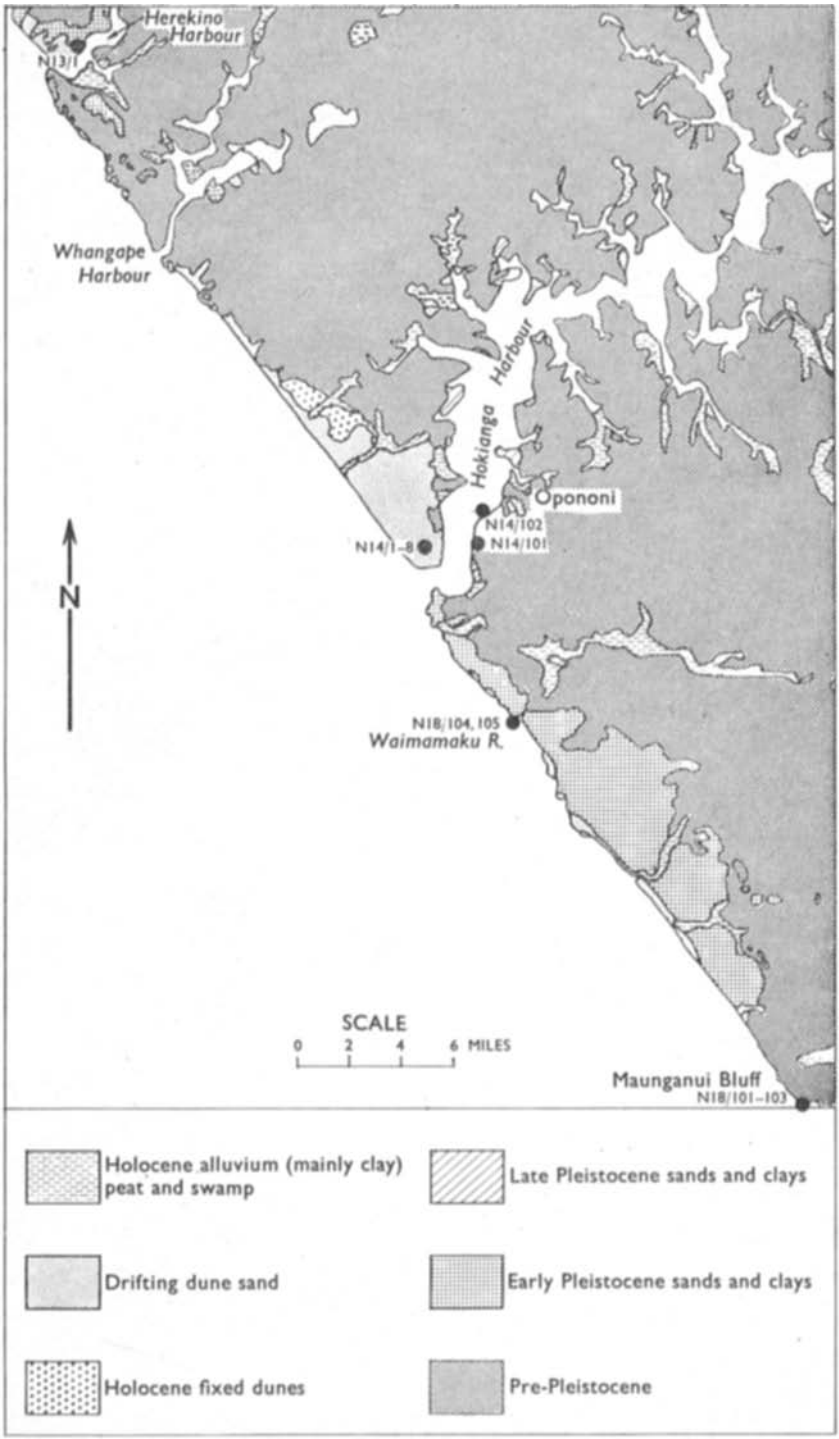

FIG. 8—Quaternary geology and sample positions in Area 3 (b)—Hokianga Harbour.

of their feldspar-quartz ratios and thus the amount of direct relationship between them and the highly siliceous sands is not known. Weathering of these deposits, particularly to podsols, would produce a highly quartzitic and easily eroded sand which, when deposited in the inner part of the harbour, would not be contaminated by relatively highly feldspathic sands being transported along the coast. Mixing of the two types of sand along the southern portion of the harbour coast of North Kaipara Barrier has produced an average quartz content of 64% for N28/102–106.

Weathering of the Quaternary sand deposits themselves and subsequent erosion and inclusion of these more weathered products in consecutively younger sand deposits should tend to increase the less easily weathered quartz content of the youngest Quaternary sediments, within both the coastal and harbour environments, but more especially in the latter. This is indeed the case. Late Quaternary weathering of coastal sands (N14/101b; N18/101; N23/105a, b; Table 4) has increased the quartz percentage from the modern, unweathered, west-coast average of 52% to 60%. The more prolonged weathering of the earlier Quaternary sands found below the 230 ft and older terraces (Table 4) in North Kaipara Barrier, has produced averages of 72% quartz. Probable derivation by erosion of these older sediments has produced the average of 70% quartz found in the alluvial and/or estuarine sediments on the eastern margin of North Kaipara Barrier. The similarity of these latter two figures, 72% and 70% quartz, means that the northern arm, at least, of Kaipara Harbour is an almost closed system into which little outside sediment is entering.

Apart from grains less than 0·15 mm which are always angular, most of the sands are angular to sub-angular, with decreasing angularity in the younger deposits. The exception is N23/110 which is an almost pure quartz sand with a median grain size of 0·23 mm and which, except for its fine fraction, is well rounded.

Area 4—Kaitaia to North Cape (Fig. 9)

On shore the Quaternary sediments consist mainly of widespread dunes with well developed sandy beaches and some alluvial plains (Fig. 9). Off-shore deposits have been investigated only off Kokota Spit where silica sands continue down to depths of many fathoms (Schofield, 1969).

Modern Beach and Dune Sand

West Coast: Much of the extensive sand deposits along the west coast consists mainly of moving dune sand, interspersed with minor patches of lightly cemented sands. The quartz content does not range far from 60% (Table 5) and the mafic mineral content seems to be above 1%. The total feldspar content ranges from 21% to 33%, the potassium feldspar crystals being relatively abundant compared with other areas. The area of greatest potassium feldspar content lies in dunes adjacent to Ninety Mile Beach, north of The Bluff, where a range of 9·5% to 12·6% was found in N4/157, 158, and 159.

The quartz grains are mainly angular with rare crystal faces, but some are slightly rounded.

TABLE 4—Sands of Kaipara North Head to Hokianga Harbour* (Figs. 7 and 8)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na‡	Mafics	Residue	Shell	F/Q§	Na/K‖	A.F.S. Clay	Grid Ref. (See note to Table 1)	Type of Sample B = beach D = dune
N14/102	0·19	50·2	5·1	34·5	3·2	6·9	<1·0	0·8	6·8	nil	910222(45) B	Modern beach (high tide) and foredune, arranged from north-west to south-east (average quartz 52%)
N14/1-8	0·20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	nil	c.883208 D	
N18/104	0·29	37·5	2·7	49·5	6·4	4·0	<1·0	1·4	18·4	nil	931115(44) B	
N18/105	0·22	56·3	4·6	31·0	4·1	3·9	nil	0·6	6·7	nil	931116(44) D	
N18/102	0·27	53·3	5·5	35·5	1·6	3·9	nil	0·8	6·5	nil	095902(44) B	
N18/103	0·23	45·8	5·6	37·8	3·6	7·0	<1·0	0·9	6·8	nil	098901 D	
N22/102	0·22	56·5	3·8	25·8	10·0	3·8	nil	0·5	6·8	nil	188788(43) B	
N22/101	0·19	39·5	2·4	23·6	32·0	3·5	nil	0·7	9·9	nil	189787(43) D	
N23/109	0·22	52·0	5·9	28·4	8·1	5·5	nil	0·7	4·8	nil	260687(64) B	
N27/115	0·20	60·2	7·5	22·2	5·7	4·0	nil	0·5	3·0	nil	383530(43) B	
N27/116	0·16	55·4	5·5	28·5	4·2	6·8	nil	0·6	5·2	nil	383530(43) D	
N27/117	0·18	58·7	8·7	23·5	2·5	6·4	nil	0·5	2·7	nil	387533(43) D	
N27/118	0·19	58·8	9·2	20·3	2·9	8·7	nil	0·5	2·2	nil	c.448469(43) D	
N33/101	0·36	30·4	2·4	66·0	0·0	1·3	1·0	2·3	27·5	nil	c.704187(65)	Kaipara Harbour entrance
N14/101a	0·23	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	8	907210(45)	Late Pleistocene beach and dune along west coast. Clay content secondary (average quartz 60%)
N14/101b	0·25	31·6	2·3	60·9	0·6	4·6	<1·0	2·0	26·5	2	907210(45)	
N18/101	0·25	55·9	6·5	32·1	2·4	3·1	nil	0·7	4·9	3	095904(44)	
N23/105a	0·16	76·6	6·5	5·3	3·9	7·7	nil	0·2	0·8	6	263685(64)	
N23/105b	0·16	76·5	5·9	8·1	3·4	6·1	nil	0·2	1·4	13	263685(64)	
N27/111	0·15	93·7	3·6	1·3	0·1	1·3	nil	0·1	0·4	22	485481(43)	Late Pleistocene alluvial and/or estuarine, along east coast of North Kaipara Harbour. Clay content almost wholly primary (average quartz 70%)
N27/112	0·16	75·8	11·4	7·0	0·2	5·6	nil	0·2	0·6	16	484482(43)	
N27/103	0·19	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	10	c.597384(43)	
N27/104	0·17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	15	c.597384(43)	
N28/101	0·23	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	6¶	c.668302(65)	
N28/102	0·20	54·0	5·3	39·5	0·0	1·2	n.d.	0·8	7·5	1¶	c.668302(65)	
N28/103	0·18	64·0	5·7	28·0	0·5	1·9	n.d.	0·5	4·9	1¶	c.668302(65)	
N28/104	0·21	65·0	7·0	28·0	0·0	0·0	n.d.	0·5	4·0	5	c.668302(65)	
N28/105	0·17	76·0	7·7	13·0	3·4	—	nil	0·3	1·7	12	c.668302(65)	
N28/106	0·17	62·5	6·0	30·0	0·3	0·8	n.d.	0·6	5·0	15	c.668302(65)	

N23/108	0·22	78·2	6·4	15·4	0·0	0·0	nil	0·3	2·4	9	318687(64)	Below 75 ft and 110 ft terraces
N23/106b	0·12	93·0	3·9	2·8	0·0	0·0	nil	0·7	0·7	21	391660(64)	
N27/106	0·14	94·2	1·8	1·3	0·2	2·5	nil	0·0	0·7	24	392595(43)	———
N27/101	0·18	59·4	9·4	31·0	0·0	0·0	nil	0·7	3·3	8¶	502479(43)	Possibly older than 110 ft
N28/107	0·14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	28	*c.*653313(65)	
N22/103	0·26	60·6	0·8	37·8	0·3	0·5	<1·0	0·6	47·2	5	186829(43)	From 230 ft terrace. Clay content probably mainly secondary (average quartz 72%)
N23/101a	0·11	81·0	6·4	7·2	0·7	4·6	nil	0·2	1·1	36	229839(64)	
N23/101b	0·20	72·7	4·3	16·6	0·0	6·4	nil	0·3	3·9	22	229839(64)	
N23/101c	0·21	91·8	0·2	3·6	0·0	4·4	nil	0·0	18·0	16	229839(64)	
N23/107	0·18	57·7	2·5	22·1	6·3	11·4	nil	0·4	8·8	8	278685(64)	
N27/113	0·19	68·2	6·0	21·9	0·5	3·4	nil	0·4	3·6	18	409595(43)	
N27/107a	0·18	74·7	6·9	11·9	2·3	4·2	nil	0·3	1·7	16	387589(43)	
N27/107b	0·21	70·8	4·3	21·8	0·4	2·7	nil	0·4	5·1	14	387589(43)	
N27/110a	0·17	74·4	6·6	8·6	1·0	9·4	nil	0·2	1·3	17	480470(43)	
N27/110b	0·19	59·3	9·4	24·2	0·7	6·4	nil	0·6	2·6	8	480470(43)	
N27/102	0·13	86·0	5·0	8·0	0·3	0·5	nil	0·2	1·6	40¶	627332(43)	
N22/104	0·17	68·3	13·7	12·7	2·1	3·2	nil	0·4	0·9	9	183817(43)	Older than 230 ft terrace (average quartz 71%)
N23/102	0·16	81·3	4·0	9·2	0·0	5·5	nil	0·2	2·3	22	210837(64)	
N27/108	0·16	71·9	8·2	10·6	2·6	6·7	nil	0·3	1·3	14	374580(43)	
N27/109	0·18	62·7	8·8	17·6	5·1	5·8	nil	0·4	2·0	12	440483(43)	
N23/110	0·23	100·0	0·0	0·0	0·0	0·0	nil	—	—	nil	442634(64)	East of harbour (average quartz 96%)
N27/114	0·11	92·0	7·9	0·1	0·0	0·0	nil	0·1	—	37	511544(43)	

* See note to Table 1.
† K = potash feldspar.
‡ Na = soda-calc feldspar.
§ F/Q = ratio of total feldspar/quartz.
|| Na/K = ratio of soda-calc feldspars/potassium feldspar.
¶ Approximate only.

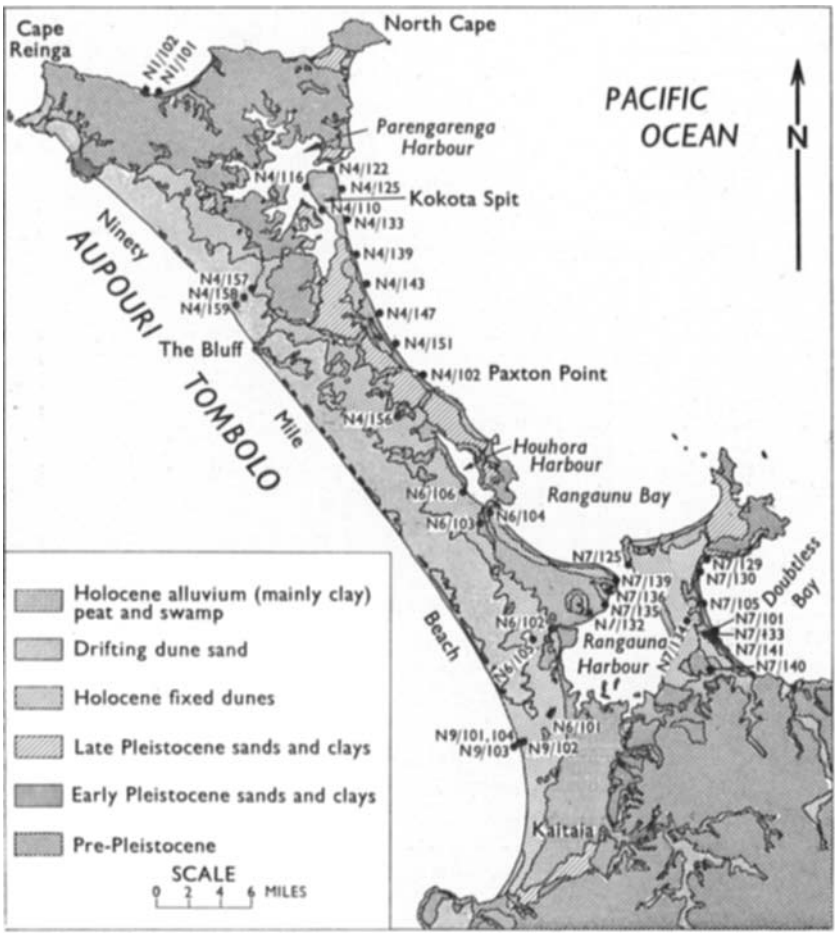

FIG. 9—Quaternary geology and sample positions in Area 4—Kaitaia to North Cape.

East Coast: The modern beach and dune sands along the east coast of the Kaitaia – North Cape area, including the well known and very extensive Parengarenga quartz sands, have a high quartz content in marked contrast to the more feldspathic sands along the west coast of the same region.

The quartz sands of the Parengarenga area include the 4-mile-long Kokota Spit that separates the Parengarenga Harbour from the Pacific Ocean. Total silica (quartz plus the silica contained in feldspars, etc.) is always greater than 95% but Fe_2O_3 is generally greater than 0·1% on the harbour side of the spit and less than 0·1% on the ocean side (Schofield, 1969). Off-shore sediments to the east and coastal sands to the south continue to be high in silica and low in iron, and thus add to the large glass-sand reserves within the sandspit.

Somewhat similar sands are present along the shores of Rangaunu and Doubtless Bays but tend to be slightly less rich in quartz (Table 5) and in most instances comparable in mafic mineral content to the sands on the harbour side of Kokota Spit.

Only 15% of the Parengarenga glass sands is moderately well rounded; the bulk is mainly sub-angular, although more rounded than the highly angular sand along the shores of Doubtless Bay. These, in turn, are less angular than the exceptionally angular dune sands east of Lake Ohia (N7/140) that are almost certainly derived from locally formed podsols. The short distance of wind transport of these extremely angular sands is shown by the lack of rounding and frosting.

Weathered Sands

Without detailed geological fieldwork it is difficult to determine the origin of some of the weathered sand deposits. Nevertheless, judged by the well sorted nature of their sand fraction, they appear to be mostly either dune or beach.

Clay content: Weathering of mineral grains other than quartz in these sands has produced a clay content that tends to increase with age and decrease with depth.

Samples N6/103 and 104, and N7/132, 133, and 135 are all from weathered dune and beach sands of Late Quaternary age and, except for the topmost, humus portion of the soil, are representative of the top few feet. The two youngest, N7/133 and N6/104, are followed in order of age by N6/103, N7/135, and N7/132 and have A.F.S. clay contents of 3·4, 4·0, 5·9, 7·0, and 7·9% respectively. This increase of clay with age continues into the older weathered dunes, e.g., sample N4/156a has 30% A.F.S. clay and represents the top 4·5 ft (the underlying 6 ft of loose brown sand, N4/156b, is still high in A.F.S. clay at 9%). Similarly, the A.F.S. clay contents for N6/102 and 105, and N7/134a and 134b range from 5·5% to 12·3%, the lower percentages being due to exclusion of the more clayey top few feet. The low content of 2·1% A.F.S. clay for N6/101 is also due to this effect of decrease in clay with depth.

TABLE 5—Sands of Area 4—Kaitaia to North Cape* (Fig. 9)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na‡	Mafics	Residue	Shell	A.F.S. Clay	Grid Ref. (See note to Table 1)	General Locality	Type of Sample
N9/103	0·16	57·0	5·4	19·4	8·3	10·0	nil	nil	673785(42)	West Coast	Beach
N9/101	0·14	51·8	6·4	19·9	7·5	14·6	nil	nil	674785(42)	West Coast	Modern dune
N9/104	0·15	53·8	4·8	18·7	16·5	6·2	nil	nil	674785(42)		
N9/102	0·16	55·0	6·3	15·6	9·9	13·2	nil	nil	675785(42)		
N4/157	0·16	71·2	9·5	11·3	0·7	7·1	nil	nil	387266(54)		
N4/158	0·18	66·2	11·7	14·6	1·3	6·1	nil	nil	380260(54)		
N4/159	0·18	60·5	12·6	20·8	1·1	5·1	nil	nil	370254(54)		
N1/101	0·32	73·0	1·3	9·5	13·6	3·0	17·0	nil	280478(61)	Spirits Bay Beach	Beach
N1/102	0·21	82·0	4·4	10·5	2·5	0·4	1·0	nil	273479(61)	Spirits Bay Beach	Beach
N4/107-117	0·18	94·5	2·2	2·3	0·54	0·31	n.d.	nil	See Schofield (1969)	Kokota Spit, harbour coast	Beach and foredune
N4/118-123	0·19	94·5	2·4	2·5	0·14	0·22	n.d.	nil		Kokota Spit, harbour entrance coast	
N4/124-134	0·21	94·5	2·9	2·0	0·14	0·49	n.d.	nil		Kokota Spit, ocean coast	
N4/135-154	0·18	92·0	4·1	3·2	0·15	0·48	n.d.	nil		Coast south of N4/124-134 and north of Paxton Point	
N4/101-106	0·15	89·6	5·1	4·4	0·88	0·07	1·0	nil		South of Paxton Point	
N7/125-128	0·21	86·9	5·7	6·4	0·45	0·35	n.d.	nil	794974(64)	Heads of Rangaunu Harbour	Beach and foredune
N7/139	0·18	88·3	5·5	5·3	0·40	0·40	n.d.	nil	782956(64)		
N7/131	0·17	87·8	4·9	5·1	0·0	2·4	n.d.	nil	*c.*782955(64)		
N7/136	0·17	83·5	4·4	11·6	0·20	0·0	n.d.	nil	774945(64)		

N7/101-104	0·14	89·0	3·9	5·2	1·3	0·35	1·5	nil	885898(64)	Tokerau Beach Doubtless Bay	Beach
N7/105-111	0·17	89·8	3·2	2·1	3·0	1·5	3·0	nil	874929(64)		
N7/112-118	0·13	89·7	4·2	4·0	0·97	1·1	3·0	nil	872966(64)		
N7/119-124	0·12	80·9	6·2	9·8	1·7	2·4	4·0	nil	880979(64)		
N7/140	0·14	98·5	0·5	0·9	0·0	0·0	nil	nil	883860(64)	Lake Ohia	Dune from podsol
N7/133	0·17	83·6	4·8	4·8	2·0	4·8	1·0	3·4	882895(64)		Weathered Late Pleistocene
N6/104	0·14	74·0	5·6	7·8	2·2	10·4	nil	4·0	642029(50)		
N6/103	0·13	73·4	6·8	16·3	1·5	2·0	nil	5·9	638020(50)		
N7/135	0·14	75·0	10·1	11·4	1·0	2·5	nil	7·0	769928(64)		
N7/132	0·16	55·5	3·6	30·6	9·6	0·7	nil	7·9	756918(64)		
N6/102	0·14	68·9	10·3	15·5	0·6	4·7	nil	12·3	713907(50)		
N6/105	0·15	65·9	10·1	12·1	6·5	5·4	nil	5·5	692895(50)		
N7/134a	0·15	71·0	10·4	12·6	1·2	5·0	nil	10·1	858911(64)		
N7/134b	0·14	77·5	12·0	8·8	0·5	1·2	nil	8·5	858911(64)		
N7/141	0·16	90·8	2·2	3·9	1·2	2·0	6·0	n.d.	886898(64)		
N4/156a	0·12	92·2	6·7	1·0	0·0	0·3	nil	30·0	544130(54)		More-weathered Pleistocene sands excluding topmost few feet, excepting N4/156a
N4/156b	0·15	73·9	10·4	4·8	1·8	9·1	nil	9·0	544130(54)		
N6/106	0·15	68·5	6·4	16·5	2·0	6·6	nil	n.d.	618052(50)		
N6/101	0·15	64·0	16·8	16·8	1·2	1·0	nil	2·1	710814(50)		

* See note to Table 1.
† K = potash feldspars.
‡ Na = soda-calc feldspars.

Mineral content: The quartz content of the sand fraction of these weathered sands tends to be intermediate between unweathered highly quartzitic, east-coast and lower-quartzitic, west-coast sands. The mafic-mineral content does not appear to have been affected by the weathering although theoretically the ferromagnesian silicates may tend to disappear with prolonged weathering, the mafic oxides—magnetite, chromite, etc.—being the last to go.

Area 5—Bay of Islands (Fig. 10)

Area 5—Bay of Islands—extends from west of Matauri Bay in the north-west to Ngunguru in the south-east (Fig. 10) and has few sand deposits.

Sampling has been limited almost solely to modern beach sands except for a few shallow-water marine samples collected from near Whangaruru by Dr A. W. B. Powell, formerly of the Auckland Institute and Museum, and a foredune sample from Ngunguru.

Except for some rounding in N11/104, the sands of Area 5 are highly angular and well sorted. The median grain sizes of beach sands in the vicinity of the Bay of Islands are fine to medium (0·14–0·38 mm) whereas those of Ngunguru are fine (0·14–0·15 mm) and the off-shore sands in the Whangaruru area are superfine (0·08–0·13 mm).

With the exception of those at Ngunguru, the sands of Area 5 (Table 6) are typified by a high "residue" content that consists mainly of rock fragments, and also by a high shell percentage. Both of these contents can be greater than 75%. The mineralogy of the sand at Ngunguru is similar to the feldspathic sands of Area 6 to the south (q.v.).

Area 6—Whangarei Harbour to Tokatu Point (Fig. 11)

With the exception of the Aupouri Tombolo in Area 4, the extensive dunes between Ocean Beach in the north and Mangatawhiri Spit in the south make up the greatest region of coastal progradation along the east shore of Northland (Figs. 11 and 14).

Modern Beach and Dune Sand

Grain size, sorting, and angularity: Median grain sizes (Table 7) for the well sorted beach and dune sands range from 0·13 to 0·45 mm, the highest for a dune sand being 0·28 mm. Coarseness depends on the degree of coastal exposure or shelter, so that the long open coasts between Pakiri and Mangawhai, and between Langs Beach and a point 2 miles north of Waipu contain the coarsest medians ranging from 0·22 to 0·45 mm; whereas the beach near Marsden Point, being sheltered by Bream Head, has median grain sizes of 0·16 to 0·19 mm comparable with 0·13 to 0·22 mm for samples from the relatively sheltered Mangatawhiri Spit.

The grain size is the only important control on degree of angularity in these sands—the smaller the grain the greater its angularity. Thus below 0·15 mm the sand is angular, between 0·15 and approximately 0·25 mm it is sub-angular, and above 0·25 mm it is sub-rounded.

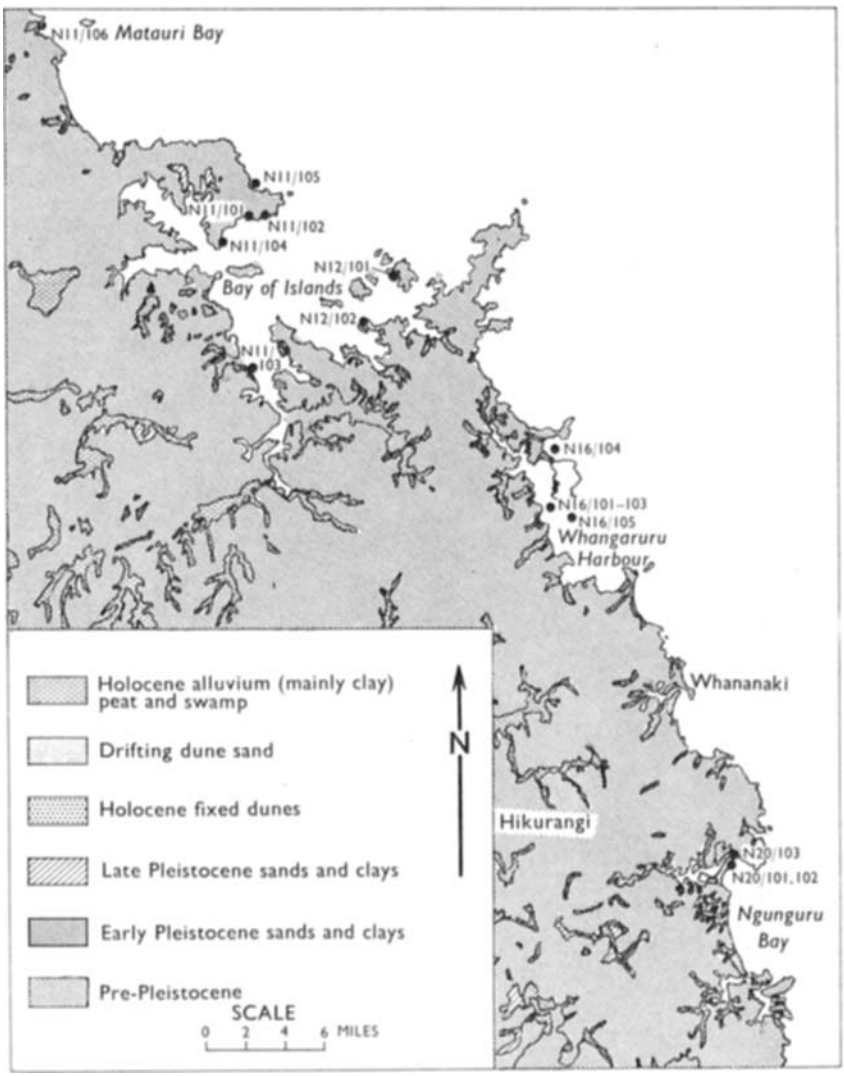

FIG. 10—Quaternary geology and sample positions in Area 5—Bay of Islands.

TABLE 6—Sands in Area 5—Bay of Islands* (Fig. 10)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na‡	Mafics	Residue	Shell	F/Q§	Na/K	Grid Ref. (See note to Table 1)	General Locality	Type of Sample
N11/106	0·14	48·6	12·1	18·5	0·8	20·0	23·0	0·6	1·5	415798(63)	Bay of Islands and Matauri Bay	Beach sands
N11/105	0·28	7·2	8·5	3·8	1·9	79·0	n.d.	1·7	0·4	603661(63)		
N11/102	0·24	5·5	1·9	8·2	0·0	85·0	8·0	1·8	4·3	616640(63)		
N11/101	0·16	53·8	9·6	13·6	3·3	18·8	5·0	0·4	1·4	603637(63)		
N11/104	0·30	6·0	2·8	9·2	10·0	72·0	48·0	2·0	3·3	575613(63)		
N11/103	0·15	59·5	6·0	29·0	2·0	4·0	5·0	0·6	4·8	600502(63)		
N12/102	0·30	2·8	4·3	9·1	0·3	84·0	41·0	4·8	2·1	703543(42)		
N12/101	0·38	7·2	2·9	1·7	0·4	88·0	52·0	0·6	0·6	730592(42)		
N16/104	0·08	18·6	4·0	30·5	1·7	45·5	3·0	1·9	7·6	*c.*865438(42)	Whangaruru	Shallow marine
N16/101	0·10	62·0	3·3	9·6	1·8	23·7	30·0	0·2	2·9	*c.*863388(42)		
N16/102	—	—	—	mainly shell fragments				—	—	uncertain		
N16/103	0·13	13·6	5·5	42·5	0·5	37·8	40·0	3·5	7·7	uncertain		
N16/105	—	—	—	mainly shell fragments				—	—	uncertain		
N20/101	0·15	37·6	0·2	54·7	1·3	6·1	10·0	1·5	—	023079(57)	Ngunguru	Beach and foredune
N20/102	0·14	28·5	1·9	62·0	3·0	4·7	8·0	2·2	32·6	023079(57)		
N20/103	0·14	35·5	3·7	48·5	1·8	10·6	8·0	1·5	13·1	023083(57)		

* See note to Table 1.
† K = potash feldspar
‡ Na = soda-calc feldspar.
§ F/Q = ratio of total feldspar to quartz.

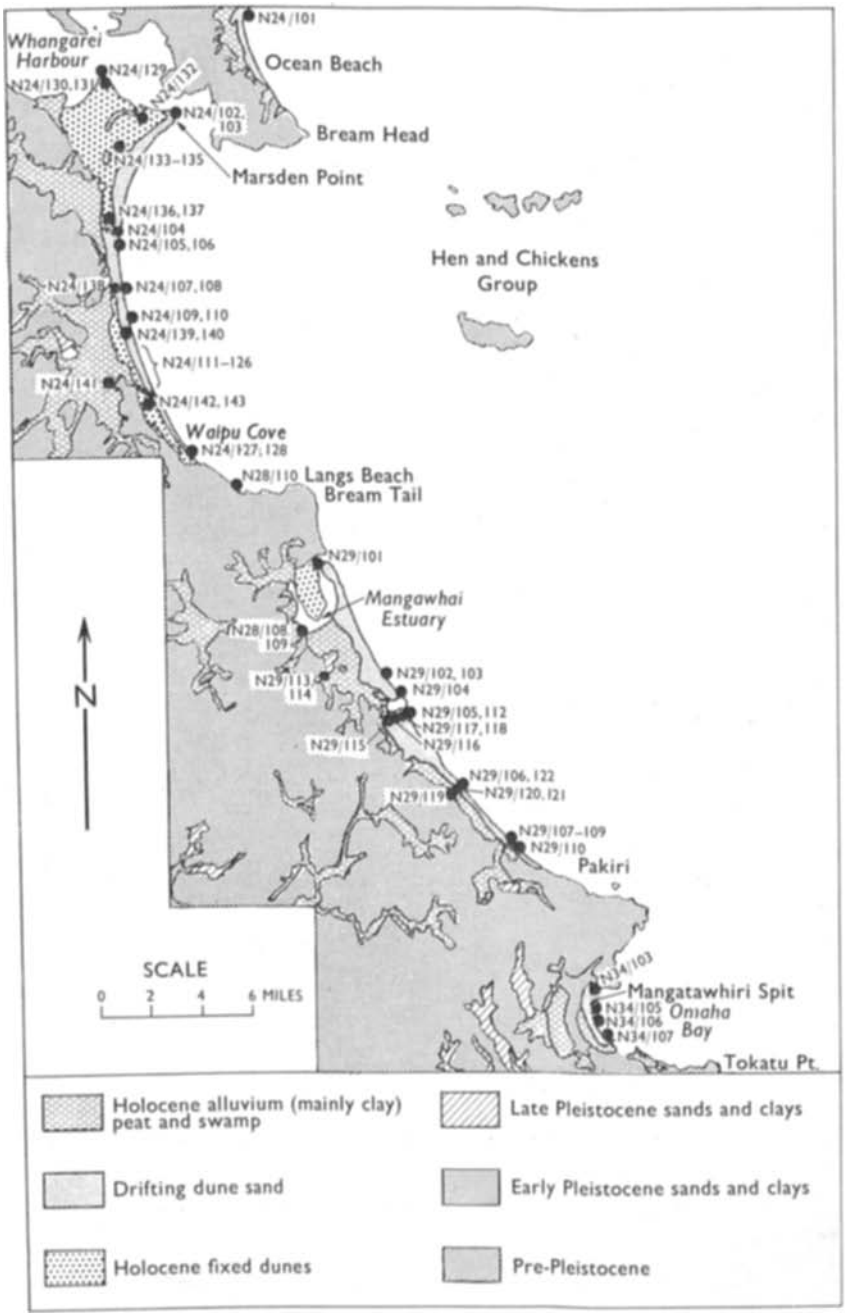

FIG. 11—Quaternary geology and sample positions in Area 6—Whangarei Harbour to Tokatu Point.

TABLE 7—Modern Beach and Foredune Sands in Area 6* (Arranged From North to South) (Fig. 11)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na‡	Mafics	Residue	Shell	F/Q§	Grid Ref. (See note to Table 1)	Type‖	General Locality
N24/101	0·22	31·5	1·0	63·5	1·6	8·6	5·0	2·5	063896(60)	B	Ocean Beach
N24/129	0·25	25·5	0·8	57·6	7·6	2·8	<1·0	1·8	966854(60)	B	Whangarei Harbour
N24/102	0·17	25·5	1·9	64·0	4·0	4·3	<1·0	2·6	012825(60)	B	Northern half of Marsden Point to Waipu Cove beach
N24/103	0·17	23·5	1·0	67·0	4·3	4·3	<1·0	2·9	012825(60)	D	
N24/104	0·19	20·5	1·1	70·5	3·3	5·0	<1·0	3·5	981750(60)	—	
N24/105	0·19	25·5	1·1	67·5	2·9	3·1	<1·0	2·7	974744(60)	D	
N24/106	0·16	25·5	0·2	69·0	0·2	5·3	<1·0	2·7	974744(60)	B	
N24/108	0·17	19·5	2·5	71·5	2·8	3·7	1·5	3·8	975715(60)	B	
N24/107	0·19	24·3	1·1	68·5	1·3	4·8	<1·0	2·9	975715(60)	D	
N24/110	0·24	19·4	0·4	71·5	0·6	8·2	9·0	3·7	978697(60)	B	Southern half of Marsden Point to Waipu Cove beach
N24/109	0·24	23·0	0·4	69·0	2·3	5·3	3·0	3·0	978697(60)	D	
N24/112	0·23	24·0	0·2	66·0	1·9	7·8	6·0	2·8	981686(60)	B	
N24/111	0·18	25·0	1·5	68·0	2·4	2·6	<1·0	2·8	981686(60)	D	
N24/113	0·30	27·4	0·0	70·0	nil	2·7	8·0	2·6	982682(60)	B	
N24/114	0·19	22·0	0·7	68·0	2·8	6·5	4·0	3·1	983678(60)	B	
N24/115	0·29	25·0	0·2	72·0	3·1	0·0	4·0	2·9	983674(60)	B	
N24/117	0·31	24·0	0·0	63·0	4·8	8·0	4·0	2·6	986570(60)	B	
N24/116	0·22	26·5	0·4	70·0	3·8	0·0	3·0	2·6	985670(60)	D	
N24/118	0·27	23·5	1·3	62·0	9·0	4·6	6·0	2·7	987666(60)	B	
N24/119	0·32	21·0	1·0	69·0	2·5	7·0	6·0	3·3	988662(60)	B	
N24/120	0·24	18·2	1·3	70·5	2·1	8·2	5·0	3·9	990658(60)	B	
N24/121	0·33	21·0	1·0	74·0	0·5	3·3	9·0	3·6	992654(60)	B	
N24/122	0·22	21·5	1·2	71·0	2·5	4·3	4·0	3·4	994650(60)	B	
N24/123	0·28	24·0	0·9	68·0	1·8	5·0	3·0	2·9	995646(60)	B	
N24/124	0·25	21·0	0·6	63·5	1·1	5·6	4·0	3·1	996643(60)	B	
N24/125	0·28	17·7	0·2	51·0	25·5	5·7	5·0	2·9	996643(60)	D	
N24/126	0·23	35·5	0·7	57·0	3·5	2·8	<1·0	1·6	994637(60)	B	
N24/127	0·26	24·0	0·2	59·5	13·0	3·0	4·0	2·5	020600(60)	B	
N24/128	0·20	20·5	0·4	73·5	2·8	2·8	4·0	3·6	020600(60)	D	

N28/110	0·45	31·4	0·7	59·0	1·6	7·6	21·0	1·9	056579(65)	B	Langs Beach
N29/101	0·23	21·8	1·5	70·0	5·5	1·5	<1·0	3·3	104533(42)	B	Mangawhai Harbour
N29/103	0·42	33·0	0·3	57·0	0·6	8·5	<1·0	1·7	148461(42)	B	Mangawhai Heads to Pakiri River
N29/102	0·23	28·5	1·3	62·0	1·9	6·5	nil	2·2	148461(42)	D	
N29/104	0·26	23·3	0·6	67·5	1·2	7·3	4·0	2·9	160446(42)	B	
N29/105	0·28	22·7	0·2	67·0	0·8	9·0	2·0	3·0	167431(42)	B	
N29/112	0·24	25·6	0·6	60·0	6·5	7·3	<1·0	2·4	166431(42)	D	
N29/116	0·27	26·7	0·9	55·0	14·0	3·2	nil	2·1	160428(42)	D	
N29/115	0·27	23·2	0·6	60·0	12·0	5·0	nil	2·6	*c.*153428(42)	D	
N29/106	0·41	26·5	0·0	65·0	nil	8·7	<1·0	2·4	204383(42)	B	
N29/122	0·25	26·5	0·7	62·0	7·7	2·9	nil	2·4	203383(42)	D	
N29/119	0·26	26·3	0·4	56·0	15·0	2·7	nil	2·2	198378(42)	D	
N29/109	0·29	19·0	0·4	72·5	0·4	8·0	6·0	3·8	235350(42)	B	
N29/108	0·35	19·4	0·9	70·0	0·2	9·3	11·0	3·7	235350(42)	B	
N29/107	0·23	23·0	1·5	71·5	0·8	3·2	2·0	3·2	235350(42)	D	
N29/110	0·45	26·8	0·4	64·0	nil	9·0	7·0	2·4	241344(42)	B	
N34/103	0·22	26·4	1·4	69·0	1·4	2·0	<1·0	2·7	293249(62)	B	Mangatawhiri Spit (Schofield, 1967a)
N34/105	0·13	32·7	2·2	62·5	0·4	2·1	<1·0	2·0	292232(62)	B	
N34/106	0·14	21·0	3·2	73·0	1·0	1·8	<1·0	3·6	293225(62)	B	
N34/107	0·14	27·0	3·6	64·2	1·6	3·3	2·0	2·5	301212(62)	B	

* See note to Table 1.
† K = potash feldspar.
‡ Na = soda-calc feldspar.
§ F/Q = ratio of total feldspar to quartz.
‖ B = beach (high tide). D = dune (foredune).

Mineralogy: Table 7 shows that all modern sand deposits north of Tokatu Point are highly feldspathic, the total feldspar content ranging from 51% to 76%. Most of the feldspar is non-potassic, the amount of potassium feldspar being generally less than 1·5%. Those with greater amounts of potassium feldspar (maximum of 3·6%) are all relatively fine grained with medians between 0·13 and 0·17 mm.

The next highest constituent is quartz with 18% to 35%. Mafic minerals and the "residue" (rock fragments and unidentified) range from 0 to 25% (commonly less than 4%) and 0 to 9% respectively.

Sands of identical mineralogical content are found on Mangatawhiri Spit and in Omaha Bay, north of Tokatu Point. These are described in detail by Schofield (1967a).

Sands With Clay

Clay and carbon content: No accurate measurements of A.F.S. clay have been made but approximate estimates for N24/130–143; N28/108–9; N29/113–4, 117–8, and 120–1 are given in Table 8. Samples N24/130 and 131 may be of interest to foundrymen because of a natural carbon bond, the organic content (mainly carbon) being approximately 0·36% and 0·39% respectively.

Grain size, sorting, and angularity: Apart from the presence of clay (mainly secondary) the weathered sands of Area 6 are all well sorted. The median grain size ranges from 0·17 to 0·26 mm, more than 50% being 0·23 mm or greater. Angularity is similar to that described for the local modern beach and foredune sands.

Mineralogy: Except for the important absence of shell fragments and for a slight increase in quartz—the average for unweathered and weathered sands being 24% and 28% respectively—the mineralogy of the weathered sands is very similar to the unweathered modern beach and foredune sand.

Area 7—Auckland and Hauraki Gulf (Fig. 12)

The greater part of the coastline in this area (Fig. 12) is undergoing erosion and thus most of the beaches consist of locally derived sand that does not extend beyond 5 fm in depth—most of the Hauraki Gulf in this area being floored by silty or sandy mud. The major exception to this sedimentary distribution in this part of the gulf is an area of sand in the Colville Channel between the northern end of Coromandel Peninsula and Great Barrier Island, and which extends eastwards to a depth of 35 fm. The sand contains pumice and was almost certainly deposited by the Waikato River during the Last Glaciation when sea level stood 50 fm or more below the present level and when the Waikato River flowed at times down the Hauraki Plains (Area 8) into the Hauraki Gulf. Marine muds have since covered most of the sandy plain that had formed in the gulf, except in areas where marine currents have been strong enough to stop the mud from settling. Colville Channel is one such exception.

TABLE 8—Sands with Clay in Area 6 (Fig. 11)

Sample	Median (mm)	% on shell-free basis					Shell	A.F.S. Clay‡	Grid Ref. (See note to Table 1)	Type of Sample
		Qtz	Feldspar K*	Feldspar Na†	Mafics	Residue				
N24/130	0·23	34·0	1·0	53·0	7·5	4·2	nil	3·0	966854(60)	?Estuarine or beach with secondary clay
N24/131	0·19	30·5	1·1	55·5	11·9	1·3	nil	3·5	966854(60)	
N28/108	0·17	29·0	2·5	57·5	9·5	1·5	nil	7·0	094485(65)	
N28/109	0·21	21·4	1·2	62·0	12·2	3·7	nil	n.d.	094485(65)	
N24/132	0·20	29·0	2·2	63·0	4·4	1·3	nil	4·0	988825(60)	Weathered dune
N24/133	0·23	31·0	0·7	63·0	2·5	3·2	nil	2·0	977806(60)	
N24/134	0·25	25·5	1·9	65·5	3·8	3·2	nil	n.d.	977806(60)	
N24/135	0·23	25·7	0·7	66·0	4·3	3·6	nil	n.d.	977806(60)	
N24/136	0·23	31·0	0·9	64·0	0·7	3·3	nil	2·0	965754(60)	
N24/137	0·22	35·0	1·3	56·0	3·1	4·5	nil	1·0	965754(60)	
N24/138	0·24	33·5	1·8	58·0	3·7	3·0	nil	5·0	973714(60)	
N24/139	0·26	26·0	1·0	57·0	13·0	2·0	nil	4·5	977686(60)	
N24/140	0·26	32·0	0·4	49·0	18·0	0·8	nil	1·0	977686(60)	
N24/142	0·25	31·5	0·4	58·5	6·5	3·3	nil	6·0	992637(60)	
N24/143	0·25	24·5	0·6	67·5	4·7	2·3	nil	n.d.	992637(60)	
N29/113	0·20	26·0	1·3	62·0	7·8	2·9	nil	5·0	112463(42)	
N29/114	0·20	18·8	1·0	63·0	12·0	5·0	nil	2·0	112463(42)	
N29/117	0·22	29·5	0·8	58·5	11·0	0·4	nil	8·5	163430(42)	
N29/118	0·21	23·0	0·8	50·0	24·0	2·3	nil	2·5	163430(42)	
N29/120	0·26	32·0	1·0	59·0	6·0	1·7	nil	1·5	200380(42)	
N29/121	0·26	23·0	1·2	67·5	6·0	2·1	nil	1·0	200380(42)	

* K = potash feldspar.
† Na = soda-calc feldspar.
‡ Approximate only.

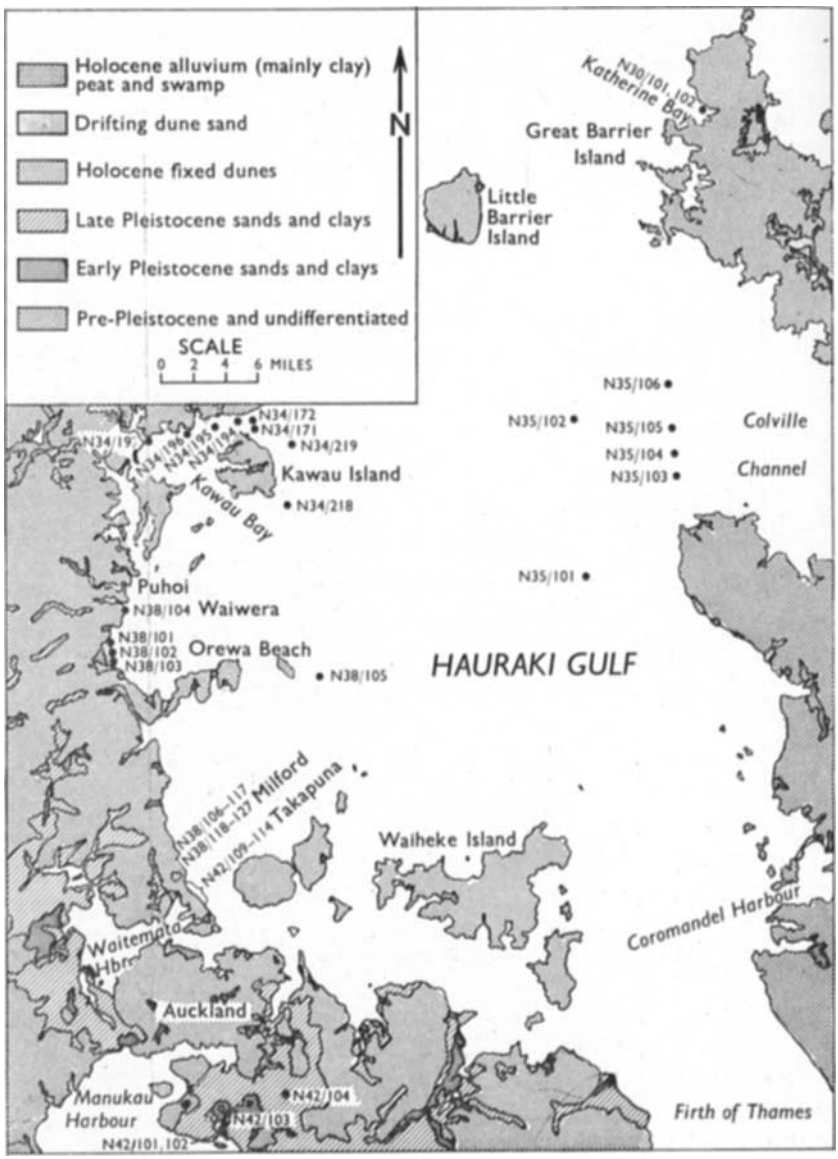

FIG. 12—Quaternary geology and sample positions in Area 7—Auckland and Hauraki Gulf.

Marine Sands of Colville Channel

The angular, well sorted sands (N35/101 to 106, Table 9) occur at 24 to 31 fm and have median grain sizes ranging from 0·11 to 1·35 mm. Mineralogically they closely resemble the coastal sands between Whangarei Harbour and Tokatu Point in Area 6, the averages for Colville Channel sand being 18% quartz, 63% feldspar, 8% mafic minerals, and 10% "residue"; those for Area 6 being 24, 67, 4, and 5% respectively.

Marine Shell Sand, Katherine Bay

Samples of sand collected by Dr A. W. B. Powell from Katherine Bay, Great Barrier Island, are of interest because of their shell content. The two collected were N30/101 with a lime content of 71% and N30/102 with 21% lime. Their exact location is not known but that with 71% lime came from only 8 fm and that with 21% came from 13 fm. Further prospecting seems warranted if this could produce a cheap source of lime for Great Barrier Island.

Coastal Sands, Kawau Bay to Takapuna

The east coast, from Kawau Bay to Takapuna Beach, is characterised by coastal erosion that has formed long lines of cliffs and wave-cut platforms. These are cut almost wholly in sandstones and siltstones of the Waitemata Group, except for some Mesozoic rocks in the region of Kawau Bay and for a little basalt between Milford and Takapuna.

Grain size, sorting, and angularity: Apart from coarse-grained shelly sands in the North Channel between Kawau Island and the mainland (N34/194–196, 171–172) the sands of the east coast region between Kawau Bay and Takapuna are angular, well sorted, and have median grain sizes ranging from 0·11 to 0·25 mm.

Mineralogy: When mineral percentages are calculated on a shell-free and "residue"-free basis (Table 10) it is obvious that there is a much stronger resemblance of these coastal sands with the sandstones of the Waitemata Group than with the sands of the Colville Channel, averages of which are also shown in Table 10. Southwards there is an increase in quartz from 51% at Kawau Bay to 69% at Orewa and 80% near Milford (Table 10), and, although a more thorough investigation of the Waitemata beds is required—for their quartz content may also change southwards—it seems most likely that this increase of quartz is a function of environmental energies; Kawau Bay being sheltered compared with the Orewa and Milford regions, and Orewa being possibly slightly more sheltered than Milford. Similarly, there is a southward increase of the tougher potassium feldspar relative to soda-calc feldspar as shown by the Na/K ratios in Table 10. The southward decrease in median grain size, small increase in quartz and marked increase in basalt fragments south of its coastal outcrop near Milford (Table 11) shows that, for at least the Milford area, there is an effective southward longshore drift. The wear and tear caused by this drift may also partly account for the relative increase in quartz and potassium feldspar in a southward direction.

TABLE 9—Sands of Area 7 (Fig. 12)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K*	Feldspar Na†	Mafics	Residue	Shell	A.F.S. Clay (approx)	Grid Ref. (See note to Table 1)	Type of Sample
N30/101	0·5	n.d.	n.d.	n.d.	n.d.	n.d.	c.75·0	—	Katherine Bay	Marine, Hauraki Gulf
N30/102	0·12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	Katherine Bay	
N35/101	0·11	14·0	2·0	77·0	4·5	2·3	n.d.	32·0	c.723032(53)	
N35/102	0·12	12·6	0·4	55·0	7·5	23·7	n.d.	16·0	c.718186(53)	
N35/103	1·2	16·4	0·6	59·0	9·6	14·0	n.d.	n.d.	819113(53)	
N35/104	0·4	16·4	0·0	66·0	12·5	5·5	20·0	1·0	c.821136(53)	
N35/105	1·35	31·0	0·7	48·0	10·0	10·0	n.d.	n.d.	c.821160(53)	
N35/106	0·3	17·0	2·8	66·5	5·2	8·5	n.d.	3·0	c.823209(53)	
N34/171	0·44	17·0	1·6	14·0	3·3	64·0	50·0	0·0	369160(62)	
N34/172	1·25	12·0	0·6	14·0	0·6	72·0	90·0	0·0	369171(62)	
N34/194	3·0	37·0	1·3	42·0	3·1	16·7	95·0	0·0	350170(62)	
N34/195	1·5	37·0	1·0	41·0	1·3	20·0	95·0	0·0	318157(62)	
N34/196	0·38	n.d.	n.d.	n.d.	n.d.	n.d.	c.50·0	0·0	298157(62)	
N34/197	0·12	64·0	5·0	27·0	1·7	3·0	<1·0	0·0	253152(62)	
N34/218	1·0	28·0	0·0	63·0	2·7	6·5	n.d.	n.d.	c.409090(62)	
N34/219	‡	14·0	6·0	43·0	1·5	35·5	n.d.	n.d.	c.407151(62)	
N38/105	0·23	40·0	—	6·5	3·5	50·0	n.d.	5·0	c.439901(61)	
N38/104	0·15	49·0	4·3	11·0	14·0	21·5	1·0	0·0	226976(61)	Beaches from Waiwera southwards to Takapuna
N38/101	0·11	64·0	5·4	20·0	4·3	6·5	nil	0·0	210937(61)	
N38/102	0·12	69·0	3·5	21·0	4·1	2·6	nil	0·0	214926(61)	
N38/103	0·19	71·0	9·5	12·0	0·5	7·2	nil	0·0	217913(61)	
N38/106-111	0·25	48·5	6·3	4·1	4·3	36·6	n.d.	0·0	c.282723(61)	
N38/112-116	0·25	50·6	4·8	4·3	4·4	36·0	n.d.	0·0	c.285718(61)	
N38/118-120	0·24	49·0	5·1	3·9	3·8	38·4	n.d.	0·0	Castor Bay	
N38/121-123	0·23	50·9	6·3	3·7	4·3	34·7	n.d.	0·0	Castor Bay	
N38/124-127	0·22	58·2	6·7	4·5	2·6	28·0	n.d.	0·0	Milford Beach	
N42/109-114	0·18	57·5	7·7	4·9	1·2	28·3	n.d.	0·0	Takapuna Beach	

* K = potash feldspar.
† Na = soda-calc feldspar.
‡ Silty clay.

TABLE 10—Coastal Sands, Kawau Bay to Takapuna Compared with Sands of Waitemata Group and of Colville Channel Area

	Colville Channel N35/101-6	Kawau Bay N34/194-7 N34/171-2	Orewa Beach N38/101-4	Milford* N38/106-27 N42/109-14	Waitemata† N42/10, 106-7 N48/101a, 102	
Quartz (Q)	18	33	63	53	56	Shell-free basis
Feldspar (F)	63	30	22	10	42	
Mafics	8	2	6	3	2	
Residue	10	35	9	34	0·3	
Quartz	20	51	69	80	56	Shell and residue free basis
Feldspar	71	46	24	15	42	
Mafics	9	3	7	5	2	
F/Q	3·5	0·9	0·3	0·2	0·7	
Na/K‡	57·1	14·5	2·8	0·7	1·7	
Median (mm)	0·58	1·11	0·14	0·23	0·13	

* The Milford area includes beaches from just north of Castor Bay to Takapuna.
† For sample details see Schofield (in press).
‡ Na/K = ratio of soda-calc feldspars to potassium feldspars.

TABLE 11—Beach Sand Averages from North of Castor Bay Southwards to Takapuna

	N38/ 106-111	N38/ 112-116	N38/ 118-120	N38/ 121-123	N38/ 124-127	N42/ 109-114
Quartz*	77	79	79	78	81	81
Feldspar*	16	14	14	15	15	17
Mafics*	6·4	6·9	6·2	6·6	3·6	1·7
Residue	37	36	38	35	28	28
Basalt % in residue	n.d.	6	10	9	10	19†
Median (mm)	0·25	0·25	0·24	0·23	0·22	0·18

* Shell and "residue" free basis.
† South of basaltic coastline; all other average basalt percentages are from beaches north of the basalt outcrops.

TABLE 12—Sand Fraction of "Estuarine Sands" in Areas 7 and 1*

Sample	Quartz %	Feldspar %	Mafic Minerals %
N42/101	88	5	7
N42/102	91	6	3
N42/103	88	6	6
N42/104	91	6	3
N47/101a	98	1·5	nil
N47/101b	98	1·5	nil

* See note to Table 1.

Quaternary Sand With Clay

Investigation of Quaternary deposits in Area 7, other than modern beach and marine, have been limited to Late Pleistocene "Estuarine" sands (Table 12) that underlie terraces up to 50 ft above sea level and in which the clay is predominantly primary. This description includes similar deposits (N47/101a and 101b) in Area 1 immediately south of Auckland.

Clay content: When unoxidised the A.F.S. clay is almost white and ranges from 7·3% to 46% (Schofield, in press). Dr A. Ewart, formerly of the New Zealand Geological Survey, estimated that the A.F.S. clay of N42/102 consists of 65% quartz, 15% kaolin, 10% sericite, and 10% feldspar with a trace of magnetite.

Grain size, sorting, and angularity: Grain sizes range from 0·03 to 0·13 mm (Schofield, in press), quartz grains being mostly angular with some being sub-angular. The cumulative grain-size curves (Fig. 3b) show an unusual bimodal distribution, the two main parts being a well sorted fine to super-fine sand fraction and a silt and clay fraction—the silt grades being almost absent in samples N42/101, 102, and 103. Grading analyses of modern estuarine beaches (N42/115, 116, Fig. 3B) show the same bimodal sorting,

such sorting suggesting mixing of materials from two environments—probably beach or dune sand with estuarine mud. Furthermore their positions relative to present estuarine deposits also suggest an estuarine origin despite the apparent absence of marine fossils.

Mineralogy: Table 12 shows that all these sands have a high quartz content. The mafics of N42/101–104 have been examined by Dr Ewart who records sub-rounded grains of magnetite and ilmenite in all samples except that ilmenite was not recorded in N42/101. Biotite and muscovite, up to 5% in N42/101, are also common to all samples except N42/104. In addition, N42/102 contained minor pyroxene and olivine; and N42/104 contained minor hypersthene.

Area 8—Coromandel Peninsula (Fig. 13)

The Coromandel Peninsula consists mainly of andesites in the west, rhyolites and their derivatives in the east, and Mesozoic argillites and greywackes in the north. Part of the Hauraki Plains is also present within Area 8 (Fig. 13) but is underlain mainly by mud and peat. The southern part of the plains consists of the Hinuera Formation which contains sand similar to that in the Colville Channel (Area 7, q.v.) and Waikato River (Area 1, q.v.) except that the pumice content is generally very high. The west coast beaches of the Coromandel Peninsula consist almost solely of gravel and hence this reconnaissance has been restricted to its east coast beaches and dunes.

Modern Beach and Dunes

Grain size, sorting, and angularity: Median grain sizes range from 0·18 to 0·44, 74% being of medium coarseness, i.e., between 0·25 and 0·5 mm (Table 13). As is usual, the sorting of these angular, to slightly sub-angular beach and dune sands is excellent.

Mineralogy: The dominant feature is a high feldspar content, the ratios of feldspar to quartz, F/Q, and soda-calc feldspar to potassic feldspar, Na/K, being similar to those found in the Hauraki Gulf between Whangarei and Tokatu Point (Area 6) and Colville Channel (Area 7). Normally the total feldspar (Table 13) lies above 50%, except at Orokawa Bay where mafic mineral content is high, and except at Hahei and Tairua where the F/Q ratios are low. Only one sample was collected from Tairua but three samples from Hahei are consistent in showing a relatively low feldspar content (Table 13). The local provenance in the Hahei area is wholly rhyolitic and thus a high feldspar content could be normally expected. However, the unexpected low feldspar content is almost certainly due to hydrothermal alteration common to the rhyolites in the immediate hinterland, altering the feldspar to clay but leaving quartz untouched. If further samples from Tairua show that the local beach sand is consistently similar to that at Hahei, it could mean that the known areas of hydrothermal alteration in the Tairua area form only part of much larger deposits of kaolinised rhyolites in the headwaters of the Tairua River.

South-eastwards along the 6-mile beach between Waihi and Bowentown, there is an increase in the tougher quartz, relative to feldspar (see F/Q ratios, Table 13). This may mean that the effective longshore drift is

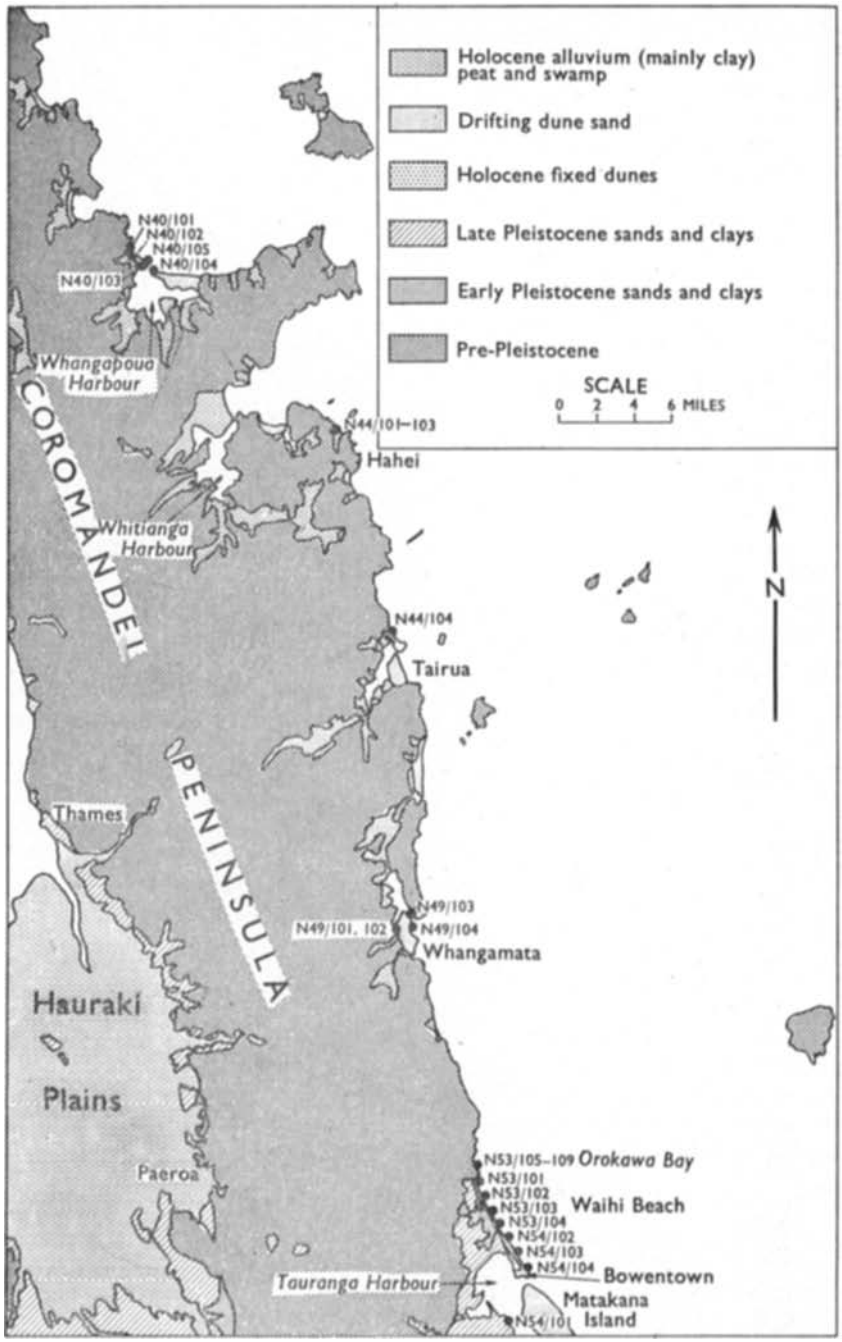

FIG. 13—Quaternary geology and sample positions in Area 8—Coromandel Peninsula.

TABLE 13—Coastal Sands Along East Coast of Coromandel Peninsula* (Fig. 13)

Sample	Median (mm)	% on shell-free basis: Qtz	Feldspar K†	Feldspar Na‡	Mafics	Residue	Shell	F/Q§	Na/K	Grid Ref. (See note to Table 1)	Locality
N40/101	0·21	25·0	3·0	57·2	13·9	0·5	3·0	2·4	19	107783(49)	Whangapoua beach and dune
N40/102	0·23	22·0	0·8	54·8	14·7	7·7	0·0	2·5	68	113775(49)	
N40/103	0·18	20·5	4·4	72·2	0·8	2·0	10·0	3·7	16	121767(49)	
N40/104	0·32	31·5	1·0	59·5	2·1	6·2	1·5	1·9	59	127765(49)	
N40/105	0·29	29·0	1·2	64·0	1·5	3·9	8·0	2·2	53	122769(49)	
N44/101	0·43	80·0	0·6	12·6	0·3	6·5	6·0	0·16	21	294625(57)	Hahei and Tairua beaches
N44/102	0·26	46·0	2·6	16·4	29·6	5·2	16·0	0·41	6	300621(57)	
N44/103	0·24	35·0	1·7	15·5	3·4	45·0	23·0	0·49	9	306617(57)	
N44/104	0·40	51·2	0·0	32·0	0·3	16·5	10·0	0·63	—	347439(57)	
N49/101	0·18	27·5	2·0	59·5	8·5	2·8	nil	2·2	30	352174(53)	Whangamata beach
N49/102	0·20	24·8	1·7	60·0	9·4	3·9	nil	2·5	35	352174(53)	
N49/103	0·19	17·1	3·8	53·5	17·1	8·4	6·0	3·4	14	366183(53)	
N49/104	0·28	26·8	1·3	49·8	2·3	20·2	10·0	1·9	38	366175(53)	
N53/105	0·36	16·5	0·7	29·8	50·2	2·7	8·0	1·8	43	423961(65)	Orokawa beach
N53/106	0·42	28·9	1·1	32·3	34·5	3·3	12·0	1·2	29	424957(65)	
N53/107	0·44	35·0	0·9	26·5	32·7	5·0	18·0	0·78	29	425955(65)	
N53/108	0·39	37·8	0·0	44·4	14·6	3·1	21·0	1·2	—	425959(65)	
N53/109	0·39	26·4	0·8	40·2	28·0	4·5	22·0	1·6	50	424957(65)	
N53/101	0·22	20·8	3·9	62·0	2·1	11·3	12·0	3·2	16	424946(65)	Beach—from Waihi beach to Bowentown
N53/102	0·26	15·3	3·5	61·0	17·4	2·8	<1·0	4·2	17	431930(65)	
N53/103	0·19	18·0	2·8	53·0	25·0	0·9	<1·0	3·1	19	438915(65)	
N53/104	0·28	18·9	3·3	68·5	2·8	6·3	n.d.	3·8	21	445904(65)	
N54/102	0·28	24·8	2·3	63·5	5·6	4·0	2·0	2·6	28	456887(65)	
N54/103	0·29	14·7	1·5	38·5	43·5	2·0	5·0	2·7	26	465874(65)	
N54/104	0·37	31·0	1·2	52·7	4·4	10·8	4·0	1·7	44	473862(65)	
N54/101	0·30	51·0	2·7	29·0	18·0	nil	5·0	0·62	11	452817(65)	Ongari Pt beach, Tauranga Harbour

* See note to Table 1.
† K = potash feldspar.
‡ Na = soda-calc feldspar.
§ F/Q = ratio of total feldspar to quartz.

towards Bowentown, further evidence being given by the fact that part of this beach is along a spit that has grown outwards towards Bowentown. However, there is an anomaly. Evidence elsewhere in the Auckland and Northland region suggests there should also be a south-eastwards increase in potassic feldspar, relative to soda-calc feldspar, as the latter is normally weaker in resisting transport, but the reverse is true along the Waihi to Bowentown beach (*see* Na/K values, N53/101–104, N54/102–104, Table 13).

PART 2—COASTAL SAND MOVEMENT

Introduction

The onshore, offshore, and longshore movements of coastal sand is a complex study in that reversal of movement may occur. Nevertheless, it is hoped that the information so far gained is sufficient to show the net effect of such movements. Before any such conclusion can be reached it is necessary to examine the *Regional Régime* as is shown by major progradational features which have been influenced by regional ocean currents and by dominant wind direction. Secondly, it is necessary to simplify the sand deposits into different *Sand Facies.*

REGIONAL RÉGIME

The dominant winds blow from a westerly direction and produce spectacular seas along the west coast that are usually considerably rougher than those encountered along the east coast. These conditions have resulted in production of an almost straight west coast in marked contrast to the crenellated east-coast outline (Figs. 14 and 15). Most of the west coast, in the area under study, consists of prograded areas in the form of magnificent ancient barriers that protect the Manukau and Kaipara Harbours (the Manukau, South Kaipara, and North Kaipara Barriers) and of the Aupouri Tombolo that ties the North Cape region to the mainland. These progradational features range from 25 to 60 miles long and have a fairly consistent width of 5 miles. They rise to several hundred feet above sea level, the highest point being 934 ft at the northern end of the Manukau Barrier. They preserve complicated evidence of fluctuating sea levels that date back to at least early Quaternary times (Brothers, 1954; Kear, 1964) but most probably date back to the Pliocene for Pliocene faunas inland of the Manukau Barrier lived within an estuarine environment whereas those along the west coast, south of the Waikato River, lived in open ocean conditions (Schofield, 1958). This means that despite some present-day erosion, the west coast has been essentially stable or in a state of dynamic equilibrium for a long period of time. Periods of progradation have probably alternated with periods of erosion, the latter being favoured by rising sea level and the former by falling sea level (Schofield, 1967a). But, because of an overall drop in sea level during the Quaternary and because of an ample supply of sand the net result has been one of stability and progradation along the west coast.

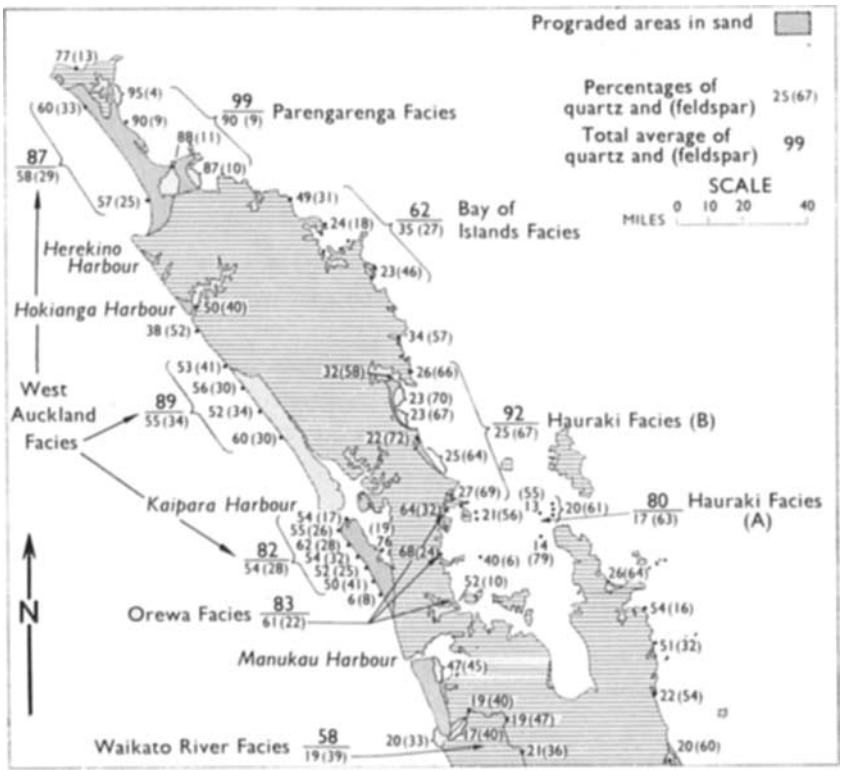

FIG. 14—Distribution of sand facies in the Northland–Auckland region and their average quartz and feldspar content.

The presence of dominant coastal currents along the west coast is demonstrated by the directons of barrier growth. Whereas the net growth of the Manukau and South Kaipara Barriers has been northwards (Fig. 15), that for the North Kaipara Barrier and smaller barriers in front of the Herekino and Hokianga Harbours that lie north of Kaipara Harbour, has been southwards. Almost certainly the surface ocean currents named the West Auckland and Westland Currents (Brodie, 1960) converge at an area opposite Kaipara Harbour (Fig. 15) which is a little more specific than the wider area of convergence suggested by Brodie (1960). In view of the age of these barriers it can be reasonably concluded that these currents have been active since the Pliocene, if not from earlier times, and that convergence has generally remained opposite the entrance to Kaipara Harbour. Nevertheless this entrance, at present, appears to be shifting northwards. As a result the older Quaternary sediments are being eroded at the southern end of the North Kaipara Barrier (Fig. 7), whereas the Holocene Papakanui Spit (Fig. 4) has developed a mile beyond the northern end of the South

Kaipara Barrier. This may mean that the convergence area of the West Auckland and Westland Currents has a net movement within certain limits and that the entrance width to Kaipara Harbour is in equilibrium with the rest of the régime.

At first sight the very much smaller sand spits of the east coast—Whananaki and Ngunguru Spits (Fig. 10); Mangatawhiri Spit in Omaha Bay (Fig. 11), and the other smaller spits at the mouth of the Puhoi and at Waiwera (Fig. 12, Schofield, 1967a)—suggest north-westward directed ocean currents that conflict with the south-eastward directed flow of Brodie's (1960) East Auckland Current, but these north-westward directed currents could be the result of local eddies caused by promontories along the irregular east coast.

Sand Facies

Classification of the coastal sands in the Northland and Auckland regions has been complicated to some extent by mixing and by localised trends but as the survey progressed certain regional trends became clear that enabled

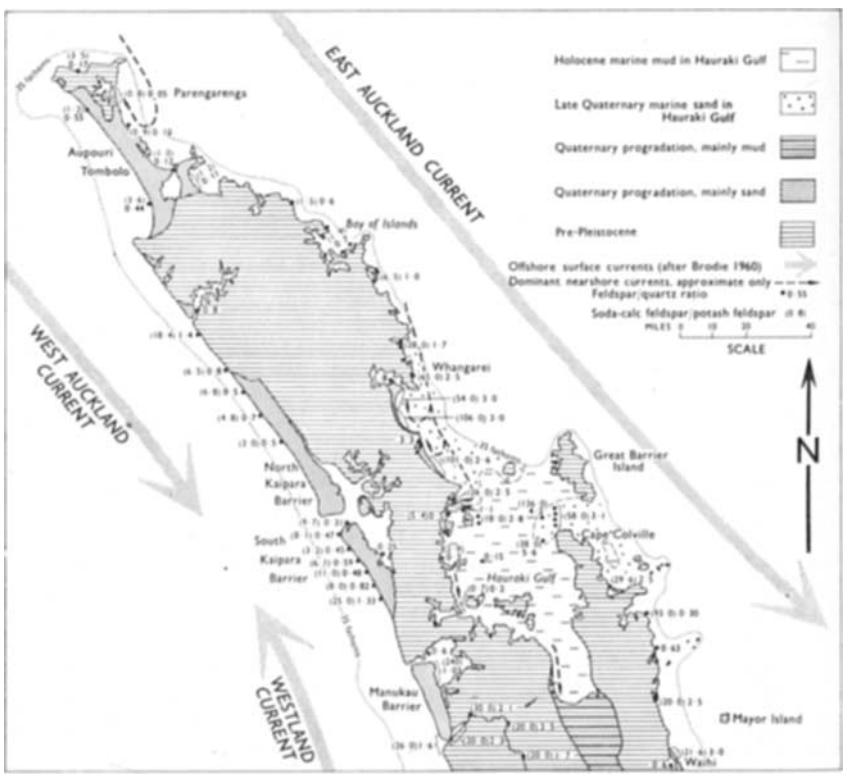

FIG. 15—Feldspar to quartz, and soda-calc feldspar to potash feldspar ratios in the Northland–Auckland region; areas of Quaternary progradation; and location of offshore and probable nearshore ocean currents.

fairly clear-cut regional facies to be determined. In determining these facies most of the samples have been restricted to modern river, beach, or marine sand, but some modern foredune sands have been included where these compare favourably with the adjacent beach sand. On the other hand, some samples, affected by local influences, have been left out during the averaging of the remainder but these have been very few. Localised averages were first made (Fig. 14) and where similar these were further grouped to form more regional averages (Fig. 14 and Table 14). The result has been the recognition of one marine facies in the Hauraki Gulf, Hauraki (A) Sand Facies; four coastal facies along the east coast—Parengarenga, Bay of Islands, Hauraki (B), and Orewa sand facies; one river facies, Waikato River Sand Facies; and only one coastal facies along the west coast—the West Auckland Sand Facies.

Egmont Blacksand Facies

There is an additional sand facies along the west coast that is described by Kear (1965)—black sand mainly derived from Mt Egmont, 130 miles southward. No further description is given here but because of its influence on the sands of the Manukau and South Kaipara Barriers, i.e., as far north as the convergence of the West Auckland and Westland Currents, it is here named the Egmont Blacksand Facies.

Waikato River, Hauraki (A) and Hauraki (B) Sand Facies

The Waikato River and Hauraki (A) sand facies have a high residue content (Table 14) composed chiefly of rhyolitic rock fragments and characterised by moderate amounts of pumice. Almost certainly the marine facies, Hauraki (A), found on the floor of the Hauraki Gulf, was deposited there when the Waikato River flowed into the gulf (Henderson, 1918) and when sea level was 300 ft or more lower than its present position. At this time the gulf floor would have been a vast terrestrial plain underlain mainly by rhyolitic sands with marginal fans built of more localised materials brought in by local streams. Since this plain became inundated by the sea, the

TABLE 14—Sand Facies—Their Broad Minerology on a Shell-free Basis

Sand Facies	Quartz	Total Feldspar	Mafic Minerals	Residue	F/Q*	Na/K†
Waikato River	19	39	4·1	37·9	2·0	23
Hauraki (A)	18	63	8·2	10·8	3·5	70
Hauraki (B)	25	67	3·8	4·2	2·7	72
West Auckland						
northern	58	29	4·5	8·5	0·50	3
central	55	34	6·2	4·8	0·62	5
southern	54	28	12·5	5·5	0·52	8
Parengarenga	90	9	0·7	0·3	0·10	1
Bay of Islands	35	27	2·5	35·5	0·77	3
Orewa	61	22	2·7	14·0	0·36	3

* F/Q = ratio of total feldspar to quartz.
† Na/K = ratio of soda-calc feldspar to potash feldspar.

greater part has been covered by marine mud except in areas where ocean currents have been strong enough to keep the mud from settling. There are two such areas—the Colville Channel and the northern portion of the gulf where it is not sheltered by the Coromandel Range and its extension, Great Barrier Island (Fig. 15). The latter area lies south-east of Whangarei Harbour and the sand on the sea floor extends down to 35 fm (Fig. 15) beyond which a belt of mud occurs. This 35 fm limit is probably the approximate depth to which ocean currents are able to keep the gulf floor free of mud in this area. Southwards, as the gulf becomes more and more sheltered this sand-mud contact shallows. Thus it is at about 20 fm in Omaha Bay (Schofield, 1967a) and less than 5 fm further south.

As well as high "residues" the Waikato River and Hauraki (A) sand facies have high feldspar/quartz ratios—2·0 and 3·5 respectively. The only other facies with a comparable ratio of 2·7 is Hauraki (B), the other six facies (Table 14) being 0·77 or less. Because of the high feldspar content, Hauraki (B) is almost certainly a coastal derivative from Hauraki (A), the prolonged coastal transport being sufficient to wash out the pumice and to lower the feldspar relative to the quartz, the latter being more resistant to transport. Concurrently the mafic material content has been lowered from 8·2% to 3·8%, and the "residue" from 10·8% to 4·2%.

The high "residue" in the Waikato River Facies probably means that besides erosion of the loose sediments of the Hinuera Formation and Taupo Pumice Alluvium, some rhyolitic rock is also being eroded by the Waikato River. On the other hand, the small quantities of "residue" in Hauraki (B) means that it has been little modified by the Bay of Islands Sand Facies which lies to the north. Nevertheless, some mixing of the Bay of Islands and Hauraki (B) Sand Facies has occurred in an intermediate area off Ngunguru (Figs. 10, 14, and 15) where intermediate quartz and feldspar values exist.

Although Dr K. R. Gill did not examine Hauraki (A), further evidence for relating the Waikato River (and thus Hauraki (A)) with Hauraki (B) Sand Facies lies in their similar mineral content. Dr Gill's examination of the mafic minerals (Fig. 16) shows that the order of dominance in the mafic silicates is ortho-pyroxene, hornblende, and clinopyroxene for both the Waikato River and Hauraki (B) Sand Facies. Also the soda-calc feldspar in both is andesine which is the common plagioclase in the acidic volcanic rocks of the Taupo Volcanic Zone (Ewart, 1966).

Orewa Sand Facies

The Orewa Sand Facies is localised along the west shores of the southern parts of the Hauraki Gulf where the coastal rocks and hinterland consist almost solely of the Waitemata Group. It is thus not surprising that mineralogically it closely resembles the Waitemata sandstone (p. 807 of Part 1—Distribution).

It is characterised by a moderately high average quartz content of 61%, and fairly low mafic-mineral and "residue" content. A southward directed longshore movement and differing coastal energies have modified this facies slightly (*see* p. 807 of Part 1—Distribution).

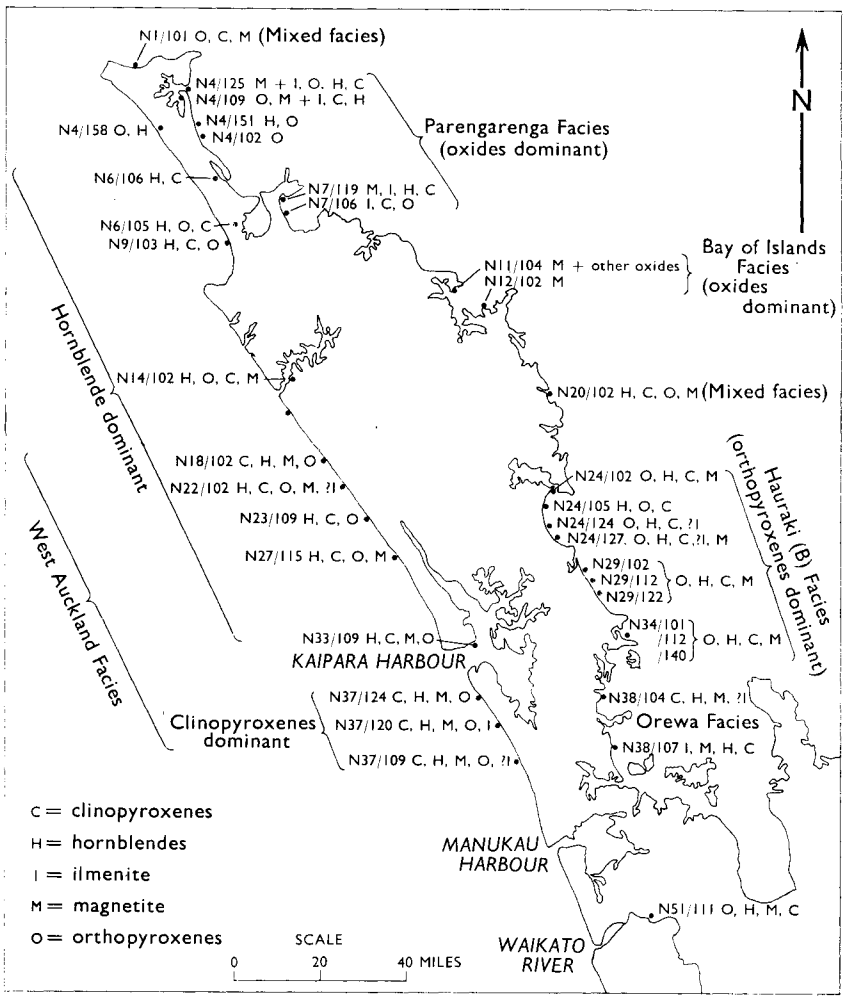

FIG. 16—Distribution of mafic minerals in their order of abundance as determined by Dr K. R. Gill. There is no abundant epidote as is recorded by Summerhayes (1969) for the North Cape region. Both Summerhayes and Gill used bromoform to separate out the heavy minerals but a check sample collected from the west end of Spirits Bay beach (where Summerhayes records epidote as being the most abundant heavy mineral) has been shown to contain little or no epidote, either under the microscope or by X-ray diffractometer (Dr A. Wodzicki, pers. comm.).

Insufficient samples of the mafic minerals have been examined to determine any dominance but in neither of the two samples studied by Dr Gill has orthopyroxene been detected. However, the orthopyroxene hypersthene, as well as augite, has been found in the local Waitemata sediments (Ballance, 1964).

Bay of Islands Sand Facies

The Bay of Islands Sand Facies (Table 14) is derived mainly by local coastal erosion of indurated sandwackes and siltwackes of Permian to Jurassic age. It is characterised by high "residue" and high shell contents; quartz and feldspar being almost equal. It occurs where there is practically no coastal progradation and where the marine floor falls steeply seawards compared with gentler slopes within the Hauraki Gulf and along much of the west coast (compare position of 35 fm contour in Fig. 15), i.e., it occurs in areas where little or no coastal sand is being derived from the sea floor. In view of these facts, its removal could mean a long period of time for replenishment

Parengarenga Sand Facies

The modern Parengarenga Sand Facies is restricted to the east coast between Parengarenga Harbour and Doubtless Bay. It has also been found as more ancient coastal deposits along the landward side of Kaipara Harbour (p. 788 of Part 1—Distribution). It is characterised by a very high quartz content, normally in excess of 90%, and by a silica content often in excess of 95%. Similar highly quartzitic deposits, but containing high percentages of primary clay, have been found as terrestrial and estuarine deposits in the Manukau and Kaipara Harbour areas.

Although minor amounts of the quartz in the Parengarenga area may be derived from nearby keratophyres the bulk is derived from nearby podsols. This conclusion is based on two facts. Firstly, the two areas in which the Parengarenga Sand Facies is important are also the only areas where mature, sandy podsols are prevalent (*see* maps and text of Taylor *et al.*, 1954). These podsols are formed by leaching processes enhanced by certain types of vegetation, and when mature, the sandy podsols include several inches of almost pure, angular, loose, quartz sand. Secondly, the high angularity of all but 15% of the Parengarenga Sand Facies at Parengarenga (p. 795 of Part 1—Distribution) means that the bulk of this material has not been sorted to the extent that would be required to separate quartz from other minerals if it were derived from rocks such as keratophyres after being reduced to sand by purely mechanical means.

The Parengarenga Sand Facies of the Aupouri Tombolo region is the only facies known to contain chromite which is most likely derived from the adjacent ultrabasic complex (Dr K. R. Gill, pers. comm.). In the northern and eastern parts of the Aupouri Tombolo the dominant mafic silicate is orthopyroxene but this dominance is usurped southwards by a green hornblende (Schofield, 1969).

West Auckland Sand Facies

The West Auckland Sand Facies has a remarkably consistent mineralogical content (Table 14) along a long coastline stretching from the Aupouri Tombolo to the South Kaipara Barrier (Figs. 14 and 15). The average feldspar-quartz ratio lies consistently between 0·5 and 0·62 but there does appear to be a northward increase in potash feldspar relative to soda-calc feldspars (*see* Na/K ratios, Table 14) which may mean that the sand in the northern regions has been transported greater distances—potash feldspar being more resistant to mechanical breakdown (Pettijohn, 1957)—or that derivation of the feldspars in the northern regions has been from a more potash rich source than that for the southern region.

As well as this regional trend, more localised trends can be recognised—namely decrease in both the feldspar/quartz and soda-calc/potash feldspar ratios, southwards along the North Kaipara Barrier and northwards along the South Kaipara Barrier (Fig. 15). These trends may be due to the wearing down of feldspar, particularly the wearing down of soda-calc feldspars, during their transport towards the Kaipara Harbour entrance, and is further evidence for the influence of the West Auckland and Westland Currents (p. 815 and Fig. 15), or they could be due to mixing with more quartzitic sands from Kaipara Harbour.

In accounting for the origin of the West Auckland Sand Facies, its widespread nature possibly provides part of the answer. It seems likely that not only are the west coast ocean conditions strong enough to quickly bring the west coast to maturity but they are powerful enough to rapidly mix several facies into one. For example, although large quantities of rhyolitic and highly feldspathic sand has been transported to the west coast by the Waikato River, in amounts probably equal to or in excess of the quantity it transported to the Hauraki Gulf, there remains no such facies as the Hauraki (B) Sand Facies which is still found widespread on the east coast. Similarly, although highly quartzitic dune and estuarine sands, almost identical to the Parengarenga Sand Facies, are present within the shelter of the Kaipara and Manukau Harbours, they have lost their identity along the open west coast. Another important facies not found along the west coast is the Orewa Sand Facies which is essentially derived by erosion of the Waitemata Sandstones. Yet in view of the widespread nature of the Waitemata Group and of its progenitors such material must also be present along the west coast.

The order of dominance of the mafic silicates within the West Auckland Sand Facies north of the Kaipara Harbour entrance is hornblende, clinopyroxene, and orthopyroxene. The contribution of mafic minerals from the Parengarenga Sand Facies and of orthopyroxene from the Orewa Sand Facies would have been negligible and thus it is not surprising that the dominant orthopyroxene of the Waikato River Facies is no longer dominant in the West Auckland Facies.

South of the Kaipara Harbour entrance the order of dominance in the mafic silicates is clinoyproxene, hornblende, and orthopyroxene, i.e., the latter still holds the minor position but clinopyroxene is dominant over hornblende. This change is probably the result of mixing with the Egmont Blacksand Facies in which the order of dominance in the mafic silicates is also clinopyroxene, hornblende, and orthopyroxene (Gow, 1967).

CONCLUSIONS

The West Coast of the Auckland–Northland region is distinguished by its straightness and by its large deposit of coastal sand, both in offshore positions (McDougall and Brodie, 1967) and in onshore barriers that rise to over 900 ft above sea level. These large barriers have been in existence since at least early Pliocene times, the west coast shoreline having been essentially stable since then. Slight differences in the otherwise well mixed and widely distributed West Auckland Sand Facies show that distribution of sand along the west coast has been dominated by the major West Auckland and Westland Currents described by Brodie (1960).

In contrast to the west coast, the east coast is crenellated and characterised by the presence of four localised coastal facies which have retained their identity instead of being mixed as is the case with the derivation of the West Auckland Sand Facies. The crenellated coastline has also caused local coastal eddies so that many of the east coast spits have grown north-westwards in a direction opposite to the trend of the East Auckland Current. The east coast is further characterised by only small amounts of prograded coastal deposits when compared with the large amounts on the west coast. This difference may be due to both or either of two causes—relative lack of sedimentary supply and less wave energy along the east coast. Sedimentary supply is certainly important in the derivation of the coastal Hauraki (B) Sand Facies. This facies extends from slightly north of Whangarei southwards to Tokatu Point, forming the most extensively prograded region along the east coast. It coincides with an extensive offshore belt of sand that extends down to 35 fm (Fig. 15). Northwards, this 10- to 15-mile-wide belt of offshore sand narrows to 2 miles and less, whereas southwards it is replaced by offshore sandy silt and mud. The highly feldspathic nature of both the coastal and offshore sands in this region, as distinct from the more quartzitic Orewa Sand Facies and the quite different Bay of Islands Sand Facies, shows that the coastal Hauraki (B) Sand Facies has been derived mainly from offshore deposits. It also demonstrates that both factors—namely a local source of marine sand supply, and wave energy—have been important in causing the greater amounts of progradation in this region.

It seems likely, therefore, that the greater amounts of west-coast progradation may be controlled by similar factors. Here, wave energy is likely to be greater and wave base is likely to be deeper than those on the east coast for the prevailing winds are from the west. There also seems to be a consistently wide belt of offshore sand extending to depths below 50 fm from at least Kaipara Harbour southwards to Mt Egmont (McDougall and Brodie, 1967). Judging from rather scattered information on the marine charts this belt is likely to persist northwards to areas beyond the Aupouri Tombolo.

It can be concluded, therefore, that, although stream and coastal erosion of rocks must be the ultimate source of all sand in the Northland–Auckland region, it seems that much of this material was initially stockpiled in the form of offshore belts; but, as lowering of sea level has been the overall trend during the Quaternary, there has been a shoreward movement of material from this stockpile to produce the extensive, ancient barriers along the west coast and the lesser areas of progradation along the east coast.

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REFERENCES

BALLANCE, P. F. 1964: The sedimentology of the Waitemata Group in the Takapuna Section, Auckland. *N.Z. Jl Geol. Geophys. 7 (3)*: 466–99.

BROTHERS, R. N. 1954: The relative Pleistocene chronology of the South Kaipara District, New Zealand. *Trans. R. Soc. N.Z. 82*: 677–94.

BRODIE, J. W. 1960: Coastal surface currents around New Zealand. *N.Z. Jl Geol. Geophys. 3 (2)*: 235–52.

EMERY, K. O. 1938: Rapid method of mechanical analysis of sands. *J. sedim. Petrol. 8 (3)*: 105–11.

EWART, A. 1966: Review of mineralogy and chemistry of the acidic volcanic rocks of Taupo Volcanic Zone, New Zealand. *Bull. Volcan. 29*: 147–72.

GOW, A. J. 1967: Petrographic studies of ironsands and associated sediments near Hawera, South Taranaki. *N.Z. Jl Geol. Geophys. 10 (3)*: 675–96.

HAYES, J. R.; KLUGMAN, M. A. 1959: Feldspar staining methods. *J. sedim. Petrol. 29 (2)*: 227–32.

HENDERSON, J. 1918: Notes on the geology of the Waikato Valley near Maungatautari. *N.Z. Jl Sci. Technol. 1*: 56–60.

KEAR, D. 1964: Coastal sand deposits—north-western North Island. *N.Z. Jl For. 9 (2)*: 139–45.

——— 1965: Geology of New Zealand's ironsand resources. *Publs. 8th Commonw. Min. Metall. Congr. (Austr. and N.Z.), Paper 219.*

KEAR, D.; HAY, R. F. 1961: Sheet 1, North Cape, "Geological Map of New Zealand, 1 : 250,000". Department of Scientific and Industrial Research, Wellington.

MCDOUGALL, J. C.; BRODIE, J. W. 1967: Sediments of the Western Shelf, North Island, New Zealand. *Mem. N.Z. oceanogr. Inst. 40. (Bull. N.Z. Dep. scient. ind. Res. 179.)*

PETTIJOHN, F. J. 1957: "Sedimentary Rocks." Harper, New York.

SCHOFIELD, J. C. 1958: Pliocene shell beds south of Manukau Harbour. *N.Z. Jl Geol. Geophys. 1 (2)*: 247–55.

*Present address: Geology Department, University of Queensland, Brisbane, Australia.

SCHOFIELD, J. C. 1967a: Sand movement at Mangatawhiri Spit and Little Omaha Bay; with appendices by P. E. Hyde, W. F. Ponder, H. R. Thompson, and J. C. Schofield. *N.Z. Jl Geol. Geophys. 10 (3)*: 697–731.

——— 1967b: Sheet 3, Auckland. "Geological Map of New Zealand, 1 : 250,000." Department of Scientific and Industrial Research, Wellington.

——— 1969: Reconnaissance survey of silica sands, Parengarenga. *In* Industrial minerals and rocks 1968: *Inf. Ser. Dept scient. ind. Res. 63*: 76–92.

——— (in press): Industrial sands of Northland and Auckland. *In* Industrial minerals and rocks 1969. *Inf. Ser. Dep. scient. ind. Res. 63.*

SUMMERHAYES, C. P. 1969: Recent sedimentation around northernmost New Zealand. *N.Z. Jl Geol. Geophys. 12 (1)*: 172–207.

TAYLOR, N. H. *et al.* 1954: General survey of the soils of North Island, New Zealand. *N.Z. Soil Bur. Bull. n.s. 5.*

THOMPSON, B. N. 1961a: Sheet 2A, Whangarei. "Geological Map of New Zealand 1 : 250,000." Department Scientific and Industrial Research, Wellington.

——— 1961b: Sheet 2B, Barrier. "Geological Map of New Zealand 1 : 250,000." Department of Scientific and Industrial Research, Wellington.