BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1982/1

THE NATURE AND MINERALOGY OF BEACH AND DUNE SANDS ON THE CENTRAL AND NORTHERN NEW SOUTH WALES AND SOUTHERN QUEENSLAND COASTS

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CONTENTS

ABSTRACT

A study of 167 beach and dune sand samples collected from the east coast of Australia between Newcastle and Fraser Island indicates that the sands are typically quartzose ($>$ 90% quartz), fine-medium grained, and well or very well sorted with high kurtosis values. The beach and foredune sands have skewness values ranging from positive to negative with a fairly strong tendency towards negative values, probably produced by winnowing in the beach zone. Pleistocene and transgressive dunes appear from earlier evidence to be mainly positively skewed.

The heavy-mineral fraction of the sands is typically composed of opaques (ilmenite, magnetite, leucoxene, opaque rutile and iron oxides), tourmaline, zircon, translucent rutile, hornblende, epidote and pyroxenes, with lesser amounts of garnet, andalusite, monazite, apatite and staurolite. This assemblage is similar to the assemblages encountered in nearshore sand bodies sampled during the 1980 cruise of the research vessel Sonne. The heavy minerals are probably derived from a variety of sources which include Tertiary volcanics, Palaeozoic metamorphics and Precambrian schists and gneisses.

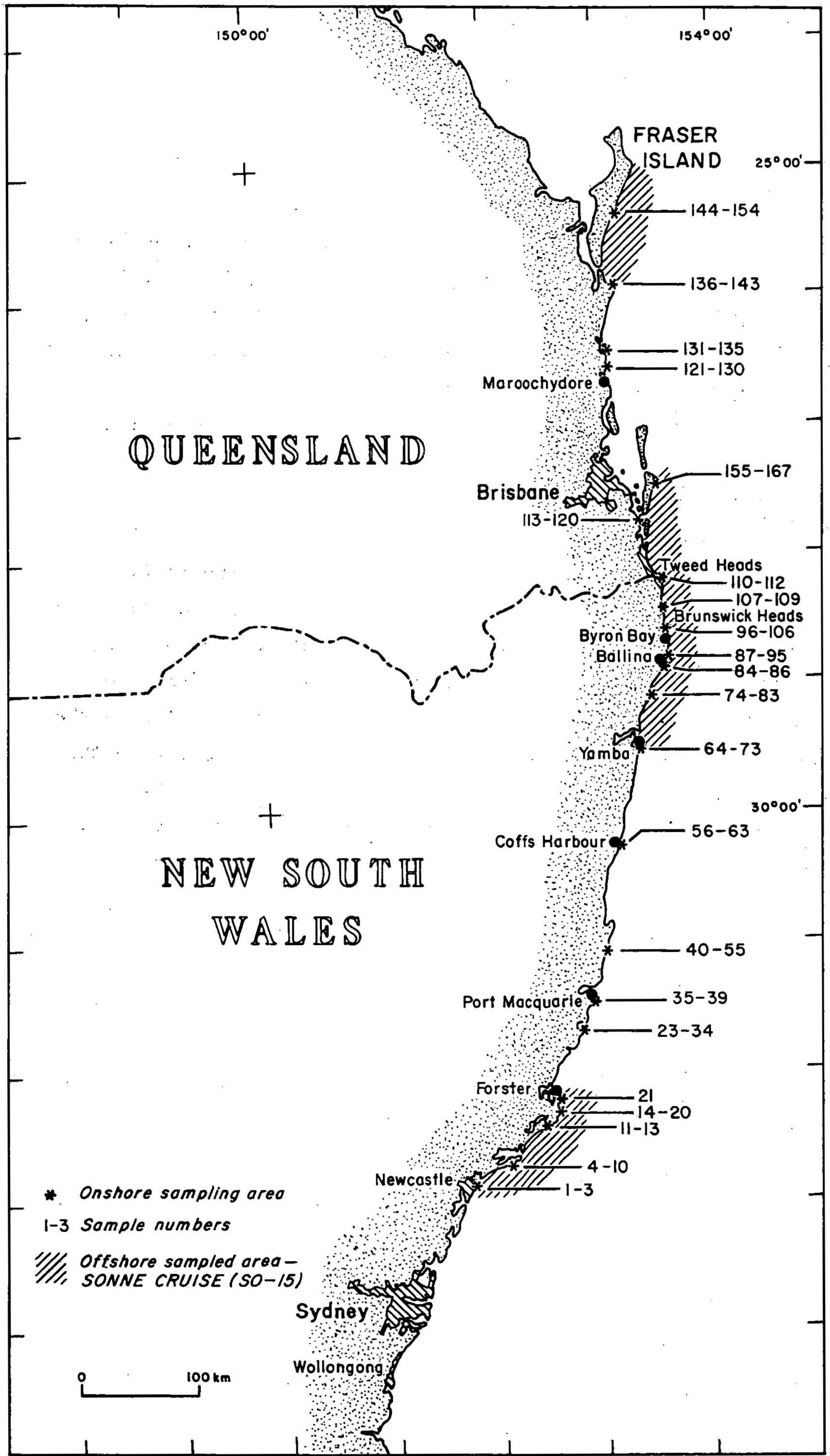


Fig.1 Location of the Sampling Areas

INTRODUCTION

Between 19 February and 3 March 1981, a program of beach and dune sampling was undertaken on the central and northern New South Wales and southern Queensland coasts. The aim of this work was to provide, in a reconnaissance survey, information on the texture and mineralogy of the coastal sands, particularly the heavy-mineral fraction, to enable a comparison to be made between sediments collected on the east Australian continental shelf in 1980 by the West German research vessel *Sonne* and the modern beach/dune sands.

Previous work

Although fairly detailed studies have been made of the economic minerals in the main heavy-mineral placer and dune deposits on the east coast (e.g. Beasley, 1948, 1950; Gardner, 1955; Whitworth, 1959), little work has been undertaken to determine the textural characteristics of the beach/dune sands or their total heavy-mineral compositions. Exceptions to this on parts of the coast include Hails (1967, 1969) and Ly (1978).

Nature of the coast

The central and northern New South Wales and southern Queensland coasts are high-energy coasts characterised by zeta-shaped or arcuate bays consisting of sand barriers bordering fluvial-deltaic plains (Langford-Smith & Thom, 1969; Hails, 1967). The barriers, which are generally flanked at either end by bedrock headlands, commonly form two systems, the inner (Pleistocene) and outer (Holocene) barriers, separated by inter-barrier swamps or lagoons. The modern beach and foredune form the seaward margin of the Holocene barrier.

METHODS

Sampling was undertaken between Newcastle and Fraser Island (Fig. 1). It was concentrated in four areas (Newcastle-Forster, Yamba-Byron Bay, Brunswick Heads-North Stradbroke Is., and southern Fraser Island) onshore of the four areas sampled during the 1980 *Sonne* cruise. In all, 154 beach sand samples and 13 dune samples were taken (Table 1). Most of the beach samples were collected at approximately the high tide mark.

In all cases, the sample was taken over an area of approximately $2m^2$ and down to a depth of about 2cm. The material was then split to approximately 4kg.

In the laboratory, the samples were washed in fresh water and oven dried at $80^{o}C$. A 2g and a 100-200g split were then prepared for grainsize and heavy-mineral analysis, respectively.

The grainsize analyses were carried out with a settling tube, and moment measurements of mean grainsize, standard deviation (sorting), skewness and kurtosis computed (see Mayo, 1972). Heavy-mineral analyses were carried out by static separation of the light and heavy-mineral fractions in tetrabromoethane (sp. gr. 2.96), followed by counting of between 400 and 600 grains of the heavy-mineral fraction under a polarising microscope using the "ribbon" grain counting technique of Galehouse (1971). This produces results as "number percents" which, because of the generally well-sorted nature of the heavy-mineral separates in the study, closely approximate volume percentages.

RESULTS

(1) GRAINSIZE ANALYSES

Beach Sands

Although coarse-grained moderately-sorted beach sands occur in places along the coast (e.g. in the Hills-Kororo Beach area, Fig. 1 sample numbers 61-63) most of the beach sands sampled are fine to medium grained and well sorted (Figs. 2, 3 & Appendix 1). This uniformity in texture probably reflects: the relatively uniform high wave energy conditions along the coast (Thom and others, 1973, 1978), the present-day low level of sand-size sediment input from coastal rivers (Ford, 1963; Roy, 1977), the probable movement and mixing of sand during and immediately after periods of low sea-level, and the present-day tendency (particularly in the far north) for sand to undergo northward littoral drift along beaches and around headlands. This latter movement, which is produced by the oblique orientation of the beaches with respect of the predominant southeasterly swell, tends to be inhibited south of about 32°S by the more normal alignment of beaches to the predominant swell and by prominent headlands which tend to strongly compartmentallize embayments (Thom and others, 1978; Roy and others, 1980; Roy & Thom, 1981).

The sands, which are typically quartzose ($>$90% quartz), are unimodal. Most of them have high kurtosis values indicating a high degree of peakedness compared to a lognormally distributed grainsize population.

Skewness values range from positive (fine-skewed) to negative (coarse-skewed) with a fairly strong tendency towards negative values (Fig. 2C). This tendency, which was also noted by Ly (1978), is probably caused by the preferential removal of the finer fraction from the size distribution by winnowing (see Friedman, 1961).

The beach sands are, in general, better sorted and coarser grained than "nearshore sands" (Fig. 4), which extend extend from the shoreline down to about 30m of water and form large accummulations off prominent

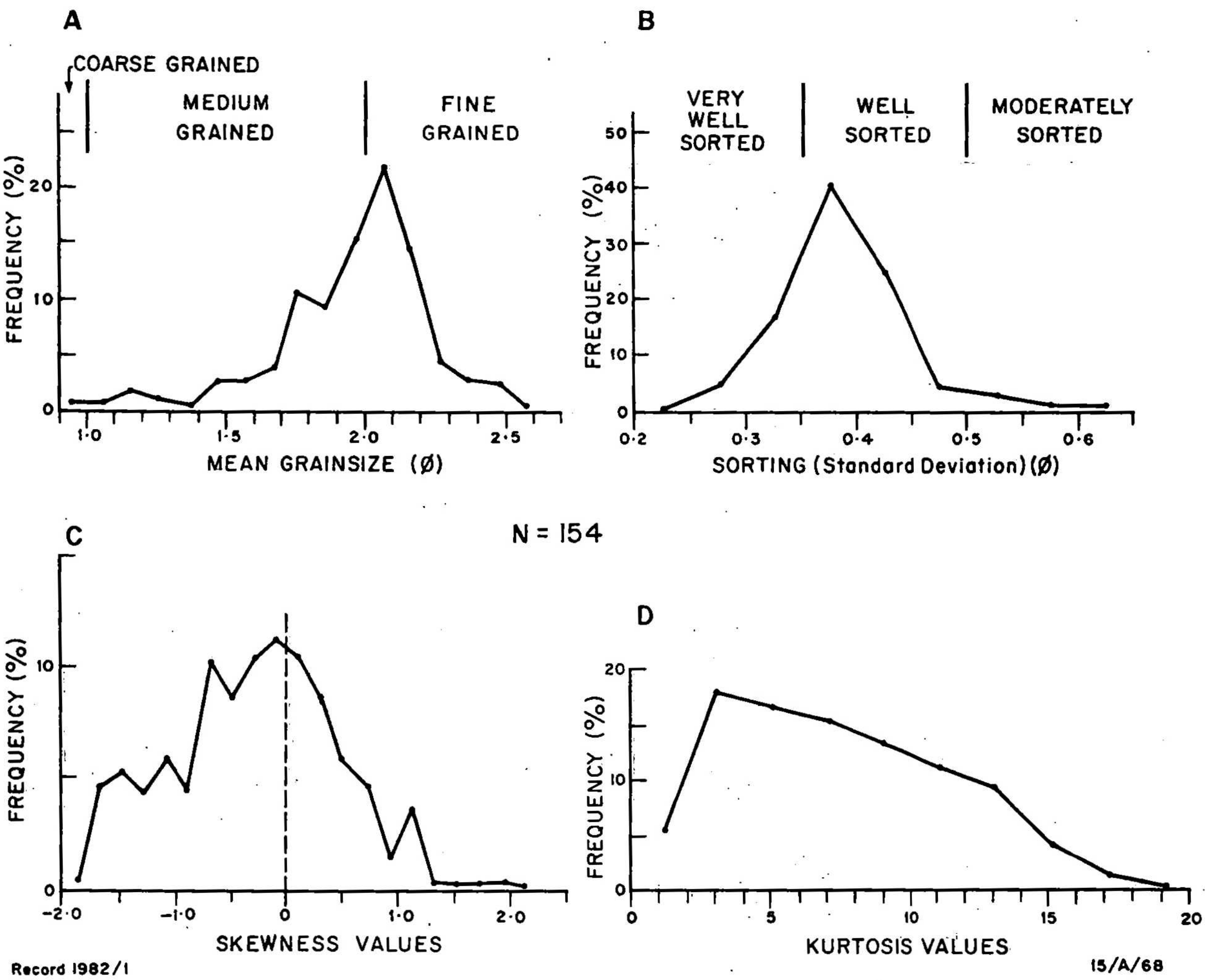
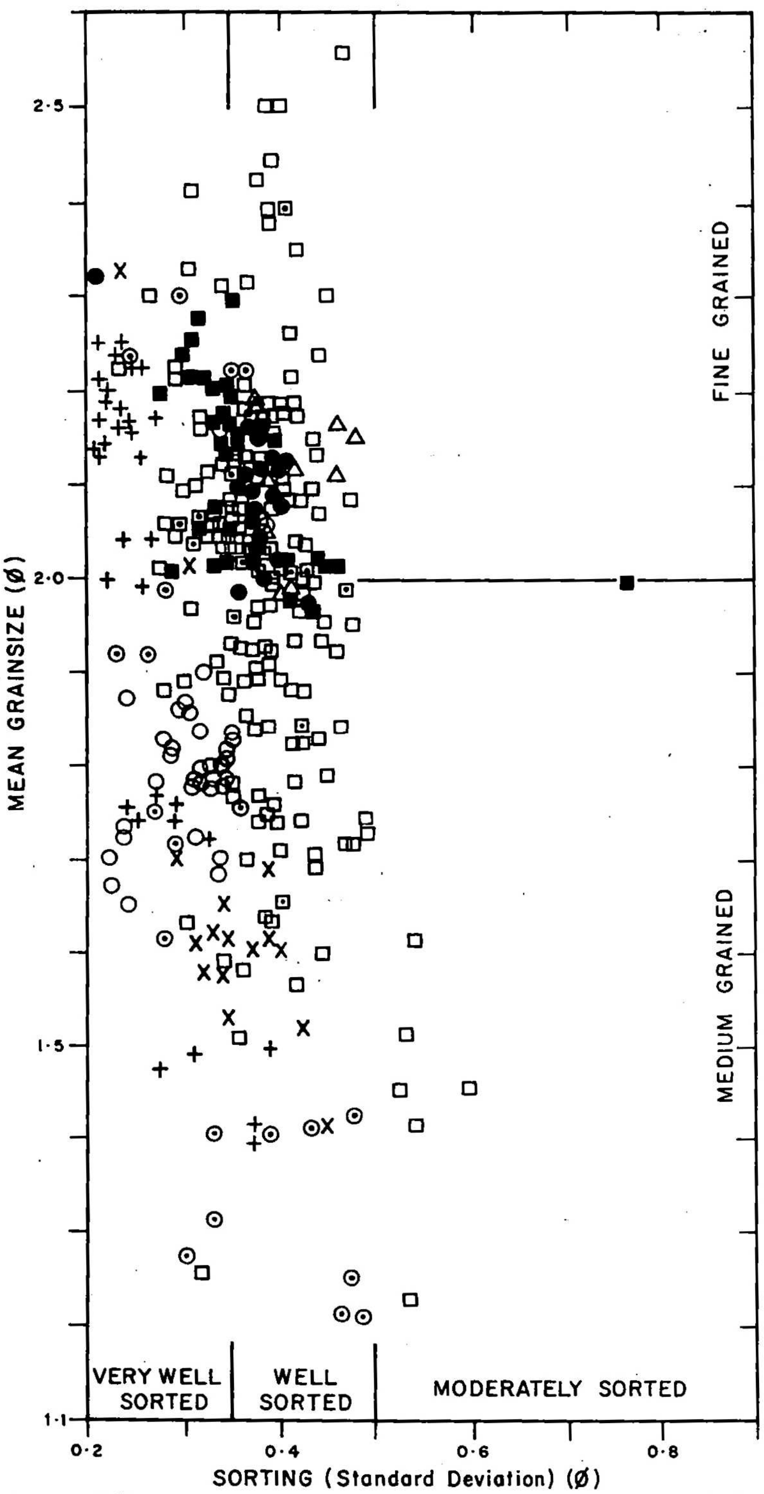


Fig. 2 Summary of the Grainsize Characteristics of the Beach Sands. Plots shows Frequency Distributions.



□ Modern Beach Sands, } Newcastle –
⊡ Dune Sands, } Fraser Island

FROM HAILS (1967):
○ Inner Barrier Sands (Pleistocene), } Hat
● Outer Barrier Sands (Holocene), } Head
△ Inner Barrier Sands, Killick Creek
■ Outer Barrier Sands, Front Beach

FROM LY (1978):
+ Mobile Transgressive Dunes, } Newcastle–Port Stephens area
X Frontal Ridge Sands,
⊙ Beach Sands

NOTE: *Some moderately-well sorted coarse-grained sands (not shown on this diagram) occur on the central part of Newcastle Bight and in the Hills–Kororo Beach area.*

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Fig.3 Plots of Mean Grainsize and Sorting of Sands from various Environments on the East Australian coast.

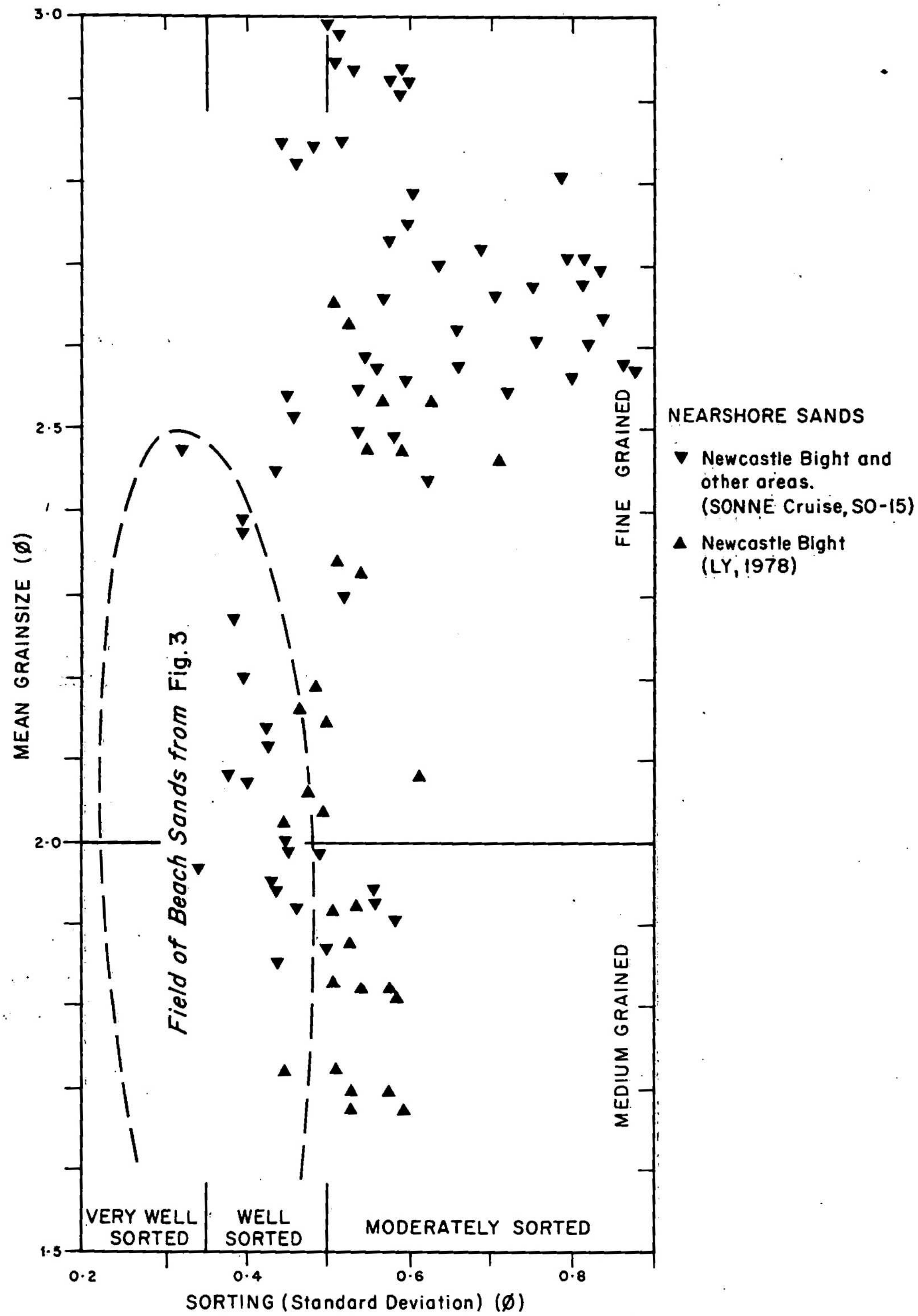

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Fig. 4 Comparison between the Mean Grainsize and Sorting of the Beach and Nearshore Sands.

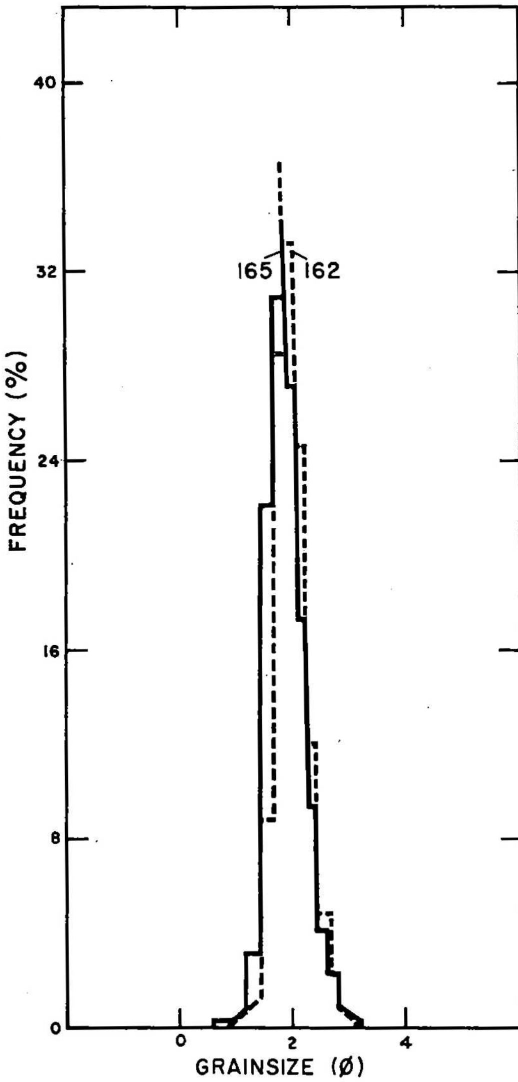
headlands (Roy & Crawford, 1980; Colwell and others, 1981). This difference between the two sands is probably caused by the high wave (sorting) energy of the beach zone and the movement of finer sand material into the nearshore zone as a result of winnowing.

The nearshore sands contain the highest heavy-mineral concentrations recorded during the Sonne cruise. This reflects the fact that the nearshore sands form a continuation to the modern-day beach profile whereas the other sediments sampled during the Sonne cruise are largely either Holocene partly relict marine sands or Pleistocene-Early Holocene paralic sediments which appear to have undergone partial reworking with marine transgressions. There is little evidence from the Sonne cruise for the preservation of Holocene barriers on the shelf - most of the sand originally in the barriers apparently moved landwards with the advancing shoreline of the Holocene transgression to form a major part of the present-day coastal beach/dune and nearshore deposits. A similar reworking of uncemented barrier deposits probably took place in the Pleistocene.

Dune Sands

Only a few sands were collected during the survey (Table 1). However, the results of these analyses, and the work of Hails (1967) in the Port Macquarie-Hat Head area and of Ly (1978) in the Newcastle-Port Stephens area, indicate a close similarity in mean grainsize and sorting between the modern beach sands and the adjacent dune sands (see Figs. 3 and 5).

There is, however, evidence from Ly (1978) and Hails (1967) that sands of mobile transgressive dunes in the Newcastle-Port Stephens area and of Pleistocene dunes in the Port Macquarie-Hat Head area tend, unlike the present-day beach and foredune sands, to be positively rather than negatively skewed. This may be due to aeolian transport, involving the preferential movement of fine material over coarser material, an effect which would be expected to increase with time or distance of transport of the material away from its source. A similar trend favouring positive skewness (as measured by the method of moments) was noted by Friedman (1961) and Chappel (1967) for dune sands from a variety of locations and environments within the United States and elsewhere. A discussion of other possible reasons for the positive skewness of dune sands is given by McLaren (1981).



	MEAN	ST. DEV.	SKEWNESS	KURTOSIS
---- BEACH SAMPLE (162)	2·0	0·34	−0·15	9·11
—— DUNE SAMPLE (165)	1·9	0·36	−0·18	8·00

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Fig.5 Grainsize distribution histogram of a typical beach sample and the adjacent dune sample

The similarity in mean grainsize and sorting between the beach sands and the adjacent dune sands (Figs. 3 and 5) of course reflects the fact that the Holocene dune and foredune sands originate by deflation of the adjacent beach under the influence of the onshore winds which predominate along this stretch of the coast. This movement of sand, which in many cases produces a major loss of sediment from the beach zone (see for example Newcastle Bight; Roy & Crawford, 1980), may be interrupted by (1) dune stabilisation and (2) wave erosion (see Thom, 1974).

(2) HEAVY-MINERAL ANALYSIS

Previous work on the heavy-mineral deposits of the central and northern New South Wales and southern Queensland coasts (principally Beasley, 1948, 1950; Gardner, 1955; Whitworth, 1959; Connah, 1961; Peterson, 1965; Winward, 1974; Gardiner, 1975; and Cooper and others, 1979) in general indicates that:

(1) Heavy minerals occur mainly as beach placers in both the inner (Pleistocene) and outer (Holocene) barriers and as disseminated deposits in high dunes. Lesser deposits occur beneath inter-barrier swamps.

(2) The beach placers commonly consists of rich seams enclosed by largely barren sand. The rich seams consist almost entirely of zircon, rutile and chromite-rich ilmenite with minor monazite, and can in some cases be traced for a few thousand metres along the coast and for several tens of metres across strike. In most areas these seams have been extensively mined.

(3) The highest and thickest and now largely worked-out concentrations tend to occur at the northern end of beaches (abutting headlands) where the predominant southeasterly swell has its greatest effect.

(4) Although heavy-mineral accumulations commonly occur on present-day beaches, they are rarely preserved owing to subsequent wave and wind action.

The work cited above was concerned mainly with the principal mining areas and concentrated upon the major economic minerals rutile, zircon, monazite and ilmenite[1]. The present study differs from the above studies in examining quantitatively the total heavy-mineral fraction of beach and dune sands along the coast; previous work of this sort is restricted mainly to the work of Hails (1969) on the mid-north coast.

The results of the present study are given in Figure 6 and in more detail in Appendix 2. They show that in addition to zircon, rutile, ilmenite and monazite, other minerals - notably magnetite, tourmaline, hornblende, leucoxene, pyroxene and epidote but including garnet, andalusite, apatite and staurolite - make up a major proportion of the heavy-mineral fraction of the beach and dune sands.[2]

The composition of the heavy-mineral fraction of the sampled beach and dune sands differs quite considerably from that of the "beach sand concentrates" of areas mined during the 1940's and 1950's which, according to Whitworth (1959), contained only about 3% of minerals other than zircon, rutile, ilmenite. This difference in mineralogy probably results from a high degree of concentration of the heavier heavy minerals (notably zircon, rutile, ilmenite and monazite with specific gravities >4.2) in the beach placer deposits ("beach sand concentrates") leaving the heavy-minerals fraction of the surrounding sand relatively enriched in the lighter heavy minerals and, in a number of areas, the selective removal of rutile, zircon, ilmenite and monazite from the sands by mining.

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1. In some previous cases (e.g. Gardiner, 1975), determinations of the respective percentages of the various economic minerals were made solely from mine production figures.

2. A similar list of accessory minerals was given by Whitworth (1959) (with no abundances) and by Hails (1969), and also applies to the offshore situation (see Colwell and others, 1981).

Fig. 6 Heavy–Mineral Assemblages on the East Coast

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As shown in Figure 6, considerable variations occur in the composition of the heavy-mineral assemblage present in the sands along the coast. These variations reflect a number of factors including differential sorting of the suites due to variations in the specific gravities of the heavy minerals and differences in wave and wind energy (e.g. the high tourmaline values between Sugarloaf Bay and Forster), past mining (e.g. the low zircon, rutile and monazite values in the Crescent Head-Hat Head area), and input from local sources, for example the increase in hornblende at the northern end of Newcastle Bight (a feature attributed by Ly, 1976, to the erosion of nearby Carboniferous volcanics), and the increase in garnet on northern New South Wales and southern Queensland beaches (probably coming from either Palaeozoic metamorphics or Jurassic sediments). Unfortunately, in most areas insufficient sampling has been undertaken to identify specific local variations of the sort identified by Hails (1969).

A comparison between the results of this study and the results of initial analyses of sediments sampled during the Sonne cruise (See Colwell and others, 1981), indicate a general similarity between the heavy-mineral fraction of the beach sands and of the nearshore sands; the proportion of unstable heavy minerals increases on the middle and outer shelf (von Stackelberg & Riech, 1981).

PROVENANCE OF THE HEAVY MINERALS

The question of the provenance of the heavy minerals on the east coast has been discussed and debated by a number of workers, e.g. Beasley (1948, 1950), Gardner (1955), Whitworth (1959), Hails (1969), Winward (1974) and Byrnes (1975). Unfortunately, a number of factors - the fairly complex geology of eastern Australia (Fig. 7), the probably multicyclic nature of many of the heavy minerals, and the complex history of Quaternary sedimentation on the shelf (longshore drift, sediment movement with sea-level change, etc.) - make the identification of specific sources for many of the minerals difficult.

Overall, the currently available evidence (mainly from Gardner, 1955 and Whitworth, 1959) suggests that:

1. Most of the rutile, zircon and monazite (ultrastable) are derived from the rocks of the Precambrian shield of central Australia. Most of this material has probably undergone fairly extensive recycling

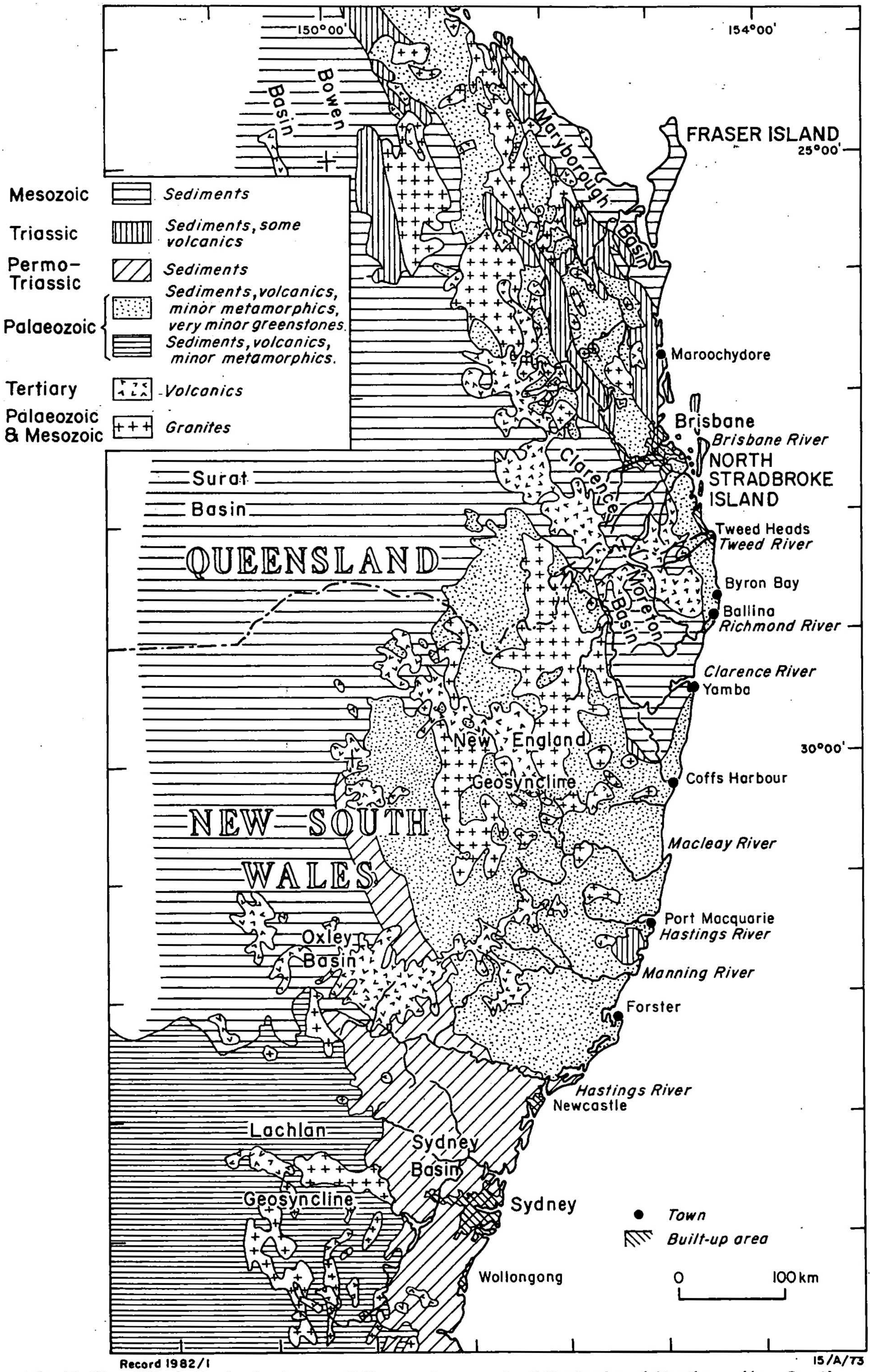
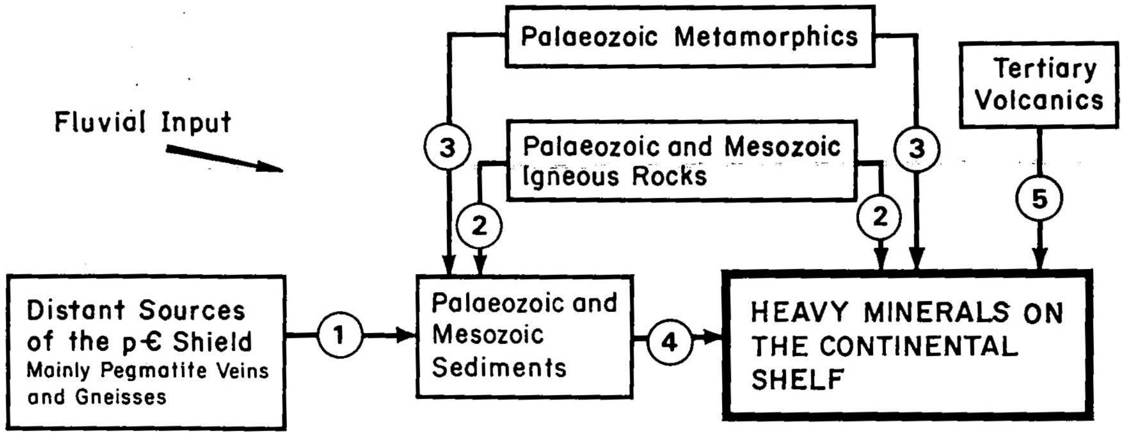


Fig. 7 Simplified Geological map of the eastern part of Central and Northern New South Wales and Southern Queensland. (Quaternary units not shown).

SOURCES



FACTORS INFLUENCING THE FINAL CONCENTRATION OF HEAVY MINERALS ON THE PRESENT - DAY BEACHES

1.... *WAVE ENERGY*
2... *STORMINESS*
(Effecting sorting within the Beach Zone)

3.... *SEA LEVEL CHANGE (Major sediment movement onshore during Marine Transgressions)*

4.... *LONGSHORE SEDIMENT MOVEMENT*

5.... *DIAGENETIC EFFECTS (e.g. The diagenetic conversion of Ilmenite to Leucoxene)*

MAJOR HEAVY MINERALS

1 Rutile, Zircon, Tourmaline, Monazite, Garnet, Staurolite

2 Magnetite, Tourmaline, Pyroxenes, Ilmenite, Hornblende, Epidote, Apatite, Zircon, (Monazite), (Rutile)

3 Andalusite, Staurolite, Epidote, Garnet, Apatite, Hornblende, (Monazite)

4 Rounded Rutile, Zircon, Tourmaline, Monazite, Garnet, Staurolite

5 Ilmenite, Magnetite, Pyroxenes, Hornblende

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Fig. 8 Summary of the Postulated Provenance of the East Coast Heavy-Mineral Sands through various Phanerozoic sediments, the last major stage of which was probably the erosion of Mesozoic sandstones of the Clarence-Moreton and Sydney Basins (Fig. 7). A less significant contribution, particularly in the case of zircon, comes from Palaeozoic and Mesozoic granites (Byrnes, 1975).

2. The remainder of the heavy minerals, except for much of the garnet (which is probably derived from the Precambrian schists and gneisses of central Australia), are most likely much younger than most of the rutile, zircon and monazite. They come from a variety of sources which include granites and pegmatites, volcanics, and low to medium-grade metamorphic rocks of various ages.

A summary of the postulated provenance of the minerals and the factors influencing their final concentration on the present-day beaches is given in Figure 8. Although highly likely, most of the routes shown in this Figure remain to be validated (if this is possible in some cases) either by extensive sampling of drainage basins and probable source rocks, or by other means, for example the radiometric dating of various types of zircon (rounded, zoned etc) and monazite. Some work along these lines is currently being undertaken at Aachen and the Australian National Universities.

SUMMARY AND CONCLUSIONS

1. The beach and dune sands sampled between Newcastle and Fraser Island are typically fine to medium grained and well or very well sorted. This uniformity in texture probably results from the fairly uniform high energy conditions of the coast, the present-day low level of sediment input from coastal rivers, longshore drift, and the mixing and movement of sands during and immediately after periods of low sea level. The sands are typically quartzose ($>$ 90% quartz). Grains are typically angular to subround.

2. The beach and foredune samples range from positively to negatively skewed (as measured by the method of moments), although most are negatively skewed. This tendency towards negative values probably results from the winnowing and transport of finer material by wave action.

3. The composition of the heavy-mineral fraction varies somewhat along the coast, probably as a result of sorting, input from local sources and past mining. In general, the main components of the heavy-mineral fraction are opaques (ilmenite, magnetite, leucoxene, opaque rutile and iron oxides), tourmaline, hornblende, zircon, translucent rutile, epidote and pyroxenes, with lesser amounts of monazite, apatite, garnet, staurolite and andalusite.

4. The heavy minerals are almost certainly derived from a variety of sources which include Precambrian schists and gneisses, Palaeozoic metamorphics, and Phanerozoic igneous rocks.

ACKNOWLEDGEMENT

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Table 1 Location of Samples

1-3	Stockton Beach, s. end Newcastle Bight
4-6	Northern end Newcastle Bight
7	" " " " . Foredune
8	" " " " . Holocene dunes
8A	" " " " . Pumice layer
9-10	Anna Bay
11-13	Sugarloaf Bay
14-16	S. end of Wallis Lake Beach
17-18	Central part Wallis Lake Beach
19-20	Northern end Wallis Lake Beach
21	Forster (One Mile) Beach
22-25	Rainbow Beach, s. end, near Bonnie Hills
26-28	Lake Cathie Beach
29-31	Lighthouse Beach between L. Cathie and Pt. Macquarie
32-34	N. end of Lighthouse Beach, Pt. Macquarie.
35-36	S. end Pt Macquarie - Pt Plomer beach. High tide mark.
37-39	South of Pt. Plomer
40-42	North of Pt. Plomer
43-45	Big Hill Point - Delicate Nobby. High tide.
46-48	Just south of Crescent Head
49	Crescent Head. Wet concentrate.
50-51	Killick Beach
52-54	Just south of Hat Head, Killick Beach
55	Just south of Hat Head, Killick Beach, dune
56-60	Park Beach, Coffs Hbr.
61-63	Hills-Kororo Beach
64-73	Yamba to just north of Angourie Pt.
74-75	S. of Evans Hd. Point
76	Just N. of Evans Hd. Point
77-78	Dunes behind Evans Hd. Point
79-81	Evans Hd. township beach
82-83	Broadwater Beach
82A	Sandrock
84-86	South Ballina Beach
87-88	Whites Point Beach
89-91	Lennox Head township beach
92	Lennox Head township beach. High beach

93-95	Beach just south of Broken Head
96-98	Suffolk Park Beach
99-102	Just south of Cape Byron
103-105	Just north of Cape Byron
106	Just north of Cape Byron. High tide level
110-112	Kingscliff Beach
113-118	Southport Spit north from "Seaworld"
121-125	Alexandra Hd. - Maroochydore
123A	Sandrock
126-127	Mooloolabah Beach
128-130	Coolum Beach
131-132	Peregian Beach
133	Peregian Beach. Foredune
134-135	Ocean Beach
136	Rainbow Beach. Dunes
137-143	Rainbow Beach, mid-tide level
144-154	Hook Pt. to approx. 8 km south of Happy Valley, Fraser Island.
155-157	High dunes N. Stradbroke Is.
158-163	N. Strad. Island, south of Pt. Lookout
164-167	Dune sands, immediately inland of foredune near Pt. Lookout, N. Strad. Is.

All samples, unless otherwise stated, are from approximately the high tide mark.

APPENDIX 1 - GRAINSIZE DATA

SAMPLE	MEAN GR.SIZE	ST. DEV.	SKEW-NESS	KURTOSIS	SAMPLE	MEAN GR.SIZE	ST. DEV.	SKEW-NESS	KURTOSIS
1	2.02	.37	-.95	12.39	35	1.80	.45	-0.20	3.64
2	1.93	.37	-.45	9.23	36	1.93	.39	0.51	2.83
3	2.06	.32	-.75	13.98	37	1.83	.42	0.07	7.03
4	2.31	.36	-.39	5.84	38	2.15	.43	-0.67	6.45
5	2.35	.42	-1.37	10.43	39	2.30	.45	-1.15	10.28
6	2.21	.41	-1.93	15.23	40	2.02	.39	-0.02	5.27
7	2.13	.36	-1.04	8.81	41	2.04	.35	-0.57	10.02
8	2.39	.39	-1.21	12.02	42	1.90	.40	-1.11	9.68
9	2.42	.37	-.86	10.25	43	2.07	.44	-1.57	11.59
10	2.44	.39	-1.79	15.41	44	1.96	.45	-0.53	5.76
11	1.82	.31	-1.20	23.50	45	2.02	.40	0.27	3.00
12	1.89	.28	.56	7.58	46	1.75	.38	0.48	3.42
13	1.89	.35	-3.79	29.48	47	1.57	.41	-0.36	6.39
14	2.06	.28	-1.23	13.15	48	1.57	.36	0.35	4.85
15	1.90	.30	-1.70	23.01	49	–	–	–	–
16	2.01	.27	-1.48	21.22	50	1.79	.41	0.86	1.48
17	1.11	.35	1.18	9.30	51	1.45	.52	0.37	1.04
18	1.26	.32	1.07	8.95	52	1.76	.40	0.46	4.67
19	1.13	.32	1.18	10.88	53	1.98	.45	-0.72	6.96
20	1.13	.39	2.09	10.19	54	2.02	.44	-0.02	4.83
21	1.64	.30	0.58	12.38	55	2.00	.39	-0.87	12.03
23	2.13	.44	-.07	2.79	56	1.93	.46	-0.71	4.78
24	2.24	.44	-.59	5.99	57	1.73	.47	0.17	2.51
25	2.10	.43	0.01	3.21	58	1.51	.53	0.20	1.39
26	1.78	.36	-0.08	4.39	59	1.41	.54	0.23	0.65
27	1.90	.36	0.70	1.49	60	1.22	.53	0.06	3.47
28	1.75	.42	-0.10	4.63	61	0.97	.63	0.88	2.94
29	1.75	.49	-.34	5.42	62	1.44	.60	0.67	1.21
30	1.72	.40	0.72	4.24	63	1.02	.60	0.71	1.80
31	1.76	.39	0.75	2.32	64	1.77	.37	0.47	7.26
32	1.61	.44	0.62	2.37	65	1.94	.35	-0.62	10.66
33	1.83	.41	0.28	1.64	66	2.05	.35	0.27	5.77
34	1.64	.39	0.09	6.77	67	1.98	.42	-0.73	6.80

APPENDIX I - GRAINSIZE DATA (cont.)

SAMPLE	MEAN GR.SIZE	ST. DEV.	SKEW-NESS	KURTOSIS
68	2.07	.39	0.06	5.86
69	2.18	.40	-0.33	8.42
70	2.13	.37	-0.29	7.20
71	1.92	.38	-0.25	4.37
72	1.85	.38	1.04	3.41
73	1.92	.34	1.16	7.08
74	1.77	.35	0.19	4.55
75	1.60	.34	0.34	7.22
76	1.97	.37	-0.69	7.33
77	2.06	.34	-0.44	8.56
78	—	—	—	—
79	2.50	.38	0.38	0.94
80	2.50	.39	-0.01	5.74
81	2.56	.46	-1.23	11.41
82	2.17	.37	-0.29	5.85
83	2.19	.41	0.04	6.85
84	1.93	.38	0.32	4.71
85	1.50	.35	0.63	0.41
86	1.71	.36	0.41	6.05
87	1.91	.37	-0.65	9.77
88	1.95	.44	-1.24	9.85
89	2.37	.38	-1.75	17.17
90	2.11	.39	-0.79	11.34
91	2.31	.34	0.23	3.42
92	2.10	.40	-0.87	8.93
93	2.25	.38	-1.51	15.40
94	2.30	.37	-0.78	8.68
95	2.12	.36	-1.13	14.66
96	1.99	.41	-0.51	7.05
97	1.97	.42	0.75	4.57
98	1.94	.41	-0.93	9.19
99	2.05	.38	-1.65	16.62
100	1.97	.31	-0.01	12.13

SAMPLE	MEAN GR.SIZE	ST. DEV.	SKEW-NESS	KURTOSIS
101	2.16	.32	-0.61	11.60
102	2.26	.41	-1.17	12.03
103	2.03	.41	-0.57	6.70
104	2.09	.42	-0.68	7.17
105	2.09	.41	-0.99	9.79
106	1.97	.38	-0.72	9.90
107	2.13	.40	-0.02	5.58
108	1.85	.42	-1.72	13.36
109	2.04	.42	-1.13	10.48
110	2.15	.38	-1.53	11.41
111	—	—	—	—
112	2.18	.42	-1.84	13.12
113	2.13	.34	-0.96	12.23
114	1.93	.36	0.46	9.75
115	2.06	.34	0.17	2.71
116	2.04	.37	-0.43	7.32
117	2.00	.43	-1.50	11.75
118	2.08	.36	-0.86	14.24
119	1.98	.34	-1.01	14.13
120	1.85	.38	-0.52	8.17
121	1.70	.44	-0.16	3.27
122	1.72	.46	0.59	3.25
123	1.71	.43	0.01	4.02
124	2.02	.40	-0.16	8.86
125	1.84	.44	0.04	1.40
126	2.09	.47	-0.02	3.90
127	1.74	.47	0.09	2.97
128	1.62	.54	-0.22	1.46
129	1.76	.39	1.10	5.58
130	1.64	.39	0.30	2.97
131	2.04	.42	-0.06	2.96
132	1.89	.42	-0.26	5.34
133	1.85	.46	0.05	2.42

APPENDIX 1 - GRAINSIZE DATA (cont.)

SAMPLE	MEAN GR.SIZE	ST. DEV.	SKEW-NESS	KURTOSIS
134	—	—	—	—
135	—	—	—	—
136	2.03	.38	-1.64	15.72
137	2.15	.38	-1.34	13.49
138	2.13	.35	-0.40	7.93
139	2.21	.36	-0.73	9.85
140	—	—	—	—
141	2.03	.38	-1.18	12.26
142	2.07	.33	-0.17	10.10
143	2.18	.37	-0.40	8.56
144	1.86	.36	-0.11	10.71
145	—	—	—	—
146	1.90	.34	-0.09	12.69
147	2.08	.35	-0.03	7.23
148	2.19	.39	-1.48	10.51
149	2.12	.39	-2.25	17.12
150	2.06	.37	-0.35	5.15
151	2.11	.39	-0.49	6.50
152	2.18	.40	-0.53	5.44
153	2.08	.35	-0.51	9.62
154	2.08	.35	-0.19	5.66
155	2.00	.42	-0.43	4.20
156	2.00	.43	-0.30	4.87
157	1.96	.47	-0.22	5.63
158	2.11	.32	-0.23	11.02
159	2.05	.29	0.13	2.40
160	2.11	.37	-1.41	13.78
161	2.04	.34	.21	3.87
162	2.05	.34	-0.15	9.11
163	2.10	.30	0.09	7.33
164	2.04	.35	0.02	5.22
165	1.96	.37	-0.19	8.00
166	1.66	.40	-0.08	4.46
167	2.06	.35	0.08	4.07

Appendix 2 - Heavy-mineral Assemblages

Sample BS	Opaques *	Zircon	Brown Tourmaline	Blue Tourmaline	Translucent Rutile	Hornblende	Pyroxene	Epidote	Garnet	Andalusite	Monazite	Apatite	Topaz	Staurolite	Kyanite	Spinel	"others"	Unknowns + irons aragonite (shell)	ZTR index Ø
1	49.6	19.7	6.4	0.7	15.1	2.3	2.9	1.6	0.4	0.6	0.2	0	0.1	0.1	0	0	0	0.3	83
2	50.7	9.5	13.0	0.5	11.2	6.3	3.5	3.8	0.3	0.5	0	0	0	0	0	0	0	0.5	69
3	41.6	16.8	14.4	0.9	13.6	5.2	2.9	2.6	0.9	0.6	0.3	0	0	0	0	0	0	0.3	78
4	45.9	6.0	12.1	0.4	2.8	21.6	5.2	3.9	0.2	0.9	0.2	0.2	0	0.2	0	0	0	0.4	39
5	52.4	6.1	7.6	0.7	5.4	16.4	4.7	4.4	0.5	1.0	0	0	0	0	0	0.1	0	0.6	41
6	54.7	8.6	9.4	0.5	4.6	13.7	3.5	3.2	0.5	0.5	0.3	0	0	0	0	0	0	0.3	51
7(D)	52.4	6.0	5.6	0.8	8.7	14.3	4.8	5.4	0	0.8	0.4	0	0	0	0	0	0	0.8	44
8(D)	51.3	5.9	8.0	1.0	16.3	12.0	2.4	1.9	0	0.5	0.3	0	0	0	0	0	0	0.2	64
9	50.8	5.6	9.8	1.3	3.2	16.5	5.1	5.9	0	1.1	0	0.3	0	0	0	0	0	0.5	40
10	45.0	2.9	10.1	1.3	2.1	28.6	4.5	2.9	0.5	0.3	0.3	0.3	0	0	0	0	0	1.3	30
11	56.6	9.4	20.8	1.3	3.1	2.5	1.6	2.2	0.3	1.3	0	0	0	0	0	0	0	0.9	80
12	58.3	4.7	23.8	0.9	1.7	3.8	2.1	1.3	0.4	1.7	0	0	0	0	0	0.4	0	0.9	75
13	61.4	4.1	23.6	1.1	1.5	4.1	0.7	1.5	0	1.5	0	0	0	0	0	0	0	0.4	78
14	58.5	13.8	17.4	0.9	4.2	1.2	0.8	1.3	0.4	0.9	0.2	0.3	0	0	0	0	0	0	88
15	51.9	11.3	23.9	2.0	4.1	1.3	1.7	1.5	0.2	1.1	0	0	0	0	?0.2	0.2	0	0.7	86
16	50.7	2.4	32.2	2.1	1.2	1.5	2.4	2.9	0.9	2.7	0	0.3	0	0	0	0	0	0.9	77
17	49.8	1.5	35.9	3.9	2.7	0.4	2.7	1.9	0	0.4	0	0.4	0	0	0	0	0	0.4	88
18	52.5	2.2	35.5	1.1	2.2	0.6	2.0	2.0	0.3	0.8	0	0.3	0	0	0	0	0	0.6	87
19	48.2	2.8	37.9	2.4	2.4	0	1.6	2.0	0	0.8	0	0.4	0	0	0	0	0	1.6	88
20	56.0	21.2	14.7	0.4	5.8	0.2	0.4	0.5	0.2	0.4	0.4	0	0	0	0	0	0	0	96
21	48.2	10.9	28.4	0.4	8.0	0.7	0.9	0.5	0.4	0.7	0.2	0.2	0	0	0	0	0	0.5	92
23	55.4	15.8	10.0	1.2	4.8	4.9	2.8	3.9	0.1	0.3	0.1	0.1	0	0	0	0	0	0.5	71
24	57.8	16.2	9.3	0.3	3.4	2.6	5.2	4.0	0.2	0.5	0.2	0	0	0	0	0	0	0.3	70
25	53.3	5.3	15.6	1.2	2.0	8.2	5.3	7.0	0.4	0.4	0	0.4	0	0	0	0	0	0.8	52
26	56.3	15.2	8.9	1.1	10.6	0.4	3.5	1.9	0.2	0.6	0.4	0	?0.2	?0.2	0	0	0	0.5	82
27	53.9	10.7	13.8	0.6	6.6	1.7	4.5	4.1	0.6	2.1	0.2	0	0	?0.2	0	0	zoisite 0.2	0.6	71
28	59.7	6.6	12.9	0.7	4.4	4.4	4.7	3.7	0.2	0.9	0.2	0.2	0	?0.5	0	0	0	0.7	61
30	54.6	14.4	12.5	1.3	6.0	2.1	3.6	3.8	0.1	1.0	0.1	0	0	0	0	0	0	0.3	75
31	54.7	5.8	16.9	0.3	3.9	6.7	6.9	2.2	0.8	1.1	0	0	0	0.6	0	0	0	0	59
33	57.7	17.0	8.5	0.3	6.2	2.7	5.5	1.2	0.1	0.3	0	0.1	0.1	0	0	0	0	0.2	76
34	58.8	8.4	15.5	1.3	3.1	1.8	7.1	2.6	0.3	0.5	0	0	0	0.3	0	0	0	0.3	69
35	50.9	16.0	8.6	0.3	6.4	4.0	8.0	3.7	0.3	0.3	0.6	0	0	0.3	0	0	0	0.6	64
36	52.6	15.6	9.6	0.4	7.9	2.6	4.2	3.9	0.2	0.9	0.7	0.2	0	?0.2	0	0	zoisite 0.2	0.7	71
37	59.0	4.6	12.3	1.6	5.2	3.8	6.8	4.6	0.3	1.1	0	0.3	0	0	0	0	0	0.3	58
38	54.3	13.8	9.5	1.4	6.3	3.4	6.8	2.9	0.5	0.9	0.2	0	0	0	0	0	0	0	68

NOTE: * includes ilmenite, magnetite, opaque rutile, leucoxene and iron oxides

Ø ZTR index (Hubert 1962) does not include opaque rutile

Sample BS	Opaques *	Zircon	Borwn Tourmaline	Blue Tourmaline	Translucent Rutile	Hornblende	Pyroxene	Epidote	Garnet	Andalusite	Monazite	Apatite	Topaz	Staurolite	Kyanite	Spinel	"others"	Unknowns + ironst. aragonite (shell)	ZTR index ø
39	51.1	5.8	15.7	1.5	6.2	4.0	10.2	2.9	0.4	0.7	0.4	0	0	?0.4	0	0	0	0.7	60
40	51.8	7.9	20.3	2.4	4.6	1.5	7.9	1.3	0.4	0.7	0.2	0.2	0	0.4	0	0	0	0.2	73
41	53.6	11.8	11.5	0.9	6.1	3.0	7.0	3.0	0.6	1.2	0.3	0	0	?0.3	0	0	0	0.6	65
42	48.6	9.7	17.1	1.8	6.1	2.0	10.0	2.6	0.5	1.0	0	0	0	0.3	0	0	0	0.3	67
43	56.2	25.9	4.6	0.2	4.8	1.0	5.0	1.0	0.2	0.6	0.2	0	0	0.2	0	0	Cassiterite 0.2	0	81
44	48.6	24.3	12.2	0.8	6.8	0.8	4.2	0.7	0.1	0.7	0.1	0.1	0	?0.4	?0.1	0	0	0.3	86
45	51.2	17.1	12.7	0.9	4.0	2.2	5.6	3.7	0.3	0.6	0.3	0	0	0.6	0.3	0	0	0.3	71
46	47.1	12.6	19.3	1.4	1.8	5.6	8.4	2.5	0.2	0.6	0.2	0	0	0	0.2	0	0	0.2	66
47	45.3	2.3	35.1	2.3	0.2	2.5	8.8	2.0	0	1.1	0	0	0	0	0	0	0	0.5	73
48	48.9	1.1	32.5	1.1	1.5	3.0	7.1	1.9	0	0.7	0	0.4	0	0	?0.4	0	zoisite 0.4	1.1	71
50	58.3	1.0	13.1	0.5	1.5	12.8	8.3	1.5	0.5	1.5	0	0	0	0	0	0	0	1.0	39
52	55.2	4.6	19.3	1.1	0.9	8.9	5.2	2.9	0.3	0.9	0	0.3	0	0	0	0	0	0.6	58
53	54.4	3.6	14.6	0.5	0.8	14.8	10.2	0.8	0	0.3	0	0	0	0	0	0	0	0	43
54	60.1	2.0	16.0	1.0	0.6	12.1	5.9	1.8	0	0.4	0	0	0	0	0	0	0	0	49
55(D)	49.4	14.1	10.5	0.4	21.2	0.6	2.2	0.9	0.3	0.1	0.1	0	0	0	0	0	0	0	91
56	57.3	15.1	9.1	0.8	12.9	1.6	1.1	1.6	0	0	0.3	0	0	0	0	0	0	0.3	89
57	51.4	30.3	6.4	0.2	9.9	0.3	0.7	0.2	0.1	0.3	0.1	0	0	0	0	0	0	0	96
58	73.6	13.8	6.0	0	4.3	0.5	1.2	0.2	0.2	0	0.2	0	0	0	0	0	0	0	91
59	67.1	10.7	6.4	1.4	5.7	3.6	2.9	1.4	0	0.7	0	0	0	0	0	0	sphene 0.2	0	74
60	80.8	6.1	9.9	0.3	1.7	0	0.6	0.3	0.3	0	0	0	0	0	0	0	0	0	94
62	52.5	19.8	12.1	0.7	9.6	1.8	2.1	0.4	0	0.8	0.3	0	0	0	0	0	0	0	89
63	37.8	43.8	1.3	0.2	13.8	0	1.0	1.2	0.4	0.2	0.4	0	0	0	0	0	0	0	95
64	36.3	39.5	17.9	1.1	3.2	0.2	0.5	0.2	0.2	0.9	0	0	0.2	0.2	0	0	0	0	96
65	48.0	25.5	15.4	1.3	6.5	1.0	1.1	1.0	0.2	0	0	0.2	0	0	0	0	0	0	84
66	46.9	40.5	7.1	0.3	3.6	0.6	0.7	0.1	0	0.05	0.05	0	0	0	0	0	0	0	97
67	49.4	19.4	21.3	0.3	4.1	1.9	1.7	0.2	0.2	1.2	0	0	0	0.2	0	0	sphene 0.2	0	89
68	50.6	19.9	15.1	0.3	5.1	2.7	2.7	1.5	0.3	0.9	0.3	0.3	0	0	0	0	0.3	0	82
69	56.3	3.7	23.3	0.4	3.0	5.9	4.8	1.1	0	1.5	0	0	0	0	0	0	sill. 0.2	0	70
70	57.1	6.1	24.9	1.6	1.6	4.1	1.6	0.8	0.4	1.4	0	0	0	?0.2	0	0	zoisite 0.2	0.2	80
71	43.6	37.8	10.2	0.3	5.8	0.7	0.2	0.5	0.1	0.5	0.2	0.2	0	0	0	0	0	0	96
72	38.9	39.8	10.9	0.2	6.7	0.7	0.7	0.9	0.2	0.6	0.1	0.1	0	?0.2	0	0	sphene 0.2	0	94
73	42.5	16.9	28.6	1.3	5.8	2.3	1.0	0.3	0.3	0.6	0	0.3	0	0	0	0	0	0	91
74	83.8	0.6	6.8	0.3	0.2	3.9	1.6	0.6	0.6	1.0	0	0	0	0	0	0	sphene 0.3	0.1	49

NOTE: *includes ilmenite, magnetite, opaque rutile, leucoxene and iron oxides

ø ZTR index (Hubert 1962) does not include opaque rutile

Sample BS	Opaques *	Zircon	Brown Tourmaline	Blue Tourmaline	Translucent Rutile	Hornblende	Pyroxene	Epidote	Garnet	Andalusite	Monazite	Apatite	Topaz	Staurolite	Kyanite	Spinel	"others"	Unknowns + irons† aragonite (shell)	ZTR index Ø
75	84.5	1.1	5.4	1.1	0.4	3.6	0.7	0.4	2.2	0.4	0	0	0	0	0	0	0	0.4	53
76	49.5	18.8	9.8	1.0	14.7	1.9	0.6	0.6	2.1	0.8	0	0	0	0	0	0	0	0.1	88
77(D)	52.6	10.8	12.1	0.6	15.4	2.6	0.2	0.4	4.8	0.2	0.2	0	0	0	0	0	0	0	82
78(D)	45.6	29.8	5.5	0.5	14.0	1.2	0.6	0.5	1.9	0.2	0.1	0	0	0	0	0	sphene 0.1	0.1	91
79	46.9	2.0	16.9	1.1	1.1	27.2	2.2	0.8	0.8	0	0	0	0	0	0	0	sill. 0.1	0.2	40
80	53.1	1.0	11.5	0	1.0	29.2	1.7	0.2	0.5	1.2	0	0.5	0	0	0	0	0	0	29
81	52.2	1.7	8.9	0.3	2.0	32.4	0.3	0	1.0	0.7	0	0	0.3	0	0	0	0	0	27
82	54.6	24.0	5.3	0.3	11.1	1.1	0.6	1.1	1.3	0.3	0	0.1	0	0	0	0	0	0.1	90
83	56.2	22.6	7.6	0.3	8.6	1.5	0.9	1.1	0.4	0.4	0	0	0	?0.1	0	0	sphene 0.1	0.1	90
84	50.2	8.8	13.9	0.9	3.8	6.8	3.0	0.9	9.3	1.1	0.2	0.2	0	0	0	0	0	0.4	55
87	47.6	34.3	4.3	0.2	11.0	0.8	0.3	0	0.8	0.1	0.5	0	0	0	0	0	0	0	95
88	44.3	40.3	3.2	0.3	10.5	0	0	0.2	0.5	0	0.5	0	0	0	0	0	zoisite 0.2	0	97
89	49.6	12.3	18.2	1.1	3.2	9.1	2.1	0.5	2.7	0.3	0.3	0.3	0	0	0	0	0	0.3	69
90	46.4	18.9	12.7	0.4	6.7	7.1	2.5	0.3	2.9	0.6	0.2	0	0.2	0	0.2	0	0	0.4	72
91	43.2	38.9	6.4	0.3	6.6	1.9	0.5	0.7	0.9	0.2	0.3	0	0	0	0	0	0	0.2	92
92(HB)	41.9	46.0	2.8	0.3	5.7	1.1	0.5	0.2	1.1	0	0.2	0	0	0.2	0	0	0	0.2	94
93	52.4	28.7	5.7	0.4	7.9	1.4	0.6	1.6	1.0	0.2	0.2	0	0	0	0	0	0	0	90
94	47.5	11.1	19.3	0.7	6.4	7.7	2.7	2.2	0.5	1.2	0.2	0.2	0	0	0	0	0	0.2	71
95	53.7	12.1	16.0	1.2	6.5	4.6	1.8	1.0	2.0	0.6	0	0	0	0	0	0	0	0.4	77
96	53.9	7.4	17.8	0.7	1.4	15.4	1.2	0.7	0.2	0.7	0	0.2	0	0	0	0	0	0.2	59
97	46.1	8.4	17.7	0.4	1.5	22.1	1.1	0.4	1.1	0.7	0	0.4	0	0	0	0	0	0.2	52
98	50.5	4.7	18.1	0.6	1.2	21.5	0.9	0.6	0.9	0.3	0	0	0	0	0	0	0	0.6	50
99	52.1	16.4	19.5	1.2	4.7	2.1	1.8	0.3	1.1	1.0	0	0	0	0	0	0	0	0	87
100	35.6	4.1	42.9	1.9	0.9	7.6	1.6	1.3	2.5	0.6	0	0.6	0	0	0	0	zoisite 0.3	0	77
101	47.7	8.0	25.1	1.1	3.2	7.3	1.9	1.5	1.1	1.7	0.2	0.2	0	0	0	0	zoisite 0.4	0.4	71
102	51.0	9.8	25.3	0.7	3.5	4.9	1.4	1.0	1.4	0.5	0	0.2	0	0	0	0	0	0.3	80
103	52.6	6.4	19.2	1.3	2.1	14.1	1.7	0.4	1.3	0.4	0	0.4	0	0	0	0	0	0	61
104	43.9	22.9	14.6	0.4	8.7	6.9	0.8	1.0	0.4	0.2	0	0	0	0	0	0	0	0.2	83
105	43.1	3.4	27.3	0.8	4.5	9.2	2.0	1.6	1.4	1.0	0	0.4	0	0	0	0	0	0.2	72
106(HB)	43.4	19.9	15.0	0.9	12.8	2.1	0.7	0.5	3.8	0.6	0.1	0.2	0	0.1	0	0	0	0	86
107	47.3	16.6	11.2	0.8	2.3	16.4	2.3	1.3	1.0	0.5	0	0.3	0	0	0	0	0	0	59

NOTE: * includes ilmenite, magnetite, opaque rutile, leucoxene and iron oxides

Ø ZTR index (Hubert 1962) does not include opaque rutile

Sample BS	Opaques *	Zircon	Brown Tourmaline	Blue Tourmaline	Translucent Rutile	Hornblende	Pyroxene	Epidote	Garnet	Andalusite	Monazite	Apatite	Topaz	Staurolite	Kyanite	Spinel	"others"	Unknowns + ironst + aragonite (shell)	ZTR index Ø
109	57.2	1.4	18.4	1.1	1.1	15.2	2.2	1.1	0.5	1.1	0	0.5	0	0	0	0	0	0.3	51
110	39.6	26.7	17.6	0.4	5.3	1.2	1.5	0.3	6.5	0.4	0.1	0.1	0	0	0	0	0	0.1	83
111	41.3	19.3	19.3	0.7	6.3	1.0	2.7	0.3	6.3	1.3	1.3	0	0	0	0	0	0	0	78
112	37.3	7.1	34.3	3.0	4.7	2.7	2.7	0.6	5.9	1.5	0.3	0	0	0	0	0	0	0	78
113	42.7	4.5	29.3	2.4	4.5	7.6	3.9	1.0	1.0	2.4	0	0	0.3	0	0	0	0	0.5	71
114	51.7	19.1	13.3	0.6	10.8	1.4	1.0	0.5	1.0	0.3	0	0	0	0.1	0	0	0	0.1	91
115	53.7	13.9	14.0	0.8	10.2	3.0	1.9	0.4	1.3	0.4	0	0	0.2	0	0	0	0	0.2	84
116	52.8	8.3	18.2	1.3	5.7	5.9	4.9	0.6	0.8	0.9	0.2	0.2	0	0	0	0	0	0.2	71
117	52.4	8.8	19.7	0.9	6.6	7.5	3.1	0	0.2	0.7	0	0	0	0	0	0	0	0.2	76
118	48.1	15.2	18.6	1.0	4.8	6.9	3.1	0.2	1.0	0.5	0	0	0	0	0	0	sphene 0.3	0.4	76
121	56.4	19.5	5.4	0.3	6.8	1.1	0.3	0	9.2	0.5	0.3	0.3	0	0	0	0	0	0	74
122	49.4	29.8	3.0	0	6.7	0.4	0.4	0	9.7	0.4	0.2	0	0	0	0	0	0	0	78
123	51.3	14.3	15.2	0.9	4.9	4.5	0.9	0	7.6	0.4	0	0	0	0	0	0	0	0	72
125	48.5	13.8	18.3	1.5	3.0	5.4	1.5	0	5.4	2.7	0	0	0	0	0	0	0	0	71
126	53.1	5.8	17.7	2.3	1.6	13.2	2.3	0.6	2.6	0.6	0	0	0	0	0	0	0	0.3	58
128	49.4	29.2	3.3	0.2	11.9	1.0	1.2	0.2	2.9	0.2	0.4	0	0	0	0	0	0	0	88
129	59.1	13.8	6.5	0.9	10.0	0.6	0.6	0	7.4	1.0	0.2	0	0	0	0	0	0	0	76
130	53.6	14.1	14.0	0.8	6.9	2.6	0.7	0	5.6	1.0	0	0	0	0	0	0	0	0.7	77
131	59.2	21.8	5.0	0.6	8.4	1.6	0	0.3	2.5	0.3	0.3	0	0	0	0	0	0	0	88
132	52.4	28.2	4.9	0.5	10.0	0	0.2	0	3.4	0	0.5	0	0	0	0	0	0	0	92
133	53.3	23.2	3.5	0.3	13.7	0.1	0.3	0.3	4.7	0.1	0.3	0	0	0	0	0	0	0	87
134	68.9	12.1	1.6	0	10.7	0	0.2	0.2	5.8	0	0	0	0	0	0	0.2	0	0.2	78
135	63.0	17.5	3.8	0.3	8.8	0.4	0.4	0.1	5.3	0	0	0	0	0	0	?0.1	0	0.3	82
136(D)	49.5	19.8	12.7	1.5	12.9	1.9	0.6	0.2	0.2	0.2	0	0	0	0	0	0	0	0.4	93
137	63.8	4.2	17.4	0.5	3.2	8.6	0.7	0.5	0.5	0.7	0	0	0	0	0	0	0	0	55
138	68.2	7.2	11.5	0.7	8.6	1.9	0.5	0	1.0	0.5	0	0	0	0	0	0	0	0	88
139	57.5	6.8	21.0	1.4	3.8	5.7	0.7	1.1	1.1	0.7	0	0.2	0	0.2	0	0	0	0	78
140	63.9	15.7	6.9	0.5	8.6	2.9	0.3	0.5	0.5	0.2	0	0	0	0	0	0	0	0	88
141	57.7	14.8	13.4	0.8	8.0	2.7	0.3	0.1	1.3	0.5	0.3	0.1	0	0	0	0	0	0	87
142	59.2	8.8	16.8	0.9	7.0	5.4	0.9	0.4	0.4	0.2	0	0.2	0	0	0	0	0	0	82
143	45.6	4.3	25.1	0.7	1.7	18.2	1.6	0.5	0.7	1.0	0	0.3	0	0	0	0	0	0.3	58
144	57.5	10.7	12.5	0	1.4	11.4	2.9	0.4	1.3	0.7	0	0	0	0	0	0	glaucophane 0.4	0.4	58
145	60.9	18.4	7.0	0.6	7.0	3.7	1.1	0.1	0.8	0.3	0.1	0	0	0	0	0	0	0	84
146	58.0	16.5	12.5	0.5	5.9	3.8	1.2	0.3	0.8	0.5	0	0	0	0	0	0	0	0.2	84

NOTE: * includes ilmenite, magnetite, opaque rutile, leucoxene and iron oxides

Ø ZTR index (Hubert 1962) does not include opaque rutile

Sample BS	Opaques *	Zircon	Brown Tourmaline	Blue Tourmaline	Translucent Rutile	Hornblende	Pyroxene	Epidote	Garnet	Andalusite	Monazite	Apatite	Topaz	Staurolite	Kyanite	Spinel	"others"	Unknowns + ironst. aragonite (shell)	ZTR index Ø
147	60.2	8.6	14.8	1.1	6.9	4.9	1.5	0.4	1.1	0.2	0	0.2	0	0	0	0	0	0.2	79
148	49.1	6.7	22.1	1.9	4.0	11.5	0.9	0.6	1.4	1.1	0	0.2	0	0	0	0	glaucophane 0.3	0.2	68
149	44.7	10.2	18.5	0.6	5.4	15.7	1.0	0.6	0.6	2.6	0	0	?0.2	0	0	0	0	0	63
150	63.1	10.0	11.9	0.6	4.9	6.4	0.4	0.8	1.0	1.0	0	0	0	0	0	0	0	0	74
151	57.4	9.1	14.6	0.7	4.6	9.1	2.3	0.5	0.5	0.9	0.2	0.2	0	0	0	0	0	0	68
152	54.7	6.0	18.8	0.6	4.9	10.1	1.1	0.9	1.3	1.1	0	0.4	0	0	0	0	glaucophane 0.2	0	67
153	55.1	10.7	14.0	0.8	4.6	9.6	2.9	0.5	1.1	0.5	0	0	0	0	0	0	glaucophane 0.2	0.2	67
154	62.7	7.2	14.7	0.3	2.7	8.0	2.7	0	0	1.1	0	0.3	0	0	0	0	0	0.3	67
155 (HD)	53.0	25.0	5.9	0.6	14.5	0	0	0	0	0.2	0.7	0	0	0	0	0	0	0	98
156(HD)	49.4	15.5	15.2	0.7	18.5	0	0	0	0	0.2	0.2	0.2	0	0	0	0	0	0.2	99
157(HD)	48.5	23.9	6.1	0.6	20.6	0	0	0	0	0	0.4	0	0	0	0	0	0	0	99
158	47.3	12.7	19.6	0.8	8.0	6.0	3.6	0.5	0.6	0.9	0	0	0	0	0	0	0	0	78
159	48.2	12.0	22.8	0.3	7.5	3.6	3.3	0	0.8	0.8	0	0	0.3	0	0	0	zoisite 0.3	0	82
160	51.8	4.4	26.6	1.3	3.8	7.2	2.2	0.1	0.6	1.3	0	0.1	0	0	0	0	0	0.5	75
161	47.0	9.6	22.8	1.4	4.6	6.8	4.1	0.9	0.9	1.1	0.5	0.2	0	0	0	0	0	0	72
162	55.2	13.0	13.4	0.6	5.2	6.7	3.0	0	0.9	0.8	0	0.3	0	0	0	0	sphene 0.3	0.3	72
163	47.7	12.3	20.9	0.5	5.4	8.2	2.1	0.7	1.2	0.7	0	0	0	0	0	0	0	0.2	75
164(D)	58.0	16.9	7.2	2.1	10.7	0.7	0	2.6	0.9	0.3	0	0	0	0	0	0	0	0	88
165(D)	42.0	16.5	13.9	2.2	20.7	1.4	1.0	0.1	1.1	0.9	0.2	0	0	0	0	0	0	0.1	92
166(D)	36.5	3.6	17.6	1.2	4.3	16.4	4.1	0.5	15.2	0.5	0	0	0	0	0	0	0	0	42
167(D)	35.9	12.0	27.4	0.9	16.9	1.6	2.0	0.4	1.4	1.0	0.1	0.1	0	0	0	0	0	0.3	90

Notes

1. Percentages based upon grain counts of between 400 and 600 grains.
2. In virtually all cases the heavy-mineral fraction is moderately well or well sorted with a mean grainsize between 2 and 3 Ø.
3. Light fractions are typically well or very well sorted with a mean grainsize between 1.5 and 2.5 Ø.
4. All samples, except where indicated, were taken at approximately the high tide mark of the beach.

D: Dune samples

HB: High beach

HD: High dunes (N. stradbroke Is.)