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THE ORIGIN OF BEACH SEDIMENTS ON THE NORTH QUEENSLAND COAST

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Abstract

Petrographic and granulometric analyses of North Queensland beach sediments indicate their affinity with sediments delivered to the coast by rivers, and it is shown that the beaches are largely derived from fluvial sediment reworked, sorted and distributed by the dominant south-easterly waves in coastal waters. Beach sediments are generally quartzose, with subordinate felspars and admixtures of coralline sediment near fringing reefs and lithic material near river mouths and rocky shore sectors. The prevailing northerly drift of shore sediment is reduced, and locally reversed, on sectors sheltered from the dominant south-easterly waves by headlands, reefs and islands. Variations in beach sediment are related to wave conditions, distance from river-mouth sources, and patterns of drift. Four Mile Beach, near Port Douglas, is identified as anomalous in its morphological and sedimentological characteristics. It has been cut off from former sources of sediment, both fluvial and longshore, as a result of reef extension around the mouth of Mowbray River, and is now essentially a relict beach system attaining sedimentological maturity.

INTRODUCTION

The North Queensland coast between Townsville and Cape Kimberley (Fig. 1) includes sandy beach sectors interspersed with rocky and boulder-strewn shores, giving place to mangrove-fringed shores where wave action is reduced in the lee of headlands, islands, or fringing reefs. Some of the sandy beaches line steep and cliffed sectors of the coast; others form the seaward fringe of depositional sandy barriers, on which stages in progradation are marked by beach ridge patterns. Ocean swell is largely excluded from this part of the coast by the Great Barrier Reef, and the sandy formations are built by locally generated waves on a smaller scale, with more intricate variation, than the 'surf beaches' shaped by ocean waves on the east coast of Australia south from Fraser Island.

BEACH SEDIMENTS

In the course of a traverse along the North Queensland coast samples of beach material were collected for petrographic and granulometric study, and determination of carbonate content. The aim was to use sedimentological evidence to show where the beach material had come from and how it was delivered.

There is often considerable variation in petrography and granulometry over the surface of a beach. In North Queensland there is typically an upper beach of coarser sand, with a relatively steep gradient, above mid-tide level, and a lower beach or foreshore of finer sand, often accompanied by silt and clay, with a gentler gradient. Within each of these zones there are further variations related to minor morphological features such as berms, beach cusps, ripples, and bars. Vertical sections in a beach often show contrasted laminae, each of which represents a particular depositional phase in the recent history of the beach, related to wave and current effects accompanying fluctuations of weather and tide. Some of the coarser laminae may however be lag deposits, produced when a layer deposited under one set of wave conditions has been subsequently winnowed and deprived of its finer fraction under another set of wave conditions.

These variations within a beach sector complicate the task of obtaining information on the general petrographic and granulometric characteristics of beach sediments along the North Queensland coast. Ideally the beaches should all be sampled intensively and systematically, and these norms derived from statistical analysis of the results, but this would be a huge task over more than 300 kilometres of coast. Instead, a practical method was devised for beach sampling designed to avoid the more obvious local variations. Within each beach sector, samples were taken from the upper and lower beach zones near the northern and southern ends, and at the middle of the sector. At each site, samples were taken from the beach surface at the centre of a circle of radius 3 metres, within which the superficial sediment appeared to be uniform. This procedure was tested at four sites by taking ten samples within such a circle and comparing the results of granulometric analyses. On beaches of coarse, medium and fine sand these were almost identical; on a beach of very coarse sand there was slight variation, the mean grain size differing by up to ± 0.10 ø from that of the first sample taken. Comparability of samples along the length of the coast was sought by carrying out the sampling programme within a ten day period of calm weather conditions. However, similar petrographic and granulometric results were obtained from samples taken at each of four selected beach sites on five different occasions over a period of four years, suggesting that variation in the derived parameters over time would be limited.

The samples taken are therefore considered to be representative of prevailing sedimentology on North Queensland beaches. The carbonate content of each sample was calculated from loss of weight following treatment with dilute hydrochloric acid. The relative proportions of quartz, felspar, other minerals, and lithic grains were estimated from samples inspected under a microscope, and heavy minerals separated in bromoform. A fraction of each sample was washed, dried and passed through a set of quarter-phi sieves to determine granulometric parameters for descriptive purposes, following the method of Folk and Ward (1957). Table 1 gives relevant data from selected samples, illustrating the following generalisations.

Sandy beach material on the North Queensland coast is predominantly quartzose. Felspars are also present, especially in the coarser sediments close to river mouths (samples 73, 98, 237), but they rarely exceed 5% of a sample. Lithic fragments (slate, schist, granite, basalt) are common near rocky shore outcrops (sample 35), where they are typically angular or subangular, and near river mouths (samples 69, 98), where they are typically well rounded. The finer beach and foreshore sediments contain bleached mica, mainly biotite (samples 42, 74, 81, 102). Heavy minerals are rare (no sample yielding more than 0.01%), ilmenite and magnetite being the most frequent, with hornblende, rutile and zircon only occasional.

There is a close relationship between the petrography of the beach sands and of fluvial sands in the beds of the major rivers draining to the coast (samples 6, 26, 67, 96, 122, 172). The fluvial sands are also predominantly quartzose, with subordinate felspar, lithic fragments, and minor quantities of heavy minerals, usually ilmenite and magnetite. The contrast is in granulometry (Fig. 2). Beach sands are generally better sorted than fluvial sands, and are usually negatively-skewed, whereas fluvial sands tend to be positively-skewed (*cf* Friedman 1962,

Table 1. Characteristics of beach materials.

Sample No.	Locality	Site	Modal Class	Mean (∅)	Sorting Coefficient	Skewness	Quartz %	Carbonates %	Other Main Constituents
6	Herbert River	shoal	v.c.s.	—0.37	0.79	+0.19	>80	0.1	F.L.
18	Allingham	upper beach	m.s.	1.19	0.54	—0.17	>90	0.7	F.L.
19	Allingham	lower beach	f.s.	2.05	0.35	—0.20	>80	8.1	F.L.
24	Cardwell N.	upper beach	m.s.	1.88	0.48	+0.38	>90	0.8	F.M.
25	Cardwell S.	upper beach	v.c.s.	—0.86	0.55	—0.13	>90	0.2	F.L.
26	Tully River	shoal	v.c.s.	—0.46	0.61	+0.26	>80	0.1	F.L.
32	Mission Beach	upper beach	m.s.	1.54	0.70	+0.09	>90	2.9	F.M.H.
35	Clump Point	near rocks	f.s.	2.42	0.32	—0.09	<10	90.0	L.M.H.
41	Garners Beach	upper beach	f.s.	2.09	0.49	—0.02	>70	20.4	F.L.
42	Garners Beach	lower beach	f.s.	2.71	0.57	—0.09	>60	27.5	M.L.
43	Garners Beach	behind reef	c.s.	0.38	1.10	+0.22	>50	41.5	L.F.
52	Kurrimine	upper beach	v.c.s.	—0.59	0.57	—0.26	>80	2.8	F.L.
53	Kurrimine	lower beach	f.s.	2.22	0.46	—0.04	>80	5.4	F.L.
60	Etty Bay	beach in cove	f.s.	2.42	0.44	—0.27	>70	11.2	L.M.
67	Johnstone River	shoal	c.s.	0.89	0.78	+0.01	>70	0.1	F.L.H.
69	Gladys Inlet	upper beach	c.s.	0.63	0.49	—0.02	>90	0.2	F.L.H.
73	Ella Bay	upper beach	v.c.s.	—0.09	0.49	—0.10	>80	0.5	F.L.H.
74	Ella Bay	lower beach	c.s.	0.94	0.96	—0.64	>80	12.1	M.F.L.H.
80	Bramston Beach	upper beach	c.s.	0.16	0.46	—0.26	>90	0.8	F.L.
81	Bramston Beach	lower beach	f.s.	2.32	0.62	—0.26	>80	2.6	M.L.H.
96	Russell River	shoal	c.s.	0.58	0.86	+0.08	>90	0.1	F.L.H.
98	Mutchero Inlet	upper beach	c.s.	0.82	0.48	—0.26	>80	0.9	F.L.
100	Oombunghi	upper beach	c.s.	0.53	0.32	—0.34	>80	0.4	F.L.
101	Oombunghi	lower beach	f.s.	2.15	0.45	—0.51	>80	3.2	M.F.H.
102	Oombunghi	near rocks	f.s.	2.48	0.40	—0.10	>80	2.7	M.F.H.
122	Barron River	shoal	v.c.s.	—0.09	0.51	+0.02	>90	0.2	F.L.
154	Holloways Beach	upper beach	f.s.	2.06	0.86	—0.28	>90	2.0	F.L.
155	Holloways Beach	lower beach	v.f.s.	3.21	0.59	—0.36	>90	2.2	M.F.L.
162	Buchan Point	upper beach	c.s.	0.98	0.56	+0.18	>80	10.8	F.L.
163	Buchan Point	lower beach	v.f.s.	3.16	0.46	—0.13	>70	15.6	M.F.L.H.
164	Yule Point	upper beach	f.s.	2.20	0.50	—0.20	>80	7.3	F.L.
166	Yule Point	behind reef	m.s.	1.39	0.63	—0.17	<10	90.3	L.
167	Yule Point	on reef	m.s.	1.55	0.29	+0.11	>80	7.9	F.L.
172	Mowbray River	shoal	—	0.15	2.06	+0.10	>80	0.1	L.F.
191	Four Mile Beach	mid-beach	f.s.	2.29	0.36	--0.03	>90	6.6	L.
192	Four Mile Beach	rear of beach	f.s.	2.43	0.25	—0.08	>90	4.2	L.
193	Four Mile Beach	foredune	f.s.	2.17	0.29	+0.35	>90	5.4	L.
194	Four Mile Beach	north end	f.s.	2.42	0.36	—0.16	>60	31.9	L.M.
195	Four Mile Beach	south end	m.s.	1.82	0.40	—0.20	>50	44.8	L.M.
202	Port Douglas	upper beach	f.s.	2.38	0.38	—0.16	>70	22.3	F.L.H.
203	Port Douglas	lower beach	f.s.	2.75	0.88	—0.01	>70	21.2	M.F.L.H.
222	Cooyar	upper beach	c.s.	0.17	0.63	+0.05	>90	3.8	F.L.H.
223	Cooyar	lower beach	f.s.	2.25	2.55	—0.11	>80	14.3	M.F.L.H.
237	Wonga	upper beach	granules	—3.95	1.42	—0.21	>90	0.5	L.F.
238	Wonga	lower beach	f.s.	2.89	0.45	—0.02	>90	6.2	M.L.H.
251	Snapper Island	upper beach	pebbles	—5.60	1.80	—0.68	< 5	96.5	L.

Notes on Table 1.

Parameters derived by the method of Folk and Ward (1957). Modal class is expressed in terms of the Wentworth scale (very coarse sand, medium sand, fine sand, etc.). Sorting coefficients can be classified as very well sorted (less than 0.35), well sorted (0.35 to 0.50), moderately sorted (0.50 to 1.00), poorly sorted (1.00 to 2.00) and very poorly sorted (over 2.00). Other main constituents, given in order of decreasing abundance, are Felspars (F), Lithic grains (L), Micas (M), and Heavy Minerals (H).

Duane 1964, and others). The range of grain sizes found in river channel sediments can be matched within adjacent coastal sectors *as a whole*, and it appears that fluvial sediment delivered to the coast during floodwater discharge from the rivers is separated by wave action into well-sorted beach materials, emplaced on sectors of the shore in patterns related primarily to wave energy conditions.

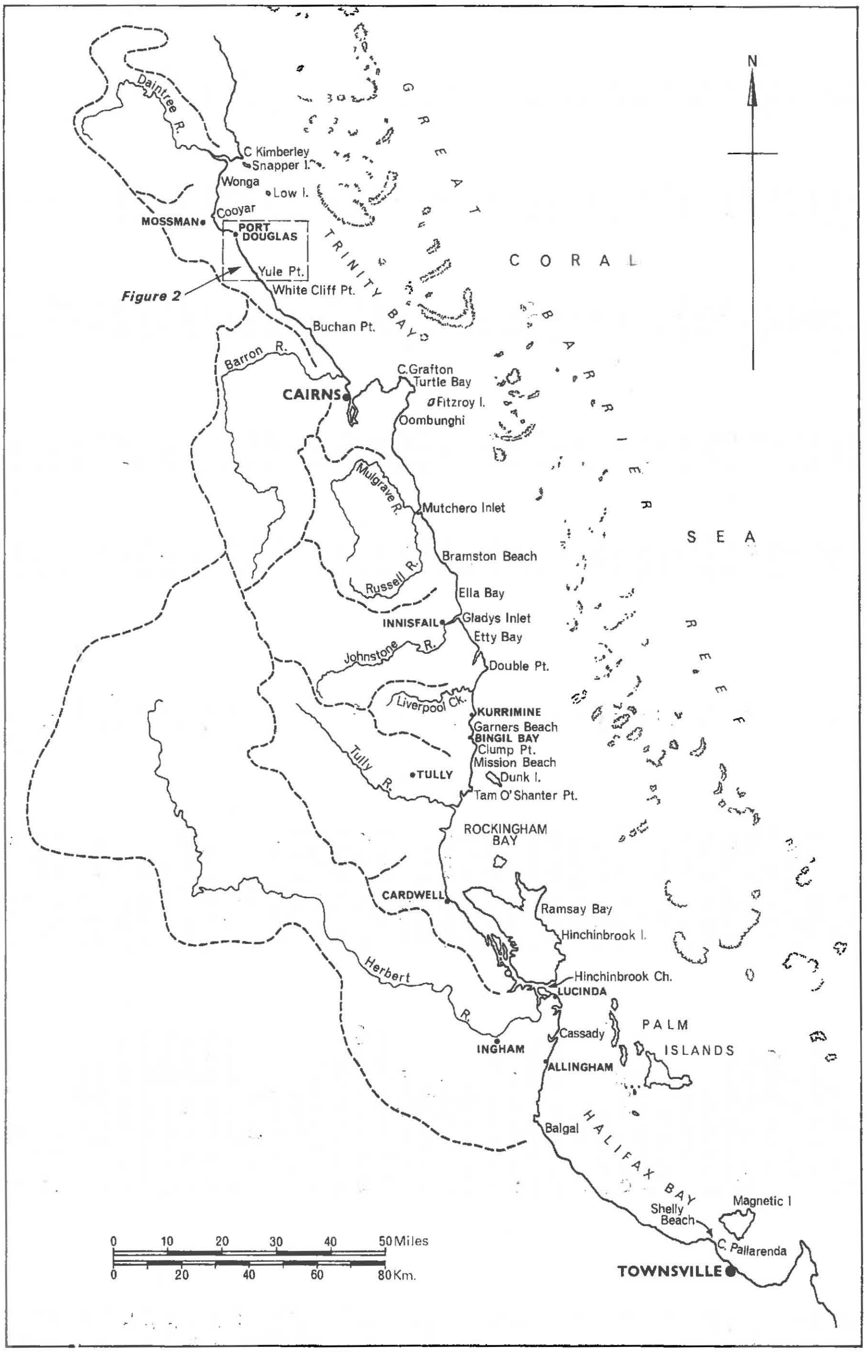

Figure 1 Location map.

Despite the proximity of the major coral structures of the Great Barrier Reef the beaches on the mainland coast of North Queensland are generally poor in coralline material. Exceptions to this are found close to fringing reefs, as at Yule Point (Fig. 4), where locally the beach consists largely of coral sand and shingle (sample 166), notably the broken sticks of staghorn coral (*Acropora* spp.). Such coralline beaches are common on the shores of reef-fringed high islands such as Snapper Island (sample 251), while on cays and low wooded islands (e.g. Low Isles) the beaches consist almost entirely of locally-derived reef debris.

The proportion of shelly material in beaches on the mainland coast is also small, but increases in the vicinity of rocky headlands (sample 35) and fringing reefs (sample 43), which provide a habitat for an abundant nearshore shelly fauna. The best example is Shelly Beach, on the northern shore of Cape Pallarenda, which includes sectors composed entirely of shell fragments.

Active cliffing is rare on the North Queensland coast, but weathering of rock formations exposed on the shore contributes lithic fragments to local beach sediments. On granitic coasts (e.g. Hinchinbrook Island and Cape Grafton) the quartzose beaches contain material derived from the weathered mantle, both by runoff from slopes above high tide level and by wave action from slopes now submerged by the sea.

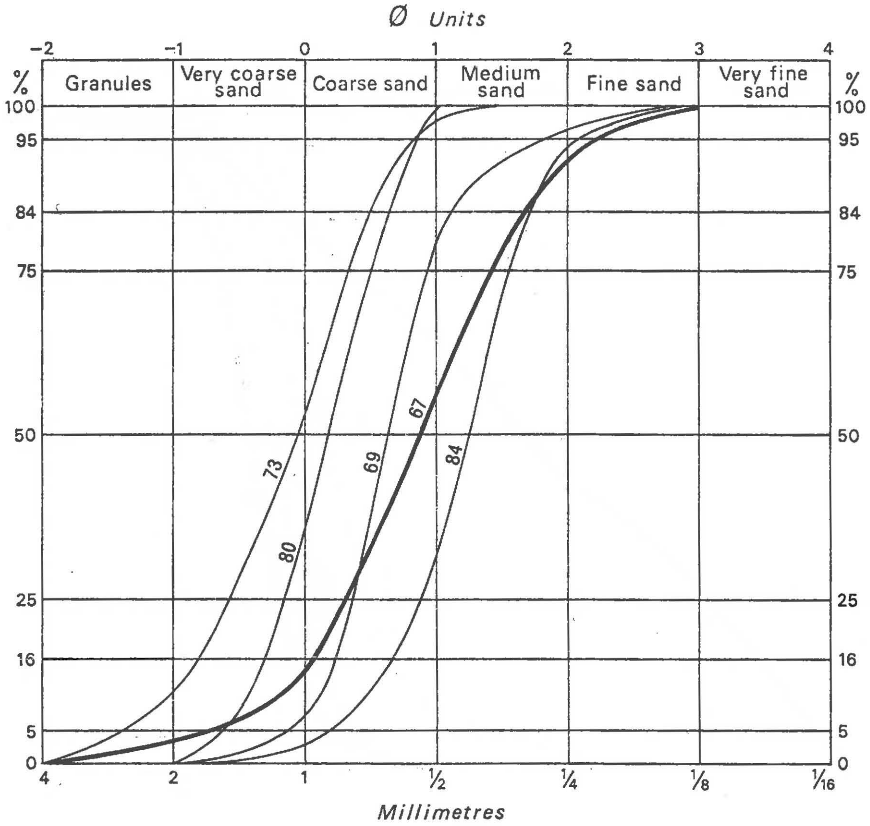

Figure 2 Cumulative frequency curves to illustrate the contrast in granulometry between sample 67 from the Johnstone River and derived upper beach sediments on the coast north from the river mouth (samples 69, 73, 80, 84).

The richest variety of beach material is on Garners Beach (samples 41, 42, 43), which in addition to quartz-felspar sand has coralline and shelly material from an adjacent reef, lithic fragments from local rock outcrops, particles of disintegrated beach rock, ferruginous sandrock derived from nearby outcrops of Pleistocene barrier sands, and micaceous sand and mud amid sparse mangroves on the foreshore. This is exceptional. In general, the sedimentological evidence supports the geomorphological conclusion that the beaches of North Queensland have been mainly derived from sediment supplied to the coast by rivers (Bird 1969, Bird & Hopley, 1969).

Emplacement of beach materials

The major rivers draining to the North Queensland coast (Daintree, Barron, Mulgrave, Russell, Johnstone, Tully, and Herbert) all have sandy material in their channels, derived largely from erosion of weathering mantles of granitic and arenaceous rock outcrops in their headwater regions. During the floods which follow episodes of heavy rainfall, mainly in the wet summer season, quantities of fluvial sediment are washed down to the mouths of these rivers, and into the sea. As the floods subside, this material is reworked, sorted, and distributed by wave action. Much of the sandy fraction is delivered to beaches, but the silt and clay also delivered by these rivers remains longer in suspension, and is more

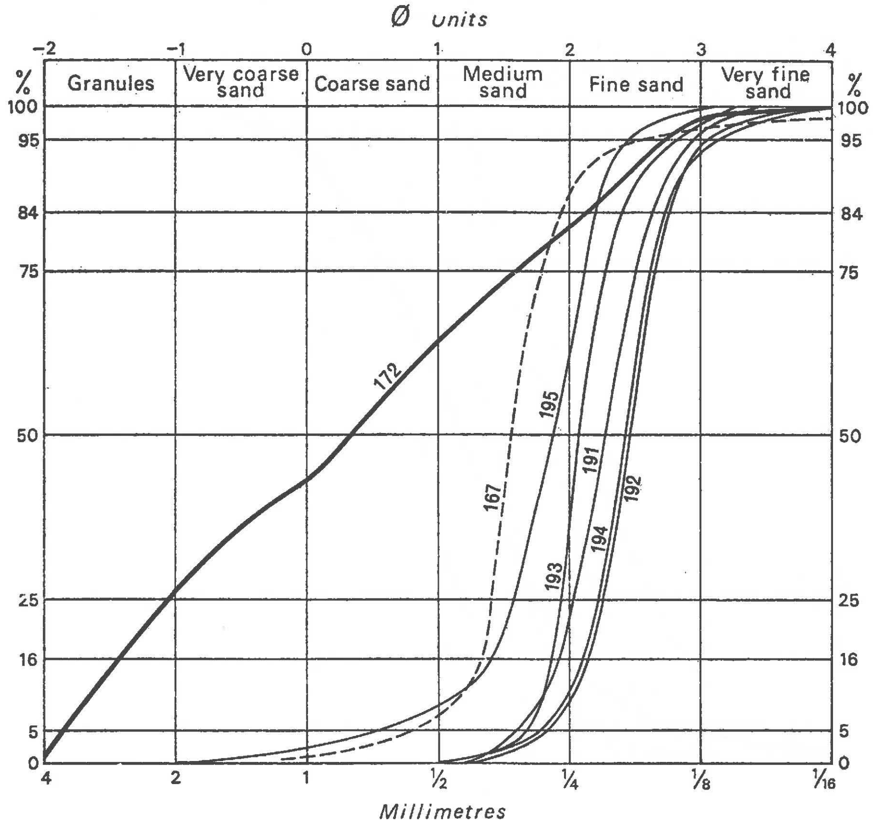

Figure 3 Cumulative frequency curves to show typical sediments from Four Mile Beach (samples 191 to 195) in comparison with sample 172 from the Mowbray River and sample 167 from the tidal sandflats off Yule Point.

widely dispersed. Some of it is deposited on the foreshore on sheltered sectors of the coast, often as mudflats colonised by mangroves, but much of it comes to rest eventually on the sea floor in a zone of fine-grained sediment lying between the coarser shore sediments and the outlying reefs and associated coralline material (Maxwell 1968, Maxwell & Swinchatt 1970).

The dominant waves in coastal waters are generated by the prevailing south-easterly winds. At Low Isles, for example, winds from the south-eastern quadrant represent 73.6% of all winds recorded over the years 1957-61 . The result is that waves tend to move beach material northwards along east-facing sectors of the coast, so that beaches of fluvially-derived sand extend north from each of the major river mouths. The Johnstone, for example, has delivered sand to Gladys Inlet, and this has been spread northwards along the coast from Flying Fish Point to nourish the extensive beach system in Ella Bay, whereas the coast south of Gladys Inlet remains rocky, with very little beach development.

The predominant northward drifting diminishes in the lee of headlands, islands or fringing reefs, which partly or wholly exclude the south-easterly waves from shore sectors. Within such sectors the less frequent waves from northerly or north-easterly directions may become dominant, reversing the pattern of drifting. This has been shown in the Cairns district, in the lee of Cape Grafton peninsula, where the sand yield from the Barron River is moved southwards by wave action. At stages when the Barron opened farther north, on the coastal sector more exposed to south-easterly wave action, its sandy yield was carried northward along the shore and delivered to the beaches bordering Trinity Bay (Bird 1969, 1971a). The presence of very coarse quartzose sand on the shores of Rockingham Bay south of the Tully River at Cardwell (sample 25) may be related to the similar exclusion of south-easterly wave action by Hinchinbrook Island, enabling fluvial sand to drift southwards here. The Daintree, which delivers sand to the northern part of Trinity Bay, opens to a sector of the coast which has been built up by sandy deposition along a shoreline orthogonal to the south-easterly waves, which here have a fetch of more than 80 kilometres. The Daintree mouth lies in the 'shadow' of Low Isles to the south-east, and is now deflected southwards by a sand spit. Sand delivered to the coast by the Daintree has moved southwards rather than northwards, because wave refraction around Snapper Island and the prevalence of a current from the north-east through the intervening Penguin Channel have impeded northward movement of sand towards Cape Kimberley.

The Great Barrier Reef does not completely exclude ocean waves from these coastal waters. Swell enters through gaps in the Reef such as Trinity Opening, north of Cairns, and reaches sectors of the mainland coast, albeit in a form much attenuated by wave refraction. Waves from this source can be detected on calm days moving in to the coast between Buchan Point and Yule Point, and they are responsible for the gently-curved sandy shoreline at Hartley's Beach, just south of White Cliff Point. Arriving from the north-east, they contribute to the southward drifting of beach material already mentioned on the Barron delta shoreline, leading to the rapidly-growing spit at Casuarina Point (Bird 1971a).

LOCAL VARIATIONS

Mention has been made of the local variations encountered within beach sectors on the North Queensland coast. A full analysis of these is beyond the scope of the present paper, but certain relationships may be noted. Inspection of Table 1 will show that upper beach samples are often better sorted than those from the lower beach or foreshore. The separation of an upper from a lower beach is thought to be due to sorting by swash and backwash action, the more powerful swash moving coarser material to the upper beach, and sorting it more effectively. There is lateral variation in grain size on both upper and lower beaches: the lower beach on a sector exposed to stronger wave action (sample 74) can be coarser than the upper beach on a relatively sheltered sector (sample 202).

Lateral variations in beach granulometry are complex. The relationship between modal grain size and wave energy is complicated by the fact that material derived from fluvial sources tends to become finer northward away from river mouths (samples 26, 32, 35). Beach material is often locally coarser in the vicinity of rocky shores exposed to strong wave action, where turbulence is unfavourable for the deposition of fine sediment (sample 237). However, beaches adjacent to rocky shores remote from river-mouth sand sources may be comparatively fine in texture, as at Oombunghi (sample 102) and Etty Bay (sample 60). Further complications exist where river mouths have changed position in Recent times, as on the Herbert, Tully and Barron deltas. Such changes may leave sectors with relatively coarse beach material in positions where such material is no longer

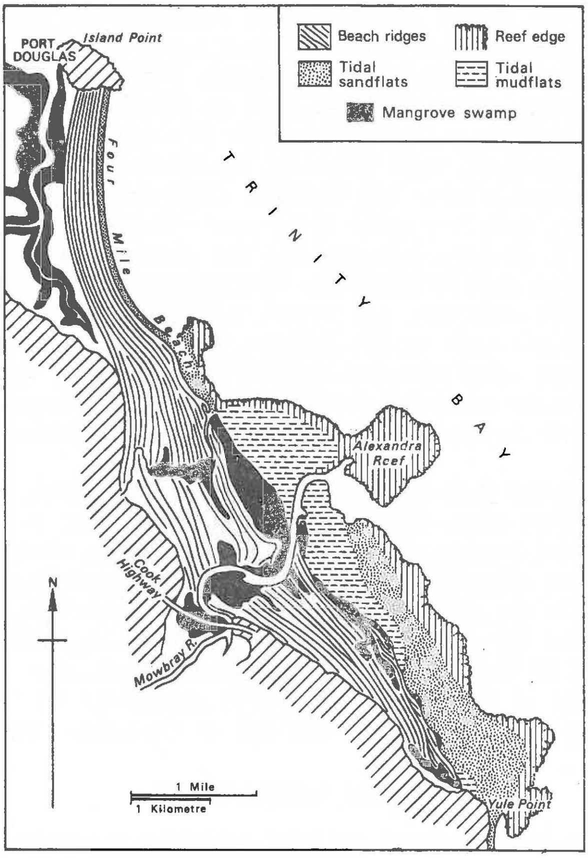

Figure 4 Coastal landforms between Yule Point and Point Douglas, North Queensland.

being supplied. The curious transition from fine to coarse upper beach sand southward along the shore of Rockingham Bay near Cardwell (samples 24, 25) may be explicable in terms of changes in the position of outflow from the Tully.

In general there is less variation in petrography than in granulometry along the North Queensland beaches. It was noted however that felspars tend to be commoner in the coarser beach sands, and that mica and heavy minerals are more abundant in the finer shore sediments. With the exception of slate fragments, lithic grains are also commoner in the coarser beach sands.

In analysing and attempting to explain variations in petrography and granulometry of beach sediments on the North Queensland coast, certain sectors stand out as anomalies. Prominent among these is Four Mile Beach, near Port Douglas (Fig. 4). The fact that this is the only beach in North Queensland along which one can easily drive an ordinary car is an indication of its unusual morphological and sedimentological features.

Four Mile Beach

The beach extends southwards from the rocky headland at Island Point and curves out to a cuspate foreland in the lee of a fringing coral reef before passing behind mangroves at the mouth of a tidal creek. Farther south, the coast has an extensive fringe of mangroves on either side of the estuary of Mowbray River, which opens to the sea by way of a channel flanked by coral reefs. The mangroves front a sandy beach ridge system which continues south-eastward to Yule Point, another rocky headland. An account has already been given of the fringing reefs near Yule Point (Bird 1971b). They originated as nearshore reefs which became attached to the mainland as the result of progradation of the depositional shoreline, with the formation of sandy beach ridges and mangrove swamps. The reefs have grown seaward on either side of the Mowbray outflow, and the pattern of their growth has, in turn, influenced the configuration of the prograding shoreline.

Four Mile Beach is also backed by sand ridges parallel to the shoreline. These developed as beach ridges, emplaced by wave action, and surmounted by dunes up to 3 metres high. Island Point has been tied to the mainland by this sandy barrier, and thus constitutes a tombolo. On its landward side is an extensive mangrove-fringed tidal creek system opening northward into Mossman Bay.

Port Douglas has a mean spring tide range of 1.8 metres (Admiralty Tide Tables 1971). Four Mile Beach is up to 100 metres wide at low spring tides, and thus has an average transverse gradient of about 1 in 55, a little over 1°. The profile steepens slightly towards the rear of the beach, approaching the first foredune, but this distinction between an upper and lower beach is barely perceptible, except near the southern end where coarser material is present as an upper beach and the foreshore becomes muddy.

Four Mile Beach is thus a remarkably uniform sand deposit (Fig. 3). It consists of fine pale grey quartzose sand, very well sorted (sample 191), firmly packed and thus readily trafficable, especially on the damp zone exposed at low tide (cf. Krumbein 1959). The chief petrographic variation is in the proportion of carbonate sand derived from shells and coral, which increases towards the northern and southern ends of the beach (samples 194, 195), where these organisms are abundant in coastal waters.

Four Mile Beach thus differs from other beaches on the North Queensland coast in being relatively uniform, firmly-packed sand, and in its pale grey colour, the sand grains being bereft of the yellow-brown iron oxide staining characteristic of most North Queensland beach sands. It is rarely subject to strong wave action, partly because the extensive reefs near Yule Point shelter it from the direct impact of south-easterly waves, and partly because the offshore profile is very gentle: at low spring tides the water a kilometre offshore is barely 3 metres deep.

The parallel ridges behind Four Mile Beach represent a Holocene sand accumulation, for they overlap a coral reef which has yielded a radiocarbon age of 4130 ± 110 years B.P. (Bird 1971c). The older ridges, exposed in sections on the north bank of the Mowbray River downstream from the Cook Highway bridge, include coarse sand and gravel of the type carried by the Mowbray (sample 172) but the younger ridges to seaward consist entirely of sand (sample 193). This transition indicates a change in the nature of sediment delivered to the prograding shoreline. Fluvial sand and gravel supplied by the Mowbray is now channelled out to the sea floor off Alexandra Reef, and is no longer supplied to adjacent beaches. Another source of beach material has been the quartzose and coralline sediment on the tidal sandflats at Yule Point (samples 166, 167). This is drifting northwards, and may formerly have reached Four Mile Beach, but under existing conditions it is intercepted and carried seaward in the outflow channel from the Mowbray (Fig. 4).

It is therefore suggested that Four Mile Beach has become largely a relict beach, cut off from former fluvial and longshore sand supply, and now receiving only fine-grained biogenic material. Repeated reworking of a beach sand in such a situation has led to its becoming very well sorted and relatively uniform, to the loss of iron oxide coatings on the sand grains, and to a reduction in felspar content. In these terms, Four Mile Beach is attaining sedimentological maturity in the sense defined by Pettijohn (1949); it stands in contrast with the immaturity of actively-nourished beaches on other parts of the North Queensland coast.

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