GEOLOGICAL CONTROLS ON PROCESS-RESPONSE, S.E. AUSTRALIA

by

P.S. Roy* and A.W. Stephens*

ABSTRACT

Results of regional geological studies on the southeastern Australian coast and inner continental shelf suggest that broad relationships between nearshore sediments and morphologies are often the result of factors other than incident waves and wave-induced currents. Five main factors (including wave action) have been identified:

1. degree of compartmentization and sand bypassing,
2. incident wave energy,
3. offshore sand loss to deep water sinks,
4. inherited sediment characteristics,

and 5. substrate control.

It is thought that these factors have controlled coastal evolution in the past and also influence present-day coastal changes. Identification of the role played by individual factors in specific areas provides valuable information on coastal sediment budgets.

INTRODUCTION

Many coastal engineering problems focus on the interaction of marine processes and sediments. Hydrodynamic process are usually seen as the dominant control on the coastal sediments and morphologies. Because of this, many studies use measurements of dynamic processes taken over short time periods to predict sediment response. We suggest that geological factors also influence process-response relationships. Past geological events have both a direct impact on processes themselves, and their imprint modifies the way in which sediments and morphologies react to present-day dynamic conditions. Geological interpretation of sediment patterns and seabed morphologies can provide information on the cumulative effects of variable dynamic processes operating over a time span ranging from decades to millenia. These data can be used to test results derived by other techniques such as direct process measurements, sand tracing and theoretical predictions.

* Marine Geology Section,
Geological Survey of New South Wales, Department of Mineral Resources, Box 5288, G.P.O., Sydney, Australia, 2001.

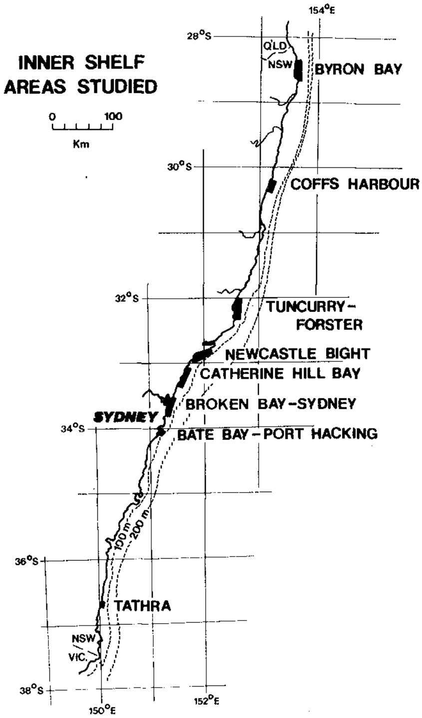

Figure 1. New South Wales coastal zone showing inner shelf areas discussed in text.

Studies in several areas along the New South Wales (N.S.W.) coast (Figure 1) have documented modes of coastal evolution and identified a number of geological controls which affect responses of sediment and morphology to nearshore processes.

COASTAL SETTING

The N.S.W. coast comprises sand barriers between rock headlands in embayed bedrock compartments. It is subject to a moderate to high energy wave climate with dominant waves from the south and south-east. A high degree of compartmentization exists on the south and central coast where rock headlands extend into deep water but in the north, sediment by-passing commonly occurs between embayments as a result of northward littoral drift (Thom and Roy, in press). Rivers do not supply significant quantities of sand to the coast (Roy and

Crawford, 1977). Most barriers on the coast are of Holocene age and lie seawards of a variety of estuarine and alluvial deposits infilling coastal valleys (Roy et al. 1980). In parts of central and northern N.S.W. the Holocene barriers onlap older barriers of Pleistocene age but in some embayments Holocene barriers are absent and Pleistocene sand deposits are exposed at the coast. The barriers formed during the Last Interglacial and Postglacial periods of high sea level (Langford-Smith and Thom, 1969; Marshall and Thom, 1976; Thom et. al., 1978; Thom and Roy, in press).

Sediments

Three main sediment units are recognised on the inner half of the N.S.W. continental shelf: nearshore sand, inner shelf sand and mid-shelf muddy sand (Figure 2). Sedimentation is believed to be presently active in the nearshore and mid-shelf zones but on the inner shelf the sand is palimsest (Swift et al., 1971).

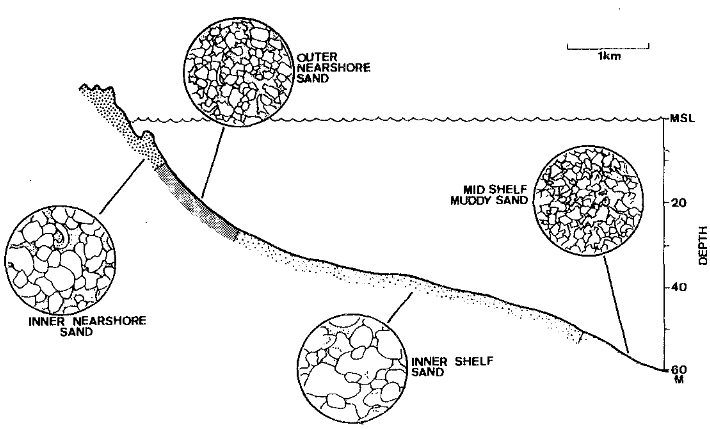

Figure 2. Typical, concave-up sea bed profile showing normal arrangement of sediment types. Lithologies (insets) illustrating grainsizes and shapes are drawn from photomicrographs at the same scale; stippled areas are open spaces.

Nearshore Sand

Nearshore sands comprise inner and outer nearshore sand types although the latter is not found at all embayments. They normally occupy a concave-up nearshore zone that varies greatly in width

(0.7 - 2.6 km) and depth range (15-30 m). Both inner and outer nearshore sand types occupy a zone of active reworking that corresponds to the seaward face of the coastal barriers.

Inner nearshore sand includes the beach and extends seawards of the longshore bar to depths of 4 - 12 m. It is fawn, quartzose, medium to coarse grained, moderately to well sorted (unimodal to bimodal) and composed of rounded grains. Usually it contains less than 10% shell fragments and less than 20% of the grains are ironstained although in a few embayments values are much higher. Texture and composition may vary widely between compartmented embayments. Landward of the longshore bar, grainsize changes reflect variations in surf zone processes and morphologies; seaward of the bar, sand size usually decreases with increasing depth. Bedforms vary from small ripples to large symmetrical and asymmetrical sand waves.

Outer nearshore sand lies seaward of the inner nearshore sand unit, often with a relatively sharp boundary and extends to depth of 15-30 m. It is olive grey, quartzose, fine grained, well sorted (unimodal) and composed of sub-angular to rounded grains. Shell content and iron staining are usually similar to the associated inner nearshore sand although outer nearshore sand is texturally more uniform between embayments. Despite decreasing wave turbulence, grainsize usually shows little variation with increasing depth. Small symmetrical wave-formed ripples are the typical bed form.

Inner Shelf Sand

Inner shelf sand occupies the gently sloping inner shelf surface and extends seawards from the zone of nearshore sand to depths of 50-60 m+. It is orange-brown (due to extensive ironstaining), quartzose, medium to coarse grained and, in places, gravelly. It is generally poorly sorted (polymodal) and composed of well rounded grains. Shell content is highly variable but is usually less than 20%. Mud occasionally forms a minor component (<5%), mainly in the outer part of the unit. Inner shelf sands are texturally variable both within and between regions. Symmetrical (wave-formed) megaripples commonly occur in areas of coarse sand and gravel. Algae coatings on pebbles indicate that movement occurs mainly during high energy events.

Inner shelf sands do not conform to a classical "equilibrium" trend of fining seaward. They are essentially relict deposits that are presently being reworked.

Mid-Shelf Muddy Sand

Muddy sediments occur discontinuously over large areas of the mid-shelf seawards of the 50-60 m isobath (Thom and Roy, in press). They comprise dark grey, fine to very fine sand plus mud and support an abundant fauna of foraminifera, polychaetes and bivalves. Sand grains are angular to subangular and non-ironstained. Lithic content in the sand is usually higher than in other sediment on the inner shelf. In places the muddy unit contains a coarse sand mode that is thought to be related to an underlying relict sand substrate; intermixing is presumably by bioturbation.

From the occurrence of fine sediment in this region we infer a low energy "window" between the wave-dominated inner shelf and the current-dominated outer shelf and upper continental slope (not discussed here).

The normal relationship between sediments and morphology seawards of the surf zone is for nearshore sands to form a moderately steep, concave-up slope (Figure 2); grainsizes generally decrease seawards with increasing depth. This region corresponds to an active zone in dynamic semi-equilibrium with the local wave climate. Further seawards the palimpsest, inner shelf sands form a more gently sloping planar surface. The relatively abrupt change in grainsize between fine outer nearshore sand and coarser inner shelf sand suggests that the latter do not presently contribute significantly to the modern coastal sediment budget.

Barrier sediments on the N.S.W. coast were derived from three sources: (a) the inner continental shelf, (b) coastal sand barriers of Pleistocene age, and (c) modern fluvial supply.

(a) The majority of the barrier and nearshore deposits are formed of sand reworked from the inner shelf and transported onshore during and since the Postglacial Marine Transgression (Roy et al., 1980; Thom and Roy, in press). This sediment type is mainly composed of mature, rounded and partly iron oxided-coated quartz sand and shell that has been repeatedly reworked, mainly by marine processes during one or more glacial/interglacial cycles. Locally it is termed "marine" sand (Roy and Crawford, 1977).

(b) In areas where Pleistocene barriers are exposed at the coast, marine erosion of these deposits supplies sand to the modern beach and nearshore zones. The parent sand is "marine" in character and, except for leaching of shell and the absence of iron oxide coatings, its erosion product is similar to the sand forming the Holocene barriers.

(c) Rivers supply sand to only a few small embayments in southern N.S.W. (R. Kidd, unpubl. Ph.D. Thesis, 1980). "Fluvial" sand is typically immature (angular) and contains abundant lithic (rock and feldspar) grains. Elsewhere, medium to coarse river sand is deposited in the lower river valleys and in coastal estuaries (Roy and Crawford, 1977). Fine to very fine terrestrial sand and mud that is carried to the sea during floods is transported (diffused) across the inner shelf and deposits in the mid-shelf region (Thom and Roy, in press).

Barrier Formation

Considerable radiocarbon age data on shelly beach and nearshore facies in prograded beach ridge systems (Thom, 1978; Thom et al., 1978) show that most Holocene barriers accreted between about 6000 and 3000 years ago, with a few continuing to grow up to 1000 years ago. Over this time span, sea level on the tectonically stable southeast Australian margin has remained fairly constant (± 1 m) (Thom et al. 1969, 1972; Cook and Polach, 1973; Thom and Chappell, 1975; Belperio, 1979; Jones et al., 1979).

Thus it is reasonable to assume that barrier building occurred under marine conditions broadly similar to those operating today. The composition of most barrier deposits clearly shows that they are formed of sand reworked from the inner shelf; not from modern fluvial sources. In some areas there was undoubtedly a strong littoral drift supply from upcoast, but in closed compartments the sand feed was essentially in an onshore direction. Figure 3 shows the latter situation for an embayment that is closed in terms of littoral drift inputs and outputs. The original 6000 year profile configuration has been reconstructed by transposing the volume of sand in the existing barrier to the offshore sea bed. A prograded wedge of barrier deposits (stippled) composed of beach and nearshore sand forms the inshore part of the profile. Further seawards are inner shelf sands that have acted as a sand source for barrier building in the past. Thus the inner part of the profile is aggradational while its outer part is erosional. From this reconstruction it is clear that, during barrier formation, sand was transported landwards in water depths considerably deeper and from further seawards than is apparently occurring today as indicated by the present active zone of nearshore sediments. There is virtually no evidence in N.S.W. that barriers are still prograding: in fact the reverse is generally the case. What has stopped them growing?

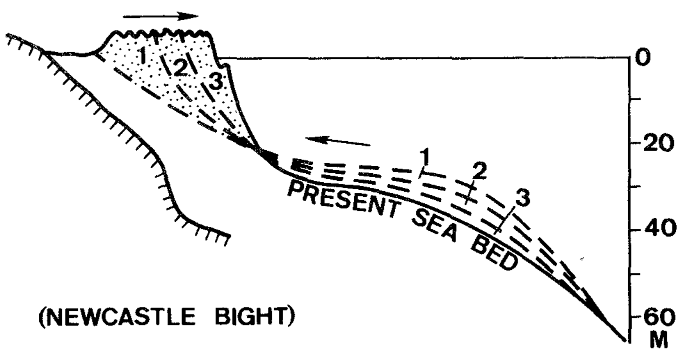

Figure 3. Model of mid Holocene barrier development in a compartmented embayment showing inferred movement of sand from the inner shelf under sea level conditions similar to the present day. Numbers 1-3 represent the chronological sequence of barrier growth and corresponding sea bed erosion. Arrows show directions of beach ridge progradation and associated sand supply from offshore.

One possibility is that the sand supply was cut off once a wave-formed profile of equilibrium was established. Further, from the preceeding discussion, we would expect the equilibrium profile to extend to water depths of 50 m or more. In these depths the open ocean wave climate is broadly consistent along the N.S.W. inner shelf although local variations occur in the inshore zone due to refraction and diffraction effects. Thus, if waves were the principal control limiting barrier development, we would anticipate general similarities in profile shape (especially in its outer part) and in sediment patterns between embayments.

Figure 4 shows a selection of shore-normal profiles across the N.S.W. inner continental shelf. General similarities in the inner parts of these profiles suggest that equilibrium conditions may exist in water depths above about 15 m. Below this depth, the wide diversity in gradients and morphologies are difficult to account for in terms of a simple, wave-controlled equilibrium profile of the type proposed by Zenkovitch (1967). Obviously, factors other than wave action are important in producing present-day sea bed patterns. Interest in the morphology and sediments in coastal embayments and on the inner shelf arises from the belief that factors controlling barrier development in the past also influence modern shoreline changes.

CASE STUDIES

Geological investigations have been carried out in a number of areas along the N.S.W. coast in conjunction with coastal engineering studies by the N.S.W. Department of Public Works. These projects were

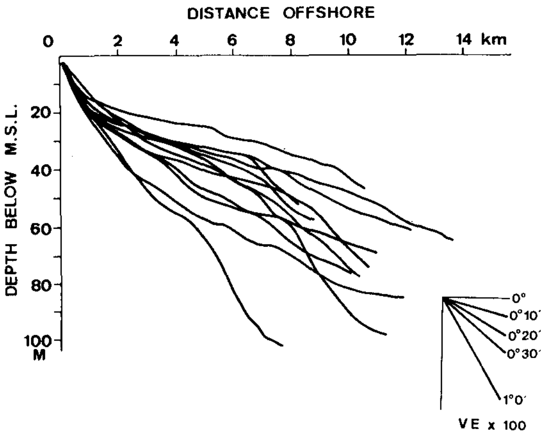

Figure 4. Shore-normal sea bed profiles from open ocean embayments in N.S.W. showing the diversity of shapes.

aimed mainly at providing information on coastal erosion and its management. Results from several areas illustrate the ways in which geological factors have influenced coastal sedimentation. The areas are: Byron Bay and Coffs Harbour in northern N.S.W. and Newcastle Bight in central N.S.W. (figure 1).

Byron Bay

The Byron Bay embayment (figure 5) is an example of an open, zetaform bay in which southeasterly swell waves generate a strong northward littoral drift and ocean currents cause an offshore sediment loss (Roy et al., in press). Uninterrupted sediment bypassing is indicated by the continuity of the nearshore sediment zone around headlands. Despite variations in incident wave energy, inner nearshore sand is of uniform composition and texture throughout the area due to longshore mixing. Progressive deepening and steepening of the shoreface towards the north is related to increasing wave energy in the same direction (see profiles A and B in Figure 5).

Alongshore variations in the energy and obliquity of the incident waves produce higher littoral drift rates in the north than in the south (Figure 6). As a result of this drift differential, the embayment between Cape Byron and Hastings Point is eroding into old Pleistocene sand deposits. Average rates of shoreline recession are 0.6 m/yr based on historical data (40-90 years) and between 0.25 and 0.35 m/yr from radiocarbon evidence spanning the past 400 years.

The present imbalance between drift gains and losses is attributed to three causes: (a) a regional increase in obliquity of the coast to the dominant wave approach; this tends to increase littoral drift rates towards the north.

(b) both regional and long-term tendencies in northern N.S.W. for embayments to become compartmented earlier in the south than in the north thus causing a gradual reduction in sand supply to areas downdrift.

(c) a long-term loss of nearshore sand at Cape Byron at the southern end of the bay to deep water sinks offshore (see below).

It is probable that, in mid Holocene times, onshore transport of sand from the inner shelf resulted in barrier development in Byron Bay as it did in most other embayments in N.S.W. However, eventually the Byron Bay barrier was eroded as a drift imbalance developed and it is likely that recession rates have gradually increased over the Late Holocene, mainly due to (b) above.

Areas of offshore sediment loss are identified by abnormalities in the shape, width and depth range of the nearshore sediment zone. In the north this zone is narrow and extends to depths of about 25 m. Profiles are concave-up and indurated Pleistocene sediments, exposed on the shoreface to depths of 18 m, indicate that the whole nearshore zone is erosional. However in central and southern parts of the area, the nearshore

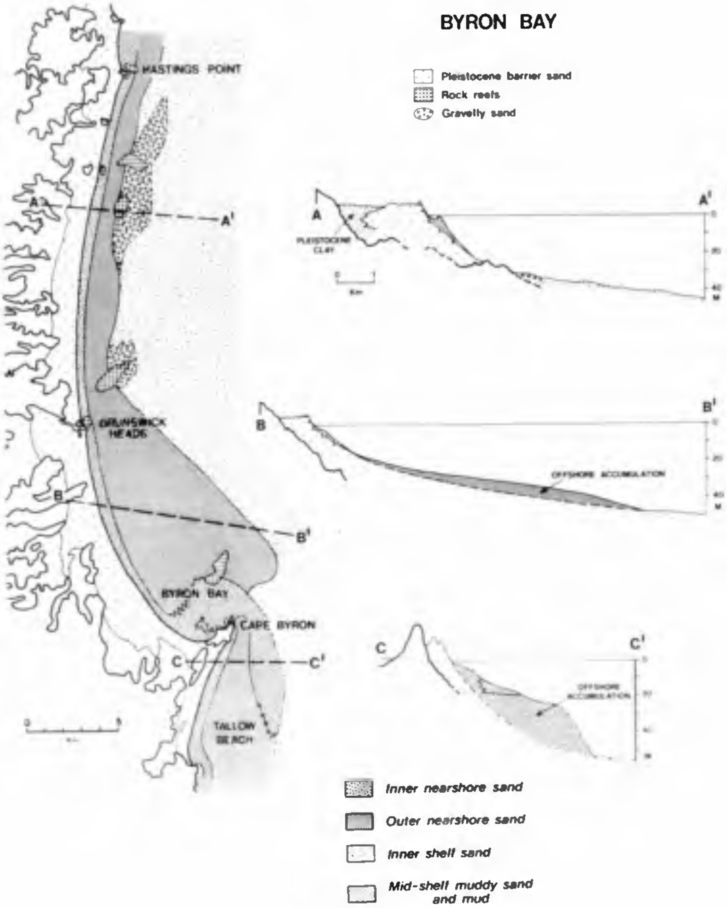

Figure 5. Byron Bay offshore area showing distribution of sediments and inferred Holocene stratigraphy. The inner parts of cross sections A and B show a thin wedge of active nearshore sand above an eroding Pleistocene substrate. Accumulations of nearshore sand lost from the shoreface since mid Holocene times occur in profiles B and C. Bedrock margin onshore indicated by solid, heavy line.

sediment unit widens and extends to depths of 50 m, twice the normal depth, and profiles become convex-up (figure 5, profiles B and C). These trends are attributed to deposition of sand in offshore sinks by southward flowing ocean currents (figure 6). During strong southeasterly swell action, nearshore sand which drifts northwards along Tallow Beach is "jetted" past Cape Byron. At times when the southward flowing East Australian Coast Current impinges on the headland, wave-suspended sand is entrained and transported southwards. In this area low amplitude, current-formed sand waves occur in depths of 20 m +. Deposition occurs in a southward trending lobe (figure 5) where the ocean current diverges from the coast, velocities weaken and eddies form (Figure 6). Accumulation of a smaller volume of finer outer nearshore sand over a broad area to the north of Cape Byron is probably due to a clockwise sediment circulation generated by wave drift inshore and ocean currents offshore.

A regional alongcoast movement of sediment is indicated by the continuing supply of sand to both depositional sites. Northward littoral drift in the surf zone together with deep water wave drift from the south and (possibly) ocean current transport from the north within the outer nearshore zone are probable supply mechanisms (Figure 6). The principal source of beach and nearshore sand in this area is from the erosion of Pleistocene barriers both within the embayment and up coast (i.e. to the south).

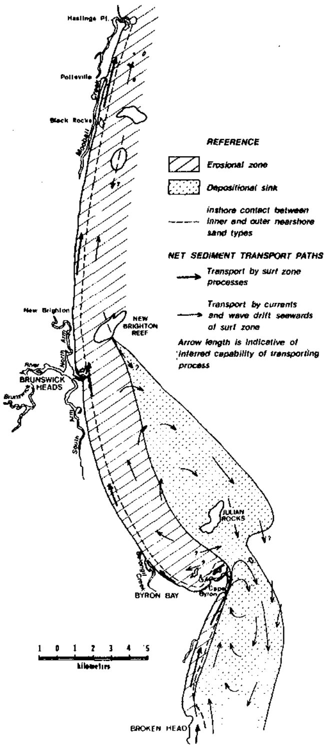

Figure 6. Byron Bay area showing regions of offshore erosion and deposition and inferred sediment transport mechanisms and paths.

The deposit to the south of Cape Byron is up to 20 m thick and has been calculated to contain approximately 160 million m^3 of outer nearshore sand above an initially concave-up substrate. Assuming deposition commenced about 6000 years ago, the average rate of sand loss from the nearshore system has been about 26,000 m^3/yr of inner and 58,000 m^3/yr of outer nearshore sand.

Coffs Harbour

This area lies within a sector of bedrock controlled coast; rock reefs occur extensively offshore (figure 7). Changes in coastal orientation and bedrock embayment size are responsible for contrasting coastal development north and south of Coffs Harbour. Southern embayments are relatively large and contain extensive Pleistocene estuarine deposits that originally accumulated behind sand barriers of the same age. These Pleistocene barriers have subsequently been destroyed by marine erosion, presumably towards the close of the Last Interglacial. Later, they were replaced by Holocene beachridge barriers that prograded in bay mouth positions. The coast north of Coffs Harbour is characterised by small embayments and pocket beaches with narrow Holocene barriers backed, in most areas, by bedrock.

Nearshore and inner shelf sediments form a generally thin veneer above bedrock or a Pleistocene clay substrate. Maximum thicknesses occur beneath the southern barriers (Figure 7, cross section C-C') but elsewhere, nearshore sediments are commonly less than 2 m thick. The continuity of the inner nearshore sand unit is interrupted by Coffs Harbour and by a number of headlands to the north of the harbour. This sediment unit is wider and extends to greater depths (c. 12 m) in the south than in the north (c.5-8 m). Beach and inner nearshore sand in the south is uniformly medium grained and the beaches have wide surf zones but in the north beaches are coarse, steeply sloping and usually reflective in character. Outer nearshore sand forms a continuous zone alongshore but is interspersed by rock reefs and exposures of coarse inner shelf sand and gravel that form the underlying substrate. Outer nearshore sand forms a thin "mobile carpet" that is completely remobilised under even moderate storm conditions. This unit occurs in depths ranging from 12-25 m in the south and 5-20 m in the north.

Shore-normal profiles in the south are steeper and more concave than in the north where the underlying substrate exerts an over-riding control on sea bed configurations (Figure 7).

Since harbour construction commenced in 1915, northward littoral drift has been interrupted and sand has been trapped in the southern embayment. Historical data spanning the last 40 years indicate that the northern end of this embayment has prograded up to 100 m and about 5 million m^3 of sand has deposited on the beach and in the inner nearshore zone. Over approximately the same period, more than 1.5 million m^3 of mainly fine, outer nearshore sand has accumulated inside the Harbour and off its mouth where the sea bed has developed a marked convexity.

It is reasonable to assume that, prior to harbour construction, northward littoral bypassing operated, albeit at a low rate, throughout the whole region. The northern beaches at this time are reported to have

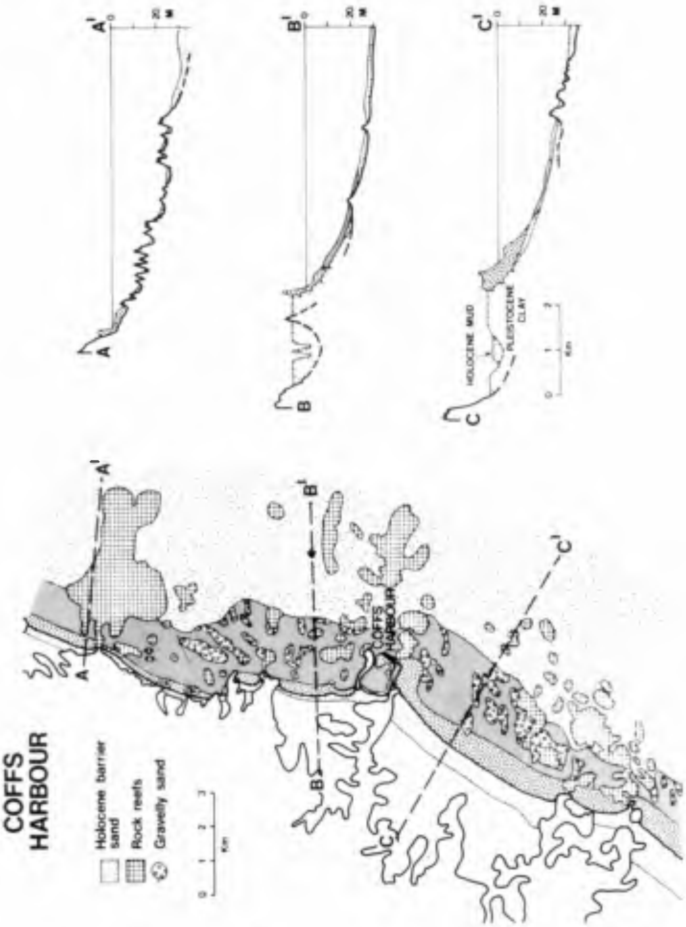

Figure 7. Coffs Harbour area showing surface sediment units and stratigraphic sections. Progressive increase in barrier size towards the south is related to bedrock embayment size. Note change in coastal orientation at Coffs Harbour. (Key to offshore sediments shown in Figure 5).

been fine grained, gently sloping and dissipative in character. The response of these northern beaches to the cessation of updrift sand supply in the period following harbour works has been strongly influenced by the shallow substrate. Coastal retreat has been mitigated not only by the bedrock hinterland but also by the character of the offshore sea bed. Radiocarbon dating on subsurface shell samples from within the zone of fine outer nearshore sand suggests that the underlying, coarse inner shelf sediments are reworked during storms to depths in excess of 1 m below the sea bed. Their periodic exposure has released coarse sand and fine gravel that has migrated onshore. As a result beaches in this area have coarsened and steepened and, in at least one case, have prograded slightly in historical times.

Newcastle Bight

Newcastle Bight (figure 8) is a broad shallow embayment oriented normal to the dominant wave regime. There is a large gross littoral drift but no net drift. It has acted as a sand trap during two periods of interglacial high sea level, and is the best known example of a dual barrier system on the N.S.W. coast (Thom, 1965; Roy, 1980, Thom et al. in press).

The oldest sand deposits on the inner continental shelf of Newcastle Bight form a drowned coastal barrier (proto-barrier) located 3-6 km seawards of the present coastline in water depths of 55-60 m+. An associated sequence of estuarine clay in the subsurface extends shorewards from the proto-barrier and underlies the onshore barriers (Inner and Outer Barriers, Figure 8). The clay unit is up to 60 m thick and is of polycyclic origin. Both the proto-barrier and estuarine deposits predate the Inner Barrier which is of Last Interglacial age (Roy and Crawford, 1980).

Sandy strandline deposits overlie the clay substrate offshore and occupy the inner shelf plain between the proto-barrier and the concave-up nearshore zone. These inner shelf sands contain gravels related to an old drainage system of the Hunter River; they form a basal transgressive unit beneath the Outer Barrier.

The Outer Barrier is Holocene in age and comprises beach ridges transgressed on three separate occasions by dunes. To the rear of the barrier, estuarine backbarrier deposits infill the interbarrier depression. Modern muds and sandy muds blanket the seaward face of the proto-barrier in water depths greater than 60 m.

The Newcastle Bight sediment budget is in deficit due to the loss of beach sand landwards into presently mobile dunes. Present-day inputs of sand to the nearshore zone by littoral drifting, cliff erosion, biogenic production and river supply are small. In historical times the shoreline has receded at rates of 1-2 m/yr (Gordon and Roy, 1977; Roy and Crawford, 1980).

On the seaward face of the Holocene barrier is a zone of nearshore sand which is compartmented by deep water rock reefs at either end of the embayment. The contact between nearshore and inner shelf sand types is abrupt and occurs at depths of between 15 and 30 m. The nearshore zone shows a number of alongshore trends: In the centre of the embayment where sediments are coarse the nearshore profiles are steep, a single bar is

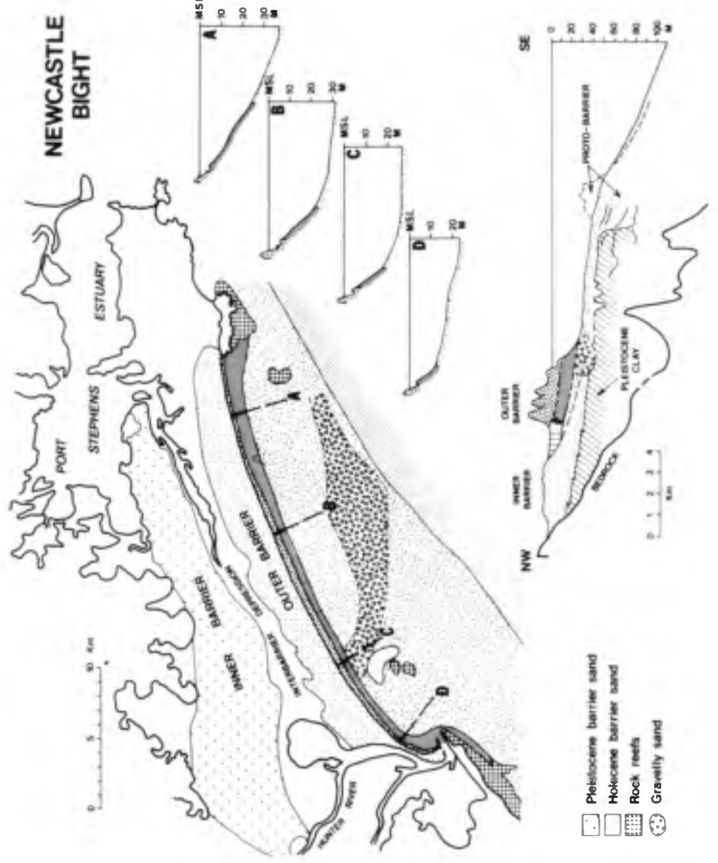

Figure 8. Newcastle Bight showing dual barriers onshore and offshore sediment distribution; gravelly sands are related to an old course of the Hunter River. Stratigraphic section is based on onshore drilling and marine seismic data for the axial part of the embayment. (Key to offshore sediments shown in figure 5).

developed and the nearshore sand zone is narrow. Towards the northeast where sediments are finer, profile slopes are more gentle, multiple bars are developed and the nearshore sand zone is wide. Grain size trends in the inner nearshore sand unit mirror those within the eroding Holocene barrier. This barrier is composed of sand reworked from the inner shelf. Here the sediments are coarse, relict fluvial deposits in the centre of the bay and fine, relict dune sand at its northeastern end (Roy and Crawford 1980). Their onshore transport has produced a similar size grading in the barrier. Subsequent shoreline erosion has thus exposed barrier deposits of different grain sizes on the beach and shoreface with the result that nearshore morphologies vary alongshore. Despite a large gross drift, continuing erosion has allowed inherited grain size characteristics to dominate in controlling the profile shapes.

DISCUSSION

Based on studies of the type described above, at least five main factors can be identified as influencing the relationships between sediments and morphology in coastal embayments of southeastern Australia. These are:

1. Compartmentization
2. Incident Wave Energy
3. Offshore Deposition
4. Inherited Sediment Characteristics
5. Substrate Control.

1. Compartmentization

Varying degrees of compartmentization and sediment bypassing are shown by the plan distribution of nearshore sand types. In the Byron Bay region (Figure 5) the continuity of inner and outer nearshore sand units around headlands at either end of the embayment indicate that this compartment is open to littoral bypassing although drift rates within it vary. The Coffs Harbour area (Figure 7) is compartmented with respect to inner nearshore sand but not outer nearshore sand although subtle differences in grainsize within the latter unit suggest that alongshore mixing rates are relatively low. In Newcastle Bight (Figure 8), both inner and outer nearshore sand units terminate against headlands and submarine rock reefs at either end of the embayment. In this case alongshore gains and losses of sand to the sediment budget are negligible.

2. Incident Wave Energy

Local variations in wave energy within an embayment are reflected by relationships between nearshore sediments and morphology. This is best displayed in zetaform bays which are oriented obliquely to the dominant wave climate and, in southeastern Australia, are hooked at their southern ends (e.g., Byron Bay). In areas of low wave energy the sea bed is shallower and shoreface profiles are less steep than in more exposed sites (see trend between south, central and north profiles of the Byron Bay embayment, Figure 9a). These morphological changes may or may not be accompanied by grainsize trends in the beacn and nearshore sand units. In compartmented bays with negligible littoral bypassing

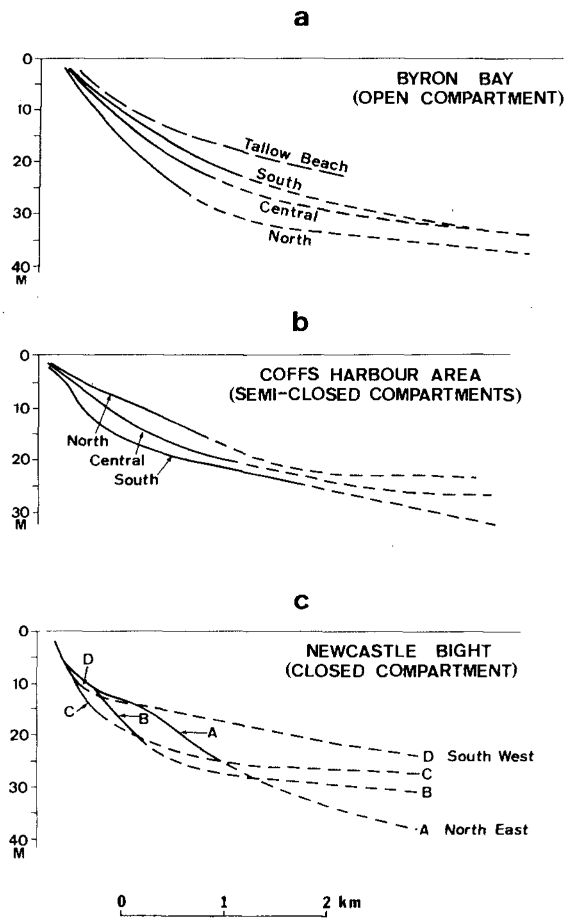

Figure 9. Shore-normal sea bed profiles for three areas each showing progressive variations in shape and distribution of nearshore (solid lines) and inner shelf (dashed lines) sediment units.

grainsizes coarsen in response to increasing wave energy (e.g., Pearl Beach in Broken Bay, Chapman, 1978). However, in compartments open in terms of littoral bypassing (these are almost invariably "zeta" shaped in N.S.W.), sand sizes are uniformly well mixed alongshore (e.g., Byron Bay).

Zetaform bays usually evolve erosionally due to a drift differential within an open littoral drift system. Eventually, shoreline retreat and headland emergence prevents further littoral throughout and, providing no other sand loss mechanisms operate, the bay achieves a stable configuration. The presence or absence of alongshore grainsize trends in such bays is a useful criterion to determine whether a stable planform has been achieved, especially where headland bypassing is difficult to establish by other methods.

3. Offshore Deposition

For sediment budget calculations, permanent sand losses into transgressive dune fields and estuarine tidal deltas are usually easily recognised. Newcastle Bight and Bate Bay (Figure 1) are embayments that have lost sand into transgressive dunes; Broken Bay and Port Hacking are drowned river valleys containing large flood tide deltas composed of "marine" sand. Less obvious are sand losses to relatively deep water offshore. The progressive accumulation of sand offshore in water depths of up to 50 m cause abnormal distributions of nearshore sediments types and sea bed profiles that are convex, rather than concave-up.

In Byron Bay (Figures 5 and 6), loss of nearshore sand by ocean current action to offshore sinks is excerbating coastal erosion within the embayment. Here volume estimates of the sand contained in the offshore sinks are based on assumptions that the transporting mechanisms have operated since sea level reached its present position about 6000 years ago and that a pre-existing substrate on which deposition has occurred can be recognised in the subsurface.

At Tathra (Figure 1), river sand is jetted seawards during major floods and deposited offshore in water depths of up to 26 m. In this embayment a major flood in 1971 appears to have initiated shoreline recession of up to 40 m as sand was transported alongshore (northwards) to infill the overdeepened river mouth and reform the river mouth bar (Gordon and Lord, unpubl. Public Works Department report., 1980). Onshore transport of excess sand from the bay bed has not yet (i.e., 9 years later) restored the shoreline to its pre-flood configuration. In this case it remains to be determined whether the supply of river sand to the bay during mid and late Holocene times has produced net, long-term shoreline accretion despite short-time erosion following floods. If not, then presumably other mechanisms, as yet unidentified, cause a continuing loss of river supplied sand from the bay (to deep water offshore?) in which case the shoreline may be experiencing long-term retreat.

4. Inherited Sediment Characteristics

The source of Holocene sediments infilling most sandy embayments in N.S.W. was from the inner continental shelf, and was the result of marine reworking during and following the Postglacial Marine Transgression (Thom et al., 1978; Roy et al., 1980). In embayments which are suffering erosion, the composition of the Holocene barriers may control nearshore sediment-morphology relationships and over-ride dynamic influences. This situation has only been found in compartments with no littoral drift throughput.

In Newcastle Bight (Figure 8), shoreface erosion into coarse grained barrier sands in the centre of the embayment has resulted in steep but relatively shallow nearshore slopes (profiles C in Figure 9c). Towards the northeast, sands become finer and profiles have responded to similar wave conditions by becoming more gently sloping but deeper (profiles A and B in Figure 9 c).

A similar situation appears to exist in Shoalhaven Bight, 120 km south of Sydney. Here the over-riding influence of inherited sediment textures is highlighted by a northward fining of the beach and nearshore sediments despite an increase in wave energy in the same direction (Wright, 1970).

These relationships demonstrate that a number of different nearshore configurations may accomodate a given incident wave regime. The controlling factor is sediment size; the dependent variable is morphology.

Substrate Control

Holocene barriers have accumulated on a gently inclined substrate that includes medium to coarse sands and gravels. Where this substrate had been transgressed and is exposed on the sea bed, it forms the inner shelf sand unit. Under eroding conditions, landward retreat of the seaward face of the coastal barriers intersects the rising surface of the underlying substrate. As a result, nearshore sediment patterns and morphologies are modified: nearshore sediment zones become narrow and occur at shallower than normal depth while profiles flatten and become more planar.

In the Coffs Harbour area these trends are increasingly developed towards the north (Figure 9 b). Reworking and onshore transport of sand from the shallow substrate in the region north of the harbour has presumably been responsible for the relatively coarse nature of the adjacent onshore deposits both during their formation in mid Holocene times and more recently after harbour works interrupted the littoral sand supply.

In the Byron Bay area coastal retreat over an inclined substrate has exposed patches of gravelly, inner shelf sand on the lower shoreface between Brunswick Heads and Hastings Point (Figure 5). In contrast, offshore deposition in the Tallow Beach embayment immediately to the south of Byron Bay (Figure 5) has resulted in a shallower and more gently sloping sea bed than in nearby areas with similar wave exposure (compare the Tallow Beach profile in figure 9a with that from the northern part of the Byron Bay embayment).

In the Forster-Tuncurry area (Figure 1) large embayments either side of Cape Hawke show contrasting offshore morphologies that have influenced barrier development onshore. The sea bed off the southern embayment is deep and steeply sloping; the Holocene barrier here is narrow. The northern embayment has a wide, shallow inner shelf plain that has acted as a large sand source during barrier building in the past. Both Holocene and Pleistocene beachridge barriers are well developed in this embayment.

CONCLUSION

Geological studies of marine deposits along the N.S.W. coast have led to the identification of a number of factors that have played an important role in producing present-day nearshore morphologies and sediment patterns. The geological setting in which these factors operate is a tectonically stable shelf and coast with a very small supply of modern sediment and a moderate to high energy wave climate. Here, coastal barriers in bedrock embayments are mostly composed of sand derived from the inner shelf; many barriers are presently eroding.

Although incident waves are the principal sand transporting mechanism on the open coast, their influence on many coastal sand deposits is modified by the nature of the local bedrock and older sediment surfaces at the coast and on the inner shelf. These modifications are reflected by: the extent to which sand is exchanged between embayments (factor 1); variations in embayment orientation and incident wave energy within the embayment (factor 2); the range of shoreface morphologies produced by different inherited sediment types (factor 4); differing shoreface responses to changes in sediment supply (factor 5). In isolated cases, ocean currents modify wave-induced sand transport patterns and produce atypical nearshore sediment distributions and morphologies (factor 3).

Recognition of factors such as these provide information on how specific coastal sand deposits originally formed and have evolved subsequently. Except possibly for factor 3, they do not directly quantify sediment budgets but rather provide a framework within which the importance of separate budgetary components can be assessed. Undoubtedly additional factors remain to be identified on this coast. Certainly, on coasts which are presently receiving large sediment influxes, have lower energy or are undergoing relative sea level change, other factors will be found to be important.

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