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Geological Model of Long Term Coastal Erosion at Seven Mile Beach, Lennox Head, Northern New South Wales

INTRODUCTION

Beach erosion on the N.S.W. coast has received considerable attention during the past 10 years. This submission attempts to review existing theories, and to present a geological model of coastal evolution for the northern N.S.W. coast. Specifically the model will be applied to Seven Mile Beach to evaluate the potential for long term coastal erosion.

The N.S.W. coastline is generally oriented north-south and is oblique to the dominant south and southeasterly swell direction. Therefore a potential exists for northerly littoral drift. South of about 32° S (Sugarloaf Point - Seal Rocks) embayments are strongly compartmented, but further north littoral bypassing occurs along many sectors (Roy and Thom, 1975; Roy and Crawford, 1977; Roy et al, 1980).

Existing Models of Long Term Erosion

Three possible causes for long-term erosion were discussed by Thom (1974):

1. Changes in sea level
2. Changes in wave energy or storminess
3. Changes in sediment supply

Changes in Sea Level

Sea level history has been determined for a number of areas along the east coast of Australia. The detailed studies show that sea level reached its present position about 6000 to 7000 years ago, and has remained fairly stable (± 1m) ever since (Thom et al, 1969; 1972; Cook and Polach, 1973; Thom and Chappell, 1975; 1978; Jones et al, 1979) Belperio 19 There is no unequivocal published evidence to show that sea level on the northern New South Wales coast could have been substantially higher during the past 6000 years. Some unpublished data, which has not yet been properly evaluated, is suggestive of a short-lived Holocene sea level stand perhaps 1 to 2 m below the present. The morphologic effects, if any, of sea level changes smaller than ± have not been evaluated for the high energy, wave dominated N.S.W. coast (Thom, 1978).

Changes in Wave Energy

Thom (1978) has presented a climatic model for periods of increased wave-climate storminess, and their effects on shoreline erosion/accretion and dune movement/stabilization. His model invokes periods of enhanced cyclogenesis in the Tasman Sea due to the action of blocking atmospheric high pressure systems. While this model appears reasonable with respect to predicted hydrodynamic and morphological responses, explanations for the episodic component of the model are not yet definitive.

Changes in Sediment Supply

Sandy barriers along most of the N.S.W. coast consist of marine sand supplied from the inner continental shelf during the Holocene epoch (10,000 years ago till the present). Changes through time have been evaluated for the inner shelf supply by Thom (1974, 1978), Davies (1974) and Roy and Stephens (in prep.). It is generally agreed that the reserve of sand, eroded from the inner shelf and deposited as prograded beach-ridge barriers, has dwindled in late Holocene time. Thom (1978) and Thom et al (1978) have shown that for a number of barriers on the south and central coast, onshore transport and barrier progradation generally ceased 3000 years ago, although a few barriers continued to grow until about 1000 years ago. Roy and Crawford (1977) have shown that coastal rivers have not contributed significant quantities of sand grade material to Holocene barriers or modern shorelines in northern N.S.W. River-supplied sand in N.S.W. is confined to a few com partmented embayments on the south coast (Roy and Stephens, 1980a).

Several localized studies have focussed on variations in littoral drift supply as a cause of coastal erosion. Delft (1970) showed that the coastal alignment of the zetaform Gold Coast embayment, combined with the dominantly oblique southeasterly swell, induced a progressive northward increase in the rate of northerly littoral drift. The deficit in the littoral sand budget so produced, is made up by backshore erosion of the coastal sand deposits. Gordon et al (1978), Roy and Stephens (1980b), Gordon and Lord (1980) and Roy et al (in prep.) have shown that variations in sediment supply, within the littoral drift system of Byron Bay, are causing long-term coastal erosion. The Byron Bay-Hastings Point embayment suffers from a littoral drift differential, due to a progressive northward increase in northerly littoral drift rates. An additional budgetary deficit in the system is produced by ocean current transport and permanent offshore sand losses to a depositional sand lobe south of Cape Byron.

Unfortunately the initial studies at the Gold Coast and Byron Bay did not provide sufficient data for an overview of erosion potential for the entire region. Roy and Crawford (1977) have attributed long-term erosion to dwindling sand supplies due to northward littoral drift, wind losses into coastal dunes, and to other minor losses, in a system which receives no modern external sand supply.

Gordon and Lord (1980) described a "generalized understanding model" for coastal processes along the New South Wales coast, which involves two geological factors: (1) onshore transport of a finite store of inner shelf sand with consequent beach-ridge barrier progradation in mid Holocene time, and (2) late Holocene dominance of littoral drift processes as the offshore sand supply diminished. Gordon and Lord (1980) saw this second phase as a cause of long-term beach erosion, in view of negligible modern sand supply from either rivers (Roy and Crawford, 1977) or offshore sources (Gordon and Roy, 1977). Implicit in their generalized model is the notion that this mechanism of erosion applies only to a littoral-drift bypassing coast.

Integrated Models

Thom and Bowman (1980) have expanded on Thom's (1978) climatic model of periods of increased storminess, and have described resultant beach erosion and permanent sand losses into transgressive dunes. They integrated the component of dwindling offshore supply, to provide a predictive model for long-term erosion potential. The net result of fluctuations in storminess and dwindling supplies of nearshore sand, is that "periods of beach face erosion, at either the long or short term scale, are becoming more severe" (Thom and Bowman, 1980). Their model, although determined for a compartmented coast with transgressive foredunes, also applies to a littoral bypassing coast.

A littoral drift geological model is presented below and applied specifically to evaluation of erosion potential at Seven Mile Beach.

MODEL FOR NORTHERN N.S.W.

Seven Mile Beach fits a predictive geological model of long-term coastal erosion in northern N.S.W., which is presently being developed by the writer.

Coastal erosion in this region is believed to be related to variations in littoral drift rates, which result in a deficit in the sediment budget. In brief, the predictive model states that a Pleistocene-backed shoreline on a littoral drift bypassing coast, must necessarily be suffering from long-term erosion. For Seven Mile Beach in particular and the region as a whole, long term erosion is attirbuted to two causes, involving (1) coastal alignment, and (2) compartmentization.

Coastal Alignment

The regional model of long-term erosion applies from the Clarence River mouth to the Gold Coast. Northwards from the Clarence River mouth, embayments are aligned progressively more obliquely to the dominant south-easterly swell. Regional long-term erosion therefore results from progressively higher northerly littoral drift rates for successive embayments to the north.

Seven Mile Beach is on a sector of this coastline where embayments to the south are aligned less obliquely to the dominant south-easterly swell and have lower littoral drift rates. Littoral drift inputs from the south around Lennox Head are lower than littoral outputs to the north past Broken Head. The sediment deficit is balanced by backshore erosion of coastal sand deposits.

Compartmentization

South of this region, the coastal sand systems are fully compartmented (no headland bypassing of littoral drift sand). Immediately south of Seven Mile Beach the embayments are also eroding and shorelines are becoming more embayed. At Broken Head, at the northern end of Seven Mile Beach, full headland bypassing is occurring. Since the coast to the south is compartmented, the sand supply for the northward littoral drift system is dwindling with time.

Variation in Erosion Rates

Combining these two modes of coastal erosion, it can be seen that not only is the present littoral drift supply inadequate for the present littoral drift demand, but that the supply situation is going to deteriorate in the future. The two modes of erosion result in complex variations of erosion rates over time.

A zetaform embayment in this coastal region evolves by more rapid erosion at the southern "protected" end of the beach due to higher littoral drift differentials in the "hook" of the zetaform shoreline. At first, erosion is rapid, but with time the embayment becomes well indented and achieves a similar shoreline orientation to updrift embayments. As a result, littoral drift rates decrease and erosion rates begin to decline. In the north, most of the littoral drift demand is being made up with littoral drift input from the southern eroding beaches, due to full headland bypassing. With continued erosion, the zone of total compartmentization extends progressively northwards, and the dwindling supply begins to have a local impact. Local erosion rates could then increase markedly.

The geological model predicts long-term coastal erosion, but has a largely theoretical basis. However, this interpretation is independently supported by evidence from the Quaternary geological setting of Seven Mile Beach.

QUATERNARY GEOLOGY

Quaternary coastal sediments in the area are related to two separate phases of deposition. The first depositional period occurred during the last Interglacial high sea-level stillstand, and the resultant deposits are of Pleistocene age. The second phase occurred during the present "stillstand" period with sea-level at or near its present position. The latter deposits are of Holocene age.

Pleistocene Sediments

Landward of Seven Mile Beach is an erosion scarp, which is fronted by a low, inipient foredune during normal weather conditions. The scarp is capped by an intermittent, low Holocene dune. Some of the beach face north of Lake Ainsworth has been sand mined for heavy minerals by beach-scraping. Inspite of this disturbance, geological interpretations of the erosion scarp can be made with confidence. Anger holes and observations in sewerage trenches have allowed confirmation of the dune scarp interpretations.

The erosion scars consists of leached white Pheistocene sand, and is the horizon of an ancient, well developed podsolic soil. The B horizon of this soil probably underlies the foot of the erosion scarp. Such B horizons usually consist of dark brown to yellow-brown, humate impregnated quartzose sand. They are variously termed "coastal sandrock", "indurated sand", "coffee rock", and "waterloo rock". The white A2 horizon and the dark brown B horizon are merely different soil horizons of the one depositional unit.

This unit comprises a Pleistocene prograded beach-ridge barrier which extends several hundred metres inland. The barrier consists of two sets of degraded parallel foredune/beach ridges, which are separated by an interbarrier depression. Like the erosion scarp, the Pleistocene barrier is characterized by deep podsolic soils produced during thousands of years of soil development. The leached A2 soil horizons at the rear of Lennox Head village have been measured at two undisturbed sites. These showed A2 horizons greater than 2m and greater than 3.5m thick respectively. The full thickness was not penetrated. Such a thick A2 horizon is typical of Pleistocene sands, and contrasts with iron-stained Holocene sandy soils elsewhere in the region, in which the A2 horizons are generally weakly developed or only 0.5 to 1.4m thick.

The degree of leaching and surface weathering suggest that this bi-partite barrier can be correlated with similar barriers of known Pleistocene age along the central and northern N.S.W. coast.

The barrier beach ridges were probably deposited between 130,000 and 120,000 years ago, when sea-level was 2 to 5m higher than the present level, during the Last Interglacial high sea-level stand.

Holocene Sediments

Holocene sediments are of limited extent at Seven Mile Beach. The active zone of beach cut-and-fill is part of the Holocene sand system, a large component of its volume having been derived directly from erosion of Pleistocene sands in updrift embayments to the south.

Along the beach an intermittent Holocene foredune exists as a thin capping on top of the flat Pleistocene barrier surface. This dune cap has formed during periods of short-term turn and incipient foredune building, when beach sand has been blown up the face of the buried scarp. Subsequent erosion has removed the seaward face of the primary foredune, and an intermittent foredune cap is all that remains. The field inspection showed that a well developed incipient foredune is presently forming. The Holocene sands are light fawn coloured and contain a small proportion of iron-stained quartz grains. They are in marked contrast to the leached, white Pleistocene sands.

Lake Ainsworth occupies a depression within the Pleistocene barrier, which is not likely to have been formed by erosion in Holocene time. The high degree of soil permeability combined with the flat topography and lack of a stream catchment should have prevented stream incision during lower sea level periods. It is possible that the depression was formed in Pleistocene time, and has not yet been infilled. Its bed probably consists of organic mud and peat, although this has not been confirmed in the field. A small Holocene barrier exists seawards of Lake Ainsworth, and has been maintained by wash-over and foredune building processes.

Along the surf zone a Holocene cobble pavement has been formed by northward littoral drift from the Lennox Head basaltic outcrops. In at least two sites, the cobbles overly and are partly imbedded in a thin layer of peat only 20 to 30 cm thick. The peat was found only towards the southern end of the beach during the brief field reconnaissance, and more extensive fieldwork would be needed to trace its lateral extent.

Coring in the surf zone at one location showed a peat layer overlying Pleistocene sand, and at another site the peat overlay Holocene (?) estuarine sand. The peat is undoubtedly of Holocene age and represents accumulation of plant material on the bed of a back-barrier lagoon or swamp, when the shoreline was well seaward of its present position.

The observation of tree stumps in growth position at about 1 to 2m below present mean sea level by Mr. K. Parr (P.W.D., Lismore) suggests that sea level was at a lower elevation at the time of tree growth. This may have occurred either during the final phase of the last major sea level rise (Postglacial Marine Transgression) about 7500 to 6500 years ago, or during a slight fall of sea level during the Holocene "stillstand" (6000 yrs ago to the present). In the first half of the present century a small back-barrier lagoon existed landwards of the peat outcrops of the surf zone. Earlier in the Holocrene this lagoon may have extended further seaward as the depositional environment of the peat.

Interpretation

The normal situation on the New South Wales coast 6000 to 3000 years ago was for coastal progradation of Holocene beach-ridge barriers. No equilibrium profiles were present in these areas at the close of the Postglacial Marine Transgression. This resulted in onshore transport of marine sand from the inner continental shelf. Profiles in the Seven Mile Beach region are not likely to have been different from the normal situation along the remainder of the N.S.W. coast. Onshore transport should also have occurred at Seven Mile Beach.

That a Holocene barrier is not present, shows that coastal erosion has removed it. The erosion has been so severe that any former Holocene barrier or back-barrier sands have been entirely removed, resulting in a beach backed by Pleistocene sediments.

Peat exposed in the surfzone is also interpreted as indicating significant long term erosion. Its young age, environment of deposition and soft nature shows that its present surface has been exposed only recently to high energy surf zone processes. It is likely to be continually eroding at present, even though partly protected by the cobble mantle.

DISCUSSION

For a littoral bypassing coast with evolving zetaform embayments, shoreline stability is attained only when sediment demand diminishes to equal the supply. In practice, equal supply and demand would never be achieved because of a diminishing updrift supply due to progressive compartmentization. Since supply is tending towards zero, stability will only be reached when output reaches zero. The end result is a fully compartmented coast of stable zetaform embayments.

Embayments on a littoral drift coast, which have additional, permanent sand losses to offshore "sinks", tidal deltas, and dune sheets, would have increased tendencies for long-term erosion. In these cases the regionally diminishing supply is diminishing locally as well.

Man can speed up these natural trends. The rate at which sand supply dwindles, and hence the rate at which erosion proceeds, will be increased by removal of sand from the system, e.g. sand quarrying, breakwater and groyne building, terminal revetment building.

The geological data can only show that long-term erosion is occurring, and the model attempts to explain the cause of erosion. This analysis shows that there are three possible causes of long term coastal erosion sediment supply, climatic, and sea-level variations. The sediment supply model of long term erosion involves two separate causes: unfavourable coastal alignments inducing littoral drift differentials, and dwindling littoral supply maintaining the deficits. Operating together the latter two modes of erosion produce variations in intensity of erosion with respect to both time and spatial position in the littoral drift system.

Unfortunately the geological model is not yet accurate enough for quantitative estimation of future erosion rates at any particular locality. However, the model shows that not only is erosion likely to be widespread in northern New South Wales, but also that there is little reason to expect an amelioration of the erosion hazard in the immediate future.

SUMMARY

Seven Mile Beach at Lennox Head has three important attributes, which taken together indicate long-term coastal erosion.

Firstly, it lies on a section of coastline where embayments to the south are progressively aligned less obliquely to the dominant south-easterly swell direction. This induces a littoral drift imbalance between supply and demand resulting in backshore erosion. Littoral drift rates along Seven Mile Beach will be higher than for the Evans Head-Ballina embayment to the south.

Secondly, it forms one sector of a major littoral drift system, which probably extends from south of the Clarence River northwards to the northern entrance to Moreton Bay in southeast Queensland. Further to the south no bypassing occurs. This also induces a littoral drift imbalance, due to a diminishing supply from updrift (southern) embayments, and consequent backshore erosion.

The predictive model is independently supported by geological evidence at Seven Mile Beach. The coastline has insignificant volumes of Holocene barrier sand. Instead it is leached by coastal sediments of Pleistocene age. In one locality, soft Holocene back-barrier peat is exposed in the surf zone indicating a receding barrier. Any former Holocene barrier has been entirely removed by coastal erosion.

The predictive geological model suggests a littoral drift differential as the mechanism for coastal erosion. Erosion will probably continue to cut into the Pleistocene sands until Seven Mile Beach is totally compartmented with respect to headland bypassing of littoral drift sand.

Since the littoral drift system extends for several hundred kilometres to the north, any man-induced changes at Seven Mile Beach are likely to influence the intensity of natural erosion further north. Management decisions adopted today should be evaluated for their influence in the coming years on both the immediate area and on the region to the north.

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