BEACH EROSION-ACCRETION AT TWO TIME SCALES

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Introduction

Erosion and accretion on the beachface have been studied at two time scales on the central and south coast of New South Wales, Australia. This research aims at providing a temporal perspective to contemporary problems of beach erosion in areas where the historic map record of changes in shoreline position is poor. Field work has been concentrated at two localities Moruya (lat. 35° 53'S long. 150°09'E) and Newcastle Bight (lat. 32°48'S long. 151°55'E)(Fig. 1).

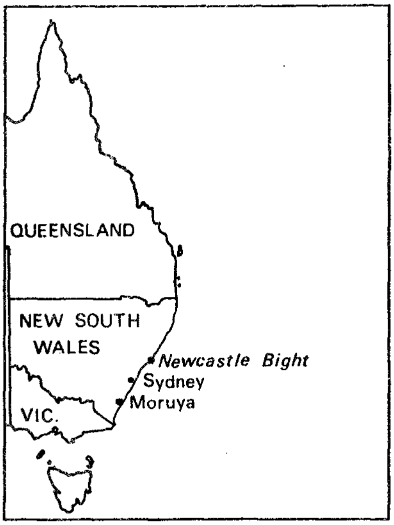

Figure 1. Location map of eastern Australia.

Beach and inshore systems on the N.S.W. coast exhibit pronounced morphologic and dynamic variability with respect to both time and local environment (Wright et al., 1977; Wright, Thom and Chappell, 1979; Chappell and Eliot, 1979; Short, 1978, 1979). Beach systems on this coast are characterized on a regional scale by a steep, narrow inner continental shelf and nearshore zone (Wright, 1976), and by pronounced compartmentalization with alternating rocky headlands and embayed sandy beaches (Davies, 1974; Roy et al., 1980, in press). The compartments are of widely varying dimensions, and often involve the blocking of estuaries, lagoons and swamps by a variety of bay-barrier types (Thom, 1974; Thom et al., 1978).

Open-ocean beaches display highly dynamic foreshore and inshore topographies in response to a relatively high energy, but variable, wave regime (McKenzie, 1958; Thom et al., 1973; McLean and Thom, 1975; Wright et al., 1979). The wave regime is characterized by a variable wind-wave climate, superimposed on a persistent long-period southerly to southeasterly swell. Significant wave heights of 1.5 m are exceeded for 50% of the time, with deepwater storm wave heights being known to exceed 10 m (Lawson and Abernethy, 1975). Southerly and southeasterly waves are the highest. Severe storm waves can occur at any time of the year. The loss of wave power by bottom friction seaward of the breaker zone averages only 3.4% of the incident deepwater wave power along the open coast (Wright, 1976). However, the distribution of wave power within an embayment will vary appreciably with exposure and degree of indentation.

Both localities discussed in this paper are exposed to high energy waves and strong onshore winds (Fig. 1). Moruya (Fig. 2) faces due east whereas Newcastle Bight (Fig. 3) is oriented more towards the south. Since sea level has been at its present position along this coast for the last 6000 to 6500 years (Thom and Chappell, 1975), both localities have experienced sand barrier development. At Moruya, a simple Holocene beach-ridge plain has formed seawards of "drowned" river valleys and an ancient bedrock cliff (Fig. 2). The barrier of similar age at Newcastle Bight is more complex. Figure 3 shows an elongate sand complex blocking an interbarrier depression. A Pleistocene "Inner Barrier" occurs landward of this depression. The Holocene barrier at Newcastle Bight is composed of beach ridges (eastern end), overlain by vegetated and mobile transgressive dunes. The complex morphology of this locality expresses partial eolian reworking of a prograded barrier since sea level has been at its present position.

Geologic Scale of Coastal Erosion-Accretion

One time scale used in the study of shoreline erosion and accretion is termed "geologic" and is measured in radiocarbon years before present (BP, where the "present" is AD1950). All radiocarbon dates on marine shell material used here have been corrected for the "environmental" or "ocean reservoir effect" caused by the lack of equilibrium between ocean and atmospheric ^{14}C. Calibration of radiocarbon years to calendar years, by correcting for secular variations in the radioactive isotope ^{14}C (Clark, 1975), have not been made although more accurate

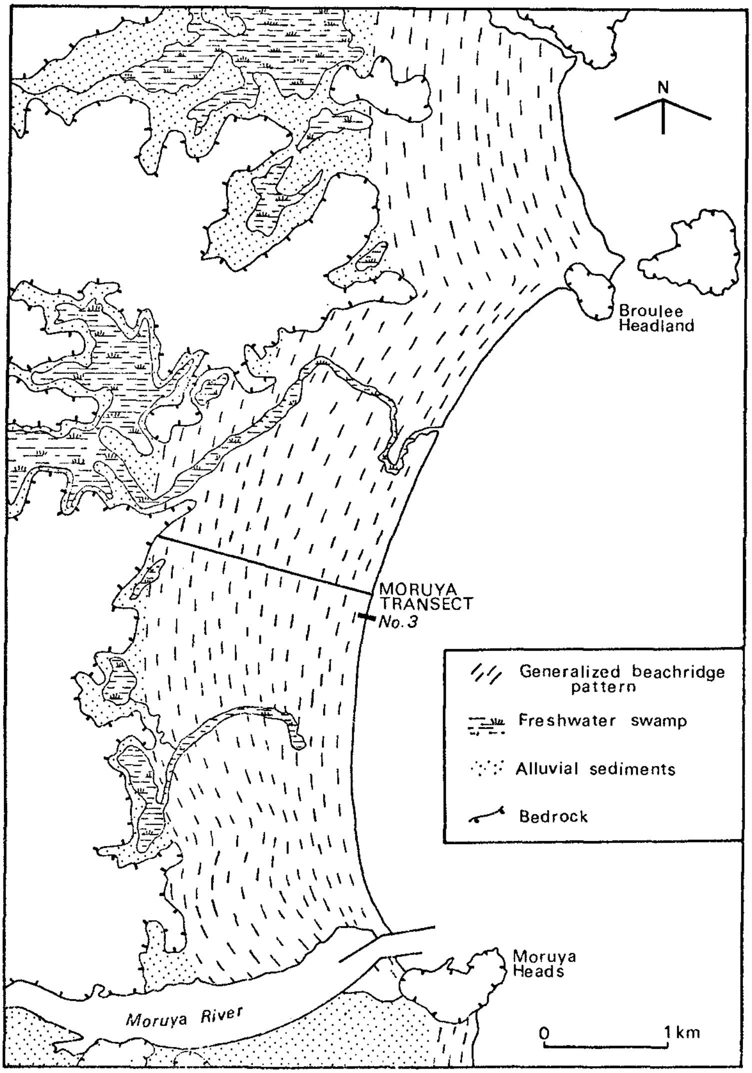

Figure 2. Moruya beach ridge plain, showing drillhole transect and beach profile number 3.

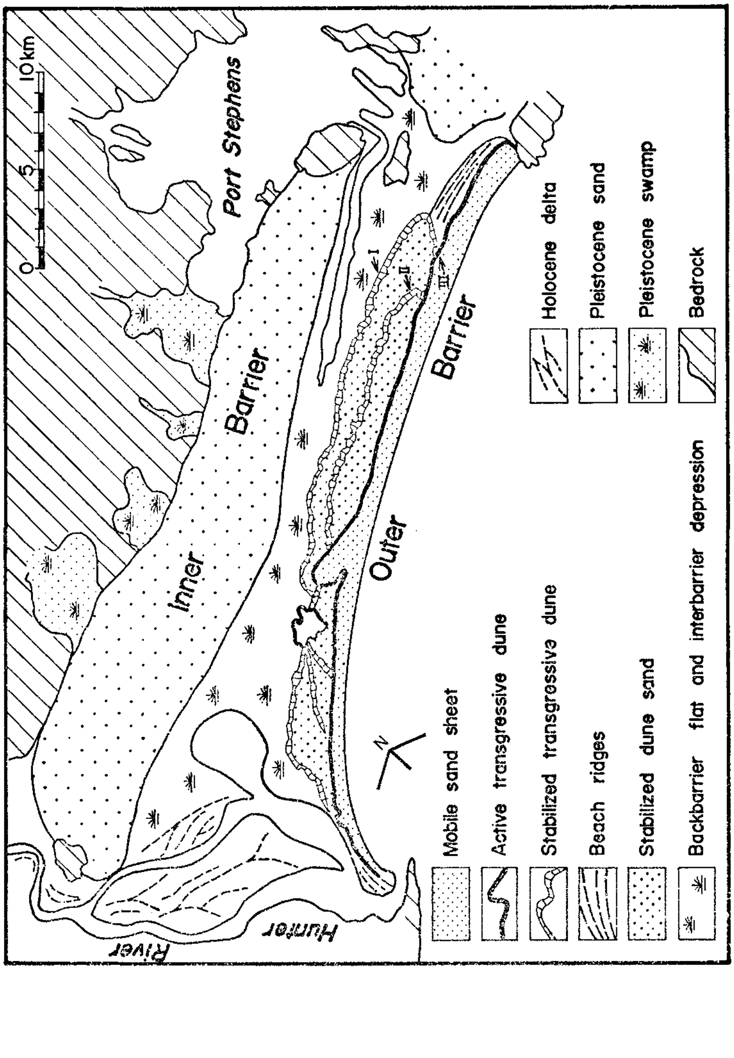

Figure 3. Morphological map of Newcastle Bight. Note beach ridges at eastern end of Outer Barrier and transgressive dune ridges I, II and III.

estimates of rates of shoreline accretion would require calibration. Details of dating techniques used in this study, and the dates themselves, are discussed in Thom et al. (1978).

Sampling of materials for radiocarbon dating involved power auger drilling. Samples of shell were collected from various depths below barrier surfaces. Shells and shell fragments associated with the nearshore environment of deposition (especially the species *Bankivia fasciata*) were submitted for dating.

The pattern of accretion at Moruya, based on an analysis of 30 ^{14}C dates, is summarised in Figure 4. This figure highlights changes in the rate of shoreline accretion and volumetric addition for a single cross-section in the centre of the embayment. The diagram involves the grouping of ^{14}C dates into episodes. Two points arise from this figure.

(a) The dates show a relatively rapid decline in the rate of accretion with time with little evidence of progradation in the last 2000 years in the vicinity of the section.

(b) In the centre of the embayment the amount of sediment added to the coast has also declined with time.

At Moruya, it is likely that accretion did not decline at a continuous rate. There is evidence at this locality and elsewhere on the N.S.W. coast for the dates to cluster into discrete episodes (Thom, 1978; Thom et al., 1978).

Several factors must be evaluated in any attempt to explain the pattern in Figure 4. Alongshore transport of sand bypassing headlands cannot be regarded as a significant contributor to sand budgets since sea level has been at its present position (Davies, 1974). Furthermore, erosion of bedrock cliffs or supplies of sand from rivers to the beachface can be shown to be negligible. River sand supplies are typically trapped in estuaries. The barriers are composed of rounded quartz-rich "marine" sands; these are clearly differentiated mineralogically from the angular felspathic and lithic-rich "fluvial" and cliff-eroded sands. Variations in sea level over the last 6000 to 6500 years along this coast have not been documented, and cannot be used to explain patterns of shoreline movement. Therefore, it appears that the trends shown in Figure 4 relate to equilibration of the inner shelf gradient and profile form to the wave climate since sea level stabilized at its present position. Readjustment of nearshore profiles from a condition of disequilibrium, which existed after the termination of the Postglacial Marine Transgression, to a condition of equilibrium involving no further accretion, is being discussed elsewhere (Chappell and Thom, in prep. based on principles discussed in Chappell, 1980). Superimposed on this adjustment process are fluctuations in rates of accretion in response to changing wave climates in the Holocene (Thom, 1978). At Moruya, these changes are expressed by clusters of ^{14}C dates differentiating periods of marked shoreline accretion from periods of limited or no accretion.

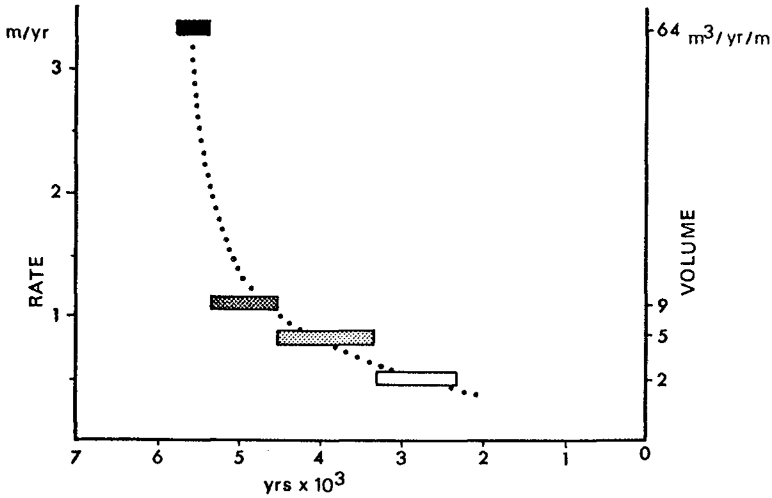

Figure 4. Changes in accretion rates and volumetric addition, Moruya beach ridge plain.

However, the sand barrier at Newcastle Bight, exposed to strong southerly winds, has experienced a different geomorphological history.

The morphological map of the Holocene or Outer Barrier at Newcastle Bight (Fig. 3) depicts a "core" of beach ridges at the eastern end overlain by three discrete, massive dune ridges. Two of these dune ridges (I and II) are vegetated by an *Eucalyptus* woodland and are over 15 km long and 30 m high. The third ridge (III) is unvegetated and is currently transgressing the vegetated dunes and beach ridges from the south. These "waves" or "surges" of sand represent episodes of eolian instability in the backshore, probably following periods of high wave energy (Thom, 1978). The sequence of deposition based again on drilling and radiocarbon dating can be summarized as follows:

(a) Accretion following termination of the postglacial sea level rise approximately 5500 to 6500 years ago;

(b) Initiation and landward movement of Ridge I in excess of 4500 years ago;

(c) Stabilization of Ridge I by vegetation and possible accretion of the shoreline;

(d) Initiation and landward movement of Ridge II approximately 2000 years ago;

(e) Stabilization of Ridge II by vegetation involving foredune growth;

(f) Initiation and landward movement of Ridge III 300 to 500 years ago accentuated by human disturbance in last 100 years.

The sequence at Newcastle Bight can be best explained by long-term equilibration of inner shelf and nearshore profiles to fluctuating wave regimes following sea level "stillstand" (see below). As at Moruya, there is little evidence for supplies of river sand or alongshore sand reaching the beach or mobile dunes over this time period (Roy, 1977; Roy and Crawford, 1977; Ly, 1978).

Synoptic Scale of Coastal Erosion-Accretion

The other time scale applicable to the study of beachface erosion and accretion is termed "synoptic". This involves fortnightly to monthly measurement of beach-nearshore profiles from fixed datum points. At Moruya, six profiles have been monitored since January, 1972. Progress reports on trends revealed by these profiles have been published (Thom et al., 1973; McLean and Thom, 1975), and morphodynamic conditions associated with particular beach configurations have also been reported (Wright et al., 1979; Wright, Thom and Chappell, 1979).

The prime objective of this monitoring is to relate beach-face morphology to seasonal and year-to-year changes in wave and atmospheric climate. It is clear that the beachface responds strongly to year-to-year variability in wave climate. Periods of one year or more of distinct beachface accretion are separated by years when east and southeast storms predominate and the beachface erodes (e.g. 1974–75). Figure 5 highlights the changes in cross-sectional area expressed by one profile near the centre of the Moruya embayment (comparable data are not available for Newcastle Bight, but similar studies in the Sydney area by Short and others reveal similar trends for the period 1975–76 to the present). Four phases are suggested in Figure 5 for the period 1972 to 1980:

(a) growth in beach cross-sectional area to mid 1973 compared to the reference profile in January, 1972;

(b) dramatic erosion of beachface and foredune in 1973 and 1974;

(c) oscillating erosion and accretion involving fluctuation in sectional area (and beachface volumes) to 1978;

(d) a steady build-up of beach sand from 1978 to the present, to levels well in excess of the reference cross-sectional area.

Beachface erosional periods of the type witnessed in 1973–74, involved "clusters" of storms over a minimum period of 6 months which are generated off the east coast in the Tasman Sea. Sustained periods of erosion are of irregular incidence with similar events to 1974–75 being recorded in 1912, 1950 and 1967 (Thom, 1974, Table 1). Accretion periods are associated with zonal westerly flow in winter and the absence of the marginal effects (high swell wave) of tropical cyclones in summer. There are also periods of a year or more in duration when the beachface does not significantly accrete or erode (e.g. 1976–78).

Discussion

The two time scales of study are linked by a climatic model of variation in the magnitude and frequency of storminess (Thom, 1978). The synoptic scale provides the "modern analog" for understanding changes of the geologic scale. Short-term wave conditions are associated with processes responsible for short-term climatic variability. Sea surface temperature distribution and changes in sea ice extent are two broad scale forcing mechanisms which influence major cyclonic frequencies in the Tasman Sea region. These forcing mechanisms interact with the general circulation in the atmosphere to create climatic "disturbances". In turn they may be influenced by solar cycles (Stevenson, 1980). Years with frequent extratropical cyclones can be linked to increased atmospheric "blocking" action to the east of New Zealand. In contrast, relatively non-stormy years are dominated by zonal flow, that ~~is~~, the more-or-less continuous movement of pressure systems across southern Australia. Expanded to a longer time scale, it is postulated that, for periods of several hundred years, the magnitude and frequency of storminess changes.

During more stormy periods, like the Little Ice Age of the 16th and 17th centuries, wave and wind conditions promoted beachface and

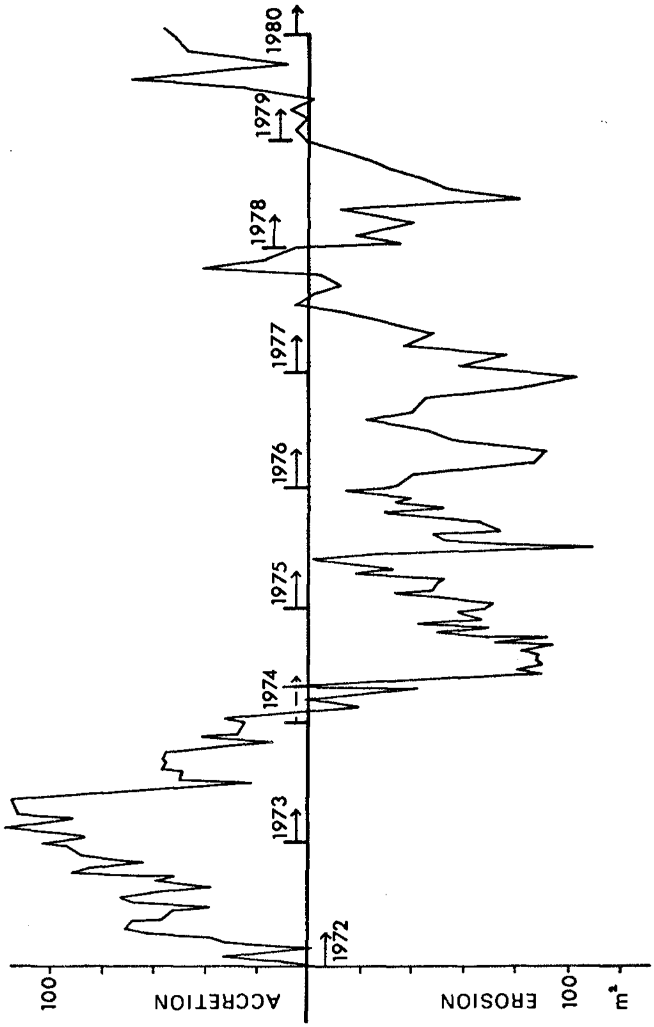

Figure 5. Change in beach cross-sectional area: Moruya profile 3, 1972-1980. Reference zero is cross-sectional area in January 1972.

foredune erosion. Those embayments facing south endured more severe foredune erosion and the initiation of transgressive dunes (e.g. Newcastle Bight). In contrast, the more sheltered bays underwent vertical foredune building, or where gradients were less steep, no shoreline accretion. During non-stormy periods, backshore colonization of sand-binding plants became more dominant, encouraging stabilization of blowouts and mobile sand sheets. Locally, beachface accretion may have occurred where nearshore sand supplies were abundant.

The above discussion highlights the role of one major variable, wave energy, in the erosion-accretion balance within sandy bays of the N.S.W. coast. The other major variable is the changing supply of sand in the nearshore zone as the inner shelf configuration adjusts to a long-term equilibrium condition. We see this equilibration process as a long-term trend upon which is superimposed fluctuation in wave energy. Thus, as barriers grow, the nearshore zone is progressively depleted of sand. Nearshore profiles are steepening during this period as no fresh inputs, or very limited fresh inputs, are available from offshore, alongshore or from river sources on this coast. As a consequence, progressively less material is available for beachface accretion in non-stormy periods.

The net result of these two factors, fluctuations in storminess and dwindling supplies of nearshore sand, is that periods of beachface erosion, at either the long or short term scale, are becoming more severe. It is possible that erosional conditions in the last 1000 years are more severe compared to the previous 5000 years of sea level "still-stand". Any deterioration in global climate involving more storms of high intensity will be manifested in more severe erosion in the future than in the past. Major schemes of artificial beach nourishment may be required in these circumstances on the N.S.W. coast.

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