Coastal Engineering 57 (2010) 92–97

Contents lists available at ScienceDirect

Coastal Engineering

journal homepage: www.elsevier.com/locate/coastaleng

Role of geological inheritance in Australian beach morphodynamics

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ARTICLE INFO

Available online 24 October 2009

Keywords:
Australia beaches
Geology
Beaches
Bedrock
Beach morphodynamics

ABSTRACT

The Australian coast contains 10,685 beaches which occupy 49% of the 30,000 km coast and average 1.37 km in length. Their relatively short length is largely due to the presence of bedrock, calcarenite and laterite, which form boundaries to many of the beaches, as well as occurring as rocks, reefs and islands along and off the beaches. This geological inheritance plays a major role in Australian beach systems — determining their length and through wave refraction and attenuation influencing beach location, shape, type, morphodynamics and circulation, which in turn influence sediment transport and the backing dune and barrier systems. This paper uses a database covering every Australian beach to review the role of headlands, rocks and reefs on Australian beaches. Major effects are the short average beach length; reduction in breaker height resulting in lower energy beach types; wave refraction resulting in increased beach curvature; the presence of topographic rips on moderate and higher energy beaches and megarips during high wave conditions; and the interruption of and/or trapping of longshore sand transport leading to beach rotation.

1. Introduction

The Australian coast is 29,901 km in length, with 49% of the coast consisting of 10,685 sandy beaches. The beaches average only 1.37 km in length (standard deviation $\sigma = 3.5$ km), the relatively short length largely a result of geological inheritance in the form of headlands, rocks and reefs, which truncate many beach systems and thereby form boundaries to the vast majority of the beaches. This paper addresses the following issues: (1) What are the reasons for the dominant role of geological inheritance along the coast, as well as the regional variation in geological control; (2) What is the impact of the headlands and rocks on wave shoaling and transformation; (3) What is the impact of the transformed waves on beach morphodynamics; and (4) What role do the controls play in sediment transport.

The predominance of relative short headland-bound beaches around Australia is a product of several factors:

1) The regional geology which determines the first order shoreline geology including its orientation, gradient, structure and hardness.
2) Regional prevalence of coral reefs, beachrock and laterite rocks and reefs in the north and calcarenite (beachrock and dunerock) in the south and west.
3) The regional climate which has denuded the bedrock to form valleys and supply terrigenous sediment on the coast.
4) The regional wave climate which influences the coastal sediment budget.
5) The Holocene sea level rise which flooded coastal valleys to form headland-bound embayments, and in the south and west flooded lithified Pleistocene barriers to form submerged reefs, islets, islands, as well as boundary cliffs and headlands; and
6) The Holocene sea level stillstand which over the past several thousand years has permitted the higher energy south to develop generally 'mature' sediment-deficient shores.

In this paper an Australia-wide beach database (Short, 2006a) is used to investigate the role of geological inheritance on beach morphodynamics.

2. Geological inheritance

2.1. Regional geology

The Australian continent is dominated by ancient deeply weathered and denuded geology ranging in age from Pre Cambrian in the west to the younger Triassic in the east. Not only is much of the rock old, but also resilient consisting of intrusive and extrusive igneous, extensive metasedimentary and generally hard deeply jointed sedimentary strata. The rocks have generally been exposed to a long period of denudation resulting in deeply incised valleys and alternating ridges. Where the denuded bedrock is exposed at the coast it forms alternating headlands and embayments, together with rocks, reefs, islets and islands. The headlands are generally very resilient with sloping rocky shorelines associated with the metasedimentary and intrusive igneous rocks, and rock platforms forming in sedimentary and extrusive igneous rocks. The most bedrock-controlled section of coast is the 4333 km long Kimberley coast, for the most part dominated by deeply weathered and incised sedimentary rocks, which at the coast form cliffs and drowned joint-aligned valleys. Small embayed and pocket beaches occupy only 16% of the

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doi:10.1016/j.coastaleng.2009.09.005

rocky Kimberley coast with an average length of only 0.53 km ($\sigma = 1.16$ km). Nationwide there are only a few pockets of Tertiary sediments, predominately limestone, which occur in some coastal basins and even these tend to form limestone cliffs, such as 370 km of cliff-edged Nullabor Plain and Victoria's rugged Port Campbell coast (Fig. 1).

The only three beaches exceeding 100 km are all located along the shoreline of active sedimentary basins, namely the 222 km long Ninety Mile Beach along the Gippsland Basin, the 212 km long Coorong across of the mouth of the Murravian Basin and the 222 km long Eighty Mile Beach along the Canning Basin, while the fourth longest beach is only 55 km in length.

2.2. Quaternary geology

The entire continent is also relatively stable. This has permitted successive high sea level stillstands to return to approximately the same location (Murray-Wallace, 2002). As a consequence much of the coast is onlapped and overlapped by successive deposits of Quaternary marine sediments in the form of beaches and dunes. When exposed at the shore as unconsolidated sediments, as in southeast Queensland and northern NSW, they are readily eroded forming eroding beaches and scarped Pleistocene dunes. However along the 9000 km long south and west coasts where carbonate-rich sediment predominate in an arid to semi-arid climate; this has resulted in the formation of extensive lithified calcarenite barriers (Semeniuk and Johnson, 1985; Short, 1988a,b, 2002). Depending on their elevation relative to sea level these calcarenite barriers form submerged reefs, exposed rocks, reefs, islets and islands, and cliffs, including the massive 124 km long, 80–240 m high Zuytdorp Cliffs in Western Australia, which are part of a larger 300 km long section of calcarenite cliffs and pocket beaches. One third of the entire coast is therefore affected by beach and dune calcarenite.

In the north coral reefs occur discontinuously as fringing, barrier and scattered reefs off the coast between Ningaloo Reef in the west (23.5°S) and southern Great Barrier Reef (24°S) in the east, a shoreline distance of 16,000 km. At the coast coral reefs occur directly off 1429 beaches, including 249 beaches with fringing reef extending to their base (Short, 2006a). Most of the reefs lie kilometres off the coast and impact the shoreline through their partial to complete attenuation of ocean waves, resulting in lower energy sea-dominated shorelines. In the case of the 3000 km long Great Barrier Reef most ocean waves break on the outer reefs, resulting in a lower energy sea-dominated mainland shore. The beaches fronted by fringing reefs receive no waves at low tide; while at high tide waves are attenuated and refracted across the reef leading to crenulate low energy reflective

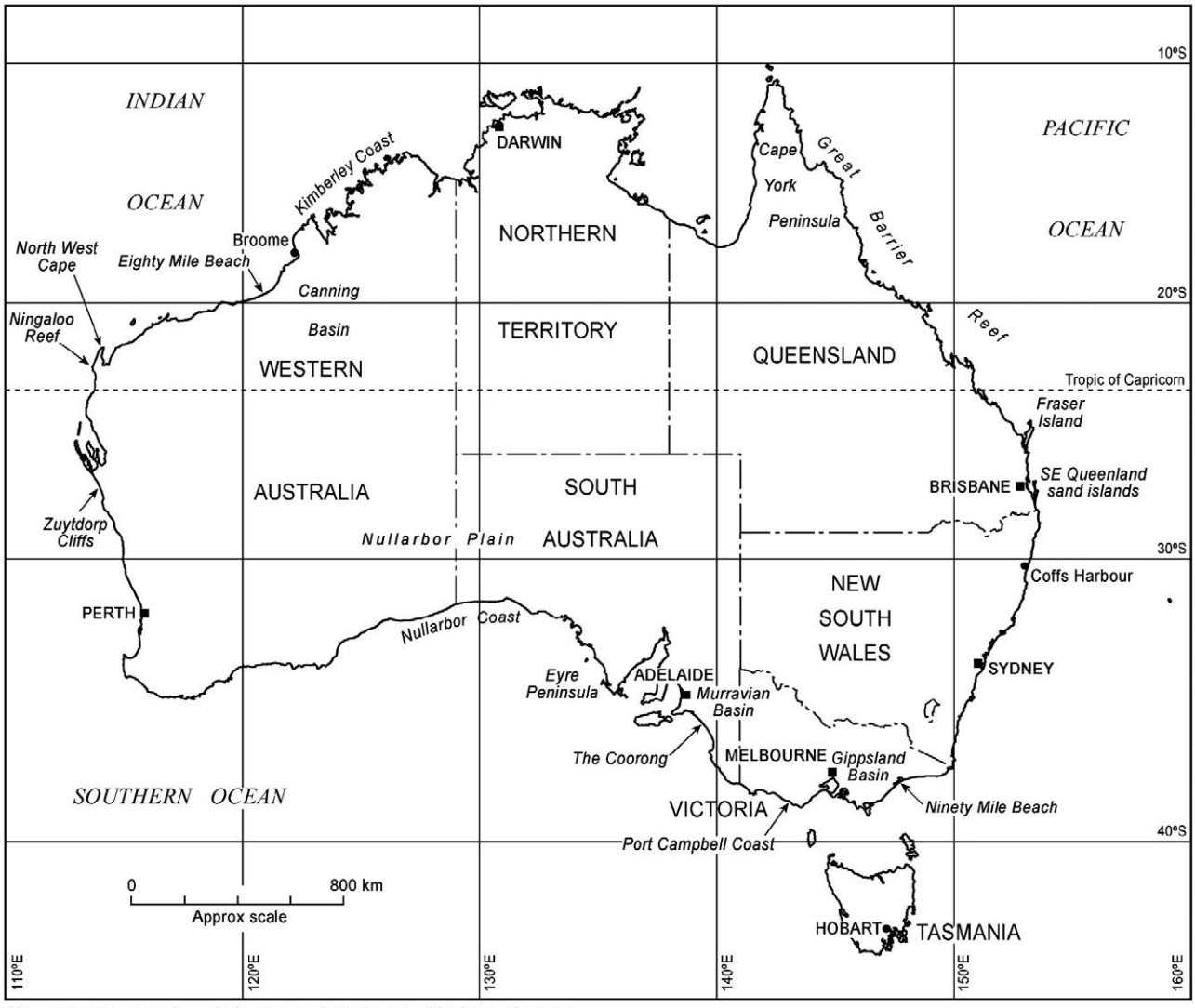

Fig. 1. Map of Australia showing the locations mentioned in text.