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Carbonate sediment dynamics and compartmentalisation of a highly modified coast: Geraldton, Western Australia

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ABSTRACT

The coastal zone off Geraldton in temperate Midwestern Australia was investigated to identify sediment dynamics and sediment budget components of two main embayments. An integrated analysis of hydrodynamics, geomorphology, sediments and habitat data was required to overcome a lack of previous examinations of sediment dynamics in the region. The seaward extent of the nearshore transport system was assessed. An improved understanding of coastal sediment dynamics and its relationship to coastal stability and assets was also achieved. The system is complex, with biogenic sediment input, as well as carbonate dune and river-derived sediments. Coastal erosion at Geraldton is mitigated by nourishment activities which require sand bypassing. Natural and artificial sediment sinks were identified, and are mainly located in the northern embayment where beach erosion is more significant. A dredged shipping channel needed to provide access to port facilities modifies the local sediment dynamics. This study provides new information for managing the Geraldton coast, which may be applicable to similar regions of Western Australia and carbonate coasts elsewhere.

1. Introduction

Geraldton is an urban and industrial centre located in a remote area of Western Australia (Fig. 1). Coastal infrastructure is vital for sustaining local and international maritime shipping activities and sediment erosion occurs along the town beaches. This phenomenon also occurs in other sites of Western Australia where maritime infrastructure and human use of the coast occur. The need for this study arose when coastal managers were investigating options to mitigate an erosive trend along the town beaches, currently stabilised through sand bypassing and nourishment activities. The project aimed to provide a greater understanding of the coastal system in terms of coastal evolution, sediment input, transport and storage. Budgetary study of littoral systems has been recently described as a vehicle to providing a comprehensive overview of coastal areas (Aagaard, 2011; Anfuso et al., 2013). It provides recognition of sediment inputs and outputs, together with an understanding of coastal evolution and sediment transport pathways. Qualitative and quantitative sediment budgets are defined following the identification of littoral cells (Rosati, 2005), which are often used to understand how coastal processes interact across administrative boundaries (Cooper and Pontee, 2006; Anfuso et al., 2011). Sediment cells were defined by McInnes et al. (1998) as: "a length of coastline which is relatively self-contained as far as the movement of sand or shingle is concerned, and where interruption to such boundaries should not have a significant effect on adjacent sediment cells". A comparison of the methodologies commonly used to identify sediment cells is presented herein and support understanding of the different approaches used by the scientific community. In Western Australia processes of sediment transport down-drift of cuspate forelands, tombolos and other similar features occur on a regular basis (Eliot et al., 2013; Stul et al., 2014) and an example of these processes is presented in this paper. The overall objectives of this paper include (1) description of the littoral coastal evolution of the study area; (2) assessment of the cross-shore sediment transport system; (3) understanding of processes regulating sediment supply and storage; (4) identification of sediment cells; (5) and the formulation of a qualitative sediment budget model.

Multiple approaches should be used to consider the offshore boundary of sediment movement (Hilton and Hesp, 1996; U.S. Army Corps of Engineers, 2002). Hence, sedimentological, geomorphic, hydrodynamic and coastal evolution data were used in this investigation. From a sedimentological perspective, any study of seabed mobility should be based upon an accurate sediment distribution map (Velegrakis et al., 2007), especially when bioclastic input of sediment has been identified as the main sediment source for the coast of Western Australia (Short, 2010). Hilton and Hesp (1996) and Carter (1988) state that "the boundary between wave-worked and non-wave-worked sediment may be apparent from the sediment size, grain preservation or faunal

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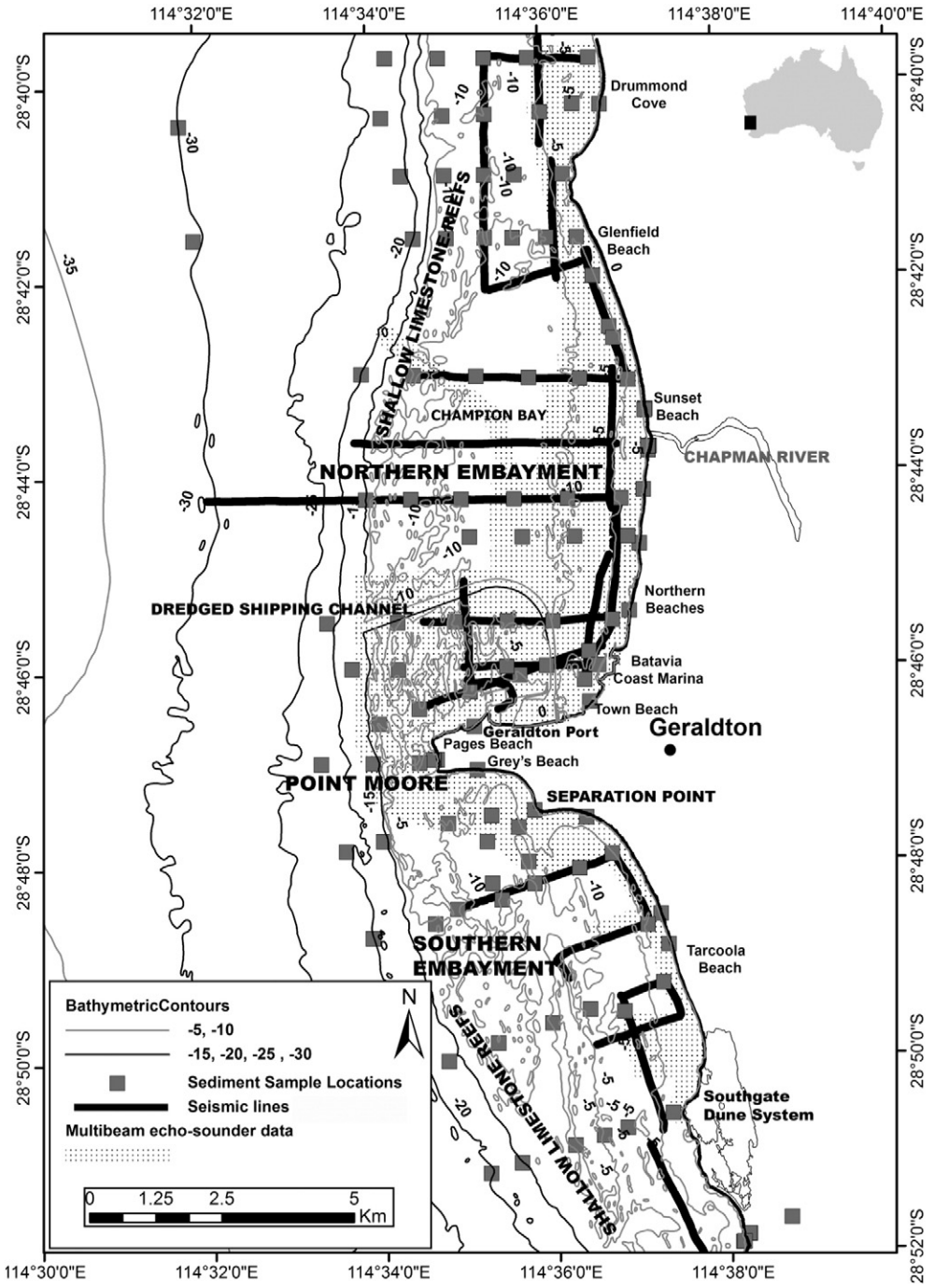

Fig. 1. Location map with localities and geomorphic features referred to throughout the text. The spatial extents of multibeam echo-sounder and seismic data analysed in this study are also illustrated, together with sediment sample locations.

community structure", and this was investigated in the study area. Additionally, the measurement of seabed forms, such as bedform height, wavelength and symmetry/asymmetry are used to identify water flows determining sediment transport on the seabed (Ashley, 1990; Ryan et al., 2007). The asymmetry of seabed bedforms reflects the dominance of bottom currents (i.e. offshore versus onshore currents) oriented transversally to the bedform crests (Ashley, 1990; Hilton and Hesp, 1996). The transition from symmetric to asymmetric bedforms is arguably linked to variations in water depth, grain size, and bottom current velocity, as well as wave period and asymmetry. However modal wave base is generally interpreted to occur when asymmetric bedforms become dominant (Ashley, 1990; Hilton and Hesp, 1996), and this was adopted here. Further, shoreline movement analyses have been widely applied in the past to qualitatively and quantitatively estimate longshore and cross-shore sediment transport (Rodríguez and Dean, 2009; Anfuso et al., 2011). This study integrates a range of datasets that are not normally considered together in localised analysis of sediment dynamics, providing a background for sediment transport modelling practices at a regional level. The importance of coastal geomorphology in driving cross-shore sediment transport is also outlined in this paper, and can be compared to the settings of oceanic coasts elsewhere.