Marine Geology 374 (2016) 14–30

Contents lists available at ScienceDirect

Marine Geology

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

Origins of Holocene coastal strandplains in Southeast Australia: Shoreface sand supply driven by disequilibrium morphology

Michael A. Kinsela [a,b,*], Marc J.A. Daley [a,b], Peter J. Cowell [a]

[a] Geocoastal Research Group, School of Geosciences, Madsen Building (F09), The University of Sydney, New South Wales 2006, Australia
[b] Office of Environment and Heritage, NSW Government, 59 Goulburn Street, Sydney, New South Wales 2000, Australia

ARTICLE INFO

Article history:
Received 25 June 2015
Received in revised form 22 January 2016
Accepted 23 January 2016
Available online 28 January 2016

Keywords:
Coastal barrier system
Morphodynamics
Quaternary
Sea level change
Shoreface
Southeast Australia

ABSTRACT

Coastal barriers store depositional records of past environmental conditions, such as sea level, wave climate and sedimentary regime. The embayed highstand coast of southeast Australia features a diverse range of coastal sand barriers, suggesting varying depositional responses to Holocene environmental conditions. In particular, the varying chronologies of prograded-barrier strandplains along a passive margin, with a predominantly autochthonous sedimentary regime, raises questions about relative sea-level change, and sediment sharing within and between compartments during the Holocene. Here we apply detailed geological data and geochronology from the Holocene prograded-barrier system at Tuncurry, within a morphodynamic modelling approach, to investigate the depositional response of the coastal system to possible drivers of strandplain growth, including: (1) forced regression driven by mid- to late-Holocene relative sea-level fall; (2) time-varying external sand supply via the alongshore transport system; and, (3) shoreface sand supply in response to disequilibrium morphology and stable sea level. Comparison between the simulated depositional response of the coastal system and the geological records suggests that progressively weakening and depth-decaying shoreface sand supply, in response to disequilibrium morphology, was the primary driver of Holocene strandplain growth. Alongshore sand transport into the Tuncurry compartment via a headland-attached shelf sand body may have provided a secondary sand source, although the simulated barrier-shoreface evolution precludes a dominant external sand supply. Mid- to late-Holocene sea level-fall from a highstand level within the range of uncertainty in available indicators (1.5 m above present), could only have contributed a minor portion of strandplain growth, by process of forced regression. The simulations demonstrate the potential sensitivity of strandplain chronologies to the sampling location (i.e. shoreface or dune facies), which emerges from coupled barrier-shoreface evolution that may support time-decaying volumetric growth and steady shoreline progradation simultaneously. Shoreface sand supply driven by the ongoing relaxation of disequilibrium morphology may persist at subtle rates (1–2 m^3/m/yr) today on some southeast Australian beaches, promoting shoreline stability, and potentially moderating initial shoreline response to sea-level rise.

1. Introduction

Coastal barriers are elongate and shore-parallel depositional landforms primarily formed by shallow-marine, aeolian and estuarine processes. Although the term ‘coastal barrier’ is often used in reference to barrier islands (Oertel, 1985), the depositional system spans from the junction of fluvial and estuarine environments, seaward to the shoreface toe (Cowell et al., 2003a; Roy et al., 1994). The barrier complex separates protected backbarrier depositional environments (e.g. estuaries, lakes, rivers) from the exposed shoreface, beach and dunes, unless the inherited physiography precludes backbarrier deposition (Roy et al., 1994; Swift et al., 1991). The barrier complex typically comprises shoreface, beach and dune facies, and may store a detailed record of past environmental conditions and deposition within a prograded coastal strandplain (Dougherty, 2014; Goodwin et al., 2006). Development and preservation of the barrier system depositional environments may vary depending on initial conditions and the balance of controls on sedimentation, giving rise to diverse barrier morphostratigraphy (Belknap and Kraft, 1985; Roy et al., 1994; Thom, 1984).

The controls on sedimentation include: relative sea level; energy climate (waves, currents and wind); sedimentary regime (sediment characteristics and rate of supply); and the antecedent geomorphology (inherited substrate and geological framework), which determines the accommodation space for sediment and the nature of the autochthonous sediment supply (Swift et al., 1991). While the first few controls above have long been considered fundamental to deposition (Curray, 1964; Sloss, 1962), recent modelling studies have demonstrated the sensitivity of coastal barrier evolution to initial conditions, particularly

* Corresponding author at: Office of Environment and Heritage, NSW Government, 59 Goulburn Street, Sydney, New South Wales 2000, Australia.
E-mail address: michael.kinsela@environment.nsw.gov.au (M.A. Kinsela).

http://dx.doi.org/10.1016/j.margeo.2016.01.010
0025-3227/

the inherited substrate and geology (Cowell et al., 1995; Dillenburg et al., 2000; Lorenzo-Trueba and Ashton, 2014; Moore et al., 2010; Roy et al., 1994; Stolper et al., 2005; Storms et al., 2008; Tortora et al., 2009). The inheritance of evolving initial conditions gives rise to morphodynamic feedback that manifests in self-organising and state-determining behaviours, and which regulates the depositional response to stochastic system forcing (Cowell and Thom, 1994; Murray et al., 2014b; Wright and Thom, 1977). This allows complex morphostratigraphy to arise within a coastal barrier system without proportionate variability in forcing (Murray et al., 2014a).

The coastal barriers of modern coasts formed during the relatively stable conditions of late-Quaternary sea-level highstands, and passive or emergent tectonic settings have the greatest potential for deposition and preservation (Woodroffe and Webster, 2014). This is because deposition is usually reduced during transgression, and barriers may become diminished, overstepped or reworked (Cowell et al., 1995; Lorenzo-Trueba and Ashton, 2014; Moore et al., 2010; Roy et al., 1994; Storms et al., 2008; Tortora et al., 2009). Where that was avoided, stacked series of coastal barriers corresponding to successive sea-level highstands may be preserved (Bateman et al., 2011; Murray-Wallace, 2002; Thom et al., 1981c). The diverse barrier morphostratigraphy of southeast Australia (Roy and Thom, 1981; Roy et al., 1994; Thom, 1984), suggests that controls on Holocene sedimentation varied, despite a passive-margin setting, autochthonous sedimentary regime and relatively stable sea level.

The prograded barriers of southeast Australia (Fig. 1a) feature strandplains formed of relict foredune ridges that extend up to 5 km inland from the modern shoreline. The sedimentology of the regressive sand facies indicate that progradation was not supplied by local fluvial sources (Roy et al., 1994; Thom, 1984). Rather, the strandplains comprise palimpsest 'marine sands' that experienced successive reworking across the continental shelf from the Miocene onwards (Roy and Thom, 1981, 1991; Thom et al., 2010). The chronologies of some barriers have been studied by applying radiocarbon dating techniques to organic materials (e.g. marine and estuarine shells, mangroves, wood fragments) retrieved from shoreface and backbarrier facies (Roy et al., 1997; Thom et al., 1981a, 1981b). More recently, optically stimulated luminescence (OSL) dating has been applied to quartz sand grains retrieved from buried dune facies on some strandplains (Goodwin et al., 2006; Oliver et al., 2014). Despite good agreement between sites that barrier progradation commenced around 6–7.5 kyr BP, subsequent rates of strandplain growth appear to have varied between sites (Fig. 2). The sedimentology and diverse chronologies of the prograded barriers allow for various possible drivers of strandplain growth, including relative sea-level change (Lewis et al., 2013; Sloss et al., 2007), alongshore sand transport (Boyd et al., 2008), and shoreface sand supply to beaches (Cowell et al., 2001).

Here we investigate the origins of Holocene prograded-barrier strandplains found in southeast Australia. We use morphodynamic modelling based on a process-behaviour method (Storms, 2003; Storms et al., 2002) to simulate the depositional response of the coastal barrier system to feasible Holocene forcing scenarios, and evaluate the simulated coupled barrier-shoreface evolution against detailed geological records. Three primary drivers of Holocene strandplain growth are tested: (1) enhanced shoreface sand supply by process of forced

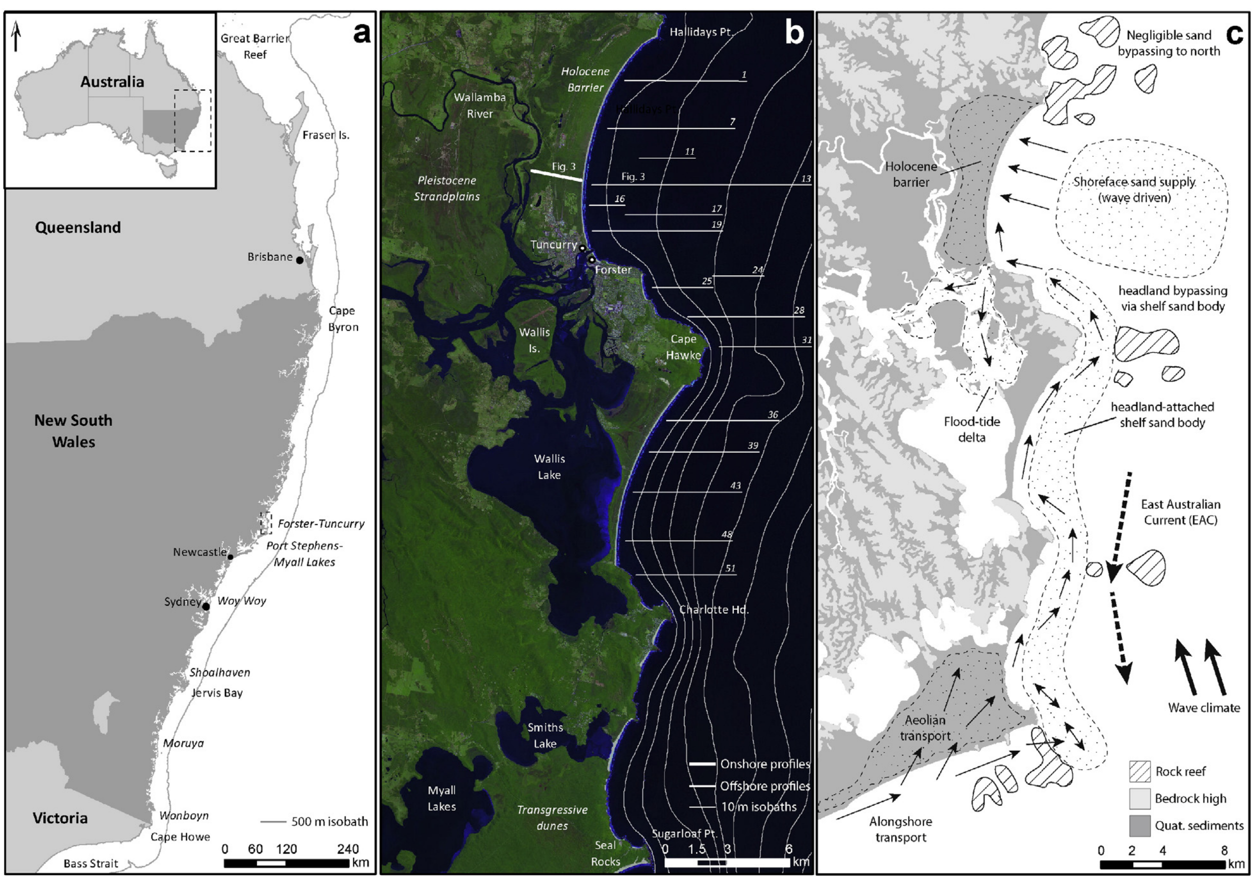

Fig. 1. The Forster-Tuncurry region in southeast Australia, showing locations of detailed geological sampling, key depositional features, and the regional sedimentation model (© CNES 2011, Distribution AIRBUS DS). (a) The southeast Australian margin stretches from Cape Howe in the south, to Fraser Island in the north, and features a diverse range of coastal barriers that vary with the geomorphology of the margin. Locations and coastal barriers mentioned in the text are shown. (b) The Forster-Tuncurry region includes a northern compartment between Hallidays Point and Cape Hawke, and a southern compartment between Cape Hawke and Charlotte Head. The Quaternary geology of the region has been interpreted from geophysical, sedimentology and geochronology data collected along an onshore transect and a series of offshore sampling lines (Roy et al., 1997). Representative data from the onshore transect and offshore Line 13 is shown in Fig. 3. (c) A regional sedimentation model based on the geological data infers that northward alongshore sand transport via a headland-attached shelf sand body provided an important source of sand supply to the northern compartment during sea-level highstands (Roy et al., 1997).