Estuarine, Coastal and Shelf Science 193 (2017) 25–36

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Stepped Holocene sea-level rise and its influence on sedimentation in a large marine embayment: Maputo Bay, Mozambique

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ARTICLE INFO

Article history:
Received 21 June 2016
Received in revised form
15 May 2017
Accepted 18 May 2017
Available online 19 May 2017

Keywords:
Holocene
Environmental changes
Stratigraphy
Shoreline progradation
Stepped sea-level rise
8.2 ka event

ABSTRACT

The sedimentary record in large marine embayments holds important information on Holocene environmental and sea-level changes. This paper investigates the evolution of a large subtropical marine embayment, Maputo Bay, in southern Mozambique. Using a combination of sediment cores, stable isotope data, seismic reflection profiling and ^{14}C dating, we show complex back-barrier changes during the Holocene and link these to stepped rises in sea level. Our data reveal a sea-level "slowstand" followed by an abrupt rise that we correlate with the 8.2 ka global rise in sea level. Sedimentological, isotope and seismic evidence point to a subsequent slowstand interspersed by two punctuated rises in sea level that formed clear tidal ravinement surfaces. Sedimentary changes in the embayment are primarily forced by sea-level change, whereby tidal ravinement surfaces sandwich normal regressive packages formed via marginal progradation and shallowing of the system during "slow-" or still-stands. Large marine embayment systems hold great potential in unravelling relative sea-level change. Axiomatically, this reduces their utility as archives of climate-change.

1. Introduction

Large marine embayments, particularly those that are partially separated from the ocean by barriers or barrier islands, contain important archives of environmental change. Their stratigraphic evolution can provide insights into barrier migration/aggradation during transgression (Simms et al., 2006; Mallinson et al., 2010, 2011; Zaremba et al., 2016) or system shallowing and back-barrier aggradation during stillstands (Benallack et al., 2016). This is especially so for the Holocene, where repeated small-scale oscillations in sea level produce sedimentary successions that document phases of shoreline transgression, regression and associated back-barrier sedimentation (e.g., Woodward et al., 2014; Zecchin et al., 2014). Coupled to this are system modifications due to climatic change. An embayment's proximity to adjoining coastal plains means that terrestrial environmental changes can also be recorded via proxies in the sedimentary succession. Sea level and climatic variability, as drivers of geomorphic change in a large subtropical marine embayment form the focus of this paper. We document the Holocene stratigraphy of Maputo Bay, on the southern Mozambique coast (Fig. 1) with the aim of identifying back-barrier changes and their relationship with changes in relative sea level and/or climate.

1.1. Previous studies on southern African sea-level variability

At the onset of the Holocene, sea-level rose from ~130 m below present mean sea level (MSL) at the last glacial maximum (LGM) to levels similar to present by 5–6 kyr BP (Fig. 2a) (Ramsay, 1995; Ramsay and Cooper, 2002; Carr et al., 2010). In southern Africa, this transgression has been recorded mainly in back barrier estuarine fill sequences (Ramsay and Cooper, 2002) and overstepped shoreline deposits on the submerged continental shelf (Green et al., 2014). Ramsay (1995) produced a 9 kyr BP record of sea-level changes from the South African east coast, that showed sea levels reached a high stand of +3.5 m at 4.65 ^{14}C kyr BP (Fig. 2a). Similar high stands have been recorded elsewhere in the Southern Hemisphere, on the west coast of South Africa (0–3 m, Compton, 2001), in south Australia (1–3 m, Belperio et al., 2002), south- and north-east Australia (1.7 m, Baker et al., 2001; 2 m, Larcombe et al., 1995; respectively) and Brazil (2.1 m, Angulo et al., 2006). In South Africa

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http://dx.doi.org/10.1016/j.ecss.2017.05.015
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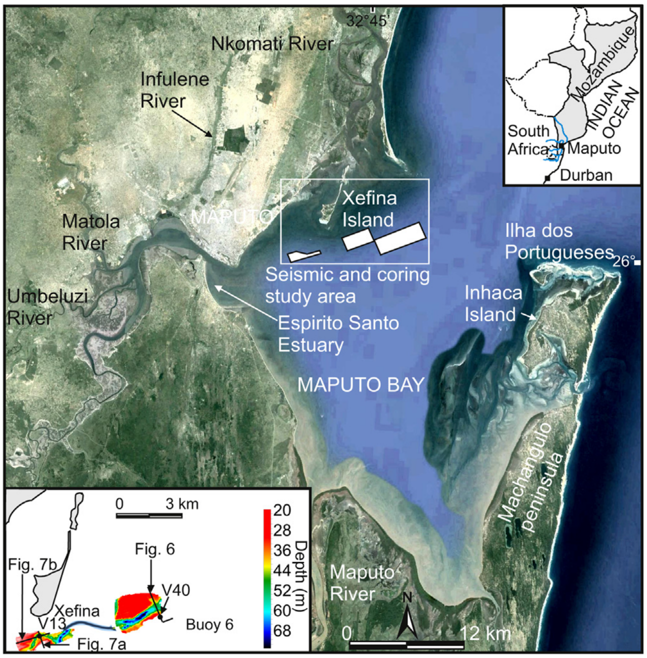

Fig. 1. Locality map of Maputo Bay detailing the major fluvial inputs, the position of Inhaca Island and the area studied. The inset details the location of the seismic reflection profiles, core localities and the underlying last glacial maximum (LGM) incised valley surface described in the text. Satellite image from Google Earth.

this was followed by a drop below present level before rising to another high stand at 1.6 ^{14}C kyr BP (Compton, 2001; Ramsay, 1995).

In Mozambique, Norström et al. (2012) identified a sea-level highstand ~3 m above present at ~ 6.6 kyr BP. At 6.3 kyr BP diatom records showed a change to a freshwater environment that was attributed to a drop in sea level from the highstand (Fig. 2b). The Mozambique data roughly overlaps with of the late Holocene record of Ramsay and Cooper (2002).

2. Regional setting

Maputo Bay covers an area of 1875 km^2 (Canhanga and Dias, 2005) (Fig. 1). It has an open connection to the Indian Ocean on its northern side, while the southern side of the bay is protected by the Machangulo peninsula and Inhaca Island that act as partial barriers for the embayment. Inhaca Island dates back to at least Marine Isotope Stage 5, when calcium carbonate cemented aeolianites, remnants of an older dune-barrier system, were formed (Armitage et al., 2006). The system is underlain by two main incised valley networks, the youngest of which corresponds to the Last Glacial Maximum (LGM) (Green et al., 2015) (Fig. 1 inset). Most of the sediment fill of the incised valley system occurred during the postglacial relative sea-level rise.

Tidal amplitude is 3.5 m during spring tides and strong tidal currents occur (de Boer et al., 2000; Silva et al., 1993). Current speeds reach up to 0.17 ms^{-1}, and 0.70 ms^{-1} within the channels between Machangulo peninsula and Inhaca Island, respectively (De Boer et al., 2000). According to Canhanga and Dias (2005), the bay is mostly less than 10 m deep, except in areas adjacent to the Indian Ocean, where depths >15 m occur. A number of tidal channels occur in the Bay, many of which are used for navigation. The sediments comprise mud near the river mouths, and become sandier towards the main marine inlet (Silva et al., 1993).

Four rivers discharge into Maputo Bay: the Maputo to the south; the Nkomati to the north and the Umbeluzi and Matola to the west; all merging at the Espiritu Santo estuary. The capital city, Maputo, is situated at the mouth of the Espiritu Santo. The cumulative runoff from these rivers is about 190 m^{3}s^{-1}. Water temperatures near the Espiritu Santo estuary range from 19.2 to 28.0 °C (Silva et al., 1993). Salinity and temperature profiles of the Bay indicate that the water masses are vertically homogeneous (Canhanga and Dias, 2005).

The surrounding geology comprises Tertiary and Quaternary unconsolidated deposits, with the latter comprising four Pleistocene Formations and five main Holocene deposits (Vicente et al., 2006). Holocene deposits are characterised by calcarenites of the Costa do Sol Formation; the Xefina Formation that comprises coastal dune sands; and the other unconsolidated cover sediments

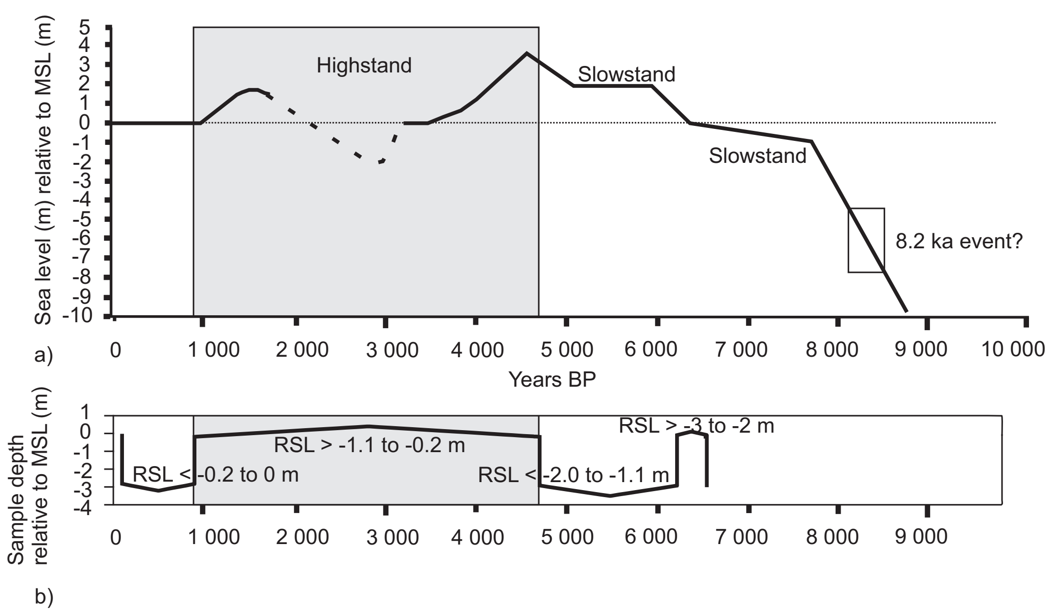

Fig. 2. Southern African sea level curves a) Holocene sea levels from the east coast of South Africa (modified from Ramsay, 1995); and b) maximum/minimum relative sea-level values (arrows) and for the nearby Macassa Bay, Mozambique (modified from Norström et al., 2012). Note the general correspondence between the two relative sea level curves indicating a 3500 BP Holocene high (Grey box). The 8.2 ka jump in sea-level rise is tentatively juxtaposed with the SE African curves.