Catena 153 (2017) 131–142

Contents lists available at ScienceDirect

Catena

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

Sea level controls on palaeochannel development within the Swan River estuary during the Late Pleistocene to Holocene

Giada Bufarale [a,*], Michael O'Leary [b], Alexandra Stevens [b], Lindsay B. Collins [a]

[a] Department of Applied Geology, Curtin University, Bentley, WA 6102, Australia
[b] Department of Environment and Agriculture, Curtin University, Bentley, WA 6102, Australia

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form 31 December 2016
Accepted 9 February 2017
Available online 16 February 2017

Keywords:
Wave-dominated estuary
Late Pleistocene
Sea level fluctuations
High-resolution seismic stratigraphy
Swan River palaeochannels
Palaeodrainage evolution

ABSTRACT

High-resolution seismic profiles were conducted across the metropolitan area of the Swan River estuary (Perth, Western Australia) to explore the sub-surficial stratigraphic architecture, down to a depth of about 40 m below the river bed. The acoustic profiles revealed a complex system of palaeochannels where three main unconformities (R1, R2, R3) bound as many seismic units (U1, U2, U3), over the acoustic basement. Integrating these data with sediment borehole analysis, LiDAR data and available literature of the geology and stratigraphy of the area, it was possible to determine the development of these stratigraphic units, in response to Late Pleistocene and Holocene sea level fluctuations and conditioned by pre-existing topography and depositional palaeoenvironments during the last ~130,000 years. The deepest unit (U3) can be interpreted as the Perth Formation, which consists of interbedded sediments that were deposited in a large palaeo-valley downcutting into the underlying acoustic basement (bedrock: Tamala Limestone and Kings Park Formation), under a fluvial to estuarine setting, existing between ~130 and 80 ky BP (in the Last Interglacial).
The middle unit (U2), composed of heterogenic fluvial (possibly lacustrine) and estuarine sediments, represents the Swan River Formation. Similarly to the Perth Formation, the formation infills channels incised in older formations and reflects the hydrogeological conditions linked with sea level fluctuation changes during the Last Glacial low stand. Holocene (last ~10 ky) fluvial and estuarine deposits form the shallowest unit (U1). These sediments have a highly variable internal structure, ranging from heavily layered, filling palaeochannels, to hard and chaotic, atop pre-existing topographic highs. The wave-dominated Swan River system shares several similarities with a number of estuaries worldwide, such as Burrill Lake (NSW, Australia) and Arcachon Lagoon (Aquitaine, France). This research represents the first environmental high-resolution acoustic investigation in the middle reach of the Swan River estuary.

1. Introduction

Understanding the geomorphic development and sedimentary evolution of riverine, estuarine and deltaic environments under the high amplitude sea level changes that characterise the Pleistocene and Holocene Epochs has been the focus of a number of studies worldwide.

For instance, research performed along the lower Murray River (South Australia) and the adjacent Lacepede Shelf revealed that the stratigraphic and structural architecture of the area is the product of both climate and sea level variations throughout the Pleistocene and the Holocene, resulting in formation of dunes, karst features and ancient infilled channels and lagoons (i.e. Bourman et al., 2000; Hill et al., 2009). Similarly, sea level fluctuations, together with palaeo-topography, have controlled the Quaternary sequence stratigraphy of the Brisbane River (Queensland, Australia. Evans et al., 1992). Palaeochannels and cut-and-fill structures, formed as a response to sea level changes during the Late Pleistocene and Holocene, have also been widely recognised across Europe, America and Asia, for example along the Atlantic French and Spanish coasts (Chaumillon et al., 2010; Menier et al., 2011; Blanco et al., 2015), the Gulf of Mexico (Anderson et al., 2014), in Tokyo Lowland (Tanabe et al., 2015), and beneath the Mekong River and Red River deltas in Cambodia and Vietnam, respectively (Tamura et al., 2009; Hori et al., 2004).

Here we investigate the role that sea level oscillations, hydrodynamic conditions and pre-existing geomorphological settings had in controlling the development and evolution of the Swan River (SW Australia) during the past ~130 thousand years (ky). The study area differs from the previously mentioned studies in that the immediate coastal region is characterised by a mixed carbonate siliciclastic sedimentary system.

This study aims to construct a more detailed picture of Late Pleistocene and Holocene sequence stratigraphy and sedimentary architecture of the middle reach (Melville Waters) of the Swan River, using high-

* Corresponding author at: Department of Applied Geology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.
E-mail address: giada.bufarale@postgrad.curtin.edu.au (G. Bufarale).

http://dx.doi.org/10.1016/j.catena.2017.02.008
0341-8162/

resolution shallow seismic data, ground truthed with geotechnical borehole data, in order to better understand how changing sea level driven fluctuations (base level) have influenced the evolution of the estuary throughout this period.

1.1. Previous work

The Swan River estuary is located in the south west of Western Australia and flows westward through the Perth Metropolitan area, into the Indian Ocean, at the City of Fremantle. Baker (1956) carried out the first scientific study of the Quaternary sedimentation in the Perth Basin, including the Swan River. He produced seven geological cross-sections using borehole data in various bridge and wharf sites (Fig. 1, highlighted in pink). On the basis of these cross-sections and further geotechnical studies (Jones and Marsh, 1965; Ove Arup, 2001; Coffey Geosciences, 2002), Gordon (2003a, 2012) proposed an inferred location of three palaeoriver channel systems within the upper reach and Perth Waters of the Swan River estuary (Fig. 1). In addition, a number of recent geotechnical studies (i.e. Golder Associated Pty Ltd., 2008, 2012) took place along the northern shore of the Swan middle reach (Perth Waters, between the Narrows Bridge and Barrack Square jetties, see Fig. 1) as part of the Elizabeth Quay development, a major waterfront project that involved the construction of an extensive artificial inlet. Boreholes and localised geophysical investigations (subbottom profiling, seismic refraction and electrical resistivity imaging) identified potential palaeochannel structures and a total of three primary seismic reflectors above the bedrock.

These palaeoriver channels represent the geomorphological and sedimentary response of the Swan River estuary to orbitally driven changes in sea level, spanning ~130 ky to present. This period captured the peak of the Last Interglacial (MIS 5e; 127 to 116 ky) with sea levels between 3 and 6 m above present. The period between 110 ky and 80 ky saw sea level oscillating between −10 and −30 m below present (MIS 5d, c, b and a). After 40 ky global cooling saw sea levels fall to around −125 m at the Last Glacial Maximum (LGM), which peaked around 18 ky BP. Global deglaciation after 18 ky saw rapidly rising sea levels reaching near present elevations around 7 ky BP (Bufarale and Collins, 2015).

Thus, sea level-driven changes in base level and the influence this had on fluvial sediment dynamics, together with the pre-existing geomorphology, likely played a major role in controlling the development of the Swan River estuary during the Last Glacial cycle (Churchill, 1959, cf. geological heritage in Chaumillon et al., 2010; Menier et al., 2011).

The sedimentology and geology of the Swan River and its estuary have, so far, been principally studied in a geotechnical context for planning and construction of bridges and harbour works and mainly limited to the middle reach and mouth of the Swan estuary. Much of this data remains largely unpublished, or is present in the form of state government and consultancy reports (e.g. Australian Hydrographic Services, 1971; McKimmie Jamieson and Partners, 1987; Main Roads Western Australia, 1998; Ove Arup, 2001; Coffey Geosciences, 2002; Coffey Geosciences, 2010; Golder Associated Pty Ltd., 2008).

2. Geological and regional setting

The Perth Region is located in the south west of Western Australia and stretches between 31° 20′ S (Gingin Brook and Moore River) and 32° 35′ S (South Dandalup River), covering an area of about 4000 km^2 (Davidson, 1995). The region is largely occupied by the 30 km wide Swan Coastal Plain, bound to the west by the Indian Ocean and to the east by the north-south orientated Darling, Gingin and Dandaragan Scarps. These scarps represent the western margin of the Darling Plateau, a weathered Archaean crystalline low-relief plain (Davidson, 1995).

The Swan Coastal Plain lies along a passive continental margin and, together with the Rottnest Shelf, represents the surficial sediments of the Perth Basin. Formed as a north-south rift valley during the

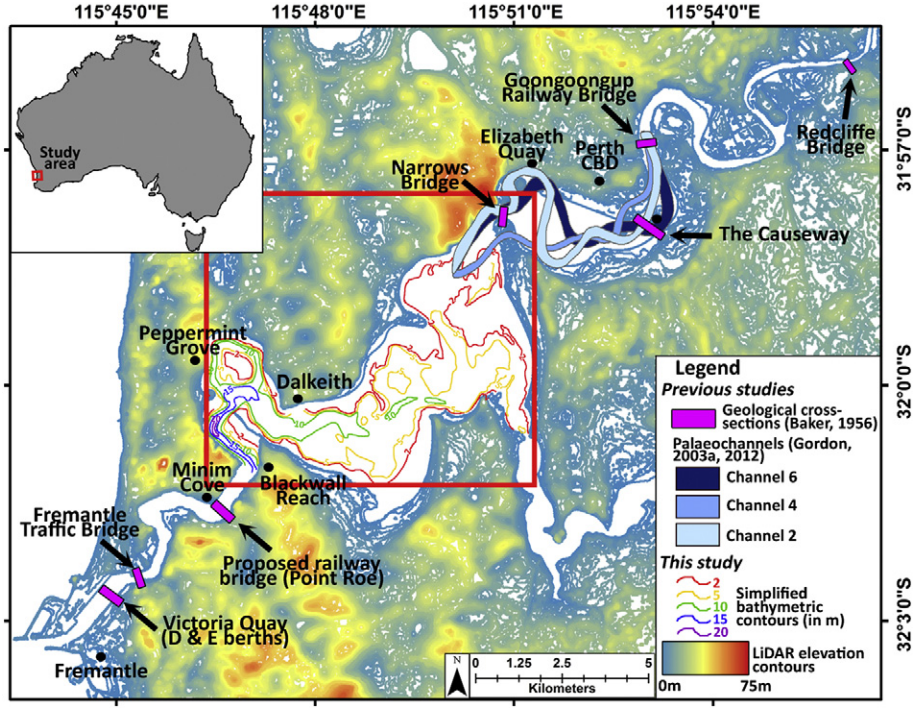

Fig. 1. Locality map showing the study area and locations mentioned in the paper. Simplified palaeochannels proposed by Gordon (2003a, 2012) are represented by 3 shades of blue, representing 3 cutting events. Baker's (1956) cross section locations are highlighted in pink. This study focused on the wide, underfilled middle reach of the Swan estuary, whereas Gordon's studies were restricted to the upper reach of the estuary. Simplified bathymetric contours, limited to the studied area, are also shown.
(Source: Department of Transport).