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Research paper

Influence of bathymetry and oceanic currents on the development of carbonate platforms: Northern Carnarvon Basin, Northwest Shelf of Australia

Carla M. Sanchez [a, b, *], Craig S. Fulthorpe [b], Ronald J. Steel [a]

[a] Department of Geological Sciences, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA
[b] University of Texas Institute for Geophysics, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA

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ABSTRACT

Cenozoic continental-shelf deposition in the Northern Carnarvon Basin was dominated by heterozoan carbonates until siliciclastic sediments prograded across the shelf in the late-middle Miocene to Pliocene. These siliciclastic sediments were deposited as outer-shelf and shelf-edge deltas, which created subtle bathymetric highs. Interpretation of extensive, high-quality multichannel seismic data shows broad, flat-topped carbonate platforms overlying the remaining bathymetric highs following the retreat of deltaic sedimentation. Platform geometries suggest that a combination of relative sea-level changes and ocean currents controlled their internal architectures. Clinoforms on the northeastern flanks of the platforms are more steeply dipping than those on the southwestern flanks and this platform architecture may reflect strengthening, or initiation, of a proto-Leeuwin Current. The earliest platform developed in the northeast and successive platforms migrated southwest (along strike), a process that could have resulted either from differential compaction of the underlying clastic depocenters, or variable rates of tectonic subsidence along depositional strike, probably in combination with environmental factors.

1. Introduction

The influence of siliciclastic depositional systems on subsequent tropical carbonate sedimentation has been previously documented (Choi and Ginsburg, 1982). However, the temporal stratigraphic variability resulting from the interaction between siliciclastic sediments and cool, sub-tropical water carbonates is poorly known. Understanding the interaction of siliciclastic and carbonate depositional systems is a topic of interest for stratigraphers and sedimentologists. Mixed carbonate-siliciclastic settings are also of particular significance for the petroleum industry because such intervals often form important reservoirs.

Mixed carbonate-siliciclastic stratigraphy comprises the Cenozoic sedimentary record in the Northern Carnarvon Basin (NCB) area (Bradshaw et al., 1988; Cathro, 2002; Cathro et al., 2003; Sanchez, 2011; Sanchez et al., 2012). The Oligocene to Miocene in the NCB was dominated by prograding heterozoan carbonate sedimentation (Cathro, 2002; Cathro et al., 2003). Open-shelf carbonate sedimentation was interrupted in the middle Miocene when a complex series of siliciclastic progradational pulses deposited the Bare Formation (Fig. 2; Sanchez, 2011; Sanchez et al., 2012). Shelfal carbonate sedimentation resumed between the late Miocene and the Pliocene (Delambre Formation, Fig. 2). Modern shelf sedimentation in the NCB area is dominated by heterozoan carbonate growth, typical of cooler water, eastern sides of oceans or temperate to polar latitudes (James, 1997; James et al., 2004).

This paper presents results from seismic stratigraphy analysis and seismic geomorphology in an attempt to investigate possible controls on carbonate sedimentation following a major siliciclastic progradation event. Our interpretations indicate that broad carbonate platforms developed in the NCB during the Plio-Pleistocene. The platforms are characterized by flat tops and steep, asymmetrical slopes; a geometry commonly associated to tropical organisms (Read, 1985; Pomar 2001) but also found in some cool, subtropical carbonate platforms (Isern et al., 2004). Integration with previous studies focused on siliciclastics in the NCB (Sanchez, 2011; Sanchez et al., 2012) suggests that underlying Miocene delta lobes likely created subtle bathymetric highs in the Pliocene seafloor, which subsequently influenced the spatial distribution of overlying flat-topped carbonate platforms.

* Corresponding author. 12203 Clearfork Drive, Houston, Texas, 77077. U.S.A.
E-mail address: carlasphelps@gmail.com (C.M. Sanchez).

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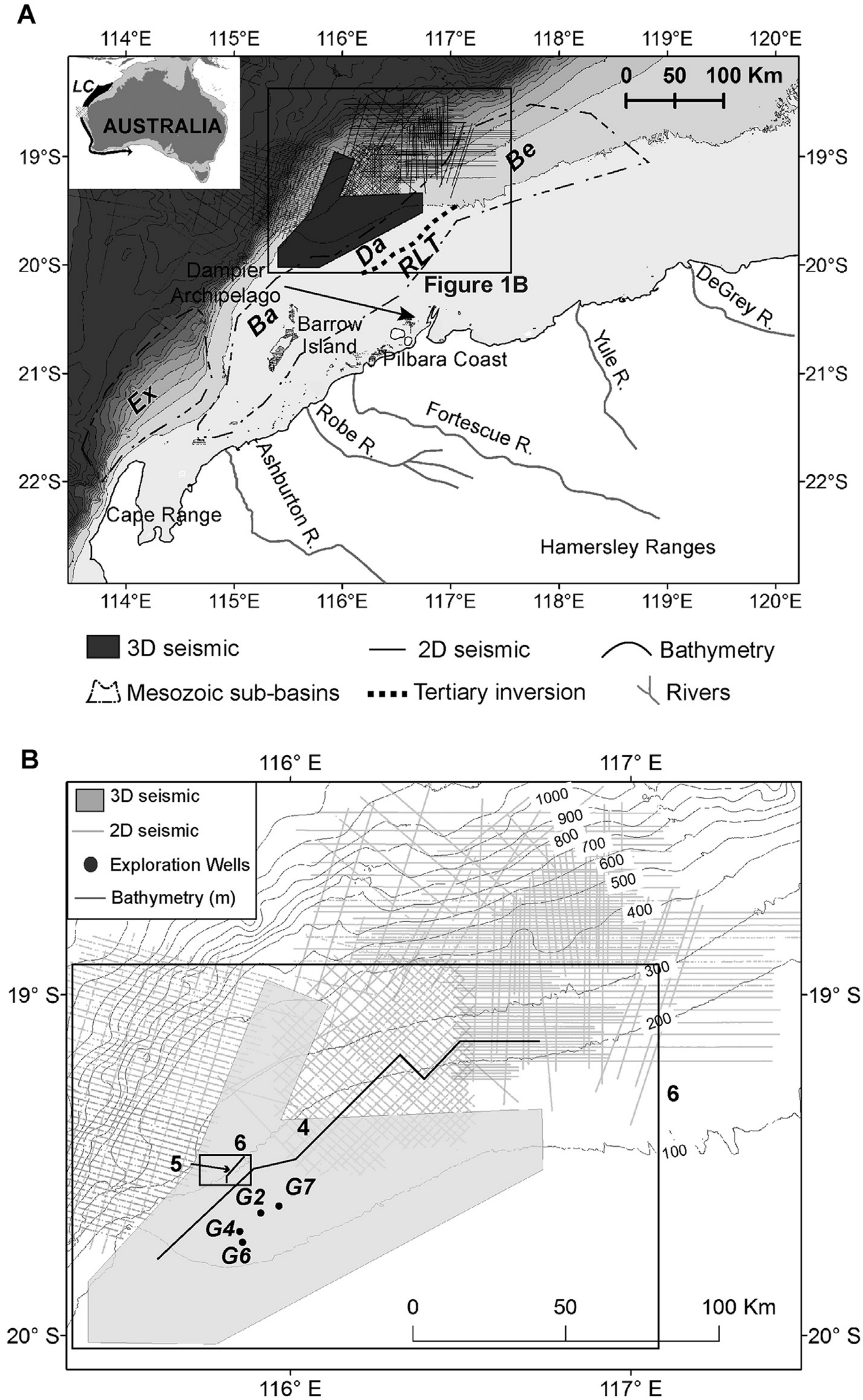

Fig. 1. (A) Map showing location of the study area, available seismic data (dark grey polygon represents 3D volume; lines represent 2D profiles; see also panel B), Mesozoic sub-basins of the Northern Carnarvon Basin (outlined by dashed lines; Ex = Exmouth, Ba = Barrow, Da = Dampier, Be = Beagle; Stagg and Colwell, 1994; Romine et al., 1997; Cathro et al., 2003), and modern rivers draining the Hamersley Ranges (Semeniuk, 1996). Bathymetric contours are at 100 m intervals (Webster and Petkovic, 2005). Thick, dashed line shows the location of localized Miocene inversion along the Rosemary-Legendre Trend (RLT) caused by collision of Australia with the Indonesian arc (Cathro and Karner, 2006). Inset map shows the location of the study area, with respect to both the Australian continent and the Leeuwin Current which flows along the Western Australian shelf edge (Tomczak and Godfrey, 1994). (B) Areas covered by 3D (grey polygon) and 2D (individual line segments) industry multichannel seismic data used in this study. Bathymetric contours are at 100 m intervals (Webster and Petkovic, 2005). Exploration wells referenced are also shown: G2 = Goodwyn-2; G4 = Goodwyn-4; G6 = Goodwyn-6; G7 = Goodwyn-7. Note locations of Figs. 4, 5 and 9.

The influence of ocean currents on subtropical carbonate platforms has been previously studied using seismic data (Isern et al., 2004). The modern, warm (>24 °C), poleward-flowing Leeuwin Current (LC) is active near the shelf edge in the study area (Fig. 1A, inset; Holloway and Nye, 1985; Cresswell, 1991; Tomczak and Godfrey, 1994; Holloway, 1995; Martinez et al., 1999). The timing