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Amplitude of late Miocene sea-level fluctuations from karst development in reef-slope deposits (SE Spain)

Jesús Reolid [a,*], Christian Betzler [a], Juan Carlos Braga [b]

[a] Institut für Geologie, CEN - Centrum für Erdsystemforschung und Nachhaltigkeit, Universität Hamburg, Bundesstraße 55, 20146 Hamburg, Germany
[b] Departamento de Estratigrafía y Paleontología, Universidad de Granada, Avenida Fuentenueva s/n, 18002 Granada, Spain

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ABSTRACT

A prograding late Miocene carbonate platform in southern Spain revealing different sea-level pinning points was analysed with the aim to increase the accuracy of reconstruction of past sea-level changes. These pinning points are distinct diagenetic zones (DZ) and the position of reef-framework deposits. DZ1 is defined by the dissolution of bioclastic components and DZ2 by calcitic cement precipitation in dissolution pores. Calcite cements are granular and radiaxial fibrous, and are of meteoric origin as deduced from cathodoluminescence, EDX spectroscopy, as well as from $\delta^{13}C$ and $\delta^{18}O$ isotope analyses. DZ3 has moldic porosity after aragonitic bioclasts with minor granular calcitic cements. DZ1 and DZ2 indicate karstification and the development of a coastal palaeoaquifer during a sea-level lowstand. DZ3 diagenetic features are related to the final subaerial exposure of the section during the Messinian Salinity Crisis. Facies and diagenetic data reveal a complete cycle of sea-level fall (23 ± 1 m) and rise (31 ± 1 m). A robust age model based on magneto- and cyclostratigraphy for these deposits places this cycle between 5.89 and 5.87 Ma. Therefore, for the first time, this work allows a direct comparison of an outcrop with a pelagic marine proxy record of a specific Neogene sea-level fluctuation.

1. Introduction

Past sea-level stands or fluctuations in sea level may be reconstructed using: (1) sedimentologically defined pinning points, that is, points in an outcrop that indicate ancient sea-level positions relative to an arbitrarily defined, geologically useful starting elevation (Goldstein and Franseen, 1995), (2) the interpretation of seismostratigraphic relationships (Zhong et al., 2004), and (3) the $\delta^{18}O$ analysis of deep-water benthic foraminifera as an ice-volume proxy (Miller et al., 2005, 2011). Several curves showing Neogene sea-level fluctuations were developed using these proxies (Haq et al., 1987; Miller et al., 2011), but these curves show discrepancies and uncertainties for the fluctuation amplitudes, especially for high-frequency changes.

In nearshore carbonate deposits, there were several attempts to reconstruct past sea-level changes based on the sedimentary infilling of coastal karst pockets, which can change from meteoric-vadose to meteoric-phreatic or to marine in response to sea-level fluctuations (Van Hengstum et al., 2011), and on the occurrence and distribution of calcitic cement fabrics (Meyers, 1978; Li et al., 2014).

In this paper, a test is proposed to verify and reconcile postulated amplitudes of late Miocene high-frequency sea-level changes interpreted from deep-water oxygen isotopes with those recorded in shallow water deposits. The superbly exposed Cariatiz carbonate platform in southern Spain (Riding et al., 1991; Braga and Martín, 1996; Cuevas-Castell et al., 2007; Rodríguez-Tovar et al., 2013; Reolid et al., 2014) is well dated by planktic foraminiferal assemblages and magnetostratigraphy (Sánchez-Almazo et al., 2007), and the sedimentological expression of both highstand and lowstand sea-level positions can be traced in the outcrop. The present research, based on combined LIDAR and outcrop mapping (Reolid et al., 2014), as well as petrographic and isotopic analyses, uses the position of coral-reef framework and distinct early diagenetic zones to trace sea-level changes during the formation of a single high-frequency sequence. Thus, a unique opportunity arises for testing the validity of the amplitudes of global sea-level fluctuations interpreted from proxies in pelagic sequences. This study provides a timely contribution with regard to the discussion on the occurrence of past high-frequency high-amplitude sea-level changes.

2. Geological setting

The Cariatiz carbonate platform is located at the northern margin of the Sorbas Basin in southeastern Spain, which is bounded by metamorphic rocks from the Internal Betic Zone of the Betic Cordillera (Fig. 1). During the Messinian, the basin was rimmed by carbonate platforms, such as that of Cariatiz, changing basinwards to marls and diatomites (Martín and Braga, 1994). The carbonate-platform top is an unconformity surface onlapped by a carbonates-siliciclastics sequence (Martín et al., 1993; Riding et al., 1998, 1999).

* Corresponding author.
E-mail address: jesus.reolid@uni-hamburg.de (J. Reolid).

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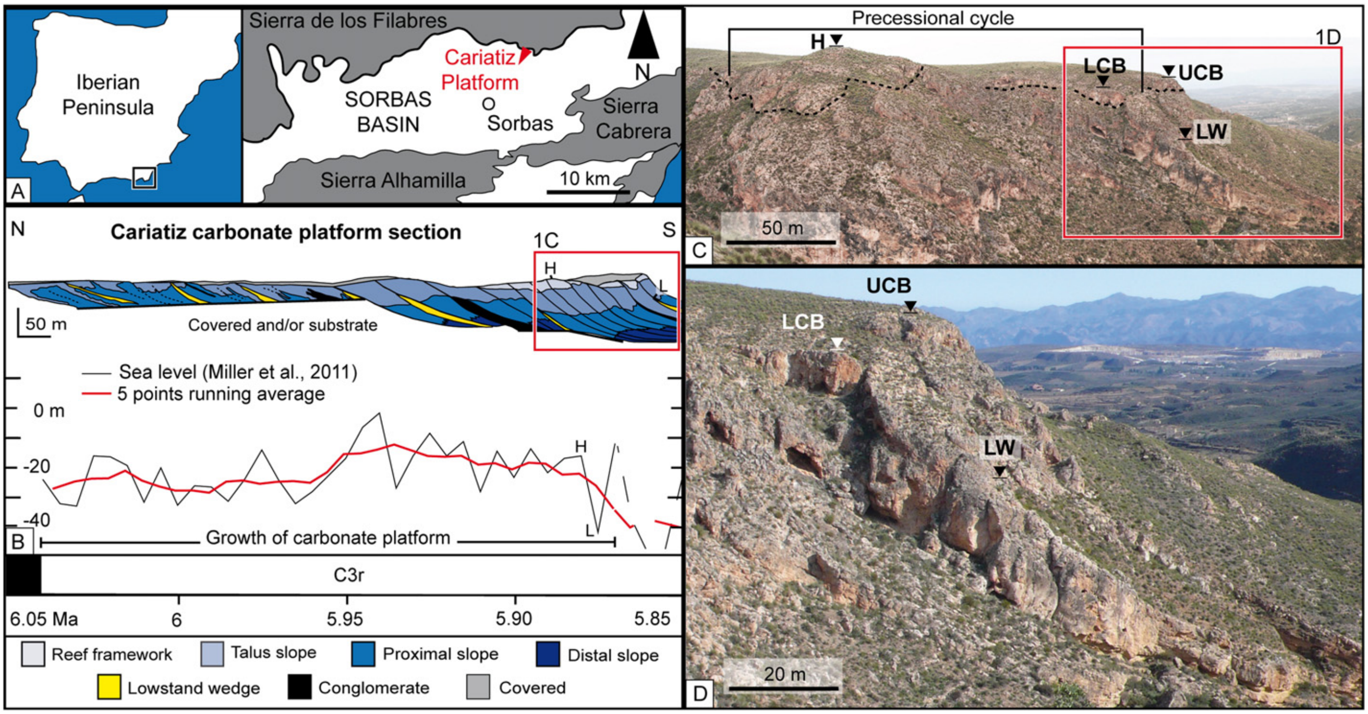

Fig. 1. A Location of the Cariatiz carbonate platform in the Sorbas Basin, SE Spain (red triangle). B Cariatiz carbonate platform section with facies distribution according to Reolid et al. (2014), magnetostratigraphy according to Krijgsman et al. (1999), and global sea-level curve from Miller et al. (2011). H and L represent respectively the position of the highstand (elevation 554 m) and lowstand (elevation 509 m) of the last precessional cycle in the Cariatiz reef (C2.7 in Braga and Martín, 1996; Rodríguez-Tovar et al., 2013) and in the curve of Miller et al. (2011). C Field panorama of the last precessional cycle of the Cariatiz reef including the highstand (H), the last clinoform bodies (LCB), and the lowstand wedge (LW), and the clinoform body (UCB) of the following cycle. Triangles indicate the position of the highstand of the precessional cycle (H) and relative highstands (LCB and UCB) and lowstand (LW). Dashed lines mark the base of the reef-framework facies. D Close up of the studied sub-Milankovitch cycle. The top of the LCB is at 37° 8.809′ N and 2° 6.181′ W, and has an elevation of 532 m.

The last progradation stages of the Cariatiz carbonate platform comprise a series of facies belts consisting of lagoonal deposits, reef-framework, and reef-slope deposits (Braga and Martín, 1996; Reolid et al., 2014). The reef-framework and reef-slope facies are arranged into clinoform-delimited bodies, thinning downslope and basinwards. The reef crest is a distinct part of the reef framework located at the very top of the reef and likely formed at or just below sea level (Riding et al., 1991; Braga and Martín, 1996), as in other late Miocene reefs of the Mediterranean region (Pomar and Ward, 1994; Goldstein and Franseen, 1995).

The stacking pattern, depositional geometries, and facies distribution throughout the section (Braga and Martín, 1996; Cuevas-Castell et al., 2007; Reolid et al., 2014), together with $\delta^{13}C$ and $\delta^{18}O$ values of planktonic and benthic foraminifera in distal slope deposits (Rodríguez-Tovar et al., 2013) indicate that the entire platform formed during four to five obliquity cycles of sea-level change with a superposition of seven to nine precessional cycles separated by basinward-thickening lowstand wedges. The precise number of obliquity and precessional cycles recognised varies in the different, above-mentioned studies. Within the sediment packages deposited during the precessional cycles, clinoform bodies reflect higher-frequency cyclicity in the sub-Milankovitch band. The total duration of platform growth estimated from the obliquity cycles is approximately 180 ky (Cuevas-Castell et al., 2007; Rodríguez-Tovar et al., 2013).

Magnetostratigraphic and biostratigraphic data indicate that the entire Cariatiz carbonate platform was deposited during the single period of reverse polarity of Chron C3r (Sánchez-Almazo et al., 2007), which has its lower boundary dated at 6.04 Ma (Krijgsman et al., 1999). This age constraint combined with cyclostratigraphic data reveals that the selected clinoform bodies for this study were deposited at the end of the last precessional cycle recorded between 5.89 and 5.87 Ma. During this period, the northern margin of the Sorbas Basin was tectonically stable and since then has uplifted at an average rate of 0.11 $\pm$ 0.005 mm/yr (Braga et al., 2003). In the direction of progradation, N160E, the present tectonic tilt of this platform is ca 1.6° (Braga and Martín, 1996).

3. Methods

The different facies and diagenetic zones were mapped at the outcrop and sampled with a hand drill, recovering plugs of 15 $\times$ 5 cm (Fig. 2). Polished slabs and 40 thin sections were analysed to identify microfacies and cements, and selected thin sections were analysed by cathodoluminescence microscopy (Lumic HC5-LM) and EDX spectroscopy (Zeiss LEO-1455VP) in the Institute of Geology, University of Hamburg. Representative cement samples were subsampled for $\delta^{13}C$ and $\delta^{18}O$ isotopic analyses at the Scientific Instruments Centre, University of Granada (Spain). The $\delta^{13}C$ and $\delta^{18}O$ values are reported relative to VPDB with and standard deviation of less than 0.05‰ with respect to the NBS 19. Platform-slope dimensions and the extension of diagenetic zones were extracted from LIDAR data with a spatial resolution of 5 cm, as presented in Reolid et al. (2014).

4. Results

The selected part of the Cariatiz reef section consists of two clinoform bodies (LCB, UCB) separated by a lowstand wedge (LW; Figs. 1, 2A). These are the last episodes of the Cariatiz carbonate platform development, which change here to the basinal sediments of the Sorbas Basin (Braga and Martín, 1996; Rodríguez-Tovar et al., 2013; Reolid et al., 2014).