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Patterns in the distribution of Aptian rudists and corals within a sequence-stratigraphic framework (Maestrat Basin, E Spain)

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ABSTRACT

The ecological zonation of, and environmental controls on rudist and coral assemblages on carbonate platforms of the Old World have received more attention for Late Cretaceous examples than for their Early Cretaceous counterparts. This study accordingly investigates the vertical and lateral distribution of Aptian rudist bivalves and scleractinian corals on a carbonate platform succession from the western Maestrat Basin (E Iberian Peninsula). Here, colonial corals grew profusely on an isolated platform top environment during an earliest highstand stage of a long-term trend of relative sea level, as well as on marly slope settings during higher-frequency transgressive pulses. During the later highstand stage within a longer-term relative sea-level cycle, a facies belt dominated by autochthonous rudist bivalves overlaid the coral meadow that had developed on the isolated platform top. The internal part of this carbonate platform with rudists is dominated by slender elevator caprinids such as *Caprina parvula*, whereas requieniids and polyconitids predominate in the external zone. The abundance of caprinids in the internal platform is remarkable given that caprinid lithosomes of late Early Aptian age are usually rare in the northern margin of the Tethys. The proliferation of caprinids in this case was probably favoured by the apparently more isolated nature of the carbonate platform. On the slopes, the coral communities that flourished during higher-frequency transgressive pulses are overlain by carbonates with rudists, mainly requieniids, shed from the platform top during normal and forced regressive higher-frequency changes of relative sea level. Accordingly, the vertical change from coral-dominated to rudist-dominated facies in both platform top and slope settings records progradation. To decipher the long-term relative sea-level changes that controlled the deposition of this carbonate succession, a sequence stratigraphic analysis was performed. Two depositional sequences including a late Early Aptian (intra *Dufrenoyia furcata* Zone) forced regressive stage of relative sea level, which subaerially exposed and incised the Early Aptian succession to a depth of 21 m, were recognised. The incisions were back-filled with peritidal deposits during the subsequent marine onlap. The rudist- and coral-bearing carbonates were deposited along platform top to slope profiles lacking a barrier margin, and hence, lagoon environments.

1. Introduction

In the sedimentary record of Cretaceous carbonate platforms, rudists and corals are found both coexisting and in discrete facies (Gili et al., 1995a). In the Old World, studies of the ecological distribution of rudist and coral assemblages on platform settings and the environmental controls on them are mostly restricted to Late Cretaceous carbonates (e.g., Carbone and Sirna, 1981; Masse and Philip, 1981; Camoin et al., 1988; Grosheny and Philip, 1989; Scott et al., 1990; Gili, 1993; Gili et al., 1995a, 1995b; Skelton et al., 1995; Götz, 2003; Pomar et al., 2005), whereas Early Cretaceous examples have received less attention (e.g., Masse and Philip, 1981; Masse et al., 1998a).

To further investigate the vertical replacement and lateral zonation of Early Cretaceous rudists and scleractinians on carbonate platforms, the present study examines the Aptian succession exposed along La Serna Creek in the western Maestrat Basin (E Iberian Peninsula). This sedimentary record is rich in rudist and coral faunas, which thrived on platform top and slope settings. Basin marls are found underlying and interfingered with these rudist- and coral-dominated carbonates. The succession is not significantly deformed; it is approximately 370 m-thick and continuous along 6 km, which permits an in-depth analysis of facies architecture and depositional stratal geometries. The platform carbonates investigated are also placed within a sequence stratigraphic framework to decipher the long-term relative sea-level changes that governed their deposition.

Thus, the depositional model presented in this paper integrates the rudist and coral palaeoecology, facies architecture and sequence stratigraphy of the carbonate platform system, aiming to portray its depositional

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dynamics. The study complements previous works on the Aptian of the western Maestrat Basin by Weisser (1959), Salas (1987), Vennin and Aurell (2001), Bover-Arnal et al. (2009, 2010, 2011a, 2011b, 2012), Embry et al. (2010), Skelton et al. (2010), Moreno-Bedmar et al. (2009, 2010, 2012), Garcia et al. (2014), Pascual-Cebrian (2014) and Cors et al. (2015), but provides a contrasting view of the outcrops analysed herein to that given by Peropadre et al. (2013).

2. Geological setting

The Maestrat Basin is located in the eastern part of the Iberian Chain (E Iberian Peninsula) (Fig. 1A). This chain developed by tectonic inversion of Mesozoic rift deposits during the Paleogene–Early Miocene (Salas et al., 2001). Mesozoic rifting resulted from the opening of the Bay of Biscay and the spreading of the Central Atlantic Ocean (Salas and Casas, 1993). During the Aptian, the Maestrat Basin was compartmentalised into seven sub-basins, namely the Galve, Aliaga, Morella, Oliete, El Perelló, Penyagolosa and Salzadella sub-basins (Salas and Guimerà, 1996) (Fig. 1B), where continental to hemipelagic mixed carbonate-siliciclastic sedimentary successions up to a kilometre thick were deposited (Canérot et al., 1982).

The rocks studied crop out in the southern part of the Galve sub-basin (western Maestrat Basin) (Fig. 1B), between the towns of Jorcas, Miravete de la Sierra and Villarroya de los Pinares (Province of Teruel) (Fig. 1C), along the western, southern and eastern sides of a broad, slightly undulating stepped plateau (Muela Seca), which is limited to the south by La Serna Creek (Fig. 1C). This sedimentary succession can be subdivided into three lithostratigraphic units with the rank of formations: Forcall, Villarroya de los Pinares and Benassal (Canérot et al., 1982). In the area studied, the Forcall Formation is around 120 m-thick and characterised by an alternation of marls, marly limestones, limestones and silty limestones with abundant *Palorbitolina lenticularis* and ammonoids. This formation registered the four Early Aptian standard Mediterranean ammonite zones of Reboulet et al. (2011, 2014): *Deshayesites oglanlensis*, *Deshayesites forbesi*, *Deshayesites deshayesi* and *Dufrenoyia furcata* (Moreno-Bedmar et al., 2010; Garcia et al., 2014) (Fig. 2). The Villarroya de los Pinares Formation, circa 80 m-thick in La Serna Creek, is mainly characterised by micrite-supported carbonates with rudist bivalves and corals, and grainstones containing peloids and skeletal components such as orbitolinids and fragments of echinoids and oysters. In the outcrops investigated, the Villarroya de los Pinares Formation accumulated during the late *Dufrenoyia furcata* Zone time span (Moreno-Bedmar et al., 2010; Garcia et al., 2014) (Fig. 2) and it corresponds to an isolated carbonate platform, termed La Serna platform (Bover-Arnal et al., 2010), which developed on an upthrown part of a tilted block fault (Fig. 3). This platform is located to the south of the highstand and lowstand carbonate platforms of El Morrón and Las Mingachas studied by Bover-Arnal et al. (2009). The overlying Benassal Formation is about 170 m-thick in La Serna Creek and consists of an alternation of marls containing colonial corals and limestones with rudist bivalves, corals and nerineid gastropods. The base of this formation lies in the uppermost *Dufrenoyia furcata* Zone (Moreno-Bedmar et al., 2012; Garcia et al., 2014), but the rest of the formation is Late Aptian in age (Bover-Arnal et al., 2010; Pascual-Cebrian, 2014) (Fig. 2). In the study area (Fig. 1C), the upper part of the Benassal Formation is not preserved due to recent erosion.

3. Methods and database

Bed-to-bed sedimentological, palaeontological and palaeoecological analyses were performed along the Aptian rocks incised by La Serna Creek (Fig. 1C). The resulting model of depositional evolution, facies architecture and sequence stratigraphy was derived from the mapping of lithofacies, biofacies, stratal terminations and surfaces with sequence stratigraphic significance onto photomosaics of the outcrops. Facies were characterised on the basis of architectural and sedimentologic heterogeneity along superposed platform top to slope to basin depositional profiles. Therefore, each of the facies is representative of a platform top, slope or basin depositional environment. Sequence stratigraphic terminology follows Catuneanu et al. (2009). The duration of long-term cyclic variations in depositional trends so characterised is consistent with the third-order relative sea-level cycles of Vail et al. (1991). Ninety rock samples were collected for thin sections to determine rock textures and components. The classifications of rock textures used follow Dunham (1962) and Embry and Klovan (1971). Ages of strata were taken from Sr isotopic data measured by Pascual-Cebrian (2014) on rudist shells from the study area, and biostratigraphic analyses performed in the Galve sub-basin (orbitolinids and rudists in Bover-Arnal et al., 2010; ammonoids in Moreno-Bedmar et al., 2009, 2010, 2012; Garcia et al., 2014).

4. Long-term sequence stratigraphic interpretation and facies description

The Aptian rocks exposed along La Serna Creek in the southern Galve sub-basin (Fig. 1B–C) are subdivided into two depositional sequences: A and B (Fig. 2). A two-dimensional block diagram displaying the sequential evolution of the long-term relative sea-level change and the platform-to-basin facies architecture is provided in Fig. 4. With the aim of providing a facies and strata architectural analogue both for outcrop and for subsurface Aptian carbonate systems, seven major lithofacies giving rise to seismic-scale building blocks of the sedimentary succession are distinguished (Fig. 4). The facies differentiated include: (i) requieniid–polyconitid-dominated platform top, (ii) caprinid-dominated platform top, (iii) branching coral-dominated platform top, (iv) orbitolinid-dominated platform top, (v) incision back-fill, (vi) slope and (vii) basin (Fig. 4). The geographical situation of the outcrops and the macro- and microfacies shown in the study are displayed in Fig. 5.

4.1. Depositional Sequence A

4.1.1. Transgressive deposit

During the transgressive stage of Depositional Sequence A, basinal marls of the Forcall Formation were deposited in the area studied (Figs. 2, 4, 6–8A). They are found at the toe of slope clinoforms and expand basinwards. Interbedded with them are calcareous nodules, turbidites, and centimetre- to decimetre-thick tabular and nodular stratified yellow and grey beds exhibiting mudstone to wackestone textures. The turbidites and the mudstone–wackestone limestones contain silt-sized quartz particles and display infrequent *Thalassinoides* and other unidentified burrows. The deposits are rich in ammonoids and orbitolinids such as *Palorbitolina lenticularis* and *Praeorbitolina cormyi*. Key ammonites identified at species level are *Roloboceras hambrovi*, *Deshayesites deshayesi* (Fig. 8B) and *Dufrenoyia dufrenoyi* (Fig. 8C), which in this region are assigned to the Early Aptian *Deshayesites forbesi*, *Deshayesites deshayesi* and *Dufrenoyia furcata* zones, respectively (Fig. 2; Moreno-Bedmar et al., 2010). Other foraminifera, nautiloids, brachiopods, echinoids, oysters, other bivalves and gastropods are present as well.

At the lower part of this marly transgressive succession is a basin-wide, continuous limestone horizon formed by a decimetre-thick bed of rock-forming orbitolinids overlain by a several metre-thick (up to 5 m) bindstone. The binding was performed by *Lithocodium aggregatum* encrusting mainly fragments of corals, and specimens of the rudists *Caprina douvillei* and *Horiopleura dumortieri*. This deposit is described and illustrated in Schlagintweit et al. (2010), Bover-Arnal et al. (2011b) and Schlagintweit and Bover-Arnal (2012).

4.1.2. Highstand normal regressive deposit

The highstand limestone strata correspond to the Villarroya de los Pinares Formation (Fig. 2). The maximum flooding surface is interpreted to be located at the top of the basinal marls deposited during rapid