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Paleoenvironmental reconstruction of a downslope accretion history: From coralgal-coralline sponge rubble to mud mound deposits (Eocene, Ainsa Basin, Spain)

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ABSTRACT

In the Lutetian intraslope Ainsa sub-basin, small, sub-spherical, carbonate mud mounds occur associated with hemipelagic marls and mixed gravity flow deposits. The studied mud mounds consist of a mixture of allochthonous, parautochthonous and autochthonous components that show evidences of reworking, bioerosion, and accretion by different fossil assemblages at different growth stages. The crusts of microbial-lithistid sponges played an important role stabilizing the rubble of coralgal-coralline sponges and formed low-relief small benthic patches in a dominant marly soft slope environment. These accidental hard substrates turned into suitable initiation/nucleation sites for automicrite production (dense and peloidal automicrites) on which the small mud mounds dominated by opportunistic epi- and infaunal heterozoan assemblages grew. A detailed microfacies mapping and paleoenvironmental analysis reveals a multi-episodic downslope accretion history starred by demosponges (coralline and lithistid sponges), agariciid corals, calcareous red algae, putative microbial benthic communities and diverse sclerobionts from the upper slope to the middle slope. The analyzed mud mound microfacies are compared with similar fossil assemblages and growth fabrics described in many fossil mud mounds, and with recent deep-water fore reefs and cave environments.

1. Introduction

In submarine slope systems, the input of sediments and nutrients is a consequence of downslope transport by several gravity-driven mechanisms (Middleton and Hampton, 1973; Mulder and Cochonat, 1996), along slope transport by deep-water bottom currents (e.g. contour and upwelling currents, Shanmugan, 2008), internal waves (Pomar et al., 2012), and hemipelagic sedimentation (Stow and Tabrez, 1998). Thus, the submarine slope morphology is very varied but broadly it can be separated into canyon and intercanyon areas (open slope), where the combination of several factors such as heterogeneity of seafloor/substratum, rate of sedimentation, nutrient availability and local disturbances can produce the spatial patchiness of macro- and meiobenthos (Gage, 1996), and control the in situ carbonate production by the benthic communities. We provide a new case of study of carbonate production resulting from the spatial patchiness of benthic communities on the Middle Eocene open marly slope of the Ainsa sub-basin, where the final deposits are small mud mounds. The mud mounds are seen here as biosedimentary buildups which are part of the reef system and dominated by fine-grained carbonates (more than 50% of rock volume), with different matrix-supported fabrics that are composed of automicrites and allomicrites (see review in Rodríguez-Martínez, 2011). The mud mound factory (sensu Schlager, 2003) has been widespread from deep aphotic basinal to shallow-water platform settings from the Proterozoic times, reaching a maximum development during the Paleozoic, before the beginning of their decline from mid-Cretaceous (see examples and reviews in Monty et al., 1995; Reitner and Neuweiler, 1995; Kopaska-Merkel and Haywick, 2001; Kiessling et al., 2002; Bourque et al., 2004; Vennin et al., 2007; and references therein). Thus, the occurrences of Paleogene mud mounds are exceptional, ranging from shallow-water biodetrital mud mounds (Taberner and Bosence, 1995), mid-ramp microbialite coral-mounds (Zamagni et al., 2009) to bryozoa mud mounds in an aphotic shelf context (Serra-Kiel et al., 2003).

The Eocene slope system of the Ainsa sub-basin reveals the interplay between a terrigenous slope and a flanking carbonate slope developed toward the foreland basin, which produces different facies assemblages as slope mudstones and marls, contorted mudstones and marls (slides and slumps), limestone breccias and olistostromes, channel fills, and interchannel deposits (Arbués et al., 2011). The occurrence of mud mound deposits has never been reported in the Ainsa sub-basin. However, in such dynamic and mixed sedimentary environment, the presence of isolated, sub spherical-shaped, boulder sized, and massive carbonate deposits such as small mud mounds within slope marls could be interpreted as allochthonous olistoliths from the shallow carbonate

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platform. A careful sedimentary and microfacies analysis of these carbonate deposits reveals diverse sessile benthic assemblages with numerous bioerosion phases, embedded in a fine-grained carbonate matrix which is structured in massive, accretionary and geopetal fabrics. The purposes of this study are: i) to differentiate and describe the main components of the diverse constructive growth fabrics and bioerosion episodes recorded in the mud mound deposits; ii) to establish the accretion history of these mud mounds and clarify the paleoenvironmental conditions of their multi-episodic build-up, demise and burial in the slope; and iii) to compare the key components and fossil assemblages from the Lutetian mud mounds of the Ainsa sub-basin with similar fossil and recent occurrences.

2. Geological and stratigraphical setting

The Eocene South-Pyrenean foreland basin comprises the Tremp-Graus, Ainsa and Jaca-Pamplona sub-basins, from southeast to northwest (Fig. 1). The stratigraphy of the Eocene foreland basin record (Tremp-Graus, Ainsa, Jaca-Pamplona) has been subdivided, grouped, modified and re-grouped in different basin-wide allogroups which are bounded by major stratigraphic unconformities (Remacha et al., 1987, 1998; Mutti et al., 1988; Barnolas et al., 1991; Barnolas and Gil-Peña, 2001; Das Gupta and Pickering, 2008). The Ainsa Basin is adjacent to the South-Pyrenean Central Unit (SPCU in Fig. 1) and its Eocene synorogenic filling has been controlled by the southward displacement of the cover thrust sheets (1-3 in Fig. 1). During the Eocene, the so-called 'intraslope minibasin' of Ainsa (Moody et al., 2012) hooked up the eastern fluvial-deltaic systems of the Tremp-Graus Basin with the western deep-water turbidite fans of the Jaca Basin (Muñoz et al., 1998).

The Ainsa Basin infilling is around 4 km thick, spanning the Early and Upper Eocene (Fig. 2). It consists of the siliciclastic and carbonate slope deposits, the siliciclastic turbidite fans and the resedimented carbonates of the San Vicente Formation (Van Lunsen, 1970; SV1-SV4 in Fig. 2A), which are overlain by deltaic deposits of the Sobrarbe Fm (De Federico, 1981; So in Fig. 2A) and ultimately by alluvial deposits of the Escanilla Fm (Garrido-Megías, 1968; Es in Fig. 2A) during latest Lutetian to Priabonian (Bentham et al., 1992; Mochales et al., 2012). The Ainsa basin infilling shows five stratigraphic discontinuities that subdivide the basin record into four major unconformity-bounded units (Arbués et al., 1998; Muñoz et al., 1998). The analyzed record is part of the tectono-sedimentary unit III (Fig. 2A; Muñoz et al., 1998; Arbués et al., 1998). The outcrop is located in the eastern limb of the Boltaña anticline (Figs. 1 and 3), in the southern margin of the Ara River, close to the Boltaña locality, and belongs to Las Paules Member (De Federico, 1981). Southwards, Las Paules Mb is laterally equivalent to the Guara Fm (Puigdefàbregas, 1975; redefined by Barnolas et al., 1991 and Samsó et al., 1994; Figs. 2B and 3), a carbonate ramp developed in the southern passive foreland margin during Ypresian (middle Cuisian) to late Lutetian (Rodríguez-Pintó et al., 2013). Northwards, Las Paules Mb is interlayering with the siliciclastic turbidite systems (collectively referred as the Hecho Group by Mutti et al., 1972; Figs. 2B and 3). In general, according to De Federico (1981), Las Paules Member corresponds to marls (upper and middle slope deposits), marly slumps and olistostromes (lower slope deposits), conglomerates and sandstones (channel and interchannel turbidite deposits). The studied outcrop from the open marly slope is coeval to the uppermost part of Banastón-Fiscal turbidite system of Mutti et al. (1985) (Banastón Allogroup 4 of Remacha et al., 1998; Banastón V of Mansurbeg et al., 2009; Banastón VI of Pickering and Bayliss, 2009), and its age is between C20r to C20n Chrons according Oms et al. (2003). In the eastern limb of the Boltaña anticline, near Boltaña village, the Banastón conglomerates and sandstones facies have been interpreted by Rampone and Estrada (1986-1987, see their fig. 3) as channel-lobe transition deposits (type II stage of growth, fig. 7 of Mutti et al., 1985), that vertically grade into channel-levée deposits interbedded in a thick marly slope interval (type III stage of growth of Mutti et al., 1985). The analyzed mud mound deposits occur in the uppermost part of this marly slope interval interbedded with channel-levée deposits.

3. Materials and methods

The studied small mud mounds occur intebedded in slope marls (Figs. 4A, B and D), which vertically grade into mixed clastic deposits. In the examined section (Fig. 4A), the prevalent deposits consist of structureless, irregular to nodular bedded gray marls and mm- to cm-scale mudstone levels (*Mrl-Mstn* in Fig. 4A) with accessory packages of chiefly thin-bedded sandstones (*Tbt S* in Figs. 4A–B) and minor medium-bedded, coarse-grained bioclastic sandstones and calcirudites (*Mbt gS* in Fig. 4A). 23 samples were cut as large polished slabs and their corresponding large thin sections were done (10x15 cm, 12x20 cm) for petrographic and microfacies analysis. In addition, serial cuts and its corresponding thin sections were done from selected samples to check up the spatial relationships between component assemblages

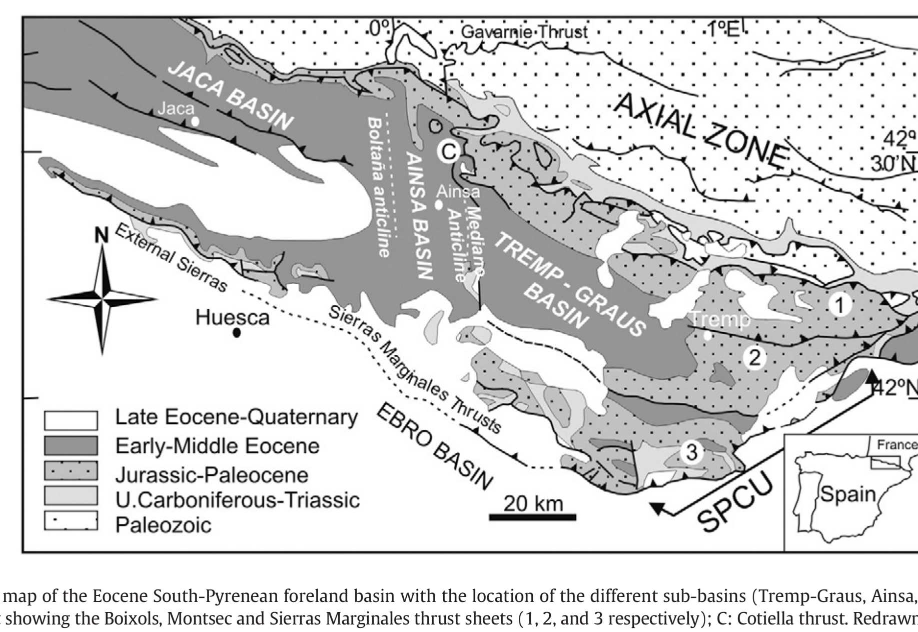

Fig. 1. Simplified geological map of the Eocene South-Pyrenean foreland basin with the location of the different sub-basins (Tremp-Graus, Ainsa, and Jaca-Pamplona). SPCU: the South-Pyrenean Central Unit showing the Boixols, Montsec and Sierras Marginales thrust sheets (1, 2, and 3 respectively); C: Cotiella thrust. Redrawn and modified from Dreyer et al. (1999) and Hoareau et al. (2009).