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The Miocene Sommières basin, SE France: Bioclastic carbonates in a tide-dominated depositional system

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ABSTRACT

The Miocene Sommières Basin in SE France is a semi-enclosed depression that was connected to the Mediterranean Sea by a flooded paleo-incised valley and then filled by a suite of sediments comprising carbonate grains coming from temperate factories that were largely deposited in tidal-dominated paleoenvironments. The strata are partitioned into two sequences that reflect repeated flooding of the incised valley system, one of several similar situations in this region of France. The carbonate grains are mostly bioclasts, namely from barnacles, bryozoans, coralline algae (encrusting, branching, and rhodoliths), echinoids, and benthic foraminifers (large and small) with ostracods, sponge spicules and planktic foraminifers prominent in muddy facies. Particles were produced by shallow water carbonate factories on hard substrates (valley walls in particular), associated with subaqueous dunes, and in deeper water basinal settings. Each depositional sequence is underlain by an eroded and bored hard surface that is progressively overlain by TST subaqueous tidal dunes or storm deposits that grade up, in one case, into HST marls (the HST of the upper sequence has been removed by erosion). The lower sequence is ebb tide dominated whereas the upper sequence is flood tide dominated. The succession is interpreted to represent a TST whose tidal currents were focused by the narrow valley and a HST that reflected flooding of the overbanks. This stratigraphic and depositional motif is comparable to that in other spatially separated Neogene paleovalleys that are filled with tide-dominated clastic carbonates in the region. Together with other recently documented similar systems, these limestones constitute an important new group of carbonate sand bodies in the carbonate depositional realm.

1. Introduction

1.1. Basin outline

Clastic carbonates, whose depositional attributes are largely formed by hydrodynamic processes, are a long recognized but only recently researched group of limestones (Wilson, 1982; Nelson, 1988; James and Clarke, 1997; James and Lukasic, 2010). They are typically composed of biogenic particles that range from ooids and bioclasts in tropical settings to biofragmental components in cooler neretic environments. The rocks are, because of their porosity and permeabilty characteristics, particularly important as hydrocarbon reservoirs.

Among intrabasinal clastic carbonates, those formed in environments dominated by tidal currents might be significant in the geological record (Stride, 1982; Reynaud and Dalrymple, 2012) particularly those in seaways and at the outlet of tidal seaways into a larger tidal basins (Kamp et al., 1988; Anastas et al., 1997; Reynaud et al., 2006; Longhitano, 2011; Reynaud et al., in press-a). Whereas their hydrodynamics through sea-level changes can be understood and predicted by paleotidal modeling (Uehara et al., 2006; Wells et al., 2007, 2010; Mitchell et al., 2010), changes in the carbonate factories in relationship with the evolution of the tidal systems through time is still poorly understood.

Some of the most spectacular and well exposed bioclastic carbonate successions where this relationship can be detected fill a series of Miocene paleo-incised valleys in southern France. In this paper, we document the carbonate record of a semi-enclosed tidal embayment, the Sommières Basin, that was connected to the western Mediterranean by a narrow seaway, the Aubais Valley. Our purpose is first to define depositional facies in terms of sediment composition and depositional setting, then to interpret the successions in a sequence stratigraphic framework, and finally to discuss the relationships between the evolution of the carbonate factories and variation in hydrodynamic processes induced by paleogeographic changes controlled by long-term relative sea-level changes.

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1.2. Regional framework

The Sommières Basin is one of the peripheral parts of the Perialpine Foreland Basin at its junction with the Western Mediterranean Sea (Fig. 1A). From the Late Burdigalian to the Langhian, most of the Perialpine Basin was a narrow marine seaway, extending from the Mediterranean to the Black Sea (formerly Paratethys; Fig. 1A). Tidal offshore to estuarine deposits have been described in many parts of this basin (Fig. 1A). A particularly dense and well studied network of ancient tidal embayments and incised valleys crop out along the Rhône River in SE France (Fig. 1B). The major marine flooding of this area occurred in the Burdigalian, with the deposition of extensive shelf deposits above folded, Mesozoic to Paleogene strata. This event was coincident with the break-up unconformity of the Western Mediterranean margins (Séranne, 1999), amplified by high eustatic levels. The transgression flooded EW trending synclines related to the formation of the Pyrenees in the Paleogene (Demarcq, 1970). Whereas foreland deformation of the Perialpine Basin caused thick strata to accumulate east to the Rhone River (Crumeyrolle et al., 1991), vertical movements and deformation of the basement were much reduced to the West, where the Sommières Basin is preserved. There, most of the deposits passively onlap the basement.

During the Burdigalian, the Sommières Basin was a 15 km wide semi-enclosed depressionconnected to the Mediterranean Sea through the Aubais Valley, a 2 km wide corridor which had its inlet near Gallargues (Fig. 2). Opening of the Western Mediterranean during the Middle to Upper Miocene reactivated the Nîmes fault (Fig. 1B), a feature that marks the boundary between a continental to shallow marine domain to the NW (where the Sommières Basin lies) that was uplifted after the Burdigalian (Séranne et al., 2002), and the subsiding shelf margin of the Gulf of Lion (Bache et al., 2009). As a consequence, the Sommières Basin was almost filled up with sediments at the end of the Burdigalian, and only a few meters of "Helvetian" (Upper Burdigalian to Langhian?) deposits are preserved above the main fill in the most offshore part of the basin (Fig. 2). Besides the uplift, the post-Burdigalian deformation is weak, but part of it could be a slight syncline folding of the basin, as suggested by the centripetal dip of strata at the basin borders (Fig. 2). Later Miocene to Quaternary erosion modified the former basin topography, so that some parts of the basin are now more elevated than the surrounding basement rocks (Fig. 2).

1.3. Background stratigraphy

Miocene deposits in Sommières Basin and Aubais Valley comprise three units that are less than 100 m in total thickness and that, from bottom to top, correspond to (Demarcq, 1970): (i) the Sandy Molasse, a calcareous sandstone containing bivalves (pectinids and oysters), echinoids, and bryozoans; (ii) the Sandy Marl, a silty mudstone with fewer macrofossils (but some pectinids); (iii) the Calcareous Molasse, a sandy bioclastic calcarenite with high content in bivalves (mostly pectinids) and echinoids. To the SE of the basin, close to the marine outlet, the Calcareous Molasse is locally more quartzose than in the Sommières Basin, but still contains a high proportion of pectens and bryozoans (Bonnet, 1969). These units are respectively early, middle, and late Burdigalian in age (Berger, 1974). The term molasse (sensu Demarcq, 1970) herein refers to a mixed silici-bioclastic arenite, while the "calcareous molasse" of SE France correspond to facies with over 50% carbonate bioclasts. The "Helvetian" marls that cap the series and are preserved to the SE of the basin (Fig. 2) are not be considered in this article.

The Burdigalian succession in the Sommières Basin and Aubais Valley is similar to that in most other sub-basins of the Perialpine Basin in SE France and has been the basis of a regional sequence stratigraphic interpretation (Rubino et al., 1990). In this interpretation, the Sandy Molasse (locally called "greenish" due to its high glauconitic content) is the lower transgressive systems tract of the first Burdigalian sequence (Lower to Mid Burdigalian), whereas the overlying Sandy Marls correspond to the highstand systems tract. In most sub-basins, the Calcareous Molasse is generally considered as the transgressive systems tract of the succeeding Upper Burdigalian sequence (Besson et al., 2005), but has also locally been interpreted to represent a forced regressive systems tract (Reynaud et al., 2006, in press-b).

Whereas the Miocene molasse of the Perialpine Basin of SE France was formerly thought to be in stratigraphic superposition with locally lateral facies transitions (from the calcareous facies against the basin borders to the marly facies in the basin centers; Demarcq, 1970), most of them have been recently reinterpreted as a multistorey cut-and-fill system of incised valleys (Besson et al., 2005). Because of the karstic nature of the thick Cretaceous limestones forming most of the bedrock, these valleys were deprived of upstream siliciclastic input. This relationship suggests that they may have been rias through which tidal currents were be amplified, as was

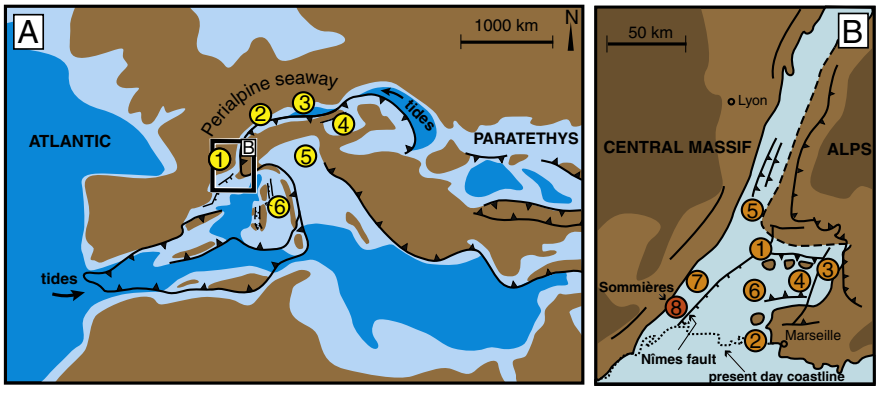

Fig. 1. A. Paleogeography of Europe in the Lower Miocene (Upper Burdigalian highstand). Modified from Dercourt et al. (2000) and Barrier and Vrielynck (2008). Numbered labels indicate locations where tidal deposits similar to those in Uzès Basin have been described. 1: France (e.g. Lesueur et al., 1990); 2: Swiss (e.g. Homewood and Allen, 1981); 3: Germany (e.g. Keller, 1989); 4: Hungary (Sztanó, 1995); 5: Italy (Massari et al., 1986); 6: Corsica (André et al., 2011). Light blue: shelf. Deep blue: deeper basins. Light brown: land. B. Detailed map of the Rhodanian Basin. Modified from Sissingh (2001) and Besson (2005). Sub-basins where tidal deposits have been studied (only among the initial works are cited): 1—Valréas (Lesueur et al., 1990), 2—Basse-Provence (Rubino, 1988); 3—Digne (Tessier and Gigot, 1989), 4—Forcalquier (Rubino et al., 1990), 5—Crest (Lesueur et al., 1990), 6—Carpentras (Parize et al., 1997), 7—Uzès (Reynaud et al., 2006), 8—Sommières (this paper).