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A riparian plant community from the upper Maastrichtian of the Pyrenees (Catalonia, NE Spain)

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ABSTRACT

Angiosperms began to colonise riparian habitats very soon in their evolutionary history, probably already in the Aptian, but it is still poorly known when flowering plants finally dominated entirely these kind of communities as they do in the present. A new fossil plant locality (Molí del Baró-1) from the upper Maastrichtian of the Southern Pyrenees is described in which meandering river facies represent one of the first riparian communities formed only by angiosperms. The fossil assemblage consists of abundant leaves, seeds, logs and sporomorphs. Angiosperms remains dominate in all these cases and the leaf sample is mostly composed of a new eudicot willow-like species, *Saliciphyllum gaetei* sp. nov., the palm *Sabalites longirhachis* and an helophytic monocot. Pollen remains suggest that the later belonged to Typhaceae. Most of these plant remains were parautochthonous and deposited in a pond formed in the accretional part of a meander loop. The locality of Molí del Baró-1 represents an unique plant fossil assemblage in the uppermost Cretaceous of southern Europe. It clearly differs from those reported in other Maastrichtian localities of the Pyrenees (Fumanya and South Isona) and from the Campanian-Maastrichtian of Austria and Romania. In addition, it reflects a surprisingly modern physiognomy for a Late Cretaceous riverine plant assemblage that was built up with willow-like plants, palms and reeds.

1. Introduction

The rise of angiosperms to dominate many plant communities and an explosion in their diversity during the Cretaceous changed drastically the plant kingdom, and so affected the whole terrestrial ecosystems. Angiosperms evolved gradually in both time and space, being strongly constrained from the Barremian to the Albian by their ecophysiology and their living environments (Feild et al., 2011; Coiffard et al., 2012). In the Early Cretaceous, European riverine plant communities were rich in conifers, mainly belonging to the Cheirolepidiaceae and the Cupressaceae-Taxodiaceae (Gomez et al., 2001, 2002; Coiffard et al., 2012). As early as the Aptian, these communities began to accommodate early angiosperms in river bank and floodplain environments, but flowering plants represented only a small part of the whole community in terms of taxonomic diversity. From the Cenomanian to the Campanian angiosperms already formed an important part of riparian communities both in levee and floodplain meandering river environments, alongside with other seed-plants and ferns that still represented one third to half of the assemblage (Coiffard et al., 2012).

There is a general agreement that angiosperms dominated all types of environments from lower to middle latitudes during the Maastrichtian. The plant fossil record from outside Europe appeared to be surprisingly rare in this age (Nichols and Johnson, 2008). Nevertheless, this has been beginning to change during the last few years with new data from North America and New Zealand (Spicer and Collinson, 2014). In Europe, continental beds containing Maastrichtian plant micro-, meso- and megafossils have been reported from France, Germany, Poland, Portugal, Romania, and Spain (Petrescu and Duşa, 1980; Nichols and Johnson, 2008; Friis et al., 2010; Halamski, 2013). Plant fossils are abundant and

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diverse in the Maastrichtian transitional to continental beds of the Tremp Formation from the northeastern Iberian Peninsula (Mey et al., 1968).

The first palaeobotanical studies in localities belonging to the Tremp Formation were conducted during the 1970s and were mainly focused on sporomorphs (Médus, 1970, 1972). Palynological works continued during the 1980s (Porta et al., 1985; Ashraf and Erben, 1986; Médus et al., 1988) and the first attempts to study the biostratigraphical significance of charophytes were carried out (Babinot et al., 1983; Feist and Colombo, 1983). Since the 1990s to the present, palynological studies of various localities and palaeoenvironments of the Tremp Formation have been focused both on miospores (Médus et al., 1992; Mayr et al., 1999; López-Martínez et al., 1999; Fernandez-Marrón et al., 2004; Torices et al., 2012; Villalba-Breva et al., 2012, 2015) and megaspores (Batten et al., 2011). In 1979, the first plant megafossil assemblages were discovered near the village of Isona, in the Tremp Syncline (Barrón and Diéguez, 1992; Vicente i Castells, 2002). The plant community that lived in the coastal wetlands of the Tremp Formation was reconstructed based on charophytes, sporomorphs and plant megafossils collected from the locality of Fumanya, Vallcebre Syncline (Villalba-Breva and Martín-Closas, 2011; Villalba-Breva et al., 2012). Overall, cheirolepidiacean conifers and palms usually dominated, whereas ferns did only locally. By contrast, palynology, palaeobotany and plant taphonomy from the locality of South Isona (Tremp Syncline) suggested that woody angiosperms were diverse and dominated in the fluvial settings of the Tremp Formation, with ferns being abundant in the understory of riparian communities (Marmi et al., 2014; Villalba-Breva et al., 2015), while floodplain ponds were dominated by characeans, especially by species belonging to genus *Microchara* (Vicente et al., 2015).

In the present study we report plant micro-, meso- and megafossils collected from the upper Maastrichtian of the Molí del Baró-1 locality, in the southeastern Pyrenees (Catalonia, northeastern Spain). The aims of the study are: i) to reconstruct the plant community based on sedimentology and taphonomy, ii) compare with other coeval localities in terms of composition and diversity, and iii) discuss the evolution of plant communities in fluvial settings from the Upper Cretaceous of Europe.

2. Geological setting

The studied area is located to the north of the village of Sant Romà d'Abella, northeastern edge of the Tremp Syncline, Lleida Province, Catalonia, northeastern Spain (Fig. 1A and B). Shallow marine, transitional to continental materials of the Arén (Areny) and Tremp Formations are widely exposed in the Tremp Syncline (Mey et al., 1968). They record a marine regression that began at the Campanian-Maastrichtian boundary (Rosell et al., 2001; Riera et al., 2009). The Tremp Formation was divided into four informal units by Rosell et al. (2001), described from the base to the top as follows: (1) a marine to continental transitional Grey Unit mainly composed of grey marls, lignites, charophyte limestones and sandstones; (2) a fluvial Lower Red Unit with red lutites, sandstones and palaeosols; (3) the lacustrine Vallcebre Limestone and laterally equivalent strata; and (4) the fluvial Upper Red Unit consisting of red lutites, sandstones, and conglomerates. In the Tremp Syncline, palaeontological and biostratigraphic data suggest a Maastrichtian age for the Grey and Lower Red Units of the Tremp Formation (Riera et al., 2009 and references therein; Villalba-Breva and Martín-Closas, 2013).

The locality of Molí del Baró-1 corresponds to the upper part of the Lower Red Unit, which was deposited in a fluvial environment with limited tidal influence (Rosell et al., 2001; Riera et al., 2009; Díez-Canseco et al., 2014). The general stratigraphic succession consists of sandstones representing meandering channels interbedded within thick reddish mudstone units (floodplain deposits). The bed containing the plant fossils occurs 70 m below the limestones of Tossal de la Doba and, approximately, 100 m below the limestones of Sant Salvador de Toló and Suterranya (Riera et al., 2009), which were attributed to the Palaeocene based on charophyte biostratigraphy by Feist and Colombo (1983). Non-reworked planktonic foraminifera confirmed the Palaeogene age of these limestones (Díez-Canseco et al., 2014). Vila et al. (2012) placed the Molí del Baró-1 in the 29r magnetochron, resulting in a late Maastrichtian age (Fig. 1C).

The studied section belongs to a major, 10–15 m-thick, sandstone body divided into two units separated by a reactivation surface (Fig. 2A). These lower and upper units evidence two main episodes of river activity. The whole sandstone body exhibits a fining-upward trend ranging gradually from coarse sandstones to siltstones and mudstones. Plant bioturbation is extensively developed as colour mottling and often obliterates sedimentary structures. When visible, often in the lower parts of an accretion bar, they appear as cross-laminations followed by current ripples to the top of each bar (Fig. 2A and B). The channel architecture is determined by normally graded—from sandstones to mudstones—-lateral accretions configuring inclined heterolithic stratification (IHS, Fig. 2A), a feature observed in meandering rivers (Thomas et al., 1987; Miall, 1996) and also described in other sandstone bodies of the Tremp Formation (Díez-Canseco et al., 2014).

Interbedded between the accretion surfaces, marly deposits (about 45% of $CaCO_3$) yield the main fossiliferous beds (i.e., beds 2 and 3 in Fig. 2C and D). Bed 2 consists of a 20 m-long marl that is 0.3–1 m thick at the top of the lower sandstone unit (Fig. 2A and B). Sandy lenses (bed 3), around 8–15 cm thick but which exhibit limited lateral continuity, appear within these fine sediments. Their contacts are diffuse, passing gradually to the adjacent marls, and no erosive bases are observed. The deposits of bed 3 contain more quartz grains than the marls of bed 2. The major coarse components of the lenses are intraclasts such as edaphic nodules (both of carbonate and oxide). They also contain oncoids and coated grains, as well as fewer rhizolith fragments, charophytes and planktonic foraminifera. In addition to plants, the marls (bed 2) and the coarser level (bed 3) yielded vertebrate, arthropod and mollusc remains (work in progress). Based on all this evidence, the sediments of Molí del Baró-1 are interpreted as the inner, non-erosive part of a meander loop recording periods of low energy flow, with accumulation of mud in the meander margins, alternating with periods of higher energy flow, with accumulation of sands on the lateral accretion surfaces. The lenses within the marls may be the result of local sedimentary processes, not necessarily linked to the current activity (e.g. collapse of the river margins, floodplain sediment arrivals due to rainfall).

3. Materials and methods

Fieldwork at the locality of Molí del Baró-1 was conducted during the summers of 2002, 2007, 2010 and 2011. One hundred and eighty-five hand rock specimens with leaves, stems and seeds were collected from beds 2 and 3 (Fig. 2B) and are currently housed in the collection of the Museu de la Conca Dellà (MCD) (Isona i Conca Dellà, Lleida, Catalonia, Spain). In addition, pictures were taken of a large log and of sixteen palm leaves, which could not be collected during the excavation. Detailed stratigraphy of the locality was carried out in 2010 and 2011 and the exact stratigraphic location of specimens ($n = 108$) was determined during these two campaigns.

Plant fossils were photographed with a Panasonic DMC-FZ18 digital camera and details were examined and photographed