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The chronostratigraphic framework of the South-Pyrenean Maastrichtian succession reappraised: Implications for basin development and end-Cretaceous dinosaur faunal turnover

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ABSTRACT

The evolution of the end-Cretaceous terrestrial ecosystems and faunas outside of North America is largely restricted to the European Archipelago. The information scattered in this last area can only be integrated in a chronostratigraphic framework on the basis of robust age constraints and stratigraphy. Therefore, we have revisited the puzzling age calibration of the sedimentary infilling from the Isona sector in the Tremp syncline (South-Central Pyrenees), an area renowned for its rich Maastrichtian dinosaur fossil record. Aiming to shed light to existing controversial age determinations, we carried out a new magnetostratigraphic study along the ~420 m long Orcau and Nerets sections of that area. Our results reveal that most of the succession correlates to the early Maastrichtian (mostly chron C31r) in accordance to ages proposed by recent planktonic foraminifera biostratigraphy. The resulting chronostratigraphic framework of the entire Maastrichtian basin recorded in the Tremp syncline shows that a significant sedimentary hiatus of about 3 My characterizes most of the late Maastrichtian in the study area. This hiatus, related to an abrupt migration of the basin depocenter, is temporally close to similar hiatuses, decreases in sedimentary rates and facies shifts recorded in other southwestern European areas. The present chronologic framework sets the basis for a thorough assessment of end-Cretaceous terrestrial faunal turnover and extinction patterns, and the establishment of a more rigorous Pyrenean basin evolution analysis.

1. Introduction

The Pyrenees, together with other European regions such as Provence (France) and the Hateg Basin (Romania), yield one of the most important uppermost Cretaceous continental record outside the Western Interior of America (Csiki-Sava et al., 2015). The exceptional stratigraphic successions and thousands of vertebrate fossil sites recovered there represent a key to understanding the evolution of the last ecosystems of the Mesozoic Era. Hence, the narrative of the last 5 My before dinosaur extinction, mainly based on the American fossil record, has been recently complemented with data from Europe (e.g. Canudo et al., 2016; Csiki-Sava et al., 2016; Vila et al., 2016).

One of the major requirements for correlating biotic events is achieving a high-resolution chronostratigraphic framework for these terrestrial successions. In contrast to marine settings, the continental record (often in red bed successions) has a paucity of reliable biochronological markers. In Europe, they have been traditionally restricted to charophytes and palynology. Initially, magnetostratigraphic data of European Upper Cretaceous formations were limited to studies in Provence (Westphal and Durand, 1990) and the Corbières (Galbrun, 1997) in France, and the Àger Basin in Spain (Galbrun et al., 1993). However, paleomagnetism has been progressively implemented in the last decade for the end-Cretaceous European record, not only in the South-Pyrenean Basin (Oms et al., 2007; Pereda-Suberbiola et al., 2009; Vila et al., 2012; Canudo et al., 2016) but also in northern Spain (Corral et al., 2016), the south of France (Fondevilla et al., 2016) and the Hateg Basin in Romania (Panaiotu and Panaiotu, 2010; see also Csiki-Sava et al., 2016). Altogether, these studies contribute to building a strong correlation of most of the European Campanian–Maastrichtian successions with the global polarity time scale (GPTS).

Despite these generally good results, published paleomagnetic results in the Isona area of the Tremp syncline (Figs. 1, 2) which is, by far, the richest fossiliferous region of the Pyrenees, show some ambiguities. In the absence of biochronological markers, Vila et al. (2012) regarded a long undetermined polarity interval as belonging to the late Maastrichtian following the magnetostratigraphic pattern of other areas of the South-Pyrenean Basin (Fig. 3). Later, Sellés and Vila

Abbreviations: GPTS, global polarity time scale; NRM, natural remanent magnetization; ChRM, characteristic remanent magnetization; AF, alternating fields; MAD, maximum angular deviation; VGP, virtual geomagnetic pole.

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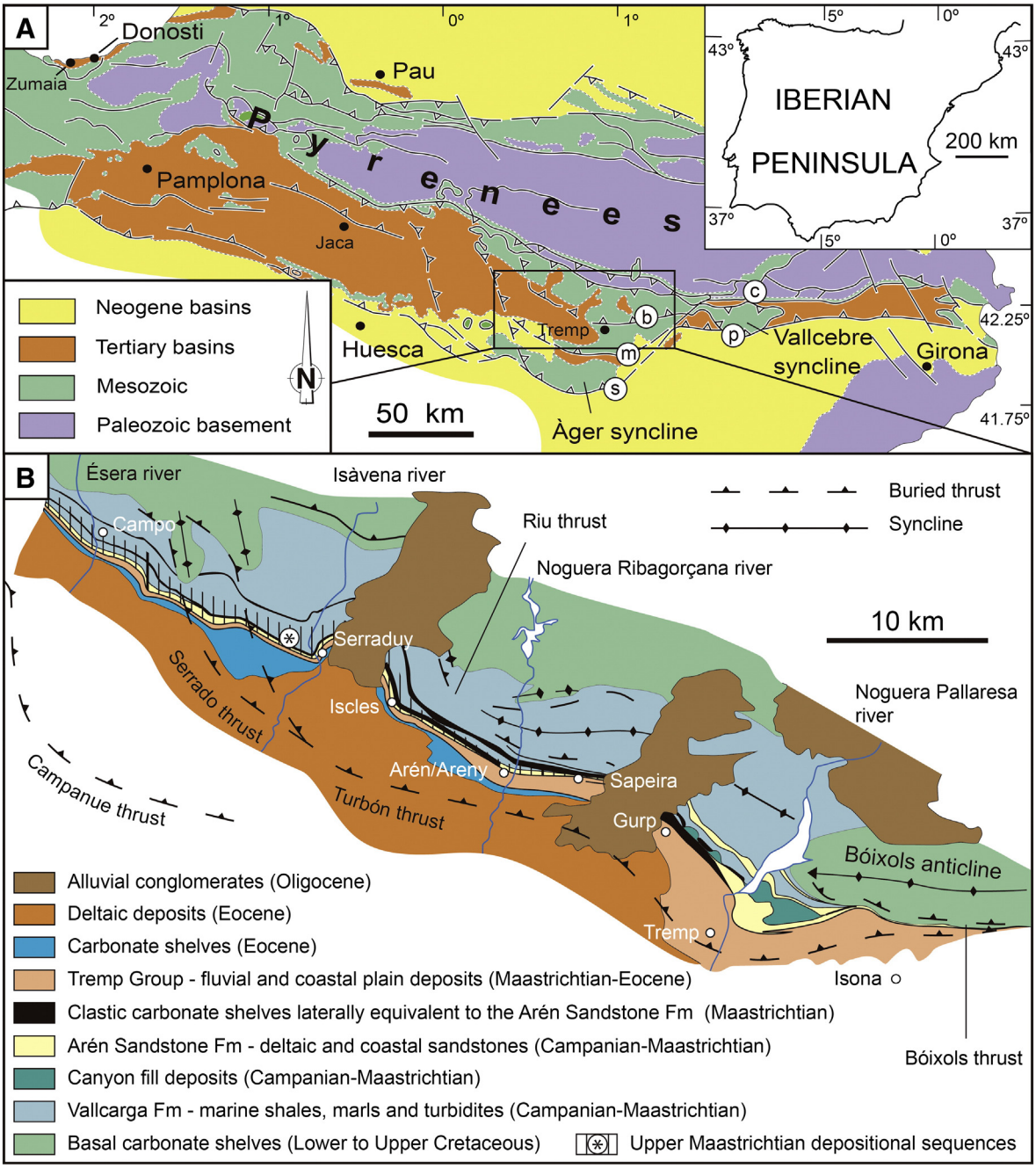

Fig. 1. Geological setting of the studied sections. A, geological map of the Pyrenees. Legend: b, Bóixols thrust; c, Cadí sheet; m, Montsec thrust; p, Pedraforca thrust; s, Serres Marginals thrusts. Modified from Riera et al. (2009). B, enlargement of the Tremp syncline. Modified from Ardèvol et al. (2000). Compare the asterisk-marked area with Figs. 8, 9.

(2015) attempted to provide precise ages for the vertebrate sites of the Maastrichtian Conques and Talarn Fms (both included in the Tremp Gr, formerly referred as Tremp Fm) using dinosaur eggshell oospecies as biochronological markers. The upper Maastrichtian they proposed for most of the stratigraphic succession at this location ran counter to the ages given by previous work. Their results are at odds with the ages provided by the correlation of the red beds of the Tremp Gr with its marine equivalents (Ardèvol et al., 2000; López-Martínez et al., 2001) and those recent age constraints proposed by the striking discovery of non-reworked planktonic foraminifera in the fluvial-deltaic settings of Orcau, near Isona (Díez-Canseco et al., 2014) (Fig. 3). In fact, these latter authors argued that most of the Mesozoic portion of the Tremp Gr belongs to the lower Maastrichtian.

Due to the important fossil record of the Isona area and its centrality to the study of the last dinosaurs that roamed the European Archipelago, we performed a new paleomagnetic study in the Tremp Gr to discern which age proposal is more robust. The excellent exposures and the significantly dipping strata that crop out around the Orcau and Nerets localities allow a good test of the tentative results of Vila et al. (2012), mostly carried along gently or flat-lying successions. Additionally, the obtained enhanced magnetostratigraphy and the chronostratigraphic framework contribute to a robust integration/correlation of the stratigraphy of the easternmost part of the Tremp syncline with its western, basinward equivalents.

2. Geological setting

2.1. Regional context of the study area

The Pyrenean range corresponds to an alpine fold-and-thrust belt developed between the Iberian and the European plates, in a