Cretaceous Research 57 (2016) 402–413

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

Constraining the age of the last marine sediments in the late Cretaceous of central south Pyrenees (NE Spain): Insights from larger benthic foraminifera and strontium isotope stratigraphy

Esmeralda Caus [a, *], Gianluca Frijia [b], Mariano Parente [c], Raquel Robles-Salcedo [a], Raquel Villalonga [d]

[a] Departament de Geologia (Paleontologia), Universitat Autònoma de Barcelona, Campus Bellaterra, 08193 Barcelona, Spain
[b] Institut für Erd- und Umweltwissenschaften, Universität Potsdam, Germany
[c] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II, Napoli, Italy
[d] Departament d'Estratigrafia, Paleontologia i Geociències Marines, Facultat de Geologia, Universitat de Barcelona, 08028 Barcelona, Spain

ARTICLE INFO

Article history:
Received 14 April 2015
Received in revised form
31 May 2015
Accepted in revised form 31 May 2015
Available online 19 June 2015

Keywords:
Larger benthic foraminifera
Strontium isotope stratigraphy
Late Cretaceous
Campanian-Maastrichtian boundary
Tremp basin
Pyrenees
NE Spain

ABSTRACT

The uppermost Cretaceous (upper Campanian–Maastrichtian) marine deposits of the central south Pyrenees host a rich larger benthic foraminiferal fauna and several rudist-rich levels. These marine deposits are directly overlain by the continental facies of the Arén and Tremp Formations, which are famous for their fossil dinosaur remains. Larger benthic foraminiferal distribution documents an important faunal turnover in all the carbonate platform environments within the photic zone, from open marine to littoral areas. Biostratigraphy indicates that this turnover occurred close to the Campanian-Maastrichtian boundary. This is also confirmed by strontium isotope stratigraphy which indicates an earliest Maastrichtian age for the appearance of the larger benthic foraminiferal assemblage constituted by *Lepidorbitoides socialis*, *Clypeorbis mammillata*, *Wannierina cataluniensis*, *Orbitoides gruenbachensis*, *Siderolites* aff. *calcitrapoides*, *Fascispira colomi*, *Omphalocyclus macroporus* and *Laffiteina mengaudi*. In particular, a numerical age of 71 Ma is obtained for the *Hippurites radiosus* level, just a few meters below the first continental deposits of the Arén *sensu stricto* Formation. The youngest marine sediments of the central south Pyrenees are early Maastrichtian in age. This is also an important constraint for the age of the end-Cretaceous dinosaur fossil localities of the Tremp basin.

1. Introduction

The Pyrenees are a doubly vergent, structurally complex chain resulting from the north-south crustal shortening due to the collision between the Iberian and European plates, that took place from latest Cretaceous to Oligocene–Miocene times (Roest & Srivastava, 1991; Rosenbaum, Lister, & Duboz, 2002). In its central part, along the profile built in the frame of the project "Étude Continentale et Océanique par Réflexion et Réfraction Sismique" (ECORS profile; Berástegui, Losantos, Muñoz, & Puigdefàbregas, 1993; Muñoz, 1992), the southern Pyrenees show three imbricated thrust sheets, which, from north to south, are: Bóixols, Montsec and Serres Marginals thrust sheets (Muñoz, Martínez, & Vergés, 1986) (Fig. 1). The regional detachment level for these thrust sheets are Upper Triassic evaporites. The Bóixols thrust sheet consists of a Mesozoic sequence, made mainly of Lower Cretaceous deposits, which was emplaced during the latest Santonian to Maastrichtian. Its thrust front is unconformably overlain by the Arén Formation (Mey, Nagteggal, Roberti, & Hartevelt, 1968) and the Tremp Group (Cuevas, 1992). The Montsec thrust sheet, whose age of emplacement is Early Eocene, includes Mesozoic (mainly Upper Cretaceous) and Palaeogene deposits. The Upper Cretaceous deposits are partially contemporaneous with those attributed to the Arén Fm and Tremp Group in the Bóixols thrust sheet. The Serres Marginals thrust sheet consists of several imbricate tectonic units, which are characterised by a drastic reduction of the thickness of Upper Cretaceous deposits from north to south (Pocoví, 1978). The youngest Upper Cretaceous marine deposits are overlain by a thick unit of charophyte limestone (gray Garumnian in

* Corresponding author.
E-mail addresses: esmeralda.caus@uab.es (E. Caus), frijia@geo.uni-potsdam.de (G. Frijia), mariano.parente@unina.it (M. Parente), raquelroblesalcedo@gmail.com (R. Robles-Salcedo), r.villalonga@ub.edu (R. Villalonga).

http://dx.doi.org/10.1016/j.cretres.2015.05.012
0195-6671/

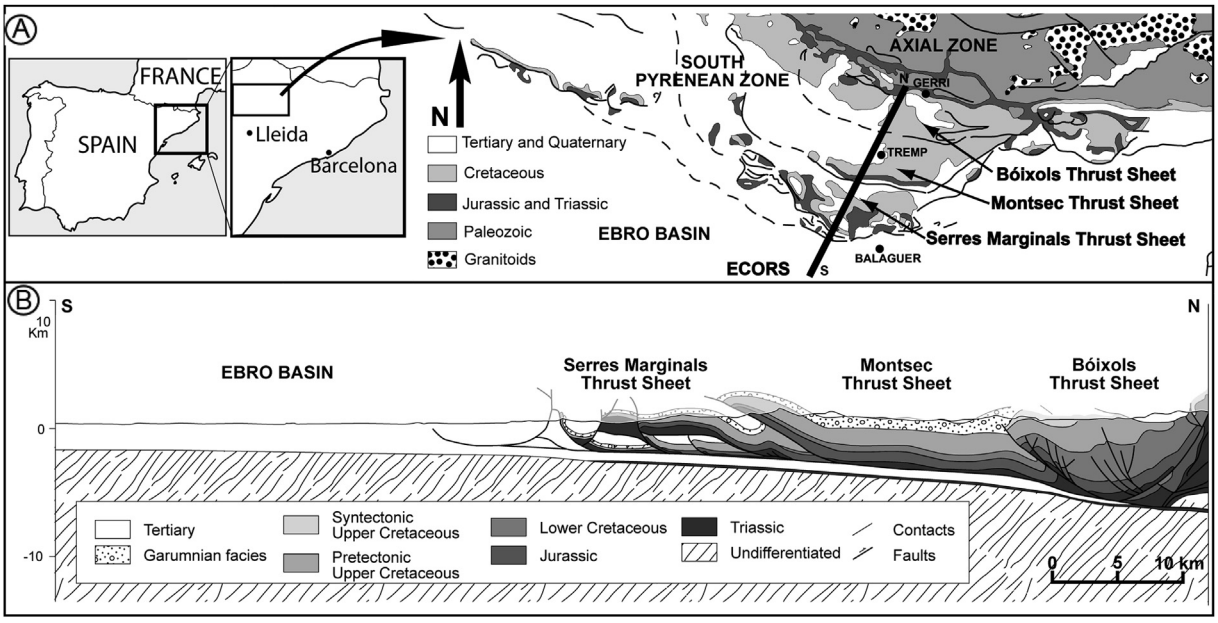

Fig. 1. A. Simplified geological map of the south-central Pyrenees with the position of the ECORS profile; B. Geological cross-section of the south-central Pyrenees along the ECORS profile (Modified from Berástegui et al., 1993, Berástegui, Caus, & Puig, 2002).

Rosell, Llompart, & Linares, 2001). The age of the emplacement of the Serres Marginals thrust sheet is Late Eocene-Early Oligocene.

The Upper Cretaceous deposits of the above mentioned thrust sheets represent a transect from deep to shallow marine and continental environments, in the south margin of the Pyrenean basin, which was a narrow and deep gulf extending parallel to the present day Pyrenean Mountains and opening to the Atlantic Ocean. During the latest Cretaceous times the effects of the compressive movements related with the Pyrenean (Alpine) Orogeny reached this part of the basin. Due to the westward propagation of the compressional front, the basin depocenter moved progressively from east to west (Choukroune, 1976). This is documented in the sedimentary record of the central south Pyrenees by a regressive trend, from deep to shallow marine, coastal and, finally, to the continental deposits of the Arén Fm and Tremp Group or coeval strata. The uppermost part of the Arén Fm and the lower part of the Tremp Group contain a rich fossil record of dinosaur bones, tracks and eggs which have been the subject of many paleontological studies (see for instance López-Martínez, 2001; Riera, Oms, Gaete, & Galobart, 2009 and the papers cited therein). However, the age of these strata is controversial. Some studies suggest an early Maastrichtian age while others prefer to assign them to the late Campanian (see Riera et al., 2009, and the papers cited therein for discussion).

The aim of this study is to present new data on the age of the last marine sediments in the Late Cretaceous of central South Pyrenees (NE of Spain), obtained from larger benthic foraminifera (LBF) biostratigraphy and strontium isotope stratigraphy (SIS).

2. Materials and methods

The study has been performed in three separate tectonic units (Bóixols, Montsec and Serres Marginals thrust sheets) along the ECORS profile (Fig. 1). Four stratigraphic sections have been studied for the Bóixols thrust sheet. Seventy six samples were collected and 120 thin sections were prepared for micropaleontological and biostratigraphical analysis from an interval, maximum 30 m thick, which is very rich in larger foraminifera (see figure 4 in Robles-Salcedo, Rivas, Vicedo, & Caus, 2013; for the detailed position of samples and the complete list of LBF). For the Montsec thrust sheet two stratigraphic sections have been studied. We collected forty eight samples for LBF studies, from which more than three hundred thin sections have been obtained. A single section, 160 m thick, has been studied for the Serres Marginals thrust sheet. We collected more than forty samples for LBF, from which more than two hundred thin sections have been obtained. All the samples and thin sections used for the micropaleontological-biostratigraphical part of this work are deposited at the Department of Geology (Paleontology) of the Universitat Autònoma de Barcelona.

Eighteen samples coming from four different stratigraphic levels at three different localities were analysed for SIS (see Table 1). We analysed the low-Mg biotic calcite of fossil shells of rudists, a few ostreids and some unidentified bivalve fragments. Samples selected in the field were passed through an accurate screening, following the procedure described in detail in previous works (Boix et al., 2011; Frijia & Parente, 2008b; Frijia, Parente, Di Lucia, & Mutti, 2015). This procedure integrates petrographic observations (standard optical and cathodoluminescence microscopy, SEM) and geochemical analyses (minor and trace element concentrations) to assess the degree of diagenetic alteration, following the guidelines of McArthur (1994). For some samples we also analysed the micritic matrix enclosing the shell fragments, in order to get deeper insight into the diagenetic processes (Table 1).

All the geochemical analyses (ICP-AES for elemental concentration and thermal-ionization mass spectrometry for Sr isotope ratio) were performed at the Institute for Geology, Mineralogy and Geophysics of the Ruhr-University (Bochum, Germany). Details on analytical procedures and the external reproducibility of the analyses can be found in Boix et al. (2011) and Caus, Parente, Vicedo, Frijia, and Martínez (2013).

Numerical ages were obtained from the "look-up" table of McArthur, Howarth, and Bailey (2001; version 5: 04/13) after correcting the $^{87}Sr/^{86}Sr$ values measured in the lab for inter-laboratory bias by adjusting the long term mean of the USGS EN-1 standard