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Late Hauterivian–early Barremian calcareous nannofossil biostratigraphy, palaeoceanography, and stable isotope record in the Subbetic domain (southern Spain)

Roque Aguado [a,*], Miguel Company [b], Luis O'Dogherty [c], José Sandoval [b], José María Tavera [b]

[a] Departamento de Geología y CEACTierra, Universidad de Jaén, EPS Linares, E-23700 Linares, Spain
[b] Departamento de Estratigrafía y Paleontología, Universidad de Granada, Facultad de Ciencias, E-23071 Granada, Spain
[c] Departamento de Ciencias de la Tierra, Universidad de Cádiz, CASEM, E-11510 Puerto Real, Spain

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ABSTRACT

Two sections in the Subbetic domain of the Betic Cordillera (Río Argos and Arroyo Gilico), encompassing the latest Hauterivian–earliest late Barremian interval, and including the Faraoni level equivalent (FLE) and the 'Mid-Barremian event' (MBE), were selected for stable isotope analyses and calcareous nannofossil investigation. Six calcareous nannofossil bioevents were identified throughout the study interval, which were used in the identification of NC5B, NC5C, NC5D and NC5E subzones. Calcareous nannofossil bioevents and subzones have been directly correlated to Tethyan ammonite biostratigraphical zonation and with respect to a detailed carbon and oxygen stable isotope stratigraphy. An integrated analysis of calcareous nannofossil assemblages and chemostratigraphic data (carbon and oxygen isotopes) enabled the reconstruction of the surface water conditions throughout the study interval. Calcareous nannofossil assemblages record several episodes of relative eutrophication of surface water that correlate with relative minimum values in the stable oxygen isotope curves. These eutrophication episodes are interpreted as the result of probably warmer and wetter climatic conditions in the continental hinterlands adjacent to the Subbetic Basin, which led to an enhanced runoff and increased freshwater input to the sea. During these episodes, surface waters were enriched in nutrients and probably had a lower salinity, favouring the development of a high nutricline and, occasionally, water stratification and development of localized dysoxic/anoxic bottom sedimentary environments. Most of these episodes are of minor importance, and only two of them (those correlating with FLE and MBE), had sufficient impact on the marine environments to generate deviations in the stable carbon isotope record and localized deposition of organic-rich sediments. This suggests that global dysoxic/anoxic episodes, such as those linked to OAEs, probably do not represent singular events in a normally undisturbed environment, but are part of long-lasting periods of environmental change.

1. Introduction

A peculiarity of the Cretaceous is evidence for warm greenhouse conditions linked to high atmospheric CO_2 concentrations, low latitudinal temperature gradients, and high sea levels (Huber et al., 1995; Wilson and Norris, 2001; Heimhofer et al., 2004; Hay, 2008; Föllmi, 2012). Activated seafloor spreading rates lead to high sea-level and intense volcanic outgassing (Erba, 1994; Leckie et al., 2002; Tejada et al., 2009). In this context, some exceptional episodes of accelerated global change, linked to perturbations of the global carbon cycle, took place (Schlanger and Jenkyns, 1976; Jenkyns, 1980, 2010; Arthur et al., 1985). These episodes, known as 'Ocean Anoxic Events'(OAEs), left a distinct imprint on life and the environment and had a primary record in widespread marine black shale deposition (Föllmi, 2012). In addition, some other minor Cretaceous perturbations of the carbon cycle also linked to biotic changes and eventually to the deposition of organic-rich sediments, are less widespread or recorded only at a regional scale (Föllmi et al., 2012). This applies to the late Hauterivian 'Faraoni event' and its equivalents (Cecca et al., 1994, 1996; Coccioni et al., 1998, 2006; Baudin et al., 1999, 2002, 2006; Erba et al., 1999;

* Corresponding author: Fax: +34 0953 648 622.
E-mail address: raguado@ujaen.es (R. Aguado).

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Bellanca et al., 2002; Aguado et al., 2003; Company et al., 2005a, 2007; Tremolada et al., 2009; Föllmi et al., 2012), and the 'Mid-Barremian event' (Coccioni et al., 2003, 2006; Godet et al., 2006; Sprovieri et al., 2006; Yilmaz et al., 2012; Huck et al., 2013), which have been identified mainly in several basins of the western Mediterranean Tethys. These minor perturbations are of interest since they may offer information on the environmental changes that gave rise to more widespread OAEs as the early Aptian OAE 1a (Stein et al., 2011; 2012; Föllmi et al., 2012).

The Hauterivian and Barremian rocks outcrop extensively in many areas of the Subbetic basin (Betic Cordillera, southern Spain), which was a pelagic domain of the southern passive margin of the Iberian Plate. Two sections in the Subbetic (Río Argos and Arroyo Gilico), encompassing the uppermost Hauterivian–lowermost upper Barremian interval, and including the Faraoni level equivalent (FLE) and the 'Mid-Barremian event' (MBE) were selected for stable isotope analyses (bulk sample) and calcareous nannofossil investigation. Both sections have a continuous sedimentation as well as accurate and well-established ammonite biostratigraphic control (Hoedemaeker, 1995; Hoedemaeker and Leereveld, 1995; Aguado et al., 2001, 2008a; Company et al., 2003a, 2003b, 2005a), which makes them a good choice for complementary investigations.

The main objectives of the present study are: (1) to achieve a direct and accurate calibration of Tethyan calcareous nannofossil and ammonite biostratigraphic frameworks together and with respect to the $\delta^{13}C$ and $\delta^{18}O$ curves for the investigated interval; (2) to depict the main environmental changes throughout the latest Hauterivian–early Barremian through the study of the fluctuations in the composition and abundance of nannofossil assemblages; (3) to document the presence of FLE and MBE through biostratigraphic, sedimentological, and geochemical data in sediments from the Subbetic, and its possible links with environmental changes.

2. Geological setting and lithology

The two studied sections are located in the Murcia region, SE Spain (Fig. 1). The Río Argos section crops out on the right bank of the River Argos, some 8 km WSW of Caravaca (geogr. coord.: 38° 4′ 13″ N 1° 56′ 54″ W). The Arroyo Gilico section is situated on a small foothill north of the Cambrones Mountain, 17 km ENE of Caravaca and 8 km SES of Calasparra (geogr. coord.: 38° 9′ 35″ N 1° 56′ 54″ W).

The Río Argos section (64 m thick) encompasses the stratigraphic interval between the upper Hauterivian (*Crioceratites balearis* ammonite Subzone) and the lowermost Barremian (*Psilotissotia colombiana* Subzone, Fig. 2), whereas the Arroyo Gilico section (72 m thick) covers the interval between the upper Hauterivian (*Crioceratites binelli* Subzone) and the lowermost upper Barremian (*Barrancyloceras barremense* Subzone, Fig. 3). Sedimentation seems to have been continuous throughout the two sections, with no evidence of interruptions or condensations, except for a small hiatus partially affecting the *Crioceratites krenkeli* and *Crioceratites angulicostatus* subzones in the Río Argos section related to the occurrence of a slumped interval (Company et al., 2003a).

From a geological viewpoint, the two sections belong to the Subbetic Zone, a complex tectonostratigraphic unit that palaeogeographically roughly corresponds to the pelagic domain of the southern passive margin of the Iberian Plate during the Alpine tectonic cycle (Triassic to early Miocene). The morphology of this Subbetic basin was quite irregular due to a severe intracontinental rifting, which gave rise to well-defined swells and troughs bordered by extensional faults that were tectonically active during the Jurassic and the Early Cretaceous (Vera, 2001; Vera et al., 2004).

The lithologic successions of the two sections are similar (Figs. 2, 3) and consist of a rhythmic alternation of yellowish to grey marly limestone beds (5–75 cm thick) and grey marlstone interbeds (10–200 cm thick), which corresponds to the Miravetes Formation (Veen, 1969). Texturally, these sediments are mudstones and wackestones with radiolarians and foraminifers. The lime fraction is mostly made up of calcareous nannofossil remains (Hoedemaeker and Leereveld, 1995; Gressier, 2010), while clay minerals are, by far, the main components of the detrital fraction. In the Río Argos section, this monotonous alternation is broken by the presence of a thin black shale layer (bed 148), which is the local expression of the Faraoni Level (Fig. 2), a well-known organic-rich horizon that has been recognized within the uppermost Hauterivian sediments in several basins of the western Mediterranean

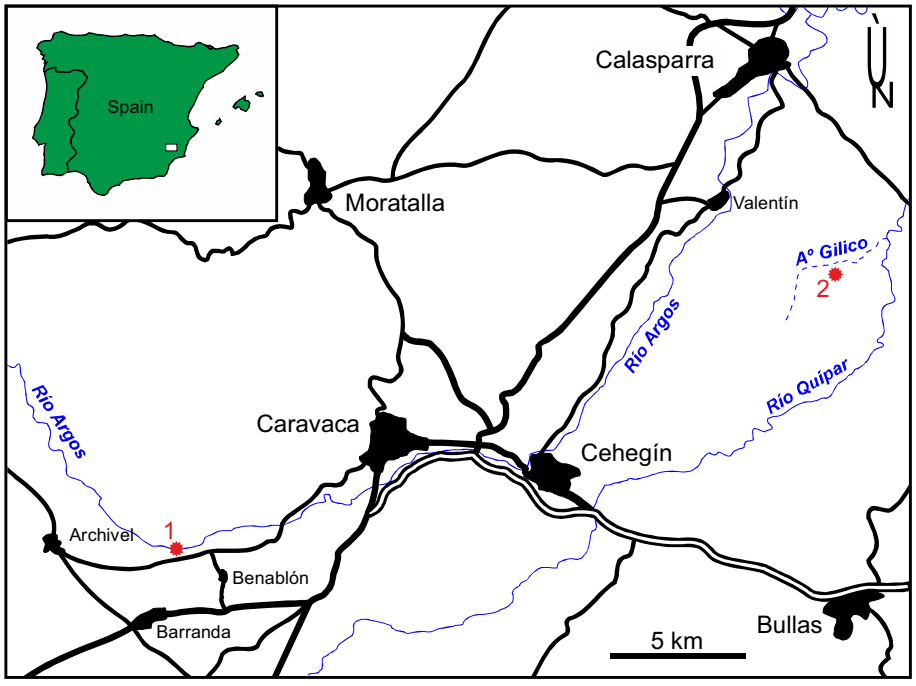

Fig. 1. Location sketch for Río Argos (1) and Arroyo Gilico (2) sections near Caravaca and Cehegín (Murcia Province).