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An orbital floating time scale of the Hauterivian/Barremian GSSP from a magnetic susceptibility signal (Río Argos, Spain)

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ABSTRACT

An orbital floating time scale of the Hauterivian–Barremian transition (Early Cretaceous) is proposed using high-resolution magnetic susceptibility measurements. Orbital tuning was performed on the Río Argos section (southeast Spain), the candidate for a Global boundary Stratotype Section and Point (GSSP) for the Hauterivian–Barremian transition. Spectral analyses of MS variations, coupled with the frequency ratio method, allow the recognition of precession, obliquity and eccentricity frequency bands. Orbitally-tuned magnetic susceptibility provides minimum durations for ammonite biozones. The durations of well-constrained ammonite zones are assessed at 0.78 myr for *Pseudothurmannia ohmi* (Late Hauterivian) and 0.57 myr for *Taveraidiscus hugii* (Early Barremian). These results are consistent with previous estimates from the other reference section (Angles, southeast France) and tend to show that the Río Argos section displays a complete succession for this time interval. They differ significantly from those proposed in the Geologic Time Scale 2008 and may help to improve the next compilation. The Faraoni Oceanic Anoxic Event, a key Early Cretaceous oceanographic perturbation occurring at the *P. ohmi*/*P. catulloi* subzone boundary has a duration estimated at 0.10–0.15 myr, which is similar to previous assessments.

1. Introduction

Detailed biostratigraphy and sequence stratigraphy, correlated throughout Western Europe, provide a reference framework for studying the Late Hauterivian–Early Barremian stratigraphic interval (Hoedemaeker and Leereveld, 1995; Company et al., 2003; Hoedemaeker and Herngreen, 2003). However, the durations of the Hauterivian and Barremian stages are still being debated because (1) stage duration is based on a magnetostratigraphic model which postulates a constant rate for Hawaiian sea-floor spreading (Ogg and Smith, 2004) and (2) biozone and magnetochron inter-calibration has recently been modified (McArthur et al., 2007). For instance, a duration of 1.9 myr was attributed to the latest Hauterivian *P. ohmi* Biozone in the Geologic Time Scale 2004 (GTS 2004; Gradstein et al., 2004), whereas a duration of only 0.2 myr was proposed for the same zone in the Geologic Time Scale 2008 (GTS 2008; Ogg et al., 2008). A cyclostratigraphic approach could provide independent data to constrain the duration of ammonite biozones and thus improve the next GTS (Hinnov and Ogg, 2007).

Earth's orbital cycles are known to have a strong periodic influence on climate and sedimentation (Hays et al., 1976). Palaeoclimate proxies are frequently used to detect orbital forcing in sedimentary series in order to establish accurate orbital time scales, notably for the Cenozoic (Lourens et al., 2004). Orbital forcing is also perceived in Cretaceous series, where numerous recent studies using cyclostratigraphic approaches have successfully extended the GTS up to that period (Locklair and Sageman, 2008; Voigt and Schönfeld, 2010; Husson et al., 2011). Magnetic susceptibility (MS) is a powerful proxy to detect palaeoclimate changes (Reynolds and King, 1995; Ellwood et al., 2000). It quantifies the ability of a sample to be magnetized in response to an external magnetic field. This response depends on the ferromagnetic, paramagnetic and diamagnetic mineral content of the sample. In hemipelagic environments, MS fluctuations are often inversely correlated to calcium carbonate content because this diamagnetic mineral, which is dominant in hemipelagic sediments, dilutes iron-bearing

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minerals (Mayer and Appel, 1999; Weedon et al., 2004; Boulila et al., 2008). As a result, MS fluctuations largely reflect terrigenous flux and/or primary productivity, which can be induced, at least in part, by astroclimate changes (Crick et al., 1997; Boulila et al., 2010a). The MS method is popular as it is rapid, non-destructive and reproducible. It offers sufficiently high-resolution acquisitions, which are particularly appropriate for cyclostratigraphic analyses (Mayer and Appel, 1999; Weedon et al., 2004).

The aim of this paper is to contribute to the improvement of the temporal framework of the Early Cretaceous. The interval studied focuses on the Hauterivian/Barremian transition (the *Pseudothurmannia ohmi* and *Taveraidiscus hugii* ammonite zones) outcropping at Río Argos (southeast Spain), the Global boundary Stratotype Section and Point (GSSP) candidate section. The *P. ohmi* Biozone contains an oceanic anoxic event correlated throughout the Western Tethys domain: the Faraoni Oceanic Anoxic Event (F-OAE; Cecca et al., 1994). This event is linked to biological turnovers and to a carbonate productivity crisis (Company et al., 2005; Bodin et al., 2006). The only available durations for these ammonite biozones and the F-OAE are based either on the Pacific magnetostratigraphic model (Ogg and Smith, 2004; Ogg et al., 2008) or on lithological cycle counting (Bodin et al., 2006). Here, we provide a high-resolution cyclostratigraphic analysis from MS measurements. The inferred orbital tuning is independent of magnetostratigraphic models and subjective cycle counting. After comparison of this orbital calibration with previously published data, a new temporal framework is proposed.

2. Geological setting

The Río Argos reference section, located in the Subbetic Domain near the town of Caravaca de la Cruz (Fig. 1A), shows a continuous stratigraphic interval for the Hauterivian/Barremian transition (Hoedemaeker and Herngreen, 2003). The deposits are composed of moderately bioturbated, undisturbed marl-limestone couplets. The macrofauna, mainly represented by ammonites and occasionally by brachiopods, irregular echinoids and belemnite guards, is typical of hemipelagic environments, with an estimated water-depth of several hundreds of metres (Hoedemaeker and Leereveld, 1995; Fig. 1B). The abundance of ammonite specimens provides a precise biostratigraphic framework at the subzone level (Company et al., 2003). The *P. ohmi* Zone extends from bed 144 to bed 171 (Fig. 2), i.e., from the *P. ohmi* first appearance datum (FAD) to the *T. hugii* FAD (Company et al., 2003). The *P. ohmi* zone is divided into the *P. ohmi*, *Pseudothurmannia catulloi* and *Pseudothurmannia picteti* subzones (Fig. 2). Subzones are bounded at the FAD of each index species. The *T. hugii* Zone extends from bed 171 to bed 193, from the *T. hugii* FAD to the *Kotetishvilia nicklesi* FAD. It is divided into the *T. hugii* and *Psilotissotia colombiana* subzones (Fig. 2). Continuous sedimentation is supported by the occurrence of all ammonite subzones and the absence of any evidence of subaerial exposure, erosional features or condensation levels, as revealed by meticulous field observation of sedimentological patterns. An organic-rich horizon, identified in the Late Hauterivian, is associated with the F-OAE (Fig. 2), which constitutes a key level for interbasinal correlations (Baudin, 2005; Bodin et al., 2007).

3. Material and methods

3.1. Magnetic susceptibility (MS)

A total of 202 rock samples (ca. 10 g) were collected with an even step of 20 cm along a 40.9-m section. Massic MS was measured with a laboratory Kappabridge MFK-1B, Agico®. Empty and sample-filled plastic boxes were measured. Sample values, corrected from blanks, were normalized to sample weight. They are expressed in m^3/kg and given with a precision of $\pm 8 \times 10^{-10}$ m^3/kg (95% confidence level), about two orders of magnitude below the values observed for samples.

3.2. Calcium carbonate content

Powdered rock samples were also analysed for calcium carbonate content using a calibrated Bernard calcimeter. Values are given with a precision of between 1 and 5% (Lamas et al., 2005). Data are available from the Pangaea data library: http://doi.pangaea.de/10.1594/PANGAEA.775274.

3.3. Data processing

The MS series was linearly detrended and then spectral analyses were performed using the multi-taper method (MTM),

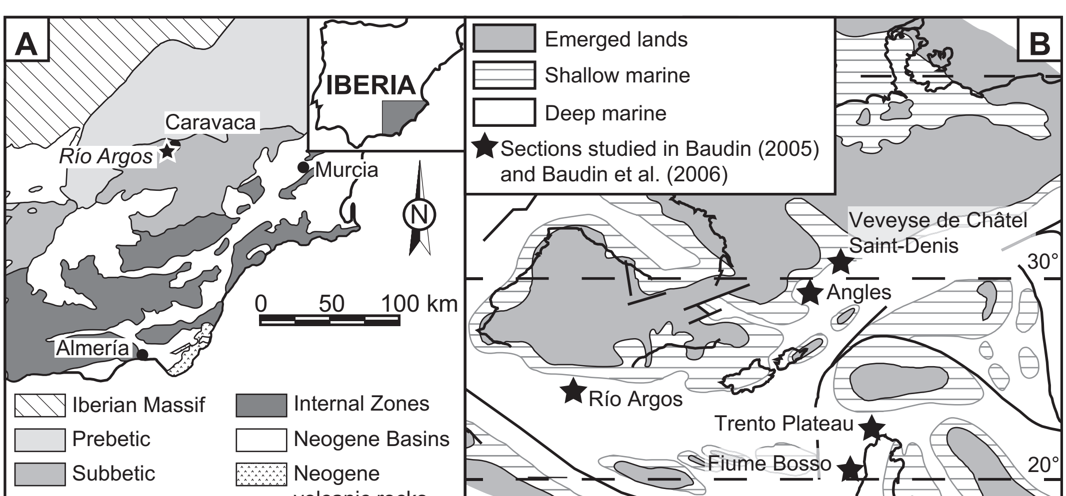

Fig. 1. A, simplified geological map of the Betic Cordillera and location of the Río Argos section. B, palaeogeographic map of the Western Tethys for Hauterivian–Barremian times with location of the sections in which the F-OAE is identified. Modified from Baudin (2005).