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A calcareous nannofossil and organic geochemical study of marine palaeoenvironmental changes across the Sinemurian/Pliensbachian (early Jurassic, ~191 Ma) in Portugal

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ABSTRACT

The Sinemurian/Pliensbachian boundary (~191 Ma) is acknowledged as one of the most important steps in the radiation of planktonic organisms, especially primary producers such as dinoflagellates and coccolithophores. To date, there is no detailed study documenting changes in planktonic assemblages related to palaeoceanographic changes across this boundary. The aim of this study is to characterize the palaeoenvironmental changes occurring across the Sinemurian/Pliensbachian boundary at the São Pedro de Moel section (Lusitanian Basin, Portugal) using micropalaeontology and organic geochemistry approaches. Combined calcareous nannofossil assemblage and lipid biomarker data document for a decrease in primary productivity in relation to a major sea-level rise occurring above the boundary. The Lusitanian Basin was particularly restricted during the late Sinemurian with a relatively low sea level, a configuration that led to the recurrent development of black shales. After a sharp sea-level fall, the basin became progressively deeper and more open during the earliest Pliensbachian, subsequently to a major transgression. This sea-level increase seems to have been a global feature and could have been related to the opening of the Hispanic Corridor that connected the Tethys and palaeo-Pacific oceans. The palaeoceanographic and palaeoclimatic changes induced by this opening may have played a role in the diversification of coccolithophores with the first occurrence or colonization of Tethyan waters by placolith-type coccoliths.

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1. Introduction

The early Jurassic is punctuated by episodes of organic matter (OM) deposition and preservation, probably testifying to the sporadic development of dysoxic/anoxic conditions in the epicontinental basins of the western Tethys associated with peculiar tectonic and climatic conditions (e.g., Jenkyns et al., 2002; Rosales et al., 2004; van de Schootbrugge et al., 2005). Amongst them, the Sinemurian/Pliensbachian interval is of particular interest because in some areas like the Lusitanian (Portugal), Basque-Cantabrian (Spain) and Bristol Channel and Wessex (England) basins, laminated OM-rich levels (black shales) are characterized by a very high (up to 20%) total organic carbon (TOC) content (Jenkyns et al., 2002; Deconinck et al., 2003; Rosales et al., 2004; Van de Schootbrugge et al., 2005; Duarte et al., 2010). In the Lusitanian Basin, the richness in organic matter makes the late Sinemurian–early Pliensbachian one of the most important intervals of potential oil source rocks (e.g., Duarte et al., 2010, 2012; Silva et al. 2013).

The Sinemurian/Pliensbachian boundary (~191 Ma) has been well documented for its macroinvertebrate record (e.g., Mouterde, 1967; Antunes et al., 1981; Dommergues and El Hariri, 2002; Meister et al., 2012; Comas-Rengifo et al., 2013; Duarte et al., 2014), and a precise stratigraphic framework has allowed definition of the Global Stratotype Section and Point (GSSP) of the Pliensbachian Stage at Wine Haven, Yorkshire (Meister et al., 2006). This time interval is also recognized as one of the most important steps in the radiation of planktonic organisms, especially primary producers such as dinoflagellates (van de Schootbrugge et al., 2005) and coccolithophores (Bown et al., 2004). It is around this boundary that first occurred the placolith coccolith-type (for example *Similiscutum*), which marks an important event in the diversification history of the coccolithophores. This radiation is probably linked to major palaeoceanographic changes related

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to the opening of the Hispanic Corridor described by some authors (van de Schootbrugge et al., 2005; Dera et al., 2015). A negative excursion in the carbon isotopic composition ($\delta^{13}C$) in carbonates has been recorded in the Cleveland Basin (England) and interpreted as a major perturbation in the carbon cycle (e.g., Jenkyns et al., 2002; Korte and Hesselbo, 2011). In spite of this, there is no detailed study documenting changes in planktonic assemblages across the Sinemurian/Pliensbachian boundary, while the palaeoceanographic and/or productivity changes occurring at that time are poorly understood. In addition, only few studies have provided isotopic data for the Sinemurian/Pliensbachian, and the main features and causes of the $\delta^{13}C$ excursion remain unclear (e.g., Hesselbo et al., 2000; Jenkyns et al., 2002; Duarte et al., 2014).

The aim of this study is thus to appraise the palaeoenvironmental changes occurring across the Sinemurian/Pliensbachian boundary at the São Pedro de Moel section (Lusitanian Basin, Portugal) using micropalaeontology and organic geochemistry approaches at high resolution, and to relate these changes to the palaeoceanographic events characterizing the western Tethys in the early Jurassic. Sedimentological analyses combined to bulk organic matter characterization, calcareous nannofossil quantification, and lipid biomarker analysis allow for the first time discussing the changes in primary productivity, the major evolutionary events and their links with sea-level changes in Sinemurian/Pliensbachian sediments.

2. Geological setting

The composite São Pedro de Moel section comprises the sections of Água de Madeiros (39°44′27″ N; 9°02′20″ W) and Polvoeira-Pedra do Ouro (39°43′18″ N; 9°02′56″ W) and outcrops along the coastline of central-western Portugal, approximately 110 km north of Lisbon (Duarte and Soares, 2002; Duarte et al., 2012) (Fig. 1a). This locality was palaeogeographically located in the central-western part of the Lusitanian Basin. In the Jurassic, this narrow and north–south elongated basin developed at the western margin of the Tethys Ocean, and resulted from the aborted rifting of the proto-Atlantic (Manspeizer, 1988; Soares et al., 1993). The Lusitanian Basin was bounded to the East by the Iberian Meseta and to the West by the Variscan (granitic and metamorphic) Berlenga-Farilhões Horst (Fig. 1b and c). The Lusitanian Basin was connected to the north-western European epicontinental basins and to the Hispanic Corridor to the south, thus representing a key location between the proto-Atlantic and Tethyan oceanic domains (Fig. 1b). The peculiar setting of São Pedro de Moel in the central deepest part of the basin accounts for the completeness of the upper Sinemurian–lower Pliensbachian sedimentary record in a relatively expanded 58 m-thick section. Numerous ammonite and calcareous nannofossil bioevents are recorded in this section, providing a detailed biostratigraphic framework (e.g. Mouterde, 1967; Antunes et al., 1981; Meister et al., 2012; Comas-Rengifo et al., 2013; Mattioli et al., 2013; Duarte et al., 2014; Boussaha et al., 2014). The studied time interval includes the Ammonite Oxynotum, Raricostatum and Jamesoni Zones and the Nannofossil NJT 3a, NJT 3b and NJT 4 Zones (Fig. 2).

In the upper Sinemurian/lower Pliensbachian, the sedimentation was characterized by marl-limestone alternations with common occurrence of black shales (organic carbon-rich sedimentary levels), belonging to the Água de Madeiros and Vale das Fontes formations. The Água de Madeiros Formation can be subdivided into the Polvoeira and Praia da Pedra Lisa members (Duarte and Soares, 2002; Duarte et al., 2004, 2010; Duarte, 2007). Interpretation of the depositional environments of the São Pedro de Moel section and its sequence stratigraphical evolution have been presented by Boussaha et al. (2014) and are summarized in Fig. 2. Briefly, the first 42 m of the section are characterized by a 2nd-order transgression (see Duarte et al., 2010)

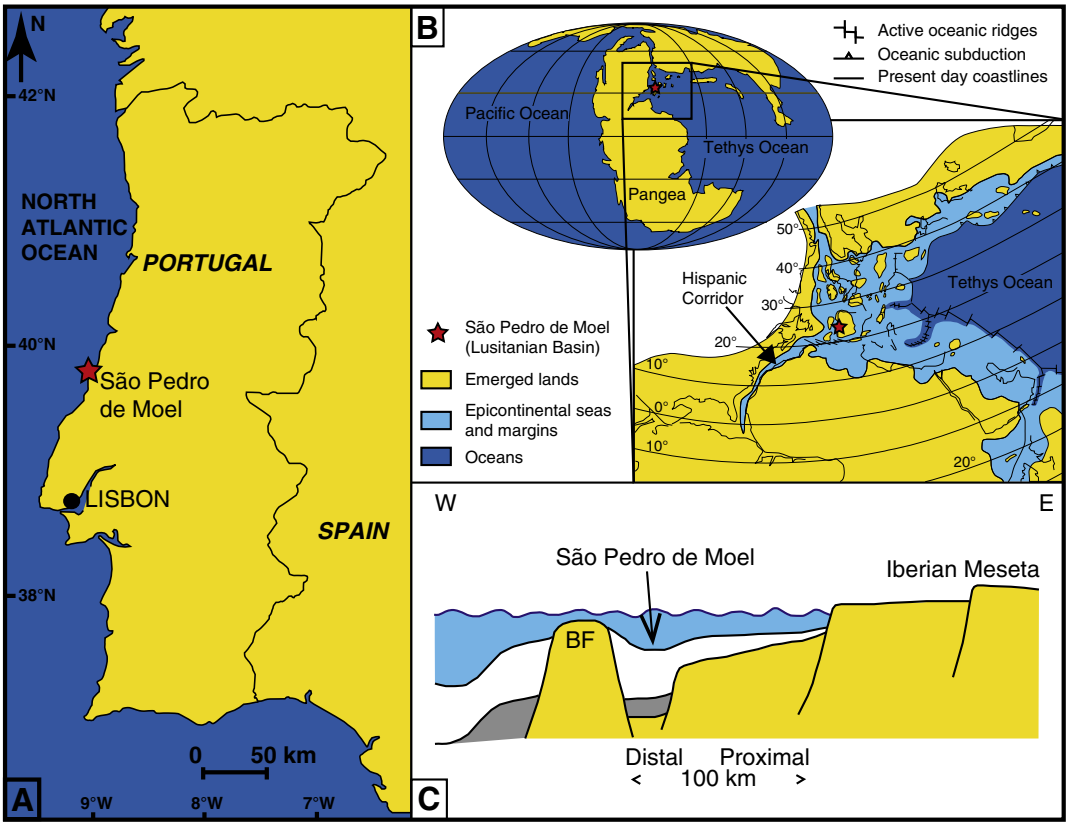

Fig. 1. A) Location of the São Pedro de Moel section (adapted from Reggiani et al., 2010). B) Palaeogeographic map of the early Jurassic (after Scotese, 2001) and location of the São Pedro de Moel section (Lusitanian Basin) during the early Jurassic (modified after Bassoulet et al., 1993). C) Distribution of the studied section on a schematic proximal–distal profile through the Lusitanian Basin during the early Jurassic; BF means Berlenga-Farilhões (modified after Vanney and Mougenot, 1981).

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