Palaeogeography, Palaeoclimatology, Palaeoecology 412 (2014) 17–31

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Timing of sea level, tectonics and climate events during the uppermost Oxfordian (Planula zone) on the Iberian ramp (northeast Spain)

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ARTICLE INFO

Article history:
Received 19 July 2013
Received in revised form 30 June 2014
Accepted 15 July 2014
Available online 23 July 2014

Keywords:
Late Oxfordian
Sedimentology
Clay minerals
Micropalaeontology
Sequence stratigraphy
Cyclostratigraphy

ABSTRACT

The middle Oxfordian warming climate and sea-level rise initiated the development of vast carbonate platforms in some western European basins. At the same time, however, siliciclastics and siliceous sponges dominated certain marginal areas of the Iberian ramp. There, siliciclastic input was particularly prominent during the latest Oxfordian and may have been related to a global sea-level fall, synsedimentary tectonic activity, or humid climatic conditions in the hinterland. Field analyses and computer modelling have been previously used to determine the factors that controlled sedimentation. However, it is still unclear if the specific conditions that prevailed during the latest Oxfordian were due to eustasy, tectonics or climate, and when precisely they occurred. Here, we document major changes in sedimentological, micropalaeontological, and mineralogical records on the Iberian ramp during this interval. Detailed sedimentary facies and palynofacies analyses combined with sequence-stratigraphic and cyclostratigraphic analyses of the Ricla Barranco section enable the establishment of a high-resolution time frame. Based on the quartz and mica percentage fluctuations, one large- and seven small-scale sequences are defined. The large-scale sequence boundaries correlate with third-order sequence boundaries Ox 8 and Kim 1 defined by Hardenbol et al. (1998). The large-scale maximum-flooding surface corresponds to the base of the most calcareous interval and to the maximum abundance of marine phytoplankton and opaque, equidimensional phytoclasts. The small-scale sequences correspond to the 100-kyr orbital eccentricity cycle. Calcareous nannofossils and clay minerals were used as palaeoclimatic proxies. Nannofossil abundances and fluxes are lower in the upper part than in the lower part of the interval studied, suggesting a decrease in sea-surface trophic conditions, also shown by an increase in the relative abundance of oligotrophic taxa. This upper part is also characterised by an increase in smectite, which coincides with the base of the large-scale highstand deposit, and is interpreted as reflecting the establishment of dry conditions. A first increase in smectite occurs in the lower part of the succession, and coincides with high percentages of quartz and mica. This latter mineralogical assemblage is interpreted as recording the onset of the Late Jurassic to Early Cretaceous rifting stage, which occurred just before the Planula–Galar ammonite subzone transition. The present study points out a return toward optimum conditions for carbonate sedimentation only 300 kyr after the prominent increase in siliciclastic input due to tectonic activity. The recovery of carbonate production was accompanied by a global sea-level rise and by decreasing rainfall on nearby land.

1. Introduction

The middle Oxfordian warming and rise in sea level favoured the development of broad carbonate platforms in some western European basins (e.g., Dromart et al., 2003; Aurell et al., 2010; Brigaud et al., 2014; Pellenard et al., 2014). At the same time, certain marginal areas of the Iberian ramp presented a very different kind of sedimentation in which siliciclastics and siliceous sponges dominated. In particular, the influence of siliciclastics was prominent during the latest Oxfordian, which has been related to tectonic activity (Bádenas and Aurell, 2001; Aurell et al., 2010). During the Late Jurassic and the Early Cretaceous, the evolution of the Iberian rift system is linked to northward propagation of rifting from the central Atlantic and the gradual opening of the North Atlantic oceanic basin (Martin-Chivelet et al., 2002). The Iberian basin, located in the central eastern part of the plate is one of these rift

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http://dx.doi.org/10.1016/j.palaeo.2014.07.014

systems (Alvaro et al., 1978; Salas and Casas, 1993; Van Wees et al, 1998). The intracontinental rifting started in this basin during the latest Oxfordian. The reactivation of some basement faults at the end of the Oxfordian induced both the uplift of the edges and the subsidence of the middle part of the ramp (e.g., Aurell and Meléndez, 1993). When compared to the middle Oxfordian, the late Oxfordian coral reefs in the northern hemisphere developed in a more southward position (Martin-Garin et al., 2012). These reefs contain abundant microbialites, which reflect meso- to eutrophic conditions and suggest nutrient input under a humid climate. Eutrophication due to high terrigenous input or local palaeoceanographic changes producing cold-water influxes would explain the absence of coral reefs on the Iberian ramp during the Oxfordian (Aurell et al., 2010). Field analyses and computer modelling have been previously used to better understand the factors that controlled sedimentation (Aurell et al., 1995, 1998). However, it is still unclear if these specific conditions were eustatically, tectonically or climatically induced, and when exactly they occurred. So far, high-frequency cycles, probably eustatic and climatic in origin, have been defined in the interval comprising the base of the Transversarium ammonite zone and the top of the Bimammatum zone (Strasser et al., 2005).

Here, we document major changes in sedimentological, micropalaeontological, and mineralogical records on the Iberian ramp during this key period of the late Oxfordian. The Ricla Barranco section has been chosen because its stratigraphic record is complete due to its location on the subsiding mid-ramp. Detailed facies and palynofacies analyses combined with high-resolution sequence-stratigraphic and cyclostratigraphical interpretations enable the stratigraphic correlation with contemporaneous series in adjacent basins and the definition of a high-resolution time frame. As suitable material for oxygen-isotope measurements to determine palaeotemperature was lacking, calcareous nannofossils and clay minerals were used as palaeoclimatic proxies. Calcareous nannofossil assemblages are affected by variations in trophic and thermal regime of sea surface waters and their fluctuations in abundance can be partly interpreted as climatic changes. Clay minerals resulting from the alteration of primary minerals reflect specific climatic conditions. The present study is the first attempt to reconstruct sea level, tectonic, and climatic events within the latest Oxfordian with a time-resolution in the order of 100 kyr.

2. Geological setting

In the Iberian basin of northeast Spain, during the Late Jurassic, shallow and homoclinal ramps opened toward the East, into the Tethys Sea (Fig. 1). Tectonic events around the Oxfordian–Kimmeridgian boundary caused significant changes in the sedimentation pattern, which led to a major unconformity between the Oxfordian and the Kimmeridgian depositional sequences (i.e., depositional sequences J3.1 and J3.2 in Aurell and Meléndez, 1993; see Fig. 2). According to the available ammonite biostratigraphy (e.g., Bádenas et al., 1998; Delvene, 2001; Strasser et al., 2005), the studied succession at Ricla Barranco corresponds to the entire Planula zone of the Tethyan province, which includes the Planula and the Galar subzones (Fig. 2). The boundary between these two subzones is located close to bed 145 in the section studied (Delvene, 2001) (Fig. 3). The Planula zone, traditionally assigned to the Upper Oxfordian, is considered to be coeval with the lowermost Kimmeridgian of the Boreal province (Matyja et al., 2006 in Gradstein et al., 2012) (Fig. 2).

The interval studied comprises the siliciclastic-rich "middle interval" and the marly-dominated "upper interval" of the Sot de Chera Formation (Bádenas et al., 1998) (Fig. 2). These two lithological units are bounded by a regional unconformity located at the boundary between the Planula and the Galar subzones.

The coarsening-up siliciclastic-rich "middle interval" of the Sot de Chera Formation resulted from the more proximal deltaic system progradation as part of the highstand systems tract of the Oxfordian

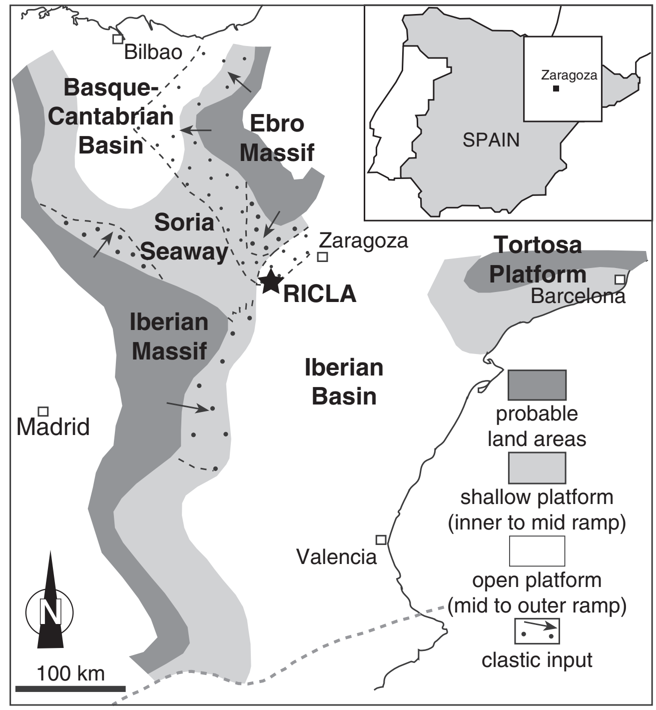

Fig. 1. Palaeogeography of the Middle–Late Oxfordian in NE Spain (modified from Bádenas and Aurell, 2001; Aurell et al., 2003; Strasser et al., 2005).

depositional sequence J3.1 (Aurell and Meléndez, 1993) (Fig. 2). The thickness of this interval has significant lateral variability, suggesting synsedimentary tectonic activity. The tectonic reactivation of some basement faults by the end of the Oxfordian also involved the uplift of the edges of the basin and the increase of the coarse clastic sediment supply (e.g., Aurell et al., 2010).

The "upper interval" of the Sot de Chera Formation mostly comprises marls with a high amount of mica and plant remains, and scattered ostracodes, bivalves and scarce ammonites, pointing to a low-energy, relatively open-marine environment (Aurell et al., 1998, 2010). These marls display a wedge-shaped geometry, and were interpreted as belonging to the lowstand systems tract of the Kimmeridgian depositional sequence J3.2 (Aurell and Meléndez, 1993) (Fig. 2), or as having been deposited during the early transgressive stage of the T–R Kimmeridgian sequence (e.g., Aurell et al., 2003, 2010).

While eustatic fluctuations probably controlled sedimentation during the early and the middle Oxfordian, the late Oxfordian deposits mainly recorded the local synsedimentary tectonics (Aurell and Meléndez, 1993). Aurell et al. (1995) used computer modelling to address the relative importance of the various factors that are considered to control the origin and the evolution of the Iberian Late Jurassic carbonate ramps. They showed that the geometries observed in the field come from the superposition of 20 and 100 kyr cycles on a third-order cycle. The higher-order cycles are in the Milankovich frequency band and may be eustatic in origin. The third-order cycle and its timing do not correspond to the Exxon eustatic curve and may be a local, relative sea-level change.

3. Materials and methods

The Ricla Barranco section, called Ri8 in Aurell (1990) and Delvene (2001), or 1 in Bádenas et al. (1998), is located 6 km north-northwest of the village of Ricla in the Zaragoza province of northeastern Spain (Fig. 1). The exposed succession is 103 m thick and spans the entire Upper Oxfordian Planula zone. The section was studied with respect to sedimentary and organic facies, sequence- and cyclostratigraphy, calcareous nannofossils, and clay mineralogy.