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Paleoclimatic control of biogeographic and sedimentary events in Tethyan and peri-Tethyan areas during the Oxfordian (Late Jurassic)

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Abstract

The paleobiogeographical distribution of Oxfordian ammonites and coral reefs in northern and Central Europe, the Mediterranean area, North and East Africa, and the Middle East and Central Asia is compared with the distribution in time and space of the most important lithofacies. Interest in the Oxfordian is focused on changes in facies and in biogeographical patterns that can be interpreted as the results of climatic events. Paleotemperature trends inferred from oxygen isotopes and paleoclimatic simulations are tested against fossil and facies data. A Late Callovian–Early Oxfordian crisis in carbonate production is indicated by the widespread absence of Lower Oxfordian reefal formations. There is a gap (hiatus) in deposition on epicontinental platforms, with Middle Oxfordian deposits resting paraconformably on Upper Callovian, while shales accumulated in adjacent intracratonic basins. Simultaneously, in Mediterranean Tethys, radiolarites accumulated in deep troughs while Rosso Ammonitico facies formed on pelagic swells. However, deposition on swells was also discontinuous with numerous gaps (hiatuses) and sequences that are much reduced in thickness. Middle Callovian deposits are generally overlain by Middle Oxfordian limestones. The dearth of carbonates is consistent with a cooling event lasting about 1 My. By the middle Oxfordian a warming, leading to "greenhouse" type conditions, is suggested on the basis of both biogeographical (mostly coral-reef distribution) and geochemical data. Carbonates spread onto an extensive European platform while radiolarites reached a maximum development in the Mediterranean Tethys. Two distinct latitudinal belts, with seemingly different accumulation regimes, are therefore inferred. Similar latitudinal belts were also present in the late Oxfordian, when carbonates were widespread. The distribution of reefal facies in the late Oxfordian–early Kimmeridgian fits relatively well with GCMs simulations that imply low rainfall in the Tethyan Mediterranean area and slightly higher precipitation in central and northern Europe. Local salinity variations, reflecting more arid or humid conditions, may bias the paleotemperature signal inferred from

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δ^{18}O values. Biogeographical and facies distributions, combined with δ^{18}O values, unravel the ambiguity and support a Late Callovian–Early Oxfordian cooling followed by warming in the later Oxfordian.

Keywords: Paleobiogeography; Paleoclimates; Ammonites; Corals; Oxfordian; Tethys

1. Introduction

Biogeographical and geochemical research in Europe over the last two decades has provided evidence for important climatic fluctuations in the Jurassic period and despite some early assertions based on biogeographical data (e.g. Haug, 1908–1911), geological and paleontological data traditionally point to a warm, equable climate for at least the Late Jurassic. However, although geological evidence may be sparse or unconvincing (Price, 1999) simulations of climatic regimes using General Circulation Models (GCMs), do not rule out the seasonal formation of ice caps in particular periods of the Late Jurassic–Early Cretaceous (Moore et al., 1992a,b; Ross et al., 1992; Valdes and Sellwood, 1992; Sellwood and Valdes, 1997; Sellwood et al., 2000).

For the Late Jurassic, global biogeochemical models predict high pCO_2 levels (Berner, 1994) and increasing atmospheric CO_2 levels in the Oxfordian are supported by higher plant biomarker changes (van Aarssen et al., 2000). On the basis of paleotemperature values calculated on oxygen isotopes of skeletal material from tropical seawater, Veizer et al. (2000) proposed an icehouse mode for the Late Jurassic. To explain this apparent contradiction (high pCO_2 levels and cold climate), these authors suggested decoupling the relationship between atmospheric CO_2 and global climate, at least for this interval of the Phanerozoic.

However, because the raw data are sporadically distributed in time both kinds of models produce paleotemperature curves for very coarse chronologic intervals. Although climates in the Jurassic were generally characterized by “greenhouse” type conditions, with greater temporal resolution it appears likely that there were brief climatic fluctuations (“cold snaps”) of variable amplitude have probably occurred (Jenkyns et al., 2002; Dromart et al., 2003a).

Within Upper Jurassic strata, Oxfordian deposits are of particular value for testing paleoclimatic reconstructions based on GCMs and geochemistry against geological and paleontological records. Interregional facies variations, and changes in the biogeographical distribution of ammonites and reef corals from mid-latitudes of the Boreal region towards low latitudes of Tethyan areas, and vice versa, are the kinds of phenomena that might be expected to be controlled by paleoclimatic changes (Dromart et al., 2003a,b). The paleoclimatic control on both facies and biotic distributions have been advocated by Weissert and Mohr (1996) and by Bartolini et al. (1996) and is supported by stable isotopes (δ^{13}C, δ^{18}O) data, although high-resolution carbon and oxygen isotope data are still insufficient to provide trends for the Late Callovian–Early Oxfordian and most are from condensed sections (Norris and Hallam, 1995; Jenkyns, 1996; Cecca et al., 2001). A distinct, positive carbon isotope excursion, suggesting a major perturbation in the carbon cycle, has been identified in the Middle Oxfordian Transversarium Zone (Jenkyns, 1996; Weissert and Mohr, 1996; Bartolini et al., 1996; Wierzbowski, 2002). A contrasting negative excursion, within the upper part of the Transversarium Zone, has been interpreted as reflecting a sudden release of frozen methane hydrate along continental margins (Padden et al., 2001). This would have amplified the greenhouse climate of the middle Oxfordian, inducing “a thermal maximum” period, similar to that of the late Paleocene.

1.1. Aims

The aims of this paper are:

(1) to analyse biogeographical changes in distribution of coral reefs and ammonites during the Oxfordian on the basis of data from Tethyan and peri-Tethyan areas (northern and central Europe,