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Upper Cretaceous oceanic red beds (CORBs) in the Tethys: occurrences, lithofacies, age, and environments

Xiumian Hu[a,*], Luba Jansa[b], Chengshan Wang[c], Massimo Sarti[d], Krzysztof Bak[e], Michael Wagreich[f], Jozef Michalik[g], Ján Soták[g]

[a] *Department of Earth Sciences, Nanjing University, Nanjing 210093, PR China*
[b] *Department of Earth Sciences, Dalhousie University, Halifax B3H 3J5, Canada*
[c] *Department of Earth Sciences, China University of Geosciences, Beijing 100083, PR China*
[d] *Department of Marine Science, Università Politecnica delle Marche, Ancona 60131, Italy*
[e] *Institute of Geography, Cracow Pedagogical University, 30-084 Krakow, Poland*
[f] *Institute of Geological Sciences, University of Vienna, A-1090 Vienna, Austria*
[g] *Geological Institute, Slovak Academy of Sciences, Sk-842 26 Bratislava, Slovakia*

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Abstract

A major change in oceanic sedimentation from mid-Cretaceous organic carbon-enriched deep-sea deposits to predominantly Upper Cretaceous oceanic red beds (CORBs), represented mainly by deep-sea red shales and marls, occurred during the Late Cretaceous and early Tertiary in the Tethys. A variety of earth processes such as organic carbon draw-down, tectonic, palaeoceanographic, eustatic and palaeoclimatic changes, or a combination of these could cause such a change, the main significance of which is that it demonstrates that the deep ocean basins ceased to be the preferential burial site for organic carbon. A compilation of available data on CORB occurrences, composition, and age indicate that: (1) CORBs are found in a broad geographic belt extending from the Caribbean across the central North Atlantic, southern and eastern Europe to Asia; with limited occurrences in the Indian ocean; (2) both the first and the last occurrences of CORBs are diachronous; (3) CORBs are of pelagic and hemipelagic origin and were deposited in a variety of environments from continental slope to deep oceanic basin, above and below the carbonate compensation depth (CCD); (4) total organic carbon (TOC) is mostly $<0.1\%$; haematite is relatively abundant, up to 10% in red shales; (5) the termination of CORB deposition in the Alps, Carpathians, and Himalayas was mostly a result of major tectonic events associated with intensification of continental plate migration and initial stages of collision of the Indian and Asian plates and the African and European continental plates. We suggest that changes in dissolved oxygen in the deep ocean were mainly the result of changes in the location and formation of deep water and changes in ocean circulation. It is more than probable that a score of different earth processes, including changes in climate, all acting in concert, were involved in such a major change in the deep-sea environment and location of the carbon reservoir.

Keywords: Oceanic red beds; Upper Cretaceous; Oxic environment; Tethys; Stratigraphy; Sedimentology

1. Introduction

The occurrence of Upper Cretaceous oceanic red beds (CORBs) has been known for at least 140 years, since Štur (1860) and Gümbel (1861) first described them from the Púchov beds in the Carpathians and the Nierental beds in the Eastern Alps. Biostratigraphic and sedimentological studies followed, particularly in Italy, Slovakia, Poland, and Austria (e.g., Birkenmajer, 1977; Premoli Silva, 1977; Butt, 1981; Premoli Silva and Sliter, 1994; Bak, 1998, 2000a,b). Minor attention has been

* Corresponding author.
E-mail address: huxm@nju.edu.cn (X. Hu).

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paid until now to the Tethys, the wide distribution, correlation, and significance of the oxidation of these deposits for palaeoceanographic reconstructions, and their relationships to the distinctly different, underlying mid-Cretaceous black shales. The latter include organic carbon-enriched beds associated with Oceanic Anoxic Events (OAEs) (e.g., Schlanger and Jenkyns, 1976; Jenkyns, 1980). Recently, Late Cretaceous oceanic red beds were discovered in southern Tibet (Wang et al., 1999, 2000; Hu, 2002), which further confirmed their global extent.

In this paper we use the term CORBs (Cretaceous oceanic red beds) for those reddish sediments that were deposited in situ in marine environments. Therefore, the red colour is regarded as syndepositional and indicates that deposition occurred in a strongly oxic bottom environment. This definition of oceanic red beds does not include red sediments that were derived from the erosion of continental red beds (van Houten, 1964) and transported from continental to marine environments (Turner, 1980).

Modern deep-sea red clays (e.g., Glasby, 1991) are deposited under low productivity gyres, particularly in the Pacific Ocean. This prompts the question: Is the occurrence of Late Cretaceous pelagic red beds associated with changes in biotic productivity in the Tethys Ocean, eustasy, climate, or oceanic circulation? What is the triggering mechanism? Before we could begin to answer the latter question it was necessary to compile occurrences of CORBs, and their composition, biostratigraphy and depositional environment, in order to provide a basis for more specialized studies under the auspices of International Geological Correlation Programme Project 463. Despite many similarities in the development and characteristics of CORBs in the Tethys, there are enough differences for us to present the data by region before we attempt a synthesis of the results.

2. Stratigraphic framework

Compilation of CORB data faces several major problems. First, many CORBs were deposited below the CCD, so calcareous microfossils are absent and siliceous microfossils are rare. Therefore, it is difficult to use biostratigraphy for exact age determination. Second, the definition of microfossil zones in previous studies of CORBs results in different chronostratigraphic correlations. Here we apply the planktonic foraminiferal zones established by Premoli Silva and Sliter (1994), Robaszynski and Caron (1995) and Bralower et al. (1995), and the Cretaceous stratigraphic scale of Gradstein et al. (1995). Third, many CORB occurrences in the Alps, Carpathians and Himalayas are in parts of fault blocks and nappes that are tectonically disconnected from their original depositional sites and even from their original geographic positions.

3. CORBs in the Tethys

3.1. North Atlantic

Upper Cretaceous–Palaeocene pelagic red beds in the North Atlantic basins (Fig. 1, Locality 1) (Jansa et al., 1979) are varicoloured, locally zeolitic, non-calcareous claystone. They form the Plantagenet Formation, which is a relatively thin, but widespread unit that overlies black claystone of the mid-Cretaceous Hatteras Formation (Jansa et al., 1979). This formation is 92.3 m thick at its type locality, DSDP Site 386. These CORB claystone beds are up to 10–20 cm thick and vary in colour from dusky yellowish brown to moderate brown to dusky dark red with some light greenish grey beds. The main minerals are illite and montmorillonite (60–ca. 80%) and, in order of decreasing abundance, quartz, disordered cristobalite, and feldspars. Zeolites (clinoptilolite, phillipsite) form 6–20%. Iron and manganese oxides including micronodules occur in minor amounts. Rare primitive agglutinated foraminifera and poorly preserved radiolarians are present. Thin, irregular lamination is the only sedimentary structure in the formation.

The transitional zone between the Plantagenet Formation and the underlying Hatteras Formation is interlaminated red and green-grey claystone centimetres to a few metres thick (Fig. 2A). The top of the Plantagenet Formation grades into the overlying Palaeogene Bermuda Rise Formation, which comprises siliceous clay and chert.

The earliest Turonian–Palaeocene age of the Plantagenet Formation is not constrained by microfossils, but is bracketed by the ages of the underlying and overlying strata (Jansa et al., 1979; de Graciansky et al., 1987). The lack of calcareous microfossils indicates that deposition occurred below the CCD, and the presence of iron oxides and agglutinate foraminifers suggest an oxygenated depositional environment on the ocean floor (Jansa et al., 1979; de Graciansky et al., 1987). The average accumulation rate for the Plantagenet red beds was less than 2 mm/ka. The composition and depositional environment of the Plantagenet Formation in the central North Atlantic was similar to modern red clays of the deep Pacific Ocean (Glasby, 1991), which were also deposited below the CCD at similar low sedimentation rates.

3.2. Subbetic Zone, Spain

Cretaceous hemipelagic red beds crop out extensively in the External Zone of the Betic Cordillera in southern