Chemical Geology 341 (2013) 1–15

Contents lists available at SciVerse ScienceDirect

Chemical Geology

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

# Geochemical disturbance and paleoenvironmental changes during the Early Toarcian in NW Europe

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ARTICLE INFO

*Article history:*
Received 19 July 2012
Received in revised form 27 December 2012
Accepted 7 January 2013
Available online 18 January 2013

Editor: U. Brand

*Keywords:*
Early Toarcian
Oceanic anoxic event
Paleoenvironment
Trace metals
Productivity
Paris Basin

ABSTRACT

The Early Toarcian oceanic anoxic event (OAE) is associated with a rapid and severe environmental change whose causes are still a matter of debate. A new paleoenvironmental interpretation is proposed, based on a multidisciplinary dataset (chemical, mineralogical and paleontological) obtained from a borehole drilled by Andra (French National Radioactive Waste Management Agency) in the Lower Toarcian of the eastern Paris Basin (France).

During the earlymost Toarcian (Tenuicostatum Zone), the presence of well oxygenated sea-water is reflected by an abundant and diverse fauna, along with paleoredox proxies (U/Al, Mo/Al and V/Al) typical of oxidizing conditions, associated with predominant mechanical weathering on the continent. At the base of the Serpentinum Zone, an important paleoenvironmental change is marked by an initial phase of organic matter enrichment (~12% TOC) during the negative shift of $\delta^{13}C$ (Carbon Isotope Excursion: CIE). Euxinic/anoxic conditions, indicated by cobalt enrichment and the development of framboidal pyrite, lead to the disappearance of the benthic and pelagic fauna and allow organic matter to be preserved in the sediments. At this time, the low concentration of paleoproductivity proxies (Cd, P, Ni and Zn) suggests weak chemical weathering on the continent due to a rather arid climate. Low concentrations of Sr and coccoliths are due to an input of fresh water probably coming from the Arctic through the Laurasian seaway. Thus, the isolation of the Paris Basin from the Tethyan realm and the influx of freshwater favour haline stratification and the preservation of organic matter.

Following the CIE, oxygen concentration gradually increases up to a maximum flooding surface dated as coeval with the Serpentinum Zone, Elegantulum Subzone. Paleoproductivity proxies indicate a weak primary productivity.

The top of the Lower Toarcian is characterized by a second enrichment in organic matter (~12% TOC) due to an important input of nutrients. This enhanced primary production generates euxinic/anoxic conditions in the sediment and in part of the water column, leading to a high enrichment in paleoredox proxies (Mo, U, V, Co) and causing the sudden disappearance of the benthic fauna and a progressive decline of the pelagic fauna. The metal enrichment is related to intense chemical weathering on the continent due to a more humid climate.



## 1. Introduction

A major oceanic anoxic event (OAE) occurred during the Early Toarcian, giving rise to black shale deposition and carbon cycle disturbances that have been described in numerous sedimentary basins (Jenkyns, 1985, 1988; Hesselbo et al., 2000, 2007). This event (referred to here as T-OAE) is of both economic and scientific interests because the associated deposits form an important source rock and because the global extent of the event reflects a major paleoenvironmental disturbance. For several decades, many studies have proposed various scenarios concerning the origin of this event (Hesselbo et al., 2000; Van de Schootbrugge et al., 2005; Svensen et al., 2007; Suan et al., 2008). Sedimentological studies show that, in most of the outcrops, black shales appear at the base of the Lower Toarcian (Falciferum/Serpentinum Zone). Nevertheless, the chronostratigraphic range of these deposits is variable and can, in extreme cases, extend up to the Bifrons Zone. In many areas, a considerable negative excursion in $\delta^{13}C$ values is recorded in bulk rock, organic matter and fossil wood sampled from the Exaratum Subzone (e.g. Hesselbo et al., 2000; Röhl et al., 2001;

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http://dx.doi.org/10.1016/j.chemgeo.2013.01.003

Jenkyns et al., 2002). Two main hypotheses have been put forward to explain this negative $\delta^{13}C$ excursion: Firstly, the Carbon Isotope Excursion (CIE) could be due to the recycling of remineralized carbon from the deeper parts of an intermittently stratified water column up into the photic zone, where it would have been incorporated by photosynthetic phytoplankton (Küspert, 1982; Röhl et al., 2001; Van de Schootbrugge et al., 2005). Secondly, the CIE may result from the rapid release of carbon dioxide to the ocean–atmosphere system caused by the dissociation of methane hydrate (Hesselbo et al., 2000; Jenkyns, 2003). The near synchronism between the T-OAE and the negative C-isotope perturbation has led to potentially misleading interpretations of a common origin for these two paleoceanographic phenomena. Organic enrichment in the sedimentary record and carbon isotope perturbation, even though they are linked through the short-term global carbon cycle, need to be examined separately because their stratigraphic ranges are not necessarily comparable (Hesselbo et al., 2000; McArthur et al., 2008; Pearce et al., 2008; Hermoso et al., 2009). In this way, a major question arises: do the same factors control the accumulation and preservation of organic matter before, during and after formation of the $\delta^{13}C$ anomaly (CIE)?

To address this question, we examine the stratigraphic distribution of biological, mineralogical and redox-sensitive markers, as well as geochemical proxies of detrital input and paleoproductivity throughout the Lower Toarcian interval of the NE Paris Basin. This interval is partly characterized by the negative carbon isotope excursion recorded throughout the NW-Tethyan realm. We attempt to establish a link between all these markers and their paleoenvironmental significance. The paleoenvironmental reconstructions for the studied area are compared with environmental disturbances recorded on different sites over NW Europe, in order to i) differentiate the local from the regional disturbances; and ii) to reconstruct paleoenvironmental variations across the NW Europe.

## 2. Geological setting

The EST433 borehole was drilled in 2008 by ANDRA (French National Radioactive Waste Management Agency) near the locality of Bure (eastern Paris Basin), not far from the underground laboratory for experimental studies relating to the disposal of radioactive waste (Fig. 1). The borehole provided a continuous recovery of core-samples from the Triassic to the Upper Jurassic. The studied K2-5 core section is 9 m long, sampling an interval from 1037.10 to 1028.10 m depth (with respect to ground level datum), and comprises Lower Toarcian sediments. The lithology of the basal Toarcian (Tenuicostatum Zone) is represented by marine calcareous sandstones with abundant detrital quartz (Middle Liassic sandstones), followed by marls and calcareous marls (containing several organic-rich and laminated intervals, making up the "Schistes carton" formation) assigned to the Serpentinum Zone (Fig. 2).

## 3. Analytical methods

### 3.1. Paleontological, mineralogical, carbon and sulphur analyses

The identification of the ammonites and ostracods was carried out classically at the species level. The concentration of coccolithophoridae, based on 47 samples, was estimated by SEM imaging using visual charts and from several areas of each sample. Bulk mineralogy and clay mineral assemblages were determined from 71 powder samples by X-ray diffraction (XRD). For clay mineral assemblages, diffraction scans were

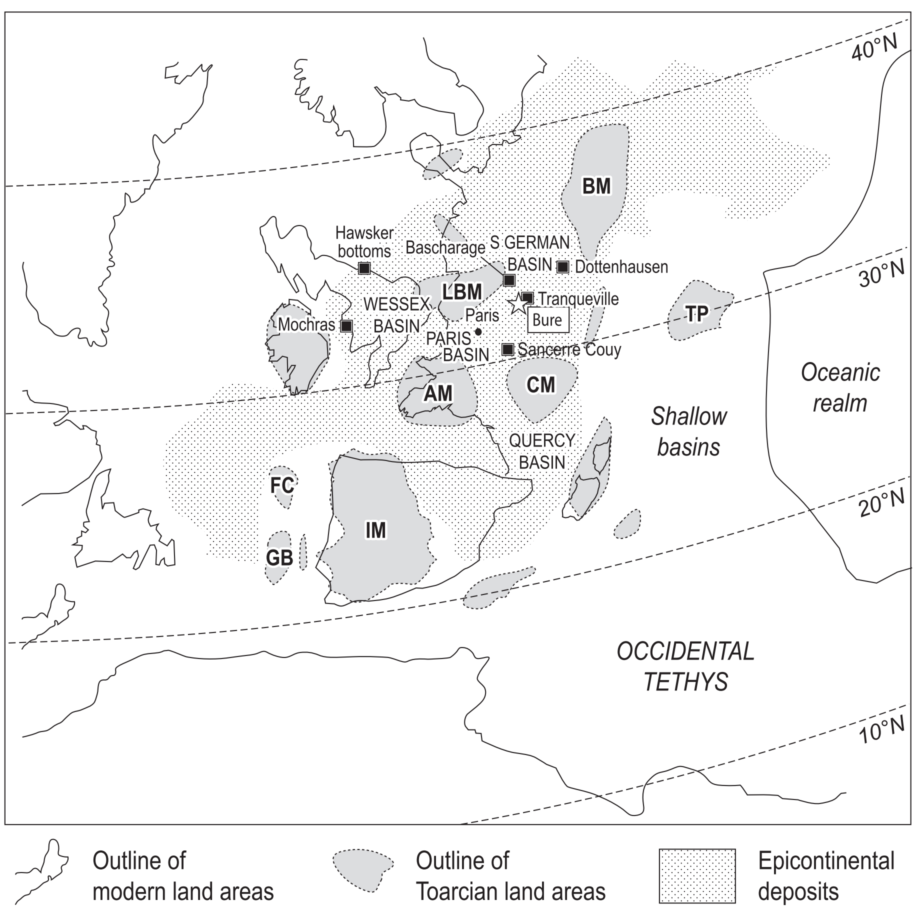


**Fig. 1.** Paleogeographic map of the Early Jurassic archipelago (redrawn after Van de Schootbrugge et al., 2005). FC: Flemish Cap; GB: Galica Bank; IM: Iberian Meseta; AM: Armorican Massif; CM: Central Massif; LBM: London-Brabant Massif; TP: Tisza Plate; BM: Bohemian Massif.