Earth and Planetary Science Letters 404 (2014) 273–282

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Chronology of the Early Toarcian environmental crisis in the Lorraine Sub-Basin (NE Paris Basin)

Wolfgang Ruebsam [a,*], Petra Münzberger [b], Lorenz Schwark [a,c]

[a] Department of Organic Geochemistry, Institute of Geoscience, University of Kiel, Germany
[b] Geological Survey Luxembourg, Luxembourg
[c] WA-OIGC, Curtin University, Perth, Australia

ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form 30 July 2014
Accepted 3 August 2014
Available online 23 August 2014
Editor: J. Lynch-Stieglitz

Keywords:
OAE
duration CIE
Early Jurassic
orbital forcing
Viking Corridor
condensation

ABSTRACT

Early Toarcian (Jurassic; ∼183 Ma) sediments recorded profound environmental changes, including mass extinction, global warming, marine transgression as well as widespread bottom water anoxia and organic matter accumulation on the Western Tethyan shelf. Enhanced organic matter accumulation was accompanied by a positive carbon isotope excursion (CIE) in pelagic carbonate, which marks the Toarcian Oceanic Anoxic Event. These environmental changes were accompanied by a major perturbation of the global carbon cycle, expressed by negative CIE, interrupting the positive trend. The duration of the carbon cycle perturbation is still debated, with estimates for the negative CIE range from ∼200 to ∼600 kyr. Here we present ultra high-resolution (<1 kyr) measurements of magnetic susceptibility and sediment color from a marine section located in the Lorraine Sub-Basin (NE Paris Basin) documenting Milankovitch-controlled fluctuations in depositional conditions that occurred superimposed onto the overall sea level evolution. Differences in the wavelength of the sedimentary cycles indicate variable sediment accumulation rates that mainly resulted from rapid sea level fluctuations. The most pronounced sea level rise that took place within the uppermost *tenuicostatum zone* resulted in a strong condensation of the basal Schistes Carton formation. Strong condensation can explain the discrepancy between durations previously calculated for the CIE placed at this stratigraphic interval. Our data support durations of ∼900 kyr and ∼600 kyr for the positive and negative CIE, respectively. The cyclostratigraphy-based timescale further proposes a duration of >555 kyr for the *tenuicostatum zone* and 1310 kyr for the *serpentinum zone*. The durations of the *elegantulum* and *falciferum subzones* can be estimated to ∼790 kyr and ∼520 kyr, respectively. A change in the orbital response from eccentricity- to obliquity-forcing, evident from other locations, is well-expressed in the Lorraine Sub-Basin and occurred within the CIE interval. The strong impact of the obliquity component in post-event deposits hints to processes most effective at high latitudes, such as the waxing and waning of polar ice. Paleogeographic features of the Western Tethyan shelf supported the tele-connection of higher to lower latitude processes via water exchange through the Viking Corridor.

1. Introduction

The Lower Toarcian (Early Jurassic, ∼183 Ma) is characterized by its event-character including mass extinctions at the Pliensbachian–Toarcian boundary and at the *tenuicostatum–serpentinum* boundary (Harries and Little, 1999; Caswell et al., 2009). Both extinction events are marked by pronounced negative shifts in carbon isotope values recorded in organic matter and carbonate, which indicate (global) perturbations of the carbon cycle (Suan et al., 2008; Littler et al., 2010; Kemp et al., 2011). The global or trans-regional character of the negative carbon isotope excursion at the Pliensbachian–Toarcian boundary remains to be confirmed. These events occurred during a period of rapid global warming that may mark the transition from an icehouse to a greenhouse world (e.g. Dera et al., 2011 and references therein). Cyclostratigraphic investigations at several locations across the Tethyan shelf document a shift from eccentricity- and precession- to obliquity-dominant orbital forcing and reveal further evidence for fundamental changes in the global climate system and water storage (Hinnov and Park, 1999; Suan et al., 2008; Huang and Hesselbo, 2014; Boulila et al., 2014). The global warming caused an acceleration of the hydrological cycle (Cohen et al., 2004) and led

* Corresponding author.
E-mail address: wr@gpi.uni-kiel.de (W. Ruebsam).

http://dx.doi.org/10.1016/j.epsl.2014.08.005

to an eutrophication of the Tethyan shelf seas that contributed to the widespread deposition of organic-rich sediments (Baudin et al., 1990), which are attributed to the Toarcian Oceanic Anoxic Event (T-OAE) (Jenkyns, 1988). Furthermore, rapid high-amplitude sea level fluctuations, superimposed on the 2nd order transgression that occurred throughout the *tenuicostatum* and *serpentinum zones* (Hardenbol et al., 1998; Gély and Lorenz, 2006), resulted in highly fluctuating depositional conditions and led to the formation of depositional hiatuses and condensed stratigraphic intervals that are documented for the upper Pliensbachian and lowermost Toarcian (e.g. Röhl and Schmidt-Röhl, 2005; Léonide et al., 2012; Pittet et al., 2014).

Timing, chronology and duration of these events and environmental perturbations are still debated, whereby a robust timescale for this period is of major importance for the understanding of triggering mechanisms, especially for those causing the pronounced carbon cycle perturbation that is closely related to the T-OAE (Hinnov and Park, 1999; Suan et al., 2008; Kemp et al., 2011; Huang and Hesselbo, 2014; Boulila et al., 2014). Here we present a timescale at the ammonite subzone scale deduced from spectral analysis. Our results highlight the importance of changes in astronomical forcing superimposed onto the general sea level evolution and reveal that changes in sea level and sediment supply result in strongly differing sediment accumulation rates that are well expressed by cyclostratigraphy.

2. Study site

The study site is located in the Lorraine Sub-Basin (NE Paris Basin, Fig. 1B) at a paleolatitude of ∼35°N (Golonka, 2007). The Lorraine Sub-Basin was one of several partly enclosed basins on the structurally rich western Tethyan shelf and situated close to the London-Brabant and Rhenish Massifs. The shelf sea was connected with the Arctic Ocean via the Viking Corridor and opened to the Tethyan Ocean towards the southeast (Fig. 1A).

3. Lithology and stratigraphy of Core FR-210-078

Drill Core FR-210-078 derived from southern Luxembourg provided about 30 m of continuously and exceptionally well-preserved sediments spanning the uppermost Pliensbachian and lower Toarcian, represented by the Grès médioliasiques and Schistes Carton Fm. Lithological inspection of the core indicates significant differences in sedimentation style and sediment composition between the formations (Figs. 2, S2). The Grès médioliasiques Fm (31.97–39.92 m; Interval 4) consists of homogeneous light-grey to grey marls with minor contributions of silt, strongly affected by bioturbation and potentially by erosional events. Sedimentation most likely occurred in a high-energetic shallow marine environment above the wave and storm base. A thin interval from 37.95 to 37.87 m, which marks the Pliensbachian–Toarcian boundary, consists of dark-grey bituminous laminated claystones that are rich in pyrite. The Schistes Carton Fm (9.55–31.97 m; Intervals 1–3) mainly consists of grey to dark-grey bituminous marls that are rich in pyrite and show a distinct lamination, which indicates deposition in a low energetic environment below the wave and storm base. Detailed inspection reveals that these laminated sediments were frequently interrupted by intercalated horizons that show an indistinct lamination and a partly homogeneous sedimentation style, which indicate enhanced bioturbation and sediment reworking (Fig. S2). Horizons with indistinct lamination are most pronounced in the lower part of the Schistes Carton Fm (Interval 2). The basal Schistes Carton Fm (30.75–31.97 m; Interval 3) differs from the upper part, as this interval shows the lowest carbonate content (Fig. 2) and thus rather represents bituminous claystones (black shale, *sensu lato*) than bituminous marls. Biostratigraphic

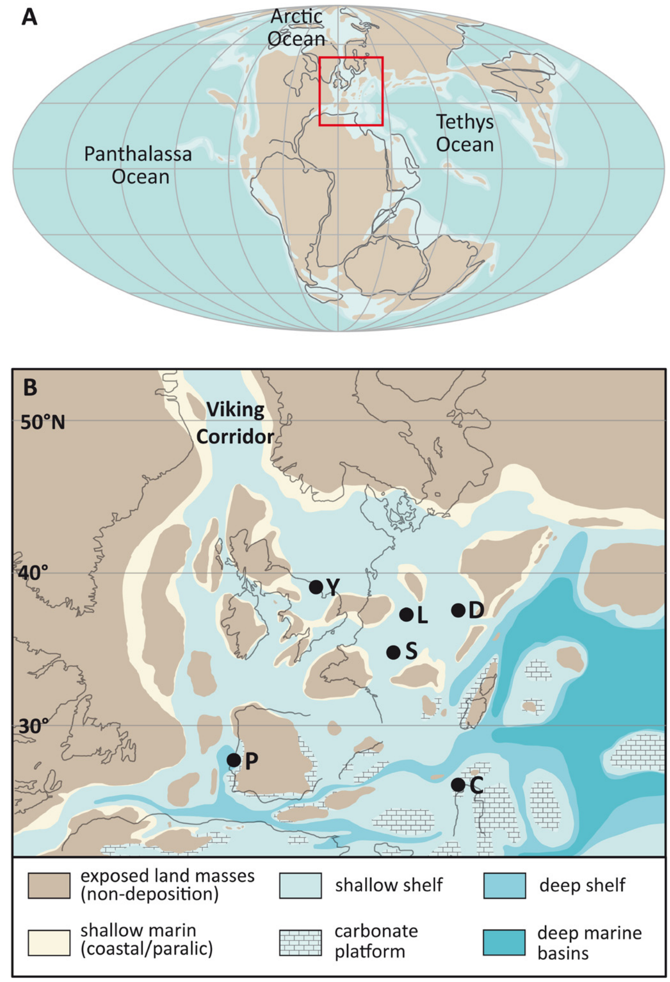

Fig. 1. A) Global paleogeographic setting during the early Toarcian after Golonka (2007, 2011) (landmasses shown in brown, shelf areas in light blue, ocean basins in dark blue; position of the Western Tethyan shelf marked in red). **B)** Paleogeography of the western Tethyan shelf area (modified after Bassoulet et al., 1993 and Thierry et al., 2000) and locations with cyclostratigraphic data (C: Colle di Sogno/Lombardy Basin; D: Dotternhausen/South German Basin; P: Peniche/Lusitanian Basin; S: Sancerre/South-Central Paris Bain; Y: Yorkshire/Cleveland Basin). The study site (L) is located in the Lorraine Sub-Basin (NE Paris Basin). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

framework adapted from Guérin-Franiatte et al. (2010) places the Pliensbachian–Toarcian boundary at 37.90 m. The *serpentinum zone* spans the sediment interval from 31.82 m to approximately 6 to 7 m; the *serpentinum–bifrons* boundary was not recovered in Core FR-210-078 (Fig. S1). Within the *serpentinum zone* the *elegantulum* and *falciferum subzones* can be distinguished. The boundary between both ammonite subzones was placed at 21.22 m.

4. Methods

4.1. High-resolution measurements

A core half was subjected to continuous high-resolution measurements including spectrophotometry (SP) and magnetic susceptibility (MS). Measurements were taken directly on the core half parallel to the strata at fixed steps of 1 cm. Spectrophotometric parameters were measured using a Konica Minolta CM-700d spectrometer. Results are recorded in the CIE L*a*b*chromaticity space. Magnetic susceptibility measurements were performed using a Bartington MS3 device equipped with a MS2 sensor (sensitivity $2 * 10^{-6}$ SI). Ultra-high resolution L*a*b* data sets (resolution