Earth and Planetary Science Letters 301 (2011) 365–372

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

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

Stepwise atmospheric carbon-isotope excursion during the Toarcian Oceanic Anoxic Event (Early Jurassic, Polish Basin)

Stephen P. Hesselbo [a,*], Grzegorz Pieńkowski [b]

[a] Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK
[b] Polish Geological Institute - National Research Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland

ARTICLE INFO

Article history:
Received 8 July 2010
Received in revised form 9 November 2010
Accepted 9 November 2010
Available online 8 December 2010

Editor: M.L. Delaney

Keywords:
Pliensbachian–Toarcian
palaeoclimate
carbon cycle
Oceanic Anoxic Event
sea-level change
terrestrial organic matter

ABSTRACT

During the Mesozoic (250–64 Ma) intervals of about 0.5 Myr were subject to severe environmental changes, including high sea-surface temperature and very low oxygen content of marine water. These Oceanic Anoxic Events, or OAEs, occurred simultaneously with profound disturbance to the carbon cycle. The carbon-isotope anomaly in the Early Jurassic that marks the Toarcian Oceanic Anoxic Event (T-OAE) at ~182 Ma is characterized in marine sections by a series of dramatic steps towards lighter values. Herein we present new carbon-isotope data from terrestrial organic matter (phytoclast separates), collected through a Late Pliensbachian–Middle Toarcian coastal and marginal marine succession in the Polish Basin, a setting where hinterland climate and sea-level change are well recorded. The results show that the shift to light carbon-isotope values in the woody organic matter, and therefore also in atmospheric carbon dioxide, similarly occurred in major steps. The steps are here correlated with those identified from marine organic matter, where they have previously been attributed to 100 kyr eccentricity forcing of climate. The results provide strong support for orbitally and climatically controlled release of isotopically light carbon from gas hydrates into the ocean–atmosphere system in a series of rapid bursts. Additionally, a link between the carbon-isotope steps and shoreline movements can be demonstrated. Individual peaks of the negative excursion are mostly associated with facies indicative of sea-level rise (flooding surfaces). However, at the same time inferred higher atmospheric carbon-dioxide content may be expected to have resulted in increased rainfall and temperature, leading to accelerated weathering and erosion, and consequently increased sediment supply, progradation and regression, causing some mismatches between isotope shifts and inferred sea-level changes. Enhanced abundance of megaspores derived from hydrophilic plant groups, and marked increase in kaolinite, are coincident with the overall development of the negative isotope excursion. The combined data suggest that each 100-kyr cycle in carbon-isotope values was characterized by increasingly severe palaeoclimatic change, culminating in extremely hot and humid conditions co-incident with the peak of the final most negative carbon-isotope excursion. The chemostratigraphic correlation allows very precise dating of the Late Pliensbachian–Middle Toarcian coastal and marginal marine sedimentary succession in the Polish Basin.

1. Introduction

The most profound environmental change in the Jurassic Period took place during the Early Toarcian Oceanic Anoxic Event (T-OAE) (Jenkyns, 1988). Marine depositional settings across Europe show evidence for widespread anoxia in the form of coeval black shale, and high seawater palaeotemperatures are inferred from isotopic and elemental anomalies (Cohen et al., 2007; Jenkyns, 2010; Jenkyns et al., 2002; McArthur et al., 2008). A negative carbon-isotope excursion, with an average $\delta^{13}C$ amplitude of approximately −7‰ (VPDB), possibly the largest such anomaly in whole Phanerozoic, has been described from marine and terrestrial materials. High-resolution datasets in marine sections have shown that the shifts to light carbon-isotope values occur as a series of stratigraphically abrupt steps (Hermoso et al., 2009; Jenkyns et al., 2001; Kemp et al., 2005) — for example as determined from Yorkshire, UK (Fig. 1).

However, what is still poorly known about this event is its manifestation in non-marine and marginal marine environments. Although the prominent negative carbon-isotope anomaly has been described, at a relatively low resolution, from terrestrial organic matter in fully marine deposits (Hesselbo et al., 2000, 2007), the same excursion towards light isotopic values has been documented from only a single marginal marine site, on the island of Bornholm, Denmark (Hesselbo et al., 2000, 2007; McElwain et al., 2005). Furthermore, the stepwise character of the excursion has not hitherto been identified from non-marine materials.

* Corresponding author.
E-mail addresses: stephen.hesselbo@earth.ox.ac.uk (S.P. Hesselbo), grzegorz.pienkowski@pgi.gov.pl (G. Pieńkowski).

0012-821X/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsl.2010.11.021

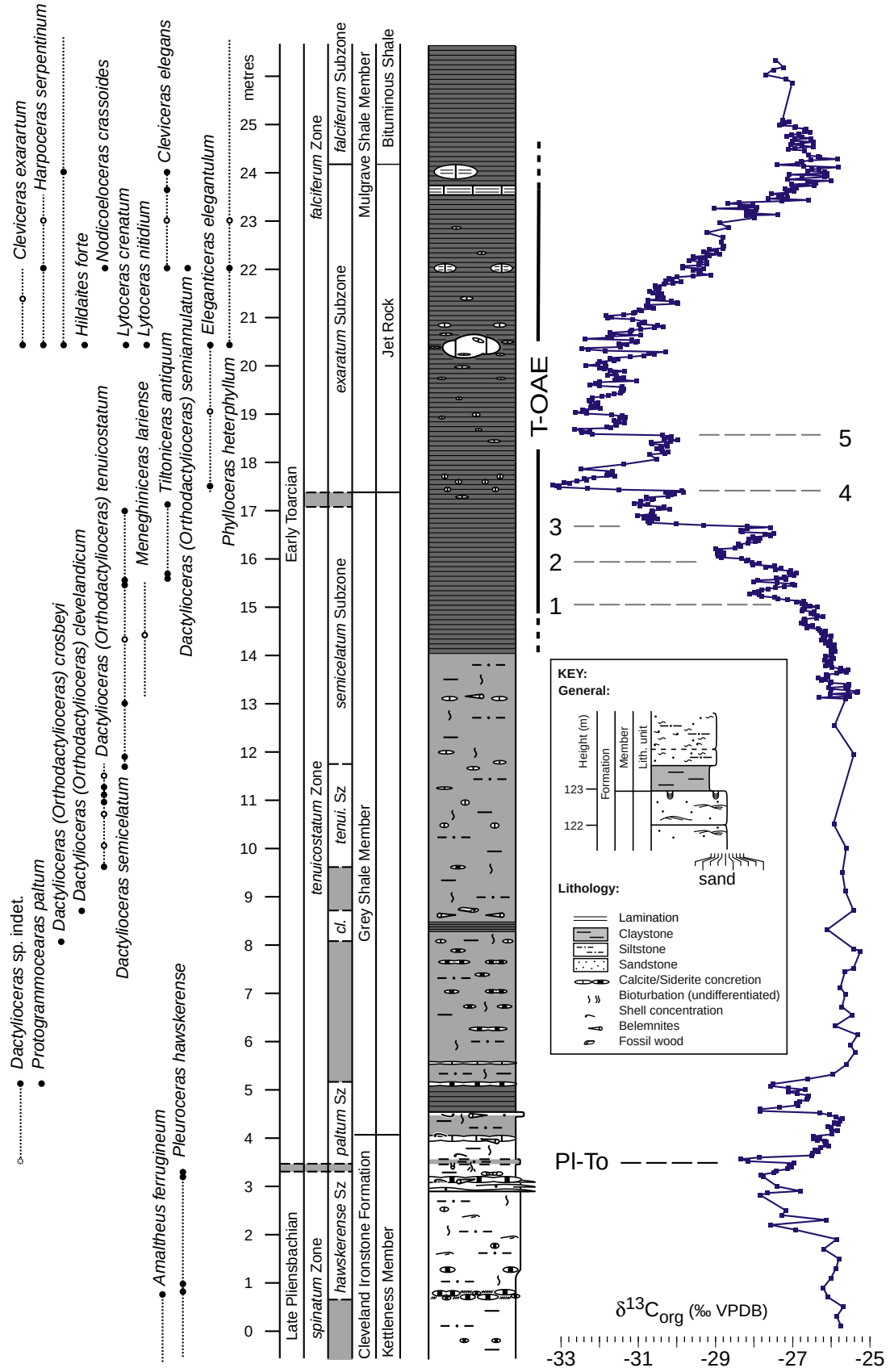

Fig. 1. Summary graphic log for the Pliensbachian–Toarcian boundary and T-OAE at Hawsker Bottoms, Yorkshire, UK. Graphic log from Hesselbo and Jenkyns (1995) and Littler et al. (2010). Ammonite range data from Howarth (1992) and Page (2004). Carbon-isotope data from Hawsker Bottoms and other Yorkshire localities from Kemp et al. (2005) and Littler et al. (2010). Numbering of steps in the carbon-isotope curve is from this study.