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Secular environmental precursors to Early Toarcian (Jurassic) extreme climate changes

Guillaume Suan [a,*], Emanuela Mattioli [a], Bernard Pittet [a], Christophe Lécuyer [a], Baptiste Suchéras-Marx [a], Luís Vítor Duarte [b], Marc Philippe [a], Letizia Reggiani [a,c], François Martineau [a]

[a] Laboratoire CNRS UMR 5125 "PaléoEnvironnements & PaléobioSphère", Université Claude Bernard Lyon 1, Campus de la Doua, F-69622 Villeurbanne, France
[b] Departamento de Ciências da Terra, IMAR-CMA, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, 3000-272 Coimbra, Portugal
[c] Dipartimento di Scienze della Terra, Università di Perugia, Piazza Università, 06123 Perugia, Italy

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A B S T R A C T

The Early Toarcian Oceanic Anoxic Event (T-OAE), about 183 myr ago, was a global event of environmental and carbon cycle perturbations, which deeply affected both marine biota and carbonate production. Nevertheless, the long-term environmental conditions prevailing prior to the main phase of marine extinction and carbonate production crisis remain poorly understood. Here we present a ~8 myr-long record of Early Pliensbachian–Middle Toarcian environmental changes from the Lusitanian Basin, Portugal, in order to address the long-term paleoclimatic evolution that ultimately led to carbonate production and biotic crises during the T-OAE. Paleotemperature estimates derived from the oxygen isotope compositions of well-preserved brachiopod shells from two different sections reveal a pronounced ~5 °C cooling in the Late Pliensbachian (*margaritatus–spinatum* ammonite Zones boundary). This cooling event is followed by a marked ~7–10 °C seawater warming in the Early Toarcian that, after a second cooling event in the mid-*polymorphum* Zone, culminates during the T-OAE. Calcium carbonate ($CaCO_3$) contents, the amount of nannofossil calcite and the mean size of the major pelagic carbonate producer *Schizosphaerella*, all largely covary with paleotemperatures, indicating a coupling between climatic conditions and both pelagic and neritic $CaCO_3$ production. Furthermore, the cooling and warming episodes coincided with major marine regressions and transgressions, respectively, suggesting that the growth and decay of ice caps may have exerted a strong control on sea-level fluctuations throughout the studied time interval. This revised chronology of environmental changes shows important similarities with Neogene and Paleozoic episodes of deglacial black shale formation, and thus prompts the reevaluation of ice sheet dynamics as a possible agent of Mesozoic events of extinction and organic-rich sedimentation.

1. Introduction

Geochemical, sedimentological and paleontological data indicate that the Late Pliensbachian–Early Toarcian mass extinction event (~183 myr ago, Early Jurassic) was accompanied by severe environmental changes that included development of anoxic conditions, changes in the hydrological cycle, marked variations in seawater temperatures and changes in marine and terrestrial biota (Jenkyns, 1988; Philippe and Thévenard, 1996; Macchioni and Cecca, 2002; Bailey et al., 2003; Cohen et al., 2004; Wignall et al., 2005; Rosales et al., 2006; Suan et al., 2008a; Gómez et al., 2008). It has been suggested that these major environmental changes could have been triggered by massive releases of greenhouse gases, possibly involving the destabilization of marine gas hydrates or the thermal metamorphism of organic-rich sediments during the intrusive phase of the eruption of the Karoo–Ferrar large igneous province (Hesselbo et al., 2000; Cohen et al., 2007; Svensen et al., 2007). Shallow-water carbonate platforms and calcareous nannofossils, as well as benthic and pelagic invertebrates, were particularly affected by these major environmental changes, notably across the Pliensbachian–Toarcian boundary and during an episode of widespread organic-rich deposition defined as the Toarcian Oceanic Anoxic event (T-OAE) (Bassoullet and Baudin, 1994; Harries and Little, 1999; Cobianchi and Picotti, 2001; Macchioni and Cecca, 2002; Erba, 2004; Mattioli et al., 2004; Tremolada et al., 2005; Wignall et al., 2005; Mattioli et al., 2008; Suan et al., 2008a). Most studies relate these mass extinctions and biocalcification crises to pulses of CO_2-induced environmental changes, namely by enhanced nutrient input due to accelerated hydrological cycle, productivity-driven anoxia, rise in seawater temperatures and changes in the saturation state of the ocean with respect to calcite (Erba, 2004; Mattioli et al., 2004; Tremolada et al., 2005; Wignall et al., 2005; Mattioli et al., 2008; Gómez et al., 2008).

* Corresponding author. Present address: Institut de Géologie et de Paléontologie, Université de Lausanne, Anthropole, CH-1015 Lausanne, Switzerland.
E-mail addresses: suanguillaume@yahoo.fr, suan@unil.ch (G. Suan).

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