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Litho-, bio- and chemostratigraphy across the Cenomanian/Turonian boundary (OAE 2) in the Vocontian Basin of southeastern France

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ABSTRACT

The Oceanic Anoxic Event 2 (OAE 2) was one of at least two large oceanic anoxic events during the Cretaceous Period, and it is characterized in the stratigraphic record by double positive peaks in the $\delta^{13}C$ curves of carbonate and organic carbon. Since the positive $\delta^{13}C$ shift is believed to have resulted from massive burial of isotopically depleted organic carbon generated globally in anoxic oceanic environments, the positive $\delta^{13}C$ shift tend to coincide with widespread deposition of organic-rich sediments. In the case of OAE 2, however, the organic-rich horizons do not accord exactly with the two intervals with positive $\delta^{13}C$ shifts at many sites such as Pueblo, Tarfaya, Eastbourne, and Gubbio (e.g., Tsikos, H., Jenkyns, H.C., Walsworth-Bell, B., Petrizzo, M.R., Forster, A., Kolonic, S., Erba, E., Premoli Silva, I., Baas, M., Wagner, T., Sinninghe Damesté, J.S., 2004. Carbon-isotope stratigraphy recorded by the Cenomanian–Turonian Oceanic anoxic event: correlation and implications based on three key localities. Journal of the Geological Society, London 161, 711–719).
The Thomel Level of the Cenomanian/Turonian (C/T) boundary in the Vocontian Basin (southeastern France) accumulated during the OAE 2, and it is marked by frequent intercalations of black shale and organic-rich marl. Detailed litho-, bio- and chemostratigraphy analyses across the C/T boundary in the Vocontian Basin indicate that the $\delta^{13}C_{carbonate}$ profile fluctuation across the Thomel Level corresponds well with changes in lithofacies, total organic carbon (TOC), and calcium carbonate ($CaCO_3$) abundance. Positive $\delta^{13}C$ excursions within the OAE 2 correlate with basal and middle parts of the Thomel Level that are characterized by high TOC, low $CaCO_3$, and predominantly contain organic-rich sediments such as black shale and dark gray marl. On the other hand, negative $\delta^{13}C$ intervals within the OAE 2 correspond with lower and upper parts of the Thomel Level that consist of marly limestone and limy marl with low TOC and high $CaCO_3$ values. Since the fluctuation of redox conditions during Thomel Level deposition in the Vocontian Basin coincides well with the global carbon burial rate indicated by its $\delta^{13}C$ profile, the Thomel Level could be an ideal candidate for the reference section of the OAE 2.

1. Introduction

The mid-Cretaceous represents a prominent warm interval in Earth history; it was marked by average global surface temperatures more than 14 °C higher than those of today (e.g., Huber et al., 1995; Tarduno et al., 1998; Clarke and Jenkyns, 1999; Huber et al., 2002), poleward expansion of carbonate platforms (Johnson et al., 1996; Takashima et al., 2007b), a lack of permanent ice sheets (Frakes et al., 1992; Moriya et al., 2007), and a sea level ~100–200 m higher than that of today (Haq et al., 1987; Miller et al., 2005; Müller et al., 2008). During the climax of Cretaceous warming, anoxic environments frequently expanded in global oceans in "Oceanic Anoxic Events" (Schlanger and Jenkyns, 1976). Of these anoxic events, the Cenomanian/Turonian boundary event (also called OAE 2) is known as the largest oceanic anoxic event during the Cretaceous. Anoxic environments stretched from the photic zone to deeper than 3500 m during the OAE 2 (Thurow et al., 1992; Sinninghe Damesté and Köster, 1998; Pancost et al., 2004), deposited organic carbon-rich sediments worldwide (Fig. 1), and may have caused the extinction of about 20% of marine genera (Raup and Sepkoski, 1986).

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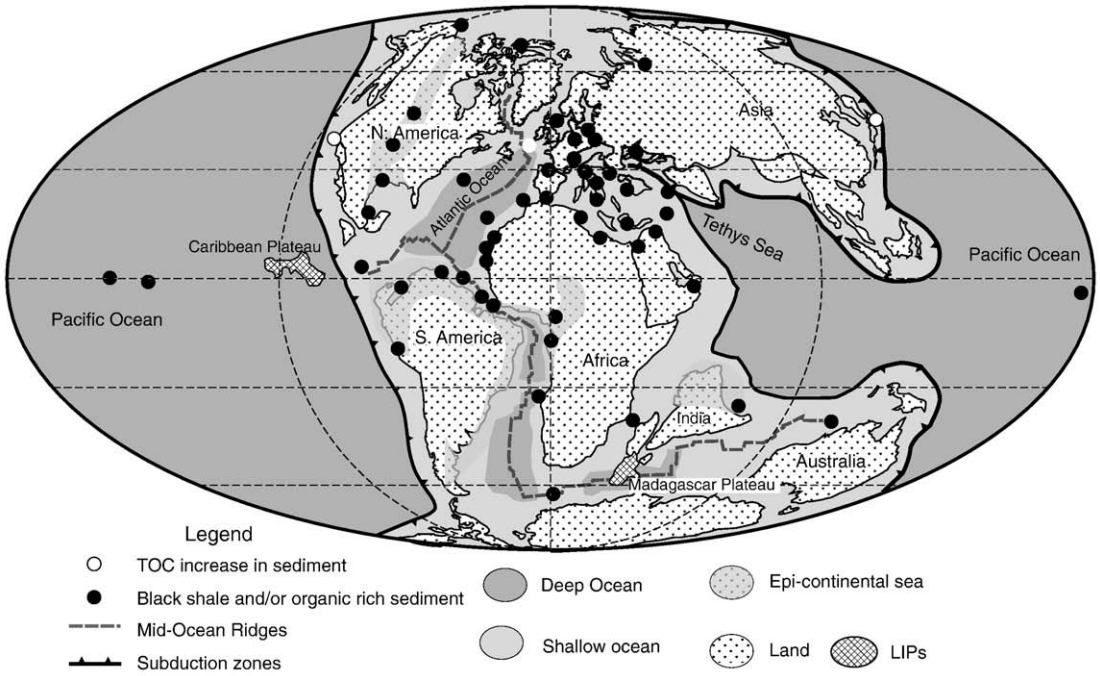

Fig. 1. Distribution of black shales, organic-rich sediments and Large Igneous Provinces around the Cenomanian/Turonian boundary. Modified from Takashima et al. (2006).

To know how and why the anoxic ocean region increased worldwide during the OAE 2, it is necessary to correlate high-resolution integrated litho-, bio- and chemostratigraphy in various oceans and/or paleo-depths. Excess burial of organic carbon in global anoxic oceans, an event which preferentially sequesters isotopically light carbon, resulted in prominent positive $\delta^{13}C$ ($^{12}C/^{13}C$) excursions in marine and terrestrial carbon records across the OAE 2 interval (e.g., Scholle and Arthur, 1980; Arthur et al., 1988). In some sections, high-resolution analyses of the carbon isotope ratio change have been performed on microfossils and lithofacies at the OAE 2 horizon (e.g., Jenkyns et al., 1994; Scopelliti et al., 2004; Tsikos et al., 2004; Kolonic et al., 2005; Erbacher et al., 2005; Caron et al., 2006; Sageman et al., 2006; Kuroda et al., 2007). These results revealed that the organic carbon-rich horizons around the OAE 2 do not accord exactly with the two intervals of positive $\delta^{13}C$ shifts at many sites such as Pueblo, Tarfaya, Eastbourne, and Gubbio. Such discrepancies between total organic carbon contents and $\delta^{13}C$ probably reflect the unique interaction among local paleoceanographic and diagenetic conditions at each site and the global event (Tsikos et al., 2004).

The upper Cenomanian to upper Turonian succession in the Vocontian Basin of southeastern France formed in the northwest Tethyan margin, and the strata consist mainly of hemipelagic limestones and marls. A distinct black shale- and dark gray marl-dominated interval named the Thomel Level (Crumière, 1990) is intercalated at the Cenomanian/Turonian boundary. The Thomel Level is considered to be the sedimentary expression of OAE 2 in the

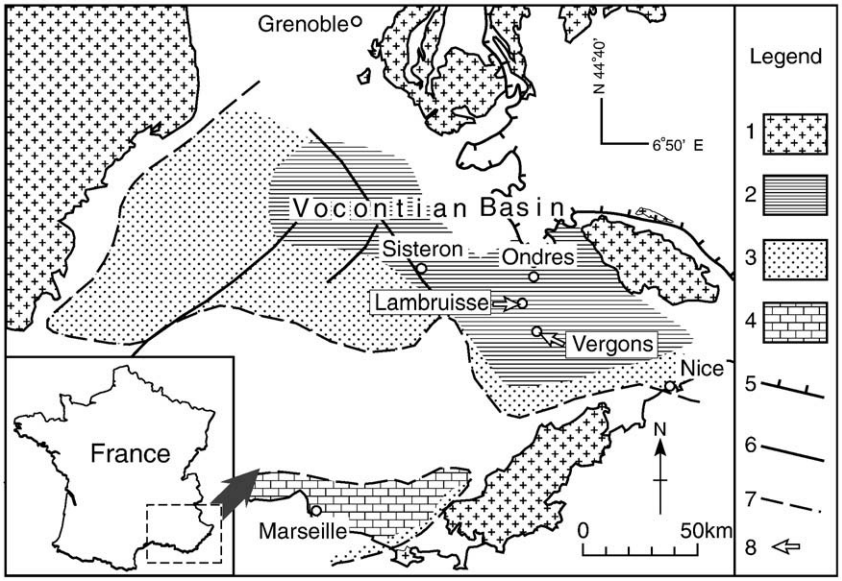

Fig. 2. Distribution of lithofacies around the Dauphinois Basin, SE France. 1. Paleozoic crystalline rocks, 2. basin facies (black shales, marls and pelagic limestones), 3. shelf facies (sandstones, sandy bioclastic limestones), 4. carbonate platform facies (rudist bearing limestones). Modified from Crumière et al. (1990).