Palaeogeography, Palaeoclimatology, Palaeoecology 297 (2010) 367–376

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

# Palaeoceanographic differences of early Late Aptian black shale events in the Vocontian Basin (SE France)

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ARTICLE INFO

*Article history:*
Received 16 March 2009
Received in revised form 23 July 2010
Accepted 27 August 2010
Available online 21 September 2010

*Keywords:*
Black shales
Aptian
Cretaceous
Calcareous nannofossil
Tethys
Sea-level
Carbon isotopes

ABSTRACT

A high-resolution study focussing on the distribution of calcareous nannofossils and carbon isotopes was carried out to improve the understanding of mid-Cretaceous black shale formation. The studied interval of the early Late Aptian is characterized by two major black shale couplets, the Niveau Noire 4 (NN4) and Niveau Noire Calcaire 2 (NNC2), of the Serre Chaitieu section in the Vocontian Basin (SE France; Bréhéret, 1997). This interval occurs within a long-term negative carbon isotope excursion of >1.5‰ following the Early Aptian Oceanic Anoxic Event 1a (OAE1a). In contrast to the local NN4 black shales, the black shales of NNC2 are of regional significance and occur at the end of the major negative carbon isotope excursion of the early Late Aptian. Time equivalent black shales are suggested to be coeval with black shales found in the Western Tethys and Atlantic Ocean (Herrle et al., 2004). Calcareous nannofossil analyses and carbon isotopes indicate higher surface water productivity (mesotrophic), warmer surface water, and higher sea-level during the formation of the NN4 black shales. In contrast, the formation of the NNC2 black shales took place during a cooler phase, lower surface water productivity, and lower sea-level. A sea-level fall may cause a restriction of water mass exchange between the open-marine Western Tethys and the Vocontian Basin. This resulted in a longer residence time of the bottom water, decreased ventilation and less mixing of surface waters and thus enhanced preservation of organic matter at the sea floor. Our results indicate that the black shale formation of NN4 and NNC2 was caused by different processes such as increased surface water productivity and enhanced preservation of organic matter at the sea floor. Thus, we emphasize the role of different forcing factors which control the formation of local and regional black shales. The most important factors are sea-level fluctuations, increasing productivity, and changes in precipitation and evaporation rates.



## 1. Introduction

The mid-Cretaceous has been commonly characterized as a time period when the Earth's climate was in an extreme greenhouse mode and temperatures were elevated on a global scale (e.g. Savin, 1977; Wilson et al., 2002; Jenkyns et al., 2004; Jenkyns, 2010). The land–sea configuration, with large continents in the northern and southern hemisphere separated by the narrow western Tethyan and Atlantic oceans, rendered the low-latitudes highly sensitive to monsoonal activity (Barron et al., 1985; Oglesby and Park, 1989; Wortmann et al., 1999; Herrle et al., 2003a,b; Friedrich et al., 2005; Hofmann et al., 2008; Wagner et al., 2008). Although not entirely responsible for mid-Cretaceous deep water formation, low-latitude sites played an important role in this process and therefore for the formation of black shales in marine marginal and open ocean environments (e.g. Brass et al., 1982; Voigt, 1996; Herrle, 2002; Friedrich et al., 2003, 2008; Herrle et al., 2003a,b).

During the mid-Cretaceous numerous black shale horizons were deposited in the western Tethys and Atlantic Ocean. Some of these black shales are synchronous and observed at global scale and therefore have been termed Oceanic Anoxic Events (OAEs, Schlanger and Jenkyns, 1976). In addition to the OAEs, regionally and locally distributed black shales are common in the Aptian to Albian successions of the western Tethys and the Central Atlantic (e.g. Tornaghi et al., 1989; Bréhéret, 1994, 1997; Herrle et al., 2004; Tiraboschi et al., 2009). These black shale horizons are partly characterized by a cyclic occurrence and have been interpreted as a result of changes in seasonality (e.g. de Boer, 1982; Herbert and Fischer, 1986; Erba, 1992; Erba and Premoli Silva, 1994; Bellanca et al., 1996; Herrle, 2002; Friedrich et al., 2003; Galeotti et al., 2003; Herrle et al., 2003a,b; Tiraboschi et al., 2009). However, the processes of both the OAE and locally and regionally black shale formations are still a matter of debate (e.g. Leckie et al. 2002; Meyers and Negri, 2003; Heimhofer et al., 2006; Negri et al., 2006; Tiraboschi et al., 2009; Jenkyns, 2010) and have been mainly linked to improved preservation

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doi:10.1016/j.palaeo.2010.08.015

due to oxygen depletion and the enhanced burial of organic matter due to increased productivity (e.g. Schlanger and Jenkyns, 1976; Bralower and Thierstein, 1984; Pederson and Calvert, 1990; Erba, 1992, 1994, 2004; Erbacher et al., 1996, 2001; Kuypers et al., 2001; Leckie et al. 2002; Herrle et al., 2003a,b; Bornemann et al., 2005; Hofmann et al., 2008; Wagner et al., 2008; Tiraboschi et al., 2009; Jenkyns, 2010).

To obtain insight into palaeoenvironmental change and formation of regional and local black shales, we studied two black shale couplets the Niveau Noire 4 (NN4) and Niveau Noire Calcaire 2 (NNC2) of the Serre Chaitieu section in the Vocontian Basin (SE France; Bréhéret, 1997; Herrle et al., 2004). Both black shales were formed during the long-term negative carbon isotope excursion of 1.5‰ of the early Late Aptian following the major positive carbon isotope excursion of OAE 1a (Herrle et al., 2004). In contrast to the locally distributed NN4, which occurs only in the Vocontian Basin, the NNC2 is probably coeval with an organic-rich horizon in the Atlantic Ocean (NW Africa) and with a black shale horizon of the Roter Sattel section in Switzerland (see Herrle et al., 2004 for discussion). We used calcareous nannofossils as a proxy for surface water temperature and productivity to investigate the palaeoenvironmental dynamics of the early Late Aptian Vocontian Basin on geologically short time scales (<400 kyrs).

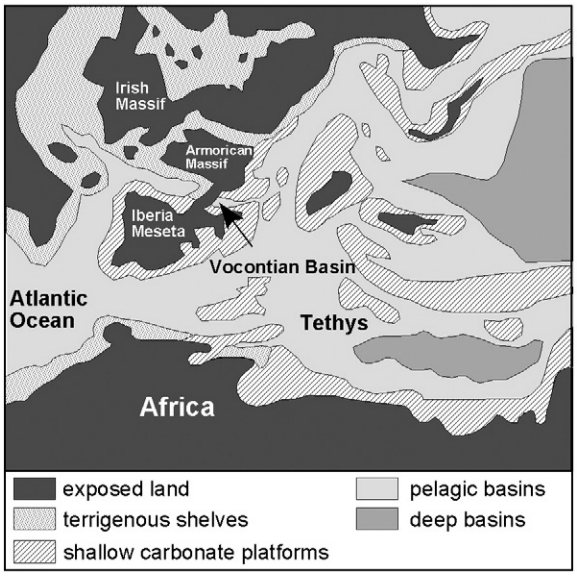


**Fig. 2.** General palaeogeographic map of the Tethyan realm during the Aptian, modified after Masse et al. (1996) and Friedrich et al. (2003). The Vocontian Basin is marked by an arrow.

## 2. Location, palaeogeography, and lithology

The studied Serre Chaitieu section is located in the northern part of the Vocontian Basin near Lesches-en-Dios, SE France (Fig. 1; Lambert III coordinates X: 853 213, Y: 3259 250). During the mid-Cretaceous the Vocontian Basin was situated at a palaeo-latitude of 25° to 30°N at the northern margin of the western Tethys (Savostin et al., 1986; Fig. 2). Following the reconstruction of Masse et al. (1996) the Vocontian Basin is characterized as a marginal basin with a narrow connection in the east to the Western Tethyan Ocean during the mid-Cretaceous. Friedrich et al. (2003) assume that the connection to the east is restricted by a sill. The basin was surrounded by slopes and platforms with a hemipelagic facies intercalating with shallow-water carbonates (e.g. Arnaud-Vanneau et al., 1979; Fries and Parize, 2003).

### 2.1. Studied interval and lithological description

The studied Serre Chaitieu section consists of about 140 m of Early to Late Aptian bioturbated marlstones intercalating with black shale

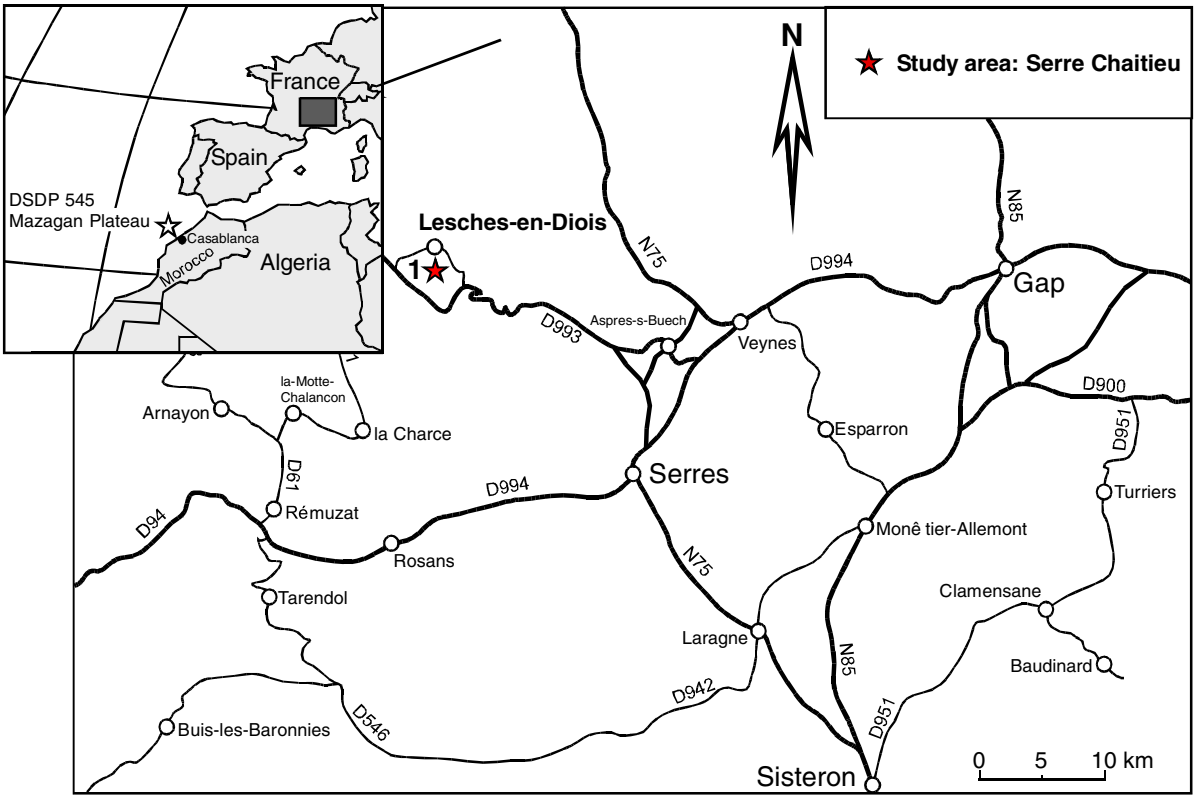


**Fig. 1.** Palaeogeographic map of the Vocontian Basin during the Aptian, modified after Arnaud and Lemoine (1993). The investigated section at the Serre Chaitieu is marked by an asterisk.