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Albian oceanic anoxic events in northern Tunisia: Biostratigraphic and geochemical insights

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ABSTRACT

Albian pelagic successions of the Nebeur area in northwestern Tunisia consist of radiolarian-bearing and organic-rich black shale beds, which represent the lower part of the Fahdene Formation. The carbonate content of the organic-rich beds ranges between 40 and 48%. Total organic carbon (TOC) analyses via Rock Eval pyrolysis yielded values ranging between 0.7 and 2.8% and a mixed marine/terrestrial origin. T_{max} values vary between 424 and 450 °C, indicative of submature to mature organic matter. High resolution planktic foraminiferal and radiolarian biostratigraphy suggest that the black shales beds span the mid- to late Albian, confined to the middle part of the *Ticinella primula* zone, upper *Biticinella breggiensis* zone and lower *appeninica* + *buxtorfi* zone. Episodes of organic-rich deposition in the "Tunisian Trough" are interpreted as being the sedimentary record of the global oceanic anoxic events OAE1b, c, and d respectively. Age-diagnostic radiolarian assemblages recovered from late Albian organic-rich black shales lie within the UA13–UA14 boundary biochronozones. The abundance of radiolarian and calcispheres (i.e. *pithonella*) within the black shales suggests high productivity periods and eutrophic conditions probably triggered by upwelling currents.

1. Introduction

The Albian time was a period characterized by global sea level rise and geodynamic activity expressed by high production of oceanic crust leading to a large degassing rate of CO_2 (Caldeira and Rampino, 1991; Larson (b), 1991). Increased atmospheric CO_2 contents are thus thought to have induced a global "greenhouse" climate (Barron and Washington, 1985; Bice and Norris, 2002). A direct consequence of the above events was the enhanced preservation of organic-rich sediments throughout Western Mediterranean basins of the Tethys (Bréhéret, 1997; Karakitsios et al., 2004; Luciani et al., 2004; Coccioni et al., 2006), recording discrete Oceanic Anoxic Events (Schlanger and Jenkyns, 1976).

Oceanic Anoxic events (OAEs) are widely thought to represent short-lived periods (<1 my) of increased organic carbon burial (Leckie et al., 2002), accompanied by positive carbon isotope excursions in bulk carbonate and organic matter. In some instances, such as with the Toarcian and lower Aptian OAEs, these positive isotopic excursions are preceded by rapid negative excursions (Jenkyns, 1980; Bralower et al., 1993; Strasser et al., 2001; Leckie et al., 2002; Gröcke et al., 2006; Robaszynski et al., 2010). It is also speculated that the Albian was specifically a "hyper-siliceous" period, characterized by the deposition of both organic-rich and biogenic silica-rich sediments (De Wever and Baudin, 1996; Racki and Cordey, 2000).

The widespread occurrence of marine anoxia during OAEs is believed to have been caused largely by massive igneous activity (Turgeon and Creaser, 2008) and increased phytoplankton productivity (Jarvis et al., 2002). Several theories and models have been proposed to explain black shale accumulation scenarios. Erbacher et al. (1996) have distinguished between P-OAE and D-OAE, reflecting increased oceanic productivity and sedimentation of terrestrial organic matter respectively. Galeotti et al. (2003) have postulated two main models for OAE development, namely 1) the preservation model, involving decreased ventilation on the seafloor and low rate of remineralization of organic matter; and 2) the productivity model, which is based on elevated primary productivity causing dysoxic/anoxic environment on the sea floor.

The Albian organic-rich black shale successions outcropping in the northwestern Tethyan margin have been intensively studied using planktic foraminiferal, calcareous nannofossil and radiolarian biostratigraphy, in order to constrain the timing of the OAEs 1b, c and d,

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associated marine biota extinction and turnover events (Erbacher and Thurow, 1997; Premoli silva et al., 1999; O'Dogherty and Guex, 2002; Luciani et al., 2004; Coccioni et al., 2006; Danelian et al., 2007). However, this is not the case for sections of the North African margin, where radiolarian and planktic foraminiferal age-calibration of the Albian OAEs has received less attention. Ammonite and planktonic foraminifera biostratigraphy in conjunction with geochemistry, have been focused primarily on the study of Albian pelagic successions of Northern Tunisia (Burollet, 1956; Massin and Salaj, 1970; Salaj, 1980; Dali-Ressot, 1987; Talbi, 1991; Saïdi and Belayouni, 1994; Memmi, 1999; Ben Haj Ali et al., 2002; Robaszynski et al., 2007; Ben Haj Ali and Ben Haj Ali, 2008; Chihaoui et al., 2010). Although radiolarian-bearing and organic-rich black shales of Albian age have been identified in the same region (Ben Haj Ali and Ben Haj Ali, 1996; Tandia, 2001), no previous studies have hitherto provided a precise age-calibration of organic-rich black shale horizons recording oceanic anoxic events. The objectives of this paper are therefore: 1) to provide an integrated biostratigraphic and geochemical framework of such organic-rich sections based on planktic foraminifera and radiolarian assemblages; 2) to correlate identified OAE intervals with time-equivalent sections from the northwestern Tethyan margin; and 3) to interpret these records in the context of depositional and palaeo-environmental evolution in the Tethyan realm during the Albian.

2. Geological setting

The Nebeur area is located in the northwestern extremity of the 'Domes Belt' of Northern Tunisia (Fig. 1A) and it is palaeogeographically included within a subsidence basin known as the 'Tunisian Trough" ('Sillon Tunisien' of Burollet, 1956). The Domes Belt is a complex structural domain characterized by strike slip faults and Triassic extrusions. The latter have been interpreted as either diapiric (Perthuisot, 1978) and/or interstratified with Albian and Turonian pelagic sediments (Vila et al., 1996; Ghanmi et al., 1999).

The tectonic complexity of the Domes Belt is the result of the succession of two main deformation phases. The first phase is of an early Cretaceous age and is the consequence of the Africa–Eurasia relative plate motion that led to the opening of the Ligurian Tethys Sea (Chikhaoui et al., 1998) and, subsequently, to the disintegration of the Tunisian margin (Martinez et al., 1991). This tectonic event resulted in tilted block topography and triggered halokinetic dynamics. Such tectonic architecture is responsible for instability in the sedimentation patterns, characterized by hiatuses at the horst top as well as in subsiding basins (Chikhaoui et al., 1991, 1998; Memmi, 1999). The second deformation phase is linked to orogenic processes during the late Miocene. It is characterized by compressive tectonics which affected post-Neogene structures and reactivated pre-existing faults. The resulting inter-fingering faults have created tectonic 'corners' and multidirectional folds trending NE–SW, N–S and E–W (Chikhaoui and Turki, 1995).

The associated depositional systems are characterized by mixed argillaceous and siliclastic facies (Valanginian to Aptian) (Bolze, 1954; Chikhaoui et al., 1998), overlain by an Albian to late Cenomanian pelagic facies of monotonous alternations of marl and limestone couplets, termed the Fahdene Formation (Burollet, 1956). The late Cretaceous (Cenomanian to Late Campanian) succession of the Mellegue paleograben comprises an up to 5000 m-thick sequence of largely pelagic sediments.

The study area can be divided into three major structure components, namely the Mellegue paleograben, and the Koumine and southern Nebeur horsts (Chikhaoui et al., 1991) (Fig. 1B).

Based on outcrop exposure and the interpreted geodynamic context, two sections were chosen for this study (Figs. 2,3): the Koudiat Berkouchia section, which borders the Triassic extrusion of South-Nebeur horst, and the Srassif section which is located in the Mellegue paleograben.

3. Materials and methods

A total of 140 samples of marl and limestone were collected for biostratigraphic and geochemical examinations. Organic-rich levels were sampled at relatively higher resolution (approximately every 50 cm). Soft samples were soaked in hydrogen peroxide solution and then washed using standard techniques. Samples were sieved sequentially using meshes of 500 μm–250 μm – 125 μm–63 μm.

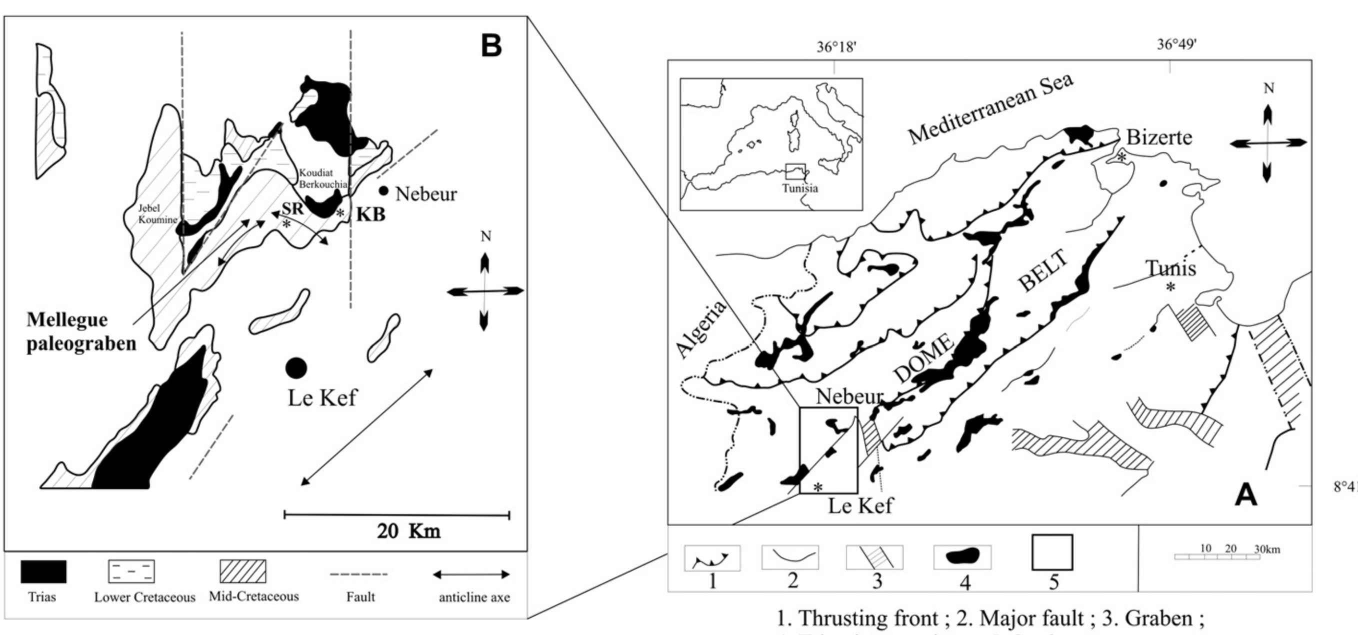

Fig. 1. Location of the study area (A) – Structural map of Nebeur area (B).