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The micropaleontological record of marine early Eocene oil shales from Jordan

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ABSTRACT

Core OS-28 located in central Jordan offers an expanded record of calcareous nannofossils and benthic foraminifera for the early Eocene of the southern Tethys. The oil shale succession of the studied interval covers calcareous nannofossil biozones NP10, NP11, NP12 and NP13. Microfossils document the biotic response of calcareous nannofossils and benthic foraminifera to short and long term warming trends of the early Eocene following the Paleocene-Eocene Thermal Maximum (PETM). On a global scale, two early Eocene short term shifts to higher atmospheric CO_2 concentration are recorded by negative $\delta^{13}C$ excursions. These are known as Eocene Thermal Maximum 2 and 3 (ETM2, ETM3). Stable isotope records ($\delta^{13}C_{org}$, $\delta^{13}C_{carb}$, $\delta^{18}O_{carb}$) from the study area do not show these negative excursions, which elsewhere can be correlated with the two hyperthermal events known from early Eocene successions. The absence of negative $\delta^{13}C$ signals otherwise typical for ETM2 and ETM3 is explained by a diagenetic alteration of the isotope signal after deposition.

High abundances of the nannofossil taxon *Sphenolithus* spp. in biozone NP10 indicate less fertile conditions for this interval than for the overlying biozone NP11. Throughout biozones NP11 to NP13 *Coccolithus pelagicus* and *Toweius* spp. are the dominant taxa of the assemblages, suggesting a mesotrophic environment. Surface waters experienced a temperature change from warm to moderate-warm. The benthic foraminifera in calcareous nannofossils biozone NP10 and in the lower part of NP11 reflect oligo-mesotrophic and moderate to well oxygenated bottom water conditions. Throughout the upper part of biozones NP11, NP12 and NP13, the benthic foraminifera are characterized by an increasing abundance of *Anomalinoides zitteli*, *Lenticulina* spp. and *Valvulineria scrobiculata*. This coincides with enriched total organic matter content (TOC), indicating a shift to mesotrophic conditions and a moderate oxygen supply of the bottom waters. Based on the micropaleontological observations made in core OS-28 the early Eocene is first characterized by an increase and subsequently by a decrease of nutrients and oxygen. The composition of both, benthic and planktic communities was rather controlled by variations of regional environmental parameters than by global ones. These include strong runoff, climatic variability and the architecture of the basin.

1. Introduction

The early Eocene (~56–52 Ma) was a period of rapid climate change that resulted in globally warm conditions. This overall trend in increased warmth was punctuated by two hyperthermal events, the Eocene Thermal Maximum 2 and 3 (ETM2, ~53.6 Ma; ETM3, ~52.5 Ma). Also known as the Elmo or H1-Event (Kennett and Stott, 1991; Lourens et al., 2005; Stap et al., 2010) and the X or K-event (Cramer et al., 2003; Galeotti et al., 2010; Zachos et al., 2010) respectively. In both hyperthermals are associated with short-term rapid increases in CO_2 in the atmosphere-ocean system (Zachos et al., 2001; Zachos et al., 2008) as evidenced by two negative carbon isotope excursions (CIE), resulting from a massive release of ^{13}C-depleted carbon during these transient episodes (Dickens et al., 1995; Lourens et al., 2005). The ETM2 and the ETM3 are marked by a negative carbon shifts of ~+1‰ and (Lourens et al., 2005; Röhl et al., 2005; Galeotti et al., 2010; Zachos et al., 2010; Leon-Rodriguez and Dickens, 2010). These events are recorded in sediments associated to the calcareous nannofossil biozones NP11 and NP12 respectively (Agnini et al., 2009, 2016; Galeotti et al., 2010; Leon-Rodriguez and Dickens, 2010; Stassen et al., 2012; Shamrock and Watkins, 2012; D'Onofrio et al., 2016).

The Paleocene-Eocene Thermal Maximum (PETM, ~56 Ma), which predates the two early Eocene hyperthermals, had a profound impact on both benthic and planktic marine flora and fauna including an extinction event of benthic foraminifera (Tjalsma and Lohmann, 1983; Thomas, 2007) and turnover in planktic foraminifera (Kelly et al., 1998), calcareous nannofossil (Aubry et al., 2007) and dinoflagellate (Sluijs et al., 2007, 2008). Elevated temperatures, carbonate dissolution, and shifts in the

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composition of marine flora and fauna (Cramer et al., 2003; Thomas et al., 2006; Nicolo et al., 2007) are documented from ETM2 and ETM3, although at lower magnitudes than during the PETM.

Previous studies of calcareous nannofossils from the ETM2 and ETM3 intervals globally did not reveal either variations in their assemblage composition or evidence of excursion taxa (Agnini et al., 2009, 2016; Gibbs et al., 2012; Shamrock and Watkins, 2012; D'Onofrio et al., 2016). Benthic foraminifera assemblage turnover is documented at the PETM in shelf and deep water sections (Thomas, 2007; Stassen et al., 2009; Stassen et al., 2015), but no extinctions have been observed for ETM2 (Stassen et al., 2012; D'haenens et al., 2012, 2014) or ETM3 (Agnini et al., 2009).

We record here new data on the distribution of calcareous nannofossils and benthic foraminifera and geochemistry from the early Eocene, based on the analyses of a cored well (OS-28) from central Jordan. This study aims at reconstructing the surface and bottom water conditions during the early Eocene by documenting the diversity and abundance patterns of calcareous nannofossils and benthic foraminifera. Furthermore, we want to test whether the two post-PETM hyperthermal events (ETM2, ETM3) are recorded in the sediments and in the stable isotope records ($\delta^{13}C_{org}$, $\delta^{13}C_{carb}$, $\delta^{18}O_{carb}$).

2. Material and methods

Core OS-28 has a total cored depth of 146.5 m and is located approximately 110 km east of Amman in the Azraq-Hamza Basin in east central Jordan (Fig. 1A). The core was drilled by the Jordan Oil Shale Company (JOSCO B.V.) in 2010. The cored sediments stratigraphically belong in the Belqa Group, part of the Um Rijam Chert-Limestone Formation of early Eocene age (Andrews, 1992). Lithologically, the studied interval (43.50–37.90 m; 5.60 m thick) can be subdivided into sequences of light grey marly and white chalky limestones. The studied succession is heavily bioturbated by the trace fossil *Phycosiphon incertum*. The interval from 42.95 and 42.65 m is missing due to a recovery gap in the core (Fig. 2).

2.1. Calcareous nannofossils and benthic foraminifera

Calcareous nannofossil slides were prepared from 107 samples following the random settling technique of Geisen et al. (1999). 300 specimens/slides were counted using an Olympus BX-51 light microscope with cross-polarized light and a magnification of 1250×. Photos were taken using an Olympus SC100 digital color camera to document the most important taxa (Plate 1). Calcareous nannofossils were identified following the taxonomic concepts of Perch-Nielsen (1985), Bown (1998) and Bown (2005).

For benthic foraminifera a total of 13 samples were dried and soaked in a Na_2CO_3 solution. Subsequently they were washed over a stacked 500 μm, 125 μm and 63 μm sieve set. A representative split for quantitative analysis (300 benthic foraminifera per sample) was obtained from the >125 μm fraction by using an Otto microsplitter. For this study, the benthic and planktic foraminiferal numbers (BFN, PFN) and the planktic-benthic ratios (%P) were calculated (Fig. 3B). The benthic foraminifera were identified by using the taxonomic concepts of LeRoy (1953), Van Morkhoven et al. (1986) and Speijer (1994); for details see Appendix A. Paleobathymetric interpretations are based on Van Morkhoven et al. (1986) and Speijer (1994), who define inner neritic (IN: 0–50 m), middle neritic (MN: 50–100 m), outer neritic (ON: 100–200 m) and upper bathyal conditions (UB: 200–500 m). Scanning Electron Microscopy (SEM) was used to identify the most important taxa of benthic foraminifera (Plate 2).

Species richness (S), Shannon diversity (H (s), Shannon and Weaver, 1949) and dominance (D) were calculated based on the relative counts of calcareous nannofossils and benthic foraminifera (Fig. 3 A, B). Cluster analyses (CA) were carried out in R-mode on selected taxa using the Pearson correlation, grouping taxa with similar distribution patterns through time (CA; Figs. 4, 5). Detrended correspondence analyses (DCA) in Q-mode (grouping of associations) were performed to identify and compare paleoecological factors prevailing during the early Eocene (Figs. 6, 7). The most abundant calcareous nannofossils (≥1.5% in at least one sample) are documented (Fig. 4).

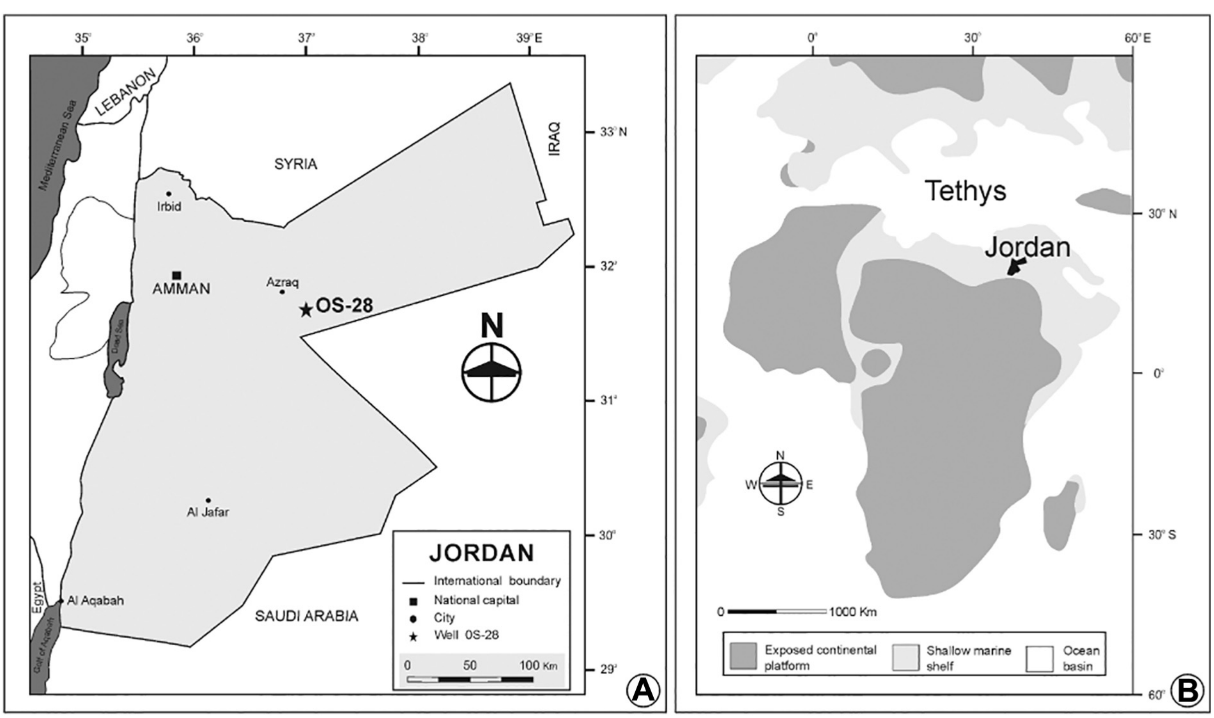

Fig. 1. A. Location map of core OS-28 in Jordan. B. Paleogeographic map of the Tethys during the late Cretaceous and Paleogene. Modified from Li and Keller (1998), Abed (2013) and Alqudah et al. (2014).

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