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Cenomanian–turonian stable isotope signatures and depositional sequences in northeast Egypt and central Jordan

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ABSTRACT

Lithostratigraphic, biostratigraphic and microfacies studies of two Cenomanian-Turonian shallow-marine, siliciclastic-carbonate successions at Gebel Ekma plateau (southwestern Sinai, Egypt) and Wadi Karak section (central Jordan) are calibrated with $\delta^{13}C$-, profiles to reveal relative sea-level changes within a sequence stratigraphic framework. The study provides significantly enhanced stratigraphic resolution and key sections for regional correlation. Lithofacies are dominated by well-developed peritidal to subtidal facies associations indicating deposition in a rimmed carbonate shelf setting. Biostratigraphic analysis indicates the presence of 6 ammonite zones, 3 calcareous nannofossil zones and 3 planktonic foraminiferal zones within the Cenomanian to Turonian succession. Six, third-order depositional sequences, bounded by correlatable sequence boundaries can be traced across the African-Arabian platform. Comparison with $\delta^{13}C$ records in deeper water pelagic sequences help to improve the resolution of the boundaries of each depositional sequence. Recognition of time gaps at the sequence boundaries on the platform, recorded in different parts of African-Arabian platform, is attributed to local tectonic activity, associated with the change from passive to active margins, which are overprinted by the global eustatic signature.

1. Introduction

Stable carbon isotope stratigraphy calibrated with integrated planktonic biostratigraphy and facies tract changes represent a powerful tool for regional stratigraphic correlation. Oceanic Anoxic Event 2 (OAE2) which occurred at the Cenomanian/Turonian (C–T) boundary (about ~93.9–94.5) coincides with maximum and falling 405-kyr eccentricity is the most widespread and best defined OAE of the mid-Cretaceous (Jenkyns, 1980; Turgeon and Creaser, 2008; Meyers et al., 2012; Laurina et al., 2016).

The C–T boundary interval represents a classic example of an OAE as it is typified by the development of organic carbon-rich deposits on a global scale, with a positive shift in carbon-isotope values in marine carbonates (e.g. Arthur et al., 1988; Hasegawa, 1997). The carbon isotope excursion and the distribution of organic-rich sediments during OAE 2 have been described from numerous surface outcrops and deep sea cores around the world (e.g. Pratt and Threlkeld, 1984; Schlanger et al., 1987; Arthur et al., 1988; Thurow et al., 1992; Hasegawa, 1997; Holbourn and Kuhnt, 2002; Tsikos et al., 2004). The interval is characterized by major perturbations in oceanographic conditions such as deep water pelagic realms, ocean upwelling and anoxia (Schlanger and Jenkyns, 1976). Global, biogeochemical cycles resulted in submarine burial of organic carbon, which in turn, resulted in a positive shift in $\delta^{13}C$ of organic carbon and carbonate (Schlanger et al., 1987; Arthur et al., 1985a, 1985b,1988; Hayes et al., 1989) and an overturn of macro- and microfaunas, including molluscs, planktonic foraminifera and calcareous nannoplankton (Leckie, 1985; Elder, 1989; Premoli Silva et al., 1999; Leckie et al., 2002; Erba, 2004). These perturbations in global oceanographic conditions are reflected in eustatic sea-level changes that resulted in transgressive, southeastward onlap of Neo-Tethys during Cenomanian-Turonian times onto the Arabian Plate (Sharland et al., 2004; Powell and Moh'd, 2011).

In Egypt and Jordan, previous studies focused on improving the sequence stratigraphic framework of the Cenomanian-Turonian platform succession (e.g., Bauer et al., 2003; Schulze et al., 2005; Saber, 2012; El-Hariri et al., 2012; Anan et al., 2013; Farouk, 2015). However, there are disagreements on the timing and correlation of the depositional events. To better constrain these depositional events across the Arabian Plate in Jordan and Egypt this

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paper focusses on the shallow-marine, siliciclastic-carbonate successions of Cenomanian-Turonian age at Gebel Ekma plateau (southwestern Sinai, Egypt) and Wadi Karak (central Jordan).

Lithostratigraphic, biostratigraphic (ammonite, planktonic foraminifera, and calcareous nannofossils) and microfacies analyses were calibrated with $\delta^{13}C$ (see below) analyses to investigate relative sea-level changes and the sequence stratigraphy framework. This has allowed maximum flooding surfaces (MFS), and the regional correlation of sequence boundaries. Relative sea-level fluctuations on the southern margin of Neo-Tethys have been determined, and the relative importance of global eustacy and the effect of local tectonics on the development of depositional sequences enable correlation with the global sea-level charts (Hardenbol et al., 1998; Stampfli and Borel, 2002; Haq and Al-Qahtani, 2005; Haq, 2014). Biostratigraphic calibration of the age of the recorded sequences provides a means of correlating third-order sequence stratigraphic surfaces across the African/Arabian platform and with other regions of Neo-Tethys. The study has enabled a better understanding of how the disruption in the carbon cycle influenced the neritic biological communities in shallow carbonate/siliciclastic settings during the Cenomanian-Turonian age.

2. Materials and methods

Two well-exposed stratigraphic sections of the shallow-marine, Cenomanian-Turonian succession in Egypt and Jordan have been studied (Fig. 1): the Gebel Ekma plateau (28°47′45″N; 33°13′19″E) in southwestern Sinai and Wadi Karak (31°02′17″N; 35°34′55″E) in central Jordan. Lithofacies analyses of these sections are based on field observations, including lithology, faunal content and microfacies analysis. For the latter study, sixty-five thin-sections were prepared to examine the petrography and microfacies following the classification schemes of Dunham (1962) and Pettijohn et al. (1987). Ninety samples from the Wadi Karak section and fifty two samples from the Gebel Ekma plateau section were selected for stable isotope analysis ($\delta^{13}C$ and $\delta^{18}O$) with sample spacing of between 0.20 to 1 m; these were calibrated with integrated planktonic biostratigraphy including ammonites, calcareous nannofossils and planktonic foraminifera to provide an improved local and regional biostratigraphical correlation. The chronostratigraphic framework used in this study is based on the planktonic foraminiferal biozonations of Caron (1985) and Robaszynski et al. (2000), and the CC nannofossil zonation of Sissingh (1977) and Perch-Nielsen (1985). Ammonite zonation is based on the Egyptian ammonite zones (Farouk, 2015), while the chronostratigraphic time scale is based on Gradstein et al. (2012).

The bulk-carbonate samples were dried, micro-drilled and weighed prior to grinding. Carbon and oxygen isotope measurements were performed in the Environmental Isotope Laboratory, Department of Geosciences, University of Arizona using an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). Total carbon and sulfur were determined by analysis using a LECO SC632 device, while the total organic carbon (TOC) was determined by carbon analyzer (TOC 2000) after the removal of carbonates by 10‰ hydrochloric acid in the Egyptian Petroleum Institute central laboratory.

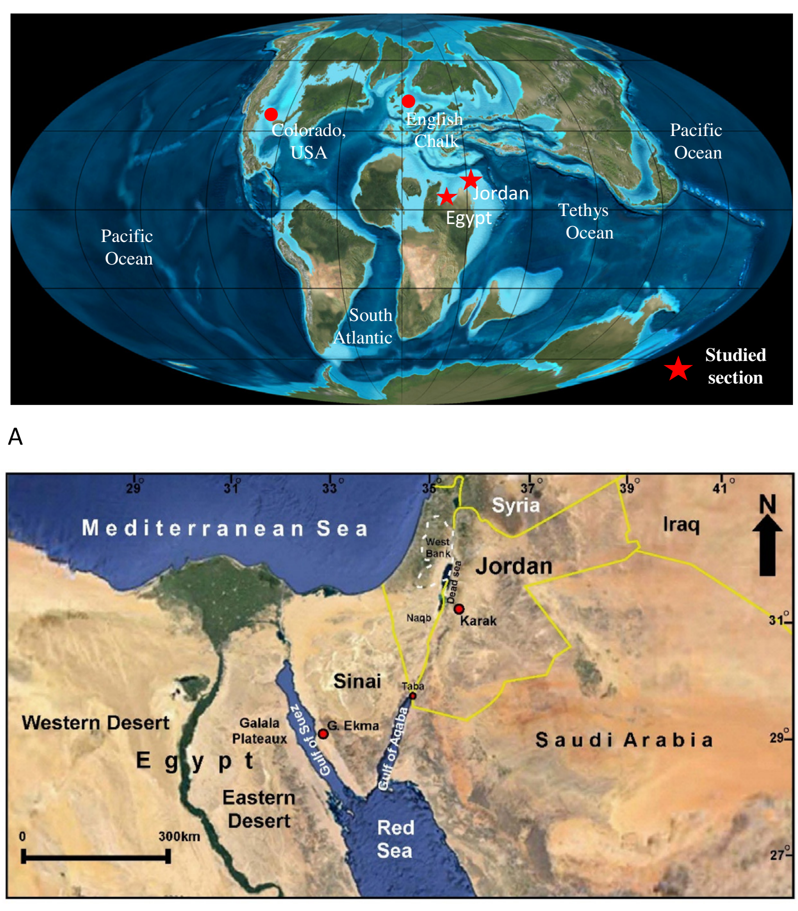

Fig. 1. (A) Cenomanian-Turonian paleogeography and location of sites. Reconstructions after R.C. Blakey, NAU Geology (http://cpgeosystems.com). (B) Landsat image showing the location of the studied sections (Gebel Ekma in northeast Egypt and Karak section in central Jordan; source from Google Earth).