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Stable-isotope stratigraphy of the Cenomanian–Turonian (Upper Cretaceous) boundary event (CTBE) in Wadi Qena, Eastern Desert, Egypt

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ABSTRACT

A high-resolution $\delta^{13}C$ isotope record from Cenomanian–Turonian boundary interval of shallow marine successions in Egypt is presented. The $\delta^{13}C$ curves show the typical features of the globally documented Cenomanian–Turonian positive excursion, including three of the main positive isotope peaks defining the Cenomanian–Turonian Boundary Event (CTBE). Based on high-resolution ammonite biostratigraphy, the CTBE started in the study area above the Late Cenomanian *Neolobites vibrayeanus* Zone within the Galala Formation, directly above the global sequence boundary Cenomanian 5 (SB Ce 5). A stratigraphic gap at that level cuts out the lower a-peak of the CTBE. The Cenomanian–Turonian boundary is located within the upper part of the positive excursion between carbon excursion peaks c and d, coinciding with the boundary between the Late Cenomanian *Vascoceras cauvini* and the Early Turonian Vascoceratid zones. The CTBE ended up-section of peak d, at the base of the *Choffaticeras* spp. Zone. The amplitude of the positive $\delta^{13}C$ excursion in Egypt is very high (reaching 6.5‰ vs. V-PDB) and largely matches curves of European standard sections and others localities from different basins. Furthermore, the Lower Turonian Holywell Isotope Event, an important marker within the lowermost Turonian, has tentatively been recognized. The positive carbon stable isotope curves presented herein represent the outreach of the oceanic anoxic event (OAE) 2 in shallow-water nearshore sequences.

1. Introduction

The early Late Cretaceous Cenomanian–Turonian Boundary Event (CTBE) is one of the most important global Cretaceous positive carbon stable isotope events (e.g., Jarvis et al., 2006; Voigt et al., 2008; Wendler, 2013). This event occurred across the Cenomanian–Turonian boundary (about 93.9 Myr ago; Hinnov and Ogg in Gradstein et al., 2012) and reflects by one of the most extreme carbon cycle perturbations in Earth's history (oceanic anoxic event (OAE) 2, e.g., Sageman et al., 2006; Voigt et al., 2008; Jenkyns, 2010; Jarvis et al., 2011). Cretaceous OAEs, as originally defined by Schlanger and Jenkyns (1976) and Jenkyns (1980), were periods during which much of the world's oceans became severely depleted in oxygen and widespread deposition of organic carbon-rich sediments took place. Burial of organic carbon, which preferentially sequesters isotopically light carbon during OAEs, resulted in a positive $\delta^{13}C$ excursion in the geologic record and even if black shales are not developed, the carbon isotope excursions are useful markers for recognizing OAEs and facilitate trans-continental correlation (e.g., Gröcke et al., 1999; Takashima et al., 2006; Wendler et al., 2011). The positive carbon isotopic excursion accompanying OAE2 has been mainly been recorded from pelagic carbonate sediments (e.g., Jarvis et al., 2006, 2011; Voigt et al., 2007, 2008; van Bentum et al., 2009; Richardt and Wilmsen, 2012; Bomou et al., 2013), subordinately also from shallow marine successions (e.g., Elrick et al., 2009; Gertsch et al., 2010b; Wilmsen et al., 2010) and in terrestrial organic matter (e.g., Nemoto and Hasegawa, 2011). The importance of the less well studied nearshore OAE2 records, such as that of Egypt, is related to the fact that these settings are situated at the interface between open-ocean and terrestrial realms; such settings document important physical, biological, and climatic processes (e.g., sea-level changes) not readily detected in either pelagic or terrestrial deposits alone (Elrick et al., 2009). However, only a few studies (Gertsch et al., 2010a; El-Sabbagh et al., 2011; Anan et al., 2013) on Cenomanian–Turonian boundary nearshore successions in Egypt have been

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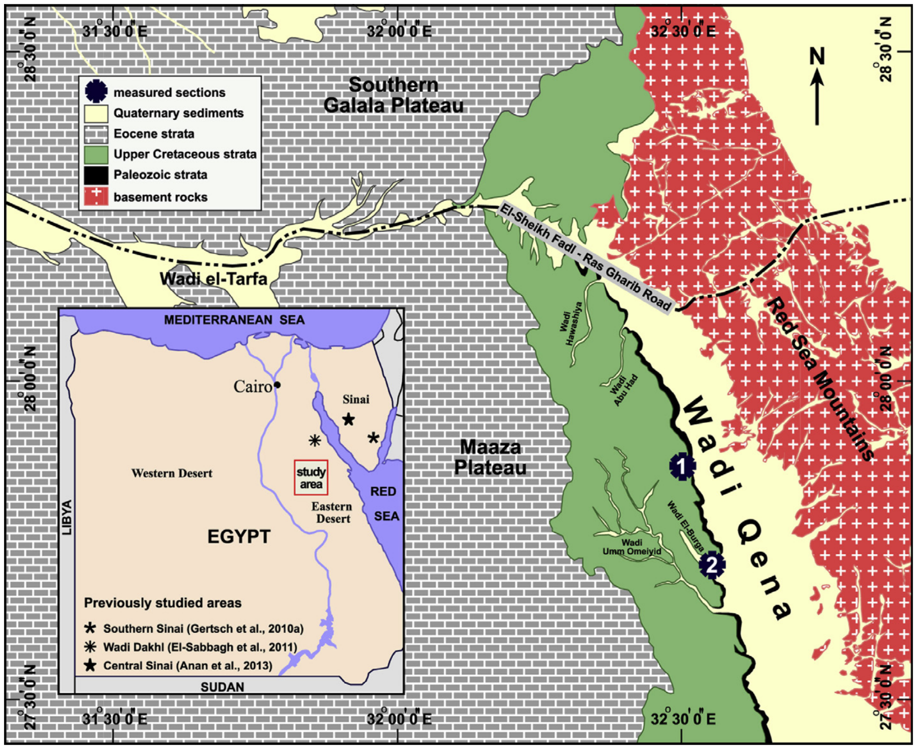

Fig. 1. Simplified geological map of the study area (modified after Conoco, 1987) with indication of the study area in Egypt and position of the measured Upper Cenomanian–Lower Turonian sections in Wadi Qena. Furthermore, the positions of sections where the CTBE isotope excursion has been studied in Egypt are provided.

conducted so far, leading to the identification of the CTBE excursion. The present paper aims at enhancing the knowledge about this important event by means of the stable isotopes ($\delta^{13}C$ and $\delta^{18}O$) records derived from well exposed sedimentary successions in Wadi Qena (Fig. 1), plotted against detailed litho-, bio- and sequence stratigraphic logs, providing a high-resolution stratigraphic reconstruction of the CTBE in Egypt. In addition, the $\delta^{13}C$ curve of the study area is correlated to the European CTBE reference section at Eastbourne, England, and to the Tethyan Pont d'Issole section, France, and to the Middle East Ghawr Al Mazar section, Jordan.

2. Geological setting

Marine Cenomanian–Turonian rocks are well-exposed in the northeastern part of Egypt in Sinai and the Eastern Desert. Wadi Qena occupies a large area in the northern and central parts of the Eastern Desert with well-exposed Upper Cretaceous successions at the western margin of the wadi (Fig. 1). From the southern slopes of the Southern Galala Plateau, Wadi Qena extends south-southeastwards for about 200 km down to the town of Qena where it grades into the River Nile valley. Wadi Qena is bordered by the serrated, varicoloured basement rocks of the Red Sea Mountains in the east and the uniform, elevated and flat-topped Maaza Plateau consisting of Eocene limestone in the west (Fig. 1).

Wadi Qena clearly developed along faults that run parallel to the Gulf of Suez and the Red Sea Mountains, which are well exposed at numerous places within the wadi, especially on the eastern side (Bandel et al., 1987). Most of the Paleozoic strata are non-marine and well-distributed in the northern part of the wadi. Marine transgression took place in the study area during early Late Cretaceous times when Egypt was situated at the southern margin of the Neotethys (Fig. 2). Following the Late Cenomanian transgression, the shoreline was located in southern part of Wadi Qena, indicated by strong siliciclastic input and the disappearance of marine strata to the south (e.g., Wilmsen and Nagm, 2013). The Cenomanian–Turonian ages witnessed the most widespread Cretaceous transgression in Egypt, with maximum flooding during Early Turonian times (e.g., Sharland et al., 2001; Wilmsen and Nagm, 2013). As a consequence, a widespread peri-continental shelf sea covered large parts of the area. The marine transgression continued (with some intermittent phases of regression) during the later parts of the Late Cretaceous and the Paleogene, documented by well-exposed and widely distributed Coniacian–Eocene strata as exposed in the western part of Wadi Qena (Fig. 1). The most recent sediments in the study area are the Quaternary alluvial fans which cover the low-lying plains of Wadi Qena (Fig. 1).

3. Sections and stratigraphic framework

Two sections from the central part of Wadi Qena in the north Eastern Desert have been measured in great detail at the western margin of the wadi. The mid-Wadi Qena section (no. 1 in Fig. 1) is located 30 km south of the El-Sheikh Fadl–Ras-Gharib road at 27°52′24″N and 32°32′48″E. The second section (Wadi El-Burga section, no. 2 in Fig. 1) is located 15 km south of mid-Wadi Qena section at the mouth of Wadi El-Burga entering Wadi Qena (27°45′12″N and 32°33′37″E). The succession starts with a non-marine sandstone unit (Naqus Formation) of Paleozoic age which consists of kaolinitic, white to yellowish-brown, well-sorted, medium to coarse-grained, cross-bedded sandstone with scattered quartz granules and pebbles. The top of the Naqus Formation contains intensive root traces that may indicate truncated paleosols, marking an erosional unconformity at the base of the overlying Galala Formation (Figs. 3 and 4). This surface has been equated with the late Middle Cenomanian sequence boundary Cenomanian 4 (SB Ce 4) that fused with the early Late Cenomanian transgressive surface of the following sequence (Wilmsen and Nagm, 2013).

The Galala Formation starts with silty, glauconitic sandstones yielding the trace fossil *Thalassinoides* isp. and fragmented mollusc