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Thanetian transgressive-regressive sequences based on foraminiferal paleobathymetry at Gebel Matulla, west-central Sinai, Egypt

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A B S T R A C T

Qualitative and quantitative analysis of Thanetian foraminiferal assemblages at Gebel Matulla in west-central Sinai has been carried out. Three benthic foraminiferal assemblages are recorded from shallowest to deepest as *Cibicidoides pseudoacutus*, *Angulogavelinella avnimelechi*, *Gavelinella danica* witch evidences of fluctuations from middle neritic to upper bathyal environments. Changes in the foraminiferal population enabled us to classify the Thanetian succession into two fourth order transgressive-regressive (T–R) sequences. Three sequence boundaries are identified, at the Selandian/Thanetian (S/T) boundary, within the Thanetian succession, and the Paleocene/Eocene (P/E) boundary. It occurs at the top part of the maximum regression associated with major discontinuities and changes in depositional regimes as well as vertical facies changes. Broad correlation with eustatic records based upon integrated microplanktonic biostratigraphy suggests that the fluctuations of foraminiferal population were controlled by global sea-level changes.

1. Introduction

The Thanetian Stage is the uppermost stratigraphic stage of the Paleocene Epoch and spans the time from 59.2 to 56 Ma. According to Global Stratotype Section and Point (GSSP), the base of the Thanetian occurs in the Zumaya section of northern Spain, occurs within the upper part of nannofossil Zone NP6 and equivalent planktic foraminifera P4a Subzone corresponds to the base of magnetochron C26n (Schmitz et al., 2011). The Thanetian Stage is not associated with any significant change in marine micro-fauna or flora, so that it is difficult to use faunal content to correlate it globally and identify its base (Schmitz et al., 2011). In Egypt, the Selandian/Thanetian boundary is extremely difficult to delineate, and it lies within the middle of the Tarawan Chalk Formation, in southern Egypt (Berggren et al., 2012).

The Paleocene microplanktonic biostratigraphy in Sinai was subjected to a detail investigation during the last years (e.g. Lüning et al., 1998; Samir, 2002; Ayyad et al., 2003; Speijer, 2003; Farouk and Faris, 2008; Faris and Farouk, 2012; Khozyem et al., 2013). Furthermore, the Thanetian Stage and its relative sea-level fluctuations are stratigraphically controversial in Egypt and remains a particular subject of debate.

In order to understand the controls on sequence development, it is first necessary to determine the paleoenvironments and relative sea level. Foraminifera are diverse, abundant and widely distributed in Egyptian Paleocene deposits, and they are excellent indicators of paleodepth and oceanic productivity (e.g., Van der Zwaan et al., 1999; Alegret and Ortiz, 2012). It is therefore reasonable to expect that the foraminiferal facies of a particular sedimentary package will contain important information reflecting transgressive-regressive (T-R) developments.

A T–R sequence was originally defined as a sedimentary unit comprised of a transgressive phase, which shows an upward deepening event, and a regressive phase, which shows an upward shallowing event; the two phases are separated by a maximum flooding surface (Johnson and Murphy, 1984; Johnson et al., 1985; Embry, 1993, 1995, 2002). This definition is useful in hemipelagic facies that lack a physical boundary (Lüning et al., 1998; King, 2013). T-R sequences may enable workers to objectively determine correlative conformity across different areas by using the maximum regressive surface (Embry, 1995). The

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present study aims to 1) to establish a high resolution biostratigraphic scheme based on the integration of planktonic foraminiferal and calcareous nannofossil datums; 2) detect paleoenvironmental changes and faunal turnover during the Thanetian succession at Gebel Matulla using qualitative and quantitative analyses of foraminiferal assemblages; 3) classify this succession into T-R cycles; and 4) correlate the Gebel Matulla sequence with other localities inside and outside Egypt to detect episodes of eustatic sea level change.

2. Material and methods

A total of 22 samples covering the Thanetian interval were collected from Gebel Matulla section (29°01′02″N, 33°12′45″E; Fig. 1), sampled at intervals from 0.2 to 0.5 m. T-R sequences and their boundaries are recognized on the basis of foraminferal paleobathymetry and major lithofacies shifts. Age control for the study interval relies primarily on planktic foraminifera and calcareous nannofossil biostratigraphy. About 20 g of dry rock sample were soaked in 10‰ hydrogen peroxide, disaggregated in water, washed through a 63 μm sieve, and then dried for foraminiferal analyses. All residues were investigated under an Olympus SZX7 binocular microscope. Nannofossils were identified by preparing smear-slides, and examined under a light microscope at 1250× magnification by both cross-polarized and phase-contrast methods.

3. Results

3.1. Lithofacies

The Paleocene succession consists of, in stratigraphic order from older to younger, the Dakhla Shale (Danian–Selandian), Tarawan Chalk (Thanetian), and Esna Shale (Thanetian–Ypresian). The lithofacies in this study includes the calcareous mudstones of the Dakhla Shale Formation followed upwards by pale yellow gray to medium gray, variably argillaceous chalky limestone with few chert nodules in the Tarawan Chalk and finally the Esna Shale, with calcareous shales and mudstones with a few calcareous sandstone ledges towards the top (Fig. 2). The Tarawan Chalk is marked by a sharp contact and vertical facies change near the Dakhla Shale/Tarawan Chalk and the Tarawan Chalk/Esna Shale formational boundaries (Fig. 2).

3.2. Planktic foraminiferal biostratigraphy

Planktic foraminifera are extremely varied in their abundance, diversity, and preservation. In this study, the planktic biostratigraphy has been identified in the studied interval according to zonal scheme of Berggren and Pearson (2005) and Wade et al. (2011). Zonation is based on the highest and lowest occurrence (HO and LO, respectively) of the marker species. The *Globanomalina pseudomenardii* (P4) Zone is classified into three subzones P4a, P4b and P4c. Zonation relies on the following markers: the LO of *Globanomalina pseudomenardii* identifies the base of Subzone P4a, the HO of *Parasubbotina variospira* identifies the base of Subzone P4b, and the LO of *Acarinina soldadoensis* identifies the base of Subzone P4c. The dominant species in the P4 Zone include angular morozovellids such as *Morozovella acuta*, *Morozovella aequa*, *Morozovella velascoensis*, *Morozovella occlusa*, in addition to *Acarinina mckannai*, *A. strabocella* and *Subbotina velascoensis*.

Some bioevents (e.g., the LO's of *Morozovella aequa, M. acuta,* Fig. 3) show variations in the stratigraphic ranges in the basal part of the studied section, within the P4a Subzone, while in other zonal schemes these bioevents are found relatively high within Subzone P4b (Olsson et al., 1999). Similarly early occurrences have also been reported by Arenillas (2011) in the Caravaca section in Spain as well as in Egypt (Faris and Farouk, 2012; Farouk and Faris, 2013).

The *M. velascoensis* (P5) Zone is defined as the interval between the HO of *G. pseudomenardii* and the LO of *A. sibaiyaensis* (Berggren and Pearson 2005; Wade et al., 2011). In this biozone, the morozovellids decrease in abundance and diversity, associated by increase of acarininids (*A. soldadoensis*) and subbotinids (*S. velascoensis* and *S. triangularis*). A planktic foraminiferal faunal turnover is obvious with the incursion and dominance of warm-water acarininids such as *Acarinina africana, A. sibaiyaensis* and *Morozovella allisonensis* (Fig. 3).

3.3. Calcareous nannofossil biostratigraphy

Nannofossils are frequent to common with moderate to good preservation in the studied section. Four nannofossil zones (NP5, NP6, NP7/8 and NP9) have been identified in the studied interval according to zonal scheme of Martini (1970, 1971). The basal part of the studied interval (samples 107–109) belongs to the *Fasciculithus*

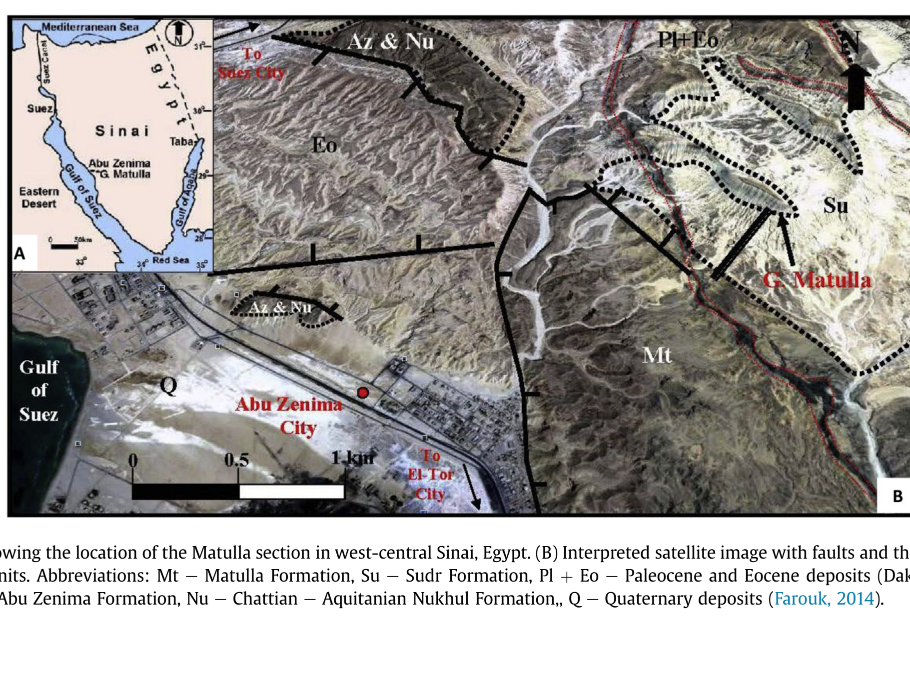

Fig. 1. (A) Schematic map showing the location of the Matulla section in west-central Sinai, Egypt. (B) Interpreted satellite image with faults and the distribution of Cretaceous and Cenozoic lithostratigraphic units. Abbreviations: Mt – Matulla Formation, Su – Sudr Formation, Pl + Eo – Paleocene and Eocene deposits (Dakhla, Tarawan, Esna and Thebes formations), Az – Oligocene Abu Zenima Formation, Nu – Chattian – Aquitanian Nukhul Formation,, Q – Quaternary deposits (Farouk, 2014).