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Paleotemperatures and paleodepths of the Upper Cretaceous rocks in El Qusaima, Northeastern Sinai, Egypt

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ABSTRACT

The planktonic foraminiferal morphogroups and planktonic quantitative analysis as well as the lithological variations across the Coniacian to Maastrichtian sediments of El Qusaima section (Northeastern Sinai, Egypt) are studied in detail in order to detect the prevailing paleoecological conditions along these sediments. At the studied area of El Qusaima section there is a gradual cooling started at the base of *Globotruncana elevata* Zone (early-middle Campanian) of the lower part of the Markha Member and continued till *Globotruncana aegyptiaca* Zone (Late Campanian) of the upper part of the Markha Member. This trend corresponds to the onset of a global cooling that began at about 73 Ma (Late Campanian) and ended the Cretaceous greenhouse climate mode. At El Qusaima section, a gradual warming started at the base of *Pseudogumbelina palpebra* Zone (Late Maastrichtian) and continued till *Plummerita hantkeninoides* Zone (latest Maastrichtian) due to the high abundance of *Plummerita hantkeninoides* and *Plummerita reicheli*, which have been flourishing in warm waters. So this warming near the end of the Maastrichtian is a global event as shown by many authors.

1. Introduction

The faunal and lithological variations across the Coniacian – Maastrichtian succession in Egypt have been dealt with by many workers (e.g., Cherif et al., 1989; Shahin and Kora, 1991; Ayyad et al., 1996; Lüning et al., 1998 and Bauer et al., 2001). However, no attention has been given to the planktonic foraminiferal morphogroups across these sediments and their significance. Therefore, this paper presents detailed information on the planktonic characteristic morphogroups that have prevailed during the Cretaceous and evaluate evidence for sea level fluctuation of El Qusaima section, which located in northeastern Sinai (Egypt), about 13 km west of Sinai-El Naqab boundary and 90 km south-west of El Arish town, (Latitudes 30° 20′ and Longitudes 34° 20′. The area of El Qusaima includes a good exposed of Upper Cretaceous sequence in two mountains (Gebel El Risha which includes a Turonian–Campanian sequences and Gebel Al Ain which includes a Maastrichtian-Eocene sequences) separated by a major fault along it runs Wadi El Risha (Fig. 1).

1.1. Paleotemperatures

The Cretaceous represents one of the most remarkable episodes of greenhouse climate in Earth's history. It was characterized by high atmospheric CO_2 concentrations, low latitudinal temperature gradient and unusually high deep water temperature in the global ocean (Hay, 1995). The release of mantle CO_2 from this very active volcanic episode may have in fact directly caused the warm mid-Cretaceous greenhouse climate (Larson, 1991).

Barrera and Huber (1990), Barrera (1994), Barrera et al. (1997) and Li and keller (1998a) studied the oxygen isotope in southern middle and high latitudes in sites 525 and 690 and illustrated that the major climatic cooling at the Campanian–Maastrichtian boundary may be associated with continental ice accumulation on Antarctica. A global cooling during the Campanian and Maastrichtian has been suggested based on planktonic and benthic foraminiferal stable isotope data (e.g., Clarke and Jenkyns, 1999; Huber et al., 2002). The Campanian/Maastrichtian cooling is thought to have had significant impact on the formation of deep water masses in the world's oceans (e.g., MacLeod and Huber, 1996; Barrera and Savin, 1999).

The Maastrichtian climate was characterized by long-term cooling followed by short-term warming and rapid cooling near the end of the Maastrichtian (Shackleton et al., 1984; Barrera and Huber, 1990; Barrera, 1994; Li and Keller, 1998a,b, 1999). Salinity fluctuations indicate that during the short-term global warming, high-latitude deep-water production was significantly reduced and warm saline deep waters, probably originating in the shallow middle and low latitude regions of the Tethys, flooded the ocean basins (Li and Keller, 1998b). The rapid warming may have been caused by increased CO_2 due to major Deccan Trap volcanism (Courtillot

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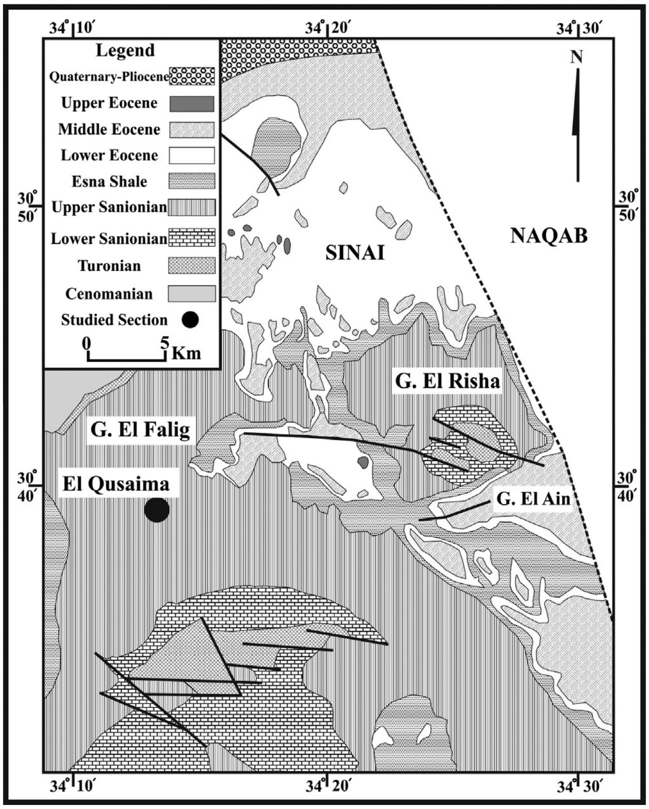

Fig. 1. Locality map.

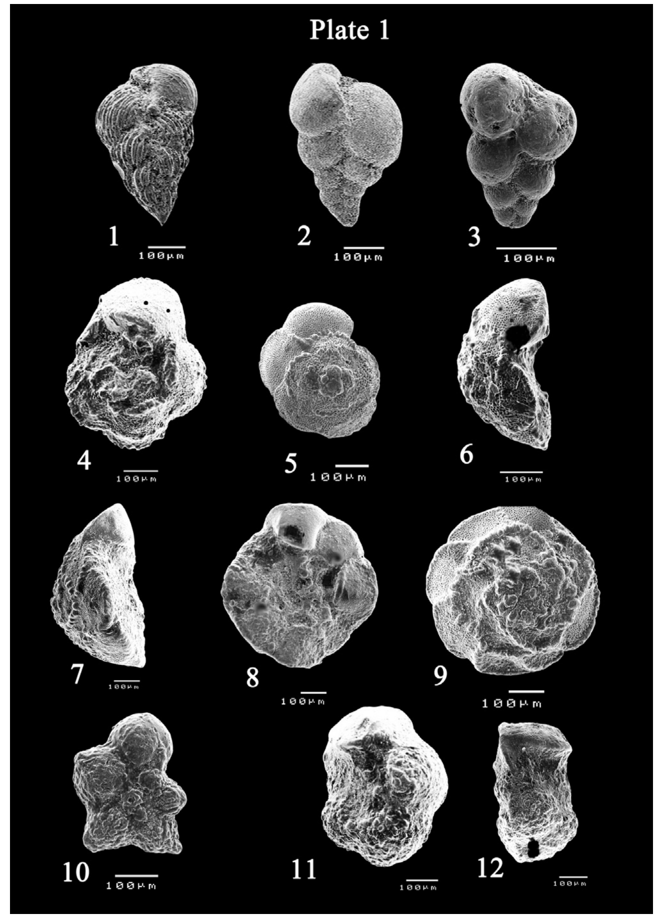

Plate 1. Scale bar = 100 μm. 1- *Pseudogumbelina costulata* (Cushman). 2, 3- *Heterohelix globulosa* (Ehrenberg). 4- *Globotruncana aegyptiaca* Nakkady, ventral view. 5, 6- *Globotruncanita conica* (White), (5) dorsal view, (6) side view. 7, 8- *Globotruncanita dupeublei*, (7) side view, (8) ventral view. 9- *Globotruncana esnahensis* Nakkady, dorsal view. 10- *Plummerita hantkeninoides* (Brönnimann), (a) ventral view. 11, 12- *Gansserina gansseri* (Bolli), (11) ventral view, (12) side view.

et al., 1996; Hoffmann et al., 2000) and possibly an impact event, as suggested by the recent discovery of glass spherule deposits in upper Maastrichtian sediments (Stinnesbeck et al., 2001 and Keller et al., 2002). Between 450,000 and 200,000 year preceding the K/T boundary, global climate warmed rapidly, rising both sea surface and intermediate water temperature by as much as 3–4 °C. Climate cooling accelerated during the final 100,000 kyr of the Maastrichtian (Li and Keller, 1998a,b), where the planktonic foraminiferal populations were directly affected by these extreme climatic oscillation. Throughout the late Maastrichtian species diversification almost ceased and species extinction exceeds evolution (Abramovich et al., 1998; Li and Keller 1998a,c).

Douglas and Savin (1978) recorded the warmest isotopic temperature during the Cretaceous in globigerinids, *Rugoglobigerina* and *Globigerinelloides*, and those with the highest δ^{18} O values (i.e., colder) in the globotruncanids. The adults of ornamented rugoglobigerinids lived at highest temperatures, where the rugotruncanids and the single and double keeled globotruncanids float deeper than the rugoglobigerinids and register slightly temperatures (Boersma and Shackleton, 1981).

1.2. Paleodepths

de Rijk et al. (1999) investigated the percentage abundance of planktonic foraminifera in present day sediment assemblages near the Nile Delta, where they found that depth and percentage of planktonics (%P) in the total foraminiferal population are related through the expression:

$$\text{Depth} = e^{(\%P+819/24)}$$

This expression was used also by Wilson (2003) to estimate the range of paleodepths in part of the Miocene age Brasso Formation of Central Trinidad. It is suggested that this expression may be applicable in the Trinidadian region because it and the eastern Mediterranean Sea are influenced by freshwater delivered by major rivers. So, on the basis of the above mention, it is suggested to follow this expression in El Qusaima section region in part of the Cretaceous age. Moreover, Olsson and Nyong (1984) argued that the inner shelf depth (10–50 m) is characterized by low planktonic percentages with low species diversity and high benthic foraminiferal percentages. Also, they pointed out that higher planktonic percentages (8–25%) and diversity characterize the middle shelf depth (50–100 m). Meanwhile, the outer shelf depth (100–200 m) is characterized by 30–70% planktonic and middle slope depth (400–800 m) is characterized by 90% planktonic and slight increase in benthic diversity. Paleodepth determination from foraminiferal taxa has been generally based of keeled/non keeled planktonic foraminiferal ration, planktonic species diversity (species richness), planktonic and benthonic foraminiferal percentages and planktonic/benthonic foraminiferal ratio.

2. Geological setting

El Qusaima is a small village lies in Northeastern Sinai. Said (1962) observed the missing of the Santonian unit in many parts of north Sinai, where the Turonian dolomitized limestone is succeeded on top by the Upper Senonian chalk. Bartov and Steinitz