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Paleocene-Eocene transition at Naqb Assiut, Kharga Oasis, Western Desert, Egypt: stratigraphical and paleoenvironmental inferences

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Abstract

This work depends on the study of the lower part of the Esna Formation which encompasses the Paleocene-Eocene (P-E) transition in Egypt as well as at Naqb Assiut section, Kharga Oasis, Western Desert. The Paleocene/Eocene (P/E) boundary is represented by El Dababiya Quarry Member which consists of five distinctive beds (nos. 1-5) at the GSSP. On the other hand, at Naqb Assiut section this boundary is only represented by the upper two beds (nos. 4&5), whereas, the lower three beds (nos. 1-3) are missing due to a hiatus. This hiatus is marked by the occurrence of an irregular surface contains pebbles and phosphatic materials. This hiatus may be related to the echo of Sryian Arc Orogeny at the P/E time. Biostratigraphically; four planktonic foraminiferal zones are defined from base to top as: *Acarinina soldadoensis*/*Globanomalina pseudomenardii* and *Morozovella velascoensis* (late Paleocene), *Acarinina sibaiyaensis* and *Pseudohastigerina wilcoxensis*/*Morozovella velascoensis* (early Eocene). The *Acarinina sibaiyaensis* Zone which represents the P//E/ boundary is characterized by the occurrence of intrazonal hiatus at it's lower part. The benthonic foraminiferal taxa contain abundant representatives of Midway-type fauna (~91 % of the whole assemblages), beside few Velasco-type faunal ones (~9 %), indicating an outer neritic (150-200 m) water depth of deposition during the P-E transition. Quantitative analysis and composition of benthonic foraminiferal assemblages are indicative for various environmental changes around the P/E boundary. They reflected a high diversity, increase of epifaunal taxa, and low-intermediate productivity conditions, which indicates a well-ventilated bottom water and oligo - to mesotrophic conditions during the late Paleocene age. Rapid extinction of about 18 % of the entire benthonic foraminiferal species started at the P/E boundary, where the last occurrence of *Angulogavelinella avnimelechi* is pronounced at the base of this boundary. There is a decline in the preceding faunal characteristics of the late Paleocene and signified an increase in the abundance of agglutinated and buliminid species. These characters are revealed some environmental stressful conditions of low oxygen and increased productivity. During the early Eocene, the environmental conditions are improved leading to the recovery of most benthonic and planktonic foraminifera.

Keywords: Benthonic and planktonic foraminifera; P/E boundary; Midway-type fauna; Velasco-type fauna; Paleobathymetry; biostratigraphy; paleoenvironment.

1. Introduction

During the last few decades, much researches have been focused on the Paleocene-Eocene transition, on the study of the abrupt and temporal period of extreme global warming event (Zachos *et al*., 1993) and its effects on the various marine and terrestrial biota (Aubry *et al*., 1998). The planktonic foraminiferal fauna show good diversification and faunal turnover after and before the P/E boundary event (Canudo & Molina, 1992; Lu & Keller, 1995; Canudo *et al*., 1995; Arenillas & Molina, 1996; Lu *et al*., 1996; Arenillas *et al*., 1996). Also, the P/E boundary was marked by the mass extinction of benthonic foraminifera (Thomas, 2007), which is commonly known as the Benthonic Extinction Event (Tjalsma, 1977; Schnitker, 1979; Tjalsma and Lohmann, 1983; Thomas, 1990, 2003). The Global Stratotype Section and Point (GSSP) of the P/E boundary was defined at El Dababiya Village, south Luxor, Egypt. The P/E boundary at the GSSP was located at the base of five characteristic beds known as Dababaiya Quarry beds within the Esna Formation (Dupuis *et al*., 2003). Aubry et al. (2007) raised the stratigraphic rank of these beds into a member (e.g. El Dababiya Quarry Member). The base of this distinctive member is equivalent to the Paleocene Eocene Thermal Maximum (PETM) and the base of Carbon Isotope Excursion (CIE). It is characterized by the extinction of *Angulogavelinella avnimelechi*, the influx of planktonic foraminiferal excursion taxa (e.g. *Acarinina sibaiyaensis*, *A. Africana*, *Morozovella allisonensis*) and that of the *Discoaster araneus-Rhomboaster* spp. assemblage (Dupuis *et al*., 2003).

Kharga Oasis is one of the most common Egyptian depressions in the Western Desert, which lying between Lat. 24º and 26º N, with about 200 km to the west of the Nile Valley (Fig. 1). It is bounded by a north - south western side of an irregular and continuous escarpment, where the Naqb Assiut section is located at the northern part of this scarp, and opened from the southern and south western parts. At Kharga Oasis, several studied were carried out on the Paleocene-Eocene rocks such as Hewaidy, 1983; Luger, 1985; Tantawy, 1998; Mahfouz, 2008; El-Azabi and Farouk, 2010; Khalil and Al Sawy, 2014. These studies were concentrated on the general stratigraphy of the Kharga Oasis, except for Mahfouz (2008) who was focused his study on the P/E boundary.

To investigate the P/E lithological boundary, study the planktonic and benthonic foraminiferal fauna and their extinction across the P-E transition, high resolution study is carried out on the Naqb Assiut section. Qualitative and Quantitative analyses of these planktonic and benthonic fauna will be documented here to show; the planktonic foraminiferal zones, the relative abundances of their species across the extinction level. Moreover, the uses of the benthonic foraminiferal morphogroups (Corliss, 1985) are used to deduce paleoxygenation conditions of bottom water environment. Also, the foraminiferal indices (e. g.; genus and species richness, Fisher α – diversity,......etc.) are used to detect the nature of the P/E boundary and infer the paleoenvironmental changes throughout the P-E transition of the present area.

2. Materials and methods

A total of eighteen samples have been collected from the Esna Formation at Naqb Assiut section with close sample spacing around the boundary. About 200 g of dry rock/sediment were disaggregated in water with diluted hydrogen peroxide (H_2O_2). Afterwards, samples were washed through a sieve with 63 µm, and the obtained residues were dried. This procedure was repeated until foraminifera with clean surface texture were recovered. Population counts follow the method of Buzas (1990) and were based on random splits of at least 300 specimens (Table1).

Quantitative studies of planktonic and benthonic foraminiferal species are depended mainly on representative splits of about 300 specimens > 63µm (Table 1). All representative specimens are picked and mounted on microslides for identification and a permanent record. Studying the benthonic foraminiferal morphogroup analysis (e. g. Corliss, 1985; Jones and Charnock, 1985; Corliss and Chen, 1988) allows deducing probable microhabitat preferences and environmental conditions (Table 2) related to sea-water oxygenation (e. g., Bernhard, 1986; Jorissen *et al*., 1995; Kaminski and Gradstein, 2005). It expressed here as the epifaunal and infaunal morphotypes (E/I %). Relative abundances of most common benthonic taxa (Fig. 8), calcareous to agglutinated ratios (C/A %), and other proxies referred to diversity such as; the Fisher α index (Murray, 1991), in addition to both of the distinct depth-controlled benthonic fauna of the Midway-type and the Velasco-type faunal ratios (MF/VF %,) (Berggren and Aubert, 1975).

The comparison between fossils and recent benthonic foraminiferal data, the occurrence and abundance of depth-related species and the use of their upper limits (Van Morkhoven *et al*., 1986; Alegret *et al*., 2001, 2003) allowed inferring the paleodepth of these assemblages. Moreover, ratios of most important planktonic foraminiferal groups such as the acarininids, morozovellids and subbotinids are calculated (Fig. 9). Microslides, rock-samples and residues are deposited in the Geological Museum of the Geol. Depart., Fac. Sci., Minia University.

3. Lithostratigraphy:

The P-E transition generally lies within the lower part of Esna Formation in Egypt. The Esna Formation was first described by Beadnell (1905) to define the shale succession between Duwi Formation at the base and Thebes Formation at the top. Said (1962) restricted the Esna Formation of Beadnell (1905) into the shale succession from Tarawan Formation (chalky limestone) at the base to the Thebes Formation (Limestone) at the top. Abdel-Razik (1972) classified the Esna Formation into two members, El Hanadi Member at the base and El Shaghab Member at top. Also, He (op,cit) proposed Abu Had Member for the lower part of the Thebes Formation. Recently, Aubry *et al*., (2007) modified the classification of Abdel-Razik (1972) and subdivided the Esna Formation into four members from base to top: El-Hanadi, El Dababiya Quarry, El-Mahmiya and Abu Had (Fig. 4) and they considered the last member as a member of Esna Formation rather than Thebes Formation. At the study section, the lower part of the Esna Formation was sampled and described (total thickness about 10.70 m, Figs. 2 & 3). It represents El-Hanadi, El Dababiya Quarry and the lower part of El-Mahmiya members. These members will be discussed briefly as follows:

3.1. El-Hanadi Member (7.70m):

This member was originally introduced by Abdel Razik (1972) to describe the lower part of Esna Formation (5 meters of shale succession) overlies the Tarawan Formation and underlies El Shaghab Member at Gabal El Shaghab, east of El Hanadi Village near Esna City. El Hanadi Member has been emended by Aubry *et al*. (2007) to be coeval the lower part of the Esna Formation below El Dababiya Quarry Member. It is equivalents to the Esna Unit 1 of Dupuis *et al*., (2003) (Fig 4).

At Naqb Assiut section, El-Hanadi Member consists of about 7.70 m. thick. (samples 1- 12), grayish green, papery shale (~ 6.75 m., samples 1-9) at base, which varies gradually into massive marl (0.95 m. thick., samples no. 10-12) at top (Figs. 2 & 3).

3.2. El Dababiya Quarry Member (0.90 m.):

This Member was originally introduced by Aubry *et al*. (2007) as El Dababiya Quarry Member instead of El Dababiya Quarry Beds of Dupuis *et al*., (2003) in the Global Standard Stratotype section and Point (GSSP) of the P/E boundary at the Village of El Dababiya. El Dababiya Quarry Member constitutes a distinctive lithologic succession of five characteristic beds (1-5) of about 3.68 m thick at it's type locality. Bed no. 1 is a dark clay (~0.63 m thick); bed no. 2 is a phosphatic brown shale (~ 0.50 m thick); bed no. 3 is a creamy phosphatic shale (~ 0.84 m thick); bed no. 4 is a grey calcareous shale (~ 07.1 m thick) and bed no. 5 is a marly calcarenitic limestone (~ 1.00 m thick). At Naqb Assiut section, El Dababiya Quarry Member is only represented by the upper two beds (nos. 4&5) (Figs. 2-5) from base upward as:

- Bed no. 4: It attains about 20 cm thick. It is massive marl with phosphatic materials and pebbles at base. The lower surface of this bed is irregular and bioturbated. It is coeval to bed no. 4 of the same member at the GSSP section and is here representing by sample no. 13. The criteria at the base of this bed indicate the occurrence of a hiatus at the P/E boundary.

- Bed no. 5: It is about 70 cm. It is a yellowish chalky limestone and is coeval to bed no. 5 of El Dababiya Quarry Member at the GSSP section. This bed is here representing by samples no. 14 and 15.

3.3. El-Mahmiya Member (2.00m.):

This member was originally defined by Aubry *et al*. (2007) to cover the Esna Unit 2 of Dupuis *et al*., (2003) at El Dababiya Village. The lower part of this member (~ 2m thick) is only considered in this study. It consists of marly shale, and it is represented by samples no. 16 -18.

4. Planktonic Foraminiferal Biostratigraphy:

According to the important planktonic foraminiferal species, four zones for the P-E transition are recognized at Naqb Assiut section (Figs. 6&7). The planktonic foraminiferal zonal scheme of Berggren and Pearson, (2005) and it's categories of zones are here applied. The proposal planktonic foraminiferal zones arranged from base to top as follows:

4.1. *Acarinina soldadoensis*/*Globanomalina pseudomenardii* Zone

This zone was defined as Concurrent-Range Zone by Berggren *et al*. (1995) to cover the interval from the Lowest Occurrence (LO) of *A. soldadoensis* (Brönnimann) to the Highest Occurrence (HO) of the *G. pseudomenardii* (Bolli). It represents the greater part of El-Hanadi Member (~ 6.75 m. thick, samples 1-9). The *A. soldadoensis*/*G. pseudomenardii* (P4c) Zone is conformably overlain by the *Morozovella velascoensis* (P5) Zone at the study section.

4.2. *Morozovella velascoensis* Zone

M. velascoensis Zone was defined as Partial Range Zone by Berggren & Pearson (2005) to cover the interval from the HO of *G. pseudomenardii* (Bolli) to the LO of the *Acarinina sibaiyaensis* (El Naggar). Berggren & Ouda (2003 a, b) subdivided P5 Zone (sense of Berggren *et al*., 1995) into three subzones namely: P5a (latest Paleocene), P5b to recognize the Carbon Isotope Excursion (CIE) and Paleocene/Eocene Thermal Maximum (PETM) interval and P5c to recognize the post CIE and PETM interval (earliest Eocene). Berggren & Pearson (2005) used P5 Zone (=P5a Subzone of Berggren & Ouda, 2003 a,b) to recognize the latest Paleocene and used E1 (=P5b Subzone of Berggren & Ouda, 2003 a,b) to recognize the CIE & PETM interval and E2 Zone (=P5c Subzone of Berggren & Ouda, 2003 a,b) to recognize the post CIE & PETM interval (Fig. 7).

In the present work, the *M. velascoensis* (P5) Zone is defined as a partial range zone from the HO of *G. pseudomenardii* (Bolli) to the LO of Planktonic Foraminiferal Excursion Taxa such as: *A. africana* (El Naggar) and *A. sibaiyaensis* (El Naggar) at the P/E boundary. It represents the uppermost part of El-Hanadi Member (~ 1 m. thick, samples 10-12). *M. velascoensis* (P5) Zone is unconformably overlain by the *A. sibaiyaensis* (E1) Zone due to the missing of the lower part bed 1-3 of El Dababiya Quarry Member. This zone is equivalent to P5 Zone of Berggren & Pearson, (2005) (Fig. 7).

4.3. *Acarinina sibaiyaensis* Zone

This zone was originally defined by Molina *et al*. (1999) to cover the interval from the LO of the nominate taxon to the LO of *Pseudohastigerina wilcoxensis* (Cushman & Ponton). It is here defined as a Lowest Occurrence zone according to the definition of Molina *et al*. (1999). The *A. sibaiyaensis* Zone represents the main part of El Dababiya Quarry Member (~0.90 m. thick, samples 13-15). The lower part of this zone is missing due to the absence of the lower three beds of El Dababiya Quarry Member. *A. sibaiyaensis* (E1) Zone is conformably overlain by the *Pseudohastigerina wilcoxensis*/*Morozovella velascoensis* Zone. This zone is equivalent to the upper part of E1 Zone of Berggren & Pearson, (2005) (Fig. 7).

4.4. *Pseudohastigerina wilcoxensis*/*Morozovella velascoensis* Zone

It was originally defined as Concurrent-Range Zone by Berggren and Ouda (2003) from the LO of *P. wilcoxensis* (Cushman & Ponton) to the HO of *M. velascoensis* (Cushman). It is completely equivalent to *P. wilcoxensis* Zone of Molina *et al*. (1999), the upper part of *M. velascoensis* (P5) Zone of Berggren *et al*. (1995) (Fig. 7) and E2 Zone of Berggren & Pearson, (2005). It represents the lower part of El-Mahmiya Member (~ 2.0 m. thick, samples 16-18).

5. Paleobathymetry

Benthonic foraminiferal assemblages of the upper Paleocene sediments at Naqb Assiut section are cosmopolitan and dominated by elements of the so-called Midway-type fauna (MF, ~ 93% of the whole assemblages), typical of outer neritic water depths (150 ~ 200 m), beside few deeper-water (upper bathyal)

Velasco-type faunal elements (VF, ~ 7 %). The Midway-type faunal elements include outer neritic species such as; *Bulimina quadrata, Cibicidoides alleni, C. succedens, Gyroidinoides girardana, G. subangulata, Lenticulina midwayensis, L. pseudomamilligera, Loxostomoides applinae, Marginulinopsis tuberculata, Siphogenerinoides eleganta, Stilostomella midwayensis, Valvulineria scrobiculata, Bulimina farafraensis, Oridorsalis plummerae, Spiroplectinella esnaensis* together with some nodosariids and others (Speijer, 1994;Alegret *et al*., 2005). Upper bathyal taxa (VF) are encountered with low numbers within El Hanadi Member and comprises of *Angulogavelinella avnimelechi, Anomalinoides rubiginosus, Neoflabellina jarvisi, Gaudryina pyramidata* and others. It is interesting to find the *A. avnimelechi* in the lower part of the section (with few specimens), which is common in the Paleocene outer neritic to upper bathyal deposits in Tethyan and European basins (Speijer *et al*., 1995; Speijer and Schmitz, 1998; Dupuis *et al*., 2003; Alegret *et al*., 2005; Ernst *et al*., 2006). Also, the lower Eocene sediments are characterized by the scarcity of VF (~ 5%) and the abundance of MF (~ 95%) as well as the dominance of opportunistic faunas (e. g., *Valvulineria scrobiculata, Anomalinoides egyptiacus, A. zitteli, Stainforthia farafraensis* and *Bulimina farafraensis*) at the P/E boundary, which are thrived in the shallow-outer neritic environment (Speijer, 1994; Speijer and Schmitz, 1998). These indicate that, the Naqb Assiut area was not deeper than 200 m. during the early Eocene age. Consequently, the stratigraphic distribution of most of the Paleocene – Eocene benthonic assemblages and the presence of both elements (MF and VF) suggest an outer neritic (~ 150-200 m. water-depth) environment.

6. Foraminiferal associations

The Paleocene benthonic foraminiferal assemblages of the Esna Formation at Naqb Assiut section (lower part 7.70 m. thick., El Hanadi Member, samples 1-12) are diverse and heterogeneous (α= 26.8, H (S)= 4.1, respectively, Fig. 9). Calcareous foraminifera represent the major component of the assemblage (75 – 85 %), while the agglutinated forms are minor ones (15 – 25 %). Among the calcareous taxa; *Loxostomoides applinae, Cibicidoides alleni, Osangularia plummerae, Bulimina midwayensis, Lenticulina midwayensis,* and *L. navicula* are most abundant (Fig. 9). Benthonic assemblages consist of a mixture of epifaunal

(42 – 60 %) and infaunal (40 – 58 %) morphogroups. Planktonic foraminiferal assemblages within the *Acarinina soldadoensis/Globanomalina pseudomenardii* (P4c) and *Morozovella velascoensis* (P5) zones are diverse and rich in tropical – subtropical species. The *Neoflabellina jarvisi, Angulogavelinella avnimelechi, Lenticulina pseudomamilligera, Laevidentalna gracilis* and *Discorbis pseudoscopos* (Fig. 9 and Table 1) disappeared at the P/E boundary. The agglutinated individuls of *Spiroplectinella dentata* and *pseudoclavulinids* are increased somewhat in abundance. On the other hand, the *Clavulinoides asper whitei* and *Gaudryina pyramidata* are disappeared at the P/E boundary. The diversity and species richness ratios of the assemblages reached immediately its acme below the P/E boundary (sample no. 12), where the epifaunal morphogroups decreased. They are exactly declined at the P/E boundary. The infaunal morphogroups (Table 2) are increased at the P/E boundary (~79 % at the base of El Dababiya Quarry Member, sample no. 13). The lowermost part of El Dababiya Quarry Member (sample no. 13, Figs. 8 & 9) is almost barren of benthonic foraminifera, whereas planktonic foraminifera are common. They are dominated by some agglutinated taxa of mainly pseudoguadryinids, spiroplectamminids and verneuilinids, in addition to few specimens of nodosariids (Table 1). The acarininids dominate the planktonic foraminiferal assemblages (~ 43%), relative to the morozovellids and subbotinids (~ 11% and ~ 28%, respectively).

In the upper part of the El Dababiya Quarry Member, the benthonic foraminiferal assemblages are recovered, where the percentages of diversity and species richness of the assemblages (Fig. 9) are gradually increased towards the uppermost part of the member. Assemblages are dominated by the benthonic calcareous foraminifera (~83%) of mainly bagginid and stainforthiid species, such as; *Valvulineria scrobiculata, Stainforthia farafraensis, Globocassidulina subglobosa, Anomalinoides zitteli* and *A. aegyptiacus*. Here, the lenticulinids (~ 43 %) are replaced by the buliminids (~57 %), and include *Bulimina farafraensis, B. midwayensis and B. esnaensis* (Figs. 8 & 9 and Table 1).

At the uppermost part of the section (El Mahmiya Member, samples no. 16-18, Fig. 9), in spite of the increase of calcareous taxa (~90%), the diversity and species richness are decreased (Fig. 9). Acarininids maintained with its relative abundance (~ 37 %), in regard to the morozovellids and subbotinids (~ 22% and ~ 30%, respectively, Fig. 9). Also, the buliminids are still dominated in this zone with ~ 65 % against ~ 35% for the lenticulinids (Fig. 9).

7. Paleoenvironmental inferences

The quantitative analyses of the benthonic foraminiferal assemblages allow us to explain the foraminiferal distribution pattern of studied section across the P/E boundary.

The upper Paleocene benthonic foraminiferal assemblages in Naqb Assiut (El Hanadi Member, samples 1-12, Fig. 9) are diverse and composed mainly of Midway-type faunas (MF average of ~ 93 % of total assemblages), against a minor Velasco-type ones (VF ~ 7%, Fig. 9). It has a high foraminiferal number (with average of ~ 1703 specimens in the 125 µm size fraction per gram dry sediments), Fisher α- diversity index (average of ~ 26.8) and Species richness (65 species, Fig. 9). This interval contains a mixed morphogroups (Corliss, 1985, 1991; Corliss and Chen, 1988; Widmark, 1997; Culver, 2003) of more epifaunal taxa (~ 52%) than infaunal ones (~ 49%), suggesting a well ventilated, normal marine and oligo - to mesotrophic levels. Presence of mixed epi-and infaual morphotypes suggests less abundant food resources to benthos (Jorissen *et al.*, 1995; Van der Zwaan *et al.*, 1999) or living in mesotrophic conditions (Gooday, 2003). This interval is dominated by *Loxostomoides applinae*, *Spiroplectinella dentata*, *Cibicidoides alleni* and *Lenticulina navicula*. The presence of calcareous thick-walled taxa, such as *Cibicidoides alleni*, *C. pseudoacutus* and *Lenticulina midwayensis* indicates high oxygen levels. According to Berhnard (1986) and Speijer and Wagner (2002), the *Gyroidinoides* and *Lenticulina* are epifaunal and oxic bottom water genera (plano-convex or lenticular morpho groups). Moreover, the upper Paleocene benthonic foraminiferal assemblages are enriched and dominated by the *Lenticulina* spp. (~ 66% of the assemblages), on the contrary of the buliminids (~ 34%). This confirmed the well-oxygenated bottom waters or low to intermediate productivity conditions. With respect to the planktonic foraminifera, *Acarinina*, *Morozovella* and *Subbotina* make up 88 % of the total planktonic assemblage in this interval (Fig. 9). Frequencies of *Igorina*, *Parasubboina* and *Globanomalina* form a relative percentage less than 12%. So, the benthonic foraminiferal assemblages of the upper Paleocene sediments suggest an outer neritic environment (~ 150-200 m water depth), associate with oligo- to mesotrophic levels and aerobic conditions at the sea floor with low to intermediate productivity.

The P/E boundary is recorded at the base of a ~ 20 cm thick phosphatic marl bed. The lower surface of this bed is irregular, bioturbated, and contians pebbles and phosphatic materials, which indicates a short period of hiatus at the P/E boundary (Fig. 9). This bed contains remarkable warm taxa, suchas; *Acarinina sibaiyaensis* and *A. africana*. At the same time, the agglutinated taxa are represented very well. The benthonic foraminiferal distribution pattern (Table 1) revealed generally that 89% of MF species (e.g. *Stilostomella midwayensis, Gavelinella danica, Tritaxia midwayensis, Loxostomoides applinae, Coryphostoma midwayensis, Spiroplectinella dentata, Cibicidoides alleni, Siphogenerinoides eleganta, Gyroidinoides subangulata, Tappanina selmensis, Bulimina midwayensis, Gaudryina textulariformis, Anomalinoides aegyptiacus, Pyramidulina vertebralis, Eponides lunatus*), and 6 % of VF ones (e.g. *Clavulinoides amorpha, C. trilatera, Anomalinoides rubiginosus, Bulimina trinitatensis, Marssonella oxycona oxycona, M. oxycona trinitatensis*) (Berggren and Aubert, 1975) occur above the P/E boundary. On the other hand, 5% of VF species extinct near the same boundary (e.g. *Bolivinopsis spectabilis, Neoflabellina jarvisi, Clavulinoides asper whitei, Gaudryina pyramidata, Angulogavelinella avnimelechi*) (Fig. 9, and Table 1). Within this bed, there is a relative increasing in the infaunal morphogroup (~79%) as well as in the agglutinated foraminiferal taxa (Fig. 9). This interval has a drop in the foraminiferal number (~1200 specimens in the 125 µm size fraction per gram dry sediments). Accordingly, the deposition of this interval may be in middle-shallow outer neritic setting (50-150m water depth) associated with oceanic environmental stresses probably related generally to moderate trophic and oxygen deficiency conditions.

The upper part of El Dababiya Quarry Member consists of chalky limestone bed of 0.70 m thick (samples 14-15). It contains high relative percentage of both planktonic and benthonic foraminiferal species. Within this bed, the environmental conditions are improved with enough nutrients and oxygen content. There are an increasing in the foraminiferal faunal number (~ 1362 specimens in the 125 µm size fraction per gram dry sediments), Fisher α- diversity (Fig. 9). Also, it is dominated by the MF taxa (~ 97 % MF against 3 % for the VF). Also, the agglutinated taxa are marked by decreasing in their relative abundance. Moreover, the buliminids (~ 57 %) are exceeded the lenticulinids (~ 43%) (Fig. 9). At the same time, the planktonic foraminiferal assemblages are almost maintained its faunal characteristics, where their main elements of *Morozovella*, *Acarinina*, and *Subbotina* are making up 84%, while the remainder ones (*Igorina*, *Parasubboina, Pseudohastigerina* and *Globanomalina*) are reached ~ 16% of the whole planktonic assemblages. This interval is dominated by the *Valvulineria scrobiculata, Anomalinoides aegyptiacus, A. zitteli*, and *Stainforthia farafraensis* of outer neritic setting (paleodepth 150-200m). Accordingly, the deposition of this interval may reflect an outer neritic shelf environment, associated with high productivity and increased food supply conditions.

The topmost part of the Naqb Assiut section is represented by a marly shale bed of about 2.00 m. thick (samples 16-18) which is belonging to the El Mahmiya Member. It witnessed somewhat low diversity values in both planktonic and benthonic foraminiferal taxa. This interval is characterized by a foraminiferal number fluctuates between 1196 and 1674 specimens in the 125 µm size fraction per gram dry sediments. Here, the MF taxa are continued almost with the same abundance of the preceding interval (~97 % of the whole assemblage), while the VF ones are represented with few numbers (Fig. 9). Buliminids and lenticulinids taxa make up ~65% and ~35% of the relative abundance of benthonic foraminiferal taxa erspectively (Fig. 9). The high relative abundance of buliminids is thought to be due to the abundance of food supply (Fontanier *et al*., 2002; Gooday, 2003; Alegret and Thomas, 2004). Moreover, the infaunal morphogroups are here increased and reached ~ 61% (Fig. 9), on the expense of the epifaunal ones (~ 39%). This indicates a high nutrient flux to the sea floor.

Benthonic foraminiferal assemblages of this interval are characterized by the abundance of *Stainforthia farafraensis, Valvulineria scrobiculata,* then *Anomalinoides* spp. (e.g., *A. aegyptiacus, A. zitteli,* and *A. umbonifera*) and

Bulimina farafraensis. According to Speijer (1994) and Speijer and Schmitz (1998), the presence of *V. scrobiculata, S. farafraensis, A. aegyptiacus, A. zitteli* indicates an outer neritic setting (~150-200 m), associated with high food supply and increased productivity conditions.

8. Conclusions

Similar to the GSSP of the P/E boundary at Dababiya Village, south of Luxor (~35), Egypt, the P/E boundary at Naqb Assiut section lies at the base of El Dababiya Quarry Member within the lower part of the Esna Formation. El Dababiya Quarry Member consists of five distinctive beds (1-5) at the GSSP locality. On the other hand, at the study section, the lower beds of El Dababiya Quarry Member (1-3) are missing and the upper beds are only represented (4and 5).

The lower surface of the bed no. 4 is irregular, bioturbated and contains pebbles and phosphatic materials. The bed (4) attains about 20 cm thick, but the bed (5) attains about 70 cm thick. The correlation of the beds of El Dababiya Quarry Member at the GSSP and Naqb Assiut section indicates the occurrence of a hiatus at Naqb Assiut. This hiatus is related to a syn-sedimentary tectonic event at the P/E boundary, which may be related to the echo of Syrian Arc Orogeny in Egypt during this time.

Biostratigraphically, four planktonic foraminiferal zones are identified for the P/E transition from base to top: *Acarinina soldadoensis*/*Globanomalina pseudomenardii* (P4c) and *Morozovella velascoensis* (P5) for the late Paleocene, *Acarinina sibaiyaensis* (E1) and *Pseudohastegerina wilcoxensis/Morozovella velascoensis* (E2) for the early Eocene. The P/E boundary is defined at P5/E1 zonal boundary, with intarzonal hiatus at the base of E1 Zone (early Eocene).

The benthonic foraminiferal assemblages as well as their quantitative analyses indicate generally a deep outer neritic setting (150-200 m water depth) of deposition during the late Paleocene and early Eocene age. Characteristics of the different P-E faunal assemblages are discriminated into the following:

-The late Paleocene faunal assemblages of El Hanadi Member were highly diverse. It is mainly dominated by the *Loxostomoides applinae*, *Cibicidoides* spp. and *Lenticulina* spp. These taxa indicate high oxygen levels, oligo- to mesotrophic, and low to intermediate productivity conditions. Paleobathymetrically, most of these benthonic faunal taxa indicate outer neritic environment (150-200 m).

-At the P/E boundary (base of El Dababiya Quarry Member, phosphatic marl bed), benthonic foraminiferal assemblages exhibit a major faunal turnover due to the occurrence a hiatus. This interval contains agglutinated benthonic foraminiferal assemblages. The marl bed of El Dababiya Quarry Member may be attributed to the occurrence of upwelling with nutrient-rich deep water. It is marked by an oceanic dysoxic conditions, this is documented by the occurrence of phosphatic materials increasing in the relative abundance of agglutinated foraminiferal taxa. Also, it is marked by the lowest diversity in the infaunal taxa. The benthonic foraminiferal fauna indicate a middle shallow-outer neritic setting (50-100 m water depth).

-Within the upper part of El Dababiya Quarry Member (chalky limestone bed), there is increasing in the diversity of both planktonic and benthonic foraminiferal with respect to the lower part. It witnessed some environmental changes that led to the recovery of most benthonic foraminiferal assemblages. The *Anomalinoides aegyptiacus* and abundant buliminids are indicative to stress environmental condition with low oxygen levels and high productivity. The benthonic foraminiferal taxa indicate a shallow outer neritic setting (100 m water depth).

-During the early Eocene (El Mahmiya Member) there are a relative decreasing in the diversity values of the benthonic foraminiferal fauna. *V. scrobiculata, S. farafraensis* and buliminids dominated the benthonic foraminiferal assemblages, which are thought to be representatives of high food and increased productivity conditions. The benthonic foraminferal taxa indicate an outer neritic setting (150-200 m water depth).

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Figure Caption

Fig. 1. Geological map of Kharga Oasis shows the location of Naqb Assiut outcrop, Western Desert, Egypt (modified after Said, 1990).

Fig. 2. A Field photograph shows the P/E boundary at Naqb Assiut section, B. Field photograph shows pebbles, collophane and coprolite grains at the basal part of El Dababiya Quarry Member, C. Field photograph shows bioturbation at base of El Dababiya Quarry Member.

Fig. 3. Lithostratigraphic columnar section of the P-E succession at Naqb Assiut section, Western Desert, Egypt.

Fig. 4. Lithostratigraphic correlation for the P-E transition rocks at the present work with other pervious ones.

Fig. 5 Lithostratigraphic correlation between El Dababiya Quarry Member at the GSSP and Naqb Assiut sections.

Fig. 6. Biostratigraphic distribution chart of the planktonic foraminiferal species recorded throughout the P-E succession at Naqb Assiut section, Western Desert, Egypt.

Fig. 7. Comparison between the present planktonic foraminiferal zones with some local and international ones.

Fig. 8. Stratigraphic distribution and relative abundance of most common benthonic foraminiferal taxa and its turnover across the P/E boundary (dashed line) at Naqb Assiut section. Taxa whose abundance is ≥ 2 % in at least one sample have been plotted. For other taxa see Table (1).

Fig. 9. Benthonic foraminiferal indices, percentages of planktonic foraminiferal *Acarinina* and *Morozovella*, and paleoenvironmental inferences across the Paleocene/Eocene boundary at Naqb Assiut section, Western Desert, Egypt.

Plate Captions

Plate1. (Scale bar is 100 µm); 1-2 *Globanomalina pseudomenardii* (Bolli), sample no. 5 ; 3-4 *Morozovella velascoensis* (Cushman), sample no. 18; 5-6 *Morozovella occlusa* (Loeblich & Tappan), sample no. 8 ; 7-8 *Acarinina africana* (El Naggar), sample no. 14; 9-10 *Acarinina sibaiyaensis* (El Naggar), sample no. 14; 11-12 *Acarinina soldadoensis* (Brönnimann), sample no. 2; 13-14 *Subbotina triloculinoides* (Plummer), sample no. 6 ; 15-16 *Pseudohastigerina wilcoxensis* (Cushman & Ponton), sample no. 17.

Plate 2. (Scale bar is 100 µm); 1 *Ammodiscus glabratus* Cushman and Jarvis, Sample no. 1; 2 *Ammosphaeroidina pseudopauciloculata* (Myatlyuk), sample no. 3; 3 *Bolivinopsis spectabilis* (Grzybowski), sample 2; 4 *Spiroplectinella dentata* (Alth), sample no. 2; 5 *Ammoglobigerina altiformis* (Cushman and Renz), sample no. 6; 6 *Karrerulina conversa* (Grzybowski), sample no. 13; 7 *Gaudryina pyramidata* Cushman, sample no. 6, 8 *Bermudezina danica* (Franke), sample no. 1; 9 *Tritaxia midwayensis* (Cushman), sample no. 3; 10 *Dorothia bulletta* (Carsey), sample no. 4; 11 *Marssonella oxycona oxycona* (Reuss), sample no. 2;

12 *Calvulinoides amorpha* (Cushman), sample no. 7; 13 *Calvulinoides trilatera* (Cushman), sample no. 11;14 *Pseudoclavulina farafraensis* LeRoy, sample no. 2; 15 *Spiroloculina proboscidae* Schwager, sample no. 3; 16 *Laevidentalina colei* (Cushman and Dusenbury), sample no. 4; 17 *Nodosaria longiscata* d'Orbigny, sample no. 3; 18 *Pyramidulina latejugata* (Gumbel), sample no. 4; 19 *Frondicularia goldfussi* Reuss, sample no. 1; 20 *Lenticulina midwayensis* (Plummer), sample no. 2; 21 *Lenticulina navicula* (d'Orbigny), sample no. 5; 22 *Lenticulina pseudomamilligera* (Plummer), sample no. 6; 23 *Marginulinopsis tuberculata* (Plummer), sample no. 5; 24 *Saracenaria triangularis* (d'Orbigny), sample no. 7; 25 *Neoflabellina paleocenica* Titova, sample no. 3; 26 *Lagena hispida* Reuss, sample no. 4; 27 *Glandulina laevigata* (d'Orbigny), sample no. 6; 28 *Loxostomoides applinae* (Plummer), sample no. 2; 29 *Tappanina selmensis* (Cushman), sample no. 4; 30 *Globocassidulina subglobosa* (Brady), sample no. 5; 31 *Stainforthia farafraensis* (LeRoy), sample no. 15; 32 *Siphogenerinoides eleganta* (Plummer), sample no. 8; 33 *Bulimina midwayensis* Cushman and parker, sample no. 2; 34 *Bulimina farafraensis* LeRoy, sample no. 10; 35 *Bulimina esnaensis* LeRoy, sample no. 18; 36 *Globobulimina ovata* (d'Orbigny), sample no. 3, 37 *Coryphostoma midwayensis* (Cushman), sample no. 4.

Plate 3. (Scale bar is 100 μm); 1 *Fursenkoina* sp., sample no. 2; 2 *Pleurostomella paleocenica* Cushman, sample no. 11; 3 *Stilostomella midwayensis* (Cushman and Todd), sample no. 4; 4,5 *Valvulineria scrobiculata* (Schwager), sample no. 16; 6,7 *Eponides lotus* (Schwager), sample no. 6; 8 *Discorbis pseudoscopos* Nakkady, sample no. 7; 9,10 *Cibicidoides alleni* (Plummer), sample no. 4; 11,12 *Cibicidoides succedens* (Brotzen), sample no. 5; 13 *Allomorphina trigona* Reuss, sample 7; 14 *Quadrimorphina allomorphinoides* (Reuss), sample no. 6; 15,16 *Alabamina midwayensis* Brotzen, sample no. 6; 17,18 *Valvalabamina depressa* (Alth), sample no. 3; 19 *Osangularia plummerae* Brotzen, sample no. 2; 20,21 *Oridorsalis plummerae* (Cushman), sample no. 6; 22,23 *Anomalinoides aegyptiacus* (LeRoy), sample no. 15; 24,25 *Anomalinoides rubiginosus* (Cushman), sample no. 1; 26 *Anomalinoides zitteli* (LeRoy), sample no. 16; 27,28 *Gyroidinoides subangulata* (Plummer), sample no. 2; 29 *Angulogavelinella avnimelechi* (Reiss), sample no. 11; 30,31 *Gavelinella danica* (Brotzen), sample no. 2; 32 *Karreria fallax* Rzehak, sample no 4.

Table Captions

Table 1. Benthonic foraminiferal species count from Naqb Assiut section, Western Desert, Egypt.

Table 2. Habitat preferences of the abundant calcareous and agglutinated benthonic foraminiferal taxa at Naqb Assiut section, Western Desert, Egypt.

ACCEPTED MANUSCRIPT

SAMPLE No.	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18
Bolivinopsis spectabilis	2	4	0	2														
Bermudezina danica	2	0	0	0	0	3	4	2	4									
Lagena hispida	5	0	8	6	5	6	4	5	4									
Frondicularia goldfussi	4	4	2	3	2	4	3	4	3	4	3							
Karreria fallax	4	3	5	4	3	4	3	5	3	3	4							
Neoflabellina jarvisi	2	2	3	1	2	5	3	2	2	3	4	2						
Glandulina laevigata	2	0	3	0	0	3	4	4	3	1	5	2						
Lenticulina pseudomamilligera	3	3	2	2	3	5	5	3	4	3	2	3						
Laevidentalina gracilis	2	0	4	5	4	5	4	3	0	4	4	3						
Marginulinopsis tuberculata	2	0	2	0	2	0	3	0	3	3	4	5						
Stilostomella stephensoni	6	5	4	0	0	3	4	4	0	2	3	3						
Ammodiscus glabratus	4	3	3	2	2	4	3	0	4	2	3	2	1					
Bathysiphon cf. discretus	6	3	4	4	3	6	5	6	3	4	4	3	2					
Ammosphaeroidina pseudopauciloculata	2	3	3	1	2	4	3	0	1	2	4	2	1					
Ramulina navarroana	7	5	6	5	0	4	5	4	0	5	6	3	0	4				
Pseudoclavulina farafraensis	5	7	6	0	5	0	3	5	6	5	2	3	5	7				
Stilostomella midwayensis	9	7	0	6	0	5	7	5	7	5	8	4	0	5	4			
Gavelinella danica	5	6	5	4	6	7	5	6	6	5	7	4	0	3	2			
Tritaxia midwayensis	3	0	7	8	6	4	6	7	8	5	6	5	4	5	6			
Clavulinoides amorpha	2	0	4	0	0	0	4	5	4	0	5	2	0	2	3			
Nodosaria (?) longiscata	3	0	5	4	0	6	0	4	5	3	4	3	1	4	5	4		
Laevidentalina colei	9	7	0	5	5	3	4	2	5	2	4	3	0	5	3	4		
Spiroloculina tenuis	6	5	3	3	4	0	3	5	2	6	11	5	0	4	6	3	5	
Loxostomoides applinae	14	21	19	16	15	17	22	19	21	19	12	4	0	3	4	4	2	

Coryphostoma midwayensis	5	0	11	8	0	0	0	5	0	7	2	2	0	5	4	3	4	
Spiroplectinella dentata	8	11	9	11	8	6	8	6	8	7	3	3	4	6	5	7	6	
Pseudoclavulina maqfiensis	4	6	0	5	4	0	0	4	5	4	1	1	0	4	6	5	3	
Cristellariopsis proinops	3	4	5	3	2	4	5	4	2	5	4	2	0	6	4	4	3	
Cibicidoides alleni	8	6	9	11	13	9	8	10	8	9	6	4	0	5	3	4	2	
Pseudonodosaria manifesta	7	4	4	0	0	0	6	0	4	5	4	3	0	5	4	5	4	
Laevidentalina cylindroides	4	0	5	0	0	3	0	0	4	2	3	1	0	3	4	7	4	
Spiroloculina proboscidea	4	6	6	3	6	7	5	6	3	3	5	2	0	4	5	9	6	
Valvalabamina depressa	4	6	9	6	7	5	7	8	7	5	6	3	0	4	4	8	7	
Valvalabamina planulata	5	4	6	4	5	3	5	5	3	3	5	2	0	3	5	7	5	
Siphogenerinoides eleganta	9	10	8	6	0	0	0	8	7	5	0	3	0	5	8	6	5	
Osangularia plummerae	8	9	7	6	6	9	5	8	6	5	3	2	0	4	4	5	6	
Lenticulina navicula	9	7	5	6	5	6	5	8	6	7	6	4	0	7	4	8	6	
Cibicidoides succedens	5	6	4	5	6	5	2	7	4	5	4	3	0	4	3	2	3	
Globocassidulina subglobosa	6	0	0	6	5	3	5	0	4	0	5	2	0	6	9	7	11	9
Alabamina midwayensis	4	6	7	5	6	8	6	5	4	9	5	3	0	2	4	3	5	4
Pyramidulina latejugata	5	4	0	6	5	7	5	3	5	4	5	3	1	6	4	3	2	4
Gyroidinoides subangulata	6	7	6	5	4	5	7	7	5	4	6	2	0	4	4	6	8	11
Gyroidinoides girardana	3	5	4	3	2	3	4	5	3	4	4	1	0	5	2	3	6	9
Valvulineria scrobiculata	3	5	2	3	5	5	6	5	4	3	3	4	0	10	15	13	14	19
Anomalinoides rubiginosus	2	1	1	1	0	0	1	1	1	1	0	1	0	0	0	1	0	1
Tappanina selmensis	7	5	6	5	0	0	0	0	0	0	0	1	0	4	4	5	8	7
Reussoolina apiculata apiculata	6	0	5	4	0	3	0	4	5	3	0	3	0	4	4	3	2	5
Bulimina farafraensis	3	0	0	8	6	4	0	0	0	4	0	2	0	5	7	9	14	10
Bulimina midwayensis	7	9	8	7	10	5	7	0	3	4	0	2	0	5	6	5	7	4
Bulimina trinitatensis	4	0	0	0	5	3	0	0	0	0	6	2	0	0	0	0	0	3

Globobulimina ovata	5	8	6	0	9	7	0	0	7	6	0	3	0	4	5	8	6	12
Marssonella oxycona trinitatensis	2	0	2	2	0	0	2	0	3	2	3	2	1	0	0	0	0	4
Marssonella oxycona oxycona	4	3	4	3	6	3	4	5	4	4	3	3	2	3	2	3	0	2
Spiroplectinela esnaensis	4	4	0	6	5	0	5	4	4	3	3	2	4	5	3	5	9	8
Spiroplectinella knebeli	3	4	0	4	5	0	4	3	3	0	4	2	3	7	5	4	2	4
Dorothia bulletta	2	0	0	3	0	2	0	0	0	3	5	4	2	3	4	3	2	2
Gaudryina textulariformis	4	0	0	0	6	4	5	3	6	5	5	3	0	4	4	8	6	4
Quadrimorphina allomorphinoides	3	4	6	0	0	0	0	0	4	4	0	2	0	3	3	5	3	4
Saracenaria triangularis	3	3	0	0	3	0	4	3	0	4	9	4	0	2	2	1	3	3
Lenticuina midwayensis	6	5	7	8	9	6	9	8	7	10	5	3	0	3	6	5	7	8
Lenticulina turbinata	4	4	5	7	5	6	5	6	5	6	6	4	0	3	5	7	3	4
Anomalinoides zitteli	2	3	2	4	7	0	0	4	3	3	2	1	0	9	14	13	10	8
Anomalinoides spissiformis	3	4	7	5	4	3	6	5	4	7	4	3	0	5	4	3	2	3
Anomalinoides aegyptiacus	2	3	3	7	6	2	0	1	2	3	2	2	0	9	15	11	10	13
Oridorsalis plummerae	5	4	5	7	4	8	5	6	5	4	6	3	0	6	8	7	5	9
Angulogavelinella avnimelechi		2	1	1	1	0	1	0	1	2	3	1						
Neoflabellina paleocenica		4	5	2	4	4	1	3	3	2	2	2						
Discorbis pseudoscopos		3	5	4	6	4	5	7	5	4	5	3						
Ammoglobigerina altiformis		2	1	2	1	3	1	2	1	0	4	2	3					
Pyramidulina paupercula		4	5	0	4	6	4	4	5	4	4	2	1	4				
Gaudryina elegantissima		6	0	5	4	3	4	4	5	0	0	3	5	6	2			
Fursenkoina sp.		5	0	0	4	6	0	0	0	0	0	2	0	6	8	6	7	13
Bulimina esnaensis		2	0	4	0	0	0	2	0	0	0	2	0	3	4	5	8	11
Pyramidulina vertebralis		3	7	5	4	4	3	5	6	7	5	3	1	3	4	3	2	4

Bulimina quadrata		4	0	3	0	4	0	0	4	5	3	3	0	4	3	5	4	6
Vulvulina colei		5	0	0	0	0	0	0	3	3	0	2	2	2	3	0	0	4
Anomalinoides umbonifera		2	3	2	2	2	3	1	1	2	2	1	0	5	3	7	10	15
Karrerulina conversa			1	0	0	0	0	0	0	0	0	0	2	2				
Allomorphina trigona				3	0	3	4	0	0	0	0	0	0	2	0	3	2	3
Trifarina esnaensis				5	10	0	5	0	0	0	0	0	0	3	5	8	12	11
Clavulinoides asper whitei					4	3	2	0	0	0	0	1						
Gaudryina pyramidata					4	3	2	0	0	0	3	2						
Eponides lunatus					2	3	1	4	2	2	4	0	0	4	5	5	6	9
Eponides lotus					2	4	3	2	1	2	4	2	0	3	4	7	8	11
Cibicidoides pseudoacutus						6	8	6	3	7	6	4	0	2	2			
Clavulinoides trilatera								3	4	2	2	1	0	3	3			
Stainforthia farafraensis											2	3	0	11	16	13	14	19
Pleurostomella paleocenica											2	0	0	2	0	3	5	2
Eouvigerina aegyptiaca														5	3	2	8	9
Total number of individuals	300	300	300	300	300	300	300	300	300	300	299	202	45	294	300	303	302	291

Epifaunal calcareous

Rounded trochospiral
Anomalinoides rubiginosus [1]
Gavelinella danica

Plano-convex trochospiral
Angulogavelinella avnimelechi
Anomalinoides zitteli
Cibicidoides spp.[1]
Gyroidinoides girardana [1]
Valvulineria scrobiculata [2, 4]
Gyroidinoides subangulata
Valvalabamina spp.
Alabamina midwayensis

Biconvex trochospiral
Anomalinoides aegyptiacus [3, 8]
A. spissiformis
A. umbonifera
Cibicidoides pseudoacutus
Eponides lunatus
Eponides spp.
Cibicidoides alleni
C. succedens
Oridorsalis plummerae [4]
Osangularia plummerae
Discorbis pseudoscopos

Biconvex planispiral
Lenticulina spp. [1, 6, 7]

Concavo-convex trochospiral
Karreria fallax

Milioline
Quinqueloculina
Spiroloculina spp.

Palmate
Frondicularia spp.
Neoflabellina spp.

Epifaunal agglutinated

Tubular or branched
Bathysiphon [5, 8]

Coiled flattened – streptospiral
Ammodiscus spp. [3]

Rounded trochospiral
Ammosphaeroidina sp. ?

Infaunal calcareous

Cylindrical tapered
Bulimina spp.
Fursenkoina sp.
Globobulimina ovata
Glandulina laevigata ?
Laevidentalinids
Pyramidulinids
Nodosariids
Pseudonodosaria manifesta
Siphogenerinoides eleganta
Eouvigerina aegyptiaca
Pleurostomella spp.
Stilostomella sp. [3, 8]
Trifarina esnaensis
Stainforthia farafraensis
Tappanina selmensis

Coiled-rectilinear
Saracenaria spp.
Marginulinopsis sp.
Cristellariopsis proinops

Flattened tapered
Loxostomoides applinae
Coryphostoma midwayensis

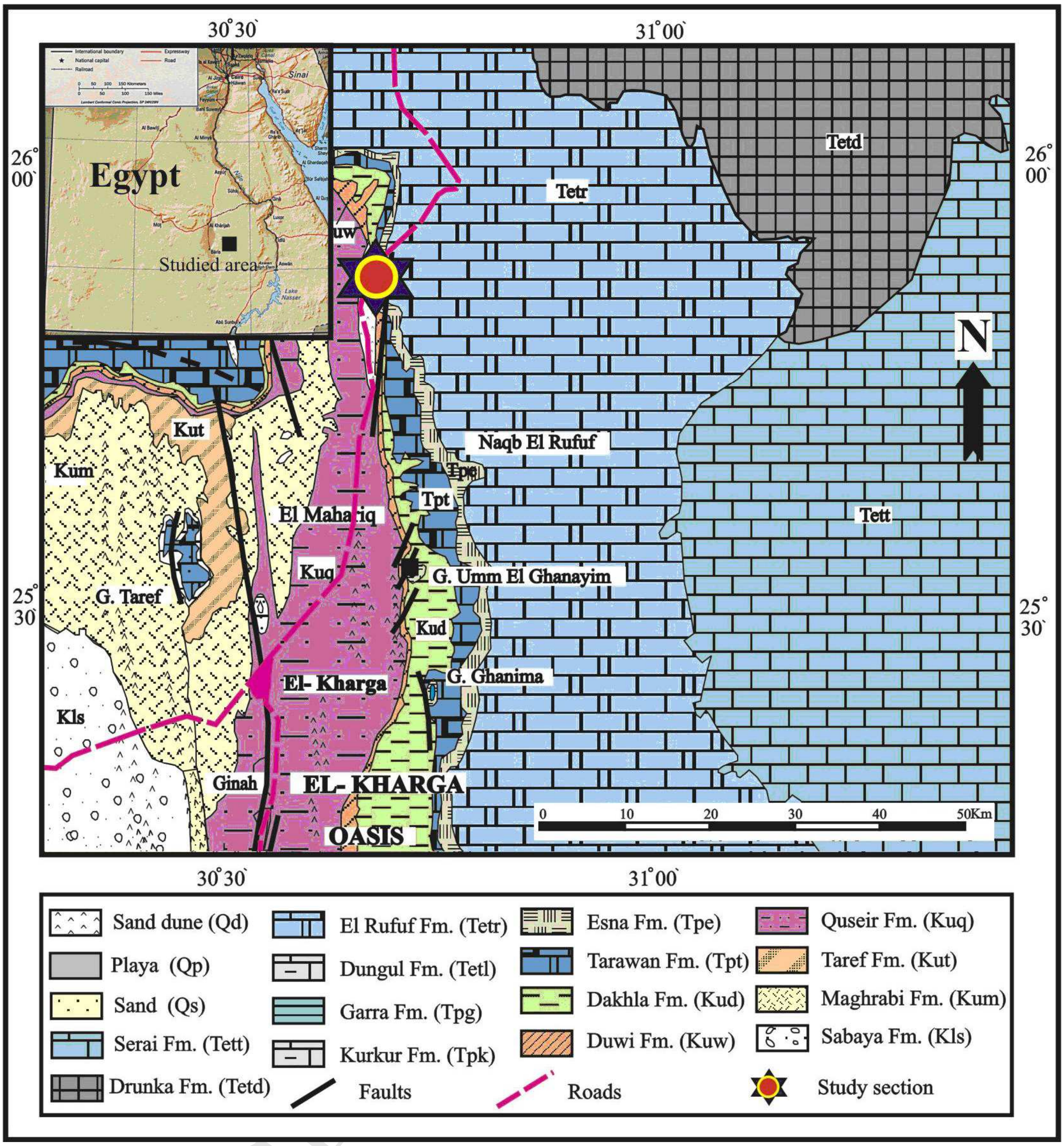
Spherical – globose
Lagena spp.[1]
Globocassidulina subglobosa
morphina allomorphinoides
Allomorphina sp.
Reussoolina spp. [1]

Irregular
Ramulina navarroana

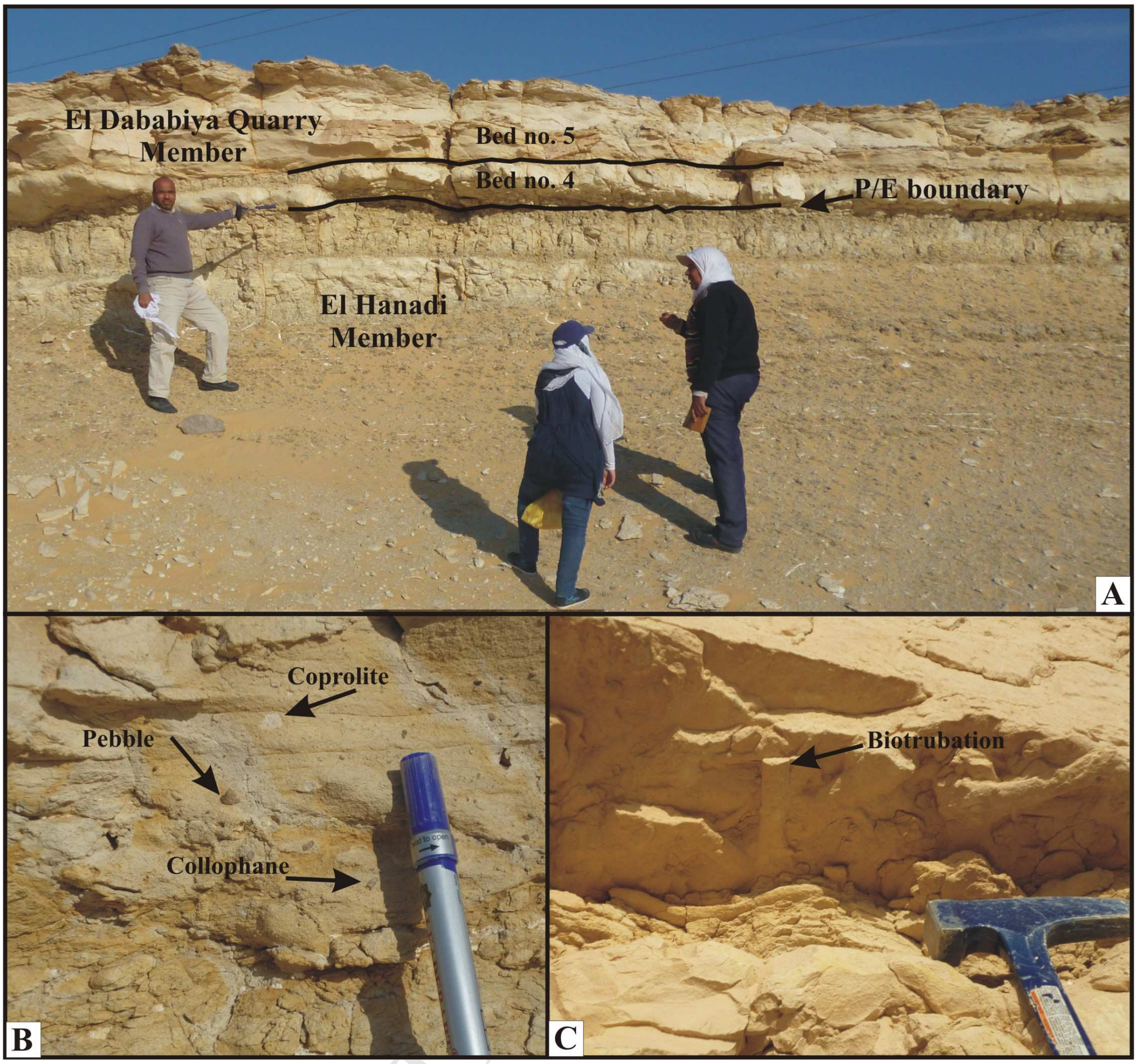
Infaunal agglutinated

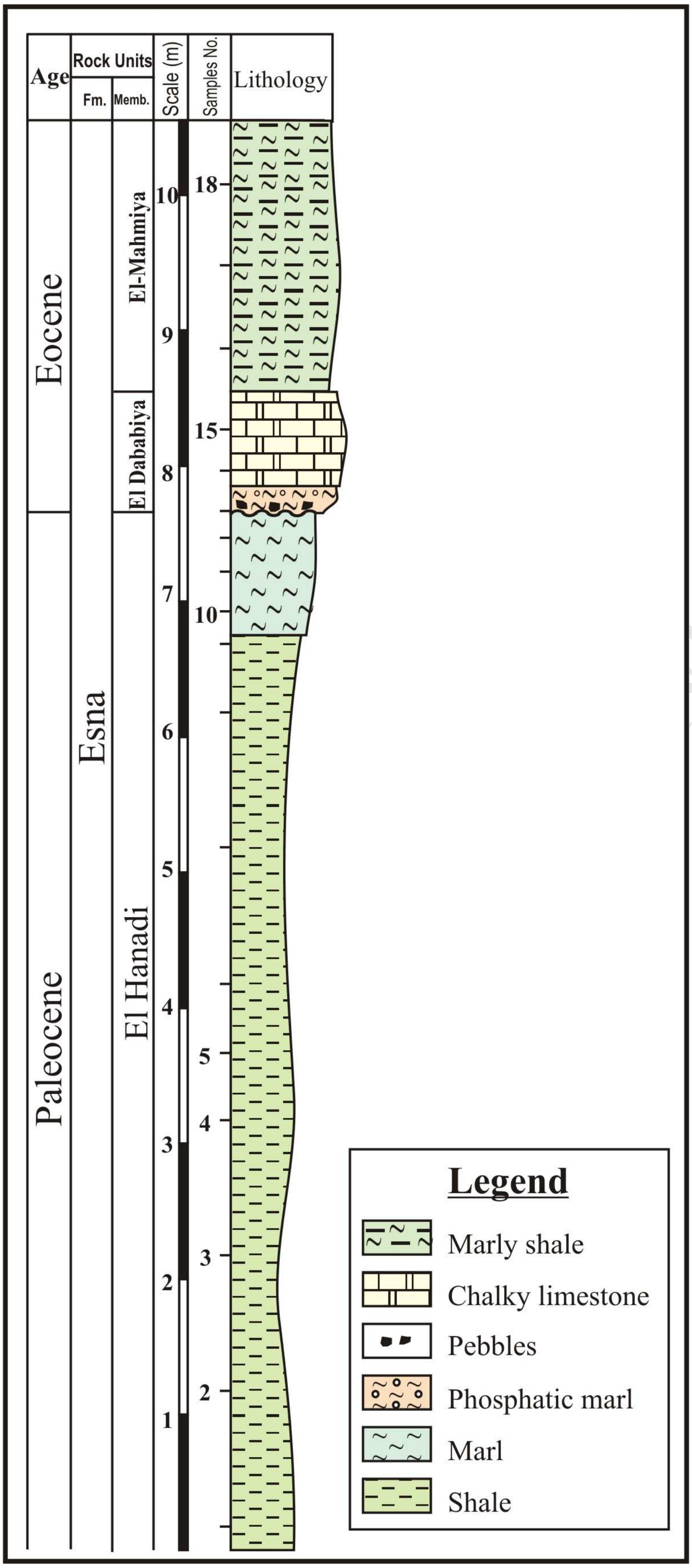
Elongate multilocular
Gaudryina spp.
Bolivinopsis spectabilis
Vulvulina spp.
Karrerulina conversa
Spiroplectinella dentate
Spiroplectinella esnaensis
S. knebeli
Clavulinoides amorpha
C. trilateral
Dorotia bulleta
Gaudryina pyramidata [8]
Marssonella oxycona [8]
Pseudoclavulina spp.
Tritaxia midwayensis
Bermudezina danica

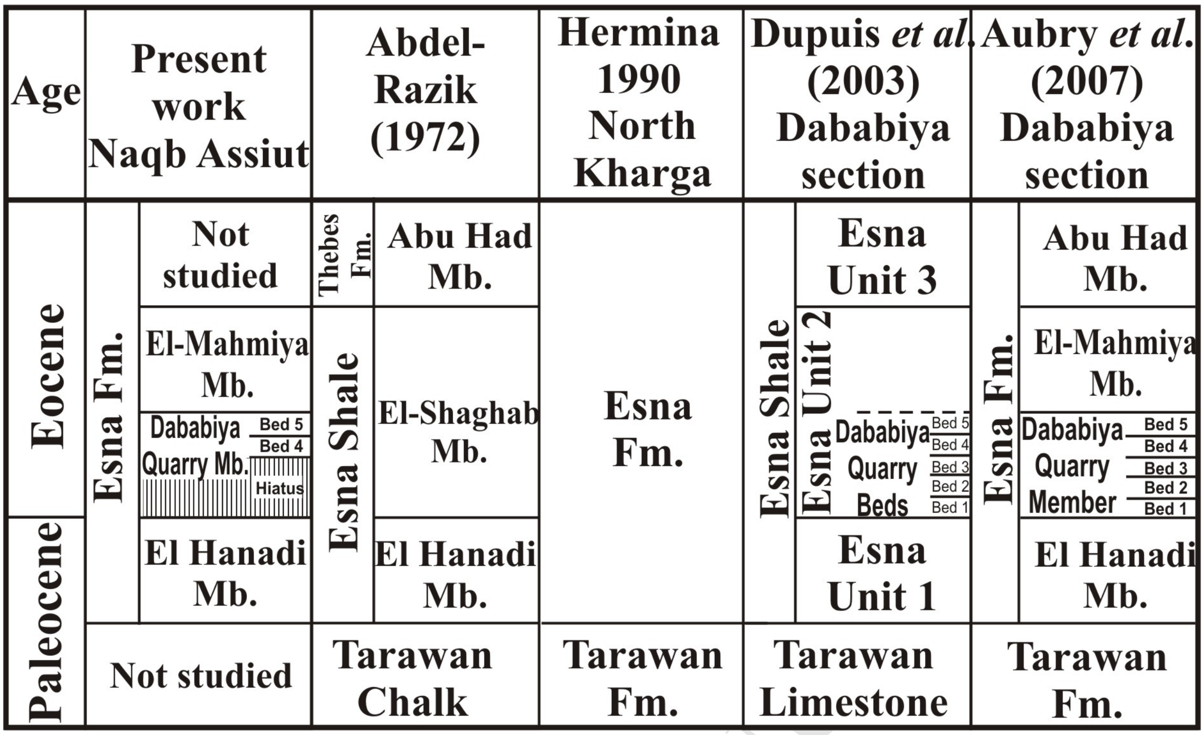
[1]Widmark and Malmgren (1992); [2]Speijer and Schmitz (1998); [3]Speijer and Wagner (2002); [4]Widmark and Speijer (1997); [5]Peryt *et al*. (1997); [6]Corliss (1991); [7]Thomas and Schackleton (1996); and [8]Kaminski *et al*. (1996).

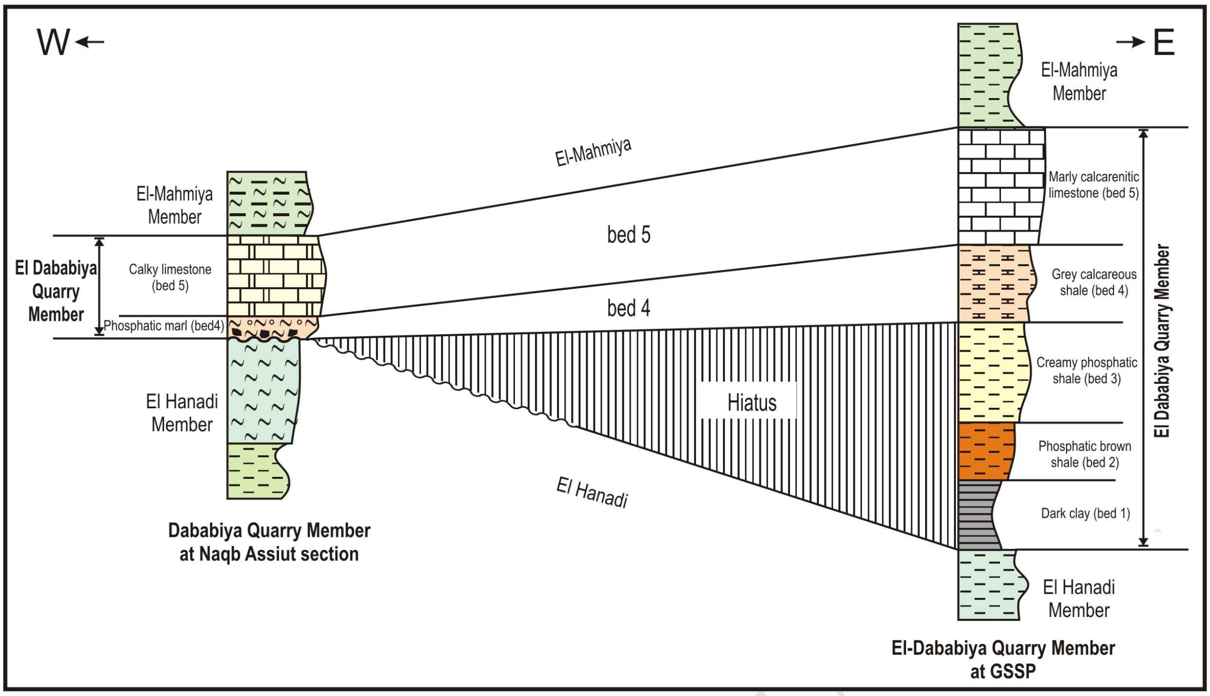


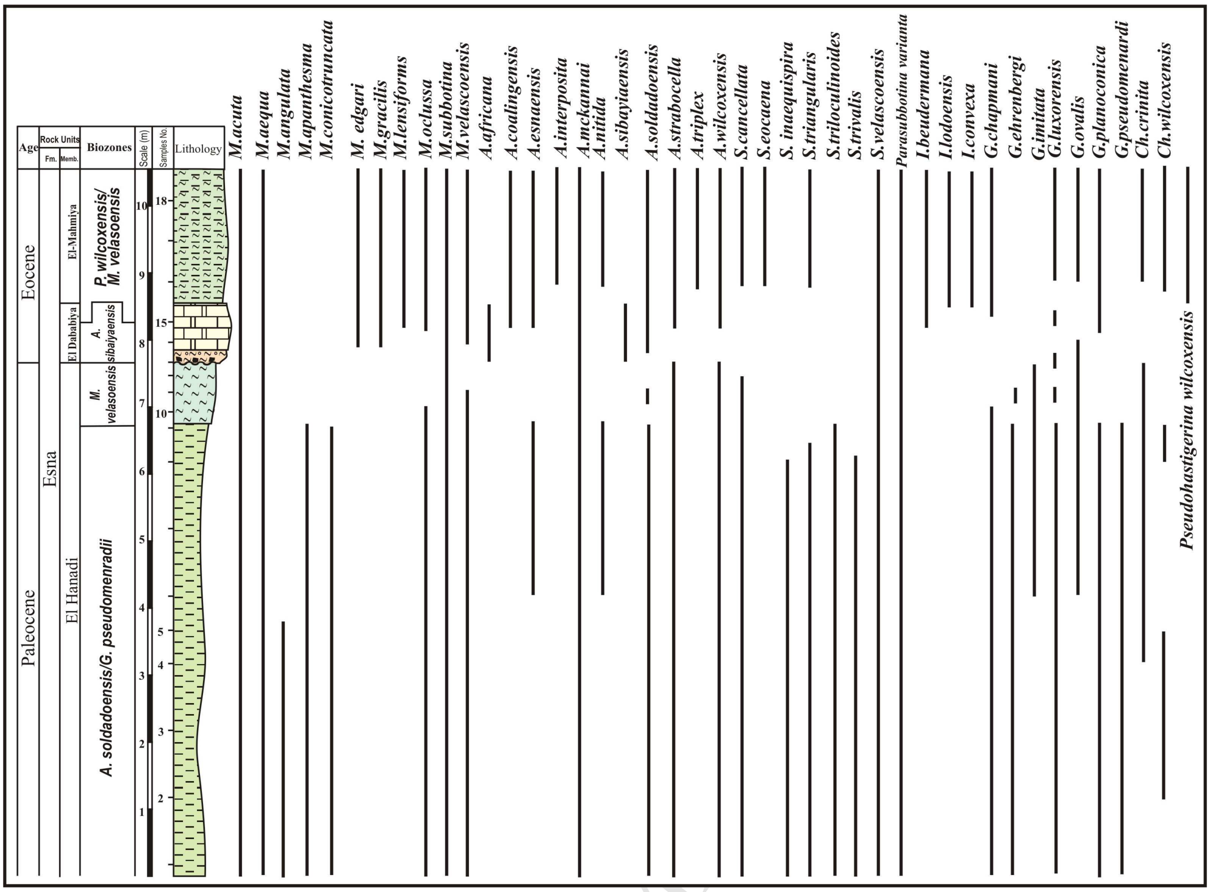
30°30`
31°00`
26° 00`
25° 30`
Egypt
Studied area
Tetd
Tetr
Tett
uw
Kut
Kum
El Mahariq
Kuq
G. Taref
Kls
Naqb El Rufuf
Tpe
Tpt
G. Umm El Ghanayim
Kud
G. Ghanima
El- Kharga
Ginah
EL- KHARGA
OASIS
N
0
10
20
30
40
50Km
Sand dune (Qd)
Playa (Qp)
Sand (Qs)
Serai Fm. (Tett)
Drunka Fm. (Tetd)
El Rufuf Fm. (Tetr)
Dungul Fm. (Tetl)
Garra Fm. (Tpg)
Kurkur Fm. (Tpk)
Faults
Esna Fm. (Tpe)
Tarawan Fm. (Tpt)
Dakhla Fm. (Kud)
Duwi Fm. (Kuw)
Roads
Quseir Fm. (Kuq)
Taref Fm. (Kut)
Maghrabi Fm. (Kum)
Sabaya Fm. (Kls)
Study section


El Dababiya Quarry Member
Bed no. 5
Bed no. 4
P/E boundary
El Hanadi Member
A
Coprolite
Pebble
Collophane
B
Biotrubation
C

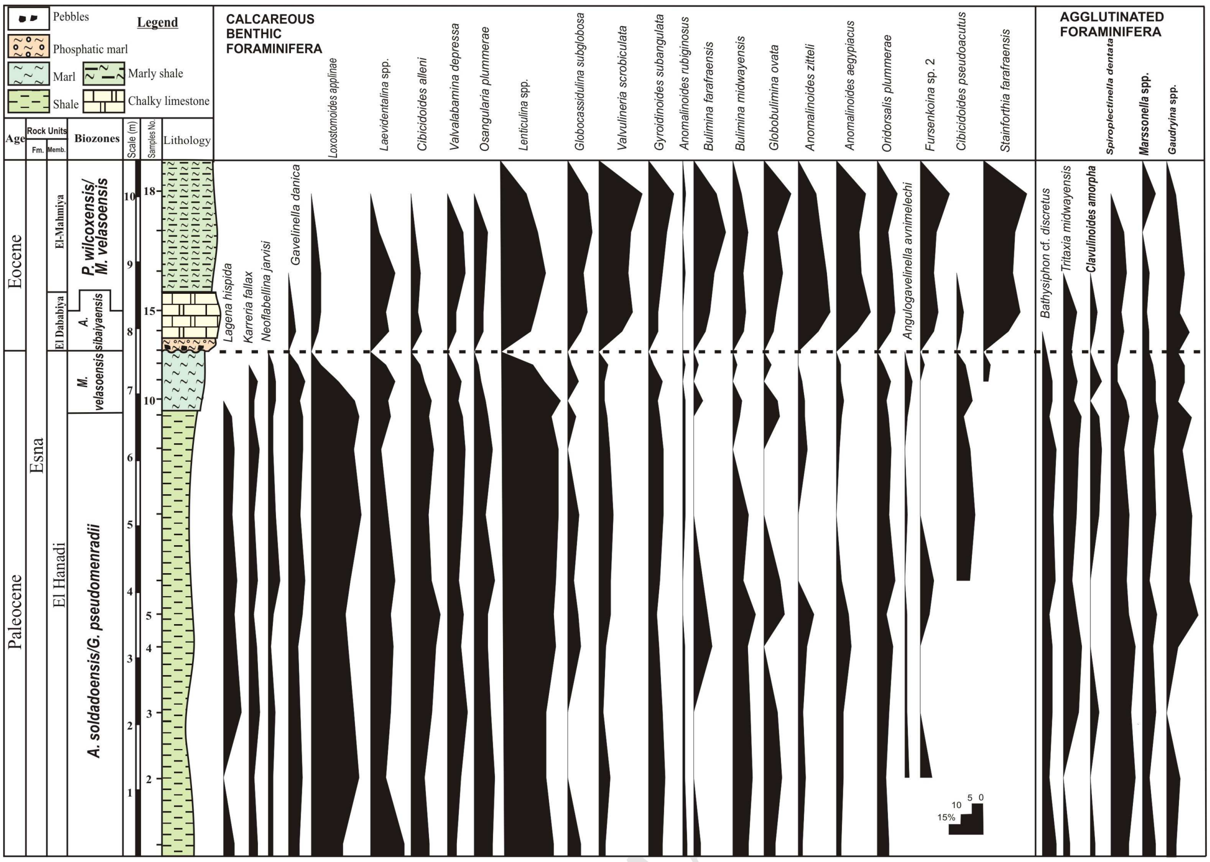

Age
Rock Units
Fm.
Memb.
Scale (m)
Samples No.
Lithology
Eocene
Paleocene
Esna
El-Mahmiya
El Dababiya
El Hanadi
10
9
8
7
6
5
4
3
2
1
18
15
10
5
4
3
2
Legend
Marly shale
Chalky limestone
Pebbles
Phosphatic marl
Marl
Shale


Age
Present work Naqb Assiut
Abdel-Razik (1972)
Hermina 1990 North Kharga
Dupuis et al. (2003) Dababiya section
Aubry et al. (2007) Dababiya section
Eocene
Paleocene
Esna Fm.
Not studied
El-Mahmiya Mb.
Dababiya Quarry Mb.
Bed 5
Bed 4
Hiatus
El Hanadi Mb.
Not studied
Thebes Fm.
Abu Had Mb.
Esna Shale
El-Shaghab Mb.
El Hanadi Mb.
Tarawan Chalk
Esna Fm.
Tarawan Fm.
Esna Shale
Esna Unit 3
Esna Unit 2
Dababiya Quarry Beds
Bed 5
Bed 4
Bed 3
Bed 2
Bed 1
Esna Unit 1
Tarawan Limestone
Esna Fm.
Abu Had Mb.
El-Mahmiya Mb.
Dababiya Quarry Member
Bed 5
Bed 4
Bed 3
Bed 2
Bed 1
El Hanadi Mb.
Tarawan Fm.

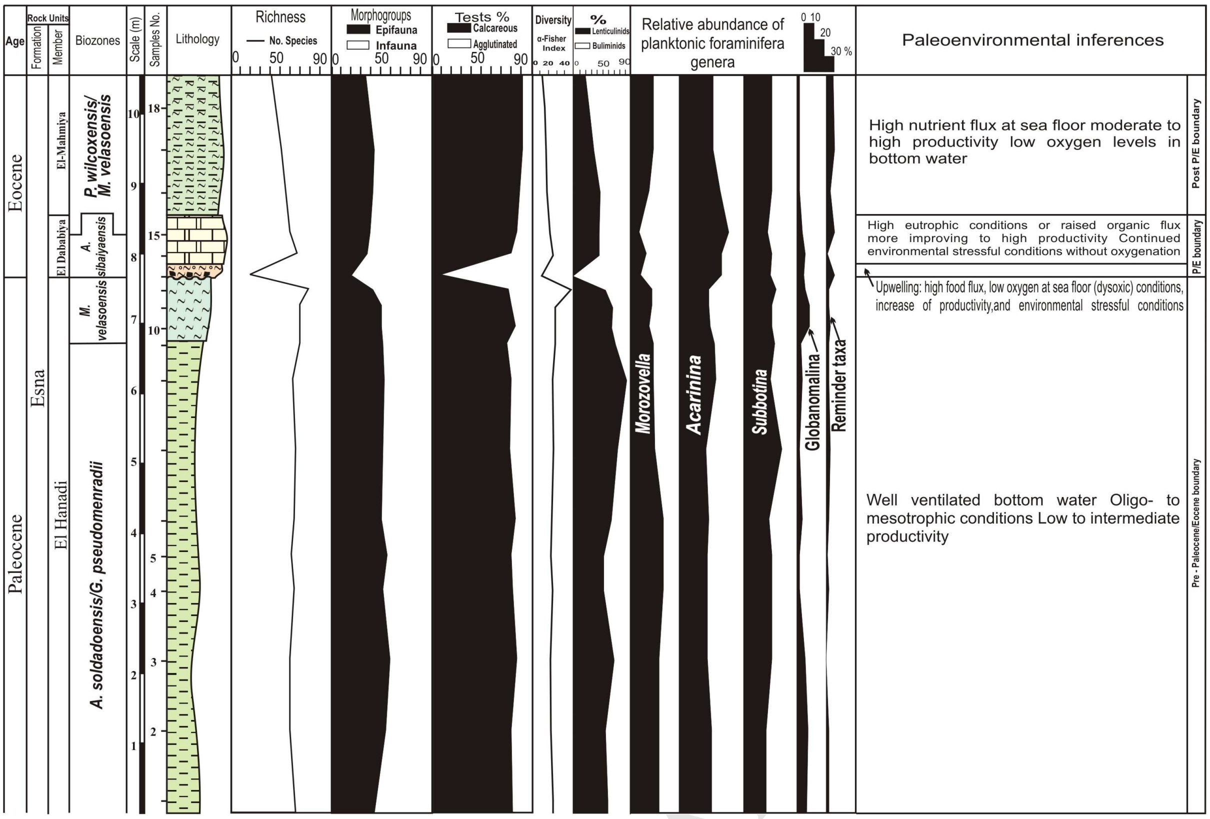

W
E
El-Mahmiya Member
Calky limestone (bed 5)
Phosphatic marl (bed4)
El Dababiya Quarry Member
El Hanadi Member
Dababiya Quarry Member at Naqb Assiut section
El-Mahmiya
bed 5
bed 4
Hiatus
El Hanadi
El-Mahmiya Member
Marly calcarenitic limestone (bed 5)
Grey calcareous shale (bed 4)
Creamy phosphatic shale (bed 3)
Phosphatic brown shale (bed 2)
Dark clay (bed 1)
El Dababiya Quarry Member
El Hanadi Member
El-Dababiya Quarry Member at GSSP

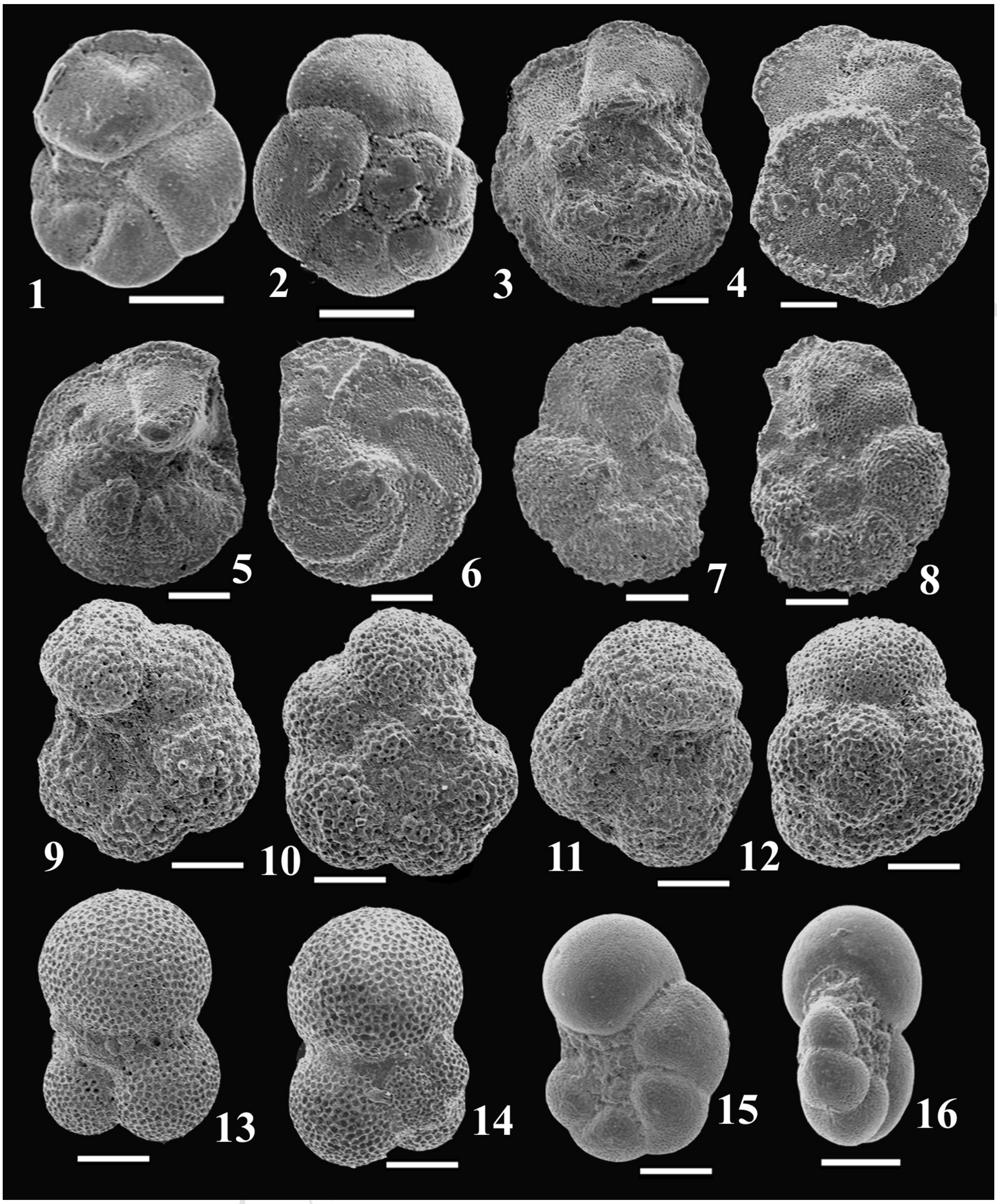

Age
Rock Units
Fm.
Memb.
Biozones
Scale (m)
Samples No.
Lithology
Eocene
Paleocene
Esna
El-Mahmiya
El Dababiya
El Hanadi
P. wilcoxensis/ M. velasoensis
A. sibaiyaensis
M. velasoensis
A. soldadoensis/G. pseudomenradii
M.acuta
M.aequa
M.angulata
M.apanthesma
M.conicotruncata
M. edgari
M.gracilis
M.lensiforms
M.oclussa
M.subbotina
M.velascoensis
A.africana
A.coalingensis
A.esnaensis
A.interposita
A.mckannai
A.nitida
A.sibayiaensis
A.soldadoensis
A.strabocella
A.triplex
A.wilcoxensis
S.cancellata
S.eocaena
S. inaequispira
S.triangularis
S.triloculinoides
S.trivalis
S.velascoensis
Parasubbotina varianta
I.beudermana
I.lodoensis
I.convexa
G.chapmani
G.ehrenbergi
G.imitata
G.luxorensis
G.ovalis
G.planoconica
G.pseudomenardi
Ch.crinita
Ch.wilcoxensis
Pseudohastigerina wilcoxensis

<table>
<tr><th>Age</th><th>Datum events</th><th>The present study</th><th colspan="2">Berggren et al. (1995) Standard</th><th colspan="2">Berggren & Ouda (2003) Dababiya section (GSSP)</th><th colspan="2">Berggren & Pearson (2005)</th><th colspan="2">Wade et al. (2011)</th></tr>
<tr><td rowspan="2">Eocene</td><td>M. velascoensis
P. wilcoxensis</td><td>P. wilcoxensis-M. velascoensis</td><td rowspan="3">P5</td><td rowspan="3">M. velascoensis</td><td rowspan="3">P5</td><td>P5c</td><td>E2</td><td>P. wilcoxensis-M. velascoensis</td><td>E2</td><td>P. wilcoxensis-M. velascoensis</td></tr>
<tr><td>A. sibaiyaensi & A. africana</td><td>A. sibaiyaensis</td><td>P5b</td><td>E1</td><td>A. sibaiyaensis</td><td>E1</td><td>A. sibaiyaensis</td></tr>
<tr><td rowspan="2">Paleocene</td><td>G.pseudomenardii</td><td>M. velascoensis</td><td>P5a</td><td>P5</td><td>M. velascoensis</td><td>P5</td><td>M. velascoensis</td></tr>
<tr><td>A. soldadoensis</td><td>A. soldadoensis-G.pseudomenardii</td><td>P4c</td><td>A. soldadoensis-G.pseudomenardii</td><td>P4</td><td>P4c</td><td>P4c</td><td>A. soldadoensis-G.pseudomenardii</td><td>P4c</td><td>A. soldadoensis-G. pseudomenardii</td></tr>
</table>



Legend
Pebbles
Phosphatic marl
Marl
Marly shale
Shale
Chalky limestone
Age
Rock Units
Fm.
Memb.
Biozones
Scale (m)
Samples No.
Lithology
Eocene
Paleocene
Esna
El-Mahmiya
El Dababiya
El Hanadi
P. wilcoxensis/ M. velasoensis
A. sibaiyaensis
M. velasoensis
A. soldadoensis/G. pseudomenradii
CALCAREOUS BENTHIC FORAMINIFERA
Lagena hispida
Karreria fallax
Neoflabellina jarvisi
Gavelinella danica
Loxostomoides applinae
Laevidentalina spp.
Cibicidoides alleni
Valvalabamina depressa
Osangularia plummerae
Lenticulina spp.
Globocassidulina subglobosa
Valvulineria scrobiculata
Gyroidinoides subangulata
Anomalinoides rubiginosus
Bulimina farafraensis
Bulimina midwayensis
Globobulimina ovata
Anomalinoides zitteli
Anomalinoides aegypiacus
Oridorsalis plummerae
Angulogavelinella avnimelechi
Fursenkoina sp. 2
Cibicidoides pseudoacutus
Stainforthia farafraensis
AGGLUTINATED FORAMINIFERA
Bathysiphon cf. discretus
Tritaxia midwayensis
Clavulinoides amorpha
Spiroplectinella dentata
Marssonella spp.
Gaudryina spp.
15%
10
5
0


Age
Rock Units
Formation
Member
Biozones
Scale (m)
Samples No.
Lithology
Richness
No. Species
Morphogroups
Epifauna
Infauna
Tests %
Calcareous
Agglutinated
Diversity
α-Fisher Index
%
Lenticulinids
Buliminids
Relative abundance of planktonic foraminifera genera
Paleoenvironmental inferences
Eocene
Paleocene
Esna
El-Mahmiya
El Dababiya
El Hanadi
P. wilcoxensis/ M. velasoensis
A. sibaiyaensis
M. velasoensis
A. soldadoensis/G. pseudomenradii
Morozovella
Acarinina
Subbotina
Globanomalina
Reminder taxa
High nutrient flux at sea floor moderate to high productivity low oxygen levels in bottom water
High eutrophic conditions or raised organic flux more improving to high productivity Continued environmental stressful conditions without oxygenation
Upwelling: high food flux, low oxygen at sea floor (dysoxic) conditions, increase of productivity,and environmental stressful conditions
Well ventilated bottom water Oligo- to mesotrophic conditions Low to intermediate productivity
Post P/E boundary
P/E boundary
Pre - Paleocene/Eocene boundary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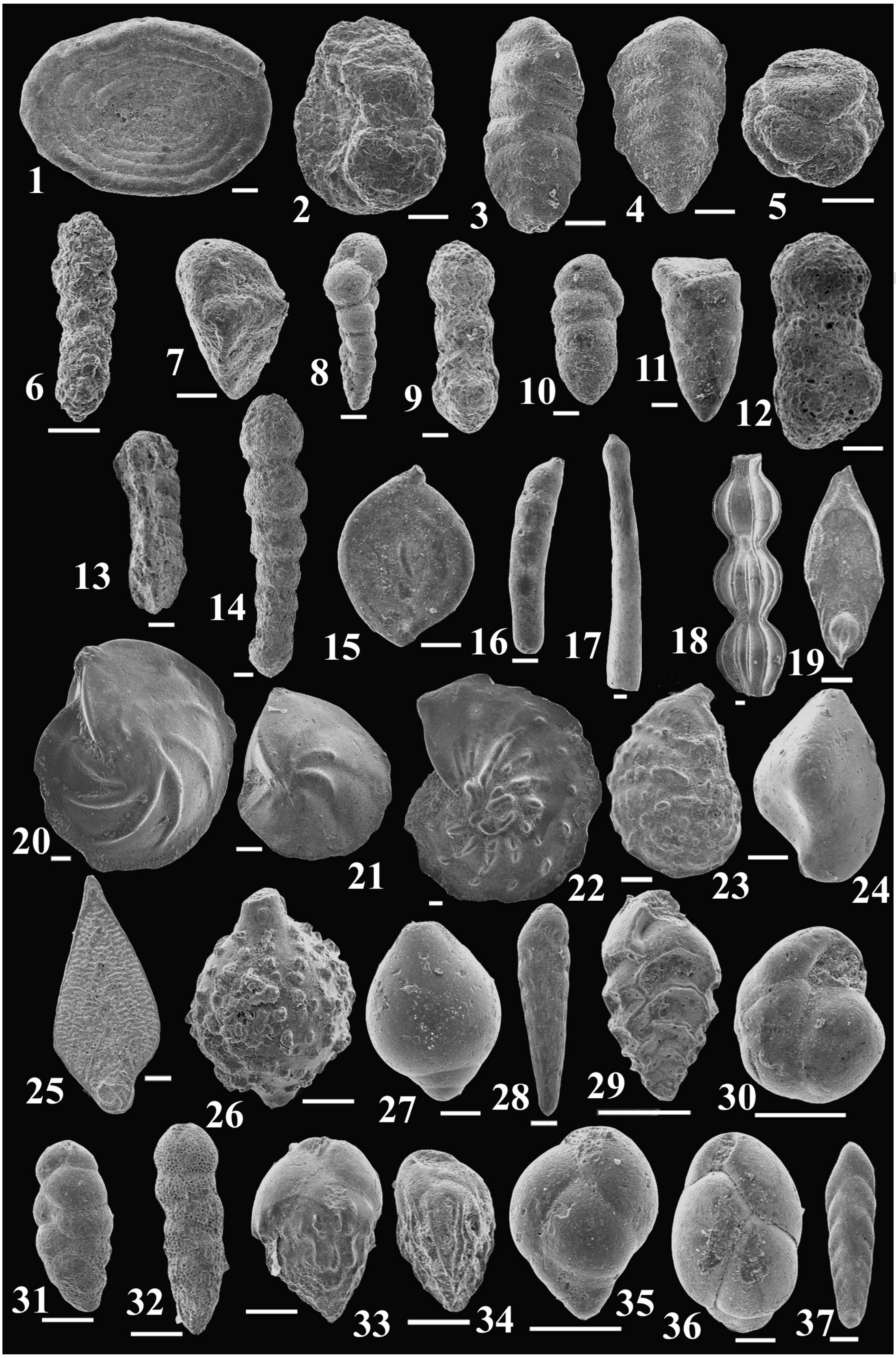
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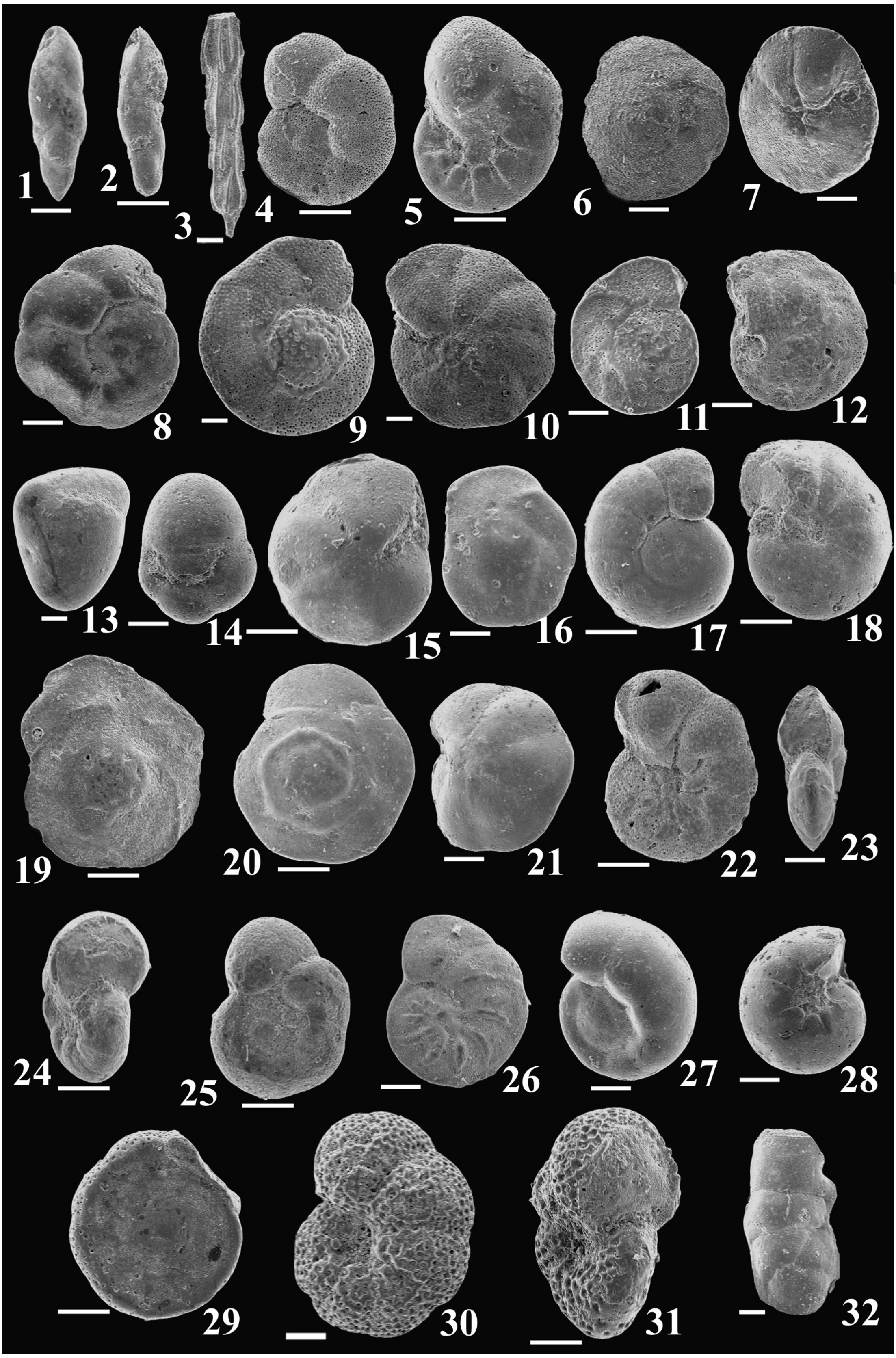
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-The lithostratigraphy of the P-E transition at Naqb Assiut, Western Desert, Egypt is studied.
-The biostratigraphy of this transition is carried out and four planktonic foraminiferal zones are defined.
-The P/E boundary is documented and discussed.
-The benthonic foraminiferal fauna during this interval are analyzed and discussed.
-The Paleobathymetrical and paleoenvironmental changes across the P/E boundary are explained.