Foraminiferal Biostratigraphy, Stages Boundaries and Paleoecology of the Uppermost Maastrichtian - Lower Eocene Succession at Esh El-Mellaha Area, North Eastern Desert, Egypt

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Abstract: The uppermost Maastrichtian- lower Eocene succession exposed at three sections located on the western flank of Esh El-Mellaha range, north Eastern Desert at Wadi Dib, Wadi Abu Had, and Bir Mellaha sections from north to south are detailed examined for their foraminiferal contents. This time interval is represented by the uppermost part of the Sudr, Esna, and Thebes formations from base to top. These rock units are found very rich with foraminiferal assemblages. **209** foraminiferal species have been identified. This include **71** planktonic species which are belonging to **24** genera, **6** subfamilies, **7** families, **4** superfamilies and **1**suborder; and **138** benthic species belonging to **60** genera, **24** subfamilies **33** families, **18** superfamilies and **3** suborders. The planktonic assemblage is used to classify the studied interval into twelve planktonic foraminiferal biozones; three of latest Maastrichtian (*Pseudoguembelina hariaensis* (CF3), *Pseudoguembelina palpebra* (CF2), and *Plummerita hantkeninoides* (CF1) zones); three of early Paleocene (Danian): *Globanomalina compressa* (P1c), *Praemurica trindadensis* (P1d), and *Praemurica uncinata* (P2) zones; one of early late Paleocene (Selandian): *Morozovella angulata* (P3a) Zone; one of latest Paleocene (latest Thanetian): *Morozovella velascoensis* (P5) Zone; two of earliest Eocene (Sparnacian): (*Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) and *Morozovella marginodentata* (E3) zones; and two of early Eocene (Ypresian): *Morozovella formosa formosa* (E4) and *Morozovella aragonensis / Morozovella subbotinae* (E5) zones. Also, this interval is classified into five benthic zones, one of latest Maastrichtian: *Bolivinoides draco draco* Zone; one of early Paleocene (middle – late Danian): *Siphogenerinoides eleganta* Zone; one of late early Paleocene (latest Danian) to early late Paleocene (Selandian) *Alabamina midwayensis* Zone; one of latest Paleocene (latest Thanetian): *Gavelinella danica* Zone; and one of early Eocene: *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* Zone. The Cretaceous/ Paleogene (K/P_g) boundary is located between (CF1) and (P1c) zones at Bir Mellaha, while at both Wadi Abu Had, and Wadi Dib sections it is located between (CF3) and (P1d) zones. The Danian/ Selandian (D/S) boundary is located between (P2) and (P3a) zones; Selandian/ Thanetian (S/ Th.) boundary is located between (P3a) and (P5) zones; while the Paleocene / Eocene (P/E) boundary is located between (P5) and (E2). Three sedimentary gaps are detected in the studied stratigraphic sequence; the first one is located between the Sudr and the Esna formations and includes K/Pg boundary; the second is located within the middle part of the Esna Formation and it includes S/Th boundary; while the third sedimentary gap is located within the uppermost part of Esna Formation and it includes the P/ E boundary. The planktonic and benthonic foraminiferal assemblages are used to build a paleoecologic interpretations and sea level changes over the study area during the uppermost Maastrichtian-lower Eocene time.
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Introduction

Esh El-Mellaha range is located at the southwestern part of the Gulf of Suez region, between latitudes 27°24' N and 27°49' N and longitudes 33°11' E and 33°40' E., north Eastern Desert, Egypt (Fig.1.A). It easily stretches along the western coast of the Gulf of Suez, on the Ras Gharib-Hurghada desert road. On the western flank of Esh El-Mellaha range, three upper Maastrichtian- lower Eocene exposures were measured. These are from north to south: Wadi Dib (latitude 27° 48' 40''N and longitude 33° 13' 05'' E), Wadi Abu Had (latitude 27° 39' 37'' N and longitude 33° 21' 45'' E), and Bir Mellaha (latitude 27° 34' 51'' N and longitude 33° 25' 56'' E.), (Fig.1B).

A few previous studies of planktonic foraminiferal biostratigraphic classification of the Upper Maastrichtian - Lower Eocene were done at the Esh El-Mellaha area if it compared with other localities in Egypt. On the other hand, the benthic foraminiferal biostratigraphy was not studied indetails previously at this area. The most important works include: Abdallah *et al*., 1984; Prat *et al*., 1986; Aref *et al*., 1988; Cherif and Ismail, 1991**;** and Ismail, 2012.

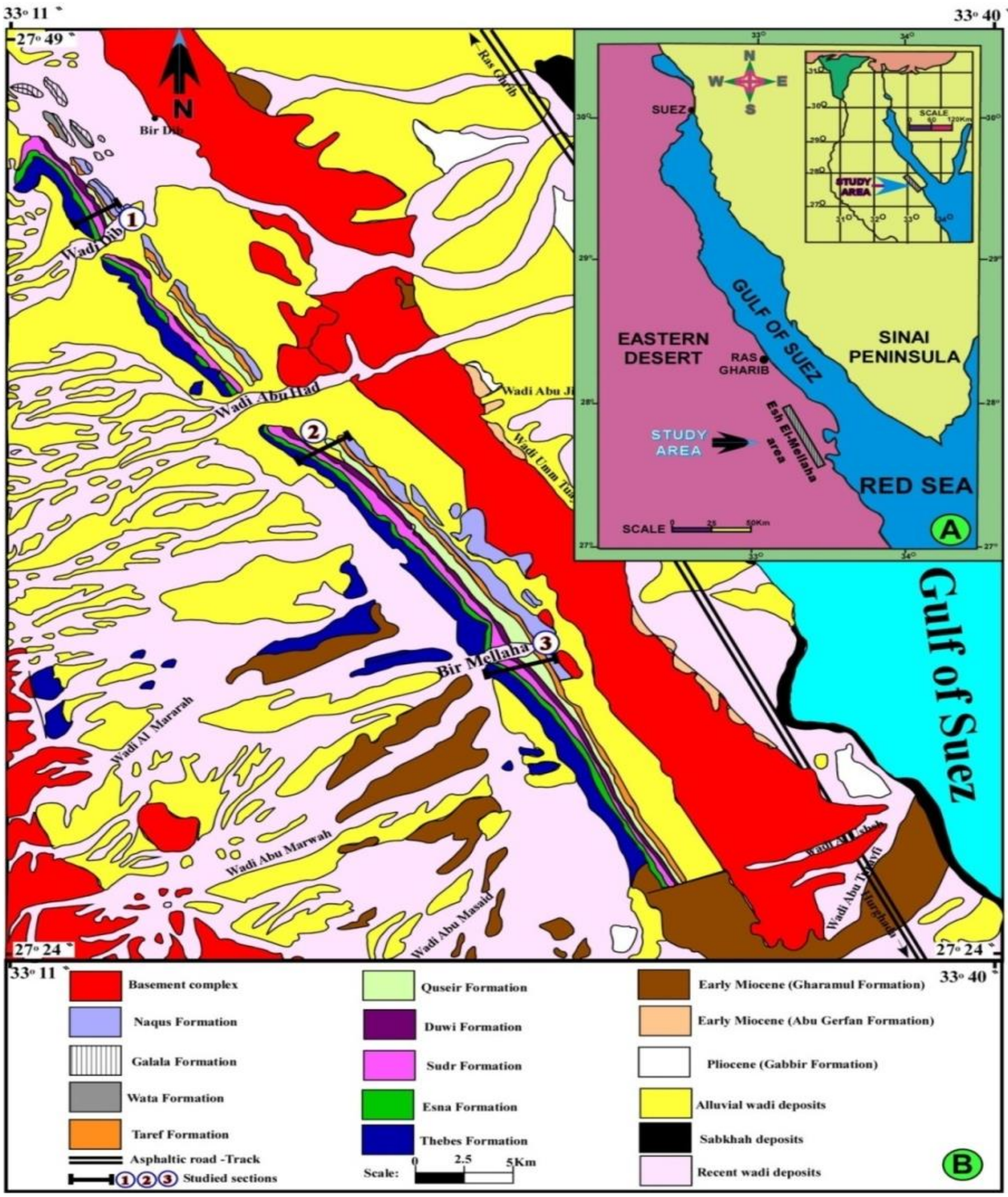

Fig. 1: (A) Location map of the study area, and (B) geologic map of the study area.

The exposed Upper Maastrichtian – Lower Eocene succession on the western flank of the Esh El-Mellaha area is represented by the following three rock units from base to top:

1. Uppermost part of the Sudr Formation

In the present study area, the upper part of the Sudr Formation is represented by upper part of Abu Zeneima Member which composed of yellowish-white to pale grey soft argillaceous limestone and chalky limestone sequence. It attains about 4.5 m thick a Wadi Dib section, about 5m thick at Wadi Abu Had section, and about 12 m thick at Bir Mellaha section. The age of this part of the Sudr Formation is assigned to uppermost part of Upper Maastrichtian depending on its index planktonic foraminiferal species (Figs. 3-5).

2. Esna Formation

It was originally introduced as Esna Shale by Beadnell, 1905 to describe 60m of green to grayish green shales that underlying the Eocene *Operculina limestone* in Gebel Oweina, southeast Esna region. Subsequently, this shale unit was raised to

Formational rank and named as Esna Formation by Said, 1962. Said, 1960 assigned the Esna Shale at its type area to Upper Paleocene- Lower Eocene age. In our study area, the Esna Formation consists of yellowish pale brown to green shale in the lower part intercalated with thinly bedded argillaceous limestone in the upper part (Fig. 2. B). This rock unit completely devoid from any macro faunal content, while it is found very rich with the foraminiferal assemblages of Paleocene to Lower Eocene age (Figs. 3-5). It attains about 22 m thick a Wadi Dib section, about 20 m thick at Wadi Abu Had section, and about 24 m thick at Bir Mellaha section. Said, 1960 showed that the Esna Shale at its type area overlies the Tarawan Formation and underlies the Thebes Formation. In the present study area, the Esna Formation overlies the Sudr Formation and underlies the Thebes Formation (Fig. 2. A & 2. B). The lower boundary of the Esna Formation with the underlying Sudr Formation is unconformably and it is represented the K/P_g boundary in the study area. This boundary is clear and well marked by the occurrence of wavy irregular and sharp contact depending on abrupt facies changes from snow white chalky limestone with upper Maastrichtian foraminiferal content of Sudr Formation at base and dark green to grey shale with Paleocene foraminiferal content of Esna Formation at top.

3. Thebes Formation

It was originally proposed and described by Hume, 1911and emended by Said, 1960, at its type locality "Gebel Gurnah (opposite Luxor), Nile Valley". In the present study area, the measured part of the Thebes formation attains about 14 m thick at Wadi Dib section, about 13 m thick at Wadi Abu Had, and about 8 m thick at Bir Mellaha section. Lithologically, it composed of pale white; porcellaneous chalky limestone succession and sometimes concretional limestones with brown to black flint bands and nodules. This rock unit is represented the top of the studied successions; It overlies the Esna Formation with conformable surface and forms a steep scarp above the Esna Formation. The lower contact of the Thebes Formation with the underlying Esna Formation is sharp contact and easily distinguished in the field and lies between light grey to green fissile shale intercalated with argillaceous thinly bedded limestones of Esna Formation below and pale white, porcellaneous chalky limestone with brown to black flint bands and nodules of the Thebes Formation above. The Thebes Formation has been dated as early Eocene age as proofed by different authors as; Youssef, 1954; Said, 1960 & 1962 & 1990; El Naggar, 1966; Luger, 1988; and Berggren and Ouda, 2003. In the present study area, we are studied only the lower part of this Formation, which yields no macrofossils at the three studied sections and the early Eocene (Ypresian) age is suggested for this measured part of Thebes Formation based on its rare planktonic foraminiferal content.

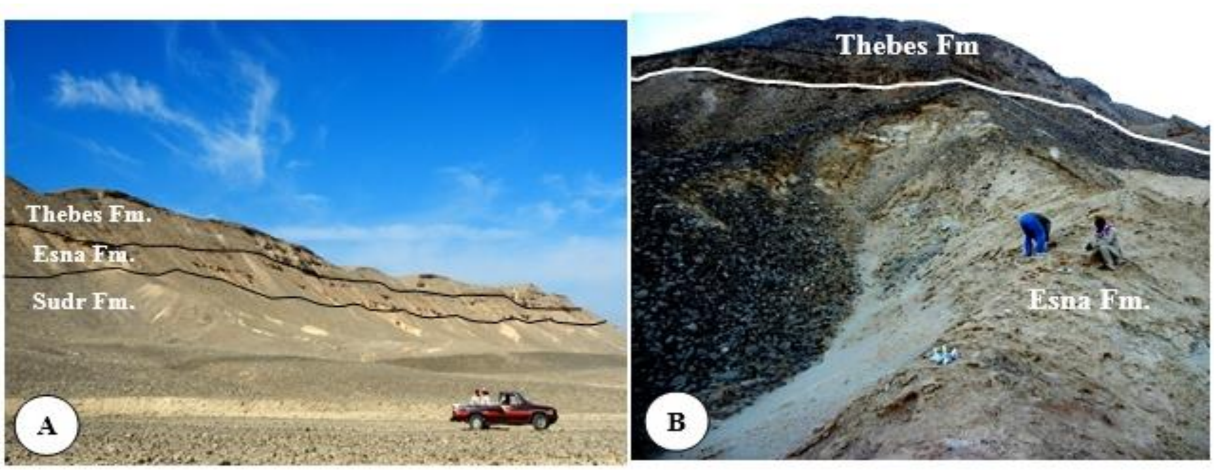

Fig. 2: **Field photographs showing (A) The studied succession Sudr, Esna, and Thebes formations at Wadi Dib section, looking north East. (B) The contact between the Esna and Thebes formations at Wadi Abu Had section, looking west.**

The main targets of the present work on the upper Maastrichtian- lower Eocene at Esh El Mellaha area are: **1.** Planktonic and benthonic foraminiferal biostratigraphic classification of the upper Maastrichtian- Lower Eocene (Ypresian) interval at Esh El-Mellaha area; **2.** Studying the nature of the Cretaceous / Paleogene (K/P_g); Danian/ Selandian (D/S); Selandian/ Thanetian (S/Th); and Paleocene/ Eocene (P/ E) boundaries and their affects on the recorded planktonic and benthonic foraminiferal assemblages at the studied sedimentary sequence. **3.** Using both the planktonic and benthonic foraminiferal assemblages to build a paleoecologic interpretations and sea level changes over the study area during the studied time interval.

Biostratigraphy

209 foraminiferal species have been identified. This include **71** planktonic species which are belonging to **24** genera, **6** subfamilies, **7** families, **4** superfamilies and **1** suborder; and **138** benthic species belonging to **60** genera, **24** subfamilies, **33** families, **18** superfamilies and **3** suborders have been identified from the three studied sections. These identified foraminiferal species are photographed by Scanning Electron Microscope (SEM) in the laboratories of the Egyptian Mineral Resources Authority and shown on (plates 1- 5). Depending on the vertical distribution chart of these recorded foraminiferal species at the three studied sections (Figs. 3-9), two foraminiferal biostratigraphic schemes for the uppermost Maastrichtian– lower Eocene sedimentary sequence at Esh El-Mellaha area are established; the first is based on the planktonics and the other on the benthonics as follows:

I. Planktonic foraminiferal biostratigraphy

Many planktonic foraminiferal zonal schemes for the upper Maastrichtian –lower Eocene (Ypresian) interval were established. For more accurate biostratigraphic resolution, the identified planktonic foraminiferal species in the three studied sections at Esh El-Mellaha area are used to distinguish twelve planktonic foraminiferal biozones based on zonal schemes of Li *et al*., 1999 for the upper Cretaceous and Berggren & Pearson 2005 for the lower Paleogene interval (Figs. 3-5). Three of latest Maastrichtian**: 1.** *Pseudoguembelina hariaensis* (CF3), **2.** *Pseudoguembelina palpebra* (CF2), and **3.** *Plummerita hantkeninoides* (CF1) zones which were described in details by Hewaidy *et al*., 2017; while the other nine zones are recorded in the lower Paleogene interval and a detailed description of them from older to younger as follows:

4- *Globanomalina compressa* (P1c) Zone (Partial range Zone)(early Paleocene (middle Danian))

This planktonic foraminiferal biozone was defined by Keller *et al*., 1995; Where, they subdivided the *Gl. compressa / P. inconstans- P. uncinata* Subzone (P1c) of Berggren *et al.*, 1995 into (P1c and P1d) based on the first occurrence of the *P. trindadensis* (Bolli). In the present study, It is defined as a biostratigraphic interval extended from the first appearance of *Globanomalina compressa* (Plummer) at the base to the first appearance of *Praemurica trindadensis* (Bolli) at the top. It is directly overlies the K/P_g boundary and recorded only at Bir Mellaha section and it attains about 2m thick. It is assigned to early Paleocene (Middle Danian) (the base of this Zone is at 62.87 Ma according to Berggren *et al*., 1995 and Berggren and Pearson, 2005, and the top is at 62.20 Ma according to Keller *et al*., 2002). This Zone is equivalent to the lower part of *M. trindadensis* Zone of Toumarkine & Luterbacher (1985), Hewaidy (1987), Hewaidy *et al*. (1991); the lower part of *P. trindadensis* Zone of Shahin & El-Nady (2001); the lower part of *G. compressa / P. inconstans- P. uncinata* Subzone P1c of Berggren *et al*. (1995), Tantawy *et al*.(2001), Samir (2002), El Sabbagh (2007); the lower part of *Gl. compressa/ P. inconstans* Subzone P1c of Berggren and Pearson (2005). It is also equivalent to the P1c Subzone of Keller *et al*. (1995), and Keller *et al*.(2002 a, b).

5- *Praemurica trindadensis* (P1d) Zone (Partial range zone)(early Paleocene (middle to late Danian))

The *Praemurica trindadensis* (P1d) Zone was originally proposed by Bolli, 1957a. In the present study, the definition of Keller *et al*., 1995 is used to include a biostratigraphic interval extended from the first appearance of *Praemurica trindadensis* (Bolli) at the base to the first appearance of *Praemurica uncinata* (Bolli) at the top. This biozone overlies (P1c) Zone at Bir Mellaha section and attains about 1m thick; while at both Wadi Dib and Wadi Abu Had sections it is directly overlies the K/P_g boundary and attains about 4m thick. It is assigned to early Paleocene (Middle to Late Danian) (the base of this biozone is at 62.20 Ma according to Keller *et al*.,2002 and the top is at 61.37 Ma according to Berggren and Pearson, 2005). It is equivalent to the upper part of *M. trindadensis* Zone of Toumarkine & Luterbacher (1985), Hewaidy (1987), Hewaidy *et al*. (1991); the upper part of *P. trindadensis* Zone of Shahin & El-Nady (2001); the upper part of *Gl. compressa/ P. inconstans- P. uncinata* Subzone (P1c) of Berggren *et al*. (1995), Tantawy *et al*.(2001), Samir (2002), El Sabbagh (2007), Al- Wosabi & Abu Shama (2007), Faris and Farouk (2012); the upper part of *Gl. compressa / P. inconstans* Subzone (P1c) of Berggren and Pearson (2005). Also, it is equivalent to the (P1d) Subzone of Keller *et al*. (1995), and Keller *et al*., (2002 a, b).

6- *Praemurica uncinata* (P2) Zone (Partial range zone)(late early Paleocene (late Danian))

This biozone was originally proposed by Bolli, 1957a and emended by Bolli, 1966. In the present study, it is defined as a biostratigraphic interval extended from the first appearance of *Praemurica uncinata* (Bolli) at the base to the first appearance of *Morozovella angulata* (White) at the top. It attains about 4.5m thick at Wadi Dib section, about 2.5m thick at Wadi Abu Had section, and about 3m thick at Bir Mellaha section. It is assigned to late early

Paleocene (late Danian) (61.37 Ma - 61.00 Ma according to Berggren and Pearson, 2005). It is marked by forms with angular- conical chambers in the initial portion of the last whorl such as: *P. uncinata* (Bolli), and *P. praecursoria* (Morozova). Berggren and Pearson, 2005 used the top of this Zone to placement the early Paleocene (Danian) / Late Paleocene (Selandian) (D/S) boundary. It is equivalent to the *M. uncinata* Zone of Toumarkine & Luterbacher, 1985, Hewaidy, 1987, Hewaidy *et al*., 1991; *P. uncinata- M. angulata* Zone (P2) of Berggren *et al*., 1995; Olsson *et al*., 1999. It also equivalent to the *P. uncinata* Zone (P2) of Tantawy *et al*., 2001; Shahin & El-Nady, 2001; Samir, 2002; Berggren and Pearson, 2005; Al- Wosabi and Abu Shama, 2007; Wade *et al*., 2011, and Obaidallah, 2012.

7- *Morozovella angulata* (P3a) Zone (Partial range zone) (early late Paleocene (Selandian))

This Zone was proposed by Alimarina, 1963. According to Berggren *et al*., 1995 and Berggren and Pearson, 2005 this biozone is defined as a biostratigraphic interval extended from the first appearance of the *Morozovella angulata* (White) at the base to the first appearance of *Igorina albeari* (Cushman and Bermudez) at the top. In the present study, due to absence of the upper part of this biozone " *Igorina albeari* (Cushman and Bermudez)" it is defined as a biostratigraphic interval extended from the first appearance of *Morozovella angulata* (White) at the base and followed by a sedimentary hiatus (Hiatus-2) where the early late Paleocene (Selandian) *Morozovella angulata* Zone is directly followed by Late Paleocene (Latest Thanetian) *M. velascoensis* Zone. In the study area, this hiatus represents the Selandian/Thanetian (S/Th) boundary. This biozone is recorded at both Wadi Abu Had and Bir Mellaha sections only and it attains about 2m thick. It is assigned to early late Paleocene (Selandian) (61.00-60.00 Ma according to Berggren *et al*., 1995, and Berggren and Pearson, 2005). In this biozone, species of *Morozovella* with angular- conical chambers throughout their youngest whorl become predominant such as (*M. angulata* (White), *M. conicotruncata* (Subbotina) and others). Typical representatives of the genus *Acarinina* forms a conspicuous part of the planktonic foraminiferal assemblages. This zone is equivalent to the *M. angulata* Zone of Toumarkine & Luterbacher, 1985, Luger, 1985, Hewaidy, 1987, Shahin & El- Nady, 2001, Samir 2002, Al-Wosabi and Abu Shama, 2007, Faris and Farouk, 2012, Obaidallah, 2012, Farouk and El-Sorogy, 2015; the *M. angulata- I. albeari* Interval Subzone (P3a) of Berggren & Miller, 1988; Berggren *et al*., 1995; Berggren and Norris, 1997; Olsson *et al*., 1999. It also equivalent to *I. pusilla* Partial range Subzone (P3a) of Berggren and Pearson, 2005 and Wade *et al*., 2011.

8- *Morozovella velascoensis* (P5) Zone (Partial range zone) (latest Paleocene (latest Thanetian))

The *Morozovella velascoensis* Zone was proposed by Bolli, 1957a. According to Berggren and Pearson, 2005, this biozone is defined as a biostratigraphic interval characterized by the partial range of the nominate taxon extended between the last appearance of *G. pseudomenardii* (Bolli) at the base to the last appearance of *Acarinina sibaiyaensis* (El Naggar) at the top. In this study, due to absence of both *G. pseudomenardii* (Bolli), and *Acarinina sibaiyaensis* (El Naggar), this biozone is defined as a biostratigraphic interval extended from above the Selandian/Thanetian (S/Th) boundary at both Wadi Abu Had and Bir Mellaha sections or Danian/ Thanetian (D/Th) boundary at Wadi Dib section at the base to the Paleocene/ Eocene (P/E) boundary at the top. It attains about 5m thick at both Wadi Dib and Bir Mellaha sections, and about 3m thick at Wadi Abu Had section. It is assigned to latest Paleocene (latest Thanetian) (55.9-55.5 Ma) according to Berggren and Pearson, 2005. In the study area, several species make their first appearance within this biozone, but become dominant only within the basal early Eocene assemblages such as *M. edgari* (Premoli Silva & Bolli), *M. subbotinae* (Morozova), and *M. formosagracilis* Bolli. This Zone is equivalent to the lower part of *Morozovella velascoensis* interval Zone of Toumarkine and Luterbacher, 1985, Luger, 1985, Hewaidy, 1987, Shahin &, El Nady 2001, Samir, 2002, Hamad, 2009; the lower part of *M. velascoensis* interval Zone (P5) of Berggren *et al*., 1995; (P5a) Subzone of Berggren & Ouda, 2003. It is also coeval with *Morozovella velascoensis* Zone (P5) of Berggren and Pearson, 2005, Wade *et al.*, 2011.

9- *Pseudohastigerina wilcoxensis* / *Morozovella velascoensis* (E2) Zone (Concurrent-range zone) (earliest Eocene (earliest Sparnacian- late Sparnacian)

This planktonic foraminiferal biozone was proposed by Molina *et al*., 1999. In the present study, it is defined as a biostratigraphic interval characterized by the concurrent biostratigraphic ranges of the nominate taxa between the first appearance of *Pseudohastigerina wilcoxensis* (Cushman & Ponton) at the base to the last appearance of *Morozovella velascoensis* (Cushman) at the top. It attains about 1m thick at Wadi Dib section, and about 1.5m thick at both Wadi Abu Had and Bir Mellaha sections. This biozone is assigned to earliest Eocene (earliest Sparnacian- late Sparnacian) (55.35-54.5 Ma) according to Berggren and Pearson, 2005. According to Molina *et al*, 1999, the base of this biozone is used to mark the beginning of the lower Eocene (Sparnacian) in the study area. The planktonic foraminiferal assemblages of this biozone are dominated by lightly built representatives of the genus *Morozovella* as for example; *M. subbotina* (Morozova) and *M. formosagracilis* Bolli. *A. soldadoensis soldadoensis* (Bronnimann) and its relatives are abundant within assemblages from this zone. It is equivalent to the upper part of *Morozovella velascoensis* Zone of Toumarkine & Luterbacher, 1985, Shahin & El Nady, 2001; the upper part of *Morozovella velascoensis* (P5) Interval Zone of Berggren *et al*., 1995; *Pseudohastigerina wilcoxensis* Subzone of Molina *et al*., 1999; *Pseudohastigerina wilcoxensis*/ *Morozovella velascoensis* Zone (E2) of Berggren and Pearson., 2005, Wade *et al*., 2011; (P5c) Subzone of Berggren & Ouda, 2003; and the upper part of *Ac. sibaiyaensis / M. velascoensis* (P5b) Subzone of Hamad, 2009.

10- *Morozovella marginodentata* (E3) Zone (Partial-range zone) (earliest Eocene (latest Sparnacian-early Ypresian)

The *Morozovella marginodentata* Zone (E3) was proposed by Berggren and Pearson, 2005. In the present study, it is defined as a biostratigraphic interval characterized by the partial range of the nominate taxon between the last appearance of *Morozovella velascoensis* (Cushman) at the base to the first appearance of *Morozovella formosa formosa* Bolli at the top. It attains about 1m thick at both Wadi Dib and Wadi Abu Had sections, and about 1.5m thick at Bir Mellaha section,. It is assigned to earliest Eocene (latest Sparnacian- early Ypresian) (54.5- 54.0 Ma) according to Berggren and Pearson, 2005). It is equivalent to *Morozovella edgari* Zone of Toumarkine & Luterbacher, 1985; *Morozovella subbotinae / Pseudohastigerina wilcoxensis* Partial range Zone (P6b) of Berggren and Miller, 1988; *Morozovellavelascoensis-Morozovella formosa/ Morozovella lensiformis* Zone (P6a) of Berggren *et al.*, 1995, Berggren & Ouda, 2003; *Morozovella marginodentata* partial range Zone of Berggren and Pearson, 2005, Wade *et al.,* 2011.

11- *Morozovella formosa formosa* (E4) Zone (Partial-range zone) (early Eocene (early Ypresian))

This planktonic foraminiferal biozone was proposed by Blow, 1979. In the present study, it is defined as a biostratigraphic interval between the first appearance of the nominate taxon *Morozovella formosa formosa* Bolli at the base and the first appearance of *Morozovella aragonensis* (Nuttall) at the top. It attains about 1.5m thick at both Wadi Dib and Wadi Abu Had sections, and about 1m thick at Bir Mellaha section. It is assigned to early Eocene (early Ypresian) (54.0 -52.3 Ma) according to Berggren and Pearson, 2005. It is approximately equivalent to *Morozovella subbotina* Zone of Toumarkine & Luterbacher, 1985, Shahin & El Nady, 2001, Hamad, 2009; *Morozovella formosa- Morozovella lensiformis* Subzone (P6c) of Berggren and Miller, 1988; *Morozovella formosa/ Morozovella lensiformis-Morozovella aragonensis* Zone (P6b) of Berggren *et al*., 1995, Berggren & Ouda, 2003; *Morozovella formosa* Zone (E4) of Berggren and Pearson, 2005, and Wade *et al*., 2011.

12- *Morozovella aragonensis / Morozovella subbotinae* (E5) Zone (Con-current-range zone) (early Eocene (Ypresian))

This biozone was proposed by Berggren and Miller, 1988. In the present study, it is defined as a biostratigraphic interval characterized by a concurrent range of the nominate taxa between the first appearance of *Morozovella aragonensis* (Nuttall) at the base and the last appearance of *Morozovella subbotinae* (Morozova) at the top. It attains about 10m thick at both Wadi Dib and Bir Mellaha sections, and about 12m thick at Wadi Abu Had section. This biozone is considered as the youngest recorded biozone in the study area, and is assigned to early Eocene (Ypresian) (52.3-50.8 Ma) according to Berggren and Pearson, 2005. It is equivalent to *Morozovella formosa formosa* Zone of Toumarkine & Luterbacher, 1985, Shahin & El Nady, 2001, Hamad, 2009; *Morozovella aragonensis / Morozovella formosa* Zone (P7) of Berggren & Miller, 1988, Berggren *et al*., 1995, Berggren & Ouda, 2003a & b; *Morozovella aragonensis / Morozovella subbotinae* Zone (E5) of Berggren & Pearson, 2005, Wade *et al*., 2011.

The recorded planktonic species within these biozones at the three studied sections are shown on Figs. 3-5. A correlation between the distinguished twelve planktonic foraminiferal biozones at the three studied sections is shown on Fig. 6; and a comparison between these biozones established here and those proposed by different authors is shown on Tab. 1.

II. Benthonic Foraminiferal biostratigraphy

The benthonic foraminiferal biostratigraphic studies of the upper Maastrichtian- lower Eocene time interval were carried out by many authors inside and outside of Egypt and there are a large amount of publications, the most important ones are summarized in Tab. 2.

Depending on the vertical distribution of the recorded benthonic foraminiferal species at the three studied sections, five benthonic foraminiferal zones are distinguished within the upper Maastrichtian – lower Eocene sequence and are arranged from older to younger as follows:

A. *Bolivinoides draco draco* Zone

The *Bolivinoides draco draco* Zone is defined as a total range of the nominate taxon and is recorded from the uppermost part of the Sudr Formation (upper part of Abu Zeneima Member) at the three studied sections. It attains about 12m thick at Bir Mellaha section, 5m thick at Wadi Abu Had section, and about 4.5m thick at Wadi Dib section. This biozone is equivalent to *Bolivinoides draco* Zone of northern Libya (Barr, 1970), northern Sinai (Hewaidy, 1987), western Sinai (Shahin, 1988); *Hormosina ovulum gigantea* Zone of Poland (Geroch & Nowak, 1983). Also, it may be equated with *Praebulimina carseyae* Zone of El-Dawy & Hewaidy (2002); *Angulogavelinella abudurbensis* Zone of El-Dawy & Hewaidy (2003) from Egypt. In the present study, this biozone is of latest Maastrichtian age and is correlated with to both *Pseudoguembelina hariaensis* (CF3), *Pseudoguembelina palpebra* (CF2), and *Plummerita hantkeninoides* (CF1) planktonic zones (Figs. 7-9).

B. *Siphogenerinoides eleganta* Zone

This zone is defined in the study area as a biostratigraphic interval from the first appearance of *Siphogenerinoides eleganta* Plummer in the base to the first appearance of *Alabamina midwayensis* Brotzen in the top. In the present study, the *Siphogenerinoides eleganta* Zone directly overlies the Cretaceous/ Paleogene ($K/P_{g)}$ boundary and it is recorded from the lower most part of the Esna Formation at the three studied sections. It attains about 3m thick at Bir Mellaha section, 4m thick at both Wadi Abu Had and Wadi Dib sections. It is equivalent to the middle part of: *Bolivinoides delicatulus* Zone of the north Sinai (Said & Kenawy, 1956), west Sinai (Shahin, 1988); *Rzehakina epigona fissistoma* Zone of Poland (Geroch & Nowak, 1983); *Cibicidoides vulgaris* Zone of Central Egypt (Anan & Hewaidy, 1986); *Gavelinella danica* Zone of NE Sinai (Hewaidy, 1987); *Orthokarstenia higazyi* of Kharga Oasis (Anan & Sharabi, 1988). It may be equated with the lower part of the *Angulogavelinella avnimelechi - Anomalinoides rubiginosa* Zone of DSDP (Berggren & Miller, 1989); *Lagena hispida/ Spiroplectammina dentata* of west -central Sinai (Ismail, 1992); *Alabamina midwayensis* Eastern Gulf Coast U. S. A (Fluegeman *et al*., 1990); *Siphogenerinoides eleganta* Zone of Sinai (El-Deeb & El-Gammal 1994); *Angulogavelinella avnimelechi/ Nuttallides truempyi* Subzone of north Eastern Desert (El-Dawy, 2001); *Bulimina quadrata / Bulimina midwayensis*of Egypt (El Dawy & Hewaidy, 2002); *Gavelinella beccariiformis* Zone of Egypt (El Dawy & Hewaidy, 2003). Also, it equivalent to the upper part of *Vulvulina colei* of El-Gammal & El-Deeb & 2015 Egypt. In the present study area, this biozone is of early Paleocene (Middle – late Danian) and is correlated with both *Globanomalina compressa* (P1c), and *Praemurica trinidadensis* (P1d) planktonic zones. (Figs. 7-9).

C. *Alabamina midwayensis/ Gavelinella beccariiformis* Zone

In the study area, this zone is defined as a biostratigraphic interval from the first appearance of *Alabamina midwayensis* Brotzen in the base to the last appearance of *Gavelinella beccariiformis* (White) in the top. It is recorded from the middle part of the Esna Formation at the three studied sections. It attains about 5m thick at Bir Mellaha section, 4.5m thick at both Wadi Abu Had and Wadi Dib sections. It is equivalent to both the upper part of *Bolivinoides delicatulus* and the lower part of *Neoflabellina jarvisi* zones of north Sinai (Said & Kenawy, 1956); the uppermost part of *Bolivinoides delicatulus* Zone and the lower part of *Bolivinoides jarvisi* Zone of west Sinai (Shahin, 1988); *Orthokarstenia higazyi* Zone of Kharga Oasis (Anan & Sharabi, 1988); *Angulogavelinella avnimelechi - Anomalinoides rubiginosa* Zone of DSDP Berggren & Miller (1989); the lower part of: *Cibicidoides lectus* Zone of S. U S S R (Saperson & Janal, 1980)*; Rzehakina epigona fissistoma* Zone of Poland (Geroch & Nowak, 1983); *Alabamina midwayensis* Zone of Egypt (El-Gammal & El-Deeb & 2015). Also, this zone may be equated with the middle part of both: *Cibicidoides vulgaris* of Central Egypt (Anan & Hewaidy (1986); *Gavelinella danica* of north-east Sinai (Hewaidy, 1987); *Alabamina midwayensis* Zone of Eastern Gulf Coast U. S. A (Fluegeman *et al*., 1990); *Siphogenerinoides eleganta* Zone of Sinai (El-Deeb & El-Gammal 1994); *Angulogavelinella avnimelechi/ Anomalinoides rubiginosa* Subzone of north Eastern Desert (El-Dawy, 2001); *Bulimina quadrata / Bulimina midwayensis* Zone of Egypt (El Dawy & Hewaidy, 2002); *Gavelinella beccariiformis* Zone of Egypt (El Dawy & Hewaidy, 2003); the upper part of *Lagena hispida/ Spiroplectammina dentata* of west -central Sinai (Ismail, 1992);. In the present study area, this biozone is of late early Paleocene (late Danian) and early late Paleocene (Selandian) age and it is correlated with *Praemurica uncinata* (P2), and *Morozovella angulata* (P3a) planktonic zones. (Figs. 7-9).

D. *Gavelinella danica* Zone

This biozone is defined as a biostratigraphic interval of the last appearance of *Gavelinella beccariiformis* (White) in the base to the first appearance of *Marginulina wetherellii intercostata-Marginulina wetherellii longiscata* Zone at the top. It is recorded from the upper part of the Esna Formation at the three studied sections. It attains about 3 m thick at Wadi Abu Had, and about 5m at both Bir Mellaha and Wadi Dib sections. In the present study, the *Gavelinella danica* Zoneis equivalent to the uppermost part of the *Bulimina farafraensis* Zone of Farafra Oasis (Le Roy, 1953); *Heterolepa torques* Zone of S. U S S R (Saperson & Janal, 1980); *Spiroplectammina spectabilis* Zone of Poland (Geroch & Nowak, 1983); *Loxostomoides applinae* Zone of central Egypt (Anan

& Hewaidy, 1986); *Gavelinella danica* Zone of north-east Sinai (Hewaidy, 1987); *Orthokarstenia higazyi* of Kharga Oasis (Anan & Sharabi, 1988); *Bolivinoides jarvisi* of western Sinai (Shahin, 1988); *Angulogavelinella avnimelechi* - *Anomalinoides rubiginosa* Zone of DSDP (Berggren & Miller, 1989) the lower most part of *Loxostomoides applinae / Spiroplectammina dentata* Zone of west -central Sinai (Ismail, 1992); the upper part of *Alabamina westraliensis* Zone of Eastern Gulf Coast (U. S. A) Fluegeman *et al*., 1990; *Siphogenerinoides eleganta* Zone of Sinai (El-Deeb & El-Gammal, 1994); *Loxostomoides applinae* Subzone of north Eastern Desert (El-Dawy, 2001); *Bulimina quadrata / Bulimina midwayensis* Zone of Egypt (El Dawy & Hewaidy, 2002); *Gavelinella danica* Zone of Egypt (El Dawy & Hewaidy, 2003); *Lenticulina midwayensis/ Alabamina wilcoxensis* Zone of Egypt (El-Gammal & El-Deeb & 2015). In the present study area, this biozone is of latest Paleocene (latest Thanetian) age and is correlated with *Morozovella velascoensis* (P5) planktonic Zone. (Figs. 7-9).

E. *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* Zone

This biozone is defined as a biostratigraphic interval of the nominate taxa. It is recorded in the topmost part of the Esna Formation and extended to the measured part of the Thebes Formation. It attains about 14m thick at Bir Mellaha section, 16m thick at Wadi Abu Had section, and about 13.5m thick at Wadi Dib section. It is equivalent to *Eponoides lotus* Zone of Farafra Oasis (Le Roy, 1953); *Heterolepa libyca* Zone of Crimea, North Caucasus and Turkmenia USSR (Saperson and Janal, 1980); *Marginulina wetherellii intercostata* Zone of El Qusaima area, north-east Sinai, Egypt (Hewaidy, 1987); *Anomalinoides capitatus- Hanzawaia ammophila* of DSDP (Berggren & Miller, 1989); *Loxostomoides applinae / Spiroplectammina dentata* Zone of west - central Sinai (Ismail, 1992); *Bulimina farafraensis / Bulimina esnaensis* of Egypt (El Dawy & Hewaidy, 2002); *Heterolepa libyca- Cibicidoides proprius* Zone of Egypt (El Dawy & Hewaidy, 2003). In the present study area, the *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* Zoneis of earliest Eocene (earliest Sparnacian) to early Eocene (Ypresian) age and it is correlated with *Pseudohastigerina wilcoxensis / Morozovella velascoensis* (E2), *Morozovella marginodentata* (E3), *Morozovella formosa formosa* (E4), and *Morozovella aragonensis /Morozovella subbotinae* (E5) planktonic zones. (Figs. 7- 9). A correlation between the three studied sections based on these five recorded benthonic foraminiferal zones are shown on Fig. 10.

Stages Boundaries in the Study Area

The stages boundaries of the latest Maastrichtian-early Eocene (Ypresian) interval at Esh El-Mellaha area includes the Cretaceous/ Paleogene (K/Pg), Danian/Selandian (D/S), Selandian/Thanetian (S/Th), and Paleocene/Eocene (P/E) boundaries. These stages boundaries are discussed below and arranged from the oldest to the youngest as follows:

1. The Cretaceous/ Paleogene (K/Pg) boundary

Many planktonic and benthonic foraminiferal authors were studied the K/P_g boundary inside and outside of Egypt and the most important publications are (Keller, 1988, 1989, 1996; Arenillas *et al*., 2000; El Naggar, 1966; Luger, 1985; Hermina, 1990; Hewaidy and Soliman, 1993; Hewaidy, 1987, 1994; Abd el-Kireem and Samir, 1995, and Tantawy *et al*., 2001). The most of these publications were showed that this boundary is characterized by the presence of gap or hiatus in the stratigraphic sequence across this boundary. This hiatus is probably caused by a global eustatic low stand of the sea level which occurred during the end of the Cretaceous. This caused the extinction of all planktonic and some benthonic foraminiferal species at this boundary and this sometimes marked by the presence of a abrupt change in sedimentation across this boundary. In Egypt, The continuity of sedimentation across (K/p_g) boundary differs from north to south. In northern Egypt, this boundary is more complete and it is recorded by some authors between the late Maastrichtian planktonic zone *Abathomphalus mayaroensis* Zone and the oldest Paleocene *Parasubbotina pseudobulloides* Zone (e.g. El-Deeb and El-Gammal,1994,1997; Shama and El-Gammal,1996; Anan, 2008, 2012; Orabi and Khalil, 2014). On the other hand, in southern Nile and Western Desert, no continuous open marine sediments of (K/Pg) have been recorded, where it is usually located at the base of a conglomerate horizon making a distinct hiatus of varying magnitude (Youssef, 2003; Orabi and Khalil, 2014; Orabi & Hassan, 2015), where the *Praemurica trindadensis* (P1d) Zone as the oldest Paleocene zone there such as recorded by Hewaidy, 1983 at Kharga Oasis.

In the present study area, the Cretaceous /Paleogene (K/Pg) boundary is located at the formational boundary between the topmost part of the Sudr Formation and the lower part of Esna Formation and it is marked by the following:

A- Presence of a sedimentary hiatus (Hiatus-1) in the studied sedimentary sequence across this boundary at the three studied sections and this hiatus is differentiated in its magnitude from north to south in the study area. At both Wadi Dib and Wadi Abu Had sections, the (K/P_g) boundary is marked by a sedimentary hiatus represented by the absence of two latest Maastrichtian planktonic foraminiferal biozones " *Pseudoguembelina palpebra* (CF2), *Plummerita* *hantkeninoides* (CF1)" and the earliest Paleocene planktonic foraminiferal biozones *Guembeliteria cretacea* Zone (P0), *Parvularugoglobigerina eugubina* (Pa), and *Euglobigerina edita* Zone (P1) with its included three subzones [*Parasubbotina pseudobulloides* subzone (P1a), *Subbotina triloculinoides* subzone (P1b), and *Globanomalina compressa* subzone (P1c)]; where the late Maastrichtian *Pseudoguembelina hariaensis* Zone (CF3) is directly overlain by late Danian *Praemurica trindadensis* Zone (P1d). Based on Berggren and Pearson, 2005 the magnitude of this hiatus at these two sections is about 4.08 Ma extended from 65.45-61.37 Ma. On the other hand, at Bir Mellaha section the two latest Maastrichtian planktonic foraminiferal biozones" *Pseudoguembelina palpebra* (CF2), *Plummerita hantkeninoides* (CF1)" in addition to the early Paleocene *Globanomalina compressa* subzone (P1c) are recorded and the K/Pg boundary here is marked by a hiatus represented only by absence of earliest Paleocene planktonic foraminiferal biozones *Guembeliteria cretacea* Zone (P0), *Parvularugoglobigerina eugubina* (Pa), and the earliest two subzones of *Euglobigerina edita* Zone (P1) [*Parasubbotina pseudobulloides* subzone (P1a), and *Subbotina triloculinoides* subzone (P1b)]; where the latest Maastrichtian *Plummerita hantkeninoides* (CF1) is directly overlain by middle to late Danian *Globanomalina compressa* subzone (P1c). Based on Berggren and Pearson, 2005, the magnitude of this hiatus at this section is about 2.13 Ma extended from 65.00- 62.87 Ma.

B- According to the recorded benthonic foraminiferal zones in the present study, the Cretaceous/Paleogene (K/Pg) boundary lies between *Bolivinoides draco draco* and *Siphogenerinoides eleganta* zones.

PLATE - 1

1. ***Globoconusadaubjergensis* (Bronnimann, 1953),** 1a: ventral view, 1b: side view, 1c: dorsal view, sample 122, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
2. ***Parasubbotina variospira* (Belford, 1984),** 2a: ventral view, 2b: side view, 2c: dorsal view, sample 123, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
3. ***Parasubbotina pseudobulloides* Plummer, 1926,** 3a: ventral view, 3b: side view, 3c: dorsal view, sample 121, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
4. ***Subbotina inaequispira* Subbotina, 1953,** 4a: ventral view, 4b: side view, 4c: dorsal view, sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
5. ***Subbotina triloculinoides* (Plummer, 1926),** 5a: ventral view, 5b: side view, 5c: dorsal view, sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
6. ***Subbotina velascoensis* (Cushman, 1925**), 6a: ventral view, 6b: side view, 6c: dorsal view, sample 129, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
7. ***Pseudohastigerina wilcoxensis* (Cushman & Ponton, 1932),** 7a: ventral view, 7b: side view, 7c: dorsal view, sample 127, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
8. ***Acarininasoldadoensissoldadoensis* (Bronnimann, 1952),** 8a: ventral view, 8b: side view, 8c: dorsal view, sample 127, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
9. ***Acarinina mckannai* (White, 1928),** 9a: ventral view, 9b: side view, 9c: dorsal view, sample 127, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
10. ***Acarinina nitida* (Martin, 1943),** 10a: ventral view, 10b: side view, 10c: dorsal view, sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
11. ***Morozovella acuta* (Toulmin, 1941),** 11a: ventral view, 11b: side view, 11c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).
12. ***Morozovella angulata* (White, 1928),** 12a: ventral view, 12b: side view, 12c: dorsal view, sample 124, Esna Formation, Bir Mellaha section, late Paleocene (Selandian).
13. ***Morozovella formosagracilis* Bolli, 1957,** 13a: ventral view, 13b: side view, 13c: dorsal view, sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
14. ***Morozovella formosa formos*a Bolli, 1957,** 14a: ventral view, 14b: side view, 14c: dorsal view, sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
15. ***Morozovella edgari* (Premoli Silva & Bolli, 1973),** 15a: ventral view, 15b: side view, 15c: dorsal view, sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
16. ***Morozovella conicotruncata* (Subbotina, 1947),** 16a: ventral view, 16b: side view, 16c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).
17. **& 18.*Morozovella subbotinae* (Morozova, 1929),** 17a & 18a: ventral view, 17b & 18b: side view, 17c & 18c: dorsal view, 17: sample 127, 18: sample 128, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
19. ***Morozovella marginodentata* Subbotina, 1953,** 19a: ventral view, 19b: side view, 19c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
20. ***Morozovella caucasica* (Glaessner, 1937),** 20a: ventral view, 20b: side view, 20c: dorsal view, sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
21. **& 22.*Morozovellavelascoensis* (Cushman, 1925a),** 21a & 22a: ventral view, 21b & 22b: side view, 21c & 22c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).
23. ***Morozovella aragonensis* (Nuttall, 1930),** 23a: ventral view, 23b: side view, 23c: dorsal view, sample 130, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
24. ***Morozovella quetra* (Bolli, 1957),** 24a: ventral view, 24b: side view, 24c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
25. ***Morozovella aequa* (Cushman & Renz, 1942),** 25a: ventral view, 25b: side view, 25c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).
26. ***Praemurica uncinata* (Bolli, 1957a),** 26a: ventral view, 26b: side view, 26c: dorsal view, sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
27. ***Praemurica praecursoria* (Morozova, 1957),** 27a: ventral view, 27b: side view, 27c: dorsal view, sample 123, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
28. ***Praemurica trinidadensis* (Bolli, 1957a),** 28a: ventral view, 28b: side view, 28c: dorsal view, 28a, 28b: sample 121, 8c: sample 122, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
29. ***Praemurica inconstans* (Subbotina, 1953),** 29a: ventral view, 29b: side view, 29c: dorsal view, sample 122, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
30. ***Globanomalina compressa* (Plummer, 1926),** 30a: ventral view, 30b: side view, 30c: dorsal view, sample 121, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

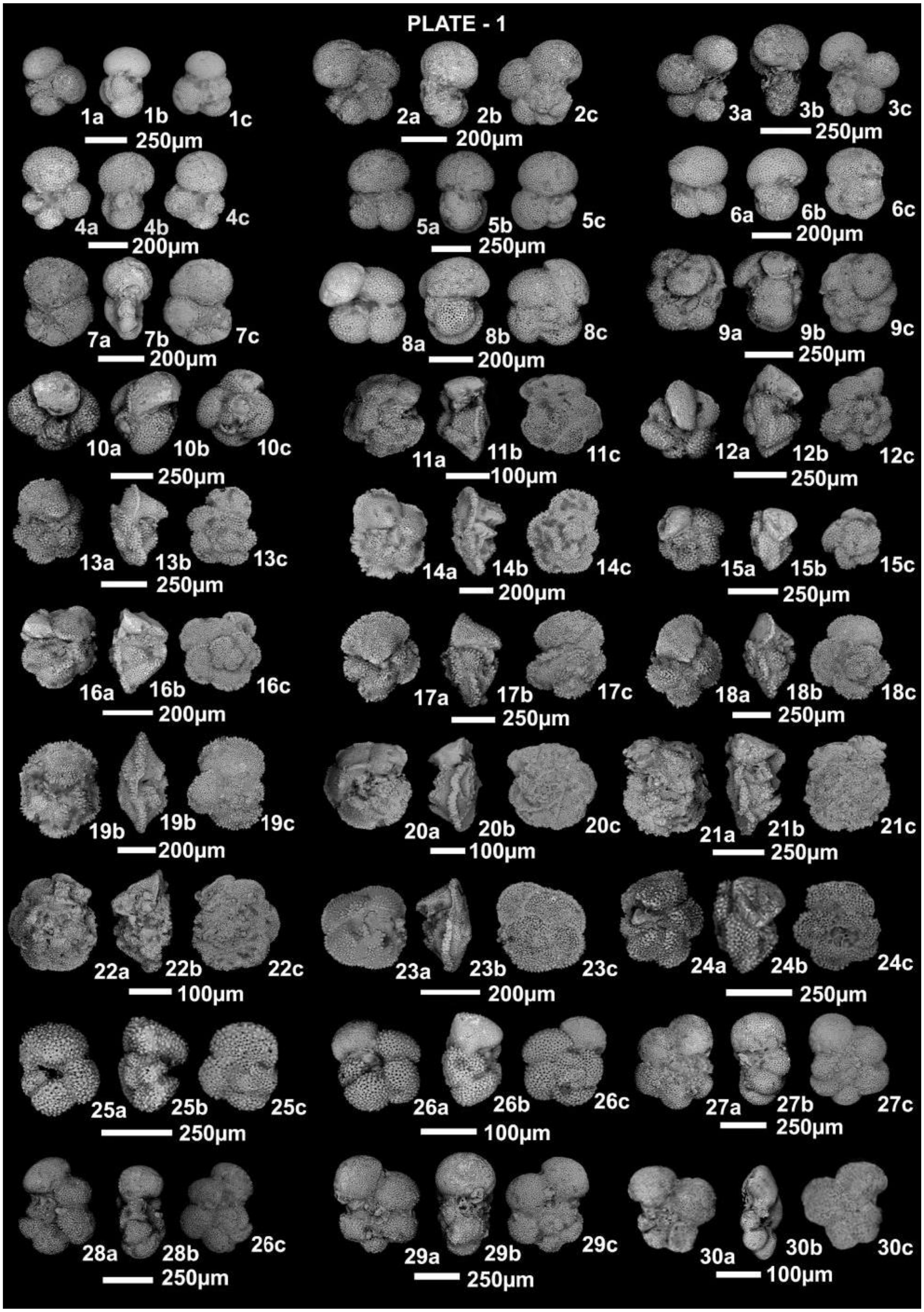
PLATE - 1
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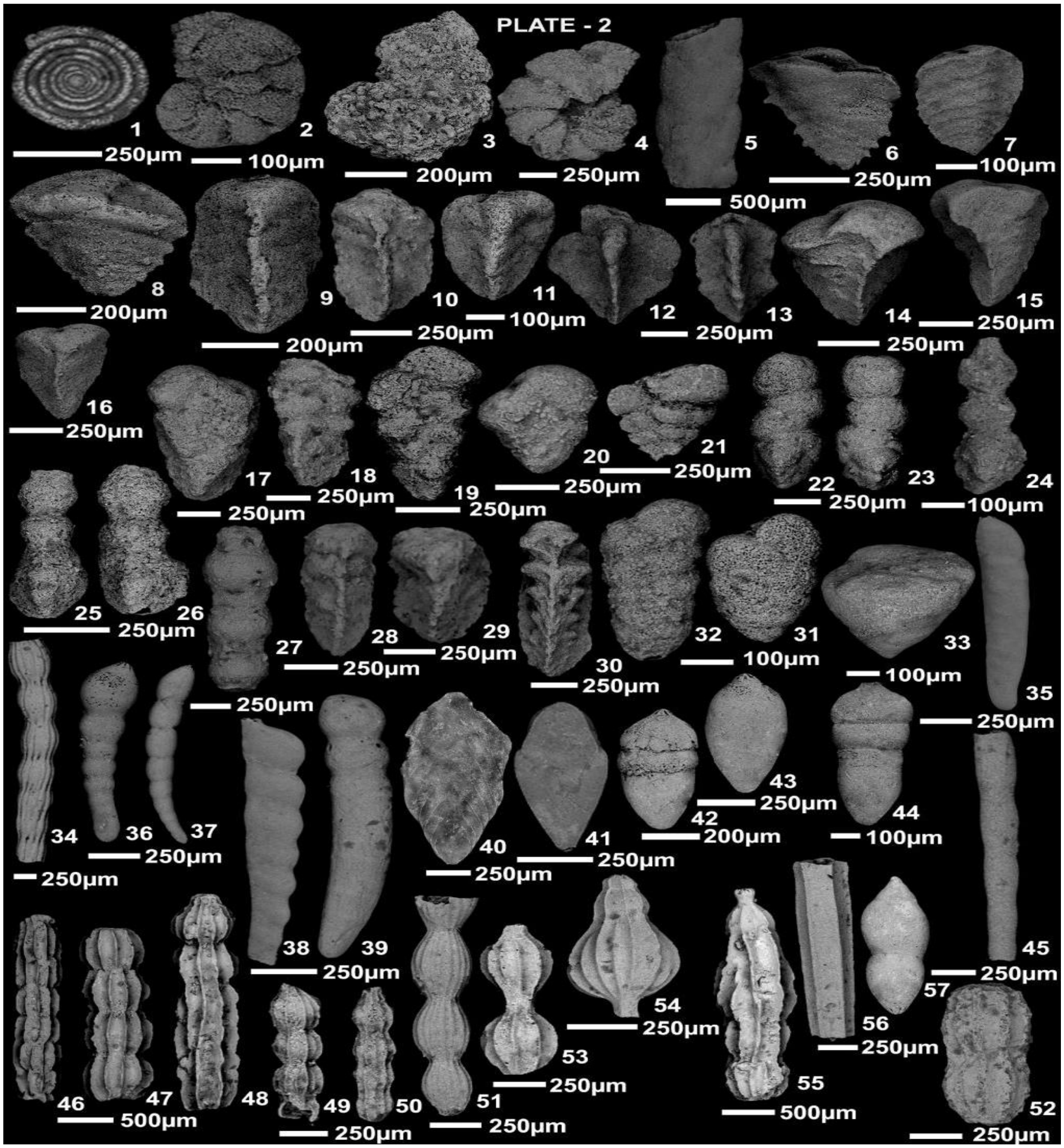
C- Presence of an abrupt change in the sedimentation across the K/P_g boundary in the study area, where the argillaceous limestone of the topmost part of the Sudr Formation changed upwardly to dark grey to green shale of the lower part of the Esna Formation.

PLATE – 2

1. ***Ammodiscus cretacea*** **(Reuss, 1845),** sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).
2. ***Ammobaculites expansus*** **Plummer, 1933,** sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
3. ***Ammobaculites subcretaceus*** **Cushman & Alexander, 1930**: sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
4. ***Insculptarenula texana*** **(Cushman and Waters, 1927),** sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
5. ***Bolivinopsis clotho*** **(Grzybowski, 1901),** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
6. ***Spiroplectinella dentata*** **(Alth, 1850),** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
7. ***Spiroplectinella esnaensis*** **(Le Roy, 1953),** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
8. ***Spiroplectinella knebeli*** **(Le Roy, 1953),** sample118, Sudr Formation, Bir Mellaha section, Latest Maastrichtian.
9. ***Tritaxia barakai*** **Said & Kenawy, 1956,** sample 112, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
10. ***Tritaxia midwayensis*** **(Cushman, 1936),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
11. ***Verneuilina karreri*** **Said and Kenawy, 1956,** sample 117, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
12. **&**. **13-*Verneuilina luxorensis*** **Nakkady, 1950,** 12: sample 126, 13: sample 127, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
14. ***Gaudryina aissana*** **Ten Dam & Sigal, 1950,** sample 117, Sudr Formation, Bir Mellaha section, late Maastrichtian.
15. ***Gaudryina soldadoensis*** **Cushman and Renz, 1942,** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
16. ***Gaudryina pyramidata*** **Cushman, 1926,** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
17. ***Gaudryina rugosa*** **D' Orbigny, 1840,** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
18. ***Gaudryina elegantissima*** **Said & Kenawy, 1956,** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
19. ***Gaudryina africana*** **(Le Roy, 1953),** sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
20. ***Textularia nilotica*** **(Schwager, 1883),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
21. ***Textularia concava*** **Karrer, 1868,** sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
22. **& 23**. ***Pseudoclavulina globulifera*** **Ten Dam & Sigal, 1950,** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
24. ***Pseudoclavulina farafraensis*** **Le Roy, 1953,** sample 121, lower part Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
25. **& 26**.***Pseudoclavulina hewaidyi*** **Anan, 2008**, sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
27. ***Pseudoclavulina maqfiensis*** **Le Roy, 1953,** sample 121, lower part Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
28. ***Clavulinoides algerianus*** **Ten Dam & Sigal, 1950,** sample 122, lower part of Esna Formation, Bir Mellaha section, early Paleocene (Danian).
29. ***Clavulinoides asper*** **Cushman, 1937,** sample 122, lower part of Esna Formation, Bir Mellaha section, early Paleocene (Danian).
30. ***Clavulinoides trilaterus*** **(Cushman, 1926),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
31. ***Dorothia bulletta*** **(Carsey, 1926),** sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
32. ***Dorothia sinaensis*** **Said and Kenawy, 1956,** sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
33. ***Marssonella oxycona*** **(Reuss, 1860),** sample 128, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
34. ***Dentalina delicatula*** **Cushman, 1938,** sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
35. ***Laevidentalina granti*** **(Plummer, 1927),** sample 121, lower part Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
36. **& 37**. ***Laevidentalina basiplanata*** **Cushman, 1938,** sample 118, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
38. ***Laevidentalina megalopolitana*** **Reuss, 1855,** sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
39. **-*Laevidentalina colei*** **Cushman & Dusenbury, 1934,** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
40. ***Frondicularia archiacinana*** **D' Orbigny, 1840,** sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
41. ***Frondicularia esnehensis*** **Nakkady, 1950**, sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
42 -*Pseudonodosaria lagenoides* **(Olszewski, 1875),** sample 121, lower part Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
43. ***Pseudonodosaria manifesta*** **(Reuss, 1851),** sample 122, lower part Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
44. ***Nodosaria radicula*** **(Linnaeus, 1767),** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).
45. ***Nodosaria longiscata*** **d'Orbigny, 1846,** sample 126, topmost part of Esna Formation,, Bir Mellaha section, Early Eocene (Ypresian).
46. ***Pyramidulina affinis*** **(Reuss, 1845),** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
47. **& 48**.***Pyramidulina distans*** **(Reuss, 1855),** sample 122, lower part Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
49. **& 50**. ***Pyramidulina semispinosa*** **(Le Roy, 1953),** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).
51. ***Pyramidulina limbata*** **d'Orbigny, 1840,** sample 126, topmost part of Esna Formation, Early Eocene (Ypresian).
52. ***Pyramidulina latejugata*** **Gümbel, 1870,** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
53. ***Pyramidulina zippei*** **(Reuss, 1845),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
54. ***Pyramidulina raphinistrum*** **(Linne, 1758),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).
55. ***Pyramidulina paupercula*** **Reuss, 1845,** sample 117, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

56. ***Pyramidulina vertebralis*** **(Batsch, 1791),** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).

57. ***Lingulonodosaria arctica*** **(Gerek, 1960),** sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).



D)- Depending on the recorded foraminiferal content across the K/P_g boundary in the study area we are noted that the extinction of the typical Maastrichtian planktonic foraminiferal genera such as *Globotruncana*, *Rugoglobigerina*, and *Heterohelix* and the first appearance of the earliest Paleocene genera such as *Parasubbotina*, *Subbotina*, and *Globanomalina*. Also, a distinctive change in the benthonic foraminiferal species is observed at this boundary represented by extinction of some species that are characteristic for the latest Maastrichtian age as: *Discorbis pseudoscopos* (Nakkady), *Angulogavelinella abudurbensis* (Nakkady), *Elhasaella alanwoodi* Hamam, *Orthokarstenia esnehensis* (Nakkady), *Orthokarstenia oveyi* (Nakkady), *Orthokarstenia parva* (Cushman), and first appearance of the characteristic Paleocene species such as *Siphogeneroides eleganta* (Plummer), *Bulimina quadrata*, Plummer, *Cibicides pharaonis* (Le Roy), *Marginulinopsis tuberculata* (Plummer), and *Valvalabamina planulata* (Cushman and Renz). This extinction may be due to the uppermost Maastrichtian shallowing of the sea.

PLATE - 3

1. ***Lenticulina midwayensis* (Plummer, 1927),** 1a: ventral view, 1b: side view, 1c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

2. ***Lenticulina chitanii* (Yabe and Asano, 1937),** 2a: ventral view, 2b: side view, 2a: sample 125, 2b: sample 126, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian) to Early Eocene (Ypresian).

3. ***Lenticulina cuvillier* (Texier, 1849),** 3a: ventral view, 3b: side view, 3c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Latest Paleocene (Thanetian).

4. ***Lenticulina isidis* (Schwager, 1883),** 4a: ventral view, 4b: side view, 4c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

5. ***Lenticulina williamsoni* (Reuss, 1862),** 3a: ventral view, 3b: side view, 3c: dorsal view, sample 113, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

6. ***Lenticulina cultrata* (Montfort, 1808),** 6a: ventral view, 6b: side view, sample 130, Bir Mellaha section, topmost part of Esna Formation, Early Eocene (Ypresian).

7. ***Lenticulina navicula* (D' Orbigny, 1840),** 7a: ventral view, 7b: dorsal view, sample 114, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

8. ***Lenticulina pseudosecans* (Cushman, 1938),** 8a: ventral view, 8b: side view, 8c: dorsal view, sample 125, top part of Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

9. ***Lenticulina pseudomamilligera* (Plummer, 1927),** 9a: ventral view, 9b: side view, 9c: dorsal view, sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

10. ***Lenticulina oligostegia* (Reuss, 1860**), sample 130, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

11 & 12- ***Marginulinopsis tuberculata* (Plummer, 1927),** 11: sample 127, 12: sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

13. ***Marginulina wetherellii longiscata* Nakkady, 1950,** sample, 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

14. ***Marginulina wetherellii intercostata* Nakkady, 1950,** sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

15 & 16- ***Vaginulinopsis austinana* (Cushman, 1937),** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).

17. **& 18**. ***Vaginulinopsis midwayana* (Fox & Ross, 1942),** sample 118, Sudr Formation, Bir Mellaha section, latest Maastrichtian.

19. ***Vaginulina misrensis* Said & Kenawy, 1956,** sample 114, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

20. ***Vaginulina longiformis* (Plummer, 1927),** sample 126, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

21. ***Vaginulina cretacea* Plummer, 1927,** sample 127, Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

22. ***Citharina plummerae* Anan, 2001,** sample 122, Esna Formation, Bir Mellaha section, early Paleocene (Danian).

23. ***Neoflabellina semireticulatus* (Cushman & Jarvis, 1932),** sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

24. ***Neoflabellina jarvisi* (Cushman, 1935),** sample 125, top part of Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

25. ***Neoflabellina rugosa* (d'Orbigny, 1840),** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).

26. **& 27**. ***Saracenaria moresiana* How & Wallace, 1932,** 26: sample 126, 27: sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

28 & 29- ***Saracenaria triangularis* (d' Orbigny, 1840),** sample 119, Sudr Formation, Bir Mellaha section, Latest Maastrichtian.

30. ***Hemirobulina bassiounii* Anan, 1994,** sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

31. ***Lagena hispida* Reuss, 1862,** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

32 - ***Lagena apiculata* (Reuss, 1850),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

33 & 34- ***Ramulina navarroana* Cushman, 1927,** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

35. ***Ramulina globulifera* Brady, 1879,** sample 128, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

36. ***Bolivina incrassata* Reuss, 1851,** sample 112, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

37. ***Bolivina decurrens* (Ehrenberg, 1854),** sample114, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

38. ***Loxostomoides applinae* (Plummer, 1927),** sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

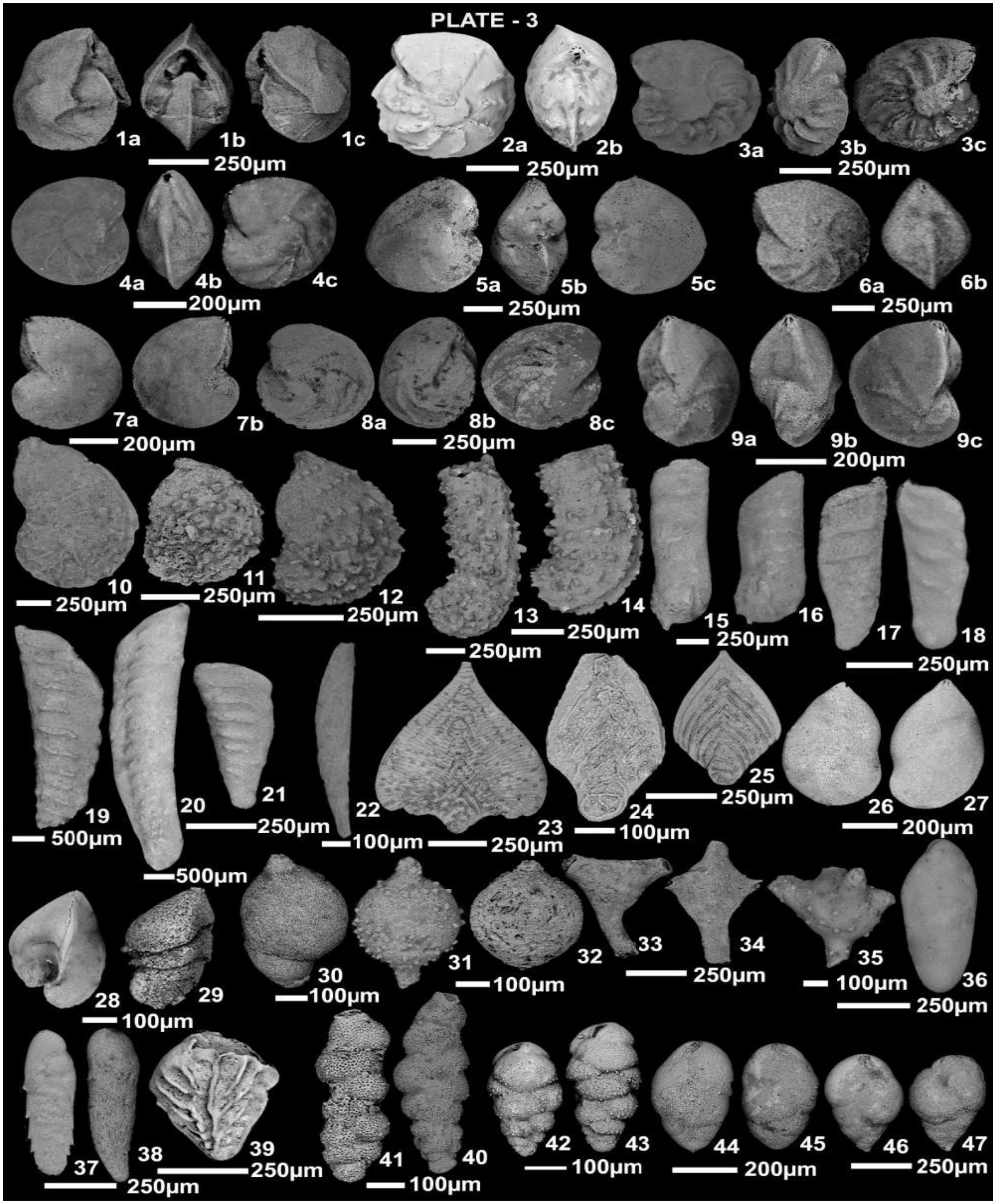
39. ***Bolivinoides draco draco* (Marsson, 1878),** sample 114, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

40. **& 41**. ***Elhasaella alanwoodi* Hamam, 1976,**40: sample 113, 41: sample 116, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

42. **& 43**. ***Pseudouvigerina cretacea* Cushman, 1931,** sample 112, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

44. **& 45**. ***Praebulimina carseyae* (Plummer, 1931),** sample 118, Sudr Formation, Bir Mellaha section, Latest Maastrichtian.

46. **& 47**. ***Praebulimina reussi* (Morrow, 1934),** sample 122, Esna Formation, Bir Mellaha section, early Paleocene (Danian).



2. The Danian / Selandian(D/S) boundary

Toumarkine and Luterbacher, 1985 were classified the Paleocene series to three stages (Early, Middle and Late) and they used the top of *Morozovella trindadensis* Zone to placement the Early/ Middle Paleocene boundary, and according to them this boundary lies between the latest early Paleocene *Morozovella trindadensis* Zone and early Middle Paleocene *Morozovella uncinata* Zone.

On the other hand, Berggren *et al*., 1995 and Berggren and Pearson, 2005 were classified the Paleocene series to two stages only [early (Danian) and Late (Selandian and Thanetian)] and according to them the early Paleocene (Danian)/ early late Paleocene (Selandian) (D/S) boundary is appeared much later where they used the top of *Praemurica uncinata* Zone (P2) to placement this boundary. Based on Berggren *et al.*, 1995 this boundary lies between the late early Paleocene (late Danian) *Praemurica uncinata- Morozovella angulata* Zone (P2) and early late Paleocene (early Selandian) *Morozovella angulata- Igorina albeari* subzone (P3a); while according to Berggren and Pearson, 2005 the D/ S boundary lies between the late early Paleocene (late Danian)*Praemurica uncinata* Zone (P2) and early late Paleocene (early Selandian) *Igorina pusilla* subzone (P3a).

PLATE – 4

1 & 2. ***Bulimina pupoides* d, Orbigny, 1846,** sample 122, Esna Formation, Bir Mellaha section, early Paleocene (Danian).

3 & 4. ***Buliminainflata* Seguenza, 1862**, sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

5. ***Bulimina quadrata* Plummer, 1927,** sample 122, Esna Formation, Bir Mellaha section, early Paleocene (Danian).

6 & 7. ***Bulimina trigonalis* Ten Dam, 1944,** sample 111, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

8 & 9. ***Buliminakugleri* Cushman & Renz, 1942,** sample 121, Esna Formation, Bir Mellaha section, early Paleocene (Danian).

10 & 11. ***Siphogenerinoides eleganta* Plummer, 1927,** 10: sample 125, 11: sample 121, Esna Formation, Bir Mellaha section, Early to Late Paleocene.

12 & 13. ***Orthokarstenia esnehensis* (Nakkady, 1950),** 26: sample 118, 27: sample 111, topmost part of Formation, Bir Mellaha section, Late Maastrichtian.

14 & 15. ***Orthokarstenia oveyi* (Nakkady, 1950),** sample 116, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

16 & 17. ***Orthokarstenia whitei* (Church, 1943),** sample 122, Esna Formation, Bir Mellaha section, early Paleocene (Danian).

18 & 19. ***Orthokarstenia parva* (Cushman, 1929),** sample 119, Esna Formation, Bir Mellaha section, Latest Maastrichtian.

20 & 21. ***Reussella aegyptiaca* Nakkady, 1950,** sample 113, Sudr Formation, Bir Mellaha section, late Maastrichtian.

22 & 23. ***Coryphostoma plaitum* (Carsey, 1926),** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).

24 & 25. ***Stilostomella midwayensis* (Cushman & Todd, 1946),** sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

26 & 27. ***Stilostomella spinea* (Cushman, 1939),** sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

28. ***Ellipsoglandulina leavigata* Silvestri, 1900,** sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).

29. ***Valvulineria aegyptiaca* Le Roy, 1953,** 29a: ventral view, 29b: side view, 29c: dorsal view, sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

30. ***Valvulineria critchetti* Le Roy, 1953,** 30a: ventral view, 30b: side view, 30c: dorsal view, sample 123, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

31. ***Valvulineria scorbiculata* (Schwager, 1883),** 31a: ventral view, 31b: side view, 31c: dorsal view, sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Selandian).

32. ***Discorbis pseudoscopos* Nakkady, 1950,** 32a: ventral view, 32b: side view, 32c: dorsal view, sample 119, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

33. ***Eponoides lotus* (Schwager, 1883),** 33a: ventral view, 33b: side view, 33c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

34. ***Eponoides lunata* Brotzen, 1948,** 34a: ventral view, 34b: side view, 34c: dorsal view, sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

35. ***Cibicidoides pseudoacuta* (Nakkady, 1950),** 35a: ventral view, 35b: side view, 35c: dorsal view, sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

36. ***Cibicidoides pharaonis* Le Roy, 1953,** 36a: ventral view, 36b: side view, 36c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

37. ***Cibicidoides grimsdalei* (Nuttall, 1930),** 37a: ventral view, 37b: side view, 37c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

38. ***Cibicidoidespseudoperlucidus* (Bykova, 1954),** 38a: ventral view, 38b: side view, 38c: dorsal view, 38a & 38b: sample 122, 4c: sample 123, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

39. ***Cibicides farafraensis* (Le Roy, 1953),** 39a: ventral view, 39b: side view, 39c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

40. ***Alabamina midwayensis* Brotzen, 1948,** 40a: ventral view, 40b: side view, 40c: dorsal view, sample 122, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

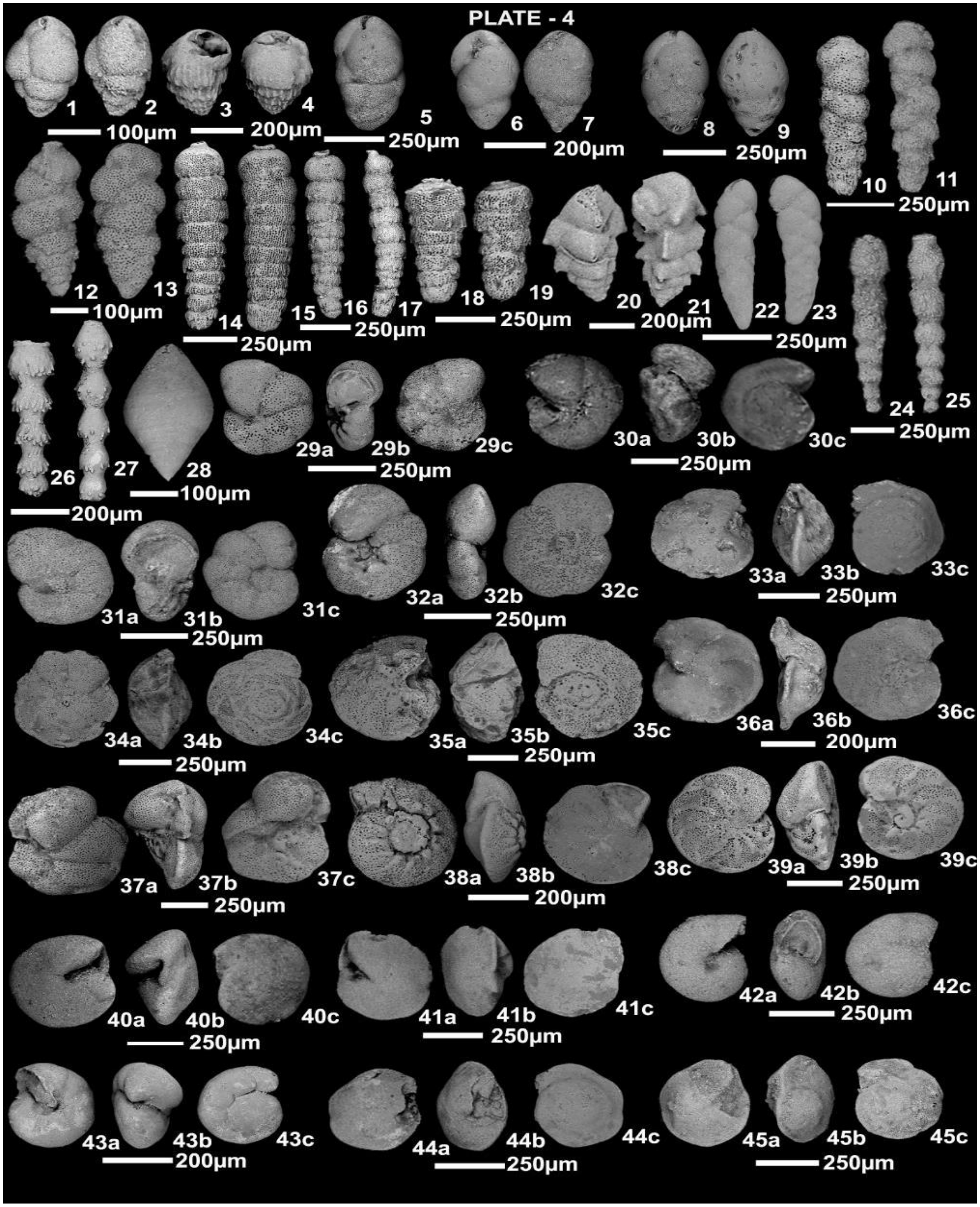
41. ***Alabamina wilcoxensis* Toulmin, 1941,**41a: ventral view, 41b: side view, 41c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

42. ***Valvalabamina depressa* (Alth, 1850),** 42a: ventral view, 42b: side view, 42c: dorsal view, 42a & 42c: sample 130, 42b: sample 122, Esna Formation, Bir Mellaha section, Early Paleocene - Early Eocene.

43. ***Valvalabamina planulata* (Cushman and Renz, 1941),** 43a: ventral view, 43b: side view, 43c: dorsal view, 43a: sample 121, 43b: sample 122, 43c: sample 123, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

44. ***Osangularia expansa* (Toulmin, 1942),** 44a: ventral view, 44b: side view, 44c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

45. ***Oridorsalis plummerae* (Cushman, 1948),** 45a: ventral view, 45b: side view, 45c: dorsal view, sample 129, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).



In Egypt, according to Obaidallah *et al*., 2009, the D/S boundary lies at the boundary between *Igorina albeari/ Praemurica carinata* and *Igorina albeari* zones within the upper part of the Dakhla Formation. Farouk and El-Sorogy, 2015 placed the D/S boundary within the *Igorina albeari* subzone (P3b) at the central and southern Western Desert and they concluded that this boundary is represented by unconformity surface where the topmost part of planktonic foraminiferal *Igorina albeari/ Globanomalina pseudomenardii* subzone (P3b) and the upper part most part of the calcareous nannofossil *Ellisolithus macelus* NP4 Zone were missing.

In the study area, the Danian/Selandian(D/S) boundary is located within the lower part of the Esna Formation and it lies between the late early Paleocene (late Danian) *Praemurica uncinata* Zone (P2) and the early late Paleocene (Selandian) *Morozovella angulata* Zone (P3a) at both Wadi Abu Had and Bir Mellaha sections following Berggren and Pearson, 2005. This means there is no hiatus recorded across this boundary here. On the other hand, at Wadi Dib section the D/S boundary is not located but we see Danian/ Thanetian (D/Th) boundary due to presence of a sedimentary gap within the lower part of the Esna Formation at this section includes all Selandian and lower Thanetian stages, where the late early Paleocene (late Danian) *Praemurica uncinata* Zone (P2) is directly overlying by Late Paleocene (latest Thanetian) *Morozovella velascoensis* Zone (P5). Based on Toumarkine and Luterbacher, 1985 this gap includes late middle Paleocene (*Morozovella angulata* and *Planorotalites pusilla pusilla*, and early late Paleocene *Planorotalites pseudomenardii* zones); while according to Berggren *et al*., 1995 and Berggren and Pearson, 2005 this hiatus includes the early late Paleocene (Selandian) *Morozovellaangulata- Globanomalina pseudomenardii* Zone (P3) and middle part of late Paleocene (late Selandian- Thanetian) *Globanomalina pseudomenardii* Zone (P4). (see Figs. 3-5).

According to the recorded benthonic zones this boundary lies within *Siphogenerinoides eleganta* Zone (Figs. 7-9 & Tab. 2).

3. The Selandian/ Thanetian (S/Th) boundary

According to Toumarkine & Luterbacher, 1985, the middle/ late Paleocene boundary lies between late middle Paleocene *Planorotalitespusillapusilla* Zone and early late Paleocene *Planorotalitespseudomenardii* Zone. Based on Berggren *et al*., 1995, the Selandian/Thanetian (S/ Th) boundary is located within the *Globanomalina pseudomenardii- Acarinina subsphaerica* concurrent-range subzone (P4a) [the lower part of *Globanomalina pseudomenardii* Taxon range Zone (P4)]; while, according to Berggren and Pearson, 2005 this boundary lies at about 58 Ma and located within the *Acarinina subsphaerica* partial range subzone (P4b) [the lower part of *Globanomalina pseudomenardii* Zone (P4)].

In the present study area the Selandian/Thanetian (S/ Th) boundary is located at the middle part of Esna Formation at both Wadi Abu Had and Bir Mellaha sections and it lies between *Morozovella angulata* (P3a) Zone and *Morozovella velascoensis* Zone (P5) and represented by a sedimentary gap (Hiatus-2) within the Esna Formation includes the upper part of *Morozovella angulata- Globanomalina pseudomenardii* interval Zone (P3), and the *Globanomalina pseudomenardii* partial range Zone (P4). Depending on Berggren and Pearson, 2005, the magnitude of this hiatus at these two sections is about 4.10 Ma extended from 60.00 Ma- 55.90 Ma. On the other hand, we can not detect the Selandian/ Thanetian (S/Th) boundary at Wadi Dib section because of the presence of a sedimentary hiatus within the Esna Formation at this section includes all Selandian and the lower part of Thanetian stages where the late early Paleocene (Late Danian) *Praemurica uncinata* Zone (P2) is directly overlain by the late Paleocene (latest Thanetian) *Morozovella velascoensis* Zone (P5). Depending on Berggren and Pearson, 2005, the magnitude of this sedimentary hiatus at this section is about 5.10 Ma extended from 61.00 Ma- 55.90 Ma. (see Figs. 3-5). This boundary in the study area is characterized by a noticeable increasing in *Morozovella* and *Acarinina* spp. and decreasing in *Parasubbotina*, *Subbotina* and *Praemurica* spp.

According to the recorded benthonic foraminiferal zones in the present study, the Selandian/Thanetian (S/ Th) boundary lies between *Alabamina midwayensis/ Gavelinella beccariiformis* and *Gavelinella danica* zones. (Figs. 7-9 & Tab. 2).

4. The Paleocene/ Early Eocene (P/E) boundary

Many of the planktonic foraminiferal authors used the top of *Morozovella velascoensis* Zone to placement the boundary between the Paleocene and Eocene (e.g. Bolli, 1957a, 1966; Krasheninnikov, 1956, Krasheninnikov & Abdel Razek, 1969; Postuma, 1971; Stainforth *et al*., 1975; and Toumarkine and Luterbacher, 1985). Berggren, 1960a, 1971 placed this boundary at the first appearance of *Pseudohastigerina wilcoxensis* (Cushman & Ponton) (*Pseudohastigerina* datum) which for all practical purposes is about age equivalent to the top of *Morozovella velascoensis* Zone. Berggren and Pearson, 2005 classified the *Morozovella velascoensis* Zone (P5) "the interval from lat appearance of *Globanomalina pseudomenardii* (Bolli) to last appearance of *Morozovella velascoensis* (Cushman)" of Berggren *et al*., 1995 into three zones (P5, E1, and E2) and shorten the range of (P5) Zone on their lower zone to cover the interval from last occurrence of *Globanomalina pseudomenardii* to first appearance of *Acarininasibaiyaensis* and according to them, the Paleocene/ Eocene boundary was placed on the top of the lower part *Morozovella velascoensis* interval Zone (P5) of Berggren *et al*., 1995, and on the top of *Morozovella velascoensis* partial range Zone (P5) of Berggren and Pearson, 2005 (Tab. 2).

In Egypt, several authors was studied the biostratigraphic interval that straddles the Paleocene/Eocene (P/E) boundary and studied the biostratigraphical changes that influenced this transitional interval. Among these authors are El Naggar, 1966; Hewaidy, 1983; Haggag, 1991; Speijer *et al*., 1995, 1997, 1998; Schmitz *et al*., 1996; Salis *et al*., 1998; Samir, 2002, Ouda, 2003; Ouda *et al*., 2003; Berggren & Ouda,2003a, b, c, and Hamad, 2009. El-Gammal, 1994; Anan, 2010 showed that the Paleocene/Eocene (P/E) boundary in the Nile Valley Facies and in Northern Egypt Faciesgenerally lies within the Esna Formation at the level of last appearance of *Morozovella velascoensis* or first appearance of *Acarinina wilcoxensis* and/ or *Pseudohastigerina wilcoxensis* that matching the P5/ P6a zonal boundary of Blow (1969).

This boundary is marked by the Thermal maximum event (PETM) where the deep and surface ocean warmed by 5º C and 4º – 8º C respectively over a period of about 100.000 years during PETM (Bralower, 2002) and this caused partially dissolution of carbonate and resulted the Benthonic foraminiferal extinction event (BEE) which recognized by many authors (e.g. Keller, 1986; Aubry *et al*., 1998; Zachos et al., 1993; Molina *et al*., 1999; Ouda & Aubry, 2003; Berggren & Ouda, 2003; Hamad, 2009; Orabi & Zaky, 2016) due to deep sea environmental changes (Thomas, 1998, 2003, Spijer & Morsi, 2002; Alegret & Ortiz, 2006; Alegret *et al*., 2009).

In the present study area, the Paleocene/Early Eocene (P/E) boundary is located within the upper part of the Esna Formation and represented by a sedimentary hiatus (Hiatus-3) at the three studied sections due to absence of *Acarinina sibaiyaensis*(E1) Zone where the *Morozovella velascoensis* (P5) Zone is directly overlain by the *Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) Zone and based on Berggren and Pearson, 2005, the magnitude of this hiatus is about 0.15 Ma extended from 55.50 Ma-55.35 Ma. On the other hand, this boundary is marked by the extinction of the large and heavily ornamented planktonic forms of the late Paleocene and also the first appearance of forms belonging to the genus *Pseudohastigerina* such as *Pseudohastigerina wilcoxensis* beside the relatively small and lightly ornamented *Morozovella* species of earliest Eocene (Figs. 3-6). According to the recorded benthonic foraminiferal zones, this boundary lies between the *Gavelinella danica* Zone and *Marginulina wetherellii intercostata - Marginulina wetherellii longiscata* Zone, and it is characterized by the most extinction of deep sea bathyal and neritic calcareous benthic foraminifera of *Gavelinella beccariiformis* assemblage such as *Neoflabellina jarvisi* (Cushman), *Angulogavelinella avnimelechi* Reiss, *Gavelinella rubiginosa* (Cushman), *Dorothia bulletta* (Carsey), *Spiroplectinella esnaensis* (Le Roy) and others, and the first appearance of newly early Eocene assemblages such as *Marginulina wetherellii intercostata* Nakkady, *Marginulina wetherellii longiscata* Nakkadyand *Heterolepa libyca* (Le Roy) and other. (Figs. 7-9 & Tab. 2).

PLATE – 5

1. ***Planularia advena* Cushman and Jarvis, 1932,** 1a: ventral view,1b: side view, 1c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

2. ***Pseudoparrella obtuse* (Burrows and Holland) in Plummer, 1927,** 2a: ventral view, 2b: side view, 2c: dorsal view, sample 127, topmost part of the Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

3. ***Anomalinoides affinis* (Hantken, 1875),** 3a: ventral view, 3b: side view, 3c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

4. ***Anomalinoidespraeacutus* (Vasilenko, 1950),** 4a: ventral view, 4b: side view, 4c: dorsal view, sample 121, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

5. ***Anomalinoides midwayensis* (Plummer, 1926),** 5a: ventral view, 5b: side view, 5c: dorsal view, sample 125, top part of Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

6. ***Anomalinoides acutus* (Plummer, 1926),** 6a: ventral view, 6b: side view, sample 119, Sudr Formation, Latest Maastrichtian.

7. ***Anomalinoidesumbonifera* (Schwager, 1883),** 7a: ventral view, 7b: side view, 7c: dorsal view, sample 126, topmost part of Esna Formation, Bir Mellaha section, Early Paleocene (Ypresian).

8. ***Anomalinoides fayoumensis* (Ansary, 1955),** 8a: ventral view, 8b: side view, 8c: dorsal view, sample 126, top part of Esna Formation, Bir Mellaha section, Early Paleocene (Ypresian).

9. ***Anomalinoides zitteli* (Le Roy, 1953),** 9a: ventral view, 9b: side view, 9c: dorsal view, sample 127, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

10. ***Anomalinoides aegyptiaca* (Le Roy, 1953),** 10a: ventral view, 10b: side view, 10c: dorsal view, sample 122, Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

11. ***Heterolepalibyca* (Le Roy, 1953),** 22a: ventral view, 11b: side view, 11c: dorsal view, sample 1126,, topmost part of Esna Formation, Bir Mellaha section, Early Eocene (Ypresian).

12. ***Gyroidinoides girardana* (Reuss, 1851),** 12a: ventral view, 12b: side view, 12c: dorsal view, sample 121, lower part of Esna Formation, Bir Mellaha section, Early Paleocene (Danian).

13. ***Gyroidinoidesglobosus* (Hagenow, 1842),** 13a: ventral view, 13b: side view, 13c: dorsal view, sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

14. ***Angulogavelinella abudurbensis* (Nakkady, 1950),** 14a: ventral view, 14b: side view, 14c: dorsal view, sample 116, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

15. ***Angulogavelinella avnimelechi* Reiss, 1952,** 15a: ventral view, 15b: side view,15c: dorsal view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian).

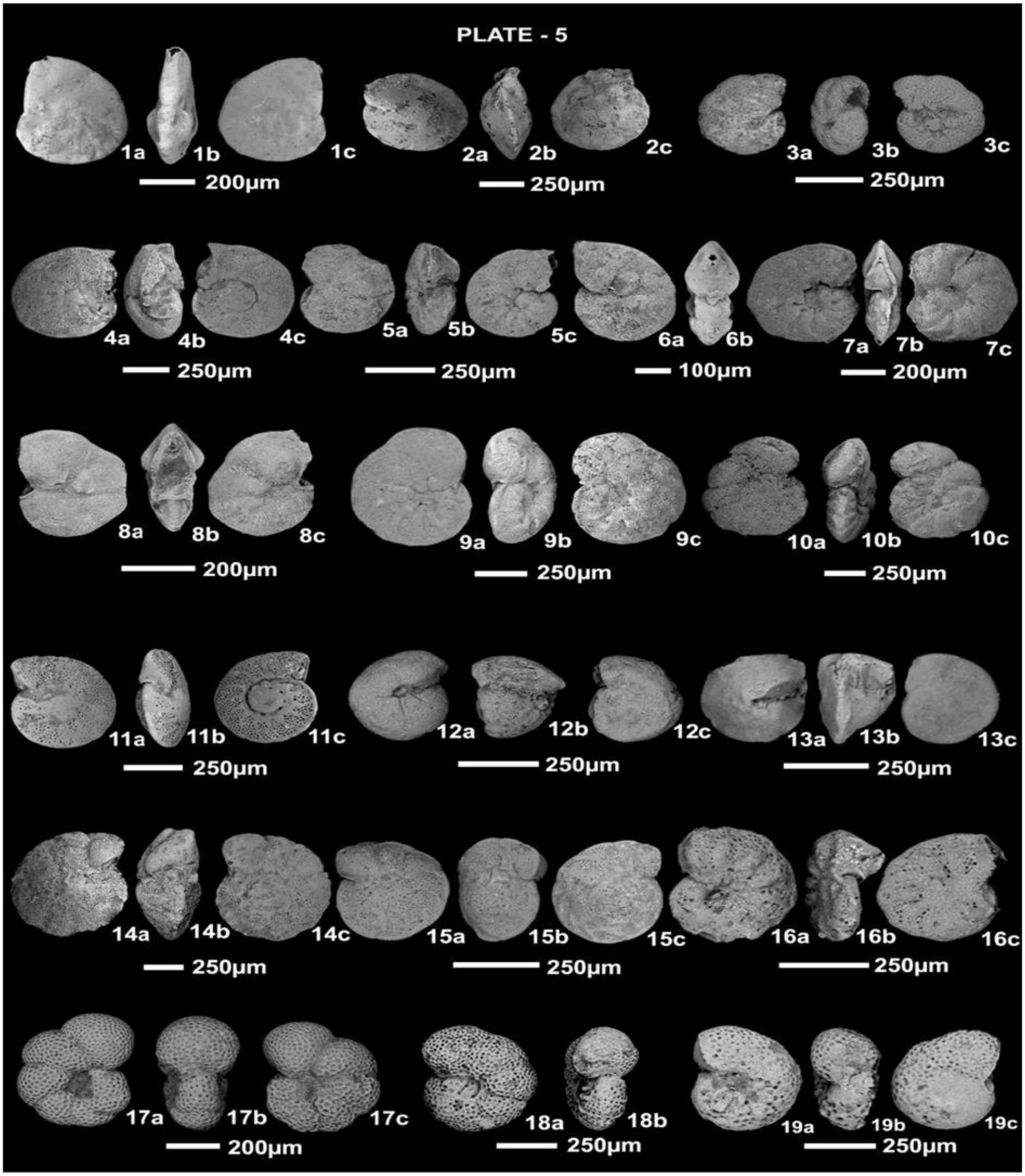
16. ***Gavelinella brotzeni* Said and Kenawy, 1956,** 16a: ventral view, 16b: side view, 16c: dorsal view, sample 119, Sudr Formation, Bir Mellaha section, Latest Maastrichtian.

17. ***Gavelinella rubiginosa* (Cushman, 1926),** 17a: ventral view, 17b: side view, 17c: dorsal view, sample 125, Esna

Formation, Bir Mellaha section, Late Paleocene (Thanetian).

18. ***Gavelinella danica*** **(Brotzen, 1940),** 18a: ventral view, 18b: side view, sample 125, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian)**.**

19. ***Gavelinella beccariiformis*** **(White, 1928),** 19a: ventral view, 19b: side view, 19c: dorsal view sample 124, Esna Formation, Bir Mellaha section, Late Paleocene (Thanetian)**.**



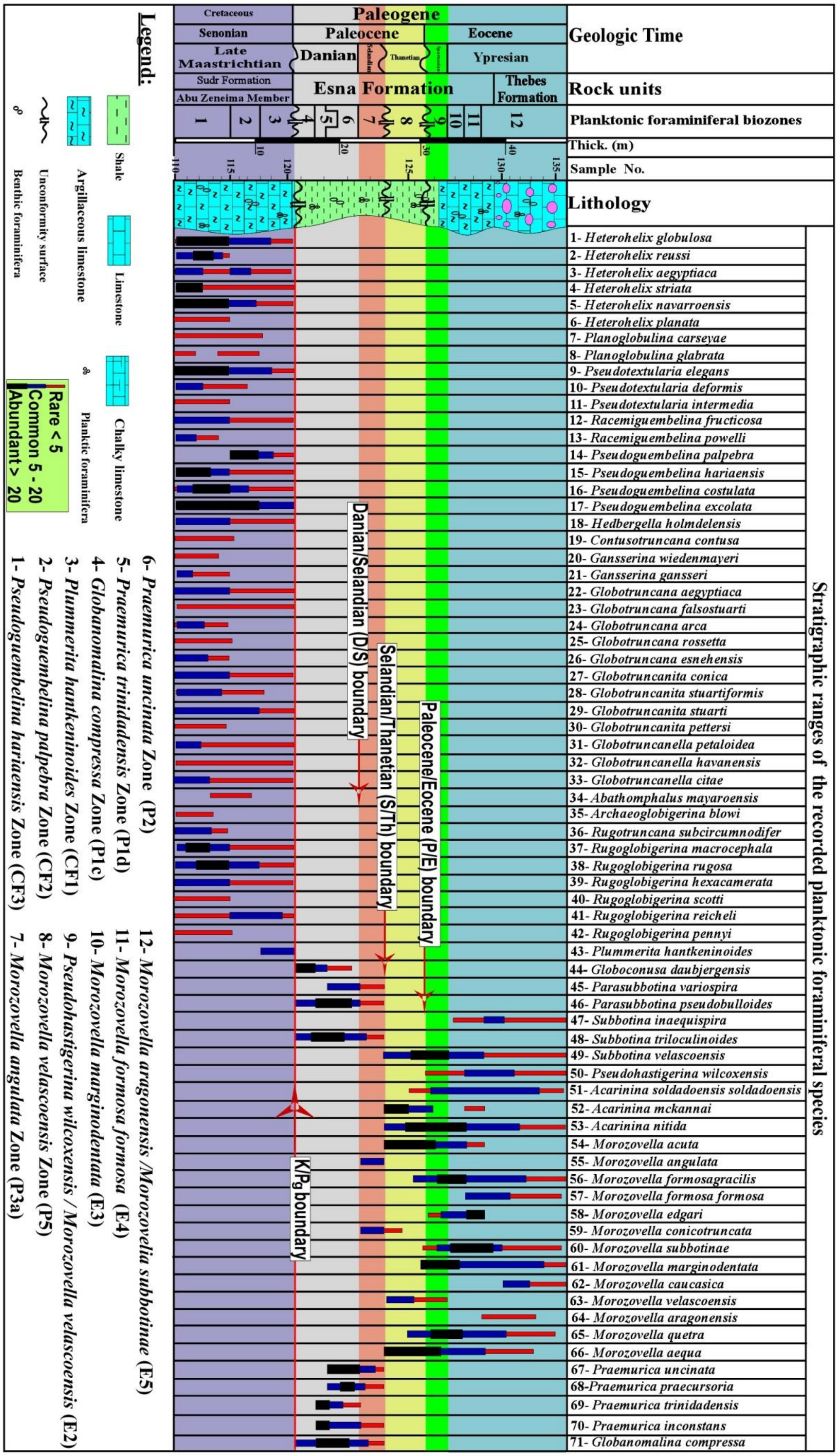


Fig. 3: Distribution chart of the identified latest Maastrichtian to early Eocene planktonic foraminiferal species at Bir Mellaha section.

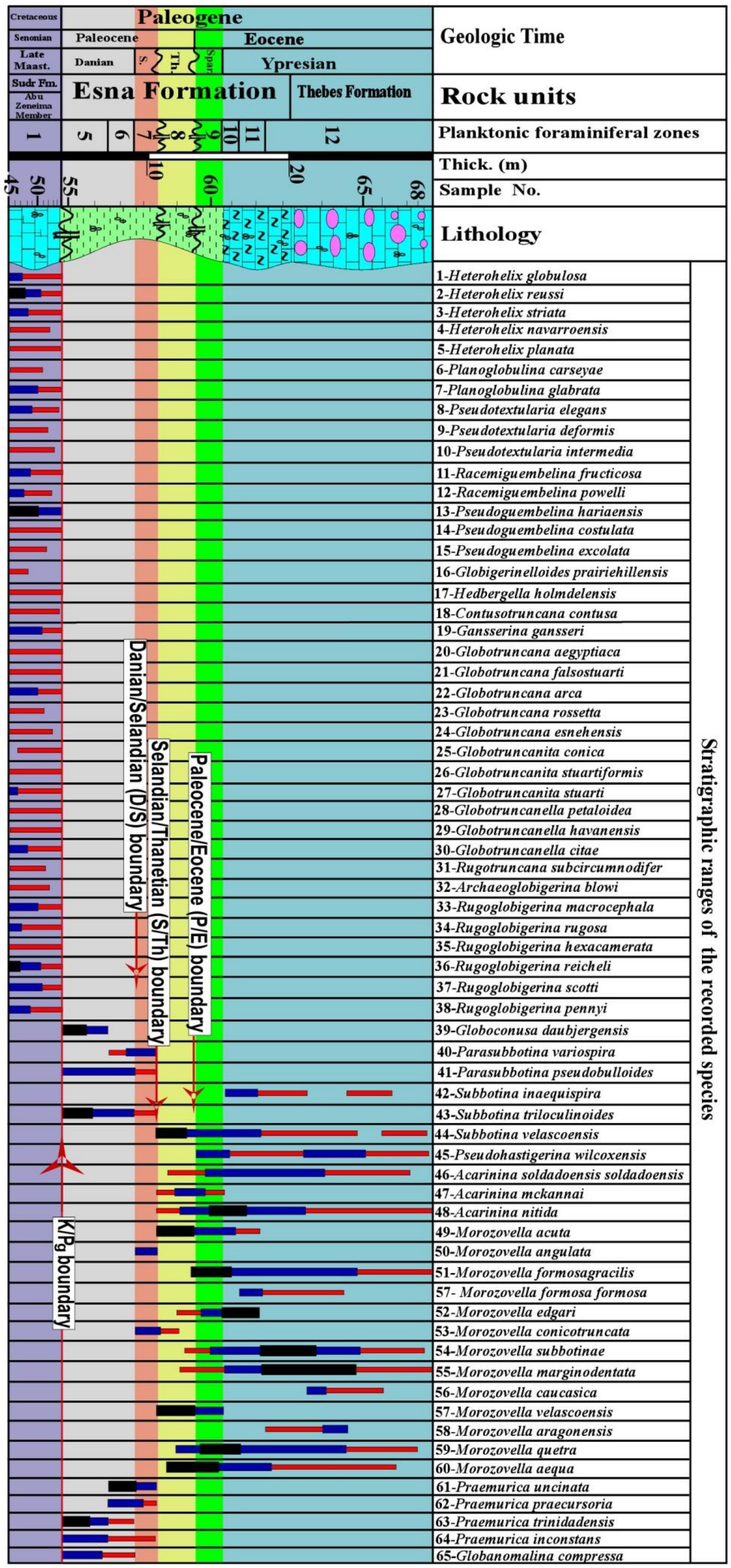


Fig. 4: Distribution chart of the identified latest Maastrichtian to early Eocene planktonic foraminiferal species at Wadi Abu Had section. For Caption see Fig. 3

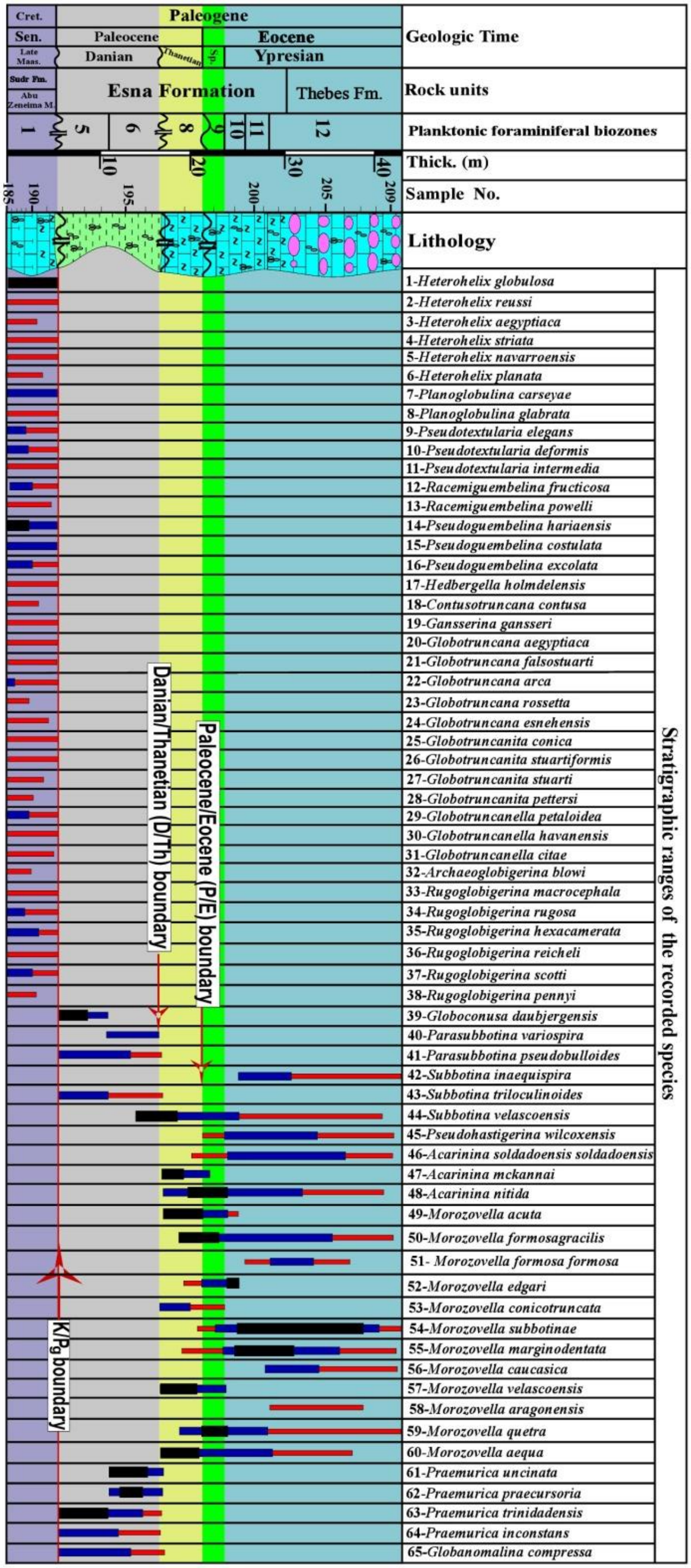


Fig. 5: Distribution chart of the identified latest Maastrichtian to early Eocene planktonic foraminiferal species at Wadi Dib section. For Caption see Fig. 3

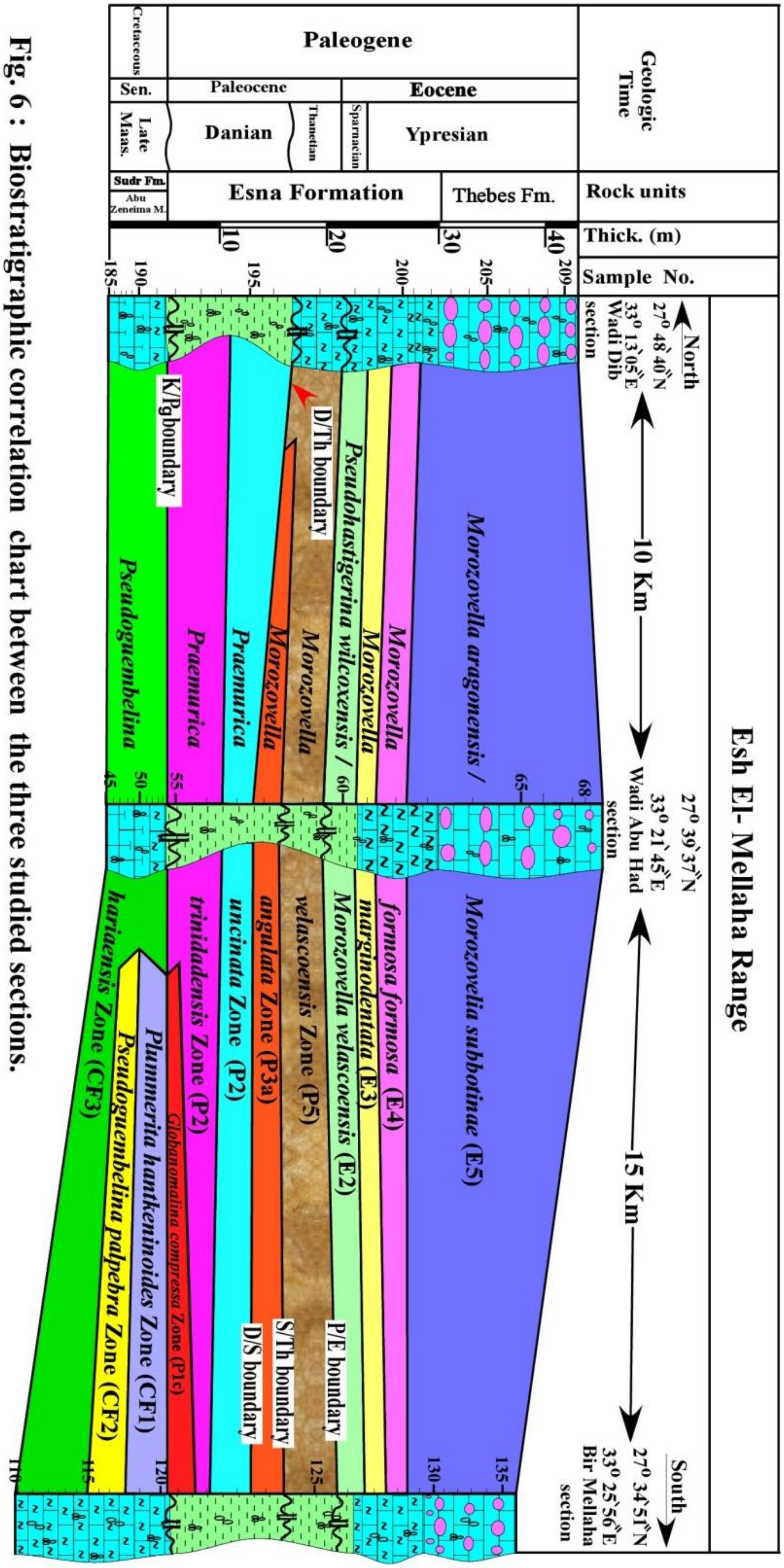
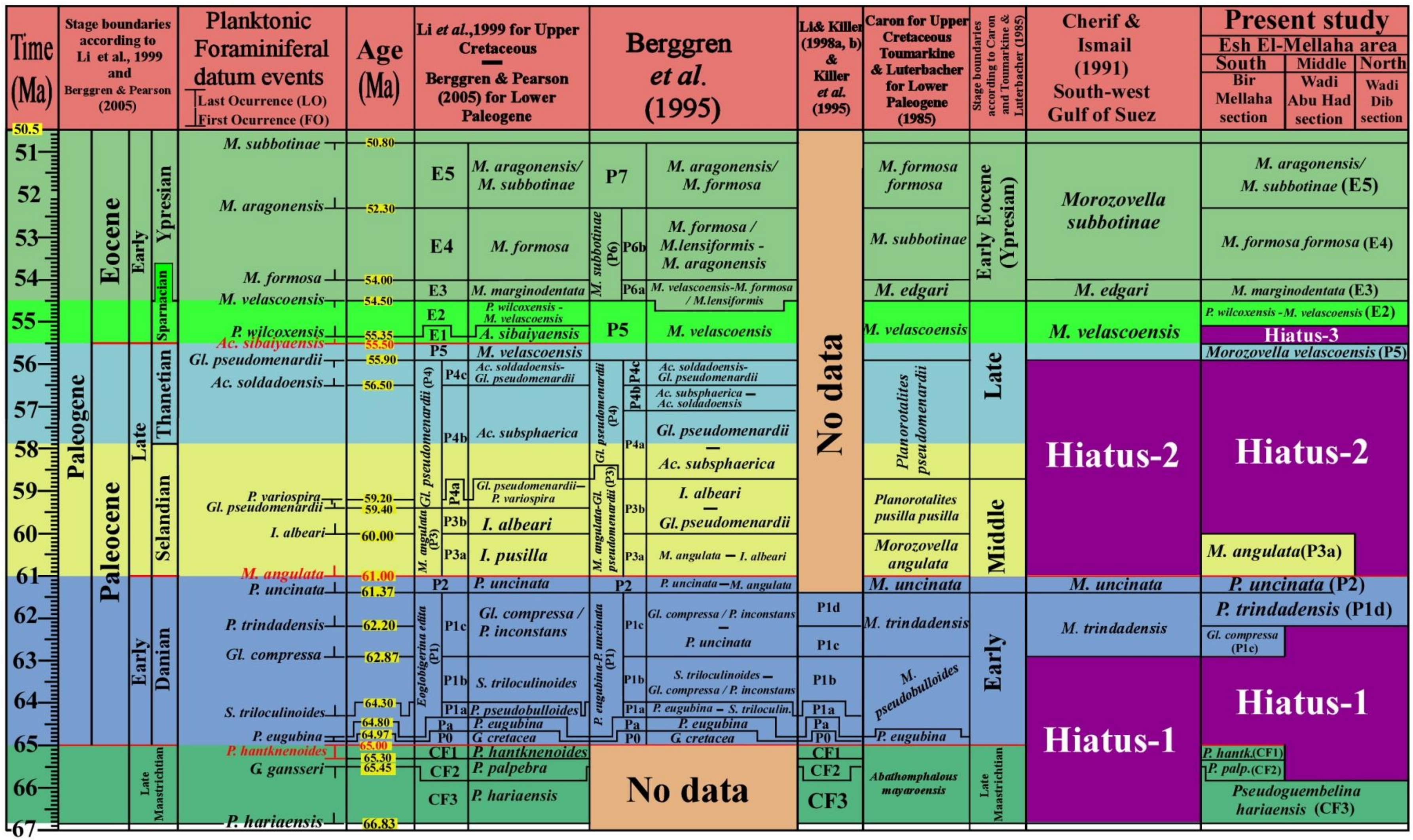


Fig. 6 : Biostratigraphic correlation chart between the three studied sections.

Tab.1: Summary of the commonly used planktonic foraminiferal zonal schemes for the upper Maastrichtian- lower Eocene, age estimated, and their coeval in the Esh El-Mellaha area. The estimated ages and datum events for the Upper Maastrichtian based on , Li and Keller, 1998a,b, Li et al., 1999, and correlation with Caron, 1985; while the estimated ages and datum events for the Lower Paleogene based on Berggren and Pearson, 2005& Keller, 1995& Berggren et al., 1995 and correlation with Toumarkine & Luterbacher, 1985.



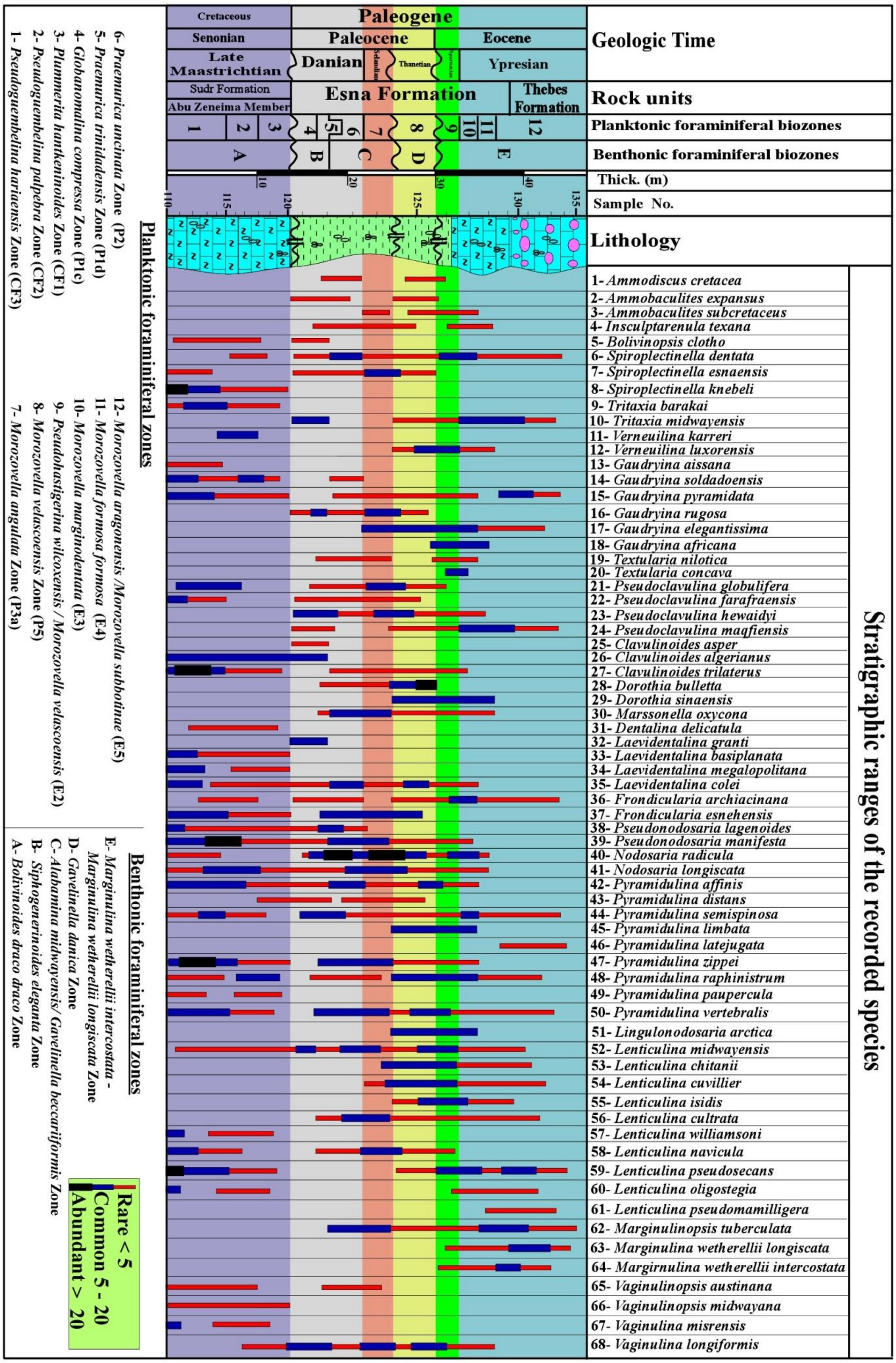
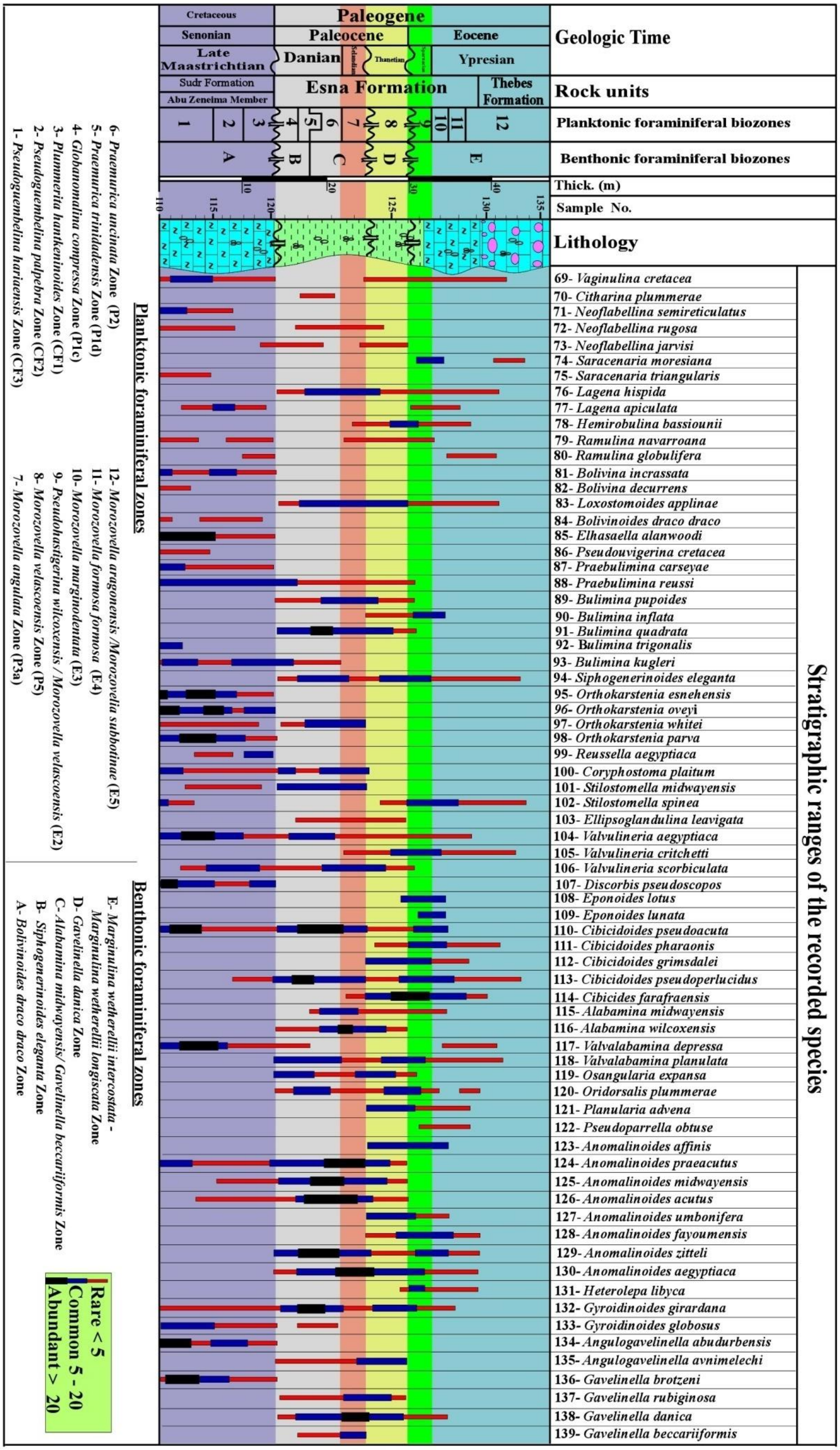


Fig. 7 : Distribution chart of the identified latest Maastrichtian-early Eocene benthonic foraminiferal species at Bir Mellaha section.



Continue Fig. 7 : Distribution chart of the identified latest Maastrichtian-early Eocene benthonic foraminiferal species at Bir Mellaha section.

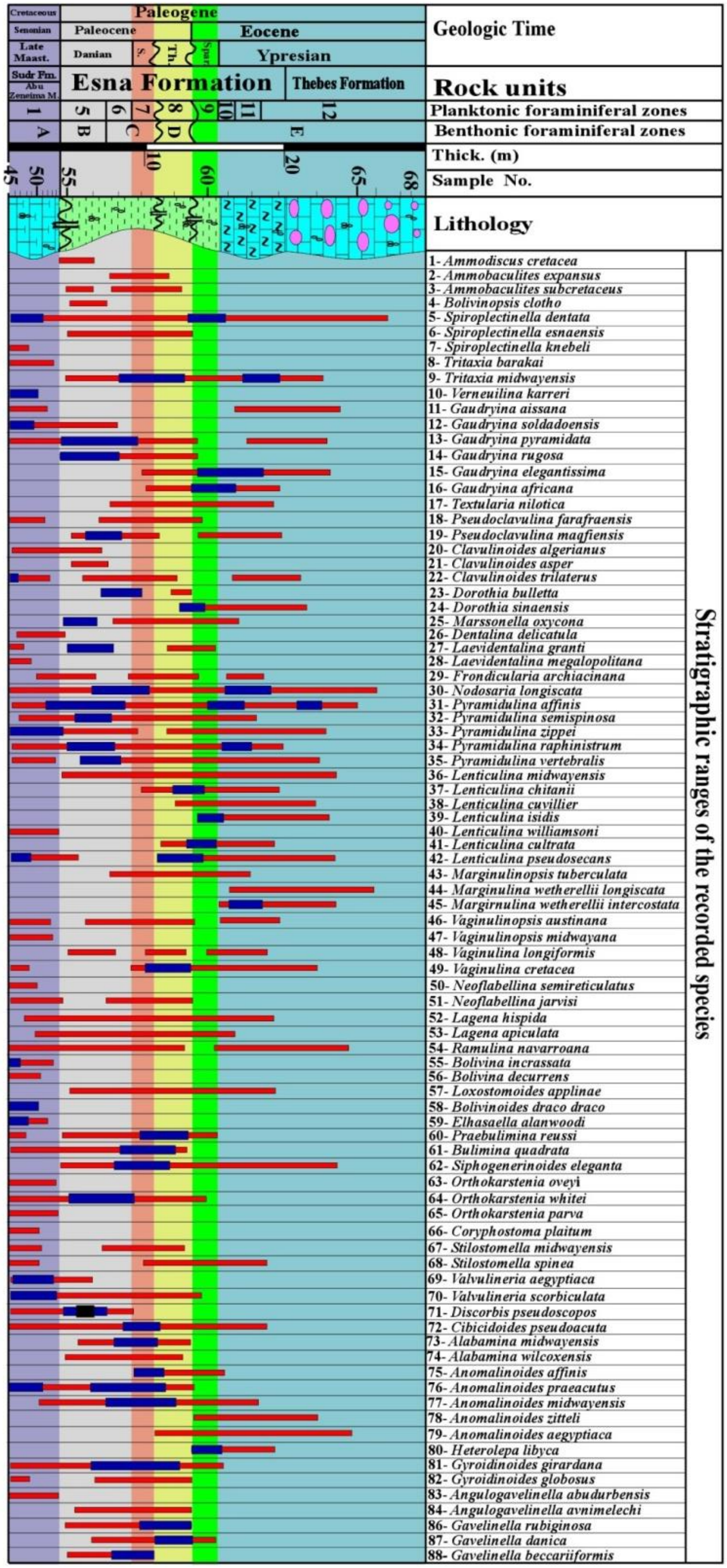


Fig. 8 : Distribution chart of the identified benthonic foraminiferal species at Wadi Abu Had section. For Caption see Fig. 7.

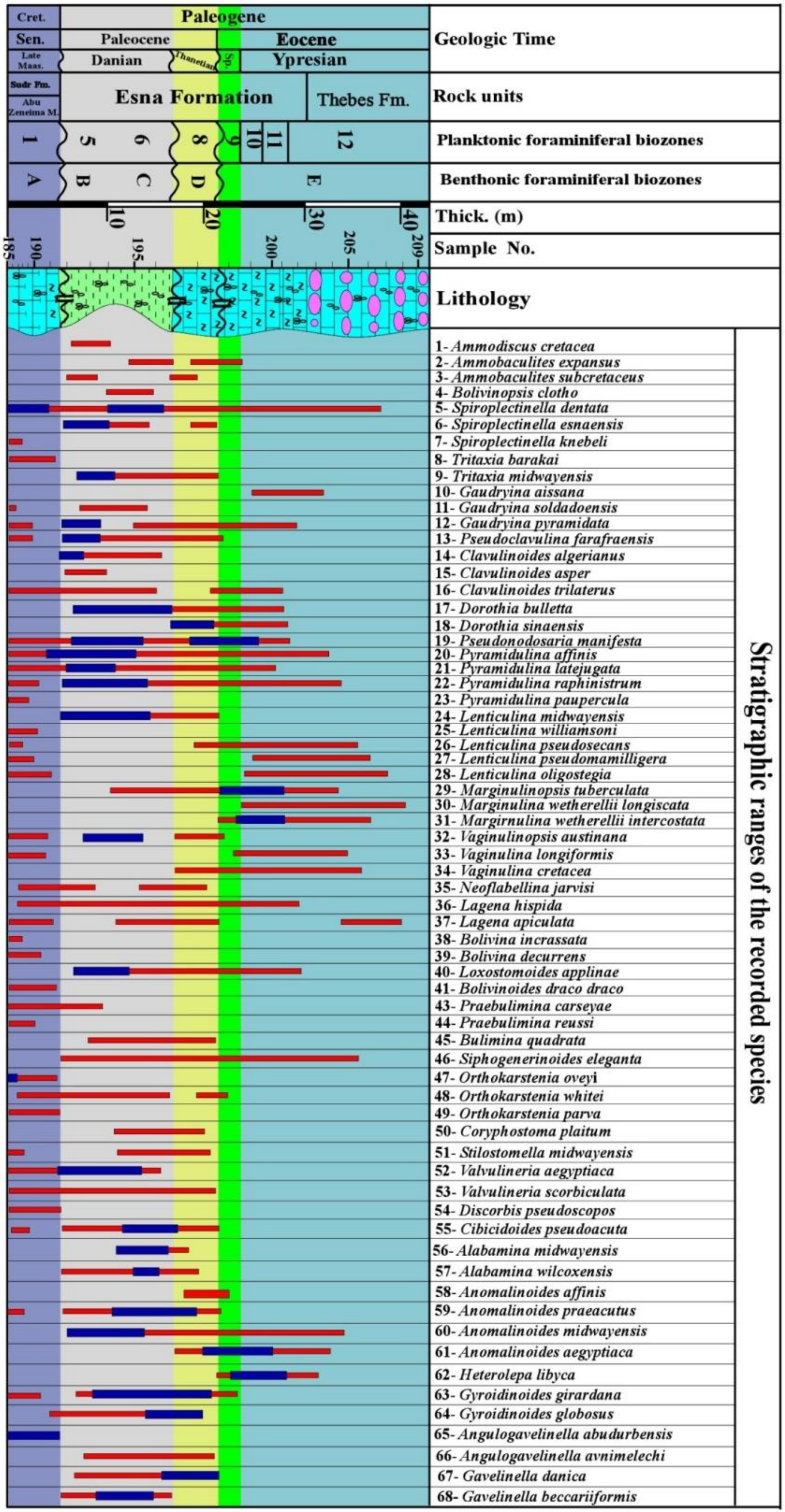


Fig. 9 : Distribution chart of the identified latest Maastrichtian-early Eocene benthonic foraminiferal species at Wadi Dib section. For Caption see Fig. 7.

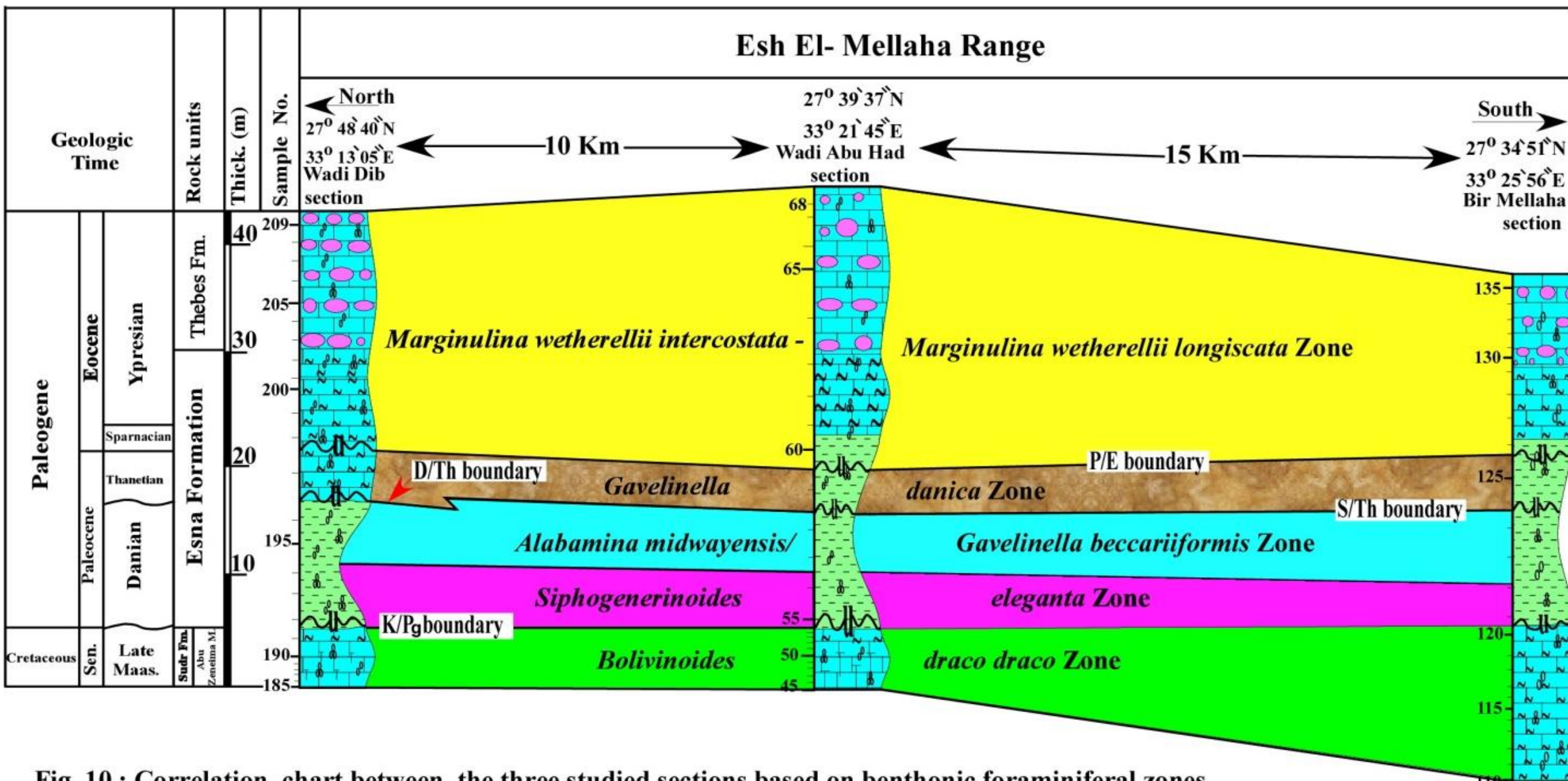
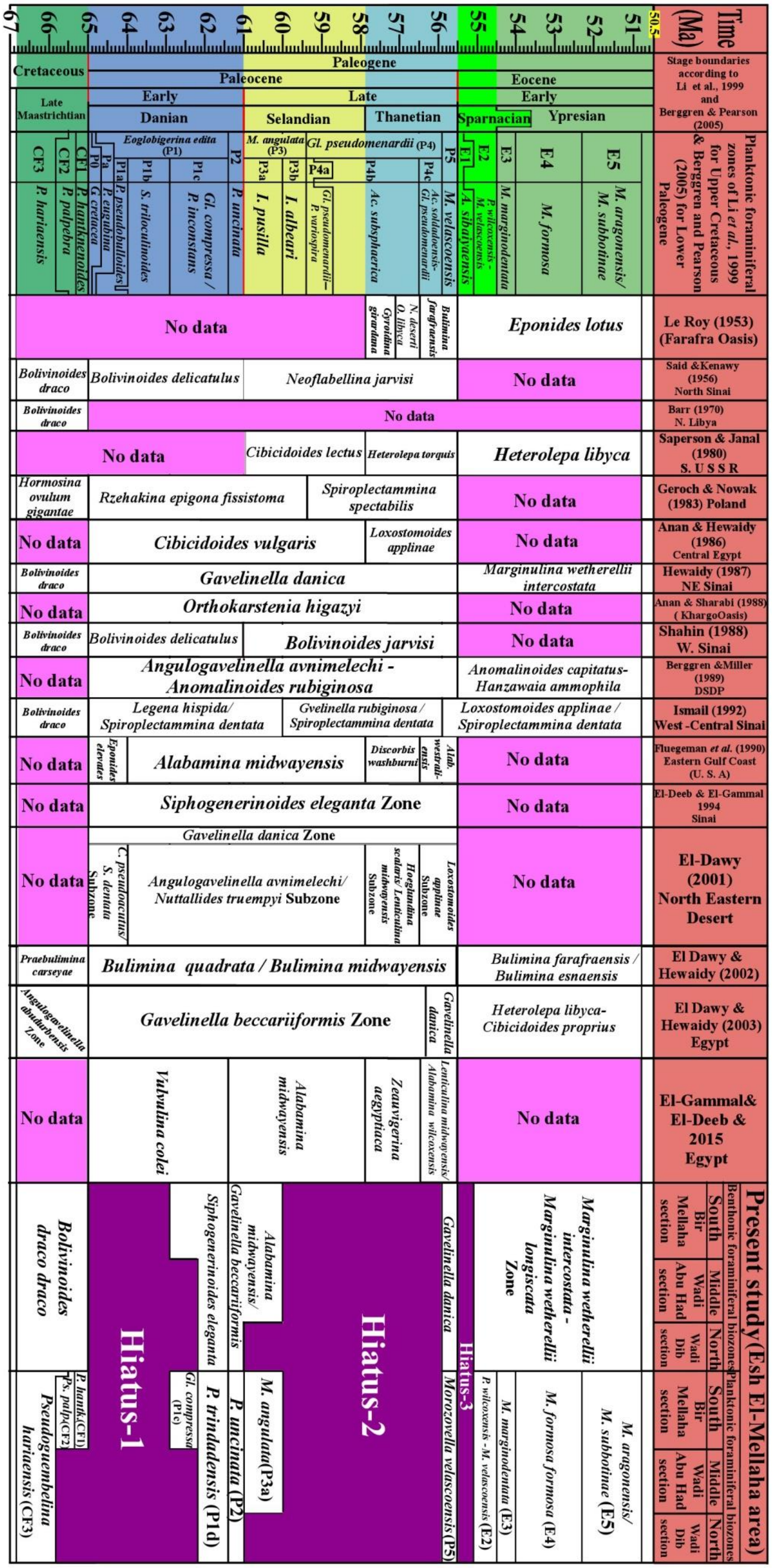


Fig. 10 : Correlation chart between the three studied sections based on benthonic foraminiferal zones

Tab. 2: Summary of the latest Maastrichtian - early Eocene benthonic foraminiferal biozones proposed by different authors inside and out-side of Egypt and their equivalents of planktonic and benthonic foraminiferal zones in the study area.



Paleoecology

The foraminiferal distribution is a function of the water depth available over the shelf during any particular interval (Hart & Bailey, 1979). So. the integration between the lithologic characters and the quantitative evolution of both planktonic and benthonic foraminiferal species and their abundance patterns are used to determine the paleodepth and the environmental conditions that prevailed during the deposition of the uppermost part of Maastrichtian-lower Eocene sequence at the Esh El-Mellaha area. This depend mainly on studying the most important paleoecological factors such as; the total number of foraminiferal species, the diversity, the statistical analysis of planktonic forams (heterohelicids, non keeled, keeled), the statistical analysis of benthonic forams (agglutinated and calcareous), the Planktonic/Benthonic (P/B) ratio, and the Agglutinated/ Calcareous (Aggl./Calc.) ratio. The detailed quantitative foraminiferal counting and the paleoecological parameters are carried out for 0.5 gram of the washed residue from all rock samples at the three studied sections and the suggested prevailed paleoenvironments are discussed in details as follows:

1. Uppermost part of the Sudr Formation (upper part of Abu Zeneima Member)

The measured part of this member is composed of yellowish-white to pale grey soft argillaceous limestone and chalky limestone sequence. It attains about 4.5 m thick at Wadi Dib section, about 5m thick at Wadi Abu Had section, and about 12 m thick at Bir Mellaha section. It is divided in the study area into three planktonic foraminiferal zones of late Maastrichtian age (*Pseudoguembelina hariaensis* (CF3), *Pseudoguembelina palpebera* (CF2), and *Plummerita hantkeninoides* (CF1) zones).

The late Maastrichtian *Pseudoguembelina hariaensis* (CF3) Zone is recorded from samples 110-115 at Bir Mellaha section, from samples 45-57 at Wadi Abu Had section, and from samples 185-191 at Wadi Dib section (Figs. 11-13). It attains about 4.5 m thick a Wadi Dib section, about 5m thick at Wadi Abu Had section, and about 6m thick at Bir Mellaha section. This interval is characterized by a very high total foraminiferal number of an average of 917 at Bir Mellaha, 902 at Wadi Abu Had, 892 at Wadi Dib; a very high diversity of an averageof 114 at Bir Mellaha, 89 at Wadi Abu Had, 74 at Wadi Dib; very high P/B ratio of an of an average of 85 % at Bir Mellaha, 80 % at Wadi Abu Had, 77 % at Wadi Dib; a very high number of planktonic foraminiferal species of which 15% are heterohelicids, 10 % are non keeled and 75 % are keeled forms at Bir Mellaha, 25% are heterohelicids, 8 % are non keeled and 67 % are keeled forms at Wadi Abu Had,30 % are heterohelicids, 5 % are non keeled and 65 % are keeled forms at Wadi Dib. It is also characterized by a low benthonic foraminiferal number of an average of 15% at Bir Mellaha, 20 % at Wadi Abu Had, 23 % at Wadi Dib; and a relatively low Aggl./ Calc. ratio of an average of 35% at Bir Mellaha, 40 % at Wadi Abu Had, 42 % at Wadi Dib. On the other hand, this interval is characterized by the presence of *Abathomphalus mayaroensis* (Bolli), *Angulogavelinella abudurbensis* Reiss, *Clavulinoides trilaterus* (Cushman), *Cibicidoides pseudoacuta* (Nakkady). So, an upper to middle bathyal environment was prevailed during the deposition of the late Maastrichtian interval of the Sudr Formation.

The latest Maastrichtian ***Pseudoguembelina palpebera*** **(CF2),** and *Plummerita hantkeninoides* (CF1) zones are recorded only at Bir Mellaha section from samples 116-120 andattains about 6 m thick. This interval is characterized by a relatively high total foraminiferal number of an average of 687; a relatively high diversity of an average of 87; a medium P/B ratio of an of an average of 52.5 %; a relatively medium number of planktonic foraminiferal species of which 43% are heterohelicids, 22.25 % are non keeled and 34.75 % are keeled forms. It is also characterized by a medium benthonic foraminiferal number of an average of 47.5 %; and a relatively high Aggl./ Calc. ratio of an average of 65 %. On the other hand, this interval is characterized by: the abundance of non-keeled planktonic forms such as *Rugoglobigerina reicheli* Bronnimann, and *Plummerita hantkeninoides* (Bronnimann) with clavate chambers which indicate a photic environment under worm water conditions; rare biconvex-keeled planktonic forms, e.g. *Globotruncana esnehensis* Nakkady and *Globotruncanita conica* White which are considered by Hart & Bailey (1979) typical for the 2nd and 3rd depth zones (about 100-150m); the occurrence of the genus *Bolivinoide*s Cushman which suggests an open oceanic conditions (Barr, 1970) but not deep water (Premolisilva & Bolli, 1973); the dominance of *Discorbis pseudoscopos* Nakkady, *Anomalinoides midwayensis* (Plummer), *Anomalinoides praeacutus* (Vasilenko). So, a middle to shallow outer neritic environments were prevailed during the deposition of the latest Maastrichtian interval of the Sudr Formation (Figs. 11-13).

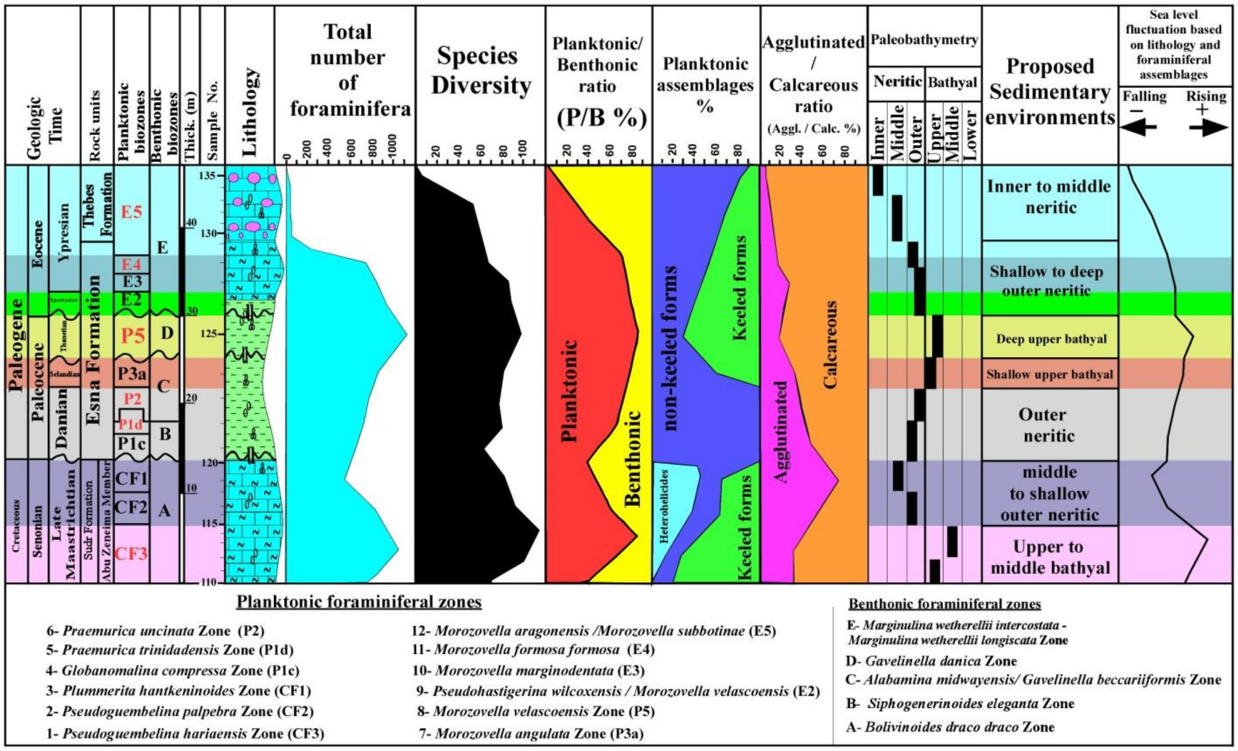


Fig. 11 : The main foraminiferal parameters with the proposed paleoenvionments in the upper Maastrichtian-lower Eocene succession at Bir Mellaha section.

2. Esna Formation

The Esna Formation is composed of yellowish pale brown to green shale in the lower part intercalated with thinly bedded argillaceous limestone in the upper part. It is divided into nine planktonic foraminiferal biozones; three in the early Paleocene (Danian) (*Globanomalina compressa* (P1c), *Praemurica trindadensis* (P1d), and *Praemurica uncinata* (P2) zones); one in the early Late Paleocene (Selandian) *Morozovella angulata* (P3a) Zone; one in the latest Paleocene (latest Thanetian) *Morozovella velascoensis* (P5) Zone; two in the Earliest Eocene (Sparnacian) (*Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) and *Morozovella marginodentata* (E3) zones); and two in the Early Eocene (Ypresian) (*Morozovella formosa formosa* (E4) and the lower part of *Morozovella aragonensis / Morozovella subbotinae* (E5) zones).

The early Paleocene (Middle Danian) *Globanomalina compressa* (P1c) Zone is recorded only at Bir Mellaha section from sample 121 and it attains about 2 m thick. The results of the statistical analysis for this interval are characterized by a middle total foraminiferal number of an average of 690; a medium diversity of an average of 63; a medium P/B ratio of an average of 50 %; a medium number of planktonic foraminiferal species represented only by non keeled forms such as *Globanomalina*, *Parasubbotina*, and *Subbotina* ssp. It is also characterized by a medium benthonic foraminiferal number of an average of 50 %; and a relatively high Aggl./ Calc. ratio of an average of 55 %. Also, this interval is marked by absence of keeled forms. So, a shallow outer neritic environment was prevailed during the deposition of the middle Danian interval of the Esna Formation.

The late early Paleocene (Middle to Late Danian) *Praemurica trindadensis* (P1d), and (late Danian) *Praemurica uncinata* (P2) zones are recorded from samples 122- 123 at Bir Mellaha section, from samples 55-57 at Wadi Abu Had section, and from samples 192-196 at Wadi Dib section (Figs. 11-13). This interval attains about 8.5 m thick a Wadi Dib section, about 6.5m thick at Wadi Abu Had section, and about 4 m thick at Bir Mellaha section. The results of the statistical analysis for this time interval are characterized by a relativelyhigh total foraminiferal number of an average of 747.5 at Bir Mellaha, 732.5 at Wadi Abu Had, 722.5 at Wadi Dib; a relatively high diversity of an average of 79 at Bir Mellaha, 55.5 at Wadi Abu Had, 45.5 at Wadi Dib; a relatively high P/B ratio of an of an average of 67.5 % at Bir Mellaha, 62.5 % at Wadi Abu Had, 59.5 % at Wadi Dib; a relatively high number of planktonic foraminiferal species represented only by non keeled forms such as *Globanomalina*, *Parasubbotina*, *Subbotina*, and *Praemurica* ssp. It is also characterized by a relatively low benthonic foraminiferal number of an average of32.5 % at Bir Mellaha, 37.5 % at Wadi Abu Had, and 40.5 % at Wadi Dib; and a medium Aggl./ Calc. ratio of an average of42.5 % at Bir Mellaha, 47.5 % at Wadi Abu Had, 49.5 % at Wadi Dib. Also, this interval is marked by absence of keeled forms and by the dominance of *Spiroplectinella esnaensis* (Le Roy), *Siphogenerinoides eleganta* Plummer, *Alabamina wilcoxensis* Toulmin, *Alabamina midwayensis* Brotzen, and *Anomalinoides acutus* (Plummer). So, a shallow to deep outer neritic environment was prevailed during the deposition of the middle- late Danian interval of the Esna Formation.

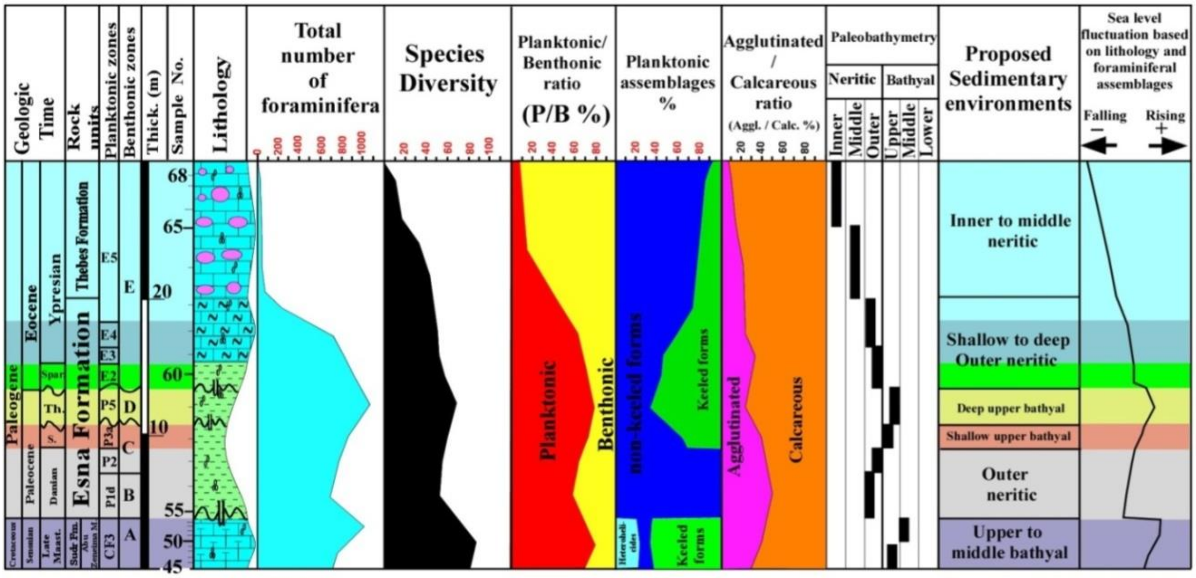


Fig. 12: The main foraminiferal parameters with the proposed paleoenvionments in the upper Maastrichtian-lower Eocene succession at Eadi Abu Had section.

The early Late Paleocene (Selandian) *Morozovella angulata* (P3a) Zone is recorded from sample 124 at Bir Mellaha section, from sample 58 at Wadi Abu Had section, and not recorded at Wadi Dib section. This time interval is characterized by avery high total foraminiferal number of an average of 898 at Bir Mellaha, 883 at Wadi Abu Had; a high diversity of an average of 81 at Bir Mellaha, 60 at Wadi Abu Had; a very high P/B ratio of an of an average of 80 % at Bir Mellaha, 75 % at Wadi Abu Had; high number of planktonic foraminiferal species of which 40 % are keeled and 60 % are non keeled forms at Bir Mellaha, 35 % are keeled and 65 % are non keeled forms at Wadi Abu Had. It is also characterized by low benthonic foraminiferal number of an average of 20 % at Bir Mellaha, and 25 % at Wadi Abu Had; and a low Aggl./ Calc. ratio of an average of 35 % at Bir Mellaha, 40 % at Wadi Abu Had. Also, this interval is marked by increasing in non keeled forms *Parasubbotina*, *Subbotina* and *Praemurica* spp. and the first appearance of keeled forms such as *Morozovella* ssp. and the dominance of *Gaudryina pyramidata* Cushman, *Marginulinopsis tuberculata* (Plummer), *Bulimina quadrata* Plummer, *Cibicidoides pseudoacuta* (Nakkady), *Anomalinoides zitteli* (Le Roy), *Gavelinella danica* (Brotzen), *Marssonella oxycona* (Reuss). So a shallow upper bathyal environment was prevailed during the deposition of the early Late Paleocene (Selandian) interval of the Esna Formation (Figs. 11-13).

The latest Paleocene (latest Thanetian) *Morozovella velascoensis* (P5) Zone is recorded from samples 125 at Bir Mellaha section, from samples 59 at Wadi Abu Had section, and from sample 197 at Wadi Dib section. This intervalcomprises the lower upper part of the Esna Formation andattains about 5 m thick at both Wadi Dib and Bir Mellaha sections, and about 3m thick at Wadi Abu Had section. The results of the statistical analysis for this interval arecharacterized by a very high total foraminiferal number of an average of 1102 at Bir Mellaha, 1087 at Wadi Abu Had, 1077 at Wadi Dib; a relatively high diversity of an average of 98 at Bir Mellaha, 69 at Wadi Abu Had, 52 at Wadi Dib; a very high P/B ratio of an of an average of 85 % at Bir Mellaha, 80 % at Wadi Abu Had, 77 % at Wadi Dib; a very high number of planktonic foraminiferal species of which 70% are keeled, and 30% are non keeled at Bir Mellaha, 65 % are keeled and 35 % are non keeled forms at Wadi Abu Had, 62 % are keeled and 38 % are non keeled forms at Wadi Dib. It is also characterized by a low benthonic foraminiferal number of an average of 15 % at Br Mellaha, 20% at Wadi Abu Had, 23% at Wadi Dib; and low Aggl./ Calc. ratio of an average of 20 % at Bir Mellaha, 25% at Wadi Abu Had, 27% at Wadi Dib. Also, this interval is marked by a noticeable increasing in *Morozovella* and *Acarinina* spp. and decreasing in *Parasubbotina*, *Subbotina*, and *Praemurica* spp., and also by the dominance of *Spiroplectinella dentata* (Alth), *Marssonella oxycona* (Reuss), *Clavulinoides trilaterus* (Cushman), *Angulogavelinella avnimelechi* Reiss, *Gavelinella rubiginosa* (Cushman). So, a deep upper bathyal environment was prevailed during the deposition of the latest Paleocene (latest Thanetian) interval of the Esna Formation (Figs. 11-13).

The earliest Eocene (Sparnacian) *Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) Zoneand early Eocene (Ypresian) *Morozovella marginodentata* (E3) *Morozovella formosa formosa* (E4) and the lower part of *Morozovella aragonensis / Morozovella subbotinae* (E5) zones are comprise the uppermost part of the Esna Formation at the three studied sections and are recorded from samples126-129 at Bir Mellaha section, from samples60- 63 at Wadi Abu Had section, and from samples 198-202. It attains about 6.5 m thick a Wadi Dib section, about 8m thick at Wadi Abu Had section, and about 6 m thick at Bir Mellaha section. This interval characterized by a relatively high total foraminiferal number of an average of 831 at Bir Mellaha,816 at Wadi Abu Had, 806 at Wadi Dib; a relatively high to medium diversity of an average of 81 at Bir Mellaha, 54 at Wadi Abu Had, 36 at Wadi Dib; high P/B ratio of an of an average of 75 % at Bir Mellaha, 70% at Wadi Abu Had, 67 % at Wadi Dib; a relatively high number of planktonic foraminiferal species of which53.3.7% are keeled, and 46.7% are non keeled at Bir Mellaha,49.3 % are keeled and 50.7 % are non keeled forms at Wadi Abu Had,48 % are keeled and 52 % are non keeled forms at Wadi Dib. It is also characterized by a relatively low benthonic foraminiferal number of an average of 25 % at Br Mellaha, 30% at Wadi Abu Had,33% at Wadi Dib; and low Aggl./ Calc. ratio of an average of 26 % at Bir Mellaha, 28% at Wadi Abu Had, 31% at Wadi Dib. Also, this interval is marked by the dominance of the genus *Marginulina*, *Marginulinopsis* Silvesteri, *Loxostomoides* Reiss, *Cibicidoides* Thalmann. So, shallow to deep outer neritic environment was prevailed during the deposition of earliest Eocene (Sparnacian)- early Eocene (Ypresian) interval of the Esna Formation.

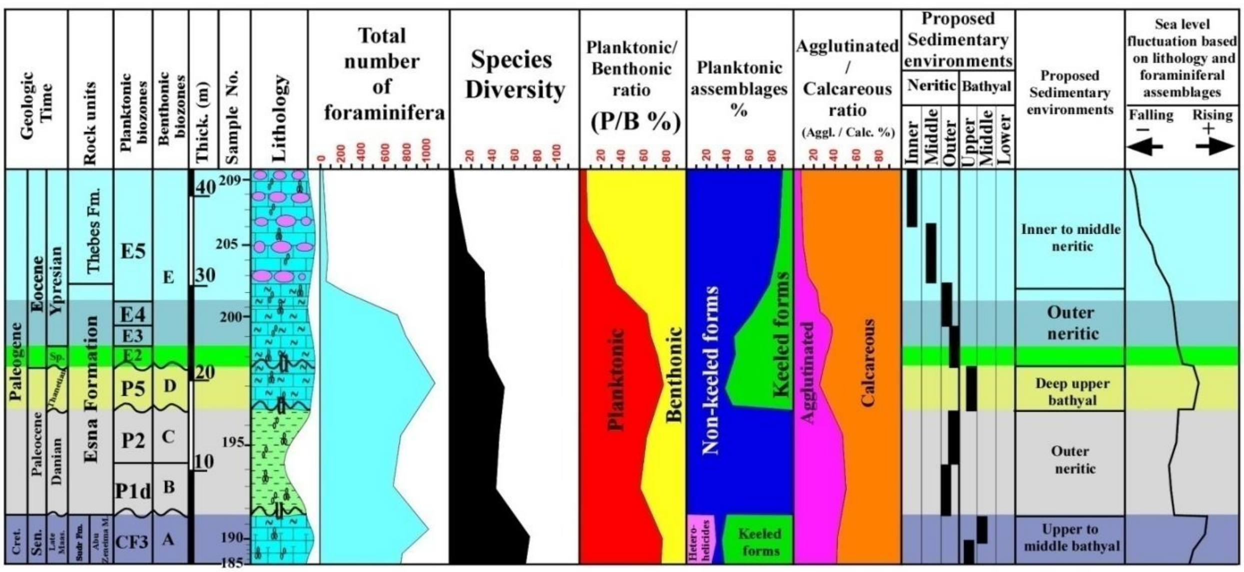


Fig. 13: The main foraminiferal parameters with the proposed paleoenvionments in the upper Maastrichtian-lower Eocene succession at Wadi Db section.

3. Thebes Formation

This rock unit is represented the top of the studied sequence at the three studied sections. The measured part of the Thebes Formation is composed of pale white; porcellaneous chalky limestone succession and sometimes concretional limestones with brown to black flint bands and nodules. It comprises the early Eocene (Ypresian) upper part of *Morozovella aragonensis / Morozovella subbotinae* (E5) Zone. This time interval is recorded from samples130-135 at Bir Mellaha section, from samples 64-68 at Wadi Abu Had section, and from samples 203-209 (Figs. 11-13). It attains about 7 m thick a Wadi Dib section, about 8m thick at both Wadi Abu Had and Bir Mellaha sections. The results of the statistical analysis for this interval are characterized by a very low total foraminiferal number of an average of 75 at Bir Mellaha, 62 at Wadi Abu Had, 49 at Wadi Dib; a low diversity of an average of 55 at Bir Mellaha, 46 at Wadi Abu Had, 33 at Wadi Dib; a low P/B ratio of an of an average of 30 % at Bir Mellaha, 25% at Wadi Abu Had, 22.5 % at Wadi Dib; a low number of planktonic foraminiferal species of which 30% are keeled, and 70% are non keeled at Bir Mellaha, 24 % are keeled and 76 % are non keeled forms at Wadi Abu Had, 21 % are keeled and 79 % are non keeled forms at Wadi Dib. It is also characterized by a high benthonic foraminiferal number of an average of 70% at Br Mellaha, 75% at Wadi Abu Had, 77.5% at Wadi Dib; and low Aggl./ Calc. ratio of an average of 18 % at Bir Mellaha, 23% at Wadi Abu Had, 25% at Wadi Dib. So, an inner to middle neritic environment of 50-100m depth was prevailed during the deposition of the Thebes Formation.

Summary and Conclusions

The present study can be summarized in the following items:

1- This work deals with the foraminiferal assemblages and their importance in the studying the nature of the uppermost Maastrichtian- lower Eocene (Ypresian) stages boundaries and the paleoecological interpretations for three exposures on the western flank of Esh El-Mellah area, north Eastern Desert, Egypt from north to south are Wadi Dib, Wadi Abu Had, and Bir Mellaha sections.

2- Lithostratigraphically, this interval is represented by the uppermost part of the Sudr, Esna, and Thebes formations from base to top and these rock units are found very rich with foraminiferal assemblages.

3- 209 foraminiferal species have been identified. This include **71** planktonic species which are belonging to **24** genera, **6** subfamilies, **7** families, **4** superfamilies and **1** suborder; and **138** benthic species belonging to **60** genera, **24** subfamilies **33** families, **18** superfamilies and **3** suborders.

4-Twelve planktonic foraminiferal biozones are distinguished; **three** of them of the latest Maastrichtian (*Pseudoguembelina hariaensis* (CF3), *Pseudoguembelina palpebra* (CF2), and *Plummerita hantkeninoides* (CF1) zones); **three** of the early Paleocene (Danian) (*Globanomalina compressa* (P1c), *Praemurica trindadensis* (P1d), and *Praemurica uncinata* (P2) zones); **one** of the early Late Paleocene (Selandian) *Morozovella angulata* (P3a) Zone; **one** of the latest Paleocene (latest Thanetian) *Morozovella velascoensis* (P5) Zone; **two** of the earliest Eocene (Sparnacian) (*Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) and *Morozovella marginodentata* (E3) zones); and **two** in the Early Eocene (Ypresian) (*Morozovella formosa formosa* (E4) and *Morozovella aragonensis / Morozovella subbotinae* (E5) zones).

5-Depending on the vertical distribution of the recorded benthonic species at these three studied sections, this interval is classified into **five** benthic zones, **one** of the Latest Maastrichtian (*Bolivinoides draco draco* Zone); **one** of early Paleocene (middle – late Danian) (*Siphogenerinoides eleganta* Zone); **one** of the late early Paleocene (latest Danian) to early late Paleocene (Selandian) (*Alabamina midwayensis* Zone); **one** of the latest Paleocene (latest Thanetian) (*Gavelinella danica* Zone); and **one** of the early Eocene (*Marginulina wetherellii intercostata-Marginulina wetherellii longiscata* Zone).

6- The Cretaceous/Paleogene (K/P_g) boundary is located at the Sudr/ Esna formational boundary. It is represented by an unconformable surface at the three studied sections and it lies between *Plummerita hantkeninoides* (CF1) and *Globanomalina compressa* (P1c) zones at Bir Mellaha section; while at both Wadi Dib and Wadi Abu Had, it lies between *Pseudoguembelina hariaensis* (CF3) and *Praemurica trindadensis* Zone (P1d). This boundary is characterized by the extinction of the typical Maastrichtian planktonic foraminiferal genera such as *Globotruncana*, *Rugoglobigerina*, and *Heterohelix* and the first appearance of the earliest Paleocene genera such as *Parasubbotina*, *Subbotina*, and *Globanomalina*. Also, a distinctive change in the benthonic foraminiferal species at this boundary represented by extinction of some species that are characteristic for the latest Maastrichtian age as: *Discorbis pseudoscopos* (Nakkady), *Angulogavelinellaabudurbensis* (Nakkady), *Elhasaella alanwoodi* Hamam, *Orthokarstenia esnehensis* (Nakkady), *Orthokarstenia oveyi* (Nakkady), *Orthokarstenia parva* (Cushman), and first appearance of the characteristic Paleocene species such as *Siphogeneroides eleganta* (Plummer), *Bulimina quadrata*, Plummer, *Cibicides pharaonis* (Le Roy), *Marginulinopsis tuberculata* (Plummer), and *Valvalabamina planulata* (Cushman and Renz). This extinction of this benthic species may be due to the uppermost Maastrichtian shallowing of the sea. According to the recorded benthonic foraminiferal zones in the present study, the Cretaceous/Paleogene (K/Pg) boundary lies between *Bolivinoides draco draco* and *Siphogenerinoides eleganta* zones.

7- The Danian/Selandian(D/S) boundary is recorded only at both Wadi Abu Had and Bir Mellaha sections. It is located within the lower part of the Esna Formation and it is represented by conformable surface where it lies between *Praemurica uncinata* (P2) and *Morozovellaangulata* (P3a) zones. Also, this boundary lies within *Siphogenerinoides eleganta* benthonic Zone.

8- The Selandian/Thanetian (S/ Th.) boundary is located at the middle part of the Esna Formation at both Wadi Abu Had and Bir Mellaha sections and it lies between *Morozovella angulata* (P3a) Zone and *Morozovella velascoensis* Zone (P5); while at Wadi Dib section, we cannot detect the (S/Th) boundary, where the late Danian *Praemurica uncinata* (P2) is directly overlain by the latest Thanetian *Morozovella velascoensis* Zone (P5). According to the recorded benthonic foraminiferal zones in the present study, the Selandian/Thanetian (S/ Th) boundary lies between *Alabamina midwayensis/ Gavelinella beccariiformis* and *Gavelinella danica* zones.

9- The Paleocene/Eocene (P/E) boundary is located within the upper part of the Esna Formation and represented by unconformable surface at the three studied sections where it lies between (latest Thanetian) *Morozovella velascoensis* (P5) Zone and Earliest Eocene (Sparnacian) *Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2).

According to the recorded benthonic foraminiferal zones, this boundary lies between the *Gavelinella danica* Zone and *Marginulina wetherellii intercostata* - *Marginulina wetherellii longiscata* Zone. Also, it is characterized by the most extinction of deep sea bathyal and neritic calcareous benthic foraminifera of *Gavelinella beccariiformis* assemblage such as *Neoflabellina jarvisi*, *Angulogavelinella avnimelechi*, *Gavelinella rubiginosa Dorothia bulletta*, *Spiroplectinella esnaensis* and others, and the first appearance of newly early Eocene assemblages such as *Marginulina wetherellii intercostata*, *Marginulina wetherellii longiscata* and *Heterolepa libyca* and other.

10- Three sedimentary hiatus are detected in the studied stratigraphic sequence at the three studied sections:

The first one includes the Cretaceous/ Paleogene (K/Pg) boundary and it lies between the Sudr and the Esna formations at the three studied sections and it is differentiated in its biostratigraphic interval from the north to south at the study area. Based on Berggren and Pearson, 2005 the magnitude of this hiatus at both Wadi Dib and Wadi Abu Had sections is about 4.08 Ma extended from 65.45- 61.37 Ma; while at Bir Mellaha section the magnitude of this hiatus at this section is about 2.13 Ma extended from 65.00- 62.87 Ma.

The second sedimentary hiatus includes Selandian/Thanetian (S/Th) boundary and it is located within the middle part of Esna Formation at both Wadi Abu Had and Bir Mellaha sections due to absence of the upper part of P3 Zone inaddition to P4 Zone where P3 Zone is directly overlain by P5 Zone and according to Berggren and Pearson, 2005, the magnitude of this hiatus at these two sections is about 4.10 Ma extended from 60.00 Ma- 55.90 Ma,. On the other hand, we cannot detected the (S/Th) at Wadi Dib section because of the presence of a hiatus within the Esna Formation at this section includes all Selandian and the lower part of Thanetian stages where P2 Zone is directly overlain by P5 Zone and based on Berggren and Pearson, 2005, the magnitude of this hiatus at this section is about 5.10 Ma extended from 61.00 Ma- 55.90 Ma.

The third sedimentary hiatus includes Paleocene/Eocene boundary and it is located within the top most part of the Esna Formation at the three studied sections due to absence of (E1) Zone where the (P5) Zone is directly overlain by (E2) Zone and based on Berggren and Pearson, 2005, the magnitude of this hiatus is about 0.15 Ma extended from 55.50 Ma- 55.35 Ma.

11-The integration between the lithologic characters and the quantitative evolution of both planktonic and benthonic foraminiferal species and their abundance patterns are used to determine the paleodepth and the environmental conditions that prevailed during the deposition of the uppermost part of Maastrichtian-early Eocene sequence at the Esh El-Mellaha area.

- The upper part of the Sudr Formation was deposited in an upper to middle bathyal environment during the CF3 Zone; while during the CF2 and CF1 zones a middle to shallow outer neritic environment was prevailed.

- The early Paleocene **(Danian)** interval of the Esna Formation(P1c),(P1d), and(P2) zones was deposited in an outer neritic environment; the early Late Paleocene (Selandian) interval of the Esna Formation (P3a Zone) was deposited in shallow upper bathyal environment; the latest Paleocene (latest Thanetian) interval of the Esna Formation (P5) Zone was deposited in a deep upper bathyal environment; and the earliest Eocene (Sparnacian) (E2) Zone and early Eocene (Ypresian) interval of the Esna Formation (E3, E4, and lower part of E5 zones) were deposited in an outer neritic environment.

- The Thebes Formation include the upper part of E5 Zone and it was deposited in an inner to middle neritic environment.

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