ISSN: 1687-1251

Egyptian Society of Applied Petrophysics

Journal of Applied Geophysics (Cairo)

Journal home page: https://jag.journals.ekb.eg/

Original Article

Foraminiferal Biostratigraphy, Paleoecology and Sequence Stratigraphy of the Upper Campanian – Lower Eocene (Ypresian) Succession at Gabal Qabeliat Section, Southwestern Sinai area, Egypt

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ARTICLE INFO

Keywords:

Planktonic
Sudr Formation
Paleoecology
Gebel Qabeliat
Sequence stratigraphy

Received: 5 June 2022;
Revised: 19 July 2022
Accepted: 21 August 2022
Published: 1 September, 2022.

ABSTRACT

The exposed Upper Campanian- Lower Eocene (Ypresian) Succession at Gabal Qabeliat section is measured and detailed examined for its foraminiferal content. 234 foraminiferal species have been identified, of them 94 planktonic and 140 benthonic species. The planktonic assemblage is used, to classify the studied interval into eighteen planktonic foraminiferal biozones: two of Late Campanian; four of Early Maastrichtian; four of Late Maastrichtian; two of Early Paleocene (Danian); one of early Late Paleocene (Selandian); one of Latest Paleocene (Latest Thanetian); two of Earliest Eocene (Earliest Ypresian) and two of Early Eocene (Ypresian). Also, this interval is classified into seven benthonic foraminiferal biozones; one of Late Campanian; one of Early Maastrichtian; one of Late Maastrichtian; one of Early Paleocene (Middle – Late Danian); one of late Early Paleocene (Latest Danian) to early Late Paleocene (Selandian); one of Latest Paleocene (Latest Thanetian) and one of Early Eocene (Ypresian). The total number of foraminiferal species, the species diversity, the P/B ratio, the Aggl./Calc. ratio; and their abundance patterns are used, to reach to a detailed paleoecologic interpretations and sea level changes prevailed during the deposition of the studied succession. The integration between the lithologic characters, detailed field examination for the stratigraphic surfaces and the foraminiferal biostratigraphic studies led to classify this interval into four 3rd depositional sequences bounded by four type- one sequence boundaries. These are one in the Upper Campanian-Maastrichtian; two in the Paleocene; and one in the Lower Eocene. The correlations between the recorded sequence boundaries in the studied section with those of the previous studies inside /outside Egypt were done.

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Journal of Applied Geophysics (Cairo): A Peer review journal, ISSN: 1687-1251

1. Introduction

The Late Campanian - Early Eocene (Ypresian) times in Northern Egypt witnessed drastic geologic and paleogeographic events, in which the Syrian Arc structural movements seem to have influenced the sedimentation patterns of the Upper Campanian-Lower Eocene (Ypresian) deposits in this area (Freund, 1965; Bartov & Steinitz, 1977 and Ott d' Estevou *et al*., 1986). Around the Gulf of Suez, these movements are masked by more intensive and recent tectonism, which led to the generation of the Gulf of Suez rift during the Late Eocene and younger times. Gebel Qabeliat lies in the southwestern part of Sinai, on the eastern bank of the Gulf of Suez, about 220 km south of Suez. It is situated between latitudes 28° 14' and 28° 41' N and between longitudes 33° 15' and 33° 37' E. It stretches in the northwestern direction, occupying the area bounded westward by Wadi Araba, eastward by El-Qaa plain, northward by Wadi Feiran and southward by El Tor. Gebel Qabeliat is an excellent sedimentary stratigraphic outcrop ranging probably in age from Permo-Carboniferous to Miocene beds. Gebel Qabeliat area represents a part of the southeastern margin of the Gulf of Suez rift, where the pre-rift tectonic movements and paleogeographic evolution of the Gulf of Suez region are represented. So, Gebel Qabeliat area occupies a critical site, as it was subjected by some tectonic events having geologic ages and these events caused some complicated structures and affected the distribution of the rock units in this region.

The present study deals with the lithostratigraphy, biostratigraphy, paleoecology and sequence stratigraphy of the Upper Campanian - Lower Eocene (Ypresian) succession, that exposed at Gebel Qabeliat area and located at latitude 28° 24' 10" N and longitude 33° 30’ 40" E **(Fig. 1).** This study is based mainly on the detailed examination of its foraminiferal contents and lithologic characters. The Upper Campanian - Lower Eocene (Ypresian) succession at Gebel Qabeliat area is found very rich in its foraminiferal assemblages, which reflect special bottom and ecologic characters. Also, the sequence stratigraphic approach as a new integrating tool in stratigraphy, is important to apply for the Upper Campanian - Lower Eocene (Ypresian) rock units in Northern Egypt, generally and Southwestern Sinai, specifically. Thus, it is the main target of the present study, to integrate the lithologic and foraminiferal assemblages, to reach to the behavior of the sea level during the Late Campanian-Early Eocene (Ypresian) time at Gebel Qabeliat area.

2. Lithostratigraphy

Depending on the lithologic characters established in the field and results in the included foraminiferal examination, the studied Upper Campanian- Lower Eocene (Ypresian) succession at Gabal Qabeliat section is classified into Sudr, Esna and Thebes formations, from base to top. This succession is unconformably underlain by the Matulla Formation of Coniacian to Santonian age **(Fig. 2).**

In the study area, the topmost part of Matulla Formation was only studied and it attains about **8** m thick. It consists of fossiliferous shale intercalated with marl, coarse-grained sandstone and conglomerate (Samples **1-4**). It is completely barren from any foraminiferal assemblages, while a few macro-invertebrate fossils are recorded in its included shale layer and are represented mainly by oyster e.g. *Plicatula ferryi* (Coquand) of Late Santonian age in addition to rare echinoids. The following is the detailed description of the studied Upper Campanian-Lower Eocene (Ypresian) rock units at Gabal Qabeliat section, from older to younger:

2.1. Sudr Formation:

This rock unit was originally introduced as the Sudr Chalk from its type area (Wadi Sudr, west Central Sinai) by Ghorab (1961). Subsequently, the name Sudr Chalk was emended by Tewfik & Ebeid (1972) into Sudr Formation. At Gabal Qabeliat section, the Sudr Formation attains about 91 m thick (Samples 5-95) and it is subdivided into a lower Markha Member and an upper Abu Zeneima Member, as follows:

2.1.1. Markha Member:

The type locality of Markha Member is at Wadi Markha, west- Central Sinai. At Gabal Qabeliat section, this member represents the lower part of the Sudr Formation and it attains about **23** m thick. It consists of poorly bedded hard, creamy argillaceous and fossiliferous limestone, very rich in foraminiferal assemblages and yielding banks of large oyster *Pycnodonte vesicularis* (Lamarck) in the lower part, intercalated with marl, and it grades into soft argillaceous limestone in the top part (Samples **5-25**).

In the study area, the Markha Member conformably overlain by the Abu Zeneima Member and it directly unconformably underlain, with asharp contact boundary, by the Matulla Formation. The lower contact of the Sudr Formation, with the underlying Matulla Formation, is easily distinguished in the field and it is characterized by abrupt facies change from the clastic nature (coarse sandstones and small granules), intercalated with fossiliferous shale and marl of the topmost part of Matulla Formation below to the fossiliferous limestone, yielding banks of large oyster *Pycnodonte vesicularis* (Lamarck) of the lower part of Sudr Formation (Markha Member) above. At Gabal Qabeliat section, the Markha Member is assigned to Late Campanian, based on its foraminiferal content.

2.1.2. Abu Zeneima Member:

The type locality of this member is at Abu Zeneima area, west Central Sinai. At Gabal Qabeliat section, the Abu Zeneima Member represents the upper part of the Sudr Formation and it attains about 68 m thick. It consists of yellowish-white to pale grey massive bedded chalky, partly cherty limestone and chalk with calcite vienlets, yielding *Pecten farafraensis* (Zittel) in the lower part, intercalated with argillaceous limestone in the middle part, grades into creamy soft argillaceous limestone in the top part (Samples **26-95**), and it was found very rich with planktonic and benthonic foraminiferal assemblages. In the study area, The Abu Zeneima Member conformably overlies the Markha Member and underlies with adisconformity surface of Esna Formation. At Gabal Qabeliat section, the Markha Member is assigned to the Latest Campanian - Latest Maastrichtian age, depending on its foraminiferal content**.**

2.2. Esna Formation:

This rock unit was originally introduced, as the Esna Shale, from its type area (Gebel Oweina, Southeast Esna) by Beadnell (1905a). Subsequently, this shale unit was raised to formational rank and named as Esna Formation by Said (1962). At Gabal Qabeliat section, the Esna Formation attains about 32 m thick and it consists of dark grey to green fissile shale at the base intercalated with marl grades into thinly bedded argillaceous limestone at the top (Samples 96-113). It is completely devoid from any macro-faunal content, while it was found very rich with foraminiferal assemblages.

In the present study area, the Esna Formation is used to describe the shales overlying the Sudr Formation and underlying the Thebes Formation. The lower boundary of the Esna Formation, with the underlying Sudr Formation, is unconformity and represents the Cretaceous/ Paleogene (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 the abrupt facies change from soft argillaceous limestone with latest Maastrichtian foraminiferal content of the topmost part of the Sudr Formation at the base to dark green, to grey shale, with Early Paleocene foraminiferal content of the lowermost part of the Esna Formation at the top. At Gabal Qabeliat, the age of the Esna Formation is ranging from Early Paleocene (Danian) to Early Eocene (Ypresian), based on its foraminiferal content.

2.3. Thebes Formation:

This rock unit was originally introduced by Said (1960a) at its type area (Gebel Gurnah (opposite Luxor), Nile Valley). At Gabal Qabeliat section, only the lowermost part of the Thebes Formation is studied. It attains about 14 m thick and consists of pale white, porcellaneous chalky limestone, with brown to black flint bands and nodules (Samples 114-125). It is completely devoid from any mega-invertebrates, while it contains a few planktonic and benthonic foraminiferal assemblages. This rock unit represents the top of the studied successions. It overlies the Esna Formation, with conformable relation, and forms a steep scarp above the Esna Formation. The lower contact of the Thebes Formation, with the underlying Esna Formation, is easily distinguished in the field and lies between the light grey shale intercalated with the argillaceous thinly bedded limestones of the Esna Formation below and pale white, porcellaneous chalky limestone, with brown to black flint bands and nodules of the Thebes Formation above. At Gabal Qabeliat section, the studied lowermost part of Thebes Formation is assigned to Early Eocene (Ypresian) age, based on its rare foraminiferal content. The correlation between the Upper Campanian- Lower Eocene (Ypresian) rock units, in Gebel Qabeliat area and those in the neighboring areas applied by different authors, is summarized in **(Table 1)**.

3. Foraminiferal biostratigraphy

The studied topmost part of Matulla Formation at Gebel Qabeliat section, Southwestern Sinai, was found barren of any planktonic and benthonic foraminiferal species and it is attributed to lower Santonian age, based on its contents of mega-fossils, such as, oysters. This barren interval attains about 8m thick (Samples 1-5). It is directly followed by a richly fossiliferous Upper Campanian –Lower Eocene (Ypresian) succession. **234** foraminiferal species have been identified, of them **94** planktonic and **140** benthonic species. The marker zonal planktonic foraminiferal species, in addition to the most dominated recorded benthonic foraminiferal species in the studied succession, are photographed by (SEM) and shown on **plates (1&2).** Depending on examination of the vertical stratigraphic distribution of both marker planktonic and benthonic foraminiferal species, two foraminiferal biostratigraphic classifications for the Upper Campanian - Lower Eocene (Ypresian) sedimentary sequences exposed at Gebel Qabeliat section are established; the first is based on the planktonics and the other on the benthonics, as follows:

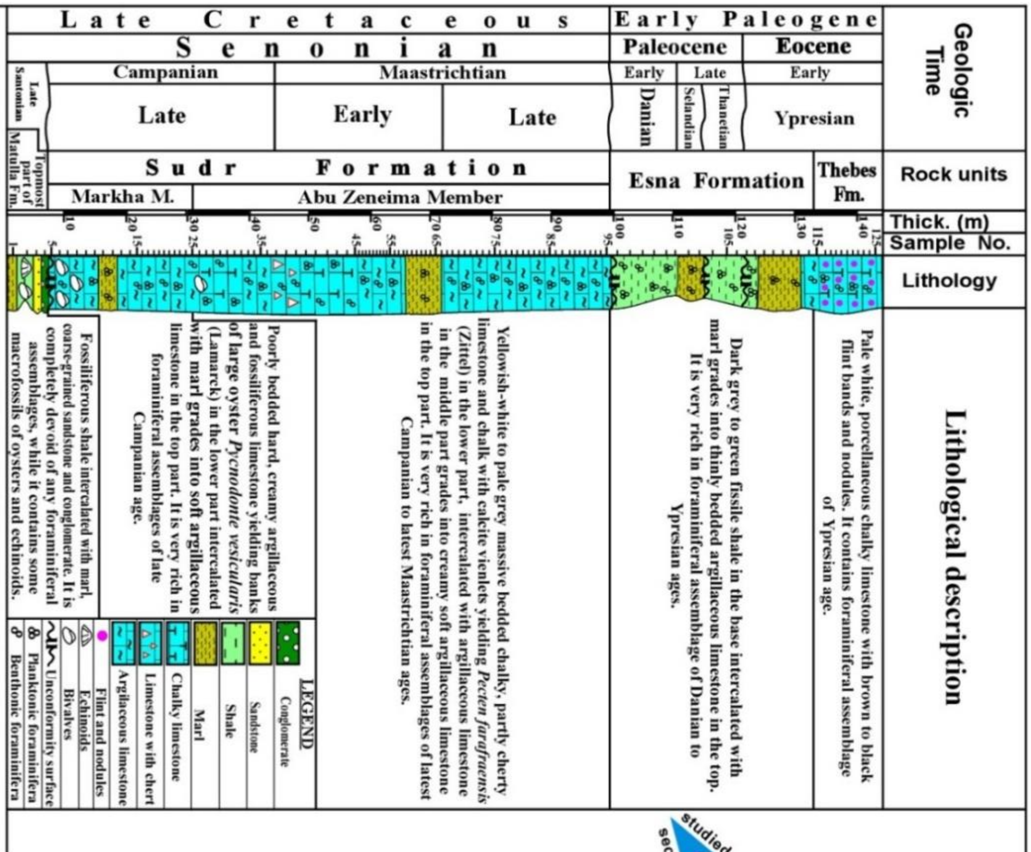


Fig. 2: Stratigraphic columnar section Gabal Qabeliat area, Southwestern Sinai.

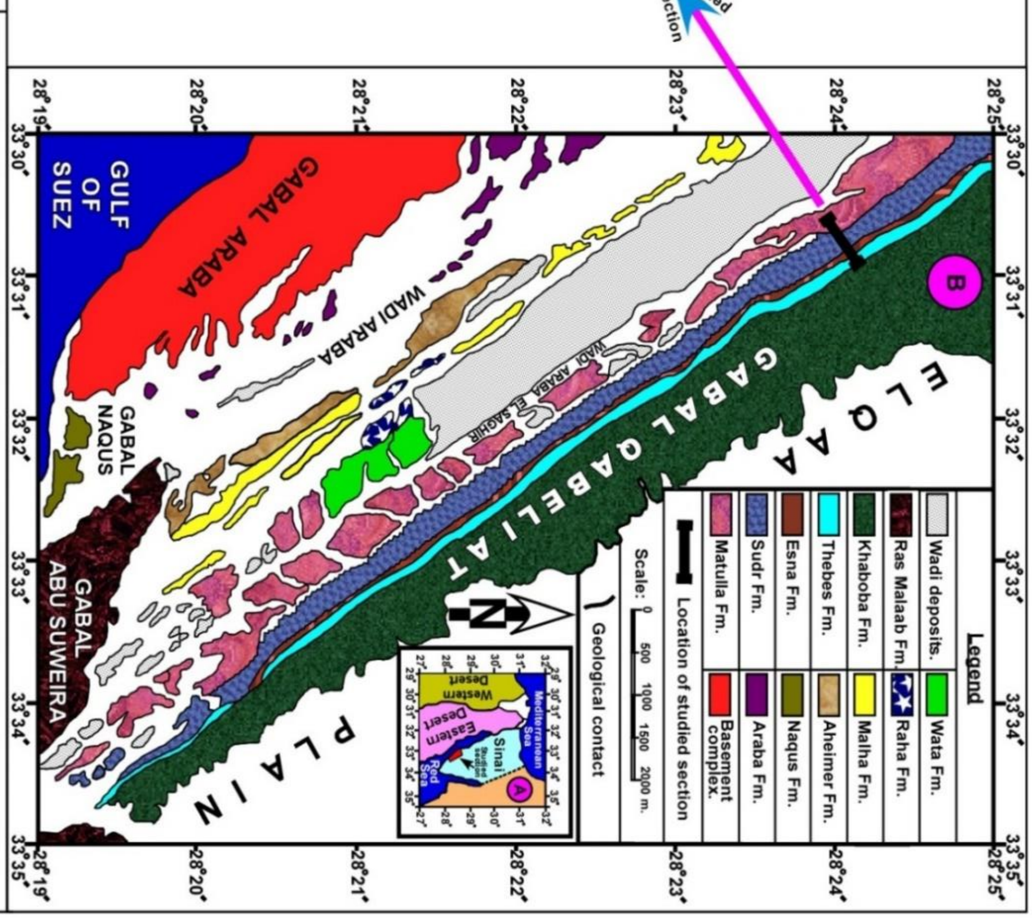


Fig. 1: Location (A) and Geological (B) maps of Gabal Qabeliat area, Southwestern Sinai.

Age			Sinai & Gulf of Suez Ghorab (1961)	West side of Wadi Araba El-Shazly et al., (1979)	Southern Galala Abu Khadrah et al. (1987)	Wadi Qena Bandel et al. (1987)	East Central Sinai Shahin & Kora (1991)	East Central Sinai Ziko et al. (1993)	Southern Galala Metwally et al. (1999)	Ataqa and Northern Galala Issawi et al. (1999)	Southern Galala Issawi et al. (1999)	West Sinai Eweda & El-Sorogy (1999)	South western Sinai Khalil & Mashaly (2004)	Southwest Gulf of Suez Ismail (2012)	Present study Gebel Qabeliat Section
Lower Paleogene	Early Eocene	Ypresian	Esna Shale	Irkas Fm.	Esna Fm.	Not studied	Not studied	Thebes Fm.	Not studied	Not studied	Not studied	Thebes Fm.: Calcareous Claystone M.; Cherty Chalky limestone M.	Thebes Fm.	Thebes Fm.	Thebes Fm.
Lower Paleogene	Paleocene	Thanetian	Esna Shale	Irkas Fm.	Esna Fm.	Not studied	Esna Shale	Esna Shale	Not studied	Not studied	Not studied	Esna Fm.	Esna Shale	Esna Shale	Esna Fm.
Lower Paleogene	Paleocene	Selandian	Esna Shale	Irkas Fm.	Esna Fm.	Not studied	Esna Shale	Esna Shale	Not studied	Not studied	Not studied	Esna Fm.	Esna Shale	Esna Shale	Esna Fm.
Lower Paleogene	Paleocene	Danian	Esna Shale	Irkas Fm.	Esna Fm.	Not studied	Esna Shale	Esna Shale	Not studied	Not studied	Not studied	Esna Fm.	Esna Shale	Esna Shale	Esna Fm.
Upper Cretaceous	Maastrichtian		Sudr Chalk: Abu Zeneima M.	Sudr Fm.	Sudr Fm.	St. Paul Fm	Sudr Chalk: Abu Zeneima M.	Sudr Chalk: Abu Zeneima M.	Sudr Fm.	Maghara El-Bahari Fm	Sudr Fm.	Sudr Chalk: Abu Zeneima M.	Sudr Fm.	Sudr Chalk: Abu Zeneima M.	Sudr Fm.: Abu Zeneima M.
Upper Cretaceous	Campanian		Sudr Chalk: Markha M.	Sudr Fm.; Duwi Fm.	Thelmet Fm.	Abu Had Fm.	Sudr Chalk: Markha M.	Sudr Chalk: Markha M.	Sudr Fm.	Adabiya Fm.	Duwi Fm	Sudr Chalk: Markha M.	Sudr Fm.	Sudr Chalk: Markha M.; Matulla Group: Duwi Fm., Quseir Fm.	Sudr Fm.: Markha M.
Upper Cretaceous	Santonian		Matulla Fm.	Duwi Fm.	Thelmet Fm.	Abu Had Fm.	Matulla Fm.	Themed Fm.	Matulla Fm.	Adabiya Fm.	Quseir M.	Matulla Fm.: Clastic Carbonate M.	Matulla Fm.	Matulla Group: Taref Fm.	Top-most part of Matulla Fm.
Upper Cretaceous	Coniacian		Matulla Fm.	Duwi Fm.	Matulla Fm.	Abu Had Fm.	Matulla Fm.	Matulla Fm.	Matulla Fm.	Adabiya Fm.	Taref M.	Matulla Fm.: Sand M., Shale M.	Matulla Fm.	Matulla Group: Taref Fm.	Not studied

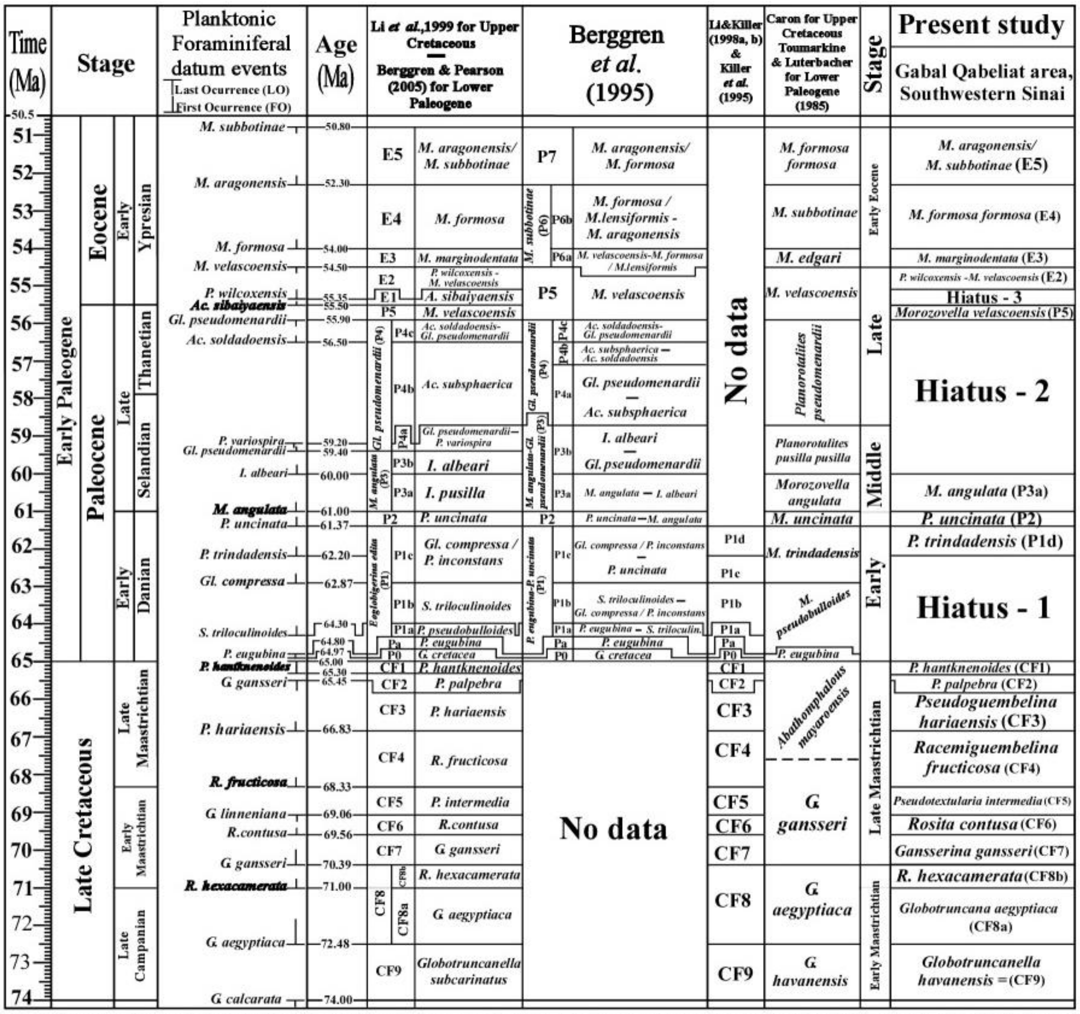
Table 1: Summary of the correlation between the Coniacian - Lower Eocene (Ypresian) rock units at Gebel Qabeliat section, Southwestern Sinai and those in the neighboring areas applied by different authors.

3.1. Planktonic foraminiferal biostratigraphy

A lot of papers were published on the planktonic foraminiferal biostratigraphic classification of the Upper Campanian – Lower Eocene (Ypresian) successions inside /outside Egypt and the most important of these include: (Bolli, 1957a, b &1966; EL-Naggar, 1966; Fahmy *et al*., 1969; Beckmann *et al*., 1969; Youssef & Abd ElMalik, 1969; Blow, 1979; Berggren, 1969; Postuma, 1971; Barr, 1972; Premoli Silva & Bolli, 1973; Berggren & Van Couvering, 1974; Stainforth et al., 1975; Abd ElMalik *et al*.,1978; Benjamini, 1980; Masters, 1984; Robaszynski *et al*., 1984; Boersma, 1984a; Caron, 1985; Toumarkine & Luterbacher, 1985; Bolli *et al.*, 1985; Al-Mogi-Labin *et al.*,1986; Hewaidy, 1987; Berggren & Miller, 1988; Huber, 1990; Shahin, 1988 &1992; Hewaidy *et al*., 1993; Haggag, 1991; Cherif & Ismail, 1991; El-Dawy *et al*.,1992; Hewaidy & Soliman, 1993; Berggren *et al*, 1995; Abd el-Kireem & Samir, 1995; El-Nady, 1995; Keller *et al*., 1995; Ayyad *et al*., 1996; Aubry 1996; Berggren & Norris, 1997; Li & Keller, 1998a,b; Marzouk & Luning, 1998; Aubry *et al.*, 1996, 1999; Luning *et al*.,1998; Olsson *et al*., 1999; Li *et al*., 1999; Molina *et al.*, 1999; Monechi *et al*., 1999 & 2000; Shahin & El-Nady, 2001; Keller *et al*., 2002; Tantawy *et al*., 2001; Samir, 2002; Luterbacher, 2004; El Sabbagh, 2007; Berggren & Pearson, 2005; Al-Wosabi & Abu Shama, 2007; Huber, 2008; Wade *et al*., 2011, Faris & Farouk, 2012; Obaidallah, 2012, and Hewaidy *et al*.,2017). In the present study, the proposed planktonic foraminiferal biozones for the Late Campanian –Maastrichtian interval are based on the zonal schemes of Caron, 1985; Li and Keller, 1998a, b and Li *et al*., 1999, while for the Paleocene-early Eocene (Ypresian) interval our proposed planktonic foraminiferal biozones are based on the zonal schemes of Toumarkine & Luterbacher, 1985; Berggren *et al*., 1995; Keller *et al*., 1995& 2002, and Berggren & Pearson 2005. Depending on the vertical distribution of the identified planktonic foraminiferal species, the studied Upper Campanian – Lower Eocene succession at Gebel Qabeliat section is subdivided into eighteen planktonic foraminiferal zones. These include ten of Late Campanian- Latest Maastrichtian age and recorded from Sudr Formation; while the other eight zones are of Paleocene - Early Eocene age and recorded from both Esna and Thebes formations. On the other hand, the comparison between these eighteen established planktonic foraminiferal biozones in the study area with their equivalents in the used zonal schemes proposed by different authors is shown in **(Table 2),** and the detailed descriptions of them at the studied section is given below and are arranged from the oldest to the youngest:

3.1.1. *Globotruncanella havanensis* Zone (Partial range Zone):

The *Globotruncanella havanensis* Zone was originally proposed by Caron, 1978 and it is defined as a biostratigraphic interval extended from the last appearance of *Globotruncanita calcarata* (Cushman), at the base to the first appearance of *Globotruncana aegyptiaca* Nakkady, at the top. In the present study area, due to the absence of the *Gobotruncanita calcarata* (Cushman), this biozone is defined as a biostratigraphic interval extended from the first appearance of *Globotruncanella havanensis* (Voorwijk) at the base to the first appearance of *Globotruncana aegyptiaca* Nakkady at the top. At Gebel Qabeliat section, this biozone is considered the oldest recorded planktonic foraminiferal biozone. It is represented by the whole thickness of the Markha Member (samples 5-25) and it attains about 23 m thick. It is assigned to Late Campanian (74.00 - 72.48 Ma), according to Li *et al*., 1999, as it equivalents to *Globotruncanella subcarinatus* (CF9) Zone. The base of this zone was used by some authors to mark the beginning of the Maastrichtian (e.g. Robaszynski *et al*., 1984 and Caron, 1985); while according to Li *et al*., 1999, this biozone belonged to the Late Campanian. In the study area, this biozone is equivalent to the lower part of *Globotruncana lapparenti tricarinata* Zone of Bolli, 1966; the lower part of *Globotruncanita stuartiformis* Zone of Postuma, 1971; the lower part of *Globotruncana tricarinata* Zone of Barr, 1972; the lower part of *Globotruncana falsostuarti* Zone of Robaszynski *et al*., 1984; Al-Mogi-Labin *et al*., 1986; the *Globotruncanella havanensis* Zone of Caron, 1985; and the *Globotruncanella subcarinatus* (CF9) Zone of Li & Killer, 1998a & b; and Li *et al.*, 1999. In Egypt, this biozone may be correlated with the lower part of *Globotruncana fornicata* Zone of El-Naggar, 1966; the *Globotruncana tricarinata* Zone of Ayyad *et al.*, 1996; the lower part of *Globotruncana falsostuarti* Zone of Hewaidy *et al*. 1993; Luning *et al*., 1998; the lower part of *Globotruncana tricarinata* Zone of Shahin, 1988; the lower part of *Globotruncana aegyptiaca* Zone of Cherif & Ismail, 1991, Shahin, 1992; *Globotruncana aegyptiaca- Globotruncanita stuartiformis* of El Dawy *et al*., 1992. It is also equivalent to the *Globotruncanella havanensis* Zone of El-Nady, 1995; Shahin & El-Nady, 2001. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix striata* (Ehrenberg), *Planoglobulina glabrata* (Cushman), *Pseudotextularia elegans* (Rzehak), *Pseudoguembelina costulata* (Cushman), *Pseudoguembelina excolata* (Cushman), *Rosita fornicata* (Plummer), *Rosita patelliformis* (Gandolfi), *Globotruncana ventricosa* White, *Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globotruncanita stuartiformis* (Dalbiez), *Globotruncanita subspinosa* (Pessagno), *Globotruncanella havanensis* (Voorwijk), *Archaeoglobigerina blowi* Pessagno, *Rugotruncana subcircumnodifer* (Gandolfi) and *Rugoglobigerina rugosa* (Plummer).



Tab. 1: Summary of the used planktonic foraminiferal zonal schemes for Upper Campanian-Lower Eocene, age estimated and their coeval at Gabal Qabeliat area, Southwestern Sinai. The estimated ages and datum events for Late Cretaceous are based on (Li and Keller, 1998a,b &Li *et al.*, 1999 and correlation with Caron, 1985); while the estimated ages and datum events for Lower Paleogene are based on (Berggren and Pearson, 2005 & Killer *et al.*, 1995 &Berggren *et al.*,1995 and correlation with Toumarkine & Luterbacher, 1985)

3.1.2. *Globotruncana aegyptiaca* Zone (CF8a) (Partial range Zone):

This biozone was originally established from the early Maastrichtian by Caron, 1985, as a biostratigraphic interval from the first appearance of the nominate taxon, at the base, to the first appearance of *Gansserina gansseri* (Bolli), at the top. Li and Keller, 1998a & b used the same biozone of Caron, 1985 with its same boundaries and named it *Globotruncana aegyptiaca* Zone (CF8). Li *et al*., 1999 subdivided *Globotruncana aegyptiaca* Zone (CF8) of Li and Keller, 1998a & b into two subzones: *Globotruncana aegyptiaca* Subzone (CF8a) at the base and *Rugoglobigerina hexacamerata* Subzone (CF8b) at the top.

At Gebel Qabeliat section, this biozone is defined, according to Li *et al.*, 1999, as a biostratigraphic interval, extended from the first appearance of *Globotruncana aegyptiaca* Nakkady, at the base to the first appearance of *Rugoglobigerina hexacamerata* Bronnimann, at the top. It is recorded from the lowermost part of Abu Zeneima Member (samples 26-36) and it attains about 12 m thick. It is assigned to Latest Campanian (72.48- 71.00 Ma), according to Li *et al*., 1999. The *Globotruncana aegyptiaca* Zone is commonly used to mark the Lower Maastrichtian in low latitudes (Robaszynski *et al*., 1984, Caron, 1985, and Li and Keller, 1998a & b); while according to Li *et al*., 1999, this biozone is assigned to the Latest Campanian and the Campanian/ Maastrichtian boundary is placed on the top of this biozone.

In the study area, the Campanian/ Maastrichtian (Ca/Ma) boundary is located within the lower part of Abu Zeneima Member and is cited on the top of *Globotruncana aegyptiaca* Zone (CF8a) and at the first appearance of *Rugogloboigerina hexacamerata* Bronnimann, following Li *et al.*, 1999. In the study area, this biozone is equivalent to the middle part of *Globotruncana lapparenti tricarinata* Zone of Bolli, 1966; the middle part of *Globotruncanita stuartiformis* Zone of Postuma, 1971; the middle part of *Globotruncana tricarinata* Zone of Barr, 1972; the middle part of *Globotruncana falsostuarti* Zone of Robaszynski *et al*., 1984; Al-Mogi-Labin *et al.*, 1986; the lower part of *Globotruncana aegyptiaca* Zone of Caron, 1985; the lower part of *Globotruncana aegyptiaca* (CF8) Zone of Li & Killer, 1998a & b. Also, it is equivalents to the *Globotruncana aegyptiaca* Subzone (CF8a) of Li *et al.*, 1999. In Egypt, this biozone may be correlated with the middle part of *Globotruncana fornicata* Zone of El-Naggar, 1966; the middle part of *Globotruncana tricarinata* of Shahin, 1988; the middle part of *Globotruncana aegyptiaca* Zone of Cherif & Ismail, 1991, Shahin, 1992; the middle part of *Globotruncana aegyptiaca- Globotruncanita stuartiformis* El Dawy *et al*., 1992; the middle part of *Globotruncana falsostuarti* Zone of Hewaidy *et al*. 1993 and Luning *et al*., 1998. It also equivalent to the lower part of *Globotruncana aegyptiaca* of El-Nady, 1995; Ayyad *et al.,* 1996 and Shahin & El-Nady, 2001. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix striata* (Ehrenberg), *Pseudotextularia elegans* (Rzehak), *Pseudoguembelina costulata* (Cushman), *Pseudoguembelina excolata* (Cushman), *Globotruncana aegyptiaca* Nakkady, *Globotruncana falsostuarti* Sigal, *Globotruncana ventricosa* White, *Globotruncana orientalis* El Naggar, *Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globotruncana bulloides* Voglar, *Globotruncanita stuartiformis* (Dalbiez), *Globotruncanita stuarti* (De Lapparent), *Globotruncanella havanensis* (Voorwijk), *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina rugosa* (Plummer) and *Rugoglobigerina scotti* Bronnimann.

3.1.3. *Rugoglobigerina hexacamerata* Zone (CF8b) (Partial range Zone):

This biozone was originally established by Li *et al*., 1999 and it is defined as a biostratigraphic interval, extended from the first appearance of *Rugoglobigerina hexacamerata* Bronnimann, at the base to the first appearance of *Gansserina gansseri* (Bolli), at the top. In the study area, this difintion is followed. At Gebel Qabeliat section, this biozone is recorded from the lower part of Abu Zeneima Member (samples 37-39), and it attains about 5 m thick. It is assigned to Early Maastrichtian (71.00- 70.39 Ma) according to Li *et al*., 1999. In the study area, the base of *Rugoglobigerina hexacamerata* biozone is used to mark the Campanian/ Maastrichtian (Ca/Ma) boundary. This biozone is equivalent to the upper part of *Globotruncana lapparenti tricarinata* Zone of Bolli, 1966; the upper part of *Globotruncanita stuartiformis* Zone of Postuma, 1971; the upper part of *Globotruncana tricarinata* Zone of Barr, 1972; the upper part of Globotruncana *falsostuarti* Zone of Robaszynski *et al*., 1984 and Al-Mogi-Labin *et al.*, 1986; the upper part of *Globotruncana aegyptiaca* Zone of Caron, 1985; the upper part of *Globotruncana aegyptiaca* (CF8) Zone of Li & Killer, 1998a & b. Also, it is equivalent to the *Rugoglobigerina hexacamerata* (CF8b) Zone of Li *et al*., 1999. In Egypt, this biozone may be correlated with the upper part of *Globotruncana fornicata* Zone of El-Naggar, 1966; the upper part of *Globotruncana tricarinata* of Shahin, 1988; the upper part of *Globotruncana falsostuarti* Zone of Hewaidy *et al*. 1993 and Luning *et al*., 1998; the upper part of *Globotruncana aegyptiaca- Globotruncanita stuartiformis* of El Dawy *et al*., 1992; the upper part of *Globotruncana aegyptiaca* of Cherif & Ismail, 1991, Shahin, 1992, El-Nady, 1995; Ayyad *et al.*, 1996; and Shahin & El-Nady, 2001. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix aegyptiaca* Ansary & Tewfik, *Planoglobulina glabrata* (Cushman), *Pseudotextularia elegans* (Rzehak), *Pseudoguembelina costulata* (Cushman), *Globotruncana aegyptiaca* Nakkady, *Globotruncana ventricosa* White, *linneiana* (d'Orbigny), *Globotruncanita conica* (White), *Globotruncanita stuartiformis* (Dalbiez), *Globotruncanita stuarti* (De Lapparent), *Globotruncanita subspinosa* (Pessagno), *Globotruncanita pettersi* (Gandolfi), *Globotruncanella citae* Bolli, *Rugotruncana subcircumnodifer* (Gandolfi), *Rugotruncana subpennyi* (Gandolfi), *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina rugosa* (Plummer), *Rugoglobigerina hexacamerata* Bronnimann, and *Rugoglobigerina scotti* Bronnimann.

3.1.4. *Gansserina gansseri* Zone (CF7) (Partial range Zone):

This biozone was introduced for the first time from the Late Maastrichtian of Trindad by Bronnimann, 1952 as a biostratigraphic interval extended from the first appearance of *Gansserina gansseri* (Bolli), at the base to the first appearance of *Abathomphalus mayaroensis* (Bolli), at the top. Robaszynski *et al*., 1984, and Caron, 1985 used the same biozone of Bronnimann, 1952 with its same boundaries. Li and Keller, 1998a & b and Li *et al*., 1999, shorten the range of this biozone, to cover a biostratigraphic interval from the first appearance of *Gansserina gansseri* (Bolli), at the base, to the first appearance of *Rosita contusa* (Cushman), at the top; and Li *et al*., 1999 considered this biozone of Early Maastrichtian age. In the study area, this biozone is defined according to Li & Keller, 1998a & b. At Gebel Qabeliat section, this biozone is recorded from the lower part of Abu Zeneima Member (samples 26-36), and it attains about 10 m thick. I t is assigned to Early Maastrichtian (70.39-69.56 Ma), according to Li *et al*., 1999. In most zonal schemes, the first appearance of this biozone informally marks the Lower-Upper Maastrichtian boundary (Robaszynski *et al*., 1984, Caron, 1985, and Li & Keller, 1998a & b). This biozone in the study area may be equivalent to the lower part of *Globotruncana gansseri* Zone of Bolli, 1966; Postuma, 1971 and Barr, 1972; the lower part of *Gansserina gansseri* Zone of Robaszynski *et al*., 1984; Caron, 1985; and Al-Mogi-Labin *et al.*, 1986; and it also equivalent to *Gansserina gansseri* (CF7) Zone of Li & Killer, 1998a & b; and Li *et al.*, 1999. In Egypt, this biozone may be correlated with the lower part of *Globotruncana gansseri* Zone of El-Naggar, 1966; Shahin, 1988 & 1992; Hewaidy *et al*. 1993; the lower part of *Gansserina gansseri* Zone of Cherif & Ismail, 1991; El Dawy *et al*., 1992; El-Nady, 1995; Ayyad *et al.*, 1996; Luning *et al*., 1998; and Shahin & El-Nady, 2001; and it also equivalent to *Gansserina gansseri* (CF7) Zone of Tantawy *et al*., 2001 and Samir, 2002. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix reussi* (Cushman), *Heterohelix striata* (Ehrenberg), *Planoglobulina carseyae* (Plummer), *Pseudotextularia elegans* (Rzehak), *Pseudoguembelina costulata* (Cushman), *Rosita plicata* (White), *Gansserina gansseri* (Bolli), *Globotruncana aegyptiaca* Nakkady, *Globotruncana ventricosa* White, *Globotruncana linneiana* (d'Orbigny), *Globotruncanella havanensis* (Voorwijk), *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina hexacamerata* Bronnimann, *Rugoglobigerina scotti* Bronnimann, *Rugoglobigerina reicheli* Bronnimann, and *Rugoglobigerina milamensis* smith and Pessagno.

3.1.5. *Rosita contusa* Zone (CF6) (Partial range Zone):

This biozone was originally proposed as *Globotruncana contusa* Zone for the Upper Maastrichtian of Tunisia Dalbiez, 1955. Li & Keller, 1998a & b defined this biozone as a biostratigraphic interval, extended from the first appearance of *Rosita contusa* (Cushman), at the base to the last appearance of *Globotruncana linneiana* (d, Orbigny), at the top. In the study area, this definition is followed. At Gebel Qabeliat section, this biozone is recorded from the middle part of the Abu Zeneima Member (samples 48-57), and it attains about 6 m thick. It is assigned to Early Maastrichtian (69.56- 69.06 Ma) according to Li *et al.*, 1999. In the study area, this biozone is equivalent to the middle part of *Globotruncana gansseri* Zone of Bolli, 1966; Postuma, 1971; Barr, 1972; the middle part of *Gansserina gansseri* Zone of Robaszynski *et al.*, 1984; Caron, 1985; Al-Mogi-Labin *et al.*, 1986; and to *Rosita contusa* (CF6) Zone of Li & Killer, 1998a & b; and Li *et al.*, 1999. In Egypt, this biozone is equivalent to the middle part of *Globotruncana gansseri* Zone of El-Naggar, 1966; Shahin, 1988, 1992; Hewaidy *et al*. 1993; the middle part of *Gansserina gansseri* Zone of Cherif & Ismail, 1991; El Dawy *et al*., 1992; El-Nady, 1995; Ayyad *et al*., 1996; Lunning *et al*., 1998; and Shahin & El-Nady, 2001. Also, it is equivalent to the *Rosita contusa* Zone (CF6) Zone of Tantawy *et al*., 2001 and Samir, 2002. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix aegyptiaca* Ansary and Tewfik, *Pseudoguembelina costulata* (Cushman), *Pseudoguembelina excolata* (Cushman), *Rosita fornicata* (Plummer), *Rosita contusa* (Cushman), *Rosita plicata* (White), *Gansserina gansseri* (Bolli), *Globotruncana aegyptiaca* Nakkady, *Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globotruncana bulloides* Voglar, *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina rugosa* (Plummer), *Rugoglobigerina hexacamerata* Bronnimann, *Rugoglobigerina scotti* Bronnimann, *Rugoglobigerina reicheli* Bronnimann, and *Rugoglobigerina milamensis* smith &Pessagno.

3.1.6. *Pseudotextularia intermedia* Zone (CF5) (Partial range Zone):

This biozone was originally introduced by Nederbragt, 1990, as the interval from the first appearance of *Planoglobulina acervulinoides*, at the base and *Racemiguembelina fructicosa*, at the top. Li & Keller, 1998a & b emended this definition to include a biostratigraphic interval, extended from the last appearance of *Globotruncana linneiana* (d, Orbigny), at the base to the first appearance of *Racemiguembelina fructicosa* (Egger), at the top. In the study area, its definition is restricted, according to Li& Keller, 1998a & b. At Gebel Qabeliat section, this biozone is recorded from the middle part of Abu Zeneima Member (samples 58-66), and it attains about 7 m thick. It is assigned to Early Maastrichtian (69.06- 68.33 Ma) according to Li *et al*., 1999. Li *et al*., 1999 used the top of *Pseudotextularia intermedia* (CF5) Zone to place the Early/ Late Maastrichtian boundary, based on the biostratigraphic correlation with the geometric time scale at DSDP site 525A, and Tunisia. This biozone is equivalent to the lower upper part of *Globotruncana gansseri* Zone of Bolli, 1966; Postuma, 1971; Barr, 1972; the lower upper part of *Gansserina gansseri* Zone of Robaszynski *et al*., 1984; Caron, 1985; Al-Mogi-Labin *et al.*, 1986; Keller, 1988 and D, Hondt & Keller, 1991. It also equivalent to *Pseudotextularia intermedia* (CF5) Zone of Li & Killer, 1998a & b and Li *et al.*, 1999. In Egypt, this biozone is equivalent to the lower upper part of *Globotruncana gansseri* Zone of El-Naggar, 1966; Shahin, 1988; Hewaidy *et al*. 1993; Shahin, 1992; the lower upper part of *Gansserina gansseri* Zone of Cherif & Ismail, 1991; El Dawy *et al*., 1992; El-Nady, 1995; Ayyad *et al*., 1996; Luning *et al*., 1998; Shahin & El-Nady, 2001. Also, it is equivalent to the *Pseudotextularia intermedia* (CF5) Zone of Samir, 2002. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix* *aegyptiaca* Ansary and Tewfik, *Heterohelix navarroensis* Loeblich, *Pseudotextularia elegans* (Rzehak), *Pseudotextularia deformis* (Kikoine), *Pseudotextularia intermedia* (De Klasz), *Gansserina gansseri* (Bolli), *Globotruncana aegyptiaca* Nakkady, *Globotruncanita conica* (White), *Globotruncanella havanensis* (Voorwijk), *Rugoglobigerina rugosa* (Plummer), and *Rugoglobigerina hexacamerata* Bronnimann.

3.1.7. *Racemiguembelina fructicosa* Zone (CF4) (Partial range Zone):

Smith & Pessagno, 1973 were originally proposed the *Racemiguembelina fructicosa* Zone as the upper zone of the *Gansserina gansseri* Subzone. They defined this zone as a biostratigraphic interval between the first appearance of *Racemiguembelina fructicosa* at the base, and *Abathomphalus mayaroensis*, at the top. Li & Keller, 1998a & b and Li *et al*., 1999 emended this definition as a biostratigraphic interval, extended from the first appearance of *Racemiguembelina fructicosa* (Egger), at the base, to the first appearance of *Pseudoguembelina hariaensis* Nederbragt, at the top. In the present study, the definition of this biozone is defined, according to Li & Keller, 1998a & b and Li *et al*., 1999. At Gebel Qabeliat section, this biozone is recorded from the middle part of Abu Zeneima Member (samples 67-75), and it attains about 9 m thick. It is assigned to Late Maastrichtian (68.33- 66.83 Ma) according to Li *et al*., 1999. In the study area, the base of the *Racemiguembelina fructicosa* Zone is used to place the Early/Late Maastrichtian boundary following Li *et al*., 1999. In the study area, this biozone is equivalent to the combined uppermost part of *Globotruncana gansseri* Zone and the lowermost part of *Globotruncana mayaroensis* Zone of Bolli, 1966; the combined uppermost part of *Gansserina gansseri* Zone and lowermost part of *Abathomphalus mayaroensis* Zone of Postuma, 1971; Barr, 1972; Robaszynski *et al*., 1984; Caron, 1985; Al-Mogi-Labin *et al.*, 1986; Keller, 1988; D,Hondt& Keller, 1991; the lower part of *Racemiguembelina fructicosa* Zone of Nederbragt, 1991. Also, it is equivalent to *Racemiguembelina fructicosa* (CF4) Zone of Li and Keller, 1998a, b and Li *et al*., 1999. In Egypt, this biozone is equivalent to the combined uppermost part of *Globotruncana gansseri* Zone and lowermost part of *Globotruncana esnehensis* Zone of El-Naggar, 1966; the combined uppermost part of *Globotruncana gansseri* Zone and lowermost part of *Abathomphalus mayaroensis* Zone of Shahin, 1988; Hewaidy *et al*. 1993; the combined uppermost part of *Globotruncana gansseri* Zone and lower part of *Globotruncana esnehensis* Subzone of Shahin, 1992; the combined uppermost part of *Gansserina gansseri* Zone and lowermost part of *Abathomphalus mayaroensis* Zone of El Dawy *et al*., 1992; Ayyad *et al.*, 1996; Luning *et al*., 1998; Shahin & El-Nady, 2001; the combined uppermost part of *Gansserina gansseri* Zone and lower part of *Globotruncana esnehensis* Subzone of El-Nady, 1995. It is also equivalent to *Racemiguembelina fructicosa* Zone (CF4) of Tantawy *et al*., 2001; and Samir, 2002. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix striata* (Ehrenberg), *Heterohelix navarroensis* Loeblich, *Planoglobulina carseyae* (Plummer), *Planoglobulina glabrata* (Cushman), *Pseudotextularia elegans* (Rzehak), *Pseudotextularia deformis* (Kikoine), *Pseudotextularia intermedia* (De Klasz), *Racemiguembelina fructicosa* (Egger), *Racemiguembelina powelli* Smith and Pessagno, *Pseudoguembelina costulata* (Cushman), *Pseudoguembelina excolata* (Cushman), *Gansserina gansseri* (Bolli), *Globotruncana aegyptiaca* Nakkady, *Rugoglobigerina rugosa* (Plummer), and *Rugoglobigerina hexacamerata* Bronnimann.

3.1.8. *Pseudoguembelina hariaensis* Zone (CF3) (Partial range Zone):

This biozone was first introduced by Nederbragt, 1990, as the total range of the zonal marker. Li& Keller, 1998a & b and Li *et al*., 1999 redefined this biozone as the biostratigraphic interval, extended from the first appearance of *Pseudoguembelina hariaensis* Nederbragt, at the base, and the last appearance of *Gansserina gansseri* (Bolli), at the top. In the present study, the definition of this biozone is used according to Li& Keller, 1998a & b and Li *et al*., 1999. At Gebel Qabeliat section, this biozone is recorded from the lower upper part of the Abu Zeneima Member (samples 76-85), and it attains about 8 m thick. It is assigned to Late Maastrichtian (66.83- 65.45 Ma) according to Li and Keller, 1998a & b. In the study area, this biozone is equivalent to the middle part of *Globotruncana mayaroensis* Zone of Bolli, 1966; the middle part of *Abathomphalus mayaroensis* Zone of Postuma, 1971; Barr, 1972; Robaszynski *et al*., 1984; Caron, 1985; Al-Mogi-Labin *et al.*, 1986; Keller, 1988; D,Hondt& Keller, 1991; the upper part of *Racemiguembelina fructicosa* Zone of Nederbragt, 1990. Also, it is equated to the *Pseudoguembelina hariaensis* (CF3) of Li and Keller, 1998a & b and Li *et al*., 1999. In Egypt, this biozone is equivalent to the upper part of *Globotruncana esnehensis* Zone of El- Naggar, 1966; the middle part of *Abathomphalus mayaroensis* Zone of Shahin, 1988, Hewaidy *et al*., 1993, El Dawy *et al*., 1992, Ayyad *et al*., 1996, Omran, 1997; Lunning *et al*., 1998; the upper part of *Globotruncana esnehensis* Subzone of Shahin, 1992; El-Nady, 1995; the upper part of *Abathomphalus mayaroensis* Zone of Shahin & El-Nady, 2001; It is also equivalent to *Pseudoguembelina hariaensis* Zone (CF3) of Tantawy *et al*., 2001; Samir, 2002; El Sabbagh, 2007; and Al-Wosabi & Abu Shama, 2007. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix navarroensis* Loeblich, *Pseudotextularia elegans* (Rzehak), *Pseudotextularia deformis* (Kikoine), *Pseudotextularia intermedia* (De Klasz), *Pseudoguembelina hariaensis* Nederbragt, *Pseudoguembelina costulata* (Cushman), *Gansserina gansseri* (Bolli), *Globotruncana aegyptiaca* Nakkady, *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina rugosa* (Plummer), *Rugoglobigerina hexacamerata* Bronnimann, *Rugoglobigerina scotti* Bronnimann, *Rugoglobigerina reicheli* Bronnimann, and *Rugoglobigerina pennyi* Bronnimann.

3.1.9. *Pseudoguembelina palpebra* Zone (CF2) (Partial range Zone):

This biozone was originally proposed by Li and Keller, 1998a & b**,** and it is defined as a biostratigraphic interval, extended from the last appearance of *Gansserina gansseri* (Bolli), at the base to the first appearance of *Plummerita hantkeninoides* (Bronnimann), at the top. In the present study, this definition is followed. At Gebel Qabeliat section, this biozone is recorded from the upper part of the Abu Zeneima Member (samples **85-90**), and it attains about **5** m thick. It is assigned to Latest Maastrichtian (65.45- 65.30 Ma), according to Li & Keller, 1998a &b. In the study area, this biozone is equivalent to the lower upper part of *Globotruncana mayaroensis* Zone of Bolli, 1966; the lower upper part of *Abathomphalus mayaroensis* Zone of Postuma, 1971; Barr, 1972; Robaszynski *et al*., 1984; Caron, 1985; Al-Mogi-Labin *et al.*, 1986; Keller, 1988; and D,Hondt& Keller, 1991. Also, it is also equated to *Pseudoguembelina palpebra* Zone (CF2) of Li & Keller, 1998a & b, and Li *et al*., 1999. In Egypt, the *Pseudoguembelina palpebra* (CF2) Zone is equivalent to the lower upper part of *Abathomphalus mayaroensis* Zone of Shahin, 1988; Hewaidy *et al*. 1993; El Dawy *et al*., 1992; Ayyad *et al*., 1996; Luning *et al*., 1998; the lower part of *Plummerita reicheli* Subzone of Shahin, 1992; El-Nady, 1995; and the lower part of *Plummerita reicheli* Zone of Shahin & El-Nady, 2001. Also it is equated to the *Pseudoguembelina palpebra* (CF2) Zone of Samir, 2002. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix striata* (Ehrenberg), *Heterohelix navarroensis* Loeblich, *Pseudotextularia elegans* (Rzehak), *Pseudotextularia deformis* (Kikoine), *Pseudoguembelina palpebra* Bronnimann & Brown, *Pseudoguembelina hariaensis* Nederbragt, *Pseudoguembelina costulata* (Cushman), *Globotruncana aegyptiaca* Nakkady, *Globotruncanella havanensis* (Voorwijk), *Abathomphalus mayaroensis* (Bolli), *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina rugosa* (Plummer), *Rugoglobigerina hexacamerata* Bronnimann, and *Rugoglobigerina reicheli* Bronnimann.

3.1.10. *Plummerita hantkeninoides* Zone (CF1) (Total range Zone):

This biozone was originally established at the Cretaceous-Tertiary boundary by Masters, 1984**.** Pardo *et al*., 1996 defined the *Plummerita hantkeninoides* Zone as the total range of the nominate taxon *Plummerita hantkeninoides* (Bronnimann) to mark the uppermost part of the Maastrichtian sediments at Agost, Spain. In the present study, this definition is followed. At Gebel Qabeliat section, this biozone is recorded from the uppermost part of Abu Zeneima Member (samples **91-95**), and it attains about **6** m thick. It is assigned to Latest Maastrichtian (65.30 – 65.00 Ma according to Li *et al*., 1999). The marker species *Plummerita hantkeninoides* (Bronnimann) is a tropical taxon found in low latitudes and absent in the middle and high latitudes. Its stratigraphic range provides a good estimate for the completeness of the latest Maastrichtian interval (Li and Keller, 1998b; Li *et al*., 1999; Abramovich and Keller, 2002; Keller *et al*., 2002b; El-Sabbagh *et al*., 2004, and El-Sabbagh , 2007), where the range of this excellent latest Maastrichtian marker species spans the last 300 kyr of the Maastrichtian, or most of the magneto-stratigraphic chron 29R below the K/P boundary, as estimated from the paleomagnetic record at Agost Spain (Groot *et al*., 1989; and Pardo *et al*., 1996). So, the *Plummerita hantkeninoides* Zone is considered as the youngest Late Cretaceous planktonic foraminiferal one (Masters, 1984; Ion, 1993; Pardo *et al*., 1996; Keller *et al*., 2002; and El-Sabbagh *et al*., 2004). The presence of this biozone indicates the completeness of the Maastrichtian age at Gebel Qabeliat section. In the study area, this biozone is equivalent to the topmost part of *Globotruncana mayaroensis* Zone of Bolli, 1966; the uppermost part of the uppermost part of *Abathomphalus mayaroensis* Zone of Postuma, 1971; Barr, 1972; Robaszynski *et al*., 1984; Caron,1985; Al-Mogi-Labin *et al.*, 1986; the upper part of Zone (CF1-2) of Li& Keller, 1998a. Also, it is also equated to *Plummerita hantkeninoides* (CF1) of Arz, 1996; Molina *et al*., 1996,and1998; Li& Keller, 1998b; Li *et al*., 1999; Arenilias *et al*., 2000; Luciani, 2002; and Adatte *et al*., 2002. In Egypt, the *Plummerita hantkeninoides* (CF1) Zone is equivalent to the topmost part of *Abathomphalus mayaroensis* Zone of Shahin, 1988; Hewaidy *et al*., 1993; El-Dawy *et al*., 1992; Ayyad *et al*., 1996; Lunning *et al*., 1998; Faris *et al.*, 2000; and Khalil & Meshaly, 2004; the uppermost part of *Plummerita reicheli* Subzone of Shahin, 1992; and El-Nady, 1995; the uppermost part of *Plummerita reicheli* Zone of Shahin & El-Nady, 2001; Also it is equated to the *Plummerita hantkeninoides* (CF1) Zone of Samir, 2002. The top of *Plummerita hantkeninoides* (CF1) Zone is used to place the Cretaceous/ Paleogene (K/$P_{g.}$) boundary at Gebel Qabeliat section. The most important planktonic foraminiferal species recorded from this biozone are: *Heterohelix globulosa* (Ehrenberg), *Heterohelix navarroensis* Loeblich, *Pseudotextularia elegans* (Rzehak), *Pseudoguembelina palpebra* Bronnimann & Brown, *Pseudoguembelina hariaensis* Nederbragt, *Pseudoguembelina costulata* (Cushman), *Hedbergella holmdelensis* Olsson, *Globotruncana aegyptiaca* Nakkady, *Globotruncana falsostuarti* Sigal, *Globotruncanella petaloidea* (Gandolfi), *Globotruncanella havanensis* (Voorwijk), *Rugoglobigerina macrocephala* Bronnimann, *Rugoglobigerina rugosa* (Plummer), *Rugoglobigerina hexacamerata* Bronnimann, *Rugoglobigerina reicheli* Bronnimann, and *Plummerita hantkeninoides* (Bronnimann).

3.1. 11. *Praemurica trinidadensis* Zone (P1d) (Partial range Zone):

Bolli, 1957a, was originally proposed the *Praemurica trinidadensis* Zone (P1d) as a biostratigraphic interval, extended from the first appearance of *Praemurica trinidadensis* (Bolli), at the base to the first appearance of *Praemurica uncinata* (Bolli), at the top. In the study area, this definition is followed. This biozone is recorded from the lowermost part of the Esna Formation (samples 96-98), and it attains about **5** m thick. It is assigned to Early Paleocene (Middle to Late Danian), the base of this zone is at 62.20 Ma, according to Keller *et al*., 2002 and the top is at 61.37 Ma, according to Berggren & Pearson, 2005. At Gebel Qabeliat section, the base of *Praemurica trinidadensis* Zone (P1d) is used to placement the Cretaceous/Paleogene (K/Pg) boundary and it coincides at the Sudr/ Esna formational boundary. At this studied section, the (K/P_g) boundary is marked by a sedimentary hiatus (Hiatus-1) represented by absence of 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 Latest Maastrichtian *Plummerita hantkeninoides* (CF1) Zone is directly overlain by the Middle to Late Danian *Praemurica trinidadensis* Zone (P1d). Based on Berggren & Pearson, 2005, the magnitude of this hiatus at this section is about 7.20 Ma, extended from 65.00 - 62.20 Ma. Also, this boundary in the study area is characterized by 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*, *Globanomalina* and *Praemurica*. Blow (1979) placed this zone as a Subzone (1b) of his more comprehensive *Globorotalia pseudobulloides* Zone (P1). Berggren *et al*., 1995 stated that, "the first appearance of *Praemurica inconstans* (Subbotina) coincides with that of *Praemurica trinidadensis* (Bolli) and considered the first appearance of *Praemurica inconstans* (Subbotina) as alternate definitive elements in recognizing ($P1_c$) Subzone". Keller *et al*., 1995 subdivided the ($P1_c$) Subzone of Berggren *et al*., 1995 into ($P1_c$ and $P1_d$), based on the first occurrence of the *Praemurica trinidadensis* (Bolli). In the study area, this biozone is equivalent to the upper part of *Globorotalia trinidadensis* Zone of Bolli,1966; and Postuma, 1971; the upper part of *Globorotalia compressa* - *Globorotalia trindadensis* Subzone of Berggren, 1969; the upper part of *Globorotalia (T.) compressa/ Eoglobigerina eobulloides simplissima* Subzone (P1b) of Blow, 1979; the upper part of *Globorotalia compressa/ Globorotalia inconstans/ Globorotalia trindadensis* Zone of Berggren & Van Couvering, 1974; the upper part of *Morozovella trindadensis* Zone of Stainforth *et al*., 1975; Masters, 1984; Toumarkine & Luterbacher, 1985; the upper part of *Morozovella trindadensis/ Planorotalites compressa* (P1c) Subzone of Berggren & Miller, 1988; and the upper *Globanomalina compressa / Praemurica inconstans- Praemurica uncinata* (P1c) Subzone of Berggren & Norris, 1997. It is also equivalent to the *Praemurica trindadensis* Zone of Keller *et al*., 1995; and Keller *et al.*, 2002; the upper part of *Globanomalina compressa* / *Praemurica inconstans- Praemurica uncinata* (P1c) Subzone of Berggren *et al*., 1995; the upper part of *Globanomalina compressa* / *Praemurica inconstans* (P1c) Subzone of Berggren & Pearson, 2005. In Egypt, this biozone may be correlated with the upper part of *Globigerina triloculinoides-Globigerina pseudobulloides* Zone of Fahmy *et al*., 1969; the upper part of *Morozovella trinidadensis* Zone of Hewaidy, 1987; Shahin, 1988; Cherif & Ismail, 1991; Haggag, 1991; Shahin, 1992; Abdel-Kireem *et al*., 1994; and El-Nady, 1995; the upper part of *Praemurica trinidadensis* Zone of Marzouk& Luning, 1998; Luning *et al*., 1998; and Shahin& El-Nady, 2001; the upper part of *Globanomalina compressa/ Praemurica inconstans- Praemurica uncinata* (P1c) Subzone of Samir, 2002; Al- Wosabi and Abu Shama, 2007; Sprong *et al*., 2011; Faris & Farouk, 2012. Also, it is equivalent to the *Morozovella trinidadensis* $P1_d$ Subzone of Luger, 1985, Abdel-Kireem & Samir, 1995; Tantawy *et al*., 2001; and El Sabbagh, 2007. The most important planktonic foraminiferal species recorded from this biozone are: *Globoconusa daubjergensis* (Bronnimann), *Parasubbotina pseudobulloides* Plummer, *Subbotina triloculinoides* (Plummer), *Subbotina cancellata* Blow, 1979, *Praemurica inconstans* (Subbotina), *Praemurica trinidadensis* (Bolli) and *Globanomalina compressa* (Plummer).

3.1.12. *Praemurica uncinata* Zone (P2) (Partial range Zone):

This biozone was originally proposed by Bolli, 1957a, 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. In the study area, this difintion is followed. This biozone is recorded from the lower part of Esna Formation (samples 99-101), and it attains about 6 m thick. It is assigned to late Early Paleocene (Late Danian), according to Berggren & Pearson, 2005, the base of this biozone is at 61.37 Ma and the top is at 61.00 Ma. This biozone is marked by forms with angular- conical chambers in the initial portion of the last whorl, such as: *Praemurica uncinata* (Bolli), *Praemurica praecursoria* (Morozova). Berggren & Pearson, 2005 used the top of *Praemurica uncinata* Zone (P2) to place the Early Paleocene (Danian) / Late Paleocene (Selandian) (D/S) boundary. In the study area, this Zone is equivalent to the *Globorotalia uncinata* Zone of Bolli, 1966; the *Globorotalia uncinata/ Globorotalia spiralis* Zone of Berggren, 1969, and Berggren & Van Couvering, 1974; lower part of *Globorotalia uncinata* Zone of Postuma, 1971; *Morozovella uncinata* Zone of Stainforth *et al*., 1975; *Globorotalia uncinata* Zone (P2) of Blow, 1979; the *Morozovella uncinata* Zone of Toumarkine & Luterbacher, 1985; the *Morozovella uncinata/ Igorina spiralis* (P2) Zone of Berggren & Miller, 1988; the *Praemurica uncinata- Morozovella angulata* (P2) Zone of Berggren *et al*., 1995; Berggren and Norris, 1997; and Olsson *et al*., 1999; *Praemurica uncinata* (P2) Zone of Berggren & Pearson, 2005; Wade *et al.*, 2011**.** In Egypt, this biozone may be correlated with the *Globorotalia uncinata* Subzone of El-Naggar, 1966; the *Morozovella uncinata* Zone of Fahmy *et al*., 1969; Hewaidy, 1987; Shahin, 1988 & 1992; Cherif & Ismail, 1991; Haggag, 1991; Hewaidy and Soliman, 1993; Abd el-Kireem and Samir, 1995; and El-Nady, 1995; the *Praemurica uncinata* Zone (P2) of Marzouk & Luning, 1998; Luning *et al*., 1998; Tantawy *et al*., 2001; Shahin& El-Nady, 2001; Samir, 2002; Al- Wosabi & Abu Shama, 2007; and Obaidallah, 2012. The most important planktonic foraminiferal species recorded from this zone include: *Globoconusa daubjergensis* (Bronnimann), *Parasubbotina variospira* (Belford), *Parasubbotina pseudobulloides* Plummer, *Subbotina triloculinoides* (Plummer), *Praemurica uncinata* (Bolli), *Praemurica praecursoria* (Morozova), *Praemurica trinidadensis* (Bolli), *Praemurica inconstans* (Subbotina) and *Globanomalina compressa* (Plummer).

3.1.13. *Morozovella angulata* Zone (P3a) (Partial range Zone):

This biozone was originally introduced by Alimarina, 1963 as the interval, extended from the first appearance of *Morozovella angulata*, at the base to the first appearance of *Planorotalities pusilla pusilla*, at the top. Berggren & Pearson, 2005 emended this definition to cover 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, its definition is restricted, according to Berggren & Pearson, 2005 and due to the absence of the upper part of this biozone *Igorina albeari* (Cushman and Bermudez), this biozone 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) in the studied stratigraphic sequence, where the early Late Paleocene (Selandian) *Morozovella angulata* (White) is directly followed by the Late Paleocene (Latest Thanetian) *Morozovella velascoensis* Zone. This hiatus is defined as Selandian/Thanetian (S/Th) boundary in the study area, and it probably corresponds to the phase of tectonic disturbance recognized by Strougo, 1986 and designated as *velascoensis* event. At Gebel Qabeliat section, this biozone is recorded from the middle part of the Esna Formation (samples 102-103), and it attains about 5 m thick. It is assigned to early Late Paleocene (Selandian) (61.00- 60.00 Ma) according to Berggren *et al*., 1995, and Berggren & Pearson, 2005. In this biozone, species of *Morozovella* with angular- conical chambers throughout their youngest whorl become predominant, such as: *Morozovella angulata* (White), *Morozovella conicotruncata* (Subbotina) and others. Typical representatives of the genus *Acarinina* form a conspicuous part of the planktonic foraminiferal assemblages. This biozone is equivalent to the lower part of *Globorotalia pusilla/ Globorotalia angulata* Zone of Bolli,1966; the lower part of *Globorotalia pusilla pusilla - Globorotalia angulata* Zone of Berggren, 1969; the upper part of *Globorotalia uncinata* Zone of Postuma, 1971; the *Globorotalia pusilla - Globorotalia angulata* Zone of Berggren & Van Couvering, 1974; the lower part of *Globorotalia angulata* (P3) Zone of Blow, 1979; the *Morozovella angulata* Zone of Toumarkine and Luterbacher, 1985; the *Morozovella angulata* (P3a) Subzone of Berggren & Miller, 1988; and the *Morozovella angulata- Igorina albeari* (P3a) Subzone of Berggren *et al*., 1995; Berggren & Norris, 1997; and Olsson *et al*., 1999. It also equivalent to *Igorina pusilla* Partial rang Subzone ($P3_a$) of Berggren & Pearson, 2005 and Wade *et al*., 2011. In Egypt, this biozone is correlated with the lower part of *Globorotalia pusilla* Subzone of EL-Naggar, 1966; the lower part of *Globorotalia angulata* Zone of Fahmy *et al*., 1969; the lower part of *Morozovella angulata* Zone of Shahin; 1988; the *Morozovella angulata - Igorina albeari* Subzone (P3a) of Samir, 2002. Also, it equivalents to the *Morozovella angulata* Zone that recorded by Luger, 1985; Hewaidy, 1987; Haggag, 1991; Shahin, 1992; Hewaidy & Soliman, 1993; Abd El Kireem & Samir, 1995; El-Nady, 1995; Marzouk& Luning, 1998; Luning *et al*., 1998; Shahin & El-Nady, 2001; Al-Wosabi & Abu Shama, 2007; Faris & Farouk, 2012; Obaidallah, 2012; and Farouk & El-Sorogy, 2015. At Gebel Qabeliat section, the base of *Morozovella angulata* Zone (P3a) is used to place the Danian/Selandian (D/S) boundary, following Berggren & Pearson, 2005. This boundary is located within the lower part of the Esna Formation and represented by aconformity surface, as it lies between the late Early Paleocene (Late Danian) *Praemurica uncinata* Zone (P2) and the early Late Paleocene (Selandian) *Morozovella angulata* Zone (P3a). The most important planktonic foraminiferal species recorded from this zone include: *Parasubbotina variospira* (Belford), *Parasubbotina pseudobulloides* Plummer, *Subbotina triloculinoides* (Plummer), *Morozovella angulata* (White), *Morozovella conicotruncata* (Subbotina), *Praemurica uncinata* (Bolli), *Praemurica praecursoria* (Morozova), *Praemurica inconstans* (Subbotina) and *Globanomalina compressa* (Plummer).

3.1.14. *Morozovella velascoensis* Zone (P5) (Partial range Zone):

This biozone was originally introduced from the typical Upper Paleocene rocks of Trindad by Bolli, 1957a and was named *Globorotalia velascoensis* Zone, to cover the interval extended from the last appearance of *Globanomalina pseudomenardii*, at the base, to last appearance of *Morozovella velascoensis*, at the top. Berggren *et al*., 1995 used the same biozone of Bolli, 1957a with its same boundaries and named it *Morozovella velascoensis* Zone (P5). Berggren & Pearson, 2005 followed Aubry *et al*., 2003& 2005 and they classified *Morozovella velascoensis* Zone of Berggren *et al*., 1995 into three biozones: 1) Latest Thanetian *Morozovella velascoensis* partial range Zone (P5), and it is equivalent to the lower part of (P5) Zone of Berggren *et al*., 1995; 2) Earliest Eocene (Earliest Ypresian) *Acarinina sibaiyaensis* Zone (E1) and it is equivalent to the middle part of (P5) Zone of Berggren *et al*., 1995; 3) Earliest Eocene (early Ypresian) *Pseudohastigerina wilcoxensis*-*Morozovella velascoensis* concurrent-range zone (E2) and it is equivalent to the upper part of (P5) Zone of Berggren *et al*., 1995. According to Berggren & Pearson, 2005, the *Morozovella velascoensis* Zone 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. At Gebel Qabeliat section, due to absence of both *Globanomalina pseudomenardii* and *Acarinina sibaiyaensis*, this biozone is defined as a biostratigraphic interval, extended from above the Selandian/ Thanetian (S/Th) boundary at the base to the Paleocene/ Eocene (P/E) boundary, at the top. This biozone is recorded from the upper part of the Esna Formation (samples 104-106), and it attains about 6 m thick. It is assigned to Latest Paleocene (Latest Thanetian) (55.90- 55.50 Ma), according to Berggren & 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: *Morozovella edgari* (Premoli Silva & Bolli), *Morozovella subbotinae* (Morozova) and *Morozovella formosa gracilis* Bolli. This biozone corresponds to the lower part of *Globorotalia velascoensis* Zone of Bolli, 1957a & b and 1966; Berggren, 1969; Postuma, 1971; and Berggren & Van Couvering, 1974. It also could be matched with the lower part of *Morozovella velascoensis* Zone of Premoli Silva & Bolli, 1973; Benjamini 1980; Toumarkine & Luterbacher, 1985; Canudo *et al*., 1995; Molina *et al*., 1999; and Pardo *et al.*, 1999; the middle part of *Globorotalia soldadoensis* (P5) Zone of Blow, 1979; the lower part of *Morozovella subbotina /Morozovella velascoensis* (P5&P6a) subzone of Berggren & Miller, 1988; and the lower part of *Morozovella aequa* of Canudo & Molina, 1992; It also equivalent to the lower part of *Morozovella velascoensis* interval Zone (P5) of Berggren *et al*., 1995; the lower part of *Igorina laevigata* and *Morozovella velascoensis* Zones of Arenillas & Molina, 1996; the lower part of *Morozovella velascoensis* (P5) Subzone of Berggren and Norris, 1997. It is also equivalent to *Morozovella velascoensis* (P5) Zone of Berggren & Pearson, 2005**.** In Egypt, this biozone is equivalent to the lower part of *Globorotalia aequa*/*Globorotalia esnaensis* Subzone of El-Naggar, 1966; the lower part of *Globorotalia velascoensis* Subzone of Fahmy *et al*., 1969; the lower part of *Morozovella velascoensis* Zone of Luger, 1985; Hewaidy, 1987; Shahin; 1988; Salis *et al*., 1998; Cherif & Ismail, 1991; Haggag, 1991; Shahin, 1992; El-Nady, 1995; Abd el-Kireem and Samir, 1995; Luning *et al*., 1998; and Shahin & El Nady, 2001; and the lower part of *M. velascoensis* Zone (P5) of Samir, 2002; Berggren & Ouda, 2003; and Hamad, 2009).

At Gebel Qabeliat section, the base of this zone is used to place the Selandian/Thanetian (S/ Th) boundary. This boundary is represented by a sedimentary gap (Hiatus-2) within the middle part of Esna Formation, including the upper part of *Morozovella angulata- Globanomalina pseudomenardii* interval Zone (P3), and the *Globanomalina pseudomenardii* partial range Zone (P4). Depending on Berggren & Pearson, 2005, the magnitude of this hiatus is about 4.10 Ma, extended from 60.00 Ma to 55.90 Ma, and it is characterized by a noticeable increasing in *Morozovella* and *Acarinina* spp. and decreasing in *Parasubbotina*, *Subbotina* and *Praemurica* spp. The most important planktonic foraminiferal species recorded in this Zone include: *Subbotina velascoensis* (Cushman), *Acarinina soldadoensis soldadoensis* (Bronnimann), *Acarinina mckannai* (White), *Acarinina nitida* (Martin), *Morozovella acuta* (Toulmin), *Morozovella formosa gracilis* Bolli, *Morozovella conicotruncata* (Subbotina), *Morozovella subbotinae* (Morozova), *Morozovella velascoensis* (Cushman), *Morozovella quetra* (Bolli) and *Morozovella aequa* (Cushman & Renz).

3.1.15. *Pseudohastigerina wilcoxensis / Morozovella velascoensis* Zone (E2) (Concurrent-range Zone):

This biozone was originally introduced by Molina *et al*., 1999 from the Eocene rocks of the Tethys, as the partial range *Pseudohastigerina wilcoxensis* Subzone. Berggren & Pearson, 2005 emended this biozone, as a biostratigraphic interval characterized by the concurrent biostratigraphic ranges of the nominate taxa extended from the first appearance of *Pseudohastigerina wilcoxensis*, at the base, to the last appearance of *Morozovella velascoensis*, at the top. In the present study, this biozone is defined a restricted to Berggren & Pearson, 2005. At Gebel Qabeliat section, this biozone is recorded from the upper part of Esna Formation (samples 107-109), and it attains about 3 m thick. It is assigned to Earliest Eocene (Earliest Ypresian) (55.35-54.5 Ma), according to Berggren & Pearson, 2005. This biozone marks the beginning of the lowermost Eocene (Ypresian) in the study area. The planktonic foraminiferal assemblages of this biozone are dominated by lightly built representatives of the genus *Morozovella* as: *Morozovella subbotina* (Morozova) and *Morozovella formosa gracilis* Bolli. Also, *Acarinina soldadoensis soldadoensis* (Bronnimann) and its relatives are abundant within this biozone. This biozone is equivalent to the upper part of *Globorotalia velascoensis* Zone of Bolli, 1957&1966; Berggren, 1969; and Postuma, 1971; the lower part of *Globorotalia velascoensis / Globorotalia subbotina* Zone of Berggren & Van Couvering, 1974; the uppermost part of *Globorotalia Gl. subbotina* (P6) Zone of Blow, 1979; the uppermost part of *Morozovella velascoensis* Zone of Benjamini 1980; and Toumarkine& Luterbacher, 1985; the upper part of *Morozovella subbotina/Morozovella velascoensis* (P6a & P5) subzones of Berggren & Miller, 1988; the lowermost part of *P. wilcoxensis* Zone of Canudo &Molina, 1992; the upper part of *M. velascoensis* (P5) Zone of Berggren *et al*., 1995;the upper part of *M. velascoensis* (P5) Zone of Arenillas & Molina, 1996; and the lower part of *Morozovella velascoensis* (P5) Subzone of Berggren and Norris, 1997; the upper part of *Ac. sibaiyaensis/ M. velascoensis* (P5b) Subzone of Pardo *et al*., 1999; *Pseudohastigerina wilcoxensis* Subzone of Molina *et al*., 1999; the *Globanomalina luxorensis* Subzone (P5c) of Speijer *et al*., $1996_{a,b}$. It is also equated to the *Ps. wilcoxensis - M. velascoensis* (E2) Zone of Berggren & Pearson, 2005.

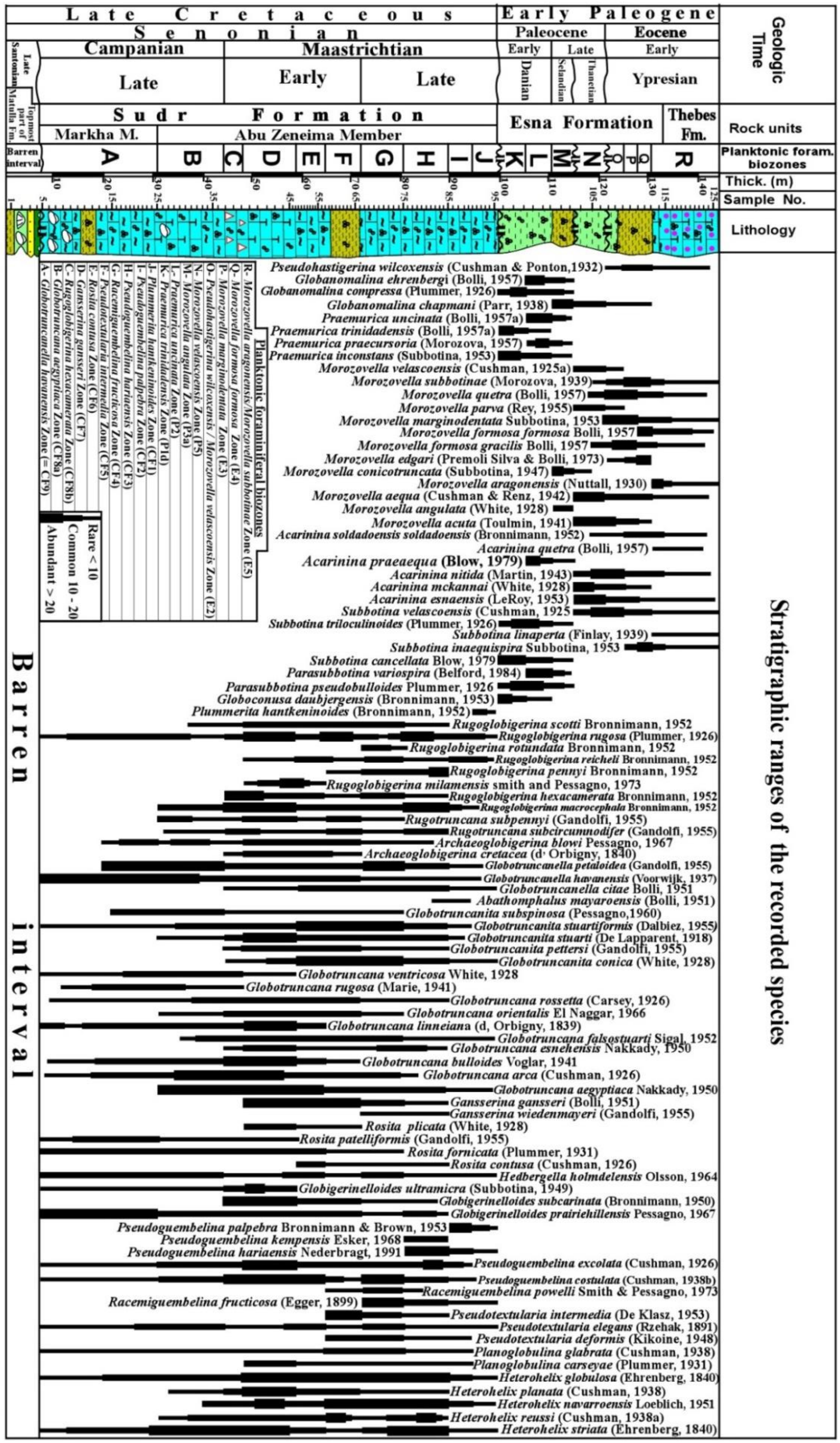
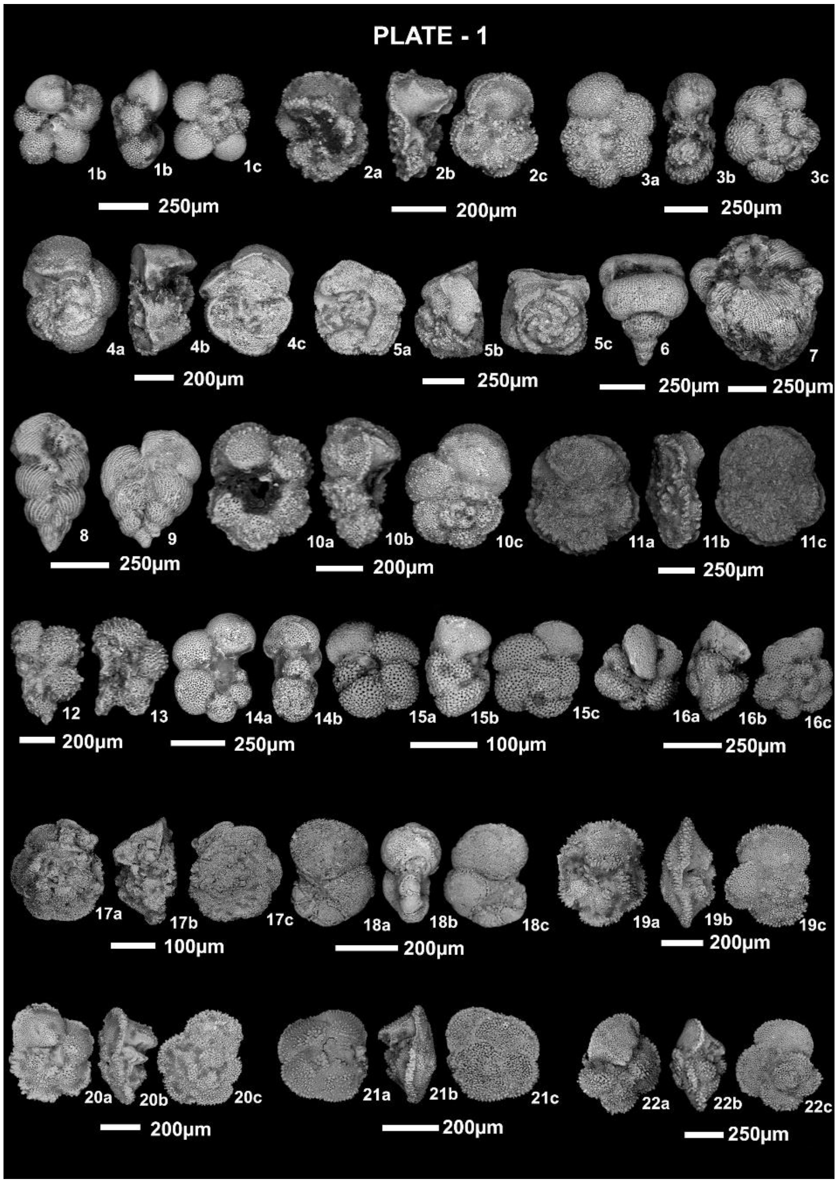


Fig. 3: Distribution chart of the identified planktonic foraminiferal species at Gabal Qabeliat area, Southwestern Sinai.



(Explanation of PLATE – 1)

(The recorded Zonal marker planktonic foraminiferal species)

1: ***Globotruncanella havanensis*** **(Voorwijk, 1937)**, sample 15, Sudr Formation.; **2:** ***Globotruncana aegyptiaca*** **Nakkady, 1950**, sample 30, Sudr Formation; **3:** ***Rugoglobigerina hexacamerata*** **Bronnimann, 1952**, sample 39, Sudr Formation.; **4:** ***Gansserina gansseri*** **(Bolli, 1951)**, sample 45, Sudr Formation; **5:** ***Rosita contusa*** **(Cushman, 1926)**, sample 50, Sudr Formation; **6**: ***Pseudotextularia intermedia*** **(De Klasz, 1953)**, sample 62, Sudr Formation; **7:** ***Racemiguembelina fructicosa*** **(Egger, 1899)**, sample 70, Sudr Formation; **8:** ***Pseudoguembelina hariaensis*** **Nederbragt, 1991,** sample 80, Sudr Formation; **9:** ***Pseudoguembelina palpebra*** **Bronnimann & Brown, 1953**, sample 88, Sudr Formation; **10:** ***Globotruncana linneiana*** **(d' Orbigny, 1839)**, sample 45, Sudr Formation.**11:** ***Abathomphalus mayaroensis*** **(Bolli, 1951)**, sample 85, Sudr Formation**. 12&13:** ***Plummerita hantkeninoides*** **(Bronnimann, 1952)**, sample 93, Sudr Formation; **14:** ***Praemurica trinidadensis*** **(Bolli, 1957a)**, sample 97, Esna Formation; **15:** ***Praemurica uncinata*** **(Bolli, 1957a)**, sample 100, Esna Formation; **16:** ***Morozovella angulata*** **(White, 1928)**, sample 103, Esna Formation; **17:** ***Morozovella velascoensis*** **(Cushman, 1925a)**, sample 105, Esna Formation; **18:** ***Pseudohastigerina wilcoxensis*** **(Cushman & Ponton, 1932)**, sample 108, Esna Formation; **19:** ***Morozovella marginodentata*** **Subbotina, 1953**, sample 110, Esna Formation; **20:** ***Morozovella formosa formos*****a Bolli, 1957**, sample 113, Esna Formation; **21:** ***Morozovella aragonensis*** **(Nuttall, 1930),** sample 115, Esna Formation; **22:** ***Morozovella subbotinae*** **(Morozova, 1929)**, sample 109, Esna Formation.

In Egypt, this biozone is equivalent to the upper part of *Globorotalia aequa*/*Globorotalia esnaensis* Subzone of El-Naggar, 1966; the upper part of *Globorotalia velascoensis* Subzone of Fahmy *et al*., 1969; the upper part of *Morozovella velascoensis* Zone of Hewaidy, 1987; Shahin; 1988; Cherif & Ismail, 1991; Haggag, 1991; Shahin, 1992; El-Nady, 1995; Luning *et al*., 1998; and Shahin & El-Nady, 2001; and the upper part of *Morozovella velascoensis* (P5) Zone of Samir, 2002. It is also equated to *P. wilcoxensis/ M. velascoensis* of Berggren & Ouda, 2003, and the upper part of *Ac. sibaiyaensis / M. velascoensis* (P5b) Subzone of Hamad, 2009. In the present study, the base of *Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) Zone is used to place the Paleocene/Early Eocene (P/E) boundary. At Gebel Qabeliat section, this boundary is located within the uppermost part of the Esna Formation and represented by a sedimentary hiatus (**Hiatus-3**), due to the absence of the Early Eocene (Earliest Ypresian) *Acarinina sibaiyaensis* (E1) Zone, where the Late Paleocene (latest Thanetian) *Morozovella velascoensis* (P5) Zone directly overlain by the Early Eocene (Early Ypresian) *Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) Zone. Based on Berggren & Pearson, 2005, the magnitude of this hiatus is about 0.15 Ma, extended from 55.50 Ma to 55.35 Ma. Also, the (P/E) boundary at Gebel Qabeliat section 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 the Earliest Eocene. The most important planktonic foraminiferal species recorded in this Zone include: *Subbotina inaequispira* Subbotina, *Subbotina velascoensis* (Cushman), *Pseudohastigerina wilcoxensis* (Cushman & Ponton), *Acarinina soldadoensis soldadoensis* (Bronnimann), *Acarinina mckannai* (White), *Acarinina nitida* (Martin), *Morozovella acuta* (Toulmin), *Morozovella formosa gracilis* Bolli, *Morozovella edgari* (Premoli Silva & Bolli), *Morozovella subbotinae* (Morozova), *Morozovella marginodentata* Subbotina, *Morozovella velascoensis* (Cushman), *Morozovella quetra* (Bolli) and *Morozovella aequa* (Cushman & Renz).

3.1. 16. *Morozovella marginodentata* Zone (E3) (Partial-range Zone):

According to Berggren & 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 *Morozovella velascoensis* (Cushman), at the base to the first appearance of *Morozovella formosa formosa* Bolli, at the top. In the present study, this difintion is followed. At Gebel Qabeliat, this biozone is recorded from the upper part of Esna Formation (samples 110-111), and it attains about **2.5** m thick. It is assigned to Earliest Eocene (early Ypresian) (54.5-54.0 Ma), according to Berggren & Pearson, 2005. This biozone is equivalent to the lower part of *Globorotalia subbotinae* Zone of Bolli, 1957 & 1966; the *Globorotalia velascoensis / Globorotalia subbotina* Subzone of Berggren, 1969; the lower part of *Globorotalia rex* Zone of Postuma, 1971. It also partially equivalent to *Globorotalia edgari* Zone of Premoli Silva and Bolli, 1973; the upper part of *Globorotalia velascoensis / Globorotalia subbotina* Zone of Berggren & Van Couvering, 1974; the *Globorotalia wilcoxensis berggreni* (P7) of Blow, 1979; the lower part of *Morozovella subbotinae* Zone of Benjamini 1980; *Morozovella edgari* Zone of Toumarkine& Luterbacher, 1985; *Morozovella subbotinae / Pseudohastigerina wilcoxensis* Partial range Zone (P6b) of Berggren and Miller, 1988; the lower middle part of *Pseudohastigerina wilcoxensis* Zone of Canudo &Molina, 1992; *Morozovella velascoensis-Morozovella formosa formosa* and/or *Morozovella lensiformis* Interval Zone (P6a) of Berggren *et al.*, 1995; the lower part of *Globorotalia subbotinae* Zone of

Arenillas& Molina, 1996; *Morozovella formosa formosa / Morozovella lensiformis* (P6a) Subzone of Berggren & Norris, 1997; the lower part of *Morozovella velascoensis- Morozovella formosa* (P6a) Subzone of Pardo *et al*., 1999; the *Morozovella edgari* Subzone of Molina *et al.*, 1999. It is also equated to the *Morozovella marginodentata* partial range Zone (E3) of Berggren & Pearson, 2005**.** In Egypt, this biozone is equivalent to the lower part of *Globorotalia wilcoxensis* Zone of El-Naggar, 1966; lower part of *Globorotalia subbotinae* Subzone of Fahmy *et al*., 1969; the lower part of *Morozovella subbotinae* Zone of Hewaidy, 1987, and Shahin, 1992; the lower part of *Acarinina wilcoxensis* Zone of Shahin; 1988, the *Morozovella edgari* Zone of Cherif & Ismail, 1991; Haggag, 1991; El-Nady, 1995; Luning *et al*., 1998; and Shahin & El-Nady, 2001**.** Also, it is equivalent to the *Morozovella formosa formosa/ Morozovella lensiformis* (P6a) Subzone of Samir, 2002. It is also equivalent to *Morozovella edgari* Zone of Berggren& Ouda, 2003, and Hamad, 2009. The most important planktonic foraminiferal species recorded in this Zone include: *Subbotina inaequispira* Subbotina, *Subbotina velascoensis* (Cushman), *Pseudohastigerina wilcoxensis* (Cushman & Ponton), *Acarinina soldadoensis soldadoensis* (Bronnimann), *Acarinina nitida* (Martin), *Morozovella acuta* (Toulmin), *Morozovella formosagracilis* Bolli, *Morozovella edgari* (Premoli Silva & Bolli), *Morozovella subbotinae* (Morozova), *Morozovella marginodentata* Subbotina, *Morozovella quetra* (Bolli), and *Morozovella aequa* (Cushman & Renz).

3.1. 17. *Morozovella formosa formosa* Zone (E4) (Partial-range Zone):

This biozone was originally named by Bolli, 1957a in Trindad. Berggren & Pearson, 2005 defined this biozone as a biostratigraphic interval, extended 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. In the present study, the definition of Berggren & Pearson, 2005 is followed. At Gebel Qabeliat, this biozone is recorded from upper part of the Esna Formation (samples 112-114), and it attains about **2.5** m thick. It is assigned to Early Eocene (Early Ypresian) (54.0 - 52.3 Ma), according to Berggren & Pearson, 2005. This biozone is approximately equivalent to the upper part of *Globorotalia subbotinae* Zone of Bolli, 1957a &1966, and Benjamini 1980; the *Globorotalia subbotinae / Pseudohastigerina wilcoxensis* Subzone of Berggren, 1969; the upper part of *Globorotalia rex* Zone of Postuma, 1971; the *Globorotalia subbotina / Globorotalia wilcoxensis* Zone of Berggren & Van Couvering, 1974; the *Morozovella formosa-Morozovella lensiformis* Partial-range Subzone (P8a) of Blow, 1979; *Morozovella subbotina* Zone of Toumarkine& Luterbacher, 1985; the *Morozovella formosa- Morozovella lensiformis* Partial-range Subzone (P6c) of Berggren and Miller, 1988; the upper middle part of *Pseudohastigerina wilcoxensis* Zone of Canudo & Molina, 1992; *Morozovella formosa formosa/ Morozovella lensiformis- Morozovella aragonensis* Interval Zone (P6b) of Berggren *et al*., 1995; the upper part of *Globorotalia subbotinae* Zone of Arenillas& Molina, 1996; the *Morozovella formosa formosa / Morozovella lensiformis - Morozovella aragonensis* (P6b) Subzone of Berggren & Norris, 1997; the upper part of *Morozovella velascoensis- Morozovella formosa* (P6a) Subzone of Pardo *et al*., 1999; the *Morozovella subbotinae* Subzone of Molina *et al*., 1999. It is also equated to *Morozovella formosa formosa* (E4) Zone of Berggren & Pearson, 2005. In Egypt, this biozone is equivalent to the upper part of *Globorotalia wilcoxensis* Zone of El-Naggar, 1966; upper part of *Globorotalia subbotinae* Subzone of Fahmy *et al*., 1969; the upper part of *Morozovella subbotinae* Zone of Hewaidy, 1987 and Shahin, 1992; the upper part of *Acarinina wilcoxensis* Zone of Shahin; 1988; the lower part of *Morozovella subbotinae* Zone of Cherif & Ismail, 1991; the *Morozovella* *subbotinae* Zone of Haggag, 1991; El-Nady, 1995; Luning *et al*., 1998; Shahin & El-Nady, 2001; Berggren& Ouda, 2003; and Hamad, 2009. Also, it is equivalent to the lower part of *Morozovella formosa formosa / Morozovella lensiformis - Morozovella aragonensis* (P6b) Subzone of Samir, 2002. The most important planktonic foraminiferal species recorded in this zone include: *Subbotina inaequispira* Subbotina, *Subbotina velascoensis* (Cushman), *Pseudohastigerina wilcoxensis* (Cushman & Ponton), *Acarinina soldadoensis soldadoensis* (Bronnimann), *Acarinina mckannai* (White), *Acarinina nitida* (Martin), *Morozovella acuta* (Toulmin), *Morozovella formosagracilis* Bolli, *Morozovella formosa formosa* Bolli, *Morozovella edgari* (Premoli Silva & Bolli), *Morozovella subbotinae* (Morozova), *Morozovella marginodentata* Subbotina, *Morozovella quetra* (Bolli) and *Morozovella aequa* (Cushman & Renz).

3.1. 18. *Morozovella aragonensis / Morozovella subbotinae* (E5) (Concurrent-range Zone):

This biozone was originally proposed by Berggren and Miller, 1988 and it is defined as a biostratigraphic interval characterized by the concurrent range of the nominate taxa, extended between the first appearance of *Morozovella aragonensis* (Nuttall), at the base and the last appearance of *Morozovella subbotinae* (Morozova), at the top. In the present study, this definition is followed. This biozone is recorded from the topmost part of Esna Formation and continued throughout the measured part of the Thebes Formation (**Samples 114-125**), and it attains about **14** m thick. It is assigned to Early Eocene (Ypresian) (52.30- 50.80 Ma) according to Berggren & Pearson, 2005.The *Morozovella aragonensis / Morozovella subbotinae* (E5) Zone is considered the youngest recorded planktonic foraminiferal biozone at Gebel Qabeliat section. This biozone is equivalent to the combined *Globorotalia formosa* and *Globorotalia aragonensis* Zones of Bolli, 1957 & 1966; *Globorotalia formosa* Zone of Berggren, 1969; and Berggren & Van Couvering, 1974; the *Morozovella aragonensis/ Morozovella formosa* Partial-range Subzone (P8b) of Blow, 1979; the *Morozovella aragonensis / Morozovella formosa* Concurrent-range Zone (P7) of Berggren & Miller, 1988; the upper part of *Pseudohastigerina Wilcoxensis* Zone of Canudo &Molina, 1992; the *Morozovella formosa* of Benjamini 1980, Toumarkine& Luterbacher, 1985; and Arenillas & Molina, 1996; the *Morozovella aragonensis /Morozovella formosa formosa* Concurrent- range Zone (P7) of Berggren *et al*., 1995; the *Morozovella formosa formosa* (P7) Zone of Berggren & Norris, 1997; It is also equivalents to *Morozovella formosa* (P6b) Subzone of Pardo *et al*., 1999; Molina *et al*., 1999; and *Morozovella aragonensis / Morozovella subbotinae* (E5) of Berrgren & Pearson, 2005. In Egypt, this biozone is equivalent to the *Globorotalia formosa – Globorotalia marginodentata* Subzone of Fahmy *et al*., 1969; the *Morozovella formosa formosa* Zone of Haggag, 1991; Shahin, 1992; El-Nady, 1995; Luning *et al*., 1998; Shahin & El-Nady, 2001; Berggren& Ouda, 2003; and Hamad, 2009. Also it is equivalent to the upper part of *Morozovella formosa formosa / Morozovella lensiformis - Morozovella aragonensis* (P6b) Subzone of Samir, 2002. The most important planktonic foraminiferal species recorded from this biozone include: *Subbotina inaequispira* Subbotina, *Subbotina velascoensis* (Cushman), *Pseudohastigerina wilcoxensis* (Cushman & Ponton), *Acarinina soldadoensis soldadoensis* (Bronnimann), *Acarinina nitida* (Martin), *Morozovella formosagracilis* Bolli, *Morozovella formosa formosa* Bolli, *Morozovella subbotinae* (Morozova), *Morozovella marginodentata* Subbotina, *Morozovella caucasica* (Glaessner), *Morozovella aragonensis* (Nuttall), *Morozovella quetra* (Bolli), and *Morozovella aequa* (Cushman &Renz).

The vertical distribution charts of the identified planktonic foraminiferal species with their equivalent zones and suggested ages at the studied section are illustrated in **(Fig. 3).**

3.2. Benthonic Foraminiferal biostratigraphy

The benthonic foraminiferal biostratigraphic studies of the Late Campanian-Early Eocene (Ypresian) time interval were carried out by many authors in/ out-side Egypt, and the most important ones include: Le Roy, 1953; Said &Kenawy, 1956; Barr, 1970; Saperson & Janal, 1980; Geroch & Nowak, 1983; Anan & Hewaidy, 1986; Hewaidy, 1987; Anan & Sharabi, 1988; Shahin, 1988; Berggren & Miller, 1989; Ismail, 1992; Fluegeman *et al*., 1990; El-Deeb & El-Gammal, 1994; Ayyad *et al*., 1997; El-Dawy, 2001; El Dawy & Hewaidy, 2002 & 2003; Khalil & Meshaly, 2004; and El-Gammal & Hamad, 2015.

At Gebel Qabeliat section, the Upper Campanian-Lower Eocene (Ypresian) succession contains abundant well preserved benthonic foraminiferal species. The vertical distributions of the identified benthonic foraminiferal species are used in the classification of this time interval, at this studied section into seven benthonic foraminiferal zones.

In the study area, the identified benthonic foraminiferal biozones are local and controlled by environmental and ecological conditions. These seven distinguished benthonic foraminiferal zones are described in the following paragraphs, from older to younger:

3.2.1. *Bolivinoides decoratus* Zone:

In the present studied area, this biozone is defined as a biostratigraphic interval, extended from the first appearance of *Bolivinoides decoratus* (Jones), at the base to the first appearance of *Bolivinoides draco miliaris* Hiltermann & Koch, at the top. At Gebel Qabeliat section, this biozone is represented by the whole thickness of the Markha Member in addition to the lowermost part of the Abu Zeneima Member (**Samples 5-36**), and it attains about **35** m thick. It is assigned to Latest Campanian age as it is correlated with both *Globotruncanella havanensis*, and *Globotruncana aegyptiaca* (CF8a) planktonic biozones.

Bolivinoides decoratus (Jones) was used as a marker species for the Late Campanian by many authors e.g. Reiss (1954), Said & Kenawy (1956), and Ismail & El Saadany, (1995). In the study area, the *Bolivinoides decoratus* Zone represents the oldest recorded benthonic foraminiferal biozone and its top is used to place the Campanian/Maastrichtian (Ca/Ma) boundary**.** Also, Hofker, 1960 noted that, the Campanian/ Maastrichtian boundary in south Limborg coincides with the uppermost extinction of the *Bolivinoides decoratus* (Jones).

This zone is equivalent to the *Bolivinoides decoratus* **Zone** of Shahin (1988) at Gabal Nezzazat; El Ashwah (1998) in the northwestern part of the Western Desert; Khalil & Meshaly (2004) at Gabal Musaba Salama, and El Ashwah (2000 & 2005& 2006) in the north Western Desert. Also, this zone may be equated with the *Cibicides praecursorius* Zone of Ayyad *et al*. (1997) at Gabal Arif El-Naga.

The most dominant benthonic species recorded from this biozone include: *Spiroplectinella knebeli* (Le Roy), *Gaudryina aissana* Ten Dam & Sigal, *Gaudryina soldadoensis* Cushman and Renz, *Gaudryina elegantissima* Said & Kenawy, *Lenticulina pseudosecans* (Cushman), *Lenticulina midwayensis* (Plummer), *Valvulineria aegyptiaca* Le Roy, *Neoflabellina semireticulatus* (Cushman & Jarvis), *Neoflabellina rugosa* (d'Orbigny), *Bolivinoides decoratus* (Jones), *Orthokarstenia whitei* (Church), *Coryphostoma plaitum* (Carsey), *Discorbis pseudoscopos* Nakkady, *Cibicidoides pseudoacuta* (Nakkady), *Valvalabamina depressa* (Alth), *Praebulimina reussi* (Morrow), *Bulimina trigonalis* Ten Dam, *Orthokarstenia whitei* (Church), *Anomalinoides praeacutus*

(Vasilenko), *Gyroidinoides girardana* (Reuss), *Gyroidinoides globosus* (Hagenow) and *Angulogavelinella abudurbensis* (Nakkady).

3.2.2. *Bolivinoides draco miliaris* Zone:

At Gebel Qabeliat section, this biozone is defined as a biostratigraphic interval, extended from the first appearance of *Bolivinoides draco miliaris* Hiltermann & Koch, at the base to the first appearance of *Bolivinoides draco draco* (Marsson), at the top. This biozone is represented by the middle part of Abu Zeneima Member (**Samples 37-66**), and it attains about 28 m. It is assigned to Early Maastrichtian age as it is correlated with *Rugoglobigerina hexacamerata* (CF8b), *Gansserina gansseri* (CF7), *Contusotruncana contusa* (CF6), and *Pseudotextularia intermedia* (CF5) planktonic biozones. *Bolivinoides draco miliaris* Hiltermann & Koch was previously recorded from the Maastrichtian by Le Roy (1953), Said & Kenawy (1956), Shahin (1988), and Ayyad *et al.* (1997).

In the study area, the Campanian/Maastrichtian (Ca/Ma) boundary is cited at the base of *Bolivinoides draco miliaris* Zone; while the top of this zone is used to place the Early /Late Maastrichtian boundary.

This biozone is equivalent to the *Bolivinoides draco miliaris* Zone defined by Shahin (1988) at Gabal Nezzazat, Hewaidy *et al*. (1993) in Northeast Sinai, El Ashwah (1997) in the northeastern part of the Western Desert, Ayyad *et al*. (1997) at Gabal Arif El-Naga, El Ashwah (1998) in the northwestern part of the Western Desert; Khalil (1998) in Sinai, El Ashwah (2003a & 2005& 2006) in north Western Desert, and Khalil & Meshaly (2004) at Gabal Musaba Salama.

The most dominant benthonic species recorded from this biozone include: *Gaudryina aissana* Ten Dam & Sigal, *Gaudryina soldadoensis* Cushman and Renz, *Gaudryina elegantissima* Said & Kenawy, *Gaudryina pyramidata* Cushman, *Ammodiscus cretacea* (Reuss), *Spiroplectinella knebeli* (Le Roy), *Spiroplectinella esnaensis* (Le Roy), *Bolivinoides draco miliaris* Hiltermann & Koch, *Bolivina incrassata* Reuss, *Bolivina decurrens (*Ehrenberg), *Elhasaella alanwoodi* Hamam, *Orthokarstenia esnehensis* (Nakkady), *Orthokarstenia oveyi* (Nakkady), *Orthokarstenia parva* (Cushman), *Orthokarstenia whitei* (Church), *Reussella aegyptiaca* Nakkady, *Lenticulina midwayensis* (Plummer), *Pseudoclavulina globulifera* Ten Dam & Sigal, *Pseudoclavulina farafraensis* Le Roy, *Vaginulinopsis austinana* (Cushman), *Vaginulina longiformis* (Plummer), *Vaginulina cretacea* Plummer, *Neoflabellina rugosa* (d'Orbigny), *Neoflabellina semireticulatus* (Cushman & Jarvis), *Valvulineria aegyptiaca* Le Roy, *Praebulimina reussi* (Morrow), *Bulimina trigonalis* Ten Dam, *Coryphostoma plaitum* (Carsey), *Stilostomella midwayensis* (Cushman & Todd), *Stilostomella spinea* (Cushman), *Valvulineria aegyptiaca* Le Roy, *Discorbis pseudoscopos* Nakkady, *Cibicidoides pseudoacuta* (Nakkady), *Valvalabamina depressa* (Alth), *Anomalinoides praeacutus* (Vasilenko), *Gyroidinoides girardana* (Reuss), *Gyroidinoides globosus* (Hagenow) and *Angulogavelinella abudurbensis* (Nakkady).

3.2. 3. *Bolivinoides draco draco* Zone:

This biozone is defined as a biostratigraphic interval represented by total range of the nominate taxon. At Gebel Qabeliat section, **it is** represented by the upper part of the Abu Zeneima Member (**Samples 67- 95**), and it attains about 28 m. It is assigned to late Maastrichtian age as it is correlated with *Racemiguembelina fructicosa*

(CF4), *Pseudoguembelina hariaensis* (CF3), *Pseudoguembelina palpebra* (CF2), and *Plummerita hantkeninoides* (CF1) planktonic biozones.

Bolivinoides draco draco (Marsson) was used as a marker species for the late Maastrichtian by many authors, e.g. (Reiss (1954), Said & Kenawy (1956), Hofker (1958), and Ismail & El Saadany, 1995). At Gebel Qabeliat section, the Early/Late Maastrichtian boundary is cited on the base of the *Bolivinoides draco draco* Zone; while the top of this zone is used to placement of the Cretaceous/Paleogene (K/Pg) boundary.

This zone is equivalent to *Bolivinoides draco* Zone of west coast of Gulf of Suez (Ansary & Tewfik, 1969), northern Sinai (Hewaidy, 1987), western Sinai (Shahin, 1988), Gabal Arif El-Naga (Ayyad *et al*., 1997), Western Desert (El Ashwah, 1998, 2003a , 2005, 2006), Sinai (Khalil, 1998), Gabal Musaba Salama (Khalil & Meshaly, 2004). Also, it may be equated with *Praebulimina carseyae* Zone of El-Dawy & Hewaidy (2002); *Angulogavelinella abudurbensis* Zone of El-Dawy & Hewaidy (2003) from Egypt.

The most dominant benthonic species recorded from this biozone include: *Spiroplectinella knebeli* (Le Roy), *Spiroplectinella dentata* (Alth), *Spiroplectinella esnaensis* (Le Roy), *Gaudryina pyramidata* Cushman, *Gaudryina aissana* Ten Dam & Sigal, *Gaudryina soldadoensis* Cushman and Renz, *Discorbis pseudoscopos* Nakkady, *Cibicidoides pseudoperlucidus* (Bykova), *Cibicidoides pseudoacuta* (Nakkady), *Verneuilina karreri* Said and Kenawy, *Valvulineria scorbiculata* (Schwager), *Valvulineria scorbiculata* (Schwager), *Valvalabamina depressa* (Alth), *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides acutus* (Plummer), *Gyroidinoides girardana* (Reuss), *Neoflabellina semireticulatus* (Cushman & Jarvis), *Neoflabellina rugosa* (d'Orbigny), *Lenticulina midwayensis* (Plummer), *Bolivina incrassata* Reuss, *Bolivina decurrens (*Ehrenberg), *Bolivinoides draco draco* (Marsson), *Bolivinoides draco miliaris* Hiltermann & Koch, *Elhasaella alanwoodi* Hamam, *Orthokarstenia esnehensis* (Nakkady), *Orthokarstenia oveyi* (Nakkady), *Orthokarstenia whitei* (Church), *Orthokarstenia parva* (Cushman), *Reussella aegyptiaca* Nakkady, *Coryphostoma plaitum* (Carsey), *Angulogavelinella abudurbensis* (Nakkady) and *Gavelinella brotzeni* Said & Kenawy.

3.2.4. *Siphogenerinoides eleganta* Zone:

In the study area, this biozone is defined as a biostratigraphic interval, extended from the first appearance of *Siphogenerinoides eleganta* Plummer, at the base to the first appearance of *Alabamina midwayensis* Brotzen, at the top. At Gebel Qabeliat section, 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 (**Samples 96-98**), and it attains about 5m. It is assigned to Early Paleocene (Middle to Late Danian) as it is correlated with *Praemurica trinidadensis* (P1d) planktonic biozone. Also, the base of this biozone is used to placement of Cretaceous/Paleogene (K/Pg) boundary. 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).

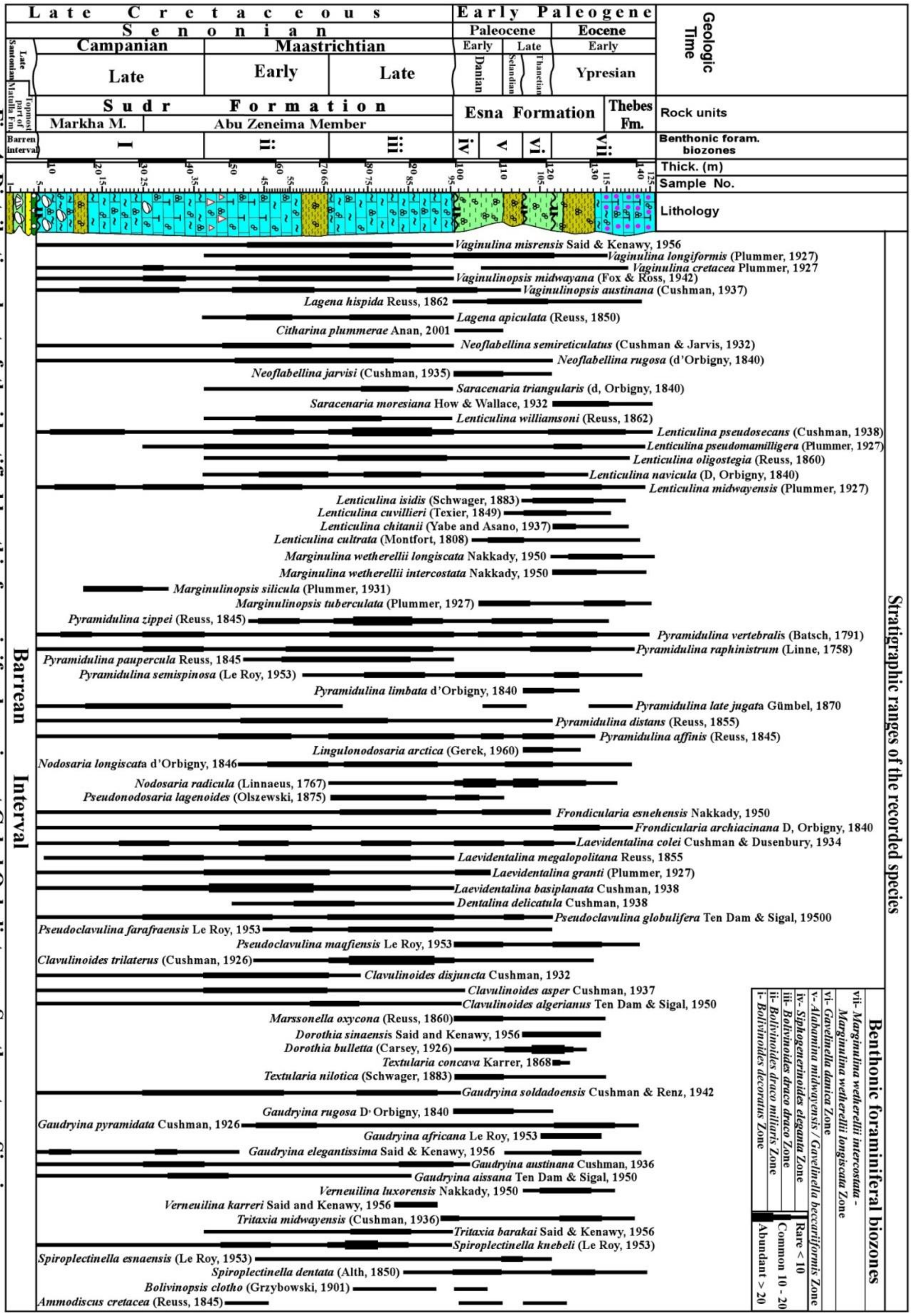
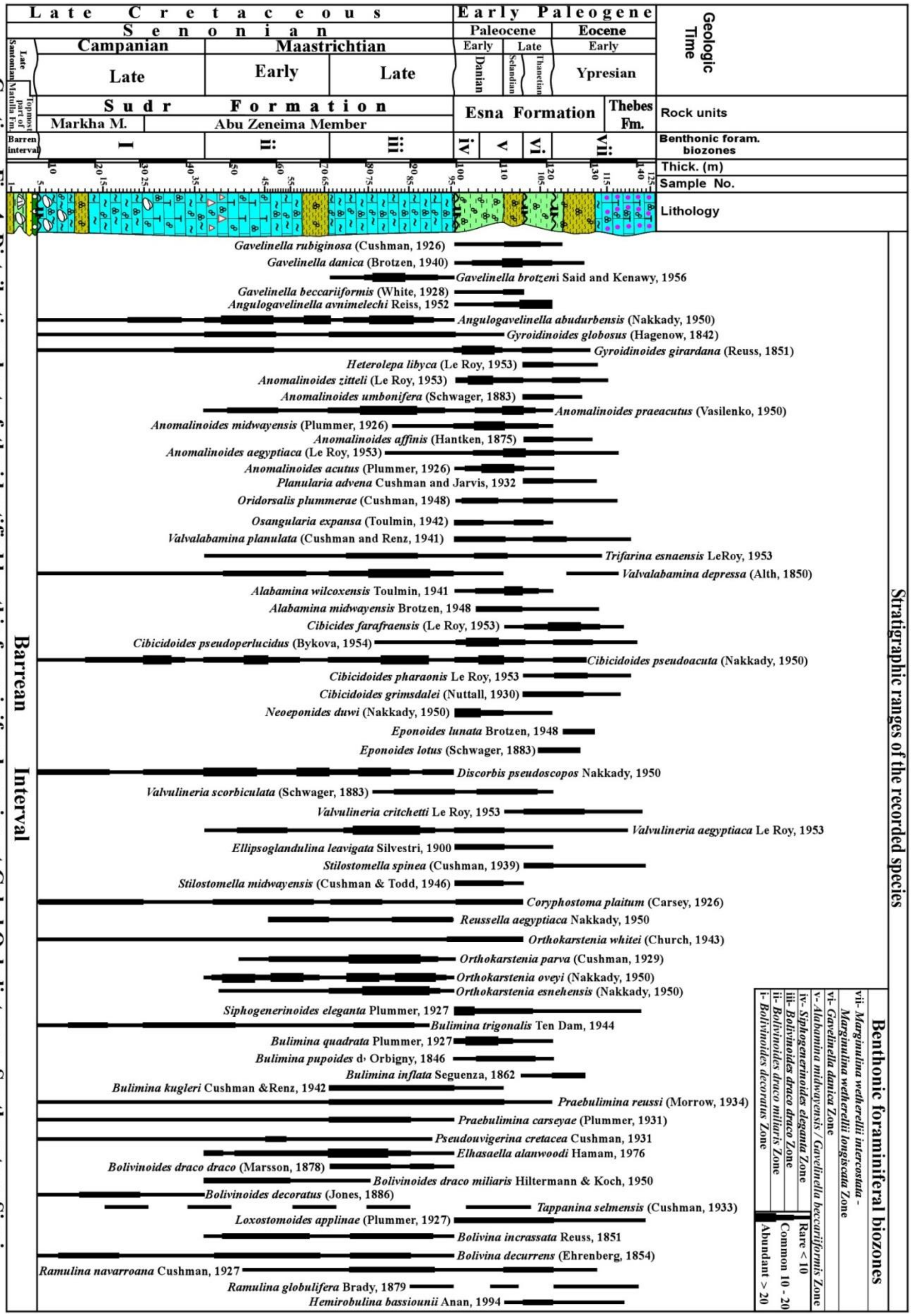
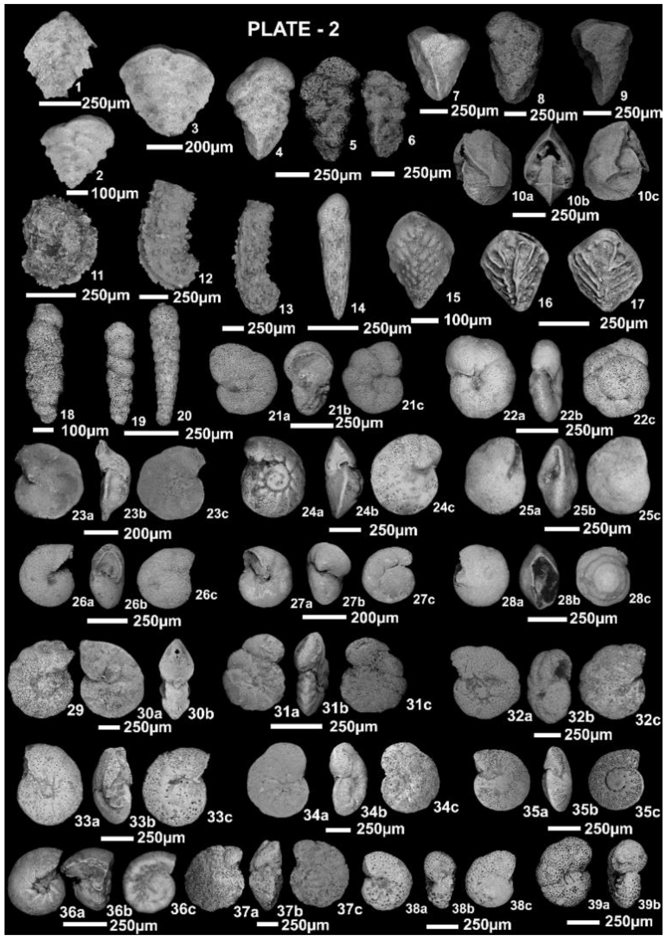


Fig. 4: Distribution chart of the identified benthic foraminiferal species at Gabal Qabeliat area, Southwestern Sinai.



Continue Fig. 4: Distribution chart of the identified benthic foraminiferal species at Gabal Qabeliat area, Southwestern Sinai.



(Explanation of PLATE – 2)

(The dominated recorded benthonic foraminiferal species)

1: ***Spiroplectinella dentata*** **(Alth, 1850),** sample 98, Esna Fm.; **2:** ***Spiroplectinella esnaensis*** **(Le Roy, 1953),** sample 100, Esna Fm.; **3:** ***Spiroplectinella knebeli*** **(Le Roy, 1953),** sample 90, Sudr Fm.; 4: *Gaudryina africana* Le Roy, 1953, sample 115, Esna Fm.; 5: *Gaudryina aissana* Ten Dam & Sigal, 1950, sample 25, Sudr Fm.; **6:** ***Gaudryina elegantissima*** **Said & Kenawy, 1956,** sample 30, Esna Fm.; **7:** ***Gaudryina pyramidata*** **Cushman, 1926,** sample 60, Esna Fm.; **8:** ***Gaudryina rugosa*** **D, Orbigny, 1840,** sample 98, Esna Fm.; **9:** ***Gaudryina soldadoensis*** **Cushman and Renz, 1942,** sample 97, Esna Fm.; **10:** ***Lenticulina midwayensis*** **(Plummer, 1927),** sample 75, Esna Fm.; **11:** ***Marginulinopsis tuberculata*** **(Plummer, 1927),** sample 100, Esna Fm.; **12:** ***Marginulina wetherellii intercostata*** **Nakkady, 1950,** sample 110, Esna Fm.; **13:** ***Marginulina wetherellii longiscata*** **Nakkady, 1950,** sample, 112, Esna Fm.; **14:** ***Loxostomoides applinae*** **(Plummer, 1927),** sample 105, Esna Fm.; **15:** ***Bolivinoides decoratus*** **(Jones, 1886),** sample 30, Sudr Fm.; **16:** ***Bolivinoides draco draco*** **(Marsson, 1878),** sample 65, Sudr Fm.; **17:** ***Bolivinoides draco miliaris*** **Hiltermann & Koch, 1950,** sample 94, Sudr Fm.; **18:** ***Elhasaella alanwoodi*** **Hamam, 1976,** sample 75, Sudr Fm.**19:** ***Siphogenerinoides eleganta*** **Plummer, 1927,** sample 97, Esna Fm.; **20:** ***Orthokarstenia oveyi*** **(Nakkady, 1950),** sample 90, Sudr Fm.; **21a-c:** *Valvulineria scorbiculata* (Schwager, 1883), sample 103, Esna Fm.; **22:** ***Discorbis pseudoscopos*** **Nakkady, 1950,** sample 92, Sudr Fm.; **23:** ***Cibicidoides pharaonis*** **Le Roy, 1953,** sample 108, Esna Fm.; **24:** ***Cibicidoides pseudoacuta*** **(Nakkady, 1950),** sample 100, Esna Fm.; **25:** ***Alabamina midwayensis*** **Brotzen, 1948,** sample 102, Esna Fm.; **26:** ***Valvalabamina depressa*** **(Alth, 1850),** sample 97, Esna Fm.; **27:** ***Valvalabamina planulata*** **(Cushman and Renz, 1941),** sample 104, Esna Fm.; **28:** ***Oridorsalis plummerae*** **(Cushman, 1948),** sample 129, Esna Fm.; **29&30:** ***Anomalinoides acutus*** **(Plummer, 1926),** sample 97, Esna Fm.; **31:** ***Anomalinoides aegyptiaca*** **(Le Roy, 1953),** sample 102, Esna Fm.; **32:** ***Anomalinoides affinis*** **(Hantken, 1875),** sample 105, Esna Fm.; **33:** ***Anomalinoides praeacutus*** **(Vasilenko, 1950),** sample 102, Esna Fm.; **34:** ***Anomalinoides zitteli*** **(Le Roy, 1953),** sample 100, Esna Fm.; **35:** ***Heterolepa libyca*** **(Le Roy, 1953),** sample 126, Esna Fm.; **36:** ***Gyroidinoides girardana*** **(Reuss, 1851),** sample 100, Esna Fm.; **37:** ***Angulogavelinella abudurbensis*** **(Nakkady, 1950),** sample 80, Sudr Fm.; **38:** ***Gavelinella beccariiformis*** **(White, 1928),** sample 102, Esna Fm.; **39:** ***Gavelinella danica*** **(Brotzen, 1940),** sample 105, Esna Fm.

The recorded *Siphogenerinoides eleganta* zone is equivalent to the middle part of: *Bolivinoides delicatulus* Zone of north Sinai (Said & Kenawy, 1956), west Sinai (Shahin, 1988); *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 *Lagena hispida/ Spiroplectammina dentata* of west - Central Sinai (Ismail, 1992); *Siphogenerinoides eleganta* Zone of Sinai (El-Deeb & El-Gammal, 1994); *Angulogavelinella rubiginosus* Zone of Sinai (Khalil, 2001; Khalil & Meshaly, 2004), *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); and also, the upper part of *Vulvulina colei* Zone of Egypt (El-Gammal & Hamad, 2015).

The most important benthonic foraminiferal species recorded from this zone are: *Ammobaculites expansus* Plummer, *Spiroplectinella dentata* (Alth), *Spiroplectinella esnaensis* (Le Roy), *Gaudryina rugosa* d'Orbigny, *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides acutus* (Plummer), *Anomalinoides zitteli* (Le Roy), *Anomalinoides aegyptiaca* (Le Roy), *Lenticulina midwayensis* (Plummer), *Loxostomoides applinae* (Plummer), *Siphogenerinoides eleganta* Plummer, *Orthokarstenia whitei* (Church), *Valvulineria scorbiculata* (Schwager), *Cibicidoides pseudoacuta* (Nakkady), *Valvalabamina depressa* (Alth), *Valvalabamina planulata* (Cushman and Renz), *Oridorsalis plummerae* (Cushman), *Gyroidinoides girardana* (Reuss), *Angulogavelinella avnimelechi* Reiss, *Gavelinella rubiginosa* (Cushman), *Gavelinella danica* (Brotzen) and *Gavelinella beccariiformis* (White).

3.2.5. *Alabamina midwayensis/ Gavelinella beccariiformis* Zone:

This biozone is defined as a biostratigraphic interval, extended from the first appearance of *Alabamina midwayensis* Brotzen, at the base to the last appearance of *Gavelinella beccariiformis* (White), at the top. At Gebel Qabeliat section, the *Alabamina midwayensis/ Gavelinella beccariiformis* Zone is recorded from the middle part of the Esna Formation (Samples 99-103), and it attains about 11m. It is assigned to late Early Paleocene (Late Danian) to early Late Paleocene (Selandian) age as it is correlated with *Praemurica uncinata* (P2), and *Morozovella angulata* (P3a) planktonic biozones.

In the study area, the top of the *Alabamina midwayensis/ Gavelinella beccariiformis* Zone is used to placement the Selandian/Thanetian (S/Th) boundary.

This zone is equivalent to combined 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); *Alabamina midwayensis* Zone of Egypt (El-Gammal & Hamad, 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); *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); *Angulogavelinella rubiginosus* Zone of Sinai (Khalil, 2001; Khalil & Meshaly, 2004).

The most important benthonic foraminiferal species recorded from this zone include: *Spiroplectinella esnaensis* (Le Roy), *Spiroplectinella dentata* (Alth), *Gaudryina rugosa* d'Orbigny, *Gaudryina elegantissima* Said & Kenawy, *Gaudryina soldadoensis* Cushman and Renz, *Gaudryina pyramidata* Cushman, *Marginulinopsis tuberculata* (Plummer), *Lenticulina midwayensis* (Plummer), *Loxostomoides applinae* (Plummer), *Valvulineria aegyptiaca* Le Roy, *Valvulineria scorbiculata* (Schwager), *Siphogenerinoides eleganta* Plummer, *Orthokarstenia whitei* (Church), *Cibicidoides pseudoacuta* (Nakkady), *Alabamina midwayensis* Brotzen, *Valvalabamina planulata* (Cushman and Renz), *Oridorsalis plummerae* (Cushman), *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides acutus* (Plummer), *Anomalinoides zitteli* (Le Roy), *Anomalinoides aegyptiaca* (Le Roy), *Gyroidinoides girardana* (Reuss), *Gyroidinoides globosus* (Hagenow), *Angulogavelinella avnimelechi* Reiss, *Gavelinella rubiginosa* (Cushman) *Gavelinella danica* (Brotzen), and *Gavelinella beccariiformis* (White).

3.2.6. *Gavelinella danica* Zone:

This biozone is defined as a biostratigraphic interval, extended from the last appearance of *Gavelinella beccariiformis* (White), at the base to the first appearance of *Marginulina wetherellii intercostata* and *Marginulina wetherellii longiscata* at the top. At Gebel Qabeliat section, the *Gavelinella danica* Zone is recorded from the lower upper part of the Esna Formation (Samples 104-106), and it attains about 6m. It is assigned to Latest Paleocene (Latest Thanetian) age as it is correlated with *Morozovella velascoensis* (P5) planktonic biozone. In the present study, the Selandian/Thanetian (S/ Th) boundary is cited on the base of the *Gavelinella danica* Zone; while the top of this biozone is used to place of the Paleocene/Eocene (P/E) boundary.

This biozone is equivalent to the uppermost part of both: *Bulimina farafraensis* Zone of Farafra Oasis (Le Roy, 1953); *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); *Loxostomoides applinae- Frondicularia phosphatica* Zone of Sinai (Khalil, 2001), *Loxostomoides applinae* Zone of Gabal Musaba Salama (Khalil& Meshaly, 2004); the lower most part of *Loxostomoides applinae / Spiroplectammina dentata* Zone of west-central Sinai (Ismail, 1992); *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 & Hamad, 2015).

The most important benthonic foraminiferal species recorded from this zone include: *Ammobaculites expansus* Plummer, *Ammobaculites subcretaceus* Cushman & Alexander, *Spiroplectinella esnaensis* (Le Roy), *Spiroplectinella dentata* (Alth), *Gaudryina elegantissima* Said & Kenawy, *Gaudryina rugosa* d'Orbigny, *Gaudryina pyramidata* Cushman, *Marginulinopsis tuberculata* (Plummer), *Valvulineria scorbiculata* (Schwager), *Cibicidoides pseudoacuta* (Nakkady), *Loxostomoides applinae* (Plummer), *Lenticulina midwayensis* (Plummer), *Siphogenerinoides eleganta* Plummer, *Cibicidoides pharaonis* Le Roy, *Alabamina midwayensis* Brotzen, *Alabamina wilcoxensis* Toulmin, *Valvalabamina planulata* (Cushman and Renz), *Oridorsalis plummerae* (Cushman), *Anomalinoides affinis* (Hantken), *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides midwayensis* (Plummer), *Anomalinoides acutus* (Plummer), *Anomalinoides zitteli* (Le Roy), *Anomalinoides aegyptiaca* (Le Roy), *Heterolepa libyca* (Le Roy), *Gyroidinoides girardana* (Reuss), *Angulogavelinella abudurbensis* (Nakkady), *Angulogavelinella avnimelechi* Reiss, *Gavelinella rubiginosa* (Cushman) and *Gavelinella danica* (Brotzen).

3.2.7. *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* Zone:

At Gebel Qabeliat section, this biozone is defined as a biostratigraphic interval represented by total range of the nominate taxa. It is recorded from the topmost part of the Esna Formation and continued throughout the measured part of the Thebes Formation (Samples 107-125), and it attains about 22m. It is assigned to Earliest Eocene (Earliest Ypresian) to Early Eocene (Ypresian) age as it is correlated with *Pseudohastigerina wilcoxensis / Morozovella velascoensis* (E2), *Morozovella marginodentata* (E3), *Morozovella formosa formosa* (E4), and *Morozovella aragonensis /Morozovella subbotinae* (E5) planktonic biozones.

At the studied section, the Paleocene/Eocene (P/E) boundary is cited on the base of the *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* Zone. 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*., 1999; Zachos *et al*., 1993; Molina *et al*., 1999; Aubry *et al.*, 2003; Ouda, 2003; Berggren & Ouda, 2003; Ouda *et al.,* 2003 Hamad, 2009; and Orabi & Zaky, 2016) due to deep sea environmental changes (Thomas, 1998 & 2003; Spijer & Morsi, 2002; Alegret & Ortiz, 2006; Alegret *et al*., 2009). So, this boundary at Gebel Qabeliat section, 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* Nakkady and *Heterolepa libyca* (Le Roy) and others.

On the other hand, this biozone is equivalent to *Eponoides lotus* Zone of Farafra Oasis (Le Roy, 1953); *Marginulina wetherellii intercostata* Zone of El Qusaima area, north-east Sinai, Egypt (Hewaidy, 1987); *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).

The most important benthonic foraminiferal species recorded from this Zone include: *Spiroplectinella dentata* (Alth), *Gaudryina africana* (Le Roy),*Gaudryina pyramidata* Cushman, *Gaudryina elegantissima* Said & Kenawy, *Lenticulina midwayensis* (Plummer), *Marginulinopsis tuberculata* (Plummer), *Marginulina wetherellii longiscata* Nakkady, *Marginulina wetherellii intercostata* Nakkady, *Pseudoclavulina maqfiensis* Le Roy, *Loxostomoides applinae* (Plummer), *Bulimina inflata* Seguenza, *Siphogenerinoides eleganta* Plummer, *Stilostomella spinea* (Cushman), *Valvulineria aegyptiaca* Le Roy, *Valvulineria critchetti* Le Roy, *Cibicidoides pseudoacuta* (Nakkady), *Cibicidoides pharaonis* Le Roy, *Alabamina midwayensis* Brotzen, *Valvalabamina depressa* (Alth), *Valvalabamina planulata* (Cushman and Renz), *Oridorsalis plummerae* (Cushman), *Planularia advena* Cushman and Jarvis, *Anomalinoides affinis* (Hantken), *Anomalinoides zitteli* (Le Roy), *Anomalinoides aegyptiaca* (Le Roy), *Heterolepa libyca* (Le Roy), *Gyroidinoides girardana* (Reuss) and *Gavelinella danica* (Brotzen).

The vertical distribution charts of the identified benthonic foraminiferal species with their equivalent zones and suggested ages at the studied section are illustrated on **(Fig. 4).**

4. Paleoecology and Sequence stratigraphy

4.1. Paleobathymetry:

The foraminiferal distribution is a function of the water depth available over the shelf during any particular interval (Hart & Bailey, 1979), because the foraminifera are very sensitive to change in the various ecological parameters (Berggren & Aubert, 1975; Van der Zwaan *et al*., 1990; and Leckie & Olsson, 2003). So, the integration between the lithologic characters and the quantitative analysis 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 Upper Campanian- Lower Eocene sequence at Gebel Qabeliat area. This depends mainly on studying the most important paleoecological factors, such as: the total number of foraminiferal species, the species diversity, the statistical analysis of planktonic forams (heterohelicids, non-keeled, and keeled), the statistical analysis of benthonic forams (agglutinated and calcareous), the planktonic/benthonic ratio (P/B %), and the agglutinated/ calcareous (Aggl./Calc.) ratio. The following is the discussion of the most important paleoecological parameters of foraminifera, which are used in interpretation of the paleoenvironmental conditions prevailed during the deposition of the studied rock units:

4.1. 1. Total number of foraminifera:

The total number of foraminiferal individuals generally increases with increasing the water depth. In the present study, the average total number of foraminifera in the rock samples varies greatly from very low (of about 30 individuals) to very high (of about 1105 individuals) reflecting greatly changes in the depositional environments.

4.1. 2. Diversity (species richness):

The diversity of foraminiferal species (total number of the recorded species at the sample) is controlled by the nutrient availability. So, it generally decreases toward the shore and increases with increasing depth from the near shore to the outer shelf depth, then decreases or remains the same on the continental slope, finally it increases in the abyssal realm (Bandy, 1953; Bandy & Arnal, 1960; Gibson & Buzas, 1973; Abd El Kireem, 1983; and Olsson & Nyong, 1984). In the present study, the species diversity varies greatly from low to very high, reflecting comparable change in the depositional environments.

4.1. 3. Analysis of dominant planktonic forams:

Douglas & Sliter, 1966 pointed out that, the deep water generally dominated by keeled planktonic foraminiferal assemblages; while both the heterohelicids and non-keeled forams are less common. In the present study, the ratio of the dominant planktonic forams (heterohelicids, non-keeled and keeled) varies greatly, reflecting changes in the water depth.

4.1. 4. Benthonic genus or genera predominance:

The benthonic foraminifera are considered as evidences on the base of the sedimentary basin, due to their restriction with the environment. So, in the present study, we traced the benthonic genus or genera predominance, which means the genus or genera that comprise the highest proportion of benthic population (Poage, 1984), and we noted that, the most dominant recorded benthonic genera are changed greatly along the studied rock units, reflecting fluctuation in their depositional environments.

4.1. 5. Planktonic / Benthonic ratio (P/B %):

It is expressed as P X 100/ (P+B); where P is the total number of the planktonic individuals and (B) is the total number of the benthonic individuals in the studied sample. This tool is considered as a very useful tool in determining the paleodepth (Van der Zwaan *et al*., 1990). According to Premoli Silva & Bolli, 1973, the planktonic/benthonic ratio has low value in the shallow marine waters and generally increases with increasing the water depth until the carbonate compensation depth (CCD). This ratio is considered to depend on the relative difference between the abundance of planktonic species, which is the highest in open oceanic environments, and the number of benthonic foraminifera, which is higher in the neritic environments than in the deeper oceanic ones (Phleger, 1964; Reiss et al.,1974; Gibson, 1989; and Van der Zwaan *et al*., 1990). Olsson & Nyong, 1984, pointed out that, the inner shelf (10-50m depth) is marked by low planktonic percentages (1-5%), with low species diversity and high benthonic percentages with higher species diversity; the middle shelf (50-100m depth) is characterized by 8-25% planktonic foraminifera; the outer shelf (100-200m depth) is marked by 30-70% planktonic foraminifera; where the continental slopes (200-800 depth) are characterized by 90% of the planktonic foraminiferal assemblages. In the present study, the P/B% greatly varies from 12 to 85%, this reflects fluctuation in the paleoenvironments from middle shelf to bathyal environments.

4.1. 6. Agglutinated/Calcareous benthic ratio (Agg. / Cal. %):

According to Saint-Marc, 1986 the agglutinated/calcareous benthic ratio (Agg./ Cal.%) is generally decreases with increasing depth. In the present study, the agglutinated/calcareous benthic ratio varies from low to high, reflecting greatly changes in the paleodepth of the proposed depositional environments. The detailed quantitative foraminiferal counting and the paleoecological parameters are carried out for one gram of the washed residue from all the collected rock samples and the suggested prevailed paleoenvironments are discussed in detail **(Fig. 5).**

4.2. Depositional sequences:

The sequence stratigraphy has been approved to be a useful tool in correlating and interpreting the depositional systems in the space and time. So, the establishing of sequence stratigraphic framework for the studied Upper Campanian – Lower Eocene succession, at Gebel Qabeliat, provides an interpretation for the observed vertical facies change and compare with the global sea level chart. In the present study, the sequence stratigraphic classification of the Upper Campanian –Lower Eocene (Ypresian) successions that exposed at Gabal Qabeliat area, is based on the lithologic characters, detailed field examination for the stratigraphic surfaces and the detailed examination of the included foraminiferal contents. Planktonic foraminifera is a useful fossil group for the high resolution age dating, as they have distinct and rapid morphological changes over time, in addition to their wide geographic distribution. The age and paleoenvironmental contrast, indicated by the foraminiferal assemblages above and below the boundary, are both a function of the magnitude of relative sea-level fall. Gabal Qabeliat area occupies a critical site, which was subjected to some tectonic events. These events were accompanied with pronounced sea level changes, through the Late Campanian – Early Eocene (Ypresian) time and were resulted some complicated structures, and affected the rock units distributed in this region. The construction of the sequence stratigraphic framework, of the Upper Campanian –Lower Eocene (Ypresian) successions in Gabal Qabeliat area is used, to explain the observed lateral and vertical facies variability, as well as to detect the sequence boundaries. The relationships of these sequences and sequence boundaries are correlated with the global sea level changes. The facies distribution, faunal contents and stratal geometry permit the identification of four third-order depositional sequences bounded by four type-1 sequence boundaries in the Upper Campanian –Lower Eocene (Ypresian) successions, exposed in the study area, reflecting four depositional cycles in the relative sea level change, during this time interval **(Fig. 6)**. These four depositional sequences are classified into their systems tracts, according to their depositional trends and the behavior of the sea level during every depositional cycle. Each sequence consists of a package of conformable sedimentary succession and bounded by two sequence boundaries. It is divided into lowstand system tract (LST), transgressive system tract (TST), and highstand system tract (HST). Due to the fast relative sea level rise over the study area, the lowstand system tract is missing nearly in all the identified depositional sequences, and the lower sequence boundaries match with the transgressive surface, that marks the base of the overlying transgressive systems tract (TST) in these distinguished sequences. The type-1 sequence boundaries are associated with the vertical borings, incised valley fill deposits, dolomitization, biozonal lack and predominantly abrupt facies changes at the base of the transgressive system tracts. The detailed description of the recorded depositional sequences and their bounding unconformity surfaces are discussed below and arranged from older to younger, as follows:

4.2. 1. The first sequence boundary (SB1):

This sequence boundary **(SB1)** is cited at the Upper Santonian **/** Upper Campanian boundary and it coincides with the Matulla /Sudr formational boundary in the study area. It is easily recognized in the field, as it represented by sharp contact and separates the mixed siliciclastic / carbonate sediments (fossiliferous shale intercalated with marl, coarse-grained sandstone and conglomerate) of the topmost part of Matulla Formation below, from the overlying transgressive carbonate facies (hard, creamy argillaceous and fossiliferous limestone, with numerous banks of the large oyster *Pycnodonte vesicularis* (Lamarck)) intercalated with marl, grades into soft argillaceous limestone) of the lower part of Sudr Formation (Markha Member) above. It is also represented by unconformity surface, due to the absence of Lower Campanian, where the underlying measured uppermost portion of the Matulla Formation contains oysters of Lower Santonian age such as *Plicatula ferryi* (Coquand), while it is completely devoid of any foraminiferal assemblages and most likely primarily denotes the effect of the major fall in eustatic sea level, that characterizes the end of the Santonian (Miller *et al.*, 1982; Haq *et al.*, 1987; and Hardenbol *et al.*, 1998). On the other hand, the overlying lower part of the Sudr Formation (Markha Member) contains foraminiferal assemblages of late Campanian age.

In Egypt, this sequence boundary (Sa. / Ca.) coincides with the Matulla / Sudr formational boundary. It was observed by various authors in Sinai (e.g. Lüning *et al*., 1998; El-Azabi & El-Araby, 2000; Obaidallah & Kassab, 2002; and Faris &Farouk, 2012), based on the obvious facies and paleontological changes. On the other hand, the regional nature of the Santonian / Campanian hiatus is exemplified by its occurrence in various wells in the northern part of the Western Desert of Egypt (Abdel-Kireem *et al*., 1994), as well as in outcrops from the Bahariya Oases (Khalifa *et al.*, 2002a) and El Qusaima area, Northeast Sinai (Hewaidy *et al.*, 1993). This sequence boundary (SB1), in the present study may, be correlated with the unconformity surface recorded by Hermina, 1990 at the Duwi/Dakhla formational boundary at both Kharga and Abu Tartur areas.

4.2. 2. Depositional sequence-1(DS1):

It represents the oldest depositional sequence in the studied interval. This depositional sequence (DS1) comprises the whole Sudr Formation. It is bounded at base by the first sequence boundary (SB1) and topped by the second sequence boundary (SB2). This depositional sequence is classified into a transgressive system tract (TST1) at the base and a highstand system tract (HST1) at the top; while the basal lowstand system tract is missing due to the fast relative sea level rise over the study area and the transgressive surface coincides with the sequence boundary (SB1).

4.2. 2. 1. Transgressive system tract- 1 (TST1):

At Gebel Qabeliat section, this transgressive system tract (TST1) lies directly above the sequence boundary (SB1) and it attains about 80 m thick. It comprises both the whole Markha Member, in addition to the lower, middle and the lower upper parts of Abu Zeneima Member. It covers the interval of the Latest Campanian *Globotruncanella havanensis* (=CF9), and *Globotruncana aegyptiaca* (CF8a) zones; the Early Maastrichtian *Rugoglobigerina hexacamerata* (CF8b), *Gansserina gansseri* (CF7), *Contusotruncana contusa* (CF6), and *Pseudotextularia intermedia* (CF5) planktonic biozones; in addition to the Late Maastrichtian *Racemiguembelina fructicosa* (CF4), and *Pseudoguembelina hariaensis* (CF3) planktonic biozones. It also comprises *Bolivinoides decoratus*, *Bolivinoides draco miliaris* and the lower part of *Bolivinoides draco draco* benthonic biozones. It is represented by retro-gradational parasequence sets of alternating deep inner to middle neritic argillaceous and fossiliferous limestone, middle to shallow outer neritic fossiliferous argillaceous limestone, deep outer neritic soft argillaceous limestone and chalky limestone, intercalated with thin fossiliferous marl, and upper to middle bathyal argillaceous limestone.

In the present study, this transgressive system tract (TST1) is classified into three stages early, middle and late:

The **early stage** of transgressive systems tract (ETST1) represents the lower part of Sudr Formation (Markha Member) at Gebel Qabeliat section and it lies directly above the sequence boundary (SB1). It covers the interval of the *Globotruncanella havanensis* (=CF9) planktonic Zone and also the lower part of *Bolivinoides decoratus* benthonic Zone of Late Campanian age. It attains about 23 m thick. It is represented by retro-gradational parasequence sets of alternating deep inner to shallow middle neritic argillaceous and fossiliferous limestone. This interval is characterized by the presence of numerous banks of the large oyster *Pycnodonte vesicularis* (Lamarck) (shallow dweller). It also marked by a low total foraminiferal number of an average of 305 individuals; a low P/B ratio of an of an average of 20 %; a low planktonic foraminiferal number of an average of 58 individuals; of these planktonics about 80-65% are heterohelicids, 15-10 % are non-keeled and **5-25 %** are keeled forms. It is also characterized by a high benthonic foraminiferal ratio of an average of 80% and a high Aggl. / Calc. ratio of an average of **65%**. On the other hand, the benthonic foraminiferal fauna of this interval is dominated mainly by inner to middle neritic species such as: *Lenticulina midwayensis* (Plummer) and *Discorbis pseudoscopos* Nakkady, according to (Berggren, 1974a; Hewaidy, 1994; and El-Dawy & Hewaidy, 2003). So, a deep inner to shallow middle neritic environment was prevailed during the deposition of (ETST1).

The **middle stage** of this transgressive system tract (MTST1) comprises the lower and middle parts of Abu Zeneima Member. It attains about 40 m thick (samples 26-66), and it covers the interval of the Latest Campanian *Globotruncana aegyptiaca* (CF8a), the Early Maastrichtian *Rugoglobigerina hexacamerata* (CF8b), *Gansserina gansseri* (CF7), *Contusotruncana contusa* (CF6), *Pseudotextularia intermedia* (CF5) planktonic biozones, and also the upper part of *Bolivinoides decoratus* benthonic Zone of Latest Campanian age in addition to *Bolivinoides draco miliaris* benthonic Zone of Early Maastrichtian age. According to the statistical analysis of the used paleoecological parameters, this (MTST1) is subdivided into two paleoenvironmental (Ecozones) units, from base to top:

The lower part of this (MTST1) includes the basal part of the Abu Zeneima Member. It attains about 12m thick (samples 26-36). It covers the interval of *Globotruncana aegyptiaca* (CF8a), and also the upper part of *Bolivinoides decoratus* benthonic Zone of Latest Campanian age. It is represented by retro-gradational parasequence sets of deep middle to shallow outer neritic fossiliferous argillaceous limestone. This interval is characterized by the presence of large oyster bank in its lower part as represented mainly by *Pecten farafraensis* (Zittel). Also, the results of the statistical analysis for this part of Abu Zeneima Member are characterized by a relatively low total foraminiferal number of an average of 430 individuals; a relatively high diversity of an average of 75 species; a medium P/B ratio of an average of 60 %; a medium planktonic foraminiferal number of an average of 256 individuals; of these planktonics 50 % are heterohelicids, 40 % are non-keeled and 10 % are keeled forms. It is also characterized by a medium benthonic foraminiferal ratio of an average of 40%; and a relatively high Aggl./ Calc. ratio of an average of 60%. On the other hand, the benthonic foraminiferal fauna of this interval is dominated mainly by middle neritic to bathyal species, such as: *Cibicidoides pseudoacuta* (Nakkady), *Valvalabamina depressa* (Alth), *Gaudryina spp.* (e.g.: *Gaudryina aissana* Ten Dam & Sigal, *Gaudryina soldadoensis* Cushman and Renz, *Gaudryina elegantissima* Said & Kenawy, *Anomalinoides praeacutus* (Vasilenko), and *Gyroidinoides girardana* (Reuss), according to (Speijer, 1994; Speijer & Schmitz, 1998; El-Dawy & Hewaidy, 2003; and Sprong *et al*., 2012). These results suggest a rise in the relative sea level which indicates a transgressive phase and middle to shallow outer neritic environment was prevailed during the deposition of lower part of (MTST1).

On the other hand, the upper part of this (MTST1) comprises the middle part of Abu Zeneima Member. It covers the interval of the Early Maastrichtian *Rugoglobigerina hexacamerata* (CF8b), *Gansserina gansseri* (CF7), *Contusotruncana contusa* (CF6), and *Pseudotextularia intermedia* (CF5) planktonic biozones, and also *Bolivinoides draco miliaris* benthonic Zone of Early Maastrichtian age. It attains about 28 m thick (samples 37-66). It is represented by retro-gradational parasequence of deep outer neritic soft argillaceous limestone and chalky limestone, intercalated with thin fossiliferous marl. The results of the statistical analysis for this interval is characterized by a high total foraminiferal number of an average of 660 individuals; a high diversity of an average of 95 species; a high P/B ratio of an average of 68 %; a high planktonic foraminiferal number of an average of 460; of these planktonics 37% are heterohelicids, 30 % are non-keeled and 33 % are keeled forms. It is also characterized by a relatively low benthonic foraminiferal ratio of an average of 32%; and a relatively low Aggl. / Calc. ratio of an average of 42.5%. On the other hand, the benthonic foraminiferal fauna of this interval are dominated mainly by middle neritic to bathyal species, such as: *Valvalabamina depressa* (Alth), *Anomalinoides praeacutus* (Vasilenko), *Gaudryina aissana* Ten Dam & Sigal, *Gaudryina soldadoensis* Cushman and Renz, *Gaudryina pyramidata* Cushman), *Cibicidoides pseudoacuta* (Nakkady), and *Gyroidinoides girardana* (Reuss), according to (Speijer, 1994; Speijer & Schmitz, 1998). These characters indicate a continuity of rising in the relative sea level which indicates a transgressive phase and a deep outer neritic environment was prevailed during the deposition of the upper part of (MTST1).

The **late stage** of this transgressive system tract (LTST1) is represented by the lower upper part of Abu Zeneima Member at Gebel Qabeliat section, that attains about 17 m thick (samples 67-85). It comprises the *Racemiguembelina fructicosa* (CF4) and *Pseudoguembelina hariaensis* (CF3) planktonic biozones, and also the lower part of *Bolivinoides draco draco* benthonic Zone of Late Maastrichtian age. It is represented by retro-gradational parasequence sets of an upper to middle bathyal argillaceous limestone. The results of the statistical analysis for this ecozone are characterized by a very high total foraminiferal number of an average of 920 individuals; a very high diversity of an average of 115 species; very high P/B ratio of an average of 80%; a very high planktonic foraminiferal number of an average of 785 individuals; of these planktonics 12% are heterohelicids, 11 % are non-keeled and 77 % are keeled forms. It is also characterized by a very low benthonic foraminiferal ratio of an average of 20%; and a relatively low Aggl. / Calc. ratio of an average of 35%. On the other hand, the benthonic foraminiferal fauna of this interval is dominated mainly by outer neritic to bathyal species, such as: *Angulogavelinella abudurbensis* (Nakkady), *Spiroplectinella esnaensis* (Le Roy), *Spiroplectinella knebeli* (Le Roy), according to (Speijer, 1994; Speijer & Schmitz, 1998; El-Dawy & Hewaidy, 2003; and Sprong *et al*., 2012). These suggest a continuity of rising in the relative sea level which indicates a transgressive phase, and an upper to middle bathyal environment was prevailed during the deposition of the late stage of this transgressive system tract (LTST1).

4.2. 2. 2. Maximum flooding surface-1 (MFS1):

The maximum flooding surface (MFS1) in this depositional sequence (DS1) lies on the top of the Late Maastrichtian *Pseudoguembelina hariaensis* (CF3) Zone, as it acts the Acme of this transgressive phase within this depositional sequence (DS1), based on the planktonic foraminiferal ratio and on the dominant planktonic and benthonic species.

4.2. 2. 3. Highstand system tract-1 (HST1):

This (HST1) represents the topmost part of Abu Zeneima Member at Gebel Qabeliat section and it attains about 11 m thick (samples 86 - 95). It comprises the *Pseudoguembelina palpebera* (CF2), and *Plummerita hantkeninoides* (CF1) planktonic zones, and also the upper part of *Bolivinoides draco draco* benthonic Zone of the Latest Maastrichtian age. It is represented by pro-gradational parasequence sets of middle to shallow outer neritic pale grey soft argillaceous limestone. The analysis of the foraminiferal contents showed that, this (HST1) is characterized by a relatively high total foraminiferal number of an average of 685 individuals; a relatively high diversity of an average of 85 species; a medium P/B ratio of an average of 51.5 %; a relatively medium planktonic foraminiferal number of an average of 360 individuals; of these planktonics 45% are heterohelicids, 23 % are non-keeled and 32 % are keeled forms. It is also characterized by a medium benthonic foraminiferal ratio of an average of 48.5 %; and a relatively high Aggl. / Calc. ratio of an average of 66 %. On the other hand, this interval is marked 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 marker for the shallow outer depth Zone (about 100-150m). Moreover, the benthonic foraminiferal fauna of this interval is dominated mainly by inner to middle neritic species such as: *Elhasaella alanwoodi* Hamam, *Orthokarstenia oveyi* (Nakkady), *Lenticulina midwayensis* (Plummer), and *Discorbis pseudoscopos* Nakkady; in addition to some middle to outer neritic species such as: *Valvulineria scorbiculata* (Schwager), according to (Berggren, 1974a; Hewaidy, 1994; and El-Dawy & Hewaidy, 2003). These characters indicate middle to shallow outer neritic environment was prevailed during the deposition of this interval, representing a regressive phase of the sea level, as indicated from the abrupt change in the results of the analysis for its foraminiferal assemblages.

The correlation of the relative sea-level curve for the Latest Campanian - Maastrichtian succession at Gabal Qabeliat area, Southwestern Sinai with those previously applied by some authors inside/ outside Egypt is illustrated in **(Fig. 7).**

4.2. 3. The second sequence boundary (SB2):

At Gebel Qabeliat section, this sequence boundary (SB2) is represented by the Cretaceous/ Paleogene ($K/P_{g.}$) boundary and it coincides on the Sudr/Esna formational boundary. It is easy to determine in the field, due to the abrupt facies change from snow white chalky and argillaceous limestone of the uppermost part of Sudr Formation below, to the overlying dark green shale of the lower part of Esna Formation above. This sequence boundary (SB2) is represented by a sedimentary hiatus (Hiatus-1) in the studied sedimentary succession, as indicated from the foraminiferal investigation and this was accompanied by abrupt change in the sedimentation across this boundary at the studied section. This hiatus is located at the change from the Latest Maastrichtian argillaceous limestones of the topmost part of Sudr Formation with *Plummerita hantkeninoides* (CF1) Zone below and the Middle to Late Danian dark grey to green shale of the lower part of Esna Formation, with *Praemurica trindadensis* Zone (P1d) above. Also, this sequence boundary is marked by a noticeable change in the benthonic foraminiferal species, due to the Uppermost Maastrichtian shallowing of the sea, as represented by extinction of some species that are characteristic for the Latest Maastrichtian age and the first appearance of the characteristic Paleocene species. According to the recorded benthonic foraminiferal zones in the present study, this sequence boundary lies between *Bolivinoides draco draco*, and *Siphogeneroides eleganta* zones.

This sequence boundary (SB6) coincides with the major unconformity surface recorded at K/Pg. boundary in many parts of Egypt (e.g. El-Naggar, 1966 at the Esna-Idfu area; Abbass & Habib, 1971 at the West Mawhoob area; Luger, 1985 at Southwest Egypt; Anan & Sharabi, 1988 at Northwest Kharga Oasis; Hermina, 1990 at Dakhla, Kharga and Farafra Oases; Hewaidy & Soliman, 1993 at Southwest Kom Ombo; Hewaidy, 1990 in Beris - Doush area ; Hewaidy, 1994 at Garra-Kurkur area; Abd El Kireem & Samir, 1995 at Farafra Oasis;

Lüning *et al*.,1998b (MA/D Sin) at central East Sinai; El-Azabi & El-Araby, 2000 at West Dakhla-Farafra stretch; and Tantawy *et al*., 2001 at the Western Desert).

4.2. 4. Depositional sequence - 2 (DS2):

At Gebel Qabeliat section, this depositional sequence (DS2) attains about 16 m thick (samples 96-103), and it comprises the lower and middle parts of Esna Formation. It is composed of dark grey to green shale. It covers the interval of the Early Paleocene (Middle to Late Danian) *Praemurica trindadensis* (P1d) planktonic Zone, (Late Danian) *Praemurica uncinata (*P2) planktonic Zone, in addition to the early Late Paleocene (Selandian) *Morozovella angulata* (P3a) planktonic Zone. It also comprises *Siphogenerinoides eleganta* and *Alabamina midwayensis/ Gavelinella beccariiformis* benthonic zones. This depositional sequence (DS2) is bounded at the base by the second sequence boundary (SB2) and topped by the third sequence boundary (SB3). It is represented only by transgressive system tract (TST2); while the basal lowstand system tract is missing, due to the fast relative sea level rise over the study area and the transgressive surface coincides with the sequence boundary (SB2). Also, the top highstand system tract is eroded and it coincides with the third sequence boundary (SB3).

4.2. 4. 1. Transgressive system tract - 2 (TST2):

At Gebel Qabeliat section, this transgressive system tract (**TST2**) is classified into three stages early, middle and late:

The **early stage** of transgressive system tract **(ETST2)** attains about **5 m** thick (sample 96 - 98). It comprises the lowermost part of Esna Formation. It covers the interval of *Praemurica trindadensis* (P1d) Zone and also *Siphogenerinoides eleganta* benthonic Zone of Early Paleocene (Middle to Late Danian) age. It is represented by retro-gradational parasequence of shallow outer neritic dark grey shale. The analysis of the foraminiferal contents showed that, this early transgressive system tract (ETST2) stage is marked by a medium total foraminiferal number of about 685 individuals; a relatively medium diversity of about 58 species; a medium P/B ratio of about 48 %; a relatively medium planktonic foraminiferal number of about 315 individuals represented only by non-keeled forms such as *Globanomalina*, *Parasubbotina*, and *Subbotina*. It is also characterized by a relatively medium benthonic foraminiferal ratio of about 52%; and a relatively medium Aggl./ Calc. ratio of about 51 %. Moreover, the benthonic foraminiferal fauna of this interval are dominated mainly by middle neritic to bathyal species, such as: *Loxostomoides applinae* (Plummer), *Siphogenerinoides eleganta* Plummer, *Oridorsalis plummerae* (Cushman), *Cibicidoides pseudoacuta* (Nakkady), *Gaudryina rugosa* d'Orbigny, *Valvalabamina depressa* (Alth), *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides zitteli* (Le Roy), and *Gyroidinoides girardana* (Reuss); in addition to some outer neritic species such as: *Anomalinoides acutus* (Plummer), according to (Berggren, 1974a; Speijer, 1994; Speijer & Schmitz, 1998; El-Dawy & Hewaidy, 2003; Sprong *et al*., 2012).

This analysis suggests a rise in the relative sea level, which indicates a transgressive phase and a shallow outer neritic environment, was prevailed during the deposition of this (ETST2) stage.

The middle stage of transgressive systems tract (MTST2) at Gebel Qabeliat section includes the upper lower part of Esna Formation, which is represented by 6 m thick (samples 99-101). It comprises the *Praemurica uncinata* (P2) planktonic Zone and also the lower part of *Alabamina midwayensis/ Gavelinella beccariiformis* benthonic Zone of Late Danian age. It is represented by retro-gradational parasequence of deep outer neritic soft grey to green shale. The results of the statistical analysis for this (MTST2) are characterized by a high total foraminiferal number of an average of 730 individuals; a high to medium diversity of an average of 75 species; a relatively high P/B ratio of an average of 63%; a relatively high planktonic foraminiferal number of an average of 450 individuals; and these planktonics 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 of 37 %; and a medium Aggl. / Calc. ratio of an average of 47 %. Moreover, the benthonic foraminiferal fauna of this interval is dominated mainly by outer neritic species such as: *Marginulinopsis tuberculata* (Plummer) and *Anomalinoides acutus* (Plummer); in addition to some middle neritic to bathyal species such as: *Loxostomoides applinae* (Plummer), *Siphogenerinoides eleganta* Plummer, *Oridorsalis plummerae* (Cushman), *Cibicidoides pseudoacuta* (Nakkady), *Gaudryina soldadoensis* Cushman and Renz, *Gaudryina pyramidata* Cushman, *Gaudryina rugosa* d'Orbigny, *Valvalabamina depressa* (Alth), *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides zitteli* (Le Roy), and *Gyroidinoides girardana* (Reuss) according to (Berggren, 1974a; Speijer, 1994; Speijer & Schmitz, 1998; El-Dawy & Hewaidy, 2003; and Sprong *et al*., 2012).

These results suggest a rise in the relative sea level which indicates on transgressive phase and a deep outer neritic environment was prevailed during the deposition of this (MTST2) stage.

The late stage of this transgressive system tract (LTST2) includes the middle part of Esna Formation, which is represented by 5m thick (samples 102-103). It comprises *Morozovella angulata* (P3a) planktonic Zone and also the upper part of *Alabamina midwayensis/ Gavelinella beccariiformis* benthonic Zone of early Late Paleocene (Selandian) age. It is represented by retro-gradational parasequence of shallow upper bathyal dark green shale. The results of the statistical analysis for this (LTST2) is characterized by a very high total foraminiferal number of an average of 895 individuals; a very high P/B ratio of an average of 82 %; a high planktonic foraminiferal number of an average of 720 individuals; of these planktonics 45 % are keeled and 55 % are non-keeled forms. It is also characterized by low benthonic foraminiferal ratio of an average of 18 %; and a low Aggl. / Calc. ratio of an average of 37 %. Also, this interval is marked by increasing in the non-keeled forms *Parasubbotina, Subbotina* and *Praemurica spp*. and the first appearance of the keeled forms such as *Morozovella ssp*. Moreover, the benthonic foraminiferal fauna of this interval are dominated mainly by middle neritic to bathyal species as: *Cibicidoides pseudoacuta* (Nakkady), *Oridorsalis plummerae* (Cushman), *Anomalinoides praeacutus* (Vasilenko), *Anomalinoides zitteli* (Le Roy), *Gaudryina spp.* (e.g. *Gaudryina pyramidata* Cushman, *Gaudryina rugosa* d'Orbigny, *Gaudryina elegantissima* Said & Kenawy), *Loxostomoides applinae* (Plummer), *Siphogenerinoides eleganta* Plummer, *Gyroidinoides girardana* (Reuss); in addition to some outer neritic species such as: *Marginulinopsis tuberculata* (Plummer), and *Anomalinoides acutus* (Plummer), according to (Berggren, 1974a; Speijer, 1994; Speijer & Schmitz, 1998; El-Dawy & Hewaidy, 2003; and Sprong *et al*., 2012).

These characters indicate a rise in the relative sea level, which indicates a transgressive phase and a shallow upper bathyal environment, was prevailed during the deposition of this stage of (LTST2).

4.2. 5. The third sequence boundary (SB3):

At Gebel Qabeliat section, this sequence boundary (SB3) is located within the middle part of Esna Formation and it coincides on the Selandian / Thanetian (S/ Th) boundary and it lies between *Morozovella angulata* (P3a) and *Morozovella velascoensis* (P5) planktonic biozones and represented by a sedimentary gap (Hiatus-2) within the Esna Formation including the upper part of (P3) Zone in addition to the whole (P4) Zone. According to the recorded benthonic foraminiferal biozones, this sequence boundary lies between *Alabamina midwayensis/ Gavelinella beccariiformis* and *Gavelinella danica* zones. This sequence boundary (SB3) coincides with (Th5) of Hardenbol *et al*., 1998 and Gradstein *et al*., 2004.

4.2. 6. Depositional sequence - 3 (DS3):

At Gebel Qabeliat section, this depositional sequence **(DS3)** comprises the lower upper part of the Esna Formation and it is bounded at the base by the third sequence boundary (SB3) and topped by the fourth sequence boundary (SB4). In the present studied area, it is represented only by a transgressive system tract (TST3); while the basal lowstand system tract is missing, due to the fast relative sea level rise over the study area, and the transgressive surface coincides with the sequence boundary (SB3). Also, top highstand systems tract is eroded and coincides with the fourth sequence boundary (SB4).

4.2. 6. 1. Transgressive systems tract - 3 (TST3):

At the present studied section, this transgressive system tract (TST3) includes the lower upper part of Esna Formation, which is represented by 6 m thick (samples 104-106). It comprises the *Morozovella velascoensis* (P5) planktonic Zone and also *Gavelinella danica* benthonic Zone of the Latest Paleocene (Latest Thanetian). It is represented by retro-gradational parasequence of deep upper bathyal dark green shale.

The results of the statistical analysis for the foraminiferal contents showed that, this transgressive system tract (TST3) is marked by a very high total foraminiferal number of an average of 1105 individuals; a relatively high diversity of an average of 96 species; a very high P/B ratio of an average of 86 %; a very high planktonic foraminiferal number of an average of 940 individuals; of these planktonics 70% are keeled, and 30% are non-keeled. It is also characterized by a low benthonic foraminiferal ratio of an average of 14 %; and low Aggl. / Calc. ratio of an average of 23 %. Also, this interval is marked by a noticeable increasing in *Morozovella* and *Acarinina spp*. and decreasing in *Parasubbotina*, *Subbotina* and *Praemurica spp*., and the benthonic foraminiferal fauna of this interval are dominated mainly by outer neritic to bathyal species, such as: *Anomalinoides affinis* (Hantken), *Valvalabamina planulata* (Cushman and Renz), *Cibicidoides pharaonis* Le Roy), *Spiroplectinella dentata* (Alth), *Spiroplectinella esnaensis* (Le Roy) in addition to outer neritic species, such as: *Anomalinoides acutus* (Plummer); and *Marginulinopsis tuberculata* (Plummer), according to (Speijer, 1994; Hewaidy, 1996, Speijer & Schmitz, 1998; and Sprong *et al*., 2012).

These characters indicate a rise in the relative sea level which indicates on transgressive phase and a deep upper bathyal environment was prevailed during the deposition of this (TST3).

4.2. 7. The Fourth sequence boundary (SB4):

At Gebel Qabeliat section, this sequence boundary (SB4) is located within the upper part of the Esna Formation, and it coincides with the Paleocene/ Eocene (P/E) boundary. It is represented by a sedimentary hiatus (Hiatus-3), due to absence of *Acarinina sibaiyaensis* (E1) planktonic biozone, where the Latest Thanetian

Morozovella velascoensis (P5) Zone is directly overlain by the Earliest Ypresian *Pseudohastigerina wilcoxensis / Morozovella velascoensis* (E2) Zone. This sequence boundary (SB4) is marked by the extinction of the large and heavily ornamented planktonic forms of the Late Paleocene and also the first appearance of the forms belonging to the genus *Pseudohastigerina* such as *Pseudohastigerina wilcoxensis* (Cushman & Ponton) beside the relatively small and lightly ornamented *Morozovella* species of Earliest Eocene.

According to the recorded benthonic foraminiferal zones, this sequence boundary (SB4) lies between the *Gavelinella danica* Zone and *Marginulina wetherellii intercostata - Marginulina wetherellii longiscata* Zone. It is characterized by the most extinction of deep sea bathyal and neritic calcareous benthic foraminifera of *Gavelinella beccariiformis* assemblage, and the first appearance of newly earliest Eocene assemblages.

4.2. 8. Depositional sequence-4 (DS4):

It represents the youngest depositional sequence in the study area. At Gebel Qabeliat section, this depositional sequence (DS4) attains about 22 m thick, and it comprises the uppermost part of Esna Formation, in addition to the measured part of the Thebes Formation of the Early Eocene (Ypresian) age. It is bounded at the base by the fourth Sequence boundary (SB4). This depositional sequence (DS4) is classified into a transgressive system tract (TST4) at the base and a highstand systems tract (HST4), at the top; while the basal lowstand system tract is missing due to the fast relative sea level rise over the study area and the transgressive surface coincides with the sequence boundary (SB4).

4.2. 8. 1. Transgressive system tract-4 (TST4):

At Gebel Qabeliat section, this Transgressive system tract - 4 (TST4), includes the uppermost part of Esna Formation, which is represented by 12 m thick (samples 107-114). It comprises the *Pseudohastigerina wilcoxensis /Morozovella velascoensis* (E2) Zone of Earliest Eocene (Earliest Ypresian) and *Morozovella marginodentata* (E3), *Morozovella formosa formosa* (E4) in addition to the lower part of *Morozovella aragonensis / Morozovella subbotinae* (E5) of the Early Eocene (Early Ypresian) age planktonic biozones. On the other hand, it also comprises the lower part of *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* benthonic biozone. It is represented by retro-gradational parasequence set of alternating shallow to deep outer neritic dark green shale and marl, at the base and argillaceous thinly bedded limestone, at the top.

The results of the statistical analysis for this transgressive system tract-4 (TST4) is characterized by a relatively high total foraminiferal number of an average of 835 individuals; a relatively high to medium diversity of an average of 83 species; high P/B ratio of an average of 76 %; a relatively high planktonic foraminiferal number of an average of 625 individuals; of these planktonics 54% are keeled, and 46% are non-keeled. It is also characterized by a relatively low benthonic foraminiferal ratio of an average of 25 %; and low Aggl./ Calc. ratio of an average of 25 %. Also, the benthonic foraminiferal fauna of this interval are dominated mainly by middle to outer neritic species, such as: *Alabamina midwayensis* Brotzen; and some outer neritic species such as: *Marginulinopsis tuberculata* (Plummer).

These characters indicate a rise in the relative sea level, which indicates a transgressive phase and shallow to deep outer neritic environment was prevailed during the deposition of this (TST4).

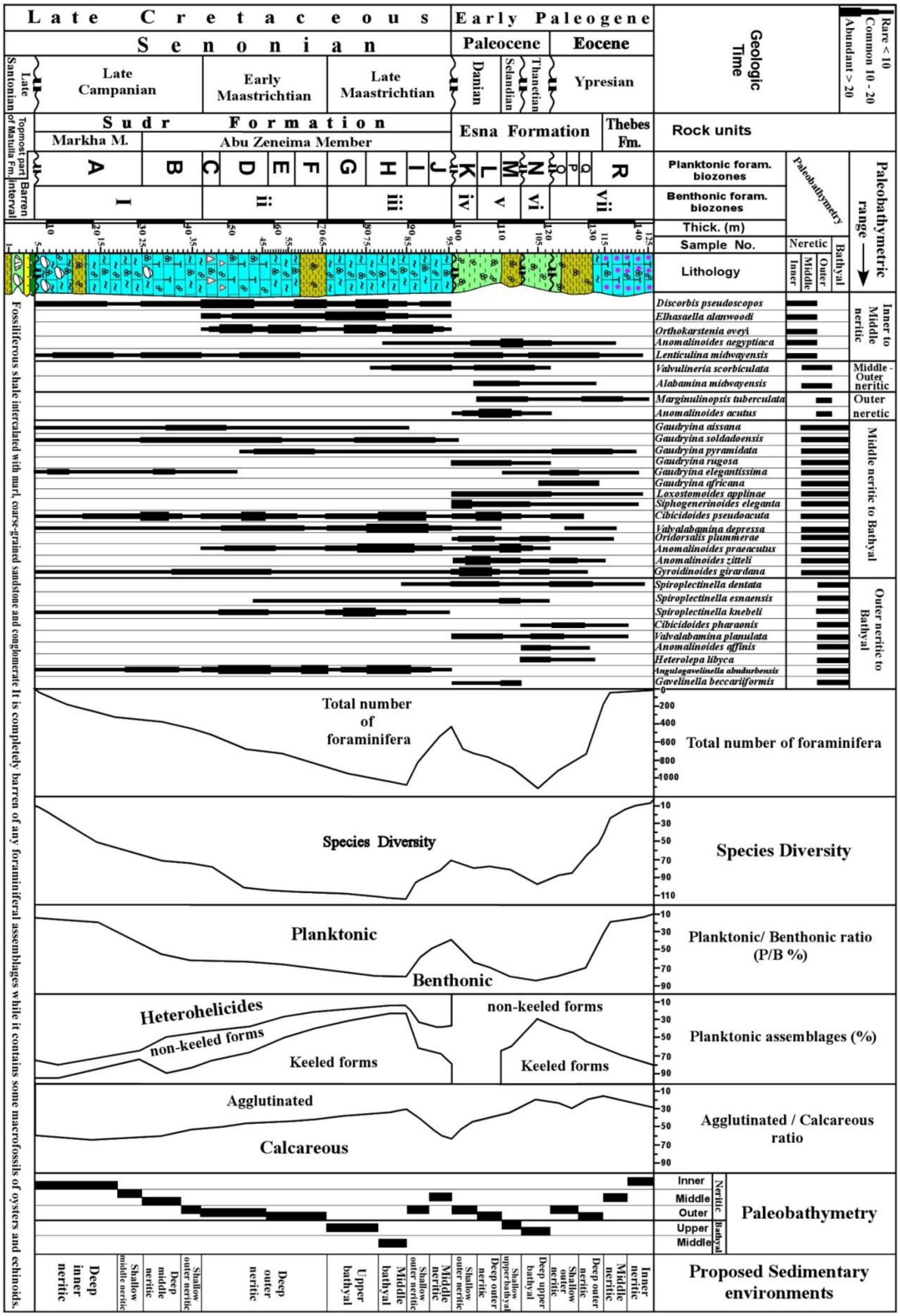


Fig. 5 : Paleobathymetric ranges of the most dominated recorded benthonic foraminiferal species, the results of the paleoecological parameters, and Proposed Sedimentary environments for the studied Upper Campanian -Ypresian rock units at Gabal Qabeliat section, west- central Sinai . (The paleobathymetric interpretations is based on: Bergrren, 1974; Luger, 1985; Cherif & Hewaidy, 1986; Hewaidy, 1990 &1994; Spjier, 1994; Hewaidy, 1996 &1997; Spjier & Schmitz, 1998; El-Dawy & Hewaidy, 2003; and Sprong *et al.*, 2012).

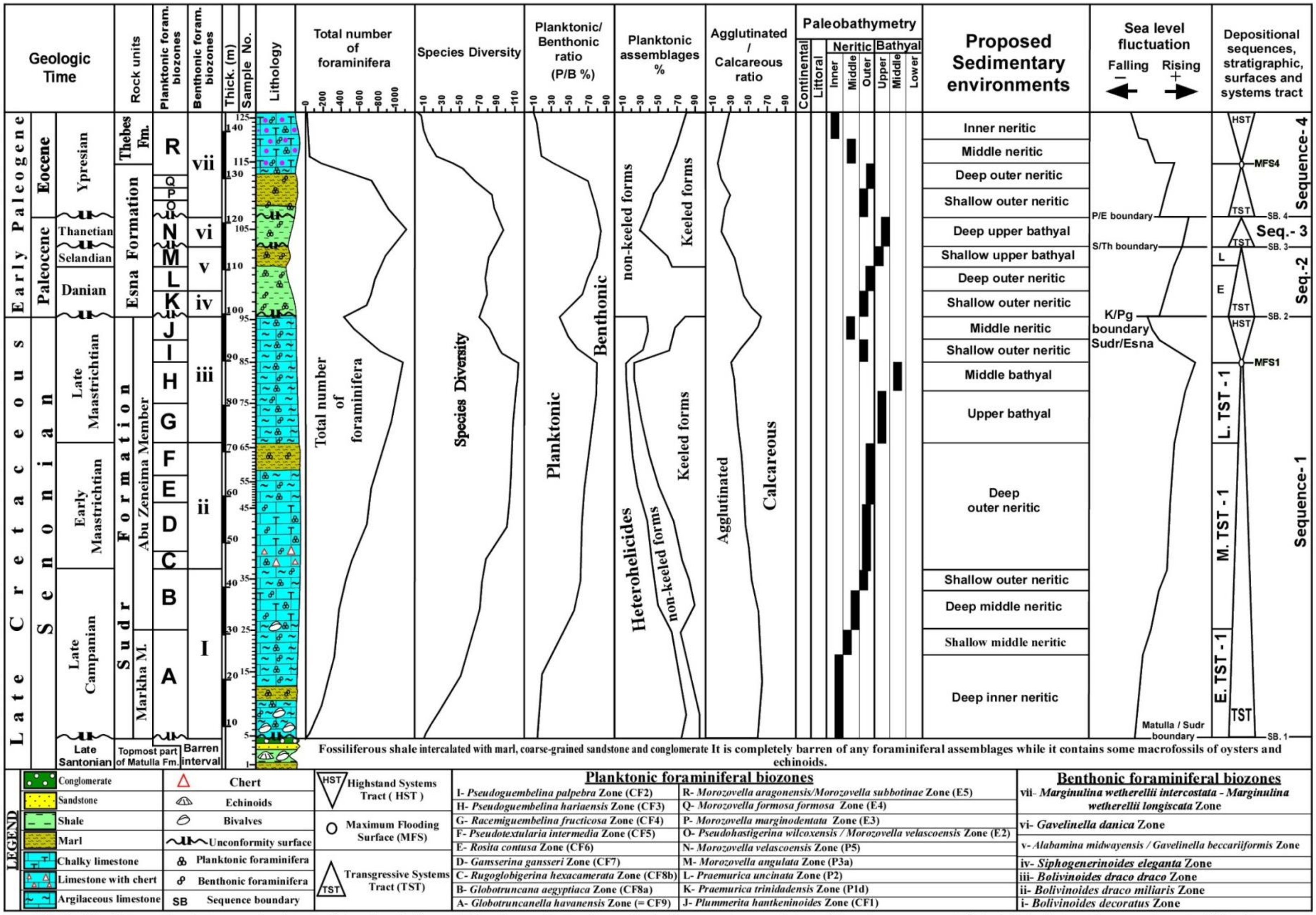


Fig.6 : The Integration between planktonic & benthonic foraminiferal zonation, paleoecological parameters and depositional sequences at Gabal Qabeliat section, west- central Sinai .

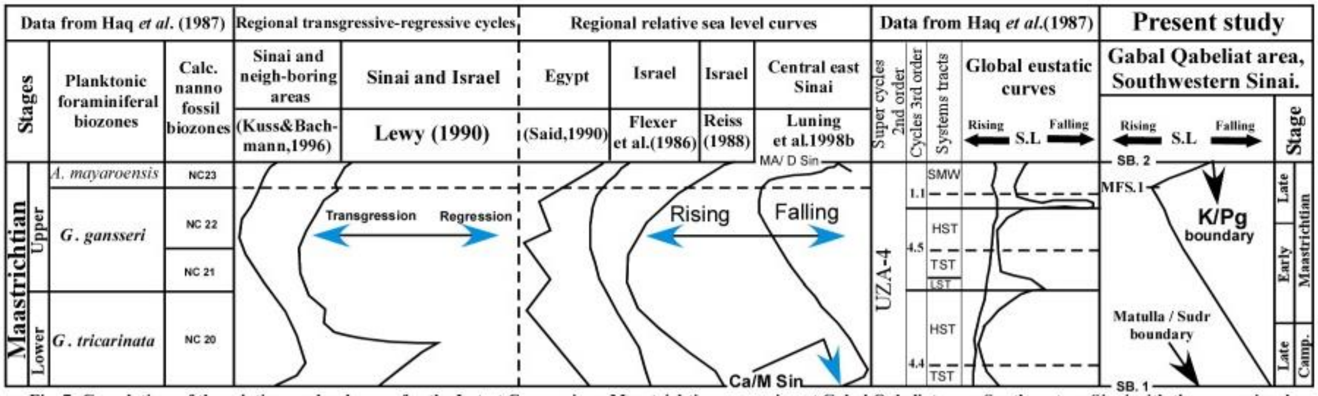


Fig. 7: Correlation of the relative sea-level curve for the Latest Campanian - Maastrichtian succession at Gabal Qabeliat area, Southwestern Sinai with those previously applied by some authors in/ outside of Egypt.

4.2. 8. 2. Maximum flooding surface-4 (MFS4):

The maximum flooding surface (MFS4) is cited on the Esna/ Thebes formational boundary and this coincides with the noticeable drop in the results of the statistical analysis for the foraminiferal content, due to change in the depositional environment from deep outer neritic during the deposition of the uppermost part of the Esna Formation, to middle neritic environment during the deposition of the lowermost part of the Thebes Formation.

4.2. 8. 3. Highstand system tract-4 (HST4):

This is the highest interval in the depositional sequence-4 (DS4). At Gebel Qabeliat section, this highstand system tract (HST4) is represented at the top of the studied succession and it comprises the studied part of the Thebes Formation. It attains about 10 m thick (samples 115-125). It covers the interval of the upper part of *Morozovella aragonensis / Morozovella subbotinae* (E5) planktonic Zone and also the upper part of *Marginulina wetherellii intercostata- Marginulina wetherellii longiscata* benthonic Zone of the Early Eocene (Ypresian) age. It is represented by pro-gradational parasequence set of alternating inner to middle neritic pale white; porcellaneous chalky limestone succession and sometimes concretional limestones, with brown to black flint bands and nodules.

This highstand system tract (HST4) is characterized by a very low total foraminiferal number of an average of 73 individuals; a low diversity of an average of 54 species; a low P/B ratio of an average of 32 %; a low planktonic foraminiferal number of an average of 23 individuals; of these planktonics 28 % are keeled and 72 % are non-keeled forms. It is also characterized by a high benthonic foraminiferal ratio of an average of 68 %; and low Aggl. / Calc. ratio of an average of 20 %. On the other hand, the benthonic foraminiferal fauna of this interval is dominated mainly by inner to middle neritic species, such as: *Lenticulina midwayensis* (Plummer). These characters indicate a drop in the relative sea level, which indicates a regressive phase and an inner to middle neritic environment was prevailed during the deposition of this (HST4).

The correlation between these recorded four depositional sequences and their bounding sequences boundaries at Gebel Qabeliat section with those of the previous studies are shown on (Fig. 8.)

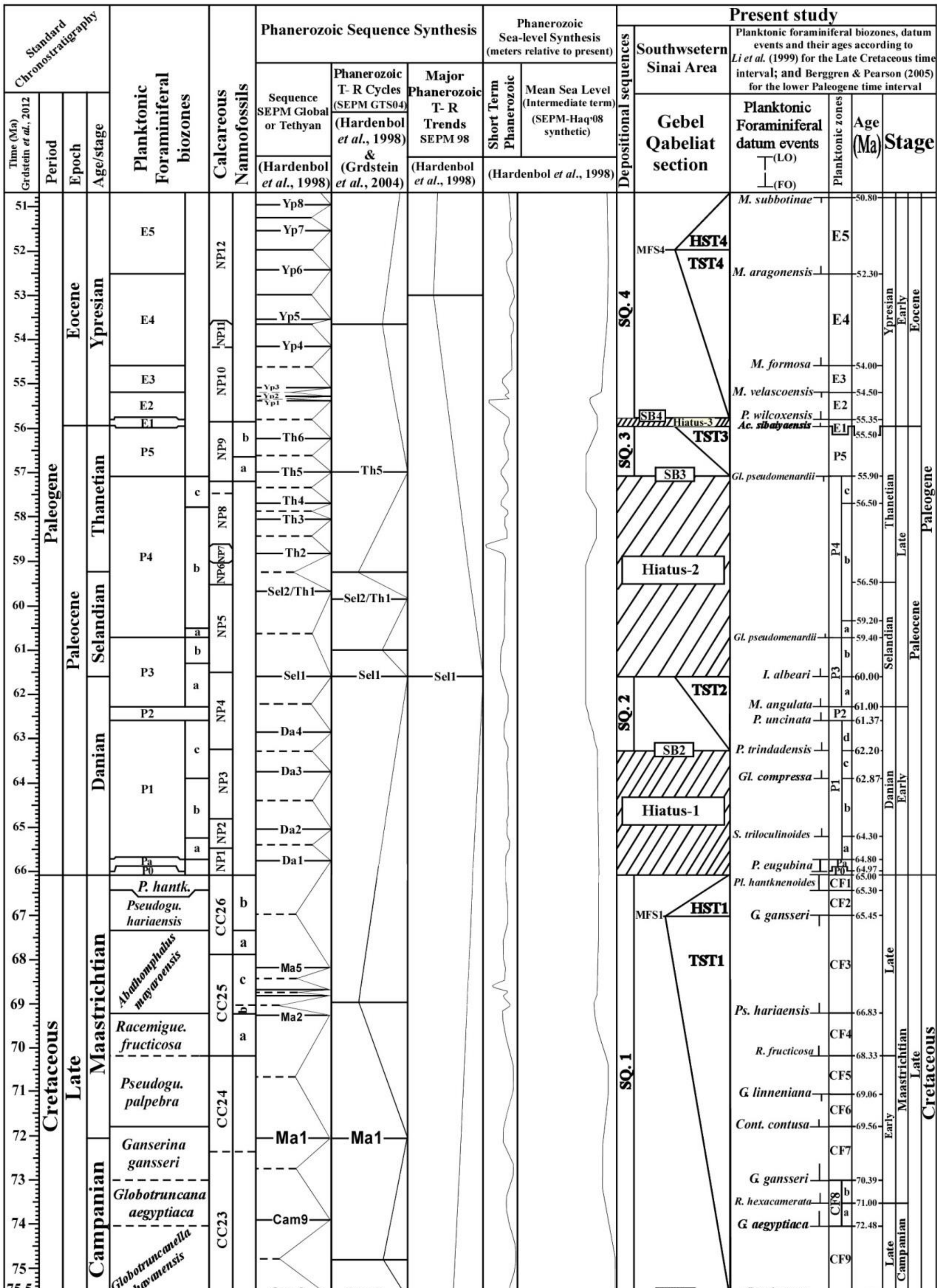


Fig. 8: Correlation of the recorded sequence boundaries iat Gebel Qabeliat section during the Late Campanian - Early Eocene (Ypresian) time interval with those of the previous studies.

5. Summary and Conclusions

1- The present study deals with the lithostratigraphy, biostratigraphy, paleoecology, and sequence stratigraphy of the Upper Campanian- Lower Eocene (Ypresian) succession exposed at Gabal Qabeliat section, Southwestern Sinai Area, Egypt. This study is based mainly on the detailed examination of their foraminiferal contents and lithologic characters.

2- Lithostratigraphically, the studied succession is classified into Sudr, Esna and Thebes formations, from base to top. This succession is unconformably underlain by Matulla Formation of Coniacian to Santonian age. These rock units are fully described. The studied topmost part of Matulla Formation was found barren of any planktonic and benthonic foraminiferal species, and it is attributed to Lower Santonian age, based on its contents of mega-fossils, such as oysters. This barren interval is directly followed by a richly fossiliferous Upper Campanian – Lower Eocene (Ypresian) succession.

3- 234 foraminiferal species have been identified. These include **94** planktonics and **140** benthonics. The marker zonal planktonic foraminiferal species, in addition to the most dominated recorded benthonic foraminiferal species are photographed by (SEM).

4- Depending on the examination of the vertical stratigraphic distribution of both marker planktonic and benthonic foraminiferal species, two foraminiferal biostratigraphic classifications for the Upper Campanian - Lower Eocene (Ypresian) sedimentary sequences, exposed at Gebel Qabeliat section are established; the first is based on the planktonics and the second is based on the benthonics.

5- The planktonic assemblage is used, to classify the upper part of Lower Campanian- Lower Eocene (Ypresian) interval into **eighteen** planktonic foraminiferal biozones; **two** of Late Campanian; **four** of Early Maastrichtian; for the first time in the study area, **four** of Late Maastrichtian**; two** of Early Paleocene (Danian); **one** of early Late Paleocene (Selandian); **one** of Latest Paleocene (Latest Thanetian); **two** of Earliest Eocene (Earliest Ypresian); and **two** of Early Eocene (Ypresian). Also, this interval is classified into **seven** benthonic foraminiferal biozones; **one** of Late Campanian; **one** of Early Maastrichtian; **one** of Late Maastrichtian; **one** of Early Paleocene (Middle – Late Danian): **one** of late Early Paleocene (Latest Danian) to early Late Paleocene (Selandian); **one** of Latest Paleocene (Latest Thanetian); and **one** of Early Eocene.

6- Paleoecologically, a detailed analysis of the included foraminiferal contents is attempted, including the total number of foraminiferal species, the species diversity, the P/B ratio, the Aggl. / Calc. ratio and their abundance patterns. The inferred paleoenvironments for each rock unit are, as follows: The Markha Member of Sudr Formation may be deposited in deep inner to middle neritic environments; while the Abu Zeneima Member may be deposited in middle neritic to middle bathyal environments. The Esna Formation may be deposited in shallow outer neritic to deep upper bathyal environments. The measured part of the Thebes Formation may be deposited in inner to middle neritic environments.

7- Sequence stratigraphically, the studied Upper Campanian- Lower Eocene (Ypresian) succession, exposed at Gabal Qabeliat section, Southwestern Sinai Area, Egypt, is classified into four 3rd order depositional sequences (DS), bounded by four type- one sequence boundaries (SB), based on the lithologic characters, detailed field examination for the stratigraphic surfaces and the foraminiferal biostratigraphic studies. These are **one** in the Late Campanian-Maastrichtian; **two** in the Paleocene; and **one** in the Lower Eocene. The correlation between these recorded four depositional sequences and their bounding sequences boundaries at the studied section with those of the previous studies inside /outside Egypt were done.

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