

## Planktonic Foraminiferal Biostratigraphy of the Campanian-Maastrichtian Sudr Formation at Esh El-Mellaha Area, North Eastern Desert, Egypt

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**Abstract:** Three upper Campanian- upper Maastrichtian exposures on the western flank of Esh El-Mellaha range, north Eastern Desert, Egypt from north to south: Wadi Dib, Wadi Abu Had, and Bir Mellaha sections are studied. This interval is represented by the Sudr Formation which is classified into Markha and Abu Zeneima members from base to top. This rock unit is found very rich in planktonic foraminiferal assemblages. Fifty seven planktonic foraminiferal species belonging to seventeen genera, six subfamilies, five families, four superfamilies and one suborder are recorded and most of them are belonging to family "Globotruncanidae" where it includes eleven genera and thirty eight species. So, the phylogenetic development of the recorded species and genera from this important family is discussed. Eleven planktonic foraminiferal biozones are distinguished in the studied sequence; one of late early Campanian to late Campanian age (*Globotruncana ventricosa* Zone); two of late Campanian age (*Globotruncanella havanensis* (=CF9) and *Globotruncana aegyptiaca* (CF8a) zones); four of early Maastrichtian age (*Rugoglobigerina hexacamerata* (CF8b), *Gansserina gansseri* (CF7), *Contusotruncana contusa* (CF6), *Pseudotextularia intermedia* (CF5) zones); and for the first time four of late Maastrichtian age (*Racemiguembelina fructifera* (CF4), *Pseudoguembelina hariensis* (CF3), *Pseudoguembelina palpebera* (CF2), and *Plummerita hantkeninoides* (CF1) zones). The Campanian / Maastrichtian boundary is located within the lower part of the Abu Zeneima Member between (CF8a) and (CF8b) zones, while the early / late Maastrichtian boundary is located within the upper part of the Abu Zeneima Member between (CF5) and (CF4) zones. Two unconformity surfaces are recorded within the Sudr Formation. The first one is recorded at the three studied sections and it lies between the Markha and Abu Zeneima Members due to absence of the late Campanian *Globotruncanita calcarata* Zone; while the second unconformity surface is recorded at both Wadi Abu Had and Wadi Dib sections only and it lies within the uppermost part of Abu Zeneima Member due to absence of the last two latest Maastrichtian CF2 and CF1 zones. [Abdel Galil A. Hewaidy, Sherif Farouk and Arafa F. El-Balkiemy. **Planktonic Foraminiferal Biostratigraphy of the Campanian-Maastrichtian Sudr Formation at Esh El-Mellaha Area, North Eastern Desert, Egypt.** *J Am Sci* 2017;13(3):41-69]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). <http://www.jofamericanscience.org>. 6. doi:[10.7537/marsjas130317.06](https://doi.org/10.7537/marsjas130317.06).

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### 1. Introduction

Esh El-Mellaha range is located at the southwestern part of the Gulf of Suez, between latitudes 27°24' N and 27°49' N and longitudes 33°11' E and 33°40' E., north Eastern Desert, Egypt (Fig.1.A). Esh El-Mellaha range is composed of igneous and metamorphic rocks covered by Miocene rock patches on its eastern flank, while, it is covered by Upper Cretaceous-Eocene rocks on its western flank. In this area, the Sudr Formation was measured in three sections. These are from north to south: Wadi Dib (latitude 27° 48' 40" N and longitude 33° 13' 05" E), Wadi Abu Had (latitude 27° 39' 37" N and longitude 33° 21' 45" E), and Bir Mellaha (latitude 27° 34' 51" N and longitude 33° 25' 56" E.), (Fig.1B).

Few previous studies dealing with the Upper Cretaceous planktonic foraminiferal paleontology and biostratigraphic classification at Esh El-Mellaha area were carried out. The most important of these are

Abdallah *et al.*, 1984, Prat *et al.*, 1986, Aref *et al.*, 1988, Aref and Ramadan, 1990, and Cherif and Ismail, 1991.

The upper Campanian – upper Maastrichtian interval in the present study area is represented by the Sudr Formation which primarily has been introduced as Sudr Chalk by Ghorab, 1961 to describe a sequence exposed at Wadi Sudr, west central Sinai. It consists of 100-130m thick of snow white chalk, partly changing to marl or argillaceous limestones containing sometimes chert bands or nodules. The name Sudr Chalk was emended by Tewfik and Ebeid, 1972 to Sudr Formation. Ghorab, 1961 subdivided this formation into a lower Markha Member of Campanian age and an upper Abu Zeneima Member of Maastrichtian age. The Sudr Formation in the study area is subdivided into two members; Markha Member at base and Abu Zeneima at top.

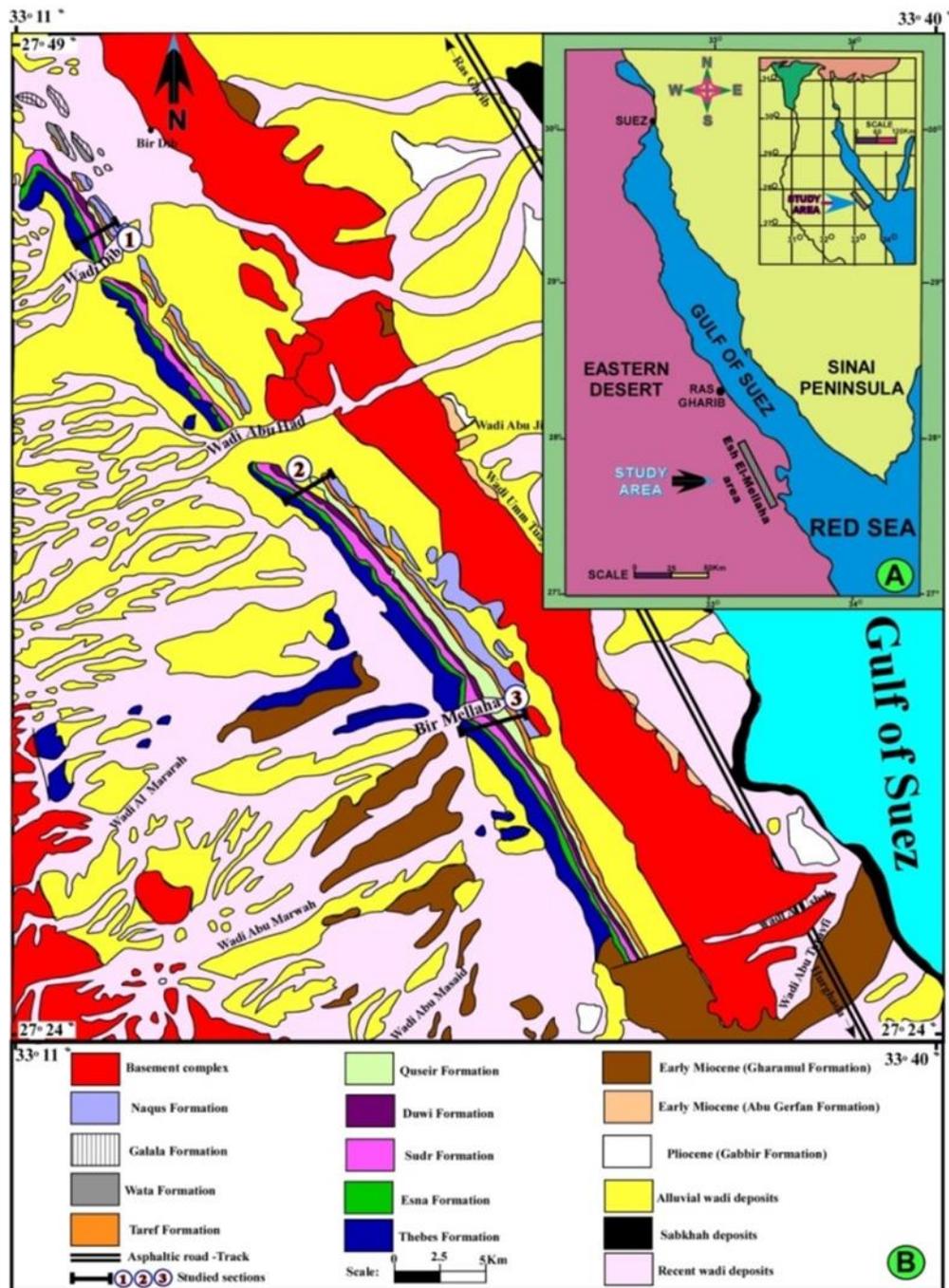


Fig. 1: (A) Location map of the study area, (B) Geologic map of the study area.

The Markha Member is composed of argillaceous and fossiliferous limestone intercalated with banks of the large oyster *Pycnodonte vesicularis* (Lamarck). It attains about 12 m thick at Wadi Dib section, about 11.5 m thick at Wadi Abu Had section, and about 17 m thick at Bir Mellaha section. The Markha Member directly overlies the Duwi Formation and underlies the Abu Zeneima Member. It is assigned

to the upper part of lower Campanian to upper Campanian ages.

The Abu Zeneima Member is composed of yellowish-white to pale grey soft argillaceous limestone and chalky limestone containing *Pecten farafrensis* (Zittel) in the lower part intercalated with thin fossiliferous shale band. It attains about 38 m thick a Wadi Dib section, about 22.5 m thick at Wadi Abu Had section, and about 49 m thick at Bir Mellaha

section. It overlies the Markha Member with disconformity surface and also underlies with disconformity surface the Esna Formation at the three studied sections. It is assigned to the upper Campanian to uppermost Maastrichtian ages.

The main targets of the present work on the Upper Campanian-Upper Maastrichtian Sudr Formation at Esh El Mellaha area are: 1. Phylogenetic analysis of the recorded species and genera of the Family "Globotruncanidae"; 2. High resolution planktonic foraminiferal biostratigraphic classification of the studied interval; 3. Campanian/Maastrichtian and early/late Maastrichtian stage boundary analysis.

#### **Systematic and Phylogenetic Development**

Fifty seven planktonic foraminiferal species belonging to seventeen genera, six subfamilies, five families, four superfamilies and one suborder have been identified from the three studied sections. These identified planktonic foraminiferal species are photographed by Scanning Electron Microscope (SEM) in the laboratories of the Egyptian Mineral Resources Authority and are shown on Plates 1- 4 and their vertical distribution is shown on Figs. 6-8.

Out of the identified fifty seven planktonic foraminiferal species, thirty eight species are belonging to the Family Globotruncanidae. Most of the zonal marker species of the studied interval are members of that family. So, the phylogenetic development of these genera and species is discussed here (Figs. 2-4). The recorded genera are *Hedbergella*, *Contusotruncana*, *Gansserina*, *Globotruncana*, *Globotruncanita*, *Globotruncanella*, *Abathomphalus*, *Archaeoglobigerina*, *Rugotruncana*, *Rugoglobigerina*, and *Plummerita*. The following is the description of the evolutionary lineages of these genera and their included species at the present study:

#### **1- Genus *Hedbergella* Bronnimann and Brown 1958**

1826 *Globigerina* d'Orbigny, p. 277; Masters, 1977, p. 446.

1955 *Hedbergina* Bronnimann and Brown, p. 529.

1958 *Hedbergella* Bronnimann and Brown: p. 16, pl. 495, figs. 7-15; 1984 Robaszynski *et al.*, p. 260; 1985 Caron, p. 57.

1959 *Praeglobotruncana* (*Hedbergella*) Banner and Blow: p. 18.

1961 *Planogyryna* Zakharova-Atabekyan: p. 50.

1973 *Praehedbergella* Gorbachik and Moullad: p.2662.

**Type species:** *Anomalina lorneiana* d'Orbigny, var. *trochoidea* Gandolfi, 1942, p. 98.

This Cretaceous genus is marked by its trochospiral biconvex test with open umbilicus, lobate rounded periphery and lack of keel or pore less

margin. A detailed synonymy of this genus is discussed by Masters, 1977.

The genus *Hedbergella* was considered as the ancestor of all genera of the Family Globotruncanidae (Caron, 1985), where, it is the oldest and most primitive genus of this family (Figs. 2-4). In the present study, genus *Hedbergella* is represented only by *Hedbergella holmdelensis* Olsson, 1964 which is marked by its more robust, larger test size, compact arrangement of its sub-globular chambers and exceptionally sparse and small perforations.

#### **2- Genus *Contusotruncana* Korchagin, 1982**

1927c *Globotruncana* Cushman, p. 81. 1941.

1982 *Contusotruncana* Korchagin, p. 114-121.

Type species: *Pulvinulina arca* var. *contusa* Cushman, p. 23.

1984 *Rosita* Robaszynski, Caron, Gonzales-Donoso and Wonders, p. 244, pl. 35; 1985 Caron, p. 67. Type species: *Rosita fornicata* (Plummer, 1931).

The genus *Contusotruncana* is marked by its moderate to high spiral side of the test, last chambers have a characteristic undulating surface and narrow double keels.

This genus was initiated from *Marginotruncana sinuosa* Porthault, 1970 by giving *Contusotruncana fornicata* (Plummer, 1931) in the Santonian time (Robaszynski *et al.*, 1984) through gradual increase in the spire height, size of chambers and placation of chamber surfaces. In the present study, this genus is represented by four species representing an evolutionary line including *Contusotruncana fornicata* (Plummer, 1931), *C. patelliformis* (Gandolfi, 1955), *C. contusa* (Cushman, 1926), and *C. plicata* (White, 1928) (Fig. 4).

*Contusotruncana fornicata* (Plummer, 1931) is marked by low trochospiral test with slightly undulating surface of the last chamber and strong double keels.

*Contusotruncana patelliformis* (Gandolfi, 1955) is marked by moderately to fairly high trochospire intermediate between *Contusotruncana fornicata* (Plummer, 1931) and *Contusotruncana contusa* (Cushman, 1926) leading to an asymmetrical profile with a flat to concave umbilical side.

*Contusotruncana contusa* (Cushman, 1926) is marked by its highly trochospiral test, two narrow keels, and deep umbilicus.

*Contusotruncana plicata* (White, 1928) is marked by its larger test with less globular chambers and depressed sutures without well-developed sutural ridges on the spiral side.

#### **3- Genus *Gansserina* Caron, Gonzales Donoso, Robaszynski and Wonders, 1984**

1927c *Globotruncana* Cushman, p. 81.



Fig. 2: Phylogeny and biostratigraphic range of the recorded species of *Archaeoglobigerina*, *Rugoglobigerina*, *Rugotruncana*, *Plummerella*, *Gansserina*, *Globotruncanella*, and *Abathomphalus* genera at Bir-Melaha area.

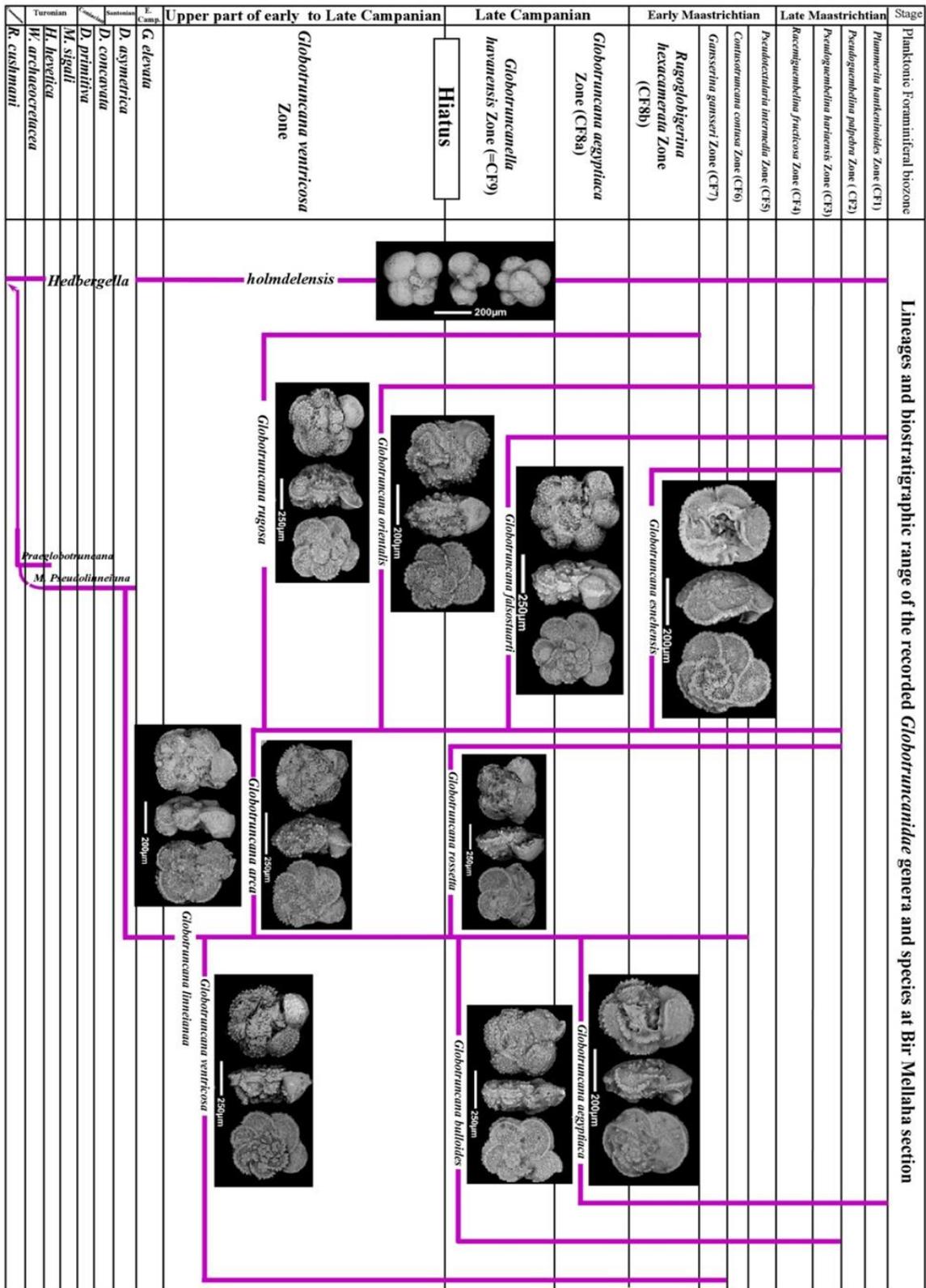


Fig. 3: Phylogeny and biostratigraphic range of the recorded species of genus *Globotruncana* at Esh El-Melaha area.

1984 *Gansserina* Caron, Gonzales Donoso, Robaszynski and Wonders, p. 292, pl. 51, figs. 1-7; 1985 Caron, p. 45.

**Type species:** *Globotruncana gansseri* Bolli, 1951, p. 196.

The genus *Gansserina* is marked by its flat spiral side, convex umbilical side, a distinct peripheral keel runs along the edge of the spiral side and rugosities on the umbilical keel.

This genus was derived from genus *Archaeoglobigerina* Pessagno, 1967 through the development of a single keel and coarse rugosities (Robaszynski *et al.*, 1984, and Caron, 1985). The evolution in this genus shows the transition from forms with two keels to single keeled forms. In the present study, this genus is represented by two species: *Gansserina wiedenmayeri* (Gandolfi, 1955) and *Gansserina gansseri* (Bolli, 1951) (Fig. 2).

***Gansserina wiedenmayeri* (Gandolfi, 1955)** is marked by a flatter chamber surface on the spiral side, a more pustules surface on the umbilical side, and lacking ad umbilical ridges and it is considered an intermediate form between single and double keeled forms where it has two keels at least on the first chamber of the last whorl.

***Gansserina gansseri* (Bolli, 1951)** is marked by having a plano-convex test with single keel, strongly convex on the umbilical side, chambers hemispherical in shape in the lateral view.

#### 4- Genus *Globotruncana* Cushman, 1927

1927 *Globotruncana* Cushman: p. 81, pl. 504, figs. 1-10 & pl. 505, figs. 1-5; 1984 Robaszynski *et al.*, p. 176, pl. 1; 1985 Caron, p. 50.

1941 *Rosalinella* Marie: p. 237, 256, 258.

1982 *Truncomarginata* Korchagin: p. 117.

1982 *Rosalinotruncana* Korchagin: p. 118.

**Type species:** *Pulvinulina arca* Cushman, 1926, p. 23.

The genus *Globotruncana* is marked by trochospiral test; chambers profile often truncated, with two keels separated by imperforate peripheral band; and periphery subcircular to strongly lobate.

This genus was derived from genus *Marginotruncana* Hofker, 1956 by changing the primary aperture from extraumbilical protected by portici to become umbilical protected by tegilla (Robaszynski *et al.*, 1984). In the present study, it is represented by ten species: *Globotruncana linneiana* (d'Orbigny, 1839), *G. bulloides* Voglar, 1941, *G. ventricosa* White, 1928, *G. rosetta* (Carsey, 1926), *G. aegyptiaca* Nakkady, 1950, *G. arca* (Cushman, 1926), *G. rugosa* (Marie, 1941), *G. orientalis* El Nagggar, 1966, *G. falsostuarti* Sigal, 1952, and *G. esnehensis* Nakkady, 1950 (Fig. 3).

***Globotruncana linneiana* (d'Orbigny, 1839)** is marked by its box- like test shape with two well raised

and widely spaced keels on all chambers. it is considered the central form of this genus and derived from *Marginotruncana pseudolinneiana* Pessagno, 1967 by migration of the extra umbilical primary aperture towards umbilical position and replacement of the portici by tegilla.

***Globotruncana bulloides* Voglar, 1941** is marked by its pronounced inflation of chambers on both the spiral and umbilical sides. It is evolved from the *Globotruncana linneiana* (d'Orbigny, 1839) by changing the shape of chambers from the subtrapezoidal flat to slightly convex to become trapezoidal and inflated.

***Globotruncana ventricosa* White, 1928** is marked by its trapezoidal chambers in the last whorl; very low trochospiral; two keels, equally developed and parallel. It is evolved from *Globotruncana linneiana* (d'Orbigny, 1839) by changing the symmetrical biconvex profile to become more biconvex umbilical side.

***Globotruncana rosetta* (Carsey, 1926)** is marked by its more rapid increase in its chamber size, two closely spaced keels at least on the first chambers of the last whorl. It is evolved from *Globotruncana mariei* Banner and Blow, 1960 by acquiring a symmetrical profile with the umbilical side more convex than the spiral side, reduction of two keels to one keel in the last chambers, and an increase in size.

***Globotruncana aegyptiaca* Nakkady, 1950** is marked by its plano-convex, low trochospiral test; rectangular chambers in last whorl and truncated by two closely spaced keels. It is evolved from *Globotruncana mariei* Banner and Blow, 1960 by developing more globular chambers, a more asymmetrical profile, and a more rapid increase in chamber size.

***Globotruncana arca* (Cushman, 1926)** is marked by its large biconvex test, truncate periphery with two widely spaced keels. It is derived from *Globotruncana linneiana* (d'Orbigny, 1839) by a change in profile from rectangular to biconvex, and a change in position of the keel band to become oblique.

***Globotruncana rugosa* (Marie, 1941)**, is marked by its convex chamber surface with pustules on the chambers on both sides, and pronounced keels. it is evolved from *Globotruncana arca* (Cushman, 1926) by changing the chamber surface to become convex, the presence of pustules on the chambers to become on both sides of the initial whorls, and the two keels on all chambers to become pronounced keels.

***Globotruncana orientalis* El Nagggar, 1966** is marked by its two keels at least on the first chambers of the last whorls. It is also evolved from *Globotruncana arca* (Cushman, 1926) by changing the two keels to become closer to each other but remaining parallel.

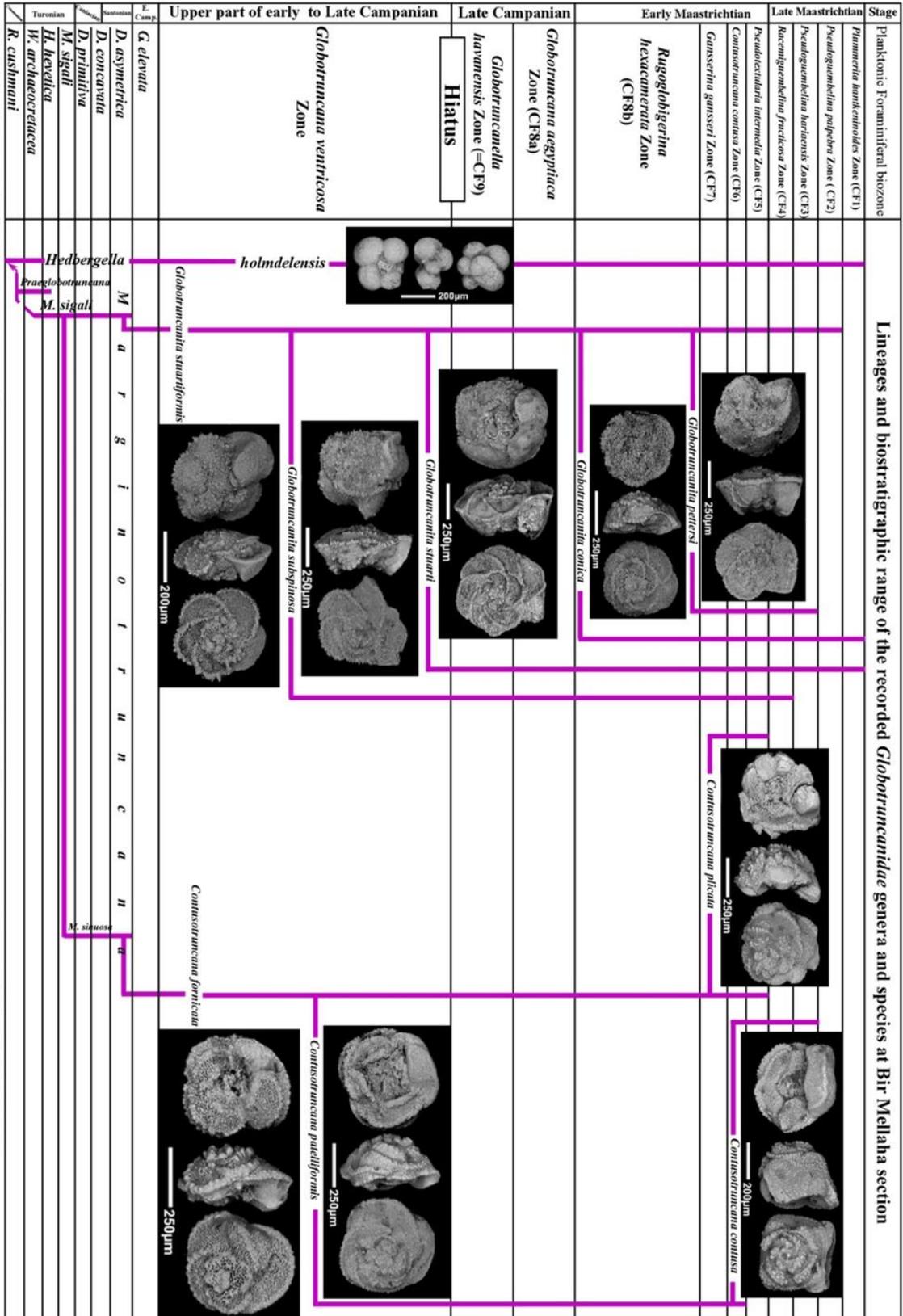


Fig. 4: Phylogeny and biostratigraphic range of the recorded species of *Globotruncanida*, and *Contusotruncana* genera at Esh El-Melaha area.

*Globotruncana falsostuarti* Sigal, 1952 is marked by presence of two keels on the earlier chambers and presence of tegilla covering the umbilical area. It is also evolved from *Globotruncana arca* (Cushman, 1926) by changing the two keels to become converging at the middle of chamber.

*Globotruncana esnehensis* Nakkady, 1950 is marked by its rectangular chambers in the last whorl, one peripheral keel on all chambers, and more curved sutures on the dorsal side. It is also evolved from *Globotruncana arca* (Cushman, 1926) by changing the umbilical keel on the last formed chambers to become reduced to absent.

#### 5- Genus *Globotruncanita* Reiss, 1957

1927c *Globotruncana* Cushman, p. 81.

1957 *Globotruncanita* Reiss: p. 3, pl. 505, figs. 6-9; 1984 Robaszynski *et al.*, p. 218, pl. 22.; 1985 Caron, p. 51.

**Type species:** *Rosalina stuarti* de Lapparent, 1918, p. 11.

The genus *Globotruncanita* is marked by its trochospiral test, umbilical primary aperture protected by portici, and single keeled.

This genus was derived from *Marginotruncana sigali* Reichel, 1950, where the primary aperture became umbilical in its position, then the two keels in the first chambers of the last whorl soon disappeared resulting in atypical single keeled *Globotruncanita* (Robaszynski *et al.*, 1984). In the present study, this genus is represented by five species: *Globotruncanita stuartiformis* (Dalbiez, 1955), *Globotruncanita stuarti* (De Lapparent, 1918), *Globotruncanita subspinosa* (Pessagno, 1960), *Globotruncanita conica* (White, 1928), *Globotruncanita pettersi* (Gandolfi, 1955) (Fig. 4).

*Globotruncanita stuartiformis* (Dalbiez, 1955) is considered the central form of this genus and it is marked by its biconvex test, and having subtriangular chambers.

*Globotruncanita stuarti* (De Lapparent, 1918) is marked by its biconvex test and regular trapezoidal shaped chambers. It is evolved from *Globotruncanita stuartiformis* (Dalbiez, 1955) by changing the form of the chambers on the spiral side from subtriangular to subtrapezoidal chambers.

*Globotruncanita subspinosa* (Pessagno, 1960) is marked by its crescent-shaped chambers with posterior lobes on each chamber, and irregular outline of the umbilico-convex test. It is evolved from *Globotruncanita stuartiformis* (Dalbiez, 1955) by changing its profile to become has posterior lobes on each chamber and umbilico-convex test.

*Globotruncanita conica* (White, 1928) is marked by its symmetrical spiro-convex test with a high spiral side and a more flat umbilical side. It is evolved from *Globotruncanita stuartiformis* (Dalbiez, 1955) by

changing the form of the chambers on the spiral side from subtriangular to trapezoidal to sub rectangular chambers.

*Globotruncanita pettersi* (Gandolfi, 1955) is marked by its fewer chambers in the last whorl, absence of a central cone on the spiral side, and presence of ad umbilical ridges. It is evolved from *Globotruncanita stuartiformis* (Dalbiez, 1955) by changing its profile to become has very low trochospiral test with trapezoidal chambers.

#### 6- Genus: *Globotruncanella* Reiss, 1957

1927c *Globotruncana* Cushman, p. 81.

1957 *Globotruncanella* Reiss: p. 136, pl. 508, figs. 8-10; 1984 Robaszynski *et al.*, p. 264; 1985 Caron, p. 51.

**Type species:** *Globotruncana citae* Bolli, 1951, p. 197= *Globotruncana havanensis* Voorwijk, 1973, p. 195.

The genus *Globotruncanella* is marked by its trochospiral test with flattened chambers and imperforate, angular periphery or passing gradually to one keel; exeraumbilical primary aperture protected by portici.

This genus was derived from genus *Hedbergella* Bronnimann and Brown 1958 by changing the primary aperture from extraumbilical –nearly peripheral protected by lips to become extraumbilical protected by portici with an imperforate peripheral band or even pustulose keel.

In the present study area this genus is represented by three species: *Globotruncanella havanensis* (Voorwijk, 1937), *Globotruncanella petaloidae* (Gandolfi, 1955), and *Globotruncanella citae* Bolli, 1951.

*Globotruncanella havanensis* (Voorwijk, 1937) is characterized by an imperforate margin instead of a true keel, and primary aperture protected by triangular porticus. It is evolved from *Hedbergella holmdelensis* Olsson, 1964 by its having umbilical system composed of portici with imperforate peripheral band.

*Globotruncanella petaloidae* (Gandolfi, 1955) is marked by the presence of 4 chambers in the last whorl which gives it petaloid aspect in equatorial view. It is evolved from *Hedbergella holmdelensis* Olsson, 1964 by changing its profile to has umbilical system composed of portici with four petaloid chambers in the last whorl.

*Globotruncanella citae* Bolli, 1951 is marked by its compressed test in edge view with rudimentary peripheral keel. It is evolved from *Globotruncanella havanensis* (Voorwijk, 1937) by changing the rounded periphery to become angular provided with a row of pustules forming a single keel.

#### 7- Genus: *Abathomphalus* Bolli, Loeblich and Tappan, 1957

1927c *Globotruncana* Cushman, p. 81.

1957 *Abathomphalus* Bolli, Loeblich and Tappan: p. 43, pl. 509, figs. 1-9; 1984 Robaszynski *et al.*, p.270, pl. 45; 1985 Caron, p. 42.

**Type species:** *Globotruncana mayaroensis*, Bolli, 1951, p. 198.

The genus *Abathomphalus* is marked by its trochospiral test, umbilical –extraumbilical primary aperture protected by tegilla, periphery with two keels, and radial umbilical sutures.

This genus was evolved from genus *Globotruncanella* Reiss, 1957 by changing the rounded periphery or even pustulose keel to become double keel (Robaszynski *et al.*, 1984 and Caron, 1985). In the present study, this genus is represented only by *Abathomphalus mayaroensis* (Bolli, 1951) which it is considered one of the more distinctive species among the Family Globotruncanidae and it is characterized by its double keel present on all chambers of the last whorl and they are composed of short, and radially oriented costellae. It is evolved from *Globotruncanella citae* Bolli, 1951 by a change angular periphery provided with a row of pustules forming a single keel to become a double keels.

#### **8- Genus *Archaeoglobigerina* Pessagno, 1967**

1927c *Globotruncana* Cushman, p. 81.

1967 *Archaeoglobigerina* Pessagno: p. 315, pl. 510, figs. 1-10; 1984 Robaszynski *et al.*, p.275; 1985 Caron, p. 43.

1978 *Fissoarchaeoglobigerina* Abdel-Kireem: p. 58.

1984 *Kassabella* El-Nakhal: p. 140.

**Type species:** *Archaeoglobigerina blowi* Pessagno, 1967.

The genus *Archaeoglobigerina* is marked by its trochospiral test, umbilical primary aperture protected by tegilla, presence of a wide imperforate peripheral band bordered by two faint keels on the globular early chambers of the last whorl.

This genus was derived from genus *Whiteinella* Pessagno, 1967 by changing the primary aperture from extraumbilical protected by portici to become umbilical protected by tegilla (Robaszynski *et al.*, 1984, and Caron, 1985).

In the present study, this genus is represented only by *Archaeoglobigerina blowi* Pessagno, 1967 which is characterized by its lobulate outline, imperforate band which occurs mainly on the first one or two chambers of the last whorl and more rapidly increasing chambers in the last whorl (Fig. 2).

#### **9- Genus *Rugoglobigerina* Bronnimann, 1952a**

1952 *Rugoglobigerina* Bronnimann: p. 16, pl. 511, figs. 13-15; 1984 Robaszynski *et al.*, p. 280; 1985 Caron, p. 72.

1955a *Globotruncana* (*Rugoglobigerina*) Bronnimann- Gandolfi, p. 15.

1956 *Kuglerina* Bronnimann and Brown, p. 557.

**Type species:** *Globigerina rugosa* Plummer, 1927, p. 38.

The genus *Rugoglobigerina* is marked by its trochospiral test, umbilical primary aperture protected by tegilla, periphery with inflated rugose chambers, umbilical sutures depressed, radial with costellae arranged in meridional pattern, globulose periphery.

This genus was evolved from genus *Archaeoglobigerina* Pessagno, 1967 by accentuation of the ornamentation of the chamber surface leading to the costellae type arranged in ameridional pattern (Fig. 2). In the present study, it is represented by eight species: *Rugoglobigerina rugosa* (Plummer, 1926), *Rugoglobigerina macrocephala* Bronnimann, 1952, *Rugoglobigerina hexacamerata* Bronnimann, 1952, *Rugoglobigerina scotti* Bronnimann, 1952, *Rugoglobigerina reicheli* Bronnimann, 1952, *Rugoglobigerina milamensis* Smith and Pessagno, 1973, *Rugoglobigerina pennyi* Bronnimann, 1952, and *Rugoglobigerina rotundata* Bronnimann, 1952. The distinction between them is based on the number of chambers in the last whorl, the rate of increase of chamber size, the height of the trochospire, and the diameter of the umbilicus.

***Rugoglobigerina rugosa* (Plummer, 1926)** is characterized by the almost flat trochospire, the rapid increase in chamber size, 4-5 chambers in the last whorl, and the absence of spine.

***Rugoglobigerina macrocephala* Bronnimann, 1952** is marked by its 3-3 1/2, exceptionally 4 globular chambers in the last whorl which more rapid increase in their size and the last one forms about half the volume of the test with a surface covered by thick rugosities and costellae.

***Rugoglobigerina hexacamerata* Bronnimann, 1952** is characterized by its typical six chambers in the last whorl, a slow increase in chamber size, a low to flat trochospire and a low height/diameter ratio.

***Rugoglobigerina scotti* Bronnimann, 1952** is marked by its compressed profile of the last chamber.

***Rugoglobigerina reicheli* Bronnimann, 1952** is characterized by the presence of strong spines on the peripheral margin of the first chamber of the last whorl.

***Rugoglobigerina milamensis* Smith and Pessagno, 1973** is marked by high trochospiral test covered by thick closely-spaced costellae arranged in a meridional pattern.

***Rugoglobigerina pennyi* Bronnimann, 1952** is characterized by 5-6 chambers increasing slowly in their size and large umbilicus.

***Rugoglobigerina rotundata* Bronnimann, 1952** is marked by 4 1/2 – 6 globular chambers with a surface covered by pustules and rugosities.

**10- Genus *Plummerita* Bronnimann, 1952b**

1952a *Rugoglobigerina* (*Plummerita*)  
Bronnimann: p. 37, pl. 511, figs. 4-6.

1952b *Rugoglobigerina* (*Plummerella*)  
Bronnimann: p. 146.

1956 *Plummerita* Bronnimann and Brown: p. 555, 556; 1984 Robaszynski *et al.*, p.290.

1971a *Plummerita* (*Plummerita*) Bronnimann-El-Naggar, p. 434.

**Type species:** *Rugoglobigerina* (*Plummerella*) *hantkeninoides hantkeninoides* Bronnimann, 1952.

The genus *Plummerita* is marked by having radially elongated chambers terminating in tubule spines in the last whorl.

This genus was derived from genus *Rugoglobigerina* Bronnimann, 1952a by changing the globular chambers to become radially elongated chambers terminating in tubulospines in the last whorl (Fig. 2).

In the present study, this genus is represented only by *Plummerita hantkeninoides* (Bronnimann, 1952) which is characterized by (5-6) inflated, triangular chambers; radial, depressed sutures, the chamber periphery rounded to compressed, some or all chambers bearing tubulospines.

**11- Genus *Rugotruncana* Bronnimann and Brown, 1956**

1927c *Globotruncana* Cushman, p. 81.

1956 *Rugotruncana* Bronnimann and Brown: p. 546, pl. 506, figs. 8-10; 1985 Caron, p. 76.

1959 *Globotruncana* (*Rugotruncana*) Banner and Blow: p. 11.

**Type species:** *Rugotruncana tilevi* Bronnimann and Brown, 1956.

The genus *Rugotruncana* is marked by its trochospiral test, globigeriniform early chambers, imperforate peripheral band and well developed double keel.

This genus was evolved from genus *Rugoglobigerina* Bronnimann, 1952a by flattening of its chambers and by development of a true double keel (Fig. 2). In the present study, this genus is represented by *Rugotruncana subcircumnodifer* (Gandolfi, 1955), and *Rugotruncana subpennyi* (Gandolfi, 1955).

***Rugotruncana subcircumnodifer* (Gandolfi, 1955)** is characterized by its 4-5 chambers in the last whorl. Two keels on all chambers of the last whorl; and its surface covered by rugosity.

***Rugotruncana subpennyi* (Gandolfi, 1955)** is characterized by its 6 chambers forming the last whorl, a flat spiral side and two more closely spaced keels, and often absent in the two final chambers.

**Biostratigraphy**

Many planktonic foraminiferal zonations schemes for the Campanian-Maastrichtian interval

were established. For more accurate biostratigraphic resolution, the identified planktonic foraminiferal species in the three studied sections at Esh El-Mellaha area are used to distinguish eleven biozones based on zonal schemes of Caron, 1985, Li and Keller, 1998a, b and Li *et al.*, 1999. The vertical ranges of these species are shown on Figs. 5-7. A comparison between the biozones established here and those proposed by different authors is shown on Table. 2. The following is a detailed description for these recorded planktonic foraminiferal biozones arranged from older to younger.

**1. *Globotruncana ventricosa* Zone (Partial range zone) (late early Campanian to late Campanian)**

This planktonic foraminiferal biozone was originally proposed by Dalbiez, 1955 from Tunisia. It is considered the oldest recorded zone in the present study. According to Caron, 1985, it is defined as a biostratigraphic interval extended from the first appearance of *Globotruncana ventricosa* White at the base to the first appearance of *Globotruncanella calcarata* (Cushman) at the top. In the study area, due to absence of *Globotruncanella calcarata* (Cushman), this zone is defined as a biostratigraphic interval extended from the first appearance of *Globotruncana ventricosa* White at base and followed by a sedimentary hiatus (Hiatus-1) where the *Globotruncana ventricosa* Zone is directly overlain by *Globotruncanella havanensis* Zone at the three studied sections. This zone attains about 9.5 m thick at Wadi Dib section, 12 m thick at Wadi Abu Had section, and about 14 m thick at Bir Mellaha section. It is assigned to the upper part of the early Campanian to the late Campanian. It is characterized by the presence of banks of large oyster *Pycnodonte vesicularis* (Lamarck). It is equivalent to the *Globotruncana ventricosa* Zone of Robaszynski *et al.*, 1984 and Caron, 1985. In Egypt, this Zone may be equivalent to the *Globotruncana ventricosa* Zone of Khalil and Meshaly, 2004. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

**2. *Globotruncanella havanensis* Zone (=CF9) (Partial range zone) (Late Campanian)**

This zone was originally proposed by Caron, 1978. In the present study, it 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. It attains about 5m thick at both Wadi Dib and Bir Mellaha sections, and about 2.5 m thick at Wadi Abu Had section. It is considered of late Campanian age (74.00- 72.48 Ma). as it is may be equivalent to *Globotruncanella subcrinatus* (CF9) Zone of Li and Keller, 1998a, b and Li *et al.*, 1999, The base of this

biozone was used by some authors to mark the beginning of the Maastrichtian (e.g. Robaszynski *et al.*, 1984 and Caron, 1985); while at the study, this biozone is belonged to the Late Campanian according to Li *et al.*, 1999. It is equivalent to the *G. lapparenti tricarinata* Zone of Bolli, 1966; the *G. havanensis* Zone of Caron, 1985; the lower part of *G. falsostuarti* Zone of Robaszynski *et al.*, 1984, Al Mogi-Labin *et al.*, 1986; the lower part of *G. stuartiformis* Zone of Postuma, 1971; the lower part *G. tricarinata* Zone of Boersma, 1984a, Barr, 1972, the lower part of *G. havanensis* Zone of Huber, 1990; the *G. subcrinatus* Zone (CF9) of Li and Keller, 1998a, b and Li *et al.*, 1999. In Egypt, this Zone may be equivalent to the lower part of *G. havanensis* Zone of El-Nady, 1995; Shahin & El Nady, 2001; the lower part of *G. lapparenti tricarinata* Zone of Beckmann *et al.*, 1969; the lower part of *G. falsostuarti* Zone of Hewaidy, 1987, Hewaidy *et al.*, 1991; the *G. tricarinata* Zone of Shahin, 1988; Ayyad *et al.*, 1996; the lower part of *G. aegyptiaca* Zone of Shahin, 1992; and the lower part of *G. aegyptiaca- G. stuartiformis* Zone of El-Dawy *et al.*, 1992. The most important recorded planktonic foraminiferal species within this zone at the three studied sections are shown on Figs. 5-7.

### **3. *Globotruncana aegyptiaca* Zone (CF8a) (Partial range zone) (Late Campanian)**

The *Globotruncana aegyptiaca* zone was originally proposed by Caron, 1985, as interval extended from the first appearance of *Globotruncana aegyptiaca* Nakkady at the base to the first appearance of *Gansserina gansseri* (Bolli) at the top. In the present study, the definition of Li *et al.*, 1999 is followed to include 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 attains about 4 m thick at Wadi Dib section, 2 m thick at Wadi Abu Had section, and about 3 m thick at Bir Mellaha section. It is assigned to the uppermost part of late Campanian age (72.48- 71.00 Ma according to Li *et al.*, 1999). The base of this biozone was used by some authors to mark the beginning of the Maastrichtian (e.g. Robaszynski *et al.*, 1984 and Caron, 1985); while at the present study, this biozone is attributed to the latest Campanian according to Li *et al.*, 1999. and the Campanian /Maastrichtian boundary is placed on the top of this biozone. It is equivalent to the middle part of *G. tricarinata* Zone of Boersma, 1984; the middle part of *G. havanensis* Zone of Huber, 1990; the lower part of *G. aegyptiaca* Zone of Caron, 1985; to the lower part of *G. aegyptiaca* Zone (CF8) of Li and Keller, 1998a, b; to the upper part of *G. falsostuarti* Zone of Robaszynski *et al.*, 1984, Almogi-Labin *et al.*, 1986. Also, it is equivalent to the *G. aegyptiaca* Subzone (CF8a) of Li *et al.*, 1999. In

Egypt, this biozone may be correlated with the middle part of *G. lapparenti tricarinata* Zone of Beckmann *et al.*, 1969; the lower part of *G. aegyptiaca* Zone of Shahin, 1992, El-Nady, 1995, Shahin & El Nady, 2001, Ayyad *et al.*, 1996; the middle part of *G. falsostuarti* Zone of Hewaidy, 1987; the middle part of *G. tricarinata* Zone of Shahin, 1988; the middle part of *G. aegyptiaca- G. stuartiformis* Zone of El-Dawy *et al.*, 1992. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

### **4. *Rugoglobigerina hexacamerata* Zone (CF8b) (Partial range zone) (early Maastrichtian)**

This zone was proposed by Li *et al.*, 1999. In the present study, 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. It attains about 1.5 m thick at Wadi Dib section and about 2 m thick at both Wadi Abu Had, and Bir Mellaha sections. It is assigned to Early Maastrichtian age (71.00- 70.39 Ma according to Li *et al.*, 1999). In the present study area, the base of this biozone is used to mark the Campanian- Maastrichtian boundary. It is equivalent to the upper part of *G. lapparenti tricarinata* Zone of Bolli, 1966; the upper part of *G. tricarinata* Zone of Boersma, 1984; the upper part of *G. tricarinata* Zone of Barr, 1972; the upper part of *G. stuartiformis* Zone of Postuma, 1971; the upper part of *G. falsostuarti* Zone of Robaszynski *et al.*, 1984, Almogi-Labin *et al.*, 1986; the upper part of *G. havanensis* Zone of Huber, 1990; the upper part of *G. aegyptiaca* Zone of Robaszynski *et al.*, 1984; and Caron, 1985; the upper part of *G. aegyptiaca* Zone (CF8) of Li and Keller, 1998a, b. Also, it is equivalent to the *Rugoglobigerina hexacamerata* Subzone (CF8b) of Li *et al.*, 1999. In Egypt, this biozone may be correlated with the upper part of *G. lapparenti tricarinata* Zone of Beckmann *et al.*, 1969; the upper part of *G. aegyptiaca* Zone of Shahin, 1992, El-Nady, 1995, Shahin & El Nady, 2001, Ayyad *et al.*, 1996; the upper part of *G. falsostuarti* Zone of Hewaidy, 1987, Hewaidy *et al.*, 1991; the upper part of *G. tricarinata* Zone of Shahin, 1988; the upper part of *G. aegyptiaca- G. stuartiformis* Zone of El-Dawy *et al.*, 1992. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

### **5. *Gansserina gansseri* Zone (CF7) (Partial range zone) (early Maastrichtian)**

The *Gansserina gansseri* zone was originally introduced for the first time from the late Maastrichtian of Trinidad by Bronnimann, 1952 as *Globotruncana gansseri* Zone to include a biostratigraphic interval from the first appearance of *Globotruncana gansseri* Bolli at the base to the first

appearance of *Abathomphalus mayaroensis* (Bolli). Robaszynski *et al.*, 1984, and Caron, 1985 used the same biozone of Bronnimann, 1952 with its same boundaries and they named it *Gansserina gansseri* Zone. Li *et al.*, 1999 considered this biozone of early Maastrichtian age and shorten its range to cover a biostratigraphic interval from the first appearance of nominate taxon at the base to the first appearance of *Contusotruncana contusa* (Cushman). In the present study, the definition of Li *et al.*, 1999 is used to include a biostratigraphic interval extended from the first appearance of *Gansserina gansseri* (Bolli) at the base to the first appearance of *Contusotruncana contusa* (Cushman) at the top. It attains about 5.5 m thick at Wadi Dib section, about 4 m thick at Wadi Abu Had section, and about 7m thick at Bir Mellaha section. It is assigned to early Maastrichtian age (70.39-69.56 Ma according to Li *et al.*, 1999). In most zonal schemes, the base of this biozone informally marks the Lower- Upper Maastrichtian boundary (Robaszynski *et al.*, 1984, Caron, 1985, 1991 and Li and Keller, 1998a, b). In the study area, it is equivalent to the lower part of *G. gansseri* Zone of Bolli, 1957a; the lower part of *Gansserina gansseri* Zone of Robaszynski *et al.*, 1984, and Caron, 1985; the lower part of *A. mayaroensis* Zone of Boersma, 1984a, and Huber, 1990; and the *G. gansseri* Zone of Wonders, 1980; and also the *G. gansseri* Zone (CF7) of Li and Keller, 1998a, b, and Li *et al.*, 1999. In Egypt, this biozone may be correlated with the lower part of *G. gansseri* of El-Naggar, 1966; Ansary and Tewfik, 1966; Beckmann *et al.*, 1969; Abdel-Kireem, 1986; Cherif and Hewaidy, 1987; Shahin, 1988, 1992; Cherif *et al.*, 1989; Luning *et al.*, 1998; the lower part of *G. gansseri* Zone of Luger, 1985; Cherif and Ismail, 1991; Anan, 1992; Hewaidy and Soliman, 1993; Hewaidy, 1994; Abdel-Kireem and Samir, 1995 and with the *G. gansseri* (CF7) of Tantawy *et al.*, 2001 and Samir, 2002. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

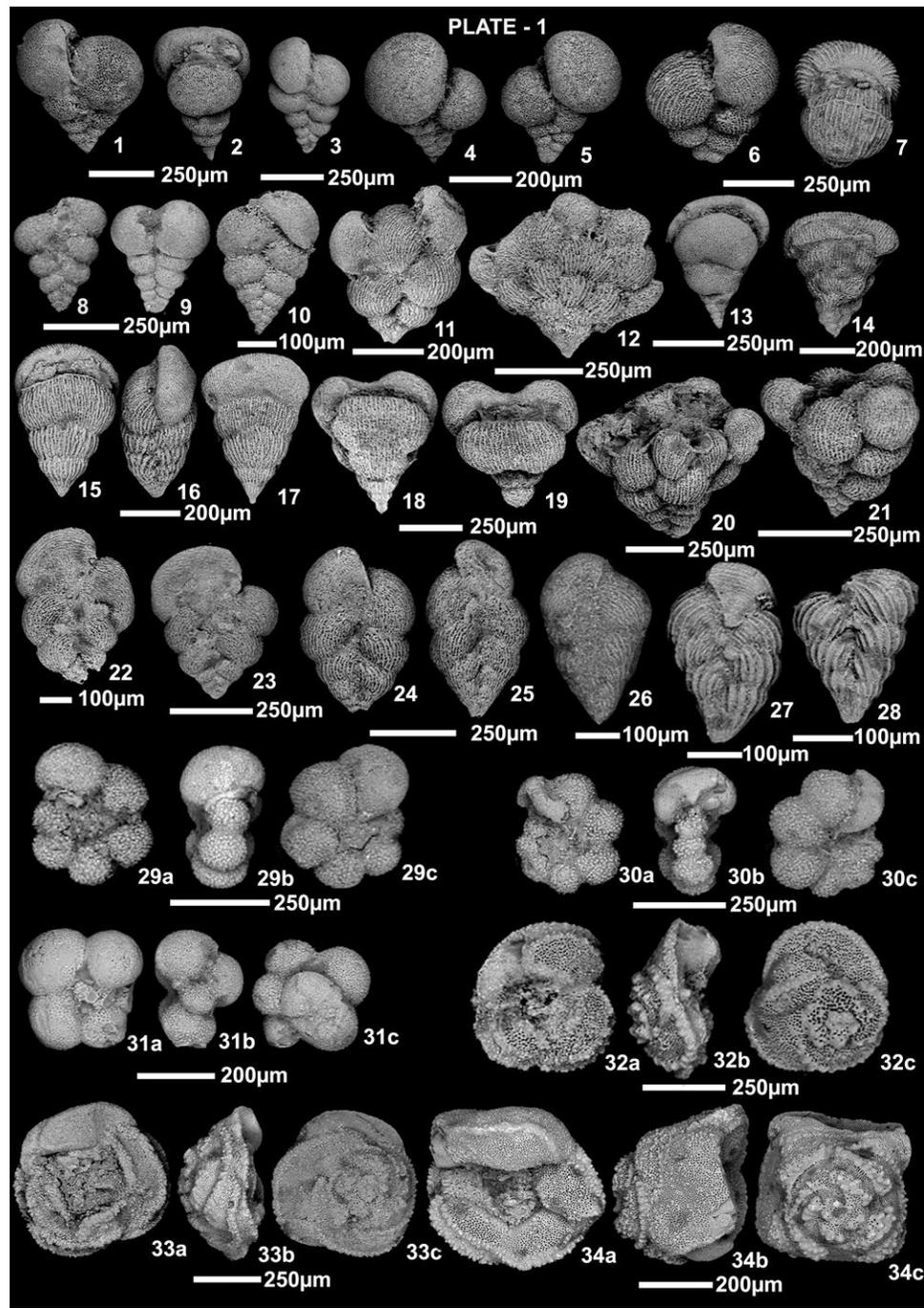
#### **6. *Contusotruncana contusa* Zone (CF6) (Partial range zone) (early Maastrichtian)**

This zone was originally proposed by Dalbiez, 1955 as *Globotruncana contusa* Zone for the upper Maastrichtian of Tunisia. In the present study, the definition of Li and Keller, 1998a, b is applied to include a biostratigraphic interval extended from the first appearance of *Contusotruncana contusa* (Cushman) at the base to the last appearance of *Globotruncana linneiana* (d'Orbigny) at the top. It attains about 3.5 m thick at Wadi Dib section, about

2.5 m thick at Wadi Abu Had section, and about 4m thick at Bir Mellaha section. It is assigned to Early Maastrichtian age (69.56- 69.06 Ma according to Li *et al.*, 1999). It is equivalent to the lower part of *Rosita contusa* Zone of Premoli-Silva & Bolli, 1973; Wonders, 1980; the lower middle part of *Gansserina gansseri* Zone of Robaszynski *et al.*, 1984, and Caron 1985; D'Hondt & Keller, 1991; and it also equivalent to the *Rosita contusa* Zone (CF6) of Li and Keller, 1998a, b and Li *et al.*, 1999. In Egypt, this biozone is equivalent to the lower part of *Rosita contusa* Zone of Abdel-Kireem *et al.*, 1994; the lower middle part of *Gansserina gansseri* Zone of El-Naggar, 1966; Luger, 1985; Abdel-Kireem and Samir, 1995. It is also equivalent to the *Rosita contusa* Zone (CF6) of Tantawy *et al.*, 2001. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

#### **7. *Pseudotextularia intermedia* Zone (CF5) (Partial range zone) (late Maastrichtian)**

The *Pseudotextularia intermedia* zone was originally introduced by Nederbragt, 1990 as the interval from the first appearance of *Planoglobulina acervulinoides* at the base to the first appearance of *Racemiguembelina fructicosa* at the top. In the present study area, the definition of Li & Keller, 1998a, b is used 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. It attains about 4 m thick at both Wadi Dib and Bir Mellaha sections, and about 2.5 m thick at Wadi Abu Had section. It is assigned to the early Maastrichtian age (69.06- 68.33 Ma according to Li *et al.*, 1999). Li *et al.*, 1999 used the top of this biozone to place the early/ late Maastrichtian boundary based on biostratigraphic correlation with the geometric time scale at DSDP site 525A, Tunisia. In the present study, this zone is probably equivalent to the upper middle part of *Gansserina gansseri* Zone of Robaszynski *et al.*, 1984; Caron, 1985; Keller, 1988; D'Hondt & Keller, 1991; the *Ps. intermedia* Zone (CF5) of Li and Keller, 1998a, b and Li *et al.*, 1999. In Egypt, this biozone is equivalent to the upper middle part of *Gansserina gansseri* Zone of El-Naggar, 1966; Beckmann *et al.*, 1969; Cherif & Hewaidy, 1987; Shahin, 1988, 1992; Anan, 1992; Omran, 1997; Luger, 1985; Abdel-Kireem and Samir, 1995 and Luning *et al.*, 1998. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

**PLATE - 1**

- 1 & 2- *Heterohelix globulosa* (Ehrenberg, 1840), sample 103, Sudr Formation, Bir Mellaha section, Early Maastrichtian.  
 3- *Heterohelix reussi* (Cushman, 1938a), sample 87, Sudr Formation, Bir Mellaha section, Late Campanian.  
 4 & 5- *Heterohelix aegyptiaca* Ansary and Tewfik, 1966, 4: sample 93, 5: sample 107, Sudr Formation, Bir Mellaha section, Late Campanian-Maastrichtian.  
 6 & 7- *Heterohelix striata* (Ehrenberg, 1840), 6: sample 104, 7: sample 84, Sudr Formation, Bir Mellaha section, Late Campanian-Maastrichtian.  
 8 & 9- *Heterohelix navarroensis* Loeblich, 1951, 8: sample 117, 9: sample 93, Sudr Formation, Bir Mellaha section, Early Late Maastrichtian.  
 10- *Heterohelix planata* (Cushman, 1938), sample 113, Sudr Formation, Bir Mellaha section, Early-Late Maastrichtian.  
 11- *Planoglobulina carseyae* (Plummer, 1931), sample 108, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 12- *Planoglobulina glabrata* (Cushman, 1938), sample 114, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 13 & 14- *Pseudotextularia elegans* (Rzehak, 1891), 13: sample 114, 14: sample 107, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 15-17- *Pseudotextularia deformis* (Kikoine, 1948), 15: sample 108, 16: sample 107, 17: sample 116, Sudr Formation, Bir Mellaha section, Late Maastrichtian.

- 18 & 19- *Pseudotextularia intermedia* (De Klasz, 1953)**, 18: sample 106, 19: sample 85, Sudr Formation, Bir Mellaha section, Late Campanian-Maastrichtian.
- 20- *Racemiguembelina fructicosa* (Egger, 1899)**, sample 106, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 21- *Racemiguembelina powelli* Smith and Pessagno, 1973**, sample 105, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 22 & 23- *Pseudoguembelina palpebra* Bronnimann & Brown, 1953**, 22: sample 116, 23: sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 24 & 25- *Pseudoguembelina hariaensis* Nederbragt, 1991**, 24: sample 112, 25: sample 117, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 26- *Pseudoguembelina costulata* (Cushman, 1938b)**, sample 115, Sudr Formation, Bir Mellaha section, Maastrichtian.
- 27 & 28- *Pseudoguembelina excolata* (Cushman, 1926)**, 27: sample 87, 28: sample 86, Sudr Formation, Bir Mellaha section, Late Campanian.
- 29- *Globigerinelloides prairiehillensis* Pessagno, 1967**, 29a: ventral view, 29b: side view, 29c: dorsal view, sample 80, Sudr Formation, Bir Mellaha section, Late Campanian.
- 30- *Globigerinelloides ultramicra* (Subbotina, 1949)**, 30a: ventral view, 30b: side view, 30c: dorsal view, sample 80, Sudr Formation, Bir Mellaha section, Late Campanian.
- 31- *Hedbergella holmdelensis* Olsson, 1964**, 31a: ventral view, 31b: side view, 31c: dorsal view, 31a & 31b: sample 77, 31c: sample 93, Sudr Formation, Bir Mellaha section, Late Campanian- Early Maastrichtian.
- 32- *Contusotruncana fornicata* (Plummer, 1931)**, 32a: ventral view, 32b: side view, 32c: dorsal view, sample 104, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 33- *Contusotruncana patelliformis* (Gandolfi, 1955)**, 33a: ventral view, 33b: side view, 33c: dorsal view, sample 80, Sudr Formation, Bir Mellaha section, Late Campanian.
- 34- *Contusotruncana contusa* (Cushman, 1926)**, 34a: ventral view, 34b: side view, 34c: dorsal view, 34a & 34b: sample 104, 34c: sample 109, Sudr Formation, Bir Mellaha section, Early-Late Maastrichtian.

#### **8. *Racemiguembelina fructicosa* Zone (CF4) (Partial range zone) (late Maastrichtian)**

Smith & Pessagno, 1973 was originally proposed this zone as the upper subzone of the *Gansserina gansseri* Zone. They defined this zone as a biostratigraphic interval between the first appearance of *Racemiguembelina fructicosa* (Egger) at the base and *Abathomphalus mayaroensis* (Bolli) at the top. In the present study, the definition Li and Keller, 1998a, b and Li *et al.*, 1999 is used to include 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. It attains about 4 m thick at both Wadi Dib, about 2.5 m thick at Wadi Abu Had section, and about 5m thick at Bir Mellaha section. It is assigned to the Late Maastrichtian age (68.33- 66.83 Ma according to Li *et al.*, 1999). It is equivalent to the combined topmost part of *G. gansseri* Zone and the lower most part of *A. mayaroensis* Zone of Robaszynski *et al.*, 1984; Caron, 1985; D'Hondt & Keller, 1991; the middle part of *A. mayaroensis* Zone of Boersma, 1984a, and Huber, 1990; the lower part of *R. fructicosa* Zone of Nederbragt, 1991; and also it is equivalent to *R. fructicosa* Zone (CF4) of Li and Keller, 1998a, b and Li *et al.*, 1999.

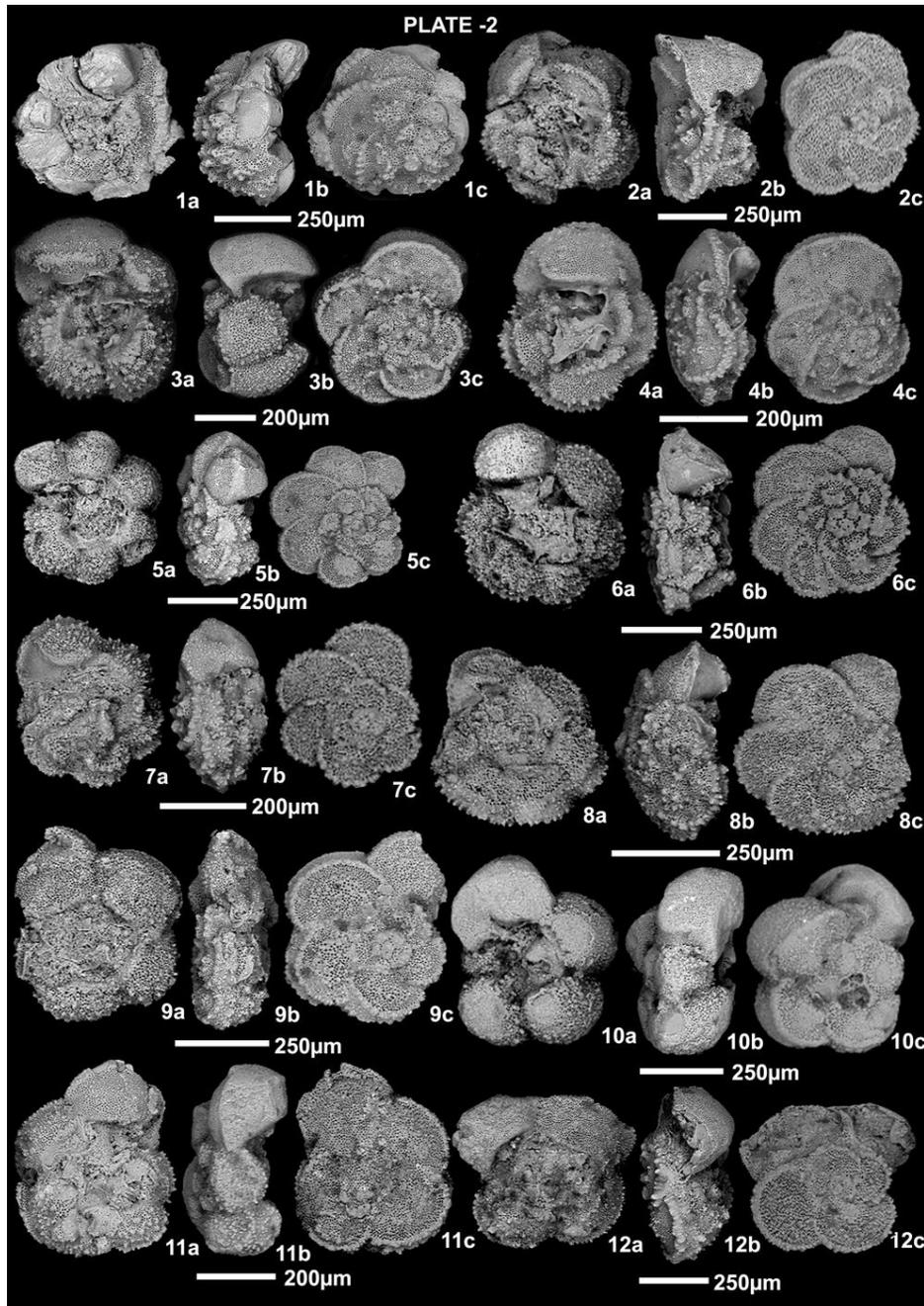
In Egypt, this biozone is equivalent to the combined topmost part of *G. gansseri* Zone and *G. esnehensis* Zone recorded by El- Naggat, 1966; the combined topmost part of *G. gansseri* Zone and the lower most part of *A. mayaroensis* Zone of Beckmann *et al.*, 1969; Ayyad *et al.*, 1996; Hewaidy, 1987, Hewaidy *et al.*, 1991; Shahin, 1988, 1992; Anan, 1992; El-Nady, 1995; Omran, 1997; Lunning *et al.*,

1998; and Shahin & El-Nady, 2001. It is also equivalent to *R. fructicosa* Zone (CF4) of Tantawy *et al.*, 2001; and Samir, 2002. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

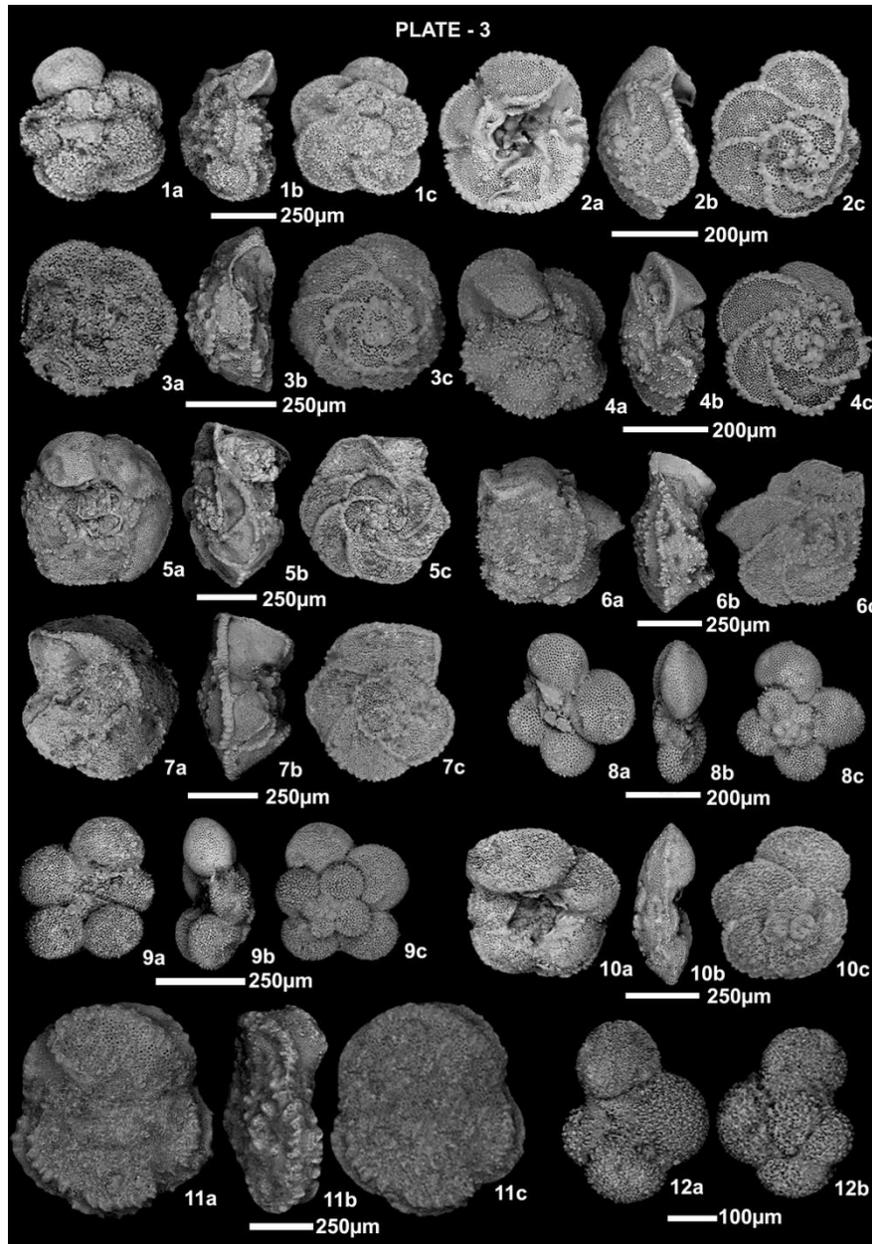
#### **9. *Pseudoguembelina hariaensis* Zone (CF3) (Partial range zone) (late Maastrichtian)**

This zone was firstly introduced by Nederbragt, 1990 as the total range of the zonal marker. In the present study, the definition of Li & Keller, 1998a, b and Li *et al.*, 1999 is used to include a biostratigraphic interval extended from the first appearance of *Pseudoguembelina hariaensis* Nederbragt at the base to the last appearance of *Gansserina gansseri* (Bolli) at the top. It attains about 4.5 m thick at both Wadi Dib, about 5 m thick at Wadi Abu Had section, and about 6 m thick at Bir Mellaha section. It is assigned to the Late Maastrichtian age (66.83- 65.45 Ma according to Li and Keller, 1998a, b). It is equivalent to the middle part of the *A. mayaroensis* Zone of Caron 1985; the lower upper part of *A. mayaroensis* Zone of Boersma, 1984a, and Huber, 1990. Also, it is equivalent to the *P. hariaensis* (CF3) of Li and Keller, 1998a, b and Li *et al.*, 1999. In Egypt, this biozone may be correlated with the lower part of *A. mayaroensis* Zone recorded by Hewaidy, 1987; the *G. esnehensis* Zone of El Naggat, 1966, and the *Ps. hariaensis* Zone (CF3) of Tantawy *et al.*, 2001; Samir, 2002; El Sabbagh, 2007; Al-Wosabi and Abu Shama, 2007. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

#### **10. *Pseudoguembelina palpebra* Zone (CF2) (Partial range zone) (latest Maastrichtian)**



- 1- *Contusotruncana plicata* (White, 1928), 1a: ventral view, 1b: side view, 1c: dorsal view, sample 104, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 2- *Gansserina wiedenmayeri* (Gandolfi, 1955), 2a: ventral view, 2b: side view, 2c: dorsal view, sample 110, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 3- *Gansserina gansseri* (Bolli, 1951), 3a: ventral view, 3b: side view, 3c: dorsal view, sample 112, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 4- *Globotruncana aegyptiaca* Nakkady, 1950, 4a: ventral view, 4b: side view, 4c: dorsal view, 4a & 4b: sample 94, 4c: sample 109, Sudr Formation, Bir Mellaha section, Early-Late Maastrichtian.
- 5 - *Globotruncana falsostuarti* Sigal, 1952, 5a: ventral view, 5b: side view, 5c: dorsal view, sample 103, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 6- *Globotruncana ventricosa* White, 1928, 6a: ventral view, 6b: side view, 6c: dorsal view, 6a & 6c: sample 105, 6b – sample 107, Sudr Formation, Bir Mellaha section, Early-Late Maastrichtian.
- 7- *Globotruncana orientalis* El Nagggar, 1966, 7a: ventral view, 7b: side view, 7c: dorsal view, 7a & 7c: sample 96, 7b: sample 107, Sudr Formation, Bir Mellaha section, Late Campanian – Late Maastrichtian.
- 8- *Globotruncana arca* (Cushman, 1926), 8a: ventral view, 8b: side view, 8c: dorsal view, sample 85, Sudr Formation, Bir Mellaha section, Late Campanian.
- 9- *Globotruncana bulloides* Voglar, 1941, 9a: ventral view, 9b: side view, 9c: dorsal view, sample 101, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 10&11- *Globotruncana linneiana* (d'Orbigny, 1839), 10a&11a: ventral view, 10b & 11b: side view, 10c & 11c: dorsal view, 10 & 11b: sample 107, 11a & 11c: sample 80, Sudr Formation, Bir Mellaha section, Late Campanian-Late Maastrichtian.
- 12- *Globotruncana rossetta* (Carsey, 1926), 12a: ventral view, 12b: side view, 12c: dorsal view, sample 105, Sudr Formation, Bir Mellaha section, Early Maastrichtian.

**PLATE - 3**

- 1- *Globotruncana rugosa* (Marie, 1941), 1a: ventral view, 1b: side view, 1c: dorsal view, sample 86, Sudr Formation, Bir Mellaha section, Late Campanian.  
 2- *Globotruncana esnehensis* Nakkady, 1950, 2a: ventral view, 2b: side view, 2c: dorsal view, sample 114, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 3- *Globotruncanita conica* (White, 1928), 3a: ventral view, 3b: side view, 3c: dorsal view, sample 100, Sudr Formation, Bir Mellaha section, Early Maastrichtian.  
 4- *Globotruncanita stuartiformis* (Dalbiez, 1955), 4a: ventral view, 4b: side view, 4c: dorsal view, 4a & 4b: sample 116, 4c: sample 117, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 5- *Globotruncanita stuarti* (De Lapparent, 1918), 5a: ventral view, 5b: side view, 5c: dorsal view, 5a: sample 116, 5b & 5c: sample 104, Sudr Formation, Bir Mellaha section, Early-Late Maastrichtian.  
 6- *Globotruncanita subspinosa* (Pessagno, 1960), 6a: ventral view, 6b: side view, 6c: dorsal view, sample 104, Sudr Formation, Bir Mellaha section, Early Maastrichtian.  
 7- *Globotruncanita pettersi* (Gandolfi, 1955), 7a: ventral view, 7b: side view, 7c: dorsal view, sample 104, Sudr Formation, Bir Mellaha section, Early Maastrichtian.  
 8- *Globotruncanella petaloidea* (Gandolfi, 1955), 8a: ventral view, 8b: side view, 8c: dorsal view, 8a & 8b: sample 104, 8c: sample 106, Sudr Formation, Bir Mellaha section, Early-Late Maastrichtian.  
 9- *Globotruncanella havanensis* (Voorwijk, 1937), 9a: ventral view, 9b: side view, 9c: dorsal view, sample 107, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 10- *Globotruncanella citae* Bolli, 1951, 10a: ventral view, 10b: side view, 10c: dorsal view, sample 84, Sudr Formation, Bir Mellaha section, Late Campanian.  
 11- *Abathomphalus mayaroensis* (Bolli, 1951), 11a: ventral view, 11b: side view, 11c: dorsal view, sample 115, Sudr Formation, Bir Mellaha section, Late Maastrichtian.  
 12- *Archaeoglobigerina blowi* Pessagno, 1967, 12a: ventral view, 12b: side view, 2a: sample 83, 2b: sample 85, Sudr Formation, Bir Mellaha section, Late Campanian.

This zone was introduced by Li & Keller, 1998a, b from DSDP Site 525A and Tunisia respectively. In the present study, 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. It is recorded only at Bir Mellaha section and attains about 3m thick. It is assigned to the Latest Maastrichtian age (65.45- 65.30 Ma according to Li and Keller, 1998a). It is equivalent to the upper part of *A. mayaroensis* Zone of Premoli Silva & Bolli, 1973; Robaszynski *et al.*, 1984; Caron, 1985; Boersma, 1984a; Huber, 1990, D'Hondt & Keller, 1991; Molina *et al.*, 1996; and it is also equated to *Ps. Palpebra* Zone (CF2) of Li and Keller, 1998a, b, and Li *et al.*, 1999. In Egypt, it is equivalent to the upper part of *A. mayaroensis* Zone of Beckmann *et al.*, 1969; Ayyad *et al.*, 1996; Hewaidy, 1987, Hewaidy *et al.*, 1990; Shahin, 1988, 1992; El-Nady, 1995; El-Dawy *et al.*, 1992; Marzouk and Luning, 1998; Abdel-Kireem & Abdou, 1979; Luning *et al.*, 1998; and also it is equated to the *Ps. Palpebra* Zone (CF2) of Samir, 2002. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

#### **11. *Plummerita hantkeninoides* Zone (CF1) (Total range zone) (latest Maastrichtian)**

Pardo *et al.*, 1996 was originally introduced this planktonic foraminiferal biozone for the latest Maastrichtian of Spain. In the present study, the definition of Li *et al.*, 1999 is used to include a biostratigraphic interval of the total range of *Plummerita hantkeninoides* (Bronnimann). It is considered as the youngest Late Maastrichtian zone (Masters, 1984; Ion, 1993; Pardo *et al.*, 1996; Keller, 2002; El-Sabbagh *et al.*, 2004, El-Sabbagh, 2007). In the present study, it occupies the topmost part of Abu Zeneima Member at Bir Mellaha section and attains about 3m thick indicating the completeness of the uppermost part of the Maastrichtian age at this section. It is assigned to the latest part of the late Maastrichtian age (65.30 – 65.00 Ma according to Li *et al.*, 1999). The upper boundary of this biozone is used to placement the Cretaceous /Paleogene (K/P<sub>e</sub>) boundary in the study area. It is equivalent to the topmost part of the *A. mayaroensis* Zone of Boersma, 1984a; Robaszynski *et al.*, 1984; Caron, 1985, and Huber, 1990. It is also equivalent to *Pl. hantkeninoides* (CF1) of Arz, 1996; Li & Keller, 1998b; Li *et al.*, 1999; the

upper part of Zone (CF1-2) of Li & Keller, 1998a&b. In Egypt, this biozone is equivalent to the *Kassabiana falsocalcarata* Zone of Luger, 1998; the upper part of *Pl. reicheli* Subzone of Shahin, 1992; El-Nady, 1995; Omran, 1997; the *Pl. hantkeninoides* (CF1) of Samir, 2002, El-Sabbagh, 2007. The most important recorded planktonic foraminiferal species within this Zone at the three studied sections are shown on Figs. 5-7.

The two latest Maastrichtian *Pseudoguembelina palpebra* (CF2) and *Plummerita hantkeninoides* (CF1) zones which recorded at Bir Mellaha section are missing at both Wadi Abu Had and Wadi Dib sections indicating presence of second unconformity surface (Hiatus-2) within the uppermost part Abu Zeneima Member at these two sections.

A correlation between the distinguished eleven planktonic foraminiferal biozones at the three studied sections is shown on Fig. 8.

#### **Stage Boundaries In The Study Area**

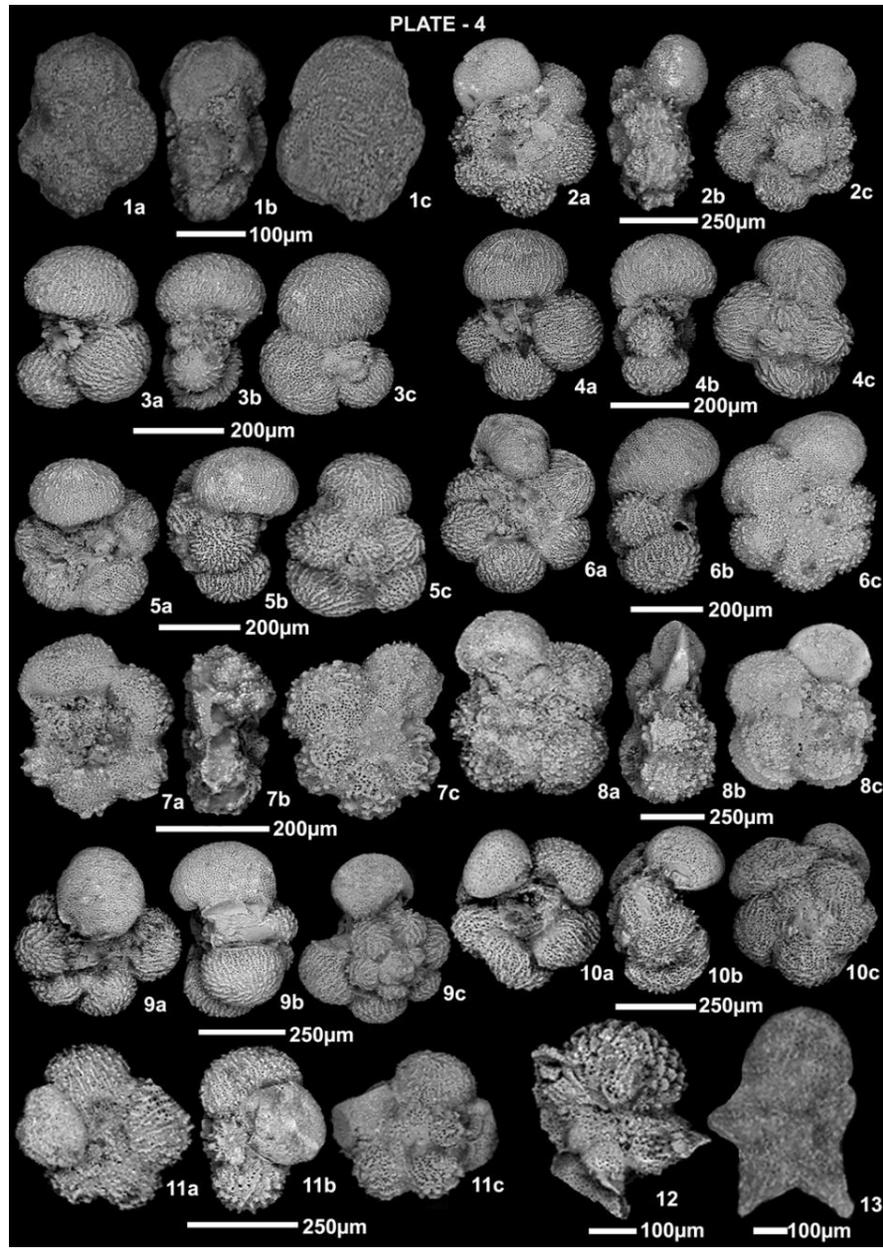
##### **1. The Campanian/ Maastrichtian boundary**

There is general agreement on placing the Campanian/ Maastrichtian boundary at the top of the *Globotruncanita calcarata* Zone (e.g. Robaszynski *et al.*, 1984; Caron, 1985; Bralower *et al.*, 1995, Li and Keller, 1998a, b, and Cherif and Ismail, 1991).

Li *et al.*, 1999 followed Gradstein *et al.*, 1995 in placement of the Campanian/ Maastrichtian boundary and they informally used the planktonic foraminiferal datum of *Rugoglobigerina hexacamerata* Bronnimann at 71 Ma for this boundary based on biostratigraphic correlation with the geomagnetic time scale at DSDP site 525A, Tunisia. This datum event is within the range of Gradstein *et al.*'s estimate of (71.60 ± 0.7 Ma) for this boundary.

Odin, 2001 in the Tercis section (France) placed this boundary at the first occurrence (FO) of *Contusotruncana contusa* (Cushman) and the FO of *Rugoglobigerina scotti* Bronnimann at 72 Ma. Recently, Gradstein *et al.*, 2012 placed this boundary within the upper part of *Gansserina gansseri* Zone at 72 Ma.

In the present study, the Campanian/ Maastrichtian boundary is located within the lower part of the Abu Zeneima Member followed Li *et al.*, 1999 in the placement of this boundary on the top of *Globotruncana aegyptiaca* Zone (CF8a) and at the first appearance of *Rugoglobigerina hexacamerata* Bronnimann Figs. 5-7 and Tab. 1.

**PLATE - 4**

- 1- *Rugotruncana subcircumnodifer* (Gandolfi, 1955), 1a: ventral view, 2b: side view, 1c: dorsal view, sample 86, Sudr Formation, Bir Mellaha section, Late Campanian.
- 2- *Rugotruncana subpennyi* (Gandolfi, 1955), 2a: ventral view, 2b: side view, 2c: dorsal view, 2a & 2c: sample 84, 2b: sample 116, Sudr Formation, Bir Mellaha section, Late Campanian-Maastrichtian.
- 3 & 4- *Rugoglobigerina macrocephala* Bronnimann, 1952, 3a & 4a: ventral view, 3b & 4b: side view, 3c & 4c: dorsal view, 3a & 4: sample 104, 3b: sample 114, 3c: sample 106, Sudr Formation, Bir Mellaha section, Early to Late Maastrichtian.
- 5- *Rugoglobigerina rugosa* (Plummer, 1926), 5a: ventral view, 5b: side view, 5c: dorsal view, sample 106, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 6- *Rugoglobigerina hexacamerata* Bronnimann, 1952, 6a: ventral view, 6b: side view, 6c: dorsal view, 6a: sample 110, 6b & 6c: sample 108, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 7- *Rugoglobigerina reicheli* Bronnimann, 1952, 7a: ventral view, 7b: side view, 7c: dorsal view, 7a: sample 80, 7b: sample 94, 7c: sample 104, Sudr Formation, Bir Mellaha section, Late Campanian- Maastrichtian.
- 8- *Rugoglobigerina scotti* Bronnimann, 1952, 8a: ventral view, 8b: side view, 8c: dorsal view, sample 92, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 9- *Rugoglobigerina rotundata* Bronnimann, 1952, 9a: ventral view, 9b: side view, 9c: dorsal view, sample 108, Sudr Formation, Bir Mellaha section, Late Maastrichtian.
- 10- *Rugoglobigerina pennyi* Bronnimann, 1952, 10a: ventral view, 10b: side view, 10c: dorsal view, sample 104, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 11- *Rugoglobigerina milamensis* Smith and Pessagno, 1973, 11a: ventral view, 11b: side view, 11c: dorsal view, sample 94, Sudr Formation, Bir Mellaha section, Early Maastrichtian.
- 12 & 13- *Plummerita hantkeninoides* (Bronnimann, 1952), ventral views, sample 118, Sudr Formation, Bir Mellaha section, Latest Maastrichtian.

Fig. 5: Distribution chart of the identified late Campanian to late Maastrichtian planktonic foraminiferal species at Bir Mellaha section.

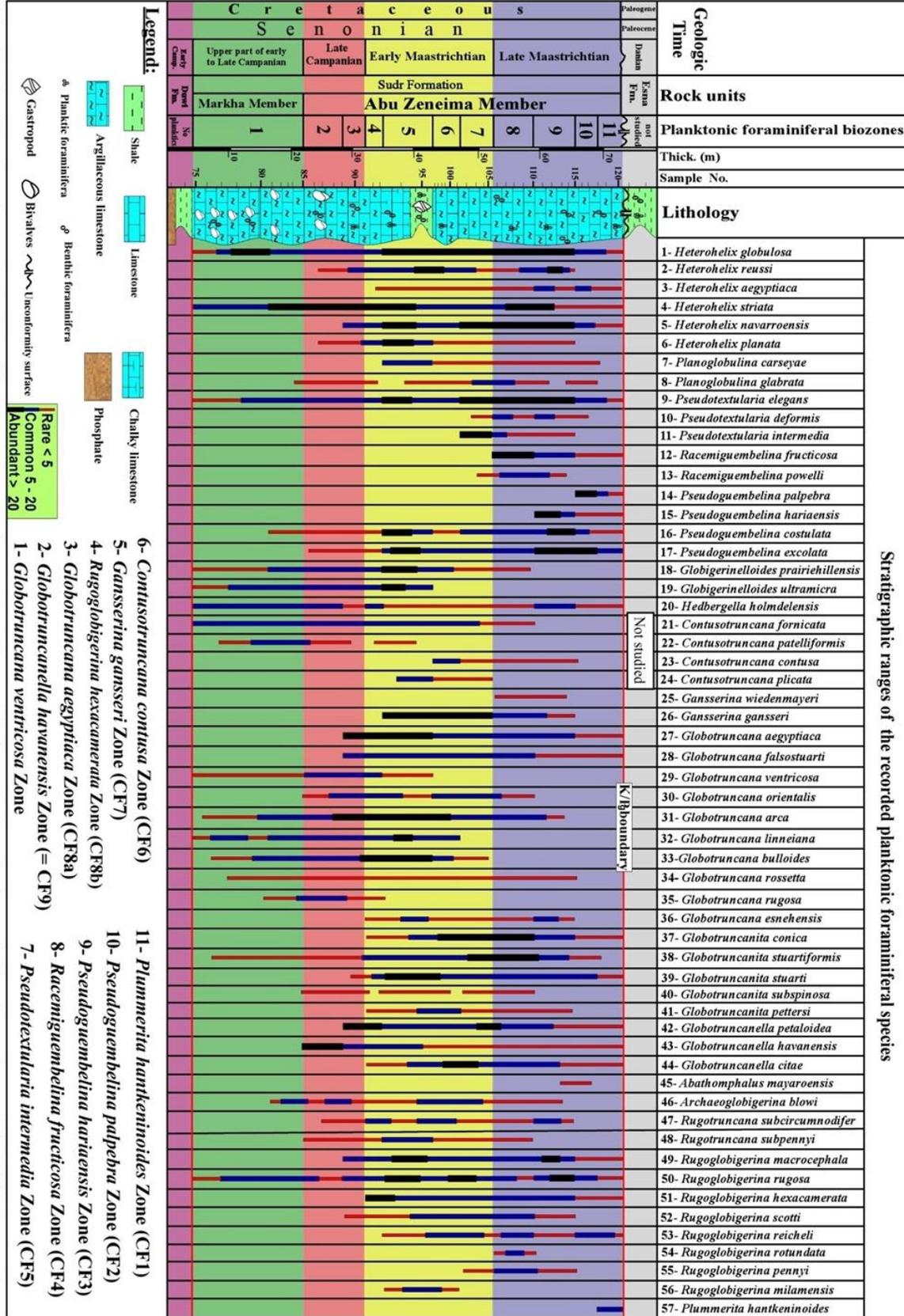
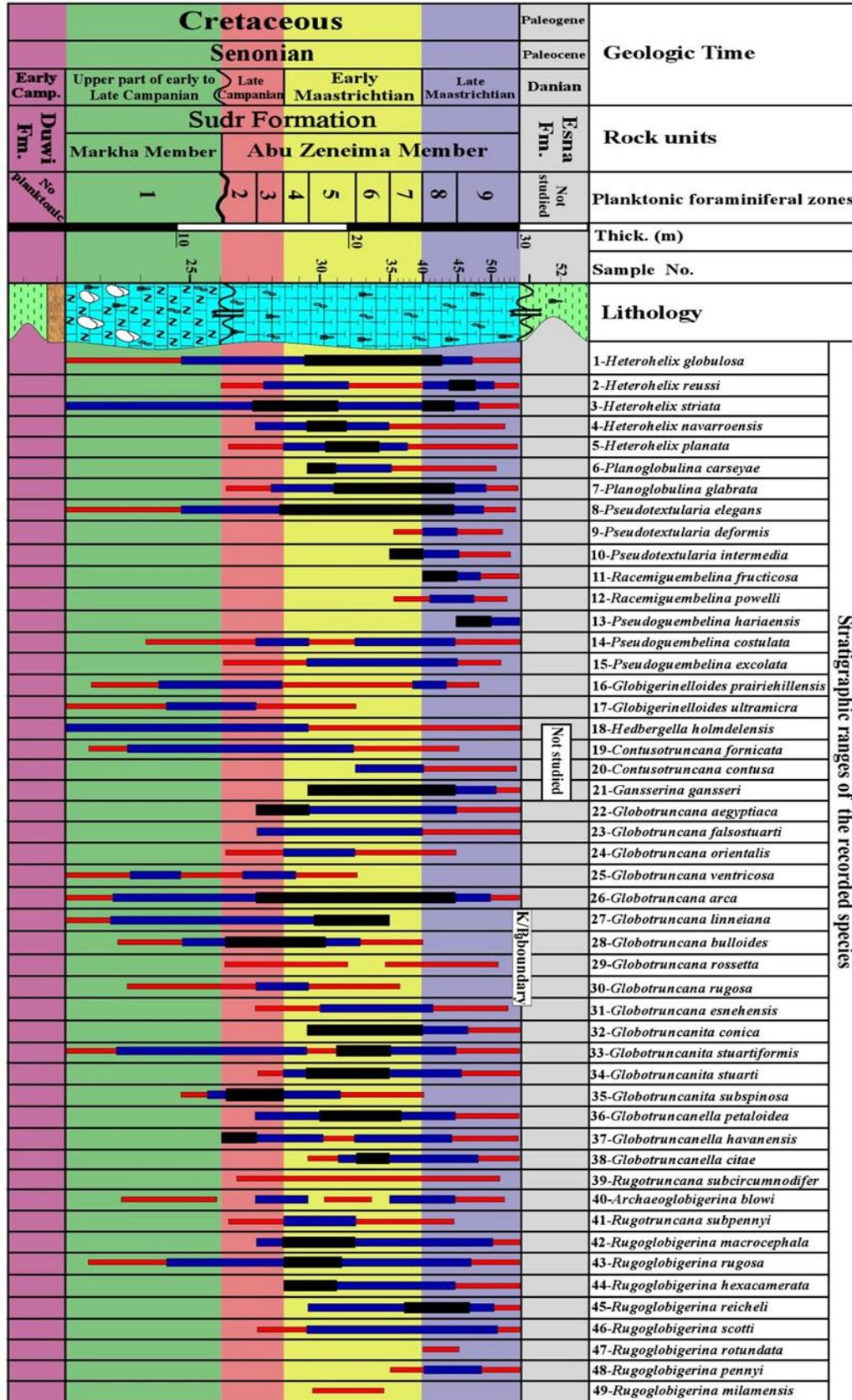
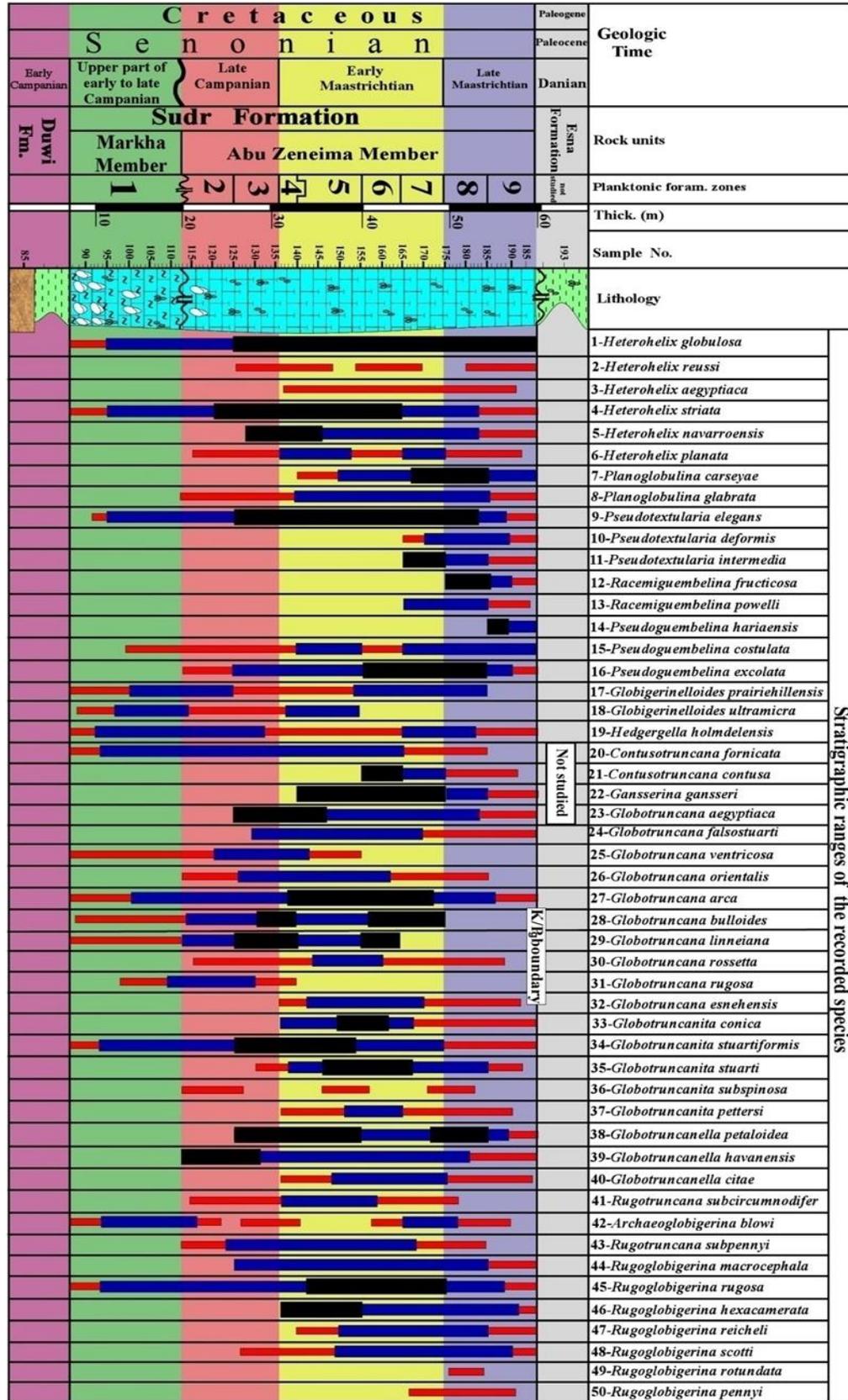


Fig. 6: Distribution chart of the identified late Campanian to late Maastrichtian planktonic foraminiferal species at Wadi Abu Had section. For Caption see Fig. 5.



Stratigraphic ranges of the recorded species

Fig. 7. Distribution chart of the identified late Campanian to late Maastrichtian planktonic foraminiferal species at Wadi Dib section. For Caption see Fig. 5.



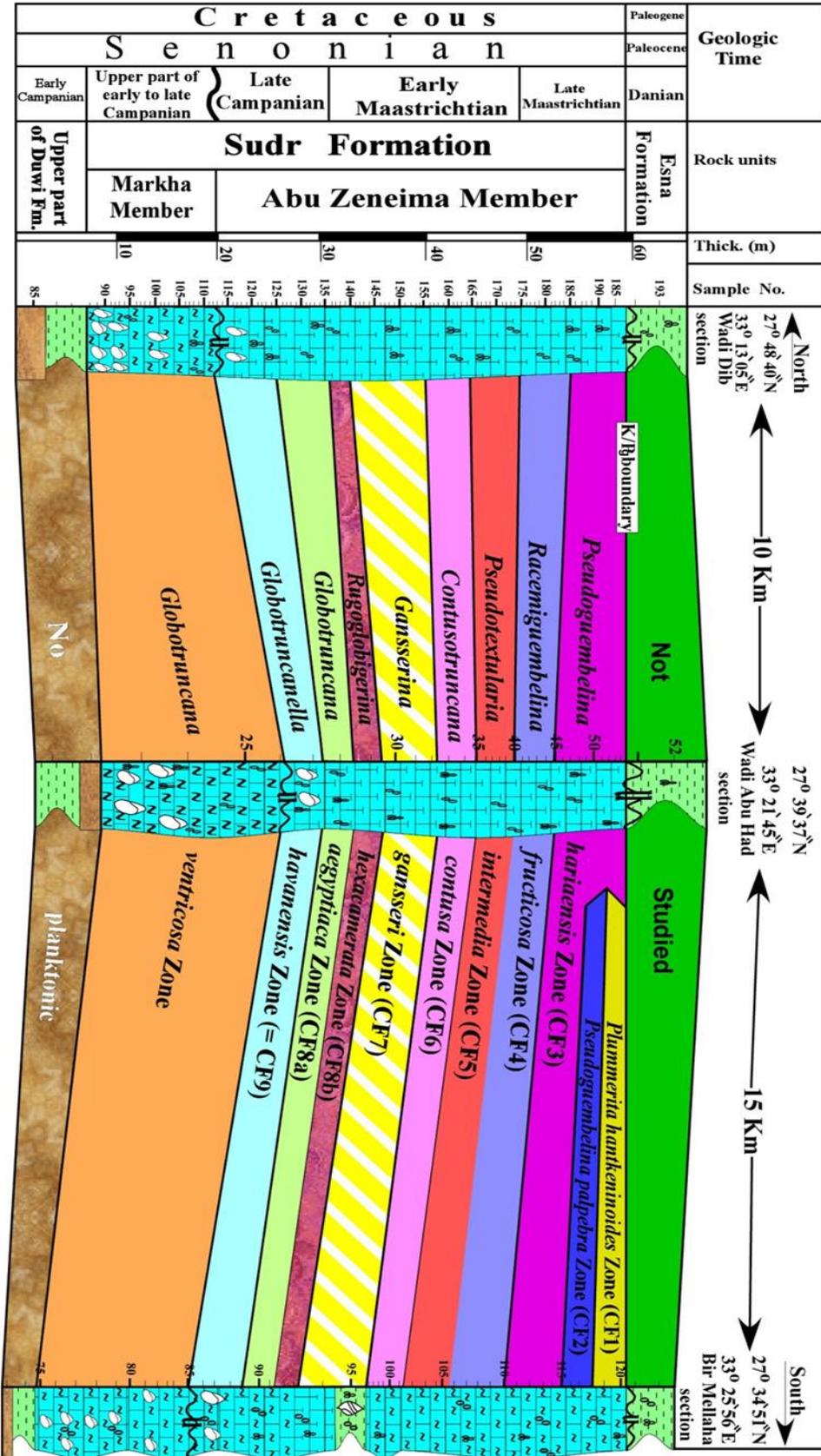


Fig. 8: Biostratigraphic correlation chart between the three studied sections.

**Tab. 1: Summary of the used planktonic foraminiferal zonal schemes for the late Campanian- Maastrichtian, age estimated and their equivalents at the Esh El-Mellaha area. The estimated ages and datum events are based on Li and Keller, 1998a, b & Li *et al.*, 1999, and Correlation with Caron, 1985.**

Time (Ma)	Stage	Planktonic Foraminiferal datum events Last Occurrence (LO) First Occurrence (FO)	Age (Ma)	Li <i>et al.</i> ,1999	Li & Keller (1998a, b)	Caron (1985)	Stage	Cherif & Ismail (1991) South-west Gulf of Suez	Present study								
									Esh El-Mellaha area								
									South Bir Mellaha section	Middle Wadi Abu Had section	North Wadi Dib section						
65	Late Maastrichtian	<i>P. hantkenoides</i> ↓	65.00	CF1	<i>P. hantkenoides</i>	CF1	<i>Abathomphalus mayaroensis</i>	Hiatus	<i>P. hantk.</i> (CF1)	Hiatus-2							
66		<i>G. gansseri</i> ↓	65.30	CF2	<i>P. palpebra</i>	CF2			<i>P. palp.</i> (CF2)								
67		<i>P. hariaensis</i> ↓	66.83	CF3	<i>P. hariaensis</i>	CF3			<i>Pseudoguembelina hariaensis</i> (CF3)								
68		<i>R. fructifera</i> ↓	68.33	CF4	<i>R. fructifera</i>	CF4			<i>Racemiguembelina fructifera</i> (CF4)								
69	Early Maastrichtian	<i>G. linneniana</i>	69.06	CF5	<i>P. intermedia</i>	CF5	<i>G. gansseri</i>	<i>G. gansseri</i>	<i>Pseudotextularia intermedia</i> (CF5)								
70		<i>R. contusa</i>	69.56	CF6	<i>R. contusa</i>	CF6			<i>Contusotruncana contusa</i> (CF6)								
71		<i>G. gansseri</i> ↓	70.39	CF7	<i>G. gansseri</i>	CF7			<i>Gansserina gansseri</i> (CF7)								
72	Late Campanian	<i>R. hexacamerata</i> ↓	71.00	CF8	<i>R. hexacamerata</i>	<i>G. aegyptiaca</i>	<i>G. aegyptiaca</i>	<i>G. aegyptiaca</i>	<i>Rugoglobigerina hexacamerata</i> (CF8b)								
73		<i>G. aegyptiaca</i>	72.48	CF8a	<i>G. aegyptiaca</i>				CF8	<i>Globotruncana aegyptiaca</i> (CF8a)							
74		<i>G. calcarata</i>	74.00	CF9	<i>G. subcarinatus</i>				CF9	<i>Globotruncanella havanensis</i> = (CF9)							
75		<i>G. calcarata</i>	74.70	CF10	<i>G. calcarata</i>	CF10	<i>G. calcarata</i>	<i>G. calcarata</i>	Hiatus-1								
76	Upper Early to Late Campanian	<i>G. ventricosa</i>	79.00	No data			<i>G. ventricosa</i>	Upper part of Early to Late Campanian	Barren interval	<i>Globotruncana ventricosa</i>							
77																	
78	Early Campanian	<i>D. asymmetrica</i>	83.00	No data			<i>G. elevata</i>	Early Campanian	Barren interval	Barren interval							
79																	
80																	
81																	
82																	
83	Sant. onian				<i>D. asymmetrica</i>		Sant. onian										

## 2. The Early/ Late Maastrichtian boundary

Planktonic foraminiferal authors have generally placed the early- late Maastrichtian boundary at the first appearance of *Gansserina gansseri* (Bolli) (e.g. Robaszynski *et al.*, 1984, Caron, 1985, and Li and Keller, 1998a, b) or at the first appearance of *Abathomphalus mayaroensis* (Bolli) (e.g. Boersma, 1984a, and Huber, 1990) or at the first appearance of *Racemiguembelina fructifera* (Egger) (e.g. Nederbragt, 1991, and Li *et al.*, 1999). In present study, we are not used the first appearance of *Abathomphalus mayaroensis* (Bolli) to place the early/ late Maastrichtian boundary because of many studies have been shown that this taxon is poor biostratigraphic marker and not a reliable zonal index species because both first appearance and last appearance of this species are diachronous (Keller, 1989, Huber, 1990, Pardo *et al.*, 1996); appear much earlier in high latitudes and is rare or absent in neritic

environment and also, this taxon is rarely present in continental shelf areas due to it is deeper dwelling habitat (e.g. Masters, 1984, 1993; Hultberg and Malmgren, 1987; Keller, 1988, 1989, 1993; Huber, 1992, Nederbragt, 1991, and Keller *et al.*, 1996). Li and Keller, 1998a, b noted that *Abathomphalus mayaroensis* (Bolli) first appears about 4m below the *Gansserina gansseri* (Bolli) at site 525A, Tunisia. However, in low latitudes the first appearance of *Abathomphalus mayaroensis* (Bolli) is generally appears much later at approximately the first appearance of *Racemiguembelina fructifera* (Egger) (e.g. Robaszynski *et al.*, 1984, and Caron, 1985). Gradstein *et al.*, 1995 proposed that the early/ late Maastrichtian boundary be placed at 69.50 Ma within the upper part of C31R. This interval corresponds to the first appearance of *Contusotruncana contusa* (Cushman) which marks the base of Zone (CF6) of Li and Keller, 1998a, b and Li *et al.*, 1999. In contrast,

Bralower *et al.*, 1995, proposed that this boundary be placed at the base of C30N at about 67.60 Ma, which corresponds to within the middle of *Racemiguembelina fructicosa* Zone (CF4) of Li and Keller, 1998a, b and Li *et al.*, 1999. Li *et al.*, 1999 were informally used the first appearance of *Racemiguembelina fructicosa* (Egger) to approximate the early/ late Maastrichtian boundary at 68.30 Ma based on biostratigraphic correlation with the geometric time scale at DSDP site 525A, Tunisia. At the three studied sections, the early/ late Maastrichtian boundary is located within the upper part of Abu Zeneima Member and we are followed Li *et al.*, 1999 in placement it at the first appearance of *Racemiguembelina fructicosa* (Egger) Figs. 5-7 and Tab.1.

### Summary And Conclusions

-This work can be summarized in the following items:

**1-**The present study deals with the high resolution planktonic foraminiferal biostratigraphy of the Upper Campanian to Upper Maastrichtian Sudr Formation and its stage boundaries for three exposures on the western flank of the Esh El-Mellah area, North Eastern Desert, Egypt from north to south are Wadi Dib, Wadi Abu Had, and Bir Mellaha sections.

**2-**Lithostratigraphically, this interval is represented by the Sudr Formation which classified into Markha and Abu Zeneima members from base to top and this rock unit is found very rich with planktonic foraminiferal assemblages.

**3-**Fifty seven planktonic foraminiferal species belonging to seventeen genera, six subfamilies, five families, four superfamilies and one suborder are recorded most them are belonged to family "Globotruncanidae" where it includes 11 genera and 38 species. So, the phylogenetic development of the recorded species and genera belonged to this important family is described.

**4-** The genus *Hedbergella* Bronnimann and Brown 1958 was considered as the ancestor of all genera of the family Globotruncanidae, where, it is the oldest and most primitive genus of this family. The genus *Contusotruncana* Korchagin, 1982 was initiated from *Marginotruncana sinuosa* Porthault, 1970 through gradual increase in the spire height, size of chambers and placation of chamber surfaces. The genus *Gansserina* Caron, Gonzales Donoso, Robaszynski and Wonders, 1984 was derived from genus *Archaeoglobigerina* Pessagno, 1967 through the development of a single keel and coarse rugosities. The genus *Globotruncana* was derived from genus *Marginotruncana* Hofker, 1956 by migration of the extra umbilical primary aperture towards umbilical position and replacement of the portici by tegilla. The genus *Globotruncanita* Reiss, 1957 was derived from

*Marginotruncana sigali* Reichel, 1950, where the primary aperture became umbilical in its position and the two keels in the first chambers of the last whorl disappeared. The genus *Globotruncanella* Reiss, 1957 was derived from genus *Hedbergella* Bronnimann and Brown 1958 by changing the primary aperture from extraumbilical –nearly peripheral protected by lips to become extraumbilical protected by portici with an imperforate peripheral band or even pustulose keel. The genus *Abathomphalus* was evolved from genus *Globotruncanella* Reiss, 1957 by changing the rounded periphery to became double keel. The genus *Archaeoglobigerina* Pessagno, 1967 was derived from genus *Whiteinella* Pessagno, 1967 by changing the primary aperture from extraumbilical protected by portici to become umbilical protected by tegilla and a wide imperforate peripheral band. The genus *Rugoglobigerina* Bronnimann, 1952a was evolved from genus *Archaeoglobigerina* Pessagno, 1967 by accentuation of the ornamentation of the chamber surface leading to the costellae type arranged in ameridional pattern. The genus *Plummerita* Bronnimann, 1952b was derived from genus *Rugoglobigerina* Bronnimann, 1952a by changing the globular chambers to become radially elongated chambers terminating in tubulospines in the last whorl. Finally the genus *Rugotruncana* Bronnimann and Brown, 1956 was evolved from genus *Rugoglobigerina* Bronnimann, 1952a by flattening of its chambers and by development of a true double keel.

**5-** Depending on the stratigraphic distribution of all recorded species within the Sudr Formation at these three studied sections, the upper Campanian- upper Maastrichtian interval biostratigraphically is classified into eleven planktonic foraminiferal biozones for the first time in the present study area: **one** of upper part of early Campanian to late Campanian age (*Globotruncana ventricosa* Zone); **two** of late Campanian age (*Globotruncanella havanensis* (=CF9) and *Globotruncana aegyptiaca* (CF8a) zones); **four** of early Maastrichtian age (*Rugoglobigerina hexacamerata* (CF8b), *Gansserina gansseri* (CF7), *Contusotruncana contusa* (CF6), *Pseudotextularia intermedia* (CF5) zones); and **four** of late Maastrichtian age (*Racemiguembelina fructicosa* (CF4), *Pseudoguembelina hariaensis* (CF3), *Pseudoguembelina palpebera* (CF2), and *Plummerita hantkeninoides* (CF1) zones). In contrast with our results, the late Maastrichtian age was not recorded previously in the study area.

**6-** The Campanian / Maastrichtian boundary in the present study area, is located within the lower part of the Abu Zeneima Member between *Globotruncana aegyptiaca* (CF8a) and *Rugoglobigerina hexacamerata* (CF8b) zones.

7- The early / late Maastrichtian boundary in the present study area, is located within the upper part of the Abu Zeneima Member between *Pseudotextularia intermedia* (CF5) and *Racemiguembelina fruticosa* (CF4) zones.

8-Two unconformity surfaces are recorded within the Sudr Formation in the present study area:

-The first one is recorded at the three studied sections and it lies between the Markha and Abu Zeneima Members due to absence of the late Campanian *Globotruncanita calcarata* (CF10) Zone, where the *Globotruncana ventricosa* Zone directly overlain by *Globotruncanella havanensis* (=CF9) Zone.

- On the other hand, the second unconformity surface lies in the topmost part Abu Zeneima Member and it is recorded at both Wadi Abu Had and Wadi Dib only where the two latest Maastrichtian *Pseudoguembelina palpebra* (CF2) and *Plummerita hantkeninoides* (CF1) zones which recorded at Bir Mellaha section are missing at these two studied sections.

#### References

1. Abd El-Kireem, M. R., 1986: Planktonic foraminifera and stratigraphy of the Tanjero Formation (Maastrichtian), northeastern Iraq – Micropaleontology, 32 (3): 215-231.
2. Abdallah, A. M., El-Dawoody, A. S. and Aboul Karamat, M. S., 1984: Stratigraphy and paleontology of the Late Cretaceous to Early Eocene succession in Esh El-Mellaha range, Eastern Desert, Egypt.-Geol. Soc. Egypt., 22nd annual Meet. Abstr. p. 15-16.
3. Abd El-Kireem, M. R., Samir, A. M., and Luterbacher, H. P., 1994: Planktonic foraminifera from the Kolosh Formation (Paleogene) of the Sulaimaniah-Dokan region, northeastern Iraq. Neues Jahrbuch und Zentralblatt für Geologie und Paleontologien Mh, 9: 517-527.
4. Abd El-Kireem M. R., and Abdou, H. F., 1979: Upper Cretaceous –Lower Tertiary succession in the Kurkur-Dungul area, Western Desert. Bull. Fac. Sci. Ain Shams Univ. 15: 87-105.
5. Abd El-Kireem, M. R. and Samir, A. M., 1995: Biostratigraphic implications of the Maastrichtian-Lower Eocene sequence at North Gunna section, Farafra Oasis, Western Desert, Egypt, Marine Micropaleont., 26: 329-340.
6. Aliyulla, Kh., 1977: Upper Cretaceous and development of foraminifera of the lesser Caucasus (Azerbaijan). Akd. Nauk Azer-baydzhan, Baku., 232 pp (In Russian).
7. Al-Mogi-Labin, A., Reiss, Z., and Caron, M., 1986: Senonian Globotruncanidae from Israel. Eclogae Geol. Helv. 79(3): 849-895.
8. Al-Wosabi, K. A. and Abu Shama, A. M., 2007: Planktic foraminiferal and calcareous nannofossils biostratigraphy around the K/T boundary at Matulla section, west central Sinai, Egypt. Jour. Paleontol. Vol. 7, 2007, p. 87-115.
9. Anan, H. S., 1994: Contribution to the stratigraphy and paleobiogeography of some diagnostic Upper Cretaceous and Paleogene foraminifera-N. Jb. Geol. Palant. Mh., 5: 257-266.
10. Ansary, S. E. & Tewfik, N. M., 1966: Planktonic Foraminifera and some new benthonic species from the subsurface Upper Cretaceous of Ezz El Orban area, Gulf of Suez.-J. Geol. U. A. R., 10 (1): 73-76.
11. Aref, M., Philobos, E. R. and Ramadan, M., 1988: Upper Cretaceous-Lower Tertiary planktonic biostratigraphy along the Egyptian Red Sea region and its tectonic implication, Bull. Fac. Sci., Assuit Univ., 17 (2-F), p-p.171-201.
12. Aref, M. and Ramadan, M., 1990: New recorded planktonic foraminifera from the Upper Cretaceous rocks of Esh El-Mellaha range, Red Sea, Egypt, M.E.R.C. Ain Shams Sci. Ser., Vol. 4, p. 123-141.
13. Ayyad, S. N., Abed, M. M., and Abu Zied, R. H., 1996: Biostratigraphy and correlation of the Cretaceous rocks in Gebel Arif El-Naga, northeastern Sinai, Egypt, based on planktonic foraminifera. Cret. Res., 17: 263-291.
14. Barr, F. T., 1972: Cretaceous biostratigraphy and planktonic foraminifera of Libya. Micropaleontol. 18(1): 1-46.
15. Beckmann, J. P., El Heiny, I., Kerdany, M. T., Said, R., and Viotti, C., 1969: Standard planktonic foraminifera zones in Egypt: Proceeding of 1<sup>st</sup> international Conference on Planktonic Microfossils, Geneva, 1: 92-103..
16. Boersma, A., 1984a: Hand book of Common Tertiary Uvigerina Microclimates Press, Stony Point, New York: 1-207.
17. Bolli, H. M., 1951: The genus *Globotruncana* in Trinidad, B. W. I. Jour. Paleont, 25: 187-197.
18. Bolli, H. M., 1966: Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. Boletin Informativo Asociacion Venezolana de Geologia, Minería Petroleo., p: 3-32.
19. Bolli, H. M., Loeblich, A. R., and Tappan, H. 1957a: Planktonic foraminifera families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae. Bull. U. S. Nat. Mus., 215: 3-50.
20. Bralower, T. J., Leckie, R. M., Sliter, W. V. & Thierstein, H. R. 1995: An integrated Cretaceous microfossil biostratigraphy. In *Geochronology, time scale and global stratigraphic correlation* (eds Berggren, W. A., Kent, D. V., Aubry, M. P. & Hardenbol, J.), *Society of Economic Paleontologists and Mineralogists, Special Publication* 54, 65–79.
21. Bronnimann, P., 1952: Trinidad Paleocene and Lower Eocene Globigerinidae. Amer. Paleont. Bull., 34: 34 pages.
22. Bronnimann, P., and Brown, N.K.Jr., 1953: Taxonomy of the Globotruncanidae. Eclogae Geologicae Helvetiae., 48: 503-561.

23. Brotzen, F., 1942: Die foraminiferengattung *Gavelinella* nov. gen. Und die Systematik der Rotaliiformes: Sver. Geol. Unders., C. 451: 1-61.
24. Caron, M., 1985: Cretaceous Planktonic foraminifera. In: Bolli, H., J. Saunders and K. Perch-Nielsen (Eds). *Plankton stratigraphy*. Cambridge University Press., P. 17-86.
25. Carpenter, W. B., 1861: On the rhizopodal fauna of the deep sea, proceedings of the Royal Society of London, 18: 59-62.
26. Carsey, D. O., 1926: Foraminifera of the Cretaceous of central Texas. Austin: Texas University. Bull., 2612:56p.
27. Cherif, O. H. and Hewaidy, A. A., 1987: Maastrichtian foraminifera from four sections in the Dakhla Shale of Central Egypt and their bathymetric implications, 3<sup>eme</sup> Symposium international Sur Les Foraminifères benthiques, Genève, p.1-20.
28. Cherif, O. H. and Ismail, A. A., 1991: Late Senonian-Tertiary planktonic foraminiferal biostratigraphy and tectonism of the Esh El-Mallha and Gharamul areas, Egypt. M.E.R.C. Ain Shams Univ. Earth Sci., Ser., 5, p. 146-159.
29. Cherif, O. H., Al-Rifa'iy, I. A., Al-Afifi, F. I. & Orabi, O. H., 1989: Planktonic foraminifera and chronostratigraphy of Senonian exposures in West-Central Sinai, Egypt. Rev. Micropaleont., 32, 3: 167-184.
30. Cushman, J. A., 1926: The Foraminifera of the Velasco Shale of the Tampico embayment San Luis Potosi, Mexico. Amer. Assoc. Petrol. Geol. Bull., 10: 581-612.
31. Cushman, J. A., 1927: New and interesting foraminifera from Mexico and Texas. Cushman Lab. Foram. Res. Contr., 3: 111-117.
32. Cushman, J. A., 1938: Cretaceous species of *Guembelina* and related genera. Cushman Lab. Foram. Res. Contr., 14: 2-28.
33. Cushman, J. A., and Ten Dam, A., 1948: *Globigerinelloides*. A new genus of the Globigerinidae. Cushman Lab. Foram. Res. Contr., 24: 24-3.
34. Dalbiez, F., 1955: The genus *Globotruncana* in Tunisia. Micropaleont., 1: 161-171.
35. Delage, Y., and Herouard, F., 1896: *Tritide Zoologie Concrete*. Vol. 1. 1a Cellule et les Protozoaires. Paris: Schleicher Freres., 584p.
36. D' Hondt, S. and Keller, G., 1991: Some patterns of planktonic foraminiferal assemblage turnover at the Cretaceous/Tertiary boundary. Mar. Micropaleontol. 17: 77-118.
37. D' Orbigny, A., 1839: Foraminifera. In: R. de la Sagra (ed.). *Histoire physique, politique et naturelle de l'île de Cuba*, Bertrand. Paris., 224.
38. Egger, J. G., 1899-1900: Foraminiferen und Osrakoden aus den Kreidemergeln der oberbayerischen Alpen: Bayerische Akad. Wiss. Abh., Math. Phys. Kl., v. 21 (1899-1902), p. 1-230, pls. 1-27.
39. Ehrenberg, C. G., 1840: Über die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen- Königlich Preussischen Akademie der Wissenschaften zu Berlin Abh., 1838.59-147.
40. Ehrenberg, C. G., 1843: Verbreitung und Einfluss des mikroskopischen Lebens in Süd und Nord America. *Abhandlungen der Königlich Preussischen Akademie der Wissenschaften zu Berlin*, 1: 291-446.
41. Eichwald, C. E. von., 1830: *Zoologia specialis*, 2. Vilnae: D.E. Eichwaldus., 323pp.
42. El-Dawy, M. H., Azab, M. M., and Dakrory, A. M., 1992: Biostratigraphy and Paleocology of the Upper Cretaceous-Lower Tertiary in Gabal Shaba, Northwest Sinai, Proc. 3rd Conf. Geol. Sinai Develop., Ismailia, p. 175-190.
43. El Nady, H., 1995: Biostratigraphy of the Late Cretaceous-Early Tertiary succession at northern Sinai. Unpublished Ph.D. Thesis, Mansoura University, 350p.
44. El Nady, H., Shahin, A., 2001: Planktonic foraminiferal biostratigraphy and paleobathymetry of the Late Cretaceous- Early Tertiary succession at north east Sinai, Egypt, Egypt. Jour. Paleontol. Vol. 1, 2001, p. 193-227.
45. El Naggar, Z. R. M., 1966: Stratigraphy and planktonic foraminifera of Upper Cretaceous – Lower Tertiary succession in the Esna-Idfu region, Nile Valley, Egypt, U. A. R.: Brit. Mus. Nat. History, Bull. Suppl., 2: 1-291.
46. El –Sabbagh, A. M., 2007: Planktonic foraminiferal analysis from the Late Maastrichtian-Early Danian sequence at western Sinai, Egypt: Evidences for environmental stresses, Egypt. Jour. Paleontol. Vol. 7, 2007, p. 31-58.
47. El-Sabbagh, A. M., Ibrahim, M. I., and Luterbacher, H. P., 2004: Planktonic foraminiferal biostratigraphy, extinction patterns and turnover during the Campanian –Maastrichtian and at the Cretaceous/ Paleogene (K/Pg) boundary in the Western Sinai, Egypt. N. Jb. Geol. Palaont. Abh., 234: 51-120.
48. Gallitelli, E., 1957: A revision of the Foraminiferal Family Heterohelicidae, In A.R. Loeblich, Jr., and collaborators, *Studies in Foraminifera*. U. S. Nat. Museum. Bull., 215: 133-154.
49. Gandolfi, R., 1955: The Genus *Globotruncana* in northeastern Colombia: Amer. Paleont. Bull., 36: 155: 1-118..
50. Ghorab, M. A., 1956: A summary of a proposed stratigraphic classification for the Upper Cretaceous rocks in Egypt. Read before the Geological Society of Egypt, 19<sup>th</sup> June 1956.
51. Ghorab, M. A., 1961: Abnormal stratigraphic features in Ras Gharib oil field.-3<sup>rd</sup> Arab Petrol. Congr. Alexandria, 1961, 10p.

52. Gradstein, F. M., Agterberg, F. P., Ogg, J. G., Hardenbol, J., Van Veen, P., Thierry, J. & Huang, Z. 1995: A Triassic, Jurassic and Cretaceous time scale. In *Geochronology, time scale and global stratigraphic correlation* (eds Berggren, W. A., Kent, D. V., Aubry, M. P. & Hardenbol, J.), *Society of Economic Paleontologists and Mineralogists, Special Publication* 54, 95-128.
53. Hewaidy, A. A., 1987: Biostratigraphy and paleobathymetry of the Esna Shale in El-Qusaima area, north Sinai, Egypt. M.E.R.C., Ain Shams Univ., Earth. Sci. Ser., 1: 180-206.
54. Hewaidy, A. A., 1994: Biostratigraphy and paleobathymetry of the Garra-Kurkur area, southwest Aswan, Egypt. M.E.R.C., Ain Shams Univ. Earth Sci. ser., 8: 48-73.
55. Hewaidy, A. A., Arafa, A. A., and El-Ashwah, A. A., 1991: Biostratigraphy of Upper Cretaceous rocks in El-Qusaima area, northeast Sinai, Egypt. *Annals Geol. Surv. Egypt*, vol. 17, p. 199-112.
56. Hewaidy, A. A. and Soliman, S. I., 1993: Stratigraphy and Paleoecology of Gebel El Borga, South-west Kom Ombo, Nile Valley, Egypt. *Egypt. Jour. Geol.* 37(2): 299-321..
57. Huber, B. T., 1990: Maastrichtian planktonic foraminiferal biostratigraphy of the Maud Rise (Weddell Sea, Antarctica): ODP Leg 113 Hole 689B and 690C. *Proc. ODP, Sci. Results* 113,489-514.
58. Huber, B. T., 1991: Maastrichtian planktonic foraminiferal biostratigraphy and the Cretaceous/Tertiary boundary at hole 738 C (Kerguelen Plateau, southern Indian Ocean). *Proc. ODP. Sci. Res.*, 119: 451-465.
59. Huber, B. T., 1992: Paleobiogeography of Campanian Maastrichtian foraminifera in the southern high latitudes. *Palaeogeogr., Palaeoclimatol., Palaeoecol.* 92, 325-360.
60. Hultberg, S.U., Malmgren, B.A., 1987: Quantitative biostratigraphy based on late Maastrichtian dinoflagellates and planktonic foraminifera from southern Scandinavia. *Cretaceous Res.* 8,211-228.
61. Ion, J., 1993: Upper Cretaceous planktonic foraminiferal biostratigraphy from the Carpathians and northern Dobrogea (Romania) related to macropaleontological zonation, *Romanian J. Stratigr.*, 75: 41-53.
62. Keller, G., 1988: Extinction, survivorship and evolution of planktonic foraminifers across the Cretaceous/Tertiary boundary at El Kef, Tunisia. *Marine Micropaleont.*, 13: 239-263.
63. Keller, G., 1989: Extended the Cretaceous/ Tertiary boundary extinction and delayed population changes in the planktonic foraminifera faunas from Brazos River, Texas. *Paleoceanogra.*, 4: 287-332.
64. Keller, G., 1993: The Cretaceous/ Tertiary boundary transition in the Antarctic Ocean and its global implication. *Marine Micropaleont.*, 21: 1-45.
65. Keller, G., 2002: *Guembelitra*-dominated late Maastrichtian planktic foraminiferal assemblages mimic early Danian in central Egypt.-*Marine Micropaleont.*, 47: 71-99.
66. Keller, G., T. Addate, W. Stinnesbeck, V. Luciani, N. Karoui-Yaakoub and D. Zaghbib-Turki, 2002: Paleoecology of the Cretaceous-Tertiary mass extinction in planktonic foraminifera. *Palaeogeogra, Palaeoclimat, Paleoecol.*, 178: 257-297.
67. Khalil, H., and Mashaly, S., 2004: Stratigraphy and stage boundaries of the upper Cretaceous- Lower Paleocene succession in Gabal Musaba Salama area, southwestern Sinai, Egypt. *Egypt. Jour. Paleontol.*, Vol. 4, p. 1-38.
68. Kikoine, J., 1948: Les Heterohelicidae du Cretace superieur pyreneen. *Bulletin de la Societe Geologique de France*, ser. 5, 18(1): 15-35, pl. 1, 2.
69. Korchagin, V. I., 1982: Sistematika Globotrunkanid [Systematics of the Globotrunkanids]. *Byulletin' Moskovskogo Obschestva Ispylatelye Prirody. Otdel Geologicheskii.*, 57(5): 114-121.
70. Li, L., and Keller, G., 1998a: Maastrichtian climate productivity and faunal turnovers in planktonic foraminifera in South Atlantic DSDP Sites 525 and 21. *Marine.Micropaleontol.*, 33: 55-86.
71. Li, L., and Keller, G., 1998b: Diversification and extinction in Campanian –Maastrichtian planktic foraminifera of northwest Tunisia. - *Eclogae Geol. Helvetiae*, 91:75-102.
72. Li, L., Keller, G., and Stinnesbeck, W., 1999: The Late Campanian and Maastrichtian in northwestern Tunisia: Paleoenvironmental inferences from lithology, macrofauna and benthic foraminiferal. *Cret. Res.*, 20: 231-252.
73. Loeblich, A. R. Jr., 1951: Coiling in Heterohelicidae. *Cushm. Found. Foram. Res. Contr.* Vol. 2, pp. 106-110.
74. Loeblich, A. R. Jr., and Tappan, H., 1957a: Correlation of the Gulf and Atlantic Coastal Plain Paleocene and Lower Eocene Formations by means of planktonic foraminifera. *Jour. Paleont.* 31: 1109-1137.
75. Loeblich, A. R. Jr., and Tappan, H. 1957b: *Woodringina*, a New Foraminiferal Genus (Heterohelicidae) from the Paleocene of Alabama. *Washington. Jour. Acad. Sci.*, 47: 39-40.
76. Loeblich, A. R. Jr., and Tappan, H., 1961: Suprageneric Classification of Rhizopodea. *Jour. Paleont.*, 35: 245-330.
77. Loeblich, A. R. Jr., and Tappan, H., 1988: Foraminiferal genera and their classification. Van Nostran Reinhold Co., New Yourk, 970p.
78. Longoria, J. F., 1974: Stratigraphic, morphologic, and taxonomic studies of Aptian planktonic foraminifera. *Revista Espafiolad Micropaleont. Numero extra ordinario.* pp. 1-107.
79. Luger, P., 1985: Stratigraphie der marinen Oberkreide und des Alttertiarsim sudwestlichen Oberrhein-Becken (SW-Aegypt), unter besonderer

- Berücksichtigung der Mikropalaontologie, Palökologie und Palaogeographie. Berliner geowiss. Abh., 63, 11-151, pls. 1-24.
80. Luger, P., 1988: Maestrichtian to Paleocene facies evolution and Cretaceous-Tertiary boundary in Middle and southern Egypt. *Revista Espanola de Micropaleontologia*, Numero extraordinaria, p. 89-90.
  81. Lunning, S., Marzouk, A. M., and Kuss, J., 1998: The Paleocene of central east Sinai, Egypt. "Sequence stratigraphy" in monotoneus hemipelgites. *Jour. Foram. Res.*, 28(1): 19-39.
  82. Marie, P., 1941: les foraminiferes de la craie a Belemnitella mucronata du bassin de Paris. *Mus. nat. Hist. nat. Paris, Mem.*, 12: 296pp.
  83. Marzouk, A. M., and Lunning, S., 1998: Comparative biostratigraphy of calcareous nannofossils and planktonic foraminifera in the Paleocene of the Eastern Sinai, Egypt: *N. Jb. Geol. Paleont.*, 207 (1): 77-105.
  84. Masters, B. A., 1984-1993: Comparison of planktonic foraminifers at the Cretaceous-Tertiary boundary from the Haria Shale (Tunisia) and the Esna Shale (Egypt). *Proc. Of 7<sup>th</sup> Expor. Semina, Egypt. General. Petr. Corpor.*, 310-324.
  85. Maslakova, N. I., 1964-1971: Contribution to the systematics and phylogeny of the Globotruncanids. *Voprosy Mikropaleontology.*, 8: 102-117.
  86. Molina, E., Arenillas, I., and Arz, J. A., 1996: The Cretaceous/Tertiary boundary mass extinction in planktic foraminifera at Agost, Spain. *Rev. Micropaleont.* 39: 225-243.
  87. Nakkady, S. E., 1950-1951: The foraminiferal fauna of the Esna Shales of Egypt. Part II, Taxonomic study of the Fauna, *Bulletin Institut d' Egypte, T. XXXIII*. pp. 398 - 430, pls. I-VIII.
  88. Nederbragt, A. J., 1990-1991: Late Cretaceous biostratigraphy and development of Heterohelicidae (planktonic foraminifera). *Micropaleont.*, 37: 329-372.
  89. Odin, G.S., 2001: The Campanian-Maastrichtian stage boundary: characterization at Tercis les Bains (France): correlation with Europe and other continents: IUGS Special Publication (monograph) Series, v. 36; *Developments in Paleontology and Stratigraphy Series*, v. 19, Elsevier Sciences Publ. Amsterdam, 910 p.
  90. Omran, M. A. B., 1997: Stratigraphical studies of the Upper Cretaceous-Lower Tertiary successions in some localities, northern Sinai, Ph. D. thesis, Faculty of Sci. Suez Canal Univ., 330pp.
  91. Orabi, O. H., 1988: Late Cretaceous Stratigraphy and geology of West-Central Sinai, Egypt: Ph.D Thesis Menofia University, Egypt. 235p.
  92. Pardo, A., Ortiz, N., and Keller, G., 1996: Latest Maastrichtian foraminiferal turnover and its environmental implications at Agost, Spain – in: MacLeod, N. & Keller, G. (eds.), *Cretaceous-Tertiary Maas Extinction: Biotic and environmental changes*-Norton, W. & Co., New Yourk: 139-172.
  93. Pessagno, E. A. Jr., 1960: Stratigraphy and micropaleontology of the Cretaceous and lower Tertiary of Puert Rico. *Micropaleont.*, 6(1): 87.
  94. Pessagno, E. A. Jr., 1967: Upper Cretaceous planktonic foraminifera from the western Gulf Coastal Plain. *Paleont. Amer.*, 5 (37), 245-445.
  95. Plummer, H. J., 1931: Some Cretaceous foraminifera in Texas. *Texas Univ. Bull.*, 3101: 109-203, Pl. 8-15, Austin, Texas.
  96. Postuma, J., 1971: *Manual of Planktonic Foraminifera*. Elsevier Publishing Co., Amsterdam, 420pp.
  97. Prat, P., Montenat, C., D' Estevou, P. and Bolze, J., 1986: La marge occidentale du Golfe de Suez d' après l' etude des Gebels Zeit et Mellaha.-I.G.A.L., Paris, p. 45-74.
  98. Premolisilva, I., and Bolli, H. M., 1973: The Late Cretaceous to Eocene planktonic foraminifera and stratigraphy of Leg 15 sites in the Caribbean Sea. *Initial reports DSDP*, 15: 499-528.
  99. Reiss, Z., 1957: The Bilamellidae, nov. superfamily, and Remarks on Cretaceous Globorotaliids. *Cushman Lab. Foram. Res. Contrib.*, 8: 127-145.
  100. Robaszynski, F. Caron, M. Gonzalz-Donoso, J. M. and Wonders, A. A. H., 1984: Atlas of Late Cretaceous globotruncanids. *Revue de Micropaleont.*, 26 (3-4): 1-305.
  101. Rzehak, A., 1891: Die Foraminiferen des kieseligen Kalkes von NiederHollabrunn und des Melettamergels der Umgebung von Bruderndorf in Niederrosterreich. *Annalen des K. K. Naturhistorischen Hofmuseums.*, 3: 257-270.
  102. Samir, A. M., 2002: Biostratigraphy and paleoenvironmental changes in the Upper Cretaceous- Early Paleogene deposits of Gebel Samra section, southwestern Sinai, Egypt, *Egypt. Jour. Paleontol.* Vol. 2, 2002, p. 1-40.
  103. Shahin, A. M., 1988: Tertiary Planktonic Foraminiferal Biostratigraphy and Paleobathymetry at Gebel Withr, Southwestern Sinai, Egypt. *N. Jb. Geol. Und Paleont, Abh*, 209 (3): 323-348.
  104. Shahin, A., 1992: Contribution to the foraminiferal biostratigraphy and paleopathymetry of the Late Cretaceous and Early Tertiary in west Central Sinai, Egypt. *Revue de Micropaleont.*, 35(2): 157-175.
  105. Sigal, J., 1952: Apercu stratigraphique sur la Micropaleontologie du Cretace: 19<sup>th</sup> *Internat. Geol. Congr., Mon. Region, Ser. 1, Algerie, No. 26*, p. 1-47, 46 text figs.
  106. Sigal, J., 1958: Notes micropaleontologiques nord-africaines. I. Du Cenomanien au Santonien: zones et limites en facies pelagique. *Compte Rendu Somm Seances, Societe Geologique de France*, 1955: 157-160.
  107. Smith, C. C. and Pessagno, E. A. Jr., 1973: *Planktonic Foraminifera and Stratigraphy of the*

- Corsicana Formation (Maastrichtian) North Central Texas. *Cushman Found. Foram. Res. Special Publication.*, No. 12.
108. Subbotina, N. N., 1953: Iskopaemye foraminifery SSSR (Globigerinidy, Khantkeninidy i Globorotaliidy) [Fossil Foraminifera of the USSR (Globigerinidae, Hantkeninidae and Globorotaliidae)]. *Trudy Vsesoyznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta (VNIGRI)*, 76, 296 pages, [In Russian].
  109. Subbotina, N. N., 1959: Planktonic foraminifera. In: *Rauzer Chernousova, D. M. and Fursenko, A. V. (eds.), Principles of paleontology, part 1, Protozoa (in Russian)*, Moscow, Akademia Nauk., SSSR: 1-368.
  110. Tantawy, A. A., Keller, G., Adatte, T., Stinnesbeck, W., Kassab, A. and Schulte, P., 2001-2002: Maastrichtian to Paleocene depositional environment of the Dakhla Formation, Western Desert, Egypt: sedimentology, mineralogy, and integrated micro-and macrofossil biostratigraphies. *Cretaceous Res.*, 22: 795-827.
  111. Tewfik, N., and Ebeid, Z., 1972: On the stratigraphy of the Upper Cretaceous in the Gulf of Suez region, Egypt. *Proc. 5<sup>th</sup> Afr. Micropal. Colloq.* Addis. Ababa, 659-704.
  112. Vogler, J., 1941: Ober-Jura und Kreide von Misol (Niederlaendisch-Ostindien): *Palaeontographica*, suppl. 4, Abt. 4, p. 246-293, pl. 19-24.
  113. Voorwijk, G.H., 1937: Foraminifera from the Upper Cretaceous of Habana, Cuba: *Koninkl. Nederlandse Akad. Wetensch., Proc. Sec. Sci.*, v. 40, p. 190-198, 3 pl.
  114. Wade, B. S., Pearson, P. N., Berggren, W. A., and Palike, H., 2011: Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. *Earth Sci. Reviews.*, 104: 111-142.
  115. White, M. P., 1928<sub>a</sub>: Some index foraminifera of the Tampico Embayment area of Mexico. *Jour. Paleont.*, 2: 177-215.
  116. White, M. P., 1928<sub>b</sub>: Some index foraminifera of the Tampico Embayment area of Mexico (Part 2). *Jour. Paleont.*, 2: 280-317.
  117. Wonders, A. A., 1980: Middle and Late Cretaceous planktonic foraminifera of the western Mediterranean area. *Utrecht Micropaleontology Bulletin*, 24: 1-158.
  118. Youssef, M. I., and Abd El Malik, W. M., 1969: Micropaleontological zonations of the Tertiary Rocks of the Tayiba-Feiran Area, West Central Sinai. 6<sup>th</sup> Arab. Sci. Cong. 675-684; Damascus.

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