



Early Paleogene benthic foraminifera of Duwi section, Red Sea coast, Egypt

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Abstract: The micropaleontological information of Duwi section at Qusseir area, Red Sea coast of Egypt, indicates that the Paleocene-early Eocene succession bears prolific and well preserved index-species of benthic foraminifera with Midway-Type Fauna (MTF) of middle-outer neritic environment is interpreted. Forty two samples are collected from this Early Paleogene succession. This succession is attributed to the shaley marl sediments belonging to the upper part of the Dakhla Shale and Esna Shale formations as well as Tarawan Chalk between them. The Paleogene succession is unconformably overlying the Maastrichtian part of the Dakhla Shale. One hundred Lagenid and Rotaliid foraminiferal species and subspecies belonging to forty nine genera are identified and forty five species of them are illustrated from Duwi section in two plates (1, 2). One out of the Lagenid illustrated species is believed to be new: *Lagena rawdhae*. The duration of the hiatus at the Cretaceous /Paleogene (K/P) boundary includes the two early Danian planktic biozones (P0 and P α , about 0.02 Ma). This depositional gap is corresponding to an interval of tectonic activity that exists in most localities in the world. In this study, an attempt is made to present some details in paleontology (Paleocene-Eocene Lagenid and Rotaliid benthic foraminifera), stratigraphy and paleogeography from Duwi section, and some other localities in the Tethys.

[Haidar Salim ANAN. **Early Paleogene benthic foraminifera of Duwi section, Red Sea coast, Egypt.** *J Am Sci* 2020;16(2):1-22]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). <http://www.jofamericanscience.org>. 1. doi:[10.7537/marsjas160220.01](https://doi.org/10.7537/marsjas160220.01).

Keywords: Benthic foraminifera, Paleogene, stratigraphy, paleontology, paleogeography, Duwi, Egypt, Tethys.

Introduction

The Dakhla Shale (of Said, 1961) extends to the base of Tarawan Chalk (of Awad and Ghobrial, 1966), and the Esna Shale (of Beadnell, 1905) extends from the top of the Tarawan Chalk to the base of the limestone of the Thebes Formation (of Said, 1960). Issawi *et al.* (1999) distinguished seven facies that characterized the sediments for the Upper Cretaceous-Lower Tertiary succession of Egypt (Fig. 1). Each type facies has certain formations, which differ from the adjacent one, though some formations may cross the boundaries between two contiguous facies. According to these authors the contact between the deep (in the north) and shallow marine facies (in the south) nearly coincides around Lat. 28° N (but about Lat. 27° N of Anan, 1987). The seven sedimentary facies in Egypt are, from north to south: (1) Sinai Facies (SF), represented by many sections: Qusaima, Nukhul, Taba, Abu Zenima sections respectively (fig. 1/1, 2, 3, 4). (2) Ataqia Facies (AF): not included in this study, for the scarce foraminiferal data in the literatures about it. (3) North Western Desert Facies (NWDF): Jiran El Ful section at Abu Rawash area (Fig. 1/5). (4) Southern Galala Facies (SGF) at northeast Eastern Desert: Wadi Ed Dakhil, Esh El Mallaha and Sufr Ed Dara sections (Fig. 1/6,7). (5)

Farafra Bahariya Facies (FBF): Maqfi section and surroundings Gunna, Esheikh Marzouk and Twin Spikes sections (Fig. 1/8). (6) Nile Valley Facies (NVF): Duwi section (this study) Gurnah and surroundings Qena and Owaina sections, Ain Dabadib and surroundings Um Elghanayem and Ghanima sections (Fig. 1/9, 10, 11). (7) Nuba Abu Ballas Facies (NABF): Bir Kiseiba section and surroundings (Fig. 1/12). Sinai Facies, Farafra Facies in the northern Egypt (mainly Sudr Chalk), Nile Valley Facies in the center (mainly Dakhla Shale and Esna Shale) and Garra El Arbain Facies (mainly Kiseiba Formation) in the Southern Egypt which suggest gradual paleogeographical changes from transitional open marine environmental facies in the northern Egypt to shallow shelf setting in the south due to paleorelief (highs and lows of the Syrian Arc System, Laramid Orogeny) in the Upper Cretaceous.

The position of Gabal Duwi in the southern Tethys is shown in figure 2. The stratigraphy and paleontologic distribution of the identified Lagenid and Rotaliid benthic foraminiferal assemblages in Gabal Duwi section, Red Sea coast of Egypt given in Figures (3, 4), respectively. Duwi section are studied by many authors, i.e.: Nakkady (1950, 1955), Krashenikov and Abdel Razek (1969), Speijer (1994), Schmitz *et al.*

(1996), Anan (1998, 2001, 2002, 2004, 2008, 2009, 2011, 2012, 2014, 2015b), Speijer et al. (2000). These studies are relevant to the present study. The biostratigraphy of the Paleogene succession on the study section is based on the planktic foraminiferal zonation of Berggren and Pearson, 2005 (after Anan, 2009).

The present study aims at throwing light on the paleontology, paleoecology, paleobathymetry and paleogeographic distribution of the early Paleogene fifty one Lagenid and another forty nine Rotaliid benthic foraminiferal assemblages in Duwi section, Red Sea coast (which represents the NVF).

Material Of Study

Forty two samples (but some sample number include more than one sample, i.e. 14, 14A) were collected from the Paleocene (*Subbotina pseudobulloides* Zone) to Ypresian (*Morozovella subbotinae* Zone) composite succession of Gabal Duwi section with about 180 m total thickness. Paleocene succession about 127 m thick (sample nos. 5-33) and Eocene succession about 40 m thick (sample nos. 34-42). The Early Paleogene succession includes the top part of the Dakhla Shale (of Said, 1961), while the Late Paleocene horizon belongs to the Tarawan Chalk (of Awad and Ghobrial, 1966) and the Late Paleocene-Early Eocene Esna Shale (of Beadnell, 1905) (Figs. 3, 4). The Cretaceous/Tertiary (K/T) boundary of Duwi section is represented by a thin layer (about 0.1 m) of *Nucula* spp. within Dakhla Shale which rests directly on about 2 m of barren black shale. The Maastrichtian chocolate marly bed with about 1.0 m thick (which underlying the dark shaley bed) yields rich and well preserved planktic and benthic foraminifera which belongs to the *Plummerita hantkeninoides* Zone.

Taxonomy

The taxonomy followed here is that of Loeblich and Tappan (1988). A brief remarks will be added to the species. The references of the identified type species are given. Some modern references have been added to complete the descriptions and synonymies. The stratigraphic distribution of the one hundred identified calcareous benthic foraminiferal species and subspecies, which belonging 49 genera, is shown in figures 3, 4 and 25 of the Lagenid as well as another 20 Rotaliid identified species and subspecies are illustrated in plates 1, 2.

Order Foraminiferida Eichwald, 1830

Suborder Lagenina Delage and Hérouard, 1896

Superfamily Nodosariacea Ehrenberg, 1838

Family Nodosariidae Ehrenberg, 1838

Subfamily Nodosariinae Ehrenberg, 1838

Genus *Chrysalogonium* Schubert, 1908

Type species *Nodosaria polystoma* Schwager, 1866

1. *Chrysalogonium longiscata* (d'Orbigny, 1846), p. 32, pl. 1, figs. 10-12.

This species was recorded from the Maastrichtian-Eocene (M-E) of Trinidad, Egypt, UAE and Pakistan.

2. *Chrysalogonium velascoensis* (Cushman, 1926), p. 594, pl. 18, fig. 12 (Pl. 1/1).

This M-E species has an elongate test, early stage is obscure and smooth, later about seven uniserial chambers ornamented by longitudinal costae, aperture terminal. It resembles the Paleocene form '*Nodosaria*' *velascoensis* of Tjalsma and Lohmann (1983), not Cushman. It was recorded from USA, Atlantic Ocean and Trinidad (Bolli *et al.*, 1994). It is rare in the early Eocene (eE) of the study section.

Genus *Dentalina* Risso, 1826

Type species *Nodosaria cuvieri* d'Orbigny, 1826

3. *Dentalina alternata* (Jones, in Wright, 1886), p. 330, pl. 27, fig. 10.

This species is rare in the early Paleocene (P), but rich in the late Paleocene of the study section, Egypt.

4. *Dentalina delicatula* Cushman, 1938, p. 40, pl. 6, figs. 19, 20.

This species was recorded from the Maastrichtian of USA, but Paleocene in the study section, Egypt.

Genus *Laevidentalina* Loeblich and Tappan, 1986

Type species *Laevidentalina aphelis* Loeblich and Tappan, 1986

5. *Laevidentalina colei* (Cushman and Dusenbury, 1934), p. 54, pl. 7, figs. 10-12 (Pl. 1/2).

This P-E species was recorded in the USA, Egypt (LeRoy, 1953), Tunisia (Aubert and Berggren, 1976), UAE (Anan, 1993a) and Bulgaria (Valchev, 2007). It is rare to common in the P-E of the study section.

Genus *Nodosaria* Lamarck, 1812

Type species *Nautilus radícula* Linné, 1758

6. *Nodosaria limbata* d'Orbigny, 1840, p. 12, pl. 1, fig. 1.

This Santonian-Ypresian species was recorded from USA, Atlantic Ocean, Caribbean, Europe, Tunisia, Egypt and UAE. It is recorded from the Paleocene of the study section.

Genus *Pseudonodosaria* Boomgaard, 1949

Type species *Glandulina discreta* Reuss, 1850

7. *Pseudonodosaria bulla* (Said and Kenawy, 1956), p. 134, pl. 3, fig. 13.

Loeblich and Tappan (1988) considered the genus *Pseudonodosaria* as a senior synonym of the genus *Rectoglandulina* as treated by Said and Kenawy (1956) for the species. Fore that the species *bulla* is treated here to belong to the genus *Pseudonodosaria*. The final chambers of this species have only one-quarter of the entire length of the smooth test. *P. bulla* is recorded from the P-eE in the study section.

8. *Pseudonodosaria manifesta* (Reuss, 1851), p. 52, pl. 1, fig. 4.

This M-E species has rounded initial end with greatest width near middle and upper portions. It is rare to common in the P-eE succession of the study section.

9. *Pseudonodosaria pygmaea* (Reuss, 1851), p. 22, pl. 2, fig. 3.

This M-E species has oval shape with smooth surface, few chambers in nodosarian arrangement and last chamber forming about two-third of the test. It is recorded from the P-eE of Duwi.

Genus *Pyramidulina* Fornasini, 1894

Type species: *Pyramidulina eptagona* Fornasini, 1894

10. *Pyramidulina affinis* (Reuss, 1845), p. 26, pl. 13, fig. 16.

This Maastrichtian-Eocene (M-E) species is rare to common in the Paleocene-Early Eocene of the study section. Nakkady (1955) proposed an accelerated tempo of evolution for the *Pyramidulina* group: *vertebralis-affinis-zippeii* in the gradual inflation of the chambers and the higher sutures.

11. *Pyramidulina latejugata* (Gümbel, 1868), p. 619, pl. 1, fig. 32.

This M-E species is characterized by its very large costate test. It is rare to common in the P-E succession of the study section, but Paleocene of Tunisia (Aubert and Berggren, 1976) and Ivory Coast, Southwest Africa (N'da *et al.* 1995).

12. *Pyramidulina vertebralis* (Batsch, 1791), p. 3, pl. 2, fig. 6.

This M-E species has longitudinal ribs along the test with flush sutures. It represents the first step of accelerated tempo of evolution for *Pyramidulina* group as noted by Nakkady (1955). It is common in the P-E succession study section.

13. *Pyramidulina zippei* (Reuss, 1845), p. 55, pl. 8, figs. 1-3.

It differs from *P. affinis* by numerous well developed costae. It is rare to common in the P-E succession of the study section.

Subfamily Frondiculariinae Reuss, 1860

Genus *Fronidularia* Defrance, 1826

Type species *Renulina complanata* Defrance, 1824

14. *Fronidularia archiaciana* d'Orbigny, 1840, p. 20, pl. 1, figs. 34-36 (Pl. 1/3).

This M-P species has a costate globular proloculus, elongate truncate marginal test, raised and curved sutures. It was recorded also from USA (Cushman, 1946), Mexico (Sliter, 1968), the Paleocene of Duwi section.

15. *Fronidularia bignoti* Anan, 2002, p. 632, fig. 2.2 (Pl. 1/4).

This Paleocene species has four to five chambers only surrounded the large proloculus, slightly depressed sutures with terminal protuberant aperture. The figured specimen *Palmula* sp. of Ali (2003, pl. 6, fig. 17) is very closed to *F. bignoti*.

16. *Fronidularia goldfussi* Reuss, 1860, p. 192, pl. 4, fig. 7.

This species was recorded Europe, USA (Cushman, 1946), Mexico (Sliter, 1968), Egypt (Anan, 2002 and this study), Pakistan (Haque, 1956) and UAE (Anan, 1993a). It is recorded in the Paleocene of Duwi section.

17. *Fronidularia nakkadyi* Futyan, 1976, p. 528, pl. 82, fig. 1 (Pl. 1/5).

This P-E species was recorded from the Paleocene of Jordan and later from Egypt (Luger, 1985; Anan, 2002), but Early Eocene by Speijer (1994). It is rare-common in the Paleocene Duwi section.

18. *Fronidularia phosphatica* Russo, 1934, p. 358, pl. 16, figs. 6-8 (Pl. 1/6).

This Paleocene species is characterized by its central raised costae along the test from initial to apertural end. *F. wanneri* Nakkady is considered here to be a junior synonym of *F. phosphatica*. It is an index marker species for the P/E boundary. It was recorded by many authors in Egypt, Morocco and Tunisia, northwest Africa (Aubert and Berggren, 1976), Ivory Coast, Southwest Africa (N'da *et al.* 1995). It is common in the Paleocene of the study section.

Genus *Tristix* Mac Fayden, 1941

Type species *Rabdogonium liasinum* Berthelin, 1879

19. *Tristix aubertae* Anan, 2002, p. 634, fig. 2.6 (Pl. 1/7).

This Danian species has triangular test face, concave triangular chambers with acute periphery. It differs from the Cretaceous *T. excavata* Reuss in its mainly triangular test face. The Egyptian specimen is quite similar to the Tunisian form (Aubert and Berggren, 1976).

Subfamily Marginulininae Wedekind, 1937

Genus *Astacolus* de Montfort, 1808

Type species *Astacolus crepidulatus* de Montrort, 1808

20. *Astacolus bifurcatus* LeRoy, 1953, p. 19, pl. 4, figs. 1, 2 (Pl. 1/8).

This Paleocene species is characterized by its coiled minor early stage but later consists of 7-8 uncoiled chambers with smooth surface. It is recorded from Egypt and UAE (Anan, 1993b).

Family Vaginulinidae Reuss, 1860

Subfamily Lenticulininae Chapman, Parr and Collins, 1934

Genus *Lenticulina* Lamarck, 1804

Type species *Lenticulites rotulatus* Lamarck, 1804

21. *Lenticulina budensis* (Hantken, 1875), p. 58, pl. 7, fig. 1 (Pl. 1/9).

This Eocene-Oligocene (E-O) species characteristically shows a decided inflation of 6-7 chambers in the last whorl, accompanied by depressed narrow sutures in the medium, moderately compressed test with acute periphery. It is recorded in the eE of Maqfi section, and also in the study section, which considered the second record of this species in Egypt.

22. *Lenticulina degolyeri* (Plummer, 1927), p. 97, pl. 7, fig. 7 (Pl. 1/10).

This Paleocene-Early Eocene species was recorded in USA, and later from Pakistan (Haque, 1956), Tunisia (Aubert and Berggren, 1976), Ivory Coast, Southwest Africa (N'da *et al.* 1995), Egypt (Anan, 2017). It is recorded in the P-E of the study section.

23. *Lenticulina midwayensis* (Plummer, 1927), p. 95, pl. 13, fig. 5; pl. 15, fig. 3.

This P-E cosmopolitan species was recorded in many sites in the Tethys: USA, Atlantic Ocean (Tjalsma and Lohmann, 1983), South America (Dailey, 1983); Tunisia (Aubert and Berggren, 1976), Egypt (Nakkady, 1959; El-Duwi, 2001; Anan, 2017, this study), UAE (Anan, 1993b, 2015b) and Pakistan (Haque, 1956).

24. *Lenticulina oligostegia* (Reuss, 1860), p. 213, pl. 8, fig. 8.

This M-P cosmopolitan species was recorded in many sites in the Tethys: USA, Europe and Egypt. It is also recorded in the Paleocene of the study section.

25. *Lenticulina pondi* Cushman, 1941, p. 56, pl. 15, fig. 4 (Pl. 1/11).

This M-P species has closed coiled, flattened numerous chambers (about 10-12) in the last whorls, curved sutures, periphery with knoblike angles, smooth surface. It was originally recorded in USA and later from Egypt (LeRoy, 1953). It is recorded in Paleocene of Duwi.

26. *Lenticulina pseudomamilligera* Plummer, 1927, p. 98, pl. 7, fig. 11 (Pl. 1/12).

This Paleocene species was recorded from USA, France (Sztrákos, 2000), Tunisia (Berggren and Aubert, 1975), Egypt (Luger, 1985; Anan and Sharabi, 1988, Anan, 2017), Nigeria (Gebhardt *et al.*, 2010), UAE (Anan, 1993a, 2015a), Pakistan (Haque, 1956). It is recorded in the PE of Duwi section.

27. *Lenticulina* sp. (Pl. 1/13).

This early Eocene species has semi-circular smooth test, 6 chambers in the final whorl, distinct, curved and depressed sutures, periphery acute with faint keel, aperture at peripheral margin with a neck. It is rare in the eE of the study section.

28. *Lenticulina washitensis* (Carsey, 1926), p. 38, pl. 7, fig. 9.

This M-P species was originally recorded in USA, and later from P-E of the study section.

Genus *Percultazonaria* Loeblich and Tappan, 1986

Type species *Cristellaria subaculeata* Cushman, 1923

29. *Percultazonaria jordanensis* (Futyan, 1976), p. 525, pl. 81, fig. 5 (Pl. 1/14).

This Paleocene species was recorded from Jordan, and also from Egypt by Anan (2015b).

30. *Percultazonaria longiscata* (Nakkady, 1950), p. 684, pl. 89, fig. 13.

This early Eocene species was recorded from Luxor, Farafra Oasis and Duwi section.

31. *Percultazonaria tuberculata* (Plummer, 1927), p. 101, pl. 7, fig. 2; pl. 14, fig. 1.

This Paleocene-early Eocene species was recorded from USA, Egypt (Said and Kenawy, 1956; Anan, 2017), Tunisia (Berggren and Aubert, 1975), UAE (Anan, 1993a, 2015b).

Genus *Saracenaria* Defrance, 1824

Type species *Saracenaria italica* Defrance, 1824

32. *Saracenaria triangularis* (d'Orbigny, 1840), p. 27, pl. 2, figs. 21, 22.

This M-E species is characterized by its completely coiled early portion of the test, and later chambers uniserial somewhat uncoiled and the test becoming triangular in transverse section. It was originally described from the Upper Cretaceous chalks of the Paris Basin, Europe, and later from USA, Egypt (Said and Kenawy, 1956; Anan 2014, this study), Czech (Hanzliková, 1972), Romania (Neagu, 1992). It is also recorded in the Paleocene of the study section.

Subfamily Palmulinae Saidova, 1981

Genus *Fron dovaginulina* Schubert, 1912

Type species *Fron dicularia inversa* Reuss, 1844

33. *Fron dovaginulina inversa* (Reuss, 1844), p. 211.

It was recorded from Maastrichtian of USA, but it is recorded in the Paleocene of the study section, Egypt and also Pakistan.

34. *Fron dovaginulina linearis* (Franke, 1928), p. 72, pl. 6, figs. 17, 18 (Pl. 1/15).

This M-P species is characterized by its nearly and flat test, truncated periphery and tapering aperture. It was recorded from USA, Europe, Egypt, UAE and Pakistan.

Genus *Neoflabellina* Bartenstein, '948

Type species *Flabellina rugosa* d'Orbigny, 1840

35. *Neoflabellina jarvisi* (Cushman, 1935), p. 85, pl. 13, figs. 7, 8. (Pl. 1/16).

This cosmopolitan species is an excellent marker species for the P/E boundary.

Genus *Palmula* Lea, 1833

Type species *Palmula sagittaria* Lea, 1833

36. *Palmula salimi* Anan, 2002, p. 636, fig. 2.7 (Pl. 1/17).

This Paleocene species is characterized by its semi-circular planispiral early stage, later seven chevron-shaped uniserial chambers, nearly rhomboidal in outline, with greatest width toward middle of the test, sutures slightly depressed and terminal aperture. The figured specimen of Ali (2003, pl. 5, fig. 16) is very closed to *P. salimi*.

37. *Palmula woodi undulata* Nakkady, 1950, p. 685, pl. 89, fig. 25

This subspecies differs from the typical form *Palmula w. woodi* in the undulation of the outer periphery which results from the shortening of the chambers as noted by Nakkady, which he recorded this subspecies from the early Paleocene shales of Duwi section of Egypt. The early Paleocene *P. w. undulata* is considered here as the ancestor of the descendent Paleocene-early Eocene *P. w. woodi*.

38. *Palmula w. woodi* Nakkady, 1950, p. 684, pl. 89, fig. 24.

This PE species is recorded from Egypt (Nakkady, 1950; Luger, 1985; this study), Tunisia (Saint-Marc, 1992), Jordan (Futyan, 1976), Iraq (Abdel-Kireem, 1983), UAE (Anan, 1993a).

Genus *Marginulina* d'Orbigny, 1826

Type species *Marginulina raphanus* d'Orbigny, 1826

39. *Marginulina gardnerae* Plummer, 1927, p. 106, pl. 5, fig. 11.

This Paleocene species was recorded in some Tethyan localities, i.e. USA, Tunisia and Egypt.

Genus *Vaginulinopsis* Silvestri, 1904

Type species *Vaginulina soluta* Silvestri var. *carinata* Silvestri, 1898

40. *Vaginulinopsis boukharyi* Anan, 2011, p. 59, pl. 2, fig. 22 (Pl. 1/18).

This Paleocene species is characterized by its large laterally compressed test, involute enrolled early stage but later five to six uniserial uncoiled with gradually increased chambers, limbate raised horizontal sutures, aperture terminal at the dorsal end. It is recorded from the Tarawan Chalk of Duwi section.

41. *Vaginulinopsis midwayana* (Fox and Ross, 1942), p. 669.

This Paleocene species is recorded from Morocco, Libya and Tunisia (Berggren and Aubert, 1975), in Egypt (i.e. Luger, 1985; Anan, 2009; Ismail, 2012, this study), UAE (Anan, 1993a).

Subfamily Vaginulininae Reuss, 1860

Genus *Citharina* d'Orbigny, 1839

Type species *Vaginulina (Citharina) strigillata* Reuss, 1860

42. *Citharina plummerae* Anan, 2001, p. 135, pl. 1, fig. 1 (Pl. 1/19).

This Paleocene species is distinguished from *C. plumoides* (Plummer, 1927) by its elongate and narrow width, raised and distinct striae. It was originally recorded in the Danian Esna Shale of Duwi section (Anan, 2001, 2017), and also from Bir Mellaha section, North Eastern Desert, Egypt (Hewaity *et al.*, 2017).

43. *Citharina trilobata* (d'Orbigny, 1840), p. 137, pl. 1, fig. 4 (Pl. 1/20).

Loeblich and Tappan (1988) considered the genus *Citharina* as a senior synonym of the genus *Vaginulina*. This M-E species is characterized by its slender elongate test, surface smooth except for the oblique limbate raised sutures which depressed between the last two chambers.

Subfamily Vaginulininae, Reuss, 1860

Genus *Planularia* Defrance, 1826

Type specie *Peneroplis auris* Defrance, in de Blainville, 1824

44. *Planularia berggreni* Anan, 2001, p. 136, pl. 1, fig. 2 (Pl. 1/21).

This Paleocene species has semicircular test with nearly flat sides, chambers increasing gradually in size, suture extending backward with raised and beaded about the umbilical area but depressed in the last chamber. It is common in Duwi section.

45. *Planularia dissona* (Plummer, 1931), p. 145, pl. 11, figs. 17, 18 (Pl. 1/22).

This M-E species is characterized by its inflated test but other last three chambers are flat. Sutures raised in the early portion of the test, but depressed in the last portion. It was recorded from USA and Egypt (Luger, 1985; Anan, 2001). It is common in Paleocene of study section.

Family Lagenidae Reuss, 1862

Genus *Lagena* Walker and Jacob, 1798

Type species *Serpula (Lagena) sulcata* Walker and Jacob, 1798

46. *Lagena rawdhae* Anan, n. sp.

Holotype: Pl. 1/23.

Dimension of the holotype: length 2.9 mm., diameter 2.4 mm.

Depository: Department of Geology, Al Azhar Univ.-Gaza, Anan collection (AZUGGD A49).

Etymology: In the memory of my late sister Rawdha Anan.

Type locality and level: sample 41, Esna Shale of Duwi section.

Age: late Paleocene-early Eocene.

Diagnosis: This late Paleocene-early Eocene new species has nearly subglobular unilocular test, slightly longer than broad, wall with numerous longitudinal costate surface (more than 30) covering only about two-thirds of the surface, neck extended with phialine

lip. It differs from the *L. sulcata* in its longitudinal costae which not extended all over the test-surface.

Remarks: The costate ornamentation in the new species partly covered the test-surface (about two-third surface size), while it is completely covered the test of *L. sulcata*.

Remarks: The M-P *Lagena. sulcata* differs from the new species P-E *L. rawdhae* in completely covering its surface by longitudinal costae. *L. rawdhae* n. sp. differs from the Quaternary-Holocene *L. apiopleura* of Loeblich and Tappan (1953) by its numerous longitudinal costate surface (more than 30), not between 12-16 costae only.

47. *Lagena sulcata* (Walker and Jacob, 1798), p. 64, pl. 14, fig. 5 (PI. 1/24).

This M-P cosmopolitan species is characterized by its globulosa-subglobulose test with numerous longitudinal costae. It was recorded from USA, France (Sztrákos, 2005), Egypt (LeRoy, 1953; Said and Kenawy, 1956; Youssef and Taha 2012; Anan, 2014b), Qatar (Hewaidy and Al-Hitmi, 1993), UAE (Anan, 1993a). It is rare in the P-E of Duwi section.

Genus *Pygmaeoseistron* Patterson and Richardson, 1988

Type species *Lagena hispidula* Cushman, 1913

48. *Pygmaeoseistron hispidum* (Reuss, 1858), p. 434.

According to Loeblich and Tappan (1988) and Patterson and Richardson (1988), the genus *Pygmaeoseistron* includes some species previously placed in *Lagena*, but with smooth to finely hispid surface without costae, and terminal aperture on a short neck rather than longitudinal striae or costae in *Lagena*. According to the law of priority, Anan (2009) considered the species *hispidula* is a senior synonym *hispidula* Cushman. The M-E It was recorded from some Tethyan localities: USA, France (Sztrákos, 2000), Egypt (Luger, 1985), Qatar (Hewaidy and Al-Hitmi, 1993), UAE (Anan, 1993a), Pakistan (Nomura and Brohi, 1995).

Subfamily Ramulinae Brady, 1884

Genus *Guttulina* d'Orbigny, 1839

Type species *Polymorphina communis* d'Orbigny, 1826

49. *Guttulina communis* (d'Orbigny, 1826), p. 266, pl. 12, figs. 1-4 (PI. 1/25).

This species was recorded from France, Poland (Pozaryska and Szczechura, 1968) and Bulgaria (Valchev, 2007). It seems that it is recorded here, which observed rare in the P-E succession of the study section.

Genus *Ramulina* T. R. Jones, 1875

Type species *Ramulina laevis* T. R. Jones, 1875 in J. Wright, 1875

50. *Ramulina navarroana* Cushman, 1938, p. 43, pl. 7, figs. 11, 12.

This M-E species was recorded from USA, Egypt (LeRoy, 1953; Anan, 2014) and Pakistan (Haque, 1956). It is rare in the P-E of the study section.

Family Ellipsolagenidae A. Silvestri, 1923

Subfamily Oolininae Loeblich and Tappan, 1961

Genus *Oolina* d'Orbigny, 1839

Type species *Oolina laevigata* d'Orbigny, 1839

51. *Oolina globosa* (Montagu, 1803), p. 523.

This Jurassic-Holocene cosmopolitan species has unilocular and globular test with smooth surface. It was recorded from Trinidad (Bolli et al., 1994), Egypt (LeRoy, 1953; Said and Kenawy, 1956; Anan, 2014), UAE (Anan, 1993b), Pakistan (Nomura and Brohi, 1995). It is rare-common in the P-E succession of Duwi section.

Suborder Rotaliina Delage and Hérouard, 1896

Superfamily Turrilinacea Cushman, 62

Family Turrilinidae Cushman, 62

Genus *Neobulimina* Cushman and Wickenden, 103

Type species *Neobulimina canadensis* Cushman and Wickenden, 103

1. *Neobulimina farafraensis* LeRoy, 1953, p. 39, pl. 8, figs. 3, 4.

This late Paleocene-early Eocene species belongs to the genus *Neobulimina* as originally described by LeRoy (1953) due its subglobular chambers in smooth test, loop-shaped opening aperture which extending up the terminal face, without elongate fusiform test and prolocular apical spines as in the genus *Stainforthia* Hofker (1956) as noted by Speijer (1994, p. 109). *N. farafraensis* was recorded in the FBF, SF, and NVF of Egypt. It seems to be confined in Egypt.

Superfamily Buliminacea Jones, 1875

Family Siphogenerenoididae Saidova, 1981

Subfamily Siphogenerenoidinae Saidova, 1981

Genus *Orthokarstenia* Dietrich, 1935

Type species *Orthocerina ewaldi* Karsten, 1858

2. *Orthokarstenia applinae* (Plummer, 1927, p. 69, pl. 4, fig. 1) (PI. 2/2).

The original author, however, called the species *Bolivina applini*, and this grammatically incorrect name thus must be maintained. Plummer (1927) noted that the initial part of her species *applinae* is obscure, but she added that the chambers of the species are smooth, except for distinct striae extending from the initial extremity upward over several early chambers. The main characteristics of this species are the crenulations of sutures between the chambers, and the longitudinal somewhat discontinuous striae. Moreover, the taxonomic status of *O. applinae* was also used by Hewaidy (1997) and Ismail (2012). On the other hand, Anan and Sharabi (1988) noted that the genus *Orthokarstenia* is recorded only in the central and southern Egypt (Nile Valley Facies, NVF, of Issawi, 1972). Later on, Hewaidy (1997) named this

area as '*Orthokarstenia* province'. Anan (1998) regarded *applinae* to the genus *Orthokarstenia* due to its triserial initial part that becomes biserial to uniserial final chambers. Moreover, Anan (1998) believes that the Paleocene-early Eocene *O. applinae* have been evolved from the Maastrichtian *O. oveyi* of Nakkady (1950), and it has been considered a guide species from the Paleocene-early Eocene boundary. On the other hand, Koutsoukos and Klasz (2000) considered the Nakkady's *oveyi* as a junior synonym of the *Orthokarstenia parva* (Cushman). It seems that the illustrated form *S. eleganta* of Hulsbos *et al.*, (1989) is closely related to *O. applinae*. This cosmopolitan species has been widely reported in the Tethys: USA, Trinidad (Bolli *et al.*, 1994), Sweden (Brotzen, 1948), Norwegian Sea (Hulsbos *et al.*, 1989), Spain (Ortiz and Thomas, 2006), Tunisia (Aubert and Berggren, 1976), Gulf of Guinea (Brun *et al.*, 1984), Ivory Coast (N'da *et al.*, 1995), Egypt (Luger, 1985; Anan, 2017), Jordan (Futyan, 1976), UAE (Anan, 1993a), Iran (VahdatiRad *et al.*, 2016) and Pakistan (Haque, 1956).

3. *Orthokarstenia eleganta* (Plummer, 1927, p. 126, pl. 8, fig. 1) (Pl. 2/3).

Anan (1998) regarded this Paleocene-early Eocene species to the genus *Orthokarstenia* due to its triserial initial part that become biserial to uniserial final chambers. It has been widely reported in many Tethyan localities: USA, Egypt (LeRoy, 1953; Anan, 2014), Tunisia (Aubert and Berggren, 1976), Saudi Arabia (Berggren and Aubert, 1975), France (Sztrákos, 2005), Spain (Ortiz and Thomas, 2006). Anan (1998) believes that *O. eleganta* have been evolved from the Maastrichtian *O. esnehensis* of Nakkady (1950), and it has been considered a guide species from the Paleocene-early Eocene boundary like *O. applinae*. This species is another distinctive form has been considered a guide species from the Paleocene-early Eocene.

4. *Orthokarstenia higazyi* (Nakkady, 1955), p. 705, text-fig. 4.

This Paleocene species was originally described by Nakkady (1955). It is characterized by its longitudinal ribs along the test among many characters. It differs from the Maastrichtian *O. esnehensis* (Nakkady, 1950) by its smooth test. Anan and Sharabi (1988) considered the Paleocene *S. elnaggari* Futyan (1976) as a junior synonym of *O. higazyi*.

5. *Orthokarstenia nakkadyi* Anan, 2009, p. 37, pl. 1, fig. 7.

This species has a distinguished character its longitudinal costae on the early chambers (the lower part of the test) but without costae ornamentation on the last chambers (the upper part of the test). The distinguished character of *Orthokarstenia nakkadyi* is the longitudinal costae on the lower part of the test

(tri- and biserial stage), but without costae ornamentation on the upper part of the test (the uniserial stage) has an illness treatment by many authors as Plummer's *eleganta* (with smooth surface, without longitudinal costae). The *O. nakkadyi* Anan (2009) was recorded from the middle Paleocene (Selandian, P4a Zone) of Duwi section, Egypt. The figured forms of Saint-Marc (1992, El Haria Formation, El Kef section of Tunisia) and El-Dawy (2001, Esna Shale of El Sheikh Fadl-Ras Gharib area, Eastern Desert of Egypt) was also recorded from the Paleocene, but Paleocene-early Eocene of the Esna Shale of Dababiya section, south of Luxor by Alegret and Ortiz (2007). On the other hand, this species *O. nakkadyi*, was recorded around the Ypresian/Lutetian transition in France (Sztrákos, 2000) and Spain (Ortiz and Thomas, 2006). For that, *O. nakkadyi* Anan has wide geographic distribution in the southern Tethys (so far, from Egypt and Tunisia) and northern Tethys (France and Spain). According to the new data (Anan, 2014a), the stratigraphic range of *O. nakkadyi* is a middle Paleocene to middle Eocene.

Family Buliminidae Jones, 1875

Genus *Bulimina* d'Orbigny, 1826

Type species *Bulimina marginata* d'Orbigny, 1826

6. *Bulimina cacumenata* Cushman and Parker, 1936, p. 40, pl. 7, fig. 3 (Pl. 2/4).

This species was recorded from the Paleocene in USA. It is common in the early Eocene of Duwi section.

7. *Bulimina farafraensis* LeRoy, 1953, p. 21, pl. 7, figs. 26, 27 (Pl. 2/5).

This species was originally recorded from the Paleocene of Maqfi section (FBF). It is also recorded in the PE transition by Hewaidy and Strougo (2001), El-Dawy and Hewaidy (2002), Speijer *et al.* (1996), Ernst *et al.* (2006), Anan (2008a, 2010b), but in the early Eocene of Dababiya section by Alegret *et al.* (2005) and Alegret and Ortiz (2007). It was also recorded from Arabian Sea (Boltovskoy and Ocampo, 1993).

8. *Bulimina midwayensis* Cushman and Parker, 1936, p. 73, pl. 4, fig. 3.

This Paleocene species was originally recorded from the Paleocene in USA, and also in Sweden (Brotzen, 1948), Tunisia (Aubert and Berggren, 1976), Egypt (Said and Kenawy, 1956) and UAE (Anan, 1993a). It is abundant in the Paleocene-early Eocene of Duwi section.

Genus *Protoglobobulimina* Hofker, 1951

Type species *Bulimina pupoides* d'Orbigny, 1846

9. *Protoglobobulimina pupoides* (d'Orbigny, 1846), p. 185, pl. 11, figs. 11, 12 (Pl. 2/1).

This species belongs to the genus *Prtooglobobulimina* according to Loeblich and Tappan

(1988). It is characterized by its smooth test, about five triserial whorls, loop-shaped aperture with a narrow curved slit and lip. This species was recorded from Maastrichtian-Eocene of Maqfi section (FBF) of Egypt, but middle Paleocene in the study section.

Subfamily Angulogerininae Galloway, 1933

Genus *Trifarina* Cushman, 1923

Type species *Trifarina bradyi* Cushman, 1923

10. *Trifarina esnaensis* LeRoy, 1953, p. 52, pl. 8, figs. 5, 6 (Pl. 2/6).

This Paleocene species is characterized by its triangular test in traverse section. It was recorded in the most facies of Egypt, and also in Tunisia (Keller, 1988), UAE (Anan, 1993a), France (Sztrákó, 2000) and North Atlantic (Culver, 2003).

Superfamily Fursenkoinacea Loeblich and Tappan, 1961

Family Fursenkoinidae Loeblich and Tappan, 1961

Genus *Fursenkoina* Loeblich and Tappan, 1961

Type species *Virgulina squamosa* d'Orbigny, 1926

11. *Fursenkoina dubia* (Haque, 1956), pl. 25, figs. 3, 4 (Pl. 2/7).

The Late Paleocene-early Eocene species *F. dubia* has an elongated biserial test, rounded to ovate in section, slightly inflated chambers, the biserial twisted chambers throughout the test axis, suture depressed with smooth surface. Our figured specimen from Duwi section, Egypt is closely related to the holotype of *F. dubia* (Haque), especially in the initial part of the test. This species was recorded, so far, from Pakistan (Haque, 1956) and Egypt (Ali, 2003; Anan, 2019a).

Superfamily Pleurostomellacea Reuss, 1860

Family Pleurostomellidae Reuss, 1860

Subfamily Pleurostomellinae Reuss, 1860

Genus *Ellipsoglandulina* Sивestri, 1901

Type species *Ellipsoglandulina laevigata* Sивestri, 1901

12. *Pleurostomella subnodosa* Reuss, 1860, p. 204, pl. 8, fig. 2.

Plummer (1927) noted that the main differences between *P. subnodosa* Reuss and *P. alternans* Schwager lies in the character of the aperture, that of the former being simple and that of the latter toothed. This species was originally described from the upper Cretaceous of Europe, USA (Cushman, 1946), Mexico (Sliter, 1968), and Maastrichtian of Abu Rawash section, west Cairo, Egypt (Anan, 1987), while in the Maastrichtian-Paleocene of Sinai, Egypt (Said and Kenawy, 1956; Anan, 2019b), and Paleocene from UAE (Anan, 1993).

Family Stilostomellidae Finlay, 1947

Genus *Orthomorphina* Stainforth, 1952

Type species *Nodogenerina havanensis* Cushman and Bermúdez, 1937

13. *Orthomorphina rohri* (Cushman and Stainforth, 1945), p. 39, pl. 5, fig. 26 (Pl. 2/8).

This Maastrichtian-Oligocene species is characterized by its globular proloculus in the uniserial test ended by rounded simple terminal aperture with everted rim. It is recorded from different Tethyan localities, i. e.: USA, Egypt (Said and Kenawy, 1956; this study), Southeast Atlantic, southwest Africa (Proto Decima and Bolli, 1978), Trinidad (Bolli *et al.*, 1994), Norwegian Sea (Hulsbos *et al.*, 1989), France (Sztrákó, 2000) and Hungary (Ozsvart, 2007).

Genus *Stilostomella* Guppy, 1894

Type species *Stilostomella rugosa* Guppy, 1894

14. *Stilostomella paleocenica* (Cushman and Todd, 1946), p. 61, pl. 10, fig. 26.

This Paleocene-early Eocene species has globular chambers in a rectilinear uniserial arrangement with terminal aperture on a short neck bordered with a distinct lip. It was recorded from different Tethyan localities: USA, Trinidad (Bolli *et al.*, 1994), Norwegian Sea (Hulsbos *et al.*, 1989), France (Sztrákó, 2000) and Egypt (Said and Kenawy, 1956; this study).

15. *Stilostomella stephensoni* (Cushman, 1936), p. 52, pl. 9, figs. 10-15.

This Maastrichtian species has elongate and tapering chambers with a distinct ring aperture and slight lip. It was recorded, so far, from USA, Egypt (Said and Kenawy, 1956; this study) and Indian Ocean (Quilty, 1992).

Superfamily Discorbacea Ehrenberg, 43

Family Bagginiidae Cushman, 62

Subfamily Bagginiinae Cushman, 62

Genus *Cancris* de Montfort, 1808

Type species *Cancris auriculus* de Montfort, 1808 = *Nautilus auricula* Fichtel and Moll, 1798

16. *Cancris auriculus* (Fichtel and Moll, 1798), p. 102, pl. 8, figs. g-i (Pl. 2/9).

This early Eocene species was recorded from Egypt (LeRoy, 1953), Norwegian Sea (Hulsbos *et al.*, 1989), France (Sztrákó, 2000). It is common in the early Eocene of the study section.

Genus *Valvulineria* Cushman, 1926

Type species *Valvulineria californica* Cushman, 1926

17. *Valvulineria aegyptiaca* LeRoy, 1953, p. 53, pl. 9, figs. 21-23 (Pl. 2/10).

This species was recorded from some authors in Egypt (i. e.: LeRoy, 1953; Said and Kenawy, 1956). It is rare to common in the Paleocene-early Eocene of the study section.

Family Eponididae Hofker, 1951

Subfamily Eponidinae Hofker, 1951

Genus *Eponides* de Montfort, 1808

Type species *Nautilus repandus* Fichtel and Moll, 1798

18. *Eponides lotus* (Schwager, 1883), p. 132, pl. 28, fig. 9.

This Eocene species has biconvex test, strongly convex dorsally but ventrally less so, a low arched slit aperture at the last chamber midway between periphery and umbilical area. This species was originally recorded from Egypt (Schwager, 1883; LeRoy, 1953; this study), and later from USA (Cushman and Todd, 1942; Bandy, 1944), Pakistan (Haque, 1956) and Bulgaria (Valchev, 2008).

Family Discorbidae Ehrenberg, 1838

Genus *Neoeponides* Reiss, 1960

Type species *Rotalia schreibersii* d'Orbigny, 1846

19. *Neoeponides duwi* (Nakkady, 1950), p. 688, pl. 90, figs. 5-7.

Nakkady (1950) originally recorded this taxon from the base of the post-Cretaceous shales of Duwi section (NVF). Later on, it was also recorded in some parts of Egypt (Hewaidy, 1987; Anan and Sharabi, 1988; Aref and Youssef, 1996). On the other hand, Anan (1998) proposed the *Discorbis p. pseudoscopos* - *Discorbis p. duwi* lineage from the Cretaceous ancestor *pseudoscopos* to the Paleocene descendent *duwi*, while Speijer (2003a) considered *duwi* appears to have no phylogenetic relationship with *pseudoscopos*, and belongs to the genus *Neoeponides* due to his revision of the characters of Nakkady's holotype. He also raised the taxonomic rank of the subspecies *duwi* to the species rank: *Neoeponides duwi*.

Superfamily Discorbinellacea Sigal, 1952

Family Parrelloididae Hofker, 1951

Genus *Cibicoides* Thalmann, 1939

Type species *Truncatolina mundula* Brady, Parker and Jones, 1890

20. *Cibicoides decoratus* (LeRoy, 1953), p. 23, pl. 6, figs. 15-17 (Pl. 2/11).

This species was recorded by many authors in Egypt (i. e.: LeRoy, 1953; Speijer, 1994; Ali, 2003; Anan, 2008). It is rare to common in the Paleocene-early Eocene of the study section.

21. *Cibicoides farafraensis* (LeRoy, 1953), p. 24, pl. 10, figs. 1-3.

This species was recorded by many authors in Egypt (i. e.: LeRoy, 1953; Said and Kenawy, 1956; Luger, 1985; Hewaidy and Strougo, 2001; Anan, 2008). It is rare to common in the early Eocene of the study section.

22. *Cibicoides libycus* (LeRoy, 1953), p. 24, pl. 5, figs. 1-3.

Both *Cibicoides alleni* (Plummer, 1927) and *C. libycus* (LeRoy, 1953) have conspicuous biumbonate test, as well as a low interiomarginal equatorial arch

aperture. *C. libycus* is characterized by its depressed sutures in both sides than elevated and taper sutures in the dorsal side and slightly in the ventral side in *C. alleni*. Accordingly, the figured specimens of some authors as *Heterolepa libyca* were treated to be related to *C. alleni*. The rang of the *C. libycus* is Paleocene-early Eocene from some localities in Egypt, but in the Paleocene of Duwi section. This diagnostic species was recorded in the most facies of Egypt (except NABF in the south), France (Sztrákos, 2005), Turkmenia (Saperson and Janal, 1980), North and South Atlantic (Clemmensen and Thomson, 2005).

23. *Cibicoides mellahensis* (Nakkady, 1950), p. 692, pl. 90, figs. 42-45.

This species was recorded from the shales of Mellaha section in Sinai and later from the Paleocene of Duwi section. It is recorded in Jordan (Futyan, 1976) and UAE (Anan, 1993a).

24. *Cibicoides pharaonis* (LeRoy, 1953), p. 24, pl. 7, figs. 9-11.

This species was recorded by many authors in Egypt (i. e.: LeRoy, 1953; Alegret *et al.*, 2005; Anan, 2008). It was originally recorded from the early Eocene (LeRoy, 1953), but in Paleocene-early Eocene by other authors from different localities in Egypt: Sinai, Dababiya section and this study.

25. *Cibicoides pseudoacutus* (Nakkady, 1950), p. 691, pl. 90, figs. 29-32.

Nakkady (1950) originally recorded this taxon from the Maastrichtian strata of Mellaha (SGF) and Duwi sections (NVF). Later on, it was recorded Abu Tartur, Kharga Oasis (Hewaidy and Cherif, 1988), Garra-Kurkur area, southeast Aswan (Hewaidy, 1994), Duwi section (Anan, 1998) and Um El Huetat section, Red Sea coast (El-Dawy and Hewaidy, 2003). This species was recorded from Egypt, Tunisia (Speijer, 1994) and France (Sztrákos, 2005).

26. *Cibicoides vulgaris* (Plummer, 1927), p. 146, pl. 10, fig. 3 (Pl. 2/12).

Berggren and Aubert (1975) noted that this species has been documented as occurring in the Midway of the Gulf Coast and an equivalent level in Argentina, but it has not been recorded in eastern side of the Atlantic or in the Tethyan *Nonionella africana* region (with the exception of Turkmenia). After that, it was recorded in the Paleocene in many sites of central Egypt: Gabal Ghanima and Gabal Dandara (Anan and Hewaidy, 1986), Ain Dabadib section, Kharga Oasis (Anan and Sharabi, 1988), southern Nile Valley (Ali, 2003), Esh El Mallaha area and Duwi section (Ismail, 2012). For that, its existence in the southern Tethys emphasizes its occurrence outside the original records in the eastern side of the Atlantic. Then, it has been recorded in the both sides of the Atlantic: USA, Argentina (Berggren and Aubert, 1975), Turkmenia

(Berggren and Aubert, 1975) and Egypt (Anan and Sharabi, 1988; Ali, 2003; Anan, 2017).

Superfamily Nonionacea Schultze, 1854

Family Nonionidae Schultze, 1854

Subfamily Pulleniinae Schultze, 1877

Genus *Pullenia* Parker and Jones, 1862

Type species *Nonionina bulloides* d'Orbigny, 1846

27. *Pullenia coryelli* (White, 1929), p. 56, pl. 5, fig. 22

This Campanian-Paleocene species has more than five chambers in a the last whorl than the other four chambers in *P. quaternaria*, or five chambers of *P. quinqueloba*. It was recorded from USA (White, 1929; Cushman, 1946), Trinidad (Bolli *et al.*, 1994), Southeast Atlantic, southwest Africa (Proto Decima and Bolli, 1978), UAE (Anan, 1993b) and Egypt (Said and Kenawy, 1956; this study).

28. *Pullenia quinqueloba* (Reuss, 1851), p. 34, pl. 3, fig. 13

This Paleocene-early Eocene species is characterized from other species of the genus *Pullenia* by its five chambers in the last involute test with long narrow slit extending over the periphery at the base of septal face. It was recorded from Europe (Reuss, 1851); Slovenia (Cimerman *et al.*, 2006), USA (Plummer, 1927), Southeast Atlantic, southwest Africa (Proto Decima and Bolli, 1978), UAE (Anan, 1993b), Egypt (LeRoy, 1953; Said and Kenawy, 1956, Ali, 2003) and Pacific Ocean, east Japan (Boltovskoy and Watanabe, 1985).

Superfamily Chilostomellacea Bandy, 1881

Family Chilostomellidae Bandy, 1881

Subfamily Chilostomellinae Bandy, 1881

Genus *Allomorphina* Reuss, 1849

Type species *Allomorphina trigona* Reuss, 1850

29. *Allomorphina trigona* Reuss, 1850, p. 380, pl. 48, fig. 14 (Pl. 2/13).

This Maastrichtian-Paleocene species is distinguished by relatively subtriangular involute smooth test, three chambers in the last whorl with narrow slit large aperture paralleling suture at the base of the last chamber. This species was recorded from Europe, USA (Plummer, 1927). It seems that the figure form *A. macrostoma* Keller by Haque (1956) from Pakistan is closely related to *A. trigona*. It is recorded, for the first time from Egypt, at least in the study section.

Family Quadrimorphinidae Saidova, 1981

Genus *Quadrimorphina* Finlay, 1939

Type species *Valvulina allomorphinoides* Reuss, 1860

30. *Quadrimorphina esnehensis* (Nakkady, 1950), p. 689, pl. 90, figs. 11-13.

Nakkady (1950) recorded this Paleocene-early Eocene species from the Paleocene shales of Abu

Durba and Wadi Danili sections (SF). Later on it was recorded from the Paleocene of Maqfi section, Farafra Oasis (LeRoy, 1953), Nekhl and Giddi sections in northern Sinai (Said and Kenawy, 1956), El Qusaima area of Sinai (Hewaidy, 1987) and Garra-Kurkur area, southwest Aswan (Hewaidy, 1994), but it was recorded also in the Maastrichtian of Abu Tartur area (NVF), Kharga Oasis (Hewaidy and Cherif, 1988), El Qusaima (Hewaidy and El Ashwah, 1993) and in northern Sinai (Ismail and El Saadany, 1995). On the other hand, the species belongs here to the genus *Quadrimorphina* (non *Valvulineria*, as originally described by Nakkady, 1950), due to its oval to subspherical test in the final whorl and its five to six chambers in the study section.

Family Alabaminidae Hofker, 1951

Genus *Alabamina* Toulmin, 1941

Type species *Alabamina wilcoxensis* Toulmin, 1941

31. *Alabamina midwayensis* Brotzen, 1948, p. 99, pl. 16, figs. 1, 2.

It was recorded by many authors in many localities (i. e.: Brotzen, 1948; Said and Kenawy, 1956; Nakkady, 1959; Aubert and Berggren, 1976; Luger, 1985; Speijer, 1994). It is rare to common in the Paleocene-early Eocene in the study section.

Genus *Valvalabamina* Reiss, 1963

Type species *Rotalina lenticula* Reuss, 1845

32. *Valvalabamina depressa* (Alth, 1850), p. 266, pl. 13, fig. 21.

The umbilical area of this Maastrichtian-early Eocene long-ranged species is covered by an umbilical flap. The figured forms of it belong to different names by some authors: *Gyroidina depressa* (of Cushman, 1946), *G. planulata* (by LeRoy, 1953; Said and Kenawy, 1956), *Valvulineria brotzeni* (by Nakkady, 1959; Anan, 2009) are related here to *V. depressa* (Alth) due to the great similarity between them. It is common in the P-e Eocene of the study section.

Family Heterolepididae Gonzáles-Donoso, 1969

Genus *Anomalinoides* Brotzen, 1942

Type species *Anomalinoides plummerae* Brotzen, 1942

33. *Anomalinoides aegyptiacus* (LeRoy, 1953), p. 17, pl. 7, figs. 21-23.

This Paleocene-early Eocene species was originally recorded from the early Eocene in Maqfi section (LeRoy, 1953), Duwi section (Speijer, 1994; Speijer *et al.*, 2000; this study), south Egypt (Ali, 2003) and later in Tunisia (Salaj, 1976),

34. *Anomalinoides desertorum* (LeRoy, 1953), p. 17, pl. 7, figs. 18-20

This Paleocene-early Eocene species was originally recorded from the Paleocene in Maqfi section (LeRoy, 1953) and later in the Arabian Sea

(Boltovskoy and Verna Ocampo, 1993), and Duwi section (Anan, 2008).

35. *Anomalinoidea leroyi* Anan, 2008, p. 367, pl. 1, fig. 12 (Pl. 2/14).

This species has medium test, ventral side convex and deeply umbilicate, dorsal nearly plan and evolute, 10-12 chambers in the last whorl gradually enlarging as added, wall coarsely perforate, sutures in both sides distinctly limbate and gently raised and curved, periphery rounded and faintly lobulate, aperture low and peripheral with distinct lip. The most outstanding characteristics of the new species than the other species of *Anomalinoidea* are the nearly planoconvex test, deep and wide umbilicate ventral side, raised sutures on both sides, rounded periphery and peripheral aperture with a distinct lip. The Maastrichtian-Danian nearly planoconvex test of *Anomalinoidea leroyi* n. sp. is closely allied to the bi-umbilicate Maastrichtian specimen *Anomalina* sp. K of LeRoy (1953).

36. *Anomalinoidea midwayensis* (Plummer, 1927, p. 141, pl. 9, fig. 7) (Pl. 2/15).

Plummer (1927) noted that the species *Truncatolina midwayensis* is found through the Midway Formation in considerable abundance, whereas variety trochoidea is only abundant locally in the basal strata only. It was recorded in USA, Sweden (Brotzen, 1948), Tunisia (Berggren and Aubert, 1975) and Egypt (Samir, 2002).

37. *Anomalinoidea praeacutus* (Vasilenko), 1950, p. 208, pl. 5, figs. 2, 3.

This Paleocene-early Eocene species was originally recorded from the later Soviet Union, Tunisia (Aubert and Berggren, 1976) and Egypt (Speijer, 1994; this study).

38. *Anomalinoidea rubiginosus* (Cushman, 1926), p. 607, pl. 2, fig. 6 (Pl. 2/16).

Berggren and Aubert (1975) noted that this Campanian-Eocene species has been recorded under a number of names in the literature. The author believes that: (1) *A. danica* is a junior synonym of *A. rubiginosus*, (2) the shape of late Cretaceous *A. rubiginosus* with moderately planoconvex and closely coiled test varies to thick biconvex pseudoplanispiral Paleocene test, (3) the different shapes of the two forms most probably refer to a water depth, (4) some Paleogene forms have slightly raised sutures in the early chambers.

39. *Anomalinoidea welleri* (Plummer, 1927), p. 143, pl. 9, fig. 6.

This Paleocene species was recorded in USA, North Atlantic (Berggren, 1974), Tunisia (Berggren and Aubert, 1975), South Atlantic (Dailey, 1983), Japan (Kaiho, 1988), S. America (Malumián and Caramés, 1997) and Egypt (El-Dawy, 2001). It is rare

to common in the Paleocene-early Eocene of the study section.

40. *Anomalinoidea zitteli* (LeRoy, 1953), p. 25, pl. 6, figs. 20-22.

This species was recorded by many authors in Egypt (i. e.: LeRoy, 1953; Speijer, 1994; Speijer and Schmitz, 1998; Hewaidy and Strougo, 2001; Anan, 2008). It is rare to common in the Early Eocene of the study section.

Family Gavelinellidae Hofker, 1956

Subfamily Gyroidinoidea Saidova, 1981

Genus *Gyroidinoidea* Brotzen, 1942

Type species *Rotalina nitida* Brotzen, 1942

41. *Gyroidinoidea aegyptiacus* Nakkady, 1959, p. 459, pl. 6, fig. 7; pl. 7, fig. 1.

Nakkady (1959) recorded this diagnostic species, with its markedly ventral and dorsal raised limbate sutures, from the Maastrichtian-Danian succession of Um Elghanayem section, Kharga Oasis of Egypt. On the other hand, Speijer (1994) included this species in the synonym of *G. girardanus*, which is not accepted here. It differs from early Paleocene *G. luterbacheri* Anan (2004) in its curved and more limbate sutures which becoming much thicker toward umbilicus. It does not record, so far, outside the original record.

42. *Gyroidinoidea depressus* (Alth, 1850), p. 266, pl. 13, fig. 21 (Pl. 2/17).

This Santonian- Eocene species has planoconvex compressed test, dorsal side nearly flat with three evolute whorls, 10-13 chambers in the final whorl, small open umbilicus and rounded periphery. It was recorded from Europe, USA (Plummer, 1931; Cushman, 1946), Trinidad (Bolli *et al.*, 1994), Egypt (Said and Kenawy, 1956; this study) and UAE (Anan, 1993b).

43. *Gyroidinoidea girardanus* (Reuss, 1851), p. 73, pl. 5, fig. 34.

This species was originally recorded from the Eocene of Germany, and later from Maastrichtian and Paleocene by different authors in different localities (i. e.: Cushman and Stainforth, 1951; LeRoy, 1953; Said and Kenawy, 1956; Nakkady, 1959; Luger, 1985; Anan and Sharabi, 1988; Kaiho, 1988; Speijer, 1994; Speijer and Schmitz, 1998; Ali, 2003; Anan, 2004). Anan (2004) proposed an lineage phylogeny for the Maastrichtian-Paleocene *G. girardanus* to the Paleocene *G. luterbacheri* Anan. It is rare to common in the Paleocene-early Eocene of the study section.

44. *Gyroidinoidea subangulata* (Plummer, 1927), p. 154, pl. 12, fig. 1 (Pl. 2/18).

This Paleocene species was recorded in USA, Rockall Bank, North Atlantic (Berggren, 1974a), North Sea (Clemmensen and Thomsen, 2005), France (Sztrákos, 2005), Tunisia (Berggren and Aubert, 1975), Egypt (LeRoy, 1953; El-Dawy, 2001; Anan, 2017), UAE (Anan, 1993b).

Subfamily Gavelinellinae Hofker, 1956

Genus *Angulogavelinella* Hofker, 1957

Type species *Discorbina gracilis* Marsson, 1978

45. *Angulogavelinella avnimelechi* (Reiss, 1952), p. 269, text-fig. 2.

This M-P species is characterized by its plano-convex test, convex umbilical side with deep umbilicus, but without umbo. It was recorded from the different localities in the Tethys: Middle East (Reiss, 1952; Luger, 1985; Anan, 1993a, b; Ernest *et al.*, 2006), North Africa (Aubert and Berggren, 1976), France (Sztrákos, 2005) and Trinidad (Bolli *et al.*, 1994). It seems that the last occurrence of *Siphogaudryina strougoi* Anan, *Verneuilina aegyptiaca* Said and Kenawy, *Angulogavelinella avnimelechi* (Reiss), *Neoflabellina jarvisi* (Cushman) and *Frondicularia phosphatica* Russo mark the P/E boundary.

Genus *Gavelinella* Brotzen, 1942

Type species *Discorbina pertusa* Marsson, 1878

46. *Gavelinella lellingensis* (Brotzen, 1984), p. 75, pl. 11, figs. 1, 2.

This Paleocene species was recorded from Sweden, and later on from Tunisia (Aubert and Berggren, 1976) and Egypt (this study). It is recorded here for the first time from Duwi section.

47. *Gavelinella scrobiculata* (Schwager, 1883), p. 129, pl. 29, fig. 18.

This P-E species is characterized by its biconvex test, with large pores on both sides. It was recorded, so far, from Egypt (Schwager, 1883, LeRoy, 1953; Luger, 1985, Speijer, 1994), Tunisia (Aubert and Berggren, 1976).

Genus *Paralabamina* Hansen, 1970

Type species *Eponides lunata* Brotzen, 1948

48. *Paralabamina lunata* (Brotzen, 1948), p. 77, pl. 10, figs. 17, 18 (Pl. 2/19).

This P-E has biconvex test, 5-6 chambers in the last whorl with a low slit aperture at the base of the last chamber. It was recorded from Sweden, Atlantic Ocean (Tjalsma and Lohmann, 1983), Southern Ocean (Alegret and Thomas, 2013), Egypt (LeRoy, 1953) and UAE (Anan, 1993a). It is rare to common in the of the study section.

Family Karreriidae Saidova, 1981

Genus *Karrereria* Rzehak, 1891

Type species *Karrereria fallax* Rzehak, 1891

49. *Karrereria fallax* Rzehak, 1891, p. 4 (in Rzehak, 1895), pl. 7, fig. 7 (Pl. 2/20).

This M-E species is characterized by its trochospirally enrolled early stage with one and more volution, alter stage uncoiled, suture slightly depressed with terminal and rounded aperture. It seems that the *Stichocibicides* sp. of LeRoy (1953) and *Rectoepionides dubia* Haque (1956) is closely related to *K. fallax* Rzehak (1891). It was recorded also from

the North Atlantic (Berggren, 1974), France (Sztrákos, 2005), Tunisia (Aubert and Berggren, 1976), Egypt (LeRoy, 1953; Luger, 1985; Ali, 2003) and Pakistan (Haque, 1956).

Paleogeography

The paleogeographic distribution of **fifty one Lagenid and another forty nine Rotaliid** identified benthic foraminiferal species and subspecies (belonging **49** genera) in different Egyptian Facies and other Tethyan countries are shown in **Tables 1, 2, respectively**.

The following remarks of the paleobiogeographic distribution of the recorded Tethyan benthonic foraminiferal species can be presented:

1. Berggren and Aubert (1975) noted that during the Paleogene a widespread geographic distribution of planktic and benthic foraminiferal elements occurred between Tethys-Caribbean-Gulf Coast regions.

2. Moore *et al.* (1978) recorded the extended realms of the Tethys, Indo-Pacific with Atlantic Oceans in the Maastrichtian-Late Eocene.

3. Haq and Aubry (1980) noted that North Africa and the Middle East formed important parts of the Tethys link between the Atlantic Ocean and the western Pacific Ocean in the Early Cenozoic.

4. Adams *et al.* (1983) noted that the continuous marine Paleogene connection between the area occupied by the present-day Mediterranean and the Indian Ocean had been lost by mid Burdigalian (early Miocene) times when a land bridge connected S. W. Asia to Arabia, which means that the faunas of the Mediterranean and Indo-West Pacific began to diverge. The final disconnection must have been caused by a general elevation of this region rather than by a global eustatic change.

5. Solakius *et al.* (1990) show that the ancestral Tethys is connected with the ancestral Atlantic and Indian Oceans via Mediterranean Sea.

6. Haynes and Nwabufu-Ene (1998) noted that the foraminiferal biofacies suggest gradual paleogeographical change from transitional marine environments to a shallow shelf, and suggested wider Tethyan connections, as far as the Carpathian and Pakistan.

The following remarks can also be presented on some genera and species have wide paleogeographic distribution:

1. The P-E *Frondicularia nakkadyi* Futyan was recorded from the Paleocene of Jordan, and later in Egypt (Anan, 2002), but early Eocene of Sprijer (1994).

2. The Paleocene species *F. phosphatica* Russo was recorded in Morocco, Tunisia (Aubert and Berggren, 1976) and Egypt (Nakkady, 1950; Luger, 1985; Anan and Hewaidy, 1986; Speijer, 1994; Anan, 2002).

3. The Paleogene *Lenticulina budensis* (Hantken) was recorded from the late Oligocene of Hungaria (Central Europe), and later from the same horizon of Puerto Rico (Caribbean Sea), but from the EE of Maqfi section (Egypt), and now from the same horizon of Duwi section, Egypt (this study).

4. The Paleocene species *Lenticulina degolyeri* (Plummer) was originally recorded from USA, and later from Pakistan (Haque, 1956), Tunisia (Aubert and Berggren, 1976), Jordan (Basha, 2005) and Egypt (this study).

5. The Maastrichtian-Paleocene cosmopolitan species *Lenticulina midwayensis* (Plummer) was recorded in many sites in the Tethys: USA, Pakistan (Haque, 1956), Egypt (Nakkady, 1959; El-Dawy, 2001), Tunisia (Aubert and Berggren, 1976), South America (Dailey, 1983) and UAE (Anan, 1993b, 2015b).

6. The Paleocene species *Lenticulina pseudomamilligera* (Plummer) was recorded from USA, Pakistan (Haque, 1956), Tunisia (Berggren and Aubert, 1975), Egypt (Luger, 1985), UAE (Anan, 1993a, 2015b) and France (Sztrákös, 2000).

7. *Citharina plummerae* Anan was recorded from central Egypt (Duwi section) and also North Eastern Desert of Egypt (Esh El-Mellaha Area) by Hewaidy *et al.* (2017).

8. *Palmula w. woodi* Nakkady has wide geographic distribution throughout the southern Tethys outside Egypt: Iraq (Abdel-Kireem, 1983), Jordan (Futyan, 1976), Tunisia (Aubert and Berggren, 1976; Saint-Marc, 1992).

9. Anan and Sharabi (1988) noted that the genus M-E *Orthokarstenia* is recorded only in the central and southern Egypt (NVF), while the genus M-P *Bolivinoidea* is prevailed in the northern Egypt.

10. *Orthokarstenia nakkadyi* Anan (2009) was treated by some authors under different names: *Siphogeronoides eleganta* (by Saint-Marc, 1992 in Tunisia; El-Dawy, 2001 and Alegret and Ortiz, 2006/2007 in Egypt), or *Rectuvigerina clavata* (by Sztrákös, 2005). All these forms have the same characters: longitudinal costae only in the lower part of the test, but smooth in the upper part of the test.

11. Berggren and Aubert (1975) noted that *Cibicidoides vulgaris* (Plummer) has not been recorded in the eastern side of Atlantic Ocean (in North America in USA and south America in Argentina), or in the Tethyan regions (except in Turkmenia). Anan and Hewaidy (1986) recorded this species, for the first time, in Egypt in three sections in the NVF in central Egypt. Later on, it was recorded also from southern Egypt, west of Aswan area by Ali (2003) and northern Egypt, west Gulf of Suaz by Ismail (2012). The figured Pakistanian specimens: *Cibicides multifarius limbata* Haque (1956, pl. 16, fig.

5), and Iranian *Anomalinoidea capitana* by VahdaiRad *et al.* (2016, pl. 2, fig. 1) are closely related to *C. vulgaris*.

12. *Cibicidoides pseudoacutus* (Nakkady) is recorded in southern Tethys by Speijer (1994) and Galeotti and Coccioni (2002) in Tunisia, and also in the northern Tethys (France) by Sztrákös (2005).

13. Anan (2010) noted that the ventrally more convex than dorsally test with acute periphery of the Paleocene-Early Eocene *Cibicidoides pharaonis* (LeRoy) changes to plano-convex test with rounded periphery in the Early Eocene *C. farafraensis* (LeRoy) in *C. pharaonis*-*C. farafraensis* lineage.

14. *Quadrimorphina esnehensis* (Nakkady) was recorded outside Egypt in other sides in the Middle East: Jordan (Futyan, 1976) and UAE (Anan, 1993a).

Paleoclimatology and Paleocology

1. Boersma (1977) noted that during a cooling the benthic forams demonstrate increased spinosity, numbers of rectilinear species, numbers of benthic relative to planktonic foraminifera, numbers of generalists of cosmopolitan species, and size of individuals.

2. Norris and Röhl (1999) noted that the Paleocene-Eocene boundary contains evidence of a warming of ~5° to ~7° within a single precessional cycle.

3. Zachos *et al.* (2001) noted that the Paleocene-Eocene (P-E) transition is characterized by a brief intensive interval of global warming and coeval with huge perturbation of the global carbon budget.

4. Aref and Youssef (2004) noted that the end of Paleocene was marked by a sudden global climatic change, upsetting oceanic and atmospheric circulation and leading to the extinction of numerous deep-sea benthic foraminifera (outer neritic-upper bathyal, i.e. *Neoflabellina jarvisi*).

5. Alegret *et al.* (2005) noted that the Global Stratotype Section and Point (GSSP) for the P/E boundary was defined at Dababiya Quarry in Egypt at the base of the CIE, which coincides with the major turnover in foraminiferal assemblages. The benthic foraminifera from Dababiya indicate an outer shelf depth of deposition during the Paleocene - early Eocene.

6. Egger *et al.* (2006) noted that the calcareous benthic foraminiferal assemblages there was no major extinction of agglutinated taxa across the P/E boundary, while Alegret and Ortiz (2007) noted that at the BEE the species richness and diversity decreased and the relative abundance of non-calcareous agglutinated foraminifera increase dramatically which may be because, among other, of the foraminiferal turnover.

7. Aubry *et al.* (2007) noted that the Paleocene/Eocene Thermal Maximum (PETM) event

in Egypt, which was the warmest event in the last 90 millions of years, extends within the lowest part of Esna Shale.

8. Ouda et al. (2016) noted that the Early Eocene El Aguz Limestone represents the invasion of the Tethyan flood during the subsequent decrease of temperature and continuously increased faunal densities as a result of gradual increase in content of dissolved oxygen at the base of PETM.

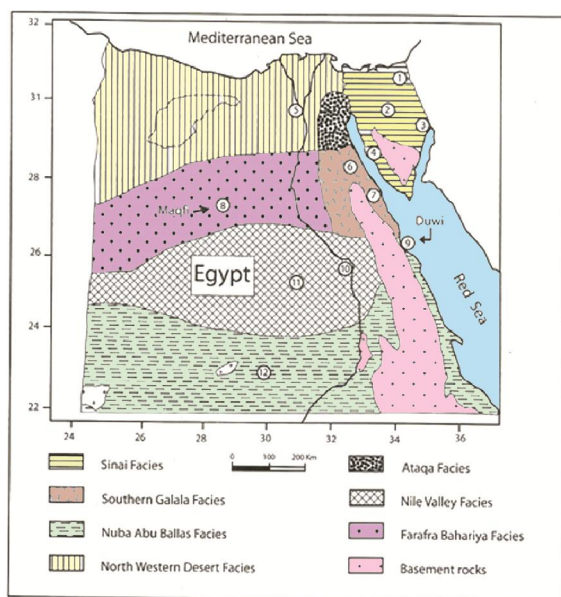


Fig. 1: Location map of the different facies in Egypt (after Issawi *et al.*, 1999). The numbers are the studied section by the author and others. Sinai (1. Qusaima, 2. Nukhul, 3. Taba, 4. Abu Zenima), North Western Desert (5. Jiran El Ful), Southern Galala (7. Wadi Ed Dakhel, 7. Esh El Mallaha and Sufr Ed Dara), Farafra Bahariya (8. Maqfi, Gunna, Esheikh Marzouk), Nile Valley (9. Duwi, 10. Gurnah, Oweina, 10. Ain Dabadib, Um El Ghanayem, Ghanima, Abu Ghurra), Nuba Abu Ballas (12. Bir Kiseiba, Kurkur, Sin El Kaddab).

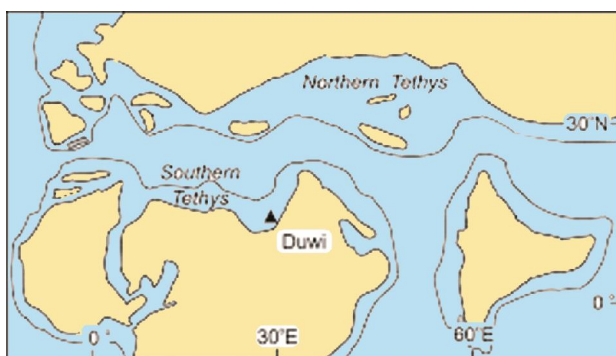


Fig. 2: Location map of Duwi section, Red Sea coast, Egypt in the Southern Tethys (after Anan, 2017).

Paleobathymetry

1. Bandy and Arnal (1960) mentioned that the species diversity increases from the shoreline to the edge of the continental shelf and then remains constant or decline at the continental slope.

2. Abdel-Kereem (1983) mentioned that the benthic foraminifera migrate through time in response to the change in the properties of both water mass and oxygen content regardless to the water depth.

3. Olsson and Nyong (1984) noted that the inner shelf environment (10-50m) is characterized by rare planktics (~ 8%) with low species diversity, while the Planktic value ranges between (8-25%) characterize the middle shelf (50-100m) with an increase in species diversity. Moreover, the outer shelf environment (100-200m) is characterized by high planktic value of 70%.

4. Anan and Hewaidy (1986) noted that the upper part of the Esna Shale (belongs to the Upper Paleocene) in the Central Egypt (Gabal Ghamima in the Kharga Oases from the west, G. Dandara and G. Gurnah in the Nile Valley and to the east Um El Huetat section in Red Sea) yields rich foraminiferal assemblage and indicates deposition in relatively middle-outer marine environmental shelf.

5. Anan (1987) noted that the high value of the calcareous/arenaceous ration in the top of the Paleocene of Jiran El Ful (Abu Rawash area, near Cairo), as well as the high value of planktic/benthic (P/B) ratio (about 70%) indicate middle-outer shelf condition (100-200 m depth).

6. Speijer (1994) noted that the benthic foraminifera from the P-E succession in the Red Sea coast of Egypt suggest middle neritic deposition and only minor sea-level variation.

7. Speijer *et al.* (2000) noted that Gabal Duwi is located near the edge of the early Paleogene epicontinental Tethys margin.

8. Ali (2003) noted that the diversity decreases from bathyal depths to coastal waters, due to larger environmental instability and nutrient supply, favoring taxa with more opportunistic strategies.

9. Hinsbergen *et al.* (2005) noted that the ratio between planktonic and benthic foraminifera is related to water depth, and the percentage planktonic (% P) generally increases with increasing distance to shore. However, next to water depth the oxygen level of bottom waters has a profound effect on the abundance of benthic foraminifera, and influence % P.

10. Alegret *et al.* (2005) noted that the Global Stratotype Section and Point (GSSP) for the PE boundary was defined at Dababiya Quarry in Egypt at the base of the Carbon Isotope Excursion (CIE) which coincides with the major turnover in foraminiferal assemblages, and benthic foraminifera indicate an outer shelf depth of deposition during the Paleocene and early Eocene, and the benthic foraminiferal

assemblages contain abundant representatives of the Midway-type fauna.

11. Zachos et al. (2005) noted that the PETM event is contemporaneous with the BFEE and also the CIE.

12. Egger et al. (2006) noted that the calcareous benthic foraminiferal assemblages there was no major extinction of agglutinated taxa across the P/E boundary, while Alegret and Ortiz (2006/2007) noted that at the BFEE the species richness and diversity decreased and the relative abundance of non-calcareous agglutinated foraminifera increase

dramatically which may be causes, among other, of the foraminiferal turnover.

13. Alegret and Ortez (2006/2007) noted that during the late Paleocene and early Eocene of Dababiya Quarry this part of the southern Tethys was occupied by an epicontinental basin, and the sediments were deposited in an outer shelf environment (~ 150-200m depth).

14. Nassif et al. (2008) regarded that the Late Paleocene rocks in Sinai, Egypt were deposited in the Middle-outer neritic environment.

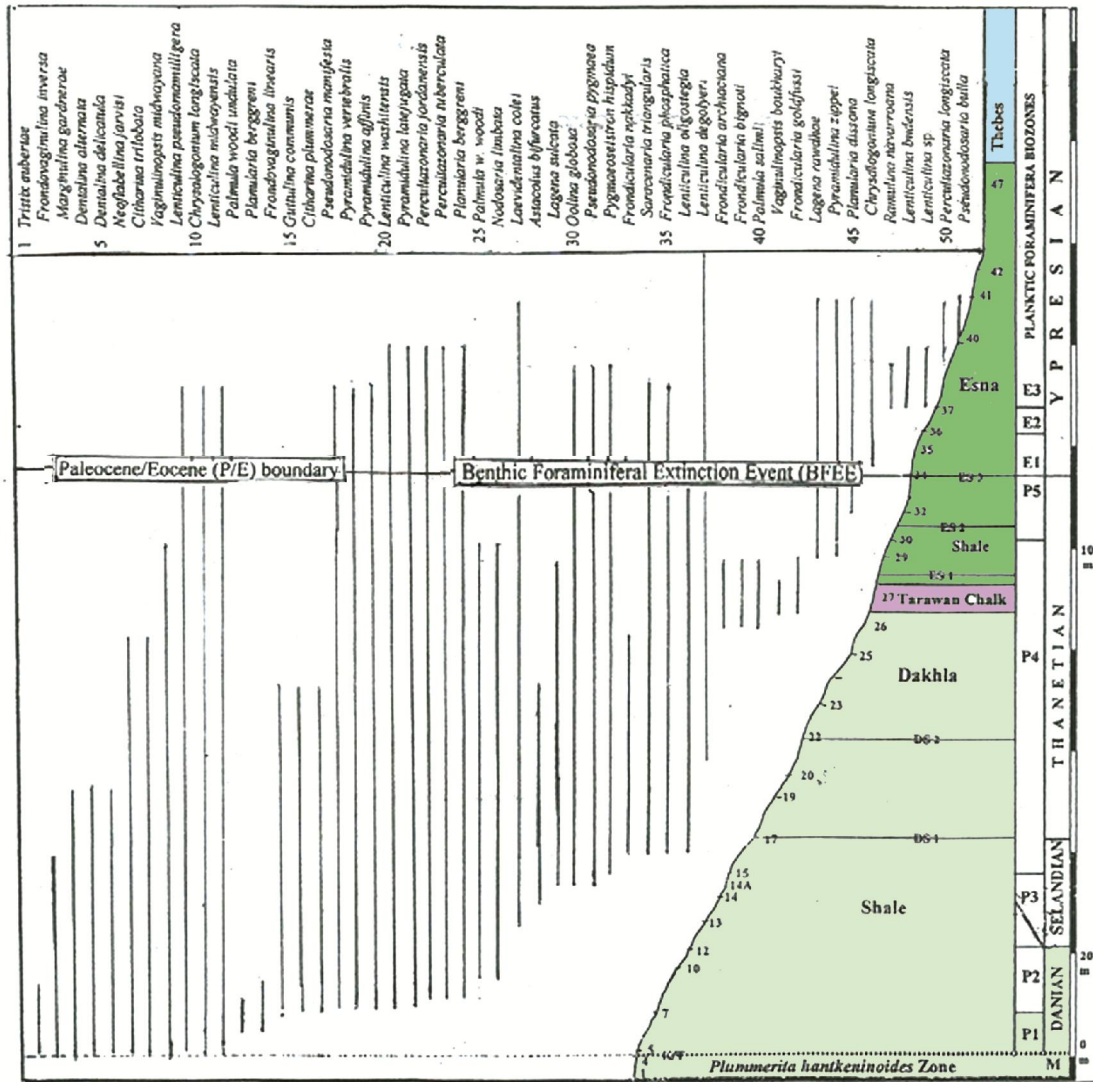


Fig. 3: Stratigraphic distribution of the identified Laginid early Paleogene benthic foraminiferal species from Duwi section, Red Sea coast, Egypt. DS 1,2 = Dakhla Shale brown ledges, ES 1,2,3 = Esna Shale brown ledges. The biostratigraphic zonation of Berggren and Pearson (2005) was used in this section by Anan (2009): P=*Eoglobigerina edita* Zone, P2=*Praemurica uncinata* Zone, P3=*Morozovella angulata* Zone, P4=*Globanomalina pseudomenardii* Zone, P5=*Morozovella velascoensis* Zone, E=*Acarinina sibaiyaensis* Zone, E2=*Pseudohastigerina wilcoxensis*/*Morozovella velascoensis* Zone, E3=*Morozovella marginodentata* Zone.

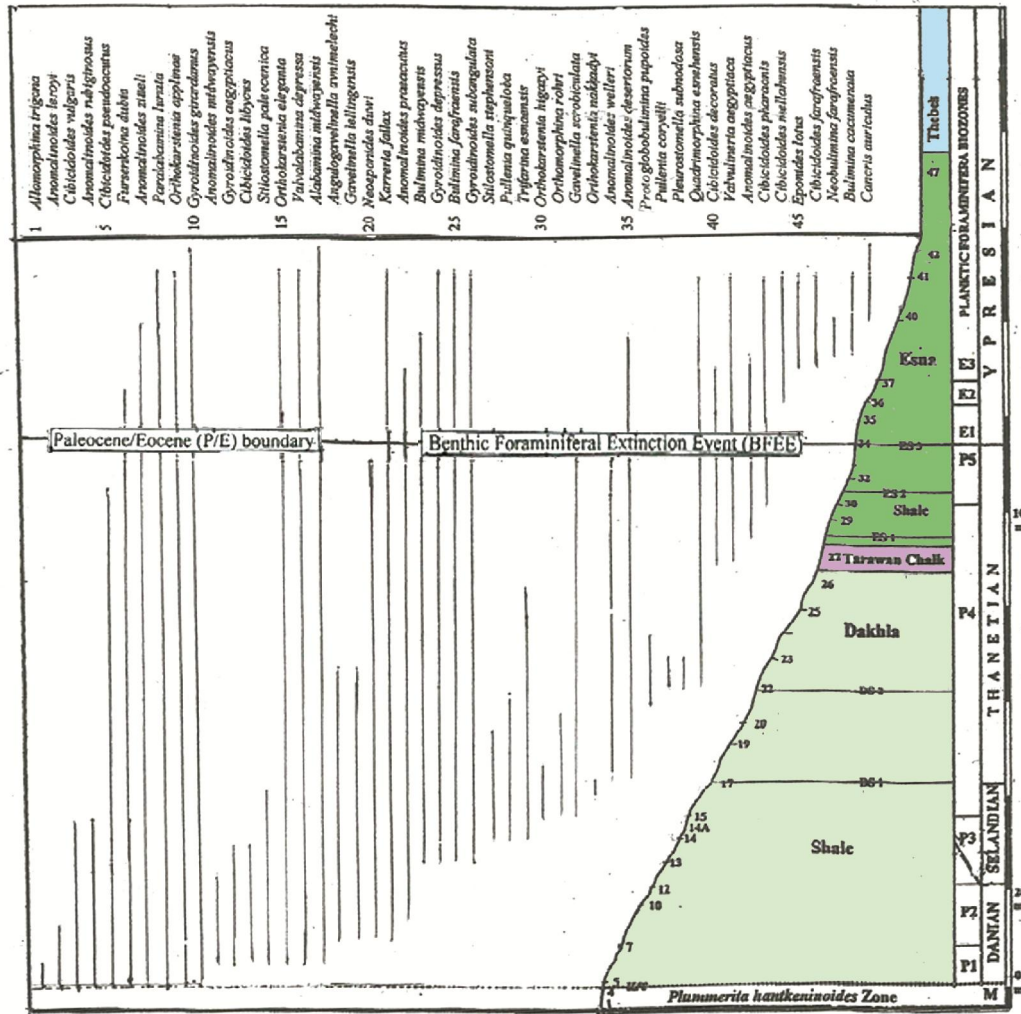


Fig. 4: Stratigraphic distribution of the identified Rotaliid early Paleogene benthic foraminiferal species from Duwi section.

Table 1: The paleogeographic distribution of fifty one Paleocene-early Eocene Lagenid benthic foraminifera in Duwi section and other Egyptian Facies: S=Sinai (1. Qusaima, 2. Nukhul, 3. Taba, 4. Abu Zenima), W=Western Desert (5. Jiran El Ful), G=Galala (6. Wadi Ed Dakhli, 7. Esh El Mallaha), Farafra Bahariya (8. Maqfi, Gunna, Esheikh Marzouk), Nile Valley (9. Duwi, 10. Gurnah, Oweina, 10. Ain Dabadib, Um El Ghanayem, Ghanima, Abu Ghurra), Nuba Abu Ballas (12. Bir Kiseiba, Kurkur, Sin El Kaddab). and other Tethyan localities: SA=South America, AO=Atlantic Ocean (USA, Mexico, Trinidad), EU=Europe (England, Spain, Italy, France, Germany, Poland, Bulgaria, Czech, Romania), T=Tunisia, J=Jordan, UAE=United Arab Emirates, Q=Qatar, P=Pakistan, JZ=Japan and New Zealand, A=Australia (O=illustrated species from Duwi section, x = recorded species).

Sp. No	Early Paleogene Lagenid benthic foraminiferal species in Duwi section	Egypt						Some Tethyan localities									
		S	W	G	F	V	N	SA	AO	EU	T	J	UAE	Q	P	JZ	A
1	<i>Chrysalogonium longiscata</i>				x	⊙	x		x	x	x		x		x	x	
2	<i>velascoensis</i>					x	x		x								
3	<i>Dentalina alternata</i>					x			x	x							
4	<i>delicatula</i>					x			x								
5	<i>Laevidentalina colei</i>			x	x	⊙	x		x	x	x		x				x
6	<i>Nodosaria limbata</i>	x	x	x		x	x		x	x	x			x			
7	<i>Pseudonodosaria bulla</i>	x				x							x				
8	<i>manifesta</i>			x		x	x		x	x	x		x				

9		<i>pygmaea</i>	x		x		x				x			x				
10	<i>Pyramidulina</i>	<i>affinis</i>	x	x	x	x	x				x	x	x	x		x	x	
11		<i>latejugata</i>			x		x	x			x	x					x	
12		<i>vertebralis</i>	x		x		x			x	x	x					x	
13		<i>zippei</i>	x	x	x		x				x							
14	<i>Frondicularia</i>	<i>archiaciana</i>			x		⊖	x		x								
15		<i>bignoti</i>					⊖											
16		<i>goldfussi</i>	x	x	x		x	x		x	x	x		x			x	
17		<i>nakkadyi</i>			x		⊖	x					x					
18		<i>phosphatica</i>					⊖	x			x	x						
19	<i>Tristix</i>	<i>aubertae</i>					⊖						x	x				
20	<i>Astacolus</i>	<i>bifurcatus</i>			x	x	⊖											
21	<i>Lenticulina</i>	<i>budensis</i>				x	⊖			x								
22		<i>degolyeri</i>					⊖		x	x		x	x				x	
23		<i>midwayensis</i>		x	x		x	x	x	x		x					x	
24		<i>oligostegia</i>			x		x	x		x	x			x				
25		<i>pondi</i>				x	⊖			x								
26		<i>Pseudomamilligera</i>			x		⊖	x	x	x		x	x				x	x
27		sp.					⊖											
28		<i>washitensis</i>					x			x	x							
29	<i>Percultazonaria</i>	<i>jordanensis</i>					⊖						x	x		x	x	
30		<i>longiscata</i>			x	x	x											
31		<i>tuberculata</i>			x	x	x	x		x		x	x					
32	<i>Saracenaria</i>	<i>triangularis</i>			x		x	x		x	x			x				
33	<i>Fronovaginulina</i>	<i>inversa</i>					x			x				x			x	
34		<i>linearis</i>	x	x	x		⊖			x	x			x			x	
35	<i>Neoflabellina</i>	<i>jarvisi</i>	x	x	x		⊖	x		x				x			x	
36	<i>Palmula</i>	<i>salimi</i>					⊖	x										
37		<i>woodi undulata</i>					x											
38		w. <i>woodi</i>					x	x					x	x				
39	<i>Marginulina</i>	<i>gardnerae</i>					x			x			x					
40	<i>Vaginulinopsis</i>	<i>boukharyi</i>					⊖											
41		<i>midwayana</i>			x		x	x		x			x	x				
42	<i>Citharina</i>	<i>plummerae</i>					⊖						x					
43		<i>trilobata</i>			x	x	⊖	x			x							
44	<i>Planularia</i>	<i>berggredi</i>					⊖											
45		<i>dissona</i>					⊖			x								
46	<i>Lagena</i>	<i>rawdhae</i>					⊖											
47		<i>sulcata</i>	x	x	x	x	⊖	x		x	x			x		x	x	
48	<i>Pygmaeoseistron</i>	<i>hispidum</i>	x	x	x	x	x	x		x	x		x	x		x	x	
49	<i>Ramulina</i>	<i>navarroana</i>	x		x	x	x	x		x				x			x	
50	<i>Oolina</i>	<i>globosa</i>	x	x	x	x	x	x		x				x			x	
51	<i>Guttulina</i>	<i>communis</i>					⊖				x							

Table 2: The paleogeographic distribution of forty nine Paleocene-Early Eocene Rotaliid benthic foraminifera in Duwi section and other Egyptian Facies: S=Sinai (1. Qusaima, 2. Nukhul, 3. Taba, 4. Abu Zenima), W=Western Desert (5. Jiran El Ful), G=Galala (6. Wadi Ed Dakhil, 7. Esh El Mallaha), Farafra Bahariya (8. Maqfi, Gunna, Esheikh Marzouk), Nile Valley (9. Duwi, 10. Gurnah, Oweina, 10. Ain Dabadib, Um El Ghanayem, Ghanima, Abu Ghurra), Nuba Abu Ballas (12. Bir Kiseiba, Kurkur, Sin El Kaddab). and other Tethyan localities: SA=South America, AO=Atlantic Ocean (USA, Mexico, Trinidad), EU=Europe (England, Spain, Italy, France, Germany, Poland, Bulgaria, Czech, Romania), T=Tunisia, J=Jordan, UAE=United Arab Emirates, Q=Qatar, P=Pakistan, JZ=Japan and New Zealand. (⊖=illustrated species from Duwi section, x = recorded species.

Sp. No	Early Paleogene Rotaliid benthic foraminiferal species in Duwi section		Egypt							Some Tethyan localities								
			S	W	G	F	V	N	SA	AO	EU	T	J	UAE	Q	P	JZ	
1	<i>Neobulimina</i>	<i>farafraensis</i>	x			x	x											
2	<i>Protoglobobulimi.</i>	<i>pupoides</i>				x	⊖	x		x								

3	<i>Orthokarstenia</i>	<i>applinae</i>						⊙	x	x	x	x	x	x	x				
4		<i>eleganta</i>						⊙	x	x	x		x						
5		<i>higazyi</i>						x				x	x						
6		<i>nakkadyi</i>						x				x	x						
7	<i>Bulimina</i>	<i>cacumenata</i>					x	x		x	x								
8		<i>farafraensis</i>					x	x					x						
9		<i>midwayensis</i>	x					⊙		x		x	x	x					
10	<i>Trifarina</i>	<i>esnaensis</i>			x			⊙	x		x	x	x	x					
11	<i>Fursenkoina</i>	<i>dubia</i>						⊙											x
12	<i>Pleurostomella</i>	<i>subnodosa</i>	x	x				x		x	x	x			x				
13	<i>Orthomorphina</i>	<i>rohri</i>			x			⊙	x		x								
14	<i>Stilostomella</i>	<i>paleocenica</i>						⊙											
15		<i>stephensoni</i>	x	x	x			x	x		x	x	x		x				x
16	<i>Cancris</i>	<i>auriculus</i>			x			⊙	x						x				
17	<i>Valvulineria</i>	<i>aegyptiaca</i>						⊙	x			x	x						
18	<i>Eponides</i>	<i>lotus</i>			x	x		⊙											
19	<i>Neoeponides</i>	<i>duwi</i>						⊙		x	x		x	x					x
20	<i>Cibicoides</i>	<i>decoratus</i>		x	x			x	x	x	x		x						x
21		<i>farafraensis</i>			x			x	x		x	x			x				
22		<i>libycus</i>				x		⊙			x								
23		<i>mellahensis</i>			x			⊙	x	x	x			x	x				x
24		<i>pharaonis</i>						⊙											
25		<i>pseudoacutus</i>						x			x	x							
26		<i>vulgaris</i>						⊙							x	x		x	x
27	<i>Pullenia</i>	<i>coryelli</i>			x	x	x												
28		<i>quingueloba</i>			x	x	x	x		x			x		x				
29	<i>Allomorphina</i>	<i>trigona</i>			x			x	x		x	x			x				
30	<i>Quadriformina</i>	<i>esnehensis</i>						x			x				x				x
31	<i>Alabamina</i>	<i>midwayensis</i>	x	x	x			⊙			x	x		x	x				x
32	<i>Valvalabamina</i>	<i>depressa</i>	x				x	x	x		x				x				x
33	<i>Anomalinoides</i>	<i>aegyptiacus</i>						⊙	x										
34		<i>desertorum</i>						x											
35		<i>leroyi</i>						x	x					x	x				
36		<i>midwayensis</i>						x			x			x					
37		<i>praeacutus</i>						⊙											
38		<i>rubiginosus</i>			x			x	x		x			x	x				
39		<i>welleri</i>						⊙						x					
40		<i>zitteli</i>			x	x		⊙	x			x							
41	<i>Gyroidenoides</i>	<i>aegyptiacus</i>						⊙											
42		<i>depressa</i>						⊙			x								
43		<i>girardanus</i>						⊙											
44		<i>subangulata</i>	x	x	x	x		⊙	x		x	x			x		x	x	
45	<i>Angulogavelinella</i>	<i>avnimelechi</i>	x	x	x	x	x	x	x		x	x		x	x		x	x	
46	<i>Gavelinella</i>	<i>lellingensis</i>	x		x	x	x	x			x				x				x
47		<i>scrobiculata</i>	x	x	x	x	x	x				x			x				x
48	<i>Paralabamina</i>	<i>lunata</i>	x				x	⊙		x	x	x			x				
49	<i>Karrerria</i>	<i>fallax</i>						⊙					x						

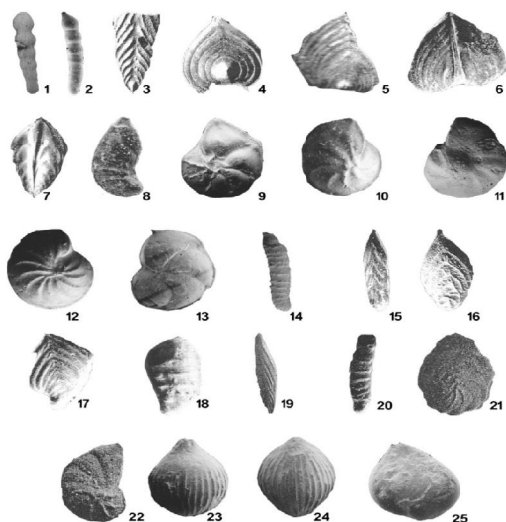
Explanations of Pl. 1

1. *Chrysalogonium velascoensis* (Cushman, 1926), sample 40 x 80, 2. *Laevidentalina colei* (Cushman and Dusenbury, 1934), s. 32 x 80, 3. *Fronidicularia archiaciana* d'Orbigny, 1840, s. 24 x 80, 4. *Fronidularia bignoti* Anan, 2002, s. 27 x 60, 5.

Fronidularia nakkadyi Futyan, 1976, s. 28 x 60, 6. *Fronidularia phosphatica* Russo, 1934, s. 28, x 60, 7. *Tristix aubertae* Anan, 2002, s. 9 x 45, 8. *Astaculus bifurcatus* LeRoy, 1953, s. 20, x 40, 9. *Lenticulina budensis* (Hantken, 1875), s. 40 x 60, 10. *Lenticulina degolyeri* (Plummer, 1927), s. 37, x 45, 11.

Lenticulina pondi Cushman, 1941, s. 26, x 30, **12**.
Lenticulina pseudomamilligera Plummer, 1927, s. 26,
 x 55, **13**. *Lenticulina* sp., s. 40 x 50, **14**.
Percultazonaria jordanensis (Futyan, 1976), s. 38, x
 50, **15**. *Fronovaginulina linearis* (Franke, 1928), s.
 26 x 125, **16**. *Neoflabellina jarvisi* (Cushman, 1935),
 s. 26 x 75, **17**. *Palmula salimi* Anan, 2002, s. 21 x 50,
18. *Vaginulinopsis boukharyi* Anan, 2011, s. 26 x 30,
19. *Citharina plummerae* Anan, 2001, s. 9 x 60, **20**.
Citharina trilobata (d'Orbigny, 1840), s. 28 x 60, **21**.
Planularia berggreni Anan, 2001, s. 6 x 75, **22**.
Planularia dissona (Plummer, 1931), s. 6 x 50, **23**.
Lagena rawdhae Anan, n. sp., s. 41 x 30, **24**. *Lagena*
sulcata (Walker and Jacob, 1798), s. 41 x 40, **25**.
Guttulina communis (d'Orbigny, 1826), s. 40 x 30.

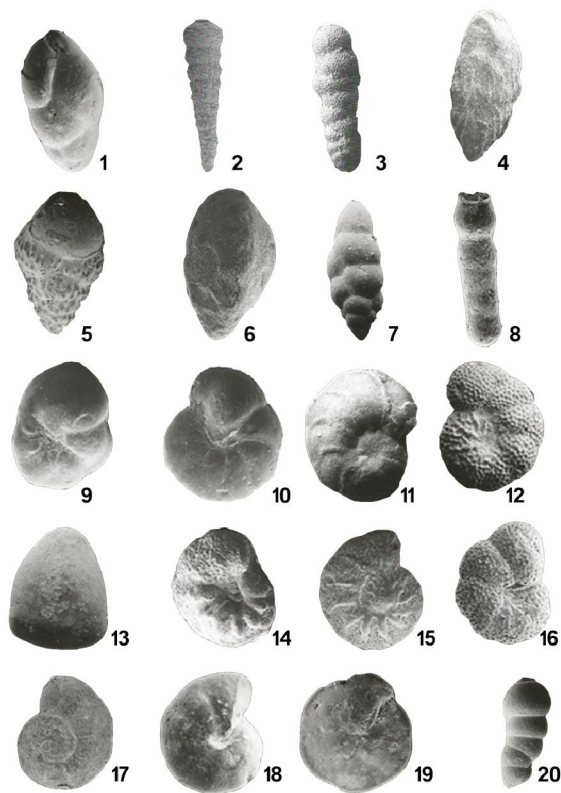
Plate 1



Explanations of Pl. 2

1. *Pratoglobulimina pupoides* (d'Orbigny, 1846), **2.**
Orthokarstenia applinae (Plummer, 1927), **3.** *O.*
eleganta (Plummer, 1927), **4.** *Bulimina cacumenata*, **5.**
B. farafraensis LeRoy (1953), **6.** *Trifarina esnaensis*
 LeRoy (1953), **7.** *Fursenkoina dubia* (Haque, 1956), **8.**
Orthomorphina rohri (Cushman and Stainforth, 1945),
9. *Cancris auriculus* (Fichtel and Moll, 1798), **10.**
Valvulineria aegyptiaca LeRoy (1953), **11.**
Cibicidoides decoratus (LeRoy, 1953), **12.** *C. vulgaris*
 (Plummer, 1927), **13.** *Allomorphina trigona* Reuss
 (1850), **14.** *Anomalinoidea leroyi* Anan (2008), **15.** *A.*
midwayensis (Plummer, 1927), **16.** *A. rubiginosus*
 (Cushman, 1926), **17.** *Gyroidinoidea depressus* (Alth,
 1850), **18.** *G. subangulata* (Plummer, 1927), **19.**
Paralabamina lunata (Brotzen, 1948), **20.** *Karrerria*
fallax Rzehak (1891).

Plate 2



Acknowledgements

Gratitude is expressed to Prof. G. Bignot in Pierre-et-Marie Curie University, Paris for his kind assistance in SEM photographs.

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