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RESEARCH ARTICLE

TAXONOMIC CONSIDERATION AND STRATIGRAPHIC IMPLICATION OF THE ACCELERATED EVOLUTION OF THE MAASTRICHTIAN-EOCENE TRANSITION OF TWENTY BENTHIC FORAMINIFERAL SPECIES IN THE TETHYS

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ABSTRACT

Within the Maastrichtian-Eocene transition in some localities in the Tethys, ten trends of accelerated evolution are recognized within twenty species belong to eight benthic foraminiferal genera: *Siphogaudryina, Textularia*, *Pseudoclavulina, Pyramidulina, Frondicularia, Hopkinsina, Gyroidinoides* and *Angulogavelinella*. Three out of the identified species are treated here to be new: *Textularia haquei, Pyramidulina leroyi* and *Hopkinsina haquei.* These lineages marked by changes in the morphology of the foraminiferal test, throughout the number, size and shape of chambers, ornamentation, size and position of aperture, suture and umbilicus. The identified Maastrichtian-Eocene species in this study are recognized in different localities in the Tethys: USA, France, Italy, Tunisia, Egypt, Jordan, UAE, Qatar and Pakistan.

KEYWORDS

Phylogeny, Maastrichtian, Eocene, benthic foraminifera, Tethys.

1. INTRODUCTION

The large number of tests available and the rapid morphologic changes throughout the Maastrichtian-Eocene in different localities in the Tethys: USA, France, Italy, Egypt, Jordan, Pakistan (Figure 1) offer an opportunity to study evolutionary lineages in some benthic foraminiferal taxa over a time of some 35 m. y. (70-35 Ma) (Solakius et al., 1990). Many attempts have been previously made to interpret the phylogeny of some benthic foraminiferal species, which could have evolved from earlier stratigraphic species and used it in phylogenetic lineages by some authors (Nakkady, 1955; Anan, 1998; Anan, 2004; Anan, 2010; Anan, 2012; Anan, 2017). The present study presented ten evolutionary lineages which marked the changes in the stratigraphy, morphological characters, arrangement of chambers and ornamentation of some benthic foraminiferal taxa throughout the Maastrichtian-Eocene in the Tethys. These lineages are: (1) Paleocene *Siphogaudryina elegantissima* Said & Kenawy → Early Eocene *S. daviesi* Haque lineage, (2) Late Paleocene-Early Eocene *Siphogaudryina tellburmaensis* (Futyan) → Early-Middle Eocene *S. africana* (LeRoy) lineage, (3) Paleocene *Textularia haquei* Anan, n. sp. → Early Eocene *T. farafraensis* LeRoy lineage, (4) Danian *Pseudoclavulina barnardi* Futyan → Early Eocene *P. maqfiensis* LeRoy lineage, (5) Middle Paleocene *Pyramidulina robinsoni* (Futyan) → Late Paleocene-Early Eocene *P. leroyi* Anan, n. sp. lineage, (6) Late Paleocene *Frondicularia bignoti* Anan → Paleocene-Early Eocene *F. nakkadyi* Futyan lineage, (7) Late Paleocene *Frondicularia pickeringi* Futyan → Late Eocene *F. gahannamensis* Ansary lineage, (8) Maastrichtian *Hopkinsina arabina* Futyan → Early Eocene *H. haquei* Anan, n. sp. lineage, (9) Maastrichtian *Gyroidinoides tellburmaensis* (Futyan) → Paleocene-Early Eocene *G. subangulata* (Plummer) lineage, and (10) Maastrichtian-Paleocene *Angulogavelinella convexa* (LeRoy) → Danian *A. bandata* Futyan lineage (Said and Kenawy, 1956; Haque, 1956; Futyan, 1976; Leroy, 1953; Anan, 2002; Ansary, 1955; Plummer, 1927).

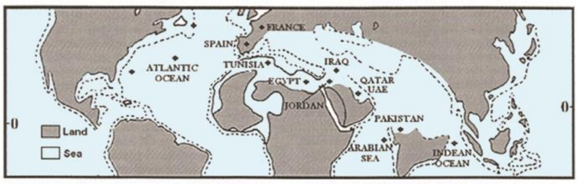

Figure 1: Paleogeographic map of Maastrichtian showing locations of some countries in the Tethys, i.e. Tunisia, Egypt, Jordan, UAE.

2. PREVIOUS STUDY

Nakkady presented an attempt of accelerated benthic foraminiferal evolution in the Mesozoic-Cenozoic transition of Egypt (Nakkady, 1955). He presented five evolutionary trends (by his own identification): (1) *Cibicides abudurbensis* Nakkady evolved to *Anomalina pseudoacuta* Nakkady, (2) *Siphogenerina esnehensis* Nakkady to *Siphogenerinoides eleganta* (Plummer), (3) *Siphogenerina esnehensis* Nakkady to *S. higazyi,* (4) *Verneuilina cretacea* Karrer to *Gaudryina pyramidata* Cushman, (5) *Eouvigerina aegyptiaca* Nakkady to *Gümbelina globulosa* (Ehrenberg). This attempt was followed later by twenty one evolutionary trends by Anan (Anan, 1998; Anan, 2004; Anan, 2010; Anan, 2012; Anan, 2017): (1) *Orthokarstenia oveyi* (Nakkady) to *O. applinae* (Plummer), (2) *Discorbis p. pseudoscopos* (Nakkady) to *D. p. duwi* (Nakkady), (3) *Verneuilina aegyptiaca* Said & Kenawy to *V. luxorensis* Nakkady, (4) *Coryphostoma incrassata* (Reuss) to *C. midwayensis* (Cushman), (5) *Anomalinoides rubiginosus* (Cushman) to *A. midwayensis* (Plummer), (6) *Gyroidinoides girardanus* (Reuss) to *G. luterbacheri* Anan, (7) *Angulogavelinella nekhliana* Said & Kenawy to *A. avnimelechi* (Reiss), (8) *Cibicidoides*

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pharaonis (LeRoy) to *C. farafraensis* (LeRoy), (9) *Bathysiphon californicus* (Martin) to *B. paleocenicus* El Dawy, (10) *Spiroplectinella knebeli* (LeRoy) to *S. paracarinata* (Said & Kenawy), (11) *Gaudryina pyramidata* Cushman to *G. ameeri* Anan, (12) *Gaudryina pyramidata* Cushman to *G. speijeri* Anan, (13) *Bolivinoides draco aegyptiaca* Anan to *B. d. draco* (Marsson) to *B. d. dorreeni* Finlay, (14) *Clavulina parisiensis* d'Orbigny to *C. pseudoparisensis* Anan, (15) *Laevidentalina granti* (Plummer) to *L. salimi* Anan, (16) *Lenticulina carinata* (Plummer) to *L. turbinata* (Plummer) to *L. chitanii* (Yabe & Asano), (17) *Percultazonaria ameeri* Anan to *P. allami* Anan, (18) *Percultazonaria alii* Anan to *P. longiscata* (Nakkady), (19) *Percultazonaria wadiarabensis* (Futyan) to *P. tuberculata* (Plummer), (20) *Palmula woodi undulata* Nakkady to *P. w. woodi* Nakkady, (21) *Gavelinella b. brotzeni* Said & Kenawy to *G. brotzeni paleocenica* Said & Kenawy.

3. Benthic Foraminiferal Phylogenetic Lineages

Minor differences in the morphology of the test, wall structure, shape and size of chambers and apertures are recognized as being of decisive specific value through the time. An attempt is made here to identified nine new evolutionary trends marked by changes in the morphology and other characters of the benthic foraminiferal test in the Maastrichtian-Eocene transition in the Tethys:

1) Paleocene *Siphogaudryina elegantissima* Said & Kenawy → Early Eocene *S. daviesi* Haque lineage (Said and Kenawy, 1956; Haque, 1956). The Egyptian Paleocene species *Siphogaudryina elegantissima* is characterized by its small elongated test, with small portion triserial, becoming eight distinct biserial chambers and arenaceous smooth wall. It differs from the descendent Pakistanian Early Eocene *S. daviesi* by its smaller test.

2) Late Paleocene-Early Eocene *Siphogaudryina tellburmaensis* (Futyan) → Early-Middle Eocene *S. africana* (LeRoy) lineage (Futyan, 1976; Leroy, 1953). The author believes that the Early-Middle Eocene *S. africana* (LeRoy) is an evolutionary development of the Late Paleocene-Early Eocene *Siphogaudryina tellburmaensis* (Futyan). This assumption is supported by the high degree of morphological relationship, especially in chamber arrangement of the test (triserial to biserial) and the terminal aperture of the last formed chamber. *S. tellburmaensis,* however, differs in having curved test and rounded terminal aperture than straight test and elongate aperture of the last chamber of *S. africana*.

3) Paleocene *Textularia haquei* Anan, n. sp. → Early Eocene *T. farafraensis* LeRoy lineage (Leroy, 1953). This Pakistanian Paleocene *Textularia haquei* species is considered here as the ancestor of the descendent Egyptian Early Eocene *T. farafraensis. Textularia haquei* species is closely related to the *T. farafraensis* species, but differs in its smaller test, moderate coarse wall, and recorded in an older stratigraphic level.

4) Danian *Pseudoclavulina barnardi* Futyan → Early Eocene *P. maqfiensis* LeRoy lineage (Futyan, 1976; Leroy, 1953). This evolutionary lineage is proposed here as another good example of an accelerated rate of evolution. The Jordanian *P. barnardi* and the Egyptian forms have sharply pyramidal triserial portion followed by flask-shaped uniserial portion with deeply sutures. The Paleocene species differs from the Early Eocene species by its more elongate test and chamber numbers of the uniserial portion than the Eocene species.

5) Middle Paleocene *Pyramidulina robinsoni* (Futyan) → Late Paleocene-Early Eocene *P. leroyi* Anan, n. sp. Lineage (Futyan, 1976). This evolutionary lineage is proposed here as another good example of an accelerated rate of evolution. *Pyramidulina robinsoni* is considered here as the ancestor of the descendent *P. leroyi* due to high degree of morphological relationship, especially in the distinct more than twenty closed spaced fine longitudinal ribs in the two species. *P. robinsoni* differs from *P. leroyi* in its shape, size and number of the uniserial chambers. The inflated semi-globular chambers in the former are changed to elongate extremely long chambers in the latter.

6) Late Paleocene *Frondicularia bignoti* Anan → Paleocene-Early Eocene *F. nakkadyi* Futyan lineage (Anan, 2002; Futyan, 1976). The morphological characters of the Late Paleocene *Frondicularia bignoti* with moderate smooth test and large proloculus, four-five uniform chambers and the first one surrounding the proloculus is considered here as the ancestor of the descendent Paleocene-Early Eocene *F. nakkadyi* throughout changing to larger test, more number uniserial chambers and smaller proloculus size.

7) Late Paleocene *Frondicularia pickeringi* Futyan → Late Eocene *F. gahannamensis* Ansary lineage (Futyan, 1976; Ansary, 1955). The former Paleocene species *Frondicularia pickeringi* has large and much compressed test distinctly rhomboidal in outline, initial portion ornamented by two to five fine ribs. It differs from the descendent Middle-Late Eocene *F. gahannamensis* by its numerous fine spaced ribs extending right across the surface test.

8) Maastrichtian *Hopkinsina arabina* Futyan → Early Eocene *H. haquei* Anan, n. sp. Lineage (Futyan, 1976). The Late Maastrichtian species *Hopkinsina arabina* has irregular triserial initial part forming half of test followed by uniserial chambers, surface covered by prominent nodes, aperture terminal, elliptical, bounded by low but distinct rim. It differs from the Early Eocene *H. haquei* by its smooth surface and elongate wide opening terminal aperture bounded by lip.

9) Maastrichtian *Gyroidinoides tellburmaensis* (Futyan) → Paleocene-Early Eocene *G. subangulata* (Plummer) lineage (Futyan, 1976; Plummer, 1927). The Maastrichtian species *Gyroidinoides tellburmaensis* is characterized by its planoconvex test, moderately deep open umbilicus, limbate and slightly raised curved sutures on spiral side, but straight radial on umbilical side. It differs from the descendent Paleocene-Early Eocene *G. subangulata* (Plummer) by its more acute periphery, more whorls, wider umbilicus and limbate sutures on spiral side.

10) Maastrichtian-Paleocene *Angulogavelinella convexa* (LeRoy) → Danian *A. bandata* Futyan lineage (Futyan, 1976; Leroy, 1953). This evolutionary lineage is proposed here as another good example of an accelerated rate of evolution. The Maastrichtian species *A. convexa* is characterized by its planoconvex test and irregularly umbilicate, straight and flush sutures with surface in the ventral side, while curved no elevated dorsal sutures. *A. convexa* differs from *A. bandata* by its unequally biconvex trochospiral test, with strongly limbate raised curved spiral sutures.

4. Annotated Species List

The reference of the type species of the identified species is given. Some modern references have been added to complete descriptions, synonymies and new taxonomic considerations. The taxonomic classification of Loeblich & Tappan is followed in this study fourteen diagnostic benthic foraminiferal species and its stratigraphic ranges of them are presented. The species concept of the identified species are mainly adapted by many authors in USA, France, Italy, Egypt, Jordan, UAE, Qatar, Pakistan (Plummer, 1927; Loeblich and Tappan, 1988; Sztrakos, 2000; Proto Decima and de Biase, 1975; Anan, 2008; Anan, 2016; Anan, 2017; Anan, 2019a; Anan, 2019b; Hewaidy et al., 2017; Anan, 1993; Hewaidy and Al-Hitmi, 1993).

Order Foraminiferida Eichwald, 1830
Suborder Textulariina Delage & Hérouard, 1896
Superfamily Verneuilinacea Cushman, 1911
Family Verneuilinidae Cushman, 1911
Subfamily Verneuilininae Cushman, 1911
Genus *Siphogaudryina* Cushman, 1935
Type species *Gaudryina stephensoni* Cushman, 1928

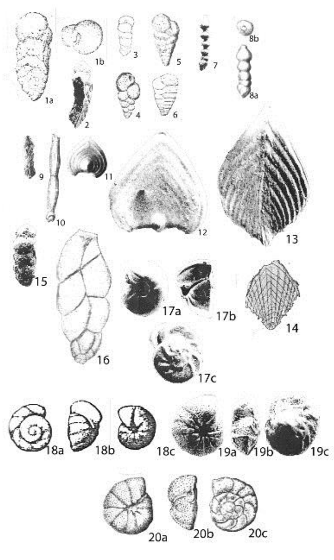

Plate 1 (all figures x 50)

Figure 1a: Siphogaudryina africana (LeRoy, 1953) side view, 1b: S. africana (LeRoy, 1953) apertural view; 2. Siphogaudryina tellburmaensis (Futyan, 1976) side view; 3. Siphogaudryina elegantissima (Said and Kenawy, 1956) apertural view; 4. Siphogaudryina daviesi (Haque, 1956) apertural view; 5. Textularia farafraensis LeRoy (1953) side view; 6. Textularia haquei Anan, n. sp. side view; 7. Pseudoclavulina barnardi (Futyan, 1976) side view, 8a. Pseudoclavulina maqfiensis LeRoy (1953) side view, 8b: P. maqfiensis LeRoy (1953), apertural view; 9. Pyramidulina robinsoni (Futyan, 1976), side view, 10. Pyramidulina leroyi Anan, n. sp., side view; 11. Frondicularia bignoti Anan (2002) front view; 12. Frondicularia nakkadyi Futyan (1976), front view; 13. Frondicularia pickeringi Futyan (1976), front view; 14. Frondicularia gahannamensis (Ansary, 1955), front view; 15. Hopkinsina arabina Futyan (1976), front view; 16. Hopkinsina haquei Anan, n. sp., front view; 17a-c, a. Gyroidinoides tellburmaensis Futyan (1976), ventral view, b: G. tellburmaensis, side view, c: G. tellburmaensis, dorsal view; 18a-c: a: Gyroidinoides subangulata (Plummer, 1927) dorsal view, b: G. subangulata, side view, c: G. subangulata, ventral view; 19a-c, a: Angulogavelinella bandata Futyan (1976), ventral view, b: A. bandata, side view, c: A. bandata, dorsal view; 20a-c, a:. Angulogavelinella convexa (LeRoy, 1953) ventral view, b:. A. convexa (LeRoy, 1953) side view, c: A convexa, dorsal view.

***Siphogaudryina africana* (LeRoy, 1953) - (Pl. I, figure 1)**
1953 *Gaudryina africana* LeRoy, p. 30, pl. 1, figures 7, 8.
1975 *Gaudryina* cf. *africana* LeRoy - Proto Decima & de Biase, p. 91, pl. 1, figure 13.
2000 *Pseudogaudryina* ? *africana* LeRoy - Sztrákos, p. 157.
2008 *Siphogaudryina africana* (LeRoy) - Anan, p. 361, pl. 1, figure 1.
2016 *Siphogaudryina africana* (LeRoy) - Anan, p. 357, figure 3o.
2017 *Gaudryina africana* LeRoy - Hewaidy et al., p. 83, pl. 2, figure 19.

Remarks: This Early-Middle Eocene species belongs to the genus *Siphogaudryina* due to its subterminal apertural face of the last-formed chamber, instead of inner marginal aperture of genus *Gaudryina* d'Orbigny. This species is recorded, so far, from Egypt, Italy and France.

***Siphogaudryina tellburmaensis* (Futyan, 1976) - (Pl. 1, figure 2)**
1976 *Gaudryina soldadoensis tellburmaensis* Futyan, p. 521 pl. 81, figures 1, 2.
2016 *Gaudryina tellburmaensis* Futyan - Anan, p. 357, figure 3ñ.

Remarks: This Late Paleocene-Early Eocene *tellburmaensis* species belongs here to the genus *Siphogaudryina* due to its subterminal aperture on the apertural face of the last formed chamber. The Jordanian *tellburmaensis* differs from the Pakistanian *elongata* of Haque, p. 35, pl. 9, fig. 5) by its curved test. It is, so far, an endemic to Jordan.

***Siphogaudryina elegantissima* (Said & Kenawy, 1956) – (Pl. 1, figure 3)**
1956 *Siphogaudryina elegantissima* Said & Kenawy, p. 123, pl. 1, figure 21
1993 *Gaudryina elegantissima* Said & Kenawy - Anan, p. 655, pl. 1, figure 16.
1993 *Gaudryina elegantissima* Said & Kenawy - Hewaidy & Al-Hitmi, p. 478, pl. 4, figures 4, 5.
2012 *Gaudryina elegantissima* Said & Kenawy - Ismail, p. 29, pl.1, figure 14.
2016 *Gaudryina elegantissima* Said & Kenawy - Anan, p. 357, figure 3l.
2017 *Gaudryina elegantissima* Said & Kenawy - Hewaidy et al., p. 83, pl. 2, figure 18.

Remarks: This Egyptian Paleocene species belongs here to the genus *Siphogaudryina* due to its subterminal aperture on the apertural face of the last formed chamber. It has an small elongated test, earliest portion small triserial, becoming eight distinct biserial chambers, very slightly inflated and gradually increasing in size as added, wall arenaceous smooth, aperture a semicircular opening at the base of the last chamber. It was originally recorded in Egypt, and later from UAE and Qatar.

***Siphogaudryina daviesi* (Haque, 1956) – (Pl. 1, figure 4)**
1956 *Gaudryina daviesi* Haque, p. 37, pl. 31, figure 14.
2019a *Siphogaudryina daviesi* (Haque) - Anan, p. 31, pl. 1, figure 3.

Remarks: This Pakistanian Early Eocene species belongs here to the genus *Siphogaudryina*. It is closely related to *S. elegantissima*, but differs in its more larger test in a younger stratigraphic level. *S. elegantissima* is considered here as the ancestor of the descendent Early Eocene *S. daviesi* throughout changing to a larger test.

Superfamily Textulariacea Ehrenberg, 1838
Family Textulariidae Ehrenberg, 1838
Subfamily Textulariinae Ehrenberg, 1838
Genus *Textularia* Defrance, 1824
Type species *Textularia sagittula* Defrance, 1824

***Textularia farafraensis* LeRoy, 1953 - (Pl. 1, figure 5)**
1953 *Textularia farafraensis* LeRoy, p. 51, pl. 2, figures 3, 4
1956 *Textularia farafraensis* LeRoy - Said & Kenawy, p. 122, pl. 1, figure 13.

Remarks: This Egyptian Paleocene-Early Eocene species has rather coarse wall with inflated biserial chambers, about twice as long as broad, periphery broadly rounded, sutures nearly straight, aperture a low arched at inner margin of the last chamber.

***Textularia haquei* Anan, n. sp. - (Pl. 1, figure 6)**
1956 *Textularia* sp. Haque, p. 32, pl. 9, figure 10.

Holotype: Illustrated specimen in Pl. 1, figure 6 x 44.
Dimension: Length 34 mm, width 15 mm.
Etymology: In the honor of Pakistanian micropaleontologist A.F.M. Mohsenul Haque.
Type locality: Khairabad Limestone, Pakistan.
Age: Paleocene.
Depository: The holotype of this species is deposited in Pakistan Geologic Survey.
Diagnosis: Test has 8-10 biserial elongate chambers gradually increasing in size as added.
Remarks: This Pakistanian Paleocene species is closely related to the Egyptian species *T. farafraensis*, but differs by its smaller test, moderate coarse wall, and recorded in an older stratigraphic level.

Superfamily Textulariacea Ehrenberg, 1838
Family Pseudogaudryinidae Loeblich & Tappan, 1985
Subfamily Pseudogaudryininae Loeblich & Tappan, 1985
Genus *Pseudoclavulina* Cushman, 1936
Type species *Clavulina clavata* Cushman, 1926

***Pseudoclavulina barnardi* (Futyan, 1976) – (Pl. 1, figure 7)**
1976 *Clavulina barnardi* Futyan, p. 522, pl. 81, figure 3 (*non* figure 4).
2016 *Clavulina barnardi* Futyan - Anan, p. 361, figure 3ab.

Remarks: This Danian species belongs here to the genus *Pseudoclavulina* due to its terminal aperture of the last formed chamber but without tooth, as in *Clavulina*. The triserial part is small and the uniserial part has slightly irregular five to eight flask-shaped chambers, with deeply excavated sutures. Its aperture is rounded terminal on a tubular neck, but without tooth. It is, so far, an endemic to Jordan.

***Pseudoclavulina maqfiensis* LeRoy, 1953 - (Pl. 1, figure 8)**
1953 *Pseudoclavulina maqfiensis* LeRoy, p. 44, pl. 2, figures 16, 17.
1956 *Pseudoclavulina maqfiensis* LeRoy - Said & Kenawy, p. 125, pl. 1, figure 31.
2012 *Pseudoclavulina maqfiensis* LeRoy - Ismail, p. 30, pl. 1, figure 18.
2016 *Pseudoclavulina maqfiensis* LeRoy - Anan, p. p. 361, figure 3aa.
2017 *Pseudoclavulina maqfiensis* LeRoy - Hewaidy et al., p. 83, pl. 2, figure 27.

Remarks: This Early Eocene species has smooth wall finish and small test, early portion conspicuously triserial and triangular in section, followed by 3-4 uniserial flask-shaped with depressed sutures, aperture rounded and terminal. It is, so far, an endemic to Egypt.
Suborder Lagenina Delage & Hérouard, 1896
Superfamily Nodosariacea Ehrenberg, 1838
Family Nodosariidae Ehrenberg, 1838
Subfamily Nodosariinae Ehrenberg, 1838
Genus *Pyramidulina* Fornasini, 1894
Type species *Pyramidulina eptagona* Fornasini, 1894

***Pyramidulina robinsoni* (Futyan, 1976) - (Pl. 1, figure 9)**
1976 *Nodosaria robinsoni* Futyan, p. 525, pl. 82, figures 5, 6.
2019b *Pyramidulina robinsoni* (Futyan) - Anan, p. 259, pl. 1, figure 6.

Remarks: Loeblich & Tappan noted that the genus *Pyramidulina* Fornasini has distinct longitudinal costae, with unornamented surface in the genus *Nodosaria* Lamarck. This Middle Paleocene species has uniserial test with inflated chambers covered by 22-24 closed spaced fine longitudinal ribs, which become obsolete on the upper half of the last chamber. It is, so far, an endemic to Jordan.

***Pyramidulina leroyi* Anan, n. sp. - (Pl. 1, figure 10)**
1953 *Nodosaria* sp. LeRoy, p. 41, pl. 4, figure 9.

Holotype: Illustrated specimen in Pl. 1, figure 10 x 47.
Age: Late Paleocene-Early Eocene.
Etymology: In the honor of American micropaleontologist L.W. LeRoy.
Depository: The holotype of this species is deposited in Cushman Collection, No. 58034.
Diagnosis: It characterized by its smooth to coarse-textured surface and rounded periphery.
Remarks: This species is distinguished by its extremely long chambers covered by closely spaced 20-22 ribs. It differs from the Middle Paleocene *P. robinsoni* Futyan by its longer elongated chambers than inflated nearly globular uniserial chambers.

Subfamily Frondiculariinae Reuss, 1860
Genus *Frondicularia* Defrance, 1826
Type species *Ramulina complanata* Defrance, in de Blainville, 1824

***Frondicularia bignoti* Anan, 2002 - (Pl. 1, figure 11)**
2002 *Frondicularia bignoti* Anan, p. 632, figure 2.2.
2011 *Frondicularia bignoti* Anan - Anan, p. 55, pl. 1, figure 12.
2019b *Frondicularia bignoti* Anan - Anan, p. 259, pl. 1, figure 8.

Remarks: This Late Paleocene species has moderate smooth test with large proloculus, 4-5 uniform chambers and the first one surrounding the proloculus, sutures slightly depressed and terminal protuberant aperture. This species differs from *F. nakkadyi* by its smaller test, fewer uniserial chambers and larger proloculus size.

***Frondicularia nakkadyi* Futyan, 1976 - (Pl. 1, figure 12)**
1976 *Frondicularia nakkadyi* Futyan, p. 528, pl. 82, figure 1.
1985 *Frondicularia nakkadyi* Futyan - Luger, p. 80, pl. 4, figure 3.
1994 *Frondicularia nakkadyi* Futyan - Speijer, p. 109.
2002 *Frondicularia nakkadyi* Futyan - Anan, p. 633, figure 2.4.
2012 *Frondicularia nakkadyi* Futyan - Youssef & Taha, p. 59, pl. 3, figure 10.
2019b *Frondicularia nakkadyi* Futyan - Anan, p. 260, pl. 1, figure 10.

Remarks: This species is distinguished by its large, flat, palmate test with smooth surface, sutures limbate and flush, proloculus slightly inflated. It differs from the Paleocene *F. phosphatica* Russo in its lacking the central raised ridge which extends from proloculus to the aperture. It was described from Late Paleocene of Jordan and Egypt, but from Early Eocene of Speijer (Anan, 2002; Hewaidy and Hitmi, 1993; Luger, 1985; Youssef and Taha, 2012).

***Frondicularia pickeringi* Futyan, 1976 - (Pl. 1, figure 13)**
1976 *Frondicularia pickeringi* Futyan, p. 526, pl. 82, figure 2.
2019b *Frondicularia pickeringi* Futyan - Anan, p. 260, pl. 1, figure 11.

Remarks: The Paleocene species has large, much compressed test distinctly rhomboidal in outline, periphery truncate in upper half of test, irregular with thin scattered transparent keel in lower half, initial portion ornamented by two to five fine ribs which in some specimens extends towards the aperture, sutures limbate and slightly depressed. It differs from Middle-Late Eocene *F. gahannamensis* (Ansary) by its numerous fine spaced ribs extending right across the surface test. It was described from the late Paleocene at Tell Burma, S. Jordan.

***Frondicularia gahannamensis* (Ansary, 1955) - (Pl. 1, figure 14)**
1955 *Flabellina gahannamensis* Ansary, p. 28, pl. 2, figure 9.
2019b *Palmula gahannamensis* (Ansary) - Anan, p. 261, pl. 1, figure 30.

Remarks: This species has rhomboid test, about 10 chevron-shaped uniserial chambers, sutures flush with the surface, wall ornamented by closely spaced fine raised longitudinal twelve ribs. It seems that this Middle-Late Eocene species, so far, is endemic to Egypt.
Suborder Rotaliina Delage and Hérouard, 1896
Superfamily Turrilinacea Cushman, 1927
Family Stainforthiidae Reiss, 1963
Genus *Hopkinsina* Howe and Wallace, 1932
Type species *Hopkinsina danvillensis* Howe & Wallace, 1932

***Hopkinsina arabina* Futyan, 1976 - (Pl. 1, figure 15)**
1976 *Hopkinsina arabina* Futyan, p. 529, pl. 82, figures 7-9.

Remarks: This Late Maastrichtian species has irregular triserial initial part forming half of test followed by uniserial chambers, surface covered by prominent nodes, aperture terminal, elliptical, bounded by low but distinct rim. It is, so far, an endemic to Jordan.

***Hopkinsina haquei* Anan, n. sp. - (Pl. 1, figure 16)**
1956 *Hopkinsina* sp. Haque, p. 138, pl. 28, figure 9.

Holotype: Illustrated specimen in Pl. 1, fig. 16 x 68.
Dimension: Length 75 mm, width 30 mm.
Etymology: In the honor of Pakistanian micropaleontologist A.F.M. Mohsenul Haque.
Type locality: Nammal Shale and Limestone, Pakistan.
Age: Early Eocene, Nammal Shales and Limestone.
Depository: The holotype of this species is deposited in Pakistan Geologic Survey.
Diagnosis: It characterized by its smooth surface, elongate terminal aperture bounded by lip.
Remarks: This Early Eocene species has triserial initial portion followed by uniserial chambers, surface smooth, and wide opening terminal aperture.
Superfamily Chilostomellacea Brady, 1881
Family Gavelinellidae Hofker, 1956
Subfamily Gyroidinoidinae Saidova, 1981
Genus *Gyroidinoides* Brotzen,1942
Type species *Rotalina nitida* Brotzen,1942

***Gyroidinoides tellburmaensis* Futyan, 1976 - (Pl. 1, figures 17-19)**
1976 *Gyroidinoides tellburmaensis* Futyan, p. 532, pl. 81, figures 10-12.
1994 *Gyroidinoides tellburmaensis* Futyan - Speijer, p. 62, pl. 3, figure 1.

Remarks: This Maastrichtian species has planoconvex test. Umbilical side has moderately deep open umbilicus. Sutures limbate and slightly raised curved on spiral side, but straight radial on umbilical side. This species differs from the Paleocene-Early Eocene *G. subangulata* (Plummer) by its more acute periphery, more whorls, wider umbilicus and limbate sutures on spiral side. *G. girardanus* (Reuss) does not have an angular periphery, raised limbate sutures on the spiral side, but has more inflated chambers. It is recorded, so far, in Jordan and Tunisia.

***Gyroidinoides subangulata* (Plummer, 1927) - (Pl. 1, figures 20-22)**
1927 *Rotalia soldanii subangulata* Plummer, p. 154, pl. 12, figure 1.
1953 *Gyroidina subangulata*; LeRoy, p. 35, pl. 3, figures 23-25.
1975 *Gyroidinoides subangulata*; Berggren & Aubert, p. 148, pl. 3, figure 2.
2003 *Gyroidinoides subangulata*; Ali, p. 120, pl. 11, figures 1-3.
2005 *Gyroidinoides subangulata*; Sztrákos, p. 188, pl. 17, figure 9.
2017 *Gyroidinoides subangulata*; Anan, p. 287, figure 6.40.

Remarks: This Paleocene-Early Eocene species was recorded in USA, Egypt, Rockall Bank in North Atlantic, Tunisia, UAE, North Sea Basin and France (Leroy, 1953; Ali, 2003; Berggren, 1974; Clemmensen and Thomsen, 2005; Sztrakos, 2005).

Subfamily Gavelinellinae Hofker, 1956
Genus *Angulogavelinella* Hofker,1957
Type species *Discorbina gracilis* Marsson,1878

***Angulogavelinella bandata* Futyan, 1976 - (Pl. 1, figures 23-25)**
1976 *Angulogavelinella bandata* Futyan, 534, pl. 83, figures 1-3.
2019b *Angulogavelinella bandata* Futyan - Anan, p. 270, pl. 3, figure 101.

Remarks: This Danian species *A. bandata* has unequally biconvex trochospiral test, slightly convex dorsal side, 11-12 chambers in the last whorl, with strongly limbate raised sutures and strongly curved on spiral side, but straight and radiate from an angular small umbilical depression. It differs from *A. avnimelechi* (Reiss) by having strongly limbate, raised sutures on the spiral side and an open umbilicus. It is, so far, an endemic to Jordan.

***Angulogavelinella convexa* (LeRoy, 1953) – (Pl. 1, figures 26-28)**
1953 *Rotalia convexa* LeRoy, p. 48, pl. 9, figures 13-15.

Remarks: This Maastrichtian species has planoconvex test, dorsal side flat, irregularly umbilicate, ventral sutures straight and flush with surface, except for last 2 or 3 chambers which are slightly depressed, dorsal sutures curved and no elevated, aperture elongate at the base of the last chamber. It differs from *A. bandata* manly by its flat dorsal side, no elevated dorsal sutures, and narrower umbilicus. Speijer, treated this species as a junior synonym of *A. avnimelechi* (Reiss).

5. Paleogeography

The evolution and distribution of the benthic foraminiferal ancestral species in the Tethys had wide geographic distribution and the descendents had also more distribution. The ancestral Tethys is connected with the ancestral Atlantic and Indian Oceans via Mediterranean Sea. The identified Maastrichtian-Eocene species in this study are recognized in different localities in the Tethys: USA, France, Italy, Tunisia, Egypt, Jordan, UAE, Qatar and Pakistan. One species *Siphogaudryina africana* are recorded in three countries in the Tethys: Egypt, France and Italy. One species *Siphogaudryina elegantissima* was recorded in three countries: Egypt, UAE and Qatar. One species *Frondicularia nakkadyi* was recorded in three countries: Jordan, Egypt and Tunisia. One species *Gyroidinoides subangulata* was recorded in three countries: USA, Egypt and Tunisia. One species *Gyroidinoides tellburmaensis* was recorded from two countries: Jordan and Tunisia. 3 species are endemic to Pakistan: *Siphogaudryina daviesi, Textularia haquei, Hopkinsina haquei.* 6 species are endemic to Egypt: *Textularia farafraensis, Pseudoclavulina maqfiensis, Pyramidulina leroyi, Frondicularia bignoti, F. gahannamensis, Angulogavelinella convexa.* 6 species are endemic to Jordan: *Siphogaudryina tellburmaensis, Pseudoclavulina barnardi, Pyramidulina robinsoni, Frondicularia pickeringi, Hopkinsina arabina, Angulogavelinella bandata.*

6. Summary and Conclusions

The large number of tests available and the rapid morphologic changes throughout the Maastrichtian-Eocene in different localities in the Tethys offer an opportunity to study evolutionary lineages in some benthic foraminiferal taxa over a time of some 35 m. y. (70-35 Ma). Ten trends of accelerated evolution are recognized in the Maastrichtian-Eocene transition within twenty species belong to eight benthic foraminiferal genera distributed in a wide Tethyan localities, from USA in the west to Pakistan in the east throughout France, Italy, Tunisia, Egypt, Jordan, UAE and Qatar: *Siphogaudryina, Textularia, Pseudoclavulina*, *Pyramidulina*, *Frondicularia*, *Hopkinsina, Gyroidinoides* and *Angulogavelinella*. These ten lineages are: (1) Paleocene *Siphogaudryina elegantissima* Said & Kenawy → Early Eocene *S. daviesi* Haque lineage, (2) Late Paleocene-Early Eocene *Siphogaudryina tellburmaensis* (Futyan) → Early-Middle Eocene *S. africana* (LeRoy) lineage, (3) Paleocene *Textularia haquei* Anan, n. sp. → Early Eocene *T. farafraensis* LeRoy lineage, (4) Danian *Pseudoclavulina barnardi* Futyan → Early Eocene *P. maqfiensis* LeRoy lineage, (5) Middle Paleocene *Pyramidulina robinsoni* → Late Paleocene-Early Eocene *P. leroyi* Anan, n. sp. lineage, (6) Late Paleocene *Frondicularia bignoti* Anan → Paleocene-Early Eocene *F. nakkadyi* Futyan lineage, (7) Late Paleocene *Frondicularia pickeringi* Futyan → Late Eocene *F. gahannamensis* Ansary lineage, (8) Maastrichtian *Hopkinsina arabina* Futyan → Early Eocene *H. haquei* Anan, n. sp. lineage, (9) Maastrichtian *Gyroidinoides tellburmaensis* → Paleocene-Early Eocene *G. subangulata* lineage, and (10) Maastrichtian-Paleocene *Angulogavelinella convexa* → Danian *A. bandata* lineage. These lineages marked by changes in the morphology of the foraminiferal test, throughout the number, size and shape of chambers, ornamentation, size and position of aperture, suture and umbilicus. Three out of the identified species are treated here to be new: *Textularia haquei, Pyramidulina leroyi* and *Hopkinsina haquei.* The species used in those evolutionary trends are originally erected from different parts in the Tethys, from west (North Atlantic, USA) to east (Indian Ocean, Pakistan) via Mediterranean, Red Sea and Arabian Gulf, and exhibits an affinity with the Midway Type Fauna (MTF) of the Gulf Coast (east USA) and in different parts of the Tethys (i.e. France, Italy, Tunisia, Libya, Egypt, Jordan, Iraq, UAE, Iran, Pakistan). Due to the high abundance of the recorded pelagic Tethyan foraminiferal assemblage from USA in the west to Pakistan in the east indicate an open connections of the Tethys, which represents middle-outer neritic environment (100-200 m depth) and shows an affinity with " Midway-Type Fauna" of Berggren & Aubert. The paleogeographic distribution of different taxa in some (not all) Tethyan localities may be due to non-detailed faunal studies, the deficiency of available literatures, or also less homogeneity in the species concept between different authors.

References

Ali, M.Y., 2003. Micropaleontological and stratigraphical analyses of the Late Cretaceous/Early Tertiary succession of the Southern Nile Valley (Egypt). Der Fakultät für Geowissenschaften van der Ruhr-Universität Bochum vorgelegte Dissertation zur Erlangung des Grades eines, 1-197.

Anan, H.S., 1993. Maastrichtian-Paleocene micropaleontology and biostratigraphy of Qarn El Barr section, Al Dhayd area, United Arab Emirates. Al-Azhar Bulletin of Science, Al-Azhar University, Cairo, 4 (2), 639-670.

Anan, H.S., 1998. Accelerated evolution in representatives of the genera *Orthokarstenia* and *Discorbis* (Benthic foraminifera) in the Maastrichtian and Paleocene of Egypt (Misr). Neues Jahrbuch für Geologie und Paläontologie, Mh., 6, 365-375.

Anan, H.S., 2002. Stratigraphy and paleobiogeography of some Frondiculariinae and Palmulinae benthic foraminiferal general in the Paleocene of Egypt (Misr). Neues Jahrbuch für Geologie und Paläontologie, Mh., 10, 629-640.

Anan, H.S., 2004. A lineage phylogeny for some Maastrichtian to Ypresian benthic foraminifera in Egypt. Egyptian Journal of Paleontology, 4, 39-57.

Anan, H.S., 2008. Maastrichtian-Paleogene LeRoy's benthic foraminiferal species from Egypt and Tethyan-Atlantic regions. Revue de Paléobiologie, 27 (2), 357-376.

Anan, H.S., 2010. Contribution to the Egyptian benthic foraminifera around the Paleocene/Eocene boundary in Egypt. Egyptian Journal of Paleontology, 10, 25-47.

Anan, H.S., 2011. Paleontology, paleoenvironments, palaeogeography and stratigraphic value of the Maastrichtian-Paleogene and Recent foraminiferal species of Anan in the Middle East. Egyptian Journal of Paleontology, 11, 49-78.

Anan, H.S., 2012. A lineage phylogeny from some Cretaceous-Tertiary agglutinated benthic foraminiferal species in Egypt and Tethys. Egyptian Journal of Paleontology, 12, 59-72.

Anan, H.S., 2016. Early Paleogene agglutinated foraminifera from the Middle East (Egypt and Arabia) and its distribution in the Tethys. Spanish Journal of Paleontology, 31 (2), 353-368.

Anan, H.S., 2017a. Evolutionary lineage of the Maastrichtian *Bolivinoides draco* group (benthic foraminifera) in Abu Zenima section, west central Sinai, Egypt. Arabian Journal of Geosciences, 10 (431), 1-7.

Anan, H.S., 2017b. Paleontology and paleogeography of the Paleogene benthic foraminiferal species of Plummer in Egypt and other Atlantic-Tethyan regions. Journal of Tethys, 5 (3), 272-296.

Anan, H.S., 2019a. Contribution to the paleontology, stratigraphy and paleobiogeography of some diagnostic Pakistanian Paleogene foraminifer in the Middle East. Earth Sciences Pakistan, 3 (1), 29-34.

Anan, H.S., 2019b. Maastrichtian-Paleogene benthic foraminifera from the Middle East and its distribution in the Tethys, a review. Journal of Microbiology & Experimentation, 7 (6), 255-278.

Ansary, S.E., 1955. Report on the foraminiferal fauna from the Upper Eocene of Egypt. Publication de l'Institut du Desert d'Egypt, 1-160.

Berggren, W.A., 1974. Paleocene benthonic foraminiferal biostratigraphy, biogeography and paleoecology of Libya and Mali. Micropaleontology, 20 (4), 449- 465.

Berggren, W.A., Aubert, J., 1975. Paleocene benthonic foraminiferal biostratigraphy, paleobiogeography and paleoecology of Atlantic-Tethyan regions: Midway-type fauna. Palaeogeography, Palaeoclimatology, Palaeoecology, 18, 73-192.

Clemmensen, A., Thomsen, E., 2005. Paleoenvironmental changes across the Danian-Selandian boundary in the North Sea Basin - Palaeogeography, Palaeoclimatology, Palaeoecology, 219, 351-394.

Futyan, A.I., 1976. Late Mesozoic and Early Cainozoic benthonic foraminifera from Jordan. Palaeontology, 19 (3), 53-66.

Haque, A.F.M., 1956. The foraminifera of the Ranikot and the Laki of the Nammal Gorge, Salt Range, Pakistan. Pakistan Geological Survey Memoir, Palaeontologica Pakistanica, 1, 1-229.

Hewaidy, A.A., Al-Hitmi, H., 1993. Cretaceous-Early Eocene foraminifera from Dukhan oil field, west Qatar, Arabian Gulf (A-Suborders Textulariina, Involutinina and Miliolina). Al-Azhar Bulletin of Science, Al-Azhar University, Cairo, 4 (2), 469-494.

Hewaidy, A.A., Farouk, S., EL-Balkiemy, A.F., 2017. Foraminiferal Biostratigraphy, Stages Boundaries and Paleoecology of the Uppermost Maastrichtian-Lower Eocene Succession at Esh El-Mellaha Area, North Eastern Desert, Egypt. Journal of American Science, 13(5), 74-113.

Ismail, A.A., 2012. Late Cretaceous-Early Eocene benthic foraminifera from Esh El Mallaha area, Egypt. Revue de Paléobiologie, 31 (1), 15-50.

LeRoy, L.W., 1953. Biostratigraphy of Maqfi section, Egypt. Geological Society of American Memoir, 54, 1-73.

Loeblich, A.R., Tappan, H., 1988. Foraminiferal genera and their classification. Van Nostrand Reinhold (VNR), New York, Part 1, 970 p., part 2, 847 p., USA.

Luger, P., 1985. Stratigraphie der marinen Oberkreide und des Alttertiars im sudwestlichen Obernil-Becken (SW-Agypten) under besonderer Berucksichtig, der Micropaläontologie, Palökologie und Paläogeographie. Berliner Geowissen-schaftliche Abhandlungen (A), 63, 1-151.

Nakkady, S.E., 1955. The stratigraphic implication of the accelerated tempo of evolution in the Mesozoic- Cenozoic transition of Egypt. Journal of Paleontology, 29 (4), 702-706.

Plummer, H.J., 1927. Foraminifera of the Midway Formation in Texas. Bulletin University of Texas, 2644, 3-206.

Proto Decima, F., de Biase, R., 1975. Foraminiferi bentonici del Paleocene, dell' Eocene inferiore e medio. *In*: Braga, G. et al.: Foraminiferi bentonici del Paleocene ed Eocene della sezione di Possagno. Schweizerische Paläontologische Abhandlungen, 97, 87-98.

Said, R., Kenawy, A., 1956. Upper Cretaceous and Lower Tertiary foraminifera from northern Sinai, Egypt. Micropaleontology, 2 (2), 105-173.

Solakius, N., Pomoni-Papaioannou, F., Alexopouios, A., 1990. On the paleogeographic distribution of the Late Maastrichtian planktonic foraminiferal genus Kassabiana Salaj & Solakius, 1984. Acta Geologica Hispanica, 25 (4), 289-298.

Speijer, R.P., 1994. Extinction and recovery patterns in benthic foraminiferal paleocommunities across the Cretaceous/Paleogene and Paleocene/Eocene boundaries. Geologica Ultraiectina, Universiteit Utrecht, 124, 1-191.

Sztrákos, K., 2000. Eocene foraminifers in the Adour Basin (Aquitaine, France): biostratigraphy and taxonomy. Revue de Micropaléontologie, 43 (1-2), 71-172.

Sztrákos, K., 2005. Paleocene and lowest Eocene foraminifera from the north Pyrenean trouph (Aquitaine, France). Revue de Micropaléontologie, 48, 175-236.

Youssef, M., Taha, S., 2012. Biostratigraphy and Paleoecology of Paleocene/Eocene (P/E) interval of some geological sections in Central Egypt. Arabian Journal of Geosciences, 1-23.