RESEARCH ARTICLE

TAXONOMICAL CONSIDERATIONS, PHYLOGENY, PALEOGEOGRAPHY AND PALEOClimatology of the Middle Eocene (Bartonian) planktic Foraminifera from Jabal Hafit, Al Ain Area, United Arab Emirates

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ABSTRACT

The taxonomical consideration, probable phylogeny and stratigraphic significance of twenty-eight middle Eocene (Bartonian) planktic foraminiferal species from the eastern limb of Jabal Hafit, Al Ain area, United Arab Emirates (UAE), Northern Oman Mountains (NOM) are presented, and twenty one of them are illustrated. Identification of these twenty-seven species belonging to ten genera Globoturborotalia, Subbotina, Globigerinathec, Inordinatosphaera, Orbulinoides, Hantkenina, Acrarinina, Morozovelloides, Pseudohastigerina and Turborotalia has led to the recognition of three biostratigraphic zones, in ascending order: Morozovelloides lehneri PRZ (E11), Orbulinoides beckmanni TRZ (E12) and Morozovelloides crassata HOZ (E13). Eight out of the identified species are reported, in this study, for the first time from Jabal Hafit: Globoturborotalia martini, Subbotina gortani, S. jacksonensis, S. senni, Globigerinathec barri, Acrarinina praetopilensis, A. punctocarinata and Morozovelloides bandyi. The second or third record of three species from J. Hafit outside its original records are recently documented by the present author: Inordinatosphaera indica, Hantkenina australis and H. compressa. The paleontology, paleoclimatology and paleogeographic distribution of the identified taxa at Jabal Hafit and other Paleogene outcrops in the UAE and Tethys are discussed and presented. The identified fauna emphasis the wide geographic areas in the Tethys, from Atlantic to Indian-Pacific Oceans via Mediterranean.

KEYWORDS

Eocene, stratigraphy, planktic foraminifera, Al Ain area, United Arab Emirates.

1. INTRODUCTION

Plate 1: 1. Globoturborotalia martini (Blow and Banner, 1962), Sample no. 15 (E12). 2. Subbotina gortani (Borsetti, 1959), S. 9 (E11). 3. Subbotina hagni (Gohrbandt, 1967), S. 15 (E12). 4. Subbotina jacksonensis (Bandy, 1949), S. 9 (E11). 5. Subbotina linaperta (Finlay, 1939), S. 15 (E12). 6. Subbotina senni (Beckmann, 1953), S. 15 (E12). 7. Globigerinathec barri (Brönimann, 1952), S. 9 (E11). 8. Globigerinathec subconglobata (Shutskaya, 1958), S. 15 (E12). 9. Globigerinathec tropicalis (Blow & Banner, 1962), S. 22 (E13). 10. Orbulinoides beckmanni (Saito, 1962), S. 15 (E12). 11. Hantkenina alabamensis (Cushman, 1925), S. 15 (E12). 12. Acrarinina bulbrookii (Boli, 1957), S. 15 (E12).

The Maastrichtian-Paleogene rocks in the United Arab Emirates (UAE) crop out as a discontinuous mountains belt (jabal)s and hills (qarn) around the western front of the North Oman Mountains (NOM) and Jabal Hafit is one of these mountains (Lat. 24° 06’ and 24° 09’ N, Long. 55° 46’ and 55° 49’ E) and has a NNW-SSE asymmetrical double plunging anticline (Figure 1). Many studies over nearly three decades have been carried out on Al Ain area (Jabal Hafit, J. Malaqet and J. Mundassa). The great abundance and wide distribution of planktonic foraminifera in marine sediments and their rapid evolution during middle Eocene time make them a powerful biostratigraphic tool for global biostratigraphy and precise regional and interregional correlation.
Plate 2: 13. Acarinina praetopilensis (Blow, 1979), Sample 24 (E13). 14. Acarinina punctocarinata (Fleisher, 1974), S. 16 (E13). 15. Acarinina rohri (Bröninmann and Bermúdez, 1953) S. 28 (E13). 16. Acarinina topilensis (Cushman, 1925), S. 22 (E13). 17. Morozovelloides bandyi (Fleisher, 1974), S. 4 (E11). 18. Morozovelloides acanthonus (Blow, 1974), S. 6 (E11). 19. Morozovelloides cerroazulensis (Cushman, 1925), S. 7 (E11). 20. Turborotalia cerroazulensis (Cole, 1928), S. 15 (E12). 21. Turborotalia pomerolii (Toumarkine and Bolli, 1970), S. 15 (E12).

The study of planktonic foraminifera from Al Ain area has had a rich history. The current work is one of a series of studying planktonic foraminiferal assemblages of the early Paleogene succession (Paleocene and Eocene) of this area by the present author and others: early/middle Paleocene (Dalain/Selandian, P1a-P3) at the eastern limb of J. Mundassa, middle/late Paleocene (Selandian/Thanetian, P3a-P5) at the eastern limb of J. Malaqet, Early Eocene at the western limb of J. Haft, early/middle Eocene (Ypresian/Lutetian, P9-P10) at the western limb of J. Haft, Eocene at western and eastern limbs of J. Haft and also late Eocene (Priabonian, P16-P17= E15-E16) at the western limb of J. Malaqet and J. Mundassa (Blow, 1979; Anan, 2016; Anan and Hamdan, 1993; Berggren and Pearson, 2005; Berggren and Pearson, 2006; Anan, 1996; Anan, 2015; Anan et al., 1992). The purpose of this paper is to present the detailed study of the planktonic foraminiferal assemblage, as well as the biostratigraphic zonation of the planktonic foraminifera examined from the middle Eocene succession (Bartonian) in the eastern limb in Jabal Haft, UAE. The middle Eocene planktic foraminiferal biozones at the eastern limb of J. Haft are followed here (Blow, 1979; Berggren and Pearson, 2006; Berggren and Pearson, 2006). Twenty-eight planktic foraminiferal species belonging to ten genera are recorded, but only twenty one species of them are illustrated (Plates 1, 2).

Figure 1: Location map of the study area (eastern limb of Jabal Haft) and also the other outcrops in Al Ain area (J. Malaqet and J. Mundassa), UAE.

2. GEOLOGICAL SETTING

The Maastrichtian-Oligocene post-nappe sediments crop out around the eastern part of the UAE at NOM. These mountains were formed in response to two main orogenic events. The regional hiatuses in the pelagic succession are also ascribed to the tectonic events, as the Late Cretaceous is a time of great tectonic activity in this critical area of Tethys, and the Eustatic sea-level changes may have had a secondary effect on the area. The first one resulted from the late Cretaceous (Coniacian-Maastrichtian) obduction of the Semail Ophiolite and associated sedimentary and volcanic rocks (Sumeini, Hawasina and Haybi groups), onto the eastern margin of the Arabian Platform. The second event reactivated in early Eocene and later times of Miocene and it is correlated to the Zagros Orogeny in Iran (Ricateau and Riche, 1980; Searle et al., 1983). It was responsible for the formation of foreland folds and thrust faults and folding of Maastrichtian-Paleogene neoautochthonous units in the foredeep along the western front of the Oman Mountains (Glennie et al., 1974; Searle et al., 1983; Nolan et al., 1990; Warrak, 1996).

The Haft structure formed after the Miocene as a result of the second late Paleogene deformation event, while noted that this structure is interpreted to be post-middle Eocene in age, and was the response to the collision of the Arabian-Eurasian Plates which began during the late Eocene and continues to the present day (Noweir, 2000; Zaineldeen and Fowler, 2003). Anan noted that the eastern limb of J. Haft anticline exposes a nearly vertical dipping middle-upper Eocene succession along the Al Ain-Mazyad asphalted road (Anan, 2005). This succession is equivalent to the mappable rock unit coded The4 (where T= Tertiary, l=lower, e= Eocene), or Ain Al Faydah Member of the Dammam Formation (Hunting Geology and Geophysics Limited, 1979; Hamdan and Bahr, 1992; Krumbein, 1942).

3. STRATIGRAPHY OF THE STUDY AREA

The eastern limb of J. Haft anticline, east of Al Ain-Mazyad asphalted road, consists mainly of an alternated marl, nummulitic marly limestone and hard limestone beds, but some gypsiferous shale beds are found. One sample of the latter gypsiferous shales (sample no. 15, bed no. 4, about 15 m thick, Figure 2) belongs to the late middle Eocene Orbivaloides beckmanni Zone (E12, about 40.5-40 Ma). This lithostratigraphic horizon belongs to the upper part of Ain Al Faydah Member and located about 135 m below the diagnostic intraformational conglomeratic bed (bed no. 13, Figure 2), which separates Ain Al Faydah Member (Tle 5) from Mazyad Member (Tle 4) from the Dammam Formation.

Figure 2: Simplified stratigraphic section of the Middle Eocene, eastern limb of Jabal Haft, UAE (The intraformational conglomeratic bed in red color).

4. PLANKTONIC FORAMINIFERAL BIOZONES

Table 1: The planktic foraminiferal distribution in the middle Eocene (Bartonian) of the eastern limb of J. Haft, Al Ain area, UAE. The neglected...
and Pearson, 2005 Berggren and Pearson, 2006).

Definition: Biostratigraphic interval characterized by the partial range of the nominate taxon between the HO of Orbulinoides beckmanni and the HO of the nominate taxon Morozovelloides crassatus.

Assemblage: The planktonic foraminiferal assemblage accompanying this zone is rather common in diversity. It contains 21 of 28 identified species: Globatorborotalia martini, Subbotina eocaena, S. gortani, S. hagni, S. linaperta, S. senni, Globigerinatheka barri, G. subglobulosa, Inordinosphaera aff. indica, Orbulinoides beckmanni, Hantkenina alabamensis, Acarinina bullbrooki, A. punctocarina, A. rohri, A. topilensis, Morozovelloides bandyi, M. coronatus, M. crassatus, M. lehneri and Pseudohastigerina micra.

5. SYSTEMATIC PALEONTOLOGY

The taxonomical consideration of Atlas of Eocene planktonic foraminifera has been used in this study (Pearson et al., 2006). Twenty-eight planktonic foraminiferal species from the Bartonian zones (E11-E13) from the eastern limb of Jabal Hafit are recorded, but twenty-one of them are illustrated (Plates 1, 2). These species are: Globatorborotalia martini (Blow and Banner), Subbotina eocaena (Gümbel), S. gortani (Borsetti), S. hagni (Gehrbandt), S. linaperta (Finlay), S. jacksonensis (Bandy), S. senni (Beckmann), Globigerinatheka barri (Brönnimann), G. subglobulosa (Shutskaya), G. tropicalis (Blow & Banner), Inordinosphaera aff. indica (Bandy & Soodan), Orbulinoides beckmanni (Saito), Hantkenina alabamensis Cushman, H. australis Finlay, H. compressa Parr, H. liebusi Shokhina, Acarinina bullbrooki (Boll), A. punctocarina Fleisher, A. prae-topilensis (Blow), A. rohri (Brönnimann & Bermúdez), A. topilensis (Cushman), Morozovelloides bandyi (Fleisher), M. coronatus (Blow), M. crassatus (Cushman), M. lehneri (Cushman & Jarvis), Pseudohastigerina micra (Cole), Turborotalia cerroazulensis (Cole) T. pomeroli (Toumarkine & Boll). Table 1 shows the planktonic foraminiferal distribution in the middle Eocene (Bartonian) of the eastern limb of Jabal Hafit, Al Ain area, UAE. Order Foraminifera (Eichwald, 1850).

Superfamily Globigerinaceae Carpenter, Parker & Jones, 1862
Family Globigerinidae Carpenter, Parker & Jones, 1862
Genus Globatorborotalia Hofker, 1976
Type Species Globigerina rubescens Hofker, 1976

Globatorborotalia martini (Blow and Banner, 1962) (Figure 3.1)
1962 Globigerina m. martini Blow and Banner 1962, p. 110, pl. 14, figure 4.
2015 Globatorborotalia martini; Pearson and Wade 2015, p. 11, figures 9-12.
Remarks: The morphology of our specimen which has 4 small size globular chambers with the reduce ultimate fifth one that extends over the umbilicus most probably falls within the species concept of Globatorborotalia martini. This species was described also from the late Eocene of Tanzania, East Africa (Pearson and Wade, 2015), but it is recorded here from a younger stratigraphic horizon in the Middle Eocene of Jabal Hafit, UAE. It is distributed in mid to low latitudes (Olsson, 2006).

Genus Subbotina Brozen & Poláry, 1961
Type Species Globigerina triloculinoides Plummer, 1927

Subbotina eocaena (Gümbel, 1868)
1868 Globigerina eocaena Gümbel, 1868, p. 662, pl. 2, fig. 109.
2006 Subbotina eocaena; Olsson et al., 2006, p. 134, pl. 6, figs. 1-7.
Remarks: considered S. eocaena evolved from the early Eocene S. pseudoeocaena Subbotina (Berggren, 1965; Subbotina, 1960). The original description of S. eocaena included the species S. eocaena Gümbel and S. gortani (Stainforth et al., 1975; Subbotina, 1953; Borsetti, 1959). However, Tagg and Luterbacher regarded G. corpulenta to develop from G. eocaena, Olsson et al. regarded it probably evolved from their S. roesenaensis by an increase in test size and the development of globular, more embracing chambers (Haggag and Luterbacher, 1993; Olsson et al., 2006). They also considered two subspecies of Subbotina (Globigerina pseudoeocaena compacta and G. p. trilobata) are junior synonym of S. eocaena (Subbotina, 1953). S. eocaena was originally described from the late Eocene of Texas, and later in the middle-late Eocene of some localities in the Tethys: North Caucasus, Egypt, Indian Ocean, Spain, UAE, France, Italy, Mexico and Iran (Plummer, 1927; Subbotina, 1960; Youssef et al., 1983; Premoli Silva and Spezzaferri, 1990; Milner, 1992; Anan, 1995; Sszakos, 2000; Luciana et al., 2002; Mukhopadhyay, 2003; Olsson et al., 2006; Vahdatirad et al., 2016).

**Table 1:**

| Bed | 2 | 3 | 4 | 5 | 9 | 10 | 11 |
|-----|---|---|---|---|---|----|----|
| 1 | Hantkenina alabamensis | x | O | x | x | x | x | x |
| 2 | Hantkenina barri | x | x | x | x | x | x | x |
| 3 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 4 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 5 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 6 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 7 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 8 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 9 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 10 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 11 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 12 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 13 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 14 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 15 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 16 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 17 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 18 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 19 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 20 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 21 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 22 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 23 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 24 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 25 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 26 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 27 | Hantkenina aff. indica | x | x | x | x | x | x | x |
| 28 | Hantkenina aff. indica | x | x | x | x | x | x | x |
Subbotina gortani (Borsetti, 1959) (Fig. 3.2)
1959 Catapsydrax gortani Borsetti (Borsetti, 1959), p. 205, pl. 1, fig. 1.
2006 Subbotina gortani; (Olsson et al., 2006) p. 138, pl. 6, 10, figs. 1-17.
Remarks: This species has globular loosely embracing chamber in highly loosely trochospiral test. It is characterized by its high spire and globular embracing chambers. Our specimen has a small aperture bordered by a faint lip. A group researcher considered Globigerina corpulenta is halfway between G. eocaena and G. gortanii (Stainforth et al., 1975). Anan noted that the later species belongs to G. eocaena, G. corpulenta, G. praeturtullina and G. gortanii lineage (Anan, 1995). It was recorded from some localities in the Tethys: India and UAE (Samanta, 1970; Anan, 1995; Abdelghany, 2002). Subbotina gortani is recorded here from the middle Eocene of J. Haft.

Subbotina hagni (Gohrbandt, 1967) (Fig. 3.3)
1967 Globigerina hagni Gohrbandt (Gohrbandt, 1967), p. 324, pl. 1, figs. 1-9.
2006 Subbotina hagni; (Olsson et al., 2006) p. 142, pl. 6.11, figs. 1-7.
2015 Subbotina hagni; (Anan, 2015) p. 18, pl. 13.1.
Remarks: This species was originally described from the middle Eocene of Austria, and later in other some localities of the Tethys: i.e. Italy, Austria, UAE (Luciana et al., 2002; Olsson et al., 2006; Abdelghany, 2002). It is recorded in the middle Eocene of the study area.

Subbotina jacksonensis (Bandy, 1949) (Fig. 3.4)
1949 Globigerina rotundata jacksonensis Bandy (Bandy, 1949), p. 121, pl. 23, fig. 6.
2006 Subbotina jacksonensis; (Olsson et al., 2006) p. 146, pl. 6. 15, figs. 1-20.
Remarks: This middle-late Eocene species probably evolved from early Eocene-early Oligocene Subbotina eocaena by developing more embracing chambers and a reduced ultimate chamber that projects over the umbilicus (Olsson et al., 2006). It is recorded here, for the first time, from the middle Eocene of J. Haft, UAE.

Subbotina linaperta (Finlay, 1939) (Fig. 3.5)
1939 Globigerina linaperta Finlay (Finley, 1939), p. 125, pl. 13, figs. 54-59.
2010 Subbotina linaperta; (Haggag et al., 2010), p. 179, figs. 17-29.
Remarks: Many authors considered this species as a basic stock from which all Eocene Globigerina groups or lineages have been differentiated (Stainforth et al., 1957; Haggag and Luterbacher, 1991). It was originally described from the middle Eocene of New Zealand, and later from the early-middle Eocene in many parts of the Tethys: Pakistan, India, Libya, Egypt, Indian Ocean, UAE, Qatar, India, southern Indian Ocean and Iran (Haque, 1956; Samanta, 1970; Barr and Briggsen, 1980; Youssef et al., 1983; Premoli Silva and Speczezarri, 1990; Cherif et al., 1992; Beckmann, 1953; Mukhopadhyay, 2003; Olsson et al, 2006; Vahdatirad et al, 2016).

Subbotina senni (Beckmann, 1953) (Fig. 3.6)
1953 Sphaeroidinella senni (Beckmann, 1953), p. 349, text-fig. 20, pl. 26, figs. 2-4.
2006 Subbotina senni; (Gumbel, 1968), p. 159, pl. 6, 17, figs. 1-20.
Remarks: This early-middle Eocene species has slightly embracing chambers of the last whorl and nearly closed umbilicus. Blow considered Subbotina senni as a possible ancestor of the genus Globigerinatheca (Blow, 1979). According to Toumarkine & Luterbacher, the value of it lies in its resistance to solution in very deep water (Toumarkine and Luterbacher, 1985). It is recorded here, for the first time, from the middle Eocene of J. Haft, UAE.

Genus Globigerinatheca Brönnimann, 1952
Type species Globigerinatheca barri Brönnimann, 1952

Globigerinatheca barri Brönnimann, 1952 (Fig. 3.7)
1952 Globigerinatheca barri (Brönnimann, 1952), p. 27 [partim], text-fig. 3a-c, g, h.
2006 Globigerinatheca barri; (Premoli Silva et al., 2006), p.177, pl. 72, figs. 1-15.
Remarks: Bolli suggested that this species may have evolved from G. subconglobata, while Haggag & Luterbacher figured this species to be evolved from the middle Eocene G. m. mexicana and gave rise to G. mexicana kugleri, but this relationship was rejected (Bolli, 1972; Haggag and Luterbacher, 1991; Premoli Silva et al., 2006). According to latter authors this species common in low and middle latitudes. It was recorded from some sites in the Tethys: i.e. Trinidad, India, Egypt (Brönnimann, 1952; Mohan and Soodan, 1970; Haggag and Luterbacher, 1991). It is recorded here, for the first time, from the middle Eocene of J. Haft, UAE.

Globigerinatheca subconglobata (Shuktsya, 1958) (Fig. 3.8)
1958 Globigerinoides subconglobata Shuktsya var. subconglobata Shuktsya (Shuktsya, 1958), p. 86, pl. 1, figs. 4-11.
2006 Globigerinatheca subconglobata; (Premoli Silva et al., 2006), p. 201, pl. 7.10, figs. 1-20.
Remarks: This species is characterized by its evolute outline, four chambers in the last whorl, crown-like flatter final chamber not enveloping or covering previous one. A group researcher, fig. 6) figured this species gave rise to G. subconglobata curvyi (Haggag and Luterbacher, 1991). In other study they has been noted that the early members of Globigerinatheca (G. subconglobata) appear for the first time in its nominate biozone B8 (Anan et al., 1992). A group scientist considered it an ancestral to all the globigerinathekid lineage or groups in E9 (Premoli Silva et al., 2006). My specimen is here considered very similar, if not identical, to the lectotype of G. subconglobata.

Globigerinatheca tropicalis (Blow & Banner, 1962) (Fig. 3.9)
1962 Globigeroperas tropicalis (Blow and Banner, 1962), p. 124, pl. 15, figs. D-F.
2006 Globigerinatheca tropicalis; (Premoli Silva et al., 2006), p. 205, pl. 7.3, figs. 9-16.
Remarks: Bolli noted that this species is the last Globigerinathekid to disappear in the late middle Eocene (Bolli, 1972). Haggag & Luterbacher (fig. 6) figured this species to be evolved from the middle Eocene G. l. index and gave rise to late middle Eocene G. index tropicalis (Haggag and Luterbacher, 1991).

Genus Inordinatosphaera Mohan & Soodan, 1967
Type species Inordinatosphaera indica Mohan & Soodan, 1967

Inordinatosphaera aff. indica Mohan & Soodan, 1967
1967 Inordinatosphaera indica (Mohan and Soodan, 1967), p. 24, figs. 1-7.
2017 Inordinatosphaera aff. indica; (Anan, 2017), p. 128, fig. 3b.
Remarks: This species was originally recorded from India documented in Loeblich & Tappan (, Loeblich and Tappan, 1988, Mohan and Soodan, 1967 Mohan and Soodan, 1). It was also recorded and illustrated outside India, for the first time, from the Bartonian Orbulinoides beckmanni Zone from sample 15 of J. Haft (UAЕ) (Anan, 2017). It is characterized by its spherical-subospherial test and irregular elongate endoform bullae. A group researchers considered Inordinatosphaera indica as a problematic genus. This species, unknown, possibly a highly unusual new form, while Loeblich & Tappan treated it as formal taxa in the Globigerinidae family, which is accepted in this study (Huber et al., 2006; Loeblich and Tappan, 1988).

Genus Orbulinoides Cordey, 1968
Type species Porticulosphera beckmanni Saito, 1962
Orbulinoids beckmanni (Saito, 1962) (Fig. 3.10)
1962 Porticalusphaera beckmanni Saito (Saito, 1962), p. 221, pl. 34, figs. 1, 2. 2006 Orbulinoides beckmanni; (Premoli Silva et al., 2006), p. 207, pl. 7.1, figs. 1-16.

Remarks: Bolli recognized four morphological groups of the genus Globigerinatae: G. index, G. mexicana, G. subconglobata and G. seminovoluta groups, and the G. subconglobata lineage ends with Orbulinoides beckmanni in one branch (Bolli, 1972). This species has been found in many tropical to warm-temperate regions: Japan, India, Pacific Ocean, Egypt, UAE, Tunisia (Saito, 1962; Mohan and Soodan, 1970; Krasheninnikov and Hoskins, 1973; Bassiouni et al., 1982; Cherif et al., 1992; Ben Ismail-Lattrache, 2000).

Family Hantkeninidae Cushman, 1927

Genus Hantkenina Cushman, 1924
Type species Hantkenina alabamensis Cushman 1924

Hantkenina alabamensis Cushman, 1924 (Fig. 3.11)
1924 Hantkenina alabamensis (Cushman, 1924), p. 3, pl. 1, figs. 1-6, pl. 2, fig. 5, text-fig. 1.
2018 Hantkenina alabamensis; (Anan, 2018), p. 125, fig. 5b.

Remarks: Coxall et al. [66] noted that the genus Hantkenina evolved gradually from the genus Clavigerinella in the earliest middle Eocene and, contrary to the long-held view, it is related to the genus Pseudohastigerina (Coxall et al., 2003). The cosmopolitan species H. alabamensis is the most advanced representative of the genus Hantkenina. It occurs from the middle-upper Eocene. The nominate species represents the H. alabamensis Zone (E16) and ends the late Eocene. (Berggren and Pearson, 2005). It is recorded in many parts of the Tethys: Mexico, New Zealand, India, Pacific Ocean, Spain, Italy, Indian Ocean, Egypt, UAE and India (Cushman; 1924; Snirivasan, 1968; Samanta, 1969; Krasheninnikov and Hoskins, 1973; Miller, 1983; Coccioni, 1988; Premoli Silver and Spezzaferri, 1990; Haggag and Luterbacher, 1991; Anan, 1995; Anan, 2018; Mukhopadhyay, 2003).

Hantkenina australis Finlay, 1939
1939 Hantkenina australis (Finlay, 1939), p. 538, pl. 56, figs. 20, 21.
2018 Hantkenina australis; (Anan, 2018), p. 127, fig. 5c.

Remarks: Coxall & Pearson noted that this species has a variable test morphology, showing features of Hantkenina dumblei and H. compressa, but it differs from both and all other species of Hantkenina in having posteriorly recovered tubulospines (Coxall and Pearson, 2006). It is probably evolved from H. dumblei (Weinzierl and Applin, 1929). It was recorded, so far, in New Zealand (Finlay, 1939; Anan, 2018).

Hantkenina compressa Parr, 1947
1947 Hantkenina compressa (Parr, 1947), p. 46, text-figs. 1-7, figs. 7-7a.
2018 Hantkenina compressa; (Anan, 2018), p. 127, fig. 5d.

Remarks: Coxall & Pearson noted that this species is intermediate in morphology between Hantkenina dumblei and H. alabamensis and overlaps stratigraphically with them both (Coxall and Pearson, 2006). It was recorded from Australia (Parr, 1974; Coxall et al., 2003; Anan, 2018).

Hantkenina liebusi Shokhina 1937
1937 Hantkenina liebusi (Shokhina, 1937), p. 427, pl. 2, figs. 2-3.
2018 Hantkenina liebusi; (Anan, 2018), p. 127, fig. 5e.

Remarks: Coxall & Pearson noted that the species H. liebusi evolved from H. mexicana in the middle Eocene in a higher stratigraphic level, and give H. australis through H. dumblei (Coxall and Person, 2006). It is recorded in the mid to low latitudes: i.e. Russia, India, Poland, Egypt, Tanzania and UAE (Shokhina, 1937; Mohan and Soodan, 1970; Gasinski, 1978; Youssef et al., 1983; Haggag, 1989; Haggag and Luterbacher, 1991; Coxall and Pearson, 2006; Anan, 2018).

Family Truncorotaloididae Loseblach & Tappan, 1961

Genus Acrinina Subbotina, 1953
Type species: Acrinina acarinata Subbotina, 1953

Globorotalia densa (Cushman) and Globorotalia (Acrinina) spinuloiflata (Bandy) as a junior synonym of A. bulbrooki (Berggren et al., 2006). This species was originally recorded in the middle Eocene of Trinidad, and later in the upper part of the early Eocene in many parts of the Tethys: Trinidad, Mexico, Italy, France, Tunisia, Egypt and UAE (Bolli, 1957; Carrero et al., 2000; Toumarkine and Bolli, 1975; Sratzkos, 2000; Ben Ismail-Lattrache, 2000; Bassiouni et al., 1982; Cherif et al., 1992).

Acrinina praetopilensis (Blow, 1979) (Fig. 4.13)
1979 Globorotalia (Truncorotaloides) toplinesis praetopilensis (Blow, 1979), p. 1043, pl. 155, fig. 9.
2006 Acrinina praetopilensis; (Berggren et al., 2006), p. 300, fig. 9.16,

Remarks: treated this species probably evolved from their early-middle Eocene species A. mcgowrani and gave rise to middle Eocene Acrinina toplinesis (Berggren et al., 2006). It is recorded, for the first time, in the J. Haft, UAE.

Figure 4: The thick intraformational conglomeratic bed (arrows) at the end of the Tle4 (bed no. 13 in Fig 2, ends the Ain Al Faydah Member).

Acrinina punctocarinata Fleisher, 1974 (Fig. 4.14)
1974 Acrinina punctocarinata (Fleisher, 1974), p. 1014, pl. 3, figs. 4-8.
2006 Acrinina punctocarinata; (Berggren et al., 2006), p. 308, pl. 9.5, figs. 1-8.

Remarks: This species has 4-5 wedge-shaped chambers in the umbilical side with deep and open restively wide umbilicus (Berggren et al., 2006). It was recorded from Arabian Sea, and later, for the first time, in Arabia, at least in UAE (Fleisher, 1974).

Acrinina rohri (Brönnimann & Bermúdez, 1953) (Fig. 4.15)
1953 Truncorotaloides rohri (Brönnimann and Bermudez, 1953), p. 818, pl. 87, figs. 7-9.
2006 Acrinina rohri; (Berggren et al., 2006), p. 312, pl. 9.20, figs. 1-16.

Remarks: This species has mainly six chambers in the last whorl increases regularly in size, flattened spiral side, less compacted test and rounded axial periphery than T. toplinesis. According to a study this species gave rise to Acrinina toplinesis (Berggren et al., 2006). It was recorded in different parts of the Tethys: Trinidad, India, Pacific Ocean, Italy, Libya, Egypt, UAE and France (Brönnimann and Bermudez, 1953; Mohan and Soodan, 1970; Krasheninnikov and Hoskins, 1973; Toumarkine and Bolli, 1975; Barr and Berggren, 1980; Bassiouni et al., 1982; Anan et al., 1992; Sratzkos, 2000).

Acrinina toplinesis (Cushman, 1925) (Fig. 4.16)
1925 Globigerina toplinesis (Cushman, 1925), p. 7, pl. 1, fig. 9.
2006 Acrinina toplinesis; (Berggren et al., 2006), p. 319, pl. 9.22, figs. 1-16.

Remarks: This species was originally described from the middle Eocene of Mexico. It was recorded also in the top early-middle Eocene from many parts of the Tethys: India; Pacific Ocean, Italy, Libya, Egypt, Indian Ocean, UAE and Tunisia (Mohan and Soodan, 1970; Krasheninnikov and Hoskins, 1973; Toumarkine and Bolli, 1975; Barr and Berggren, 1980; Bassiouni et al., 1982; Premoli Silva and Spezzaferri, 1990; Anan, 1996; Ben-Ismail-Lattrache, 2000).

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Genus *Morozovelloides* Pearson & Berggren, 2006
Type species: *Globorotalia lehneri* Cushman & Jarvis, 1929

*Morozovelloides bandyi* (Fleisher, 1974) (Fig. 4.17)
1974 *Morozovella bandyi* (Fleisher, 1974), p. 1034, pl. 14, figs. 3-8.
2006 *Morozovelloides bandyi* (Pearson and Berggren, 2006), p. 330, pl. 10.1, figs. 1-16.

Remarks: This species is distinguished by planocoarvex to lenticular test, and its strongly disjunct along axes of chambers. It is suggested to be evolved from *Acarinina praetogolensis* and gave rise to *Morozovelloides crassatus* (Pearson and Berggren, 2006). It is recorded here for the first time, in the study section, UAE.

*Morozovelloides coronatus* (Blow, 1979) (Fig. 4.18)
1979 *Globorotalia* (Morozovella) *coronata* (Blow, 1979), p. 1016, pl. 50, figs. 2-5.
2006 *Morozovelloides coronatus*; (Pearson and Berggren, 2006), p. 331, pl. 10.2, figs. 1-16.

Remarks: It has elongate-oval to subcircular test, 5 chambers in our specimens, subangular increasing gradually in size, umbilicus relatively wide and deep. It is distinguished by its muricate concholine and a wider umbilicus. It is suggested to evolved from *M. crassatus* and rise to *M. lehneri* (Pearson and Berggren, 2006).

*Morozovelloides crassatus* (Cushman, 1925) (Fig. 4.19)
1925 *Pulvinulina crassata* (Cushman, 1925), p. 300, pl. 7, fig.4.
2006 *Morozovelloides crassatus*; (Pearson and Berggren, 2006), p. 332, pl. 10.3, figs. 1-16.

Remarks: It is distinguished by its closed and small deep narrow umbilicus. It differs from *M. coronatus*, among others, in having a closed narrow umbilicus. Pearson & Berggren considered *Globorotalia spinulosa* Cushman is a junior synonym of *M. coronatus*, and they suggested to evolved it from *M. bandyi* and gave rise to *M. coronatus* (Pearson and Berggren, 2006).

*Morozovelloides lehneri* (Cushman and Jarvis, 1929)
1929 *Globorotalia lehneri* (Cushman and Jarvis, 1929), p. 17, pl. 3, fig. 16.
2006 *Morozovelloides lehneri*; (Pearson and Berggren, 2006), p. 338, pl. 10.4, figs. 1-16.

Remarks: This cosmopolitan species represents the last member of the *Morozovelloides* group, and a useful marker to the middle Eocene. It evolved from *M. coronatus* by radial elongation of the chambers and further compression of the test. It was recorded in different parts of the world: i.e., Trinidad, Pacific Oceans, Italy, Libya, Egypt, UAE, Tunisia and France (Cushman and Jarvis, 1929; Krasheninnikov and Hoskins, 1973; Toumarkine and Bolli, 1975; Bar and Berggren, 1980; Bassioni et al., 1982; Cherif et al., 1992; Ben Ismaïl-Latrache, 2000; Sztrakos, 2000).

Family Hedbergellidae (Loeblich and Tappan, 1961)

Genus *Pseudohastigerina* (Banner and Blow, 1959)
Type species *Nonion micras* (Goe, 1927)

*Pseudohastigerina micra* (Coe, 1927)
1927 *Nonion micras* (Coe, 1927), p. 22, pl. 5, fig. 12.
2015 *Pseudohastigerina micra*; (Pearson and Wade, 2015), p. 23, fig. 26.1-7.

Remarks: A group researcher noted that the genus *Hantkenina* evolved from the species *Clavigerinella eocanica* in the earliest middle Eocene and is unrelated to the genus *Pseudohastigerina* (Coxall et al., 2003). The early-middle Eocene *P. wilcosensis* appeared to gradually evolve into the smaller and more compressed the cosmopolitan middle Eocene-early Oligocene *P. micra* (Berggren et al., 1967; Haggag and Luterbacher, 1991; Palonen and Hemleben, 2006; Pearson and Wade, 2015). It was recorded in different parts of the world: i.e., Mexico, Trinidad, Egypt, Italy, UAE, India and Tanzania (Coe, 1927; Bolli, 1957; Bassioni et al., 1982; Coccioni et al., 1988; Anan et al., 1992; Mukhopadhyay, 2003; Coxall et al., 2003).

Genus *Turborotalia* (Cushman and Bermúdez, 1949)
Type species *Globorotalia centralis* (Cushman and Bermúdez, 1937)

*Turborotalia cerroazulensis* (Coe, 1928) (Fig. 4.20)
1928 *Globigerina cerro-azulensis* (Coe, 1928), p. 217, pl. 1, figs. 11-13.
2006 *Turborotalia cerroazulensis* (Molina et al., 2006), p. 274, pl. 1, fig. 4.

Remarks: The *Turborotalia cerroazulensis* lineage was described include a series of 6 subspecies, and arranged according to their first appearance in the Lower, middle and upper Eocene: *Turborotalia cerroazulensis* frontosa, *T. c. possumgoensis*, *T. c. pomori*, *T. c. cerroazulensis*, *T. c. cocoaensis*, *T. c. cuanilensis*. The two species *T. pomori* and *T. cerroazulensis* normally exist at the middle Eocene Orbulinoides beckmanni bione (E12). *T. cerroazulensis* was recorded in many localities in the Tethys: i.e., Mexico, Italy, Egypt, UAE, Libya, India, Spain (Coe, 1928; Toumarkine and Bolli, 1970; Bassioni et al., 1982; Cherif et al., 1992;1mam, 1999; Mukhopadhyay, 2005; Molina et al., 2006).

Turborotalia pomori (Toumarkine & Bolli, 1970) (Fig. 4.21)
1970 *Globorotalia cerroazulensis pomori* (Toumarkine and Bolli, 1970) pp. 140, pl. 1, fig. 13.
2006 *Turborotalia pomori*; (Molina et al., 2006), p. 274, pl. 1, fig. 3.

Remarks: According to Toumarkine & Luterbacher, *T. pomori* was probably the most abundant and widely distributed of the *T. cerroazulensis* lineage and represented in assemblages from tropical as well as temperate regions: Italy, Libya, Egypt, UAE, France, India, Spain (Toumarkine and Bolli, 1985; Toumarkine and Bolli, 1970; Barr and Berggren, 1980; Bassioni et al., 1982; Anan, 1995; Sztrakos, 2000; Mukhopadhyay, 2005; Molina et al., 2006).

5. PALEOGEOGRAPHY AND EUSTATIC SEA LEVEL

The paleogeographic distribution in some countries in the Tethyan province (Fig. 3): North America (USA, Mexico), Europe (Spain, France, Italy), North Africa (Tunisia, Libya, Egypt), West Africa (Tanzania), East Africa (Gulf of Guinea), West Asia (Qatar, UAE, Iran), Southern Asia (Pakistan, India). Based on that faunal distribution, the following remarks can be presented:

1. The Paleogene paleogeographic maps (partly or regionally), used by many authors, i.e.: show that the Tethyan Realm had been connected with the Indo-Pacific Ocean from the east to the Atlantic Ocean to the west (Berggren, 1978; Moore et al., 1978; Adam et al., 1983).
2. Hæg & Aubry [99] added that the North Africa and Middle East formed important parts of the Tethyan link between the Atlantic and the Pacific Oceans during the Early Eocene (Hæg and Aubry, 1980).
3. Anan concluded that the Tethyan Realm during the middle-late Eocene extends to the southeast and connected with the Indo-Pacific Realm via seaway separating Arabia from Iran-India region (Anan, 1995).
4. Haynes & Nwabufo-Ene suggested wider Tethyan connections, as far as the Carpathian and Pakistan (Haynes and Nwabufo-Ene, 1998).
5. Rögl noted that between the stable Eurasian Platform and the relics of the Tethys elongate deep basins had formed and north of India a marine connection stretched to the west Pacific (Rog. 1999). The western end of the relic Tethys connected the Indo-Pacific and Atlantic Oceans.
6. Meulenkamp and Sissingh noted that the Arabian Platform still largely covered by the sea in the early-middle Eocene times and was subject to a major regression in middle-late Eocene (Meulenkamp and Sissingh, 2003).
7. Anan suggested that the unconformity at the boundary between the Ain Al Faydah and Mazyad Members is associated with the major sea-level lowering (about 41 Ma), within *T. rohri Zone* (P14) (Anan, 2005). The global marked fall in the eustatic sea level took place at the end of the middle Eocene (~ 40 Ma) and 1.4 Haft.
8. Anan noted another intraformational conglomeratic bed separates between P15 and P16 of the Late Eocene (about 39 Ma) in the eastern limb of Jabal Haft (Anan, 2009). These two intraformational conglomeratic beds (represent sea-level lowering) had not been presented (Vail et al., 1977).
9. In the present study, the intraformational conglomeratic bed (ends the Ain Al Faydah Member) at the end of the Tk4 (bed no. 13, Fig. 2), suggests a minimal reworking and accumulating in low-energy environment in a short distance of transportation on a slight steepening paleoslope from the positive localized source area during the time of active tectonic.
Table 2: Middle Eocene (Bartonian) planktic foraminiferal species and some other Tethyan localities (North Africa and Southern Europe). Table 2 shows the identified middle Eocene (Bartonian) planktic foraminifera in Jabal Hafit, UAE and some other Tethyan localities (North Africa and Southern Europe) to the east. The faunal records can be presented:

1. The Middle Eocene in the eastern limb of Jabal Hafit yields 28 planktic foraminiferal species in this study, compared with 21, but only 9 species for the same stratigraphic succession (Anan et al., 1992; Cherif et al., 1992).

2. To the west of UAE, 29 species were recorded from the Bartonian in Egypt by Haggag & Luterbacher [31] including two new Egyptian species Turborotalia nukhulensis and T. siniensis.

3. In Europe, 26 species were recorded in Italy, 23 species from Spain and 21 species from France (Toumarkine and Bolli, 1975; Gonzalvo and Molina, 1996; Sztrakos, 2000).

4. To the east of UAE, 11 species were recorded from India and Indian Ocean, but only 9 species from east of Japan at Pacific Ocean (Mohan and Soodan, 1970; Krasheninnikov and Hoskins, 1973).

5. The variation of foraminiferal numbers mostly related to different factors (depth, water temperature, water-column stability, salinity, dissolved oxygen, light penetration, etc.) between these vast localities.

6. Paleoclimatology

1. Gohrbandt recorded abundant, diverse, and typical tropical planktonic foraminifera assemblages in his study of Austria, indicating deposition in a relatively deep marine environment with connection to the open-sea, while the northern site of the sequence with nummulitic limestone suggesting shallower conditions (Gohrbandt, 1967).

2. Cherif & Boukhary noted that the synthesis of stratigraphical data on uppermost Lutetian and lowermost Bartonian exposures in Egypt enables to suggest the occurrence of a regional epigeneric tectonic movement before the end of the Lutetian (Cherif and Boukhary, 1978).

3. Keller noted that general cooling trend between middle Eocene to early Late Oligocene is indicated by the successive replacement of warm middle Eocene surface water planktic species by cooler late Eocene intermediate water species (Keller, 1983).

4. Cherif & El Deeb noted that arid climate at the close of the middle Eocene became markedly wetter and seems to have been accompanied by a cooling of water temperature (Cherif and El-Deeb, 1984). Moreover, the climatic changes inferred from J. Haft area seems to have been widespread, at least in part of the Middle East.

5. Anan noted that in the middle-late Eocene time, the UAE and surrounding area had been located in the tropical and warm temperate region based on many faunal environmental elements such as the presence of keels, accessory apertures and tubular spines in some middle-late Eocene planktic foraminiferal assemblages (Anan, 1995).

6. Norris noted that the reproductive mechanisms and behavior must therefore play key roles in speciation rather than geographic barriers to dispersal (Norris, 2000).

7. A group researcher noted that the evolution of Hantkenina (with tubular spines) occurred during the initial rapid phase of Cenozoic cooling (around early-middle Eocene boundary), which followed the extremely warm climate optimum of the early Eocene (Coxall et al., 2003).

8. A group researcher noted that related species within genera tend to have similar isotopic characteristics, indicating that most speciation occurs without major changing in habitat (Pearson et al., 2004).

In this study, the middle Eocene (Bartonian) horizon at the eastern limb of Jabal Hafit, Al Ain area, UAE, have been analyzed in detail and the following conclusions have been presented:

1. Twenty-eight planktic foraminiferal species belonging to ten genera have yielded three biozones. They are, in ascending order: Morozovelloides lehneri, accessory apertures (Acarinina rohri, Globigerinatheka subconglobata and Orbilionides beckmanni), tubular spines (Hantkenina alabamensis), but shallower conditions in rich Nummulitids horizons, particularly in the top of the study section. This conclusion is in accordance with Frerichs who noted that the presence of keels, accessory apertures, and tubular spines of some of planktic foraminiferal species suggests a tropical-subtropical sea (Frerichs, 1971).

7. Summary and Conclusions

Bartonian planktonic foraminiferal assemblages of the Damami Formation in the eastern limb of Jabal Hafit, Al Ain area, UAE, have been analyzed in detail and the following conclusions have been presented:

1. Twenty-eight planktic foraminiferal species belonging to ten genera have yielded three biozones. They are, in ascending order: Morozovelloides lehneri, accessory apertures (Acarinina rohri, Globigerinatheka subconglobata and Orbilionides beckmanni), tubular spines (Hantkenina alabamensis), but shallower conditions in rich Nummulitids horizons, particularly in the top of the study section. This conclusion is in accordance with Frerichs who noted that the presence of keels, accessory apertures, and tubular spines of some of planktic foraminiferal species suggests a tropical-subtropical sea (Frerichs, 1971).

2. The Middle Eocene in the eastern limb of Jabal Hafit yields 28 planktic foraminiferal species in this study, compared with 21, but only 9 species for the same stratigraphic succession (Anan et al., 1992; Cherif et al., 1992).

3. To the west of UAE, 29 species were recorded from the Bartonian in Egypt by Haggag & Luterbacher including two new Egyptian species Turborotalia nukhulensis and T. siniensis by the same authors, but only 8 species were recorded from Tunisia (Ben Ismail-Latrache, 2000; Haggag and Luterbacher, 1991). To the east of UAE, 11 species were recorded from India and Indian Ocean, but only 9 species from east of Japan at Pacific Ocean (Mohan and Soodan, 1970; Krasheninnikov and Hoskins, 1973).
4. In Europe, 26 species were recorded in Italy, 23 species from Spain and 21 species from France (Tourmantine and Bolli, 1975; Gonzalez and Molina, 1996; Sztakos, 2000).

5. Eight out of the identified species are recorded, in this study, for the first time from Jabal Haft: Globotruncana marginata, Subbotina gortani, S. jacksonensis, S. senni, Globigerinatheka barci, Aracrinia praetoplensis, A. punctocarinata and Morozovelloides bandyi.

6. The second or third record of three species from J. Haft outside its original records are recently documented by the present author: Inordinatosphaera indica, Hantkenina australis and H. compressa (Anan, 2017; Anan, 2019).

7. The Middle Eocene (Bartonian) horizon at the eastern limb of J. Haft in general has been located in the tropical and warm temperate region based on many faunal environmental elements: presence of keel (Morozovelloides lehneri), accessory apertures (Aracrinia rohri, A. topilensis, Globigerinatheka subangulata and Orbulinaoides beckmanni), tubular spines (Hantkenina alabamenesis), but shallower conditions in rich Nummulitids horizons, particularly in the top of the study section. This conclusion is in accordance who noted that the presence of keels, accessory apertures, and tubular spines of some planktic foraminiferal species suggests a tropical-subtropical sea (Frerichs, 1971).

8. The intraformational conglomeratic bed (ends the Ain Al Faydah Member) at the end of the T4 (bed no. 13, Fig. 2), suggests a minimal reworking and accumulating in low-energy environment in a very short distance of transportation on a slight steepening paleoslope from the positive localized source area during the time of active tectonic (Fig. 4).

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