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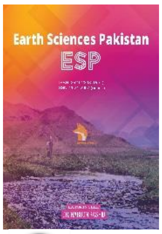

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RESEARCH ARTICLE

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-eight species belonging to ten genera *Globoturborotalia, Subbotina, Globigerinatheka, Inordinatosphaera, Orbulinoides, Hantkenina, Acarinina, 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 recorded, in this study, for the first time from Jabal Hafit: *Globoturborotalia martini, Subbotina gortanii, S. jacksonensis, S. senni, Globigerinatheca barri, Acarinina 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 presented and discussed. 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

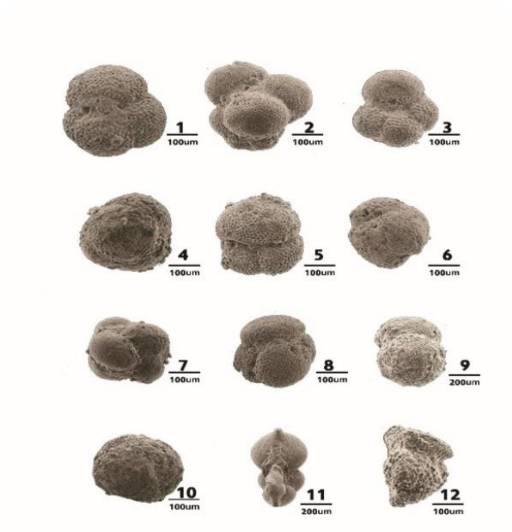

Plate 1: 1. Globoturborotalia martini (Blow and Banner, 1962), Sample no. 15 (E12). 2. Subbotina gortanii (Borsetti, 1959), S. 9 (E11). 3. Subbotina hagni (Gohrbandt, 1967), S. 15 (E12). 4. Subbotina jacksonensis (Bandy, 1949), S. 9 (E11). 5. Subbotina linaperta (Finlay, 1939), S. 15 (E12). 6. Subbotina senni (Beckmann, 1953), S. 15 (E12). 7. Globigerinatheka barri (Brönnimann, 1952), S. 9 (E11). 8. Globigerinatheka subconglobata (Shutskaya, 1958), S. 15 (E12). 9. Globigerinatheka tropicalis (Blow & Banner, 1962), S. 22 (E13). 10. Orbulinoides beckmanni (Saito, 1962), S. 15 (E12). 11. Hantkenina alabamensis (Cushman, 1925), S. 15 (E12). 12. Acarinina bullbrooki (Bolli, 19557), S.15 (E12).

The Maastrichtian-Paleogene rocks in the United Arab Emirates (UAE) crop out as a discontinuous mountains belt (jabals) and hills (qarns) around the western front of the North Oman Mountains (NOM) and Jabal Hafit is one of these mountains (Lat. 24° 06' and24° 09' N, Long. 55° 46' and55° 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.

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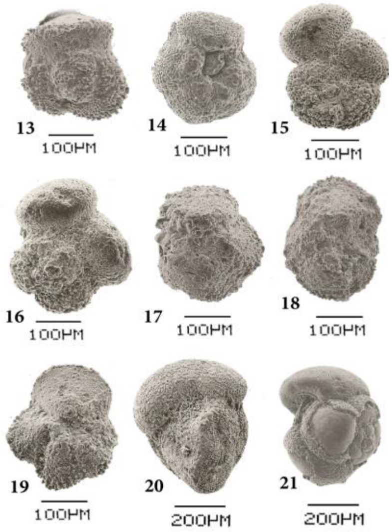

Plate 2: 13. *Acarinina praetopilensis* (Blow, 1979), Sample 24 (E13). **14**. *Acarinina punctocarinata* (Fleisher, 1974), S. 16 (E13). **15**. *Acarinina rohri* (Brönnimann and Bermúdez, 1953) S. 28 (E13). **16**. *Acarinina topilensis* (Cushman, 1925), S. 22 (E13). **17**. *Morozovelloides bandyi* (Fleisher, 1974), S. 4 (E11). **18**. *Morozovelloides coronatus* (Blow, 1974), S. 6 (E11). **19**. *Morozovelloides crassatus* (Cushman, 1925), S. 7 (E11). **20**. *Turborotalia cerroazulensis* (Cole, 1928), S. 15 (E12). **21**. *Turborotalia pomeroli* (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 planktic foraminiferal assemblages of the early Paleogene succession (Paleocene and Eocene) of this area by the present author and others: early/middle Paleocene (Danian/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. Hafit, early/middle Eocene (Ypresian/Lutetian, P9-P10=E7-E8) at the western limb of J. Hafit, Eocene at western and eastern limbs of J. Hafit 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 planktic 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 Hafit, UAE. The middle Eocene planktic foraminiferal biozones at the eastern limb of J. Hafit 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).

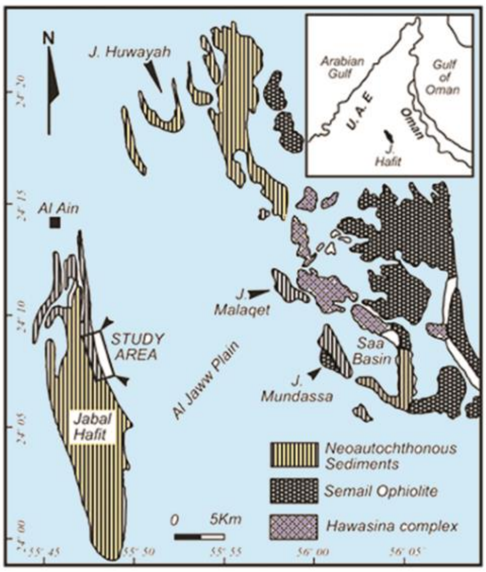

Figure 1: Location map of the study area (eastern limb of Jabal Hafit) and also the other outcrops in Al Ain area (J. Malaqet and J. Mundassa), UAE.

2. Geological Setting

The Maastrichtian-Oligocene post-nape 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, Hawasna 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 Zagaros 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 Hafit 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. Hafit 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 Tle4 (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. Hafit 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 *Orbulinoides 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 4) from Mazyad Member (Tle 5) of the Dammam Formation.

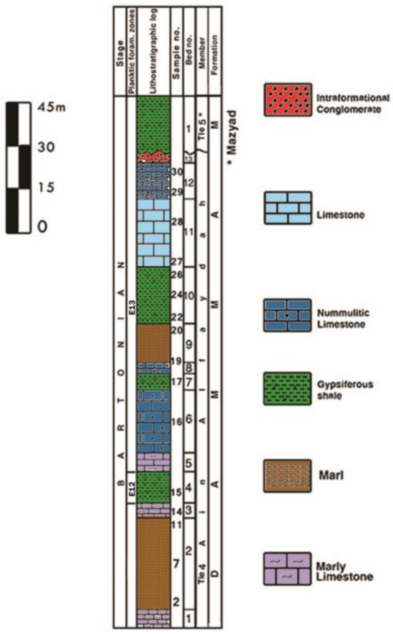

Figure 2: Simplified stratigraphic section of the Middle Eocene, eastern limb of Jabal Hafit, UAE (The intraformational conglomeratic bed in red color).

4. Planktonic Foraminiferal Biozones

Table 1: The planktic foraminifeal distribution in the middle Eocene (Bartonian) of the eastern limb of J. Hafit, Al Ain area, UAE. The neglected

beds or samples are related to hard limestone or nummulitic limestone beds (don't yeilds planktic foraminifer), Θ = illustrated species, x= recorded species.

	Middle Eocene (Bartonian) Planktic foraminiferal species no.		Eastern Limb of Jabal Hafit															
		Bed	2				3			4	5	9	10				11	
	Sample no.		2	4	6	7	9	10	11	15	16	20	22	23	24	25	26	28
1	*Globoturborotalia*	*martini*		x						Θ			x					
2	*Subbotina*	*eocaena*		x						x			x					x
3		*gortanii*		x			Θ			x	x		x				x	x
4		*hagni*					x		x	Θ			x			x		x
5		*linaperta*	x				x			Θ		x	x	x		x	x	x
6		*jacksonensis*					Θ						x					
7		*senni*								Θ			x					
8	*Globigerinatheka*	*barri*					Θ			x			x					
9		*subconglobata*	x			x				Θ			x		x			
10		*tropicalis*	x										Θ					
11	*Inordinatosphaera*	aff. *indica*								x								
12	*Orbulinoides*	*beckmanni*								Θ								
13	*Hantkenina*	*alabamensis*						x		Θ								
14		*australis*					x											

Examination of twenty-eight species belonging to ten genera has resulted in the recognition of three planktonic foraminiferal biozones in the middle Eocene (Bartonian) sequence of the eastern limb of Jabal Hafit, Al Ain area, United Arab Emirates (UAE): *Morozovelloides lehneri* PRZ (E11), *Orbulinoides beckmanni* TRZ (E12) and *Morozovelloides crassata* HOZ (E13). The planktonic foraminiferal distribution in the studied stratigraphic horizon is shown in Table 1.

E11: *Morozovelloides lehneri* Partial-Range Zone (Berggren and Pearson, 2005; Berggren and Pearson, 2006).

Definition: Biostratigraphic interval characterized by the partial range of the nominate taxon between the highest occurrence (HO) of *Guembelitrioides nuttalli* and the lowest occurrence (LO) of *Orbulinoides beckmanni.* This zone is the oldest zone identified in the present study.
Assemblage: The planktonic foraminiferal assemblage accompanying *Morozovelloides lehneri* Partial-Range Zone is rather common in diversity. It contains 22 of 28 identified species: *Globoturborotalia martini, Subbotina eocaena, S. gortanii, S. hagni, S. linaperta, S. jacksonensis, Globigerinatheka barri, G. subconglobata, G. tropicalis, Hantkenina alabamensis, H. australis, H. compressa, H. liebusi, Acarinina bullbrooki, A. rohri, A. topilensis, Morozovelloides bandyi, M. coronatus, M. crassatus, M. lehneri, Pseudohastigerina micra* and *Turborotalia cerroazulensis.*

E12: *Orbulinoides beckmanni* Total Range Zone.

Definition: Total range of the nominate taxon between its LO and HO.
Assemblage: The planktonic foraminiferal assemblage accompanying this zone is rather common in diversity. It contains 19 of 28 identified species: *Globoturborotalia martini, Subbotina eocaena, S. gortanii, S. hagni, S. linaperta, S. senni, Globigerinatheka barri, G. subconglobata, Inordinatosphaera* aff. *indica, Orbulinoides beckmanni, Hantkenina alabamensis, Acarinina bullbrooki, A. punctocarinata, A. rohri, Morozovelloides bandyi, M. coronatus, M. lehneri, Turborotalia cerroazulensis* and *T. pomeroli.*

E13: *Morozovelloides crassatus* Highest-occurrence Zone (Berggren 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: *Globoturborotalia martini, Subbotina eocaena, S. gortanii, S. hagni, S. linaperta, S. jacksonensis, Globigerinatheka barri, G. subconglobata, Acarinina bullbrooki, A. praetopilensis, A. punctocarinata, 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 planktic foraminiferal species from the Bartonian zones (E11-E13) from the eastern limb of J. Hafit are recorded, but twenty-one of them are illustrated (Plates 1, 2). These species are: *Globoturborotalia martini* (Blow and Banner), *Subbotina eocaena* (Gümbel), *S. gortanii* (Borsetti), *S. hagni* (Gohrbandt), *S. linaperta* (Finlay), *S. jacksonensis* (Bandy), *S. senni* (Beckmann), *Globigerinatheka barri* (Brönnimann), *G. subconglobata* (Shutskaya), *G. tropicalis* (Blow & Banner), *Inordinatosphaera* aff. *indica* Mohan & Soodan, *Orbulinoides beckmanni* (Saito), *Hantkenina alabamensis* Cushman, *H. australis* Finlay, *H. compressa* Parr, *H. liebusi* Shokhina, *Acarinina bullbrooki* (Bolli), *A. punctocarinata* Fleisher, *A. praetopilensis* (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 & Bolli). Table 1 shows the planktic foraminiferal distribution in the middle Eocene (Bartonian) of the eastern limb of J. Hafit, Al Ain area, UAE.
Order Foraminiferida Eichwald, 1830
Superfamily Globigerinacea Carpenter, Parker & Jones, 1862
Family Globigerinidae Carpenter, Parker & Jones, 1862
Genus *Globoturborotalia* Hofker, 1976
Type Species *Globigerina rubescens* Hofker, 1976

***Globoturborotalia martini* (Blow and Banner, 1962)** (Figure 3.1)
1962 Globigerina *m. martini* Blow and Banner 1962, p. 110, pl. 14, figure 4.
2015 Globoturborotalia *martini*; Pearson and Wade 2015, p. 11, figures. 9. 3-12.

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 *Globoturborotalia 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 et al., 2006).

Genus *Subbotina* Brotzen & Požaryska, 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. 6.9, figs. 1-7.

Remarks: considered *S. eocaena* evolved from the early Eocene *S. pseudoeocaena* Subbotina (Berggren, 1965; Subbotina, 1960). considered *Globigerina corpulenta* exists between *G. eocaena* Gümbel and *G. goortani* (Stainforth et al., 1975; Subbotina, 1953; Borsetti, 1959). Haggag & Luterbacher regarded *G. corpulenta* to develop from *G. eocaena*, while Olsson et al. regarded it, probably evolved from their *S. roesnaesnensis* by an increase in test size and the development of globular, more embracing chambers (Haggag and Luterbacher, 1991; Olsson et al., 2006). They also considered the 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, India, Mexico and Iran (Plummer, 1927; Subbotina, 1960; Youssef et al., 1983; Premoli Silva and Spezzaferri, 1990; Milner, 1992; Anan, 1995; Sztrakos, 2000; Luciana et al., 2002; Mukhopadhyay, 2003; Olsson et al., 2006; Vahdatirad et al., 2016).

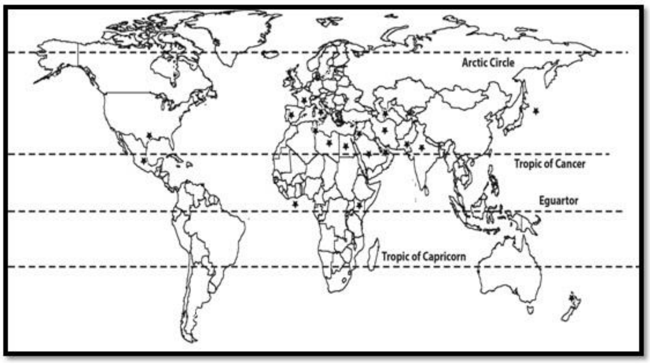

Figure 3: Paleogeographic map of the recorded species from the Middle Eocene in different localities (stars) in the world, from New Zealand in the east, to USA and Mexico in the west throughout south Asia, north and central Africa and south Europe.

Subbotina gortanii **(Borsetti, 1959)** (Fig. 3.2)
1959 *Catapsydrax gortanii* Borsetti (Borsetti, 1959), p. 205, pl. 1, fig. 1.
2006 *Subbotina gortanii*; (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 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 latter species belongs to *G. eocaena, G. corpulenta, G. praeturritilina* 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 gortanii* is recorded here from the middle Eocene of J. Hafit.

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. 1, fig. 13.

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. Hafit, 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, fig. 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 Brggren, 1980; Youssef et al., 1983; Premoli Silva and Spezzaferri, 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, 1868), 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. Hafit, UAE.

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

Globigerinatheca barri **Brönnimann, 1952** (Fig. 3.7)
1952 *Globigerinatheca barri* (Bronnimann, 1952), p. 27 (partim), text-fig. 3a-c, g, h.
2006 *Globigerinatheca barri*; (Premoli Silva et al., 2006), p. 177, pl. 7.2, 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 (Bronnimann, 1952; Mohan and Soodan, 1970; Haggag and Luterbacher, 1991). It is recorded here, for the first time, from the middle Eocene of J. Hafit, UAE.

Globigerinatheca subconglobata **(Shutskaya, 1958)** (Fig. 3.8)
1958 *Globigerinoides subconglobata* Shutskaya var. *subconglobata* Shutskaya (Shutsky,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 curryi* (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 E8 (Anan et al., 1992). A group scientist considered it an ancestral to all the other 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 *Glopigerapsis 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. i. 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. 1-7.
2017 *Inordinatosphaera* aff. *indica*; (Anan, 2017), p. 128, fig. 3.b.

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. Hafit (UAE) (Anan, 2017). It is characterized by its spherical-subspherical test and irregular elongate meandriform bullae. A group researchers considered *Inordinatosphaera indica* as a problematic genus and 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 *Porticulasphaera beckmanni* Saito, 1962

***Orbulinoides beckmanni* (Saito, 1962)** (Fig. 3.10)
1962 *Porticulasphaera beckmanni* Saito (Saito, 1962), p. 221, pl. 34, figs. 1.
2006 *Orbulinoides beckmanni*; (Premoli Silva et al., 2006), p. 207, pl. 7.11, figs. 1-16.

Remarks: Bolli recognized four morphological groups of the genus *Globigerinatheca*: *G. index, G. mexicana, G. subconglobata* and *G. semiinvoluta* 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 Osean, 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; Srinivasan, 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 early 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 Loeblich & Tappan, 1961

Genus *Acarinina* Subbotina, 1953
Type species: *Acarinina acarinata* Subbotina, 1953

***Acarinina bullbrooki* (Bolli, 1957)** (Fig. 3.12)
1957 *Globorotalia bullbrooki* (Bolli, 1957), p. 167, pl. 38, fig. 5.
2006 *Acarinina bullbrooki*; (Berggren et al., 2006), p. 269, pl. 9.6, figs. 1-16.

Remarks: A group researchers regarded that *Acarinina matthewsae* Blow, *Globorotalia densa* (Cushman) and *Globorotalia (Acarinina) spinuloinflata* (Bandy) as a junior synonym of *A. bullbrooki* (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 part of the Tethys: Trinidad, Mexico, Italy, France, Tunisia, Egypt and UAE (Bollo, 1957; Carreno et al., 2000; Toumarkine and Bolli, 1975; Sztrakos, 2000; Ben Ismail-Lattrache, 2000; Bassiouni et al., 1982; Cherif et al., 1992).

Acarinina praetopilensis (Blow, 1979) (Fig. 4.13)
1979 *Globorotalia* (*Truncorotaloides*) *topilensis praetopilensis* (Blow, 1979), p.1043, pl. 155, fig. 9.
2006 *Acarinina praetopilensis*; (Berggren et al., 2006), p. 300, pl. 9.16, figs. 1-16.

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

***Acarinina punctocarinata* Fleisher, 1974** (Fig. 4.14)
1974 *Acarinina punctocarinata* (Fleisher, 1974), p. 1014, pl. 3, figs. 4-8.
2006 *Acarinina 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).

***Acarinina rohri* (Brönnimann & Bermúdez, 1953)** (Fig. 4.15)
1953 *Truncorotaloides rohri* (Bronnimann and Bermudez, 1953), p. 818, pl. 87, figs. 7-9.
2006 *Acarinina 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. topilensis.* According to a study this species gave rise to *Acarinina topilensis* (Berggren et al., 2006). It was recorded in different parts of the Tethys: Trinidad, India, Pacific Ocean, Italy, Libya, Egypt, UAE and France (Bronnimann 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; Sztrakos, 2000).

***Acarinina topilensis* (Cushman, 1925)** (Fig. 4.16)
1925 *Globigerina topilensis* (Cushman, 1925), p. 7, pl. 1, fig. 9.
2006 *Acarinina topilensis*; (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).

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 planoconvex to lenticular test, and its strongly disjunct along axes of chambers. It is suggested to be evolved from *Acarinina praetopilensis* 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 coronet 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; Bassiouni et al., 1982; Cherif et al., 1992; Ben Ismail-Lattrache, 2000; Sztrakos, 2000).
Family Hedbergellidae (Loeblich and Tappan, 1961)

Genus *Pseudohastigerina* (Banner and Blow, 1959)
Type species *Nonion micrus* (Cole, 1927)

***Pseudohastigerina micra* (Cole, 1927)**
1927 *Nonion micrus* (Cole, 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. wilcoxensis* would appear 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; Olsson 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 (Cole, 1927; Bolli, 1957; Bassiouni 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* (Cole, 1928)** (Fig . 4.20)
1928 *Globigerina cerro-azulensis* (Cole, 1928), p. 217, pl. 1, figs. 11-13.
2006 *Turborotalia cerroazulensis*; (Molina et al., 2006)., 274, pl. 1, fig. 4.

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

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

Remarks: According to Toumarkine & Luterbacher, *T. pomeroli* 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 Luterbacher, 1985; Toumarkine and Bolli, 1970; Barr and Berggren, 1980; Bassiouni 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. Haq & Aubry [99] added that the North Africa and Middle East firmed important parts of the Tethyan link between the Atlantic and the Pacific Oceans during the Early Cenozoic (Haq 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 J. Hafit.

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 Hafit (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 Tle4 (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: J.Hafit (1=this study), J.Hafit (2=Anan et al., 1992), J.Hafit (3=Cherif et al., 1992), E=Egypt (Haggag and Luterbacher, 1991), T=Tunisia (Ben Ismail-Lattrache, 2000), I=Italy (Toumarkine and Bolli, 1974), S=Spain (Gonzalvo and Molina, 1996), F=France (Sztrákos, 2000), IN=India (Mohan and Soodan, 1970), IO=Indian Ocean (Krasheninnikov and Hoskins, 1973), PO=Pacific Ocean (Milner, 1992) (- = not recorded, x = recorded, ⊙=illustrated species).

Sp. No.	Middle Eocene (Bartonian) planktic foraminiferal species		Some Tethyan localities					Jabal Hafit			Some Tethyan localities		
			F	S	I	T	E	1	2	3	IN	IO	PO
1	*Globoturborotalia*	*martini*	x	x	-	-	-	Θ	-	-	-	-	-
2	*Parasubbotina*	*griffinae*	x	x	-	-	x	-	-	-	-	-	-
3	*Subbotina*	*angiporoides*	-	x	x	-	-	-	x	-	-	-	-
4		*corpulenta*	-	x	x	-	x	-	x	-	-	-	x
5		*eocaena*	x	x	x	-	x	x	x	-	-	-	x
6		*gortanii*	-	-	-	-	-	Θ	x	-	-	-	-
7		*hagni*	x	x	x	-	-	Θ	-	-	-	-	-
8		*jacksonensis*	-	-	-	-	-	Θ	-	-	-	-	-
9		*linaperta*	x	x	x	-	x	Θ	-	x	-	-	x
10		*senni*	x	-	x	-	x	Θ	-	-	-	-	-
11		*yeguaensis*	-	-	-	-	-	-	x	-	x	-	-
12	*Globigerinatheka*	*barri*	-	-	x	-	x	Θ	x	-	x	x	x
13		*curryi*	-	-	x	-	x	-	-	-	-	-	-
14		*index*	x	x	x	x	x	-	x	x	-	x	-
15		*kugleri*	-	-	-	-	x	-	-	-	x	x	-
16		*luterbacheri*	-	-	x	-	-	-	x	-	-	-	-
17		*mexicana*	-	x	-	-	x	-	-	-	-	-	x
18		*subconglobata*	x	x	x	x	x	Θ	x	x			-
19		*tropicalis*	x	x	x	-	x	Θ	x	-	-	-	-
20	*Inordinatosphaera*	*indica*						x			x		
21	*Orbulinoides*	*beckmanni*	-	x	-	x	-	Θ	x	x	x	x	-
22	*Hantkenina*	*alabamensis*	x	x	x	-	x	Θ	x	-	-	x	x

Table 2 shows the identified middle Eocene (Bartonian) planktic foraminifera in J. Hafit, UAE and some other Tethyan localities (North Africa and Southern Europe) to the west, India and Indian and Pacific Oceans to the east. The fowling remarks can be presented:

1. The middle Eocene in the eastern limb J. 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. sinaiensis* by the same authors. Only 8 species were recorded from Tunisia (Ben Ismail-Lattrache, 2000).

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 typically 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 epeirogenic tectonic movement before the end of the Lutetian (Cherif and Boukhary, 1978). The general influx of clastic sediments noticed in most Bartonian exposures in northeastern Egypt suggests that a marked change of climates was probably arid, Bartonian climates rather wet.

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. Hafit 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 assemblage (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 J, Hafit 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 (*Acarinina rohri, A. topilensis, Globigerinatheka subconglobata* and *Orbulinoides 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 Dammam 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 planktonic foraminiferal species belonging to ten genera have yielded three biozones. They are, in ascending order: *Morozovelloides lehneri* PRZ (E11), *Orbulinoides beckmanni* TRZ (E12) and *Morozovelloides crassata* HOZ (E13).

2. The middle Eocene in the eastern limb J. 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 & Luterbachzr including two new Egyptian species *Turborotalia nukhulensis* and *T. sinaiensis* by the same authors, but only 8 species were recorded from Tunisia (Ben Ismail-Lattrache, 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 (Toumarkine and Bolli, 1975; Gonzalvo and Molina, 1996; Sztrakos, 2000).

5. Eight out of the identified species are recorded, in this study, for the first time from Jabal Hafit: *Globoturborotalia martini, Subbotina gortanii, S. jacksonensis, S. senni, Globigerinatheca barri, Acarinina praetopilensis, A. punctocarinata* and *Morozovelloides bandyi.*

6. 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* (Anan, 2017; Anan, 2018).

7. The middle Eocene (Bartonian) horizon at the eastern limb of J, Hafit 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 (*Acarinina rohri, A. topilensis, Globigerinatheka subconglobata* and *Orbulinoides 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 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).

8. The intraformational conglomeratic bed (ends the Ain Al Faydah Member) at the end of the Tle4 (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 (Fig. 4).

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