Paleontology, paleogeography and Paleoenvironment of the Paleocene benthic foraminiferal species of Plummer in the Tethys; a review

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Abstract

Forty two Paleocene benthic foraminiferal species of the Midway Formation in the Gulf Coastal Plain of Texas, USA were firstly investigated by Plummer (1927), and its paleogeographic distribution in some other countries in the Tethyan province were recorded: North America (USA, Mexico), South America (Argentina), Europe (North Sea Basin, Spain, France, Italy, Czech Republic, Bulgaria), North Africa (Tunisia, Libya, Egypt), West Africa (Ivory Coast, Gulf of Guinea), West Asia (Turkey, Jordan, Saudi Arabia, UAE, Iran), Central Asia (Pakistan) and East Asia (Japan and New Zealand). Eight out of Plummer's new species (about 19%) seems to be confined in USA, eight species (about 19 %) are recorded in South America, while twenty two species (about 52%) in Europe, twenty eight species (about 67%) in North Africa, seventeen species (about 40%) in West Asia, seven species (about 17%) in Pakistan, three species (about 7%) in West Africa, two species (about 5%) in New Zealand and one Plummer's species is recorded in Japan, East Asia. The Tethyan continental shelf fauna (Midway-Type Fauna , MTF) of middle-outer neritic environment (~50-200 m) is interpreted for the Midway Formation. As a token of appreciation of her outstanding career and faunal contributions, she has recognized in several instances with a dedication taxa bearing Plummer name, and one new species of them was erected by the present author: *Citharina plummerae* Anan (2001) from the Paleocene of Duwi section, Red Sea coast, Egypt. The paleontology, paleoecology and stratigraphy of the Plummer's species are presented and discussed.

Keywords: Paleogene; foraminifera; Midway-type fauna; paleontology; paleogeography; Egypt; Atlantic; Tethys.

1- Introduction

Berggren and Aubert (1975) recognized two main distinct depth-controlled benthic foraminiferal assemblages represented the Paleogene (exclusive of the shallow-warm water Tethyan carbonate assemblage): the lower continental slope and abyssal plain fauna, "Velasco-type fauna, VTF" (more than 200 m depth), and the Atlantic-Tethyan regions, termed the "Midway-type fauna, MTF", (middle-outer neritic environment, about ~50-200 m depth) in different localities (Fig. 1). The MTF are characterized by some Plummer's continental shelf fauna (i.e. *Spiroplectinella expansa, Laevidentalina granti, Lenticulina midwayensis, L. pseudomamilligera, Perculta-zonaria tuberculata, Neoflabellina delica-tissima, Vaginulinopsis longiforma, Ortho-karstenia applinae, O. eleganta, Bulimina midwayensis, Alabamina limbata, Cibicidoides alleni, C. vulgaris, Anomalinoides acuta, A. midwayensis and Gyroidenoides subangulata*). In this study, another one new benthic

foraminiferal species: the Paleocene *Citharina plummerae* Anan (2011) from Egypt is added.

The present study aims at throwing light on the paleontology, paleogeography, paleo-environment and stratigraphic value for the Plummer's species.

2- Previous Studies

The first comprehensive investigation of about one hundred and fifty species from Paleocene foraminiferal faunas of the Midway Formation (in the Mexia-Corsicana area) in Texas, Gulf Coastal Plan was presented by Plummer (1927). The Midway Formation consists of the calcareous clays and silts which lie between the Navarro Formation below and the Wilcox Formation above. Plummer (op. cit.) interpreted the Midway as having been deposited in two stages (units 1, 2) separated by uplift and erosion. The latter unit 2 is considered to have been deposited in deeper water than unit 1 because of the greater abundance of planktic foraminifera.

In Central America and Caribbean, about 280 foraminiferal Paleocene species of the Gulf Coast were described and illustrated as well as several from the nearby areas of Trinidad, Cuba, Haiti and Central America by Cushman (1951) and having as its basic references the pioneer work on the Midway Formation by Plummer (1927).

In Europe (Spain), Bernaola et al. (2007) noted that the benthic foraminiferal mid-Paleocene assemblage of Zumaia section, western Pyrenees indicate a middle bathyal (~1000 m) depth of deposition, Velasco-type (Fig. 2).

In North Africa: The Midway-type faunal elements were recorded from Algeria by Ten Dam and Sigal (1950, after Berggren and Aubert, 1975). In Egypt, LeRoy (1953) presented the first comprehensive study of Paleocene Esna Shale from Maqfi section, Western Desert of Egypt, which he described more than one hundred foraminiferal species from the Lower Tertiary. He noted that the Esna Shale fauna exhibits an affinity with the Midway assemblage of Plummer. Said and Kenawy (1956) described more than two hundred and fifty foraminiferal species from Upper Cretaceous-Lower Tertiary strata from northern Sinai, Egypt, and the benthic fauna shows an affinity with Midway faunas of Plummer. Berggren (1974b) noted that the foraminiferal assemblages in Mali are dominated by shallow water and various larger foraminifera, while planktic foraminifera are rare or absent. He also noted that the foraminiferal assemblages in Libya are developed in two lithotopes: one similar to that in Mali, and the second developed in Midwayan type of fauna, together with planktic foraminifera. Berggren and Aubert (1975) noted that more than 130 species of the assemblage of Tunisian Paleocene benthic foraminiferal fauna are typically Midwayan type. Alegret et al. (2005) noted that the benthic foraminiferal assemblages in the Paleocene/Eocene in the stratotype section in Dababiya, Egypt (Fig. 3) contain abundant representatives of the Midway-type fauna. Anan (2008) noted that the Tethyan aspect (Midway-type fauna) of middle-outer neritic environment (~50-200 m) is interpreted for both Maqfi section and Duwi section, Red Sea coast, Egypt (Fig. 4).

In west Asia, Shallow water limestone and calcareous marls occurring in the region of Jabal Dukhan, Qatar exhibit strong similarity to that in Mali as noted by Berggren (1974), while Anan (1993a, b; 2015a, b) noted that the mid-Paleocene in the United Arab Emirates (UAE) is closed to the faunal assemblage of the Paleocene of Sinai (Egypt), which shows an affinity with the Midwayan type.

In south Central Asia (Pakistan), Haque (1956) noted that the absence of Globigerina and Globorotalia in the Paleocene Khairabad Limestone fauna suggests one feel that the basin of deposition was not very deep, and almost

certainly isolated from the open ocean, and the paucity of typical European and American Paleocene forms strengthens this assumption.

3- Systematic Paleontology

The taxonomy followed here is that of Loeblich and Tappan (1988). The paleogeographic distribution of forty two identified benthic foraminiferal species (belonging 29 genera) of Plummer (1927) is shown in Table 1 and Fig. 5. These species are illustrated in Fig. 6.

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Hérouard, 1896

Family **Spiroplectamminidae** Cushman, 1927

Subfamily Spiroplectammininae Cushman, 1927

Genus *Spiroplectinella* Kisel'man, 1972

Type species *Spiroplecta wrightii* Silvestri, 1903

Spiroplectinella expansa (Plummer, 1927) (Fig. 6.1)

1927 *Textularia carinata expansa* Plummer, p. 67, pl. 3, fig. 3.

1959 *Spiroplectammina expansa*; Öztemür, p. 4, pl. 3, fig. 2.

1982 *Ammobaculites expansus*; Proto Decima and Bolli, p. 116.

This species has a very faint spiral portion, neither large early planispiral coil in the genus *Spiroplectammina.* Because the name *Spiroplectammina expansa* was used earlier by Cushman 1948 (p. 5, pl. 1, figs. 19, 20) changed the *Spiroplectammina expansa* to *S. plummerae* Cushman. It was recorded in Paleocene of Texas, Italy (Proto Decima and Bolli, 1982) but Eocene in Turkey (Öztemür, 1959).

Suborder Lagenina Delage and Hérouard, 1896

Superfamily Nodosariacea Ehrenberg, 1838

Family **Nodosariidae** Ehrenberg, 1838

Subfamily Nodosariinae Ehrenberg, 1838

Genus *Dentalina* Risso, 1826

Type species *Nodosaria cuvieri* d'Orbigny, 1826

Dentalina pseudoobliquestriata (Plummer, 1927) (Fig. 6.2)

1927 *Nodosaria pseudo-obliquestriata* Plummer, p. 87, pl. 4, fig. 18.

This species is regarded here to the genus *Dentalina* due to its arcuate test with longitudinally costate surface (after Loeblich and Tappan, 1988). It was recorded, so far, from Paleocene rocks of Texas (USA).

Genus *Chrysalogonium* Schubert, 1908

Type species *Nodosaria polystoma* Schwager, 1866

Laevidentalina granti (Plummer, 1927) (Fig. 6.3)

1927 *Nodosaria granti* Plummer, p. 83, pl. 5, fig. 9.

1931 *Dentalina granti*; Plummer, p. 149, pl.11, figs. 8,9.

1951 *Chrysalogonium granti*; Cushman, p. 24, pl. 13, fig. 11.-

2003 *Laevidentalina granti*; Ali, pl. 6, fig. 7.

2005 *Chrysalogonium granti*; Sztrákos, p. 184, pl. 12, figs. 24, 25.

Plummer (1927) noted that a concise description that covers completely the range of the variations of her species is difficult to compose. Some other authors related this species to the genus *Laevidentalina*, which is followed here, due to very long, arcuate, cylindrical and smooth test with elongated chambers and apiculate rounded proloculus. It seems that the Middle-Late Eocene *Laevidentalina salimi* of Anan (2009) from UAE is most probably the

youngest form of Maastrichtian-Paleocene *L. granti*. The *Laevidentalina granti* was originally recorded from USA, and later from Egypt (Ali, 2003) and France (Sztrákos, 2005).

Table 1) Paleogeographic distribution of the Paleocene foraminiferal taxa of Plummer in the Tethys: ***1.*** *USA & Caribbean Sea,* ***2.*** *Europe (North Sea Basin, France, Spain, Italy, Czech Republic, Bulgaria),* ***3.*** *N. Africa (Tunisia, Libya, Egypt),* ***4.*** *W. Africa (Gulf of Guinea, Ivory Coast),* ***5.*** *W. Asia (Turkey, Jordan, Saudi Arabia, UAE, Iran),* ***6.*** *Central Asia (Pakistan),* ***7.*** *East Asia (New Zealand and Japan),* ***8.*** *South America (Brasil, Argentina).*

Sp. No	Benthic foraminiferal species of Plummer (1927)		Tethyan localities							
			1	2	3	4	5	6	7	8
1	*Spiroplectinella*	*expansa*	x				x			
2	*Dentalina*	*pseudoobliquestriata*	x							
3	*Laevidentalina*	*granti*	x	x	x		x			
4	*Lenticulina*	*degolyeri*	x		x			x		x
5		*midwayensis*	x		x		x	x		x
6		*navarroensis*	x	x					x	
7		*pseudocostata*	x	x	x		x			
8		*pseudomamilligera*	x	x	x		x			x
9		*turbinata*	x	x	x	x	x	x		x
10	*Percultazonaria*	*tuberculata*	x	x	x		x			
11	*Saracenaria*	*sublatifrons*	x							
12		*trigonata*	x							
13	*Neoflabellina*	*delicatissima*	x		x		x			
14	*Marginulina*	*gardnerae*	x		x					
15	*Vaginulinopsis*	*earlandi*	x		x					
16		*longiformis*	x		x					
17	*Citharina*	*plumoides*	x	x	x				x	
18	*Vaginulina*	*cretacea*	x		x		x			
19		*robusta*	x							
20	*Polymorphina*	*cushmani*	x							
21	*Ceratobulimina*	*perplexa*	x	x						x
22	*Lamarckina*	*rugulosa*	x							
23	*Orthokarstenia*	*applinae*	x	x	x	x	x	x		x
24		*eleganta*	x	x	x		x			
25	*Praeglobobulimina*	*quadrata*	x	x		x	x			
26	*Ellipsopolymorphin*	*attenuata*	x	x						
27	*Eponides*	*elevatus*	x	x	x					
28	*Discorbis*	*infrequens*	x							
29		*newmanae*	x				x			
30	*Pulsiphonia*	*prima*	x	x	x		x			
31	*Cibicidoides*	*alleni*	x	x	x		x	x		
32		*vulgaris*	x	x	x		x			
33	*Asterigerina*	*primaria*	x		x					
34	*Allomorphina*	*globulosa*	x	x						
35	*Alabamina*	*limbata*	x	x	x					
36	*Anomalinoides*	*acuta*	x	x	x		x	x		
37		*midwayensis*	x	x	x					
38		*trochoidea*	x							
39		*welleri*	x		x				x	x
40	*Gyroidinoides*	*subangulata*	x	x	x		x			
41		*aequilateralis*	x		x					
42	*Coleites*	*reticulosus*	x	x	x			x		

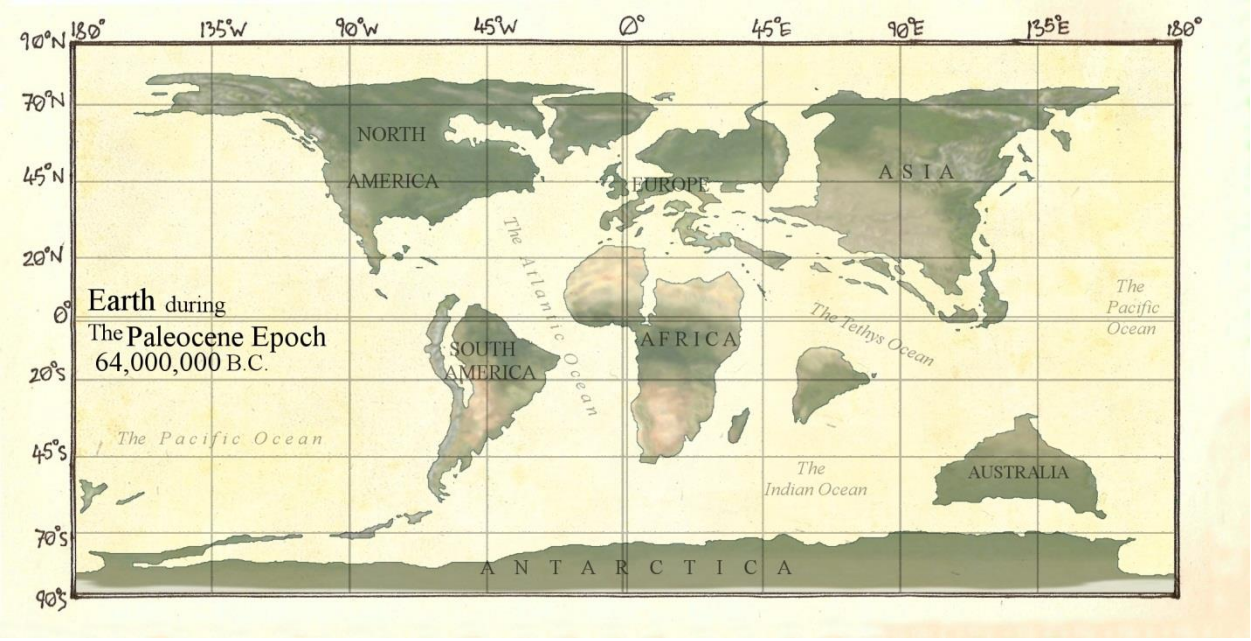

Figure 1) Paleogeographic distribution of the different oceans (Pacific, Atlantic, Tethys and Indian) in the Paleocene.

Family **Vaginulinidae** Reuss, 186

Subfamily Lenticulininae Chapman, Parr and Collins, 1934

Genus *Lenticulina* Lamarck, 1804

Type species *Lenticulites rotulatus* Lamarck, 1804

Lenticulina degolyeri (Plummer, 1927)

(Fig. 6.4)

1927 *Cristellaria degolyeri* Plummer, p. 97, pl. 7, fig. 7.

1956 *Lenticulina degolyeri*; Haque, p. 64, pl. 28, fig. 5.

1975 *Lenticulina degolyeri*; Aubert and Berggren, p. 414, pl. 2, fig. 14.

This Paleocene species was originally recorded from USA, and later from Pakistan (Haque, 1956), Tunisia (Aubert and Berggren,1976) and Jordan (Basha, 2005).

Lenticulina midwayensis (Plummer, 1927) (Fig. 6.5)

1927 *Cristellaria midwayensis* Plummer, p. 95, pl. 13, fig. 5; pl. 15, fig. 3.

1956 *Robulus midwayensis*; Haque, p. 68, pl. 19, fig. 13; pl. 28, fig. 1.

1976 *Lenticulina midwayensis*; Aubert and Berggren, p. 414, pl. 2, fig. 16.

2015b *Lenticulina midwayensis*; Anan, p. 77.

This Maastrichtian-Paleocene cosmopolitan species was recorded in many sites in the Tethys: USA, Pakistan (Haque, 1956), Egypt (Nakkady, 1959; El-Dawy, 2001), Tunisia

(Aubert and Berggren, 1976), South America (Dailey, 1983) and UAE (Anan, 1993b, 2015b).

Lenticulina navarroensis (Plummer, 1927) (fig. 6.6)

1927 *Cristellaria navarroensis* Plummer, p. 40, text-fig. 4; Plummer, 1931, p. 141.

1946 *Robulus navarroensis*; Cushman, p. 51, pl. 16, figs. 6-8.

1971 *Lenticulina (Lenticulina) navarroana*; Webb, p. 807.

2002 *Lenticulina navarroensis*; Alegret *et al*., p. 331, fig. 2.5 -, p. 185, pl. 13, fig. 47.

2005 *Lenticulina navarroensis*; Sztrákos, p. 185, pl. 13, fig. 47.

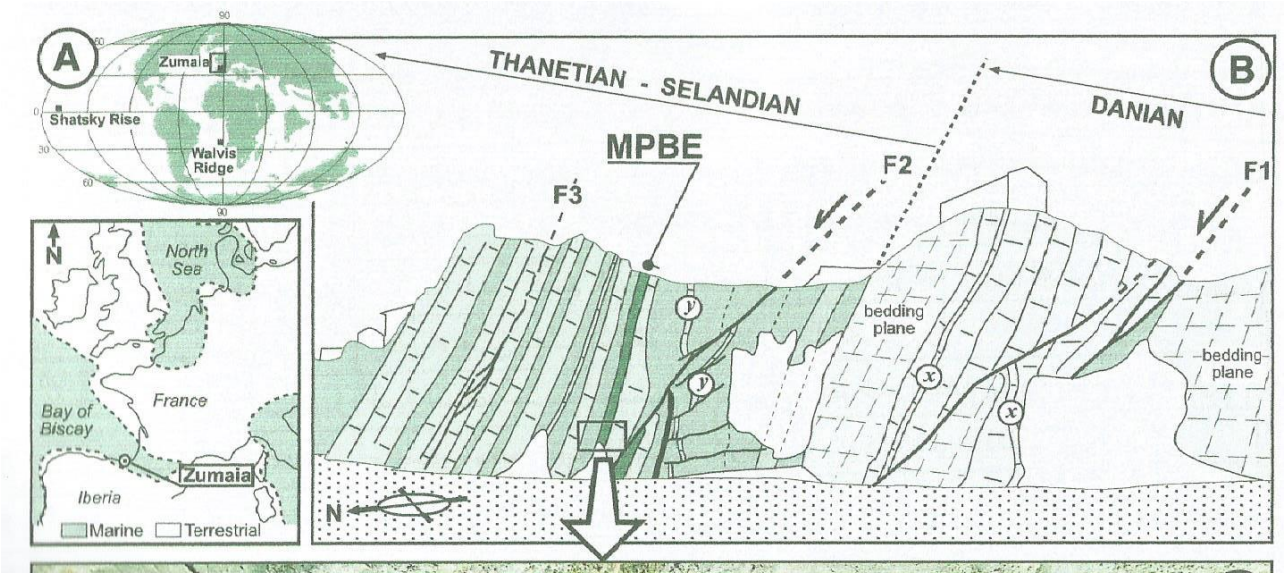

Figure 2A) Global map showing early Paleogene paleogeography and location of Zumaia section. B) Synthetic sketch of the mid-Paleocene outcrop of Zumaia section.

This Paleocene species was recorded from USA, New Zealand (Webb, 1971), Mexico (Alegret *et al*., 2002), and France (Sztrákos, 2005).

Lenticulina pseudocostata (Plummer, 1927) (Fig. 6.7)

1927 *Cristellaria pseudo-costata* Plummer, p. 98, pl. 7, fig. 9.

1956 *Robulus pseudocostata*; Said and Kenawy, p. 130, pl. 2, fig. 13.

2000 *Lenticulina pseudocostata*; Sztrákos, p. 160.

This species was recorded from the Paleocene of USA and Egypt (Said and Kenawy, 1956), but Early-Middle Eocene of France (Sztrákos, 2000).

Lenticulina pseudomamilligera (Plummer, 1927) (Fig. 6.8)

1927 *Cristellaria pseudo-mamilligera* Plummer, p. 98, pl. 7, fig. 11.

1956 *Robulus pseudo-mamilligera*; Haque, p. 64, pl. 28, fig. 3.

1975 *Lenticulina pseudomamilligera*; Berggren and Aubert, p. 143, pl. 16, fig. 8.

2015b *Lenticulina pseudomamilligera*; Anan, p.77.

This Paleocene species was recorded from USA, Pakistan (Haque, 1956), Tunisia (Berggren and Aubert, 1975), Egypt (Luger, 1985), UAE (Anan, 1993a, 2015b) and France (Sztrákos, 2000).

Lenticulina turbinata (Plummer, 1927)(Fig. 6.9)

1927 *Cristellaria turbinata* Plummer, p. 93, pl. 7, fig. 4.

1956 *Robulus turbinatus*; Haque, p. 65, pl.29, fig. 8.

1976 *Lenticulina turbinata*; Aubert and Berggren, p. 415, pl. 3, fig. 4.

2015b *Lenticulina turbinata*; Anan, p.77.

This Paleocene-Eocene species has been widely reported in many Tethyan localities: USA, Pakistan (Haque, 1956), Egypt (Said and Kenawy,1956), Tunisia (Aubert and Berggren, 1975), UAE (Anan, 1994, 2015b), Spain (Ortiz and Thomas, 2006) and Iran (VahdatiRad *et al.*, 2016).

Genus *Percultazonaria* Loeblich & Tappan, 1986

Type species *Cristellaria subaculeata* Cushman, 1923

Percultazonaria tuberculata (Plummer, 1927) (Fig. 6.10)

1927 *Cristellaria subaculeata* var. *tuberculata* Plummer, p. 101, pl. 7, fig. 2, pl. 14, fig. 1.

1975 *Marginulinopsis tuberculata*; Berggren and Aubert, p. 127, fig. 5.

1980 *Marginulinopsis* sp. 1.; Barr and Berggren, p. 187, pl. 3, fig. 6.

2015a *Percultazonaria tuberculata*; Anan, p. 22, pl. 2, fig. 14.

Plummer (1927) noted that her variety tuberculata is strictly an upper Midway species and partially similar forms are very common in Tertiary formations in Europe and everywhere. The P. tuberculata is distinguished by its compressed elongate test, first six-seven plano-spiral with medium size followed by a linear succession of compacted 6-7 chambers. Sutures are marked by rows of distinct beadlike tubercles best developed on the coiled portion of the test and giving place to more ridgelike elevations between later chambers or even to depressions in extreme maturity forms with protruding radiate aperture. For that, the Paleocene-Early Eocene Plummer's Cristellaria subaculeata var. tuberculata is treated here to belong the genus Percultazonaria. A long list of a recorded forms have been misused by some others (i.e., Said and Kenawy, 1956; Luger, 1985; Anan and Hewaidy, 1986; Hewaidy, 1987; Anan, 1994; Hewaidy and Strougo, 2001; Helal, 2002; Ali, 2003; Ismail, 2012) because most of these illustrated forms have lacking a rectilinear uncoiled chambers after the coiling stage. P. tuberculata was recorded from USA, Tunisia (Berggren and Aubert, 1975), Libya (Barr and Berggren, 1980), UAE (Anan, 1993a, 2015b) and Egypt (Anan, 2015a).

Genus *Saracenaria* Defrance, 1824

Type species *Saracenaria italica* Defrance, 1824

Saracenaria sublatifrons (Plummer, 1927) (Fig. 6.11)

1927 *Cristellaria sublatifrons* Plummer, p. 98, pl. 7, fig. 6.

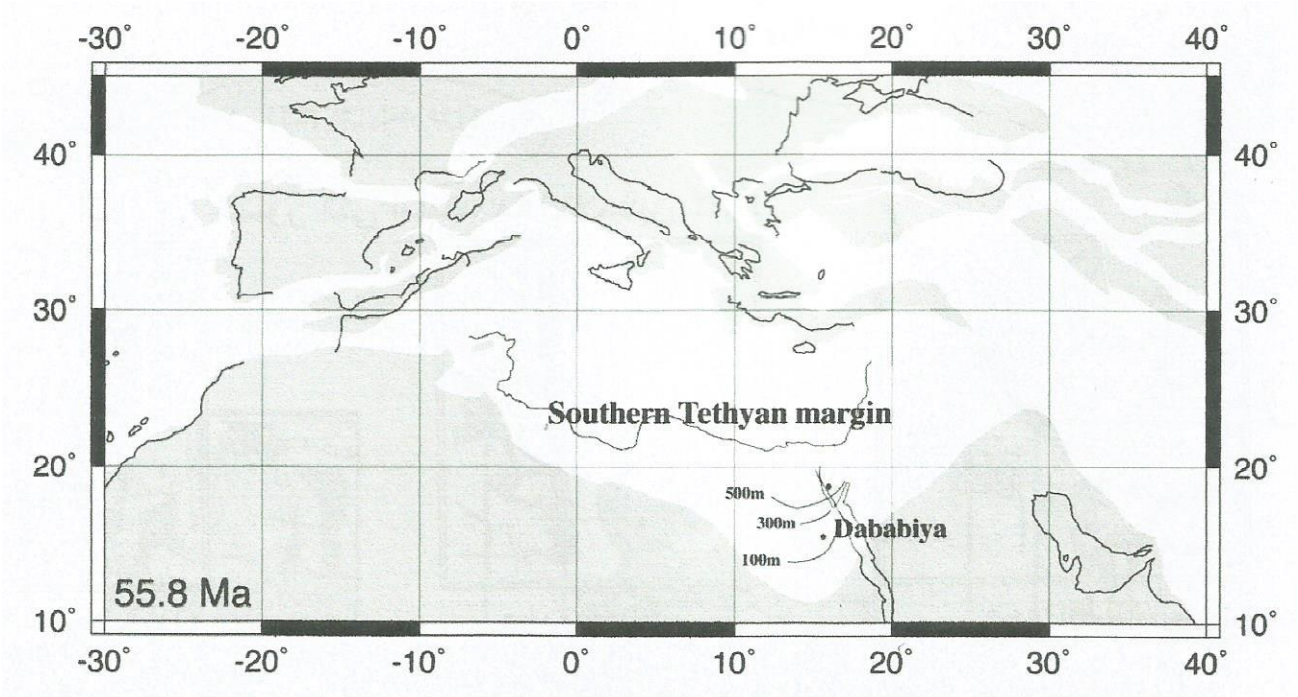

Figure 3) Paleogeography of Dababiya Quarry section, Egypt (after Alegret and Ortiz, 2006/2007).

1951 *Saracenaria sublatifrons*; Cushman, p. 27, pl. 7, fig. 27.

This Paleocene species was recorded only, so far, in USA.

Saracenaria trigonata (Plummer, 1927)(Fig. 6.12)

1927 *Cristellaria trigonata* Plummer, 0. 101, pl. 7, fig. 3.

1951 *Saracenaria trigonata*; Cushman, p. 27, pl. 7, figs. 25, 26.

This Paleocene species is, so far, an endemic species to USA.

Subfamily Palmulinae Saidova, 1981

Genus *Neoflabellina* Bartenstein, 1948

Type species *Flabellina rugosa* d'Orbigny, 1840

Neoflabellina delicatissima (Plummer, 1927) (Fig. 6.13)

1927 *Frondicularia delicatissima* Plummer, p. 120, pl. 5, fig. 4.

1975 *Neoflabellina delicatissima*; Berggren and Aubert, p. 158, pl. 1, fig. 10.

2015b *Neoflabellina delicatissima*; Anan, p. 68, pl. 1, fig. 5

This Paleocene species was recorded in USA, Tunisia (Berggren and Aubert, 1975), Egypt (El-Dawy, 2001) and UAE (Anan, 1993a, 2015b).

Genus *Marginulina* d'Orbigny, 1826

Type species *Marginulina raphanus* d'Orbigny, 1826

Marginulina gardnerae Plummer, 1927 (Fig. 6.14)

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

This Paleocene species was recorded, so far, from USA and Tunisia (Aubert and Berggren,1976).

Genus *Vaginulinopsis* Silvestri, 1904

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

Vaginulinopsis earlandi (Plummer, 1927) (Fig. 6.15)

1927 *Cristellaria earlandi* Plummer, p. 103, pl. 7, fig. 10.

1976 *Vaginulinopsis earlandi*; Aubert and Berggren, p. 418, pl. 4, fig. 4.

This Paleocene species was recorded, so far, from USA and Tunisia (Aubert and Berggren,1976).

Vaginulinopsis longiformis (Plummer, 1927) (Fig. 6.16)

1927 *Cristellaria longiforma* Plummer, p. 102, pl. 13, fig. 4.

1946 *Marginulina* sp.; Cushman, p. 64, pl. 22, fig. 25.

1956 *Vaginulina longiformis*; Said and Kenawy, p. 134, pl. 3, fig. 5a.

1976 *Vaginulinopsis longiforma*; Aubert and Berggren, 1976, p. 418, p1. 4, fig. 5.

2015b *Vaginulinopsis longiformis*; Anan, p. 71.

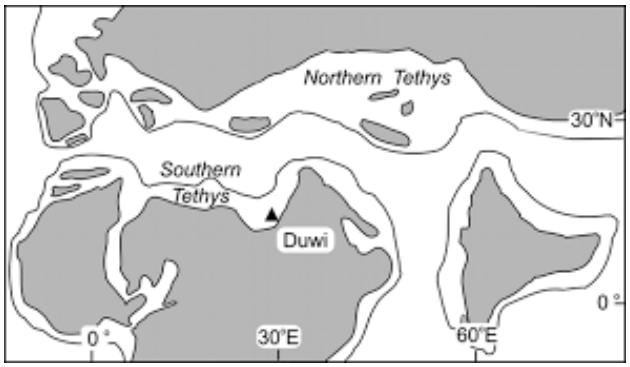

Figure 4) Paleocene Paleogeography distribution of the Northern Tethys and the Southern Tethys throughout the west Africa (extend to Nigeria), which also detected the location of the Gabal Duwi section, Egypt.

It seems that the illustrated forms of Cushman (1946) and Said and Kenawy (1956) are related here to Plummer's *Cristellaria longiformis*. It was recorded in the Paleocene of USA, Mexico and Tunisia (Aubert and Berggren, 1976), France (Sztrákos, 2005), UAE (Anan, 1993a, 2015b), but Maastrichtian-Paleocene of Egypt (Said and Kenawy, 1956).

Subfamily Vaginulininae Reuss, 1860

Genus *Citharina* d'Orbigny, 1839

Type species *Vaginulina (Citharina) strigillata* Reuss, 1846

Citharina Plummerae Anan, 2001 (Fig. 6.17a)

2001 *Citharina Plummerae* Anan, p. 135, pl. 1, fig. 1.

This Paleocene species is characterized by its wing shaped, flattened, very thin, elongate and narrow width, raised with numerous regular spaced longitudinal distinct striae parallel to the direction of growth, aperture protruding at dorsal angle. It was recorded from the Paleocene of Duwi section, Red Sea cost, Egypt (Fig. 2).

Citharina plumoides (Plummer, 1927)(Fig. 6.17b)

1927 *Vaginulina plumoides* Plummer, p. 113, pl. 6, fig. 6.

1971 *Citharina plumoides*; Webb, p. 809.

2005 *Citharina plumoides*; Sztrákos, p. 186, pl. 14, fig. 30.

The Paleocene Plummer's *Vaginulina plumoides* was recorded from USA, New Zealand (Webb, 1971), Tunisia (Berggren and Aubert, 1975), Egypt (Ali, 2003), France (Sztrákos, 2005) and North Sea (Clemmensen and Thomsen, 2005).

Genus *Vaginulina* d'Orbigny, 1826

Type specie *Nautilus legumen* Linné

Vaginulina cretacea Plummer, 1927 (Fig. 6.18)

1927 *Vaginulina gracilis cretacea* Plummer, p. 172, pl. 2, fig. 8.

1946 *Vaginulina cretacea*; Cushman, p. 8, pl. 30, figs. 11-14.

1985 *Vaginulina cretacea*; Luger, p. 85, pl. 6, fig. 10.

This Maastrichtian-Paleocene species was recorded in USA, Egypt (Luger, 1985) and Jordan (Futyan, 1976).

Vaginulina robusta Plummer, 1927 (Fig. 6.19)

1927 *Vaginulina robusta* Plummer, p. 112, pl. 6, fig. 4.

This Paleocene species is, so far, an endemic species to USA.

Family **Polymorphinidae** d'Orbigny, 1839

Subfamily Polymorphininae d'Orbigny, 1839

Genus *Polymorphina* d'Orbigny, 1826

Type species *Polymorphina burdigalensis* d'Orbigny, 1826

Polymorphina cushmani Plummer, 1927 (Fig. 6.20)

1927 *Polymorphina cushmani* Plummer, p. 125, pl. 6, fig. 9, pl. 15, fig. 1.

This Paleocene species is, so far, an endemic species to USA.

Suborder Robertinina Loeblich and Tappan, 1984

Superfamily Ceratobuliminacea Cushman, 1927

Family **Ceratobuliminidae** Cushman, 1927

Subfamily Ceratobulimininae Cushman, 1927

Genus *Ceratobulimina* Toula, 1915

Type species *Rotalia contraria* Reuss, 1851

Ceratobulimina perplexa (Plummer, 1927) (Fig. 6.21)

1927 Rotalia *perplexa* Plummer, , p. 156, pl. 12, fig. 2.

1948 *Ceratobulimina perplexa*; Brotzen, p.123, pl.19, fig.1.

This Paleocene species was recorded in USA, Sweden (Brotzen, 1948) and South America (Dailey,1983).

Genus *Lamarckina* Berthelin, 1881

Type species *Pulvinulina erinacea* Karrer, 1868

Lamarckina rugulosa Plummer, 1927 (Fig. 6.22)

1927 *Lamarckina rugulosa* Plummer, p. 140, pl. 9, fig. 3.

This Paleocene-Early Eocene species was recorded in USA and central North Pacific (Ferrer, 1975).

Suborder Rotaliina Delage and Hérouard, 1896

Superfamily Buliminacea Jones, 1875

Family **Siphogenerinoididae** Saidova, 1981

Subfamily Siphogenerinoidinae Saidova, 1981

Genus *Orthokarstenia* Dietrich, 1935

Orthokarstenia applinae (Plummer, 1927) (Fig. 6.23)

1927 *Bolivina applini* Plummer, p. 69, pl. 4, fig. 1.

1956 *Loxostomum applinae*; Haque, p. 134, pl. 15, figs. 24, 25.

1976 *Loxostomoides applinae*; Aubert and Berggren, p. 420, pl. 4, fig. 11.

1989 *Siphogerinoides eleganta* (Plummer); Hulsbos *et al*., p. 273, pl. 3, fig. 5.

1998 *Orthokarstenia applinae*; Anan, p. 371, fig. 3.3.

2016 *Loxostomoides applini*; VahdatiRad *et al*., p. 677, pl. 2, fig. 14.

This species is cited as *Loxostomoides applinae* by most authors, because it was named after Applin, she was female, giving the feminine genitive form *applinae* rather than the masculine form *applini*. The original author Plummer, however, called the species *B. applini*, and this grammatically incorrect name thus must be maintained. Plummer (1927) noted that the initial part of her species *applinae* is obscure, but she added that the chambers of the species are smooth, except for distinct striae extending from the initial extremity upward over several early chambers. The main characteristics of this species are the crenulations of sutures between the chambers, and the longitudinal somewhat discontinuous striae. Moreover, the taxonomic status of *O. applinae* was also used by Hewaidy (1997) and Ismail (2012). Anan and Sharabi (1988) noted that the genus *Orthokarstenia* is recorded only in the central and southern Egypt (Nile Valley Facies, NVF, of Issawi, 1972). Later on, Hewaidy (1997) named this area as '*Orthokarstenia* province'. Anan (1998) regarded *applinae* to the genus *Orthokarstenia* due to its triserial initial part that becomes biserial to uniserial final chambers. Moreover, Anan (1998) believes that the Paleocene-Early Eocene *O. applinae* have been evolved from the Maastrichtian *O. oveyi* of Nakkady (1950), and it has been considered a guide species from the Paleocene-Early Eocene boundary. On the other hand, Koutsoukos and Klasz (2000) considered the Nakkady's *oveyi* as a junior synonym of the *Orthokarstenia parva* (Cushman). It seems that the illustrated form *Siphogerinoides eleganta* of Hulsbos *et al*., (1989) is closely related to *O. applinae*. This cosmopolitan species has been widely reported in the Tethys: USA, Sweden (Brotzen, 1948), Pakistan (Haque, 1956), Tunisia (Aubert and Berggren, 1976), Jordan

(Futyan, 1976), Gulf of Guinea (Brun *et al*., 1984), Egypt (Luger, 1985), Norwegian Sea (Hulsbos *et al*., 1989), UAE (Anan, 1993a), Trinidad (Bolli *et al*., 1994), Ivory Coast (N'da *et al*., 1995), Spain (Ortiz and Thomas, 2006) and Iran (VahdatiRad *et al*., 2016).

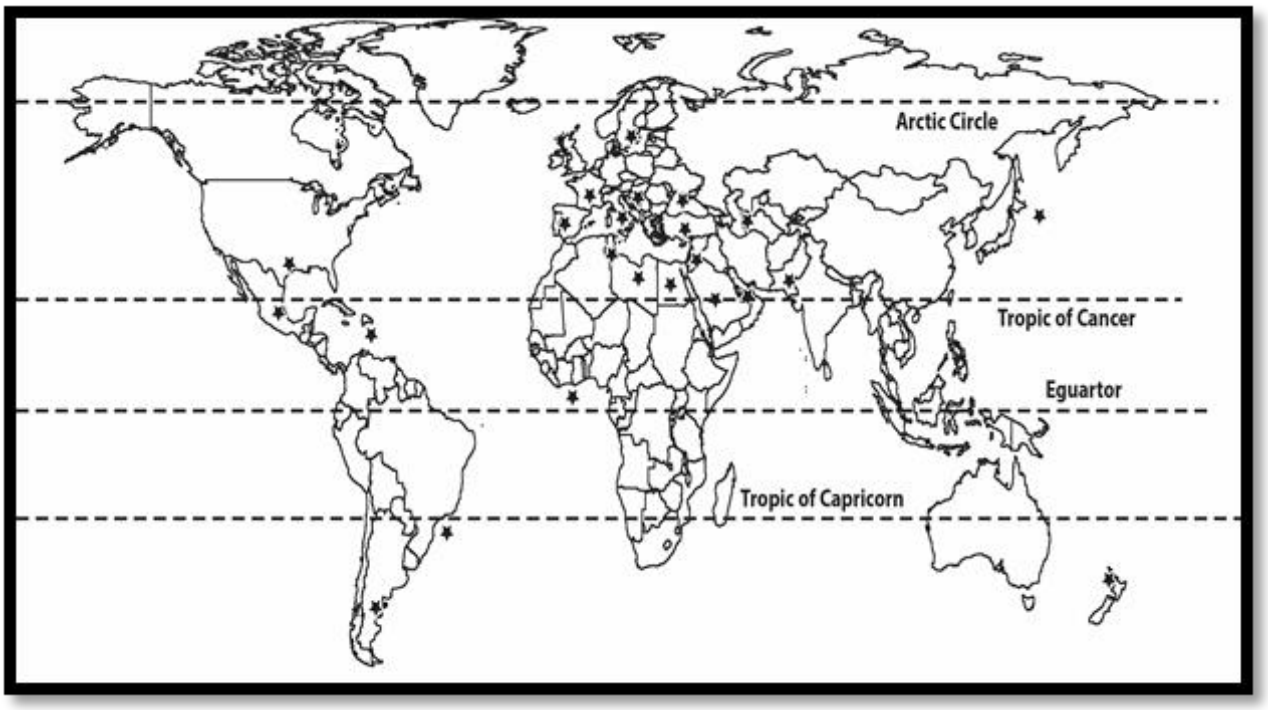

Figure 5) Paleogeographic map of the recorded species of Plummer (1927) in different localities (stars) in the world.

Orthokarstenia eleganta (Plummer, 1927) (Fig. 6.24)

1927 *Siphogenerina eleganta* Plummer, p. 126, pl. 8, fig. 1.

1953 *Siphogenerinoides eleganta*; LeRoy, p. 49, pl. 2, figs. 20, 21.

1998 *Orthokarstenia eleganta*; Anan, p. 372, fig. 3.6.

2014 *Orthokarstenia eleganta*; Anan, p. 67, pl. 1, fig. 5.

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

Family **Buliminidae** Jones, 1875

Genus *Praeglobobulimina* Hofker, 1951

Type species *Bulimina pyrula* d'Orbigny var. *spinescens* Brady, 1884.

Praeglobobulimina quadrata (Plummer, 1927) (Fig. 6.25)

1927 *Bulimina quadrata* Plummer, p. 72, pl. 4, figs. 4, 5.

2002 *Bulimina quadrata*; Samir, p. 28, pl. 3, fig. 10.

2005 *Praeglobobulimina quadrata*; Sztrákos, p. 188, pl. 7, fig. 5.

This Maastrichtian-Paleocene species was recorded in USA, Tunisia (Aubert and Berggren, 1976), Egypt (Luger, 1985; Samir, 2002), UAE (Anan, 1993b) and France (Sztrákos, 2005).

Superfamily Pleurostomellacea Reuss, 1860

Family **Pleurostomellidae** Reuss, 1860

Subfamily Pleurostomellinae Reuss, 1860

Genus *Ellipsopolymorphina* Silvestri, 1901

Type species *Dimorphina deformis* (Costa) Fornasini, 1890

Ellipsopolymorphina attenuata (Plummer, 1927) (Fig. 6.26)

1927 *Ellipsopleurostomella attenuata* Plummer, p. 131, pl. 8, fig. 6.

1951 *Nodosarella attenuata*; Cushman, p. 45, pl. 12, figs. 34-37.

1982 *Nodosarella* cf. *attenuata*; Proto Decima and Bolli, p. 118.

2005 *Ellipsopolymorphina attenuata*; Sztrákos, p. 188, pl. 15, fig. 18.

This Paleocene species was recorded in USA, Italy (Proto Decima and Bolli, 1982) and France (Sztrákos, 2005).

Family **Eponididae** Hofker, 1951

Subfamily Eponidinae Hofker, 1951

Genus *Eponides* de Montfort, 1808

Type species *Nautilus repandus* Fichtel and Moll, 1798

Eponides elevatus (Plummer, 1927) (Fig. 6.27)

1927 *Truncatolina elevata* Plummer, p. 142, pl. 11, fig. 1.

1951 *Eponides elevatus*; Cushman, p. 52, pl. 14, figs.18,19.

2000 *Eponides elevatus*; Sztrákos, 168, pl. 5, fig. 24, pl. 14, fig. 9.

This Paleocene species was recorded in USA, Tunisia (Saint-Marc and Berggren, 1988) and France (Sztrákos, 2000). Kouwenhoven *et al.* (1997) considered it representative of Midway Fauna (MF), middle neritic environment.

Family **Discorbidae** Ehrenberg, 1838

Genus *Discorbis* Lamarck, 1804

Type species *Discorbis vesicularis* Lamarck, 1804

Discorbis infrequens Plummer, 1927 (Fig. 6.28)

1927 *Discorbis infrequens* Plummer, p. 138, pl. 9, fig. 1.

This Paleocene species is, so far, an endemic species to USA.

Discorbis newmanae Plummer, 1927 (Fig. 6.29)

1927 *Discorbis newmanae* Plummer, p. 138, pl. 9, fig. 4.

This Paleocene species was recorded, so far, in USA and UAE (Anan, 1993a).

Superfamily Siphoninacea Cushman, 1927

Family **Siphoninidae** Cushman, 1927

Subfamily Siphonininae Cushman, 1927

Genus *Pulsiphonina* Brotzen, 1948

Type species *Siphonina prima* Plummer, 1927

Pulsiphonina prima (Plummer, 1927)(Fig. 6.30)

1927 *Siphonina prima* Plummer, p.148, pl.12, fig. 4 - Cushman,1951, p. 55, pl.15, figs. 7-9.

1972 *Pulsiphonia prima*; Berggren, p. 986, pl. 6, figs. 7-9.

This Paleocene species was recorded in USA, Jordan (Futyan, 1976), Tunisia (Speijer and Van Der Zwaan, 1994), North Sea Basin (Clemmensen and Thomsen, 2005) and Egypt (Ernst *et al.*, 2006).

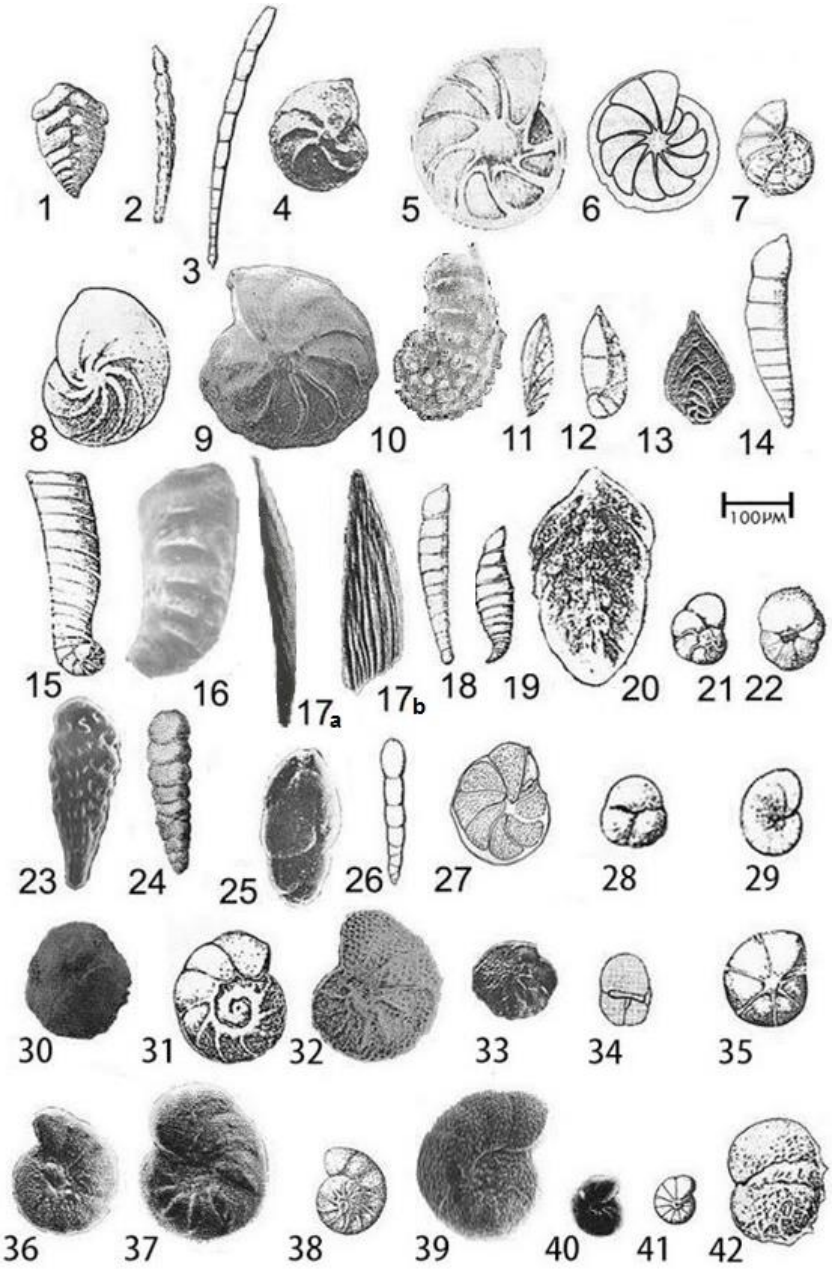

Figure 6) (Illustrations of the 42 Paleocene species of Plummer, 1927; approximately x 50. **1**: *Spiroplectinella expansa*, **2**: *Dentalina pseudoobliquestriata*, **3**: *Laevidentalina granti*, **4**: *Lenticulina degolyeri* (after Aubert & Berggren, 1976), **5**: *L. midwayensis* (after Nakkady, 1959), **6**: *L. navarroensis*, **7**: *L. pseudocostata*, **8**: *L. pseudomamilligera*, **9**: *L. turbinata*, **10**: *Percultazonaria tuberculata*, **11**: *Saracenaria sublatifrons*, **12**: *S. trigonata*, **13**: *Neoflabellina delicatissima* (after Berggren & Aubert, 1975), **14**: *Marginulina gardnerae*, **15**: *Vaginulinopsis earlandi*, **16**: *V. longiformis* (after Ismail, 2012), **17a**: *Citharina plummerae* Anan (2001), **17b**: *C. plumoides* (after Berggren & Aubert, 1975), **18**: *Vaginulina cretacea*, **19**: *V. robusta*, **20**: *Polymorphina cushmani*, **21**: *Ceratobulimina perplexa*, **22**: *Lamarckina rugulosa*, **23**: *Orthokarstenia applinae* (after Luger, 1985), **24**: *O. eleganta* (after LeRoy, 1953), **25**: *Praeglobobulimina quadrata* (after Luger, 1985), **26**: *Ellipsopolymorphina attenuata*, **27**: *Eponides elevatus*, **28**: *Discorbis infrequens*, **29**: *D. newmanae*, **30**: *Pulsiphonia prima* (after Speijer & Zwaan, 1994), **31**:*Cibicidoides alleni*, **32**: *C. vulgaris* (after Anan & Sharabi, 1988), **33**: *Asterigerina primaria* (after Berggren & Aubert, 1975), **34**: *Allomorphina globulosa*, **35**: *Alabamina limbata*, **36**: *Anomalinoides acuta*, **37**: *A. midwayensis* (after Berggren & Aubert, 1975), **38**: *A. trochoidea*, **39**: *A. welleri* (El-Dawy, 2001), **40**: *Gyroidenoides subangulata* (after Berggren & Aubert, 1975), **41**: *G. aequilateralis*, **42**: *Coleites reticulosus*.

Superfamily Discorbinellacea Sigal, 1952

Family **Parrelloididae** Hofker, 1956

Genus *Cibicidoides* Thalmann, 1939

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

Cibicidoides alleni (Plummer, 1927) (Fig. 6.31)

1927 *Truncatolina alleni* Plummer, 1927, p. 144, pl. 10, fig. 4.

1956 *Cibicides alleni*; Haque, p. 207, pl. 16, fig. 1.

1974a *Cibicidoides alleni*; Berggren, p. 446, pl. 5, figs. 1-5.

1975 *Cibicidoides alleni*; Berggren and Aubert, p. 151, pl. 5, fig. 1, pl. 7, figs. 1-3.

2001 *Cibicidoides alleni*; El-Dawy, p. 45, pl. 2, fig. 16.

This species was recorded in USA, Pakistan (Haque, 1956), North Atlantic (Berggren, 1974a), Tunisia (Berggren & Aubert, 1976), Egypt (Luger, 1985, El-Dawy, 2001), UAE (Anan, 1993a), Argentina (Malumiàn and Caramés, 1997), France (Sztrákos, 2000) and North Sea (Clemmensen and Thomsen, 2005).

Cibicidoides vulgaris (Plummer, 1927)(Fig. 6.32)

1927 *Truncatolina vulgaris* Plummer, p. 146, pl. 10, fig. 3.

1951 *Cibicides vulgaris;* Cushman, p. 66, pl. 19, figs. 7-11.

1975 *Cibicidoides vulgaris*; Berggren and Aubert, p. 154, pl. 9, fig. 6.

2003 *Cibicidoides vulgaris*; Ali, pl. 9, figs. 20-24.

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

Superfamily Asterigerinacea d'Orbigny, 1839

Family **Asterigerinidae** d'Orbigny, 1839

Genus *Asterigerina* d'Orbigny, 1839

Type species *Asterigerina carinata* d'Orbigny, 1839

Asterigerina primaria Plummer, 1927 (Fig. 5.33)

Asterigerina primaria Plummer, 1927, p.157, pl. 12, fig. 8.

This Paleocene species was recorded, so far, in USA and Tunisia (Berggren and Aubert, 1975).

Superfamily Chilostomellacea Brady, 1881

Family **Chilostomellidae** Brady, 1881

Subfamily Chilostomellinae Brady, 1881

Genus *Allomorphina* Reuss, 1849

Type species *Allomorphina trigona* Reuss, 1849

Allomorphina globulosa Plummer, 1927 (Fig. 6.34)

1927 *Allomorphina globulosa* Plummer, p. 130, pl. 8, fig. 4.

2005 *Allomorphina globulosa*; Sztrákos, p. 189, pl. 16, fig. 12.

This Paleocene species was recorded, so far, in USA and France (Sztrákos, 2005).

Superfamily Chilostomellacea Brady, 1881

Family **Alabaminidae** Hofker, 1951

Genus *Alabamina* Toulmin, 1941

Type species *Alabamina wilcoxensis* Toulmin, 1941

Alabamina limbata (Plummer, 1927) (Fig. 6.35)

1927 *Pulvinulina exigua* Brady var. *limbata* Plummer, p. 152, pl. 11, fig. 4.

1972 *Alabamina limbata*; Hanzlíková, p. 125, pl. 36, fig. 9.

This Maastrichtian-Paleocene species was recorded in USA, Czech Republic (Hanzlíková, 1972) and Egypt (Ernst *et al.*, 2006).

Family **Heterolepidae** Gonzáles-Donoso, 1969

Genus *Anomalinoides* Brotzen, 1942

Type species *Anomalinoides plummerae* Brotzen, 1942

Anomalinoides acuta (Plummer, 1927) (Fig. 6.36)

1927 *Truncatolina ammonoides acuta* Plummer, p. 142, pl. 10, fig. 2.

1948 *Anomalinoides acuta*; Brotzen, p. 87, pl. 14, fig. 2.

1951 *Anomalina acuta*; Cushman, p. 62, pl. 18, figs. 3-6.

1974a *Anomalinoides acutus*; Berggren, p. 442, pl. 3, fig. 12.

2005 *Gavelinella acuta*; Sztrákos, p. 189, pl. 10, fig. 19.

2016 *Anomalinoides acutus*; VahdatiRad *et al.*, p. 677, pl. 2, fig. 2.

Berggren and Aubert (1975) considered this species represents the Midway Fauna, but it is distributed in the neritic-upper bathyal environment by Alegret and Thomas (2005). This species was recorded in USA, Pakistan (Haque, 1956), North Atlantic (Berggren, 1974a), Tunisia (Berggren and Aubert, 1975), Egypt (Fahmy, 1975), Italy (Proto Decima and Bolli, 1982), North Sea Basin (Hulsbos *et al.*, 1989), UAE (Anan, 1993a), Argentina (Malumiàn and Caramés, 1997), Egypt (El-Dawy, 2001), France (Sztrákos, 2005), Spain (Ortiz and Thomas, 2006) and Iran (VahdatiRad *et al.*, 2016).

Anomalinoides midwayensis (Plummer, 1927) (Fig. 6.37)

1927 *Truncatolina midwayensis* Plummer, p. 141, pl. 9, fig. 7.

1948 *Anomalinoides midwayensis*; Brotzen, p. 88, pl. 14, figs. 3, 4.

2002 *Anomalinoides midwayensis*; Samir, p. 28, pl. 3, fig. 17.

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

Anomalinoides trochoidea (Plummer, 1927) (Fig. 6.38)

1927 *Anomalinoides midwayensis trochoidea* Plummer, p. 142, pl. 9, fig. 8.

Plummer (1927) noted that her subspecies *Anomalinoides midwayensis trochoidea* has more strongly trochoid dorsal coiling of the convolutions. It is, so far, an endemic to USA.

Anomalinoides welleri (Plummer, 1927) (Fig. 6.39)

1927 *Truncatolina welleri* Plummer, p. 143, pl. 9, fig. 6.

1951 *Anomalina welleri*; Cushman, p. 63, pl. 18, figs. 12.

1974a *Anomalinoides welleri*; Berggren, p. 442, pl. 3, figs. 1o, 11.

1975 *Anomalinoides welleri*; Berggren and Aubert, p. 151, pl. 5, fig. 3.

2001 *Anomalinoides welleri*; El-Dawy, p. 46, pl. 3, fig. 9.

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

Family **Gavelinellidae** Hofker, 1956

Subfamily Gyroidinoidinae Saidova, 1981

Genus *Gyroidinoides* Brotzen, 1942

Type species *Rotalia nitida* Reuss, 1844

Gyroidinoides subangulata (Plummer, 1927) (Fig. 6.40)

1927 *Rotalia soldanii subangulata* Plummer, p. 154, pl. 12, fig. 1.

1953 *Gyroidina subangulata*; LeRoy, p. 35, pl. 3, figs. 23-25.

1975 *Gyroidinoides subangulata*; Berggren and Aubert, p. 148, pl. 3, fig. 2.

2003 *Gyroidinoides subangulata*; Ali, p. 120, pl. 11, figs. 1-3.

This Paleocene species was recorded in USA, Egypt (LeRoy, 1953; Ali, 2003), Rockall Bank, North Atlantic (Berggren, 1974a), Tunisia (Berggren and Aubert, 1975), UAE (Anan, 1993b), Egypt (El-Dawy, 2001), North Sea Basin (Clemmensen and Thomsen, 2005) and France (Sztrákos, 2005).

Gyroidinoides aequilateralis (Plummer, 1927) (Fig. 6.41)

1927 *Rotalia aequilateralis* Plummer, p. 155, pl. 12, fig. 3.

1997 *Gyroidinoides aequilateralis*; Kouwenhoven *et al.*, p. 124.

This Paleocene species was recorded, so far, in USA and Tunisia (Kouwenhoven *et al.*, 1997).

Family **Coleitidae** Loeblich and Tappan, 1984

Genus *Coleites* Plummer, 1934

Type species *Pulvinulina reticulosa* Plummer, 1927

Coleites reticulosa (Plummer, 1927) (Fig. 6.42)

1927 *Pulvinulina reticulosa* Plummer, p. 152, pl. 12, fig. 5.

1951 *Coleites reticulosus*; Cushman, p. 54, pl. 15, figs. 1-5.

2005 *Coleites reticulosus*; Sztrákos, p. 189, pl. 10, fig. 6.

This Paleocene-Early Eocene species was recorded in USA, Sweden (Brotzen, 1948), Pakistan (Haque, 1956), Poland (Kozlowski, 1974), Tunisia (Aubert and Berggren, 1976) and France (Sztrákos, 2005).

4- Paleogeography

Table 1 shows the forty two Paleocene benthic foraminiferal species of Plummer from the Midway Formation of the Gulf Coastal Plain of Texas, USA and its paleogeographic distribution in some other countries in the Tethyan province: North America (Mexico), South America (Argentina), Europe (North Sea Basin, Spain, France, Italy, Czech, Bulgaria), North Africa (Tunisia, Libya, Egypt), West Africa (Ivory Coast, Gulf of Guinea), West Asia (Turkey, Jordan, Saudi Arabia, UAE, Iran), Central Asia (Pakistan) and East Asia (Japan

and New Zealand), and it is also located in Figure 5. Based on that faunal data, the following remarks can be presented:

1- Berggren (1971) suggested that during the Paleogene, the fauna of the Mediterranean and the Indo-Pacific exhibit pronounced similarities which indicate that the connection between these areas was mentioned by a marine seaway. The East Atlantic fauna was much more closely related to fauna of these to localities that it is today. In the western Atlantic a narrow connection between it and Pacific existed.

2- Haq and Aubry (1978) noted that North Africa and the Middle East formed important parts of the Tethys link between the Atlantic Ocean on one side and the western Pacific Ocean on the other in the Early Cenozoic.

3- Haynes and Nwabufo-Ene (1998) noted that the Paleocene foraminiferal fauna in West Africa is of Tethyan aspect and shows very close relations to shelf faunas in North Africa, and also suggest wider Tethyan connections, as far as Pakistan.

4- The Egyptian Paleogene assemblage studied be the present author and others suggest gradual paleogeographical changes from transitional open marine facies in the northern and central Egypt (e.g. Duwi section, Fig. 4) to shallow shelf setting in the south (Luger, 1988). Accordingly, the rarity of this assemblage at the southern Egypt due to a regression phase. The Plummer's new faunal assemblage in Egypt are not completely recorded in many sites in Egypt, which caused by a shallow depths in some parts due to paleorelief (highs and lows of the Syrian Arc System), which mainly strike at the end of the Cretaceous.

5- Eight out of Plummer's new species (about 19%) seems to be confined in USA: *Dentalina pseudoobliquestriata, Saracenaria sublatifrons, Saracenaria trigonata, Vaginulina robusta, Polymorphina cushmani, Lamarckina rugulosa, Discorbis infrequens, Anomalinoides trochoidea.*

6- Eight species out of the forty two recorded taxa of Plummer (about 19 %) are recorded in South America: *Lenticulina degolyeri, L. pseudomamilligera, L. midwayensis, L. turbinata, Ceratobulimina perplexa, Orthokarstenia applinae, Ellipsopolymorphina attenuata* and *Anomalinoides welleri.*

7- Twenty two species out of Plummer (about 52%) are recorded in Europe: *Chrysalogonium granti, Lenticulina navarroensis, Lenticulina pseudocostata, L. pseudomamilligera, L. turbinata, Marginulinopsis tuberculata, Citharina plumoides, Ceratobulimina perplexa, Orthokarstenia applinae, O. eleganta, Praeglobobulimina quadrata, Ellipsopolymorphina attenuata, Eponides elevatus, Alabamina limbata, Coleites reticulosus, Pulsiphonia prima, Cibicidoides alleni, C. vulgaris, Allomorphina globulosa, Anomalinoides acuta, A. midwayensis, Gyroidenoides subangulata.*

8- Twenty eight species (about 67%) are recorded in North Africa: *Chrysalogonium granti, Lenticulina degolyeri, L. midwayensis, L. pseudocostata, L. turbinata, L. pseudomamilligera, Marginulinopsis tuberculata, Marginulina gardnerae, Neoflabellina delicatissima, Vaginulinopsis earlandi, V. longiforma, Citharina plummerae, C. plumoides, Vaginulina cretacea, Orthokarstenia applinae, O. eleganta, Eponides elevatus, Alabamina limbata, Coleites reticulosa, Pulsiphonia prima, Cibicidoides alleni, C. vulgaris, Asterigerina primaria, Anomalinoides acuta, A. midwayensis, A. welleri, Gyroidinoides subangulata* and *G. aequilateralis.*

9- Seventeen Plummer's species (about 40%) are recorded in West Asia: *Spiroplectammina expansa, Chrysalogonium granti, Lenticulina midwayensis, L. pseudomamilligera, L. pseudocostata, L. turbinata, Marginulinopsis tuberculata, Neoflabellina delicatissima, Vaginulina cretacea, Orthokarstenia applinae,*

O. eleganta, Praeglobobulimina quadrata, Discorbis newmanae, Pulsiphonia prima, C. vulgaris, Anomalinoides acuta and *Gyroidinoides subangulata.*

10- Seven species (about 17%) are recorded in Pakistan: *Lenticulina degolyeri, L. midwayensis, L. turbinata, Orthokarstenia applinae, Coleites reticulosus, Cibicidoides alleni* and *Anomalinoides acuta.*

11- Three Plummer's species (about 7%) are recorded in West Africa: *Lenticulina turbinata*, *Orthokarstenia applinae* and *Praeglobobulimina quadrata*.

12- Two species (about 5%) are recorded in New Zealand: *Lenticulina navarroensis* and *Citharina plummerae*.

13- One species (about 2%) are recorded in Japan: *Anomalinoidea welleri*.

Based on the above observations, it emphasizes that the Tethyan Sea extended from Atlantic Ocean in the west to Indo-Pacific Ocean in the east.

5- Paleoecology and Paleoenvironment

1- Berggren (1974b) noted that the Paleocene of Sirte Basin, Libya was deposited in a transgressive sequence of more than of 200 meters, while in Mali in abroad shallow shelf sea at water depth probably less than 50 meters.

2- Proto Decima and Bolli (1982) observed a biomarker differences between the Paleocene benthic foraminiferal assemblages of some sites in the South Atlantic which may indicates that they are apparently not so much the result of the different latitudes (35ºS, 19ºS, 11ºS), but rather of variations in depth and possibly other ecological factors.

3- Kaiho (1988) noted that the extinction of the cosmopolitan fauna occurred in the latest Paleocene probably as the result of the formation of a stagnant bottom water environment.

4- Anan (1993a) noted that the Thanetian sediments in Jabal Malaqet (UAE) consist of radiolarian claystone which deposited in a deep sea Velasco-type.

5- Anan (1993b) concluded that the type of sediments (substrate) is not a fundamental environmental factor plays the control in the distribution of the benthic foraminiferal taxa in Qarn El Barr section (UAE), like the water temperature, light penetration, depth, water column stability, food supply, salinity, dissolved oxygen, etc.

6- Anan (1995) regarded the identified Paleogene species in the Middle East represent tropical-subtropical fauna.

7- Quillévéré *et al.* (2002) noted that the Site 761 (central Indian Ocean) was situated at low latitudes during the Paleocene, its surface waters were predominantly influenced by circulation originating from the Southern Ocean as indicated by inferred cool sea surface temperatures and reduced surface to deep water temperature gradient, and they suggest that deep waters in the eastern Indian Ocean were not directly fed by the Southern or Tethyan Oceans.

8- Meulenkamp and Sissingh (2003) considered the Arabian Platform still largely covered by sea in Paleocene-Middle Eocene was subjected to a major regression in the Middle-Late Eocene time.

9- Aubry *et al.* (2007) noted that in the southern margin in the Tethys and specially including the outer-shelf deposits of northeastern Egypt and the Sinai, the lower part of the Carbon Isotope Excursion (CIE) interval is associated with regional dysoxia, represented by a phosphatic coprolite-rich laminite with abundant fish teeth. They also added that the Midway-type assemblage species are dominant throughout the Dababiya section, although deeper water Velasco-type assemblage species are consistently present.

10- Bernaola *et al.* (2007) noted that the reorganization of the Paleocene foraminiferal ecosystem in Zumaia section possibly involved changes in the food flux (type and quantity) to the seafloor, thus triggering changes in the benthic foraminifera. They also added that the highly divers and heterogeneous benthic foraminiferal assemblages from the Zumaia section indicate well-oxygenated bottom water and mesotrophic conditions at the sea floor.

6- Discussion

The analysis of Paleocene foraminifera from the Midway Formation in Texas, USA is useful in correlating equivalent strata from some other Tethyan localities: North America (Mexico, Caribbean), South America (Argentina), Europe (North Sea Basin, Poland, Spain, France, Italy, Czech Republic, Bulgaria), North Africa (Algeria, Tunisia, Libya, Egypt), West Africa (Ivory Coast, Gulf of Guinea), West Asia (Turkey, Jordan, Saudi Arabia, UAE, Iran), central South Asia (Pakistan) and East Asia (Japan and New Zealand).

So far, 8 out of the 42 recorded taxa of Plummer's species (about 19%) seems to be confined in USA, while other 8 species (about 19 %) are recorded in South America. Twenty-two species (about 52%) are recorded in Europe, while 28 species (about 67%) are recorded in North Africa. Seventeen Plummer's species (about 40%) are recorded in West Asia, but 7 species (about 17%) are recorded in central South Asia (Pakistan). Only 3 Plummer's species (about 7%) are recorded in West Africa, 2 species (about 5%) are recorded in New Zealand, but only 1 species (about 2%) is recorded in Japan. The existence of a marked differences between the number of recorded taxa in different Tethyan localities in respect with the Midway Formation in Texas may be due to one or more parameters: a) the differences in ecological or environmental conditions (depth, Salinity, water temperature, dissolved oxygen, nutrient, land barrier, etc..), b) the deficiency of available literatures, and/or c) not homogeneity in the species concept according to different authors.

7- Conclusions

The Midway Formation in Texas (USA) in the Gulf Coastal Plain represents the 'Midway-type fauna' (MF), which named after Berggren and Aubert (1975), and indicates to the continental shelf benthic foraminiferal fauna (50-200 m water depth).

1- This study revised the taxonomy and paleogeography of the 42 Paleocene benthic foraminiferal species of the Midway Formation in the Gulf Coastal Plain of Texas, USA, firstly investigated by Plummer (1927).

2- Its paleogeographic distribution in some other countries in the Tethyan province, from Atlantic to Pacific Oceans, via Mediterranean and Indian Ocean, were recorded: North America (USA, Mexico), South America (Argentina), Europe (North Sea Basin, Spain, France, Italy, Czech Republic, Bulgaria), North Africa (Tunisia, Libya, Egypt), West Africa (Ivory Coast, Gulf of Guinea), West Asia (Turkey, Jordan, Saudi Arabia, UAE, Iran), Central Asia (Pakistan) and East Asia (Japan and New Zealand).

3- The high diversity of the identified Plummer's species is recorded from North Africa (28 species, about 67%) out of the 42 recorded taxa of Plummer's species, followed by Europe (21, about 52%), 17 species (about 40%) from West Asia, 8 species (about 19 %) from South America, 7 species (about 17%) from Pakistan, 3 species (about 7%) from West Africa, 2 species (about 5%) from New Zealand, while only 1 of Plummer's species was recorded from Japan.

4- The existence of a marked differences between the number of recorded taxa in different Tethyan localities in respect with the

Midway Formation in Texas may be due to one or more ecological and environmental parameters.

5- As a token of appreciation of Plummer's outstanding career and contributions, she has been recognized in several instances with a dedication taxa bearing her name. The present author added *Citharina plummerae* Anan (2001) as a new species from the Paleocene of Duwi section, Red Sea coast, Egypt.

6- Based on the faunal distribution of Plummer's fossils, it emphasizes that the Tethyan Sea extended from Atlantic Ocean in the west to Indo-Pacific Ocean in the east.

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