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RESEARCH ARTICLE

INTERCONTINENTAL GEOGRAPHIC DISTRIBUTION OF EIGHTY-EIGHT DIAGNOSTIC TETHYAN BENTHIC FORAMINIFERA

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ABSTRACT

This study illustrates and record of 88 continental benthic foraminiferal species belonging to 44 genera of the Suborders Textulariina, Miliolina, Lagenina and Rotaliina of the Maastrichtian-Neogene time were recorded from three to more than localities in the Tethys: 8 in North and South America (USA, Mexico, Caribbean, Peru, Ecuador, Brazil, Argentina, Chile), 12 in Europe (Spain, France, Belgium, Germany, Austria, Italy, Poland, Hungaria, Slovenia, Slovakia, Czech, Romania), 5 in Africa (Tunisia, Libya, Egypt, Tanzania, Nigeria), 11 in Asia (Palestine, Jordan, Iraq, Saudi Arabia, Qatar, UAE, Yemen, Iran, Pakistan, India, Turkmenia) and 2 in Pacific Ocean (Japan, New Zealand). The modern taxonomical consideration of the species is used, which were previously recorded in many different literatures in the Tethyan localities. The foraminiferal assemblage indicates an open marine environment, extended from neritic to lower bathyal environment.

KEYWORDS

Benthic Foraminifera, Maastrichtian, Paleogene, Neogene, Tethys

1. INTRODUCTION

Eighty-eight diagnostic Tethyan diagnostic benthic foraminiferal species were recorded and illustrated from wide localities in the Tethys: North and South America, Europe, Asia and southeast Pacific Ocean (Figure 1).

Figure 1: Geographic distribution of the recorded taxa from the Tethys: A) 8 localities in North and South America and Caribbean, B) 12 localities in Europe, 5 localities in Africa, 11 localities in Asia, as well as 2 localities in Pacific Ocean.

2. MATERIAL OF STUDY

Rich and well-preserved micropaleontological 88 benthic foraminiferal species of wide distributed from the Northern and Southern Tethys made it possible to elucidate them with its modern taxonomical consideration, following the Code of Zoological Nomenclature (CZN).

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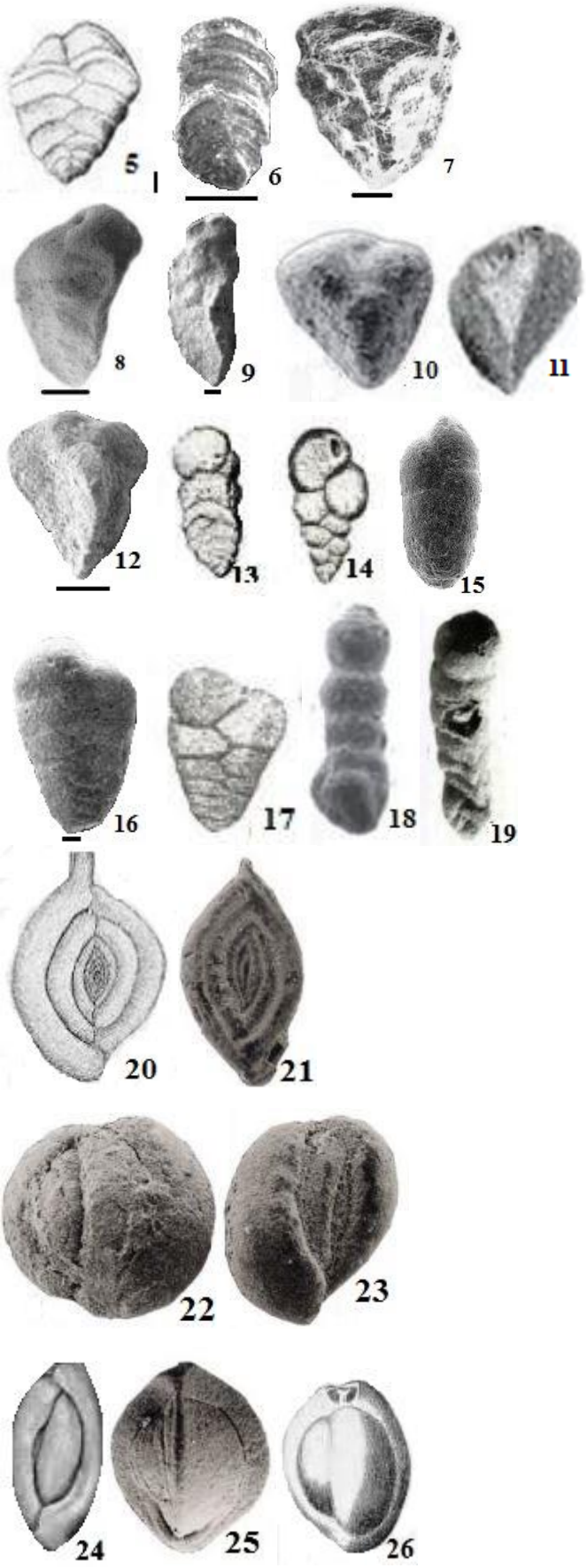
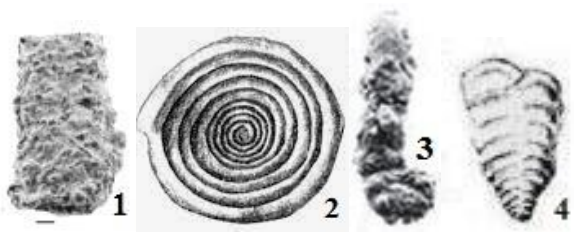
3. TAXONOMY

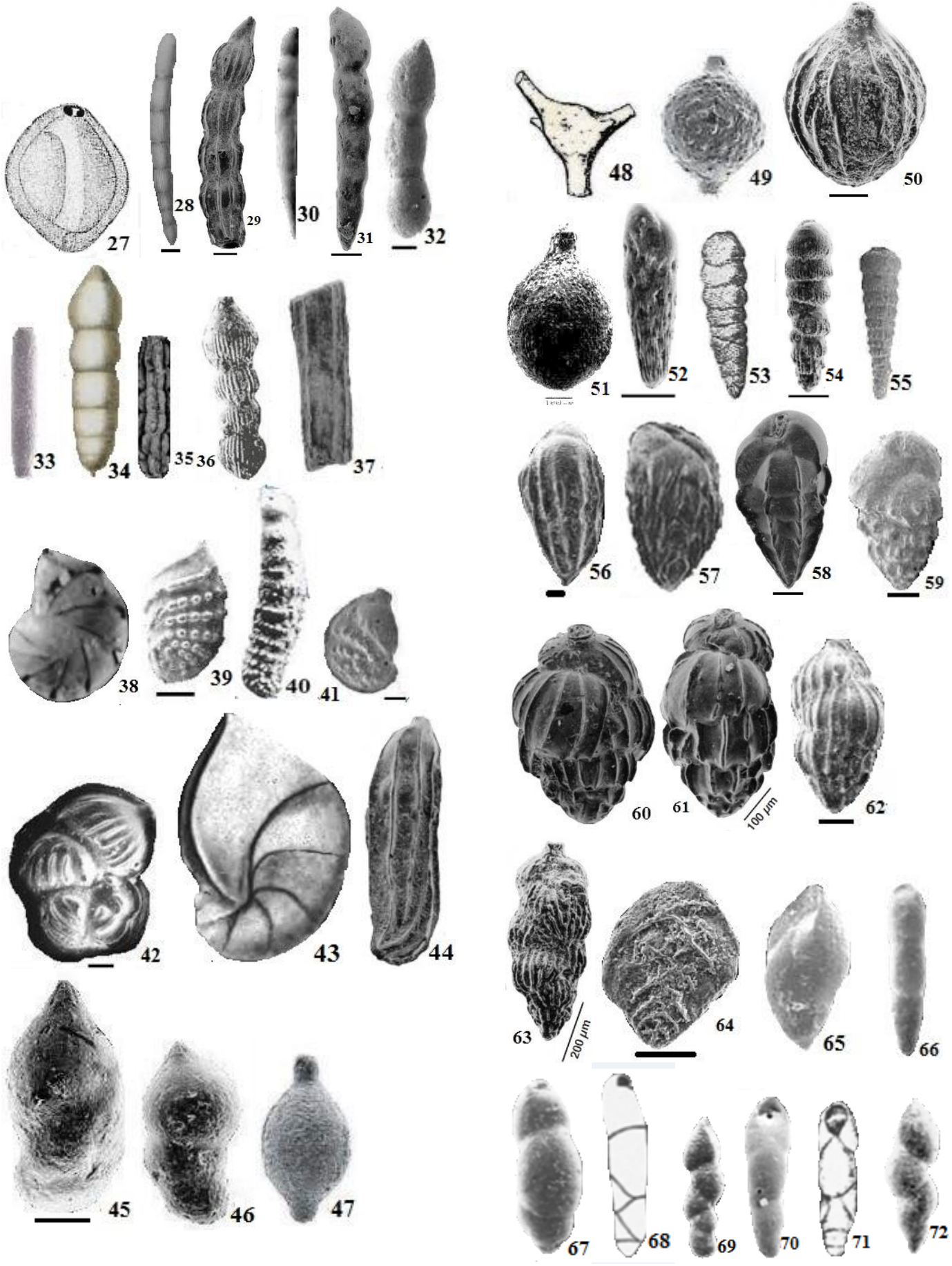
The taxonomic classification of Loeblich and Tappan in 1988 is followed here for 88 diagnostic benthic foraminiferal species, belonging to 49 genera: 19 species of arenaceous wall, 8 porcelaneous species, 24 calcareous Lagenid species, and 37 calcareous Rotaliid species, which is shown in Plate 1.

Plate 1 (Scale bars =100µm)

Figure 1. *Bathysiphon saidi* (Anan, 1994), 2. *Ammodiscus glabrata* (Cushman and Jarvis, 1928), 3. *Ammobaculites coprolithiformis* (Schwager, 1876), 4. *Spiroplectinella esnaensis* (LeRoy, 1953), 5. *Spiroplectinella knebeli* (LeRoy, 1953), 6. *Vulvulina advena* Cushman (1926), 7. *Gaudryina limbata* (Said and Kenawy, 1956), 8. *Gaudryina speijeri* (Anan, 2012), 9. *Pseudogaudryinella iranica* (Anan, 2023), 10. *Verneuilina aegyptiaca* (Said and Kenawy, 1956), 11. *Verneuilina karreri* (Said and Kenawy, 1956), 12. *Verneuilina luxorensis* (Nakkady, 1950), 13. *Siphogaudryina africana* (LeRoy, 1953), 14. *Siphogaudryina daviesi* (Haque, 1956), 15. *Dorothia bulletta* (Carsey, 1926), 16. *Textularia nilotica* (Schwager, 1883), 17. *Textularia punjabensis* (Haque, 1956), 18. *Pseudoclavulina farafraensis* (LeRoy, 1953), 19. *Clavulina pseudoparisensis* (Anan, 1984), 20. *Spiroloculina canaliculata* (d'Orbigny, 1846), 21. *Spiroloculina depressa* (d'Orbigny, 1826), 22. *Quinqueloculina hauerina* (d'Orbigny, 1846), 23. *Quinqueloculina impressa* (Reuss, 1851), 24. *Quinqueloculina seminulum* (Linnaeus, 1758), 25. *Triloculina angularis* (d'Orbigny, 1850), 26. *Triloculina gibba* (d'Orbigny, 1846), 27. *Triloculina gibba* (d'Orbigny, 1846), 28. *Chrysalogonium tenuicostatum* (Cushman and Bermúdez, 1936), 29. *Dentalina alternata* (Jones, 1886), 30. *Laevidentalina elegans* (d'Orbigny, 1846), 31. *Laevidentalina pomuligera* (Stache, 1864), 32. *Nodosaria catenula* (Reuss, 1860), 33. *Nodosaria longiscata* (d'Orbigny, 1846), 34. *Nodosaria radicula* (Linnaeus, 1758), 35. *Pyramidulina affinis* (Reuss, 1845), 36. *Pyramidulina robinsoni* (Futyan, 1976), 37. *Pyramidulina vertebralis* (Batsch, 1791), 38. *Lenticulina alabamensis* (Cushman, 1924), 39. *Percultazonaria fragaria* (Gümbel, 1868), 40. *Percultazonaria jordanensis* (Futyan, 1976), 41. *Lenticuzonaria argentinica* Anan (2023), 42. *Spincterules ariminensis* (d'Orbigny, 1846), 43. *Saracenaria triangularis* (d'Orbigny, 1840), 44. *Marginulina costata* (Batsch, 1791), 45. *Hemirobulina bullata* (Reuss, 1845), 46. *Hemirobulina hantkeni* (Bandy, 1949), 47. *Ramulina futyani* (Anan, 2015), 48. *Ramulina plummerae* (Anan, 2022), 49. *Ramulina pseudoaculeata* (Olsson, 1960), 50. *Lagena acuticostata* (Reuss, 1862), 51. *Pygmaeoseistron hispidum* (Reuss, 1858), 52. *Orthokarstenia applinae* (Plummer, 1927), 53. *Orthokarstenia eleganta* (Plummer, 1927), 54. *Orthokarstenia nakkadyi* (Anan, 2009), 55. *Orthokarstenia oveyi* (Nakkady, 1950), 56. *Bulimina alazanensis* (Cushman, 1927), 57. *Bulimina jacksonensis* (Cushman, 1925), 58. *Bulimina farafraensis* (LeRoy, 1953), 59. *Bulimina midwayensis* (Cushman and Parker, 1936), 60. *Uvigerina cocoaensis* (Cushman, 1925), 61. *Uvigerina jacksonensis* Cushman (1925), 62. *Uvigerina mediterranea* (Hofker, 1932), 63. *Uvigerina rippensis* (Cole, 1927), 64. *Aragonia aragonensis* (Nuttall, 1930), 65. *Pleurostomella acuta* (Hantken, 1875), 66. *Pleurostomella eocaena* (Gümbel, 1868), 67. *Pleurostomella incrassata* (Hantken, 1883), 68. *Pleurostomella nuttalli* (Cushman and Siegfus, 1939), 69. *Pleurostomella obtusa* (Berthelin, 1880), 70. *Pleurostomella paleocenica* (Cushman, 1940), 71. *Pleurostomella subnodosa* (Reuss, 1860), 72. *Pleurostomella velascoensis* (Cushman, 1926), 73. *Nonionella auris* (d'Orbigny, 1939), 74. *Ornatanomalina hafeezi* (Haque, 1956), 75. *Anomalinoides acutus* (Plummer, 1927), 76. *Anomalinoides fayoumensis* (Ansary, 1955), 77. *Cibicidoides abudurbensis* (Nakkady, 1950), 78. *Cibicidoides libycus* (LeRoy, 1953), 79. *Cibicidoides nammalensis* (Haque, 1956), 80. *Cibicidoides patalensis* Haque (1956), 81. *Cibicidoides proprius* Brotzen (1948), 82. *Cibicidoides pseudoacutus* (Nakkady, 1950), 83. *Cibicidoides vulgaris* (Plummer, 1927), 84. *Oridorsalis umbonatus* (Reuss 1851), 85. *Gyroidinoides girardanus* (Reuss 1851), 86. *Gyroidinoides tellburmaensis* (Futyan, 1976), 87. *Gyroidinoides zelandica* (Finlay, 1939), 88. *Hanzawaia cubensis* (Cushman and Bermúdez 1948).



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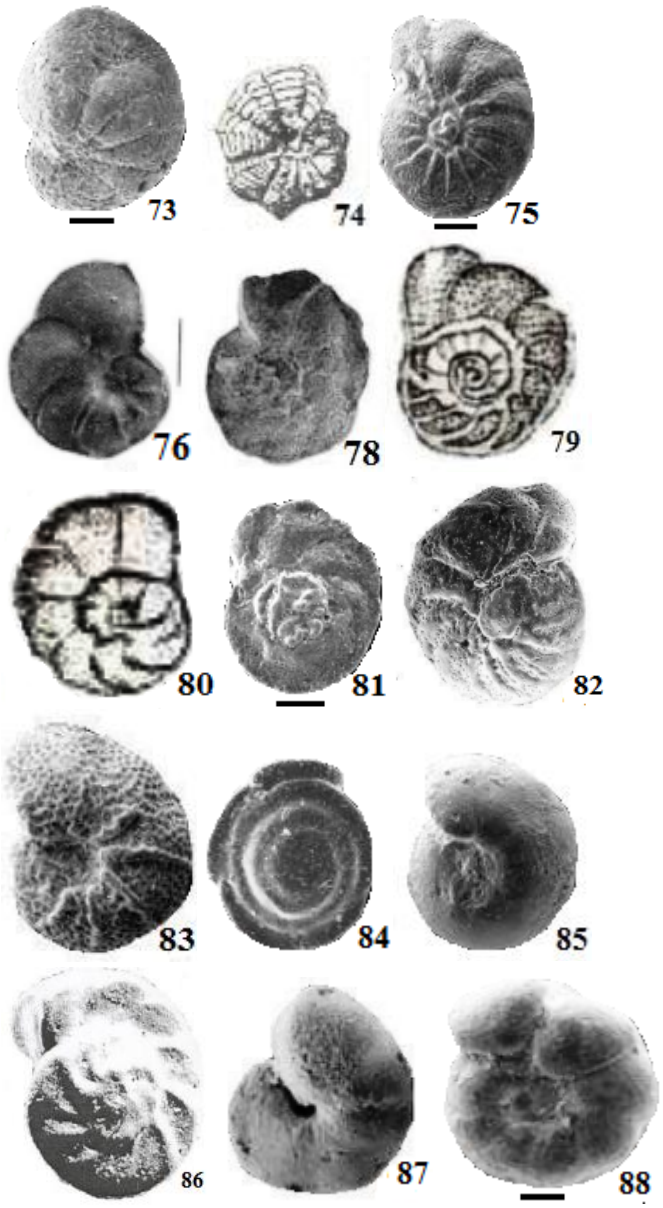

Order Foraminiferida Eichwald, 1830

Suborder Textulariina Delage and Hérouard, 1896

Bathysiphon saidi (Anan, 1994) - Eocene. Egypt (Africa), UAE (Asia), Hungaria (Europe).

Ammodiscus glabrata (Cushman and Jarvis, 1928) - Eocene. Trinidad, Tunisia, Iran.

Ammobaculites coprolithiformis (Schwager, 1876) - Maastrichtian-Paleogene. USA, France, Czech, Nigeria, Egypt.

Spiroplectinella esnaensis (LeRoy, 1953) - Paleocene-Eocene. France, Tunisia, Egypt, UAE

Spiroplectinella knebeli (LeRoy, 1953) - Eocene. Egypt, Spain, Tunisia, Jordan, UAE

Vulvulina advena (Cushman, 1926a) - Eocene. USA, Spain, Iran.

Gaudryina limbata (Said and Kenawy, 1956) - Paleocene. Tunisia, Egypt, UAE, Qatar

Gaudryina speijeri (Anan, 2012) - Eocene. Tunisia, Egypt, UAE.

Pseudogaudryinella iranica (Anan, 2023a) - Eocene. France, Iraq, Iran

Verneuilina aegyptiaca (Said and Kenawy, 1956) - Spain, Tunisia, Egypt, UAE, Iran.

Verneuilina karreri (Said and Kenawy, 1956) - Maastrichtian- Eocene. Egypt, Iraq, UAE, Qatar

Verneuilina luxorensis (Nakkady, 1950) - Eocene. Tunisia, Egypt, Palestine, UAE, Iraq, Iran.

Siphogaudryina africana (LeRoy, 1953) - Paleocene-Eocene. France, Italy, Egypt, UAE

Siphogaudryina daviesi (Haque, 1956) - Paleocene-Eocene. Egypt, UAE and Qatar Pakistan

Dorothia bulletta (Carsey, 1926) - USA, Egypt, UAE, Iran.

Textularia nilotica (Schwager, 1883) - Eocene. Egypt, Iran, Pakistan.

Textularia punjabensis Haque, 1956 - Paleocene. Egypt, Pakistan, India

Pseudoclavulina farafraensis (LeRoy, 1953) - Eocene. Egypt, UAE, Qatar, Pakistan

Clavulina pseudoparisensis Anan, 1984 - Recent. Egypt, Saudi Arabia, Yemen, UAE, Qatar.

Suborder Miliolina Delage and Héroard, 1896

Spiroloculina canaliculata a (d'Orbigny, 1846) - Eocene. France, Belgium, Austria, UAE

Spiroloculina depressa (d'Orbigny, 1826) - Maastrichtian-Holocene. France, Belgium, UAE

Quinqueloculina hauerina (d'Orbigny, 1846) - France, Egypt, UAE

Quinqueloculina impressa (Reuss, 1851) - Eocene-Oligocene. France, Germany, Egypt, UAE

Quinqueloculina seminulum (Linné, 1758) - Maastrichtian-Holocene. Ecuador, France, Belgium, Egypt, UAE

Triloculina angularis (d'Orbigny, 1850) - Eocene. France, Egypt, UAE

Triloculina gibba (d'Orbigny, 1846) - Eocene. France, Egypt, UAE

Triloculina trigonula (Lamarck, 1804) - Eocene. France, Belgium, Egypt, UAE

Suborder Lagenina Delage and Hérouard, 1896

Chrysalogonium tenuicostatum Cushman & Bermúdez, 1936. Atlantic Ocean, Belgium, Slovenia, UAE, Japan

Dentalina alternata (Jones, 1886) - Eocene. USA, Libya, UAE

Laevidentalina elegans (d'Orbigny, 1846) - Eocene. France, Caribbean, Romania, Egypt, UAE

Laevidentalina pomuligera (Stache, 1864) - Eocene. USA, Egypt, UAE

Nodosaria catenula (Reuss, 1860) - Campanian-Maastrichtian. Austria, Egypt, Iraq.

Nodosaria longiscata (d'Orbigny, 1846) - USA, Caribbean, Bulgaria, Romania, Egypt, UAE, Pakistan, Japan

Nodosaria radicula (Linnaeus, 1758) - USA, Belgium, UAE, Pakistan

Pyramidulina affinis (Reuss, 1845) - Paleocene-Eocene. USA, France, Egypt, UAE, Qatar

Pyramidulina robinsoni (Futyan, 1976) - Paleocene. Jordan, Egypt, Tanzania

Pyramidulina vertebralis (Batsch, 1791) - Paleocene-Eocene. USA, Egypt, UAE, Pakistan

Lenticulina alabamensis (Cushman, 1924) - USA, France, Egypt, UAE

Percultazonaria fragaria (Gümbel, 1868) - Eocene. USA, Caribbean, Atlantic, France, Slovenia, Slovakia, Bulgaria, Egypt, UAE, Iran

Percultazonaria jordanensis (Futyan, 1976) - Paleocene. Tunisia, Egypt, Jordan

Lenticuzonaria argentinica Anan, 2023b - Eocene-Miocene. Argentina, Chile, Tanzania, Iraq

Spincterules ariminensis (d'Orbigny, 1846) - Miocene. France, Austria,

Romania.

Saracenaria triangularis (d'Orbigny, 1840) - USA, Caribbean, Atlantic, Ecuador, France, Egypt, UAE, Pakistan

Marginulina costata (Batsch, 1791) - USA, France, Egypt, UAE

Hemirobulina bullata (Reuss, 1845) - Maastrichtian-Eocene. USA, Mexico, Caribbean, Germany, Egypt, UAE.

Hemirobulina hantkeni (Bandy, 1949) – Eocene. USA, Austria, Hungaria

Ramulina futyani Anan, 2015 - Paleocene. Czech & Bulgaria, UAE, Pakistan,.

Ramulina plummerae Anan, 2022 - Maastrichtian-Eocene. USA, Egypt, Iran.

Ramulina pseudoaculeata (Olsson, 1960) - Maastrichtian–Paleocene. USA, Mexico, Czech, Egypt, UAE.

Lagena acuticostata Reuss, 1862 - Eocene. Ecuador, Belgium, Egypt, UAE, Pakistan

Pygmaeoseistron hispidum (Reuss, 1858) - Paleocene-Eocene. USA, Atlantic, France, Egypt, Qatar, UAE

Suborder Rotaliina Delage and Hérouard, 1896

Orthokarstenia applinae (Plummer, 1927) - Paleocene-Eocene. USA, Tunisia, Egypt, Jordan, UAE, Iran, Pakistan

Orthokarstenia eleganta (Plummer, 1927) - Paleocene-Eocene. USA, Tunisia, Egypt

Orthokarstenia nakkadyi Anan, 2009 - Paleocene-Eocene. USA, Spain, France, Tunisia, Egypt

Orthokarstenia oveyi (Nakkady, 1950) - Maastrichtian. Niger Delta, Egypt, Jordan

Bulimina alazanensis Cushman, 1927 - USA, Brazil, Spain, Iran.

Bulimina farafraensis LeRoy, 1953 - Eocene. Spain, Tunisia, Egypt, Arabian Sea

Bulimina jacksonensis Cushman, 1925 - Eocene. USA, Libya, Egypt, UAE

Bulimina midwayensis Cushman & Parker, 1936 - Paleocene-Eocene. USA, Egypt, Tunisia, France, Iran.

Uvigerina cocoaensis (Cushman, 1925) . Eocene, USA, Italy, Egypt, UAE.

Uvigerina jacksonensis Cushman, 1925 - Eocene, USA, Ecuador, Libya, Egypt, UAE.

Uvigerina mediterranea (Hofker, 1932) - Eocene. Germany, Egypt, Iran.

Uvigerina rippensis Cole (1927) - Eocene. USA, Caribbean, France, Libya, Egypt, UAE.

Aragonia aragonensis (Nuttall, 1930) - Eocene. Mexico, USA, Trinidad, Spain, Italy, Egypt, Iran, New Zealand.

Pleurostomella acuta Hantken, 1875- Eocene. Paleocene-Eocene. USA, Atlantic Ocean, France, Italy, Hungaria.

Pleurostomella eocaena Gümbel, 1868 - Paleocene-Eocene. Italy, Bulgaria, Hungaria

Pleurostomella incrassata Hantken,1883 - Maastrichtian-Miocene. Atlantic Ocean, France, Italy, Hungaria.

Pleurostomella nuttalli Cushman & Siegfus, 1939 - Maastrichtian-Miocene. USA, Atlantic, France, Italy, Pacific Ocean

Pleurostomella obtusa Berthelin, 1880 - Maastrichtian-Eocene. Atlantic, Caribbean, France

Pleurostomella paleocenica Cushman, 1940 - Paleocene-Eocene. USA, Atlantic, Caribbean, France, Tunisia, Egypt

Pleurostomella subnodosa Reuss, 1860 - Maastrichtian-Paleocene. USA, Mexico, Atlantic, Egypt, Iraq

Pleurostomella velascoensis Cushman, 1926b - Maastrichtian-Eocene. USA, Caribbean, France, Egypt

Nonionella auris (d'Orbigny, 1939) - Eocene. France, Atlantic Ocean, Iran.

Ornatanomalina hafeezi Haque, 1956 - Paleocene-Eocene. Pakistan, UAE, Qatar, Iraq, S. Arabia, Nigeria

Anomalinoides acutus (Plummer 1927) - Eocene. USA, Mexico, Trinidad, Belgium, Tunisia Egypt, Iran.

Anomalinoides fayoumensis (Ansary, 1955) - Eocene. Egypt Jordan, UAE.

Cibicidoides abudurbensis (Nakkady, 1950) - Maastrichtian-Paleocene, Spain, France, Tunisia, Egypt, Palestine, UAE

Cibicidoides libycus (LeRoy, 1953) - Paleocene-Ypresian. France, Tunisia, Libya, Egypt

Cibicidoides nammalensis (Haque, 1956) - Paleocene-Eocene. Pakistan, France, Iraq

Cibicidoides patalensis (Haque, 1956) - Paleocene-Eocene. Pakistan, India, Argentina

Cibicidoides proprius (Brotzen, 1948) - Eocene. Trinidad, Mexico, Sweden, Belgium, Spain, Hungaria, Iran.

Cibicidoides pseudoacutus (Nakkady, 1950) - Maastrichtian- Eocene. France, Egypt, Tunisia

Cibicidoides vulgaris (Plummer, 1927) - Paleocene-Eocene. USA, Argentina, Egypt, Iran, Turkmenia.

Oridorsalis umbonatus (Reuss 1851) - Mexico, Trinidad, Peru, Ecuador, Germany, Belgium, Egypt, Iran.

Gyroidinoides girardanus (Reuss 1851) - Eocene. Germany, Trinidad, Peru, Spain, Tunisia, Egypt, Iran.

Gyroidinoides tellburmaensis Futyan, 1976 - Maastrichtian-Danian. Tunisia, Egypt, Jordan

Gyroidinoides zelandica (Finlay, 1939) - Eocene. New Zealand, Argentina, Egypt, Jordan, Pakistan

Hanzawaia cubensis (Cushman and Bermúdez 1948) - Eocene. Cuba, USA, Spain, Iran.

4. PALEOGEOGRAPHY

The paleogeographical map of Mintz in 1981 shows that the ancestral Tethyan Ocean in the Paleogene time is connected with the ancestral Indian, Atlantic and Pacific Oceans (Figure 2). The Paleogene paleogeographic maps of many authors (i.e. Phillips, 1971; Zachos et al., 1993) show that the Tethyan realm had been connected with the Indo-Pacific Ocean from east to Atlantic Ocean to the west. All species have -at least- three wide intercontinental geographic distribution around the world. Some remarks are presented:

Nineteen agglutinated species represents (about 21.6%) of the total species (19/88) are recorded from different continent in the world: North and South America, Europe, Africa, Asia, Japan and New Zealand in Pacific Ocean.

Eight calcareous porcelaneous species (about 0.1%) of the total species are recorded (8/88).

Twenty-four calcareous Lagenid species (about 27.3%) of the total recorded species (24/88).

Thirty-seven calcareous Rotaliid species (about 42 %) of the total recorded species (37/88).

Percultazonaria fragaria are recorded from 10 localities in the different continent of the world: USA, Caribbean, Atlantic (North America), France, Slovenia, Slovakia, Bulgaria (Europe), Egypt (Africa), UAE, Iran (Asia).

Aragonia aragonensis are recorded from 8 different localities.

Nodosaria longiscata, *Saracenaria triangularis*, *Oridorsalis umbonatus* and *Gyroidinoides girardanus* are recorded from 7 different localities.

Clavulina pseudoparisensis, *Cibicidoides abudurbensis*, *Aragonia aragonensis*, *Hemirobulina bullata*, *Pygmaeoseistron hispidum*, *Uvigerina rippensis*, *Pleurostomella acuta*, *Pleurostomella paleocenica*, *Ornatanomalina hafeezi* and *Cibicidoides abudurbensis* are recorded from

6 different localities.

Many species are recorded from five localities or less than numbers in different localities of the Tethys.

Figure 2: The paleogeographical map of Mintz (1981) shows that the ancestral Tethyan Ocean in the Paleogene time is connected with the ancestral Indian, Atlantic and Pacific Oceans.

5. PALEOENVIRONMENT

The increased percentages of infaunal morphogroups indicate an increase in the nutrient flux to the sea floor and infer moderate to high productivity rather than low oxygen levels in the sea bottom waters. The environmental and faunal recovery was occasionally interrupted by periods of environmental stress at the sea floor. The assemblages dominated by the deep-water agglutinated foraminifera in a bathyal environment, possibly middle to lower bathyal, which is much deeper than a shelf environment, while the miliolids are known to favor warm sheltered environments. The high abundance of pelagic Lagenid and Rotaliid foraminiferal assemblage indicate open connections to the Tethys and represents neritic to bathyal environment (at about 2 ± 1 km water depth), close to the lower limit of an oxygen minimum zone (Figure 3). The differences in the paleoenvironmental conditions (i.e. depth, water temperature, salinity, nutrients, dissolved oxygen, land barrier, etc.) and the deficiency of available literatures in the different localities of the Tethys, most probably cause the inhomogeneity in the species concept between different authors.

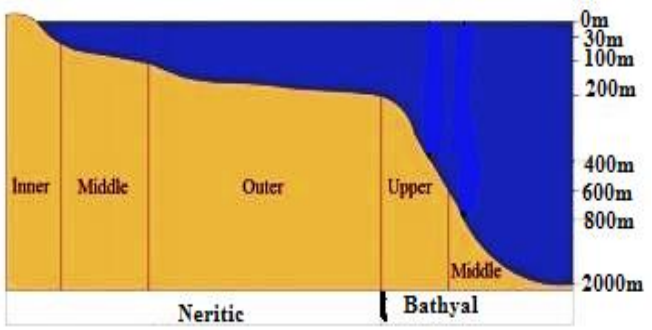

Figure 3: Different zones of the water-depths, from neritic to bathyal environment.

Abed in 2013 noted that the presence of Paleogene-Neogene marine environment supports the open flow direction of the Tethyan Circumglobal Current (TCC) in all directions, and the deep water agglutinated foraminifera, which may live around carbonate compensation depth "CCD", suggested a lower slope setting at about 1000 m water depth in an open marine basin (Abed, 2013) (Figure 4).

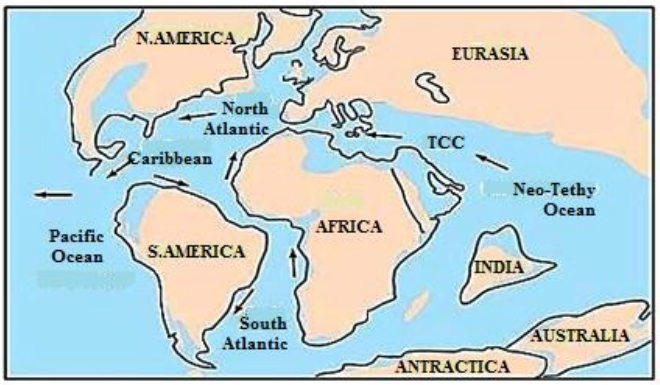

Figure 4: The Neo- Tethys Ocean during the Late Cretaceous-Paleogene times showing the open flow direction of the Tethyan Circumglobal Current (TCC) in all directions (after Abed, 2013).

6. CONCLUSIONS

The present study deals with the recording of eighty eight identified Maastrichtian-Neogene species of Agglutinated, Porcelaneous, Lagenid and Rotaliid calcareous foraminiferal genera from different localities in the Tethys: North America (USA, Mexico, Caribbean), South America (Peru, Ecuador, Brazil, Argentina, Chile), Europe (Spain, France, Belgium, Germany, Austria, Italy, Poland, Hungaria, Slovenia, Slovakia, Czech, Romania), Africa (Tunisia, Libya, Egypt, Tanzania, Nigeria), Asia (Palestine, Jordan, Iraq, Saudi Arabia, Qatar, UAE, Yemen, Iran, Pakistan, India, Turkmenia) and Pacific Ocean (Japan, New Zealand). This study confirms again that the extended realms of the Tethys have extended from the Indo-Pacific to the Atlantic Oceans via Mediterranean Sea during the study time. Environmental conditions of the identified species represent outer shelf- Bathyal environment (~200-2000m).

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