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REVIEW ARTICLE

NEW SEVEN COARSE-GRAINED PALEOGENE TETHYAN AGGLUTINATED FORAMINIFERAL SPECIES ON BOTH SIDES OF THE ATLANTIC OCEAN

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ABSTRACT

The modern taxonomical consideration is used for seven coarse-grained agglutinated benthic foraminiferal species which are belonging to six genera from four countries in the Tethys around the Atlantic Ocean USA and Europe (Spain, France and Poland). These species are believed here to be new: *Bathysiphon alegretae*, *Gaudryina pozaryskai, G. stasseni, Dorothia sztrákosae*, *Siphogaudryina ortizae*, *Pseudoclavulina thomasae* and *Clavulina sztrákosae*. Tubular taxa (e.g. *Bathysiphon*) are rare in neritic settings but common in bathyal facies, while elongated serial taxa (e.g. *Gaudryina, Siphogaudryina, Dorothia, Pseudoclavulina, Clavulina*) are most common in the upper to middle bathyal assemblages.

KEYWORDS

Paleontology, Benthic foraminifera, Paleogene, Tethys

1. INTRODUCTION

The wall of the coarse-grained arenaceous agglutinated foraminiferal group is composed of siliciclastic quartz grains material, and the cementing materials are mainly siliceous, or iron oxides. An attempt has been made to renamed seven diagnostic small coarse-grained agglutinated benthic foraminiferal species according to modern classification, than enviously introduced by different authors in USA, Spain, France, and Poland, in connection with the original figures. All the recorded agglutinated species are common in the Early Paleogene (Paleocene and Eocene). These species are also compared with other well-known species in USA, Mexico, Hungaria, Russia, Egypt, Jordan and UAE (Figure 1).

Figure 1: The geographic distribution of the identified seven coarse-grained foraminiferal species in some counties of the Northern Tethys (Spain, France, Poland) which are compared with other taxa in the Northern and Southern Tethys.

2. MATERIAL OF STUDY

The material upon which this study is based came from seven diagnostic small agglutinated foraminiferal species are distributed from four countries on both sides of the Atlantic Ocean: USA, in the western side and Europe (Spain, France, Poland) in the eastern side (Figure 2). These species are compared with other well-known species from the Northern Tethys (Hungaria, H; and Russia) and also Southern Tethys (Egypt, Jordan and UAE).

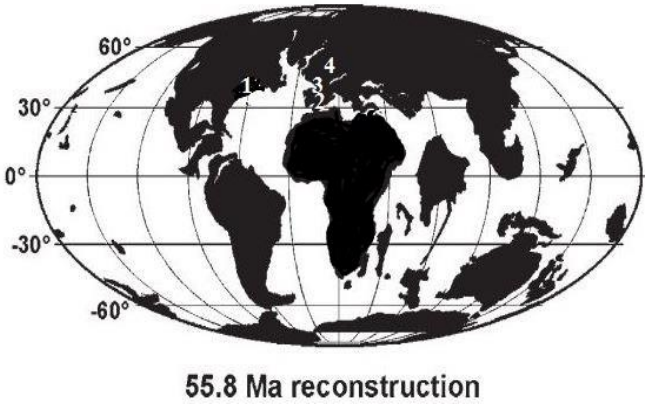

Figure 2: Location map of the four countries on both sides of Atlantic Ocean (1. USA, 2. Spain, 3. France, 4. Poland) which the identified species were recorded.

3. SYSTEMATIC PALEONTOLOGY

The taxonomy of Kaminski (2014) is followed in this study for the new seven coarse-agglutinated benthic foraminiferal species belonging to five genera from four countries around the Atlantic Ocean: USA, Spain, France and Poland. The coarse-agglutinated foraminiferal species are identified and illustrated in (Plate 1). Some modern references have been added new taxonomic considerations to complete synonymies and the description of the of the recorded species.

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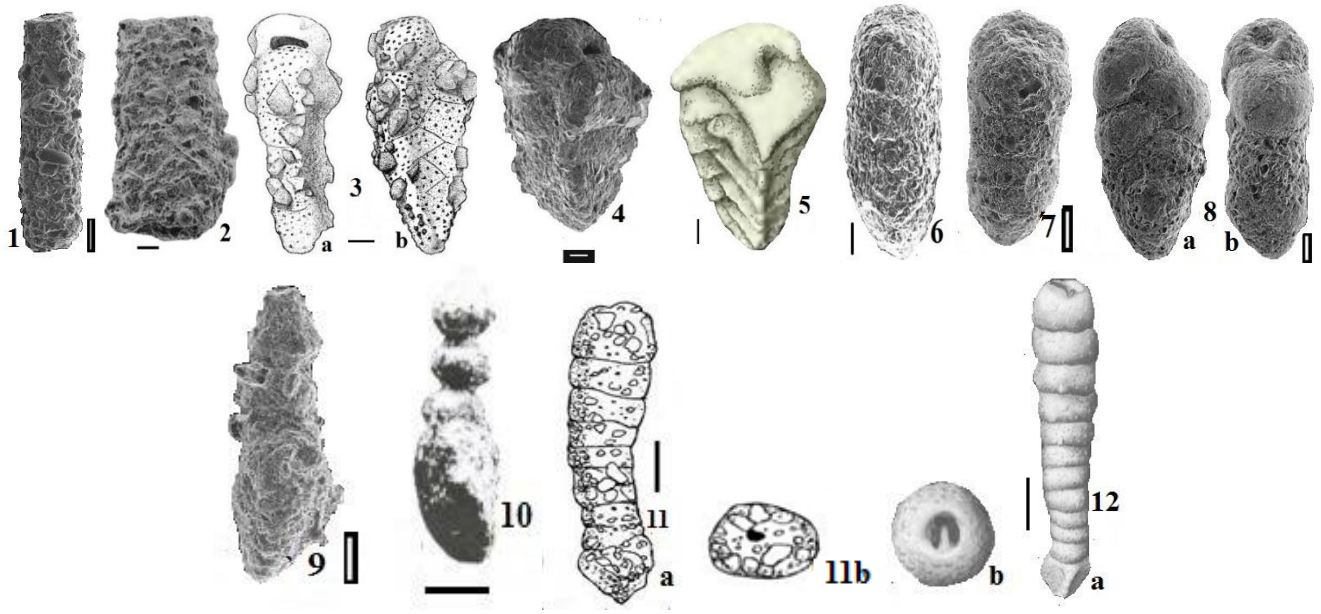

Plate 1: (All scale-bars represent 100 µm, fv=front view, sv=side view, b=apertural view) Fig. 1. Bathysiphon alegretae Anan, n. sp.; 2. Bathysiphon saidi (Anan, 1994); 3a,b. Gaudryina pozaryskai Anan, n. sp., a. fv, b. sv; 4. Gaudryina stasseni Anan, n. sp.; 5. Gaudryina pyramidata (Cushman, 1926); 6. Dorothia sztrákosae Anan, n. sp.; 7. Dorothia cylindracea (Bermúdez, 1963); 8a,b. Siphogaudryina ortizae Anan, n. sp., 8a, fv; 8b, sv; 9. Pseudoclavulina thomasae Anan, n. sp.; 10. Pseudoclavulina futyani (Anan, 2021), 11a,b. Clavulina sztrákosae Anan, n. sp.; 12a,b. Clavulina parisiensis (d'Orbigny, 1926).

Genus *Bathysiphon* Sars, 1872

***Bathysiphon alegretae* Anan, n. sp.** (=*Rhabdammina* sp. Ortiz et al, 2011, p. 4, pl. 1, fig. 19)-(Plate 1, Figure 1)

Holotype: Illustrated specimen in Plate 1, Figure 1.

Etymology: After the micropaleontologist Laia Alegret, Departamento de Ciencias de la Tierra e Instituto Universitario de Investigación en Ciencias Ambientales de Aragón, Universidad de Zaragoza, 50009 Zaragoza, Spain.

Type locality: Gorrondatxe section, Northern Spain (Figure 3).

Stratigraphic level: Early Lutetian.

Diagnosis: The species is regarded here to belong to the genus *Bathysiphon* due to its straight unbranched elongate tube than the restricted Holocene time of the genus *Rhabdammina* Sars, 1869 (Loeblich and Tappan, 1988). The test has an elongate test, coarsely agglutinated wall, may contain sponge spicules and coarse sand grains with rough exterior.

Remarks: The Early Lutetian *Bathysiphon alegretae* most probably developed to the Bartonian-Priabonian *B. saidi* (Anan, 1994, Plate 1, Figure 2) by its wider test, in the *Bathysiphon alegretae* → *B. saidi* lineage. The latter species *B. saidi* was originally described from Fayoum and Sinai of Egypt, and later from the same stratigraphic horizon of Jabal Hafit, United Arab Emirates, UAE and Hungaria (Anan, 2005; Ozsvárt, 2007).

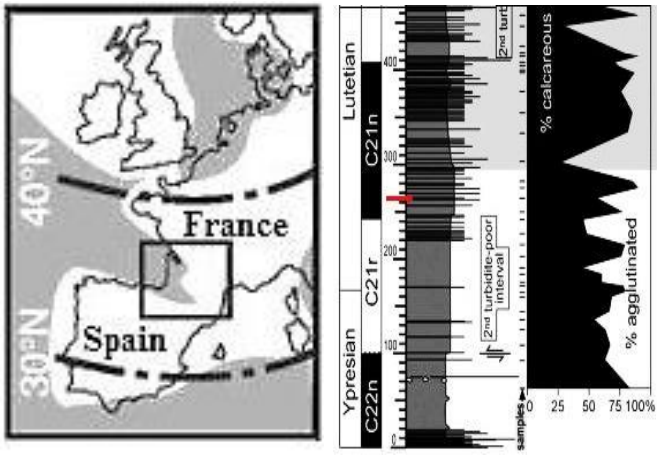

Figure 3: Location map of Gorrondatxe section, Northern Spain, and the sample location of the recorded species in the stratgraphic log of the section (Ortiz et al., 2011).

Genus *Gaudryina* d'Orbigny, 1839

***Gaudryina pozaryskai* Anan, n. sp.** (=*Gaudryina* cf. *rugosa rossica* Balakhmatova, 1955 - Pożaryska, 1965, p. 53, pl. 1, fig. 7) - (Plate 1, Figure 3a, b)

Holotype: Illustrated specimen in Plate 1, Figure 3a, b.

Etymology: After the late Polonian micropaleontologist, Krystyna Pozaryska.

Type locality: Pamietowo, northwest Poland (Figure 4).

Stratigraphic level: Danian.

Diagnosis: This new species has long test, wall very coarsely arenaceous with big angulate grains, protruding irregularly throughout the test, triangular in early triserial portion, rectangular biserially, aperture elongated, broad slit at the base of last formed chamber, sutures straight and fairly visible.

Remarks: This species differs from other species of *Gaudryina* by its coarsely arenaceous wall with big angulate grains protruding irregularly throughout the test. It was recorded from Poland, but the original species was recorded from the Maastrichtian of Russia.

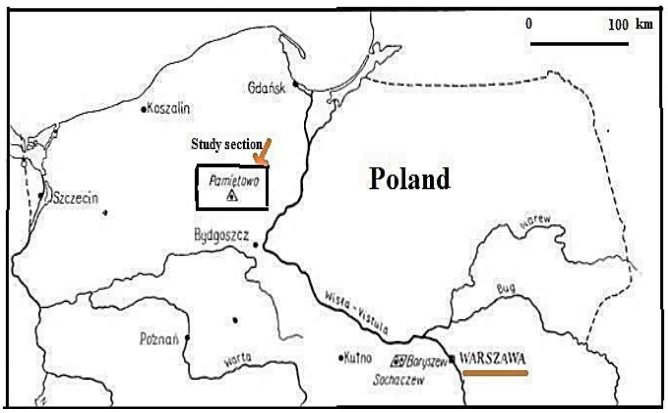

Figure 4: Location of the Pamietowo bore section, northwest Poland (Pożaryska, 1965).

***Gaudryina stasseni* Anan, n. sp.** (=*Gaudryina pyramidata* (Cushman) - Stassen et al, 2015, p. 20 , pl. 3, fig. 3) (Plate 1, Figure 4)

Holotype: Illustrated specimen in Plate 1, Figure 4.

Etymology: After Peter Stassen, Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, B-3001, Leuven, Belgium (Peter.Stassen@ees.kuleuven.be).

Type locality: Bass River section, New Jersey Coastal Plain (Figure 5).

Stratigraphic level: Late Thanetian.

Diagnosis: The New Jersey specimen (Pl. 1, fig. 4) do not differ from the figured holotype of the species *G. pyramidata* was described by Cushman (1926, Plate 1, Figure 5), except its coarsely agglutinated wall of (Stassen et al., 2015).

Remarks: *Gaudryina pyramidata* is indicated by Cushman as an index fossil for the Maastrichtian Velasco Shale (Velasco-Type Fauna, VTF) in Mexico and occur also in USA, Trinidad, Egypt, and may ranges from Maastrichtian-Danian in Spain, but Danian from other parts in the Northern Tethys: France, Italy, and Southern Tethys: Tunisia (Proto Decima and Bolli, 1978; Sztrakos, 2005; Alegret et al., 2003; Cushman, 1926; Berggren and Aubert, 1975). The new species *G. stasseni* was described from the Late Thanetian of Bass River section, New Jersey of USA.

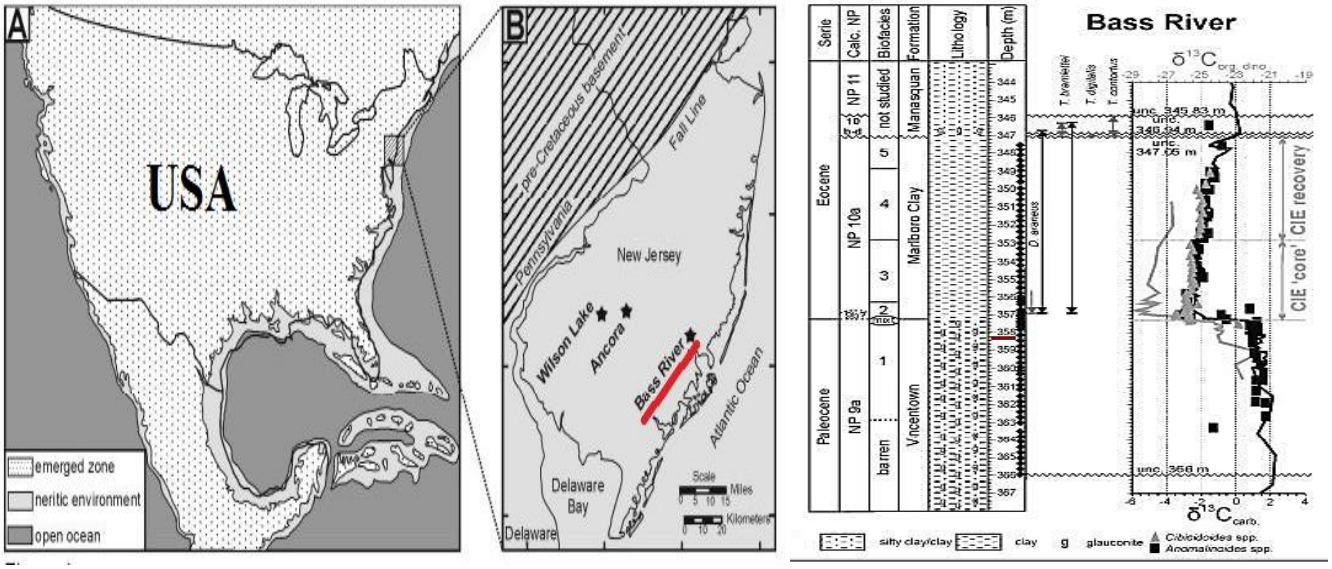

Figure 5: Location map of Bass River section, New Jersey (USA), and the sample location of the recorded species (Stassen et al, 2015).

Genus *Dorothia* Plummer, 1931

***Dorothia sztrákosae* Anan, n. sp.** (=? *Arenobulimina* sp. Sztrákos, 2005, p. 184, pl. 2, fig.7, pl. 11, fig. 30) - (Plate 1, Figure. 6)

Holotype: Illustrated specimen in Plate 1, Figure 6.

Etymology: After the French micropaleontologist Károly Sztrákos.

Type locality: Gan section, southwest France (Figure 6).

Stratigraphic level: Selandian (P4a).

Diagnosis: Test elongate and nearly parallel sides with a circular in section, early stage trochospirally enrolled, then reduced to biserial, increasing very slowly in size, wall coarsely agglutinated, aperture an interiomarginal slit of the final chamber face.

Remarks: The genus *Arenobulimina* has gradually tapering at the base of the test, not nearly parallel sides in the genus *Dorothia.* The new species *D. sztrákosae* (Plate 1, Figure 6) differs from *D. cylindracea* Bermúdez (Plate 1, Figure 7) by thicker width of the biserial stage than parallel sides of the test.

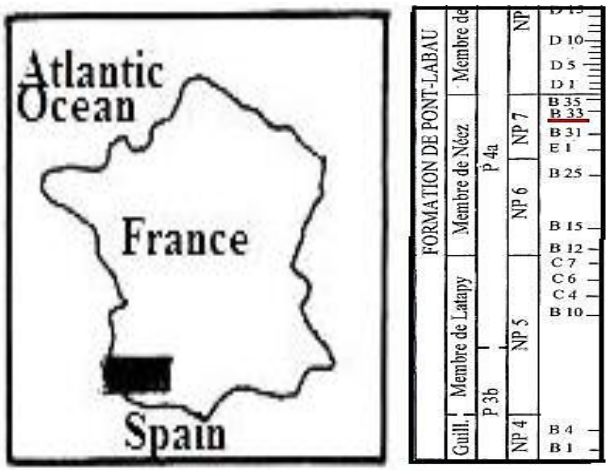

Figure 6: Location map of Gan section in southwest France, and the sample location of the recorded species (Sztrákos, 2005).

Genus *Siphogaudryina* Cushman, 1935

***Siphogaudryina ortizae* Anan, n. sp.** (=*Gaudryina arenata* (Cushman) - Ortiz & Thomas, 2006, p. 107, pl. 1, fig. 10a,b) - (Plate 1, Figure 8 a, b)

Holotype: Illustrated specimen in Plate 1, Figure 8 a, b.

Etymology: After Silvia Ortiz, Departamento de Ciencias de la Tierra, Universidad de Zaragoza, Spain. Email: silortiz@unizar.es

Type locality: Fortuna section, southeast Spain (Figure 7).

Stratigraphic level: Ypresian, sample 4.

Diagnosis: Test short and elongate coarsely agglutinated wall, which has very coarsely agglutinated, especially in early chambers triserially arranged with triangular cross section with blunt base and tapering, followed by biserially arranged rounded to oval in cross section, sutures depressed, aperture a high domed arch at the top of the apertural face.

Remarks: *Dorothia* has a low arched aperture at the base of the apertural face than clearly visible highly arched aperture in *Gaudryina*. The latter species has basal aperture interiomarginal in the final chamber instead of subterminal on the apertural face in the genus *Siphogaudryina* Cushman.

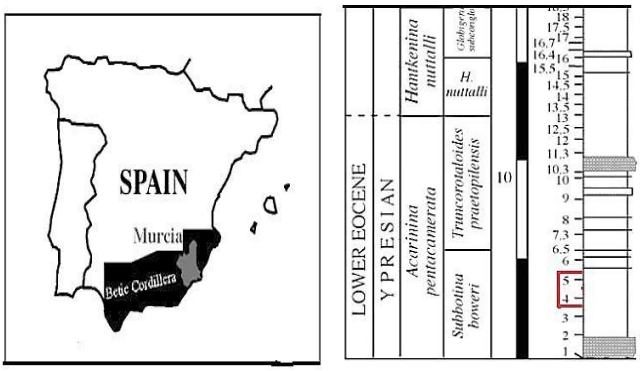

Figure 7: The location map of the Fortuna section, southeast Spain, and the sample locations of the two recorded species in the stratigraphic log of the Fortuna section (*S. ortizae*, sample 4 and *P. thomasae,* sample 5), after Ortiz & Thomas (2006).

Genus *Pseudoclavulina* Cushman, 1937

***Pseudoclavulina thomasae* Anan, sp.** (=*Pseudoclavulina* sp. A - Ortiz & Thomas, 2006, p. 108, pl. 2, fig. 1) - (Plate 1, Figure 9)

Holotype: Illustrated specimen in Plate 1, Figure 9.

Etymology: Center for the Study of Global Change, Department of Geology and Geophysics,

Yale University, New Haven, CT 06520-8109, USA. email: ellen.thomas@yale.edu

Type locality: Fortuna section, South Spain (see Figure 7).

Stratigraphic level: Ypresian, sample 5.

Description: Test coarsely agglutinated wall with very roughly finished, elongate, early triserial portion bluntly triangular in cross-section and slightly inclined, later uniserial inflated, discoidal and rounded portion separated by depressed horizontal sutures, aperture terminal, rounded, with a distinct tubular long neck.

Remarks: *Pseudoclavulina thomasae* is characterized by rough and coarsely agglutinated test, and long triserial part with indistinct chambers. This species differs from the Danian *P. futyani* Anan (Plate 1, Figure 10) by its more coarsely agglutinated wall, rougher surface, and less depressed sutures.

Genus *Clavulina* d'Orbigny, 1826

***Clavulina sztrákosae* Anan, n. sp.** (=*Clavulina parisiensis* d'Orbigny - Sztrákos, 2000, p. 78, pl. 2, fig. 6) - (Plate 1, Figure 11)

Holotype: Illustrated specimen in Plate 1, Figure 11.

Etymology: After the French micropaleontologist Károly Sztrákos.

Type locality: Adour Basin (Aquitaine, France).

Stratigraphic level: Middle Eocene.

Description: Test elongate, early stage triserial and triangular in section, later stage uniserial and rectilinear, with angular to rounded section; wall agglutinated, with considerable coarse-grained wall, suture horizontal in the uniserial stage, aperture terminal and rounded.

Remarks: The Sztrákos's specimen (Plate 1, Figure 11) differs the figured holotype of the species *Clavulina parisiensis* d'Orbigny (Plate 1, Figure 12) by its coarsely agglutinated wall and lacks an apertural tooth.

4. Paleogeographic Distribution

During the Paleogene Neotethys (~55.8 Ma) the Atlantic was connected with Indian Oceans via Mediterranean Sea, as noted by some authors (Haq and Aubry, 1978; Anan, 1995; Rögl, 1999; Stassen et al., 2015) (Figure 8).

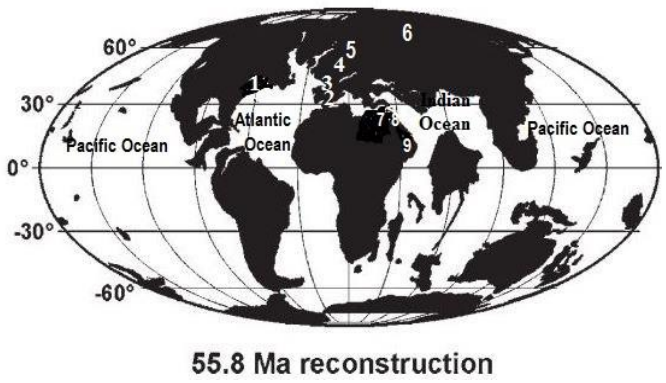

Figure 8: Location map of the recorded countries in this study (1. USA, 2. Spain, 3. France, 4. Hungaria, 5. Poland 6. Russia, 7. Egypt, 8. Jordan, 9. UAE) in the Early Paleogene time (after Stassen et al., 2015, with some modifications).

5. Paleoenvironments

Murray noted that arenaceous foraminifera tend to increase in cooler environment, which means that increase in shallow-water environments or in upper bathyal environment or more deeper (Murray, 1973). Anan noted that the Paleocene assemblage of benthic foraminiferal species (including *Gaudryina limbata*) in the Malaqet section (UAE) belongs to the MFT, middle to outer neritic environment (Anan, 1993). A group researchers noted that the tubular taxa (e.g. *Bathysiphon*) are rare in neritic settings but common in bathyal facies, while elongated serial taxa (e.g. *Gaudryina, Siphogaudryina, Dorothia, Pseudoclavulina*, *Clavulina*) are most common in the upper to middle bathyal assemblages (Nagy et al., 2000). Anan noted that most of the recorded species from the Middle-Upper Eocene of Jabal Hafit, UAE (e.g. *Bathysiphon saidi*) are endemic to the tropical-subtropical regions (Anan, 2005). Ozsvárt noted that the diversity and composition of benthic foraminiferal assemblages is strongly controlled by water temperature and salinity of water mass, in shallow and deeper region on shelves, where changes in temperature and salinity might pass off rapidly (Ozsvárt, 2007). A group researchers noted that a group researcher figured that the tubular test like the genus *Bathysiphon* has tranquil bathyal with low organic flux environment (Setoyama et al., 2011). Jones noted that the modern smaller agglutinating foraminifera occur in all marine environments, from marginal to deep, and some are tolerant of hyposalinity as well as normal marine salinity; and/or of hypoxia or dysoxia (Jones, 2014). A group researchers noted that complex-walled agglutinated foraminiferal assemblage of coarse sand grains is interpreted as of deeper littoral environment, and the genera: *Gaudryina, Siphogaudryina* are restricted to deep marine environments (Hewaidy et al., 2017). A group researchers considered some agglutinated genera in Wadi Necham section, (northwest Tunisia) yields agglutinated species, such as *G. pyramidata*, of typical bathyal to upper abyssal assemblage with high terrigenous sedimentation rate and associated moderate organic flux (Bejaoui et al., 2019). Anan noted that the faunal assemblage in Atlantic and Pacific Oceans belong to deep water agglutinated foraminifera "DWAF" which may live around carbonate compensation depth "CCC", and suggested a lower slope setting at about 1000 m water depth in an open marine basin (Anan, 2021). The Indo-Pacific and Mediterranean exhibit pronounced similarities, which indicate that the connection between the two areas mentioned by a marine seaway, and the East Atlantic fauna was much more closely related to the fauna than it is today (Figure 9).

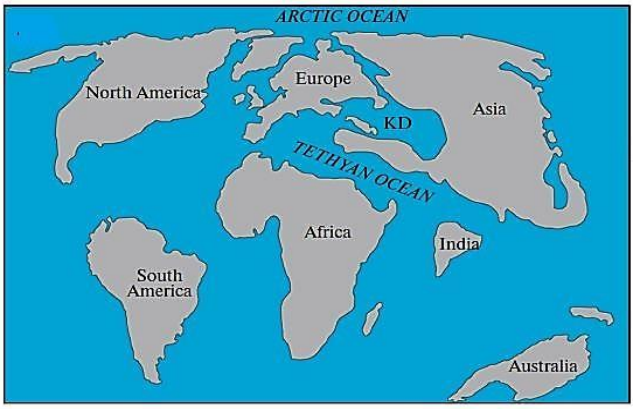

Figure 9: Paleogeography of the Neo-Tethys Ocean during the Early Paleogene showing the flow direction of the sea water from east to west in the Tethys (after Abed, 2013).

6. Conclusion

Seven Early Paleogene coarse-grained agglutinated benthic foraminiferal species are presented in this study are believed here to be new: *Bathysiphon alegretae*, *Gaudryina pozaryskai*, *Gaudryina stasseni*, *Dorothia sztrákosae*, *Siphogaudryina ortizae*, *Pseudoclavulina thomasae* and *Clavulina sztrákosae*. The recorded taxa shows deep water agglutinated foraminifera "DWAF" which may live around carbonate compensation depth "CCC", and suggested a lower slope setting at about 1000 m water depth in an open marine basin.

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