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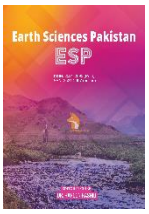

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RESEARCH ARTICLE

PERCULTALINA: A NEW LAGENID BENTHIC FORAMINIFERAL GENUS

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ABSTRACT

Percultalina n. gen. is introduced here to include the Early Paleogene benthic Lagenid foraminiferids from Jordan and Egypt (Southern Tethys) that characterized by its large lenticular initial portion followed by two or more uniserial elongate erected or inclined inflated rounded chambers, ornamented surface by elevated sutures with a row of tubercles or nodes along the sutures, and spinose surface. This new genus has been previously assigned to different genera: *Vaginulinopsis* Reuss, or *Percultazonaria* Loeblich & Tappan, or *Marginulinopsis* Silvestri. Three Early Paleogene species of the new genus are described here from two countries in Jordan: *Percultalina wadiarabensis* (Futyan) with rectilinear uniserial portion of the test (the genotype of the new genus), and Egypt: *Percultalina misrensis* Anan (n. sp.), and *P. sinaensis* with inclined uniserial portion of the test. Moreover, varied and diverse genera of the Lagenid benthic foraminifera are attempted here to study the holotypes of seven diagnostic genera of this group: *Lenticulina* Lamarck, *Cribrolenticulina* Haman, *Marginulinopsis* Silvestri, *Percultazonaria* Anan, *Leticuzonaria* Anan, *Lenticubella* Anan and *Percultalina* Anan. The taxonomic revision of these seven genera will greatly aid paleontologists and biostratigraphers to helpfully understanding.

KEYWORDS

Benthic foraminifera, Lagenid, Percultalina, Paleogene, Tethys

1. INTRODUCTION

The present study is mainly devoted to the systematic description of the new genus *Percultalina* and other two related Early Paleogene species: *Percultalina wadiarabensis* (Futyan) from Jordan, and *P. misrensis* and *P. sinaensis* from Egypt. *P. wadiarabensis* was recorded from the Late Paleocene of Wadi Arab section, near Irbid, northern Jordan, while the *P. misrensis* was recorded from the Late Paleocene of Nag El Quda section, southern Egypt, and *P. sinaensis* from the Middle Eocene of Wadi Tayiba and Wadi Bagha, western Sinai, Egypt. The records for the seven Lagenid genera, which previously mentioned, are common in the Cretaceous-Paleogene time, which originally erected in the USA, Northern and Southern Tethys (Figure 1). The intent of this study is twofold: 1) To study the new Lagenid Early Paleogene genus *Percultalina* and its three species from two countries Jordan and Egypt in the Southern Tethys and to detect its recent taxonomic consideration, stratigraphy and paleogeographic distribution of them, 2) An attempt has been made to study the holotypes of the described seven Lagenid genera of the Subfamily Lenticulininae (*Lenticulina, Cribrolenticulina, Marginulinopsis, Percultazonaria, Leticuzonaria, Lenticubella* and *Percultalina* n. gen.), as possible in connection with the original descriptions and figures (Table 1).

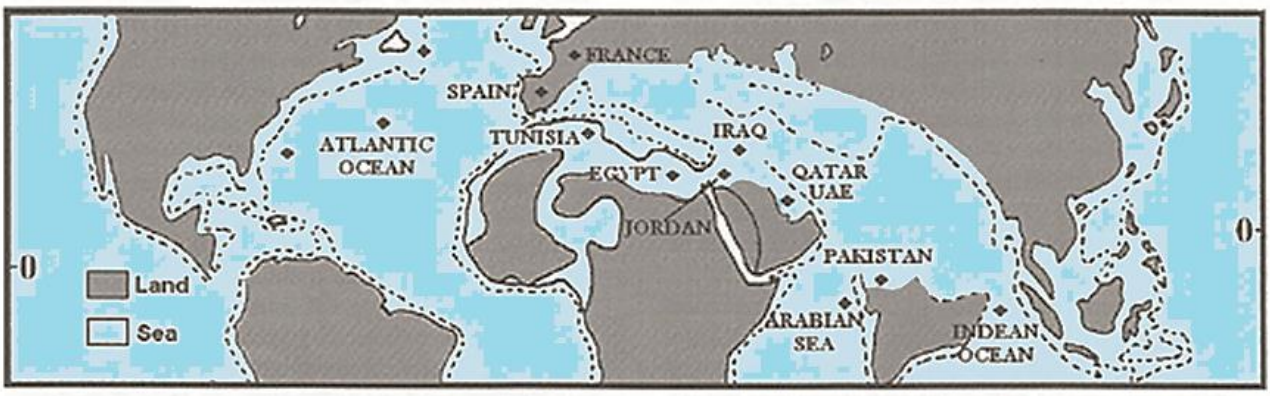

Figure 1: Late Maastrichtian paleogeographic map showing the locations of the areas in which the recorded genera were distributed (Solakius et al., 1990)

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Table 1: The synoptical diagram of seven recorded genera and main their morphocharacters.

Character / Genus	arrangement		ornamentation	suture	periphery	test shape	aperture				
	early stage	later stage					shape	single	multible	on neck	position
Lenticulina	planispiral	–	smooth	slightly curved	acute with keel	coiled involute	radial	single	–	–	exterio-marginal
Cribolenticulina	planispiral	–	row of tubercles along sutuures	radial	acute with faint keel	coiled involute	rounded	–	cribrate	on short neck	exterio-marginal
Marginulinopsis	planispiral	uniserial	longitudinal costae	slightly depressed	acute then rounded	elongate	radial	single	–	on neck	on dorsal side
Percultazonaria	planispiral	uniserial	row of nodes	raised nodes	elongate acute with faint keel	elongate	radial	single	–	on neck	on dorsal side
Lenticuzonaria	planispiral	–	row of nodes or tubercles	raised nodes	rounded spinose	coiled involute	radial	single	–	on neck	exterio-marginal
Lenticubella	planispiral	uniserial	smooth	slightly depressed	biconvex lobulate keeled	large slightly curved	radial	single	–	on neck	exterio-marginal
Percultalina	planispiral	uniserial	row of nodes and spinose	raised then depressed	rounded spinose	elongate	radial	single	–	on neck	on dorsal side

2. Faunal Discussion

The new genus *Percultalina* has a compiled characters between its large lenticular initial portion followed by two or more uniserial elongate erected chambers comprising rectilinear or inclined inflated rounded chambers, proximal portion having flanged spinose periphery, raised sutures in coiled part but depressed in the uniserial final part, heavily ornamented surface and in part covered by short spines, final chambers globular, aperture radiate terminal with short neck. This genus is characterized by its large initial coiled portion, slightly convex on both sides, and spinose periphery. It differs from the genus *Percultazonaria* by its larger initial portion, from the genus Leticuzonaria by its uniserial last portion, from the genus *Lenticubella* by its flanged spinose periphery and raised sutures in coiled part with low sharp spines, from the genus *Marginulinopsis* by its spinose surface than longitudinal costae, from the genus *Cribrolenticulina* by its uniserial last portion and its radial aperture than cribrate aperture (Table 1).

3. Taxonomy

The taxonomy of the new genus *Percultalina* and its three species (*P. wadiarabensis, P. misrensis* and *P. sinaensis*), as well as the recorded seven genera of the Lagenid benthic foraminifera are following the taxonomic classification (Loeblich and Tappan, 1988). The illustrated taxa have been shown in Plates (1, 2). The synoptical diagram of seven recorded genera and their morphocharacters is shown in Table 1.

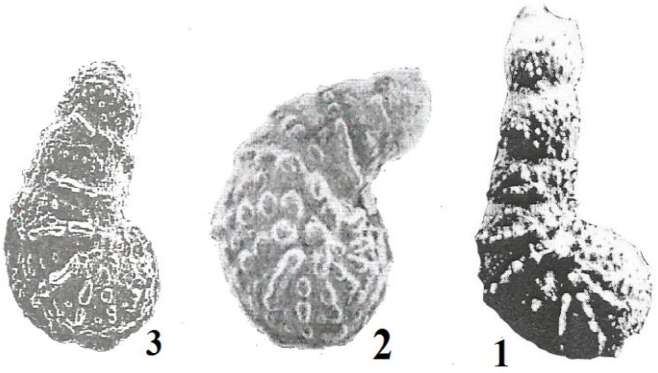

Plate 1: Figure 1 Percultalina wadiarabensis, Late Paleocene x 35, 2. Percultalina misrensis Anan, n. sp., Late Paleocene x 35, 3. Percultalina sinaensis Anan, n. sp., Middle Eocene x 30 (Futyan, 1976).

Order Foraminiferida Eichwald, 1830

Suborder Lagenina Delage & Hérouard, 1896

Superfamily Nodosariacea Ehrenberg, 1838

Family Vaginulindae Reuss, 1860

Subfamily Lenticulininae Chapman, Parr and Collins, 1934

Genus *Percultalina* Anan, n. gen. - (Pl. 1, figure 1, pl. 2, figure 7)

***Percultalina wadiarabensis* (Futyan, 1976)**

Genotype and Type species *Vaginulinopsis wadiarabensis* Futyan, 1976, p. 524, pl. 81, figures 8, 9 (non figure 7).

2020 *Percultazonaria wadiarabensis* (Futyan) - Anan, p. 69, pl. 2, figure 6a.

Holotype: Plate 1, figure 1, pl. 2, figure 7.

Dimension: Length 1. 21 mm, maximum width 0.65 mm.

Etymology: After the type locality.

Type locality: Wadi Arab, northern Jordan .

Type sample: sample 156 of the shale bed.

Age: Late Paleocene.

Diagnosis: Test planispirally large coiled, followed by three uniserial elongate erected chambers, spinose periphery, raised sutures in coiled part with low sharp spines, broadly depressed sutures in the uncoiled portion, heavily ornamented surface and in part covered by short spines, final chambers globular, aperture radiate terminal with short neck.

Remarks: This genus is characterized by its large initial coiled portion and spinose periphery. It differs from the genus *Vaginulinopsis* in more prominent early portion in its elevated costae and nodose sutural ornamentation. Anan considered this Late Paleocene genus as the ancestor of the descendent Early Eocene genus Percultazonaria (Anan, 2020). It was originally recorded, so far, from the Late Paleocene of Wadi Arab, northern Jordan (Figures 2, 3).

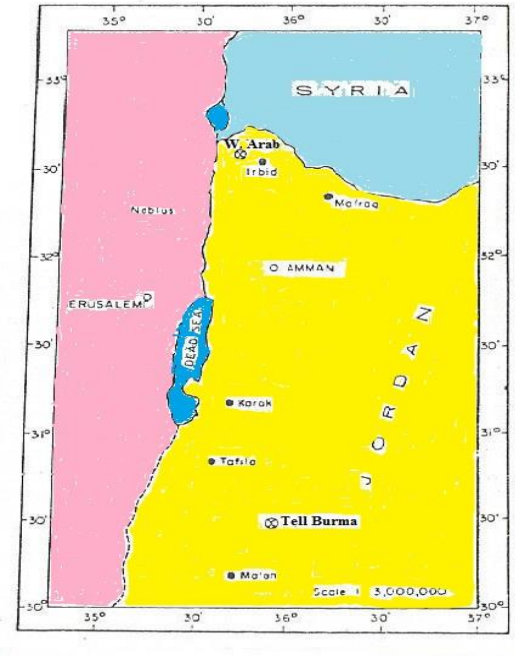

Figure 2: Location map of the Tell Burma, in southern Jordan, (the type section of the Paleocene Leticuzonaria hodae Anan, 2021a), and Wadi

Arab, in the northern Jordan (the type section of the Percultalina wadiarabensis Anan, n. gen.

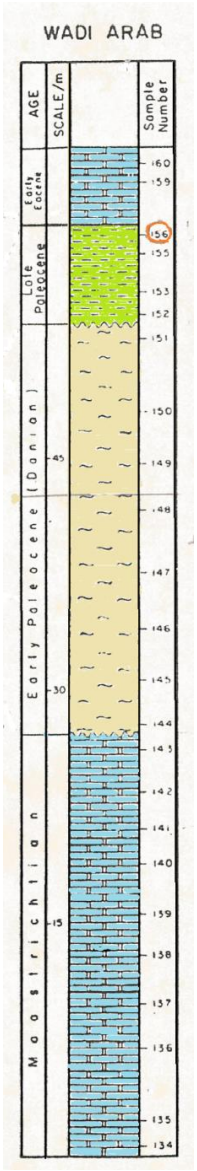

Figure 3: The lithostratigraphic log of the Wadi Arab section (northern Jordan), from base to top: chalk (in blue), marl (gray brown), shale (green) and chalk (at the top), showing the location of the type sample 156 of the new genus *Percultalina* Anan, from the Late Paleocene shale (Futyan, 1976).

***Percultalina misrensis* Anan, n. sp. (Plate 1, figure 2)**

2012 *Marginulinopsis tuberculata* (Plummer) - Youssef and Taha, p. 4289, plate 2 figure 18 (*non* figure 17).

Holotype: Plate 1, figure 2.

Dimension: Length 1. 2 mm, width 0.50 mm.

Etymology: After the type locality, Arab Republic of Egypt (Misr).

Type locality and sample no.: Nag El Quda section: sample 12 (Figures 4, 5).

Age: Late Paleocene.

Diagnosis: Test planispirally large coiled, followed by 3-4 uniserial elongate inclined chambers (about 45º NE), spinose periphery, raised sutures in coiled part with knobs along the suture lines, slightly depressed sutures in the uncoiled portion, final chambers globular to semi-globular, aperture radiate terminal with short neck**.**

Remarks: This species *Percultalina misrensis* differs from *P. wadiarabensis* in its inclined uniserial portion than rectilinear chambers, coarser knobs in the early coiled portion, and lesser depressed sutures.

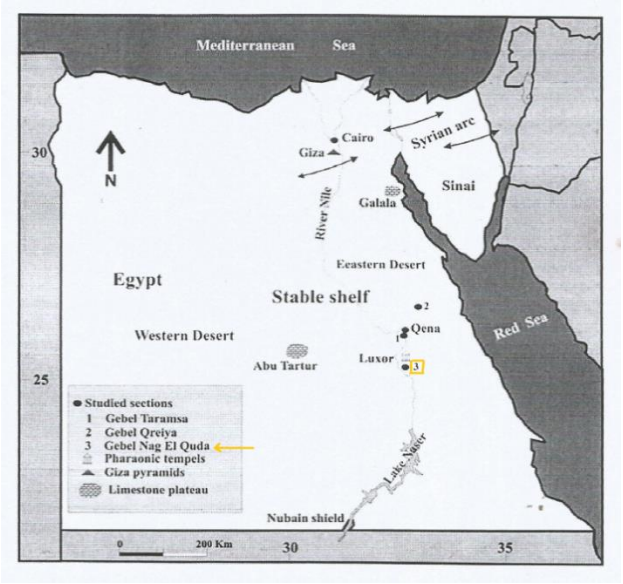

Figure 4: Location map of the Nag El Quda section, south Qena, Southern Egypt.

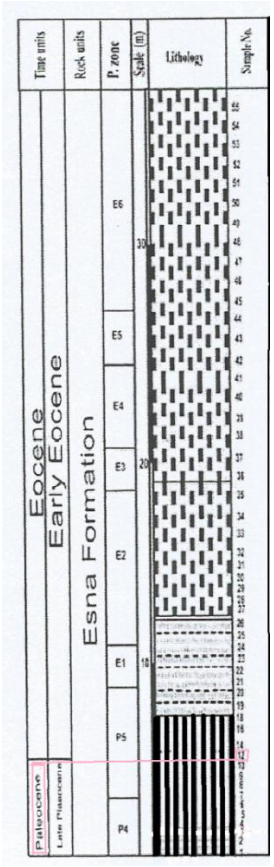

Figure 5: The lithostratigraphic log of the Nag El Quda section (Southern Egypt), showing the location of the type sample 12 of the Late Paleocene new species *Percultalina misrensis* Anan (Youssef and Taha, 2012).

***Percultalina sinaensis* Anan, n. sp. (Plate 1, figure 3)**

2000 *Marginulinopsis brantlyi* - Abul-Nasr, p. 68, figure 14. 6 (Garrett, 1941).

Holotype: Plate 1, figure 2.

Dimension: Length 1. 5 mm, width 0. 60 mm.

Etymology: After the type locality, Sinai, Egypt.

Type locality and sample no.: Wadi Tayiba section, sample 25 (Figure 6,7).

Age: Middle Eocene.

Diagnosis: Test planispirally large coiled, followed by 3-4 uniserial elongate inclined chambers (about 25º NE) , spinose faint keel in the outline periphery, raised broken sutures in coiled part, slightly depressed

sutures in the uncoiled portion, heavily ornamented surface and in part covered by small knobs, final chambers globular, aperture radiate terminal with short neck.

Remarks: This species *Percultalina sinaensis* differs from *P. wadiarabensis* inclined uniserial portion, less heavily spinose surface, and from *P. misrensis* by less inclined uniserial portion, and younger stratigraphic level.

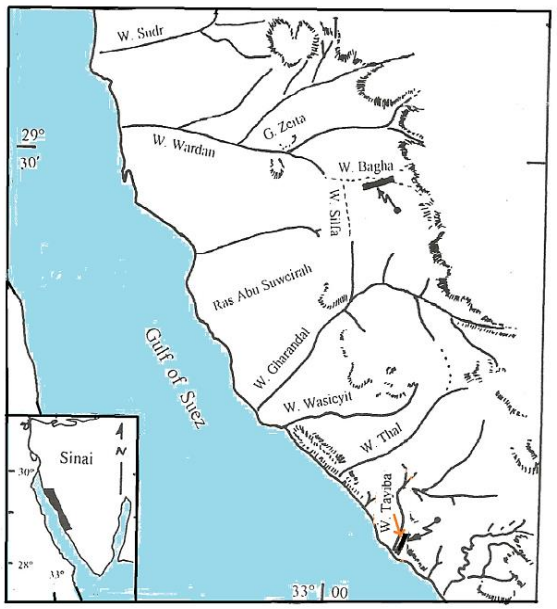

Figure 6: Location map of Wadi Tayiba section, southwest Sinai, Egypt.

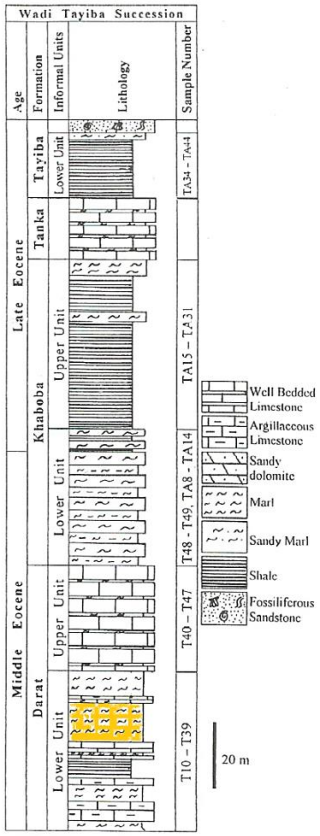

Figure 7: The lithostratigraphic log of the Wadi Tayiba section (southwest Sinai, Egypt), showing the location of the type sample 15-17 of the Middle Eocene of the new species *Percultalina sinaiensis* Anan (Abul-Nasr, 2000).

Genus *Lenticulina* Lamarck, 1804 - (Plate 2, figure 1)

Type species *Lenticulites rotulata* Lamarck, 1804, p. 186.

1988 *Lenticulina rotulata* (Lamarck) - Loeblich & Tappan, p. 405, pl. 446, figures 1, 2.

Diagnosis: Test lenticular planispiral involute, biumbonate, surface smooth, periphery angled with faint keel, sutures radial curved and raised, aperture radial and exteriomarginal.

Remarks: The representatives of cosmopolitan genus are recorded in all continents. It was originally recorded, so far, from France.

Genus *Cribrolenticulina* Haman, 1978 - (Plate 2, figure 2)

Type species *Cribrolenticulina akersi* Haman, 1978, p. 90.

1988*Cribrolenticulina akersi* Haman - Loeblich and Tappan, p. 404, pl. 445, figures 1, 2.

Diagnosis: Test lenticular planispiral involute, biumbonate, surface smooth but with a row of tubercles along the sutures, aperture exteriomarginal cribrate produced on a short neck.

Remarks: This genus differs from the genus in its cribrate aperture and row of tubercles along the sutures. It was originally recorded, so far, from USA and Mexico.

Genus *Marginulinopsis* Silvestri, 1904 - (Plate 2, figure 3)

Type species *Cristellaria bradyi* Goës, 1894, p. 64.

1988 *Marginulinopsis bradyi* (Goës) - Loeblich and Tappan, p. 406, pl. 446, figures 20, 21.

Diagnosis: Test elongate, early portion close coiled planispiral, later uniserial, surface with numerous longitudinal costae straight in the uniserial part but oblique in the coiled part, sutures horizontal straight and slightly depressed, aperture terminal on neck.

Remarks: This cosmopolitan genus is characterized by its longitudinal costae. It was originally recorded, so far, from Italy.

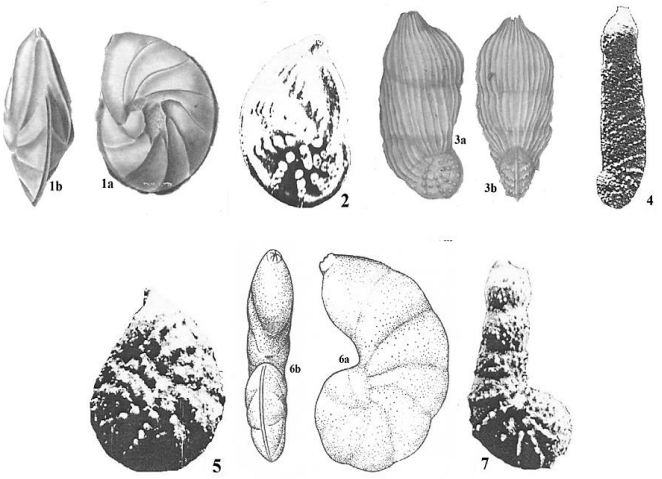

Plate 2: Figures of the holotypes of the studied genera: 1. Lenticulina (Lamarck, 1804), a. side view, b. apertural view x 20, 2. Cribrolenticulina Haman (1978) x 45, 3. Marginulinopsis Silvestri (1904) x 40, 4. Percultazonaria Loeblich & Tappan (1986) x 25, 5. Leticuzonaria Anan (2021) x 30, 6. Lenticubella Anan (2022) x 25, 7. Percultalina Anan (n. gen.) x 35.

Genus *Percultazonaria* Loeblich & Tappan, 1986 - (Plate 2, figure 4)

Type species *Cristellaria subaculeata* Cushman, 1923, p. 123.

1988 *Marginulinopsis bradyi* (Goës) - Loeblich and Tappan, p. 406, pl. 446, figures 20, 21.

Diagnosis: Test elongate somewhat flattened, early portion closed coiling, uniserial part has four to six laterally compressed chambers which are longer than high, periphery subacute to carinate in the coil and on the dorsal margin, but rounded in the ventral margin, peripheral keel may be spinose, surface ornamented by strongly elevated sutures that may be costate or broken into a row of nodes and smooth surface between sutures, aperture radiate terminal at the dorsal angle on a neck.

Remarks: This cosmopolitan genus differs from the genus Vaginulinopsis by its more prominent early coil and the elevated row of nodose sutural ornamentation. It was originally recorded, so far, from the Paleocene of USA.

Genus *Leticuzonaria* Anan, 2021 - (Plate 2, figure 5)

Type species *Leticuzonaria hodae* Anan, 2021a, p. 34, plate 1, figure 3.

2021b *Leticuzonaria hodae* Anan - Anan, p. 89, plate 1, figure 30.

Diagnosis: Test lenticular planispiral involute, surface spinose, but with a row of tubercles or broken nodes along the sutures, aperture radiate exteriomarginal.

Remarks: This genus differs from the genus Lenticulina in its tubercles, nodes and spines on the test surface and sutures. It was originally recorded, so far, from the Paleocene of Wadi Arab, northern Jordan (Figure 2)

Genus *Lenticubella* Anan, 2022 - (Plate 2, figure 6)

Type species *Darbyella irregularis* Pożaryska, 1965, p. 62, plate 8, figure 7.

2022 *Lenticubella irregularis* (Pożaryska) - Anan, p. 18, plate 1, figures 1-4.

Diagnosis: Test large, compressed, sometimes slightly convex on both sides for the first portion symmetric coiled, the remainder of test uncoiled, chambers numerous about 10, gently increasing in size as added; sutures distinct, limbate, slightly curved, depressed, surface smooth, convex; aperture radiate on the top of the last formed chamber; periphery rounded, lobate, with faint keel.

Remarks: This genus is characterized by large size, inclined uniserial portion, large radial aperture, limbate depressed sutures, and faint keel periphery. It was originally recorded, so far, from the Paleocene of Poland.

4. Paleogeography

A group researchers noted that for 260 Ma, the Tethys Ocean covered much of the face of the earth, from the Caribbean domain in the west to the Indonesian domain in the east (Vrielynck et al., 1995). From the Late Cretaceous to the present, the Tethys has been closing, with sediments in the Caribbean, Alpine-Himalayan, and Indonesian belts. Prior to that, Tethys had spread and cut Pangaea as early as the Permian. Remnants of this ocean are found only in the Central Atlantic and the Mediterranean Sea. A group researchers noted that the Tethyan Realm had been connected with the Indo-Pacific Ocean in the east and with the Atlantic Ocean to the west via the Mediterranean Sea during the late Cretaceous and early Paleogene times (Rosenbaum et al., 2002). The three species of the new genus *Percultalina* in the Jordan and Egypt, as well as the seven recorded Lagenid genera (including the new genus *Percultalina* Anan, this study) have wide geographic distribution from North America (USA and Mexico) to Egypt and Jordan (East Mediterranean, the remnant of the Tethys) via Europe (France and Italy).

5. Paleoenvironment

Benthic foraminifers represent an important means of interpreting paleoenvironments. Fifty five million years ago, the earth was subjected to a sudden climate change, it is one of the most extreme and abrupt warming events recorded in the geologic history. The new genus *Percultalina* was recorded from the Late Paleocene in Wadi Arab section (North Jordan) is accompanied also with other diagnostic keeled planktic foraminiferal (*Morozovella acuta* and *M. velascoensis*) as noted (Futyan, 1976). This assemblage is characteristic of warm stratigraphic interval as noted by which indicated to the middle–outer neritic environmental facies, and considered here to be related to the Midway-Type Fauna (MTF) (Frerichs, 1971; Berggren and Aubert, 1975). Some researchers noted that the benthic foraminiferal assemblages are mixture of Midway-type fauna and Velasco-type fauna (VF) which refer to inner neritic to outer neritic environments., and the study of benthic morphotype ratios used to recognize the environmental changes related to oxygen content and organic carbon flux (Youssef and Taha, 2012). Alegret and Ortiz noted that during the Late Paleocene of Dababiya Quarry (around of Nag El Quda section, which includes *P. misrensis*) this part of the Southern Tethys was occupied by an epicontinental basin, and the sediments were deposited in an outer shelf environment (~ 150-200 m depth) (Alegret and Ortiz, 2007). On the other hand, Abul-Nasr noted that the Middle Eocene of Wadi Tayiba section (includes *P. sinaensis* Anan, n. sp.) has been deposited in shelf environment (Abul-Nasr, 2000).

6. Conclusion

The present study deals with the paleontology, stratigraphy, and paleogeography of three identified species of the new Lagenid genus: Late Paleocene *Percultalina wadiarabensis* from Jordan, two new species from Egypt: the Late Paleocene *P. misrensis* and the Middle Eocene *P. sinaensis.* The recording of seven Late Cretaceous-Early Paleogene genera of the Lagenid benthic foraminiferal genera: *Lenticulina, Cribrolenticulina, Marginulinopsis, Percultazonaria, Leticuzonaria, Lenticubella* and *Percultalina*, and the latter genus is believed here as new. These faunal assemblages have wide geographic distribution from North America (USA and Mexico) to Jordan and Egypt (via Mediterranean, the remnant of the Tethys) and Europe (France and Italy). This study gives new evidence that the Tethyan Realm had been connected with the Indo-Pacific Ocean in the east and with the Atlantic Ocean to the west via the Mediterranean during the Late Cretaceous and Early Paleogene time

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