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RESEARCH ARTICLE

Contribution to the Knowledge of Twenty Members of the Lagenid Benthic Foraminifera in the Southern Tethys

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ABSTRACT

The modern taxonomical consideration is used for twenty Lagenid benthic foraminiferal species which are belonging to eight genera from nine countries in the Southern Tethys: Chile, Argentina, Egypt, Tanzania, Jordan, Iraq, United Arab Emirates (UAE), Iran and Pakistan: *Nodosaria catenula* (Reuss) Iraq, *Pyramidulina robinsoni* (Futyan) Jordan, *Tollmannia costata* (d'Orbigny), *Tollmannia fingeri* Anan, sp. nov., *Percultazonaria fragaria* (Gümbel), *Percultazonaria tuberculata* (Plummer), *Lenticuzonaria argentinica* Anan, *Lenticuzonaria misrensis* Anan, *Percultalina misrensis* Anan, *Hemirobulina comma* (Roemer), *Hemirobulina curvatura* (Cushman), *Hemirobulina humilis* (Reuss), *Hemirobulina nammalensis* (Haque), *Hemirobulina pachygaster* Gümbel, *Vaginulinopsis argentinica* Anan, sp. nov., *Vaginulinopsis deserti* (Said & Kenawy), *Vaginulinopsis emiratensis* (Anan), *Vaginulina boukharyi* (Anan), *Vaginulina chilensis* Anan, sp. nov., and *Ramulina shreifae* Anan, sp. nov. Nine species of these assemblage were recorded from Egypt (about 45%), 3 species from Chile (about 15%), 2 species from Argentina (about 10%), and one species (about 5%) from each of Tanzania, Jordan, Iraq, UAE, Iran and Pakistan. Four species are believed here to be new: *Tollmannia fingeri, Vaginulinopsis argentinica, Vaginulina chilensis* and *Ramulina shreifae.*

1. Introduction

The present study aims at throwing light on the paleontology and biogeography of twenty small benthic foraminiferal species that were originally erected by many authors from nine countries in the Southern Tethys. Ten of them were erected originally from Egypt (Northeast Africa), while the other species were recorded from East Africa (Tanzania), Southwest Asia (Jordan, Iraq, UAE, Iran, Pakistan) (Figure 1A) and South America (Chile, Argentina) (Figure 1B). Four out of them are believed here to be new: two species from Chile (*Tollmannia fingeri* and *Vaginulina chilensis*), one species from Argentina (*Vaginulinopsis argentinica*), and also the other one species from Egypt (*Ramulina shreifae*).

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2. Material of Study

Rich and well-preserved twenty Lagenid foraminiferal species from nine countries in the Southern Tethys (South America, Northeast and Central East Africa, and Southwest Asia) made it possible to elucidate them with its modern taxonomical consideration. Following the Code of Zoological Nomenclature, a taxonomic revision of four species of them is re-described its morphological features, which are considered here as a new species. As noted by many researchers (e.g., Finger [1]), the sample processing of foraminiferal specimens was processed from the sedimentary rock samples by (1) soaking in water or hydrogen peroxide until most of the sediment had disaggregated, (2) washing the residue over a standard 230-mesh (63-µm openings) sieve, and (3) drying by funneling through fast-flow filter paper, followed by oven-drying at 30 °C, (4) specimens were then picked with a 000 sable hair brush and sorted by species onto 63 60-grid micropaleontological slides, from which primary types were selected and transferred onto single-hole slides for reference and imaging.

3. Systematic Paleontology

The taxonomy of Loeblich & Tappan [2] is followed here. The twenty benthic foraminiferal species belonging to eight genera, which were recorded from the Maastrichtian to Ypresian of nine Southern Tethyan countries, and illustrated in Plate 1.

Order Foraminiferida Eichwald, 1830

Suborder Lagenina Delage & Hérouard, 1896

Genus *Nodosaria* Lamarck, 1812

***Nodosaria catenula* (Reuss, 1860)** (Plate 1, Figure 1)

1860 *Dentalina catenula* Reuss [3], p. 185, Plate 3, Figure 6.

1956 *Dentalina catenula* Reuss-Said & Kenawy [17], p. 132, Plate 2, Figure 24.

2019 *Laevidentalina catenula* Reuss-Jaff & Lawa[21], p. 12, Plate 1, Figure 21.● {illustrated specimen}.

Age, type locality and sample: Late Campanian-Early Maastrichtian, Dokan section, sample number DSH05-105 (Figure 2).

Remarks: *Nodosaria* differs from Laevidentalina by its elongate arcuate smooth test, rounded to fusiform proloculus, which is mostly apiculate. *Nodosaria catenula* was recorded from Austria (Northern Tethys) and later from both Egypt and Iraq (Southern Tethys).

Genus *Pyramidulina* Fornasini, 1894

***Pyramidulina robinsoni* (Futyan, 1976)** (Plate 1, Figure 2)

1976 *Nodosaria robinsoni* Futyan [4], p. 525, Plate 82, Figures 5, 6.

2006 *Nodosaria* sp. Pearson et al. [9], p. 307, Plate 4, Figure 11.

2016 *Nodosaria limbata* d'Orbigny-Orabi & Zaky [22], p. 188, Plate 3, Figure 1. ●

Type locality and sample no.: North Gunna, Farafra Oasis, Egypt, sample 65 (Figure 3A, B).

Age: Thanetian.

Remarks: Anan [23] introduced an evolutionary trend: The Middle Paleocene *Pyramidulina robinsoni* (Futyan) → Late Paleocene-Early Eocene *Pyramidulina leroyi* Anan [24]. *Pyramidulina robinsoni*, so far, was recorded from Jordan, Egypt and Tanzania.

Genus *Tollmannia* Sellier de Civrieux & Dessauvagie,

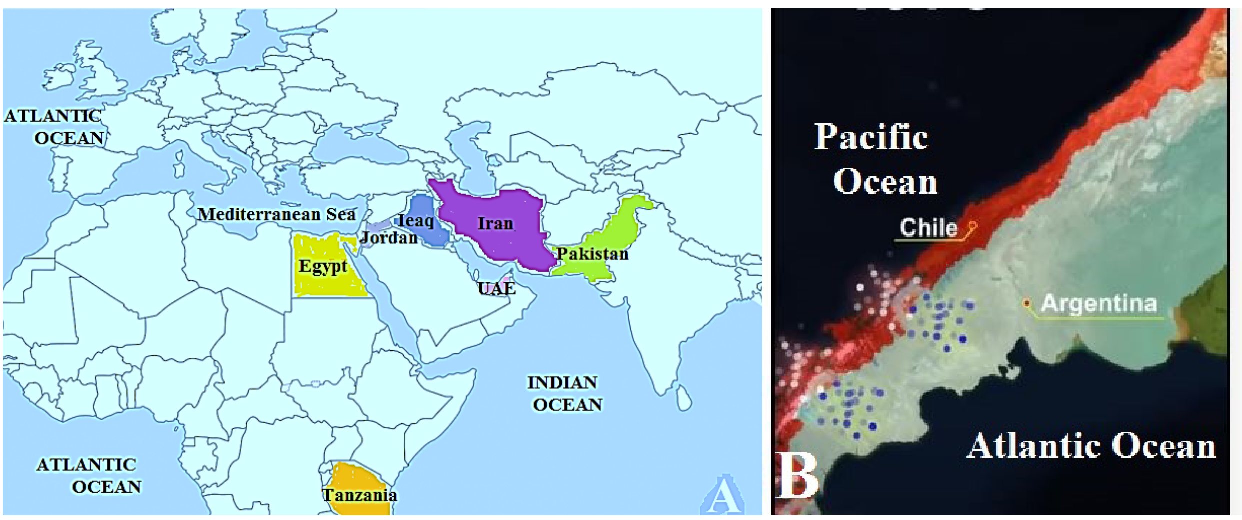

Figure 1. Location map of the Southern Tethys (A): Northeast Africa (Egypt), East Africa (Tanzania), Southeast Asia (Jordan, Iraq, UAE, Iran, Pakistan), and the southern Tethys (B): South America (Chile and Argentina).

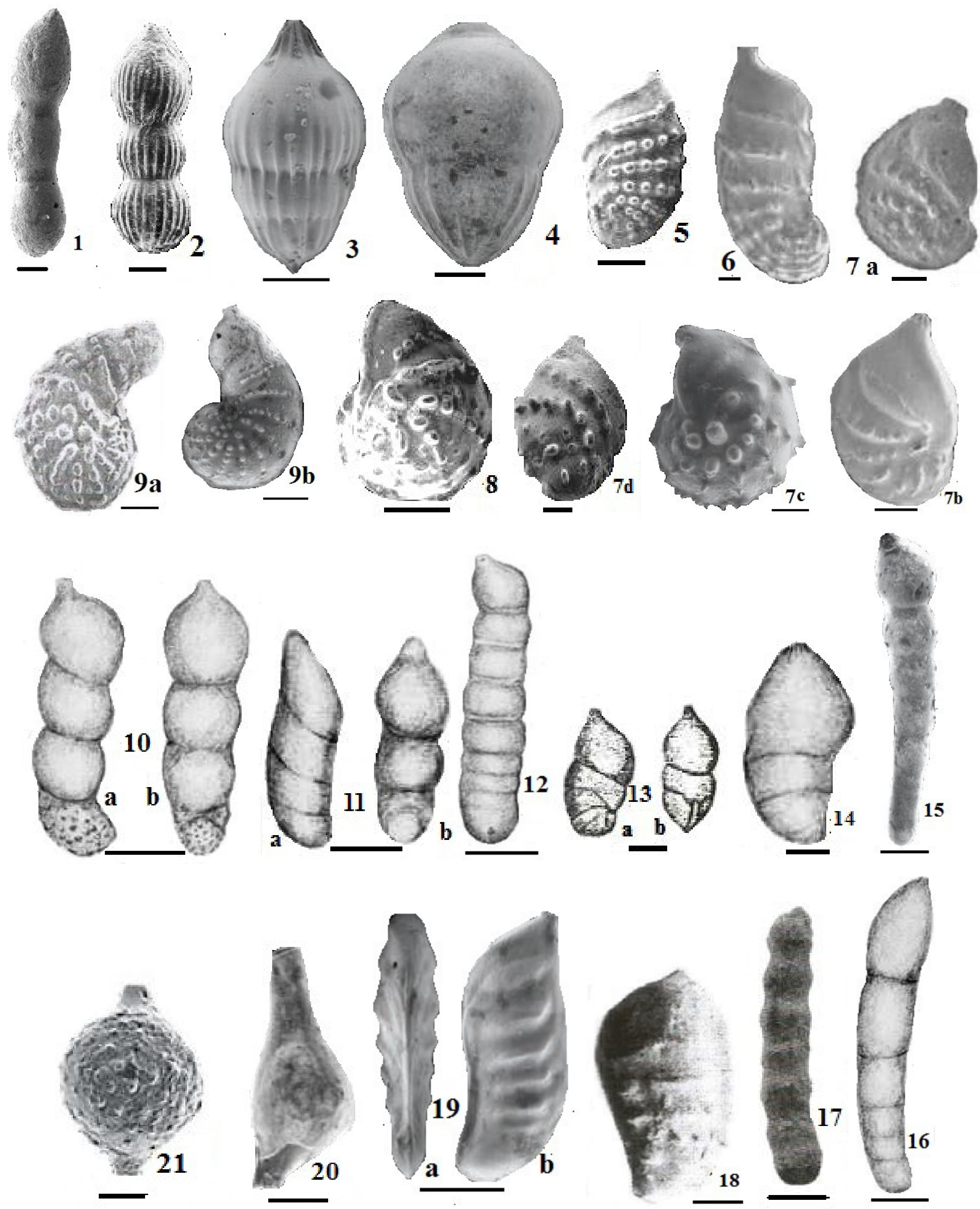

Plate 1. Figure 1. *Nodosaria catenula* (Reuss [3]), 2. *Pyramidulina robinsoni* (Futyan [4]), 3. *Tollmannia costata* (d'Orbigny [5]), 4. *Tollmannia fingeri* Anan, sp. nov., 5. *Percultazonaria fragaria* (Gümbel [6]), 6. *P. tuberculata* (Plummer [7]), 7a. *Lenticuzonaria argentinica* (Anan [8]), 7b. *Astacolus* sp.-Pearson et al. [9], 7c. *Percultazonaria* cf. *P. mamilligera* (Karrer)-Finger [1], 7d. *Marginulinopsis* sp.-Salahi [10], 8. *Lenticuzonaria misrensis* (Anan [8]), 9a,b. 9a. *Percultalina misrensis* (Anan [11]), 9b. *Percultazonaria vaughani* (Cushman)-Finger [1], 10a,b. *Hemirobulina comma* (Römer [12]), 10a. dorsal view, 10b. side view, 11a,b. *Hemirobulina curvatura* (Cushman [13]), 11a. dorsal view, 11b. side view, 12. *Hemirobulina humilis* (Reuss [14]), 13a,b. *Hemirobulina nammalensis (*Haque [15]), 13a. dorsal view, 13b. side view, 14. *Hemirobulina pachygaster* (Gümbel [16]), 15. *Vaginulinopsis argentinica* Anan, sp. nov., 16. *Vaginulinopsis deserti* (Said & Kenawy [17]), 17. *Vaginulinopsis emiratensis* (Anan [18]), 18. *Vaginulina boukharyi* (Anan [19]), 19a,b. *Vaginulina chilensis* Anan, sp. nov., 19a. side view, 19b. dorsal view, 20. *Ramulina shreifae* Anan, sp. nov., 21. *R. pseudoaculata* (Olsson [20]). (Scale bars 100 µm)

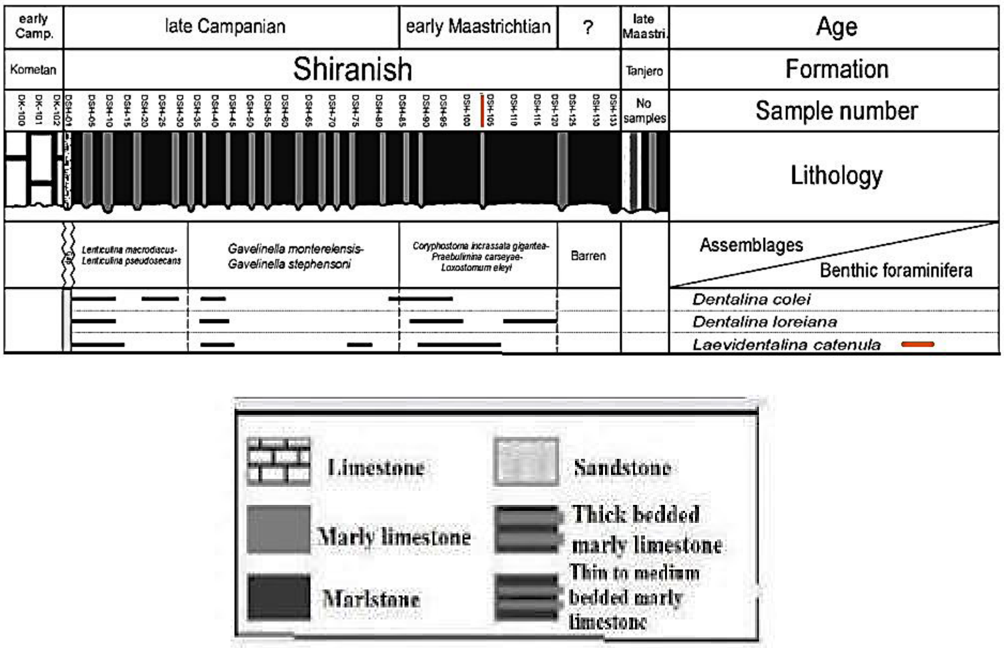

Figure 2. Stratigraphic log of the Dokan section, northeast Iraq, and the stratigraphic range of the *Nodosaria catenula* (Reuss) (after Jaff & Lawa [21]).

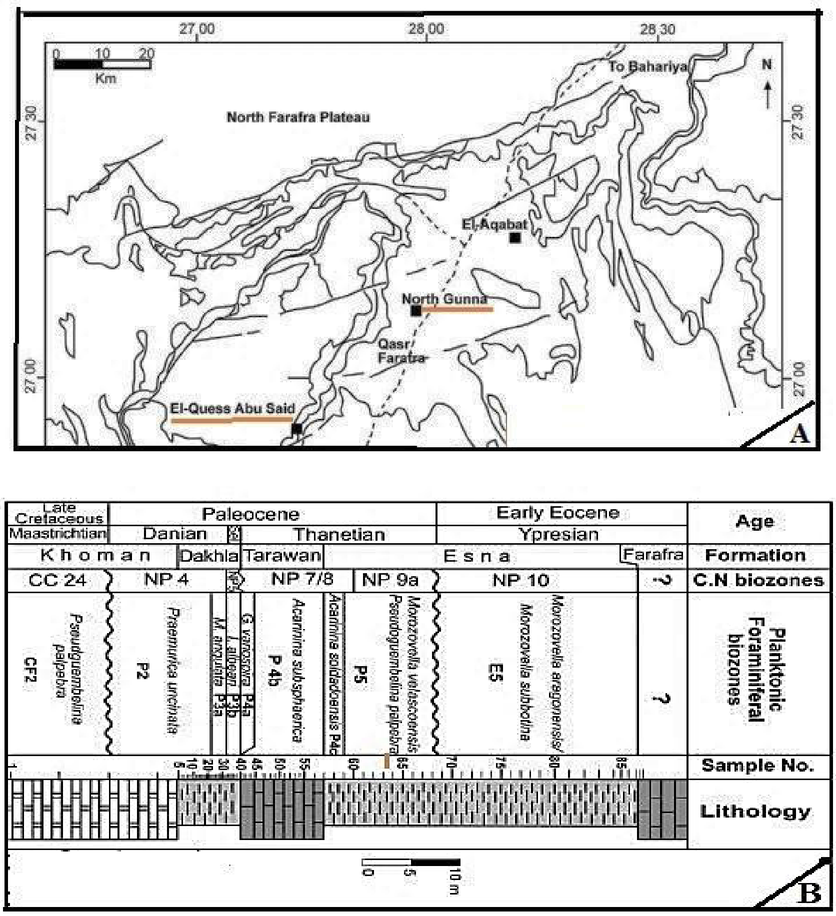

Figure 3. A. Location map of North Gunna and El-Guss Abu Said sections, Farafra Oasis, Egypt, B. Stratigraphy of North Gunna section, and the position of sample 65: Thanetian (after Orabi & Zaky [22]).

1965

Type species *Lingulina costata* subsp. *tricarinata* Tollmann, 1954 = *Lingulina costata* d'Orbigny.

Tollmannia costata **(d'Orbigny, 1846)** (Plate 1, Figure 3)

2013 *Pseudonodosaria comatula* (Cushman)-Finger [1], p. 403, Plate 7, Figure 7.●

Type locality: Navidad Formation (in the vicinity of the name-bearing town located southwest of Capital Santiago), Central Chile, sample number and depositary: University of California Museum of Paleontology (UCMP50135), PPP (collected site in the Navidad Formation) (Figure 4).

Remarks: The test has fine to coarse longitudinal ribs, then an elongate test with a smooth surface. For that, the late Early Miocene Finger's specimen *P. comatula* is treated here to belong to *T. costata* (d'Orbigny [5]) (Table 1).

Tollmannia fingeri **Anan, sp. nov.** (Plate 1, Figure 4)

2013 *Tollmannia costata* d'Orbigny-Finger [1], p. 404, Plate 7, Figure 11. ●

Holotype: Illustrated specimen in Plate 1, Figure 4.

Dimensions: Length 4.5 mm, width 3.2 mm.

Depositary: The University of California Museum of Paleontology (UCMP50135).

Etymology: After the micropaleontologist K.L. Finger, Univ. California Museum of Paleontology.

Type locality and sample: Navidad Formation, Central Chile, UCMP50135, PPP, PPT (Navidad area, Navidad Formation collecting sites) (Figure 5).

Stratigraphic level: Middle Miocene to Early Pliocene (Table 2).

Diagnosis: This new species is characterized by its fine to coarse surface longitudinal ribs, but die out distally in the last chamber, aperture terminal, slitlike, bordered by an elevated lip.

Remarks: *Tollmannia fingeri* Anan, sp. nov. differs from *T. costata* in its die out distally rib in the last chamber, and from *T. argentinica* Anan [25] in its shorter test, and without surface longitudinal ribs in the final globular chamber, than whole test. It is confined to Chile.

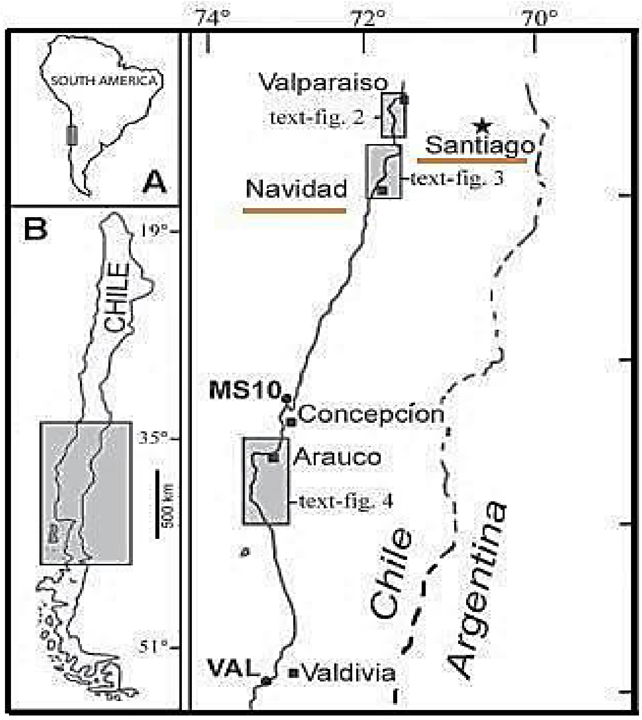

Figure 4. Location map of Navidad area, southwest the capital Santiago in central Chile (after Finger [1]).

Percultazonaria fragaria **(Gümbel, 1868)** (Plate 1, Figure 5)

1868 *Marginulina fragaria* Gümbel [6], p. 57, Plate 1, Figure 58.

2006 *Percultazonaria fragaria* (Gümbel)-Cimerman et al. [26], p. 24, Plate 5, Figures 4, 5.

2009 *Percultazonaria fragaria* (Gümbel)-Anan [27], p. 6,

Table 1. The stratigraphic range of *Tollmannia costata* in the Navidad Formation (Navidad area) and Ranquil Formation (Arauco area), Chile (VR = very rare, R = rare, F = frequent) (after Finger [1]).

Sector area	North													Central								
	Las Cruces		Navidad											Conc	Arauco							Vald
Geologic unit	EI Peral beds		Navidad Fm.											Ranquil Fm.								SDom
Locality	NLP	LPER	MOS	RAP	PPP	PPT	PPN	LBZ	PTA	MAT	NAV5	MPUP	CPUP	MS10	FRA	FRM	RQT	RQK	RAN	MIB	LEB	VAL
Pseudonodosaria aequalis	VR				R	R											VR		R			
Pseudonodosaria comatula			F		R	F			F		F		R		R		F					

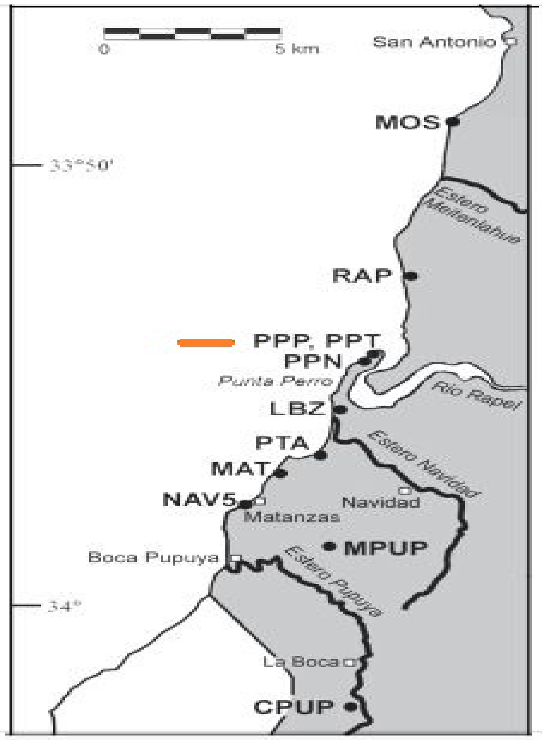

Figure 5. The sites of PPP and PPT in the Navidad Formation (Chile).

Plate 1, Figure 9.

2009 *Percultazonaria fragaria* (Gümbel)-Zlinská [28], p. 306, Plate 1, Figure 2.

2013 *Percultazonaria fragaria* (Gümbel)-Valchev et al. [29], p. 59, Plate 1, Figure 5.

2015 *Percultazonaria fragaria* (Gümbel)-Anan [30], p. 21, Plate 1, Figure 9.

2016 *Lenticulina* sp.-VahdatiRad et al. [31], p. 5 (of 13), Plate 2, Figure 8. ●

Type locality: Yaghol section, Khangiran formation, northeast of Iran (Figure 6).

Remarks: The Iranian specimen has closely characters with *P. fragaria.* It was recorded in France, Slovenia, Slovakia, Bulgaria, Egypt, UAE and Iran.

***Percultazonaria tuberculata* (Plummer, 1927)** (Plate 1, Figure 6)

1927 *Cristellaria subaculeata* var. tuberculata Plummer [7], p. 101, Plate 7, Figure 2, Plate 14, Figure 1.

2004 *Vaginulinopsis waiparaensis* (Finlay)-Pearson et al. [32], p. 40, Plate 5, Figure 8. ●

2021 *Marginulinopsis* sp. Salahi [10], p. 316, Plate 5, Figures 31, 32.

Type locality: Tanzania Drilling Project (TPD 1, 2), and stratigraphic log of TDP2 (Figure 7).

Remarks: The Tanzanian specimen belongs here to the genus *Percultazonaria*, dye to its rows of distinct beadlike tubercles best developed on the coiled portion of the test and giving place to more ridge-like elevations between later chambers with protruding radiate aperture.

***Lenticuzonaria argentinica* Anan, 2023** (Plate 1, Figure 7a–d)

2004 *Astacolus* sp.-Pearson et al. [32], p. 40, Plate 5, Figure 9. ●

2013 *Percultazonaria* cf. *P. mamilligera* (Karrer)-Finger [1], p. 412, Plate 9, Figure 8., UCMP 50169.●

2021 *Marginulinopsis* sp.-Salahi [10], p. 316, Plate 5, Figure 33. ●

2023 *Lenticuzonaria argentinica* Anan [25], p. 37, Plate 1, Figure 9. ●

Type locality and sample of *L. argentinica*: Formación Punta Torcida, AV-5, SEGEMAR 2860 (Ypresian), (Figure 8).

Remarks: The specimens of Tanzania, Chile, Iraq have closely related to *L. argentinica* Anan [25].

***Lenticuzonaria misrensis* Anan, 2021** (Plate 1, Figure 8)

2022 *Lenticulina tuberculata* (Plummer)-Farouk et al. [34], p. 32, Figures 12, 14.●

Type locality: Gharb El–Mawhob section, Dakhla Oasis (26°01'02" N, 28°13'18" E; Western Desert, Egypt) sample no. 255 (Figure 9a–c).

Remarks: The specimen of Farouk et al. [34] has identical characteristics with the *Lenticuzonaria* Anan [8].

***Percultalina misrensi*s Anan, 2022** (Plate 1, Figure 9)

2012 *Marginulinopsis tuberculata* (Plummer)-Youssef & Taha [35], p. 4289, Plate 2, Figure 18.

Table 2. The stratigraphic distribution of *Tollmannia fingeri* n. sp. in the Navidad Formation, Chile (VR = very rare, R = rare), (after Finger [1]).

Sector area	**North**												
	Las Cruces		Navidad										
Geologic unit	EI Peral beds		Navidad Fm.										
Locality	NLP	LPER	MOS	RAP	PPP	PPT	PPN	LBZ	PTA	MAT	NAV5	MPUP	CPUP
Tollmannia costata					R	VR							

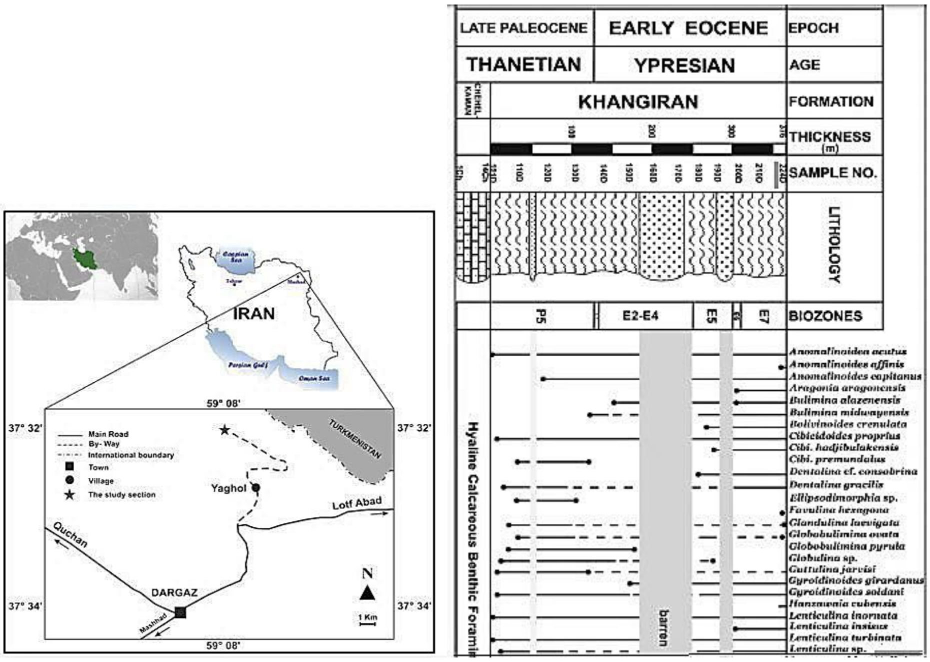

Figure 6. Location of the Yaghol section, sample location 224D (Ypresian) in the stratigraphic log of Yaghol section, North of Iran (after VahdatiRad et al. [31]).

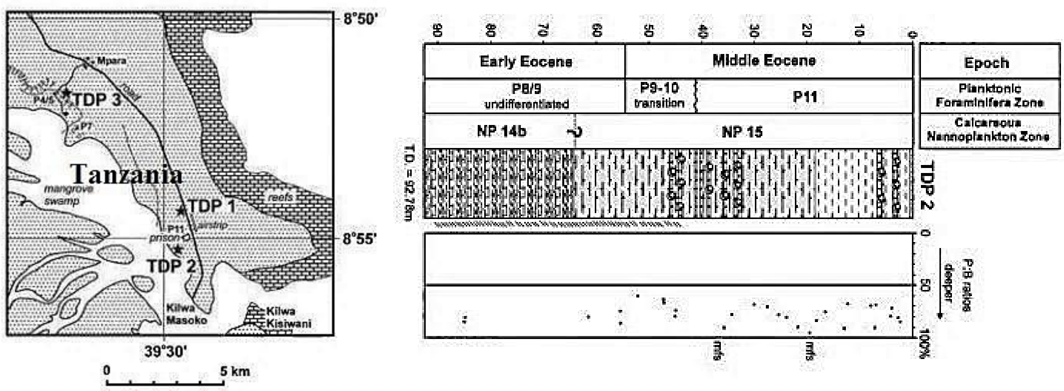

Figure 7. Location map of TPD 1, 2, and stratigraphic log of Early-Middle Eocene of Tanzania, East Africa (after Pearson et al. [32]).

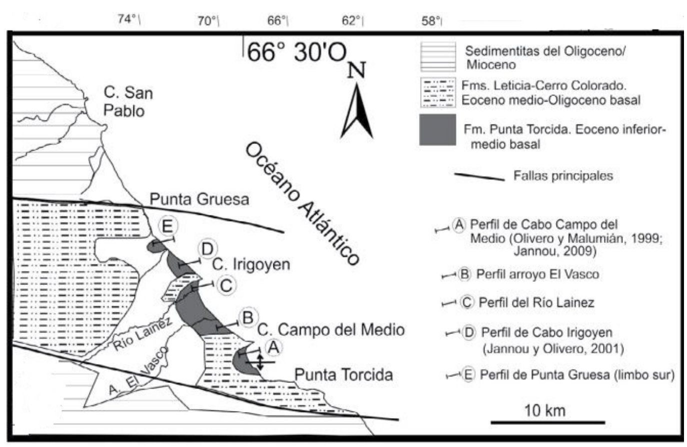

Figure 8. Geological map of de la Isla Grande de Tierra del Fuego (South Argentina), including the stratigraphy of the Punta Torcida Formation (after Jannou et al. [33]).

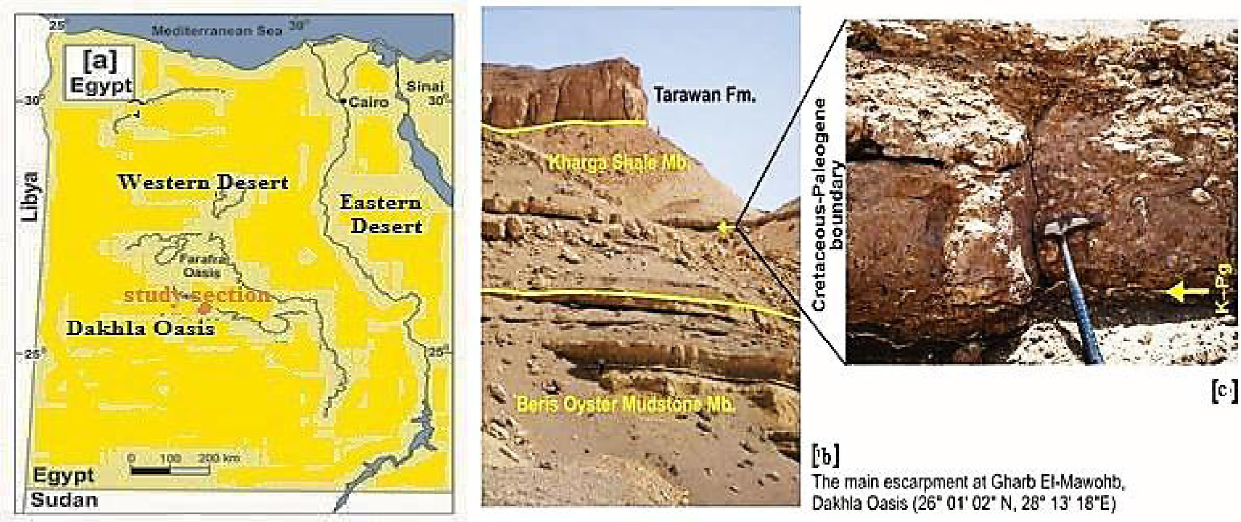

Figure 9. (a) Location map of the Gharb El-Mawhob section, Dakhla Oasis, Western Desert of Egypt, (b) stratigraphic log of the study section, (c) the K/P boundary of the study section (after Farouk et al. [34]).

2013 *Percultazonaria vaughani* (Cushman)-Finger [1], p. 412, Plate 9, Figure 10.●

2015 *Marginulinopsis tuberculata* (Plummer)-Orabi & Hassan [36], Plate 1, Figure 13.

2022 *Percultalina misrensi*s Anan [11], p. 32, Plate 1, Figure 2.

Type locality and depositary: Navidad Formation (North Chile), PPP, PPT, MPUP sites, UCMP 50171 (Figure 10).

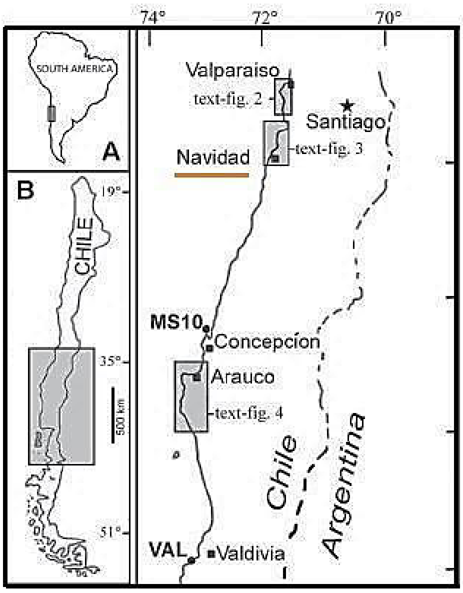

Figure 10. Location map of the Navidad section, Central Chile.

Stratigraphic range of Finger's specimen: Navidad Formation (VR = very rare, R = rare, C = common) (Table 3).

Remarks: The figured specimens of Finger [1], Youssef & Taha [35] and Orabi & Hassan [36] have closed characters with *Percultalina misrensis* Anan [11]. This species was recorded in Egypt and Chile.

Genus *Hemirobulina* Stache, 1864

***Hemirobulina comma* (Roemer, 1841)** (Plate 1, Figure 10)

1841 *Marginulina comma* Römer [12]), Plate 47, Figure 9.

1956 *Marginulinopsis comma* (Römer)-Said & Kenawy [17])., p. 132, Plate 2, Figure 19.●

Type locality and stratigraphic log of Nekhl section, North Sinai, Egypt (Figure 11),

Stratigraphic level and sample no. of the species: Figure 12.

Remarks: The genus *Hemirobulina* differs from *Marginulina* in having a smooth rather than longitudinally costate wall, It also differs mainly from *Marginulinopsis* in slightly curved early chambers than close coiled and planispiral, and lacking ribbed ornamentation on the uniserial stage. *Hemirobulina comma* was recorded from the Maestrichtian of Germany, and later from Nekhl section, Sinai of Egypt.

***Hemirobulina curvatura* (Cushman, 1938)** (Plate 1, Figure 11)

1938 *Marginulina curvatura* Cushman [13], p. 34, Plate 5, Figures 13–14.

1956 *Marginulina curvatura* Cushman-Said & Kenawy [17], p. 132, Plate 2, Figure 20.●

2003 *Marginulina curvatura* Cushman-Abdelghany [38], p. 394, Figure 3.

Type locality, Giddi section (no. 1), North Sinai, Egypt (see Figure 12).

Stratigraphic level and sample no.: Early Eocene, sample no. 859 (Figure 13).

Table 3: The stratigraphic rages of the *Percultazonaria vaughani* of Finger (= *Percultalina misrensis* Anan) (after Figure [1]).

Sector area	North												
	Las Cruces		Navidad										
Geologic unit	EI Peral beds		Navidad Fm.										
Locality	NLP	LPER	MOS	RAP	PPP	PPT	PPN	LBZ	PTA	MAT	NAV5	MPUP	CPUP
Percultazonaria vaughani	VR				R				R			C	

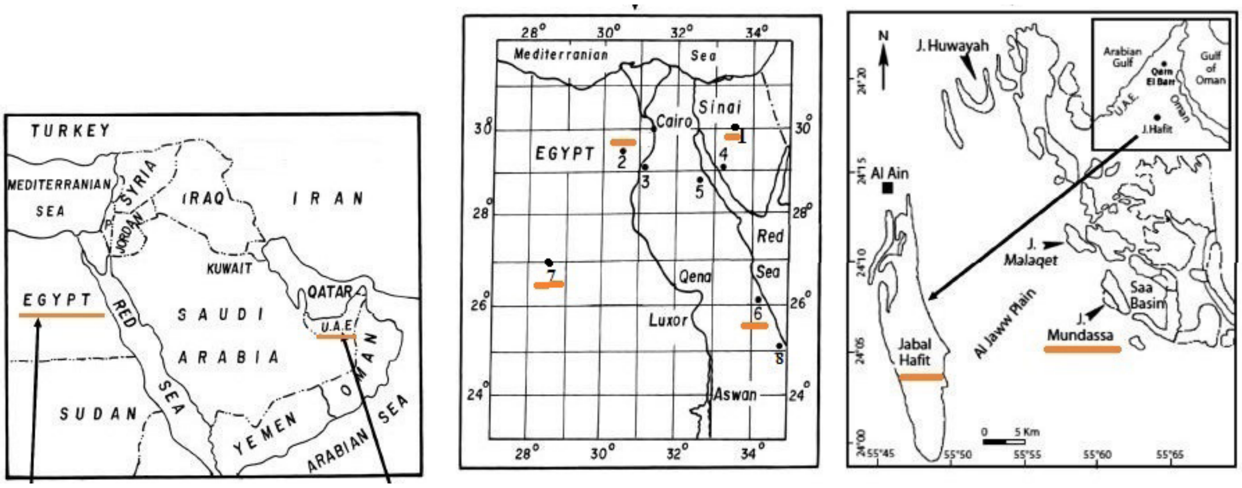

Figure 11. The location map of some studied sections in Egypt (no. 1. Nekhl and Giddi sections in North Sinai, 2, Fayum area), 7 Maqfi section; and UAE (Jabal Hafit and J. Mundassa) (after Anan [37]).

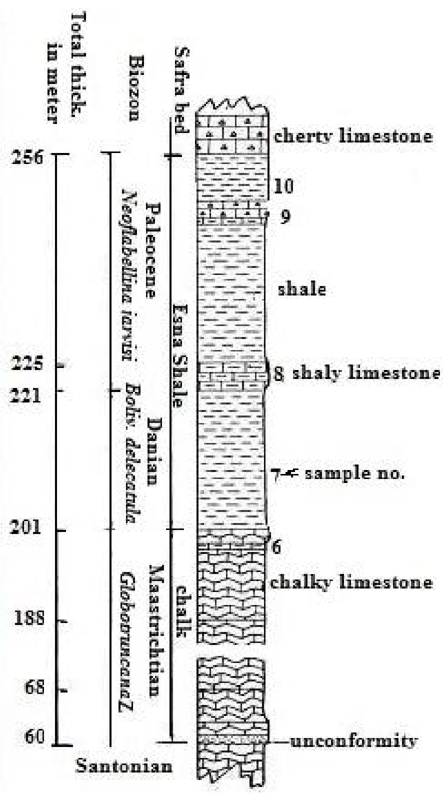

Figure 12. Stratigraphic log of Nekhl section, North Sinai, stratigraphic level and sample no. 6 of the Maastrichtian *Hemirobulina comma* (after Said & Kenawy [17]).

Remarks: The figured specimens of Said & Kenawy [17] and Abdelghany [38] are closely related to the genus *Hemirobulina.* It was recorded from USA, and also Giddi section (Sinai of Egypt) and Qarn El Barr section (UAE).

Hemirobulina humilis **(Reuss, 1863)** (Plate 1, Figure 12)

1863 *Cristellaria (Cristellaria) humilis* Reuss [14], p. 65, Plate 6, Figures 16, 17.

1946 *Marginulina humilis* (Reuss)-Cushman [39], p. 63, Plate 22, Figure 17.

1956 *Marginulina humilis* (Reuss)-Said & Kenawy [17], p. 130, Plate 2, Figure 18.●

Type locality and sample no.: Paleocene of Nekhl section (sample 7) and Giddi section (sample no. 834), North Sinai of Egypt (Figures 12, 13).

Remarks: The figured specimens of Cushman [39] and Said & Kenawy [17] are closely related to the genus *Hemirobulina.* It was recorded in the Cretaceous of Europe, USA and Mexico, while it was recorded from the Maastrichtian and Paleocene of Sinai of Egypt (Said & Kenawy [17]).

Hemirobulina nammalensis **(Haque, 1956)** (Plate 1, Figure 13)

1956 *Marginulina glabra* d'Orbigny var. *nammalensis* Haque [15], p.74, Plate11, Figures 1–4. ●

2005 *Vaginulinopsis nammalensis* (Haque)-Sztràkos [40], p. 186, Plate 14, Figure 28.

Type locality: Nammal Formation, Nammal Gorge area, Pakistan (Figure 14).

Remarks: *Hemirobulina* differs from *Vaginulinapsis* in the rounded cross section and curved but not distinctly enrolled early stage. It differs from *Marginulina* in having a smooth rather than longitudinally costate wall. For that, the figured specimens of Haque [15] and Sztràkos [40] belong to the genus *Hemirobulina. Hemirobulina nammalensis* was recorded from Pakistan (Southern Tethys), and France

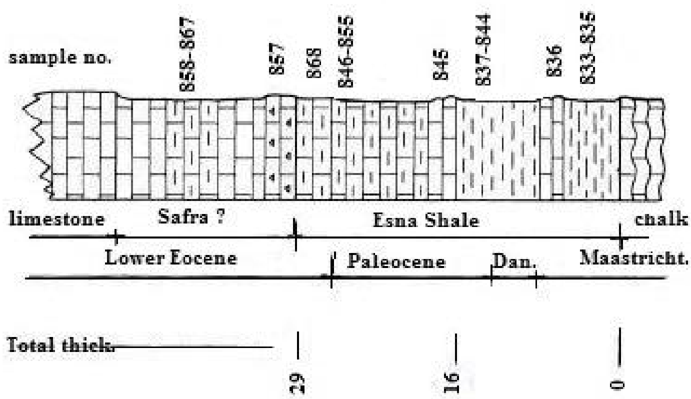

Figure 13. Stratigraphic log of Giddi section, North Sinai, Egypt (after Said & Kenawy [17]).

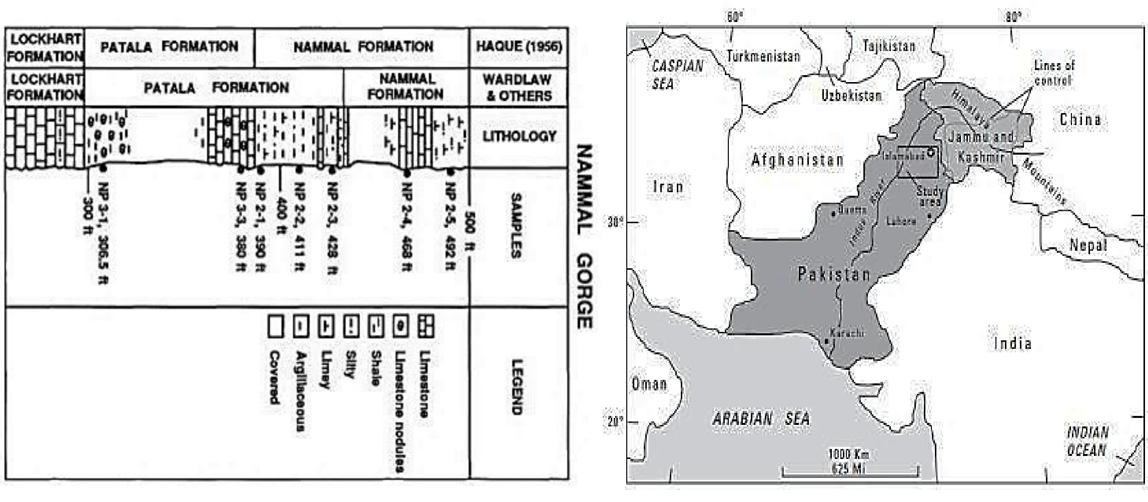

Figure 14. Lithostratigraphic section and location of Nammal Gorge at Nammal Dam: Patala and Nammal Formations of the Nammal Gorge, Salt and Sor Ranges of Pakistan (Gibson [41]).

(Northern Tethys).

***Hemirobulina pachygaster* Gümbel, 1870** (Plate 1, Figure 14)

1870 *Marginulina pachygaster* Gumbel [16], 1868 (1870), p. 632, Plate 1, Figure 60.

1953 *Marginulina pachygaster* Gumbel-LeRoy [42], p. 38, Plate 8, Figure 11.

1956 *Marginulina pachygaster* Gumbel-Said & Kenawy [17], p. 132, Plate 2, Figure 21.●

Stratigraphic level and sample no.: Maastrichtian, Nekhl section, sample no. 6 (see Figures 12, 13).

Remarks: As noted before, *Hemirobulina* differs from *Marginulina* in having a smooth rather than longitudinally costate wall. For that, the Egyptian specimens belong to the genus *Hemirobulina*. It was originally described from the Eocene of Germany, Early Eocene in Maqfi section, Western Desert of Egypt (LeRoy [42]), and Maastrichtian in Sinai of Egypt (Said & Kenawy [17]).

Genus *Vaginulinopsis* Silvestri, 1904

***Vaginulinopsis argentinica* Anan, sp. nov.** (Plate 1, Figure 15)

2022 *Laevidentalina* sp. Jannou et al. [33], p. 21, Plate 2, Figure 5.●

Holotype: Illustrated specimen in Plate 1, Figure 15.

Diameter of the holotype: Length 0.62 mm, width 0.11 mm.

Depositary: The Survey of Geology and Mineralogy of Argentina (SEGEMAR2849).

Etymology: After the State of Argentina.

Type locality and sample: Formación Punta Torcida, CI-20, SEGEMAR 2849, CM-145 (see Figure 8).

Stratigraphic level: Ypresian.

Diagnosis: This Early Eocene species has an elongate test and circular in section, early-stage planispirally enrolled and involute, the later stage includes numerous semi globular chambers added in a slight curve, sutures nearly horizontal, flush in the early stage, but depressed in the final three chambers, wall calcareous, hyaline, perforate radial, surface smooth and unornamented, aperture terminal at the dorsal angle, and produced on a neck.

Remarks: The genus *Vaginulinopsis* has a planispirally enrolled and involute early stage, which does not exist in the genus *Laevidentalina*. The *V. argentinica* Anan [12] is lacking an apiculate pro-loculus, which is characterized the genus *Laevidentalina*.

***Vaginulinopsis deserti* (Said & Kenawy, 1956)** (Plate 1, Figure 16)

1956 *Marginulinopsis deserti* Said & Kenawy [4], p. 132, Plate 2, Figure 23.

Remarks: This species Lacks the longitudinal ribs along the test surface as genus *Marginulinopsis*. It is recognizable by its slender test and slightly inflated and elongated chambers. it was recorded from Maastrichtian, Nekhl section (Egypt), sample no. 6 (see Figures 12, 13).

***Vaginulinopsis emiratensis* (Anan, 1993)** (Plate 1, Figure 17)

1993 *Marginulinopsis emiratensis* Anan [18], p. 657, Plate 2, Figure 12.

Type locality: Qarn El Barr section, Al Dhayd area, no. 1 (about 80 km north of J. Hafit, no. 2), UAE (*Abathomphalus mayaroensis* Zone). (Figure 15)

Remarks: This Late Maastrichtian specimen belongs to the genus *Vaginulinopsis*. *V. emiratensis* was described from Qarn El Barr section, Al Dhayd area (about 80 km north of J. Hafit), UAE.

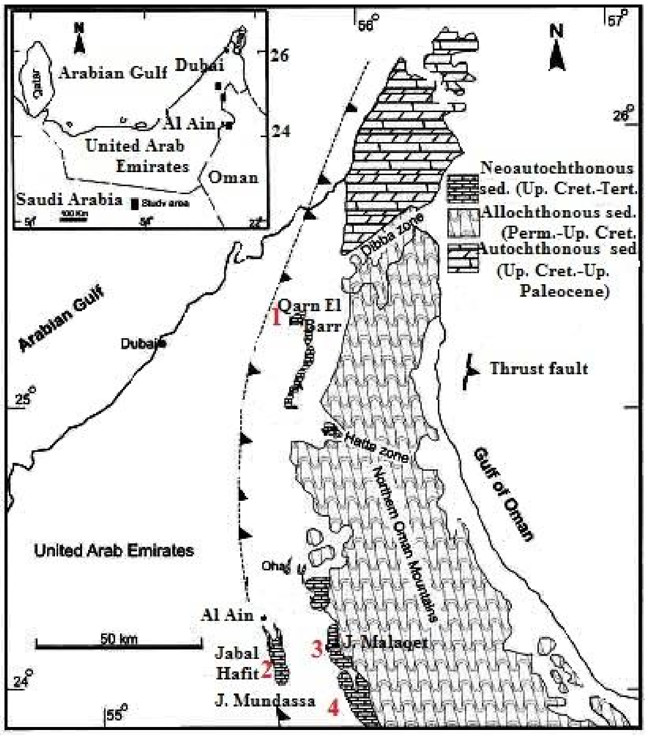

Figure 15. Location map of Qarn El Barr section (no.1) North UAE (after Abdelghany [38]).

Genus *Vaginulina* d'Orbigny, 1826

***Vaginulina boukharyi* (Anan, 2010)** (Plate 1, Figure 18)

2010 *Vaginulinopsis boukharyi* Anan [19], p. 30, Plate 1, Figure 12.

Type locality: Duwi section, Tarawan Chalk, Red Sea coast, Egypt (see Figure 12).

Remarks: This Paleocene species belongs here to the genus *Vaginulina* d'Orbigny [43] due to its thick raised sutures, then slightly depressed sutures in *Vaginulinopsis* Silvestri [44]. It is originally recorded from Duwi section, Egypt (Figure 16).

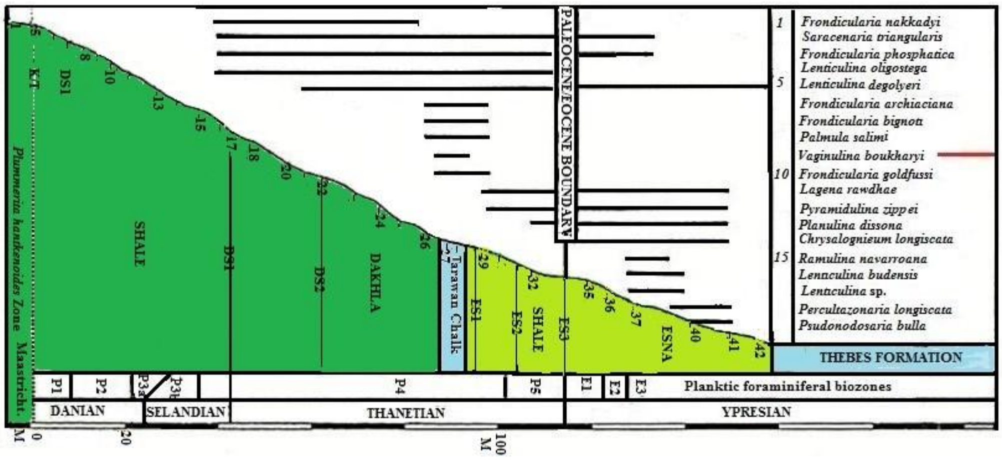

Figure 16. Stratigraphic log of Duwi section, including the stratigraphic range of the Thanetian *V. boukharyi* (after Anan [45]).

Vaginulina chilensis **Anan, sp. nov.** (Plate 1, Figure 19)

2013 *Astacolus mexicanus* (Nuttall)-Finger [1], p. 415, Plate 9, Figure 19.

Holotype: Illustrated specimen in Plate 1, Figure 19.

Diameter of the holotype: Length 0.55 mm, width 0.32 mm.

Depositary: The University of California Museum of Paleontology (UCMP).

Etymology: After the State of Chile.

Type locality: Navidad Fm. (site CPUP), Ranquil Fm. (sites FRA, FRM), (Figure 17).

Stratigraphic level: Early Oligocene to Early Miocene (Table 4).

Diagnosis: This species has an elongate uniserial rectilinear laterally compressed test, septa horizontal to slightly oblique thickened and elevated, wall calcareous perforate, surface smooth, aperture radiate at the dorsal angle, and slightly produced.

Remarks: This new species differs from *V. boukharyi* Anan [19] in its longer test, lesser and acuter width, with keel, and more elevated thick sutures.

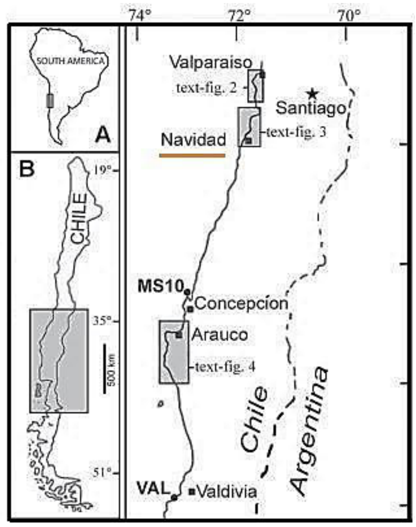

Figure 17. Location map of the Navidad section, Central Chile.

Genus *Ramulina* Jones, 1875

Ramulina shreifae **sp. nov.** (Plate 1, Figure 20)

2023 *Ramulina pseudoaculata* (Olsson)-Shreif et al. [46], p. 115, Plate 6, Figure 8.

Table 4. Stratigraphic range of *Vaginulina chilensis* in both Navidad and Ranquil Formations, North and Central Chile (after Finger [1]).

Sector area	**North**													**Central**								
	Las Cruces		Navidad											Conc	Arauco							Vald
Geologic unit	EI Peral beds		Navidad Fm.											Ranquil Fm.								SDom
Locality	NLP	LPER	MOS	RAP	PPP	PPT	PPN	LBZ	PTA	MAT	NAV5	MPUP	CPUP	MS10	FRA	FRM	RQT	RQK	RAN	MIB	LEB	VAL
Astacolus mexicanus													VR		R	F						

Holotype: Illustrated specimen in Plate 1, Figure 20.

Diameter of the holotype: Length 0.42 mm, width 0.18 mm.

Depositary: Faculty of Education, Dept. Biological and Geological Sciences, Ain Shams Univ., Egypt.

Etymology: After the micropaleontologist Abeer Shreif, Ain Shams University, Faculty of Education, Department of Biological and Geological Sciences, Cairo, 11341, Egypt.

Type locality and sample no.: El Guss Abu Said, Western Desert, Egypt, samples 1, 2 (common), (after Shreif et al. [46]).

Stratigraphic level: Ypresian (E3, *Morozovella marginodentata* Zone), Figure 18.

Diagnosis: This Early Eocene species is characterized by its ovoid smooth test, with only two not concentric ends arms of the chamber.

Remarks: This new species differs from *R. pseudoaculata* (Olsson [20]) in having a smooth surface and not concentric two ends arms of the chamber, then ornamented surface and concentric two arms.

4. Paleogeography

The twenty identified species have wide geographic distribution in nine localities in the Southern Tethys: Chile (South Pacific), Argentina (South Atlantic), Egypt, Tanzania (Northeast Africa), Jordan, Iraq, UAE, Iran and Pakistan (Southwest Asia) (see Figure 1). The paleogeographic maps recorded by many authors [47-50] show the Tethyan realm had been connected with the Atlantic Ocean from the west to the Indo-Pacific Ocean to the east, via the Mediterranean Sea, crossing the Middle East region during the Paleogene time (Table 5).

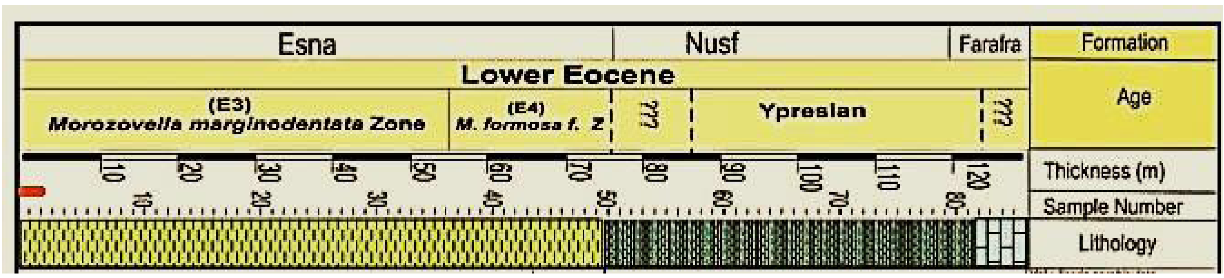

Figure 18. Stratigraphic log of El Guss Abu Said section, Farafra Oasis, Western Desert, Egypt, and the stratigraphic range of the new species *Ramulina shreifae,* samples (1, 2) (after Shreif et al. [46]).

Table 5. Paleogeographic distribution of the Early Eocene twenty Lagenid and Rotaliid benthic foraminiferal species in the different locations in the Southern Tethys, particularly the sp. nov. in this study: 1. Chile (*Tollmannia fingeri*, *Vaginulina chilensis*), 2. Argentina (*Vaginulinopsis argentinica*), 3. Egypt (*Ramulina shreifae*), 4. Tanzania, 5. Jordan, 6. Iraq, 7. UAE, 8. Iran, 9. Pakistan.

Sp. No.	species	countries	1	2	3	4	5	6	7	8	9
1	*Nodosaria*	*catenula*	-	-	x	-	-	☻	-	-	-
2	*Pyramidulina*	*robinsoni*	-	-	x	x	☻	-	-	-	-
3	*Tollmannia*	*costata*	☻	-	-	-	-	-	-	-	-
4		*fingeri*	☻	-	-	-	-	-	-	-	-
5	*Percultazonaria*	*fragaria*	-	-	x	-	-	-	x	☻	-
6		*tuberculata*	-	-	x	☻	-	-	-	x	x
7	*Lenticuzonaria*	*argentinica*	x	☻	-	-	-	-	-	x	-
8		*misrensis*	-	-	☻	x	-	-	-	-	-
9	*Percultalina*	*misrensis*	x	-	☻	-	-	-	-	-	-
10	*Hemirobulina*	*comma*	-	-	☻	-	-	-	-	-	-
11		*curvatura*	-	-	☻	-	-	-	x	-	-
12		*humilis*	-	-	☻	-	-	-	-	-	-
13		*nammalensis*	-	-	-	-	-	-	-	-	☻
14		*pachygaster*	-	-	☻	-	-	-	x	-	-
15	*Vaginulinopsis*	*argentinica*	-	☻	-	-	-	-	-	-	-
16		*deserti*	-	-	☻	-	-	-	-	-	-
17		*emiratensis*	-	-	x	-	-	-	☻	-	-
18	*Vaginulina*	*boukharyi*	-	-	☻	-	-	-	-	-	-
19		*chilensis*	☻	-	-	-	-	-	-	-	-
20	*Ramulina*	*shreifae*	-	-	☻	-	-	-	-	-	-

Note: ☻ = illustrated, x = recorded, - = not recorded.

5. Paleoecology and Paleoenvironment

Finger [1] noted that the presence of Neogene cosmopolitan deep-water benthic foraminifera in all of the assemblages supports the hypothesis that deep water masses derived from the Antarctic Circumpolar Current have enabled many Neogene deep-water foraminifera to disperse widely in the global ocean (Figure 19).

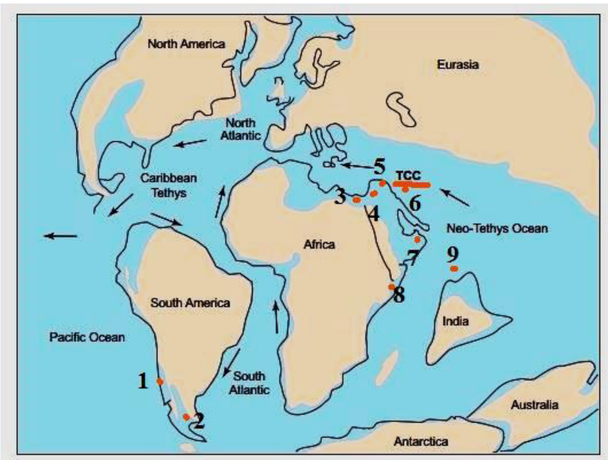

Figure 19. Paleogeography of the Neo-Tethys Ocean during the Maastrichtian showing the flow direction of the Tethyan Circumglobal Current (TCC) from east to west in the Southern Tethys (after Abed [51]); 1. Chile, 2. Argentina, 3. Egypt, 4. Jordan, 5. Iraq, 6. Iran, 7. UAE, 8. Tanzania, 9. Pakistan.

Jannou et al. [33] noted that the paleoenvironment of South Argentina would have been a shelf sea of normal salinity. LeRoy [42] noted that in certain respects the microfauna of the Esna Shale of Maqfi section (Figure 11, no. 7) exhibits an affinity with the Midway Type Fauna (MTF) of the American Gulf Coastal area, middle-outer neritic environment (50–200 m). Said & Kenawy [17] described and recorded more than twenty hundred benthic foraminiferal species from the Maastrichtian-Early Eocene strata of the two sections (Nekhl and Giddi) in northern Sinai, Egypt, and noted that these taxa showed an affinity with Midway faunas of American Gulf Coastal Plain, which indicate similarity with fauna of Trinidad and Tampico Embayment of Mexico. Anan [30] noted that the probable environment of northern Egypt is outer neritic-upper bathyal, while deeper in central Egypt, are deposited in the middle-outer neritic. Shreif et al. [46] noted that the abrupt decrease in the P/B ratio at the top of the Esna Formation and the erosional surface at the top of the Esna Formation indicate progressive or stepwise shallowing of the shelf through the succession of El Guss Abu Said, Western Desert, Egypt, and during the late Paleocene-Early Eocene. Berggren & Aubert [52] considered the Lower Tertiary fauna of the Maqfi section, Western Desert of Egypt, and the northern part of Sinai Peninsula to be predominantly related to the “Midway-type fauna, MTF”, middle-outer neritic environment (50–200 m). Futyan [4] noted that the Jordanian faunal assemblage is predominantly considered here to be related to MTF (middle-upper neritic environment, 100–200 m). VahdatiRad et al. [31] noted that the changes in the relative abundance percentage of planktonic foraminiferal species in Yaghol section, Khangiran formation, northeast of Iran indicate the warm seawater and nearly oligotrophic condition in the late Paleocene-Early Eocene. Salahi [10] noted that the diverse benthic assemblages in the Kopet-Dag (KD) in northern Iran indicate a deeper environment in comparison with Late Paleocene fauna (middle-outer neritic based on the presence of Midway-type fauna, MTF), while a deep paleowater environment is evidenced by a high proportion of lenticulinids (= *Percultazonaria fragaria*) (Figure 20).

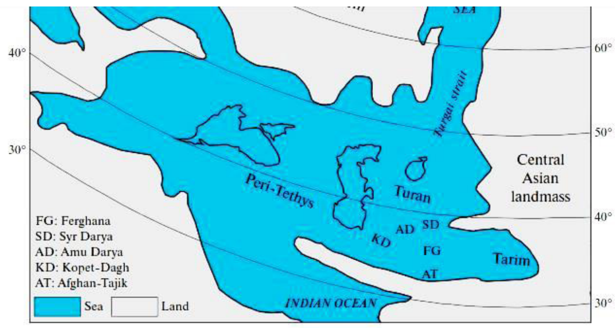

Figure 20. Peri-Tethys basin, includes Kopet-Dag area, KD (NE Iran) during the Early Paleogene (after Salahi [10]).

6. Conclusions

The modern taxonomical consideration is used for twenty Lagenid benthic foraminiferal species from nine countries in the Southern Tethys: Chile, Argentina, Egypt, Tanzania, Jordan, Iraq, United Arab Emirates (UAE), Iran and Pakistan. These species are: *Nodosaria catenula, Pyramidulina robinsoni, Tollmannia costata, Tollmannia fingeri, Percultazonaria fragaria, Percultazonaria tuberculata, Lenticuzonaria argentinica, Lenticuzonaria misrensis, Percultalina misrensis, Hemirobulina comma, Hemirobulina curvatura, Hemirobulina nammalensis, Hemirobulina humilis, Hemirobulina pachygaster, Vaginulinopsis argentinica, Vaginulinopsis emiratensis, Vaginulinopsis deserti, Vaginulina boukharyi, Vaginulina chilensis* and *Ramulina shreifae*. Nine species of these assemblage were recorded from Egypt (about 45%): *Lenticuzonaria misrensis, Percultalina misrensis, Hemirobulina comma, Hemirobulina curvatura, Hemirobulina humilis, Hemirobulina pachygaster, Vaginulinopsis deserti, Vagi-*

nulina boukharyi, Ramulina shreifae; 3 species from Chile (about 15%): *Tollmannia costata, Tollmannia fingeri, Percultalina misrensis;* 2 from Argentina (about 10%): *Lenticuzonaria argentinica, Vaginulinopsis argentinica*; and one species (about 5%) from each of Tanzania: *Percultazonaria tuberculata*, Jordan: *Pyramidulina robinsoni*, Iraq: *Nodosaria catenula*, UAE: *Vaginulinopsis emiratensis*, Iran: *Percultazonaria fragaria*, and Pakistan: *Hemirobulina nammalensis*. Four species are believed here to be new: *Tollmannia fingeri, Vaginulinopsis argentinica, Vaginulina chilensis* and *Ramulina shreifae*. The identified species are marine fauna which indicates a middle neritic-deep paleowater environment. The identified species have wide geographic distribution in the Tethys, due to open and extended realms of the Tethys, which have extended from the Indo-Pacific to the Atlantic Oceans and Mediterranean Sea during the Late Cretaceous to Early Neogene times, and the fauna exhibit pronounced similarities. The unclosed number of the members of Lagenids in the study area may be due to a lack of available literature, different latitudes, differences in paleoenvironmental conditions (depth, temperature, salinity, dissolved oxygen, nutrient, land barriers, etc.) or misidentification.

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Conflict of Interest

There is no conflict of interest.

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