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RESEARCH ARTICLE

GEOGRAPHIC DISTRIBUTION OF THE CAMPANIAN - LUTETIAN ROTALIID BENTHIC FORAMINIFERAL SPECIES OF THE GENUS *VALVULINERIA* IN THE MIDDLE EAST

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ABSTRACT

Twelve Late Campanian to Early Lutetian small Rotaliid benthic foraminiferal species of the genus *Valvulineria* Cushman are common in some Middle East localities in the Southern Tethys (Egypt, Jordan, UAE, Iraq, Iran, Pakistan), and also in some localities in the Northern Tethys (Spain, Austria, Turkey, Kazakhstan). The taxonomy of the identified species are presented and discussed. These species are: *Valvulineria aegyptiaca* LeRoy, *V. brotzeni* Nakkady, *V. critchetti* LeRoy, *V. hillsi* Haque, *V. nammalensis* Haque, *V. orali* (Inan), *V. patalaensis* Haque, *V. pseudotumeyensis* Futyan, *V. ranikotensis* Haque and *V. scrobiculata* (Schwager). Two of these illustrated species of Iran and Iraq are believed to be new: *Valvulineria iranica* and *V. iraqensis*. The prominent environment of the genus *Valvulineria* and its members most probably are the shallow carbonates and marly shale facies, which related to the middle neritic to upper bathyal environment.

KEYWORDS

Valvulineria, Benthic Foraminifera, Campanian, Paleogene, Middle East, Tethys

1. INTRODUCTION

Twelve diagnostic species of Late Campanian-Early Paleogene benthic foraminiferal genus *Valvulineria* were recorded and described from wide sites in the Northern Tethys (Spain, Austria, Turkey, Kazakhstan) and Southern Tethys (Angola, Egypt, Jordan, Iraq, Iran, UAE, Pakistan (Figure 1) (Cushman, 1926). Four species of Haque from Pakistan: *V. hillsi*, *V. nammalensis*, *V. patalaensis* and *V. ranikotensis*. Three species from Egypt: *Valvulineria aegyptiaca* LeRoy, *V. brotzeni* Nakkady and *V. critchetti* LeRoy. One species from each of Jordan: *V. pseudotumeyensis* Futyan, and Turkey *V. orali* (Inan), respectively. Another two of the illustrated species recorded from Iran and Iraq, which is believed here to be new: *Valvulineria iranica* and *V. iraqensis*.

2. MATERIAL OF STUDY

Rich and well preserved twelve Rotaliid benthic foraminiferal species from seven countries in the Middle East (Turkey, Egypt, Jordan, Iraq, Iran, UAE and Pakistan), made it possible to elucidate them with its modern taxonomical consideration, following the Code of Zoological Nomenclature (CZN). The taxonomic revision of two species of them are re-described its morphological features, which considered here as a new species: *Valvulineria iranica* and *V. iraqensis*.

Figure 1: The paleogeographic map of the Middle East countries (Turkey, Egypt, Jordan, Iraq, Iran, UAE and Pakistan), which the recognized Campanian-Lutetian members of the genus *Valvulineria* were recorded.

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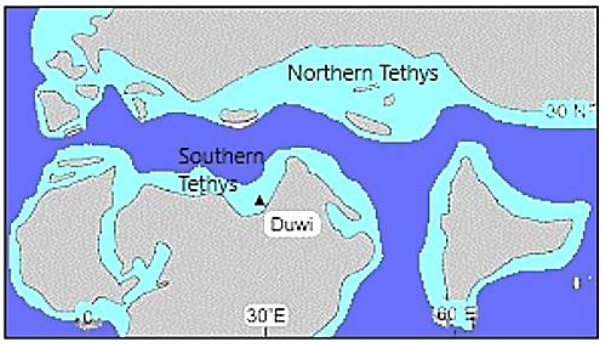


Figure 2: Location map showing the paleogeographic distribution of the Northern and Southern Tethys, including Duwi section of Egypt, Southern Tethys.

The classification is followed in this study of (Loeblich and Tappan, 1988). The genus *Valvulineria* is characterized by its finely perforate calcareous wall, unequally to equally evolute biconvex low trochospiral test, spiral side may be nearly flat and tending towards concavity, umbilical side convex, 5-10 nearly spherical chambers in the last whorl, involute low arched and elliptical aperture, extending from the umbilical end of the chamber nearly to the periphery, and covered by a thin membrane-like plate, which largely fills the umbilical area below a lunate area under a wide deep umbilical area, broadly rounded periphery. The identified species are illustrated in Plate 1.

Plate 1

(vv= ventral view, dv=dorsal view, av=aperture view, af=apertural face, p=pore)

Figure. 1. *Valvulineria aegyptiaca* LeRoy, 1953, vv x 40, **2.** *V. brotzeni* Nakkady, 1959, vv x 30, **3.** *V. critchetti* LeRoy, 1953, vv x 80, **4.** *V. hillsi* Haque, 1956, vv x 90, **5.** *V. iranica* n. sp., a, vv x 90, b, dv x 100, **6.** *V. iraqensis* n. sp., a, vv x 200, b, dv x 200, **7.** *V. nammalensis* Haque, 1956 vv x 50, **8.** *V. orali* (Inan, 2003), vv, af, p x 100, **9.** *V. patalaensis* Haque, 1956, vv x 65, **10.** *V. pseudotumeyensis* Futyan, 1976, a=av, b=dv x 35, **11.** *V. ranikotensis* Haque, 1956, vv x 60, **12.** *V. scrobiculata* (Schwager, 1883) vv x 130.

Order Foraminiferida Eichwald, 1830

Suborder Rotaliina Delage and Hérouard, 1896

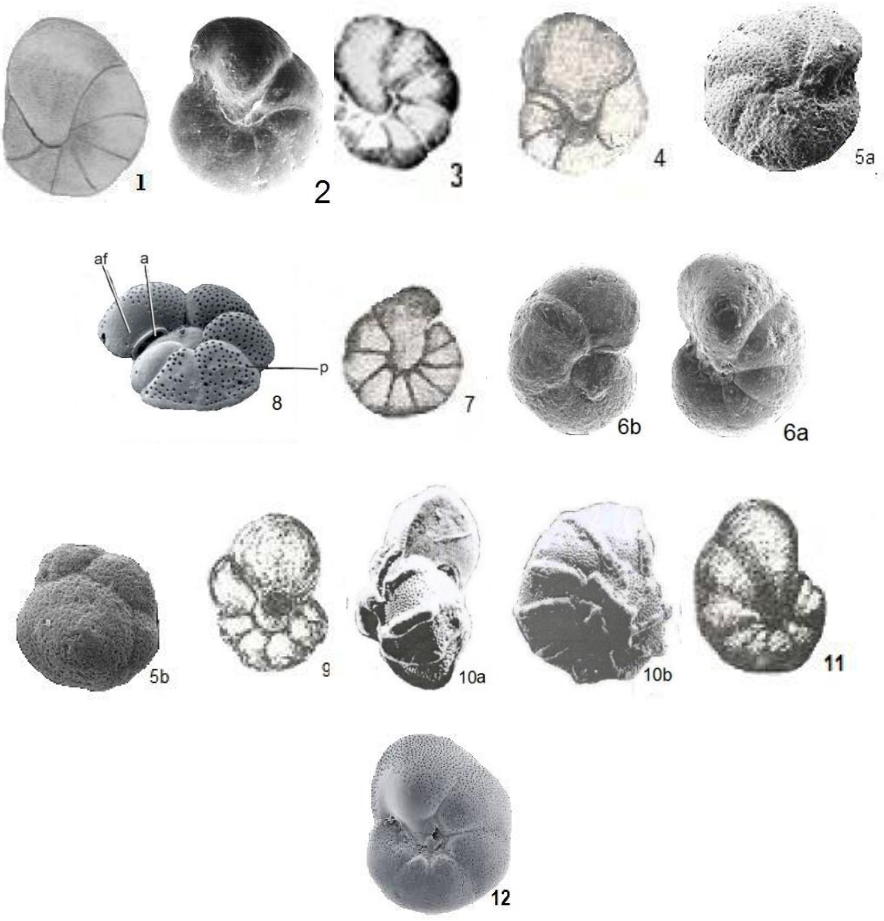
genus *Valvulineria* (Cushman, 1926)

Valvulineria aegyptiaca, p. 53, pl. 9, figure. 21-23, p. 147, pl. 4, figure. 45. ●{illustrated specimen}(Plate 1, Figure 1) (LeRoy, 1953; Said and Kenawy, 1956)

Remarks: *Valvulineria aegyptiaca* was originally recorded from Late Paleocene-Early Eocene of the Duwi section of Egypt (Figure 2), and later on from many localities in Egypt by many authors, and also UAE (Anan, 1993; Said and Kenawy, 1956; Anan, 2008; Hewaidy et al., 2017).

Valvulineria brotzeni, p. 460, pl. 7, figure. 2; Anan, 2009, p. 39, pl. 1, figure. 9)● (Plate 1, Figure 2) (Nakedly et al., 1959)

Remarks: was originally recorded *V. brotzeni* from the Danian Dakhla Shale of Um Elghanayem section, central Egypt (Figure 3, no. 16) and later from Gabal Aweina (no. 15), south Nile Valley of Egypt. It seems, so far, confined in Egypt (Nakkady, 1959).



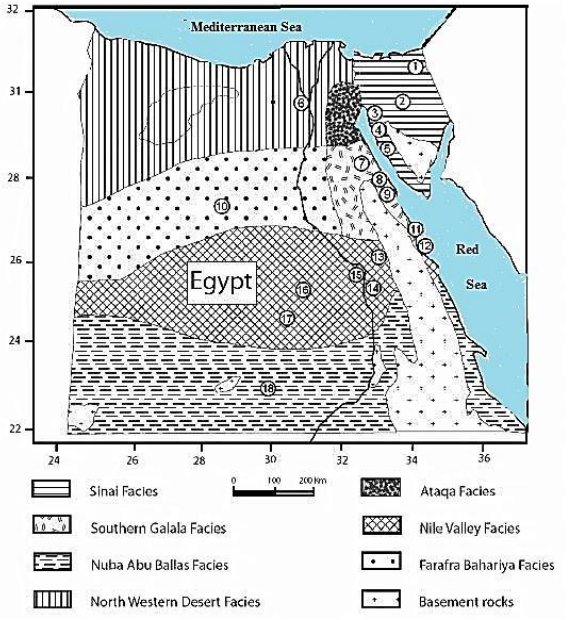


Figure 3: Location map of Egyptian different eight sedimentary facies around the K/T boundary: **1.** Qusaima, **2.** Giddi-Nekhl, **4.** Abu Zenima, **6.** Jiran El Ful, **7.** Wadi Ed Dakhl, **10.** Maqfi section, **12.** Duwi, **15.** Gurnah/Aweina, **16.** Um Elghanayem/Ghanima, **18.** Bier Kiseiba section (Issawi and Osman, 2000).

Valvulineria critchetti , p. 53, pl. 3, figure. 20-22● (Plate 1, Figure 3) (LeRoy, 1953)

Remarks: The Ypresian *Valvulineria critchetti* differs from *V. aegyptiaca* in having a rounded, plano-convex test and the last chamber less elongate, and covered small area of the ventral umbilical region. *V. critchetti* was originally recorded from the Maqfi section, Western Desert of Egypt (Figure 3.8) by and from Nile Valley by (Anan, 2019; LeRoy, 1953). It seems, so far, confined in Egypt.

Valvulineria hillsi, p. 161, pl. 12, fig. 1● (Plate 1, Figure 4) (Haque, 1956)

Remarks: The Paleocene species differs from other *Valvulineria* species by its five chambers in the last whorl consists the most size of the test, depressed umbilicus, and aperture umbilical-extraumbilical arch covered by imperforate apertural lip. It was recorded, so far, in Pakistan (Figure 1).

Valvulineria iranica **Anan, n. sp.** (=*Cibicidoides* sp, p. 319, pl. 6, fig. 15a,b)● (Plate 1, Figure 5a, b) (Salahi, 2021)

Holotype: Illustrated specimen in Plate 1, figure 5a, b.

Diameter: Length and width 0.28 mm.

Depository: The private collection of Prof. Amir Salahi, Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad, Iran.

Etymology: After the Islamic Republic of Iran.

Type locality: Kopet-Dagh Basin, NE Iran (Figure 4).

Type Section: Khangiran Formation (Figure 5).

Age: Ypresian.

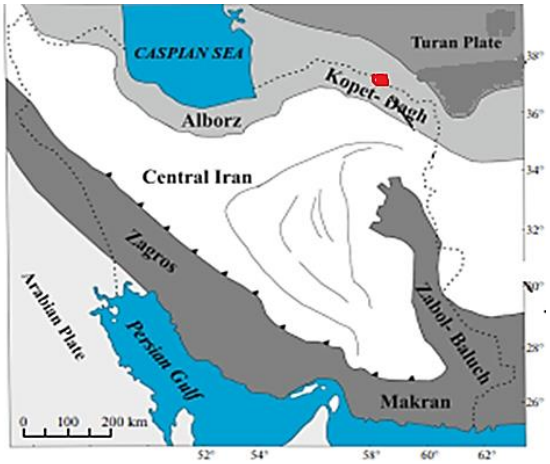


Figure 4: Location map of Kopet-Dagh Basin, NE Iran (Salahi, 2021).

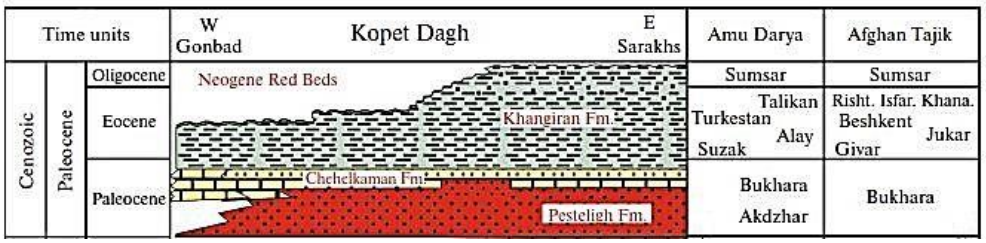


Figure 5: Stratigraphic chart of Ypresian Khangiran Formation, Kopet-Dagh Basin, NE Iran, and the type samples of *Valvulineria iranica* Anan, n. sp. (Salahi, 2021).

Diagnosis: Test smooth biconvex, but more so dorsally, 3-4 dorsal whorls with partially involute, nearly circular in transverse section, chambers 7-9 in the last whorl increasing gradually as added, sutures narrow curved ventrally and dorsally, last chamber extending slightly into ventral umbilical region, periphery rounded, slightly lobate, aperture a narrow slit at the base of the last-formed chamber, extending to umbilical region.

Remarks: *Valvulineria iranica* differs from other members of the genus by its more tight coiling, more convex dorsally than ventrally, and smaller-size umbilical region. This species may be evolved from the Egyptian *V. critchetti* due its tight coil of the two species, nearly the same number chambers in the last whorl, but differs from its biconvex test from the former than planoconvex test of the latter. It was recorded, so far, in Iran.

***Valvulineria iraqensis* Anan, n. sp.** (=*Gyroidinoides globosus* (Hagenow) –p. 16, pl. 2, figure. 17, 18● (Plate 1, Figure 6a, b) (Jaff and Lawa, 2019).

Holotype: Illustrated specimen in Pl. 1, figure. 6a,b.

Diameter: Length 0. 51 mm, width 0.31 mm.

Depository: The collection of Jaff and Lawa, Department of General Sciences, College of Education and Languages, Charmo University of Iraq; and Dept. of Geology, University of Sulaimani, Iraq, respectively.

Etymology: After the Republic of Iraq.

Type locality: Shiranish Formation, Kurdistan (Figure 6).

Type Section: Azmer section, samples nos. (ASH 25-30) (Figure 7).

Type sample number: ASH 30.

Age: Late Campanian.

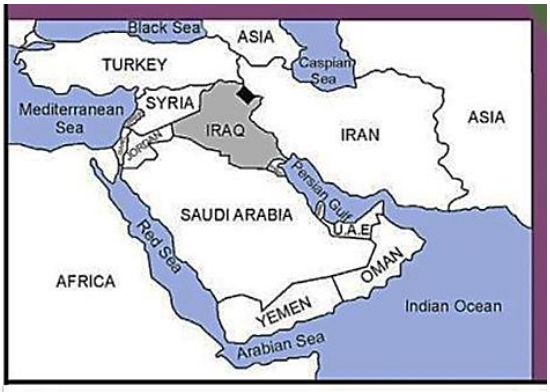


Figure 6. Location map of the Azmer section, Shiranish Formation, Kurdistan, NE Iraq (Jaff and Lawa, 2019).

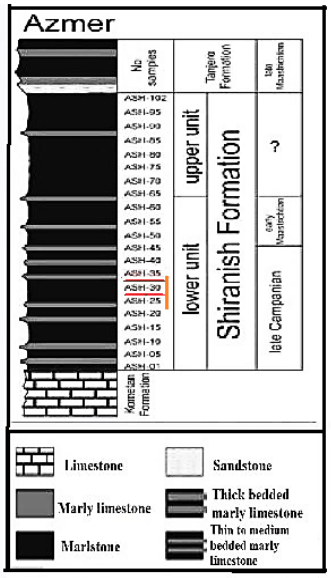


Figure 7: Stratigraphy of Azmer section, NE Iran, Late Campanian Shiranish Formation, and the type samples of *Valvulineria iraqensis* (sample nos. 25-30) (Jaff and Lawa, 2019).

Remarks: *Valvulineria iraqensis* may evolved from the Pakistanian *V. hillsi* due to its morphological relationships between them, but the former differs from the latter in its more number of chambers in the last whorl, smaller final chamber. It was recorded, so far, in Kurdistan of Iraq.

***Valvulineria nammalensis*,** p. 159, pl. 7, fig. 10● (Plate 1, Figure 7) (Haque, 1956)

Remarks: It seems that the Paleocene-Early Eocene Pakistanian species *V. nammalensis* (Figure 8) was evolved from the Egyptian Danian *V. brotzeni* Nakkady due to its many morphological relationships between others.

Valvulineria orali (=*Cocoarota orali* n. sp. Inan, 2003, p. 201, pl.1, figs.1-14)●(Plate 1, Figure 8) (Inan, 2003**).**

Remarks: The Maastrichtian to Paleogene (Early Lutetian) *V. orali* species flourished in shallow-water carbonates in the Neo-Tethyan realm, from Spain to Pakistan (through Austria and Turkey, Figure 9). Further samples in thin section from Iran and Spain are also used and illustrated. From Cantabria, northern Spain of Paleocene-Early Eocene. In Austria the species was recorded from Danian-Thanetian carbonates. In Turkey the material comes from the Eastern Pontides, and the age is Selandian or Thanetian. The specimens *Valvulineria orali* come from eastern, central and the southwestern Iran. This species has wide geographic distribution, which recorded from Spain, Austria, Turkey (N. Tethys) and Iran (S. Tethys).

Valvulineria patalaensis, p. 162, pl. 12, fig. 2● (Plate 1, Figure 9) (Haque, 1956)

Remarks: This Paleocene species is characterized by its thin imperforated apertural flap cover the umbilicus completely. It was recorded, so far, in Pakistan.

Valvulineria pseudotumeyensis, p. 531, pl. 83, figs. 4-6●(Plate 1, Figure 10) (Futyan, 1976)

Remarks: This Ypresian species is characterized by its thick raised sutures in the dorsal side more than all members of the genus. It was recorded, so far, in Jordan and Angola, throughout the Trans-Saharan Seaway, Figure 10.

Figure 8: The location map of *Valvulineria nammalensis* Haque from the study area, Salt Range of Northern Pakistan, Southern Tethys (Gibson, 2007).

Figure 9: The location of the *Valvulineria orali* (Inan) in Austria (A) and Turkey (B) in the Northern Tethys (Consorti and Schlagintweit, 2022).

Figure 10: The paleogeographic map at K/T boundary showing the connected seas from USA to Indian and Pacific Oceans via the Mediterranean Sea, as well as the locations of three Northern Tethys localities (e.g. Spain, France, Turkey) and seven Southern Tethys localities (Angola, Egypt, Jordan, Iraq, Iran, UAE, Pakistan) (Solakius et al., 1990).

Valvulineria ranikotensis, p. 161, pl. 17, fig. 10●(Plate 1, Figure 11) (Haque**,** 1956)

Remarks: This Paleocene species was recorded, so far, from Pakistan.

Valvulineria scrobiculata (=*Anomalina scrobiculata* Schwager, 1883, p. 129, pl. 29, figure. 18) ●(Plate 1, Figure 12) (Schwager, 1883)

Remarks: This Early Eocene species was recorded from Egypt and Tunisia (North Africa), and Kazakhstan (Central Asia) (Figure 11).

Figure 11: The location map of the *Valvulineria scrobiculata* (Schwager) from the Aktulagay study section of Kazakhstan, Central Asia, Northern Tethys (Deprez et al., 2015).

4. PALEOGEOGRAPHY

The twelve Rotaliid benthic foraminiferal species of the genus *Valvulineria* were originally identified from many countries in some Southern Tethys: e.g. Angola, Egypt, Jordan, Iraq, Iran and Pakistan, and also from some Northern Tethys: e.g. Spain, Austria and Turkey (Figure 12). Four species of Haque from Pakistan: *V. hillsi*, *V. nammalensis*, *V. patalaensis*, and *V. ranikotensis*. Three species of LeRoy and Nakkady from Egypt: *Valvulineria aegyptiaca*, *V. critchetti*, and *V. brotzeni*. One species of Futyan from Jordan: *V. pseudotumeyensis*, and Turkey *V. orali* (Inan). Another one of the illustrated species came from Iran, which is believed here to be new: *Valvulineria iranica* n. sp. The Tethys had been open, which connected from west with Atlantic Ocean to east with the Indian Ocean via the Mediterranean Sea during the Campanian-Paleogene.

Table 1 shows the twelve identified species of the genus *Valvulineria* in some Northern Tethys countries (Spain, Austria, Turkey, Kazakhstan) and in many countries in the Southern Tethys (Angola, Egypt, Jordan, Iraq, UAE, Iran, Pakistan). *Valvulineria orali* is recorded from four localities: Spain, Austria, Turkey and Iran. Three species are recorded from two countries: *V. aegyptiaca* (Egypt, UAE), *V. nammalensis* (Pakistan, UAE), *V. pseudotumeyensis* (Jordan, Angola), one species *V. scrobiculata* was recorded from three countries (Egypt, Tunisia and Kazakhstan). Seven species are confined to its original type localities: *V. brotzeni* and *V. critchetti* (Egypt), *V. iraqensis* (Iraq), *V. iranica* (Iran), *V. hillsi, V. patalaensis* and *V. ranikotensis* (Pakistan).

Figure 12: Location map of some countries in Europe (Spain, Austria) and the Middle East (Turkey, Egypt, Jordan, Iraq, Iran, UAE, Pakistan) and Kazakhstan.

Table 1: Paleogeographic distribution of the Late Campanian-Early Lutetian benthic foraminiferal species of the genus *Valvulineria* in some Tethyan localities: **1.** Spain, **2.** Austria, **3.** Turkey, **4.** Angola, **5.** Tunisia, **6.** Egypt, **7.** Jordan, **8.** Iraq, **9.** Iran, **10.** UAE, **11.** Pakistan, **12.** Kazakhstan. (Sp. No. = Species number, x = recorded, - = not recorded).

Sp. No.	countries species		1	2	3	4	5	6	7	8	9	10	11	12
1	*Valvulineria*	*aegyptiaca*	-	-	-	-	-	x	-	-	-	x	-	-
2		*brotzeni*	-	-	-	-	-	x	-	-	-	-	-	-
3		*critchetti*	-	-	-	-	-	x	-	-	-	-	-	-
4		*hillsi*	-	-	-	-	-	-	-	-	-	-	x	-
5		*iranica*	-	-	-	-	-	-	-	-	x	-	-	-
6		*iraqensis*	-	-	-	-	-	-	-	x	-	-	-	-
7		*nammalensis*	-	-	-	-	-	-	-	-	-	x	x	-
8		*orali*	x	x	x	-	-	-	-	-	x	-	-	-
9		*patalaensis*	-	-	-	-	-	-	-	-	-	-	x	-
10		*pseudotumeyensis*	-	-	-	x	-	-	x	-	-	-	-	-
11		*ranikotensis*	-	-	-	-	-	-	-	-	-	-	x	-
12		*scrobiculata*	-	-	-	-	x	x	-	-	-	-	-	x

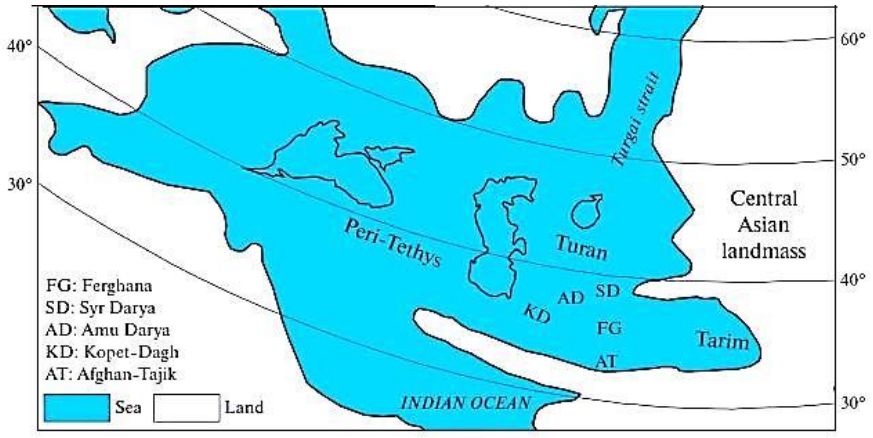


Figure 13: The Paleogene paleogeographic map of the Peri-Tethys including Kopet-Dagh area (KD), NE Iran (Salahi, 2021).

5. DEPOSITIONAL ENVIRONMENT

Valvulineria orali from Turkey was previously classified as possessing a free way of life in shallow-water carbonates in the Neo-Tethyan realm (from Spain to Turkey and Iran), while the sedimentary facies in Egypt, Jordan, Pakistan, Kazakhstan, and Iran, have middle-outer neritic environmental facies (Inan, 2003; LeRoy, 1953; Futyan, 1976; Haque, 1956; Deprez et al., 2015; Salahi, 2021). The identified species of

Valvulineria are predominantly ranges from middle neritic to upper bathyal environment (Figure 13).

6. Conclusions

The present study deals with the recording of twelve identified Rotaliid species of the genus *Valvulineria* in four localities in the Northern Tethys (Spain, Austria, Turkey, Kazakhstan) and seven localities in Southern Tethys (Angola, Egypt, Jordan, Iraq, UAE, Iran, Pakistan) in the Middle East: *Valvulineria aegyptiaca* LeRoy, *V. critchetti* LeRoy, *V. brotzeni* Nakkady (from Egypt), *V. hillsi*, *V. nammalensis*, *V. patalaensis*, *V. ranikotensis* of Haque (from Pakistan), *V. orali* (Inan) (from Turkey), *V. pseudotumeyensis* Futyan (from Jordan and Angola), and *V. scrobiculata* (from Egypt, Tunisia and Kazakhstan), *V. iranica* (Iraq) and *V. iraqensis* (Iran). The last two species *V. iranica* and *V. iraqensis* are believed to be new species. The identified species ranges from middle neritic-upper bathyal environment.

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