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Homeomorphy of some benthic foraminiferal species in the Southern Tethys

Abstract

Six diagnostic Maastrichtian foraminiferal species have been recorded and illustrated from two sections Dokan and Azmer sections in the Kurdistan region, Northeast Iraq. This assemblage proposed with other species in three countries in the Southern Tethys (Tunisia, Egypt, Iraq, United Arab Emirates and Pakistan) a homeomorphic phenomenon. The phenomenon known as homeomorphy, in which an organism simulates an unrelated organism in form and function. In biology the homeomorphy is the evolution of similar external forms from very distant ancestors, happening as a result of convergent evolution, while in paleontology this phenomenon means the existence of two or more fossil taxa that appear to have similar morphology, although they are unrelated, which they might occur in rather different stratigraphic levels, and the test consists of a number of chambers that arrange in numerous shapes and sizes. The present study added additional six benthic foraminiferal homeomorphy: (1) the Late Campanian *Pseudoclavulina farisi* Anan n. sp. and Paleocene *P. hewaidyi* Anan, (2) the Late Campanian *Gaudryina acuta* Anan n. sp. and the Danian *Gaudryina limbata* Said & Kenawy, (3) the Late Campanian *Gaudryina jaffi* Anan n. sp. and the Early Eocene *G. ameeri* Anan, (4) the Late Campanian *Gaudryina lawai* Anan n. sp. and the Early Eocene *G. speijeri* Anan, (5) *Verneuilina iraqensis* Anan n. sp. and the Early Eocene *V. luxorensis* Nakkady, (6) the Late Campanian *Tritaxia longa* Anan, n. sp. and the Early Eocene *Tritaxia elongata* (Haque).

Keywords: campanian, cenozoic, homeomorphy, benthic foraminifera, southern tethys

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Introduction

The phenomenon known as homeomorphy, means an organism simulates an unrelated organism in form and function. In biology the homeomorphy is the evolution of similar external forms from very distant ancestors, happening as a result of convergent evolution. In paleontology this phenomenon means the existence of two or more fossil taxa that appear to have similar morphology, although they are unrelated. They might occur in rather different stratigraphic levels, and the test consists of a number that are formed in different shapes and size. Most of the cases of Homeomorphy are of the planktic foraminiferal species like the Late Paleocene-Early Eocene *Morozovella velascoensis* (Cushman),[1] and Early-Middle Eocene *Morozovella caucasica* (Glaessner),[2] compared to the few cases of benthic foraminiferal species exhibiting homeomorphy. In this study, six cases of agglutinated benthic foraminiferal homeomorphy are presented from the Southern Tethys: Egypt, Iraq, UAE and Pakistan. (Figure 1)These include (1) *Pseudoclavulina* Anan n. sp. and *P. hewaidyi* Anan, (2) *Gaudryina acuta* Anan n. sp. and *Gaudryina limbata* Said & Kenawy, (3) *Gaudryina jaffi* Anan n. sp. and *G. ameeri* Anan, (4) *Gaudryina lawai* Anan n. sp. and *G. speijeri* Anan, (5) *Verneuilina iraqensis* Anan n. sp. and *V. luxorensis* Nakkady, (6) *Tritaxia longa* Anan, n. sp., and *Tritaxia elongata* (Haque).

Previous studies

An attempt was treated by Seiglie[3] for three soritid benthic foraminiferal genera. Anan (in press)[4] was presented three cases of homeomorphy in benthic foraminifera: (1) the Paleocene *Annulofrondicularia nakkadyi* (Futyan) and the Late Eocene *A. sztrakosae* (n. sp.), (2) the Late Eocene *Marginulina karimae* (Anan) and the Pleistocene *M. coarctata* Silvestri, (3) the Middle Eocene *Hemirobulina bassiounii* Anan and the Oligocene-Miocene *H. hantkeni* (Bandy).

Taxonomy and stratigraphy

Some modern references have been added to complete description and taxonomic considerations. The generic concept of the twelve identified agglutinated species in this study are adapted according to the taxonomic classification of Loeblich & Tappan,[5] and presented in Plate 1.

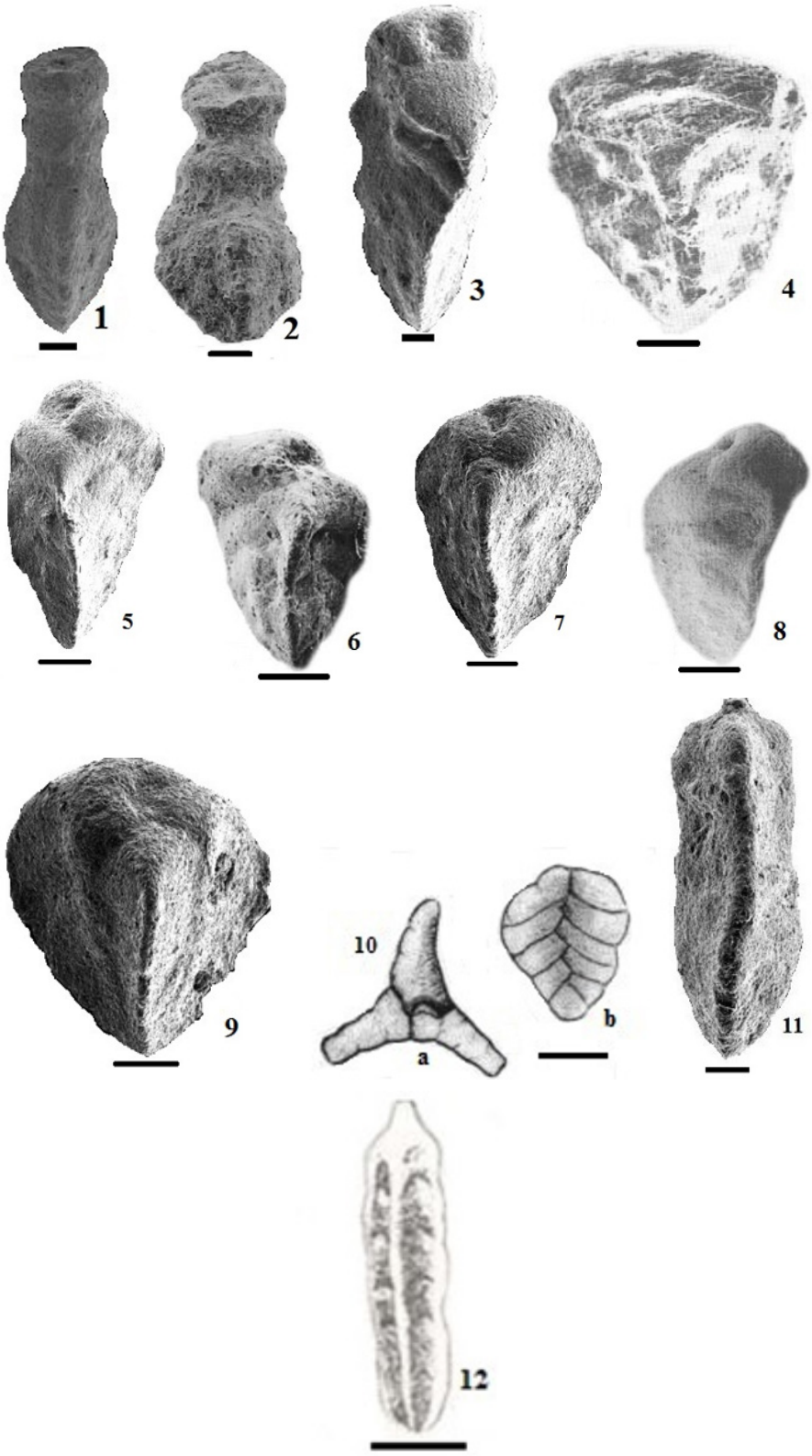

Plate 1 *Pseudoclavulina farisi* Anan (n. p.), **2.** *P. hewaidyi* Anan (2008)**, 3.** *Gaudryina acuta* Anan (n. p.), **4.** *G. limbata* Said & Kenawy (1956), **5.** *Gaudryina jaffi* Anan (n. p.), **6.** *G. ameeri* Anan (2012), **7.** *Gaudryina lawai* (Anan, n. p.), **8.** *G. speijeri* (Anan, 2012), **9.** *Vernuilina iraqensis* (Anan, n. p.), **10.** *V. luxorensis* Nakkady (1950), a. apertural view, b. side view, **11.** *Tritaxia longa* Anan (n. p.), **12.** *T. elongata* (Haque, 1956).

(All scale bars 100μm)

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Order Foraminiferida Eichwald, 1830

Suborder Textulariina Delage & Hérouard, 1896

Superfamily Textulariacea Ehrenberg, 1838

Family Pseudogaudrynidiae Loeblich & Tappan, 1985

Subfamily Pseudogaudryniniae Loeblich & Tappan, 1985

Genus *Pseudoclavulina* Cushman, 1936

Type species *Clavulina clavata* Cushman, 1926

***Pseudoclavulina farisi* Anan, n. p.** (Pl. 1, Figure 1)

2019 *Clavulinoides asper* (Cushman) - Jaff & Lawa,[6] p. 11, pl. 1, figures. 8, 9.

Holotype: Illustrated form in Plate. 1, Figure 1.

Dimension: Length 50 mm, width of the base 20 mm.

Etymology: In the honor of the micropaleontologist Prof. M. Faris, Tanta University, Egypt.

Depository: The collection of Jaff & Lawa, General Sciences Department, Education and Languages College, Charmo University; Geology Department, Sulaimani University, Iraq. (Figure 2)

Type locality: Shiranish Formation, Kurdistan, Iraq.

Type section: 8, MPK14680, Dokan section, sample number DSH-60. (Figure 3)

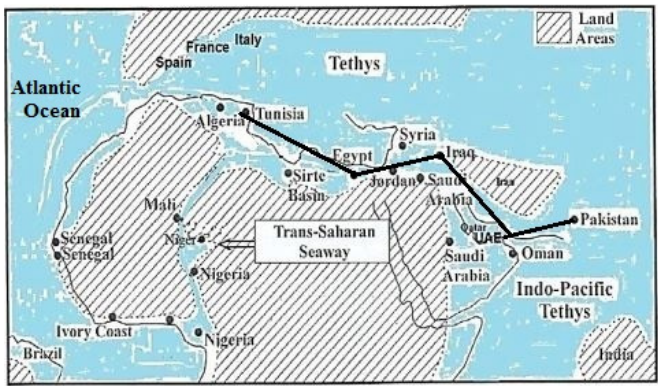

Figure 1 The Late Cretaceous-Early Paleocene paleogeographic map of the Southern Tethys (Tunisia, Egypt, Iraq, UAE, Pakistan), showing possible migration routes of the members of the twelve diagnostic benthic species.[37]

Figure 2 The location map of the two studied sections in NE Iraq: Dokan and Azmer sections (in black rectangle).[6]

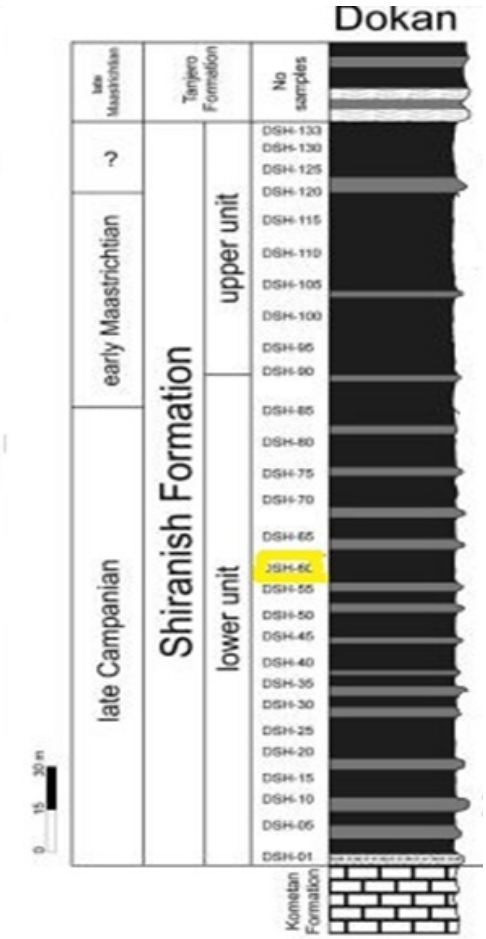

Figure 3 The stratigraphic log of Dokan section, Kurdistan, Northeast Iraq.[6]

Stratigraphic level: Late Campanian.

Diagnosis: Early stage distinctly large triserial and triangular in cross section, then uniserial with discoidal chambers and circular in top view, suture strongly depressed in uniserial stage, wall finely arenaceous, aperture terminal.

Remarks: The species *P. farisi* Anan belongs to the genus *Pseudoclavulina* due its early stage triserial and triangular then uniserial, while the genus *Clavulinoides* has triangular triserial only and uniserial discoidal-globular throughout test. *P. farisi* Anan resemble the Paleocene *P. hewaidyi* Anan, but differs from it by its longer test, longer triserial early stage, limbate sutures in the uniserial stage, and older stratigraphic horizon.

***Pseudoclavulina hewaidyi* Anan, 2008** (Plate. 1, Figure 2)

2008 *Pseudoclavulina hewaidyi* Anan,[7] p. 248, plate. 1, Figure 1.

2015 *Pseudoclavulina hewaidyi* Anan – Anan,[8] p. 249, Figure 4.21.

2017 *Pseudoclavulina hewaidyi* Anan - Hewaidy et al.,[9] p. 83, pl. 2, Figure 25.

Remarks: The Danian-Selandian species *Pseudoclavulina hewaidyi* (Anan) has distinctly large test, triserial stage and triangular in cross section, then discoidal chambers in the uniserial stage which circular in top view and strongly depressed sutures, finely arenaceous wall, terminal aperture. It was recorded from Abu Zenima section (Egypt), and J. Mundassa (UAE).

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Superfamily Verneuilinacea Cushman, 1911

Family Verneuilinidae Cushman, 1911

Subfamily Verneuilininae Cushman, 1911

Genus *Gaudryina* d'Orbigny, 1839

Type species *Gaudryina rugosa* d'Orbigny, 1840

***Gaudryina acuta* Anan, n. sp.** (Plate. 1, Figure 3)

2019 *Gaudryina austinana* Cushman - Jaff & Lawa,[6] p. 14, plate. 2, Figure 4 (*non* Figure 3).

Holotype: Illustrated form in Plate. 1, Figure 3.

Dimension: Length 45 mm, width in the top 22 mm.

Etymology: After the acuteness of the last formed chamber.

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

Type locality: Shiranish Formation, Kurdistan, Iraq

Type section: Azmer section, sample number ASH-35. (Figure 4)

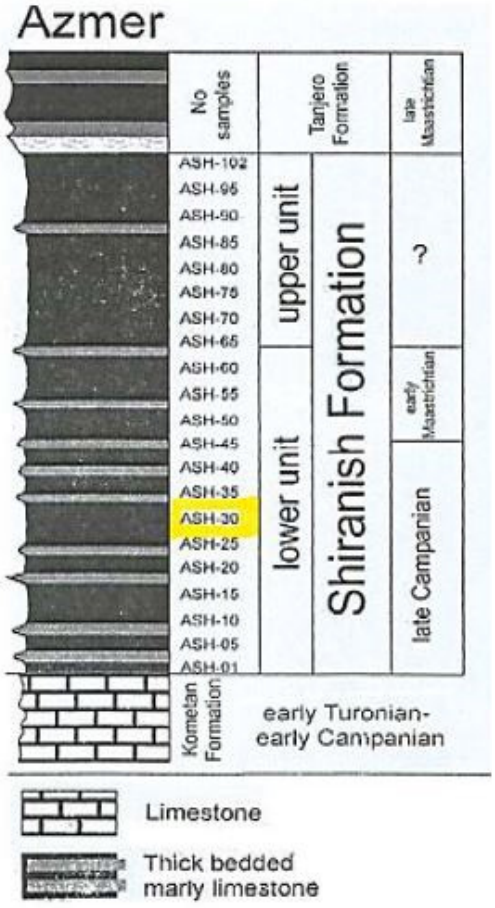

Figure 4 The stratigraphic log of Azmer section, Kurdistan, Northeast Iraq.[6]

Stratigraphic level: Late Campanian.

Diagnostic: The wall of this new species has agglutinated arenaceous with a smooth surface, the early chambers triserial and later biserial, the test of somewhat longer than broad, nearly triangular in transverse section, angles acute, chambers distinct and slightly inflated, truncate periphery, sutures deeply depressed, aperture a high opening in a semicircular of the inner margin of the last formed chamber.

Remarks: The new species *Gaudryina acuta* resembles the Paleocene *G. limbata,* but differs by its lesser length and width, more truncated test, more deeply sutures, smaller last biserial chamber, and semicircular larger opening aperture, and older stratigraphic level.

***Gaudryina limbata* Said & Kenawy, 1956** (Plate. 1, Figure 4)

1956 *Gaudryina limbata* Said & Kenawy,[10] p. 123, plate. 1, Figure 23.

1975 *Tritaxia midwayensis* (Cushman) - Berggren & Aubert,[11] p. 158, plate.1, Figure 1e (*non* 1a-d).

1993 *Gaudryina limbata* Said & Kenawy – Anan,[12] p. 314, pl. 1, Figure 6.

1993 *Gaudryina limbata* Said & Kenawy - Hewaidy & Al-Hitmi,[13] p. 478, plate. 4, figs. 6, 7.

1994 *Gaudryina pyramidata* Cushman - Bolli et al.,[14] p. 90, Figure 24. 5, 6 (*non* 4).

2016 *Gaudryina limbata* Said & Kenawy – Anan,[15] p. 357, Figure 3m.

Remarks: This species has triangular transverse section, triserial early stage and later biserial, angled acute with truncated periphery and limbate sutures. The Danian *G. limbata* differs from the Maastrichtian *G. pyramidata* in having a less elongated test, sharper edges, more limbate sutures and younger stratigraphic level. In this study, the *G. acuta* is considered the ancestor of the Maastrichtian *G. pyramidata.* The latter species was originally recorded from the Danian of Sinai of Egypt, and later from Tunisia,[11] UAE,[12,15] Qatar[13] and Trinidad.[14]

***Gaudryina jaffi* Anan, n. sp. (**Pl. 1, Figure 5**)**

2019 *Gaudryina pyramidata* Cushman - Jaff & Lawa,[6] p. 14, plate. 2, Figure 6 (*non* figures. 5, 7).

Holotype: Illustrated form in Pl. 1, Figure 5.

Dimension: Length 40 mm, width 22 mm.

Etymology: After the micropaleontologist Dr. R.B.N. Jaff, Department of General Sciences, Education & Languages College, Charmo University, Iraq.

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

Type locality: Shiranish Formation, Kurdistan, Iraq. (Figure 4)

Type section: 4, MPK14658, Azmer section, sample no. ASH-35.

Stratigraphic range: Late Campanian.

Diagnostic: The wall of the new species is agglutinated arenaceous with a smooth outer surface, longer test than broad nearly triangular in transverse section, the early chambers triserial and later biserial, elongate last chamber, the front carinate rib is very distinct in this species, which appears in the semi-final chamber of the biserial stage as well as the whole triserial portion, sutures slightly depressed, periphery acute, aperture elongate with semi-circular at the apertural face of the final biserial chamber.

Remarks: The new species *Gaudryina jaffi* resembles the Early Eocene *G. ameeri,* but differs from it by its more elongated test, more

elongated aperture in the apertural face, lesser front carinate rib, and older stratigraphic level.

***Gaudryina ameeri* Anan, 2012** (Plate. 1, Figure 6)

2012 *Gaudryina ameeri* Anan,[16] p. 63, plate. 1,Figure 7.

2021 *Gaudryina ameeri* Anan – Anan,[17] p. 86, plate. 1, Figure 9.

2022 *Gaudryina ameeri* Anan – Anan,[18] p. 28, plate. 1, Figure 13.

Remarks: The front carinate rib is very distinct in this Early Eocene species, which exists along the semi-final chamber of the biserial stage as well as the whole triserial portion. The elongate and tapering final chamber with semi-circular aperture at the apertural face in *Gaudryina ameeri* Anan differs from the semiglobular final chamber with circular aperture in the other *G. speijeri* Anan, and *G. ameeri* is shorter test than *G. speijeri*. It was endemic, so far, in Egypt.

***Gaudryina lawai* Anan n. sp.** (Plate. 1, Figure 7)

2019 *Verneuilina muensteri* Reuss - Jaff & Lawa,[6] p. 14, pl. 2, Figure 9 (*non* Figure 10).

Holotype: Illustrated form in Pl. 1, Figure 7.

Dimension: Length 39 mm, width 27 mm.

Etymology: After the micropaleontologist Dr. F.A. Lawa, Department of Geology, University of Sulaimani, Iraq.

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

Type locality: Shiranish Formation, Kurdistan, Iraq.

Type section: 9, MPK14663, Dokan section, sample number DSH-65. (Figure 3)

Stratigraphic level: Late Campanian.

Diagnosis: The wall of this new species has agglutinated arenaceous with a smooth surface, the test of somewhat longer than broad, nearly triangular in transverse section, the early chambers triserial and later biserial. The carinate rib is very distinct in this species, which exists in the triserial stage and extends to the chamber of the biserial stage, acute last chamber with more semi-circular aperture in the apertural face.

Remarks: The new species *Gaudryina lawai* resembles the Early Eocene *G. speijeri,* but differs from it by the position of the carinate rib which extends only on the chambers of the triserial stage, than on both triserial and biserial stages, the semi-circular aperture than circular aperture in the *G. speijeri*.

***Gaudryina speijeri* Anan, 2012** (Plate. 1, Figure 8)

1994 *Gaudryina* cf. *ellisorae* Cushman – Speijer,[19] p. 147, pl. 5, Figure 1.

2012 *Gaudryina speijeri* Anan,[16] p. 66, plate. 1, Figure 10.

2016 *Gaudryina speijeri* Anan – Anan,[15] p. 357, Figure 3n.

2019 *Gaudryina pyramidata* - Bejaoui et al.,[20] p. 523, pl. 11, Figure 2.

2021b *Gaudryina speijeri* Anan - Anan, p. 271,[21] plate. 1, Figure 5.

2022 *Gaudryina speijeri* Anan - Anan, p. 27,[18] plate. 1, Figure 9.

Remarks: The carinate rib is very distinct in this Early Eocene species *G. speijeri*, which exists in the triserial stage and extends to the final chamber of the biserial stage. This species differs from the Late Cretaceous *G. (Pseudogaudryina) ellisorae* Cushman in having a semiglobular last chamber with more circular aperture than the triangular last chamber, and more elongate aperture than in Cushman's specimen. It seems that the illustrated side view of *G. pyramidata* in Bejaoui et al.[20] is closely related to *G. speijeri* due to its semi-rounded final chamber, which characterized this species. This species was recorded from the Early Eocene in Egypt, and later from Tunisia.[19] and UAE.[20]

Genus *Verneuilina* d'Orbigny, 1839

Type species *Verneuilina tricarinata* d'Orbigny, 1839

***Verneuilina iraqensis* Anan, n. sp.** (Plate. 1, Figure 9)

2019 *Verneuilina muensteri* Reuss - Jaff & Lawa,[6] p. 14, plate. 2, Figure 10 (*non* Figure 9)

Holotype: Illustrated specimen in Plate. 1, Figure 9.

Diameter: (Scale bars 100 μm)

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

Etymology: After the Republic of Iraq.

Type locality: Shiranish Formation, Kurdistan, Iraq.

Type section: Azmer section, sample number ASH-30. (Figure 4)

Stratigraphic level: Late Campanian.

Diagnosis: This Late Campanian new species has agglutinated arenaceous wall with a smooth surface, pyramidal triserial test, much excavated on the three lateral faces, edges thin, chambers long, septal faces triangles.

Remarks: This new species resembles the Early Eocene species V. luxorensis, but differs by its larger test size, more acute periphery, and thicker front carinate rib.

***Verneuilina luxorensis* Nakkady, 1950** (Plate. 1, Figure 10)

1950 *Verneuilina luxorensis* Nakkady,[22] p. 683, plate. 89, figures. 6, 7. x 36

2004 *Verneuilina luxorensis* Nakkady – Anan,[23] p. 42, plate 1, figures. 2.

2016 *Verneuilina luxorensis* Nakkady – Anan,[15] p. 359, Figure 3t.

Remarks: This early Eocene species has a pyramidal triserial test, compressed and much excavated on the three lateral faces, edges thin, chambers long and narrow, septal faces in the form of isosceles triangles, richly cemented wall having a smooth surface. *V. luxorensis* differs from the Maastrichtian-Paleocene *V. aegyptiaca* by its pyramidal test, which is more compressed and much excavated on three lateral thin edges. *V. luxorensis* (the holotype is deposited in the British Museum, Natural History) was originally recorded from the Early Eocene of the Luxor section (Egypt).

Family Tritaxiidae Plotnikova, 1979

Genus *Tritaxia* Reuss, 1860

Type species *Textularia tricarinata* Reuss, 1844

***Tritaxia longa* Anan, n. sp.** (Plate. 1, Figure 11)

2019 *Clavulinoides trilaterus* (Cushman) - Jaff & Lawa,[6] p. 12, pl. 1, Figure 10.

Holotype: Illustrated specimen in Plate. 1, Figure 11.

Dimension: Length 60 mm, width 20 mm.

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

Etymology: After the long test.

Type locality: Shiranish Formation, Kurdistan, Iraq.

Type section: 10, MPK14682, Dokan section, sample number DSH-60. (Figure 3)

Stratigraphic level: Late Campanian.

Diagnosis: Species belongs to the genus *Tritaxia* having a triangular cross section. throughout the elongate test. It has agglutinated arenaceous wall with a smooth surface relatively thick and solid, elongate triangular triserial early stage commonly with carinate angles, and later stage with a few uniserial triangular chambers, sutures flush, aperture terminal rounded on neck.

Remarks: This species resembles the Early Eocene species *Tritaxia elongata* (Haque), but differs from it in its more elongate test less parallel test sides, more thicker front carinate edge, and older stratigraphic level.

***Tritaxia elongata* (Haque, 1956)** (Plate. 1, Figure 12)

1956 *Clavulinoides lakiensis elongata* Haque,[24] p. 45, plate. 21, figure 13.

1996 *Tritaxia lakiensis elongata* (Haque) – Anan,[25] p. 150, figure 3.5

2019 *Tritaxia elongata* (Haque) – Anan,[26] p. 31, plate. 1, Figure 1.

2022b *Tritaxia elongata* (Haque) – Anan,[27] p. 3, plate. 1, Figure 7.

Remarks: This test of the Early Eocene species has triangular cross elongate with section with a terminal aperture at the end of a long neck portion. It was recorded from Pakistan and UAE.[25]

Paleogeography

In the Late Cretaceous-Early Paleocene time the Neotethys was connected with the Atlantic and Indian Oceans via Mediterranean Sea.[28-32] (Figure 1) *Pseudoclavulina hewaidyi* Anan[7] expands its paleogeographic distribution from Egypt to the UAE. *Gaudryina limbata* Said & Kenawy[10] was recorded from Egypt, Tunisia, UAE, Qatar and Trinidad (Caribbean Sea). *Gaudryina ameeri* Anan[16] was originally recorded from Egypt. *Gaudryina speijeri* Anan[16] expands its paleogeographic distribution from Tunisia, Egypt and UAE. *Verneuilina luxorensis* was originally recorded from Egypt. *Tritaxia elongata* (Haque) expands its paleogeographic distribution from Pakistan to the UAE in the Southern Tethys.

Paleoenvironment

The benthic foraminifera have often been used to infer palaeodepth, and their geographic distributional patterns can also be used to infer relative changes in oxygen-level, salinity, temperature and nutrient conditions. Murray[33] noted that arenaceous foraminifera tend to increase in cooler environment. Miller et al.[34] reported that certain hydrographic properties (low oxygen, high CO3, low pH, and corrosive waters) favor the development of agglutinated assemblages. Jones[35] 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 of high sediment and organic carbon flux, and associated lowered oxygen availability, and the genera: *Gaudryina* and *Verneuilina* is restricted to deep marine environments. Jaff & Lawa[6] considered some benthic foraminifera, i.e. *Clavulinoides, Gaudryina, Tritaxia* are more adapted to outer shelf and upper and middle slope. Anan[36] noted that the Paleogene Tethyan foraminiferal assemblage from USA in the west to Pakistan in the east indicate an open connections of the Tethys which represents middle-outer neritic environment (100-200 m depth) and shows an affinity with Midway-Type Fauna «MTF» of Berggren & Aubert.[8] In this study the recorded species represent outer neritic-upper slope environment (200 m-400 m) in an open marine basin in the Southern Tethys between Atlantic and Indian Oceans via Mediterranean Sea, and most of them show an affinity with Midway-Type Fauna (MTF).

Summary and conclusions

The rich and well-preserved Campanian-Early Paleogene twelve benthic foraminiferal species of four agglutinated genera (*Pseudoclavulina, Gaudryina, Verneuilina, Tritaxia*) in six localities of the Southern Tethys: Tunisia, Egypt, Iraq, Qatar, UAE and Pakistan show homeomorphy phenomena through the modifications of morphologic features of the species. Six of these new species are confined, so far, on their mentioned locality in Iraq (*Pseudoclavulina farisi, Gaudryina acuta, Gaudryina jaffi*, *Gaudryina lawai*, *Verneuilina iraqensis* and *Tritaxia longa*). The author believes that recorded species represent outer neritic-upper slope environment (200 m-400 m) in an open marine basin between Atlantic and Indian Oceans via Mediterranean Sea, and most of them show an affinity with Midway-Type Fauna (MTF).

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Conflicts of interest

The authors declare that there is no conflict of interest.

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