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REVIEW ARTICLE

BIOSTRATIGRAPHY AND PROTEROGENESIS OF *VERNEUILINA* FAUNA FROM THE SOUTHERN TETHYS

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ABSTRACT

The Campanian-Ypresian (C-Y) fauna in the Southern Tethys (ST) include rich small benthic foraminifera (SBF) reveals significant biostratigraphic changes during the C-Y transition. A progressive evolutionary trend within the *Verneuilina* lineage allowed to establish the Campanian *V. iraqensis* Total Range Zone (TRZ), and three successive zones in the Maastrichtian-Ypresian, namely: the Maastrichtian *V. aegyptiaca* Interval Range Zone (IRZ), the Paleocene *V. laevigata* IRZ, and the Ypresian *V. luxorensis* TRZ, which may correlate with the standard planktonic foraminifera zones: *Globotruncana aegyptiaca* IRZ to *Acarinina pentacamerata* PRZ, and span about 23 M.Y. (75-52 Ma). On the other hand, a minor difference in the test morphology and differences in the stratigraphic ranges of the members of the genus *Verneuilina* are recognized as being of decisive specific value. For that, the Proterogenesis Rule can be applied here on the Late C-Y six species of the genus *Verneuilina*, and these are: *Verneuilina aegyptiaca* and *V. karreri*, *V. laevigata* and *V. luxorensis*. Another two species are believed here as new: *Verneuilina iraqensis* and *Verneuilina jordanica*. The identified species were recorded from many localities in the ST (Tunisia, Egypt, Jordan, Iraq, Iran, United Arab Emirates, Qatar and Pakistan), and one of them are recorded in Spain, in the Northern Tethys (NT).

KEYWORDS

Biostratigraphy, Proterogenesis, Paleogeography, Verneuilina, Tethys.

1. INTRODUCTION

The present study aims at throwing lights: 1) on the stratigraphy, taxonomic consideration according to the modern taxonomy of six diagnostic species of the genus *Verneuilina* d'Orbigny, 2) interpreted the benthic foraminiferal biozonation of the Late C-Y members of the genus *Verneuilina*, 3) apply the Proterogenesis evolution on the some of the assemblage, 4) paleogeographic distribution in many localities in the ST (Pakistan, Iran, UAE, Qatar, Iraq, Jordan, Egypt, Tunisia), as well as in the NT (Spain) (Caron, 1985; Berggren and Pearson, 2005). This wide geographic distribution of these taxa indicates that the ancestral Tethys was connected with the ancestral Indian Ocean (Figure 1) (d'Orbigny, 1839; Said and Kenawy, 1956; Haque, 1956; Nakkady, 1950).

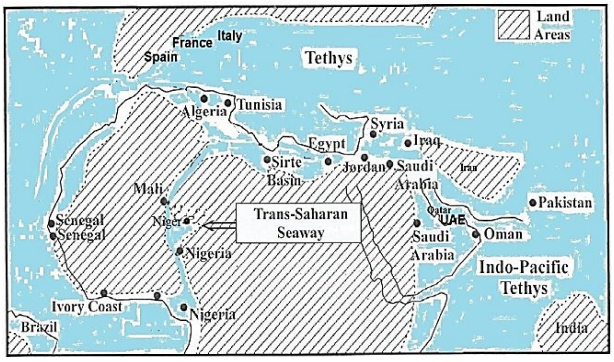

Figure 1: Paleocene paleogeographic map of the Tethys: Spain, Tunisia, Egypt, Jordan, Iraq, Qatar, UAE, Iran and Pakistan (Morsi et al., 2008).

2. *VERNEUILINA* BIOZONATION IN THE ST

Verneuilina species provide one of the most highly resolved biostratigraphic subdivisions of C-Y. A total of six specimens of *Verneuilina* have been identified from many localities in ST. The identified species, its dimensions of the test, and the acuteness of the periphery are shown in Plate 1. The stratigraphic levels of the recorded *Verneuilina* members in this study, the proposed local biostratigraphic biozones are presented in Figure 2. Three species were recorded in the Late Cretaceous (Campanian-Maastrichtian): *V. iraqensis* n. sp. (Iraq), *V. aegyptiaca* and *V. karreri* (Egypt), while the other three species are from the Early Paleogene (Paleocene-Ypresian): *V. laevigata* from Paleocene (Pakistan), *V. jordanica* from Paleocene-Ypresian (Jordan), and *V. luxorensis* also from Ypresian (Egypt and Spain) (Haque, 1956; Nakkady, 1950; Said and Kenawy, 1956). The proposed local biozonation of the members of *Verneuilina* can be presented in the followings:

- Late Campanian *Verneuilina iraqensis* Total Range Zone (TRZ): This biozone is defined as the interval from the first appearance to the last occurrence of the nominate species, and it is therefore a total range zone.
- Maastrichtian *Verneuilina aegyptiaca* Interval Range Zone (IRZ): This biozone is defined as the interval from the first appearance of the nominate species to the to the first appearance of the Paleocene *V. laevigata*.
- Paleocene *Verneuilina laevigata* IRZ Biozone: This biozone is defined as the interval from the first appearance of the nominate species to the first appearance of V. *luxorensis*.

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- Ypresian *V. luxorensis* TRZ: This biozone is defined as the interval from the first appearance to the last occurrence of the nominate species (Figure 2).

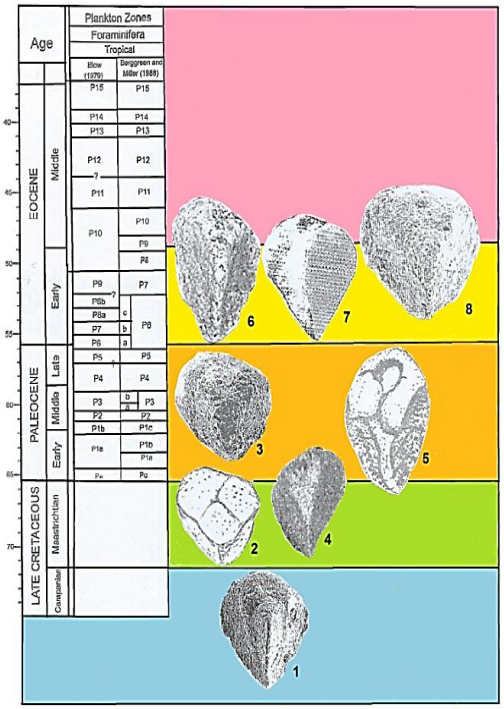

Figure 2: Stratigraphic positions of the *Verneuilina members*: **1.** *V. iraqensis* Anan, n. sp. (Late Campanian), **2, 3.** *V. aegyptiaca* Said and Kenawy (Maastrichtian-Paleocene), **4.** *V. karreri* Said and Kenawy (Maastrichtian-Paleocene)**, 5.** *V. laevigata* Haque (Paleocene), **6.** *V. jordanica* Anan, n. sp. (Ypresian), **7, 8.** *V. luxorensis* Nakkady (Ypresian).

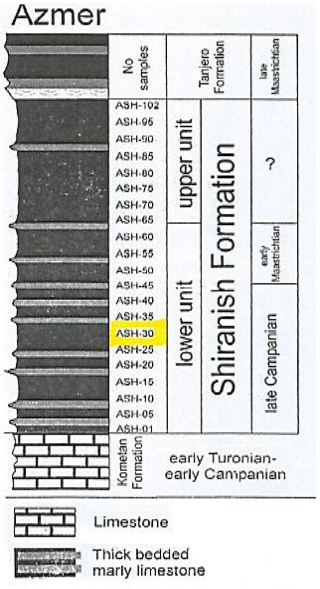

Figure 3: The stratigraphic section and location map of Azmer section, NE Iraq (Jaff and Lawa, 2019).

3. TAXONOMY

The taxonomy for six members of *Verneuilina* d'Orbigny is followed here, and the revised stratigraphic ranges of them are also presented (Plate 1) (Kaminski, 2014). The modern references have been added to complete descriptions and synonymies.

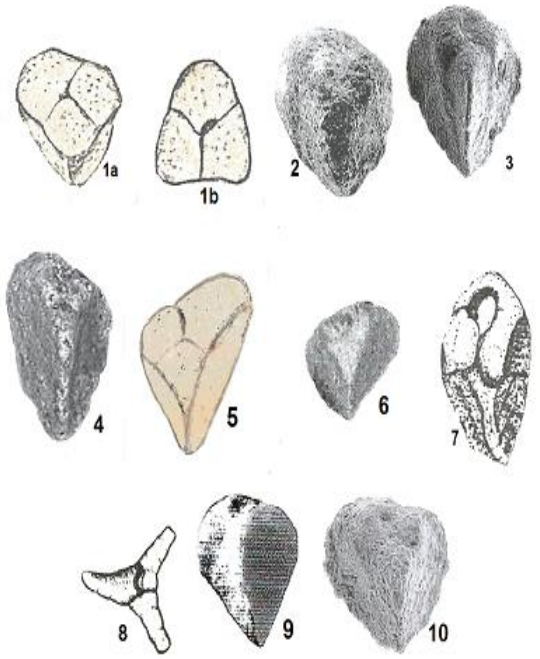

Plate 1: Figures 1, 2: Verneuilina aegyptiaca, 1, the holotype x 55:1a. side view, 1b. apertural view, 2, a hypotype; 3: V. iraqensis Anan, n. sp., the holotype x 30; 4: V. jordanica Anan, n. sp., the holotype x 45; 5, 6: V. karreri, 5. the holotype x30, 6. a hypotype x 20, 7: V. laevigata the holotype x 40; 8-10: V. luxorensis, 8. the apertural view of the holotype x 35, 9. a hypotype x 45, after, 10. a hypotype x 30, (Said and Kenawy, 1956; Anan, 1993; Aly, 2017; Haque, 1956; Nakkady, 1950; Anan, 2009; Ortiz and Thomas, 2006).

Class Foraminiferea d'Orbigny, 1826

Subclass Monothalamana Pawlowski, Holzmann & Tyszka, in Kaminski, 2014

Order Astrorhizida Lankester, 1885

Suborder Verneuilinina Mikhalevich & Kaminski, 2004

Superfamily Verneuilinacea Cushman, 1911

Family Reophacellidae Mikhalevich & Kaminski, 2004

Subfamily Verneuilininae Cushman, 1911

Genus *Verneuilina* d'Orbigny, 1839

Type species *Verneuilina tricarinata* d'Orbigny, 1840

The type species of the genus *Verneuilina* was described by Loeblich & Tappan (1988), which has an elongate test, triserially arranged chambers and triangular throughout, subcarinate to somewhat rounded margin, agglutinated fine to coarse grained wall, an interiomarginal arch aperture. Upper Jurassic-Upper Cretaceous.

***Verneuilina aegyptiaca* Said & Kenawy, 1956 - (Pl. 1, figures 1, 2)**

1956 *Verneuilina aegyptiaca* Said & Kenawy, p. 122, pl. 1, figure 16. {illustrated specimen}

1970 *Verneuilina aegyptiaca*; Al-Omari, p. 49.

1990. *Verneuilina aegyptiaca*; Almogi-Labin et al., p. 578, pl. 2, figure 1.

1993 *Verneuilina aegyptiaca*; Anan, p. 656, pl. 2, figure 2.

2016 *Gaudryina pyramidata*; VahdatiRad et al., p. 5, pl. 2, figure 17.

2016 *Verneuilina aegyptiaca*; Anan, p. 359, figure 3r.

2019 *Verneuilina aegyptiaca*; Bejaoui et al., p. 523, figure 11. 4.

Remarks: The holotype of this Maastrichtian-Paleocene species was recorded from the shale sample of Giddi section, Sinai of Egypt. It was deposited in USNM (P3954). It was recorded also from Tunisia, Egypt, Negev, UAE, Iraq and Iran.

***Verneuilina iraqensis* Anan, n. sp. - (Pl. 1, figure 3)**

2019 *Verneuilina muensteri* Reuss; Jaff & Lawa, p. 14, pl. 2, fig. 10 (*non* figure 9).

Holotype: Illustrated specimen in Pl. 1, figure 3.

Dimensions: Length 0.50 mm, width 0. 44 mm.

Etymology: After the Republic of Iraq.

Type locality: Shiranish Formation, Azmer section, Kurdistan region, northeast Iraq (Figure 3).

Age: Late Campanian.

Diagnosis: *Verneuilina iraqensis* n. sp. has pyramidal fine-grained triserial test, triangular transverse section with sharply acute edges, aperture an interiomarginal arch.

Remarks: This species is closely related to the Ypresian Egyptian *V. luxorensis* Nakkady in its sharply acute edges of test with triangular transverse section, but differs in its younger stratigraphic level, from the Late Campanian than Ypresian. This new species is, so far, an endemic in Iraq.

***Verneuilina jordanica* Anan, n. sp. - (Pl. 1, figure 4)**

2020 *Gaudryina pyramidata*; Alhejoj et al., p. 5, figure 2. 1.

Holotype: Illustrated specimen in Pl. 1, figure 4.

Dimensions: Length 0.40 mm, width o.30 mm.

Etymology: After the Kingdom Hashemite of Jordan.

Type locality: Umm Rijam Formation, Jabal Ghuzayma section, central Jordan (Figure 4).

Age: Thanetian-Ypresian *Morozovella formosa* Zone, E4 (Berggren and Pearson, 2005).

Diagnosis: This specie is characterized by its triangular elongate coarse-grained agglutinated test, triserial arranged chambers, somewhat rounded margins, aperture basal an interiomarginal arch.

Remarks: *Verneuilina jordanica* n. sp. differs from the holotype of the late Cretaceous *V. tricarinata* d'Orbigny in its more rounded margins, more coarse-grained test, and younger stratigraphic level at Thanetian-Ypresian. It is, so far, an endemic in Jordan.

***Verneuilina karreri* Said & Kenawy, 1956 - (Pl. 1, figures 5, 6)**

1956 *Verneuilina karreri* Said & Kenawy, p. 122, pl. 1, figure 17.

1993 *Valvoreussella karreri*; Hewaidy & Al-Hitmi, p. 481, pl. 6, figures 7, 8.

2016 *Verneuilina karreri*; Anan, p. 359, figure 3s.

2017 *Verneuilina karreri*; Hewaidy et al., p. 83, pl. 2, figure 11.

2017 *Verneuilina karreri*; Aly, p. 55, pl. 3, figure 7.

Remarks: has slightly elongate tapering coarsely roughly finished triserial test, slightly longer than broad, sharply angular in transverse section, chambers of uniform shape regularly increasing in size as added. The holotype of this Maastrichtian-Danian species was deposited in USNM (P3955) from the Esna Shale of Giddi section, Sinai of Egypt. It differs from *Verneuilina aegyptiaca* in having longer and bigger test, less rounded angles, and less inflated chambers. It was recorded from Sinai of Egypt, and later from UAE and Qatar.

***Verneuilina laevigata* Haque, 1956 - (Pl. 1, figure 7)**

1956 *Verneuilina laevigata* Haque, p. 34, pl. 21, figures 9, 12.

Remarks: The holotype of this Late Paleocene species was erected from the Patala Shales, Nammal Gorge, Northern Pakistan. It differs from *V. aegyptiaca* Said & Kenawy by its more acute periphery, larger test, more wider aperture opening, and younger stratigraphic horizon. It is, so far, an endemic to Pakistan.

***Verneuilina luxorensis* Nakkady, 1950 - (Pl. 1, figures 8-10)**

1950 *Verneuilina luxorensis* Nakkady, p. 683, pl. 89, figures 6, 7. ●

2006 *Clavulinoides angularis*; Ortiz & Thomas, p. 102, pl. 1, fig. 1 (*non*-figures 2-6).

2009 *Verneuilina luxorensis*; Anan, p. 34, pl. 1, figure 2.

2016 *Verneuilina luxorensis*; Anan, p. 359, figure 3t.

2017 *Verneuilina luxorensis*; Hewaidy et al., p. 83, pl. 2, figures 12,13.

Remarks: The holotype of the Ypresian species *V. luxorensis* was deposited in the British Museum, Natural History. *V. luxorensis* differs from the Maastrichtian-Paleocene *V. aegyptiaca* by its pyramidal test, more compressed and much excavated on three lateral thin edges. On the other hand, it closely related to the Late Campanian *Verneuilina iraqensis,* but these two species have different stratigraphic levels. The figured Ypresian Spanish specimen of Ortiz & Thomas from Fortuna section (Northern Tethys) is closely related to *V. luxorensis*. It is a marker species for Ypresian, and was originally recorded from Luxor section of Egypt, and later it was recorded also in Spain

4. Proterogenesis Evolution of The *Vernuilina* Fauna in The St

Schindewolf noted that the theoretical significance of Proterogenesis lies partly in its elucidation of the principal of ontogenetic modification in early juvenile stages and partly in its clear demonstration of the existing evolutionary relationships through the revision to ancestral features in adult stages (Schindewolf, 1993). In this study, this theory can be applying on the Late Campanian *Verneuilina iraqensis* with its sharply acute edges of triserial test, with triangular transverse section as a juvenile stage, to the Ypresian *Verneuilina luxorensis* with the same characters, as an adult stage (Figure 2, nos. 1 and 7).

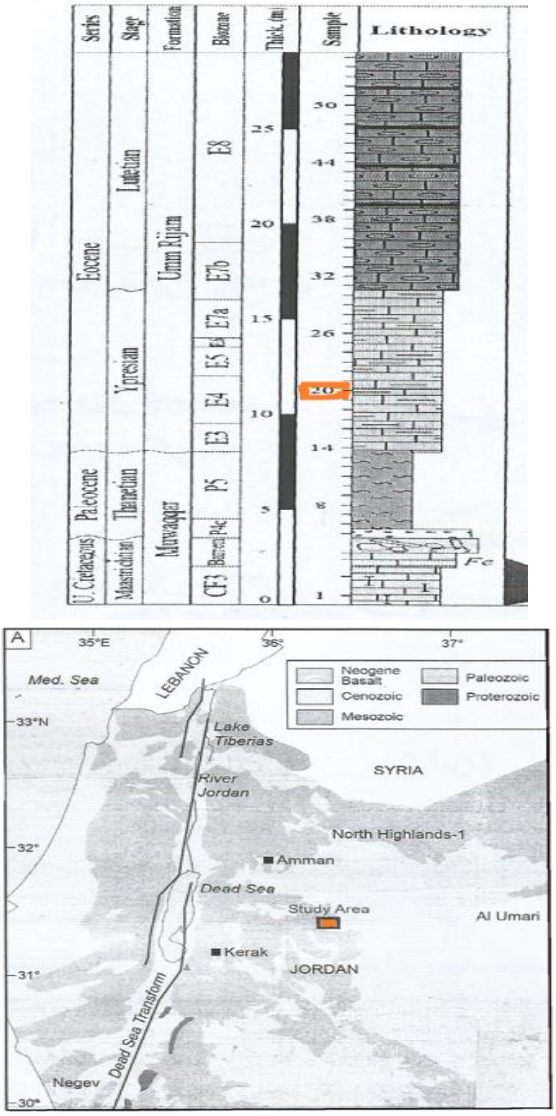

Figure 4: The stratigraphic section and location map of Ghuzayma section, central Jordan, (Alhejoj et al., 2020).

5. Paleogeography

The record of the Pakistanian species *Verneuilina laevigata*, the Jordanian species *V. jordanica,* the Egyptian species *V. aegyptiaca* (in Tunisia, Egypt, UAE, Iraq), *V. karreri* (in Egypt, Iraq, UAE, Qatar), and *V. luxorensis* (in Egypt, Spain) expands the paleogeographic distribution of the genus *Verneuilina* and its members into the Southern and Northern Tethys (Figure 5).

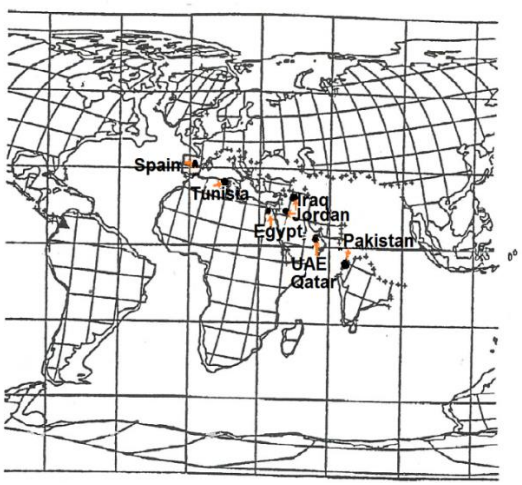

Figure 5: The Early Paleogene paleogeographic map of the Tethys: Spain, Tunisia, Egypt, Jordan, Iraq, UAE, Qatar, Pakistan (Smith et al, 1982).

6. Conclusion

The present study deals with the recording of six identified species of the agglutinated foraminiferal genus *Verneuilina* of d'Orbigny: *Verneuilina aegyptiaca* Said & Kenawy, *V. iraqensis* Anan, n. sp., *V. jordanica* Anan, n. sp., *V. karreri* Said & Kenawy, *V. laevigata* Haque and *V. luxorensis* Nakkady in seven localities in the Southern Tethys (Pakistan, UAE, Qatar, Iraq, Jordan, Egypt, Tunisia) and only one locality in the Northern Tethys (Spain). Three of these species are confined to their origin description: *V. iraqensis* (Iraq), *V. jordanica* (Jordan) and *V. laevigata* (Pakistan), while the other three species are distributed in many localities in the Sothern and Northern Tethys: *V. aegyptiaca* (Tunisia, Egypt, Iraq, UAE, Iran), *V. karreri* (Egypt, Qatar, UAE) and *V. luxorensis* (Egypt, Spain).

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