ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)
CODEN: GBEEB6

Geological Behavior (GBR)

DOI: http://doi.org/10.26480/gbr.01.2022.48.52

REVIEW ARTICLE

PALEONTOLOGY AND EVOLUTIONARY LINEAGES OF THE DIAGNOSTIC BENTHIC FORAMINIFERAL GENUS *ORTHOKARSTENIA*

Haidar Salim Anan*

Emeritus, Professor of stratigraphy and micropaleontology, Al-Azhar University-Gaza, Palestine.
Corresponding Author Email: profanan@gmail.com

ARTICLE DETAILS

Article History:

Received 08 September 2022
Revised 11 October 2022
Accepted 01 November 2022
Available online 14 November 2022

ABSTRACT

This work is focused on the members of the Late Cretaceous-Early Paleogene (K-Pg) diagnostic benthic foraminiferal genus *Orthokarstenia* which is regionally important in paleontology and stratigraphic correlations. The large number of tests available and the rapid morphologic changes, offer an opportunity to study evolutionary changes in these foraminiferal taxa over a time span of about 25 m. y. (75-50 Ma). Six species of the genus *Orthokarstenia* are presented: *O. applinae*, *O. eleganta*, *O. esnehensis, O. higazyi*, *O. nakkadyi* and *O. oveyi*, which were recorded in eight localities in the Southern Tethys: Nigeria, Tunisia, Egypt (central and north Africa), Jordan, Saudi Arabia, UAE, Iran and Pakistan (southwest Asia). Evolutionary changes of them are indicated by such criteria, such as changes in the test-size, chambers arrangement, type of sutures, periphery or surface ornamentation. These changes help to define the major faunal change of the Campanian/Maastrichtian (C/M) boundary, K/Pg boundary, and can used in biostratigraphic subdivisions and correlations based on benthic foraminifera, beside planktic foraminiferal zonation.

KEYWORDS

Paleontology, Stratigraphy, Lineages, Paleogeography, *Orthokarstenia,* Tethys

1. INTRODUCTION

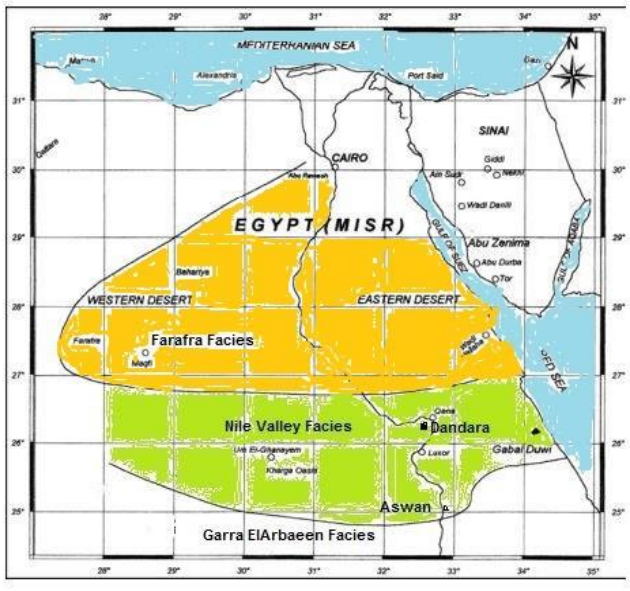

Figure 1: Location map of the seven Egyptian sedimentary facies, including some sections: Maqfi, Wadi Mellaha sections (Farafra Facies, central Egypt), Duwi, Gurnah, Dandara, Owaina sections, and Ain Dabadib, Ghanayem sections (Nile Valley Facies, southern Egypt) (Issawi, 1972).

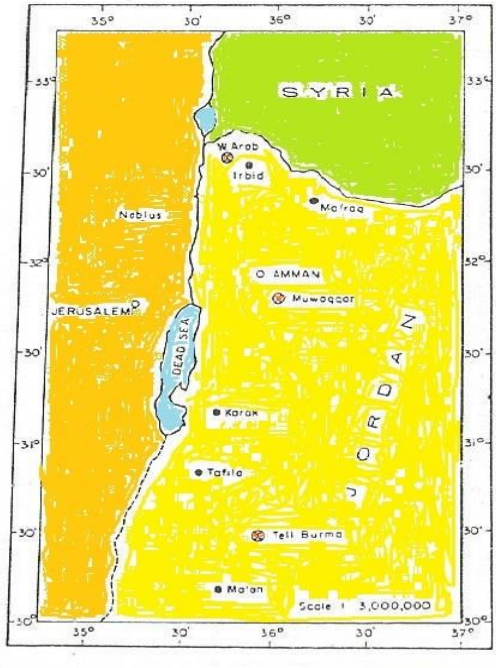

Figure 2: Location map of the three diagnostic sections in Jordan: Wadi Arab section (North Jordan), Muwaqqar section (Central Jordan) and Tell Burma section (South Jordan) (Futyan, 1976).

Quick Response Code	Access this article online	
	Website: www.geologicalbehavior.com	**DOI:** 10.26480/gbr.01.2022.48.52

Cite The Article: Haidar Salim Anan (2022). Paleontology and Evolutionary Lineages of The Diagnostic Benthic Foraminiferal Genus *Orthokarstenia. Geological Behaviour 6(1): 48-52.*

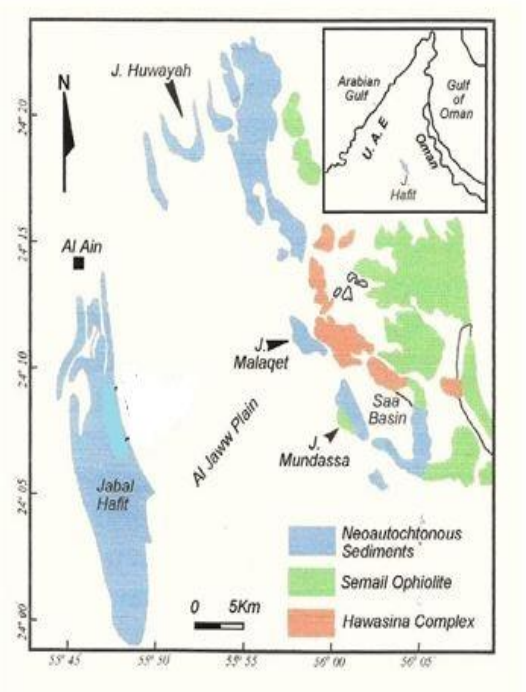

Figure 3: Geologic map of Al Ain area including the locations of Jabal Haft, J. Malaqet and J. Mundassa, UAE.

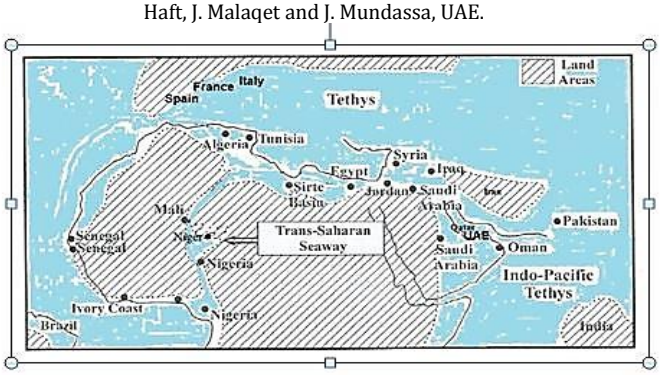

Figure 4: Maastrichtian-Paleocene paleogeographic map of the Northern Tethys (Spain, France, Italy), and Southern Tethys (Niger, Tunisia, Libya, Egypt, Jordan, Iraq, Saudi Arabia, Qatar, UAE, Iran, Pakistan), showing possible migration routes of the members of the two diagnostic benthic genera: *Bolivinoides* and *Orthokarstenia* (Morsi et al., 2008).

Anan concluded that the members of the genus *Orthokarstenia* were found mainly in the Farafra Facies and Nile Valley Facies, central and southern Egypt (Figure 1) (Anan, 1987; 1994). The members of *Orthokarstenia* (*applinae, higazyi, oveyi*) were found also in three sections, in north, central and south Jordan (Figure 2), but without record the any members of another diagnostic benthic foraminiferal genus of *Bolivinoides* (Futyan, 1976). In UAE, the *O. applinae* was recorded in the Danian shaley bed in Jabal Malaqet and in J. Mundassa (Figure 3), as well as in the Early Eocene sediments in the northeast of Iran, without record of any member of *Bolivinoides* (Anan, 1993; Anan, 2021; VahdatiRad et al., 2016). After Berggren and Aubert only *O. eleganta* was recorded in the Paleocene of Saudi Arabia (Berggren and Aubert, 1975). A group researchers recognized the absence of the Danian Stage from the Cretaceous-Tertiary of Bodashe-1 and Illepaw-1 Wells, in Niger Delta (Nigeria) and used the last occurrence of *Afrobolivina afra*, *O. parva*, *O. oveyi* and *Globotruncana* species to mark the top Maastrichtian (Figure 4) (Fadiya et al., 2014). In Pakistan and Iran, *O. applinae* was only found, without any record of any *Bolivinoides* members (Haque, 1956; VahdatiRad et al., 2016).

2. Benthic Foraminiferal Evolutionary Trends

Nakkady presented some evolutionary trends (by his own identification) of accelerated benthic foraminiferal evolution in the Maastrichtian-Paleogene transition of Egypt: (1) *Siphogenerina* (=*Orthokarstenia*) *esnehensis* Nakkady to *Siphogenerinoides* (=*Orthokarstenia*) *eleganta* (Plummer), (2) *Siphogenerina* (=*Orthokarstenia*) *esnehensis* Nakkady to *Siphogenerina* (=*Orthokarstenia*) *higazyi* Nakkady (Nakkady, 1955). This attempt was followed later by Anan in another evolutionary trends: *Orthokarstenia oveyi* (Nakkady) to *O. applinae* (Plummer) (Figure 5) (Anan, 1998). Anan added that the transitional Paleocene form of Anan, 1998 (=*Orthokarstenia nakkadyi*) has a distinguished character: "longitudinal costae on the early chambers (the lower part of the test) but without costae ornamentation on the last chambers (the upper part of the test)" (Anan, 2009).

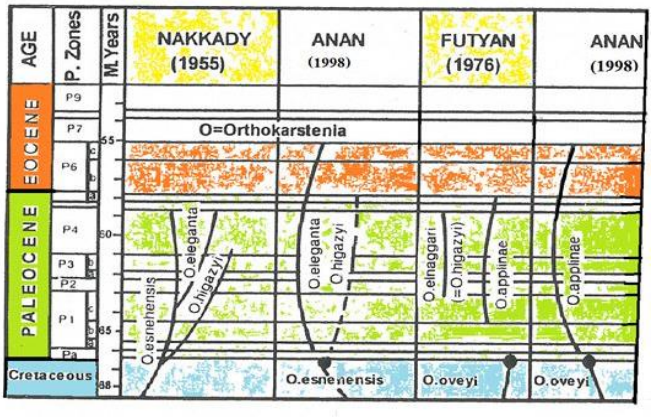

Figure 5: The phylogenitic lineages and modified stratigraphic ranges of the Cretaceous-Paleogene benthic foraminifera species of the genus *Orthokarstenia* by different authors. The solid lines indicate where the lineages are well defined, while a dashed line show a suggested but not well defined part of the lineage. The latter case is not probably due to ecological factors and not for stratigraphic reasons (Anan, 1998).

Table 1: The paleogeographic distribution of the recorded species of the genus *Orthokarstenia* in the Southern Tethys: 1. Tunisia, 2. Egypt, 3. Jordan, 4. Saudi Arabia (SA), 5. United Arab Emirates (UAE), 6. Iran, 7. Pakistan, 8. Nigeria.

Sp. No.	Paleogeographuc distribution of the Orthokarstenia species in the Southern Tethys		Tethyan localities							
			1	2	3	4	5	6	7	8
1	*Orthokarstenia*	*applinae*	X	X	X	-	X	X	X	-
2		*eleganta*	X	X	-	X	-	-	-	-
3		*esnaensis*	-	X	-	-	-	-	-	-
4		*higazyi*	-	X	X	-	X	-	-	-
5		*nakkadyi*	X	X	-	-	-	-	-	-
6		*oveyi*	-	X	X	-	-	-	-	X

3. Taxonomy and Stratigraphy

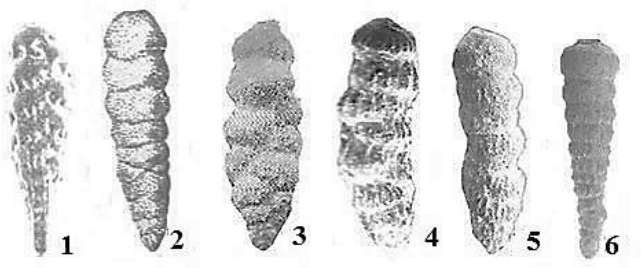

Plate 1: 1. *Orthokarstenia applinae* (Plummer, 1927) (after Ismail, 2012) x 30, 2. *O. eleganta* (Plummer, 1927) (after LeRoy, 1953) x 67, 3. *O. esnehensis* (Nakkady, 1950) (after Anan, 2009) x 93, 4. *O. higazyi* (Nakkady, 1955) (after Anan, 2009) x 70, 5. *O. nakkadyi* Anan, 2009 x 70, 6. *O. oveyi* (Nakkady, 1950) (after Anan, 2009) x 75.

The six Campanian-Maastrichtian-Early Paleogene species of the genus *Orthokarstenia* are represented by *O. applinae*, *O. eleganta*, *O. esnehensis, O. higazyi*, *O. nakkadyi* and *O. oveyi* and illustrated in Plate 1. I have followed Leoblich & Tappan's (1988) classification of Order Foraminiferida, including their recent revision of the classification.

Genus *Orthokarstenia* Dietrich, 1935

Remarks: Within the Maastrichtian and Paleocene times of Egypt, many accelerated evolution trends are recognized in the *Orthokarstenia* members. Two of these trends have already been recognized by Nakkady: (1) *Orthokarstenia esnehensis* > *O. eleganta*, (2) *O. esnehensis* > *O. higazyi,* whereas another trend from *O. oveyi* > *O. applinae* was described, for the first time (Nakkady, 1955; Anan, 1998).

***Orthokarstenia applinae* (Plummer, 1927)** - (Pl. 1, figure1)

1927 *Bolivina applini* Plummer, p. 69, pl. 4, figure 1.

1953 *Loxostomum applinae* (Plummer) - LeRoy, p. 37, pl. 8, figure 1.

1956 *Loxostomum applinae* (Plummer) - Haque, p. 134, pl. 15, figures 24, 25.

1976 *Loxostomoides applinae* (Plummer) - Aubert & Berggren, p. 420, pl. 4, figure 11.

1976 *Loxostomoides applinae* (Plummer) - Futyan, p. 521.

1998 *Orthokarstenia applinae* (Plummer) - Anan, p. 371, figure 3.3.

2016 *Loxostomum applini* (Plummer) - VahdatiRad et al., p. 6, pl. 2, figure 14.

2020 *Loxostomoides applinae* (Plummer) - Alhejoj et al., p. 5, figure 2.F.

Remarks: The initial part of Plummer's *applinae* is, however, obscure. She originally assigned her species to the genus *Bolivina,* and also stated that the chamber are smooth except for distinct striae extending from the initial extremity upward over several early chambers, and sutures in early part of the test are faint dark lines that become more distinct upward and are finally somewhat depressed and show crenulations. Thus, it is regarded to belong to *Orthokarstenia*. The Paleocene-Early Eocene *O. applinae* (Plummer) is an evolutionary development from the Maastrichtian *O. oveyi* (Nakkady) (Anan, 1998). The *O. applinae* has a wide geographic distribution, so far: USA, Sweden, Norwegian Sea, Tunisia, Jordan, UAE, Egypt, Iran and Pakistan.

***Orthokarstenia eleganta* (Plummer, 1927)** - (Pl. 1, figure 2)

1927 *Siphogenerina eleganta* Plummer, p. 126, pl. 8, figure 1.

1953 *Siphogerinoides eleganta* (Plummer) - LeRoy, p.49, pl. 2 figures 20, 21.

1976 *Siphogerinoides eleganta* (Plummer) - Aubert & Berggren, p. 421, pl. 5, figure 3.

1998 *Orthokarstenia eleganta* (Plummer) - Anan, p. 372, figure 3.6.

2015 *Siphogenerinoides eleganta* (Plummer) - Karoui-Yaakoub et al., p. 180, figure 3.

2019 *Orthokarstenia eleganta* (Plummer) - Anan, p. 7, pl. 1, figure 22.

Remarks: This species was recorded from many Tethyan localities: Tunisia, Egypt, and SA (Berggren and Aubert, 1975). According to the new data, *O. eleganta* ranges to early Middle Eocene in Tunisia (Karoui-Yaakoub et al., 2015). This is another cosmopolitan species, and common in the Paleocene-early Middle Eocene.

***Orthokarstenia esnehensis* (Nakkady, 1950)** - (Pl. 1, figure 3)

1950 *Siphogenerina esnehensis* Nakkady, p. 688, pl. 89, figure 17.

1998 *Orthokarstenia esnehensis* (Nakkady) - Anan, p. 372, figure 3.5.

2012 *Orthokarstenia esnehensis* (Nakkady) - Ismail, p. 49, pl. 4, figure 5.

2017 *Orthokarstenia esnehensis* (Nakkady) - Hewaidy et al., p. 87, pl. 4, figures 12, 13.

Remarks: Anan (1998, and this study) considered the Maastrichtian *O. esnehensis* (Nakkady) as ancestor of two subsequent Paleocene *O. eleganta* (Plummer) in *O. esnehensis-O. eleganta* lineage in one hand, and *O. higazyi* (Nakkady) in O. *esnehensis-O. higazyi* lineage in the other (Figure 6). *O. esnehensis* is, so far, an endemic to Egypt.

***Orthokarstenia higazyi* (Nakkady, 1955) -** (Pl. 1, figure 4)

1955 *Siphogenerina higazyi* Nakkady, p. 705, text-figure 4.

1976 *Siphogerinoides elnaggari* Futyan, p. 529, pl. 82, figures 3,4,10.

1988 *Orthokarstenia higazyi* (Nakkady) - Anan & Sharabi, p. 212, pl. 2, figures 8, 9.

2003 *Orthokarstenia higazi* (Nakkady) - Ali, p. 123, pl. 7, figure 15.

2019 *Orthokarstenia higazyi* (Nakkady) - Anan, p. 164, pl. 2, figure 57.

Remarks: The existed of longitudinal costae on the chambers separates the Paleocene *O. higazyi* from the smooth test surfaces of both the Maastrichtian *O. esnehensis* and the Paleocene-Early Eocene *O. eleganta* (Figure 6). It is, so far, recorded from Egypt, Jordan and UAE.

***Orthokarstenia nakkadyi* Anan, 2009** - (Pl. 1, figure 5)

1992 *Siphogerinoides eleganta* (Plummer) - Saint-Marc, p. 485, pl. 1, figure 17.

1998 Transitional form between *O. higazyi* (Nakkady) and *O. eleganta* (Plummer) - Anan, p. 368, figure 3.7.

2000 *Rectuvigerina clavata* (Franzenau) - Sztrákos, p. 106, pl. 13, figure 2.

2003 *Siphogerinoides eleganta* (Plummer) - Ali, p. 123 , pl. 7, figures 16, 17.

2006 *Siphogerinoides eleganta* (Plummer) - Ortiz & Thomas, p. 132, pl. 11, figure 4.

2009 *Orthokarstenia nakkadyi* Anan, p. 37, pl. 1, figure 7.

2021 *Orthokarstenia nakkadyi* Anan - Anan, p. 93, pl. 3, figure 59.

Remarks: The figured Paleocene forms of Saint-Marc, 1992 (Tunisia), Sztrákos, 2000 (France), El-Dawy (2001) and Alegret & Ortiz, 2007 (Egypt) has wide geographic distribution in the southern Tethys (Egypt and Tunisia) and northern Tethys (France and Spain). According to the new data, *O. nakkadyi* ranges from Middle Paleocene to early Middle Eocene (Figure 6).

***Orthokarstenia oveyi* (Nakkady, 1950) -** (Pl. 1, figure 6)

1950 *Siphogenerina oveyi* Nakkady, p. 686, pl. 89, figure 2.

1976 *Siphogenerina oveyi* Nakkady - Futyan, p. 521.

1988 *Orthokarstenia oveyi* (Nakkady) - Anan & Sharabi, p. 212, pl. 2, figures 10, 11.

2003 *Orthokarstenia oveyi* (Nakkady) - Ali, p. 123, pl. 7, figures 13, 14.

2014 *Orthokarstenia oveyi* (Nakkady) - Fadiya et al., p. 62.

2017 *Orthokarstenia oveyi* (Nakkady) - Hewaidy et al., p. 87, pl. 4, figures 14, 15.

2020 *Orthokarstenia oveyi* (Nakkady) - Alhejoj et al., p. 3.

Remarks: *Orthokarstenia oveyi* is, so far, unrecorded elsewhere out of Middle East, that may be due to another names by some authors. This species has wide geographic distribution in the: Nigeria, Egypt, and Jordan, and considered as an excellent marker species for the K/T boundary in Southern Tethys (Figures 5, 6).

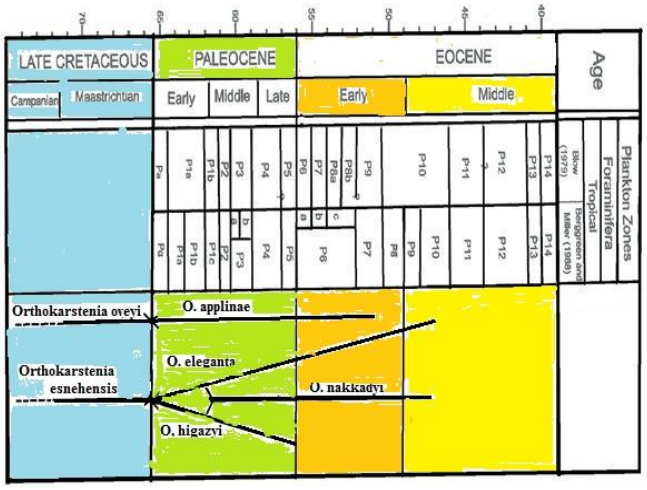

Figure 6: The proposed phylogenic lineage of the *Orthokarstenia* members in the Southern Tethys.

4. PALEOGEOGRAPHY

The Paleocene-Early Eocene *Orthokarstenia applinae* has wide geographic distributed in thirteen localities in USA, Sweden, Norwegian Sea, France, Spain, Nigeria, Tunisia, Egypt, Jordan, SA, UAE, Iran and Pakistan. *O. nakkadyi* also has distribution in the Northern Tethys (France, Spain) and also Southern Tethys (Tunisia, Egypt). *O. eleganta* in three localities in the Southern Tethys (Tunisia, Egypt, SA). *O. higazyi* also in three localities in the S. Tethys (Egypt, Jordan, UAE). *O. oveyi* also recorded in two localities in S. Tethys (Egypt, Jordan), but *O. esnaensis* is endemic, so far, in Egypt. The paleogeographic distribution of the representatives of the diagnostic members of the genus *Orthokarstenia* in the Southern Tethys is presented in Figure 8.

5. PALEOENVIRONMENT

In the Maastrichtian time, deep marine calcareous sediments were deposited in different parts of the Northern and Southern Tethys (Figure 7). An outer to middle shelf environments were suggested for the Maastrichtian in northern Egypt by Said & Kenawy and Anan, but outer neritic environment (100-200 m depth) for Tunisia by Aubert & Berggren, and shows an affinity with Midway-Type Fauna, (MTF) (Said and Kenawy, 1956; Anan, 1987; Aubert and Berggren, 1976). An upper-middle slope (200-800 m depth) was suggested by Abdel Kireem for the subsurface Maastrichtian in northern Western Desert of Egypt (Abdel Kireem, 1983). The distribution of the genus *Orthokarstenia* most probably was affected by the distribution of the phosphates in Egypt, and some members of the genus *Orthokarstenia* (*applinae, higazyi, oveyi*) are found in the Maastrichtian of Jordan most probably due to the presence of the economic Cretaceous-phosphate deposits (Alhejoj et al., 2020). Many factors which may play a role on this distribution of the genus *Orthokarstenia*: phosphate effect, water temperature, light penetration, salinity and dissolved oxygen. As example, the water temperatures in southern Egypt may be higher than that in northern Egypt during the Maastrichtian time, mainly due to the shallow nature of the water column in southern Egypt, which made the light penetration more easy and the dissolved oxygen is more than that in the deeper environment in northern Egypt. The salinity in central and southern Egypt was less than that in northern Egypt due to the effect of the fresh water supply on the shallow basin in southern Egypt. A group researchers noted that the end-Cretaceous marine mass extinction not caused by productivity collapse, but an asteroid impact caused mass extinction (Alegret et al., 2012).

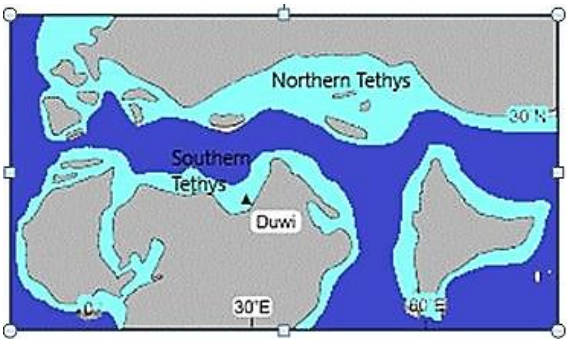

Figure 7: The paleogeographic map of the Maastrichtian showing the open Northern and Southern Tethys, with the detection of diagnostic Duwi section (Egypt) in the Southern Tethys.

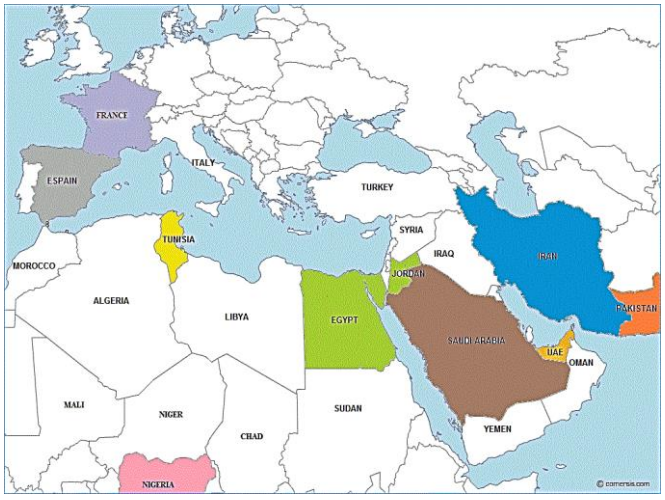

Figure 8: The paleogeographic distribution of the *Orthokarstenia* members in some countries in the Northern Tethys (Spain and France) and many countries in the Southern Tethys (Nigeria, Tunisia, Egypt, Jordan, Saudi Arabia, United Arab Emirates, Iran and Pakistan).

6. CONCLUSIONS

The six Maastrichtian-Early Paleogene species of the benthic foraminiferal genus *Orthokarstenia (O. applinae, O. eleganta, O. esnehensis, O. higazyi, O. nakkadyi* and *O. oveyi*) were recorded from eight localities in the Southern Tethys: Nigeria (west Africa), Tunisia and Egypt (North Africa), Jordan, SA, UAE, Iran and Pakistan (southwest Asia), and also four localities in the Northern Tethys (Sweden, Norwegian Sea, France, Spain), and USA. All members of the Maastrichtian-Early Paleogene genus *Orthokarstenia* were recorded from Egypt, 3 species of them from Tunisia (*O. applinae, O. eleganta, O. nakkadyi*), 3 from Jordan (*O. applinae, O. higazyi, O. oveyi*), 2 from UAE (*O. applinae, O. higazyi*), 1 from Saudi Arabia (*O. eleganta*), 1 from Iran and Pakistan (*O. applinae*), and 1 from Nigeria (*O. oveyi*) (Table 1). This taxon is predominantly considered here to be related to MTF (middle-upper neritic environment (100-200 m water depth).

ACKNOWLEDGEMENT

I would like to thank the editor of the ESP and the reviewers, and to my daughter Dr. Huda Anan for her help in preparing the figures (1-8), Table 1 and Plate 1.

REFERENCES

Abdel-Kireem, M.R., 1983. A study of the paleoecology and bathymetry of the foraminiferal assemblages of the Shiranish Formation (Upper Cretaceous), northeastern Iraq. Palaeogeography, Palaeoclimatology, Palaeoecology, 43, Pp. 169-180.

Alegret, L., Thomas, E., Lohmann, K.C., 2012. End-Cretaceous marine mass extinction not caused by productivity collapse. PNAS, 109 (3), Pp. 728–732.

Alegret, L., Ortiz, S., 2007. Global extinction event in benthic foraminifera across the Paleocene/Eocene boundary at the Dababiya Stratotype section. Micropaleontology, 52 (5), Pp. 433-447.

Alhejoj, I., Farouk S., Bazeen, Y.S., Ahmad, F., 1988. Depositional sequences and sea-level changes of the upper Maastrichtian-middle Eocene succession in central Jordan: Evidence from foraminiferal biostratigraphy and paleoenvironments. Journal of African Earth Sciences, 161, 103663, Pp. 1-13.

Ali, M.Y., 2003. Micropaleontological and stratigraphical analyses of the Late Cretaceous/Early Tertiary succession of the Southern Nile Valley (Egypt). Der Fakultät für Geowissenschaften an der Ruhr-Universität Bochum vorgelegte Dissertation zur Erlangung des Grades eines, Pp. 1-197.

Anan, H.S., 1987. Biostratigraphy and paleoecology of Maastrichtian and Paleocene benthonic foraminifera from Jiran El Ful section, Abu Rawash area, Egypt. Middle East Research Center (MERC) Ain Shams University, Earth Science Series, Cairo, 1, Pp. 207-227.

Anan, H.S., 1993. Paleocene benthonic foraminifera of Jabal Malaqet, Al Ain region, United Arab Emirates. Al-Azhar Bulletin of Science, Al Azhar University, Cairo, 4 (1), Pp. 293-320.

Anan, H.S., 1994. Contribution to the stratigraphy and paleobiogeography of some diagnostic Upper Cretaceous and Paleogene Foraminifera. Neues Jahrbuch für Geologie und Paläontologie, 5, Pp. 257-266.

Anan, H.S., 1998. Accelerated evolution in representatives of the genera Orthokarstenia and Discorbis (Benthic foraminifera) in the Maastrichtian and Paleocene of Egypt (Misr). Neues Jahrbuch für Geologie und Paläontologie, 6, Pp. 365-375.

Anan, H.S., 2009. Paleontology, paleogeography, paleoenvironment and stratigraphical implications of the Nakkady's benthic foraminiferal fauna in Egypt and Tethys. Egyptian Journal of Paleontology, 9, Pp. 31-52.

Anan, H.S., 2011. Maastrichtian small benthic foraminifera from Middle East and their distribution in the Tethys. Revue de Paléobiologie, 30 (1), Pp. 13-30.

Anan, H.S., 2014. Review on spatio-temporal distribution of three benthic foraminiferal species from Egypt and Tethys. Egyptian Journal of Paleontology, 14, Pp. 65-72.

Anan, H.S., 2019. Late Paleocene-Early Eocene benthic foraminifera from the Esna Shale of Duwi section, Egypt. British Journal of Earth Sciences Research, 7 (2), Pp. 1-25.

Anan, H.S., 2020. Punctuationlism and gradualistic evolutionary trends of eight phylogenetic lineages of Maastrichtian to Eocene and Recent benthic foraminifera from the Tethys. Jour. Sciences, 31 (1), Pp. 63-73.

Anan, H.S., 2021. Paleontology, stratigraphy, paleoenvironment and paleogeography of the seventy Tethyan Maastrichtian-Paleogene foraminiferal species of Anan, a review. Journal of Microbiology & Experimentation, 9 (3), Pp. 81-100.

Anan, H.S., 2022. Members of Lagenid small benthic foraminiferal genera *Lingulina, Tristix* and *Citharina*. Geological Behavior (GBR), 6 (1), Pp. 31-34.

Anan, H.S., Sharabi, S.A., 1988. Benthonic foraminifera from Upper Cretaceous-Lower Tertiary rocks of northwest Kharga Oasis, Egypt. MERC, Ain Shams University, Earth Science Series, 2, Pp. 191-218.

Aubert, J., Berggren, W.A., 1976. Paleocene benthonic foraminiferal biostratigraphy and paleoecology of Tunisia. Bulletin du Centre de Recherches Pau- SNPA, 10 (2), Pp. 379- 469.

Berggren, W.A., Aubert, J., 1975. Paleocene benthonic foraminiferal biostratigraphy, paleobiogeography and paleoecology of Atlantic-Tethyan regions: Midway-type fauna. Palaeogeography, Palaeoclimatology, Palaeoecology, 18, Pp. 73-192.

El-Dawy, M.H., 2001. Paleocene benthic foraminiferal biostratigraphy and paleobathymetry, El Sheikh Fadl and Ras Gharib, Eastern Desert, Egypt. Micropaleontology, 4 (1), Pp. 23-46.

Fadiya, S.L., Jaiyeola-Ganiyu, F.A., Fajemila, O.T., 2014. Foraminifera biostratigraphy and paleoenvironment of sediments from Well Am-2, Niger Delta. Ife Journal of Science, 16 (1), Pp. 61-72.

Futyan, A.I., 1976. Late Mesozoic and Early Cainozoic benthonic foraminifera from Jordan. Palaeontology, 19 (3), Pp. 53-66.

Haque, A.F.M.M., 1956. The foraminifera of the Ranikot and the Laki of the Nammal Gorge, Salt Range, Pakistan. Pakistan Geological Survey Memoir, Palaeontologica Pakistanica, 1, Pp. 1-229.

Hewaidy, A.A., Farouk S., EL-Balkiemy, A.F., 2017. Foraminiferal Biostratigraphy, Stages Boundaries and Paleoecology of the Uppermost Maastrichtian-Lower Eocene Succession at Esh El-Mellaha Area, Northeastern Desert, Egypt. Journal of American Science, 13 (5), Pp. 74-113.

Ismail, A.A., 2012. Late Cretaceous-Early Eocene benthic foraminifera from Esh El Mallaha area, Egypt. Revue de Paléobiologie, 31 (1), Pp. 15-50.

Issawi, B., 1972. Review of Upper Cretaceous-Lower Tertiary stratigraphy in central and southern Egypt. American Association of Petroleum Geologist Memoir, 56 (8), Pp. 1448-1463.

Karoui-Yaakoub, N., Ben M'Barek-Jemaï, M., Mtimet, M.S., Molina, E., 2015. Integrated stratigraphy of the Ypresian–Lutetian transition in northern Tunisia: Correlation and paleoenvironmental reconstruction. Journal of African Earth Sciences, 110, Pp.176–187.

Koutsoukos, E.M., de Klasz, I., 2000. Late Cretaceous foraminiferal biogeography (Families Bolivinidae, Buliminellidae, Gavelinellidae, Siphogenerinoididae, Turrilinidae) in northeastern Brazilian shelf and central West African basins. Cretaceous Research, 21, Pp. 381-405.

Lemon R.R., 1990. Principle of stratigraphy. Merrill Publication Company. Pp. 1-559.

LeRoy, L.W., 1953. Biostratigraphy of Maqfi section, Egypt. Geological Soc. of American Memoir, 54, Pp. 1-73.

Loeblich, A.R., Tappan, H., 1988. Foraminiferal genera and their classification. Van Nostrand Reinhold (VNR), New York, Part 1, Pp. 1-970.

Morsi, A.M., Fairs, M., Zalat, A., Salem, R.F., 2008. Maastrichtian-Early Eocene Ostracodes from west-central Sinai, Egypt. taxonomy, biostratigraphy, paleoecology and paleobiogeography. Revue de Paléobiologie, 27 (1), Pp. 159-189.

Nakkady, S.E., 1950. A new foraminiferal fauna from the Esna Shale and Upper Cretaceous chalk of Egypt. Journal of Paleontology, 24 (6), Pp. 675-692.

Nakkady, S.E., 1955. The stratigraphic implication of the accelerated tempo of evolution in the Mesozoic-Cenozoic transition of Egypt. Journal of Paleontology, 29 (4), Pp. 702-706.

Ortiz, S., Thomas, E., 2006. Lower-middle Eocene benthic foraminifera from the Fortuna Section (Betic Cordillera, southeastern Spain). Micropaleontology, 52 (2), Pp. 97-150.

Plummer, H.J., 1927. Foraminifera of the Midway Formation in Texas. Bulletin Univ. Texas, 2644, Pp. 3-206.

Said, R., Kenawy, A., 1956. Upper Cretaceous and Lower Tertiary foraminifera from northern Sinai, Egypt. Micropaleontology, 2 (2), Pp. 105-173.

Saint-Marc, P., 1992. Biostratigraphy and bathymetric distribution of benthic foraminifera in Paleocene of El Haria Formation of Tunisia. Journal of African Earth Science, 15 (3/4), Pp. 473-487.

Sztrákos, K., 2000. Eocene foraminifers in the Adour Basin (Aquitaine, France): biostratigraphy and taxonomy. Revue de Micropaléontologie 43 (1-2), Pp. 71-172.

VahdatiRad, M., Vahidinia M., Sadeghi A., 2016. Early Eocene planktonic and benthic foraminifera from the Khangiran formation (northeast of Iran). Arab Journal of Geosciences, 9, 677, Pp. 1-13.