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BIOSTRATIGRAPHY OF *BOLIVINOIDES* AND *NEOFLABELLINA* BENTHIC FORAMINIFERA IN THE UPPER CRETACEOUS SHIRANISH FORMATION, KURDISTAN REGION, NE IRAQ

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ABSTRACT

The Shiranish Formation contains diversified assemblages of both benthic and planktic foraminifera. Previous works on planktic foraminiferal biostratigraphy suggests that the formation was deposited in the Late Campanian – Early Maastrichtian time indicated by *Globotruncana aegyptiaca*, *Gansserina Gansseri* and *Contusotruncana Contusa* biozones. This work is focused on two benthic foraminifers (*Bolivinoides* and *Neoflabellina*) which are globally important in Upper Cretaceous biostratigraphic correlations. The present study is based on 235 samples collected from two different sections in the Kurdistan Region of Iraq which are Azmer (144 m) and Dokan (260 m) in thicknesses. Both areas represent nearly complete Late Cretaceous outcrops of the Shiranish Formation. Six different species of *Bolivinoides* and three different species of *Neoflabellina* benthic foraminifera are recorded and illustrated and their biostratigraphical importance are also discussed. The *Bolivinoides* are represented by *B. decoratus*, *B. delicatula*, *B. draco*, *B. laevigatus*, *B. miliaris* and *B. pustulata*. Moreover, the *Neoflabellina* are represented by *N. numismalis*, *N. permutata* and *N. rugosa*. The present results are compatible with the Late Cretaceous global distribution of *Bolivinoides* and *Neoflabellina* benthic foraminifera, which are commonly used for biostratigraphic correlations. The group of benthic faunas identified in the present work suggests that the Shiranish Formation is mostly deposited in outer shelf to slope environments with a shallowing-up succession recorded in the Earliest Maastrichtian.

الطباقية الأحيائية للمنخربات القاعية *Bolivinoides* و *Neoflabellina* في تكوين الشرانش (الطباشيري الأعلى) في إقليم كوردستان، شمال شرق العراق

روند بكر نوري جاف

المستخلص

يحتوي تكوين الشرانش على أنواع مختلفة من المنخربات القاعية والطافية. تشير أنواع المنخربات الطافية في الدراسات السابقة الى ان التكوين ترسب خلال الكامباني المتأخر – الماستريختي المبكر بدلالة الأنطقة الحياتية: *Globotruncana aegyptiaca* و *Gansserina Gansseri* و *Contusotruncana Contusa*

تركز الدراسة الحالية على المنخربات القاعية *Bolivinoides* و *Neoflabellina* المهمة عالميا في المطابقة الطباقية الأحيائية لعصر الطباشيري المتأخر. اعتمدت الدراسة على 235 عينة تم التقاطها من مقطعين في اقليم كردستان حيث يظهر تكوين الشرانش بسمك شبه متكامل هما مقطع ازمر (144 متر) ومقطع دوكان (260 متر). تم تسجيل

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ودراسة الطباقية الأحيائية لستة أجناس من *Bolivinoides* وثلاثة أجناس من *Neoflabellina*. اشتملت *Bolivinoides* على *B. decoratus*، *B. delicatula*، *B. draco*، *B. laevigatus*، *B. miliaris*، *B. pustulata* واشتملت *Neoflabellina* على *N. numismalis*، *N. permutata*، *N. rugosa*. تتطابق النتائج الحالية مع الانتشار الأحيائي العالمي للمنخربات الطافية *Bolivinoides* و *Neoflabellina* في الطباشيري المتأخر واعتمادهما في المطابقة الطباقية الأحيائية. تشير مجموعة المنخربات القاعية التي تم تسجيلها في الدراسة الحالية الى ان تكوين شرانش قد ترسب في بيئة الحوض الخارجي الى بيئة المنحدرمع وجود تتابع تضحل نحو الأعلى في البدايات المبكرة للعصر الماستريختي.

INTRODUCTION

The Shiranish Formation (Upper Campanian – Lower Maastrichtian) crops out in most of north, northwest and northeast Iraq, and is also detected in the subsurface of many wells across the central part of Iraq (Jassim and Goff, 2006). Several previous studies deal with its lithology, paleontology and stratigraphic significance (e.g. Buday, 1980; Jassim and Goff, 2006; Al-Banna, 2010; Jaff *et al*., 2015; Farouk *et al*., 2018; Jaff and Lawa, 2019; and Al-Hazaa *et al*., 2021). However, none of the above studies mentioned the importance of *Bolivinoides* and *Neoflabellina* benthic foraminifera for regional and inter-regional biostratigraphic correlations.

The foraminiferal genus *Bolivinoides* Cushman, 1927 received great attention from biostratigraphers and taxonomists in the last seventy years, almost more than any other genera of Cretaceous benthic foraminifera. This is due to the fact that most of the species of *Bolivinoides* have similar stratigraphic range globally. Consequently, they have been broadly used as a good tool for biostratigraphic correlation of Santonian-Maastrichtian strata (Dubicka and Peryt, 2016).

Through time, the morphologic changes in *Bolivinoides* lineage can be expressed by: **1)** a continuous increase in test size, **2)** the evolution from cudgel-shaped to rhomboidal outline, **3)** the development of two parallel rows of tubercles in the median part of the test and **4)** an increase in the number of lobes. These evolutionary trends noticed in the genus *Bolivinoides* seem to be similar worldwide, and has allowed to use the group in refined biozonation as reported in Australia (Edgell, 1954), Israel (Reiss, 1954), Europe (Hiltermann and Koch, 1950, 1955 and 1962; Hofker, 1958; Vassilenko, 1961; Hiltermann, 1963; Barr, 1966a and b; Van Hinte, 1967; Beniamovsky *et al*., 2012; Dubicka and Peryt, 2016; Peryt and Dubicka, 2015; Beniamovsky and Kopaevich, 2016), Trinidad (Beckmann and Koch, 1964; Bolli *et al*., 1994), Libya (Barr, 1970), the USA (Petters, 1977), the western Atlantic (Georgescu *et al*., 2011), Egypt (Khalil, 1998; El-Nady, 2006; Anan, 2011 and 2017), Iraq (Jaff *et al*., 2014), and Tunisia (Bejaoui *et al*., 2019). The benthic faunas identified in this study consist of 115 species which represent 52 genera and 25 families. In this study, both *Bolivinoides* and *Neoflabellina* benthic foraminifera are used for the first time in order to place the Kurdistan assemblages into the context of this global stratigraphy.

MATERIALS AND METHODS

The present study is based on 235 collected samples from two tectonically different sections, one at Azmer (35° 37' 30" N; 45° 31' 45" E) and the other at Dokan (35° 56' 15" N; 44° 57' 21" E (Fig.1). For friable marlstones of the Shiranish Formation, a freeze-thaw method of processing was used (Mogaddam, 2002; Jaff *et al*., 2014 and 2015; Jaff and Lawa, 2019). About 200 – 300 g of each selected sample was frozen and thawed repeatedly in a sodium sulphate solution. The processed samples were then washed using a 63 μm sieve. The residues then placed in an oven temperature of 50 ºC until the sediments dried (almost 24 hours). Different sizes of foraminifera were picked and studied using the 63 – 300 μm size

fractions. Morphological preservation of the illustrated *Bolivinoides* and *Neoflabellina* benthic foraminifera is good, although the tests are commonly recrystallized and filled with calcite. The Scanning Electron Microscope (SEM) at the University of Leicester, UK was used for foraminiferal images.

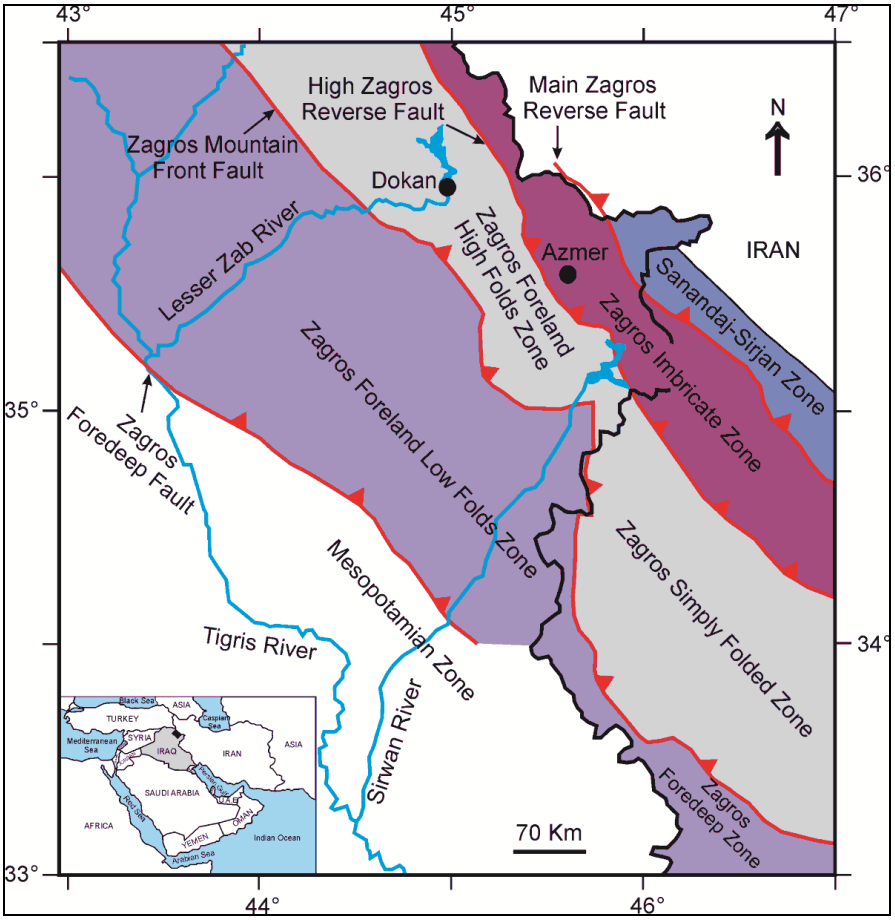

Fig.1: Main tectonic zones in the Kurdistan region, NE Iraq; major basement faults are drawn in red lines (map after Ibrahim, 2009). Locations of the studied sections are shown as black circles. Small black rectangle on inset map represents study area

GEOLOGICAL SETTING

From a structural perspective the selected sections can be allocated to two main tectonic zones which are separated from each other by major basement faults (Lawa *et al.*, 2013). Accordingly, the Azmer section is situated in the Zagros Imbricate Zone (ZIZ) of Iraq, while the Dokan section is located in the Zagros Foreland High Folds Zone (ZFHFZ) (Lawa *et al.*, 2013).

The ZIZ is intensively deformed and characterized by rock displacements and crustal thickening. Geomorphologically, it is characterized by high mountains with deep incised valleys, and is a product of imbricate thrust sheets and NE dipping thrust faults. The present structural characteristics of this zone are a result of ophiolites obduction in Late Cretaceous and Arabian – Iranian collision in Late Tertiary (Lawa *et al*., 2013). The ZFHFZ is mainly characterized by asymmetrical, double plunging, convergent and divergent folds. Additionally, other distinctive features of this zone are NW – SE trending and SW dipping thrust faults (Lawa *et al*., 2013).

LITHOLOGY

The Shiranish Formation is well exposed in the studied localities and is about 144 and 260 m thick in the Azmer and the Dokan areas respectively. According to several authors (e.g. Van Bellen *et al*., 1959; Al-Naqib, 1967; Al-Shaibani, 1973; Buday, 1980; Abawi *et al*., 1982; Abdel-Kireem, 1983 and 1986; Kennedy and Lunn, 2000; Al-Banna, 2010; Jaff *et al*., 2014 and 2015; Jaff and Lawa, 2019; Al-Hazaa *et al*., 2021) the age of the Shiranish Formation is Late Campanian to Maastrichtian, but it does not extend to the Late Maastrichtian (Kassab, 1973; Jaff *et al*., 2014 and 2015). The formation represents marine outer shelf and slope deposited carbonates and mudstones (Jaff *et al*., 2014 and 2015; Jaff and Lawa, 2019). In the studied areas, the Shiranish Formation is informally subdivided into a lower unit characterized by alternating calcareous marlstone and marly limestone, and an upper unit that is dominated by blue-coloured marlstone (Jaff *et al*., 2014 and 2015; Jaff and Lawa, 2019; see Fig.2). In both sections, the formation is separated by Mid-Campanian unconformity from the underlying Kometan Formation, and is gradationally changes to the overlying Tanjero Formation (Jaff *et al*., 2014 and 2015; Farouk *et al.*, 2018; Jaff and Lawa, 2019). The gradational boundary is placed at the first appearance of the silty-sandstone bed of the Tanjero Formation (see Fig.2).

RESULTS

During the Late Cretaceous, benthic foraminifers are very common in marine sediments. Basically, the *Bolivinoides* and *Neoflabellina* evolution are of great importance for high resolution biostratigraphy. They have been used widely for Late Cretaceous subdivision and for inter-regional correlations (e.g. Koch, 1977; Loeblich and Tappan, 1987; Hart *et al*., 1989; King *et al*., 1989; Peryt and Lamolda, 2007; Bolli *et al*., 1994; Ardestani *et al*., 2011; Jaff *et al*., 2014; Dubicka and Peryt, 2016; Georgescu, 2018; Bejaoui *et al*., 2019). In this study, both *Bolivinoides* and *Neoflabellina* benthic foraminifera are used for biostratigraphic subdivision of the Late Cretaceous successions in the Kurdistan region, NE Iraq.

BOLIVINOIDES BIOSTRATIGRAPHY

Based on the remarkable work of Dubicka and Peryt (2016) and Georgescu (2018) on the genus of *Bolivinoides*, the collected 118 specimens of *Bolivinoides* are studied and described under SEM for better understanding and identifications. The morphological structures, ornamentation and porosity features used by Georgescu (2018) for *Bolivinoides* identification; allowed to identify and illustrate six different species in the present work (see Fig.3). The species are: *Bolivinoides decoratus*, *B. delicatula*, *B. draco*, *B. laevigatus*, *B. miliaris* and *B. pustulata*. A biostratigraphical outline consisting of three biozones is developed for the Late Campanian – Early Maastrichtian stratigraphic interval. Two biozones are of interval biozone and the third is the total range biozone type. The bioevents that mark their boundaries are first occurrences (FO) of *Bolivinoides* genus. Below are short notes about each recorded biozone.

- ***Bolivinoides decoratus* Biozone**

– **Age:** early Late Campanian – Latest Campanian.

– **Definition:** Stratigraphical interval between the FO of the index species and the FO of *Bolivinoides miliaris*. It represents the lower part of the Shiranish Formation, where the formation is characterized by alternating calcareous marlstone and marly limestone (see Fig.2).

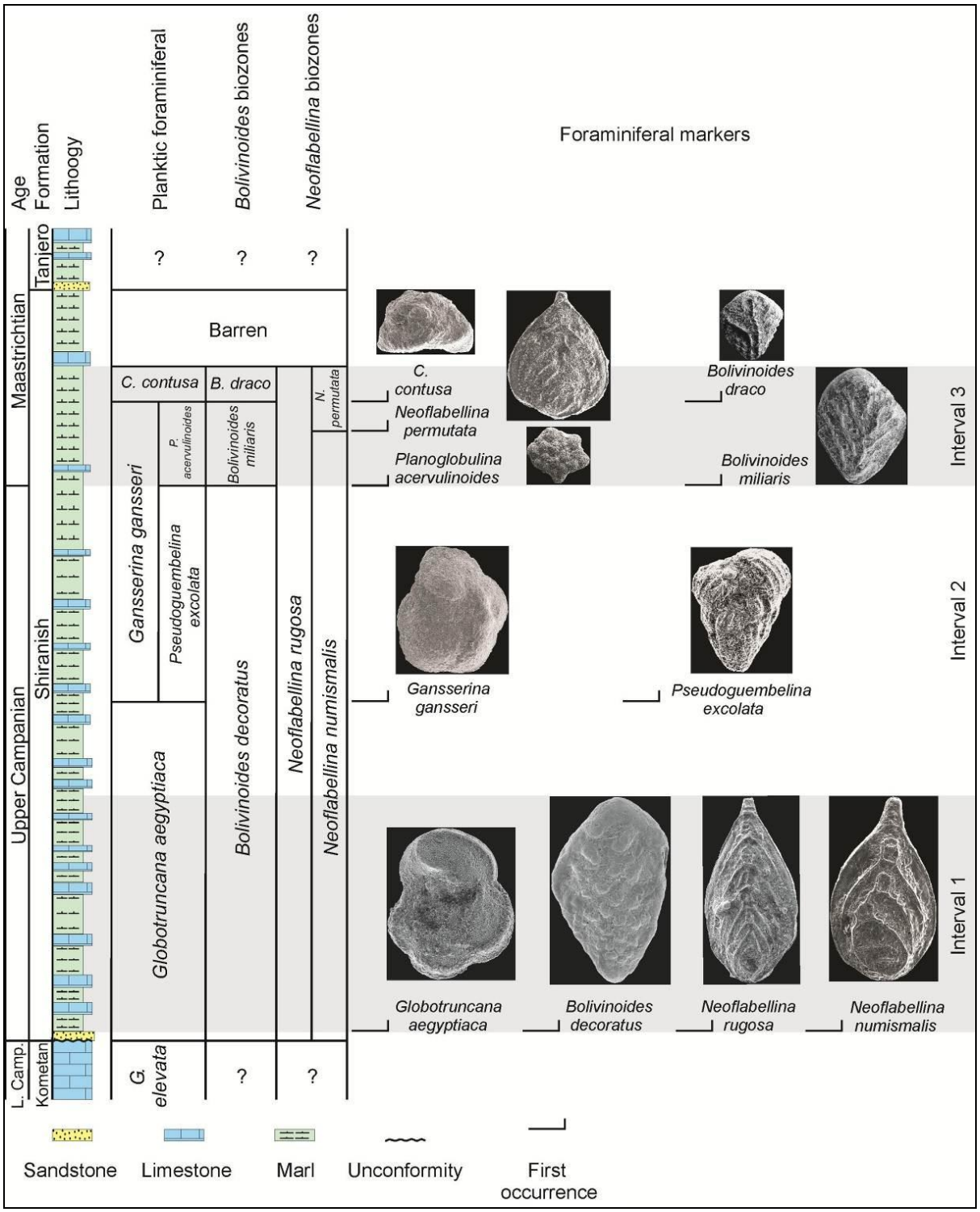

Fig.2: Generalized lithostratigraphy of the Shiranish Formation in the sections studied. Biostratigraphic subdivisions are based on planktic foraminifera (Jaff *et al*., 2015) and benthic foraminifera (this work). The white and grey areas indicate depth-related intervals of benthic foraminiferal assemblages. First occurrences of key planktic and benthic foraminifera are also shown

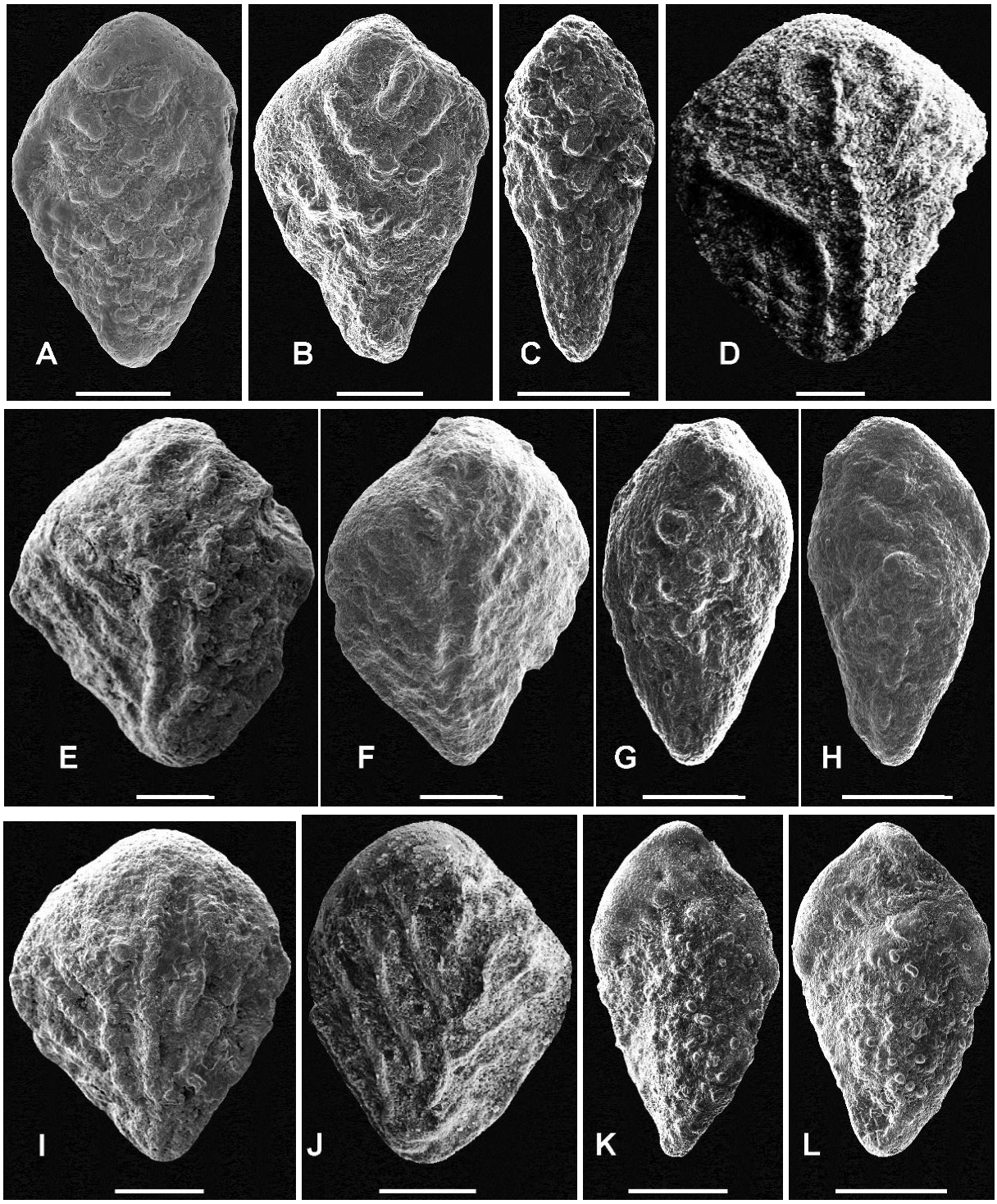

Fig.3: *Bolivinoides* benthic foraminifera in the sections studied. Scale bars 100 μm. **A, B**) *Bolivinoides decoratus* (Jones), Late Campanian; **C)** *Bolivinoides delicatula* Cushman, Late Campanian; **D-F)** *Bolivinoides draco* (Marsson), Early Maastrichtian; **G, H)** *Bolivinoides laevigatus* Marie, Late Campanian; **I, J)** *Bolivinoides miliaris* (Hiltermann and Koch); Latest Campanian – Earliest Maastrichtian; **K, L)** *Bolivinoides pustulata* Riess, Late Campanian

- ***Bolivinoides miliaris* Biozone**

– **Age:** Campanian – Maastrichtian boundary.

– Definition: Stratigraphical interval between the FO of the index species and the FO of *Bolivinoides draco*. It represents the upper part of the Shiranish Formation, where the formation is characterized by the dominance of blue coloured marlstone (see Fig.2).

- ***Bolivinoides draco* Biozone**

– **Age:** Early Maastrichtian.

– **Definition:** Stratigraphical interval between the FO and the last occurrence (LO) of the index species. It represents the uppermost part of the Shiranish Formation (see Fig.2). However, the upper boundary of this biozone is undetermined, due to the absence of both benthic and planktic foraminifera in a rapidly shallowing marine succession (see Jaff *et al*., 2014 and 2015; Jaff and Lawa, 2019).

NEOFLABELLINA BIOSTRATIGRAPHY

Good index fossils in the Late Cretaceous successions are also found in the genus *Neoflabellina* Bartenstein, 1948. The genus is characterized by rhomboid in outline and has a large test, more than 5 mm in length and 1.8 mm in breadth. The genus can be easily recognized, if present in the washed residue. It has a wide geographical distribution, recorded mostly in outer shelf and slope deposits (Wedekind, 1940; Hiltermann, 1952; Hiltermann and Koch, 1955 and 1957; Pożaryska, 1957; Sliter, 1968; Koch, 1977; Salaj, 1980; Loeblich and Tappan, 1987; Bolli *et al*., 1994; Kopaevich and Beniamovsky, 2002; Peryt and Lamolda, 2002; Peryt *et al*., 2003; Peryt and Lamolda, 2007, Ardestani *et al*., 2011; Jaff and Lawa, 2019). During the Late Cretaceous, the genus is speciated rapidly. Accordingly, it can be used as a good marker for inter-regional biostratigraphy ranging from the Late Turonian to Paleocene (e.g. Wedekind, 1940; Hiltermann, 1952; Pożaryska, 1957; Koch, 1977; Salaj, 1980; Hart *et al*., 1989; Peryt and Lamolda, 2007, Ardestani *et al*., 2011). Generally, neoflabellinids are rare components of benthic foraminifera. A total of 24 specimens are collected from the Azmer and Dokan sections. They are represented by *Neoflabellina numismalis, N. permutata, N. rugosa* and some unidentified forms (see Fig.4). Based on the stratigraphic distribution of neoflabellinids in the Shiranish Formation, the present author recognized one biozone and two subzones. The whole Shiranish Formation can be divided into *Neoflabellina rugosa* total range Biozone (Late Campanian – Early Maastrichtian). Two subzones are also recognized in the *Neoflabellina rugosa* biozone:

- ***Neoflabellina numismalis* subzone**

– **Age:** Late Campanian – Earliest Maastrichtian.

– **Definition:** Stratigraphical interval between the FO of the index species and the FO of *Neoflabellina permutata*. This subzone occupied the lower and upper parts of the Shiranish Formation (see Fig.2).

- ***Neoflabellina permutata* subzone**

– **Age:** Early Maastrichtian.

– **Definition:** Stratigraphical interval between the FO of the index species and the LO of both *Neoflabellina rugosa* and *Neoflabellina permutata*. It represents the uppermost part of the Shiranish Formation (see Fig.2). However, the upper boundary of this subzone is not recognized, due to the presence of a total barren succession of foraminifera (see Jaff *et al*., 2014 and 2015; Jaff and Lawa, 2019).

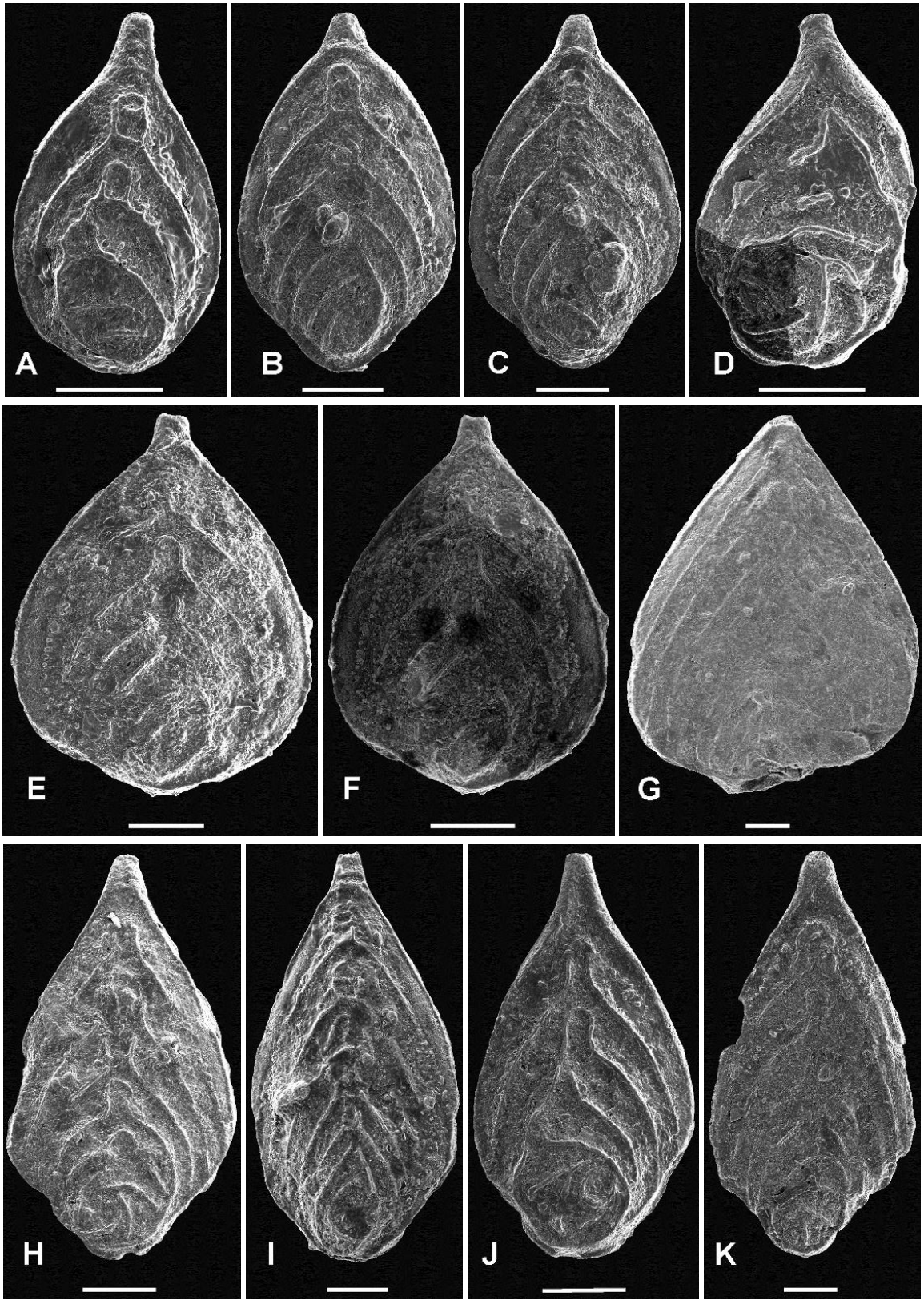

Fig.4: *Neoflabellina* benthic foraminifera in the sections studied. Scale bars 100 μm. **A-C)** *Neoflabellina numismalis* (Wedekind), Late Campanian; **D)** *Neoflabellina sp*. Late Campanian; **E-G)** *Neoflabellina permutata* (Koch), Early Maastrichtian; **H-K)** *Neoflabellina rugosa* (d'Orbigny), Late Campanian – Early Maastrichtian

DISCUSSION

The biostratigraphic importance of benthic foraminifers is less common than planktic faunas because they are largely controlled by facies (Peryt and Lamolda, 2007). Several factors affect the distribution of benthic foraminifers, such as temperature, salinity, oxygen and food supply (Murray, 1991). When the depth of the sea increases, salinity and temperature become similar over extensive areas resulting in a similar environment for benthic faunas. Thus, most deep-water foraminifers are cosmopolitan and useful for inter-regional correlation (Van Morkhoven *et al*., 1986; Peryt and Lamolda, 2007).

During the Late Campanian (Interval 1 as in the Fig.2), the benthic faunas are characterized by the common existence of the species of *Dentalina, Laevidentalina, Nodosaria, Fissurina* and *Pleurostomella* with partial occurrences of species of *Gavelinella, Gyroidinoides* and *Neoflabellina*. Mostly, based on the works of (Sliter and Baker, 1972; Sliter, 1973; Jaff and Lawa, 2019) this interval represents outer shelf depositional environment.

The highest existence of agglutinated species of the genera such as *Ammodiscus, Bathysiphon, Clavulinoides, Dorothia, Gaudryina, Glomospira, Marssonella* and *Tritaxia* are found in the Latest Campanian (Interval 2 as in the Fig.2). Accordingly, the depositional environments gradually deepened from shelf to slope (Sliter and Baker, 1972; Sliter, 1973; Jaff and Lawa, 2019).

During the Earliest Maastrichtian (Interval 3 as in the Fig.2), the lowest occurrence of agglutinated faunas, such as species of *Dorothia, Spiroplectammina* and *Quasispiroplectammina,* are recorded. The interval is also characterized by the common sporadic occurrence of species of *Fissurina, Lagena* and *Oolina*. Consequently, the assemblage of this interval represents a dramatic sea level regression from slope to outer shelf environment (Sliter and Baker, 1972; Sliter, 1973; Jaff and Lawa, 2019).

In total, the benthic faunas of the Shiranish Formation are interpreted as indicating outer shelf to slope environments. The maximum water depths are recorded in the Latest Campanian directly followed by shallowing-up successions in the Earliest Maastrichtian. A major worldwide marine regression in the Earliest Maastrichtian is also recorded by Haq *et al*. (1987) and Hardenbol *et al*. (1998).

CONCLUSIONS

- This study confirms that the Late Cretaceous distribution of *Bolivinoides* and *Neoflabellina* benthic foraminifera are useful for global biostratigraphic correlations including Iraq.

- Three *Bolivinoides* and one *Neoflabellina* biozones are recognized in the Shiranish Formation in the Azmer and the Dokan sections, NE Iraq. In stratigraphic order from oldest to youngest: the *B. decoratus* Biozone (Late Campanian – Latest Campanian); the *B. miliaris* Biozone (Campanian-Maastrichtian boundary); and the *B. draco* Biozone (Early Maastrichtian). The recorded *Bolivinoides* biozones can be correlated to the *Neoflabellina rugosa* biozone (Late Campanian – Early Maastrichtian). The latter biozone can be further subdivided into two subzones by: **1)** the FO of *Neoflabellina numismalis* (Late Campanian – Earliest Maastrichtian); and **2)** succeeding this interval, the FO of *Neoflabellina permutata* (Early Maastrichtian).

- The group of benthic faunas identified in the present work suggests that the Shiranish Formation is mostly deposited in outer shelf to slope environments, whereas, a shallowing-up succession is recorded in the Earliest Maastrichtian.

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REFERENCES

Abawi, T.S., Abdel-Kireem, M.R. and Yousef, J.M., 1982. Planktonic foraminiferal stratigraphy of Shiranish Formation, Sulaimaniah-Dokan region, northeastern Iraq. Revista Española de Micropaleontología, Vol.XIV, p. 153 – 164.

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

Abdel-Kireem, M.R., 1986. Contribution to the stratigraphy of the Upper Cretaceous and the Lower Tertiary of the Sulaimaniah-Dokan region, northeastern Iraq. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, Vol.172, p. 121 – 139.

Al-Banna, N.Y., 2010. Sequence stratigraphy of the Late Campanian-Early Maastrichtian Shiranish Formation, Jabal Sinjar, northwestern Iraq. GeoArabia, Vol.15, p. 31 – 44.

Al-Hazaa, S.H., Jaff, R.B.N., Lawa, F.A.A., Mahanipour, A. and Al-Kahtany, K., 2021. Microfacies analysis, planktonic foraminifera, and calcareous nannofossil biostratigraphy in the Campanian sequences, Kurdistan region, NE Iraq. Arabian Journal of Geosciences, Vol.14, 79pp.

Al-Naqib, K.M., 1967. Geology of the Arabian Peninsula, Southwestern Iraq. United States Geological Survey, Professional Paper, Vol.560G, p. 1 – 54.

Al-Shaibani, S.K., 1973. Microfossils from Shiranish Formation in northeastern Iraq, Asmar region. Journal of the Geological Society of Iraq, Vol.VI, p. 49 – 65.

Anan, H.S., 2011. Paleontology and stratigraphic significance of the Maastrichtian-Paleocene genus *Bolivinoides* in some tethyan regions. Egyptian Journal of Paleontology, Vol.11, p. 133 – 144.

Anan, H.S., 2017. Evolutionary lineage of the Maastrichtian *Bolivinoides draco* group (benthic foraminifera) in Abu Zenima section, west central Sinai, Egypt. Arabian Journal of Geosciences, Vol.10, 431pp.

Ardestani, M.S., Vahidina, M. and Ali, M.Y., 2011. Biostratigraphy and foraminiferal bioevents of the Abderaz Formation (Middle Turonian-Lower Campanian) in Kopeh-Dagh sedimentary basin, northeastern Iran. Egyptian Journal of Paleontology, Vol.11, p. 1 – 16.

Barr, F.T., 1966a. The foraminiferal genus *Bolivinoides* from the Upper Cretaceous of the British Isles. Journal of Palaeontology, Vol.9, p. 220 – 243.

Barr, F.T., 1966b. Upper Cretaceous foraminifera from the Ballydeenlea Chalk, County Kerry, Ireland. Journal of Palaeontology, Vol.9, p. 492 – 510.

Barr, F.T., 1970. The foraminiferal genus *Bolivinoides* from the Upper Cretaceous of Libya. Journal of Palaeontology, Vol.44, p. 642 – 654.

Bartenstein, H., 1948. Taxonomische Abgrenzung der Foraminiferen-Gattungen Palmula Lea, Flabellina d'Orbigny and Falsofalmula n. g., gleichzeitig eine Revision der Jura-Arten von ''Flabellina''. Senckenbergiana, Vol.28, p. 119 – 137.

Beckmann, J.P. and Koch, W., 1964. Vergleiche von *Bolivinoides*, *Aragonia* und *Tappanina* (Foraminifera) aus Trinidad (Westindien) und Mitteleuropa. Geologisches Jahrbuch, Vol.83, p. 31 – 64.

Bejaoui, A., Saidi, E. and Zaghbib-Turki, D., 2019. Small benthic foraminiferal biostratigraphy and palaeoecology during the Campanian-Maastrichtian transition in north-western Tunisia. Turkish Journal of Earth Sciences, Vol.28, p. 500 – 530.

Beniamovsky, V.N. and Kopaevich, L.F., 2016. The Alan-Kyr Coniacian-Campanian section (Crimean Mountains): biostratigraphy and paleobiogeography aspects. Moscow University Geology Bulletin, Vol.71, p. 217 – 233.

Beniamovsky, V.N., Alekseev, A.S., Ovechkina, M.N., Vishnevskaya, V.S., Podgaetskii, A.V. and Pronin, V.G., 2012. Upper Campanian-lower Maastrichtian sections of the northwestern Rostov region. Article 1. Description, paleontological assemblages, and lithostratigraphy. Stratigraphy and Geological Correlation, Vol.20, p. 346 – 379.

Bolli, H.M., Beckmann, J-P. and Saunders, J.B., 1994. Benthic foraminiferal biostratigraphy of the south Caribbean region. Cambridge University Press, Cambridge, UK, 408pp.

Buday, T., 1980. The Regional Geology of Iraq: Stratigraphy and Palaeogeography. State Organisation for Minerals Library, Baghdad, Iraq, 445pp.

Cushman, J.A., 1927. American Upper Cretaceous species of *Bolivina* and related species. Contributions from the Cushman Laboratory for Foraminiferal Research, Vol.2, p. 85 – 91.

Dubicka, Z. and Peryt, D., 2016. *Bolivinoides* (benthic foraminifera) from the Upper Cretaceous of Poland and western Ukraine: taxonomy, evolutionary changes and stratigraphic significance. Journal of Foraminiferal Research, Vol.46, p. 75 – 94.

Edgell, H.S., 1954. The stratigraphical value of *Bolivinoides* in the Upper Cretaceous of northwest Australia. Cushman Foundation for Foraminiferal Research Contribution, Vol.5, p. 68 – 76.

El-Nady, H., 2006. Contribution to the stratigraphic significance of the genus *Bolivinoides* and their paleoecology across the Campanian/Maastrichtian boundary in the Gabal El-Mouriefik section, Eastern Sinai, Egypt. Revue de Paleobiologie, Vol.25, p. 671 – 692.

Farouk, S., Thibault, N., Jaff, R.B.N., Faris, M., Ahmad, F. and Khashaba, A., 2018. An integrated study of upper Campanian-lower Maastrichtian carbon isotopes and calcareous plankton biostratigraphy of the Kurdistan Region, northeastern Iraq. Cretaceous Research, Vol.82, p. 64 – 80.

Georgescu, M.D., 2018. Monographic study of the Late Cretaceous representatives of the bolivinoidid benthic foraminifera. Studia UBB Geologia, Vol.62, p. 5 – 57.

Georgescu, M.D., Arz, J.A., Macauley, R.V., Kukulski, R.B., Arenillas, I. and Pérez-Rodríguez, I., 2011. Late Cretaceous (Santonian – Maastrichtian) serial foraminifera with pore mounds or pore mound-based ornamentation structures. Revista Española de Micropaleontología, Vol.43, p. 109 – 139.

Haq, B.U., Hardenbol, J. and Vail, P.R., 1987. Chronology of fluctuating sea levels since the Triassic. Science, Vol.235, p. 1156 – 1167.

Hardenbol, J., Thierry, J., Farley, M.B., Jacquin, T., de Graciansky, P.C. and Vail, P.R., 1998. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins. Society for Sedimentary Geology, Special Publication, Vol.60, p. 3 – 13.

Hart, M.B., Bailey, H.W., Crittenden, S., Fletcher, B.N. and Swiecicki, A., 1989. Cretaceous. In: Jenkins, D.G., Murray, J.W. (Eds.). Stratigraphical Atlas of Fossil Foraminifera. British Micropalaeontological Society Series, Ellis Horwood, Chichester, p. 273 – 371.

Hiltermann, H., 1952. Stratigraphische Fragen des Campan und Maastricht unter besonderer Berücksichtung der Mikropaläontologie. Geologisches Jahrbuch, Vol.67, p. 47 – 66.

Hiltermann, H., 1963. Zur Entwicklung der Benthos-Foraminifere *Bolivinoides*. In: Konigswald Von, H.R. (Ed.). Evolutionary trends in foraminifera. Elsevier, Amsterdam, p. 198 – 222.

Hiltermann, H. and Koch, W., 1950. Taxonomie und Vertikalverbreitung von *Bolivinoides*-Arten im Senon Nordwestdeutschlands. Geologisches Jahrbuch, Vol.64, p. 595 – 632.

Hiltermann, H. and Koch, W., 1955. Biostratigraphie der Grenzschichten Maastricht/Campan in Lüneburg und in der Bohrung Brunhilde. 2 Teil: Foraminiferen. Geologisches Jahrbuch, Vol.70, p. 357 – 384.

Hiltermann, H. and Koch, W., 1957. Revision der Neoflabellinen (Foram.). 1. Teil: *Neoflabellina rugosa* (Orb.) und ihre Unterarten. Geologisches Jahrbuch, Vol.74, p. 269 – 304.

Hiltermann, H. and Koch, W., 1962. Oberkreide der nördlichen Mitteleuropa. In: Simon, W. (Ed.), Leitfossilies der Mikropaläontologie. Borntraeger, Berlin, p. 216 – 245.

Hofker, J., 1958. Upper Cretaceous *Bolivinoides* guide forms. Micropaleontology, Vol.4, p. 329 – 331.

Ibrahim, A.O., 2009. Tectonic style and evolution of the NW segment of the Zagros Fold-Thrust Belt, Sulaimani governorate, Kurdistan region, NE Iraq. Unpublished PhD dissertation, University of Sulaimani, Iraq, 199pp.

Jaff, R.B.N. and Lawa, F.A., 2019. Palaeoenvironmental signature of the Late Campanian – Early Maastrichtian benthonic foraminiferal assemblages of Kurdistan, Northeast Iraq. Journal of African Earth Sciences, Vol.151, p. 255 – 273.

Jaff, R.B.N., Williams, M., Wilkinson, I.P., Lawa, F., Lee, S. and Zalasiewicz, J., 2014. A refined foraminiferal biostratigraphy for the Late Campanian – Early Maastrichtian succession of northeast Iraq. GeoArabia, Vol.19, p. 161 – 180.

Jaff, R.B.N., Wilkinson, I.P., Lee, S., Zalasiewicz, J., Lawa, F. and Williams, M., 2015. Biostratigraphy and palaeoceanography of the early Turonian – Early Maastrichtian planktic foraminifera of northeast Iraq. Journal of Micropalaeontology, Vol.34, p. 105 – 138.

Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Brno, Czech Republic, Dolin, Prague and Moravian Museum, 341pp.

Kassab, I.I.M., 1973. Planktonic foraminiferida of the Shiranish Formation type locality (Northern Iraq). Journal of the Geological Society of Iraq, Vol.6, p. 100 – 109.

Kennedy, W.J. and Lunn, G., 2000. Upper Campanian (Cretaceous) ammonites from the Shiranish Formation, Djebel Sinjar, northwest Iraq. Journal of Paleontology, Vol.74, p. 464 – 473.

Khalil, H., 1998. Late Cretaceous planktonic foraminiferal biostratigraphy, Sinai, Egypt, with special consideration to the genus *Bolivinoides*. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, Vol.7, p. 415 – 431.

King, C., Bailey, H.W., Burton, C.A. and King, A.D., 1989. Cretaceous of the North Sea. In: Jenkins, D.G., Murray, J.W. (Eds.), Stratigraphical Atlas of Fossil Foraminifera. Micropalaeontological Society Series, Ellis Horwood, Chichester, p. 372 – 417.

Koch, W., 1977. Stratigraphie der Oberkreide in Nordwestdeutschland (Pompeckjsche Scholle). Teil 2. Biostratigraphie in der Oberkreide und Taxonomie von Foraminiferen. Geologisches Jahrbuch, Vol.A38, p. 11 – 123.

Kopaevich, L.F. and Beniamovsky, V.N., 2002. The Coniacian-Santonian boundary in Mangyshlak Peninsula and Peri-Caspian Basin (West Kazakhstan). A multistratigraphic implication. In: Lamolda, M.A. (Ed.), Meeting on the Coniacian-Santonian Boundary, Bilbao, September 14-16, 2002. Abstracts and Field Guide Book, 14pp.

Lawa, F.A., Koyi, H. and Ibrahim, A., 2013. Tectono-stratigraphic evolution of the NW segment of the Zagros Fold-Thrust Belt, Kurdistan, NE Iraq. Journal of Petroleum Geology, Vol.36, p. 75 – 96.

Loeblich, A.R. and Tappan, H.N., 1987. Foraminiferal Genera and Their Classification. Van Nostrand Reinhold Company, New York, 970pp.

Mogaddam, H.V., 2002. Biostratigraphic study of the Ilam and Gurpi formations based on planktonic foraminifera in SE of Shiraz, Iran. Journal of Sciences, Islamic Republic of Iran, Vol.13, p. 339 – 356.

Murray, J.W., 1991. Ecology and Palaeoecology of Benthic Foraminifera. Longman Scientific and Technical, Bristol, 397pp.

Peryt D. and Dubicka Z., 2015. Foraminiferal bioevents in the Upper Campanian to lowest Maastrichtian of the Middle Vistula River section, Poland. Geological Quarterly, Vol.59, p. 814 – 830.

Peryt, D. and Lamolda, M.A., 2007. Neoflabellinids (benthic foraminifers) from the Upper Coniacian and Lower Santonian at Olazagutia, Navarra province, Spain; taxonomy and correlation potential. Cretaceous Research, Vol.28, p. 30 – 36.

Peryt, D. and Lamolda, M.A., 2002. Benthic foraminifers from the Coniacian- Santonian boundary interval at Olazagutia, Spain. In: Lamolda, M.A. (Ed.), Meeting on the Coniacian-Santonian Boundary, Bilbao, September 14-16, 2002. Abstracts and Field Guide Book, 19pp.

Peryt, D., Alegret, L. and Molina, E., 2003. Otwornice bentosowe a granica kreda/paleogen (K/P) w profilu Aïn Settara, Tunezja [Restructuring of benthic foraminiferal assemblages across the Cretaceous/Paleogene (K/P) boundary at Aïn Settara, Tunisia]. Przegląd Geologiczny, Vol.51, p. 1069 – 1074.

Petters, S.W., 1977. *Bolivinoides* evolution and Upper Cretaceous biostratigraphy of the Atlantic Coastal Plain of New Jersey. Journal of Paleontology, Vol.51, p. 1023 – 1036.

Pożaryska, K., 1957. Lagenidae du Crétacé Supérieur de Pologne. Palaeontologia Polonica, Vol.8, p. 1 – 190.

Reiss, Z., 1954. Upper Cretaceous and lower Tertiary *Bolivinoides* from Israel. Contributions from the Cushman Foundation for Foraminiferal Research, Vol.5, p. 154 – 164.

Salaj, J., 1980. Microbiostratigraphie du Crétacé et du Paléogène de la Tunisie Septentrionale et Orientale (Hypostratotypes Tunisiens). Institut Géologique de Dionýz Štúr, Bratislava, 238pp.

Sliter, W.V., 1973. Upper Cretaceous foraminifers from the Vancouver Island area, British Columbia, Canada. Journal of Foraminiferal Research, Vol.3, p. 167 – 186.

Sliter, W.V., 1968. Upper Cretaceous foraminifera from southern California and northwestern Baja California, Mexico. University of Kansas, Paleontological Contributions, Vol.49, p. 3 – 141.

Sliter, W.V. and Baker, R.A., 1972. Cretaceous bathymetric distribution of benthic foraminifers. Journal of Foraminiferal Research, Vol.2, p. 167 – 183.

Van Bellen, R.C., Dunnington, H.V., Wetzel, R. and Morton, D.M., 1959. Lexique Stratigraphique International. Centre National Recherche Scientifique, 333pp.

Van Hinte, J.E., 1967. *Bolivinoides* from the Campanian type section. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen (B), Vol.70, p. 254 – 263.

Van Morkhoven, F.P.C.M., Berggren, W.A. and Edwards, A.S., 1986. Cenozoic Cosmopolitan Deep-Water Benthic Foraminifera. Elf Aquitaine, Pau, 421pp.

Vassilenko, V.P., 1961. Foraminifera of the Upper Cretaceous of Mangyshlak Peninsula. Trudy VNIGRI, Vol.171, p. 1 – 487 (In Russian).

Wedekind, R., 1940. Die papillaten Flabellinen der Kreide und die Stufengliederung des Senons. Neues Jahrbuch für Mineralogie. Geologie und Paläontologie, Vol.84, p. 177 – 204.

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