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A designed model for identifications of *Dicarinella concavata* (Brotzen, 1934) and *Dicarinella asymetrica* (Sigal, 1952) planktic foraminifer species under thin sections: an example from the Kurdistan region, NE Iraq

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Abstract

The Upper Cretaceous (Early Turonian-Early Campanian) Kometan Formation in the Kurdistan region, NE Iraq has been investigated in detail for planktic foraminiferal identifications under thin sections especially focused on the species *Dicarinella concavata* and *D. asymetrica*. The two mentioned index planktic foraminifer species for Late Turonian-Latest Santonian biozones are commonly misidentified under thin sections. For this reason, a designed model has been suggested for correct identifications between the two above mentioned species. The model shows that the *D. concavata* can be identified by steep concave spiral side and by having hemi-spherical and/or ovate early and final chambers profile. However, *D. asymetrica* can be distinguished in having flat to slightly concave spiral side, sometimes strongly convex, and early and final chambers are angular. The accurate identifications of the above index planktic foraminiferal species play a great role in the precise age determination of the Upper Cretaceous lithostratigraphic units.

Keywords: Late Cretaceous, *Dicarinella concavata*, *Dicarinella asymetrica*, Kurdistan region, NE Iraq

1. Introduction

The Upper Cretaceous (Late Turonian-Latest Santonian) *Dicarinella concavata* (Brotzen, 1934) and *D. asymetrica* (Sigal, 1952) are the two most Tethyan cosmopolitan planktic foraminiferal species, which received great attention from biostratigraphers in the last decades. *Dicarinella concavata* Zone was originally defined as the interval between the first appearances (FA) of *D. concavata* to the FA of *D. asymetrica* (Sigal, 1955). On the other hand, *D. asymetrica* is a total range zone and was first used by Postuma (1971). His *Globotruncana concavata carinata* Zone, by synonymy, is equivalent to the *D. asymetrica* Zone. Afterwards, both species were successfully used from biostratigraphers for Late Cretaceous biozonations and inter-regional correlations (e.g., Barr, 1972; Caron, 1985; Sliter, 1989; Almogi-Labin et al., 1991; Premoli Silva and Sliter, 1994, 1999; Robaszynski and Caron, 1995; Robaszynski, 1998; Robaszynski et al., 2000; Premoli Silva and Verga, 2004; Babazadeh, 2007; Sari, 2006, 2009; Farouk and Faris, 2012; Elamri et al., 2014; Jaff et al., 2015; Georgescu, 2017; Petrizzo et al., 2017; Faris et al., 2019; Fang et al., 2020; Honarmand et al., 2020; Jaff and Al-Kahtany, 2020; Jaff and Lawa, 2020). Due to the morphological similarities, several published articles indicate that the two species are commonly misidentified under thin sections and/or even sometimes as picked specimens. The objective of this study is to illustrate a designed model for accurate identifications between the two species under thin sections in the Kurdistan region, NE Iraq which might be used globally. The precise documentation of the above index planktic foraminiferal species plays a great role in better identification for the age of the Upper Cretaceous lithostratigraphic units.

2. Geological Setting and Lithostratigraphy

From structural perspective point of view, the selected sections can be allocated into 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 High Folded Zone (ZHFZ) (Lawa et al., 2013; see Figure 1).

The ZIZ is intensively deformed and characterised by rock displacements and crustal thickening. Based on geomorphologic features, it is characterised 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 plates' collision in Late Paleogene (Lawa et al., 2013).

The ZHFZ is mainly characterised 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).

The Kometan Formation is broadly distributed in northeastern Iraq and is equivalent to the Khasib; Tanuma and Sa'di formations in central and southern Iraq (Figure 2). Recently the formation is dated back to the Early Turonian-Early Campanian time (Jaff et al., 2015; Jaff and Lawa, 2020).

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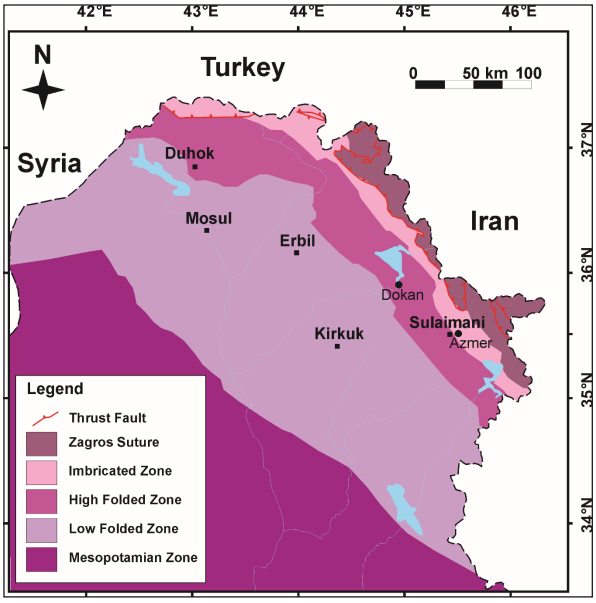

Figure 1. Tectonic divisions in NE Iraq modified after (Lawa et al., 2013). The locations of the Dokan and the Azmer sections are shown in black circles.

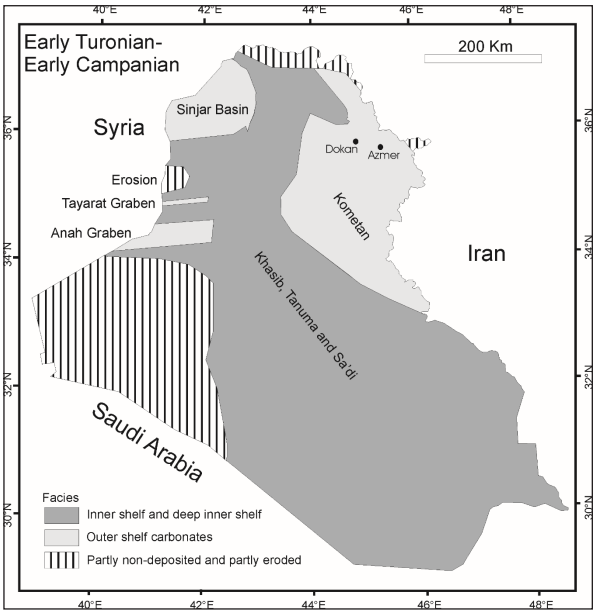

Figure 2. Paleogeographical map of Iraq during (Early Turonian-Early Campanian) with different facies and palaeoenvironments. The locations of the Dokan and Azmer sections are also shown (after Jassim and Goff, 2006).

3. Material and Methods

The present study is based on 113 samples collected from the Coniacian-Santonian pelagic limestones of the Kometan Formation in the Kurdistan region, NE Iraq. Two different localities have been selected; one at Azmer (35° 37' 30"N; 45° 31' 45"E) and the other at Dokan (35° 56' 15"N; 44° 57' 21"E; see Figure 1). First, the author tried to extract planktic foraminifera from pelagic limestones using liquid nitrogen (LN_2) method developed by (Remin et al., 2012). After several tries, the method was unsuccessful which might be related to the low quality of (LN_2) that we applied. Finally, a standard thin section size (48X28mm) prepared in MiEKiNiA Lab in Warsaw, Poland was used for planktic foraminiferal identifications. Most of the diagnostic criteria that can be used for correct planktic foraminiferal identification can be documented in axial and subaxial sections (see Figure 3). The important characteristic features that can be recognised under thin sections include the shape of the test and position and a number of marginal keels (Sliter, 1989; Sari, 2006, 2009). The images illustrated in this paper are all axial sections and were photographed with a digital Canon camera (DS126201) at the University of Leicester, UK.

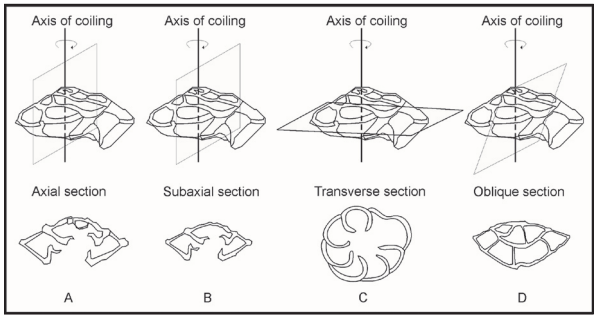

Figure 3. Planktic foraminifera test under thin sections. (A) Axial section: section passing through the axis of coiling; (B) Subaxial section: section passing parallel to the axis of coiling but not passing through the proloculus; (C) Transverse section: section passing perpendicular to the axis of coiling; (D) Oblique section: section passing neither parallel nor perpendicular to the axis of coiling (after Sari, 2006).

4. Taxonomic Notes

Planktic foraminifera noticed in the pelagic limestones of the Kometan Formation (*D. concavata* interval zone and *D. asymetrica* total range zone) are frequently abundant and have moderate diversity. Several published articles indicate that there are misidentifications between the *D. concavata* and the *D. asymetrica* species. For this reason, the present author designed a model to describe the materials in the Kurdistan region, NE Iraq and it might be used in global identifications as well (see Figure 4).

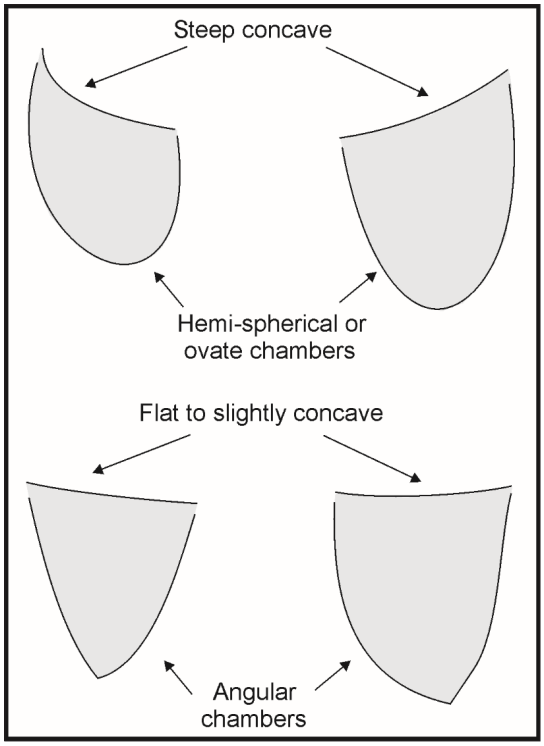

Figure 4. A designed model shows the morphological differences between *Dicarinella concavata* (top) and *Dicarinella asymetrica* (bottom) under thin sections.

The present model shows the most important characteristic features of the two species that can be easily recognised under thin sections. Furthermore, below are the original descriptions and illustrations of the holotype figured specimens of the two species by (Brotzen, 1934; Figure 5) and (Sigal, 1952; Figure 6) which are used for making strong correlations between our recorded materials in this study. Additionally, all the documented associated planktic foraminiferal species within the *D. concavata* and *D. asymetrica* zones in the Dokan and the Azmer sections are also shown in (Figures 7-8).

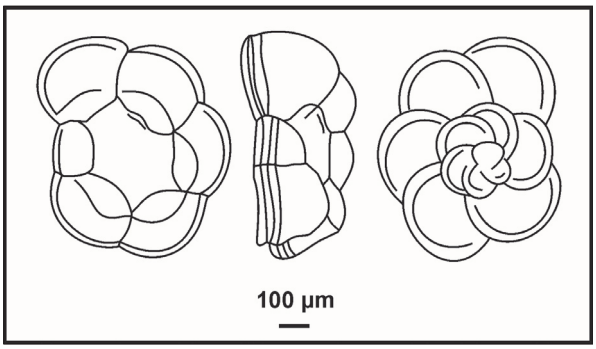

Figure 5. Holotype figured specimen of *Dicarinella asymetrica* by (Sigal, 1952).

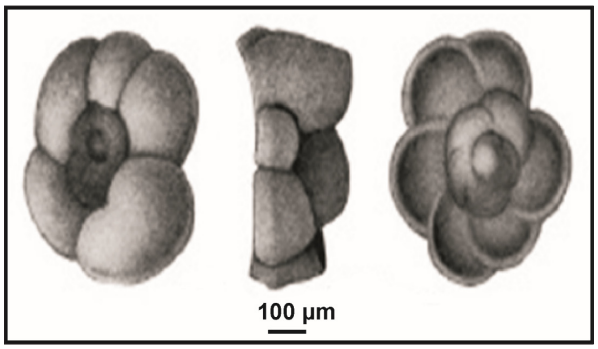

Figure 6. Holotype figured specimen of *Dicarinella concavata* by (Brotzen, 1934).

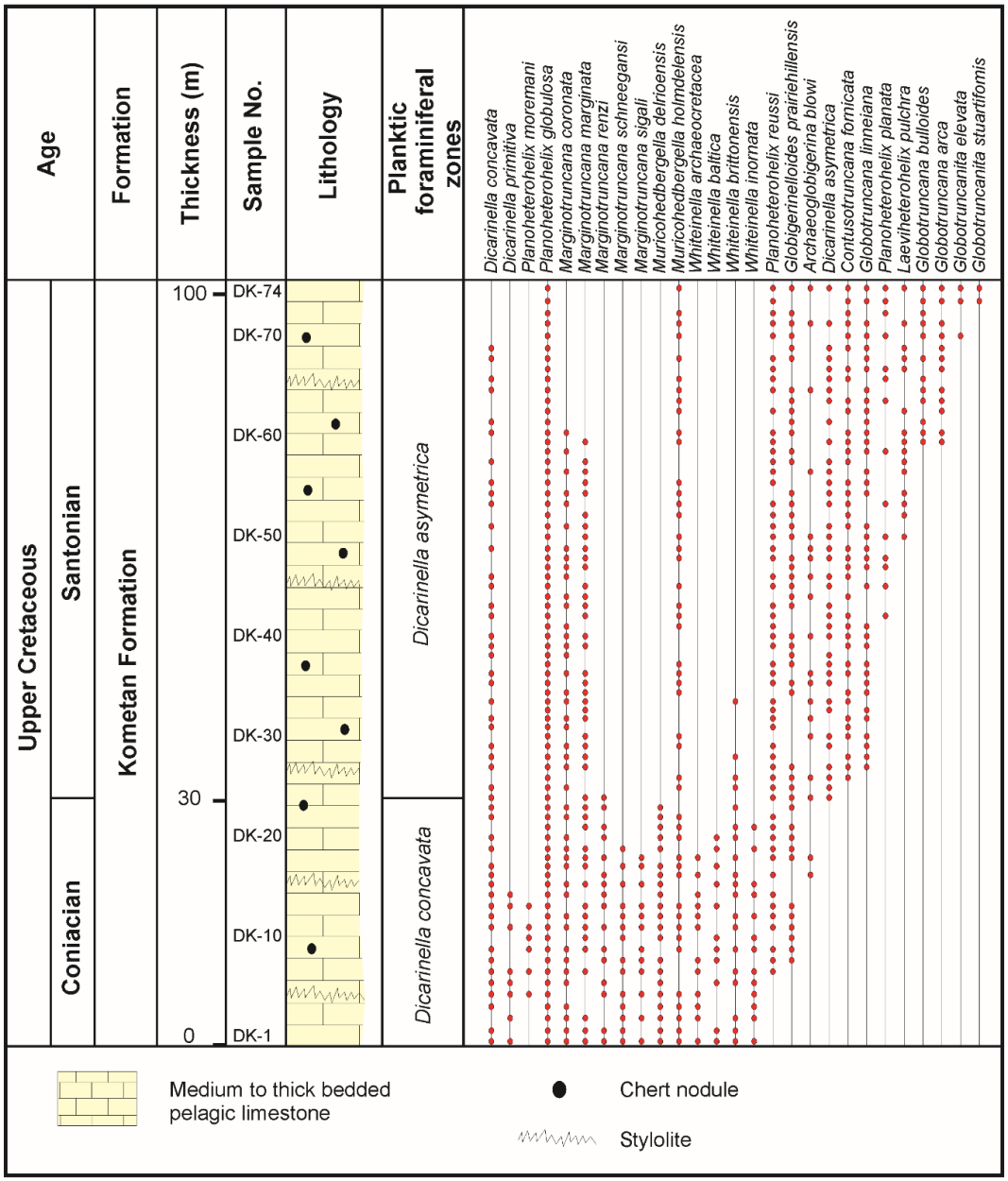

Figure 7. Coniacian to Santonian stratigraphic ranges of planktic foraminiferal species for the Kometan Formation in the Dokan section.

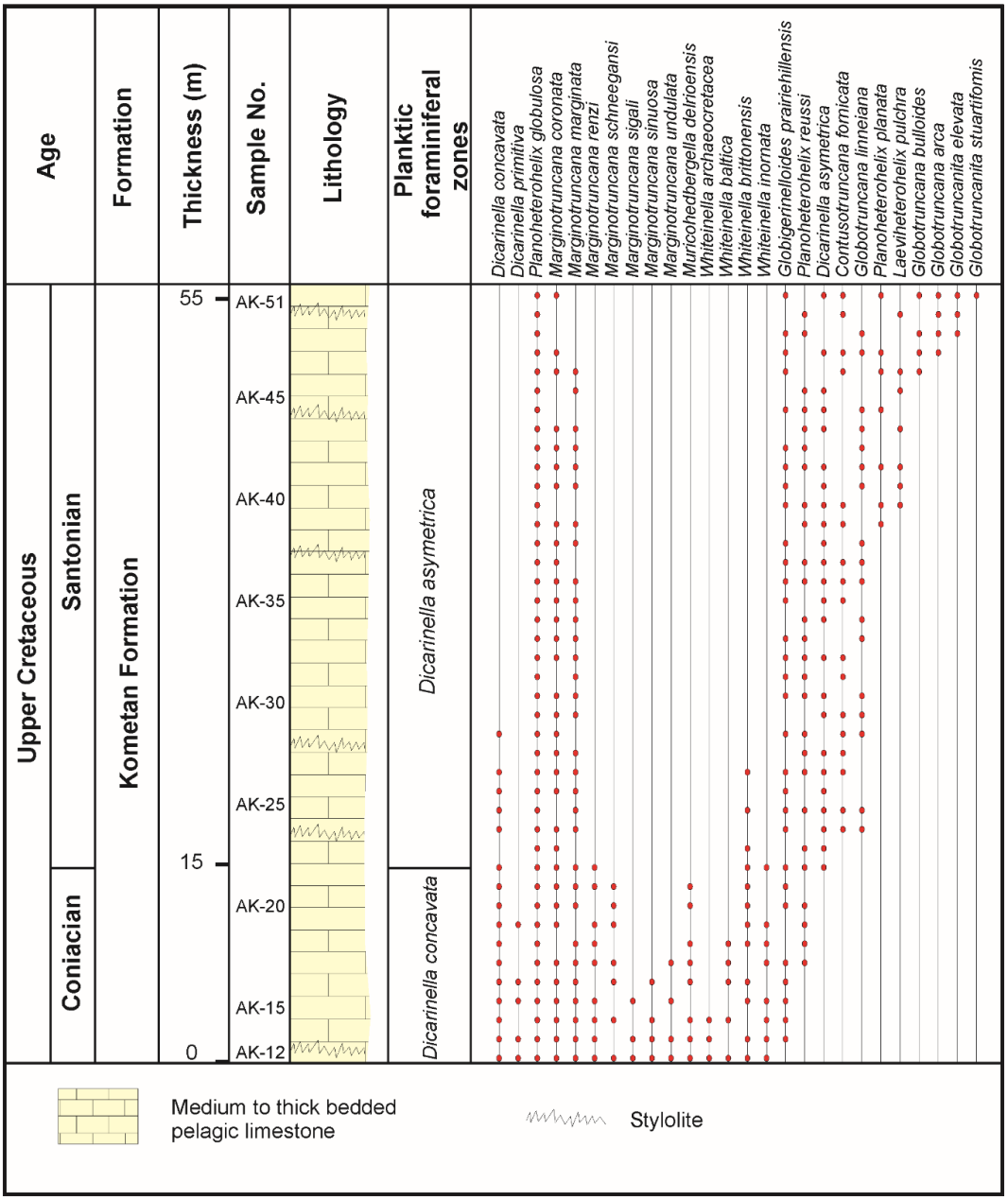

Figure 8. Coniacian to Santonian stratigraphic ranges of planktic foraminiferal species for the Kometan Formation in the Azmer section.

Genus *Dicarinella* PORTHAULT in DONZE ET AL., 1970

***Dicarinella asymetrica* (Sigal, 1952)**

Figure 9 (A-J)

Original description: *"En même temps se développe une autre espèce caractéristique par sa profonde dissymétrie du test, qui n'est pas sans présenter quelque analogie avec certains Rotalipora du Cénomanien (R. reicheli Mornad par example)".*

Original description translated from French: "A species characterised by a strong asymmetry of the test, displaying a degree of analogy with some Cenomanian *Rotalipora* (*R. reicheli* Mornad for example)".

Material: More than 130 specimens from 80 samples were recognised from the Dokan and the Azmer sections.

Description of the Kurdistani material: Large trochospiral test, spiral side flat to slightly concave, sometimes convex, umbilical side strongly convex, two well-developed widely spaced keels on the edge of the spiral side; early and final chambers angular.

Remarks: The species can be differentiated from *Dicarinella concavata* in having an angular chambers profile and in the presence of flat to slightly concave, or sometimes by strongly convex spiral side (see Figure 9).

Synonyms: *Globotruncana concavata carinata*, *Globotruncana fundiconulosa*.

Occurrence: This species is common in the upper part of the pelagic limestones of the Kometan Formation in both sections. It is restricted to the *D. asymetrica* Zone. The last appearance (LA) is at the top of the *D. asymetrica* Zone (83.64 Ma) and the FA is at the base of the *D. asymetrica* Zone (86.66 Ma) according to Gradstein et al. (2012).

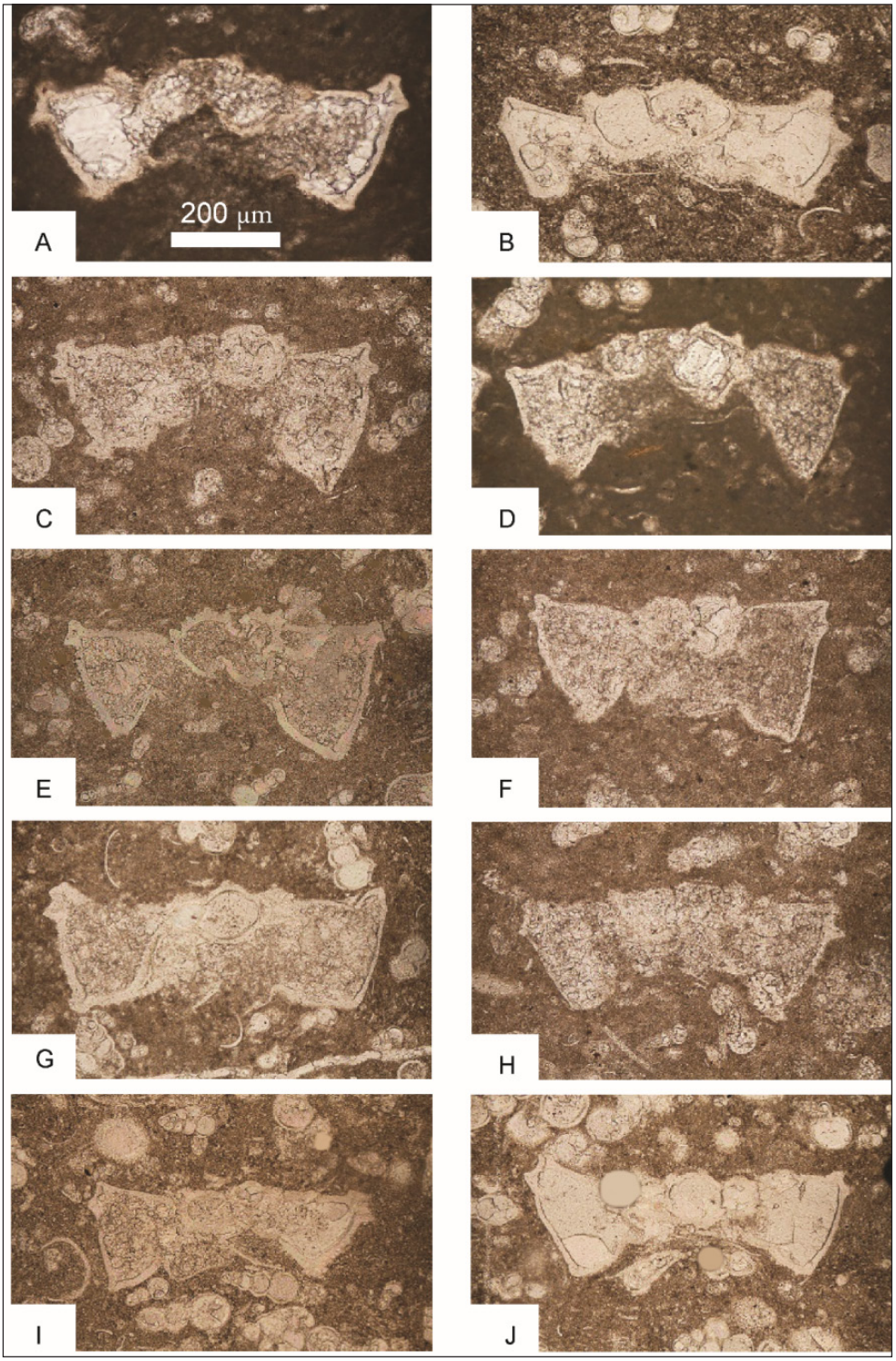

Figure 9. The axial sections of *Dicarinella asymetrica*. The scale bar is the same for all images. (A) Azmer section, sample AK-23; (B) Dokan section, sample DK-40; (C) Azmer section, sample AK-25; (D) Dokan section, sample DK-31; (E) Azmer section, sample AK-41; (F) Dokan section, sample DK-55; (G) Azmer section, sample AK-37; (H) Dokan section, sample DK-63; (I) Azmer section, sample AK-51; (J) Dokan section, sample DK-74.

***Dicarinella concavata* (Brotzen 1934)**

Figure 10 (A-J)

Original description: *"Die Spiralseite ist eingesunken und flach teller- oder schalenförmig. Sie hat eine Zentralscheibe, und der Rand ist durch einen erhobenen Saum eingefaßt. Der Nabel auf der Nabelseite ist groß und tief. Die Kammern des letzten Umganges auf der Spiralseite (6-7) sind ähnlich denen von Rotalia elevata, nur der Grat am Rande fehlt. Die Nabelseite ist wie bei R. elevata. Sie ist nahe mit dieser verwandt".*

Original description translated from German: "Spiral side depressed and flat plate or bowl-shaped. It has a central disk, and the rim is bordered by an elevated beam. The Umbilicus is on the umbilical side large and deep. Chambers of the last whorl on the spiral side (6-7) are similar to those of *Rotalia elevata* with only the ridge on the border missing.

The umbilical side is like of *R. elevata*, and is related with this species".

Material: More than 75 specimens from 33 samples were recognised from the Dokan and the Azmer sections.

Description of the Kurdistani material: Large trochospiral test, spiral side steep concave, umbilical side flat, sometimes strongly convex, two well-developed widely spaced keels on the edge of the spiral side; early and final chambers hemi-spherical and/or ovate.

Remarks: The species can be differentiated from *Dicarinella asymetrica* in having ovate and/or hemispherical chambers profile and in the presence of steep concave spiral side (see Figure 10).

Synonyms: *Globotruncana araratica, Globotruncana vridhachalensis*, *Globotruncana concavata cyrenaica*, *Marginotruncana concavata*.

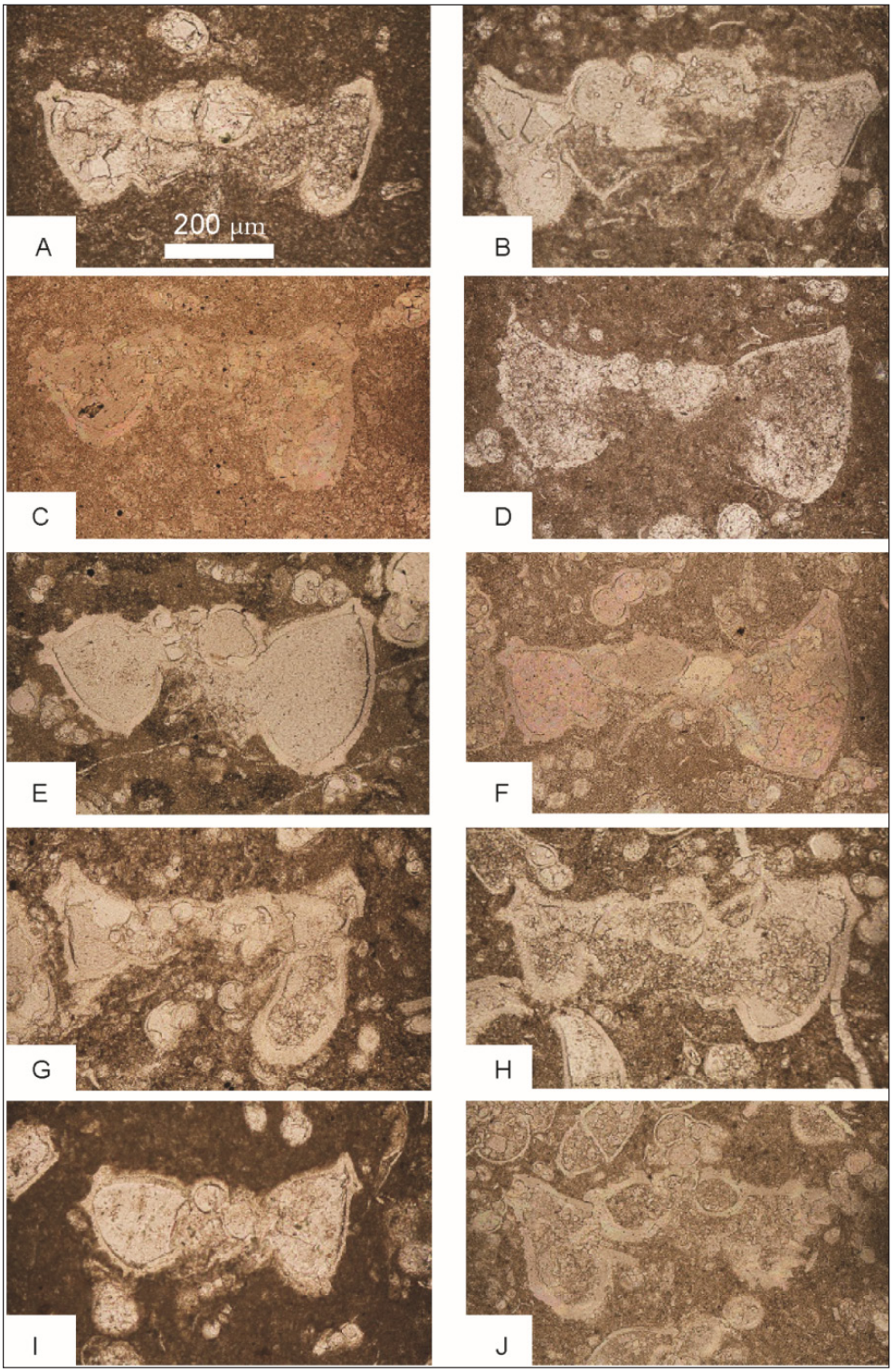

Figure 10. The axial sections of *Dicarinella concavata*. The scale bar is the same for all images. (A) Azmer section, sample AK-19; (B) Dokan section, sample DK-16; (C) Azmer section, sample AK-19; (D) Dokan section, sample DK-11; (E) Azmer section, sample AK-20; (F) Dokan section, sample DK-13; (G) Azmer section, sample AK-21; (H) Dokan section, sample DK-7; (I) Azmer section, sample AK-15; (J) Dokan section, sample DK-19.

Occurrence: This species occurs commonly throughout the pelagic limestones of the Kometan Formation in both sections. It is found in the *D. concavata* and *D. asymetrica* zones. The LA is within the *D. asymetrica* Zone (top of the Santonian Stage 83.64 Ma) and the FA is at the base of the *D. concavata* Zone (91.08 Ma) according to Gradstein et al. (2012).

5. Discussions

The two species *D. concavata* and *D. asymetrica* are widely used for Upper Turonian-Upper Santonian biozonations and inter-regional correlations in the Tethys Ocean. They also play great roles in definition of some Upper Cretaceous stages boundary interval. For instance, several authors have equated the FA of *D. concavata* with the Late Turonian (e.g., Premoli Silva and Sliter, 1994, 1999; Robaszynski and Caron, 1995; Robaszynski, 1998; Robaszynski et al., 2000; Bauer et al., 2001; Premoli Silva and Verga, 2004; Babazadeh et al., 2007; Kochhann et al., 2014). However, in some areas of Iraq, Iran, Turkey and Africa the FA of *D. concavata* has been positioned informally at the Turonian/Coniacian boundary (Salaj, 1980, 1984, 1987, 1997; Tur, 1996; Gebhardt, 2004, 2008; Sari, 2006; Farouk and Faris, 2012; Vahidinia et al., 2014; Jaff et al., 2015; El-Gammal and Orabi, 2019; Jaff and Lawa, 2020).

At the Global Boundary Stratotype Section and Point (GSSP) in Olazagutia, northern Spain and the Gubbio section in Italy the FA of *D. asymetrica* represents Latest Coniacian (Lamolda et al., 2014; Coccioni and Premoli Silva, 2015). However, Lamolda et al. (2014) used the first common occurrence of *D. asymetrica* to describe approximately the base of Santonian in the paleotropics. In other Neo-Tethyan areas, particularly in the Middle East, the FA of *D. asymetrica* is similarly used to express the Coniacian/Santonian boundary (e.g., Caron, 1985; Premoli Silva and Sliter, 1994; Robaszynski et al., 2000; Petrizzo, 2000, 2002; Sari, 2006; Farouk and Faris, 2012; Gradstein et al., 2012; Elamri et al., 2014, 2016; Jaff et al., 2015; El-Gammal and Orabi, 2019; Jaff and Lawa, 2020). Furthermore, the LA of *D. asymetrica* was proposed to describe the Santonian/Campanian boundary in the Bottaccione section of Italy (Premoli Silva and Sliter, 1994; Coccioni and Premoli Silva, 2015); Tunisia (Robaszynski et al., 2000; Elamri and Zaghbib-Turki, 2014; Elamri et al., 2014, 2016; Farouk et al., 2018); Turkey (Sari, 2006, 2009); Iran (Babazadeh et al., 2007; Honarmand et al., 2020); Egypt (Farouk and Faris, 2012; El-Gammal and Orabi, 2019); Syria (Pecimotika et al., 2014); Palestine (Meilijson et al., 2014); Kurdistan region, NE Iraq (Jaff et al., 2015; Jaff and Al-Kahtany, 2020) and in southern Tibet (Fang et al., 2020).

Due to the biostratigraphical importance of the two species as it is mentioned above, the correct identifications between them should be taking into consideration. Based on 205 specimens collected from 113 samples, the present work designed a model for accurate identifications between the two species under thin sections in the Kurdistan region, NE Iraq. The model for the Kurdistani materials are based on the illustrated holotype figured specimens of *D. concavata* by Brotzen (1934) and *D. asymetrica* by Sigal (1952). The holotype figured specimen of *D. concavata* indicates that the species should have steep concave spiral side. That is why Brotzen took the name *concavata* from the steep spiral side concavity. On the other hand, the holotype figured specimen of *D. asymetrica* appears to be flat or slightly concave in the spiral side. Based on this characterization, the latter should be differentiated from the former. The precise documentation of the above index planktic foraminiferal species play a crucial role in the exact age determination of the Upper Cretaceous lithostratigraphic units.

6. Conclusions

The achieved results of the present study can be shortened in the following:

1. Morphological similarities and misidentifications between the *D. concavata* and the *D. asymetrica* in previously published articles have allowed the author to design a model for accurate identifications.
2. From the designed model and the illustrated specimens of the Kurdistani materials, the *D. asymetrica* can be differentiated from *D. concavata* in having a flat or slightly concave spiral side, sometimes convex and in the presence of an angular early and final chambers profile.
3. The species *D. concavata* can be distinguished in having ovate and/or hemispherical chambers profile and in the presence of steep concave spiral side.
4. The correct identifications between *D. concavata* and *D. asymetrica* planktic foraminifera play great roles in the precise age determination of the Upper Cretaceous lithostratigraphic units.

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