High-Resolution Biostratigraphic Zonation across the Cretaceous/Paleogene (K/Pg) Boundary from Sulaymaniyah Area, Kurdistan Region, Northeastern Iraq

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Abstract—The **present study interprets the high resolution of the biostratigraphy across the Cretaceous/Paleogene (K/Pg) boundary from Sulaymaniyah, Kurdistan Region, and north-east Iraq, based on planktic foraminifera. The Dartw section was selected for this study, within the High Folded Zone. The biozone contact consists of lithostratigraphic resemblance and is represented by the upper part of the Tanjero Formation (late Maastrichtian) with the overlying Kolosh Formation (Danian). Four late Maastrichtian planktic foraminiferal biozones have been recorded from the Tanjero Formation: *Racemiguembelina fructicosa* Interval Zone (CF4), *Pseudoguembelina hariaensis* Concurrent Range Zone (CF3), *Pseudoguembelina palpebra* Partial Range Zone (CF2), and Plummerita hantkeninoides Total Range Zone (CF1), while three Danian planktic foraminiferal biozones and two subzones have been recorded from the Kolosh Formation: (*Guembelitria cretacea* (P0) Interval Zone, *Parvularugoglobigerina eugubina* (Pα) Total Range Zone, and *Parasubbotina pseudobulloides* (P1) Partial-Range Zone (*Globoanomalina archaeocompressa* (P1a) Partial Range Subzone, and *Subbotina triloculinoides* (P1b) Interval Subzone). High biostratigraphic resolution indicates a complete K/Pg transition with no hiatus at the studied section in the Sulaymaniyah area. The ranges of the species recognized in this study are given. Correlations with other sections in Iraq and other parts of the world, including the type Maastrichtian and Danian areas, are discussed and represented in correlation charts, together with the ranges of the important Upper Maastrichtian and Paleocene species.**

Index Terms**—High Resolution, K/Pg boundary, Kurdistan region of Iraq, Planktic Foraminifera.**

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I. Introduction

Mass extinctions have occurred many times throughout the Earth's history, one of the greatest and biggest extinctions was at the K/Pg boundary (end of Cretaceous 66 Ma) (Renne, et al., 2013). It is one of the best known for the impact triggered extinction at the Yucatan peninsula in Mexico and is known as the Chicxulub impact (Fig. 1) (Hildebrand, et al., 1991). Meteor impact theory was firstly only detected from the enrichment of platinum group elements especially Iridium, later the location of the impact was found (Alvarez, et al., 1980; Smit and Hertogen 1980; Bonté, et al., 1984; Alvarez, Claeys and Kieffer, 1995; Schulte, et al., 2010; Belza, et al., 2017). Environmental crises of the impact such as sunlight shielding, sulfuric and nitric acid rain, CO_2-induced global warming, ultraviolet penetration, and toxic effects of ground-level ozone made harsh situations across the Earth (Maruoka, 2019). Besides the impact of environmental catastrophe, another theory of the driving mechanism of the extinction is linked to Deccan volcanism in India by recording enrichment of mercury in sediments from the time of the extinction (Fig. 1) (Courtillot, et al., 1984; Hildebrand, Boynton and Zoller, 1984; Madhavaraju and Yong 2010; Font, et al., 2016; Keller, et al., 2020; Mateo, et al., 2020). The controversy between abrupt (meteoric impact) and gradual mass extinction (long-lasting volcanic activity) of which mechanisms had a great effect is still ongoing (Koeberl, 1989; Keller, 2014; Arenillas, et al., 2022). Planktic foraminifera's species suffered mass extinction from the consequences of the catastrophes, and most of the works on the boundary accepted the extinction (Smit and Ten Kate, 1982; Keller, 1988; Arenillas, et al., 2002). The K/Pg boundary in the Kurdistan Region of Iraq, which is a part of the Zagros Foreland Basin (ZFB), was recorded in sedimentary rocks between various lithostratigraphic units (Shiranish/Kolosh Formations, Shiranish/Aaliji formations, Tanjero Formation/

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Red bed series, and Tanjero/Kolosh Formations) (Bellen, et al., 1959; Ghafor, 1988; Al-Shaibani, Al-Hashimi and Ghafor, 1993; Bakkhal, et al., 1993; Ghafor, 2000; Al-Barzinjy, 2005; Jassim and Goff, 2006; Sharbazheri, Ghafor and Muhammed, 2009; 2011; Hammoudi, 2011; Al-Nuaimy, et al., 2020; Salih, Al-Mutwali and Aldabbagh, 2015; Al-Qayim, Kharajiany and Wise, 2020; Kharajiany, Wise and Al-Qayim, 2020; Bamerni, et al., 2021, Sahib and Al-Dulaimi, 2022; Lawa and Qadir, 2023). Basin configuration at the time of the late Cretaceous and early Paleogene resulted in the deposition of different facies at the same time (Jassim and Goff, 2006). As a consequence of this variation a discussion occurred about the boundary between different lithostratigraphic units shows that the occurrence of a complete K/Pg transition in Iraq (Sharbazheri, Ghafor and Muhammed, 2009; 2011; Salih, Al-Mutwali and Aldabbagh, 2015; Al-Nuaimy, et al. 2020; Mousa, Al-Dulaimi, and Mohammed, 2020; Bamerni, et al., 2021).

The research on the boundary between the Tanjero and Kolosh Formations and, the Shiranish and Kolosh Formations was mostly focused on biostratigraphy (Kassab, 1972; Ghafor, 2000; Kharajiany, Al-Qayim and Wise, 2019). The studies conducted on the boundary in particular shed light on the nature of sedimentation across the boundary and whether the boundary itself represents an unconformity or a hiatus surface. Most of the recent studies use planktic foraminifera, palynomorphs (Spores and Pollen), and nannofossils emphasizing that the Early Danian sediments exist between Tanjero and Kolosh Formations and mark the boundary as a conformable surface (i.e., without a break in sedimentation) (Al-Qayim and Al-Shaibani, 1989; Ghafor, 2000; Sharbazheri, Ghafor and Muhammed, 2009, 2011; Kharajiany, Al-Qayim and Wise, 2019; Al-Nuaimy, et al., 2020; Al-Qayim, Kharajiany and Wise, 2020; Kharajiany, Wise and Al-Qayim, 2020; Bamerni, et al., 2021), while many other studies mark the boundary as an unconformable surface (Kassab, 1972; Ghafor, 1988; Al-Shaibani, Al-Hashimi and Ghafor, 1993; Jassim and Goff, 2006; Sissakian and Al-Jubouri, 2014; Lawa and Qadir, 2023). One of the prominent works conducted on the contact between Tanjero and Kolosh Formations by Bellen, et al. (1959), concluded that in some areas of Northern Iraq, the boundary could represent conformable surfaces. These authors unfortunately did not specify the localities of these conformable surfaces. Thus, high-resolution biostratigraphic zonation will help to determine the nature of the boundary. Research works on the boundary continue to optimize the best result of recording biozones. This paper presents the high-resolution biostratigraphy of the K/Pg boundary interval to delineate the boundary in a section namely the Dartw section (Kurdistan Region, NE Iraq) between Tanjero and Kolosh Formations, by recognition of planktic foraminifera in thin sections. It is historical usage to determine the ages of marine sequences across the boundary (Sarigül, et al., 2017) and to compare these records with other areas available in the region and across Iraq.

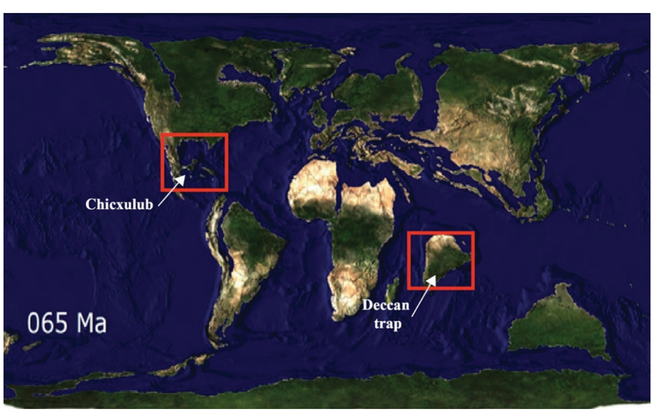

Fig. 1. Paleogeographic map at 65 Ma, showing the location of the meteorite impact and the Deccan volcanism (Scotese, 2011).

II. Geological Setting

In Sulaymaniyah Governorate, the Cretaceous and Paleocene succession is well exposed. This succession is exposed in almost all outcrops of the High Folded Zone of the Zagros Thrust-Fold around Sulaymaniyah city in the western part of the Zagros Thrust Fold Belt. The facies variation of K/Pg sections in areas around the Dartw section is between marine marl and argillaceous limestone (marly limestone), while in the furthest NE part (Imbricated Zone) of Sulaymaniyah the variation is between marine and terrestrial sediments (Tanjero and Red Bed Series) (Lawa and Qadir, 2023). At the time of the K/Pg boundary event(s), the study section was located in the ZFB, as a consequence of the convergence of the Arabian Plate with the Iranian Plate (Al-Qayim, Omer and Koyi, 2012). Structurally Dartw section is in a part of the southwestern limb of a small anticline (Yakhyan anticline) which is a part form a larger piramagrun anticline, more specifically the section is in the SE plunge of the anticline (Fig. 2). Structures around the section are striking SE-NW, parallel to the main trend of ZMB. The section is located at 35° 38’ 55.12” N and 45° 16’ 18.15”E in NE Iraq about 18.5 Km from N60W of the center of Sulaymaniah city, the coordination represents the exact boundary. In the Dartw section, the exposed outcrop of the boundary is between the Tanjero and Kolosh Formations as shown in (Fig. 2). The K/Pg boundary sequence is deposited on a carbonate platform at the northeastern margin of the Arabian Plate. The outcrop of the studied section is subdivided into two formations; based on the lithology, and stratigraphic position, these are Tanjero and Kolosh Formations. The latest Cretaceous unit is the Tanjero Formation, which was deposited by turbidite currents in the deep marine environment (Jaza, 1992; Karim, 2004). It was first described by Dunnington (1952), its type locality is in the Sirwan Valley, near Halabja Governorate, in the Kurdistan Region of Iraq, the Lithology of the Tanjero Formation is mainly composed of alternations between dark grey or olive green clastics (Sandstone and siltstone) marlstones, and argillaceous limestone with a massive conglomerate part in the proximal turbidite (Bellen, et al., 1959; Karim, 2004; Ahmed, Qadir and Müller, 2015). The depositional basin of this unit was

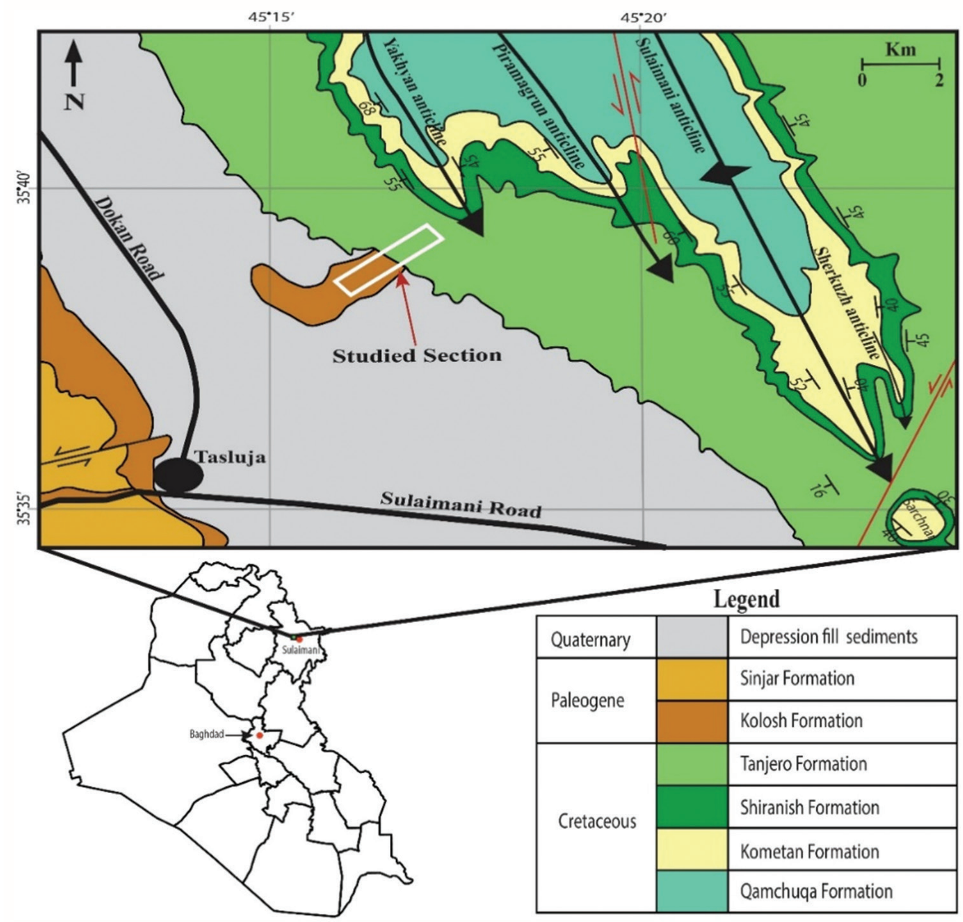

Fig. 2. Geological and location map of the studied section (after Mustafa, Mansurbeg, and Mohialdeen, 2022).

parallel to the convergence suture between the Arabian and Iranian plates in a Narrow northwest-southeast direction (Jassim and Goff, 2006). The lower part of the section could be misinterpreted lithologically as the Shiranish Formation since the strata are similar in appearance to the Shiranish Formation. However, in contrast to the Shiranish Formation, this lower part has unique thin beds of sandstone (Fig. 3). Jaza (1992) and Ismael, et al. (2011) in the Sulaymaniyah area have highlighted the problem of differentiating between Tanjero and Shiranish formations since Tanjero Formation contains intervals similar to Shiranish Formation lithologies. Both Tanjero and Shiranish formations were deposited in a single basin at the initial stage of the Zagros Foreland Basin development (Karim, 2004).

In the earliest time of the Paleogene, the basin was nearly the same as at the time of deposition of the Tanjero Formation, the Kolosh Formation started deposition. This formation was first described by Dunnington (1952; in Bellen et al., 1959) and the type locality of the formation is located in the north of Koya Town near Kolosh Village. This unit is a low-density turbidite with rhythmic alternation of sandstone and shale with beds of argillaceous limestone, limestone, and conglomerate (Bellen, et al., 1959; Al-Mashaikie Sa'ad and Mohammed, 2018; Karim and Hamza, 2023). These two formations both have a flysch deposit character deposited in the upper bathyal environment, outer shelf environment, and middle shelf area from bottom to top respectively (Jaza, 1992; Jassim and Goff, 2006; Al-Khalaif and Al-Mutwali, 2020). In the Dartw section, both formations have approximately similar lithological characteristics; the two formations are composed of interbedding between marlstone, argillaceous limestone, and sandstone. The consistency of lithology (no abrupt change) across the section makes a determination of the boundary by the field evidence impossible, especially in narrow intervals (centimeters scale) (Figs. 3 and 4). Color variation is noted in Kolosh Formation as it is darker compared to the Tanjero Formation.

III. Materials and Methods

Sixty-three rock samples for this study were taken from the Dartw section outcrop in four carried-out field trips. Intervals between individual samples are based on proximity to the boundary, at boundary transition, sample intervals are much smaller compared to distant samples (Fig. 4). Samples were collected in four stages, and especially near the boundary, samples were taken at 10cm intervals. (Fig. 3). Between each stage of field sampling, thin sections of samples were made in the workshop of the Department of Earth Sciences and Petroleum/University of Sulaimani to study planktic foraminifera, this would help us to concentrate samples at strata near the boundary. The samples are representative

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Fig. 3. Field photograph showing sample interval near the K/Pg boundary transition in Dartw section.

of the lithology variation of turbidite cycles. Thin sections from all samples for petrographic study were prepared at the workshop of the Department of Geology/University of Sulaimani. The biozonal schemes of Li and Keller (1998a; 1998b) and Coccioni and Premoli Silva (2015) for the late Maastrichtian were followed and the biochronology of Wade, et al. (2011) was used for the Danian.

IV. Results and Discussion

A. Biostratigraphic Analysis

The studied section has the highest diversity of late Maastrichtian/Danian planktic foraminifera with a total identification of 71 species from 28 genera of planktic foraminifera (46 species of Maastrichtian from eighteen genera of planktic foraminifera and 25 species of Danian from ten genera of planktic foraminifera). The biozonation of the Dartw section was found on the apportionment of the planktic foraminifera that applied to the Tanjero and Kolosh Formations (Figs. 5-7), seven biozones have been recognized from Maastrichtian - Paleocene age (Fig. 8). For the late Maastrichtian, the biozonation of Li and Keller (1998a; 1998b), was used, which subdivides the *Abathomphalus mayaroensis* zone is subdivided into four Cretaceous Foraminiferal (CF) subzones (CF1, CF2, CF3 and CF4), four for the earliest Danian, the biozonation of Keller, et al. (1995) was subdivided into three biozones (P0, P*a* and P1) and 2 subzones (P1a, and P1b) have been recognized. These biozonal schemes are shown in Fig. 9 in comparison with other commonly used biozones.

B. Biostratigraphy of the Tanjero Formation (late Maastrichtian)

Forty-six species from eighteen genera of planktic foraminifera have been identified in the Tanjero Formation (Figs. 5 and 6). Based on the stratigraphic ranges of the recognized species, four subzones of the *A. mayaroensis* zone have been recognized in the Maastrichtian.

Total Range Zone of the nominated by taxon *Abathomphalus mayaroensis*. The *A. mayaroensis* was defined previously as the interval from the first appearance datum (FAD) to the last appearance datum (LAD) of *A. mayaroensis*, which spans the entire late Maastrichtian interval (Caron, 1985; Toumarkine and Lutherbacher, 1985). It is important to mention that the zonal scheme of CF proposed by Li and Keller (1998a; 1998b), which replaces the *A. mayaroensis* Zone, with four subzones (*Racemiguembelina fructicosa* subzone, *Pseudoguembelina hariaensis* subzone, *Pseudoguembelina palpebra* subzone, and *Plummerita hantkeninoides* subzone), for much-improved age estimation for the late Maastrichtian, This zone is coeval with the standard zonation of Caron (1985) and Berregren, et al. (1995), it also coincides with the zones CF4, CF3, CF2, of Li and Keller (1998). The upper and lower boundaries were drawn with the first and last occurrences of the nominate taxon. In the Dartw section of the studied area, the *A. mayaroensis* zone encompasses 19-m thick Maastrichtian limestone with marly limestone, which can be subdivided into the four CF subzones (Li and Keller, 1998a), and were arranged from older to younger (Fig. 8):

R. fructicosa interval subzone (CF4)

This zone is defined as the interval from the FAD of *R. fructicosa* and the FAD of *A. mayaroensis* to the FAD of *P. hariaensis* (Li and Keller, 1998). The lower boundary is not covered by this section and the upper boundary is defined by the first appearance of the *A. mayaroensis*. In the Dartw section, subzone CF4 extends from 0 m to 9 m (with a 9 m thick) of the alternation of calcareous shale (Occasionally siltstone) with a 0.5 m thick argillaceous limestone bed. A bed of sandstone 2-cm thick is present at the top. This zone is recognized at the base of the Tanjero Formation and is represented in the Dartw section by an interval extending from the samples DT-9, and DT-15.

The zone is characterized by these species of Planktic foraminifera: *Abathomphalus intermedius*, *A. mayaroensis, Gansserina gansseri, Globotruncana bulloides, Globotruncana pettersi, Globotruncana arca, Contusotrancana contusa., Contusotrancana walfischensis, Globotruncanita conica,*

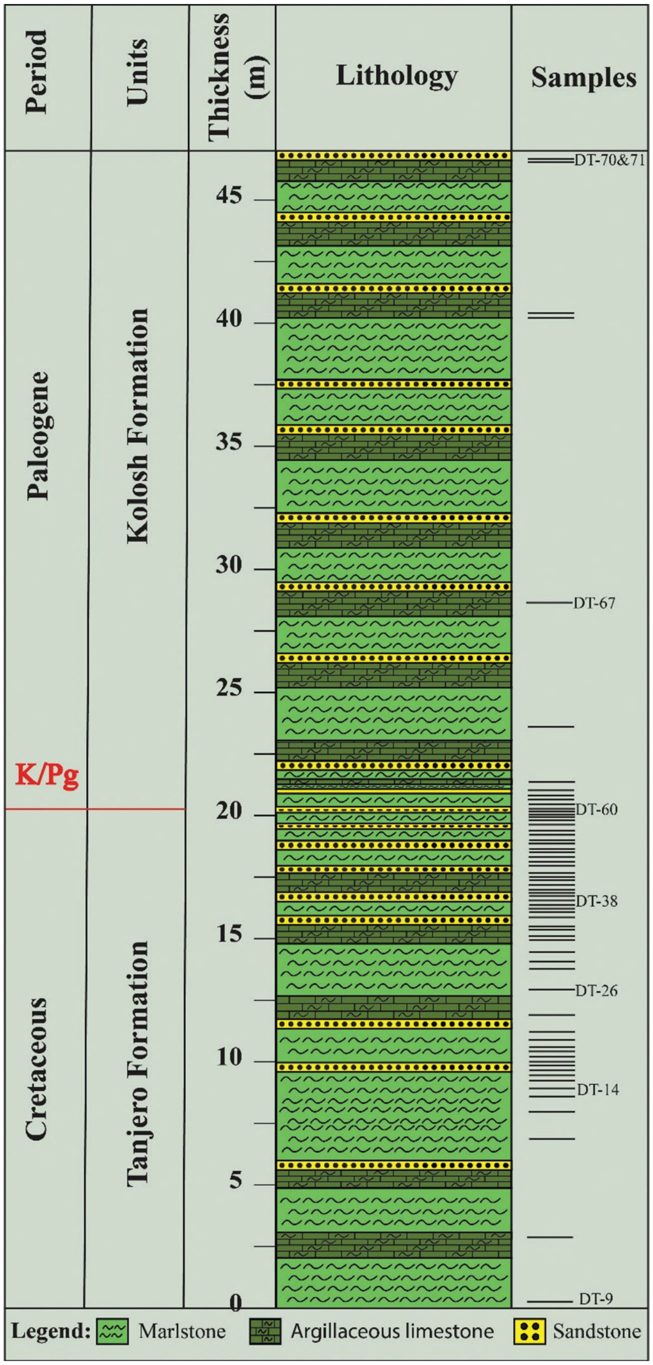

Fig. 4. Stratigraphic column of a Dartw section across the K/Pg boundary near Sulaymaniyah city, Kurdistan region, Iraq.

Globotruncanita stuarti, Hedbergella monmouthensis, Heterohelix globulosa, Heterohelix planata, Heterohelix punctulata R. fructicosa, *Rugoglobigerina rugosa, Rugoglobigerina macrocephala* and *Rugoglobigerina reicheli.* The *R. fructicosa* zone. (CF4) was introduced by Li and Keller (1998a; 1998b) as a biostratigraphic interval between the FAD of *R. fructicosa* at the base and the FAD of *P. hariaensis* at the top. according to most of the biozonation works this zone placed *R. fructicosa* zone at the lower late Maastrichtian (Abramovich and Keller, 2002) at DSDP Site 525A, Keller, et al. (1995) from Tunisia, Obaidalla (2005) and Samir (2002) from Egypt, Sharbazheri, Ghafor and Muhammed, (2009; 2011) and Al Nujaimy, et al., (2020) from Iraq. As defined above, the present subzone (CF4) of the studied section is correlatable with the lower part of *A. mayaroensis* (Abawi, Kireem and Yousef, 1982; Abdel-Kareem, 1986) from Iraq. Premoli Silva and Sliter (1999) from Italy. Caron (1985) and Robaszynski, et al. (1984) in some other localities. Sharbazheri, Ghafor and Muhammed (2009; 2011), Al-Nujaimy, et al. (2020), recorded this zone from the Dokan, Sirwan valley, Smaquli area, and they documented these planktic foraminiera *(Heterohelix navarroensis, Heterohelix globulosa. Heterohelix striata, Heterohelix punctulats, Planoglobulina carseyae, Planoglobulina brazoensis, Planoglobulina acervulinoides, Rugoglobigerina rugosa, Rugoglobigerina scotti, Rugoglobigerina hexacamerata, Rugoglobigerina macrocephala, Gansserina gansseri, Globotruncanita stuarti, Globotruncanita stuartiformis, Globotruncanita conica, Globotruncana aegyptiaca, Globotruncana falsostuarti, Globotruncana dupeublie, Globotruncana gagnebini, Globotruncana lapparenti Globotruncana arca, Globotruncana. bulloides, Contusotruncana contusa, Contusotruncana fornicate, Contusotruncana plicata, Rugotruncana circumnodifer, Rugotruncana. subcircumnodifer, Globotruncanella petaloidea, Globotruncanella havanensis, Globigerinelloides volutes, Globigerinelloides multispinata, Globigerinelloides subcarinate, Globigerinelloides prairiehillensis, Globigerinelloides bolli, Pseudotextularia elegans, Pseudotextularia deformis, Pseudotextularia intermedia, Racemiguembelina fructicosa, Racemiguembelina poweli, Pseudoguembelina costulata, Pseudoguembelina hariaensis, Pseudoguembelina palpebra, Pseudoguembelina excolata, Hedbergella monmothensis Hedbergella holmdelensis, Abathomphalus mayaroensis).*

The age calculation of this biozone by Li and Keller (1998a) recorded the time span between 68.33 Ma and 66.83 Ma. In the studied section, estimating absolute ages based on magnetochron age between a time span between 68.35 Ma and 67.25 Ma, and a high rate of deposition. Its age is early late Maastrichtian with 9-m thick.

P. hariaensis concurrent range subzone (CF3)

This zone defines the interval from the FAD of *P. hariaensis* at the base to the LAD of *G. gansseri* at the top (Li and Keller, 1998a; 1998b). This biozone spans 1 m of olive-green calcareous shale (Fig. 8). This zone is recognized at the Tanjero Formation and is represented in the Dartw section by an interval extending from the samples DT-16 to DT-22. It is characterized by these species of Planktic foraminifera: - *A. intermedius*, *A. mayaroensis, G. arca, Globotruncana calcarata, Contusutruncanita contusa, G. conica, G. stuarti, H. holmdelensis, H. monmouthensis, H. globulos*a, *H. navarroensis, Pseudoguembelina harensis, R. rugosa, R. reicheli.* The *P. hariaensis* (CF3) Zone was introduced by Li and Keller (1998a). This zone is equivalent to the middle part of the *A. mayaroensis* zone as recorded by Abawi, Kireem and Yousef (1982) and Abdel-Kireem (1986) in the northeast of Iraq. It is also correlated with the same zone that was recorded by Al-Mutwali and Al-Doori (2012), they recorded this zone as an interval zone of the zonal

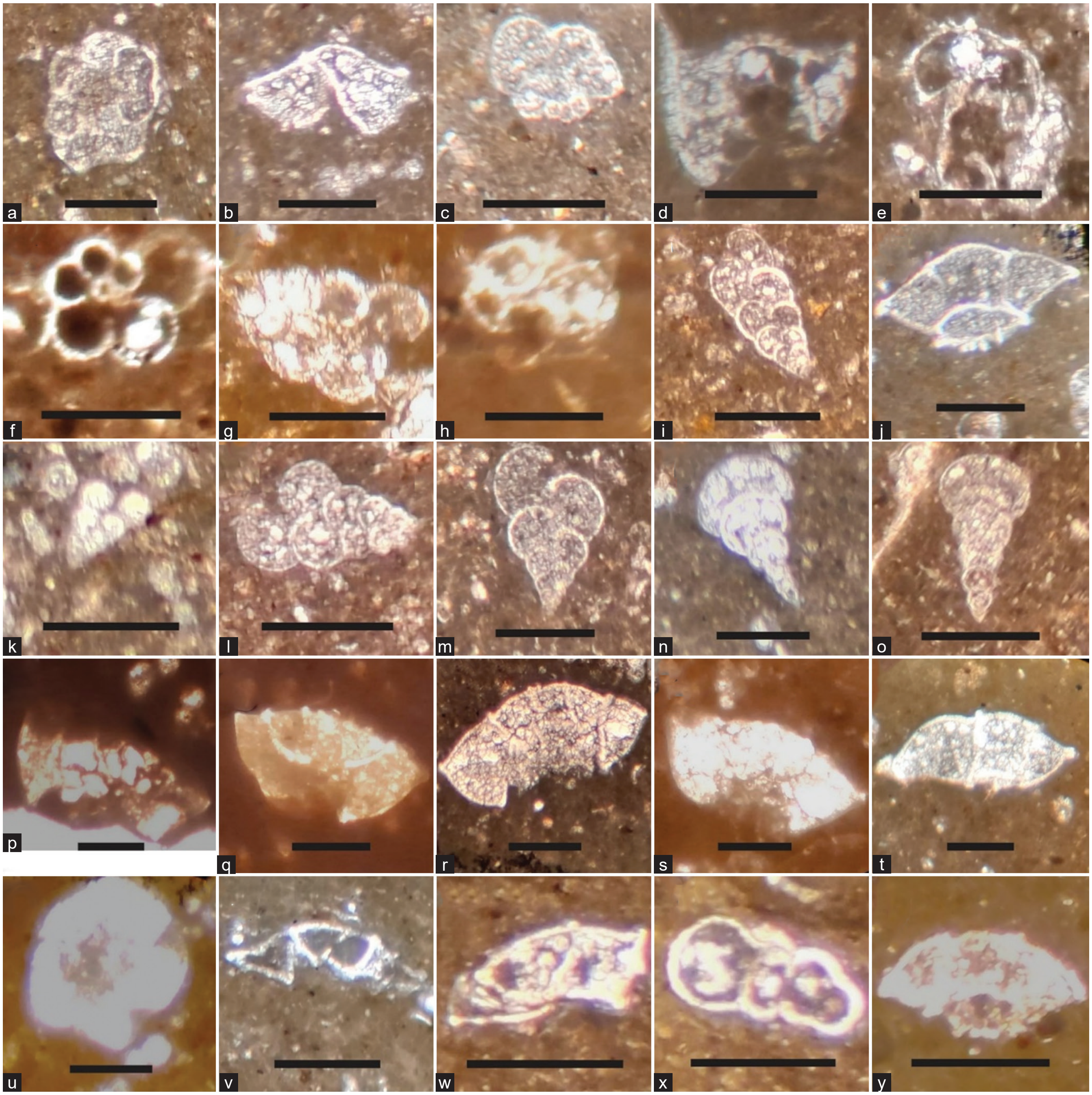

Fig. 5. (a) *Racemiguembelina fructicosa* (Egger, 1900), sample no. DT-10. (b) *Abathomphalus intermedius* (Bolli, 1951), sample no. DT-10. (c) *Abathomphalus mayaroensis* (Bolli, 1951), sample no. DT-10. (d) *Gansserina gansseri* (Bolli, 1951), sample no. DT-9. (e) *Globotruncana arca* (Cushman, 1926), sample no. DT-9. (f) *Hedbergella holmdelensis* (Olsson 1964), sample no. DT-9. (g) *Pseudoguembelina costellifera* (Masters, 1976), sample no. DT-9. (h) *Rugoglobigerina* sp., sample no., sample no. DT-9. (i) *Heterohelix navarroensis* (Loeblich 1951), sample no. DT-10. (j) *Globotruncanita conica* (White, 1928), sample no. DT-10. (k) *Planoheterohelix moremani* (Cushman, 1938), sample no. DT-10. (l) *Planoheterohelix planata* (Cushman, 1938), sample no. DT-10. (m) *Planoheterohelix globulosa* (Ehrenberg, 1840), sample no. DT-10. (n) *Pseudotextularia elegans* (Rzehak, 1891), sample no. DT-10. (*o*) *Pseudotextularia nuttalli* (Voorwijk, 1937), sample no. DT-10. (p) *A. mayaroensis* (Bolli, 1951), sample no. DT-15. (*q*) *Gansserina wiedenmayeri* (Gandolfi, 1955), sample no. DT-15. (r) *Globotruncana orientalis* (El Naggar 1966), sample no. DT-15. (s) *Globotruncana rosetta* (Carsey, 1926), sample no. DT-15. (t) *Pseudoguembelina hariaensis* (Nederbragt, 1991), sample no. DT-15. (u) *Rugoglobigerina hexacamerata* (Brönnimann, 1952), sample no. DT-15. (v) *Contusotruncana*, sample no. DT-19. (w) *Globotruncana dupeublei* (Caron, Gonzalez, Robazynski & Wonders in Robaszynski, et al., 1984) Sample No. DT- 19. (x) *Rugoglobigerina hexacamerata* (Brönnimann, 1952) SampleNo. DT-19. (y) *Globotruncana orientalis* (El Naggar 1966) Sample No. DT-19. The Bar scale = 0.5 mm.

marker with a thickness of 3.6 m, and they determined its age as middle late Maastrichtian. The abundant occurrence of these planktic foraminifera has been recognized by Hammoudi (2011), *Globotrunana aegyptiaca*, *Globotrunana*

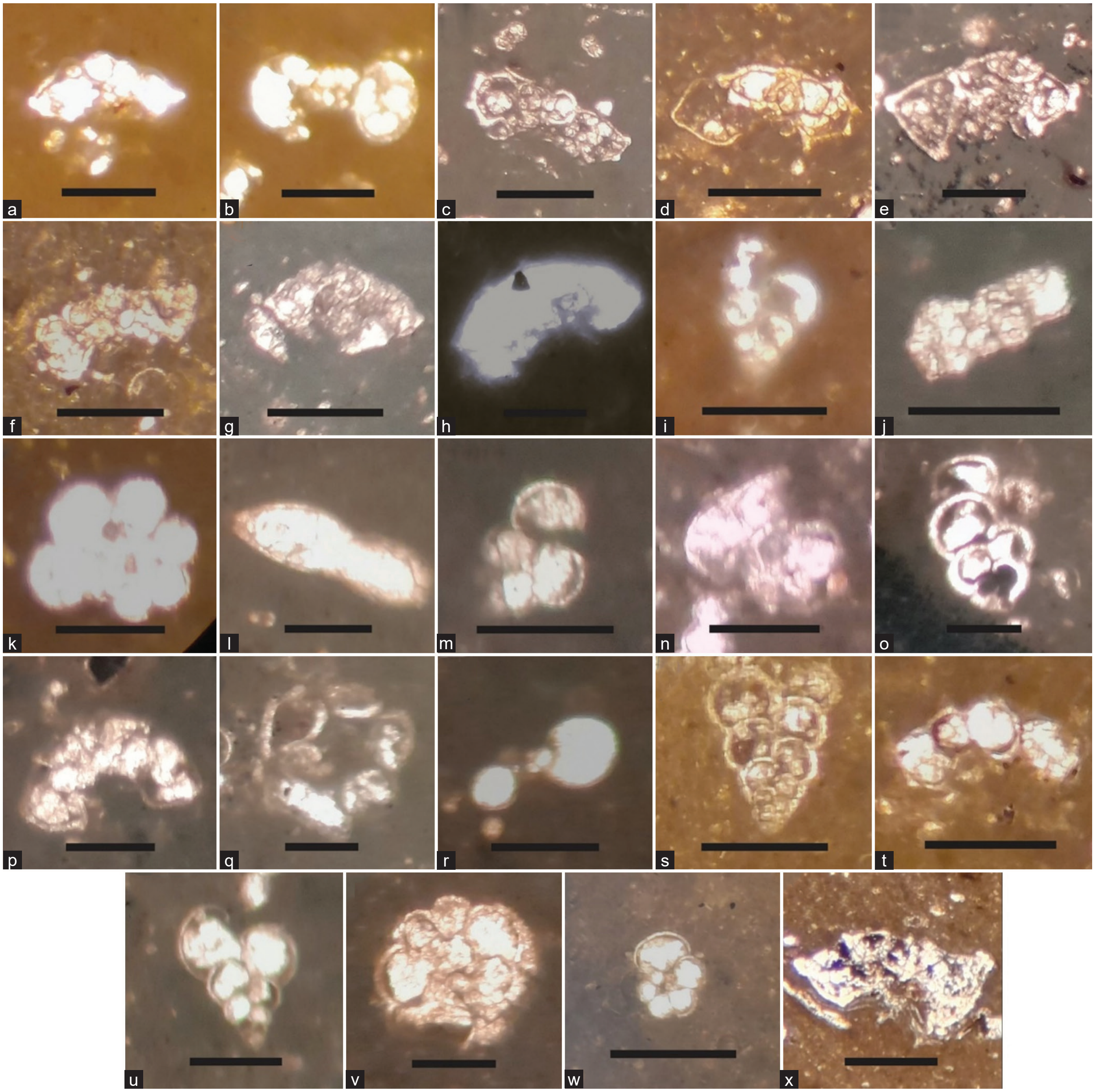

Fig. 6. (a) *Globotruncana orientalis* (El Naggar 1966), sample no. DT-22. (b) *Rugoglobigerina pennyi* (Bronnimann, 1952), sample no. DT-22. (c) *Abathomphalus mayaroensis* (Bolli, 1951), sample no. DT-27. (d) *Globotruncana falsostuarti* (Sigal, 1952), sample no. DT-27. (e) *Globotruncana dupeublei* (Caron, Gonzalez, Robazynski & Wonders in Robaszynski, et al., 1984), sample no. DT- 27- (f) *Globotruncanita angulata* (Tilev, 1951), sample no. DT-27. (g) *Globotruncana stephensoni* (Pessagno 1967), sample no. DT-27. (h) *Globotruncanita conica* (White, 1928), sample no. DT-29. (i) *Pseudotextularia intermedia* (De Klasz, 1953), sample no. DT-29. (j) *Abathomphalus mayaroensis* (Bolli, 1951), sample no. DT-55. (k) *Rugoglobigerina rotundata* (Bronnimann, 1952), sample no. DT-55. (l) *Globotruncanella petaloidea* (Gandolfi, 1955), sample no. DT-57. (m) *Guembelitria cretacea* (Cushman, 1933), sample no. DT-57. (n) *Plummerita hantkeninoides* (Bronnimann, 1952), sample no. DT-57. (o) *Archaeoglobigerina blowi* (Pessagno 1967), sample no. DT-57. (p) *Contusotruncana contusa* (Cushman, 1926), sample no. DT-57. (q) *Contusotruncana*, sample no. DT-57. (r) *Globigerinelloides subcarinatus* (Bronnimann, 1952), sample no. DT-57. (s) *Planoheterohelix globulosa* (Ehrenberg, 1840). (t) *Globotruncanella petaloidea* (Gandolfi, 1955), sample no. DT-57. (u) *Heterohelix globulosa* (Ehrenberg, 1840). (v) *Rugoglobigerina hexacamerata* (Brönnimann, 1952), sample no. DT-57. (w) *Rugoglobigerina rugosa* (Plummer, 1927), sample no. DT-53 (x) *Globotruncanita stuartiformis* (Dalbiez, 1955), sample no. DT-19. The Bar scale = 0.5 mm.

arca, *Globotrunana esnehensis*, *Contusutruncana contusa*, *R. rugosa*, *R. macrocephala*, *R. scotti*, *Rugoglobogerina hexacamerata*, *H. holmdelensis*, *H. monmouthensis*, *Hetrohelix planata*, *Hetrohelix glabrans*, *Hetrohelix globulosa*, *Hetrohelix navaroensis*, and she considered the CF3 Zone as a subzone within the *A. mayaroensis* Zone also

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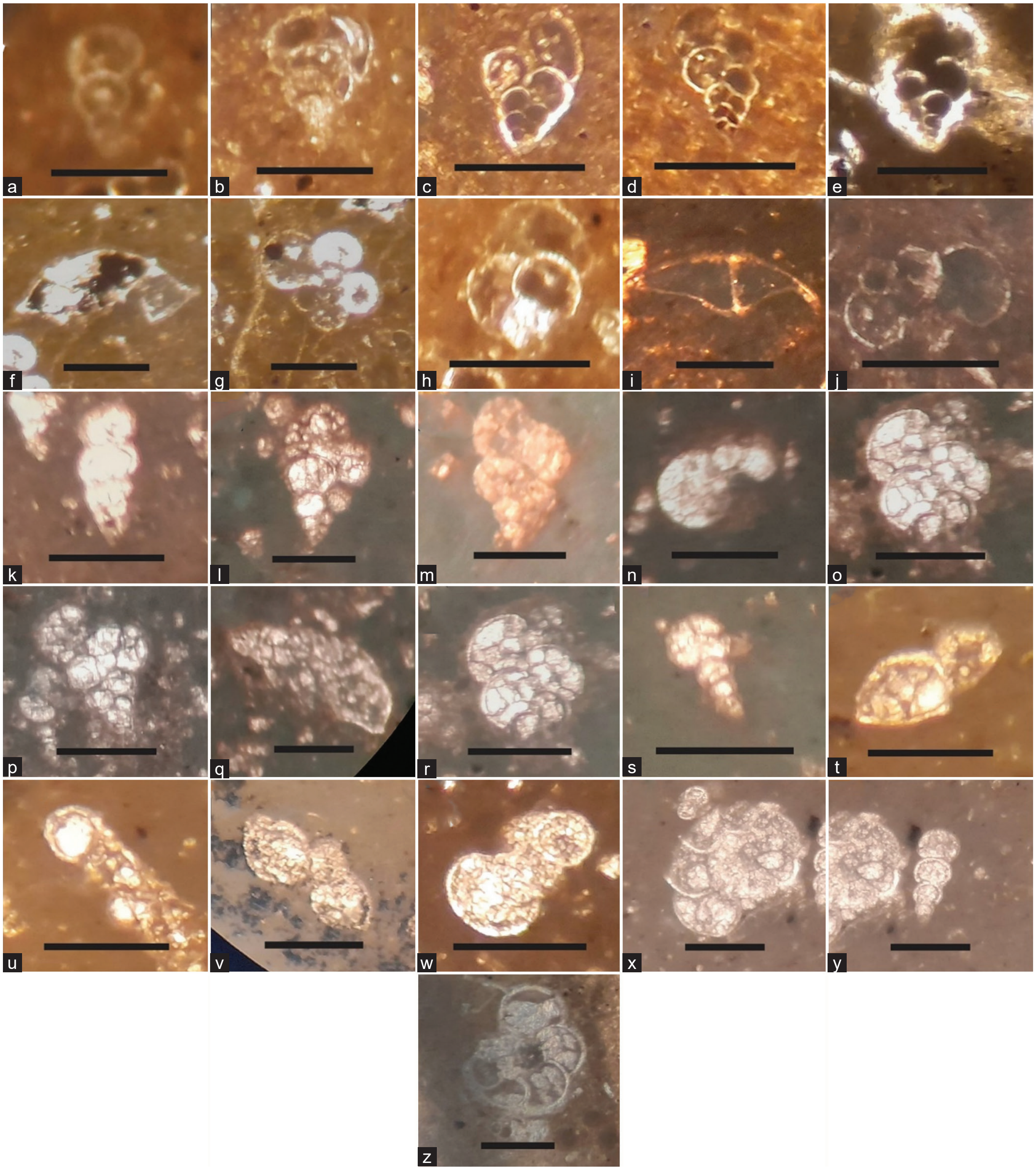

Fig. 7. (a) *Woodringina claytonensis* (Loeblich and Tappan, 1957), sample no. DT-61. (b) *Spiroplectammina dentata* (Alth, 1850) sample no, DT-61, (c) *Chiloguembelina morsei* (Kline 1943), sample no. DT-61, (d) *Guembelitria* cretacea (Cushman, 1933), sample no. DT-61, (e) *G. cretacea* (Cushman, 1933), sample no. DT-61, (f) *Hedbergella monmouthensis* (Olsson, 1960), sample no. DT-61, (g) *H. monmouthensis* (Olsson, 1960), sample no. DT-61, (h) *Parasubbotina pseudobulloides* (Plummer, 1927), sample no. DT-61, (i) *Parvularugoglobigerina extensa* (Blow, 1979), sample no. DT-61, (j) *Subbotina triangularis* (White, 1928), (k) *Woodringina claytonensis* (Loeblich and Tappan, 1957), sample no. DT-61, (l) *Chiloguembelina* sp*.,* sample no. DT-63, (m) *Chiloguembelina morsei* (Kline, 1943), sample no. DT-63, (n) *Eoglobigerina eobulloides* (Morozova, 1959), sample no. DT-63, (o) *Eoglobigerina eobulloides simplicissima* (Blow, 1979), sample no. DT-63, (p) *G. cretacea* (Cushman, 1933), sample no. DT-63, (q) *Parvularugoglobigerina eugubina* (Luterbacher and Premoli Silva, 1964), sample no. DT-63, (r) *P. pseudobulloides* (Plummer, 1927), sample no. DT-63, (s) *Pseudonodosaria appressa* (Loeblich and Tappan, 1955), sample no. DT-63, (t) *Globanomalina compressa* (Plummer, 1927), sample no. DT-65, (u) *Hedbergella holmdelensis* (Olsson, 1964), sample no. DT-65, (v) *Globanomalina compressa* (Plummer, 1927), sample no. DT-65, (w) *Globanomalina archeocompressa* (Blow, 1979), sample no. DT-65, (x) *P. eugubina* (Luterbacher and Premoli Silva, 1964), sample no. DT-65, (y) *Woodringina claytonensis* (Loeblich and Tappan, 1957), sample no. DT-65, (z) *Globanomalina archeocompressa* (Blow, 1979), sample no. DT-70. Bar scale = 0.5 mm.

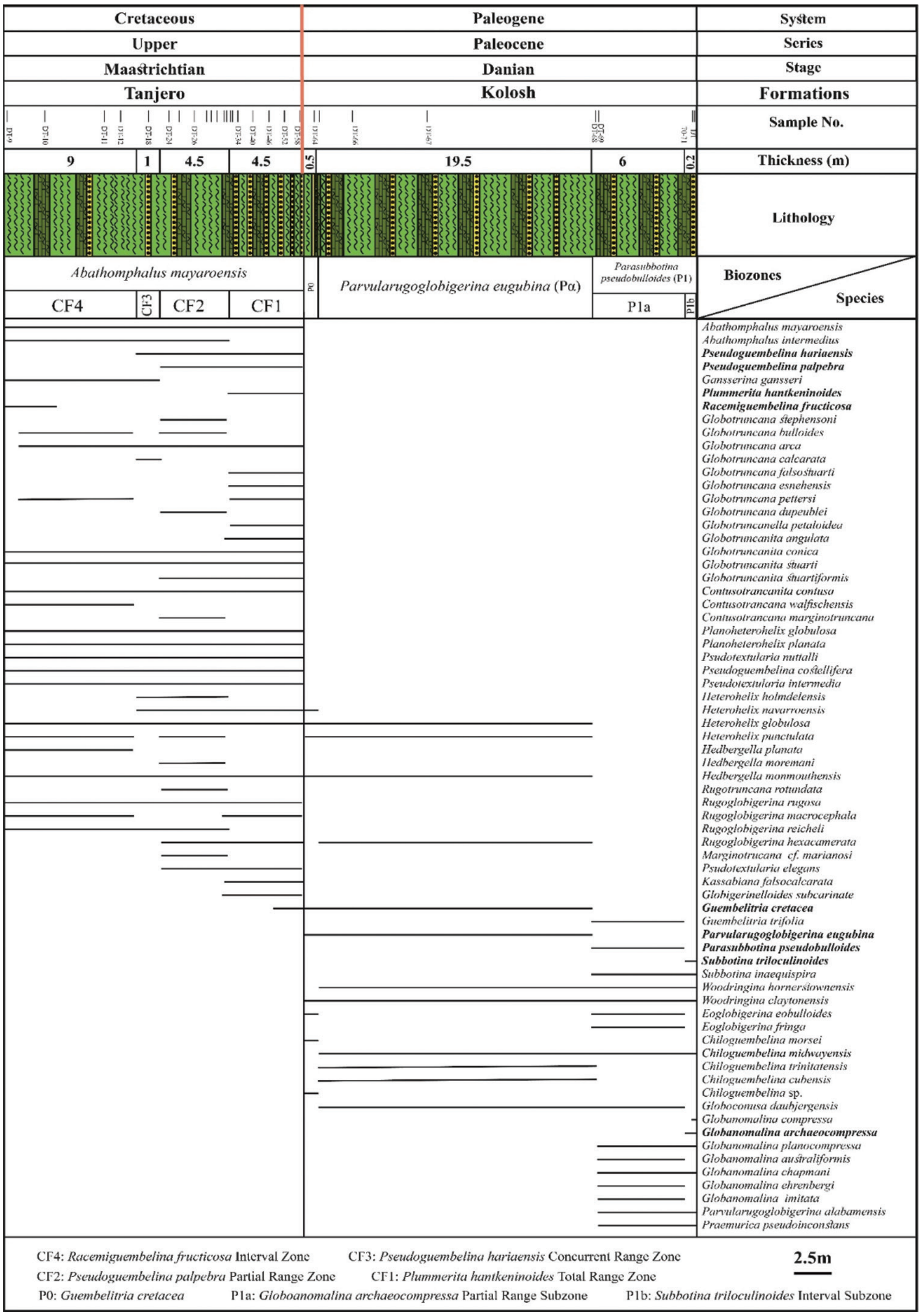

Fig. 8. Biostratigraphic range chart of identified planktic foraminifera across K/Pg boundary in the Dartw section. Biozones are based on Li and Keller (1998a; 1998b).

determined the age of this subzone as late Maastrichtian. Sharbazheri, Ghafor and Muhammed (2011) recorded this zone from the Smaquli area with 35-m thickness. They documented an increase in the abundance of planktic foraminifera within this zone, documenting the species *P. hariaensis*, *H. navaroensis*, *H. globulosa*, *Hetrohelix striata*, *Hetrohelix punctulata*, *Hetrohelix nuttalli*, *Hetrohelix reussi*, *P. carseyae, P. brazoensis*, *P. acervulinoides*, *R. rugosa*, *R. scotti*, *R. hexacamerata*, *R. macrocephala*, *Rugoglobigerina pennyi, Rugoglobigerina Reicheli*, *Rugoglobigerina rotundata*, *G. gansserina*, *Globtruncanita stuartiformis*, *G. conica, Globotruncanita pettersi*, *Globotruncanita angulata*, *Ganserina. aegyptiaca*, *Ganserina falsostuarti*, *Ganserina dupeublei*, *Ganserina lapparenti*, *Contustruncana contusa*, *Contusutruncana plicata*, *Contusutruncana patelliformis*, *P. elegans*, *P. deformis*, *Racemegumbelina fructicosa*, *P. costulata*, *P. palpebra*, *P. excolata*, *Hedbegella monmouthensis*, *H. holmdelensis*, *A. mayaroensis*, *Guembulina cuvillieri*, and *Guembelitria cretacea*.

The study of Salih, Al-Mutwali and Aldabbagh, 2015 in Northern Iraq documented a 6 m section of this zone with well-preserved, abundant planktonic foraminifera species

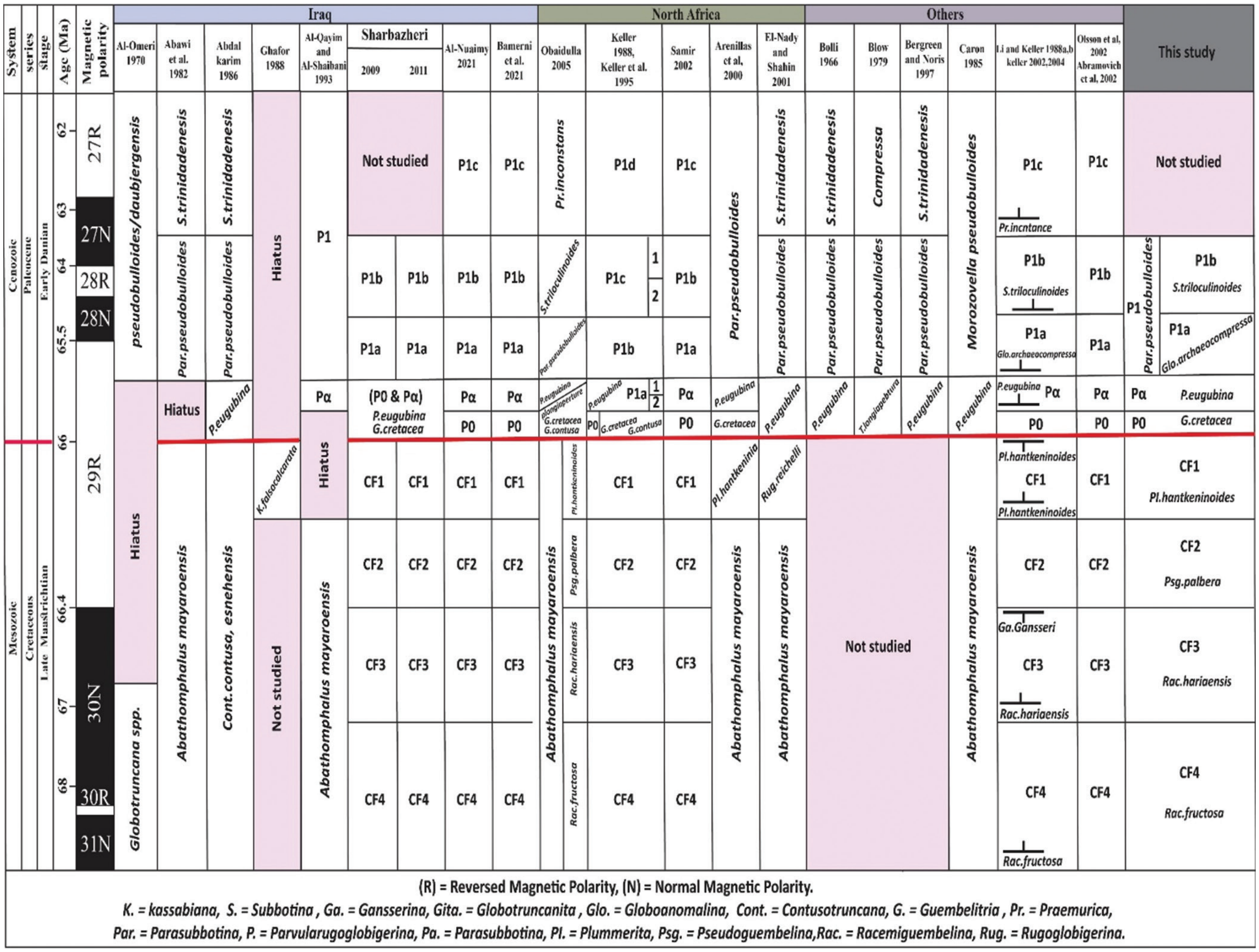

Fig. 9. Biostratigraphic correlation of the planktic foraminiferal biozones of this study with other studies.

including *P. hariaensis*, *Ganserina gansseri*, *H. globulos*a, *Heterohelix labellosa*, *Heterohelix navaroensis*, *H. striata*, *P. acervulinoides*, *P. brazoensis*, *P. carseyae*, *Pseudogumbelina elegans*, *Pseudogumbelina nuttalli*, *Racemegumbelina fructicosa*, *Racemegumbelina powelli*, *Pseudogumebelina. costulata*, *Pseudogumebelin excolata*, *Pseudogumbelina kempensis*, *Pseudogumebelina palpebra*, *H. holmdelensis*, *H. monmouthensis*, *C. contusa*, *Cont*usotruncana *patelliformis*, *Ganaserina aegyptiaca*, *G. arca*, *Globotruncana dupeublei*, *Globotruncana esnehensis*, *G. falsostuarti*, *Globotruncana mariei*, *Globotruncana rosetta*, *Globotruncana ventricosa*, *Globotrucanita stuarti*, *G. stuartiformis*, *Globotrucanita subspinosa*, *G. havanensis*, *G. petaloidea*, *Rugglobigerina hexacamerata*, *R. macrocephala*, *R. rugosa*, *Rugoglobigerina Scotti*. They reported the age of this zone to be middle–late Maastrichtian. Bamerni, et al. (2021) recorded this zone in the Duhok area, which spans an interval of 9 m in the Per Fat section and 6 m in the Xezava section and they documented these planktic foraminifera, *A. mayaroensis*, *Ab. intermedius*, *R. macrocephala*, *Racemegumbelina fructicosa*, *P. acervulinoides*, *Contusutruncana. contusa*, *H. monmouthensis*, *Ganserina gansseri*, *Psudigumbelina. palpebra*, *Psudigumbelina costulata*, *P. elegans*, *Globotrunana arca*, *Globotrunana aegyptiaca*, *G. esnehensis*, *G. stuarti*, *Globotrucanita conica*, *G. stuartiformis*, *Archaeoglobigerina cretacea*, *Trintella scotti*, *H. striata*, *H. globulos*a, *H. punctulata*, and *R. rugosa*. The current biozone (CF3), as mentioned above, can be connected to the DSDP site 525A region zone reported by Li and Keller (1988a) and Abramovich and Keller (2002) in Madagascar. Premoli Silva and Sliter, (1995) from Tunisia. Keller and Pardo (2004) in Eastern Tethys. Samir (2002) and Obaidalla (2005) in Egypt. Sharbazheri (2007; 2010) in NE Iraq, and it is correlated according to Abawi, Kireem and Yousef (1982) and Abdel-Kireem (1986a) with the middle part of *A. mayaroensis* Zone recorded in the Northeast of Iraq, Premoli Silva and Sliter (1999) in Italy, Premoli Silva and Sliter (1999) in Egypt.

The age calculation of this biozone by Li and Keller (1998a), recorded the time span between 66.83 Ma to 65.45 Ma. In the studied section, estimating absolute ages based on magnetochron age between a time span between 66.80 Ma and 66.44 Ma, and moderate rate of sedimentation. Its age is middle late maastrichtian with 1 m thick.

P. palpebra partial range subzone (CF2)

This zone spans the interval from the LAD of *G. gansseri* to the FAD *P. hantkeninoides* (Li and Keller, 1998a; 1998b). In the Dartw section, this zone spans 4.5 m of grey shale (Fig. 8). It is recognized at the Tanjero Formation and is represented in the Dartw section by an interval extending from the samples DT-22, and DT-32. The assemblage includes this planktic foraminifera: *A. intermedius*, *A. mayaroensis, C. contusa, Globotruncana conica, Globotruncana dupeublei, Contusotrancana marginotruncana, hexacamerata Globotrucanita arca, G. stuarti, G. stuartiformis, Globotruncana dupluberti, G. bulloides, Globotruncana stephensoni, H. holmdelensis, H. monmouthensis, H. globulos*a*, Heterohelix moremani, Heterohelix punctulate; H. navarroensis, P. hariaensis, Rugotruncana rotundata, P. hantkeninoides, R. hexacamerata, R. reicheli, R. rugosa, psudotextularia elegans. Marginotrucana cf. marianosi.*

The age estimation of this biozone by Li and Keller (1998a) records the upper late Maastrichtian, with a time span of 65.45 Ma to 65.30 Ma. In the studied section, estimating absolute ages based on magnetochron age between a time span between 65.4 Ma and 65.30 Ma, providing a high rate of sedimentation, its age is upper late Maastrichtian with 4.5 m thick.

P. hantkeninoides total range subzone (CF1)

The biozone CF1 is defined by the total range of *P. hantkeninoides*, which marks the last 300 ky of the Maastrichtian (Li and Keller, 1998a; 1998b and Olsson, et al., 1999). In the Dartw section, zone CF1 spans the uppermost 4.5 m of dark green calcareous shale. It is recognized at the Tanjero Formation and is represented in the Dartw section by an interval extending from the samples DT-32 and DT-58. Species identified in this interval include: *A. mayaroensis, G. aegyptiaca, P. hantkeninoides*, *Globotruncanita arca, Globotruncanita esnehensis, Globotruncanita. falsostuarti, Globotruncanita. petaloidea, Globotruncanita angulata, G. conica, Globotruncanita contusa, Globotruncanita pettersi, G. stuarti, G.stuartiformis, H. globulos*a*, H. navarroensis, H. monmouthensis, Kassabiana falsocalcarata, P. hantkeninoides, P. hariaensis, P. palpebra, P. elegans, R. macrocephala, Rugoglobigerina riecheli*, *R. rugosa, G. cretacea. R. hexacamerata, G. subcarinate* (Fig. 3). The CF1 subzone was introduced by Masters (1984), at the K-Pg boundary in Tunisia and Egypt. Coccioni and Premoli Silva (2015) stated that the zonal marker is very rare and sporadic in the classic Tethyan Gubbio section (Italy). Sharbazheri, Ghafor and Muhammed (2009; 2011) and Al-Nuaimy, et al. (2020) recorded the CF1 Zone in their study from the upper part of the Maastrichtian deposits in Kurdistan region/Iraq. They also stated that the characteristic planktic foraminiferal assemblage of this zone gradually decreased in both species richness and individual numbers from the *P. palpebra* Zone to the *P. hantkeninoides* Zone. Mousa, Al-Dulaimi, and Mohammed (2020) recorded the C1 zone in the Western Desert of Iraq and they documented common occurrences of *A. intermedius*, *A. mayaroensis*, *Glla. pschadae*, *H. monmouthensis*, *P. palpebra*, *R. hexacamerata*, the age of this zone estimated by the latest Maastrichtian. Recently *P. hantkeninoides* Zone was recorded by Bamerni et al. (2020) in the Dohuk area, North-east Iraq, with high-resolution biostratigraphic analysis of the K-Pg boundary and shows a great diversity of the planktic foraminiferal assemblages compared to the CF2 and CF3 biozones. They recorded planktic foraminifera; the most abundant taxa are *P. hantkeninoides*, *Plummerita reicheli*, *Plummerita* cf. *hantkeninoides*, *P. elegans*, *Pseudotextularia nuttalli*, *P. intermedia*, *G. stuarti*, *Globotruncanita. conica*, *Globotruncanita. stuartiformis*, *Racemegumbelina powelli*, *Plummerita carseyae*, *Plummerita brazoensis*, *Plummerita acervulinoides*, *H. striata*, *H. globulo*sa, *Heterohelix labelosa*, *Heterohelix. reussi*, *Heterohelix. navaroensis*, *Heterohelix carinata*, *R. rugosa*, *R. macrocephala*, *Racemegumbelina fructicosa*, *Pseudigumbelina costulata*, *P. hariaensis*, *P. palpebra*, *Pseudoguembelina kempensis*, *Gansserina arca*, *Ganserina rosetta*, *C. contusa*, *Contusutruncana fornicata*, *C. patelliformis*, *H. monmouthensis*, *Rugglobigerina hexacamerata*, *Archaeoglobigerina blowi*, and *Gublerina cuvillieri.*

CF1 biozone in the study section had an assemblage of planktonic foraminifera, which is comparable to the zone reported by Nederbragt, (1991) in Tunisia; Keller and Pardo (2004) in Eastern Tethys Israel; Samir (2002) and Obaidalla (2005) in Egypt; Li and Keller (1988a) from South Atlantic DSDP Site 525A; Abramovich and Keller (2002) in Madagascar; Abramovich and Keller (2002) in DSDP Site 525A, and Stinnesbeck, et al. (2002) from USA.

The present zone of *P. hantkeninoides* is equal to *A. mayaroensis* in their upper majority from all parts of the world (Canudo, Keller and Molina, 1991); Chacon and Martin-Chivelet, (2005) in Spain; Premoli Silva and Sliter (1999) from Italy; Abramovich, et al. (2005) in the eastern Mediterranean; Govindan, Ravindran and Rangaraju (1996) from India; Maestas, et al. (2003) in USA, California; Martínez (1989) and Molina, et al. (2005) from south USA, and corresponding to *Plummerita richly* Zone of Elnady and Shahin (2001) from Egypt.

The estimation of this zone age indicates the uppermost late Maastrichtian (Li and Keller, 1998a), with a complete estimate of absolute ages based on magnetochron ages 65.30 Ma to 65.00 Ma. In the studied section, estimating absolute ages based on magnetochron age between a time span between 65.35 Ma and 65.10 Ma, high rate of sedimentation, its age is latest Maastrichtian with 4.5 m thick.

C. Biostratigraphy of Kolosh Formation-Early Danian

Twenty-five species from ten genera of planktic foraminifera have been identified in the Kolosh Formation (Fig. 7). Based on the stratigraphic ranges of the recognized species, three biozones have been recognized and were arranged from older to younger (Fig. 8), the recognized biozones in this study were correlated with different locations (Fig. 9).

The Early Danian Zones in the studied section started from the *G. cretacea* zone (P0) to the *Parasubbotina* *pseudobulloides* zone (P1), representing the presence of the Danian succession in the studied section, these zones are:

G. cretacea (P0) interval zone

The base of the zone (P0) coincides with the base of dark fine-grain sandstone with plant debris, content, and the extinction of all tropical and subtropical species and within a few centimeters of the first appearance of Danian species including *G. cretacea***,** and *Parvularugoglobigerina eugubina.* The *G. cretacea* (P0) biozone is defined by the Interval range Zone of *G. cretacea* and occurs between the Hos of the Cretaceous planktic foraminiferal genera (e.g., *Plummerita*, *Abathomphalus*, *Globotruncana*, *Globotruncanita*). The *G. cretacea* interval zone is recognized at the base of the Danian Kolosh Formation and is represented in the Dartw section by an interval extending from the samples DT-61 to DT-64 with a thickness of 0.5 m of dark green calcareous shale. This zone includes minute-sized (dwarf forms) biserial and simple planktic foraminiferal taxa of the late Cretaceous such as *H. globulosa*, *H. navarroensis, H*xeterohelix *punctulata*, *Hedbergella. monmouthensis*. The zone includes these planktic foraminifera *Woodringina claytonensis, P. pseudobulloides, Eoglobigerina eobulloides, Chiloguembelina morsei, Chiloguembelina* sp.*, Parvularugoglobigirina eugubina.* The Kolosh Formation is subdivided into three main zones and two subzones that are early Paleocene (Danian) in age (Fig. 8). The similarities of these biozones are shown clearly in the earliest Danian, where the simple forms and dwarf are associated with some Cretaceous biserial foraminifera, in addition to the opportunistic occurrence of *G. cretacea*. In the field, the base of the P0 Zone is mostly identifiable by the color change of the dark fine-grain sandstone with plant debris content of the Upper Cretaceous Tanjero Formation to the alternation of calcareous shale with argillaceous limestone of the Danian Kolosh Formation.

This zone was introduced as an indication for sediments of lowermost Dania and the index is marked as early Danian by many authors (Smit and Ten Kate, 1982; Keller, 1988; Arenillas, et al., 2000; Sharbazheri, Ghafor and Muhammed, 2009; 2011), this zone is a thin interval between last appearance of *P. hantkeninoides* and *P. eugubina*. P0 is characterized by the bloom of the disaster opportunists *Guembelitria* species. *Guembelitria* is considered the only survivor that can be used as an environmental proxy for severe biotic stress conditions (Keller and Padro, 2004). *G. cretacea* as the index for P0 was first used by Smit and Ten Kate (1982), later Keller (1988) subdivided it into P0a (*G. cretacea*) and P0b (*Globoconusa conusa*) but then P0 was reviewed as the top of mass extinction and LO of *P.eugubina* (Keller, et al., 1995). P0 in Iraq was not well defined until 21st century, most probably due to the consequence of distant sample interval in the work (Kassab, 1972; Abawi, Kireem and Yousef, 1982; Ghafor, 1988; Al-Qayim and Al-Shaibani, 1989). The *G. cretacea* Zone in this study was correlated with Sharbazheri, Ghafor and Muhammed (2009; 2011), Al-Nuaimy, et al. (2020), and Bamerni et al. (2021) inside Iraq and other records of the P0 zone globally (Fig. 9). The age estimation of this biozone by Olsson, et al. (2000) and Keller and Pardo (2004), Keller (2002) they record the earliest Paleocene (Danian), with the period of 65.00 Ma to 64.97 Ma estimating absolute ages based on magnetochron ages. In the current study, estimating absolute ages based on magnetochron age between a time span from 65.05 Ma to 64.09 Ma. Its age is the Earliest Paleocene (Danian) with 0.5 m thick.

P. eugubina (Pα) total range zone

The Pα is a biozone defined by the total range of the nominal taxon *P. eugubina*. The *P. eugubina* Total Range Zone is identified in the studied section from the sample DT-65 to DT-68, with a thickness of 19.5 m of alternation of dark grey calcareous shale, alternation of calcareous shale with argillaceous limestone and sandstone. This zone has an increase in the diversity and abundance of the Danian cosmopolitan planktic foraminifera including: *Parvularugoglobigirina eugubina, G. cretacea - P. pseudobulloides, Globoconusa. daubjergensis*, *Woodringina hornerstownensis*, *Woodringina claytonensis*, *Chiloguembelina midwayensis*, *Chiloguembelina. trinitatensis*, *Chiloguembelina. cubensis*, besides the abundant and continuous extension of *G. cretacea*, this zone also has minute-sized, simple late Cretaceous taxa such as *Heterhelix globulosa*, *H. punctulata*, and *H. monmouthensis*. The P*α* in the section correlated to Bamerni, et al. (2021) in northern Iraq, Sharbazheri, Ghafor and Muhammed (2009; 2011), and Al Nuaimy, et al. (2020) in Northeastern Iraq. Bamerni, et al. (2021) recorded 52 and 27cm thickness for two sections in Duhok and documented the occurrence of *Globoconusa daubjergensis, Woodringina hornerstownensis, Woodringina claytonensis Eoglobigerina bulloides*, *Eoglobigerina fringa*, *Eoglobigerina edita*, *Chiloguembelina midwayensis, Chiloguembelina trinitatensis, Chiloguembelina cubensis*, *Globanomalina archaeocompressa*, *Globanomalina australiformis*, *Globanomalina chapmani*, *Globanomalina planocompressa*, *Guembelitria trifolia, Parasubbotina* aff. *pseudobulloides* Besides the abundant and continuous extension of *G. cretacea*, this zone also has minute-sized, simple late Cretaceous taxa such as *H. globulo*sa, *H. striata*, *H. punctulata*, *Heterohelix labelosa*, *Heterohelix navaroensis*, *H. monmouthensis*, *Pseudigumbelina. costulata*, *Archaoglobigerina blowi* and *R. hexacamerata*. The age estimation of this biozone by Olsson, et al. (2000); Li and Keller (1998a); Keller and Pardo (2004), Keller (2002), records the earliest Paleocene (Danian), with the period of 64.97 Ma to 64.90 Ma estimating absolute ages based on magnetochron ages. In the current study, estimating absolute ages based on magnetochron age between a time- span between 64.96 Ma and 64.90 Ma. Its age is the Earliest Paleocene (Danian)with 19.5-m thick.

P. pseudobulloides (P1) total range zone

P. pseudobulloides zone is defined by the total Range zone of *Parasubbotina pesudobulloides,* this zone is subdivided into two subzones (P1a, and P1b), 6.2 m thick from the sample numbers DT-68 to DT0-71. Leonov and Alimarina (1961) introduced *Globorotalia* (*Turborotalia*) *pseudobulloides-Globorotalia daubjergens*, later Bolli (1966) renamed as *Globigerina pseudobulloides* PRZ. Berggren and Miller (1988) and Berggren, et al. (1995) defined this zone by LOD of *P.eugubina* and LOD of *Praemurica uncinate.*

Globoanomalina archaeocompressa (P1a) partial range subzone

This Subzone is defined as a partial range of the nominal taxon, between the FAD of *G. archaeocompressa* and FAD of *Subbotina triloculinoides, G. archaeocompressa* Subzone (P1a) is represented in the studied section in the sample DT-69 and DT-70 with a thickness of 6 m. Many Danian planktonic foraminiferal species are identified throughout this subzone: - *P. pseudobulloides, Guembelitria trifolia*, *Subbotina inaequispira*, *Woodringina hornerstownensis*, *Woodringina claytonensis*, *Globaanomalina archaeocompressa*, *Globaanomalina planocompressa*, *Globaanomalina australiformis*, *Globaanomalina chapmani*, *Globaanomalina ehrenbergi*, *Globaanomalina imitate*, *Globoconusa daubjergensis*, *Chilogumbelina midwayensis*, *Eoglobigerina eobulloides*, *Eoglobigerina fringa*, *Chiloguembelina midwayensis, Pararugoglbigerina alabamensis*, and *Praemurica pseudoinconstans*. The *G. archaeocompressa* (P1a) subzone spans an interval of 6 m in the studied section. this zone is comparable with the P1a subzone of Sharbazheri, Ghafor and Muhammed (2009; 2011) and Al-Nuaimy, et al. (2020). It is also comparable with the global record of this zone (Fig. Correlation). Bamerni, et al. (2021) recorded 2 and 2.5 m thickness of this zone in Duhok with occurrence if identified population as *Gumbelirita cretacea*, *Gumbelirita trifolia*, *Wodringina hornerstownensis*, *Wodringina claytonensis*, *Globanomalina archaeocompressa*, *Gloanomalina planocompressa*, *Globanomalina australiformis*, *Globanomalina chapmani*, *Gloanomalina. ehrenbergi*, *Gloanomalina Imitate*, *Globocnusa daubjergensis*, *Chiloguembelina. midwayensis*, *Eoglobigerina eobulloides, Eoglobigerina fringe, Praemurica alabamensis*, *Praemurica pseudoinconstans*, and *Praemurica inaequispira*. The age estimation of this interval depends on Magnetic polarity and recorded datum events by Olsson, et al. (2000) and Keller and Pardo (2004), Keller (2002) with the period of 64.90 Ma from the end of *P. eugubina* to 64.50 Ma first occurrence of *S. triloculinoides*, estimating absolute ages based on magneto chron ages 400 Ky with 10 Ky/m. In the current study, estimating absolute ages based on magnetochron age between a time span between 64.90 Ma and 64.50 Ma. Its age is the earliest Paleocene (Danian) with 6 m thick.

S. triloculinoides (P1b) interval subzone

This subzone represents the biostratigraphic interval between the LO of *S. triloculinoides* and the LO of *Globanomalina planocompressa*. In the studied section, it extends from the samples DT-70 and DT-71, with a thickness of 0.2 m of alternation of dark grey calcareous shale (marl) with argillaceous limestone, 3 m sandstone beds of 6 cm thick at the top. Argillaceous limestone beds are 40 cm thick between very thick beds of calcareous shale. sandstones are medium-grained and mostly friable. In addition to the abundance of the marker species of this subzone *S. triloculinoides*, it also shows the continuation of the previous P1a subzone taxa such as *Woodringina hornerstownensis*, *Woodringina claytonensism S. triloculinoidesm, Globaanomalina planocompressa*, *Globaanomalina chapmani*, *Chilogumbelina midwayensis*, *Pararugoglbigerina alabamensis*, and *Praemurica pseudoinconstans*. The P1b zone was introduced by Berggren and Miller (1988), and the zone was revised by Berggren and Miller (1988). The zone correlated to P1b of Sharbazheri, Ghafor and Muhammed (2009; 2011) and Al-Nuaimy, et al. (2020). Its intervals span 2 and 4 m in the Duhok area, Northeastern Iraq, by Bamarnii, et al. (2021). They also recorded these species assemblage in Duhok as *Woodringina hornerstownensis*, *Woodringina claytonensis*, *Globaanomalina. archaeocompressa*, *Globaanomalina planocompressa*, *Globaanomalina chapmani*, *Praemurica pseudoinconstans*, *Pararugoglbigerina alabamensis, Subbotina inaequispira*, and *Chiloguembelina midwayensis.*

The age estimation of this interval depends on Magnetic polarity and recorded datum events by (Olsson, et al. (2000) and Keller and Pardo (2004), Keller (2002) with the time span of 64.5 Ma from the first occurrence of, *S. triloculinoides*, to FAD of *Globanomalina compressa* and/or *Praemurica inconstans* at the top of 63 Ma. In the current study, estimating absolute ages based on magnetochron age between a time-span between 64.50 Ma and 63.01 Ma, Its age is the Earliest Paleocene (Danian), with 0.2 m thick.

V. Conclusion

The Cretaceous/Plaeogene boundary in the Dartw section, south-west of Sulaymaniyah, reveals an expanded late Maastrichtian to Early Danian, and the boundary transition covers the uppermost part of the Tanjero Formation (late Maastrichtian) and the entire Kolosh Formation (Danian). Planktic foraminifera were very abundant and diversified during the late Cretaceous and early Danian in the studied section. The biozonation of the K-Pg boundary in the Dartw section shows continuous sedimentation based on the recognized planktic foraminifera, which subdivided into four zones of the Upper Cretaceous Tanjero Formation:

(i). *R. fructicosa* Interval Zone (CF4).
(ii). *P. hariaensis* Concurrent Range Zone (CF3)
(iii). *P. palpebra* Partial Range Zone (CF2),
(iv). *P. hantkeninoides* Total Range Zone (CF1),

While three Danian planktic foraminiferal biozones and two subzones have been recorded from the Kolosh Formation:

(i). *G. cretacea* (P0) Interval Zone,
(ii). *P. eugubina* (Pα) Total Range Zone, and
(iii). *P. pseudobulloides* (P1) Partial-Range Zone
  (a) *G. archaeocompressa* (P1a) Partial Range Subzone, and
  (b) *S. triloculinoides* (P1b) Interval Subzone.

Late Maastrichtian planktic foraminifera were much diversified and some species reached a very large size. The present biostratigraphic study provides compelling evidence for a complete K/Pg transition at the studied locality in the Dartw section.

A. Declaration

The authors declare that they have no conflicts of interest.

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