BIOSTRATIGRAPHY OF THE CRETACEOUS/PALEOGENE BOUNDARY IN DOKAN AREA, SULAIMANIYAH, KURDISTAN REGION, NE IRAQ

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ABSTRACT
The studied area is located within the High Folded Zone in Dokan area, northeastern Iraq. The Cretaceous/Paleogene boundary consists of flysch clastic beds of Tanjero and Kolosh formations, interbedded with marl. The study is achieved on the outcrops of the uppermost part of the Late Cretaceous successions (upper part of Tanjero Formation) and the Early Paleogene (lowermost part of Kolosh Formation). Based on identified planktonic foraminiferal assemblages, five biozones were recorded from the upper part of the Tanjero Formation, these zones are from bottom to top: Pseudotextularia intermedia Interval Zone (CF5), Racemiguembelina fructicosa Interval Zone (CF4), Pseudoguembelina hariaensis Interval Zone (CF3), Pseudoguembelina palpebra Interval Zone (CF2), Plummerita hantkeninoides Total Range Zone (CF1) and two biozones were recorded from the lower part of Kolosh Formation, which are: (P1a) Parvularugoglobigerina eugubina – Subbotina triloculinoides Interval Zone and (P1b) Subbotina triloculinoides – Globanomalina compressa/Präemurica inconstans Interval Zone.

The result of the present study (in contrast to previous studies) shows that the Early Danian is found for the first time in the sediments of the Kolosh Formation. It is possible that the other two zones: P0 (Guembelitria cretacea Zone), and Pa (Parvularugoglobigerina eugubina Zone) were not recorded completely or continuously in the studied area. The biostratigraphic correlations; based on planktonic foraminiferal zonations showed a comparison between the biostratigraphic zones, which were established in this study with other equivalents of the commonly used planktonic zonal scheme around the Cretaceous/Paleogene boundary, in and outside Iraq.

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INTRODUCTION

The Tanjero and Kolosh basin, as a part of the Neo-Tethys, was strongly deformed by the Alpine Orogeny during their activity, which continued from Cretaceous to Miocene; where a huge thickness of sediments were accumulated. These sediments are generally well exposed in different localities and in different types of stratigraphic units in Zagros mountain regions such as Balambo, Qulqula, Qamchuqa, Aqra – Bekhme, Kometan, Shiranish and Tanjero formations, in addition to the Kolosh and Gercus formations, and the Red Bed Series. The basins of these units have a complicated history of development and tectonics, this history was demonstrated by different characteristics of these stratigraphic units.

This study deals with the biostratigraphy of Cretaceous/ Paleogene boundary, as represented by a sequences in Qulka section, Dokan area, Kurdistan Region, NE Iraq. The zonation depends on planktonic foraminifera of the Late Maastrichtian and Early Paleocene in the Tanjero and Kolosh formations, respectively.

The studied area is located at the southern boundary (in front) of the Zagros Thrust Belt, which is developed from the basin fill of the Neo-Tethys and collision of the Iranian and Arabian Plates. Structurally, the studied area is located within two different zones (Buday and Jassim, 1987) (Fig.1).

The aim of this study includes the following aspects:
- Complete and high resolution biostratigraphic zonation of the studied area.
- Regional biostratigraphic correlation of the sections within the studied area and global correlation with other similar sequences.
- Indicating the age of the sequences, by using the new zonal scheme and the age of planktonic foraminiferal datum events with correlative and relative methods.
- The nature of the contact between Late Maastrichtian and Early Paleocene.

The Late Cretaceous and Early Paleogene sedimentary rocks in Iraq have been the subject of numerous stratigraphic and paleontological investigations. Such sediments are well developed in both surface and subsurface, sections and especially the exposed part in north and northeastern parts of the Iraqi territory.

STUDIED FORMATIONS

The following formations are concerned in this study.

- Tanjero Formation

According to Bellen et al. (1959), the Tanjero Formation is first defined and described under the name of Tanjero Formation by Dunnington (1952) from the selected type section at Sirwan valley, 2 Km to the south of Kani Karweshkan village, near Halabja town (Fig.1) and at the right bank of Sirwan river (upstream of Dialla River). The type section comprises two divisions: The lower division comprises pelagic marl, and occasional beds of argillaceous limestone, with siltstone beds in the upper part (Bellen et al., 1959). The upper division comprises of silty marl, sandstone, conglomerate, and sandy or silty organic detrital
Fig. 1: Location and geological map of the studied area (after Sissakian et al., 2000)
limestone, it interfingers with the Aqra Formation. The sandstone is composed predominantly of grains of chert and green igneous and metamorphic rocks. The conglomerates contain pebbles of Mesozoic limestones, dolomites, recrystallized limestones and radiolarian chert. The thickness of the formation is highly variable. The maximum thickness of the formation is about 2000 m between Rowandooz and Chwarta (Jassim and Goff, 2006).

The outcrops of Tanjero Formation extend into southeast Iran, where it was referred to as the Maastrichtian flysch by Kent et al. (1952) in Jassim and Goff (2006), and described as chert conglomerate by James and Wynd (1965). In Turkey, the Cretaceous parts of the Garmav Formation are equivalent to the Tanjero Formation (Buday, 1980).

Abdel-Kireem (1986a) suggested to remove the word "clastic" from the name of the formation and to add its lower part within the Shiranish Formation, during his study of the formation within the stratigraphy of Upper Cretaceous and Lower Paleogene of Sulaimaniyah – Dokan region. Abdel-Kireem (1986b) subdivided the formation into three units according to the microfacies and lithofacies during their study on planktonic foraminifera and stratigraphy of Tanjero Formation.

Karim (2004 and 2006), Karim and Surdashy (2005a, 2005b and 2006) investigated in detail the basin analysis, paleocurrent, tectonic history and sequence stratigraphy of the Tanjero Formation. They indicated an unconformity at the lower part of the formation, which was represented by about 500 m of boulder and gravel conglomerate, and found about four main incised valleys in the Sulaimaniyah area during Maastrichtian. They mentioned that this conglomerate is deposited during sea level fall (lowstand system tract).

- **Kolosh Formation**

The Kolosh Formation was first described by Dunnington (1952) in Bellen et al. (1959) at Kolosh village, north of Koy Sanjaq in the High Folded Zone; Ditmar et al. (1971) mentioned the occurrence of Sinjar Formation too at its upper part in the type locality. The formation according to the original description consists of shale and sandstone composed of green rock, chert, and radiolarite.

Bellen et al. (1959) described the following units from Kolosh type locality from the top to the base:
- 144 m of limestone and marl, with Miscellanea miscella, ostracods and miliolids.
- 30 m of limestone, with Dictyokathina simplex Smout, Lokhartia sp., Valvulinids, miliolids, ostracods.
- 113.5 m of limestone and shales, red shales and sandstone, with the same fossils but without Dictyokarthina simplex Smout.
- 6 m of limestone, with Saudia labyrinthica; miliolids and rotaliids.
- 410 m of blue shale and green sand.

According to Ditmar et al. (1971), the following fossils were distinguished in the type locality: Ammodiscus incertus, Globorotalia angulata, Globigerina bulloides, Gyroidina soldanii, Loxostoma applinae, Nodosaria zippei, Nuttalides trumpyi, Pseudovalvulinera sp., Teredolites sp., Ovulites molleti, O. cf. elongata, Trinocladus perplexus, Griphoporella Arabica, Funcoporella diplopora and Cymoporella sp.

Toward the west, the formation comprises of distal lithologic character of mudstone, siltstone, and argillaceous limestone beds; in subsurface sections at Cham Chamal, Taq Taq and Mushorah region (Jassim and Goff, 2006).

The biostratigraphy of Kolosh Formations was studied by Kassab (1972, 1974, 1975, 1976 and 1978) and Kassab et al. (1986) at the type locality and other locations in north and northeast of Iraq. They recognized the planktonic foraminiferal zones of lowermost Middle Paleocene, represented by Globorotalia uncinata Partial Range Zone.
The Late Cretaceous and Early Paleogene contact in Iraq is marked by one of the most dramatic extinction of different groups of organism; especially the planktonic foraminifera. The recognition of the major paleoclimatic change during the Late Maastrichtian has focused new attention on global climatic changes and their effect on marine organism. In particular, the last half million years of the Maastrichtian is increasingly recognized as a time of rapid and extreme climatic changes; characterized by maximum cooling at about 65.5 Ma, followed by (3 – 4)° C greenhouse warming and major Deccan volcanic activity between (65.4 – 65.2) Ma. (Li and Keller, 1998a and Keller, 2001).

Dunnington (1952 and 1957), recorded the indication of great gap in the stratigraphic column, in his biostratigraphic studies about the nature of the Cretaceous/ Tertiary contact in Dohuk, Aqra and northern Iraq. It is evidenced by the period of great regression of the ocean during Late Maastrichtian and Early Paleocene time, followed by the uplifting of the area due to the tectonic orogeny; consequently this region underwent the process of erosion and period of non-deposition. This phenomenon is applied for almost larger parts of Iraq, exactly in the region of the northern and northeastern parts.

Al-Omari (1970) during his study of foraminifera of Mesozoic and Cenozoic in wells Butmah 9 and Ainzala 16 and 17 from the northwestern part of Iraq, confirmed that the Alajji Formation overlies the Shiranish Formation unconformably. Other biostratigraphic studies carried out in Iraq, especially in the studied area are summarized in Fig. (2).

Al-Shaibani et al. (1986) during their stratigraphic analysis of the Tertiary – Cretaceous contact in Dokan area (North Iraq), placed the contact in Zone P3 ( Middle Thanetian), based on overlapping of the range of 

\[ \text{Globorotalia (T.) trinidadensis Bolli, and Subbotina velascoensis Cushman,} \]

and other species.

Ghafor and Karim (1999), during their study of biostratigraphy of the upper part of Kolosh Formation from Sartaq-Bamo area, in northeastern Iraq, recognized the 

\[ \text{Globorotalia velascoensis Zone of Upper Paleocene age.} \]

The measured part of the studied section covers 163 m of the upper part of Tanjero Formation and 54 m from the lower part of Kolosh Formation. The detailed stratigraphic section is shown in Figs. (3 and 4), on both sides of conglomerate bed (Fig.5), which was formerly supposed to be the contact or key marker for Cretaceous/ Paleogene contact in the studied area; by different authors.

All samples were collected from the studied sections at the field after removing the surface contaminated soil and trying to obtain fresh and un-weathered materials, samples were collected at interval ranged between (20 – 50) cm at or near the Cretaceous/ Paleogene contact and at interval of 50 cm to 3 m away from the contact.

The well exposed rocks of the studied section of Tanjero Formation, in Qulka section is represented by 63 m of olive green to pale grey marl, and bluish white calcareous marl, intervened by streak of limestone veins, and then 3 m dark grey to olive green soft, friable sandstone; occasionally with siltstone, clay ball and pillow structure was observed at the middle part of this interval. Followed by 59 m of interfingering Aqra Formation, which consists of well bedded, ridge forming recrystallized pale grey to yellow limestone and sandstone to silty limestone; occasionally dolomitized intercalated by thin beds of shale, calcareous shale, marl and sandstone beds through this interval.
Fig. 2: Correlation of the previous biostratigraphic zonation of Cretaceous/Paleogene contact at different localities in Iraq.
Fig. 3: Schematic geologic cross section of Dokan area
Fig. 4: Lithostratigraphic column of Qulka section in Dokan area showing lithologic characters
(Not to scale, the thickness is shown on each unit)
Fig. 5: a) The conglomerate bed of 1.5 m thick, which was previously concluded to be the contact line of Cretaceous/ Paleogene boundary in Dokan area by different authors.

b) Soft, friable and weathered intraformational conglomerate and pebbly sandstone from the lower part of Kolosh Formation, rich in reworked fossils of corals, gastropods, pelecypods, echioids and brachiopods.

The Aqra Formation is overlain by 41 m of Tanjero flysch type emergence; again by alternation of olive green to dark grey calcareous shale, marl, thinly bedded sandy limestone, friable weathered sandstone, some pebbly sandstone, bluish white marl, marly siltstone, thinly bedded recrystallized limestone, with clay ball and pillow structure.

In the studied section, it is significant to mention that there are 3 conglomerate beds at the upper part of this unit, with thickness of (0.5, 1.5 and 0.2 m), respectively. The conglomerate bed, which is with thickness of 1.5 m was previously concluded to be the marker bed of Cretaceous/ Tertiary contact, in the studied section by different authors (Fig. 5). Whereas the negate event is that the exact Cretaceous/ Paleogene contact comes after 14 m above the previously mentioned contact, without any obvious change in lithologic characters; between Tanjero and Kolosh formations as represented in sample K20, with the first appearance of Paleocene index foraminiferal taxa and disappearance of the Upper Cretaceous planktonic foraminifera of Globotruncanids, Heterohelicids and Rugoglobigerinids. The contact is placed at the base of friable, soft and weathered fine sandstone and silty sandstone of 5 m thickness, with dilution of foraminiferal content by abrupt change and without Cretaceous planktonic foraminifera.

The recognition of the major paleoclimatic transform during the Late Maastrichtian has focused new attention on climatic changes and their effect on marine organisms; this was reflected on foraminiferal survivorship in the studied area.

The Kolosh Formation consists of 5 m soft, friable, weathered sandstone, siltstone at the base, followed by dark grey shale, olive green marl and organic rich shale, alternated with thin layer of siltstone, fine sandstone, occasionally intervened with thin marly limestone layers, and 2 m of sandstone, pebbly sandstone and friable conglomerate (Fig. 5), rich in reworked fossils of solitary corals, and small gastropods, pelecypods and brachiopods at the middle part of the studied interval.
BIOSTRATIGRAPHY

The comprehensive studies of planktonic foraminiferal biostratigraphy during the last five decades have proved to be more useful and more accurate way among the large number of micropaleontological branches, especially the benthonic foraminifera.

The comprehensive and motif plan, in this work was deduced from the recent planktonic foraminiferal zonation and correlation for the sediments in tropical – subtropical regions, which is widely based on those of Berggren and Miller (1988), Li and Keller (1998a and b), Liu and Olsson (1992), Berggren et al. (1995), Berggren and Norris (1997), Olsson et al. (2000), Arenillas et al. (2001), Elnady and Shahin (2001), Samir (2002), Abramovich et al. (2002), Keller (2002 and 2004), Abramovich and Keller (2003), Obaidalla (2005), Smit (2005), and Sharbazheri (2007). Fortunately, these zonations proved satisfactory successful results, essentially achieved in different localities of the world.

According to the identified planktonic foraminiferal assemblages (Figs.6, 7 and 8), within the Tanjero and Kolosh formations the two formations are divided into 7 biozones from bottom to top, as described hereinafter (Fig.9).

**Pseudotextularia intermedia Partial Range Zone (CF5) (Part)**

Fig. 6

A and c) *Abathomphalus mayaroensis* (Bolli)
A and b) Spiral view
c) Umbilical view, Tanjero Formation, Late Maastrichtian, specimen from *R. fructicosa* Zone
d) *Pseudoguembelina hariaensis*, Nederbragt. Tanjero Formation, Late Maastrichtian, specimen from *P. hariaensis* Zone
e and f) *Pseudoguembelina palpebra*, Bronnimann and Brown. Tanjero Formation, specimen from *P. palpebra* Zone
g) *Plummerita hantkeninoides* (Bonnimann). Tanjero Formation, Late Maastrichtian, specimen from *P. hantkeninoides* Zone
h and i) *Globotruncana falsostuarti*. Sigal, 100X, Tanjero Formation, Late Maastrichtian, specimen from *R. fructicosa* Zone
j) *Contusotrancana falsocalcarata*, Kerdany and Abdelsalam, 100X, Tanjero Formation, Late Maastrichtian, specimen from *Plummerita hantkeninoides* Zone
k and l) *Globotruncanita stuartiformis*, (Dalbiez). 100X, Late Maastrichtian, specimen from *R. fructicusa* Zone, Tanjero Formation

Scale bar represents magnification on the specimens
Fig. 7

A and b) *Globotruncanita conica* White, 100X, Tanjero Formation, Late Maastrichtian, Dokan, specimen from *R. fructicusa* Zone

e) *Contusotrancana contusa* (Cushman), 100X, 6 and 7-Tanjero Formation, Late Maastrichtian, specimen from *P. hariaensis* Zone

d) *Plummerita hantkeninoides* (Bronnimann), 100X, Tanjero Formation, Late Maastrichtian, specimen from *Plummerita hantkeninoides* Zone

e and f) *Rugoglobigerina rugosa* (Plummer), 100X, Tanjero Formation, Late Maastrichtian, specimen from *P. hariaensis* Zone

g) *Rugoglobigerina pennyi* Bronnimann, 100X, Tanjero Formation, Late Maastrichtian, specimen from *P. hariaensis* Zone

h) *Rugoglobigerina hexacamerata* Bronnimann, 100X, Tanjero Formation, Late Maastrichtian, specimen from *R. fructicusa* Zone

i) *Hedbergella monmuthensis* (Olsson), 100X, Tanjero Formation, Late Maastrichtian, specimen from *Plummerita hantkeninoides* Zone

j and k) *Pseudotextularia elegans* (Rzehak), 100X, Tanjero Formation, Late Maastrichtian, specimen from *P. hariaensis* Zone

l) *Planoglobulina acervulinoides* (Egger), 100X, Tanjero Formation, Late Maastrichtian, specimen from *P. hariaensis* Zone
Fig. 8

A and d) *Subbotina triloculinoides* (Plummer), a-side view
B and d) Spiral view
c) Umbilical view, Early Paleocene, Kolosh Formation, Dokan, specimen from (P1b)
   *Subbotina triloculinoides* – *Globanomalina compressa*/*Praemurica inconstans* Zone
e) *Heterohelix globulosa* (Ehrenberg), 100X, Tanjero Formation, Late Maastrichtian,
   Dokan, specimen from *P. hariaensis* Zone
f and h) *Parasubbotina pseudobulloides* (Plummer), f-side view
g) Umbilical view, h-spiral view, Early Paleocene, Kolosh Formation, Dokan, specimen
   from P1a) *Parvularugoglobigirina eugubina – Subbotina triloculinoides* Zone
i and m) *Globanomalina archaeocompressa* (Blow)
I and k) Spiral view
J and l) Umbilical view
m) Side view, Early Paleocene, Kolosh Formation, Dokan, specimen from (P1a)
   *Parvularugoglobigirina eugubina – Subbotina triloculinoides* Zone

Scale bar represents magnification on the specimens
**Biostratigraphy of the Cretaceous/ Paleogene Boundary**

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Fig.9: Biostratigraphic range chart of planktonic foraminifera of the Cretaceous/ Paleogene boundary in Dokan area

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Woodringina clytonensis (Loeblich & Tappan) = horntownerensis (Olsin) Chiloguembelina Morse (Kline) = midwayensis (Cushman) Globobuconus daubjergensis Brommann) Parabuliminina pseudohamilites (Plummer) Subbotina trivialis (Subbotina) = triloculinoides (Plummer) Globanomalina archeocompressa (Shutskaya) Eoglobigerina edulis (Subbotina) = eubuloides Moreeova = simplicissma Blow Praemurica taurica (Morozova) = pseudoconstans (Blow) Gumbelitrix cretacea Cushman

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Due to high similarities of foraminiferal occurrences, the present zone (CF5) is equivalent to that of Li and Keller (1998b), Abramovich et al. (2002), Samir (2002). It is most likely equivalent to the upper part of Gansserina gansseri Zone, recorded in the North and Northeast of Iraq and different regions of the world (Al-Mutwali and Al-Jubouri, 2005, Al-Mutwali, 1996, Hammoudi, 2000, Caron, 1985; Obaidalla, 2005), (D’Hont and Keller, 1991). It is also equivalent to the upper part of Glt. contusa Zone of Abawi et al. (1982) and Abdel-Kareem, (1986a), and Glt. Contuse – R. fructicosa Zone of Premoli-Silva and Sliter (1995 and 1999) from Italy, and Abdel-Kareem and Samir (1995) in Egypt.

The Pseudotextularia intermedia Zone spans about 0.73 Myr (69.06 – 68.33 Ma), (730 Ky/19) m estimated absolute ages based on magnetochron ages with 38.5 Ky/m of moderate rate of deposition.

Age: late Early Maastrichtian.

Note: It is important to mention that the Pseudotextularia intermedia Zone was recorded also from the other studied sections (only the upper part) in which the lower limit was not studied. This biozone is represented by moderate diversity of planktonic foraminiferal assemblage by 43 species, in the studied area.

**Racemiguembelina fructicosa Interval Zone (CF4)**

Racemiguembelina fructicosa Zone (CF4) was introduced by Smith and Pessagno (1973) as a biostratigraphic interval between FAD of Racemiguembelina fructicosa (Egger); at the base and the FAD of Pseudoguembelina hariaensis Nederbragt; at the top. The FAD of Racemiguembelina fructicosa (Egger), in the studied section was recorded from the uppermost part of reddish to pale brown unit and covers the basal part of the Tanjero Formation (sample no. 38) to the FAD of Pseudoguembelina hariaensis Nederbragt, within the Tanjero Formation (sample no. 58).

It is important to mention that the zonal scheme of Cretaceous foraminifera (CF) proposed by Li and Keller (1998a and b), which replaces the Abathomphalus mayaroensis Zone, with four zones (R. fructicosa Zone, P. hariaensis Zone, P. palpebra Zone and P. hantkeninoides Zone), for a much improved age estimation for the late Maastrichtian.

The total range zone of A. mayaroensis Zone characterizes the Upper Maastrichtian in low latitude regions as well as the Tethyan paleogeographic realm. However, it has been found that A. mayaroensis is very rare or absent in high latitude regions (Blow, 1979) and in the present section also, consequently it is more accurate to use the new zonal scheme.

Most of the workers in the zonal scheme placed Racemiguembelina fructicosa Zone at the lower Late Maastrichtian (Li and Keller, 1998a and b; Abramovich et al., 2002), at DSDP Site 525 A, Keller et al. (1995), from Tunisia, Obaidalla (2005) and Samir (2002), from Egypt.

As defined above, the present Biozone (CF4) is correlatable with the lower part of A. mayaroensis of Abawi et al. (1982), Abdel-Kareem (1986a) and Premoli Silva and Sliter, (1995, 1999).

The age estimation of this biozone by Li and Keller (1998a), records the time span between (68.33 – 66.83) Ma (13.5 Ky/m) high rate sedimentation in Sirwan area, and high rate of deposition in Dokan area (18 Ky/m).

Age: Early – Late Maastrichtian.

**Pseudoguembelina hariaensis Interval Zone (CF3)**

The Pseudoguembelina hariaensis Zone was defined by Nederbragt (1990) as the interval of the nominate species between the FAD of Pseudoguembelina hariaensis Nederbragt and the LAD of Gansserina gansseri (Bolli). In the studied area, this zone is also marked by the

As defined above, the present biozone (CF3) is correlatable with the zone recorded by Li and Keller (1998a), records Middle – Late Maastrichtian, with time span of (66.83 – 65.45) Ma, estimating absolute ages based on magnetochron ages.

**Age:** Middle – Late Maastrichtian.

### Pseudoguembelina palpebra Partial Range Zone (CF 2)

This Zone (CF2) defines the interval between the LAD of *Gansserina gansseri*; at the base to the FAD of *Plummerita hankenioides*; at the top. Li and Keller (1998a) introduced this zone from DSDP Site 525A. The recorded planktonic assemblages of this zone are characterized by the same number (50 species diversity) with underlying *Pseudoguembelina hariaensis* Zone, and marked by the extinction of *Heterohelix punctulatus* (Cushman), *Gansserina gansseri*, *Globigerinelloides volutes* (White), and *Laeviheterohelix glabrans* (Cushman), at the upper part of this zone. Besides, the planktonic foraminifer species enduring from the underlying biozones, some species show their first appearance, e.g. *Globotruncanina falsoscalcarata* Kerdany and Abdelsalam, *Globotruncanella* sp. and *Trinitella scotti* Brominmann appeared for the first time with this zone.

The *Pseudoguembelina palpebra* Partial Range Zone (CF 2) in Sirwan valley displays spans of 25 m (Fig.9), biostratigraphically represented by decreasing species number from 49 to 38 species, and there is no any distinctive appearance of new species with this zone. The planktonic foraminifer assemblages of this zone, in the studied section is represented by
**Plummerita hantkeninoides** Total Range Zone (CF 1)

The biostratigraphic interval of this zone is defined by the total range of the nominate taxon, *Plummerita hantkeninoides* (Bonnimann). Masters (1984) introduced this zone for the first time in Egypt, introduced the *P. hantkeninoides* Zone for the latest Maastrichtian of Spain. It marks the uppermost Cretaceous biozones; as its top marks boundary of Dokan area.


The age estimation of this biozone by Li and Keller (1998a), records the upper Late Maastrichtian, with the time span of (65.45 – 65.30) Ma; estimating absolute ages based on magnetoconchon ages.

**Age:** upper Late Maastrichtian.
As defined above and based on the associated planktonic foraminiferal assemblage, the present *Plummerita hantkeninoides* Total Range Zone (CF 1) is equivalent to the same zone recorded from Tunisia (Li and Keller, 1998b); Eastern Tethys (Keller, 2004), Egypt (Keller, 2002, Samir, 2002 and Obaidalla, 2005), Pardo *et al.* (1996), Keller (1996) in Tunisia (Arenillas *et al.*, 2000 a and b); to the upper part of Zone (CF 1 – 2) from South Atlantic DSDP Site 525A (Li and Keller, 1998a); and Madagascar (Abramovich *et al.*, 2002); DSDP Site 525A (Abramovich and Keller, 2003); USA (Stinnesbeck *et al.*, 2004). The present *Plummerita hantkeninoides* Zone is equivalent to the upper most part of *Abathomphalus mayaroensis* Zone recorded from different parts of the world (Canudo *et al.*, 1991), (Smit, 2005); and (Chacon and Martin-Chivelet, 2005) Spain; (Premoli-Silva and Sliter, 1995 and 1999), Italy; (Premoli-Silva *et al.*, 1998), eastern Mediterranean; (Govindan *et al.*, 1996), India; (Maestas *et al.*, 2003), USA, California; (Luning *et al.*, 1998), south USA. And equivalent to *Plummerita reicheli* Zone of (Eludy and Shaqin, 2001 and Shaqin, 1992), from Egypt. The present *Plummerita hantkeninoides* Zone is equivalent to the *Kassabiana falsocalcarata* Zone recorded from Chalki village and Sirwan valley (Kassab *et al.*, 1986), (Kassab, 1976) and Tel Hajar 1 (Ghafor, 1988).

The age estimation of this biozone by Li and Keller (1998a), records the uppermost Late Maastrichtian, with the time span of (65.30 – 65.00) Ma, estimating absolute ages based on magnetostratigraphic ages, 12 Ky/m high rate of sedimentation, in the studied area.

**Age:** Latest Maastrichtian.

* (P0 and Pa) in Dokan area

In the present study, the earliest Paleocene *Guembelitria cretacea* Zone (P0), and *Parvularugoglobigerina eugubina* Zone (Pa) were not recorded completely or continuously in the studied area.

The Cretaceous/ Paleogene boundary in Dokan area is placed on the bottom of soft, weathered friable, fine grained sandstone and claystone of 5 m thickness, with very rare occurrence (few individuals) of *Guembelitria cretacea* Cushman and *Globoconusa daubjergensis* (Bormann), in the uppermost part of the sandstone unit. The age estimation of this interval; depending on Magnetic polarity and recorded datum events by Olsson *et al.* (2000) and Keller (2002 and 2004), with the time span of 65.00 Ma, the end of *Plummerita hantkeninoides* to 64.90 Ma; the last occurrence of *Parvularugoglobigerina eugubina*, estimating absolute age based on magnetostratigraphic ages, 100 Ky with 20 Ky/m; high rate of deposition, in the studied section.

The presence of significant amount of three local conglomerate beds in the uppermost part of the Tanjero Formation in the studied section, could be attributed either to its extremely short duration, or its restriction to near shore, or diluted in foraminiferal survivorship, rather than open ocean environments as outlined by Berggren and Norris (1997).

* (P1a) *Parvularugoglobigerina eugubina – Subbotina triloculinoides* Interval Subzone

**Definition:** Biostratigraphic interval between the LAD of *Parvularugoglobigerina eugubina* and the FAD of *Subbotina triloculinoides*. P1a; is defined in Berggren *et al.* (1995); emendation of *Parasubbotina pseudobulloides* Subzone (P1a), in Berggren and Miller (1988). In the present study, the P1a Subzone attains a thickness of 40 m, the associated planktonic foraminiferal assemblages are represented by complete occurrences of the following species: *Woodringina clytonensis* (Loeblich and Tappan), *W. hornerstownensis* (Olsson), *Chiloguembelina morse* (Kline), *W. midwayensis* (Cushman), *Globoconusa daubjergensis* (Bronnimann), *Parasubbotina pseudobulloides* (Plummer), *Subbotina trivalis* (Subbotina), *Globanomalina archeocompressa* (Blow), *S. planocompressa* (Shutskaya), *Eoglobigerina*
edita (Subbotina), *E. eobulloides* Morozova, *E. simplicissma* Blow, *Praemurica taurica* (Morozova), *P. pseudoinconstans* (Blow), *Guembelitria cretacea* Cushman, in which the *Guembelitria cretacea* Cushman is represented in the lower part, and the *Woodringina clytonensis* (Loeblich and Tappan) and *Globoconusa daubjergensis* (Bonnimann) are prolonged to the middle part of this biozone. Based on faunal similarities, the combined P1a Subzones of the studied sections could be equivalent to the lower part of *Morozovella pseudobulloides* Zone of Bolli (1966), Caron (1985), P1a Subzone of Blow (1979), Elnady and Shahin (2001), from Egypt; Arenillas et al. (2000a and b) in Tunisia. The present subzones are correlatable with P1a Subzones of Berggren and Miller (1988) and Samir (2000). In Egypt to the P1b of Keller (1988) and Keller et al. (1995), in Tunisia, to the *P. pseudobulloides* of Obaidalla (2005) in Egypt, and also it is equivalent to the P1a of Berggren and Norris (1997), Berggren et al. (1995), Keller (2002, 2004), Abramovich et al. (2002), Olsson (2000) and Smit (2005) in SE Spain. The age estimation of this interval depending on Magnetic polarity and recorded datum events by Olsson et al. (2000), Keller (2002 and 2004) with the time span of 64.90 Ma from the end of *Parvularugoglobigerina eugubina* to 64.50 Ma the first occurrence of *Subbotina triloculinoides*, the estimated age is Early Paleocene (Early Danian).

- **(P1b) Subbotina triloculinoides – Globanomalina compressa/ Praemurica inconstans**

**Interval Subzone**

**Definition:** Biostratigraphic interval between the FAD of *Subbotina triloculinoides* at the base and FAD of *Globanomalina compressa* and/or *Praemurica inconstans* at the top.

**Remarks:** Berggren et al. (1995) introduced this subzone to emend P1b (*Subbotina triloculinoides*) Subzone of Berggren and Miller (1988). In the studied section, only the lower part of this subzone is studied, which attains a thickness of 10 m. Based on faunal similarities, the combined P1b Subzones of the studied section could be equivalent to the upper part of *Morozovella pseudobulloides* Zone of Bolli (1966), Blow (1979) and Caron (1985); Elnady and Shahin (2001) and Samir (2002) from Egypt, Arenillas et al. (2000) in Tunisia, to the P1c of Keller (1988), and Keller et al. (1995), in Tunisia; to the *S. triloculinoides* by Obaidalla (2005) in Egypt. It is also equivalent to the P1b of Berggren and Norris (1997), Berggren et al. (1995), Keller (2002 and 2004), Abramovich et al. (2002), Olsson (2000) and Smit (2005) in SE of Spain. The age estimation of this interval depending on Magnetic polarity and recorded datum events by Olsson et al. (2000), Keller (2002 and 2004) with the time span of 64.50 Ma from the first occurrence of *Subbotina triloculinoides* to FAD of the *Globanomalina compressa* and/or *Praemurica inconstans* at the top of 63.00 Ma. Estimating absolute ages based on magnetochron ages, the estimated age is Early Paleocene (Early Danian).

The biostratigraphic correlation of the studied sections is based on planktonic foraminiferal zonations, which shows a comparison between the biostratigraphic zones established in this study with other equivalents of the commonly used planktonic zonal schemes around the Cretaceous/Paleogene boundary in and outside of Iraq (Fig.10).
Fig. 10: Correlation chart showing the planktonic foraminiferal biostratigraphic zones of Late Maastrichtian/Early Danian of the studied sections, with the planktonic foraminiferal zonation, commonly used in low and middle latitudes, in the new zonal scheme. (The shown age of the planktonic foraminiferal datum events are modified from different authors.)
CONCLUSIONS

This study has the following conclusions.

- The planktonic foraminifera occur continuously within the Upper Cretaceous sequences in the sedimentary succession of the studied sections, and generally show continuous sedimentary sequence without any interruption.
- Based on the geologic range and relative abundance of planktonic foraminiferal species, the studied sections across K/P boundary are precisely divided into seven biostratigraphic zones.
- Early Danian was recognized for the first time in the studied area.
- The biostratigraphic zones were correlated with their equivalents in other areas outside of the studied area and with worldwide standard biostratigraphic zones with the aid of datum events, which show the age of planktonic foraminiferal zones.
- This study does not refer possible occurrence of sediments (P0 and Pα) in the boundary but the related foraminifera are not found, as sedimentation appears to be continuous.

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**About the author**

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