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

Khalid M. Sharbazheri*, Imad M. Ghafor* and Qahtan A. Muhammed**

Received: 05/ 12/ 2010, Accepted: 04/ 05/ 2011

Key words: Biostratigraphy, Cretaceous/ Paleogene boundary, Sulaimaniyah, Kurdistan Region, Iraq

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/ Praemurica 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: P_0 (*Guembelitria cretacea* Zone), and Pα (*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.

دراسة الطباقية الحياتية للحد الفاصل بين الطباشيري/ الپاليوجين في منطقة دوكان، إقليم كوردستان، شمال شرق العراق

خالد محمود إسماعيل، عماد محمود غفور و قحطان احمد محمد

المستخلص

إن وحدات التماس بين عصرى الطباشيرى الأعلى والپاليوجين الأسفل المتكشفة في منطقة الدراسة التي تقع في نطاق الطيات العالية، وتمتد باتجاه شمال غرب - جنوب شرق على شكل شريط ضيق قريب وموازى للحدود العراقية – الإيرانية، تتكون من طبقات سميكة تتألف بشكل رئيسي من تتابعات الفليش ممثلةً بالصخور الفتاتية لتكويني تانجيرو وكولوش.

* Department of Geology, College of Science, University of Sulaimaniyah, Kurdistan Iraq
** Kirkuk Technical College, Kirkuk, Iraq

سجلت في هذه الدراسة خمسة أنطقة حياتية لتجمعات الفورامينيفيرا الطافية ضمن الجزء العلوي من تكوين تانجيرو، وكذالك تم تمييز نطاقين حياتيين ضمن الجزء السفلى لتكوين كولوش (الپاليوسين الأسفل) في منطقة الدراسة.
عكست الأنطقة الحياتية للفورامينفيرا الطافية الموصوفة فى منطقة الدراسة استمرار الترسيب عبر حد التماس بين الطباشيرى والپالوجين وعدم وجود دلائل على الانقطاع، بالإضافة إلي ذلك تم تسجيل الدانيان (Danian) لأول مرة في المنطقة، ودلت على وجود ترسيب تدريجى مستمر فى منطقة الدراسة. أجريت مضاهاة بين الأنطقة الحياتية التى سجلت فى هذه الدراسة اعتماداً على الفورامينفيرا مع الأنطقة المكافئة لها ذات الاستعمال الشائع حول حدود التماس بين الطباشيرى والپاليوجين فى داخل وخارج العراق.

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

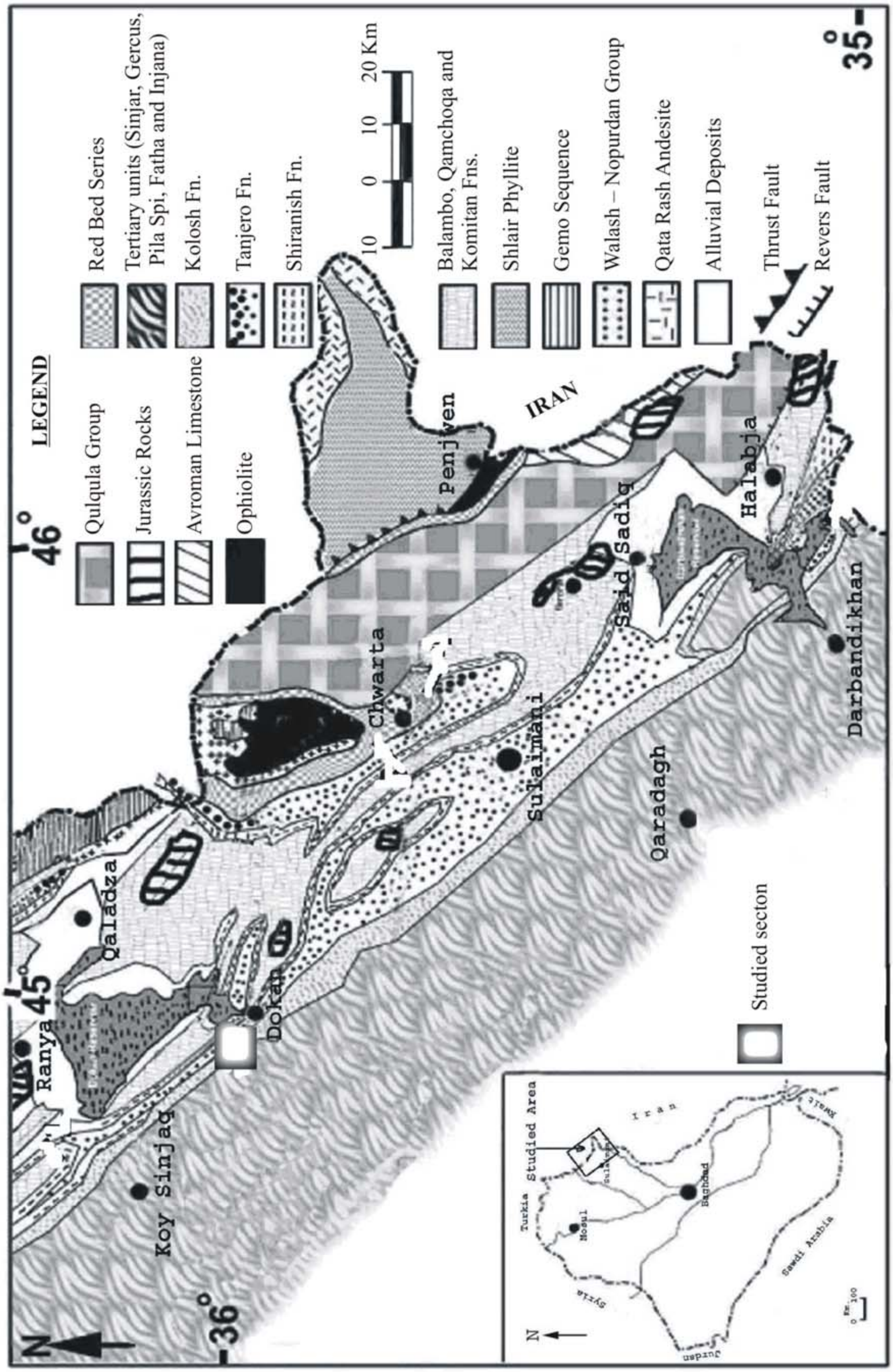

Fig.1: Location and geological map of the studied area (after Sissakian *et al.*, 2000)

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*, *Pseudovalvulineria* sp., *Teredolites* sp., *Ovulites morlleti*, *O*. cf. *elongata*, *Trinocladus perplexuz*, *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.

REVIEW OF THE LATE CRETACEOUS – EARLY PALEOGENE CONTACT

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)º 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 Aaliji 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 *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 *Globorotalia velascoensis* Zone of Upper Paleocene age.

LITHOSTRATIGRAPHY OF THE STUDIED SECTION

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.

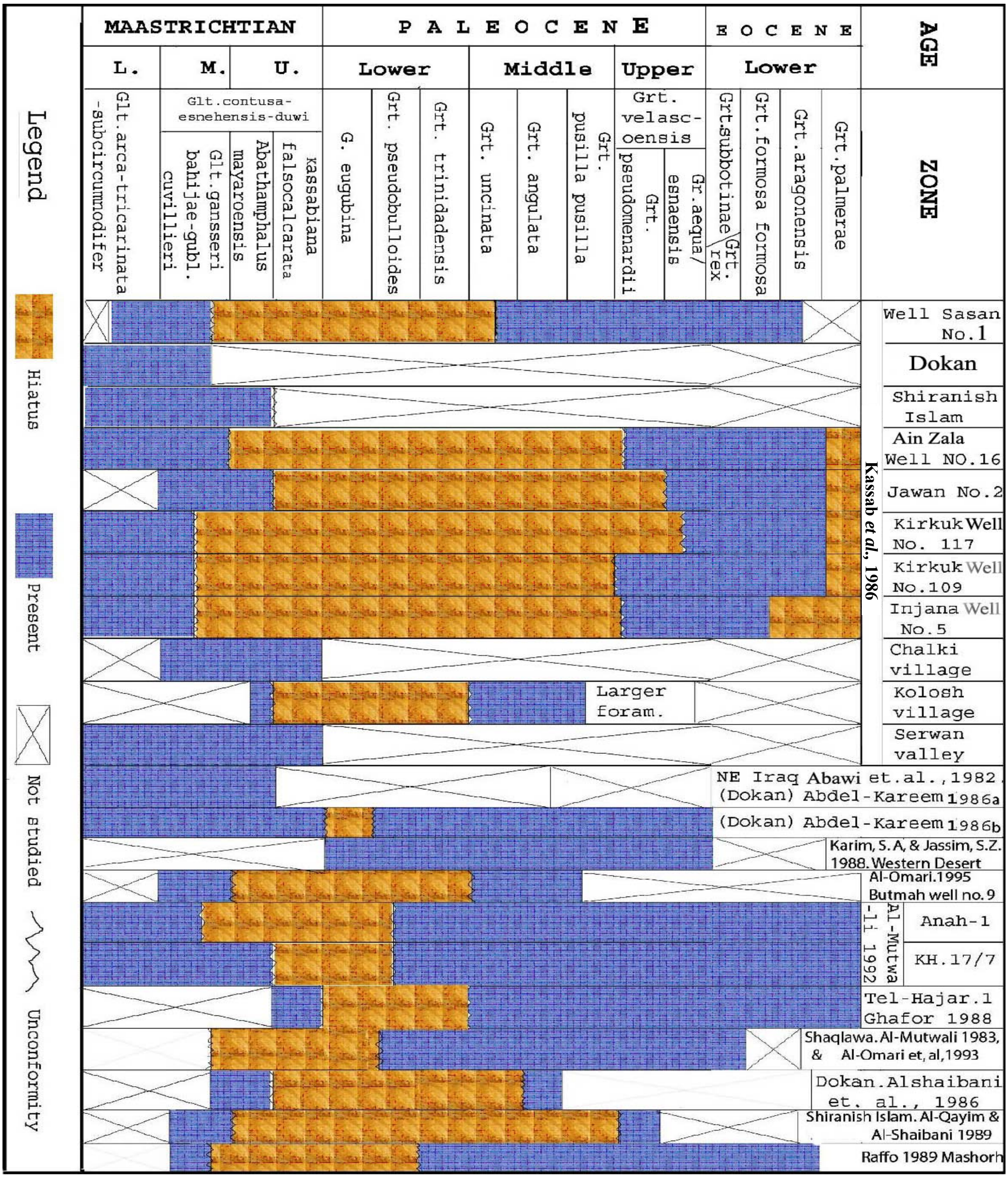

Fig.2: Correlation of the previous biostratigraphic zonation of Cretaceous/ Paleogene contact at different localities in Iraq

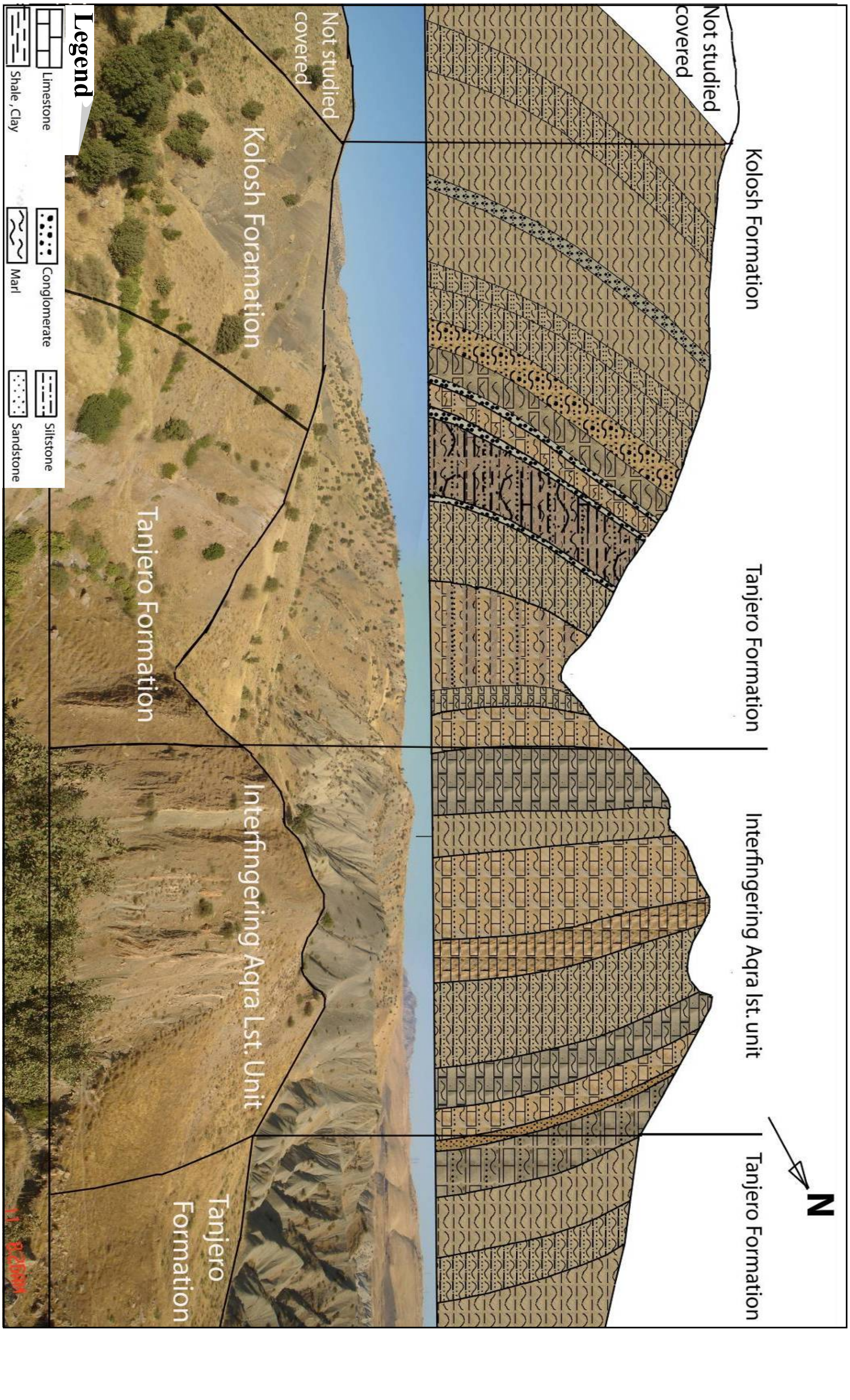

Fig.3: Schematic geologic cross section of Dokan area

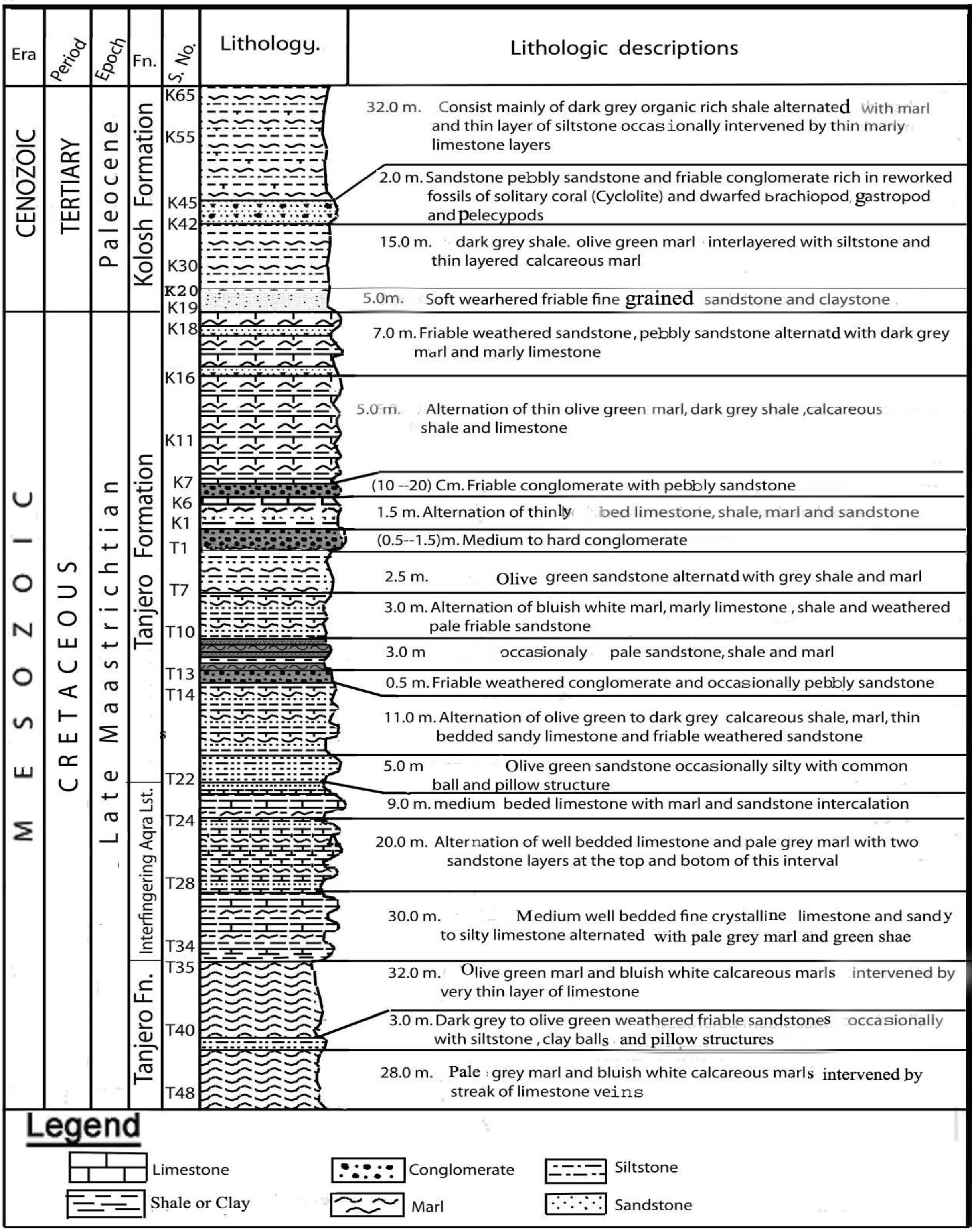

Fig.4: Lithostratigraphic column of Qulka section in Dokan area showing lithologic characters (Not to scale, the thickness is shown on each unit)

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, echinoids 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)**

The *Pseudotextularia intermedia* Zone (CF5) is defined by the last appearance datum (LAD) of the *Globotruncana linneiana* (d'Orbigny) at the base and the first appereance Datum (FAD) of *Racemiguembelina fructicosa* (Egger) at the top. Nederbragt (1990) originally, introduced this biozone as the interval from the FAD of *Planoglobulina acervulinoides*, at the base and the FAD *Racemiguembelina fructicosa*, at the top. In the present study, the definition is constrained according to Li and Keller (1998a and b). The recorded planktonic foraminiferal assemblages in this biozone are represented by well diversified forms of *Heterohelix navarroensis* Loeblish, *H. globulosa* (Ehrenberg), *H. striata* (Ehrenberg), *H. punctulats* (Cushman), *H. nauttalli* (Voorwijk), *H. reussi* (Cushman), *H. pulchra* (Brotzen), *Planoglobulina carseyae* (Plummer), *P. brazoensis* Martin, *P. acervulinoides* (Egger), *Rugoglobigerina rugosa* (Plummer), *R. scotti* (Bronnimann), *R. hexacamerata* Bronnimann, *R. macrocephala* Bronnimann, *R. milamensis* Smith and Pessango, *Gansserina gansseri* (Reuss), *G. wiedenmayeri* (Gandolfi), *Globotruncanita stuarti* (de Lapparent), *G. stuartiformis* Dalbez, *G. conica* White, *G. pettersi* Gandolfi, *G. angulata* Tilev, *Globotruncana aegyptiaca* Nakkady, *Glt. orientalis* El-Naggar, *Glt. falsostuarti* Sigal, *Glt. dupeublie* Caron *et al*., *Glt. lapparenti* Boli, *Glt. arca* (Cushman), *Glt. rosetta* Carsey, *Contusotruncana contusa* (Cushman), *C. plicata* White, *C. Patelliformis* (Gandolfi), *Rugotruncana subcircumnodifer* (Gandolfi), *R. subcircumnodifer* (Gandolfi), *Globotruncanella petaloidea* (Gandolfi), *Globigerinelloides volutes* (White), *G. subcarinatus* Bronnimann, *G. prairiehillensis* Pessango, *Pseudotextularia elegans* (Rzehak), *P. deformis* (Kikoine), *P. intermedia* (De Klasz), *Racemiguembelina poweli* Smith and Pessango, *Pseudoguembelina costulata (Cushman)*, *P. excolata* (Cushman), *Hedbergella monmothensis* (Olsson), *P. holmdelensis* Olsson, *Abathomphalus intermedius* (Bolli), *Archaeoglobigerina carteri* (Kassab), *Gublerina cuvillieri* Kikoine, *Gumbelitria cretacea* Cushman.

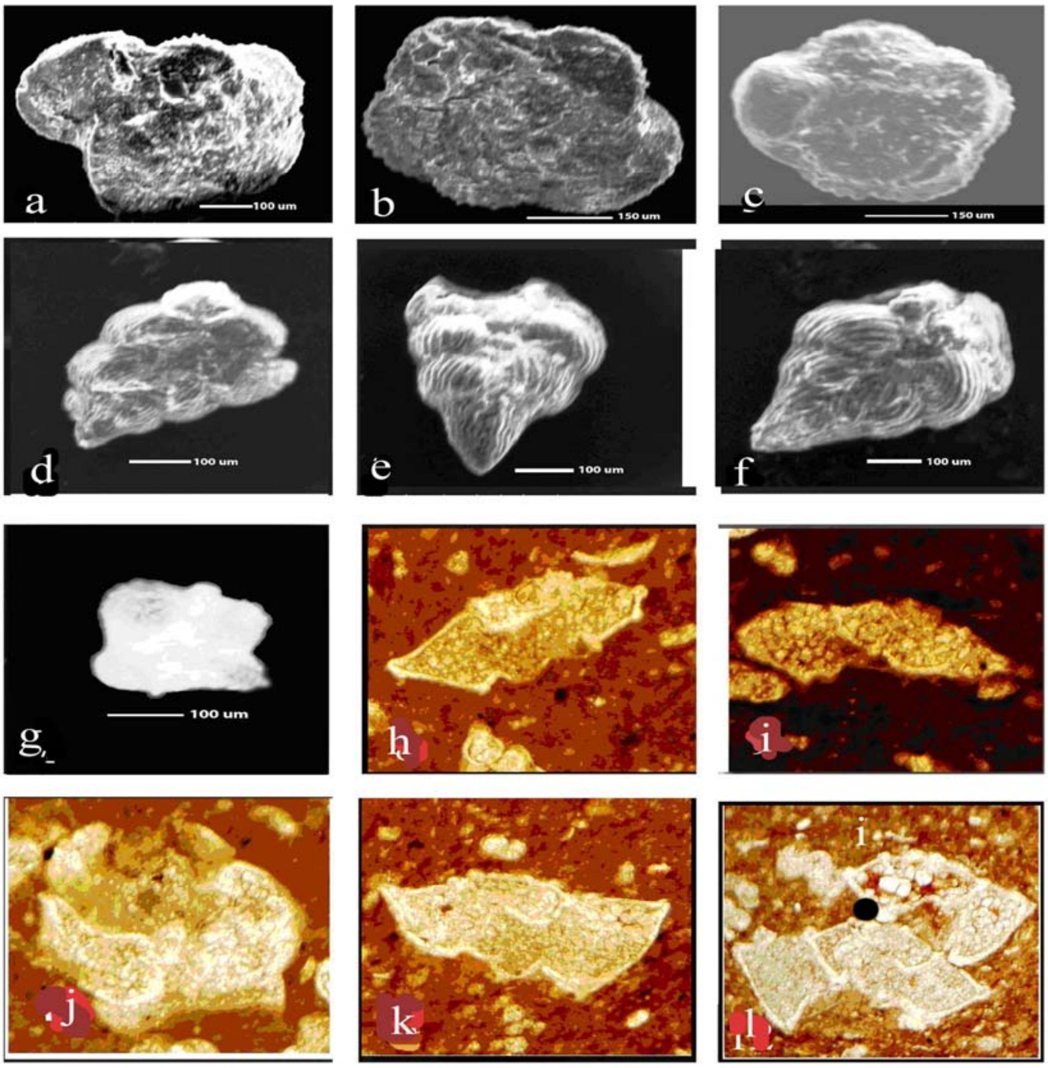

Fig.6

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* (Bronnimann). Tanjero Formation, Late Maastrichtian, specimen from *P. hantkeninoides* Zone

h and i) *Globotruncana falsostuarti*. Sigal, 100X, Tanjero Formation, Late Maastrichtian, specimen from *R. fructicusa* 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

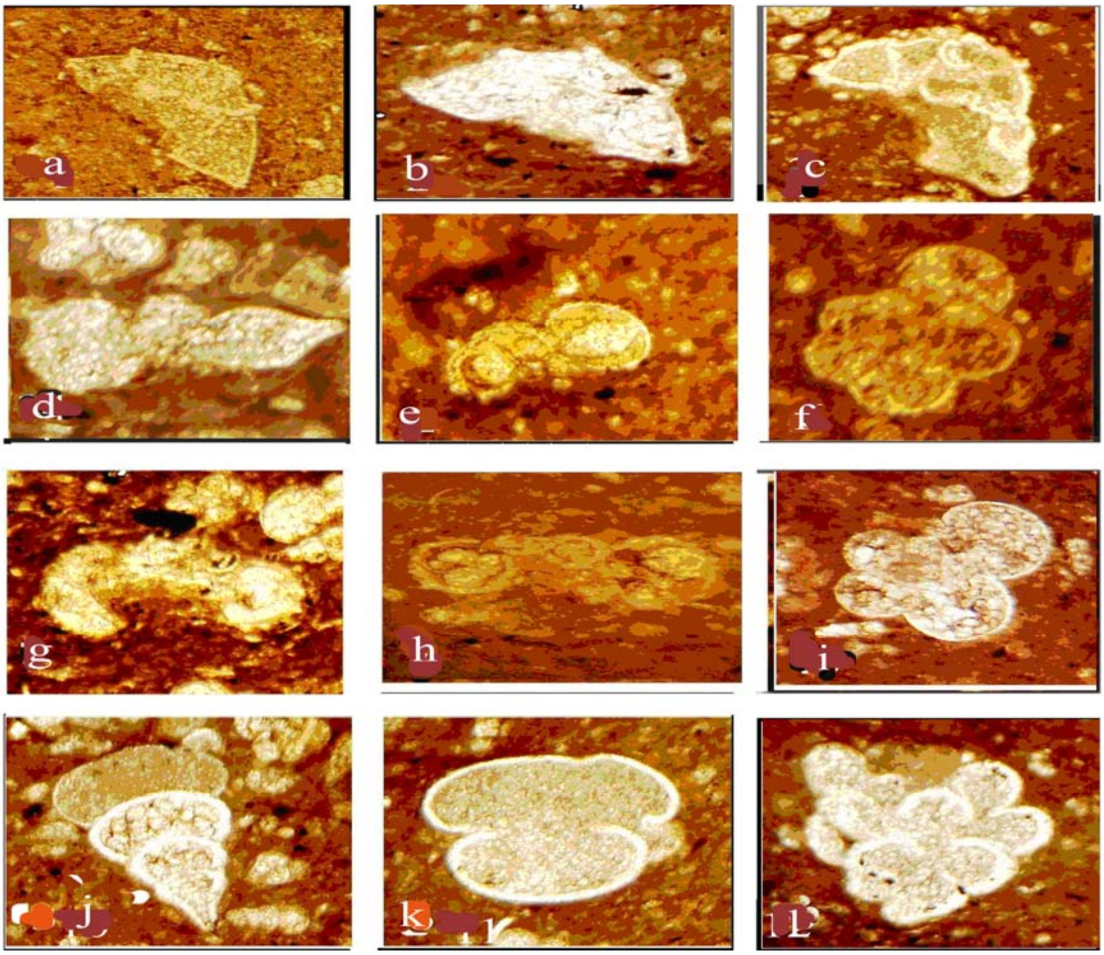

Fig.7

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

c) *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. haiaensis* 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

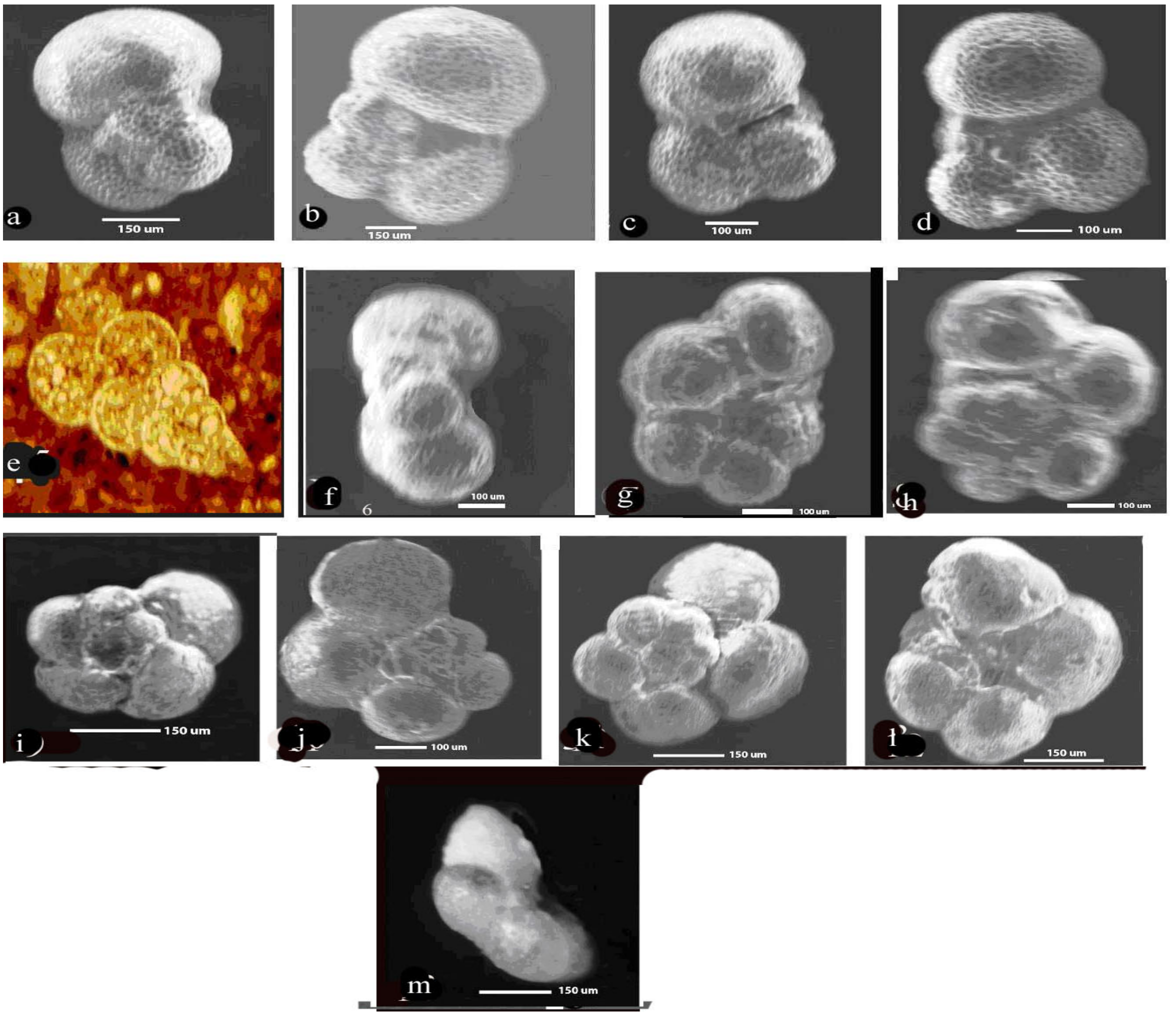

Fig.8

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

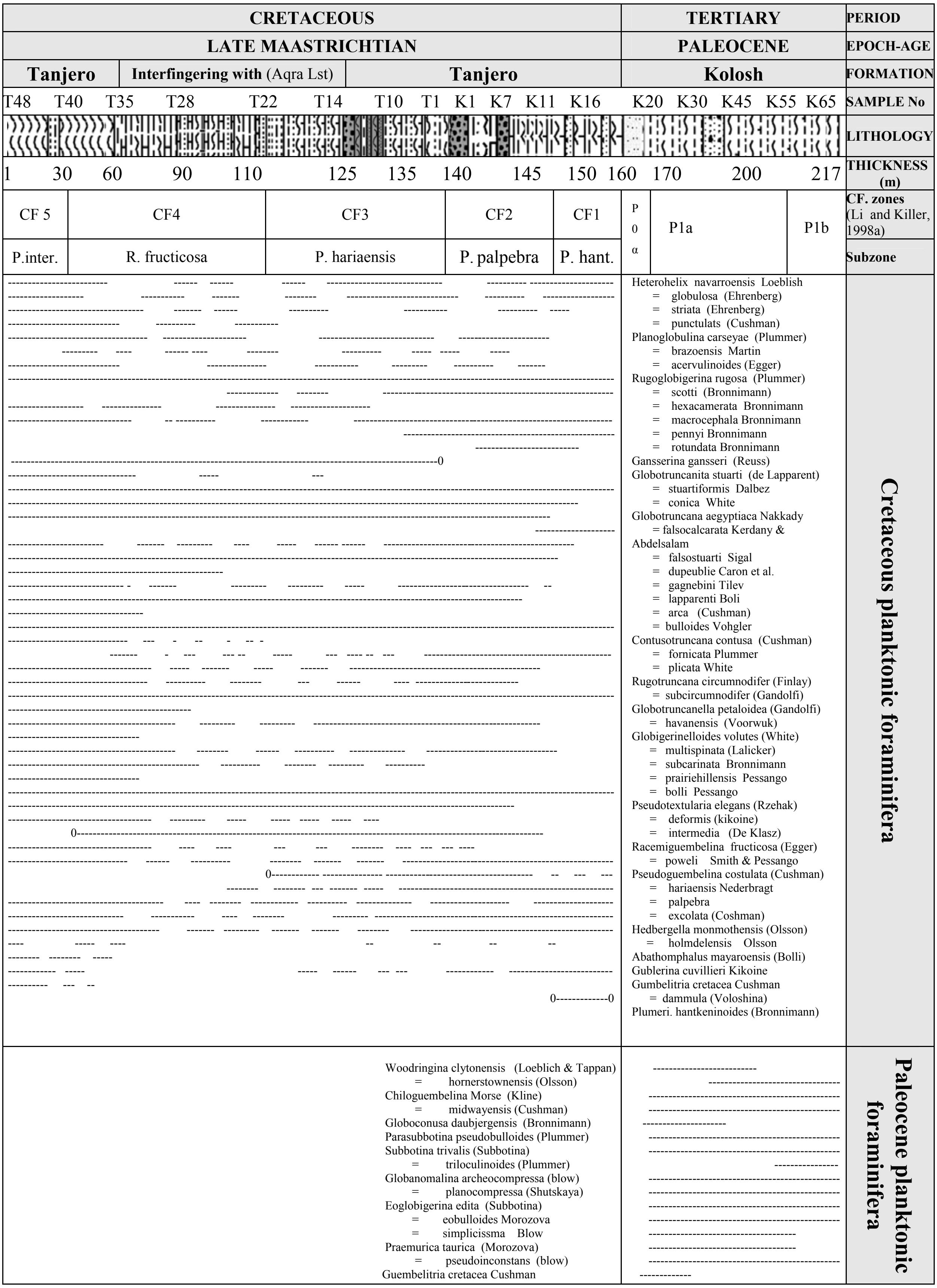

Fig.9: Biostratigraphic range chart of planktonic foraminifera of the Cretaceous/ Paleogene boundary in Dokan area

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

FAD of the nominate species to the last occurrence of *Gansserina gansseri* (Bolli). This zone shows reliable abundance of *Pseudoguembelina hariaensis* Nederbragt and other assemblages of planktonic foraminifera, which totally resemble those of the underlying *Racemiguemblina fructicosa* Zone (CF4) in Gali section, with the following planktonic forams of 50 species; like: *Heterohelix navarroensis* Loeblish, *H. globulosa* (Ehrenberg), *H. striata* (Ehrenberg), *H. punctulata* (Cushman), *H. nauttalli* (Voorwijk), *H. reussi* (Cyshman), *Laeviheterohelix glabrans* (Cyshman), *Planoglobulina carseyae* (Plummer), *P. brazoensis* Martin, *P. acervulinoides* (Egger), *Rugoglobigerina rugosa* (Plummer), *R. scotti* (Bronnimann), *R. hexacamerata* Bronnimann, *R. macrocephala* Bronnimann, *R. pennyi* Bronnimann, *R. reicheli* Bronnimann, *R. rotundata* Bronnimann, *Gansserina gansseri* (Reuss), *Globotruncanita stuartiformis* Dalbez, *G. conica* White, *G. pettersi* Gandolfi, *G. angulata* Tilev, *Globotruncana aegyptiaca* Nakkady, *Glt. falsostuarti* Sigal, *Glt. dupeublie* Caron *et al*., *Glt. lapparenti* Boli, *Contusotruncana contusa* (Cushman), *C. plicata* White, *C. patelliformis* (Gandolfi), *C. walfischensis* Todd, *C.* sp. (*nov.* sp.*?*), *Rugotruncana circumnodifer* (Gandolfi), *Globotruncanella petaloidea* (Gandolfi), *G. pschadae* (Keller), *Globigerinelloides volutes* (White), *G. subcarinatus Bronnimann*, *Pseudotextularia elegans* (Rzehak), *P. deformis* (Kikoine), *Racemiguembelina fructicosa* (Egger), *Pseudoguembelina costulata* (Cushman), *P. palpebra*, *P. excolata* (Cushman), *Hedbergella monmothensis* (Olsson), *H. holmdelensis* Olsson, *Abathomphalus mayaroensis* (Bolli), *Kuglerina rotundata (Bronnimann), Costellagerina* cf. *bulbosa* Belford, *Gublerina cuvillieri* Kikoine, *Gumbelitria cretacea* Cushman.

As defined above, the present biozone (CF3) is correlatable with the zone recorded by Li and Keller (1998a, b), Abramovich and Keller (2003); in DSDP Site 525A. Abramovich *et al*. (2002) in Madagascar, Keller *et al*. (1995) from Tunisia, Keller (2004) from Eastern Tethys, Samir (2002), Keller (2002), Obaidalla (2005) in Egypt, and Sharbazheri (2007) in NE Iraq. It is correlated with the middle part of *Abathomphalus mayaroensis* zone recorded in the Northeast of Iraq (Abawi *et al*., 1982, and Abdel-Kareem, 1986), in Italy (Premoli Silva and Sliter, 1995 and 1999, and Premoli Silva *et al*., 1998), Abdel-Kareem and Samir (1995) in Egypt.

The age estimation of this biozone 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 hantkeninoides*; 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 foraminiferal species enduring from the underlying biozones, some species show their first appearance, e.g. *Globotruncana falsoscalcarata* Kerdany and Abdelsalam, *Globotruncanella* sp. and *Trinitella scotti* Bronnimann 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 foraminiferal assemblages of this zone, in the studied section is represented by

Heterohelix navarroensis Loeblish, *H. globulosa* (Ehrenberg), *Laeviheterohelix glabrans* (Coshman), *Planoglobulina carseyae* (Plummer), *P. acervulinoides* (Egger), *Rugoglobigerina rugosa* (Plummer), *R. scotti* (Bronnimann), *R. hexacamerata* Bronnimann, *R. macrocephala* Bronnimann, *R. pennyi* Bronnimann, *R. reicheli* Bronnimann, *Globotruncanita stuartiformis* Dalbez, *G. conica* White, *Globotruncana aegyptiaca* Nakkady, *Glt. falsocalcarata* Kerdany and Abdelsalam, *Glt. falsostuarti* Sigal, *Glt. dupeublie* Caron *et al*., *Glt. lapparenti* Boli, *Contusotruncana contusa* (Cushman), *C. plicata* White, *C. walfischensis* Todd, *Rugotruncana circumnodifer* (Gandolfi), *R. subcircumnodifer* (Gandolfi), *Globotruncanella petaloidea* (Gandolfi), *G. pschadae* (Keller), *Globigerinelloides prairiehillensis* Pessango, *Pseudotextularia elegans* (Rzehak), *P. deformis* (Kikoine), *Racemiguembelina fructicosa* (Egger), *Pseudoguembelina hariaensis* Nederbragt, *P.* palpebra, *P.* excolata (Cushman), *Hedbergella monmothensis* (Olsson), *H. holmdelensis* Olsson, *Gublerina cuvillieri* Kikoine and *Gumbelitria cretacea* Cushman.

The CF2 Zone of the studied area is equivalent to the *P. palpebra* Zone of South Atlantic DSDP Site 525A (Li and Keller, 1998a, Abramovich *et al*., 2002); and in Tunisia (Li and Keller, 1998b and Arenillas *et al*., 2000); in eastern Tethys (Keller, 2004). The present *P. palpebra* Zone is equivalent to the upper part of *Abathomphalus mayaroensis* Zone, as recorded from different parts of the world, Premoli-Silva and Sliter (1995 and 1999), Molina *et al*. (1996), Canudo *et al*. (1991) from Spain; Premoli Silva *et al*. (1998) eastern Mediterranean; Maestas *et al*. (2003) in USA California; and Obaidalla (2005); Samir (2002); Elnady and Shahin (2001) and Luning *et al*. (1998) in Egypt. The present *P. palpebra* Zone is equivalent to the upper part of *Abathomphalus mayaroensis* Zone, recorded from different localities in Iraq, like Al-Mutwali and Al-Juboury (2005); Al-Mutwali (1996); Hammoudi (2000); Abawi *et al*. (1982); Abdel-Kareem (1986a and b); Kassab (1972, 1974, 1975, 1976, and 1979) and Kassab *et al*. (1986).

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 magnetochron ages.

Age: upper Late Maastrichtian.

- ***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* (Bronnimann). 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 upper limit of this zone coincides with the mass extinction of large tropical – subtropical taxa. At the studied sections, this zone covers the top 25 m of the Maastrichtian. The characteristic recorded planktonic foraminiferal assemblage of this zone shows gradual decreasing in both species and individual numbers from *Pseudoguembelina palpebra* Zone to *Plummerita hantkeninoides* Zone. From (37) to (29) species in Sirwan section. *Heterohelix navarroensis* Loeblish, *H. globulosa* (Ehrenberg), *H. striata* (Ehrenberg), *Rugoglobigerina rugosa* (Plummer), *R. scotti* (Bronnimann), *R. macrocephala* Bronnimann, *R. pennyi* Bronnimann, *R. rotundata* Bronnimann, *Globotruncanita stuartiformis* Dalbez, *G.* conica White, *Globotruncana falsocalcarata* Kerdany and Abdelsalam, *Glt. falsostuarti* Sigal, *Glt. dupeublie* Caron *et al*., *Contusotruncana contusa* (Cushman), *C. plicata* White, *Globotruncanella petaloidea* (Gandolfi), *Pseudotextularia elegans* (Rzehak), *Pseudoguembelina costulata* (Cushman), *P. hariaensis* Nederbragt, *P. palpebra*, *P. excolata* (Coshman), *Hedbergella monmothensis* (Olsson), *H. holmdelensis* Olsson, *Gumbelitria cretacea* Cushman, *Plummerita hantkeninoides* (Bronnimann).

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 (Elnady and Shahin, 2001 and Shahin, 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 magnetochron ages, 12 Ky/m high rate of sedimentation, in the studied area.

Age: Latest Maastrichtian.

▪ **(P0 and Pα) in Dokan area**

In the present study, the earliest Paleocene *Guembelitria cretacea* Zone (P0), and *Parvularugoglobigerina eugubina* Zone (*Pα*) 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* (Bronnimann), 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 magnetochron 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* (Bronnimann) 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).

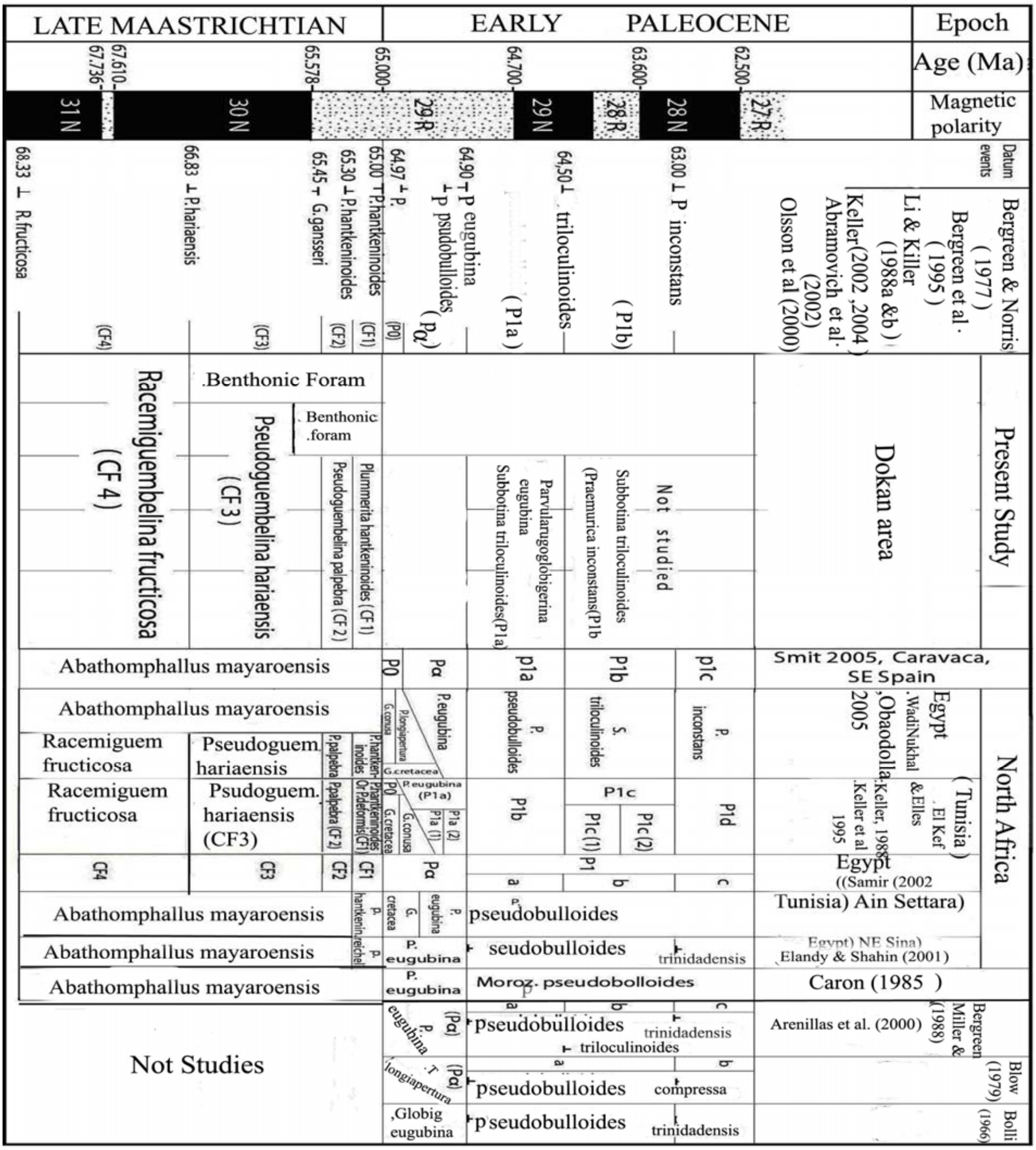

Fig.10: Correlation chart showing the planktonic foraminiferal biostratigraphic zones of Late Maastrichtian/ Early Danian of the studied sections, with the planktonic foraminiferal zonation, commonly used in low and middle latitudes, in the new zonal scheme (The shown age of the planktonic foraminiferal 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.

REFERENCES

Abawi, T.S., Abdel-Kireem, M.R. and Yousef, G.M., 1982. Planktonic foraminiferal stratigraphy of the Shiranish Formation at Sulaimaniah – Dokan region Northeastern Iraq. Revista Espanola de Micropaleontologia, Vol.14, No.1, p. 153 – 164.

Abdel-Kareem, M.R., 1986a. Planktonic foraminifera and stratigraphy of the Tanjero Formation (Maastrichtian), northeastern Iraq. Micropaleontology, Vol.32, No.3, p. 215 – 231.

Abdel-Kareem, M.R. 1986b. Contribution to the stratigraphy of the Upper Cretaceous and Lower Tertiary of the Sulaimaniyah – Dokan region, Northeastern Iraq. N. Jb. Geol. Paleont. Abh., Vol.172, No.1, p. 121 – 139.

Abdel-Kareem, M.R. and Samir, A.M., 1995. Biostratigraphic implications of Maastrichtian – Lower Eocene sequence at the north Gunna section, Farafra Oasis, Western Desert, Egypt. Marine Micropaleontology, Vol.26, p. 329 – 340.

Abramovich, S., Keller, G., Adatte, T., Stinnesbek, W., Hottinger, L., Stueben, D., Berner, Z., Ramanivosa, B. and Randriamanantenasoa, A., 2002. Age and paleoenvironment of Maastrichtian to Paleocene of the Mahajanga Basin, Madagascar: A multidisciplinary approach. Marine Micropaleontology, Vol.47, p. 17 – 70.

Abramovich, S. and Keller, G., 2003. Planktonic foraminiferal response to the Latest Maastrichtian abrupt warm event: A case study from South Atlantic DSDP Site 525A. Marine Micropaleontology, Vol.48, p. 225 – 249.

Al-Mutwali, M.M., 1983. Biostratigraphy of Kolosh Formation and the nature of its contact with Upper Cretaceous rocks in Shaqlawa area. Unpub. M.Sc. Thesis. University of Mosul, 154pp.

Al-Mutwali, M.M., 1992**.** Foraminifera, Stratigraphy and Sedimentology of the Upper Cretaceous – Lower Tertiary in selected boreholes around Khleisia Anah-Ramadi area. Unpub. Ph.D. Thesis, University of Mosul, Mosul, Iraq. 300pp.

Al-Mutwali, M.M., 1996. Planktonic foraminiferal biostratigraphy of the Shiranish Formation. Khashab well no.1, Hemren area. Northeastern Iraq. Jour. Geol. Soci. Iraq, Vol.7 (1) p. 129 – 136.

Al-Mutwali, M.M. and Al-Jubouri, F.N., 2005. Litho and Biostratigraphy of Shiranish Formation (Late Campanian – Late Maastrichtian) in Sinjar area, Northwestern Iraq. Rafidain Jour. Scie., Vol.16, No.1, Geology, Special Issue. p. 152 – 176.

Al-Omari, F.S., 1970. Upper Cretaceous and lower Cenozoic foraminifera of the three oil wells in northwestern Iraq. Unpub. Ph.D. Thesis, University of Missouri at Rolla, 208pp.

Al-Omari, F.S., 1995, (Issued in 1997). Biostratigraphy of Upper Cretaceous/ Lower Tertiary in Butmah Well no.9, North West Iraq. Iraqi Geol. Jour., Vol.28, No.2, p. 112 – 119.

Al-Qayim, B.A. and Al-Shaibani, S.K., 1989. Stratigraphic analysis of Cretaceous/ Tertiary contact, Northwest Iraq. Jour. Geol. Soc. Iraq. Vol.22, No.1, p. 41 – 52.

Al-Shaibani, S.K., Al-Qayim, B.A. and Salman, L., 1986. Stratigraphic analysis of Tertiary/ Cetaceous contact, Dokan area, North Iraq, Jour. Geol. Soci. Iraq, Vol.19, No.2. (7^{th} IGC).

Bellen, R.C., van Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq, Paris, 333pp.

Berggren, W.A. and Miller, K.G., 1988. Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology. Micropaleontology, Vol.34, No.4, p. 362 – 380.

Berggren, W.A., Kent, D.V., Swisher, III, C.C. and Aubry, M.P.,1995. A revised Cenozoic geochronology and chronostratigraphy. In: Berggren, W.A. and Norris, R.D., 1997. Biostratigraphy, phylogeny and systematics of Paleocene trochospiral planktonic foraminifera. Micropaleontology, Vol.43, supplements. 1, p. 1 – 116, text figures 1 – 17, plates 1 – 16, tables 1 – 5, and appendix 1.

Berggren, W.A. and Norris, R.D., 1997. Biostratigraphy, phylogeny and systematic's of Paleocene trochospiral planktonic foraminifera. Micropaleontology, Vol.43, supplements 1, p. 1 – 116, text figures 1 – 17, plates 1 – 16, tables1 – 5, and appendix 1.

Blow, W.H., 1979. The Cenozoic Globigerinidae, Vol.1 – 3.

Bolli, H.M., 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. Bol. Inform. Asoc. Vonezolana Geol. Min. Ret. En., Vol.9, No.1, p. 3 – 32, 4 tables.

Buday, T., 1980. Regional Geology of Iraq: Vol.1, Stratigraphy, I.I.M., Kassab and S.Z., Jassim (Eds.). GEOSURV, Baghdad, Iraq, 445pp.

Buday, T. and Jassim, S.Z., 1987. The Regional geology of Iraq: Vol.2, Tectonism, Magmatism and Metamorphism. I.I. Kassab and M.J. Abbas (Eds.), Baghdad, Iraq, 352pp.

Canudo, J.I., Keller, G. and Molino, E., 1991. Cretaceous/ Tertiary boundary extinction pattern and faunal turnover at Agost and Caravaca, SE Spain. Marine Micropaleontology, Vol.17. p. 319 – 341.

Caron, M., 1985. Cretaceous planktonic foraminifera. In: H.M., Bolli, J.B. Saunder and K., Perch-Nielsen (Eds.) Planktonic Stratigraphy, p. 17 – 87, 37 Figs, Cambridge Univ. Press.

Chacon, B. and Martin-Chivelet. J., 2005. Major Paleoenvironmental changes in the Campanian to Paleocene sequence of Caravaca (Subbetic Zone, Spain). Jour. Iberian Geol., Vol.31, No.2, p. 299 – 310.

Ditmar, V. and Iraqi Soviet team, 1971. Geological conditions and hydrocarbon prospects of the republic of Iraq, northern and central parts. Technoexport report. INOC Library, Baghdad.

D'Hont, S. and Keller, G., 1991. Some patterns of planktonic foraminiferal assemblage turnover at the Cretaceous/ Tertiary boundary. Marine Micropaleontology, Vol.17. p. 77 – 118.

Dunnington, H.V., 1952. The Tertiary/ Cretaceous boundary problem in North Iraq. No. IR/ HVD/ 611. Baghdad. INOC Library, Unpublished report, p. 1 – 66, Figs. 1 – 3.

Dunnington, H.V., 1957. The Paleocene/ Cretaceous unconformity at Aqra. Unpublished report. ivo. IR/ MUD/ 691. INOC Library, Baghdad.

Elnady, H. and Shahin, A., 2001. Planktonic Foraminiferal biostratigraphy and paleobathymetry of the Late Cretaceous/ Early Tertiary succession at northeast Sinai, Egypt. Egypt. Jour. Paleontol., Vol.1, p. 193 – 227.

Ghafor, I.M., 1988. Planktonic foraminifera and biostratigraphy of the Aaliji Formation and the nature of its contact with the Shiranish Formation in Well Tel-Hajar No.1, Sinjar area , Northwestern Iraq. Unpub. M.Sc. Thesis, University of Salahaddin, Iraq. 206pp.

Ghafor, I.M. and Kareem, K.H., 1999. Biostratigraphy of upper part of the Kolosh Formation from Sartaq-Bamo, Northeastern Iraq. JDU (Sci), Special issue: The first Scientific Conference of Dohuk University, Vol.2, No.4. p. 493 – 510.

Govindan, A. Ravindran, C.N. and Rangaraju, M.K., 1996. Cretaceous stratigraphy and planktonic foraminifera Zonation of Cauvery Basin, South India. Memoir Geological Society of India. No.37, p. 155 – 187. L Roma Rao Volume, Cretaceous stratigraphy and Paleoenvironment. Ashok Sahni (Eds.).

Hammoudi, R.A., 2000. Planktonic foraminiferal biostratigraphy of the Shiranish Formation (Upper Cretaceous) in Jambur well No.13, Northern Iraq. Raf. Jour. Sci., Vol.11, No.4, p. 50 –58.

James, G.A. and Wynd, J.G., 1965. Stratigraphic nomenclature of Iranian Oil Consortium agreement area. AAPG Bull., Vol.49, No.12, p. 2182 – 2245, Figs.98, Table 1. Tulsa, Oklahoma

Jassim, S.Z and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno. 345pp.

Karim, K.H., 2004. Basin analysis of Tanjero Formation in Sulaimaniyah area, NE Iraq. Unpub. Ph.D. Thesis, University of Sulaimani, 135pp.

Karim, K.H., 2006. Environment of Tanjero Formation as inferred from sedimentary structures, Sulaimaniyah area, NE Iraq. JAK, Vol.4, No.1, p. 1 – 18.

Karim, S.A. and Jassim. S.Z., 1988. (issued in 1993) Biostratigraphy and environmental reconstruction of the Paleocene Phosphatic sequence, Western Desert, Iraq. Jour. Geol. Soc. Iraq, Vol.21, No.2, p. 129 – 151.

Karim, K.H. and Surdashy, A.M., 2005a. Paleocurrent analysis of Upper Cretaceous Foreland basin: A case study for Tanjero Formation in Sulaimaniyah area, NE Iraq, Jour. Iraqi Sci., Vol.5, No.1, p. 30 – 44.

Karim, K.H. and Surdashy, A.M., 2005b. Tectonic and depositional history of Upper Cretaceous Tanjero Formation in Sulaimaniyah area NE Iraq. JZS, Vol.8, No.1, p. 47 – 62.

Karim, K.H. and Surdashy, A.M., 2006. Sequence stratigraphy of Upper Cretaceous Tanjero Formation in Sulaimaniyah area, NE Iraq. KAJ, Vol.4, No.1, p. 19 – 43.

Kassab, I.I.M., 1972. Micropaleontology of Upper Cretaceous/ Lower Tertiary of north Iraq. Univ. London, Unpub. Ph. D. Thesis, 310 p, 29pls., 18 text-figs., 14 charts.

Kassab, I.I.M., 1974. Biostratigraphy of Upper Cretaceous/ Lower Tertiary of North Iraq, Vol.1, Colloque Africaia de micropaleontology, Tunis. p. 277 – 325.

Kassab, I.I.M., 1975. Biostratigraphic study of the subsurface Upper Cretaceous/ Lower Tertiary of well Injana No.5, Northeast Iraq. Jour. Geol. Soc. Iraq, Special issue, p. 181 – 199, 2 pls., 5 Figs.

Kassab, I.I.M., 1976. Some Upper Cretaceous planktonic foraminiferal genera from northern Iraq. Micropaleontology, Vol.22, No.2, p. 215 – 238, pls.1 – 4.

Kassab, I.I.M., 1978. Planktonic foraminifera of the subsurface Lower Tertiary of northern Iraq. Jour. Geol. Soc. Iraq, Vol.11, p. 119 – 159. 7 Pls., 5 Figs.

Kassab, I.I.M., Al-Omari, F.S. and Al-Sawaf, N.M., 1986. The Cretaceous/ Tertiary boundary in Iraq (represented by the subsurface section of Sasan well No.1, NW Iraq). Jour. Geol. Soci., Iraq, Vol.19, No.2, p. 129 – 167.

Keller, G., 1988. Extinction survivorship and evolution of planktonic foraminifera across the Cretaceous/ Tertiary boundary at El-Kef, Tunisia: Marine Micropaleontology, Vol.13, p. 239 – 263.

Keller, G., 1996. The Cretaceous – Tertiary Mass Extinction in planktonic foraminifera: Biotic Constraints for catastrophe Theories. Cretaceous – Tertiary Mass Extinction: Biotic and Environmental Changes. MacLeod, N. and Keller, C. W.W. Norton Company, New York, London, p. 49 – 84.

Keller, G., 2001. The end-Cretaceous mass extinction in the marine realm: year 2000 assessment: Planetary and Space Science, Vol.49, p. 817 – 830.

Keller, G., 2002. *Guembelitria*-dominated Late Maastrichtian planktonic foraminiferal assemblage mimics early Danian in central Egypt. Marine Micropaleontology, Vol.47, p. 129 – 167.

Keller, G., 2004. Low diversity, Late Maastrichtian and Early Danian planktonic foraminiferal assemblages of the eastern Tethys. Jour. Foraminiferal Research, Vol.34, No.1, p. 49 – 73.

Keller, G., Li, L. and Maclleod, N., 1995. The Cretaceous/ Tertiary boundary stratotype section at El-Kef, Tunisia: How catastrophic was the mass extinction? Paleogeography, Paleoclimatology. Paleoecology 199, p. 221 – 254.

Li, L. and Keller, G., 1998a. Maastrichtian climate, productivity and faunal turnover in planktonic foraminifera in South Atlantic, DSDP sites 525A and 21. Marine Micropaleontology, Vol.33, p. 55 – 86.

Li, L. and Keller, G., 1998b. Diversification and extinction in Campanian – Maastrichtian planktonic foraminifera of northwest Tunisia. Ecol. Geol. Helv., 91, p. 75 – 107.

Liu, C. and Olsson, R.K., 1992. Evolutionary radiation of microperforated planktonic foraminifera following the K/T mass extinction event. Jour. Foraminiferal Research, Vol.22, No.4, p. 328 – 346.

Luning, S., Kuss, J., Bachmann, M., Marzouk, A.M. and Morsi, A.M., 1998. Sedimentary response to basin inversion: Mid Cretaceous – Early Tertiary, Pre-to syndeformational deposition at the Areif El-Naqa anticline (Sinai, Egypt). Institut fur palaontologie der Universitat Erlangen, Nürnberg. Facies. 38, p. 103 – 136, Pl. 35 – 37, 12 Figs.

Maestas, Y., Macleod, K.G., Douglas, R., Self-Trail, J. and Ward, Ph. D., 2003. Late Cretaceous Foraminifera, Paleoenvironments and Paleoceanography of the Rosario Formation, San Antonio Del Mar, Baja California, Mexico. Jour. Foraminiferal Research, Vol.33, No.3, p. 179 – 191.

Masters, B.A., 1984. Reevaluation of selected types of Ehrenberg's Cretaceous planktonic Foraminifera. Eclogae Geologicae Helevetiae, Vol.19, p. 95 – 107.

Molina, E., Arenillas, I. and Arz, J.A., 1996. The Cretaceous/ Tertiary boundary mass extinction in planktonic foraminifera at Agost, Spain. Revue de Micropaleontologie, Vol.39, p. 225 – 243.

Nederbragt, A.J., 1990. Late Cretaceous biostratigraphy and development of Heterohelicidae (planktonic foraminifera). Micropaleontology, Vol.37, No.4, p. 329 – 372.

Obaidalla, N.A., 2005. Complete Cretaceous/ Paleogene (K/P) boundary section at Wadi Nukhul, southwestern Sinai, Egypt: Inference from planktonic foraminiferal biostratigraphy, Revue de Paleobiologic, Geneve (2005) Vol.24, No.1, p. 201 – 224.

Olsson, R.K., Hemleben, C., Berggren, W.A., Huber, B. and Members of Paleogene planktonic foraminifera working group, 2000. Atlas of Paleocene Planktonic Foraminifera. http://services.chronos.org/foramatlas/ pages/home.htm. 281p, with 66 plates, 2 charts and 29 paleogeographic maps.

Pardo, A., Ortiz, N. and Keller, G., 1996. Latest Maastrichtian and Cretaceous/ Tertiary Boundary, Foraminiferal Turmover and Environmental Changes at Agost, Spain. Cretaceous – Tertiary Mass Extinction: Biotic and Environmental Changes. By Norman_MacLeod and Gerta Keller, W.W. Norton Company, New York, London, p. 139 – 171.

Premoli-Silva, I. and Sliter, W.V., 1995. Cretaceous planktonic foraminiferal biostratigraphy and evolutionary trends from the Bottaccione section. Gubbio, Italy: Paleontographia Italica, Vol.82, p. 1 – 89.

Premoli-Silva, I. and Sliter, W.V., 1999. Cretaceous Paleoceanography: Evidence from planktonic foraminiferal evolution in Barrera, Geological Society of America, Special Paper, 332, p. 301 – 328.

Premoli-Silva, I., Spezzaferi, S. and D'Angelantonio, A., 1998. Cretaceous foraminiferal bio-isotope stratigraphy of Hole 967E and Paleogene planktonic foraminiferal biostratigraphy of Hole 966E, Eastern Mediterranean. A.H.F., Robertson, K.C., Emeis, C., Richter and A., Camerlenghi, (Eds.). Proceedings of Ocean Drilling Program, Scientific Result, Vol.160, p. 377 – 394.

Robaszynski, F., Caron, M., Gonzalez, D.J.M. and Wonders, A.A.H., 1983 – 1984. Atlas of Late Cretaceous Globotruncanids, Revue de Microp., 26, 3 – 4, p. 145 – 305.

Raffo, S.S.D., 1989. Planktonic foraminifera and biostratigraphy of Aaliji Formation and nature of the contact with Shiranish Formation in Mushorah well No-1, Northwest Iraq. Unpub. M.Sc. Thesis, University of Mosul, Mosul, Iraq. 140pp. (in Arabic)

Samir, A.M., 2002. Biostratigraphy and paleoenvironmental changes in the Upper Cretaceous – Early Paleogene deposits of Gabal Samara section, Southwestern Sinai, Egypt. Egypt Jour. Paleontol., Vol.2, p. 1 – 40.

Shahin, A., 1992. Contribution to the Foraminiferal biostratigraphy and paleobathymetry of the Late Cretaceous and Early Tertiary in the western central Sinai, Egypt. Revue de Micropaleontology, Vol.35, No.2, p. 157 – 175.

Sharbazheri, K.M., 2007. Aging of Unconformity within Tanjero Formation in Chwarta Area (Kurdistan Region) Northeast of Iraq. Rafidain Jour. Sci., Vol.7, No.1, p. 37 – 54.

Sissakian, V.K., 2000. Geological Map of Iraq, sheet No.1, scale 1:1000000, 3rd edit. GEOSURV, Baghdad, Iraq.

Smit, J., 2005. The section of Barranco del Gredero (Caravaca, SE Spain): Acrucial section for the Cretaceous/ Tertiary boundary impact extinction hypothesis. Jour. Iberian Geol., Vol.31, p. 179 – 191.

Smith C.C. and Pessagno, E.A., 1973. Planktonic foraminifera and stratigraphy of the Corsicana Formation (Maastrichtian), North Central Texas. Special publication of the Cushman Foundation for Foraminiferal Research, Vol.12, p. 1 – 68.

Stinnesbeck, W., Keller, G., Adatte, T., Harting, M., Stuben, D., Istrate, G. and the Chicxulub Impact. International Jour. Sci., GR Geologische Kramar, U. 2004. Yaxcopoil-1 Rundschau. 10.1007/s00531-004-431-6 http://www.geo.vu.nl/users.smit/forums,html/fulltext,html.

About the author

Khalid M. Sharbazheri graduated from University of Sulaimani in 1980 with B.Sc. degree, M.Sc. in 1983 from Mosul University, and Ph.D. degree in 2008 from Sulaimani University. Currently, he is working as Assistant Professor in Sulaimani University, College of Science, Geology Department. He has 12 published articles in stratigraphy and biostratigraphic aspects and 9 unpublished articles. His major field of interest is biostratigraphy.

e-mail: khalshin@yahoo.com
is.khalid57@gmail.com

Mailing address: Iraq, Sulaimaniyah, Sulaimani University, College of Science, Geology Department