



# Cretaceous / Paleogene Boundary Analysis by Planktic Foraminiferal Biozonation in the Western Zagros Fold-Thrust Belt (Smaquli valley), Sulaimani Governorate, NE-Iraq

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## Abstract

The current work focuses to study the foraminifera assemblages within the Cretaceous/Paleogene (K/Pg) boundary outcropped in the High Folded Zone in Smaquli valley (Gali section), Kurdistan Region, and Northeastern Iraq. The boundary is nearly located between Tanjero and Kolosh Formations and their exposure mainly consists of thick succession of deep marine turbidities (flysch) and hemipelagic sediments. The study aims to indicate biological fossils assemblages and physical expressions that inherited from globally important events of the end of cretaceous. The study has extracted expressions of the well exposed successions of fine grains from which 8 biozones are identified in the uppermost section of Shiranish formation, the Shiranish- Tanjero transition area and the Tanjero formation through biostratigraphy (biozonation) and lithostratigraphic analyses. These zones, from the bottom to top, are upper part of *Globotruncana aegyptiaca* Interval Zone (CF8), which belongs to Upper part of Shiranish Formation, (Early Maastrichtian) and lower part of Tanjero Formation. The second, third, fourth and fifth zones are *Gansserina gansseri* Interval Zone (CF7), *Contusotruncana contusa* Interval Zone (CF6) (Early Maastrichtian) and *Pseudotextularia intermedia* Interval Zone (CF5), *Racemiguembelina fructicosa* Interval



Zone (CF4) respectively and all belong to lower part of Tanjero Formation (Early Maastrichtian). The sixth, seventh and eighth zones are *Pseudoguembelina hariaensis* Interval Zone (CF3), *Pseudoguembelina palpebra* Interval Zone (CF2), *Plummerita hantkeninoides* Total Range Zone (CF1) respectively that belong to upper part of Tanjero Formation (Late Maastrichtian). Moreover, four biozones of Danian (Early Paleocene) are recorded in the lower part of Kolosh Formation which are *Guembelitria cretacea* Interval Zone (p<sub>0</sub>), (base of Danian), *Parvularugoglobigerina eugubina* Total Range Zone (p<sub>a</sub>), (base of Danian), *Parvularugoglobigerina eugubina-Subbotina triloculinoides* Interval Zone (P1a) (Early Danian), *Subbotina triloculinoides-Praemurica inconstans* Interval Zone (P1b), (Middle Danian). The lithostratigraphic and biostratigraphic study revealed that no physical events (conglomerate, erosional surface, paleosoil and hardground) and has a conformable and gradational existence, which is evidenced by continuous sedimentation of the same sediments and no chronostratigraphic gaps within K / PG boundary. Biologically, it shows the gradual extinction of the Cretaceous planktic foraminifera and the sudden emergence of the Paleogene ones.

**Keywords:** Planktic foraminifera; Biostratigraphy; Biozonation; Cretaceous/ Paleogene boundary.

**DOI:** <http://doi.org/10.32894/kujss.2020.15.3.3>



## تحليل الحد الفاصل الكريتاسي / الباليوجين في نطاق الطيات الザحفة الزاكروس

### الغربية (وادي أسماقولي) محافظة السليمانية، شمال شرق العراق

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#### الملخص

تتركز الدراسة الحالية على دراسة تجمعات الفوارامنيفيرا ضمن تربات الحد الفاصل بين الكريتاسي والباليوجين المنكشفة في نطاق الطيات العالية في وادي الأسماقولي (مقطع كلي)، أقليم كردستان، شمال شرق العراق. يتموضع هذا الحد الفاصل تقريباً بين تكويناً تانجرو و كولوش ذات المكافئ المؤلفة من تتباعات و تربات المياه العميقة. (flysch) للترسبات المياه البحرية العميقة الخابطة، و تهدف الدراسة إلى تحديد تجمعات الأحافير البيولوجية والتغيرات الفيزياوية التي ورثت من الأحداث المهمة عالمياً لنهاية الطباشيري.

تضمنت الدراسة تعبيرات إضافية عن التعاقب المكشوف جيداً للترسبات دقيقة الحبيبات التي تم تحديد 8 أنطقة حياتية منها في الجزء العلوي من تكوين شيرانيش ومنطقة انتقال شيرانيش- تانجرو و تكوين تانجرو من خلال تحديد الأنطقة الحياتية Globotruncana aegyptiaca والصخرية. وهذه الأنطقة من الأسفل إلى الأعلى مماثلة بالجزء العلوي لنطاق الماسترختيان ( والذي يمثل الجزء العلوي لتكوين شيرانش والجزء السفلي لتكوين تانجرو Zone Interval CF8 )

المبكر) أما النطاق الثاني والثالث والرابع والخامس ممثلاً بالأطique التالية على التوالي والذي يعود للجزء السفلي لتكوين تانجирه والتي لها عمر (الماسترختيان المبكر).

(*Gansserina gansseri* Interval Zone (CF7), *Contusotruncana contusa* Interval Zone (CF6) (Early Maastrichtian) and *Pseudotextularia intermedia* Interval Zone (CF5), *Racemiguembelina fructicosa* Interval Zone (CF4)

أما الأطique السادس والسابع والثامن ممثلاً بالأطique التالية على التوالي والتي تعود إلى الجزء العلوي لتكوين تانجирه.

*Pseudoguembelina hariaensis* Interval Zone (CF3), *Pseudoguembelina palpebra* Interval Zone (CF2) وعمر (الماسترختيان المتأخر).

بالإضافة إلى أربعة أطique تم تسجيلها من عمر Danian ومن الجزء السفلي لتكوين كولوش والممثلاً بالأطique التالية

*Guembelitria cretacea* Interval Zone ( $p_0$ ), (base of Danian), *Parvularugoglobigerina eugubina* Total Range Zone ( $p\alpha$ ), (base of Danian), *Parvularugoglobigerina eugubina-Subbotina triloculinoides* Interval Zone (P1a) (Early Danian), *Subbotina triloculinoides-Praemurica inconstans* Interval Zone (P1b), (Middle Danian).

كشفت الدراسة الطباقية الصخريّة والحياتيّة بعدم وجود أحاديث فيزيائين مثل (وجود مدلّكات وسطوح تعريّة وترب قديمة وارض صلبة) وان الحد الفاصل بين التربات للكريتاسي والباليوجين متّوقة ومتدرّجة الترسّيب والذي يتّضح من الترسّيب المستمر لنفس الرواسب ولعدم وجود فجوة طباقية زمنية على جانبي الحد الفاصل. وكذلك من ناحية التواجد الحيّي لوحظت انقراض تدريجي للفورامينيفيرا الطافية للكريتاسي والظهور المفاجئ لأنواع الباليوجين.

**الكلمات الدالة:** الفورامينيفيرا الطافية؛ التطبّق الحيّي والأطique؛ الحد الفاصل بين الكريتاسي والباليوجين.

**DOI:** <http://doi.org/10.32894/kujss.2020.15.3.3>

## 1. Introduction:

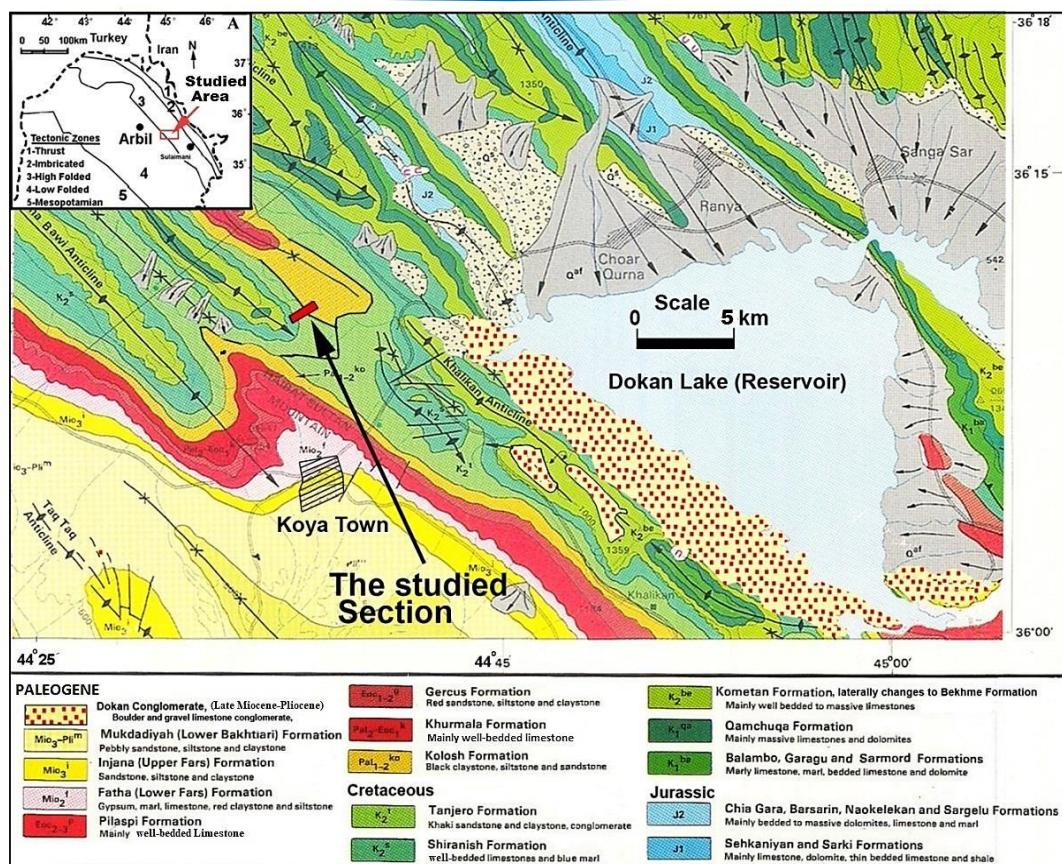
The study of the K / PG boundary over the last few decades was contentious and one of the most frequently discussed problems in stratigraphy. This controversy is obvious in literature in which many authors suggested many hypotheses to explain the events and character of the boundary see [1-4]. The key event is the cause of the international mass

extinction of many organism groups across this boundary and the distribution and number of other marine and terrestrial species have been inclined. Many authors such as [5 - 7] attributed this extinction to the multiple causes, such as plate tectonics (continental rifting), the asteroid-impact and volcanisms.

For various purposes, the K / PG boundary has been explored in different locations and regions of the world by specific methods such as tectonic, geochemical, stratigraphic and biological tracts. This boundary is not entirely studied in northerly Iraq (Kurdistan Region) particularly in the area of Sulaimani that shows important exposed sedimentary record profiles of Zagros [8]. This research is concerned with biostratigraphy in the K / PG boundary sequences in the Sulaimani region and is focused on the identification of planktic foraminifera across an outcrop section of Late Maastrichtian and Early Paleocene. This studied area is situated in northeastern Iraq, in the region of Kurdistan, at the border between Sulaimani and Erbil. The main outcrop of the examined section is located in Smaquli valley (Gali) at 25 Km to the north of Koyia town on the northeast limb of Awagird mountain at near the northeastern plunge of Safeen anticline at the latitude and longitude of (360 10- 51.3= N) (440 36- 40.8= E) respectively Fig. 1.

## **2. Materials And Methods:**

To identify the K/PG boundary, the authors sampled about 230 m of the succession and extended the sampling into part of Maastrichtian and Paleocene, across the Gali section, they excavated 152 fresh samples at 1m interval to find the approximate stratigraphic position of the boundary. After approximate location, 20 additional samples have taken at 10 cm intervals to conduct high-resolution study of the boundary. On all samples, the procedure includes picking of the index species and fixing them directionally on slides for identification under stereomicroscopes and electronic scanning. The research photographed the described species for further analysis and comparison with previously published photos. The results are valid for precise planktic foraminiferal zonation to indicate location and events associated with the studied section boundary of K / PG, in addition to similarities and contrasts with local and global studies .Fresh samples and residues are stored at the Department of Geology, Sulaimani University.



**Fig. 1:** Geological and Location maps of the studied area modified from [9].

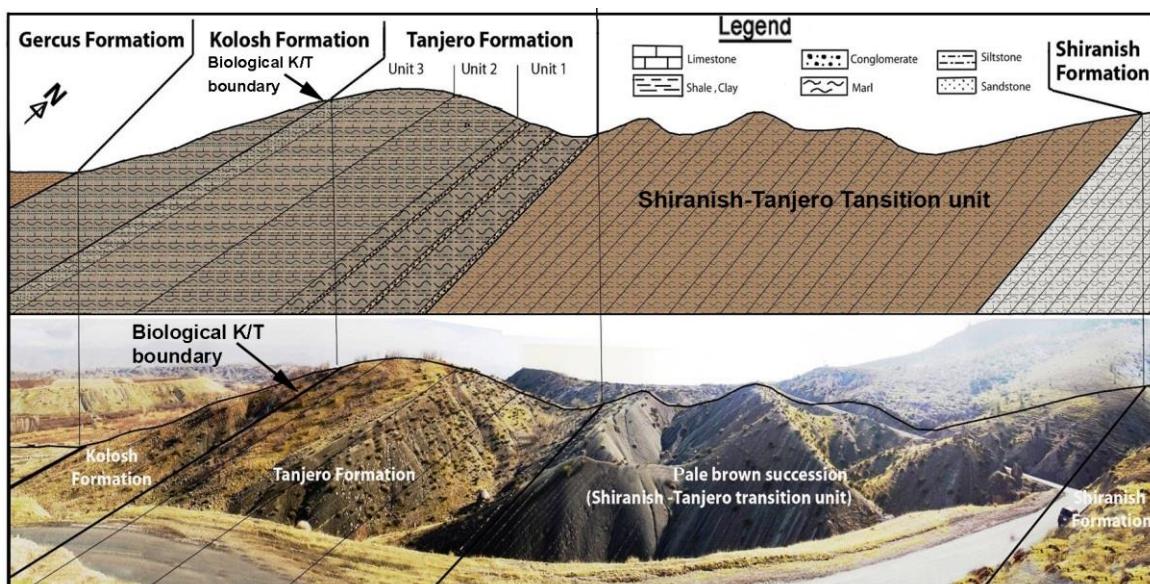
### 3. Results:

#### 3.1 Stratigraphy:

In Iraq and during Early Cretaceous, the passive Arabian margin (or Neotethys oceanic margin) covered the studied area and whole Iraq, while during Campanian the area transformed to Foreland basin due to colliding of Arabian and Iranian plates [10]. Shiranish (Campanian-Early Maastrichtian), Tanjero (Maastrichtian) and Kolosh (Paleocene) Formations are deposited in the foreland basin in which the studied rock units were deposited.

In the studied section, the lower part of Shiranish Formation consists of marl and marly limestone while its upper part mainly comprised of dark and brown calcareous shale and dark grey marl Figs. 2 and 3. Tanjero Formation consists of medium (4-40 cm) beds of sandstone (flysch type) with interbedded of marl and calcareous shale. The stratigraphy of the studied area is important because it represent the area of both lateral and vertical facies change between Shiranish and Tanjero Formations. In the studied area, about half of the latter

formation changed to former one, therefore, the thickness of Tanjero Formation and Shiranish Formation are about 80 m and 250 m respectively. The lithology of Kolosh Formation (Paleocene) is similar to that of Tanjero Formation but with more calcareous shale. The definition and description of the above Formations included in [11] and [12].



**Fig. 2:** Stratigraphic schematic cross section, showing K/PG boundary at studied section in Smaquli area.

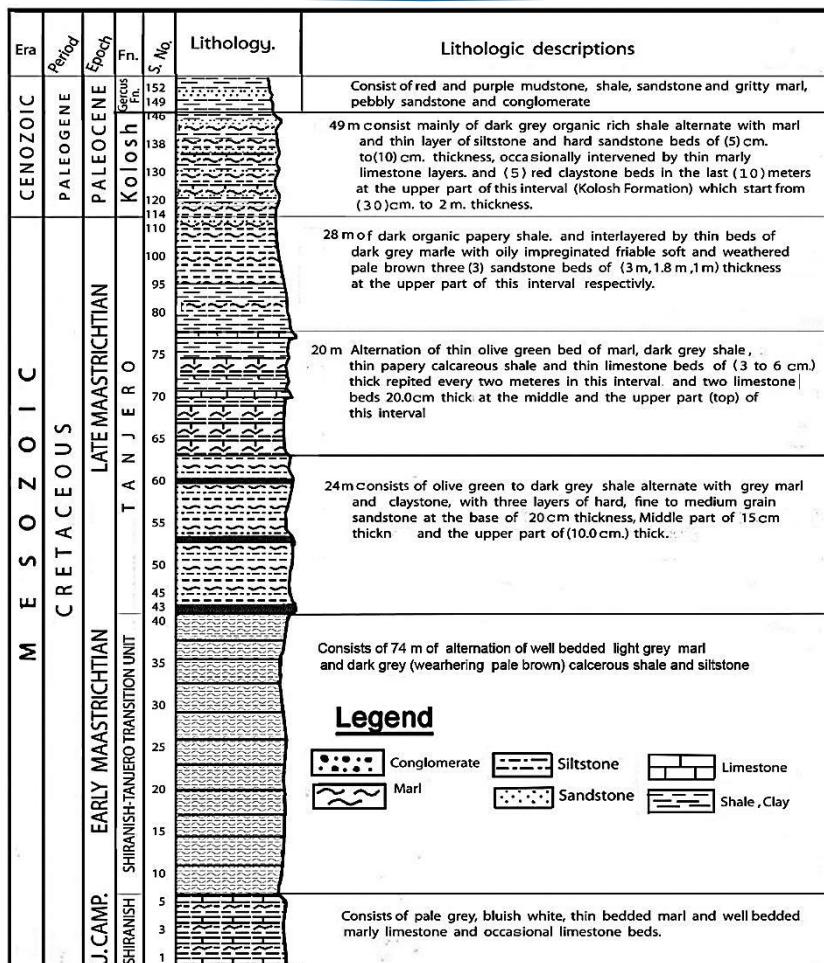


Fig. 3: Stratigraphic column of the studied section in Smaquli area.

### 3.2 Biostratigraphy:

The collected samples contain microfossils abundant groups of well-preserved planktic foraminifera of the typical Tethyan fauna and signalize the biotic evolution and radiation stage in addition to high species diversity of *Heterohelicids*, *Globotruncanids*, *Rugoglobigerinids* and *Globigerinids* in Smaquli area (Gali section). The foraminifera occurs continuously in the sedimentary sequence and normally displays uninterrupted sedimentary sequence. The foraminifer occurs continuously in the sedimentary sequence and normally displays uninterrupted sedimentary sequence occur continuously in the sedimentary sequence and generally shows incessant in sedimentary sequence without any interruptions. The samples yield 82 species belongs to 23 genera of planktic foraminifera from Maastrichtian

and 21 species belong to 14 genera recorded from lower Paleocene in the studied section (Fig. 6 – part 1 and 2).

Stratigraphic distribution of the planktic foraminifera in the studied section is shown in Fig. 6 – part 1 and 2. The zonal scheme of [22], [23], [46] and [71] is adopted using their zonal boundaries for the Cretaceous planktic foraminifera with some modification in the present study for more accurate biostratigraphical resolution.

Previously, the zonal Paleogene subdivisions of a system were established in two widely separated geographical areas in the eastern hemisphere (Caucasus Mountains) [13], and the western hemisphere (Trinidad), [14]. Discussion of all subsequent modifications to the original zonal scheme were conducted by [15-17] and [18]. In the present study, the revised Paleocene base scheme is used with other mentioned authors as in Fig. 8, We must note that Paleocene planktic foraminifera's initial, genetic radiation, phylogenetic reconstruction relation and geological ranges have been established by [19] and [20] which are the basic principles for the Paleocene Planktic Atlas working group. The *Abathomphalus mayaroensis* of Late Maastrichtian has been very rarely reported as a traditional index. It is commonly absent in the shallow, continental shelf areas in all of the areas that have been studied and can extinct prior the K / PG boundary due to the deeper basinal oceanic climate at lower latitudes restrictions of the species [21]. Hence, the biozone is limited geographically and environmentally in these situations. it is easier to avoid an unpredictable first and last data extinction scenario from being replaced by other biozones. Figs. 6 - part1 and 9.

### **3.2.1 Zonation of the Upper Cretaceous sediments:**

In the present analysis, eight biozones were reported in accordance with the established planktic foraminifera assemblages in the upper part of the Shiranish Formation, Shiranish-Tanjero transition Zone and Tanjero Formation. The identified biozones from older to younger have been defined as below.

- *Globotruncana aegyptiaca* Interval Zone (CF8, Upper Campanian)

This interval zone, initially, defined by [22], in the first appearance datum (FAD) of *Globotruncana aegyptiaca* to (FAD) of *Gansserina gansseri* (Bolli). In the present section (Smaquli area), the index taxon (FAD) is distinguished from the upper part of the Shiranish

Formation at the base of *Gansserina gansseri* (Bolli) (FAD) in sample No.8 Fig. 4.1-3 at the upper part of the reddish unit. The zone includes the typical occurrence of nominated species in the top of the Shiranish Formation for 15 m and the base part of the reddish unit for 8 m, which may not be all the intervals in the biozone since the first specimen may not be included in the FAD of the nominated species in our section.

It shows the origination of diversified planktic foraminiferal species, e.g. *Planoglobulina c arseyae* (Plummer), *P. brazoensis* Martin, *Rogoglobigerina rugosa* (Plummer), *R. scotti* (Bronnimann), *R. hexcamerata* Bronnimann, *R. macrocephala* Bronnimann, *R. rotundata* Bronnimann, *R. milamensis* Smith & Pessango, *Heterohelix navarroensis* Loeblich, *H. globulosa* (Ehrenberg), *H. striata* (Ehrenberg), *H. reussi* (Cushman), *H. nauttalli* (Voorwijk), *H. punctulata* (Cushman), *H. pulchra* (Brotzen), *Gansserina wiedenmayeri* (Gandolfi), *Globotruncanita stuarti* (de Lapparent), *G. stuartiforms* Dalbez, *G. conica* White, *Rugotruncana subcircumnodifer* (Gandolfi), *R. circumnodifer* (Finlay), *Globotruncana aegyptiaca* Nakkady, *Glt. orientalis* El-Naggar, (Carsey), *Glt. falsostuarti* Sigal, *Glt. mariei* Banner & Blow, *Glt. arca* (Cushman), *Glt. gagnebini* Tilev, *Glt. bulloides* Vohgler, *Glt. linneiana* (d Orbigny), *Glt. ventricosa* White, *Glt. insignis* (Gandolfi), *Glt. dupeublie* Caron et al., *Glt lapparenti* Boli, *Globigerinelloides voluta* (White), *G. multispiinata* (Lalicker), *G. prairiehillensis* Pessango, *G. subcarinatus* Bronnimann, *G. bolli* Pessango, *G. ultramicra* (Subbotina), *Contusotruncana fornicata* Plummer, *Gublerina cuvillieri* Kikoine, *Gumbelitria cretacea* (Cushman), *G. dammula* (Voloshina), *Globotruncanella petaloidea* (Gandolfi), *G. havanensis* (Voorwuk), *Pseudotextularia elegans* (Rzehak), *P. deforms* (Kekoine), *P.intermedia* (De Clasz), *Pseudoguembelina costulata* (Cushman), *Hedbergella monmothensis* (Olsson), *Archaeoglobigerina cretacea* (dOrbigny), *A. blowi* Passango, Figs.4 and 5.

The age of this biozone is determined as the Early Maastrichtian by [23], estimated absolutely based on magnetostratigraphic age, reported the time period of this biozone from 72.48 Ma to 70.39 Ma. The *Globotruncana aegyptiaca* Zone of Upper Campanian described by [24] and [25] in their analysis of the Eastern Mediterranean bioisotope stratigraphy. This zone is also associated with the *Globotruncanella havanensis* Partial Range Zone by [26], which is Upper Campanian age in DSDP 390A comes from Blake Nose (North Atlantic).

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**- *Gansserina gansseri* Interval Zone (CF7, Early Maastrichtian)**

The (CF7) Zone was introduced by [27] and placed in the early Maastrichtian in Trinidad [28]. This biozone in current study described from lower part of the pale-brown succession, as the interval between the FAD of *Gansserina gansseri* (Bolli) and the FAD of *Contusotruncana contusa* (Cushman) (Fig.4.5-7). The zone had an abundance of 20 m thick designated species.

The *Gansserina gansseri* Zone was informally occupied by the majority of the Authors of the zone scheme in the middle-lower Maastrichtian region e.g. [23], [29] at Site 525A. and [28], [30-32] in Egypt, respectively. Also, [33-38] in Iraq., this zone is, in general, recordable in Middle Maastrichtian [22]. In addition to the index species, this zone produced an assemblage of planktic foraminifera which is completely similar to that of the underlying *Globotruncana aegyptiaca* Zone (CF8), except for the first appearance of *Rogoglobigerina milamensis* Smith & Pessa, *Globotruncanita pettersi* Gandolfi, *Hedbergella holmdelensis* (Olsson). Age: Early Maastrichtian.

**- *Contusotruncana contusa* Interval Zone (CF6, Late early Maastrichtian).**

This zone proposed to the Upper Maastrichtian of Tunisia by [39]. It covers an interval of 25 m for the current analysis in the Gali region. The interval of this zone is set at the base of (LAD) of *Globotruncana Linneniana* (d orbigny), by the FAD of *Contusotruncana contusa* (Cushman). Fig.3.2-a. The associated foraminiferal assemblages in the present Zone (CF5) are similar to those of the overlying *Gansserina gansseri* Zone (CF7) except the FAD of *Racemiguemelina powli* Smith and Pessango, *Globotruncana rosetta* Carsey, *Rugoglobigerina scoti* (Bronnimann), *Hedbergella holmdelensis* Olsson, *Contusotruncana contusa* (Cushman), *C. patelliformis* (Gandolfi), *C. plicata* White, and mark the end of *Globotruncana gagnebini* Tilev, *Globotruncana bulloides* Vohgler, *Glt. insignis* (Gandolfi), *Glt. mariei* Banner & Blow, *Glt. ventricosa* White, *Guembelitria dammula* (Voloshina), *Globotruncanella havanensis* (Voorwuk), *Globigerinilloides boli* Passango, *Archaeoglobigerina blowi* Pessango, *A. cretacea* (d Orbigny) Fig.5. As mentioned above, the current Biozone (CF6) is corresponding to the zone reported by [23] and [29], at DSDP Site 525A, also recorded by [28] in Egypt. And by [37] in NE Iraq. the lower part of *Rosita contusa* Zone reported in varies country by many authors such as [34], [35] in the Northeast of Iraq, and [24], [40] in Italy, also [41] from Egypt, and it is also equivalent to the middle

part of *Gansserina gansseri* Zone of [34], [36] and [43] from Iraq. And [44] in Spain, [25] from USA, [45] in Egypt.

Age: Upper Early Maastrichtian.

- *Pseudotextularia intermedia* Interval Zone (CF5, Late Early Maastrichtian)

Initially, this Biozone was introduced in [46] as the FAD interval for *Planoglobulin acervulinoids* at its base and *Racemiguembelina fructicosa* FAD at the top. In this analysis, the description is restricted by [23] and [46]. The LAD of *Globotruncana linneiana* (d'Orbigny) at the base and the FAD of *Racemiguembelina fructicosa* (Egger) at the top Fig.4. 4. The interval of this zone is 19 m thick in Gali section. The associated recorded well-diversified forams observable in the stratigraphic range chart Fig. 6 - part 1. the present Zone (CF5) is correlated, due to their high similarities of foraminiferal occurrence to that of [23], [28] and [29]. And it is corresponding to the top of *Glt. contusa* Zone in Iraq [33], [34], and *Glt. contusa-R. fructicosa* Zone from Italy [40], and Egypt [41]. This zone is corresponding to the upper part of the *R. fructicosa* Zone by [26] in DSDP 390A from Blake Nose (North Atlantic). Age: Late Early Maastrichtian

- *Racemiguembelina fructicosa* Interval Zone (CF4, Early Late Maastrichtian)

As a biostratigraphic interval between *Racemiguembelina fructicosa* (Egger) FAD and *Pseudogembelina hariaensis* Nederbragt FAD, [23], [46] Fig.4.8. The FAD of *Racemiguembelina fructicosa* (Egger) Gali section in, which is reported in the top part of the reddish brown unit and covers the basal part of the Tanjero Formation (see sample No.38) in the FAD of *Pseudogembelina hariaensis* Nederbragt (see sample No.58). Figs. 3 and 6 part 1 and has a thickness of 23 m.

The most of authors worked on zonal scheme have situated the *Racemiguembelina fructicosa* in the lower Late Maastrichtian [23], [29], at DSDP Site 525A. [47], from Tunisia. [28] and [45] from Egypt. The current biozone (CF4) is correlated with the lower part of *A. mayaroensis* of [34], [48] in Iraq, [49] in Italy. Fig.8. The age calculation of this biozone reported a time period between (68.33 Ma) and (66.83 Ma) [23], determined by (1500 Ky) absolute ages with magnetostratigraphic age (62 ky / m), with a low deposition rate. Its age is Early Late Maastrichtian.

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-*Pseudoguembelina hariaensis* Interval Zone (CF3, Middle Late Maastrichtian)

This zone described as a partial range between the *Pseudoguembelina hariaensis* Nederbragt FAD and the *Gansserina gansseri* (Bolli)LAD [23]. In current study, the zone was also named for the most LAD of *Gansserina gansseri* (Bolli) by the FAD of the nominated species. Fig. 4.13.

The foraminiferal assemblages are the same as that of the underlying *Racemiguembelina fructicosa* zone, as shown in the stratigraphic range chart Fig. 6 -part 1. It is 21 m thick interval and shows a reliable abundance of *Pseudoguembelina hariaensis* Nederbragt and other foraminifera assemblages. The current biozone (CF3), as mentioned above, can be connected to the DSDP site 525A region zone reported by [23] and [29] in Madagascar. [49] from Tunisia. [50] in Eastern Tethys. [28] and [45] in Egypt. [37], [38] in NE Iraq, and it is correlated according to [34]and [48] with the middle part of *Abathomphalus mayaroensis* Zone recorded in the Northeast of Iraq, [40] in Italy, [44] in Egypt, Fig. 8.

The age estimation of this biozone shows that the Middle Late Maastrichtian has an average of absolute ages based on magnetochron ages over the period (66.83 Ma) to (65.45Mas) [23]. Estimated absolute age (1380 Ky) in the Gali section based on magnetic age at low deposition (66 Ky / m). Figure 8 shows the relative and corresponding current zones.

- *Pseudoguembelina palpebra* Interval Zone (CF2, Middle Late Maastrichtian).

This zone described from DSDP Site 525A and Tunisia by [23] and [46] respectively Fig. 4. 14-15. This zone (CF2) represented the interval between the LAD of *Gansserina gansseri* at the base to the FAD of *Plummerita hantkeninoides* at the top with 24 m covers interval Figs.4 and 5.

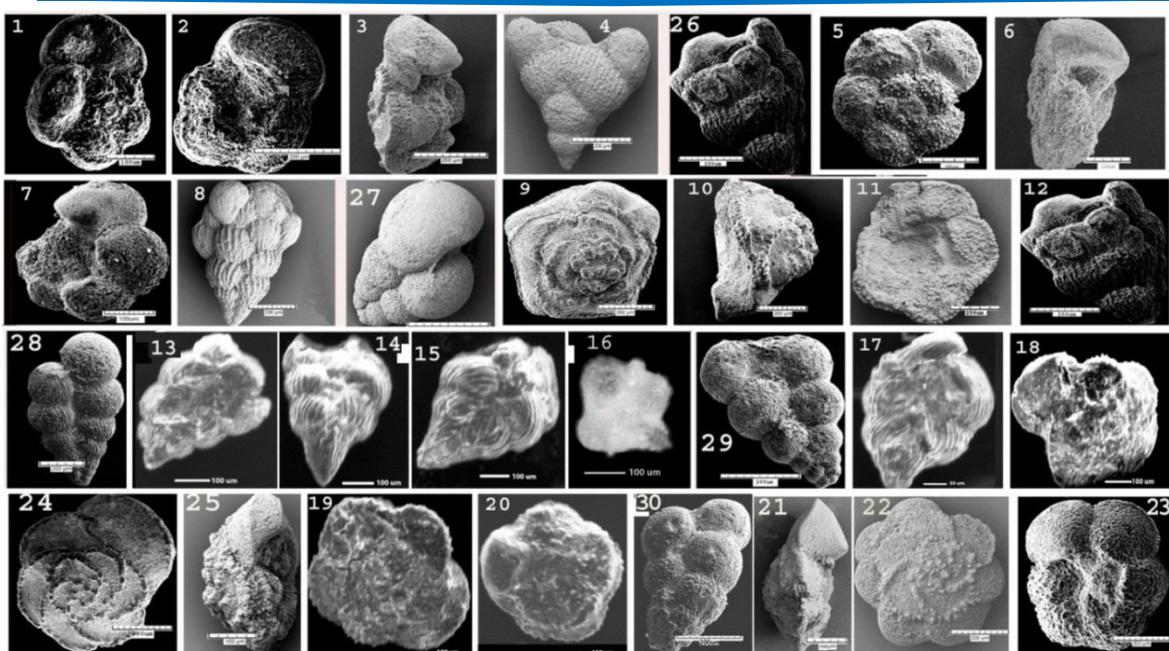
This biozone associated with planktic assemblages, was reported and indicated by the extinction of *Laeviheterohelix glabrans* (Cushman), *Globigerinelloides volutes*, *Heterohelix punctuates*, *Gansserina gansseri*, (White), and at the upper part of this zone. However, several species have their first appearance, such as *Globotruncana falsoscalcarata* Kerdany & Abdelsalam, *Trinitella scotti* Bronnimann, *Globotruncanella* sp. These species are making their original appearance; it was the first time that appeared in this zone.



The estimation of the zone age indicates the Upper Late Maastrichtian [23], with a complete estimate of absolute ages based on magnetochron ages (65.45 M) to (65.30 Ma). (150 Ky), in Gali section with (6 ky / m) large rates deposition. Fig. 8 shows the corresponding and equivalent areas of this zone. Age: Middle Late Maastrichtian.

- *Plummerita hantkeninoides* Total Range Zone (CF 1, top of the late Cretaceous)

The range of this zone is determined by [51] with the total range of the nominate taxon of *P. hantkeninoides* in the Latest Maastrichtian of Spain. This defines the uppermost biozones in the Cretaceous Fig.4.16 and marks the K / PG line. The top limit of this boundary coincides with the massive extinction of large tropical taxa. The top 15 m of the Maastrichtian zone in the area studied Figs.4 and 6- part 1. Only about one third of this zone can be present, depending on the faunal shift in the sediment thickness of Zone CF1 in the region of Tethys, but at least a portion of the variability of zones CF1 in the region of Tethys can be correlated with tectonic activity and irregular paleogeography [46]. The planktonic foraminifera structure recorded in this zone shows a progressive decrease from the *Pseudoguembelina palpebra* to the *Plummerita hantkeninoides* Zone, both in species and in individual numbers. In addition, two species *Trinitella scotti* Bronnimann, and *Plummerita hantkeninoides* (Bonnimann) show the first appearance of planktic foraminifera species originating from the underlying biozones Fig. 4.



**Fig. 4:** Planktic foraminifera of Late Cretaceous in Smaquli area, Gali section: 1-3, *Globotruncana aegyptiaca* Nakkady. 4. *Pseudotextularia intermedia* De Klasz. 5-7, *Gansserina gansseri* (Bolli). 8. *Racemiguembelina fructicosa* (Egger). 9-11, *Contusotrancana contusa*, (Cushman). 12, *Racemiguembelina powelli*, Smith&Pessango. (Specimen 1-12 from Reddish to pal brown succession, Early Maastrichtian). 13, *Pseudoguembelina hariaensis* Nederbragt. 14-15, *Pseudoguembelina palpebra*, Bronnimann & Brown, 16, *Plummerita hantkeninoides* (Bonnimann). 17, *Pseudoguembelina costulata* (Cushman). 18-20, *Abathomphalus mayaroensis* (Bolli), (Specimen 13-20 from Tanjero Formation, Late Maastrichtian). 21-22 *Globotruncana dupeublei*, Caron, Gonzalez, Donoso, Robaszynski &wonders. 23, *Globotruncana rosetta*, (Carsey). 24-25, *Contusotruncana fornicata*. (Plumer). 26, *Racemiguembelina powelli*, Smith&Pessango. 27, *Heterohelix globulosa* (Ehrenberg). 28, *Heterohelix striata*, (Ehrenberg). 29-30 *Heterohelix punctulata*, (Cushman). Scale bar = 100 μm.

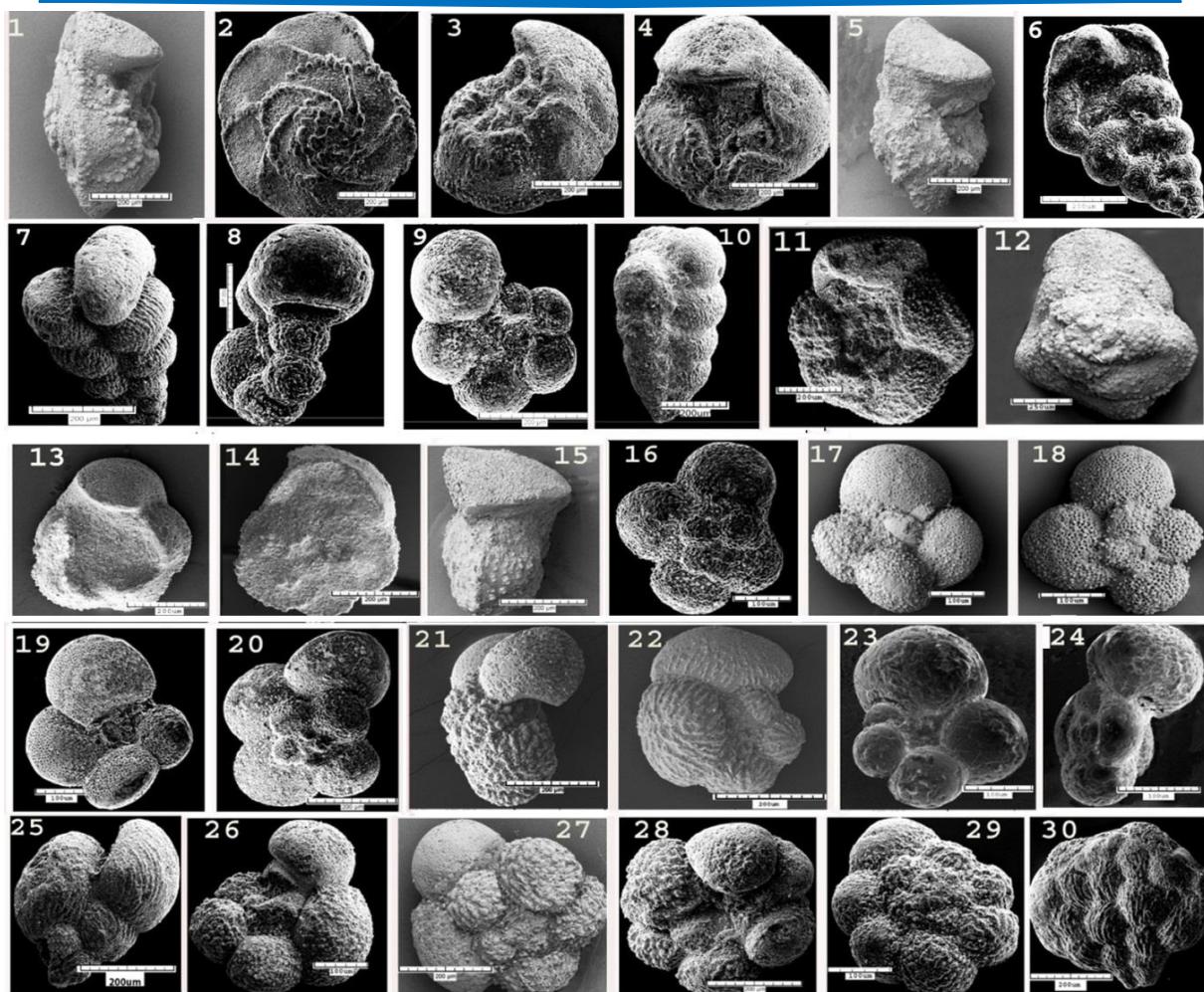
The present Zone (CF1) is centered on the associated planktic foraminifera assemblage and is similar to the zone described by [46] in Tunisia; [50] in Eastern Tethys Israel; [28] and [45] Egypt; [23] from South Atlantic DSDP Site 525A; [29] Madagascar; [54] in DSDP Site 525A and [1] from USA.



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The current zone of *plummerita hantkeninoides* is equal to *Abathomphalus mayaroensis* in their upper majority from all parts of the world [21]; [44] in Spain; [40] from Italy; [29] in eastern Mediterranean; [52] from India; [25] in USA, California; [53] and [55] from south USA, and corresponding to *Plummerita richly* Zone of [32] from Egypt.

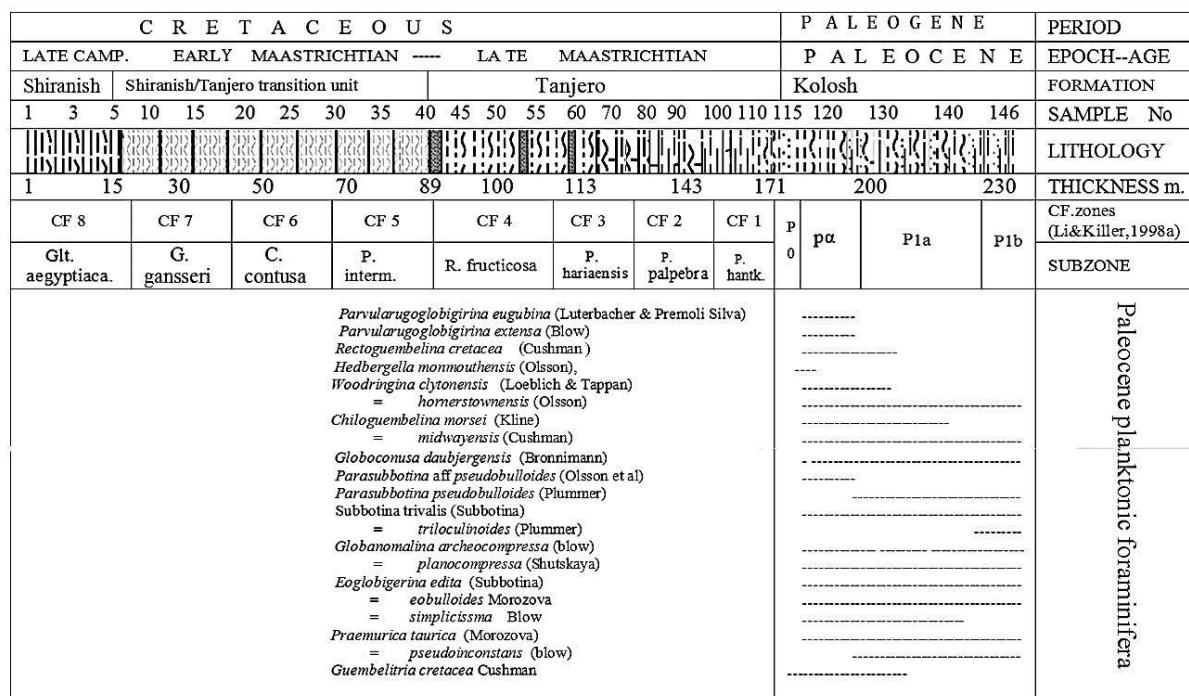
The decline in the number of species inside the *plummerita hantkeninoides* zone is reliable and has persisted at the end of this zone at the K/PG contact. In Gali Section, from (37) to (28) this is observed. The planktic foraminiferal assemblages of Maastrichtian at the stratigraphic stage corresponding to upper part of this biozone have unexpectedly disappeared. The K/PG limit is based on paleontological criteria for the mass extinction of the foraminifera planktic assemblages, as in the portion under discussion, as well as the first occurrence of the Paleocene species. Fig. 8 shows similar and related zones to the present one.



**Fig. 5:** 1-3, *Globotruncanita stuarti* (De Lapparent). 4-5, *Globotruncanita pettersi* (Gandolfi). 6, *Gublerina cuvillieri* Kikoine. 7, *Pseudotextularia elegans* (Rzehak), 8-9, *Globigerinelloides volutes* (White). 10, *Guembelitria dammula* (Voloshina). 11-12, *Contusotrancana plicata* (White). 13-15, *Globotruncanita angulata* Tilev. 16-17, *Globotruncanella havanensis* (Voorwijk). 18, *Globotruncanella pschadæ* (Keller). 19-20, *Globotruncanella petaloidia* (Gandolfi). 21-22, *Kuglerina rotundata* (Bronnimann). 23-24, *Hedbergella monmuthensis* (Olsson). 25, *Pseudotextularia deformis* (Kikoine). 26-27, *Rugoglobigerina milamensis* Smith & Pessagno. 28-29, *Rugoglobigerina rotundata*, Bronnimann. 30 *Planoglobulina acervulinoides* (Egger), Scale bar = 100 $\mu$ .

acervulinoides (Egger), Scale bar = 100 $\mu$ .

**Fig. 6 - Part 1:** Planktic foraminifera assemblages Range chart at K/PG contact in Gali section. The names of zones are from [20]. (it continues below).



**Fig 6 - Part 2:** Planktic foraminifera assemblages Range chart at K/P contact in Gali section.

The names of zones are from [20].

### 3.2.2 Zonation of the Early Paleocene sequence:

The current study represents four biostratigraphic zones in the studied section from bottom to top in accordance with defined foraminiferal planktic assemblages within the Kolosh Formation:

- *Guembelitria cretacea* interval Zone (P0, Earliest Paleocene, Danian)

The boundary contact between Tanjero and the Kolosh Formation was situated in this area to last friable brown fine sandstone (1m) beds. This layer is without of foraminifera bearing except for few forms of *Guembelitria cretacea* Cushman Fig.7.1-2. The bed is covered by 25 cm dark shale and interlayered by grey marl in which *Guembelitria cretacea* with *Hedbergella monmothensis* (Olsson) are recorded. This interval is (1.25 m) thick representing (P0) Zone and indicate K / PG contact and described by (LAD) of (*Heterohelicides*, *Rugoglobigerina*, *Globotruncana*, *Globigerinelloides*) at base and (FAD) of *Parvularugoglobigerina eugubina* (luterbacher and premoli Silva) at the top as interval between the extinctions of Cretaceous planktic foraminifera. Fig.7.3-8. The *Guembelitria*

*cretacea* Biozone is very well extended (1,25 m) and lithologically characterized by a sediment similar to Tanjero and Kolosh which is excessively distinguishable in the Smaquli section. Another important point is the lack of any reworked foraminifera within (P0) Zone and Biozones in these areas overlying.

The studied K/PG boundary is interpreted as conformable contact due to a sedimentological or erosional break lacking, no restricted low rate sedimentation and no mineralogical record found, apart from uninterrupted biostratigraphic records. The age estimation of this biozone determined as(Danian) by [20], [50]and [56], with the time span of (65.00 Ma) to (64.97 Ma). with (24 Ky/m) Large deposition level Fig. 8. The equivalent and correlative zones to the present one is observable in the Figs. 8 and 9.

- *Parvularugoglobigerina eugubina* Total Range Zone (P<sub>0</sub>, Earliest Paleocene (Danian)

The zone is defined by the entire designated taxon range [16] Fig.7. 3-8. The zone described firstly for the Early Paleocene of Central Italy [70]. Moreover, in [28], more author has included *Pv. longiapertura* with *Pv. eugubina* group e.g. [20]. In the examined section, this zone covers an interval of 18 m and demonstrates a world-wide distribution of small planktonic foraminifera assemblages.

This zone associated with the following foraminiferal assemblage species represented by *Chiloguembelina midwayensis* (Cushman), *Ch. morsei* (Kline), *Woodringina clytonensis* (Loeblich & Tappan), *W. hornerstownensis* (Olsson), *Parvularugoglobigirina extensa* (Blow), *Eoglobigerina edita* (Subbotina), *E. simplicissma* Blow, *Hedbergella monmouthensis* (Olsson), *Guembelitria cretacea* Cushman, *Rectoguembelina cretacea* Cushman, *Globanomalina archeocompressa* (blow), *Globoconusa daubjergensis* (Bronnimann), *Parasubbotina aff pseudobulloides* (Olsson et al), *Subbotina trivalis* (Subbotina), *Praemurica taurica* (Morozova), Fig. 6 part 2 and Fig.7.

This biozone was estimated at an age of (64.97 Ma) to (64.90 Ma) based on absolute period (Magnetochron Period) and (70Ky) with (4Ky / m) heightened deposition levels in Gali area, according to an approximate age of the earliest Paleocene (Danian). Figs.8, 9. Within this section, the corresponding and correlative zones are shown in Fig.8.

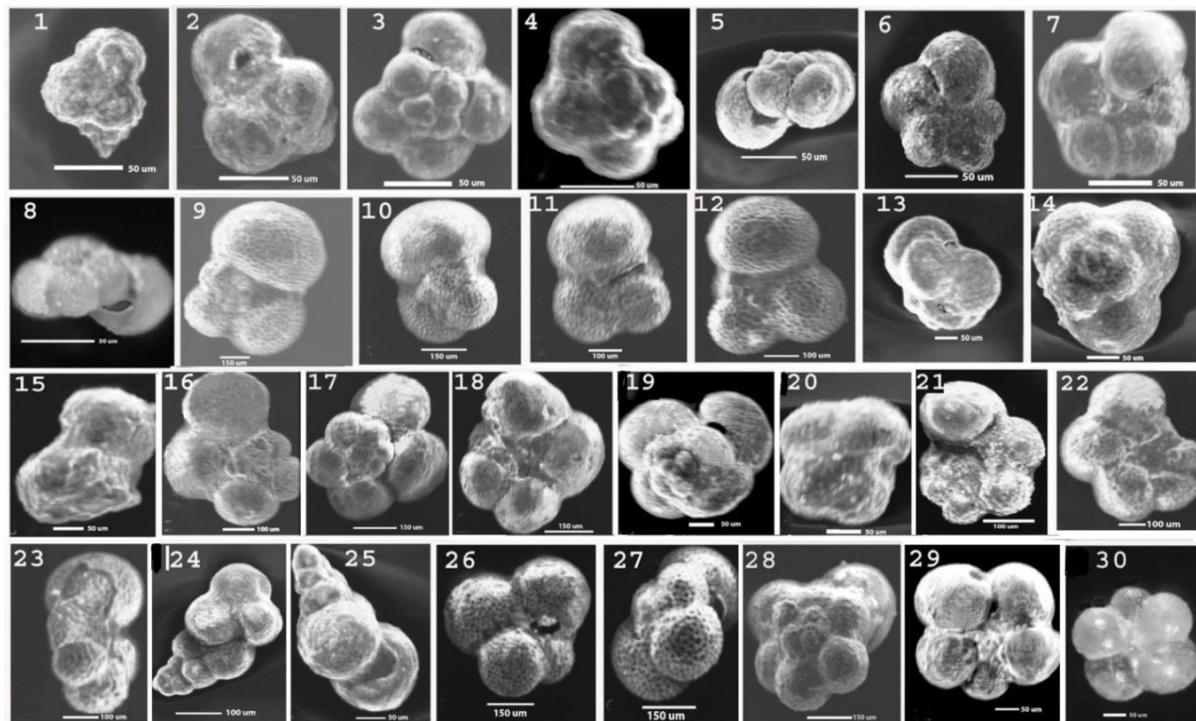
- *Parvularugoglobigerina eugubina - Praemurica uncinata* Interval Zone (P1)

This zone emended by [18] which is described by [17] at the interval between the LAD of *Parvularugoglobigerina eugubina* at the base and the FAD of *Praemurica uncinata* at the top. In [19] and (20], the P1 zone is divided into three subzones with a sequence based on the *Subbotina triloculinoides* (P1a / Ph1b boundary) and *Globanomalina compressa /Praemurica inconstans* (P1b/P1c boundary), P1a Zone and Lower part of P1b Zone were located in the studied section only Fig.6-part 2. This zone is analogous to other zones as shown in Fig. 8.

- *Parvularugoglobigerina eugubina* - *Subbotina triloculinoides* Interval Subzone (P1a, Early Paleocene (Early Danian)

This zone described and placed between *Parvularugoglobigerina eugubina* LAD and the *Subbotina triloculinoides* FAD [18]. The thickness of P1a is 25 m in Gali section in this analysis and the assemblages associated with the Pa underlying register zone is usually contrasted. However, the lower part of this zone, that represented by the following species *Hedbergella monmouthensis* (Olsson), *Parvularugoglobigerina extensa* (Blow), *P. eugubina* (Luterbacher & Premoli Silva), and *Parasubbotina aff pseudobulloides* (Olsson et al), are missing Fig.6- part 2. During the mid-term duration of this subzone, the *Guembelitria cretacea* Cushman, *Rectoguembelina cretacea* Cushman, and *Woodringina clytonensis* (Loeblich & Tappan) disappeared Fig. 7. This zone is characterized by the earliest occurrence of *Praemurica pseudoinconstans* (Blow) and *Parasubbotina pseudobulloid* (Plummer) in the Smaqli area.

The age of this range is extended with a duration (64.90 Ma) to (64.50 Ma) by [20], [50]and [56], estimating absolute ages based on magnetochron ages (16 Ky/m) high rate of deposition Fig. 7. 3-12. According to present authors, this zone is equivalent and correlative to those present in the Fig. 8.

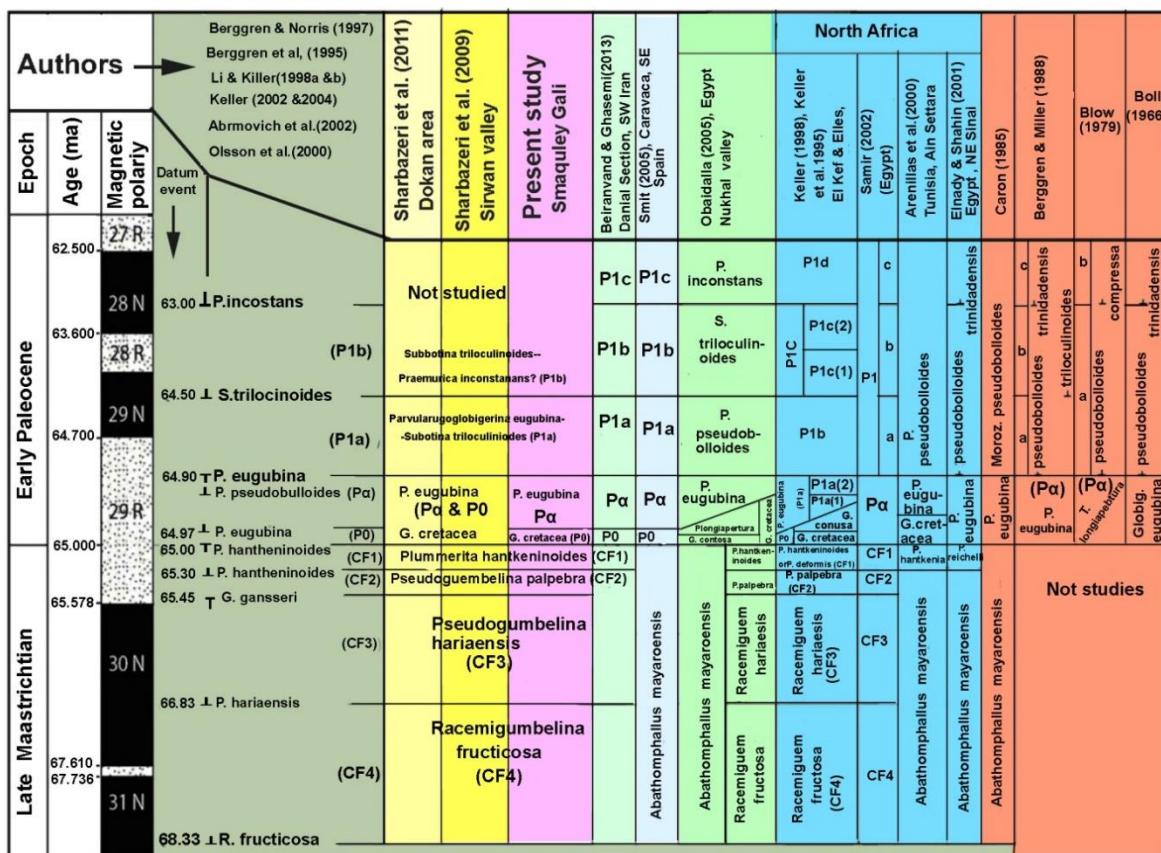


**Fig. 7:** 1-2 *Guembelitria cretacea* Cushman, from (Pa) *Parvularugoglobigerina eugubina* Zone. 3-8 *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva. 9-12 *Subbotina triloculinoides* (Plummer), 13-15 *Globoconusa daubjergensis* (Bronnimann. 16-18 *Globanomalina archaeocompressa* (Blow. 19-20 *Parvularugoglobigerina extensa* (Blow. 21-23 *Praemurica taurica* (Morozova. 24-25 *Woodringina claytonensis* Loeblich & Tappan. 26-27 *Subbotina trivals* (Subbotina. 28-30 *Eoglobigerina edita* (Subbotina), (specimen 1-30 from Kolosh Formation, Early Paleocene Smaquli).

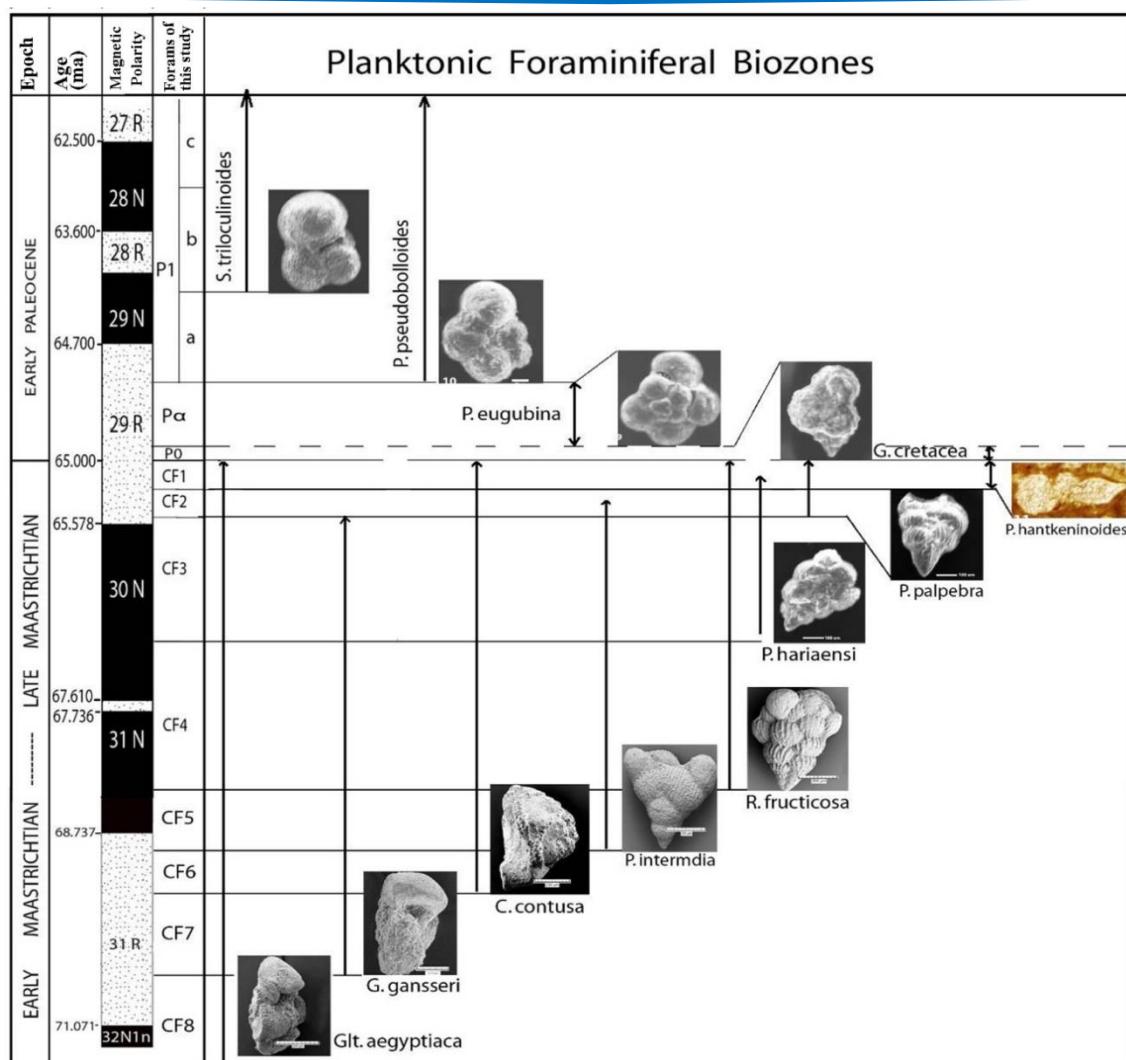
- *Subbotina triloculinoides*- *Globanomalina compressa* / *Praemurica inconstans* Interval Subzone (P1b, Early Paleocene (Early Danian)

This subzone was introduced by [18] to emend the [17] subzone P1b (*Subbotina triloculinoides*). Only the lower segment, which reaches a thickness of 10 m in the Gali area, is examined in the studied portion. This subzone's corresponding planktic assemblages varies from the subzone of P1a by *S. triloculinoides* (Plummer) Fig.7. 9-12 in addition to that recorded foraminifera shown in the stratigraphic range chart Fig. 6 part 2.

The estimated age of this period is reported according to magnetochron age by the time of 64.50 Ma, beginning with subzone of P1a to the top of zone at 63.00 Ma. [20], [50] and [56]. In Fig. 8, you will notice the equivalent and correlating zones with the current one.



**Fig. 8:** Correlation chart of planktic biostratigraphic foraminifera zones on the boundary of the studied regions, in addition to age datum (modified by several authors), with the zonation typically used in low, medium, and high latitudes.



**Fig. 9:** Sequence foraminiferal biozones arrangement in the studied Gali section.

#### 4. Discussion:

The boundary relationship between Upper Cretaceous and Lower Paleogene Formations in Iraq was controversial [11] and [12]. Different authors such as [34], [57-59] have studied it and recorded unconformable boundary due to their finding conglomerate or nondeposition (represented by absence of one or two biozones) within the upper portion of Maastrichtian and the Early Paleocene successions in Iraq. Where another studies, appear the coincidence of biostratigraphic event (foraminifera assemblages) extinction with physical ones (unconformity represented by conglomerate, non-deposition, volcanic ash, and paleosoil).



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Similarly, and recently, based on lithostratigraphy, an unconformity indicated and called it “Danian unconformity” [60].

In contrast to previous studies, the present one reveals continuous biozones across and in both sides of K/PG boundary. These biozones show a conformable boundary and continuous sedimentation without present of any conglomerate or erosional surface and paleosoil. Recent research suggested that the sediments of a part or whole of Danian are missing but recorded Danian biozones of current work clearly exposed this lack of compatibility by their presence in a lithology that geologists considered it to be an Early Paleocene Kolosh Formation and previously identified it as a K/PG boundary contact Figs. 8 and 9. The high-resolution biostratigraphic sampling and identification of present study manifested that the first Paleocene forams made their presence about 40 m above the previous contact (conglomerate bed 1m thick) of the contact of the local lithostratigraphic units (Tanjero and Kolosh Formations). The boundary is located inside dark grey silty marl and marl where there is not physical expression such as recordable amalgamation, conglomerate, paleosoil and hardground Figs.3 and 8. Also, in Dokan region where a planktonic foraminifera mass extinction was detected, 20 meters higher than a conglomerate bed (1 m thick) previously suggested as the Cretaceous / Paleogene boundary, this condition has been shown also by [61] and [62].

The same situation has find by [4] as the neighboring country of Iraq (conformable and continuous sedimentation) through this contact in Turkey. In the far overseas in Gulf of Mexico, the condition is contradictory as [2] and [63] approved that catastrophic planktonic foraminiferal mass extinction marks this boundary indicated by a clastic bed formed by bolide impact. In Spain, [55] found the same relation and mass extinction of planktons. Also [1] recorded the benthonic foraminifera decline near the clastic bed with Iridium enrichment in aforementioned gulf. Similarly, in Oman [64] concluded that this boundary nature matches with the unconformity between the existed lithostratigraphic formations in that region there were long periods of hiatus, marked by the loss of the latest Maastrichtian *Micula prinsii* and of the Paleocene nanofossil zones NP1 and NP2. In Iran, [65] obtained the same result since the base of the Paleocene within the Gurpi Formation lacks NP1 and NP2 zones, suggesting a hiatus of about 2 m y. at roughly 65.5 Ma. Ca.

The physical events for the bolide are also not observable in Iraq according to current research and are also recorded by [62] and [66], respectively in the Dokan and Higran sections, on the progressive turnover of foraminifera assemblages for relatively long periods. The absence of unconformity in current study as well as its inclusion in additional studies thus suggests seven potential explanations or evidence. The first due to remoteness of the extraterrestrial bolide object near Mexico, the physical effect of the event was not recordable in marine sediments of the Iraq and only a gradual biological effect had imprinted. The second is possibility of asynchronous mass extinction in different places of the world; therefore, the biostratigraphic event is not coincided with physical events. The third one is possibility of mass extinction by other factor such biota evolution, the flood basalts of Deccan in India and competition or environmental changes, especially [67] in particular concluded that the influence of Chicxulub 300 ka predates this boundary mass extinction. The proposed stratigraphic and micropaleontological data from the Gulf of Mexico show 3 impacts during period of time spanning the boundary with the Chicxulub effects predating the K/PG boundary by ~300 ka [68]. However, this multiple impact hypothesis has not gained support from other K/PG boundary locations free from stratigraphic complexities of near-impact sites. In addition, over 350 K/PG boundaries currently known display a distinct trend in which the thickness of ejecta deposits declines with a decreasing distance from the Chicxulub crater and thus represents a special source of ejecta at the K/PG boundary [69]. According to this later article, the mass extinction by asteroid bolide is more probable than other factor due to its environmental perturbations.

The fourth fact is missing of one or two biozones not necessarily due to unconformity (erosion or non-deposition) but it may result from diagenesis, environmental constraints, method of sampling and fossil extraction. Therefore, the fossil absence is not unique evidence for absence of sediments but it is only a circumstance condition. This condition needs several conjugate sets of unique evidence to prove unconformity, which include detail boundary condition study in ten of sections.

The fifth fact is a possible excessive enthusiasm of some authors to previous ideas due to which may neglect the effective precautions in the sampling and identification of the cross-boundary index fossils. The sixth fact is the environment refreshments proceeded through late



Maastrichtian to a total of 500 Ka before the of K/PG boundary. The climate in Maastrichtian was warmed with temperatures rising 3°C in surface and 4°C in deep waters during the last 200-400 Ka [23], but was again cooled in deep-waters prior to this boundary limit. Such climate change indicate that have recorded the Maastrichtian with significant eustatic sea-level fluctuations [72]. Nevertheless, the causal mechanisms of this cooling period are still unclear. While some researchers mainly propose oceanographic shifts, others thought that ephemeral glaciation is related to a eustatic decline. The relative timing and changes of the ocean oxygen and the carbon isotope are mostly not yet known in the eustatic sea level. This Cooling mainly reflects shifts in ocean circulation due to plate movements that cause progressive deep water sharing between deep ocean basins and a corresponding decrease in concentrations of atmospheric carbon dioxide [73]. The seven fact is the (the most important one) is the dilution of index fossil in shallow and in deep environments to the degree that their recording becomes impossible in some case. It is attributed to high rate of dilution of sedimentation in proximal deep turbidities and in carbonate or clastic dominated shelves. Therefore, this study is important because it could change with unquestionable evidence, the balance between conformable and unconformable communities in Iraq and world in favor of the first of all.

## **5. Conclusions:**

1. The high-resolution biostratigraphic study revealed eight biozones for Upper Cretaceous successions and four biozones within early Paleocene age.
2. The documented planktonic foraminiferal biozones in the studying region show a continuous sedimentation without any hiatus, as well as a gradual sedimentation in Smaquli area with the emergence of the current lower Danian planktonic foraminifera.
3. Form the current work it is clear that the biostratigraphy event (foraminifera turn over) does not coincide with lithostratigraphy (physical) events.
4. The Cretaceous/Paleogene boundary displays, the study identified both a gradual and sudden disorder trend of catastrophic extinction except (*Hedbergella monmothensis* and *Guembelitria cretacea*) in the Early Danian, during which about half of the foraminiferal

species extinct before the boundary of K/P G and a complete species extinction on the Danian boundary.

5. *Guembelitria cretacea* interval zone reported for the first time in the region that represent transitional zone between Cretaceous and Paleocene moreover being a part of early Danian foraminifera.

## References

- [1] W. Stinnesbeck, G. Keller, P. Schulte, D. Stuben, Z. Berner, U. Kramar and G. J. Lopez-Oliva. "*The Cretaceous–Tertiary (K-PG) boundary transition at Coxquihui, state of Veracruz, Mexico: evidence for an early Danian impact event*", Journal of South American Earth Sciences, 15, 497 (2002).
- [2] I. Arenillas, L. Alegret, JA. Arz, C. Liesa, A. Melendez, E. Molina and R. Soria. "*Cretaceous-Tertiary boundary planktic foraminiferal mass extinction and biochronology at La Ceiba and Bochil, Mexico, and El Kef, Tunisia*", Geological Society of America, Special Paper 356. (2002).
- [3] S. Farouk, A M. Marzouk and F. Ahmad. "*The Cretaceous/Paleogene boundary in Jordan*" Journal of Asian Earth Sciences, 94, 113 (2014).
- [4] S. Esmeray-Senlet, S. Özkan-Altiner, D. Altiner and KG. Miller. "*Planktonic foraminiferal biostratigraphy, microfacies analysis, sequence stratigraphy, and sea-level changes across the Cretaceous–Paleogene boundary in the Haymana Basin, Central Anatolia, Turkey*", Journal of Sedimentary Research 85(5), 489 (2015).
- [5] L. Alvarez, W. Alvarez, F. Asaro and HV. Michel. "*Extraterrestrial cause for the Cretaceous–Tertiary extinction*", Science, 208, 1095 (1980).
- [6] V. Courtillot, JJ. Jaeger, Z. Yang, G. Féraud and C. Hofmann. "*The influence of continental flood basalts on mass extinctions: where do we stand in: Ryder G, Fastovsky D and Gartner S (eds) The Cretaceous–Tertiary Event and Other*

---

*Catastrophes in Earth History", Special paper, Geological Society of America, 307, 513 (1996).*

[7] G. Keller, T. Adatte, W. Stinnesbeck, D. Stüben, Z. Berner, U. Kramar and M. Harting. *"More evidence that the Chicxulub impact predates the K-PG mass extinction"*, Meteoritics & Planetary Science, 39(7), 1127 (2004c).

[8] M.S. Y. Al-Bakkal, *"Geochemical and Stratigraphical High Resolution of K/pg Boundary in selected sections in Northern Iraq"*, Ph.D. Thesis, University of Mosul. Iraq. (Un Published). (2013).

[9] V K. Sissakian. *"Geological map (Scale 1:200000) of the Arbeel and Mahabad Quadrangles"*, Geosurv Baghdad. (2000).

[10] K. H. Karim, and A.M.Surdashy, *"Tectonic and depositional history of Upper Cretaceous Tanjero Formation in Sulaimaniyah area NE Iraq"*, Journal Zanko Sciences, 8(1), 47 (2005b).

[11] RC. Bellen Van, HV. Dunnington, R. Wetzel and D. Morton. *"Lexique Stratigraphique"*, International. Asie, Iraq, 3c(10a), 333 (1959).

[12] T. Buday. "Regional Geology of Iraq": Vol. 1, Stratigraphy and Palaeogeography. State Organisation for Minerals Library, Baghdad, Iraq, 445 p.(1980).

[13] V. A. Krasheninnikov, *"Geographical and stratigraphical distribution of planktonic foraminiferers in Paleogene deposits of tropical and subtropical areas"*, Akademy Nauk SSSR Geol. Inst. Trudy, 202, 1- 190(in Russian). (1969).

[14] H. M. Bolli., *"The genera Globigerina and Globorotalia in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad"*, B.W.I. In: Loeblich Jr., A.R. et al.,

---

(Ed.), Studies in Foraminifera, Bulletin of the United States National Museum. 215, 6 (1957).

[15] H. M. Bolli, "*Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera*", Bol. Inform. Asociated. Vonezolana Geology. Mining. Ret. En. 9(1), 3 (1966).

[16] W. H. Blow, "*The Cenozoic Globigerinidae*", Vol. 1-3, Leiden, E. J., Brill, 1413p., 264pls. (1979).

[17] W. A. Berggren and KG. Miller, "*Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology*", Micropaleontology, 34(4), 362 (1988).

[18] W. A. Berggren, DV. Kent, CC. Swisher III and MP. Aubry. "*A revised Cenozoic geochronology: in Berggren, W. A. and Norris, R.D., 1997. Biostratigraphy, phylogeny and systematics of Paleocene trochospiral planktonic foraminifera*", Micropaleontology, 43(1), 1 (1995).

[19] W. A. Berggren and RD. Norris, "*Biostratigraphy, phylogeny and systematics of Paleocene trochospiral planktonic foraminifera*", Micropaleontology, 43 (1), 1 (1997).

[20] R K. Olsson, C. Hemleben, WA. Berggren, B. Huber and Members of Paleogene planktonic foraminifera working group. *Atlas of Paleocene Planktonic Foraminifera*. <http://services.chronos.org/foramatlas/pages/home.htm>. 281p, with 66 plates, 2 charts. And 29paleogeographic maps. (1999).

[21] JI. Canudo, G. Keller and E. Molino, "*Cretaceous/Tertiary boundary extinction pattern and faunal turnover at Agost and Caravaca, SE Spain*", Marine Micropaleontology, 17, 319 (1991).

[22] M. Caron, "*Cretaceous planktonic foraminifera*", In BOLLI, H.M., Saunders, J.B. and Perch-Nielsen, K., (Eds) *Planktonic Stratigraphy*, 17, 37 figs. Cambridge Univ. Press. (1985).

[23] L. Li and G. Keller, "*Maastrichtian climate, productivity and faunal turnover in planktonic foraminifera in South Atlantic DSDP sites 525A and 21*", *Marine Micropaleontology*, 33, 55 (1998a).

[24] I. Premoli Silva, S. Spezzaferi and A. D Angelantonio, "*Cretaceous foraminiferal bio-isotope stratigraphy of Hole 967E and Paleogene planktonic foraminiferal biostratigraphy of Hole 966E, Eastern Mediterranean. Robertson AHF, Emeis KC, Richter C and Camerlenghi A (Eds) Proceedings of Ocean Drilling program*", *Scientific Result*, 160, 377 (1998).

[25] Y. Maestas, KG. Macleod, R. Douglas, J. Self-Trail and PD. Ward. "*Late Cretaceous Foraminifera, Paleoenvironments and Paleoceanography of the Rosario Formation, San Antonio Del Mar, Baja California, Mexico*", *Journal of Foraminiferal Research*, 33(3), 179 (2003).

[26] B. T. Huber, K. G. MACLeod, and N. A. Tur. *Chronostratigraphic framework for Upper Campanian –Maastrichtian sediments on the Blake Nose (Subtropical North Atlantic)*, *Journal of foraminiferal Research* 38 (2), 162 (2008).

[27] P. Brönnimann, "*Globigerinidae from the Upper Cretaceous (Cenomanian-Maastrichtian) of Trinidad*", *B. W. I. - Bulltin. America.Paleontology.*, 34(140), 5 (1952).

[28] A. M. Samir, "*Biostratigraphy and paleoenvironmental changes in the Upper Cretaceous-Early Paleogene deposits of Gabal Samara section, Southwestern Sinai, Egypt.*", *Egypt Journal. Paleontology*, 2, 1 (2002).

---

[29] S. Abramovich, G. Keller, T. Adatte, W. Stinnesbek, L. Hottinger, D. Stueben, Z. Berner, B. Ramanivosa and Randriamantenasoa, "*Age and paleoenvironment of Maastrichtian to Paleocene of the mahajanga Basin, Madagascar: a multidisciplinary approach*", *Marine Micropaleontology*, 47, 17 (2002).

[30] M. Faris, "*Biostratigraphy of the Upper Cretaceous-Lower Tertiary succession of Duwi Range, Quseir district, Egypt*", *Revue De Micropaleontologie*, 27(2), 107 (1984).

[31] S. Luning, J. Kuss, M. Bachmann, A. M. Marzouk and A. M. Morsi, "*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-Nurnberg, Facies*, 38, 103 (1998).

[32] H. Elnady and A. Shahin, "*Planktonic Foraminiferal biostratigraphy and paleobathymetry of the Late Cretaceous-Early Tertiary succession at northeast Sinai, Egypt.*", *Egypt. Journal. Paleontology*, 1, 193 (2001).

[33] I. I. M. Kassab, "*Biostratigraphic study of the subsurface Upper Cretaceous – Lower Tertiary of Well Injana No. 5, Northeastern Iraq*", *Journal of Geological Society of Iraq, Special issue*, 181 (1975b).

[34] T. S. Abawi, M. R. Abdel-Kireem and G. M. Yousef, "*Planktonic foraminiferal stratigraphy of the Shiranish Formation, Sulaimaniah-Dokan region Northeastern Iraq*", *Revista Espanola de Micropaleontologia*, 14(1), 153 (1982).

[35] M. R. Abdel-Kireem, "*Contribution to the stratigraphy of the Upper Cretaceous and Lower Tertiary of the Sulaimaniya –Dokan region, Northeastern Iraq*", *N. Jb. Geol. Paleont. Abh.*, 172(1), 121 (1986b).

[36] M. M. Al-Mutwali and F. N. Al-Jubouri. "*Litho and Biostratigraphy of Shiranish Formation (Late Campanian-Late Maastrichtian) In Sinjar area, Northwestern Iraq*", Rafidain Journal of Science, Geology, Special Issue, 16(1), 152 (2005).

[37] K. M. Sharbazheri, "*Aging of Unconformity within Tanjero Formation in Chwarta Area Northeast of Iraq (Kurdistan Region)*" , Rafidain Journal of Science, 7(1), 37 (2007).

[38] K. M. Sharbazheri, "*Planktonic foraminiferal biostratigraphy of the Upper Cretaceous Reddish to Pale brown succession from Smaquli Area, Northeast Iraq (Kurdistan Region)*" , Iraqi Bulletin of Geology and Mining, 6 (1), 1 (2010).

[39] F. Dalbiez, "*The genus Globotruncana in Tunisia*", Micropaleontology, 1(2), 164 (1955).

[40] I. Premoli Silva and WV. Sliter, "*Cretaceous Paleoceanography: Evidence from planktonic foraminiferal evolution, in Barrera*", geological society of America Special Paper, 332, 301 (1999).

[41] M R. Abdel-Kireem & AM. Samir, "*Biostratigraphic implications of Maastrichtian-Lower Eocene sequence at the north gunna section, Farafra Oasis, Western Desert, Egypt*", Marine Micropaleontology, 26, 329 (1995).

[42] M. M. Al-Mutwali, "*Planktonic foraminiferal biostratigraphy of the Shiranish Formation. Khashab well no. 1, Hemren area. Northeastern Iraq*" Journal Geology Science. 7(1), 129 (1996).

[43] R. A. Hammoudi, "*Planktonic foraminiferal biostratigraphy of the Shiranish Formation (Upper Cretaceous) in Jambur well no.13 Northern Iraq*", Rafidain Journal of Science, 11(4), 50 (2000).

[44] B. Chacon and J. Martin-Chivelet, "*Major Paleoenvironmental changes in the Campanian to Paleocene sequence of Caravaca (Subbetic Zone, Spain)*" , journal of Iberian Geology, 31(2), 299 (2005).

[45] N. A. Obaidalla, "*Complete Cretaceous/Paleogene (K/P) boundary section at Wadi Nukhul, southwestern Sinai, Egypt: inference from planktonic foraminiferal biostratigraphy*", Revue de Paleobiologie, Geneve, 24(1), 201 (2005).

[46] A. J. Nederbragt, "*Late Cretaceous biostratigraphy and development of Heterohelicidae (planktonic foraminifera)*" , Micropaleontology, 37(4), 329 (1991).

[47] G. Keller, L. Li & N. Macleod, "*The Cretaceous/Tertiary boundary stratotype section at El Kef, Tunisia: how catastrophic was the mass extinction*" , Paleogeography Paleoclimatology Paleoecology, 199, 221 (1995).

[48] M. R. Abdel-Kireem, "*Planktonic foraminifera and stratigraphy of the Tanjero Formation (Maastrichtian), northeastern Iraq*", Micropaleontology, 32(3), 215 (1986a).

[49] I. Premoli Silva and W V. Sliter, "*Cretaceous planktonic foraminiferal biostratigraphy and evolutionary trends from the Bottaccione section. Gubbio, Italy*", Paleontographia Italica, 82, 1 (1995).

[50] G. Keller, "*Low diversity, Late Maastrichtian and Early Danian planktonic foraminiferal assemblages of the eastern Tethys*", Journal of Foraminiferal Research, 34(1), 49 (2004).

[51] A. Pardo, N. Orti, and G. Keller, "*Latest Maastrichtian and Cretaceous/ Tertiary Boundary, Foraminiferal Turnover 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. (1996).

[52] A. Govindan, C. N. Ravindran & M. K. Rangaraju, "*Cretaceous stratigraphy and planktonic foraminifera Zonation of Cauvery Basin*", South India. Member. Geological. Society. India 37, 155 (1996).

[53] R. J. I. Martines, "*Foraminiferal biostratigraphy and paleoenvironments of the Maastrichtian Colon mudstone of northern South America*", Micropaleontology, 35 (2), 97 (1989).

[54] S. Abramovich and G. Keller, "*Planktonic foraminiferal response to the Latest Maastrichtian abrupt warm event: a case study from South Atlantic DSDP Site 525A*", Marine Micropaleontology, 48, 225 (2003).

[55] E. Molina, L. Alegret, I. Arenillas and JA. Arz, "*The Cretaceous/Paleogene boundary at the Agost section revisited: paleoenvironmental reconstruction and mass extinction pattern*", Journal of Iberian Geology, 31(1), 135 (2005).

[56] G. Keller, "*Guembelitria-dominated Late Maastrichtian planktonic foraminiferal assemblage mimics early Danian in central Egypt*", Marine Micropaleontology, 47, 129 (2002).

[57] I. I. M. Kassab, "*The genus Heterohelix (Foraminifera) from Northern Iraq*", Journal of Geological Society of Iraq, 7, 75 (1974).

[58] I. I. M. Kassab, "*Biostratigraphy of the Upper Cretaceous-Lower Tertiary of N. Iraq*", Annales des Mining. Geology. Tunis, 28(2), 277 (1978).

[59] R. B. N. Jaff, "*Sequence stratigraphic analysis of the Paleocene successions from selected outcrop and wells in Sulaimani and Kirkuk Governorates, Kurdistan Region, Iraq*", (Unpublished master thesis), University of Baghdad, University of Sulaimani, 160 (2008).

[60] F. A. Lawa, H. Koyi and A. Ibrahim, "*Tectono-stratigraphic evolution of the NW segment of the Zagros Fold-Thrust Belt, Kurdistan, NE Iraq*", Journal of Petroleum Geology, 36(1), 75 (2013).

[61] K. M. Sharbazheri, I. M. Ghafor, QAM. Al Nuaimy, "*Biostratigraphy of Cretaceous/Tertiary boundary in the Sirwan valley Sulaimani region, Kurdistan, NE-Iraq*", Geologica Carpathica, 60(5), 14 (2009).

[62] K. M. Sharbazheri, I. M. Ghafor, QAM. Al Nuaimy, "*Biostratigraphy of the Cretaceous/Paleocene boundary in Dokan area, Sulaimanyiah, Kurdistan region, Kurdistan, NE-Iraq*", Iraqi Bulletin of Geology and Mining, 7(3), 1 (2011).

[63] L. Alegret, E. Molina and E. Thomas, "*Benthic foraminifera at the Cretaceous-Tertiary boundary around the Gulf of Mexico*", Geology, 29(10), 891 (2001).

[64] M. Faris, O. Abdelghany, M. A. Saima, "*Upper Cretaceous to Lower Eocene calcareous nannofossil biostratigraphy from Malaqet and Mundassah sections western flank of the Northern Oman Mountain*", Geologia Croatica, 65(3), 393 (2012).

[65] S. Homke, J. Vergés, J. Serra-Kiel, G. Bernaola, I. Sharp, M. Garcés, I. Montero-Verdú, R. Karpuz & M H. Goodarzi, "*Late Cretaceous–Paleocene formation of the proto-Zagros foreland basin, Lurestan Province, SW Iran*", Geological Society of America Bulletin, 121, 963 (2009).

[66] R. A. Hammoudi, "*High Resolution Biostratigraphy of the K-PG Boundary in the Higrann Section, Shaqlawa Area, Northern Iraq*", Iraqi National Journal of Earth Sciences, 11(1), 23 (2011).

[67] G. Keller, T. Adatte, W. Stinnesbeck and et al, "*Chicxulub impact predates the K-T boundary mass extinction*", Proc Natl Acad Sci, USA, 101, 3753 (2004b).



[68] G. Keller, W. Stinnesbeck, T. Adatte., and D. Stueben, "*Multiple impacts across the Cretaceous-Tertiary boundary*", *Earth Science Reviews*, 1283, 1 (2003).

[69] P. Schulte, L. Alegret, I. Arenillas, JA. Arz, PJ. Barton, PR. Bown and et al, "*The Chicxulub Asteroid Impact and Mass Extinction at the Cretaceous-Paleogene Boundary*", *Science*, 327, 1214 (2010).

[70] H. P. Luterbacher & I. Premoli Silva, "*Biostratigrafia del limite Cretaceo- Terziario nell'Appennino centrale*", *Rivew. Italian.Paleontology. Stratigraphy.*, 70, 67 (1964).

[71] L. Li, G. Keller, T. Adatte, W. Stinnesbeck, "*Late Cretaceous sea level changes in Tunisia: A lidisciplinary approach*", *Geological. Society. London*, 157, 447 (2000).

[72] B. U. Haq, J. Hardenbol & P. R. Vail, "*Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change*", *SEPM,Special Publication*, 42, 71 (1988).

[73] S. Voigt, O. Friedrich and A. S. Gale, "*The Campanian-Maastrichtian (Late Cretaceous) climate transition linked to a global carbon cycle perturbation*", *Geophysical Research Abstracts*, 11, EGU-6779-1. (2009).