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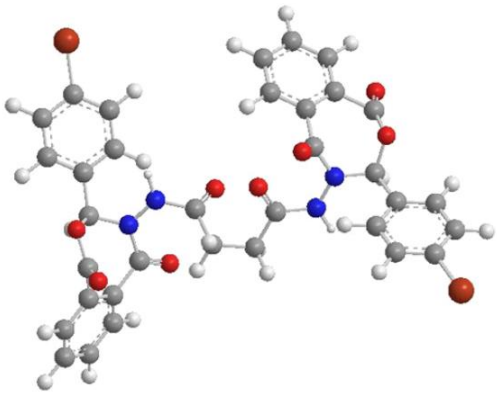

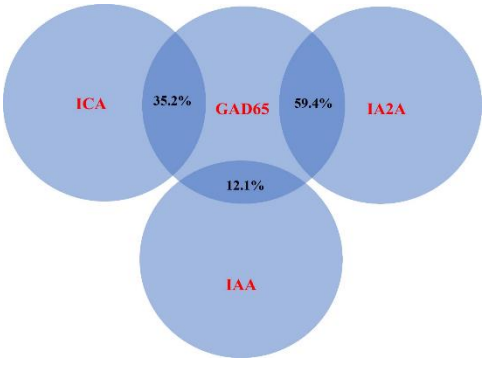

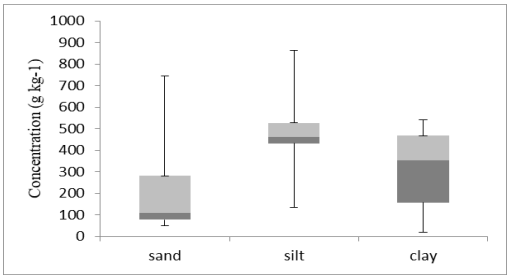

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Biostratigraphy of the Early Turonian- Late Campanian pelagic limestone (Kometan and Gulneri formations) near Sayid Sadyq Town, Kurdistan Region, NE-Iraq.

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Abstract

This study aims at the presentation of a planktonic foraminiferal biozonation of the Late Cretaceous pelagic carbonate section in the east of Sulaymaniyah governorate Kurdistan region, Northeast of Iraq. The zonation proved the occurrence of the Kometan and Gulneri formations which belong to the Early Turonian – Late Campanian age. This is achieved by taking fifty-two (52) samples from the lower part of the section to the upper one with an interval of two meters between successive samples. From these samples, sixty-two (62) thin sections are prepared and (43) species from (11) genera of planktonic foraminifera are indicated and identified in the two formations of the studied section. According to the First and Last occurrence of identified planktonic foraminiferal assemblage, the studied section is divided into seven biozones, from older to young. These biozones are *Whitenella archaeocretacea-Heterohelix moremani* Total Range Zone, *Marginotruncana sigali* Partial Range Zone, *Dicarinella concavata* Interval Range Zone, *Dicarinella asymetrica* Total Range Zone, *Globotruncanita elevata* Partial Range Zone, *Globotruncana ventricosa* Interval Range Zone, *Radotruncana calcarata* Total Range Zone. The age of the two Formations is assigned as Early Turonian- Late Campanian based on the planktonic foraminiferal ranges from the lower part of the section to the upper part. The boundary of the Gulneri and Balambo formations is gradation while there is a gap between the former formation and Kometan Formation.

Introduction

The studied section is located near Sayid Sadyq town (Figure 1) and consists of two Formations which are Gulneri and Kometan of the late Cretaceous (Figure 2 and 3) the first one comprises grey or black marly limestone about 2m thick while the second is represented by white fine-grain pelagic limestone. Lancaster Jones (1957) in [1] described the Gulneri Formation (Early Turonian) from the Dokan Dam body Northeast of Iraq, where about 1.5 m thick, and he claimed that it consisted of fine bitumen black calcareous shale, an indication of glauconite in its lower part. Bellen et al. (1959) [1] mentioned the unconformable contact of Gulneri Formation with the underlying Dokan Formation, in the dam body, and represented by the occurrence of granule conglomerate. According to Buday (1980) [2], the Formation is bounded at the top and bottom by erosional unconformities.

The foraminiferal biostratigraphy of the Gulneri Formation was studied by Abawi and Hammodi (1997) [3] in the Kirkuk area and inferred Late Turonian, while Abawi and Mahmood (2005) [4] and assigned its age to Middle-Late Turonian age in the Jambour well. The biostratigraphy of the Gulneri Formation was

also studied by Abawi et al. (2006) [5] in the type section, Dokan area., Lawa and Al-khafaf (2022) [6] studied its biostratigraphy on the Kosrat anticline and indicated that the Formation consisted of black, bituminous, finely laminated, pink color calcareous shale, and they assigned it to the Early Turonian age. Karim and Taha (2009a) [7] proved that the Guneri Formation was deposited in the deep basin and deposited during the drawing of the Arabian platform (Qamchuqa Formation) and the same idea was repeated by Lawa and Al-Khafaf (2022) [6].

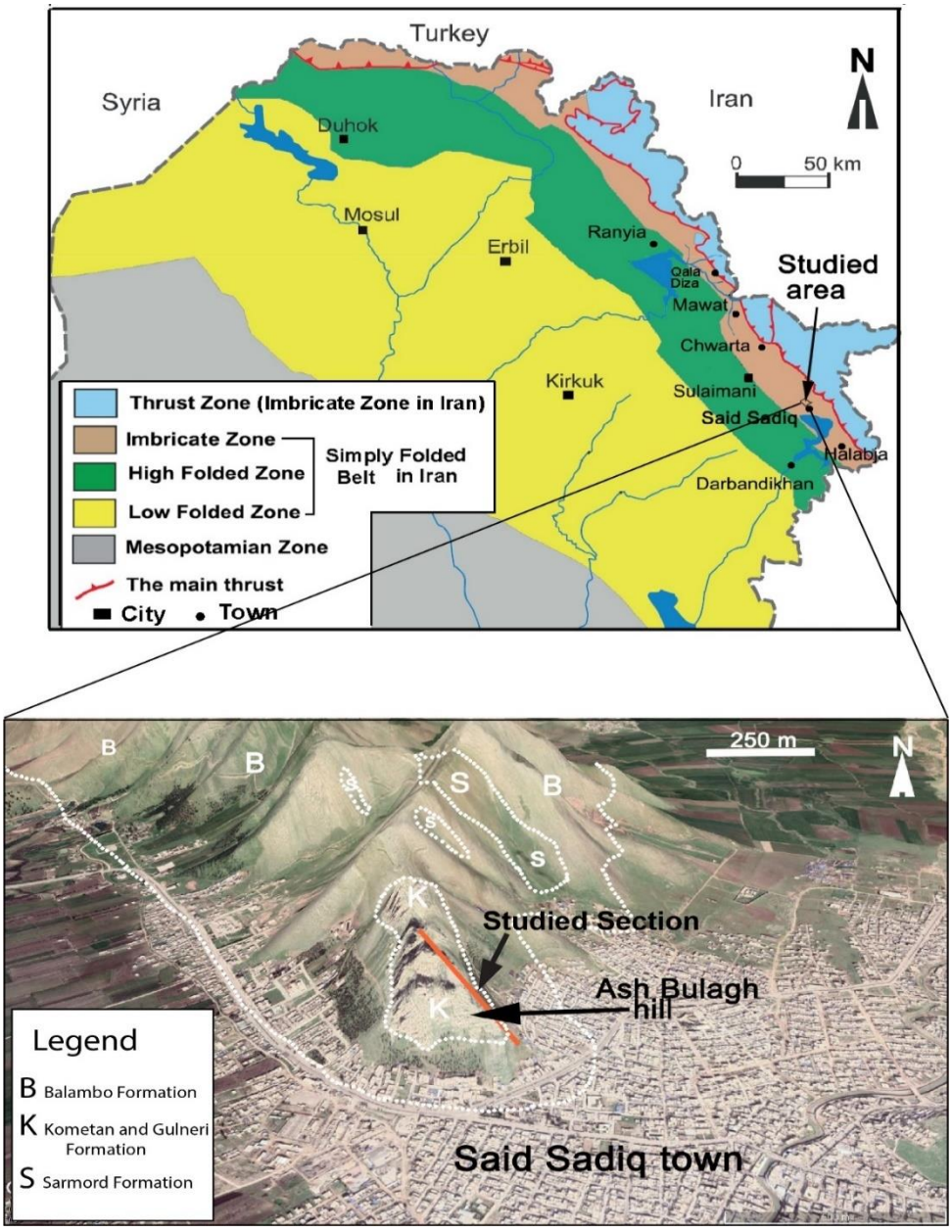

Figure 1: Location of the studied area on the tectonic Map of Jassim and Goff (2006) [13] at the top and a simple geological map (Satellite image of the Google Earth Image) of the area around the sampled section.

Dunnington (1953) [8] in Bellen et al. (1959) [1] described the type section of the Kometan Formation from the Endezah area in Northeastern Iraq. He indicated the Turonian- Santonian age of its deposition and mentioned that its lithology is composed of thin to medium bedded white to light grey limestone, with the presence of chert nodules in its upper part. Youkhanna (1976) [9] indicated Turonian–Santonian age and divided it into 3 biozones.

Al-Dhaif (1997) [10] in the Jambour field, Abawi and Hammoudi (1997) [3] in the Kirkuk area, North Iraq, and Al-Khafaf (2005) [11] in the Dokan-Endezah areas studied the foraminiferal biostratigraphy of Kometan Formation and indicates Late Turonian-Early Campanian age., Lawa and Al-Khalaf (2022) [6]

studied the Dokan, Guneri and lower part of Kometan Formation in Kosrat anticline, and indicated unconformity at the base and top of the Gulneri Formation with both Dokan and Gulneri Formations. In contrast to the unconformable boundary of the Gulneri and Kometan formations, Karim, and Taha (2009 b) [12] proved the conformable boundaries of the Gulneri Formation and the absence of unconformity. The study aims to indicate the foraminiferas content of the Gulneri and Kometan Formations and the division of their thickness to biozones in addition to indicating their ages of deposition and the nature of the boundaries of the stratigraphic units.

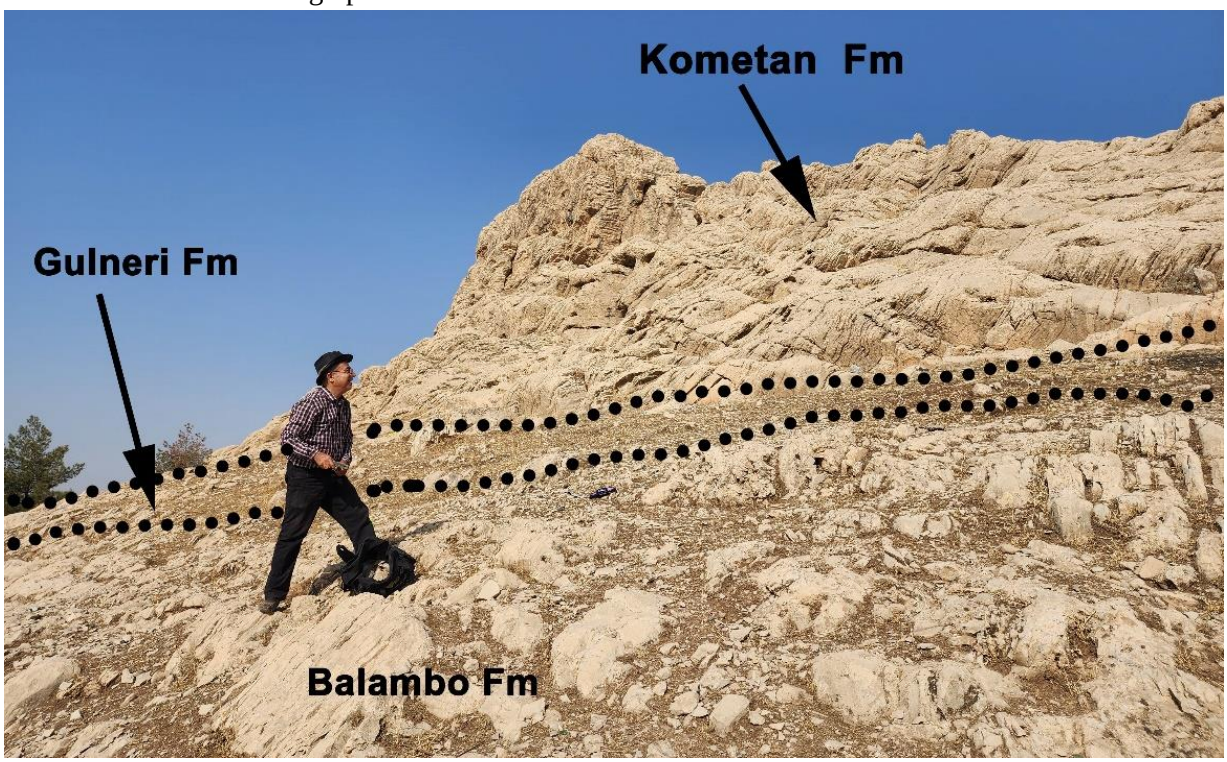

Figure 2: Base of the sampled section shows Balambo, Gulneri and Kometan formations

Figure 3: Top of the sampled section shows most of the Kometan Formation

Location and geology of the area

The sampled section is a part of northeastern Iraq in the northern boundary of the Sharazoor plain about 300 m northwest of Sayid Sadyq town, in the east of Sulaimantiah city. The section is about 100 thick and located along the southeastern side of a hill at the northwestern boundary of the latter town (Figure 1). the base of the section is located at the latitude and longitude of 35° 21' 26.53"N and 45° 51' 30.78"35" E while its top coincides with 35° 21' 2837"N and 45° 51' 21.50"E. The studied area is located inside the Iraqi Zagros collisional belt which

consists of Fold-Thrust Belts. This area, according to the tectonic classification of Buday (1980) [2] and Jassim and Goff (2006) [13] is located in the High Folded Zone. But the thickness of the latter formation is too thin to be plotted on the map (Figure 1). The section is located on a northeastern of a hanged syncline that is shaped inside a large anticline which is called Kani Panka-Sayid Sadiq anticline. In the area the Sarmord, Balambo, Kometan, and Gulneri Formations are can be recognized. In the past, Al-Fadhli et al. (1980) [14] studied the brittle structure of the studied section and assigned this outcrop as Qulqula Radiolarian Formation (they called it Qulqula Series) (Jurassic-Early Cretaceous). Later Ghafor et al. (2012) [15] proved lithologically and paleontologically that it belongs to Kometan and Guneri Formations. Below the Gulneri Formation, Balambo Formation is exposed and consists of fine-grain deep marine limestone with interbeds of marlstone (Figure 4). Below the latter Formation occurs the Sarmord Formation and exposed 1 km to the north of the section.

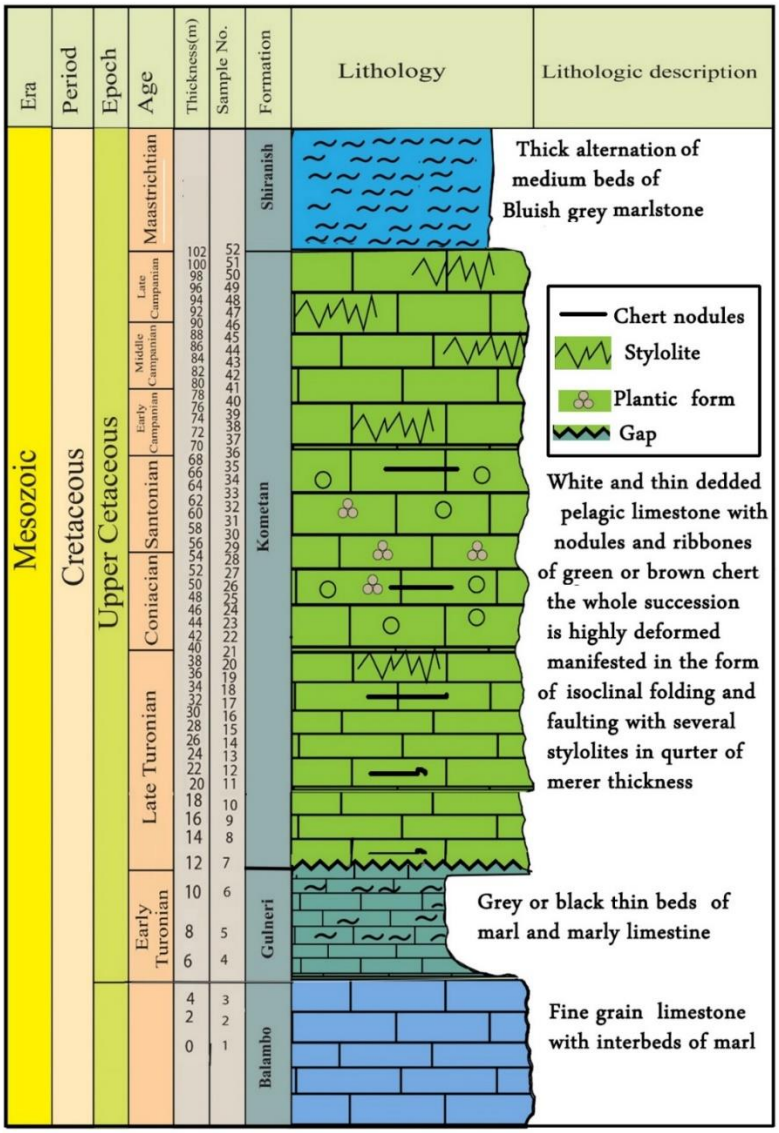

Figure 4: Lithostratigraphic column of Early Turonian –Late Campanian of the studied section.

Biostratigraphic Zonations

In this study, the occurrence and the stratigraphic distribution of the species of planktonic. foraminifera are very important and useful for biostratigraphic examination and to determine the age of the formations of the studied section. The identification and zonation of planktonic foraminifera of Postuma (1971), [16] Caron (1985) [17], Sliter (1989) [18], and Georgescu (2002) [19], are used as a framework for biostratigraphic zonation and correlation with the other equivalent of planktonic foraminiferal zonation proposed by some authors outside and inside of Iraq. (Table.1).

Fifty-two (52) samples were collected from the lower part of the studied section to the upper with the interval of (2) m and more than sixty-two (62) thin sections have been made yielded to the identification of (43) species belonging to (11) genera in the studied section (Figure 5). Depending on the First and the Last appearance of the planktonic foraminiferal assemblage of the studied section is divided into seven (7) biozones from the Lower part of the section to the upper one (Figure 5) as below:

Whitenella archaeocretacea- Heterohelix moremani Total Range Zone (Figure 6. i., Figure 7.a, e)

The biostratigraphy interval of the *Whitenella archaeocretacea* (pessagno) [20]- *Heterohelix moremani* (Cushman) [21] zone is defined by the Total Range Zone, which starts by the Last appearance datum of *Rotalipora cushmani* (Morrow) [22], and ended by the First appearance datum of *Marginotruncana sigali* (Reichel) [23],

This zone represents (6) m thick of the studied section. Which is characterized by the appearance of *Heterohelix moremani* (Cushman)[21] with the appearance of *Whitenella archaeocretacea* (pessagno) [20], the common taxa of this biozone are *Heterohelix globulosa* (Ehrenberg) [24], *Heterohelix* sp., *Whitenella inornata* (Bolli) [25], *Whitenella baltica* (Doglas and Rankin) [26], *Whitenella paradubia* (Sigal) [27], and *Hedbergella planispira* (Tappan) [28].

The age of this zone indicates Early Turonian, which is equivalent to that of Abdel-Kareem et al. (1996) [29], Caron (1985) [17], and the older part of *Globotruncana helvetica* zone of Youkhanna (1976) [9], Postuma (1971) [16]. this zone is also equivalent to that proposed by Lawa and Al-Khafaf (2022) [6], Hussain and Al-Sheikly (2015) [30], and Al-Khafaf (2014) [31], also this zone corresponds to the older part of *Marginotruncana helvetica* zone of Ghafor et al. (2004) [32], Ghafor (1993) [33].

Marginotruncana sigali Partial Range Zone (Figure 6, h., Figure 7, f)

The biostratigraphy interval of *Marginotruncana sigaliin* (Reichel) [23] zone is defined by the Partial Range Zone, which starts with the Last appearance datum of *Whitenella archaeocretacea* (pessagno) [20], and ended with the First appearance datum of *Dicarinella concavata* (Brotzen) [34],

This zone is about (28) m thick of the studied section which is characterized by the common Taxa of *Margotruncana* such as *Marginotruncana marginata* (Reuss) [35], *Marginotruncana renzi* (Gondolfi) [36], *Marginotruncana schneegansi* (Sigal) [27].

The age of this zone indicated Late Turonian, which is equivalent to *Marginotruncana sigali* zone of Sliter (1989) [18], caron (1985) [17], Al-Khafaf (2014) [31], Al-Khafaf (2005) [11], and equivalent to the upper part of *Marginotruncana helvetica zone* of Ghafor (1993) [33], Ghafor et al. (2004) [32].

Dicarinella concavata Interval Zone (Figure 6., g., Figure 7. b, h)

The biostratigraphy interval of *Dicarinella concavata* (Brotzen) [34] zone is defined by the Interval Zone, which starts with the First appearance datum of *Dicarinella concavata (*Brotzen) [34], and ended with the First appearance datum of *Dicarinella asymetrica* (Sigal) [27]. This zone comprises (15) m thick from the studied section. Species that are present in this zone are *Dicarinella hagni* , *Dicarinella* cf. *concavata* (Brotzen) [34], *Dicarinella imbricata* (Mornod) [37], *Globigerinelloides ulltramicra* (Subbotina) [38], *Hedbergella planispira* (Tappan) [28], *Heterohelix reussi* (cushman) [21], Heterohelix *striata* (Ehrenberg)

[24], *Marginotruncana coronata* (Bolli) [25], *Marginotruncana schneegansi* (Sigal) [27], *Globotruncana bulloides* (Vogler) [39], *Globotruncana carinata* (Cushman) [21], *Globotruncana lapparenti* (Brotzen) [34].

This zone assigned Coniacian age, which correlated with the older part of *Dicarinella concavata* zone of Sliter (1989) [18], Caron (1985) [17], and *Marginotruncana concavata* zone of wonder (1980) [40]. The zone was also equivalent to the older part of the *Dicarinella concavata* zone of Al-Khafaf (2014) [31], Al-Khafaf (2005) [11], Al-Dhiaf (1997) [10], Abawi and Hammoudi (1997) [3], and *Globotruncana concavata* zone of Al-Jassim et al. (1989) [41].

Dicarinella asymetrica Total Range Zone (Figure 6, f, Figure 7, d)

The biostratigraphy interval of *Dicarinella asymetrica* (Sigal) [27] zone is defined by the Total Range Zone, which starts with the First appearance datum of *Dicarinella asymetrica* (Sigal) [27], and ended with its Last appearance datum of it. This zone represents (13) m thick of the studied section, this zone contains many species such as *Dicarinella* cf. *asymetrica* (Sigal) [27], *Dicarinella algeriana(*Caron) [17], *Dicarinella primativa* (Dalbiez) [42] , *Dicarinella canaliculata* (Reuss) [35], *Globigerinelloides multispina*(Lalicker) [43], *Globigerinelloides ulltramicra* (Subbotina) [38], *Globigerinelloides praerienillensis* (Pessagno) [20], *Globotruncana laparenti* (Brotzen) [34], *Globotruncana bulloides* (Voglar) [39], *Globotruncana linneiana* (dorbigny) [44], *Globotruncana arca* (Cushman) [21], *Globotruncana angusticarinata* (Gandolfi) [36], *Globotruncana* sp.

This zone assigned Santonian age which corresponds to the upper part of *Dicarinella concavata* zone of Abdel-Kireem et al. (1996) [29], Bolli (1966) [25], also the present zone was equivalent to the *Dicarinella asymetrica* zone of Sliter (1989) [18], Caron (1985) [17]. This zone was also correlated with that of Al-Khafaf (2014) [31], Al-Khafaf (2005) [11], and with the upper part *Globotruncana concavata* zone of Al-Jassim et al. (1989) [41], Youkhanna (1976) [9], Darmian (1975) [45].

Globotruncanita elevata Partial Range Zone (Figure 6, e)

The biostratigraphy interval of *Globotruncanita elevata* (Brotzen) [34] zone is defined by the Partial Range Zone, which starts with the Last appearance datum of *Dicarinella asymetrica* (Sigal) [27], and ended ith the First appearance datum of *Globotruncana ventricosa* (White) [46].

The zone comprises (15) m thick from the studied section, the common taxa of this zone are represented by *Archaeoglobigerna blowi* (Pessagno) [20], *Heterohelix globulosa* (Ehrenberg) [24], *Heterohelix striata* (Ehrenberg) [24], *Heterohelix reussi* (Cushman) [21], *Globotruncana stuartiformis* (Dalbeiz) [42], *Globotruncana* sp., *Globotruncana bulloides* (Vogler) [39], *Globotruncana lapparenti* (Brotzen) [34], *Globotruncana arca* (Cushman) [21], *Globotruncana angusticarinata* (Gandolfi) [36], *Globotruncana linneiana* (dorbigny) [44].

This zone indicates Early- Lower Middle Campanian age, which is correlated to the older part of *Globotruncanita elevata* Zone of Abdel-Kireem et al. (1996) [29], and correlated with that of Silter (1989) [18], Caron (1985) [17], and with the older part of *Globotruncanita elevata* Zone of Wonders (1980) [40], Postuma (1971) [16]. This zone also corresponds to that of Al-Khafaf (2014) [31], Al-Khafaf (2005) [11], Abawi, and Hammoudi (1997) [3], Al. Dhaif (1997) [10].

Globotruncana ventricosa Interval Zone. (Figure 6, d., Figure 7, c, g) The biostratigraphy interval of *Globotruncana ventricosa* (White) [46] zone is defined by the Interval Zone, which starts with the First appearance datum of *Globotruncana ventricosa* (White) [46], and ended with the First appearance datum of *Radotruncana calcarata* (Cushman) [21], This zone is about (7) m thick from the study section. The most diagnostic species present in this zone include: *Archaeoglobotruncana cretacea* (d'orbigny) [44], *Archaeoglobigerina blowi* (Pessagno) [20], *Heterohelix striata (Ehrenberg)*[24], *Rosita fornicata* (Plummer) [47], *Globotruncana arca* (Cushman) [21], *Globotruncana angusticarinata* (Gandolfi) [36], *Globigerinelloides multispina*(Lalicker)[43], *Globigerinelloides ulltramicra* (Subbotina) [38],

Globigerinelloides praerienillensis (Pessagno) [20], *Hedbergella planispira* (Tappan) [28], *Hedbergella delrioensis* (Carsey) [48].
This zone characterizes by the Upper Middle Campanian age and corresponds with the same zone recorded by Sliter (1989) [18], Caron (1985) [17], Wonders (1980) [40], Al-Khafaf (2014) [31].

Radotruncana calcarata Total Range Zone (Figure 6, a, b, c., Figure 7, i)
The biostratigraphy interval of *Radotruncana calcarata* (Cushman) [21] zone is defined by the Total Range Zone, which starts with the First appearance datum of *Radotruncana calcarata* (Cushman) [21], and ended with the Last appearance datum of it. This zone consists of (12) m thick from the studied section. The most diagnostic species present in this zone include: *Heterohelix globulosa* (Ehrenberg) [24], *Heterohelix reussi* (Cushman) [21], *Heterohelix striata* (Ehrenberg) [24], *Globotruncana arca* (Cushman) [21], *Globotruncana angusticarinata* (Gandolfi) [36], *Globigerinelloides multispina* (Subbotina)[38], *Globigerinelloides praerienillensis* (Pessagno) [20].
This zone assigned Late Campanian, which is coincides with *Radotruncana calcrata* zone of Sliter (1989) [18], caron (1985) [17], Van Hint (1976) [449], Postuma (1971) [16], Bolli (1966) [25]. This zone was also equivalent to that of Al-Khafaf (2014) [31].

Table 1: Biostratigraphic Correlation of this study with the other studies inside and outside Iraq.

Age	Present Study	Al-Khafaf 2014 NE-Iraq	Al-Khafaf 2005 NE-Iraq	Abawi and Hammoudi 1997 North Iraq	A-Jassin et al. 1989 North Iraq	Youkhanna 1976 North Iraq	Abdel-Kireem et al. 1996 Egypt	Sliter 1989 Circum pacific	Caron 1985 General	VanHinte 1976 General	Postuma 1971 General
Campanian	*Ra. calcarata*	*Ra. calcarata*				*G.fornicata-stuartiformis-elevata roseita*	*G. ventricosa*	*G.calcarata*	*G.calcarata*	*G.calcarata*	*G.calcarata*
	G. ventricosa	*G. ventricosa*						*G.ventricosa*	*G.ventricosa*	*G.subspinose*	
	Gln. elevata	*Gln. elevata*	*Gln. elevata*	*Gln. elevata*	*G.fornicata-elevata-stuartiformis*		*Gln. elevata*	*Gln. elevata*	*Gln. elevata*	*G.stuartiformis*	*Gln. elevata*
										Gln. elevata	
Santonian	*D.asymetrica*	*D.asymetrica*	*D. asymetrica*	*Rosita Fornicata*	*G.fornicata*	*G. concavata S.L.*	*D.concavata*	*D. asymetrica*	*D. asymetrica*		*G.carinata*
					G. concavata					*G. concavata G. elevata*	
		D. concavata	*D.concavata*	*D. concavata*							
Coniacian	*D. concavata*							*D.concavata*	*D.concavata*	*G. sigali G. concavata*	*G. concavata*
		D.Primitiva	*D.Primitiva*	*D.Primitiva*	*G. renzi-sigali*	*G.renzi-sigali P. inornata*					
							D.Primitiva	*M. sigali*	*D.Primitiva*	*G.renzi*	*G. schneegasi*
Turonian	*M. sigali*	*M. sigali*	*M. sigali*	*M. sigali*			*M.schneegasi*		*M. sigali*	*G. sigali*	*G.helvetica*
		H.helvetica	*H.helvetica*			*G.helvetica*	*P. helvetica*	*H. helvetica*	*H. helvetica*	*G.helvetica*	
	W. archaeocretacea Heterohelix moremani										
		W. archaeo cretacea					*W. archaeo cretacea*	*W.archaeocretacea*	*W. archaeo cretacea*	*H.lahmanni*	

D=Dicarinella G=Globotruncana M=Marginotruncana R=Radotruncana
W=Whitenella Gln=Globotruncana H=Helvetoglobotruncana

Hiatus Not Studied

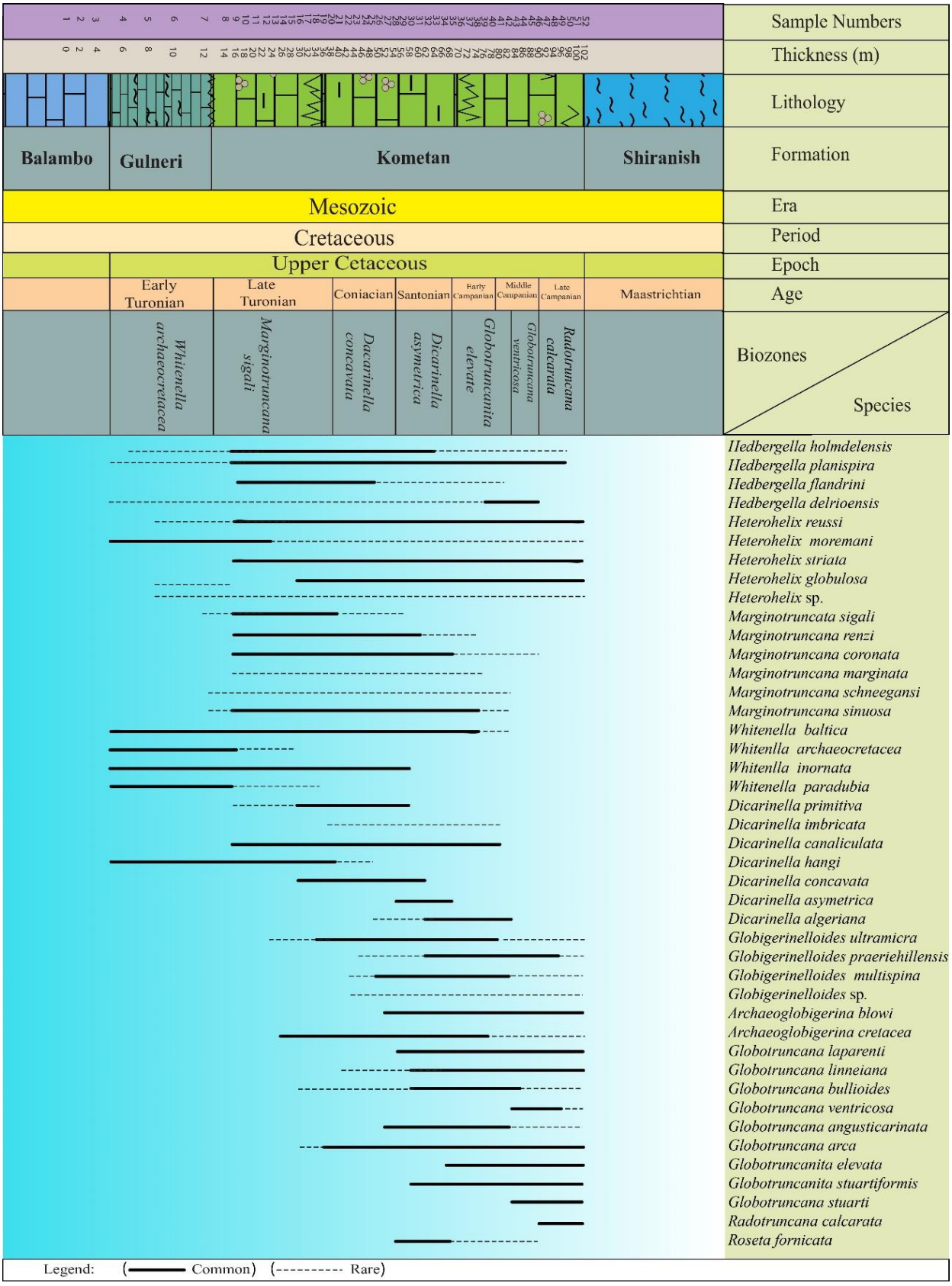

Figure 5: Distribution of Planktonic Foraminifera from the Early Turonian-Late Campanian of the studied area to first and last appearances.

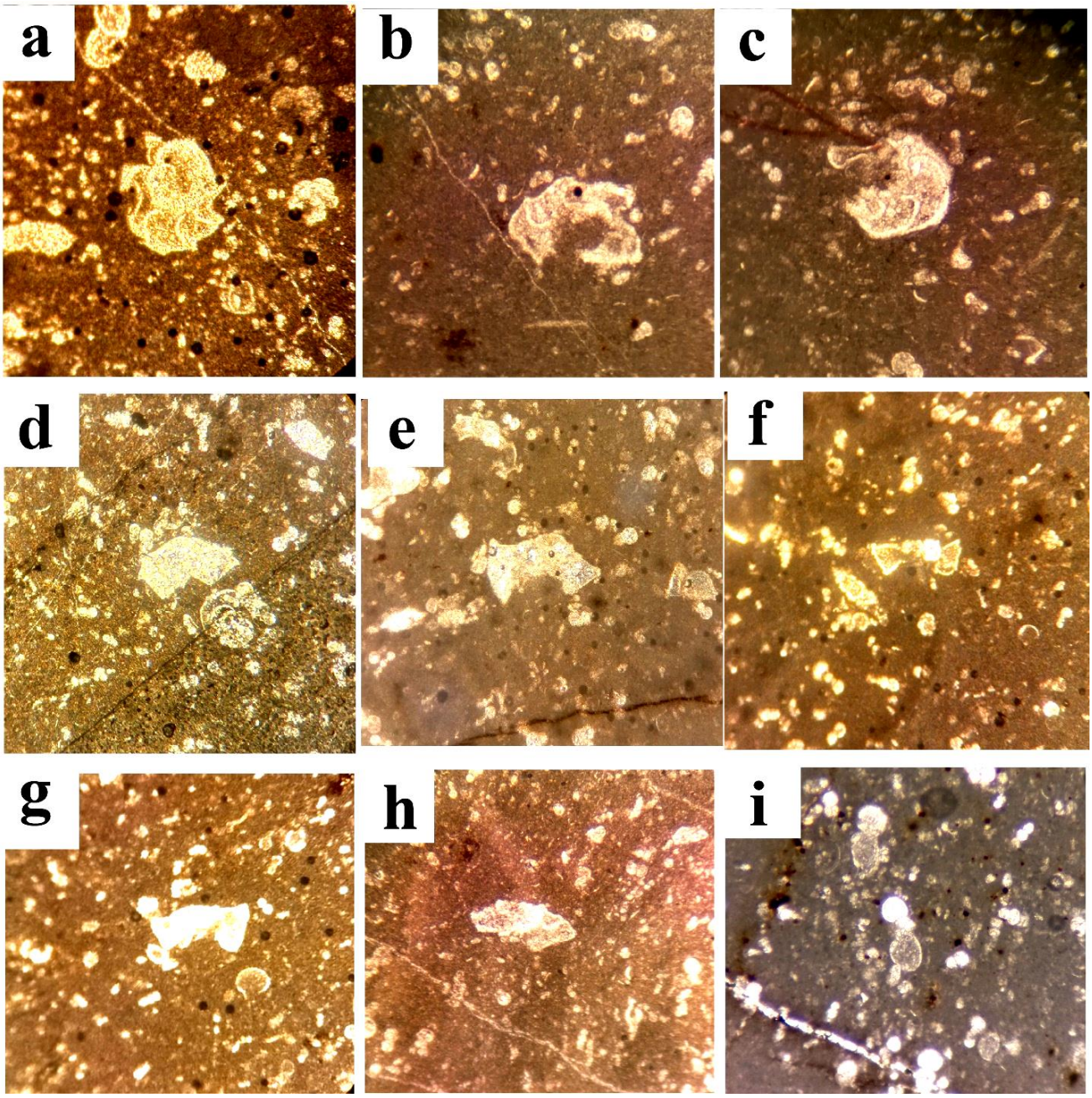

Figure 6: (a, b, and c), *Radotruncana calcarata* (Cushman) [21], a, and b, Sample No.47, c, Sample No.50, Late Campanian, Kometan formation, X90. d, *Globotruncana ventricosa* (White) [46], Sample No.43, Middle Campanian, Kometan formation, X90. e, *Globotruncanita elevata* (Brotzen) [34], Sample No.39, Early Campanian, Kometan Formation, X90. f, *Dicarinella asymetrica* (Sigal) [27], Sample No.33, Santonian, Kometan Formation, X90. g, *Dicarinella concavata* (Brotzen) [34], Sample No.25, Coniacian, Kometan Formation, X90. h, *Marginotruncana sigali* (Reichel) [23], Sample No.16, Late Turonian, Kometan Formation, X90.I, *Whitenella archaeocretacea* (pessagno) [20], Sample No.5, Early Turonian, Gulneri Formation, X90.

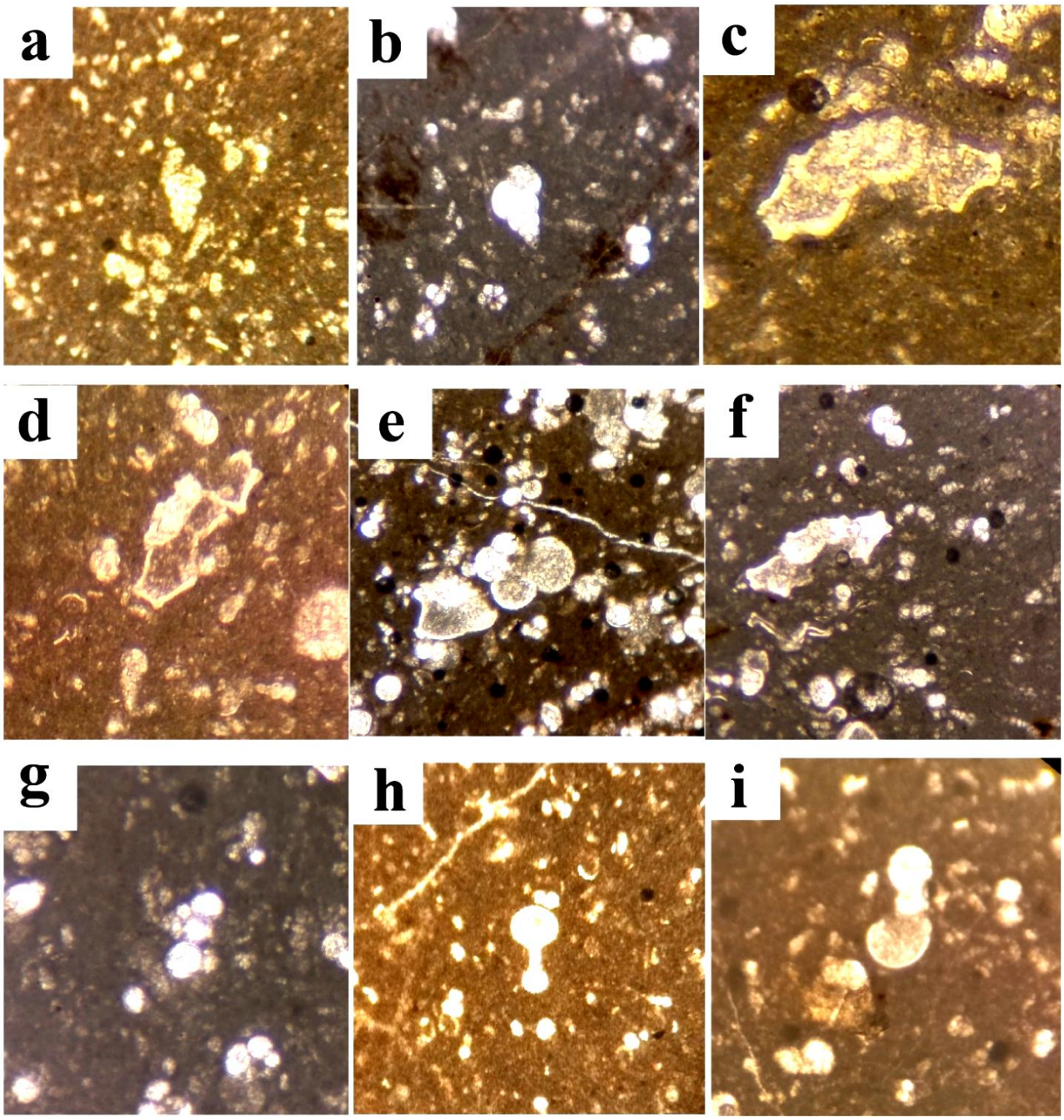

Figure 7: a, *Heterohelix moremani* (Cushman) [21], Sample No.6, Early Turonian, Gulneri Formation, X90. b, *Heterohelix globulosa* (Ehrenberg) [24], Sample No.28, Coniacian, Kometan Formation, X90. c, *Rosita fornicata* (Plummer) [47], Sample No.45, Middle Campanian, Kometan formation, X90. d, *Globotruncana linneiana* (d'Orbigny) [44], Sample No.35, Santonian, Kometan Formation, X90. e, *Whitenella baltica* (Doglas and Rankin) [26], Sample No.6, Early Turonian, Gulneri formation, X90. f, *Marginotruncana coronata* (Bolli) [25], Sample No.14, Late Turonian, Kometan formation, X90. g, *Archaeoglobigerina blowi* (Pessagno) [20], Sample No.44, Middle Campanian, Kometan Formation, X90. h, *Globigerinelloides multispina* (Subbotina) [38], Sample No.22, Coniacian, Kometan Formation, X90. i, *Hedbergella planispira* (Tappan) [28], Sample No.47, Late Campanian, Kometan Formation, X90.

Conclusions

An outcrop section of the late Cretaceous pelagic limestone is studied micropaleontologically near Sayid Sadyq town at 50 km east of Sulaimanyiah city. The pelagic limestone consists mainly of Kometan

formation which about 90m thick and Gulneri Formation (marly limestone), the biozonation of these limestones revealed (43) species that belong to (11) genera of planktonic foraminiferas. Although the limestone succession is deformed intensity but the fauna can be identified via their inspection of (63) thin sections polarizer stereoscopic microscopes. The biozonation indicated Early Turonian to Late Campanian, the division of the section includes seven biozones arranged from oldest to youngest as follows: *Whitenella archaeocretacea-Heterohelix moremani* Total Range Zone, *Marginotruncana sigali* Partial Range Zone, *Dicarinella concavata* Interval Range Zone, *Dicarinella asymetrica* Total Range Zone, *Globotruncanita elevata* Partial Range Zone, *Globotruncana ventricosa* Interval Range Zone, *Radotruncana calcarata* Total Range Zone. Due to the disappearance of the *Helvetoglobotruncana helveteca* Aafter the total range zone of the *Whitenella archaeocretacea* as well as the first appearance of the *Marginotruncana sigali* Partial Range Zone, we considered the boundary between Gulneri and Kometan formations as unconformity also emphasized by the appearance of gluconite at the base of Kometan formation in other localities. This gap is of low duration and may result from the relative sea change at the Late Turonian due to disapperance of the *Helvetoglobotruncana helveteca* in the lower part of kometan Formation. Other evidence of the gap between Gulneri and kometan formations nonextension of *Whitenella archaeocretacea-Heterohelix moremani* Total Range Zone from Gulneri to Kometan Formation. Addtionally, there is presence of about 20cm of Guloconite In Dokan area at the base of kometan formation and shift in facies association from deep marine black shale of Gulneri Formation to carbonate facies outer shelf. In this study, the *Radotruncana calcarata* is found for the first time in the Kometan Formation in this area.

Conflict of interest

The authors confirm that they are not affiliated with or involved in any organization or entity with financial interests.

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