**IRAQI BULLETIN OF GEOLOGY AND MINING (IBGM)\
IRAQ GEOLOGICAL SURVEY (GEOSURV-IRAQ)**

Vol.18, No.2, 2022 ***p 25 – 42***

BIOSTRATIGRAPHY OF DOKAN, GULNERI, AND LOWER PART OF KOMEATN FORMATIONS FROM KOSRAT ANTICLINE, SULAIMANI AREA, KURDISTAN REGION-IRAQ

Fadhil A. Lawa[1] and Araz O. Al-Khafaf[1]

Received: 08/ 06/ 2022, Accepted: 22/ 08/ 2022
Keywords: Cenomanian/ Turonian; Planktic Biostratigraphy; Dokan Formation; Gulneri Formation; Kurdistan (Iraq)

ABSTRACT

The planktic foraminiferal assemblages were recorded from the Cenomanian/ Turonian boundary from the outcrops section in Kosrat anticline (NE of Dokan dam), within the high folded-thrust zone (Sulaimani area, Kurdistan Region, Iraq). They are assigned to the Middle-Late Cenomanian *Rotalipora cushmani* partial Zone and to the lowermost Turonian *Whiteinella archaeocretacea* partial range Zone, in addition to the late Turonian age represented by *Helvetoglobotruncana helvetica* have been recorded across the Cenomanian/ Turonian boundary, where the early cretaceous platform developed into Kurdistan Foreland basin, as result of the initial phase of Arabian plate subduction beneath the Iranian (Eurasian) Plate. The high-resolution foraminiferal biostratigraphic analysis has been undertaken on the Dokan Formation, Gulneri Formation, and lowermost part of the Kometan Formation, almost revealing a minor gap between the latest Cenomanian and Early Turonian, as well as between the Ealy Turonian and the late Turonian age. The termination of Early cretaceous inner ramp (Rudists) carbonate facies associations by the middle to late Cenomanian represents by the uppermost stromatolite beds of the Qamchuqa Formation. They are overlain by rapid drowning, which is characterized by Planktic bathyal facies association with Dokan Formation. The increase in drowning is associated with the deposition of organic-rich black shale of the Gulneri Formation with a remarkable short-term gap between them. The thin black shale, which is sandwiched between the early and late carbonates sequences, almost shows a diagnostic shift in the planktic foraminiferal associations and marks the Cenomanian – Turonian Boundary Event (93.9 Ma). They are also characterized by abnormal carbon cycle perturbations in Earth's history and associated with oxygen deficiency in oceanic waters (Oceanic Anoxic Event 2 = OAE 2), in Kurdistan and northern Iraq.

INTRODUCTION

During the late Cenomanian to early Turonian, black shales were deposited on several paleogeographical basins of the Northern margin of the Arabian plate including the northeastern basins. These laminated organic-rich limestones are known as the Gulneri Formation (Lancaster, 1957 in Bellen *et al*., 1959) which are believed to have been deposited under anoxic conditions (Bellen *et al.*, 1959; Buday, 1980; Sharland *et al.*, 2001; Jassim and Goff 2006; Aqrawi *et al*., 2010; Al-Sagri, 2015). The preservation of such amounts of organic carbon was recorded worldwide around the Cenomanian/ Turonian boundary (C/T) as a

[1] Department of Geology, College of Science, University of Sulaimani,
e-mail: Fadhil.ameen@univsul.edu.iq

response to the palaeoceanographic conditions prevailing at that time. From a tectonic point of view, the Cenomanian-Turonian interval in Iraq witnessed a geodynamic inversion of the regional tectonic regime from extensional to compressional tectonism, as the subduction of the Neo–Tethyan oceanic crust gave rise to a compressive tectonic environment in which the normal displacement on the listric normal faults of the passive continental margins was thrusted. The compression led to renewed strike-slip and dip-slip reverse displacement along these faults giving rise to a phase of "block folding" in the foreland folds belt (Numan, 2000), which is initiated during the Turonian and developed up to Pliocene and known as Kurdistan Foreland Basin (Lawa, 2018). The boundary between Dokan and Gulneri formations, in certain parts of Kurdistan Zagros Fault and Thrust belt, manifests Cenomanian/ Turonian boundary, which is also considered a critical time for planktic foraminifera due to the environmental perturbations associated with Oceanic Anoxic Event 2.

From. stratigraphic point of view the recognized lithostratigraphic units are in sanding order (Qamchuqa, Dokan, Gulneri, and Kometan formations).

The Dokan and Gulneri formations are not recorded from the left bank of the Little Zab River (Ameen and Gharib, 2014). The Dokan Formation was first described by Lancaster Jones in 1957 (Bellen *et al*., 1959), from the site of Dokan dam, in the High Folded Zone northwest of Sulaimani, northeast Iraq. It is composed of 3.75 meters, light grey or white; white- weathering Planktic foraminiferal limestones, locally rubbly, with glauconitic coatings of constituent's pebble-like masses, locally worm-riddled. The formation thickens to the SW reaching 150 m in the Chamchamal wells (Buday, 1980). Further to the west, it is about fifty-three meters thick in Kirkuk, Bai Hassan, Demir Dagh, and Qara Chauq areas (Buday and Jassim, 1987). The Gulneri Formation was originally introduced by Lancaster Jones in 1957 (Bellen *et al*., 1959) from the site of the Dokan dam in the High Folded Zone, northeast of Iraq. The formation is about 1.1 – 1.2 m thick, consists of black, bituminous, finely laminated, calcareous shale with some glauconite and collophane in its lower part and should be of Early Turonian age (Bellen *et al*., 1959). According to Buday (1980), the Gulneri Formation represents the sediments of the relict sea, existing between the regression in the Cenomanian and the transgression in the Turonian. Bellen *et al.* (1959) mentioned an unconformable contact of the Gulneri Formation with the overlying and underlying Kometan and Dokan formations at the dam site, which is represented by the occurrence of micro-conglomerate. According to Buday (1980), the thin bituminous shale of Lower Turonian is bounded at the bottom and top by erosional unconformities. Abawi and Hammoudi (1997) studied the foraminiferal biostratigraphy of the Gulneri Formation in the Kirkuk area and assigned it to the Late Turonian age. According to Abawi and Mahmood (2005) the Gulneri Formation in Jambour well no. 46 (northern Iraq) is Middle to Late Turonian in age. Lawa *et al*. (2013) emphasized these unconformities and mentioned that Dokan and Gulneri formations are not present (an unconformity with a duration of 4.7 m.y) in the Tabeen Gorge, 4 Km to the southeast of Surdash village. Omer *et al*. (2015) on the Azmer anticline detected the absence of Dokan and Gulneri formations at the top of the Balambo Formation and attributed the unconformity to Mawat ophiolite obduction during the Turonian. The stratigraphy of the Turonian-early Campanian secondary sedimentary cycle in selected wells from Iraq has been studied by Hammudi (1995). A sequence stratigraphic and tectonic model for the mid-Turonian-early Campanian carbonate sequence in north Iraq was constructed by Haddad and Amin (2007), based on subsurface lithologic, thin-section, and well-log analyses of ten boreholes. Al-Sheikhly *et al*. (2015) mentioned that Dokan Formation is deposited in an open-marine deep shelf environment; it could be deposited at a deeper shelf to slope and basinal settings. While Gulneri Formation deposited in open sea shelf, as well as at outer shelf settings, the sediments consist of organic-carbon rich black shale and consider a record of the ocean anoxic event 2, Kometan Formation represents pelagic sediments characterize the deep-marine basins in open marine. Hussain and Al-Sheikhly (2015) studied the biostratigraphy and paleoecology of the Late Albian-Late Santonian succession of Surdash, Shaqlawa, and Kirkuk areas, north Iraq, including sections from the studied area.

This work aims as follows: **1)** High-resolution biostratigraphy of the Cenomanian/ Turonian boundary interval from the Kosrat section (High-Folded Thrust Zone). **2)** Determination of the Cenomanian-Turonian boundary nature and estimated gap between them. According to Sharland *et al*. (2001), in Iraq, the Maximum Flooding Surface **(MFS, K-140)**, was the last to be deposited within the Tectonic Megasequence **AP8**, before the re-organization of plate accommodation space due to inversion resulting from ophiolite obduction along g the eastern margin of the Arabian plate. This Maximum Flooding surface (MFS K-140) represent by the bituminous glauconitic shale of the Gulneri Formation and basal glauconitic of the Kometan Formation (Sharland., 2001, Ameen and Gharib, 2014)

MATERIALS AND METHODOLOGY

This study is based on an outcrop section from the Kosrat anticline, northwest of Dokan dam, from the unpaved road cuts section about 26 samples (4 from the Dokan, 6 from the Gulneri, and 16 from the Kometan formations) have been collected for biostratigraphic zonations, and correlations for the upper Cenomanian–early Turonian interval were made on the basis of standard foraminiferal studies and previous work of the Abawi and Hammoudi, (2006) and (2010). About 50 thin-section preparations were conducted in the geological laboratory of the university of Sulaimani, Kurdistan Region (Iraq). Biostratigraphic determinations and correlations for the Late Cenomanian–Early Turonian interval were made on the planktic foraminiferal zonal scheme of Keller and Pardo (2004).

GEOLOGICAL SETTING

The study area lies in the northeastern limb of the Kosrat anticline within the Western Zagros Fold-Thrust Belt (WZFTB) and is considered part of the High Folded Zone according to Sissakian and Fouad, 2015, while according to Lawa *et al*. (2013) considered as a part of the High Fold Thrust Zone (HFTZ; Fig.1). The Kosrat anticline is trending in the NW – SE direction, of steeper south-western with an average dip of 53°, while the average dip of the northeastern limb is about 17° (Stevanovic and Markovic, 2003) and mentioned that the SW continuation of the Kosrat anticline is dissected by the Little Zab Transversal Fault. An important tectonic activity occurred during the Turonian to Early Campanian time in Iraq, possibly related to the subduction of the southern branch of Neo-Tethys (Aqrawi *et al*., 2010). Therefore, the Kurdistan foreland basin formed around the northern margin of the Arabian Plate in response to the loading of the crust by thrust sheets generated as a result of compression (Jassim and Goff, 2006; and Lawa, 2018). The strata express the Zagros general NW–SE strike and forams a saddle portion that merges with the NW plunge of Sara anticline. Barno (2014) concluded that the southeastern plunge of the anticline is near the Dokan dam site and the northwestern plunge is represented by the hanging syncline with the Khalakan anticline. The fold axis of the anticline plunge is 3° in the trend of 147° and the axial plane dips 85° in the direction of 057°. In addition to the competency contrast between the competent carbonates (Kometan, Dokan, and Qamchuqa formations) and ductile shale of the Gulneri Formation, play important role in the fold styles. The time of deformation is questionable whether it’s a syn-tectonic or post-tectonic feature. Al-Khatony *et al*. (2019)

nominated the Dokan fault that separates the Kosrat anticline from the Sara anticline and extends to the Qarasird anticline. At this section, the Late Cretaceous rocks crop out on the limb of one of the Kosrat thrusted folds. Those structural complexities may distort locally the stratigraphic succession of the area. In the studied section area, a reversal fault led to the lithostratigraphic repetitions, which are calibrated into normal lithostratigraphic successions (Figs.2 and 3).

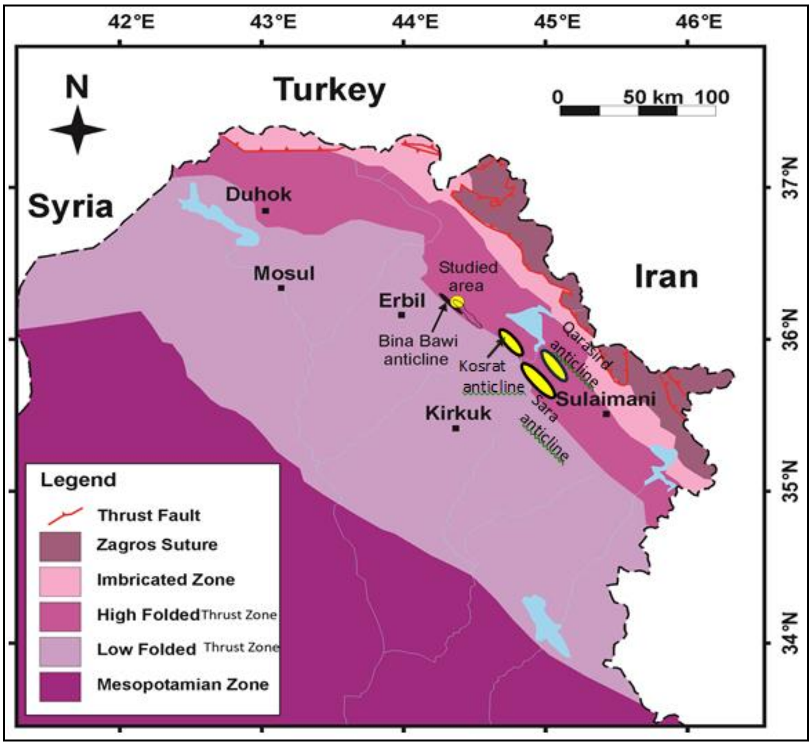

Fig.1: Geographic location of the studied Kosrat section, Dokan area, Sulaimani area, Kurdistan region, north Iraq (after Lawa *et al.,* 2013)

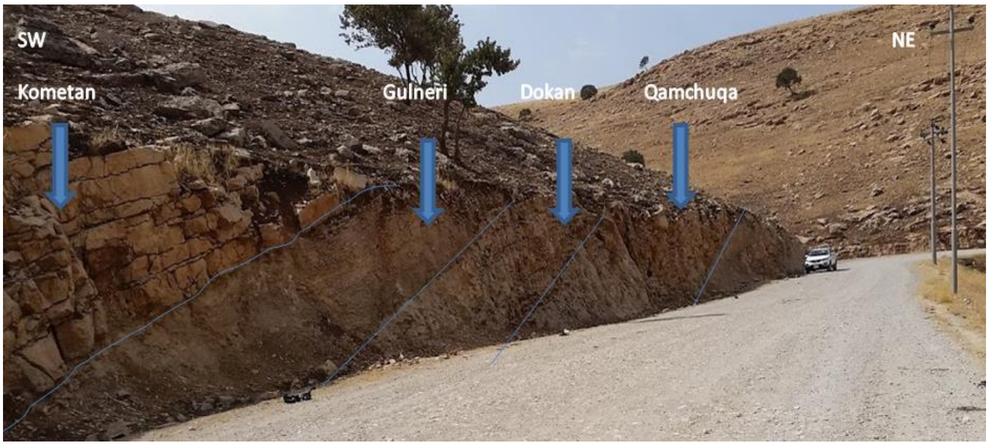

Fig.2: Shows the stratigraphic succession of Qamchuqa (Upper most part), Dokan, Gulneri, and Kometan formations (Lower most part). Kosrat section, Kurdistan Region, north Iraq

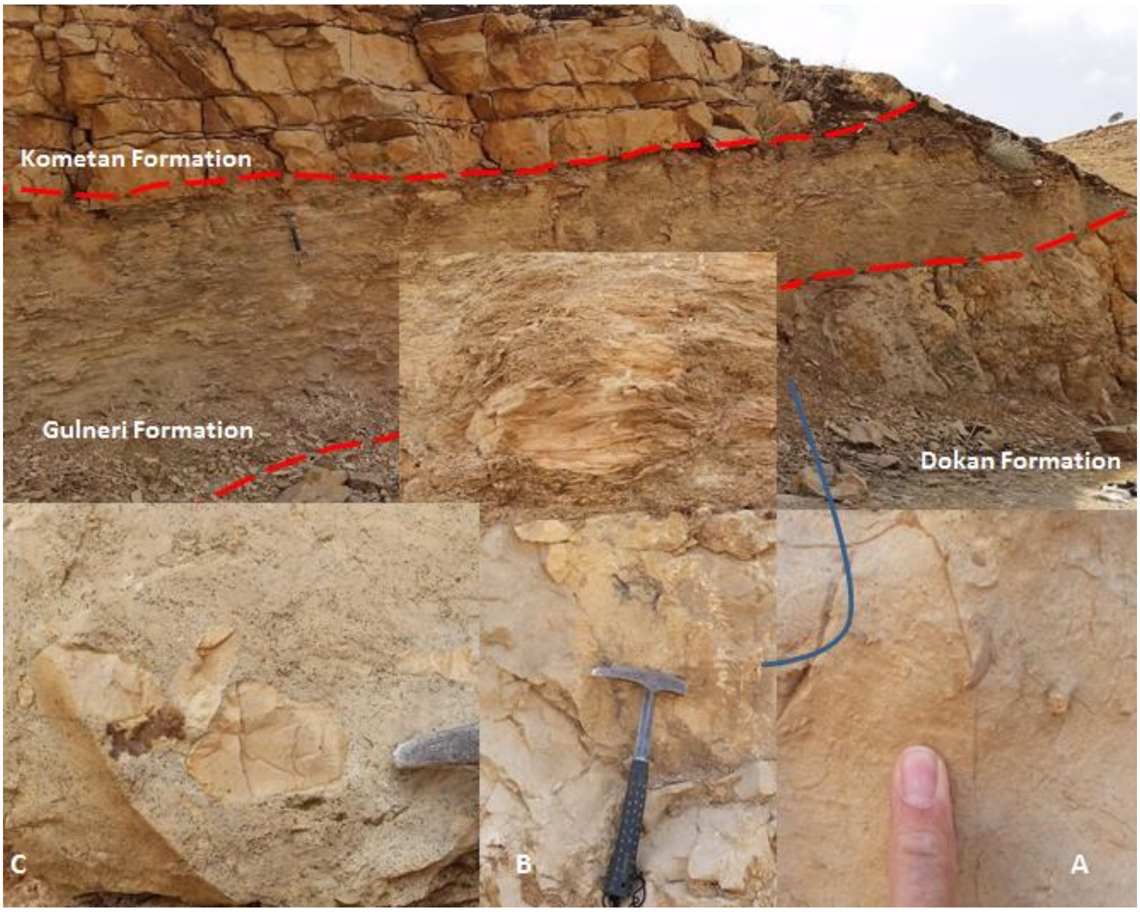

Fig.3: **A)** Pelecypods and gastropods from the top Dokan Formation, **B)** The sharp lithological boundary between the Dokan and Gulneri Formations, and **C)** The Glauconitic horizon and angular clasts between the Gulneri and Kometan formations

According to Numan (2001), the Kometan Formation was deposited in a foreland basin during the last episodes of Cretaceous Neo-Tethyan subduction namely the Late Cenomanian – Early Campanian Mariana-type subduction. The oldest exposed rocks in the core of the Kosart anticline represent by the predominated Early Cretaceous, very thick carbonate succession of the Qamchuqa Formation (Stevanovic and Markovic, 2003), (Figs.2 and 3). This unit is overlain unconformably by the Dokan Formation with remarkable lithological and facial changes (Bellen *et al.*, 1959; Buday 1980; Buday and Jassim, 1987; Jassim and Goff 2006; Aqrawi *et al*., 2010; Ameen and Gharib, 2014), which also point to the boundary between tectonostratigraphic megasequence of the Arabian Plate AP8 and AP9 (Sharland *et al*., 2001; Aqrawi *et al*., 2010). The Dokan Formation was described by Lancaster and Jones in 1957 (Bellen *et al*., 1959), in the Dokan dam section, as about 3.75 m thick carbonates and consisting of light gray or white weathering oligosteginal limestone, locally rubble, with a glauconitic coating of constituent pebble-like masses, locally worm riddled. Based on the fossils assemblages the age of this unit is assigned to be Cenomanian, possibly upper but not uppermost. The environment of the deposition is an open marine, evidenced by the abundant pelagic faunal elements, including Ammonite; it corresponds to the maximum extent of the Cenomanian transgression (Buday, 1980). Both the lower and upper contacts of the formation in the type area are unconformable (Baban and Saraj, 2007; Abawi and Hammudi, 2010). In the studied Kosrat section, the Dokan Formation is underlain by the massive, dolomitic, buff-colored Qamchuqa Formation and overlain by the Gulneri Formation with remarkable lithological changes. They are associated with Pelecypods and Gastropods bio bioclasts at the upper 40 cm (Fig.3A and 4). The Gulneri Formation, in its type section in Dokan dam, consists of black, bituminous, finely laminated calcareous hale, with some glauconite and collophane in the lower part, as well as, occupies a peculiar position within the Turonian – Lower Campanian sub-cycle (Buday, 1980). The underlying contact with Dokan Formation is an erosional unconformity while the overlying contact with the Kometan Formation is also an erosional unconformity (Buday 1980; Jassim and Goff, 2006). The sediments of the Gulneri Formation are considered a part of super sequence V, which extends from Turonian to Early Campanian, and is bounded by the major unconformity at its base (Jassim and Goff, 2006). In the studied section (Fig.3, 4 and 5) the Gulneri Formation consists of pinkish-brown weathered color that changes to the black bituminous fresh color of papery nature and mostly, finely laminated, calcareous shale with some glauconitic and cellophane in the lower part with a very thin bed of glauconite in the upper part above the Kometan Formation. The formation is also strikingly different, in its color, lithology, and bituminous content, from the overlying and underlying formations, few dwarf ammonites, and glauconites grains are recorded in the lower part that increases towards the upper boundary with the Kometan Formation (Fig.3C and 4). The Kometan Formation (Late Turonian – Early Campanian) is widespread in the north and northeastern Iraq (Kurdistan region) and represents the lower part of the AP9 (Late Turonian–Danian) tectonostratigraphic megasequence (Sharland *et al.*, 2001). Its deposits manifest the new transgression of the Tethyan sea, and also can be considered as the Pre-flysch facies of the Kurdistan Foreland Basin (KFB, Lawa, 2018; Jaff and Lawa, 2019). The Kometan Formation was first described and recognized by Dunnington (1953) in (Bellen *et al*., 1959) from Kometan village near Endezah, northeast of Rania, Kurdistan region, northern Iraq. The formation consists of white weathering, light gray, and thin- to medium-bedded highly fractured, planktic foraminiferal limestones with chert concretions in the upper parts and glauconite at the base (Fig.3A). From a lithological point of view, this unit consists of white weathering, light gray, thin to medium bedded, highly fractured limestone with irregular chert nodules, pyrite concretion, and Mn oxides (Pyrolusites and Psilomelane), usually stylolitic. In the Kosrat section (Fig.5), this unit repeated due to faulting and we consider that during our measurements. Barno (2014) concluded that the Kometan Formation thickness comparison in both limbs of the Kosrat anticline gave a clue, that between the deposition of Kometan and Shiranish formations in the north-eastern limb, the inversion had started because Kometan Formation thickness is almost double the one in the southwestern limb.

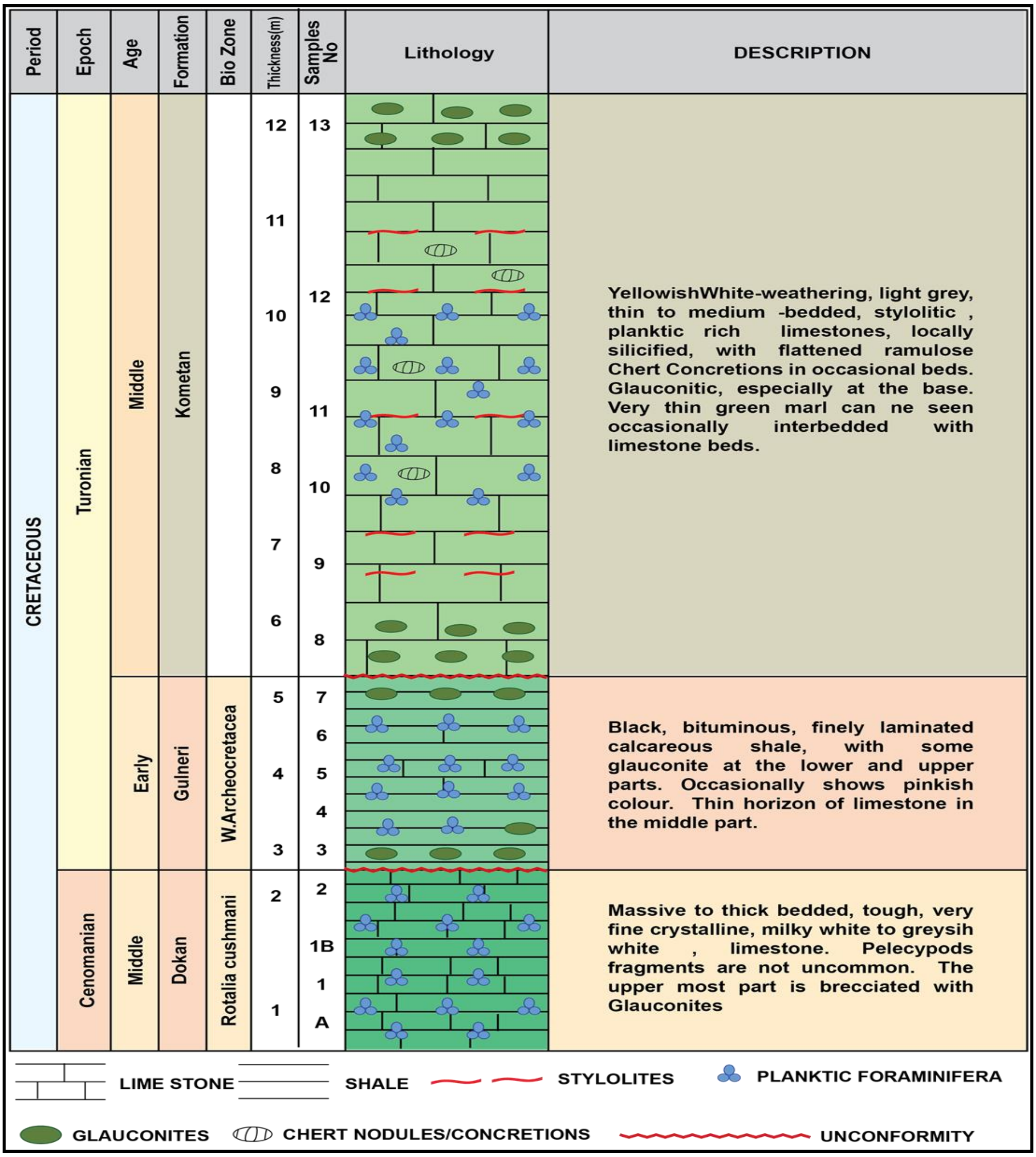

Fig.4: Generalized stratigraphic column of the studied Kosrat section, Khlakan anticline, High Folded-Thrust zone, Kurdistan region, Iraq

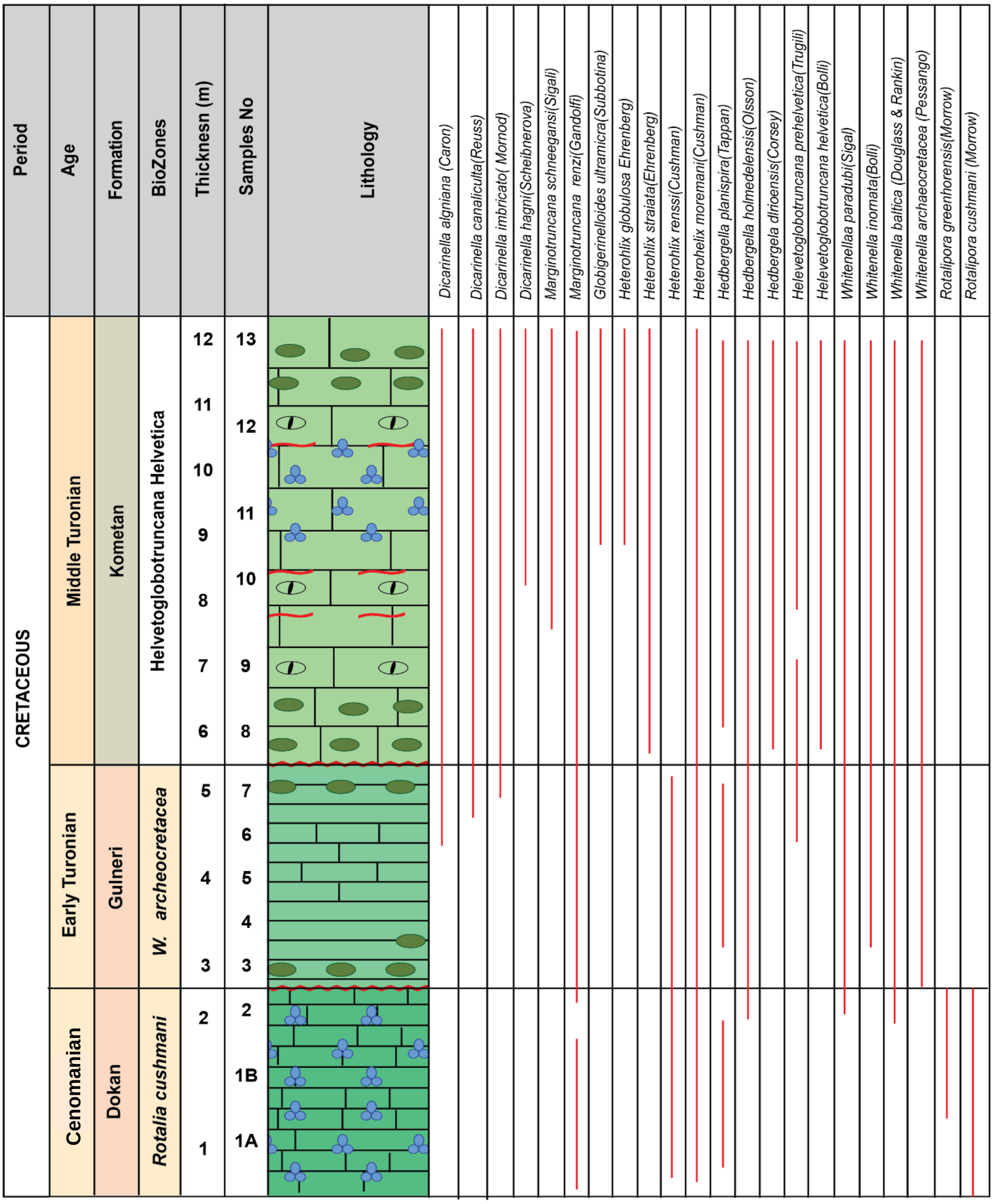

Fig.5: Biostratigraphic chart of the planktic foraminifera in the Dokan, Gulneri, and Lower most part of Kometan formations, in Kosrat Section, Sulaimani area, Kurdistan region, north Iraq

BIOSTRATIGRAPHIC ZONATIONS

The Cenomanian/ Turonian boundary is considered among the most severe Cretaceous oceanic anoxic events in the history of the earth, most of the keeled and weekly keeled foraminiferal genera suffered mass and/ or step-by-step extinctions (Arthur *et al*., 1987;

Maâmouri *et al*., 1994; Nederbragt and Fiorentino, 1999; Peryt, 2004; Scopelliti *et al*., 2004). The Dokan Formation is characterized by abundant planktic foraminifera (Figs.2, 3, and 4). Benthonic taxa also occur in fewer diversity levels but seem to be disappearing at a few beds. The reduction of the planktic foraminifera and the appearance of gastropods (*Ampullina dupinii*) and pelecypods at the upper 40 cm of this unit point to this event. Upwards to the Gulneri Formation, the planktic foraminifera is less diverse, smaller in size, and less abundant, and dwarf ammonites also occur sporadically. The calcareous black shale laminations (Fig.3B), which are characteristic of the formation, consist of millimeter-scale white layers composed largely of planktic foraminiferal tests, alternating with dark organic-rich clay laminae. The high-resolution planktic foraminiferal analysis has allowed the recording of the following zones:

1- *Rotalipora cushmani* Partial Range Zone. (Fig.6a – d) Generally, the *R. Cushmani* zone is defined by the total range of the marker species and characterizes the middle to late Cenomanian (Caron *et al*., 2006; Lanci *et al*., 2010). Soua (2005) subdivided the *Rotalipora cushmani* zone into two subzones, *R. montsalvensis*, and *Dicarinella* algeriana subzones. It is defined by the interval spanning between the LA of *R. montsalvensis* and the LA of *R. cushmani* and it characterizes the late Cenomanian. Besides the *R. montsalvensis*, the *R. cushmani, and R. greenhornensis* LA, some other bio-events are observed, such as the LA of *Praeglobotruncana delrioensis*, followed by the FA of *Whiteinella archaeocretacea*. It is worth mentioning that the total range zone of *R. cushmani*, the first occurrence at 95.9 (Base), and the last occurrence at (94Ma.Top).

2- *Whitenella archaeocretacea* zone/ *Hetereohilx moremani* Total Range subzone (Fig.6e and f; and Fig.7a; Tables 1 and 2). The *W. archaeocretacea* (Pessagno) zone along the Cenomanian–Turonian boundary is divided into three subzones, as in Keller and Pardo (2004); Peryt (2004); and Pioro (2005): a lower *Globigerinoides bentonensis* subzone, a middle *Dicarinella hangi* (Scheibnerova) subzone, and an upper *Heterohlix. moremani* (Cushman) subzone. Along this boundary, only the *Heterohlix. moremani* (Cushman) subzone can be seen and this represents the Gulneri Formation; therefore, this subzone is defined by the appearance of *Heterohlix moremani* (Cushman) and the first appearance of *Helvetotruncana helvetica* (Bolli) zone. The base of the *Whitenella archeocretacea* zone is defined by the extinction of all *Rotalipora* species at top of the Dokan Formation about 40 cm below the boundary with the Gulneri Formation. This zone represents the Gulneri Formation, which is about 1.5 m thick, representing the Cenomanian – Turonian Oceanic Anoxic Euxinic Event (OAE2) along the Cenomanian–Turonian boundary (which is characterized by a *Heterohelix* shift) that is rich with others *Heterohelix* spp., such as *Heterohelix globulosa* (Ehrenberg), *H. reussi* (Cushman) and *H. moremani* (Cushman), with *Whitnella* spp., such as *Whitnella paradubia* (Sigal) and *Whitnella baltica* (Douglas), with *Globigerinoides* spp. The Global **OAE2** event is associated occasionally with missing zones of the Middle to Late Cenomanian. The presence of a condensed section is represented by 1.2 m of black shale above more than 600 m of carbonates and the presence of a glauconitic horizon, in addition to the mass extinction of a planktic foraminiferal group and the appearance of a new group. and correlates with the first shift in *Heterohelix* in the Early Turonian age (Hussain and AI-Sheikhly, 2015; Al-Khafaf, 2005).

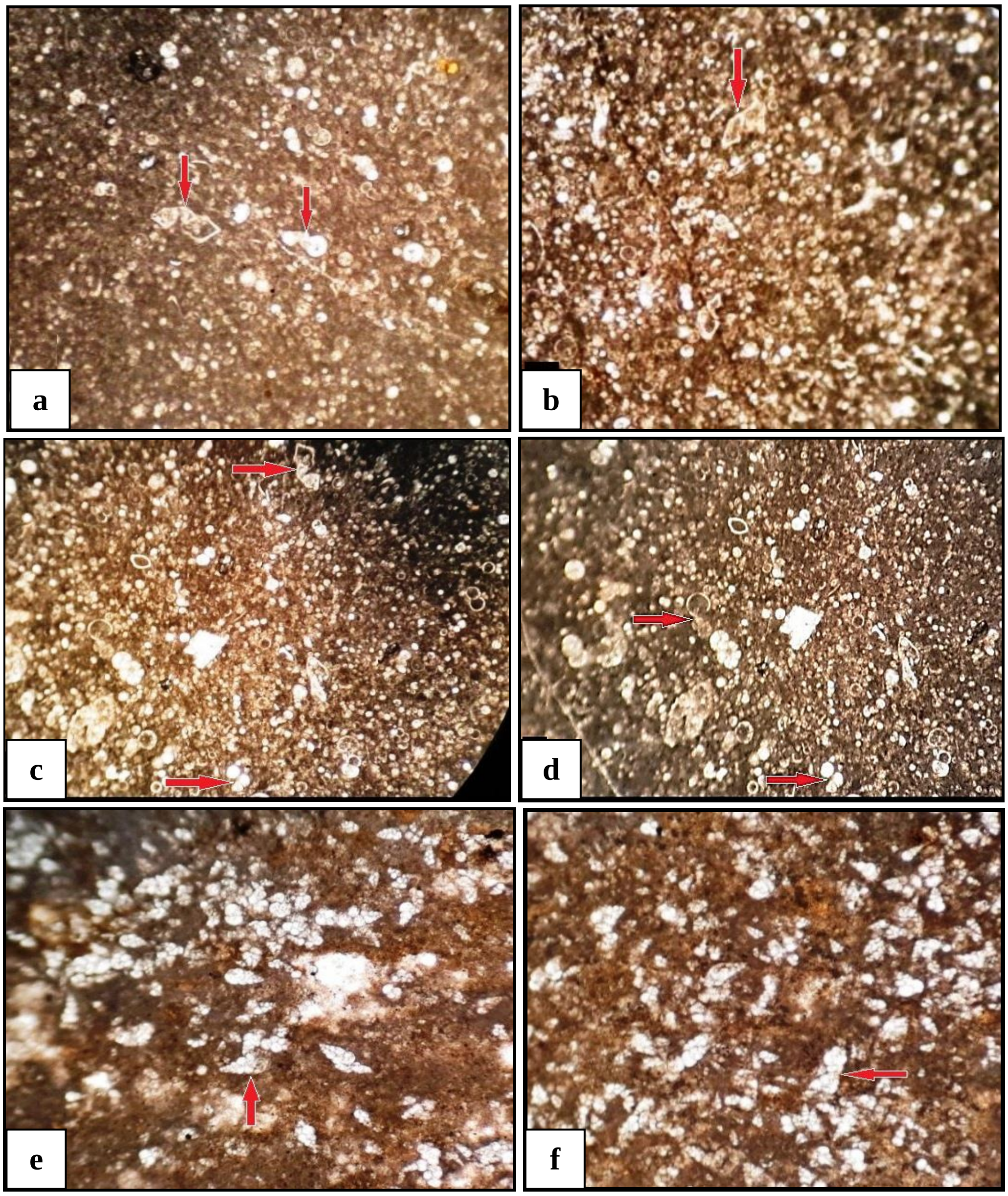

Fig.6:

1) *Rotalipora cushmani* (Morrow), *Helvetoglobotruncana praehelvetica* (Trujillo), Late Cenomanian, Dokan Formation X40.
2) *Rotalipora greenhornensis* (Morrow), Late Cenomanian, Dokan Formation. X40.
3) *Rotalipora cushmani* (Morrow), *Whiteinella pradubia* (Sigal) Late Cenomanian, Dokan Formation. X40.
4) *Whiteinella pradubia* (Sigal), *Hedbergella holmedelensis* (Olsson), Late Cenomanian, Dokan Formation. X40.
5) *Heterohelix moremani* (Cushman), Early Turonian, Gulneri Formation. X40.
6) *Helvetoglobotruncana praehelvetica* (Trujillo) Early Turonian, Gulneri Formation. X40.

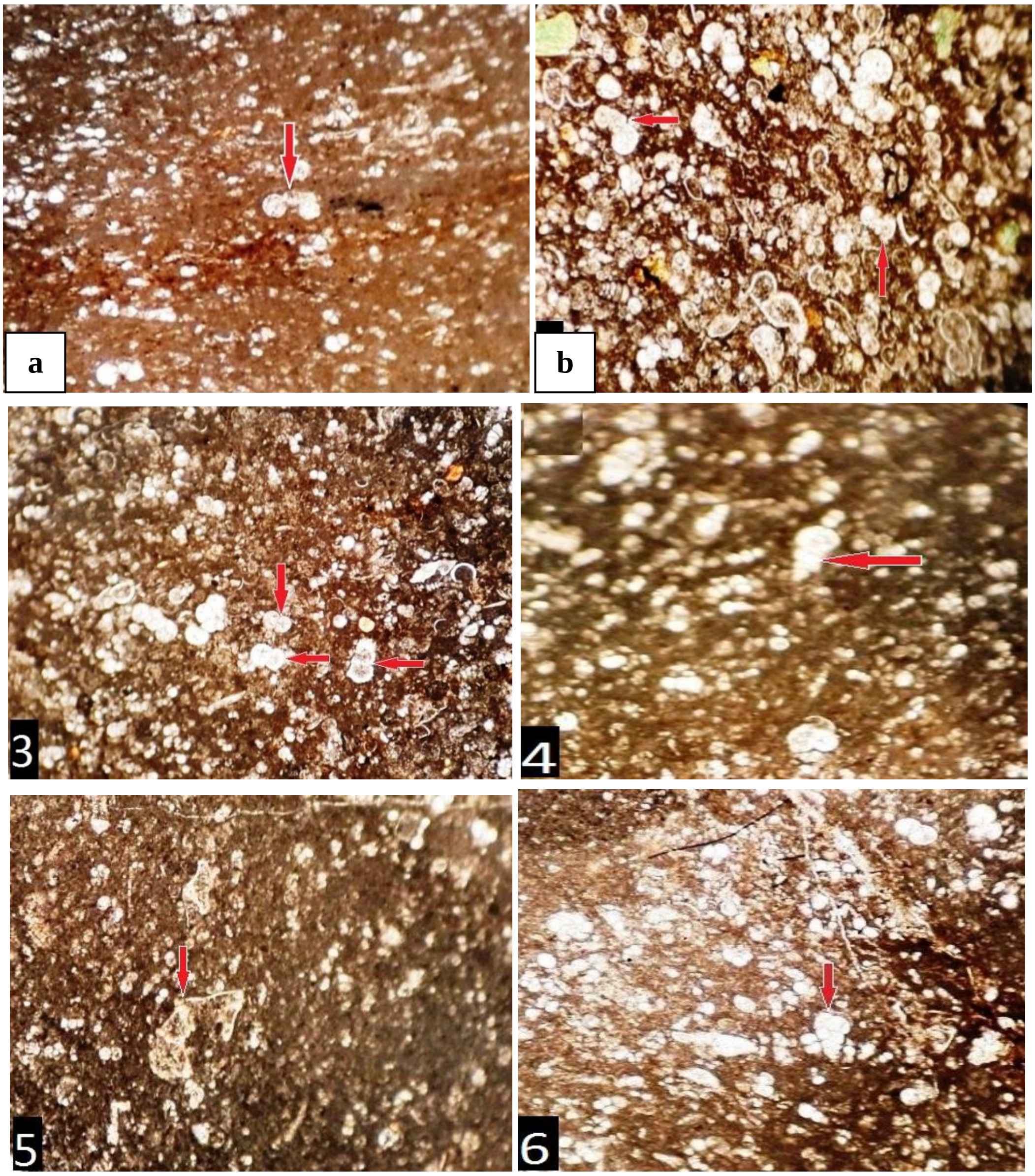

Fig.7:

1) *Whiteinella archaeocretacea* (Pessagno), Early Turonian, Gulneri Formation. X40.
2) *Helvetoglobotruncana helvetica* (Bolli), Middle Turonian, Kometan Formation. X40.
3) *Heterohelix striata (*Ehrenberg), Middle Turonian, Kometan Formation. X40.
4) *Heterohelix reussi* (Cushman), Middle-late Turonian, Kometan Formation. X40.
5) *Marginotruncana schneegansi* (Sigal), Middle-late Turonian, Kometan Formation. X40.
6) *Heterohelix globulosa* (Ehrenberg), Middle Turonian, Kometan Formation. X40.

Table 1: Shows the international and local biostratigraphic correlation with the present study

Formation	AGE	Bolli, 1966 General	Sliter, 1989 Circum Pacific	Keller and Pardo 2004	Abawi and Hammoudi, 1997 N. Iraq	A bawi and Mohamed 2005	Abawi *et al.*, 2006	Abawi and Hammoudi, 2010 Kurdistan	Ameen and Gharib 2014	Cetean et al 2008	Present work
	Late Turonian	*Globotruncana helvetica*	*Marginotruncana sigali*	*Marginotruncana sigali*	*Marginotruncana sigali*	*Marginotruncana sigali*			*Marginotruncana sigali*	**Not Studied**	**Not Studied**
Kometan(l.part)	Middle Turonian		*Helvetoglobotruncana helvetica*	*Helvetoglobotruncana helvetica*	GAP	*Helvetoglobotruncana helvetica*	*Helvetoglobotruncana helvetica*		*Helvetotruncana elvetica*	*W. archaeocretacea Zone*	*Helvitoglobotrucana helvetica*
Gulneri	Early Turonian	*Praeglobotruncana gigantea*	*Whiteinella archaeocretacea*	*H.moremani D. hagni- G.bentonensis -*		GAP	*H.moremani*		*Heterohelix moremani (1.2 m)*		*Whitenella archeocretacea*
Dokan	Late -Cenomanian	*Rotalipora cushmani*	*Rotalipora Cushmani*					*Rotalipora cushmani*	*Rotalipora cushmani*	*Rotalipora cushmani*	*Rotalipora cushmani*

Table 2: Ages for planktic foraminiferal and ammonite first (FAD) and last (LAD) of the uppermost Cenomanian lowermost Turonian succession

Index planktic foraminifera and Ammonites	Age	REFERENCE	THIS STUDY
***Helvetoglobotruncana helvetica* FAD**	93.29±0.2 Ma	Hardenbol *et al*. (1998)	*Helvetoglobotruncana helvetica*
***Watinoceras devonense* FAD**	93.49±0.2 Ma	Hardenbol *et al*. (1998)	GAP
***Neocardioceras juddii* LAD**	93.49 ±0.2 Ma	Hardenbol *et al*. (1998)	*Heterohlix Moremani Whiteinella archeocretacea* FAD Dwarf Ammonite
***Heterohelix shift* OAE 2 δ13C peak (2) excursion max.**	93.78 ±0.02 Ma*	Keller and Pardo 2004	
***Globigerinelloides bentonensis* LAD**	93.86 ±0.05 Ma*	Keller and Pardo 2004	GAP
***Dicarinella hagni* FAD**	93.86 ±0.05 Ma	Keller and Pardo 2004	
***Rotalipora cushmani* LAD**	93.90 ±0.02 Ma	Keller and Pardo 2004	*Ampullia gastopods Rotalipora cushmani* LAD
OAE 2 δ 13C peak 1 93.91F0.02 Ma	93.91 ±0.02 Ma	Keller and Pardo 2004	
OAE 2 δ 13C excursion onset	94.00F0.02 Ma*	Keller and Pardo 2004	
***Rotalipora greenhornensis* LAD**	93.95F0.02 Ma*	Keller and Pardo 2004	*Rotalipora greenhornensis* LAD
***Rotalipora deekei* LAD**	93.95 Ma	Keller and Pardo 2004	Not appear.
***Whiteinella archeocretacea* FAD**	94.50 Ma	Keller and Pardo 2004	
Mid-Cenomanian δ 13C shift (MCE)	95.71 Ma	Keller and Pardo 2004	
***Whiteinella paradubia* FAD**	95.85 Ma	Keller and Pardo 2004	

3- *Helvetoglobotruncana helvetica* Partial Range Zone (Fig.7b – f). It is defined by the total range of the index species with a middle Turonian age. Its range starts from the First occurrence (base): at the base of *Helvetoglobotruncana. helvetica* zone (0% up, 93.5 Ma, in Turonian stage), and its Last occurrence (top): at top of *Helvetoglobotruncana helvetica* zone (100% up, 92.6 Ma, in Turonian stage). But in this study only the lower part of this zone is recorded within the lower 6 meters of the Kometan Formation, therefore is a partial range zone. The first appearance of *Helvetoglobotruncana helvetica* coincides with the thriving of several other double-keeled species such as *Marginotruncana renzi* and *Marginotruncana sigali*, and combined by higher frequencies of the benthonic foraminifera They are associated with *Heterohelix* spp., *Hedbergella* spp. as W. *baltica* (Douglas), and *Helvetotruncana praehelvetica*, with abundant non-keeled species of *Whitnella* spp., and double-keeled species of *Dicarinella* spp., and *Marginotruncana* spp. This zone coincides with the *H. helvetica* zone of Caron (1985); Silter (1989); Wonders (1992), and Nishi *et al*. (2003). Therefore, the age of this zone is Middle Turonian. also, this zone coincides with the *M. sigali* zone of Abawi and Hammoudi (1997); and Al-Khafaf (2005); Al-Khafaf (2014).

DISCUSSIONS

Bellen *et al*. (1959) mentioned that the Dokan limestone comprises the sediments of an intra-Cenomanian transgression, and follows up on an eroded surface, which was dictated by post-Albian or late-Albian regression. It is followed by the Gulneri shale, which contains the sediments of a later (early but probably not earliest Turonian) transgression, following a second probably intra-Cenomanian regression. Such transgression and regression cycle coincide with major unconformity on the Arabian plate margin which is well known as pre-Aruma unconformity (Sharland *et al*., 2001; Ameen and Gharib, 2014; Lawa *et al*., 2013). According to the last version of the International Chronostratigraphic Chart (Version 2, 2022, By IUGS), the top of the Cenomanian age is dated as 93.9 Ma., and this coincides with the top of *Rotalia cushmani* zone. Therefore, the Late Cenomanian age is characterized by the total disappearance and extinction of nominated taxon and combined by shallowing parasequences from the planktic predominated facies to bioclastic grainstone rich in Pelecypods (Inoceramids) and gastropods (Ampullinids). Abawi *et al*. (2006) mentioned that the Dokan limestone boulders show the occurrence of *Rotalipora* spp., reworked and included in the lower part of the Gulneri shale, hence, the occurrence of *Rotalipora* cf. *appenninica Renz,* which is registered by Bellen *et al*. (1959) within the fossil assemblage of the Gulneri Formation, is actually derived from the limestone boulder. Gertsch *et al.* (2010) mentioned that the *Heterohelix moremani* assemblage coincides with the second peak of the d13C excursion and contains abundant low oxygen tolerant *Heterohelix moremani*. In addition to that and throughout the global ocean, *Heterohelix* dominated assemblages first appear shortly after the second d13C peak and mark the change to oceanic anoxia (Leckie *et al*., 1998; Keller *et al.*, 2001; Keller and Pardo, 2004; and Gertsch *et al*., 2010). Therefore, the Gulneri sediments represent the low diversified and dwarfish foraminiferal fauna, the dominant occurrence of the low oxygen tolerant Heterohelicids, and the organic-carbon-rich black shale and coincide with the ocean anoxic event 2 across the Cenomanian–Turonian Boundary. According to Abawi and Mahmood (2005), the Gulneri Formation in Jambour well no. 46 (northern Iraq) is Middle to Late Turonian in age. Voigt *et al*. (2008) mentioned that the *Rotalipora cushmani* Zone is defined as the interval from the FO of *R. cushmani* to the last occurrence (LO) of rotaliporids, while the *Whiteinella archaeocretacea* Zone is defined as the interval between the extinction-level of rotaliporids and the FO of *Helvetoglobotruncana helvetica*.

In this study, there is a minor gap between the *Rotalia cushmani* zone and *whiteinella archeocretacea* zone, manifested by the disappearance of *Dicarinella hagni* as well as by the reworked boulders of Dokan in the base of the Gulneri Formation. It's worth to emphasized that *Whiteinella archaeocretacea* Zone (across the OAE 2 interval) is generally poorly diversified and dominated by small-sized biserial taxa, *hedbergellids*, and *Schackoinids*, all taxa indicative of meso-eutrophic conditions. A complete assemblage yielding large-sized oligotrophic specimens is restored only in the Turonian *Helvetoglobotruncana helvetica* Zone (Leckie *et al*., 1998; Keller *et al*., 2001; and Keller and Pardo, 2004). Lawa *et al*. (2013) cited the presence of these unconformities and mentioned that Dokan and Gulneri formations are not present (an unconformity with a duration of 4.7 m.y) in the Tabeen Gorge 4 Km to the southeast of Surdash village. The same claimed unconformities are mentioned by Omer *et al*. (2015) on the Azmir anticline and they detected the absence of Dokan and Gulneri formations at the top of the Balambo Formation. They attributed the unconformity to the tectonic uplifting of the Mawat Ophiolite obduction during the Turonian and reactivations of the Chaq Chaq fault. Scotes (1997) shows that in his paleogeographic map (Fig.8).

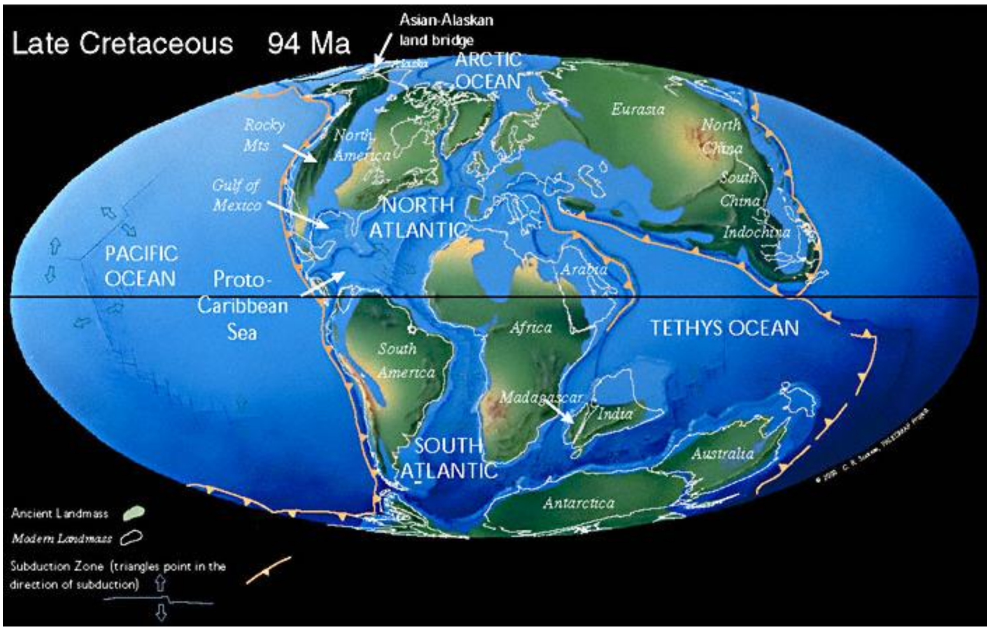

Fig.8: Shows the Cenomanian–Turonian paleogeography and initial subduction of the Arabian plate (After Scotes, 1997)

CONCLUSION

- The Gulneri Formation consists of black shale essentially, about 1.5 m in thickness, and possibly reflects the oxygen deficiency in oceanic waters (Oceanic Anoxic Event 2 = OAE 2), and points to a condensate section in Kurdistan and northern Iraq.
- The lower and upper boundaries of the Dokan Formation are unconformable contact, which is reworked boulders of the Dokan Formation within the base of the Gulneri Formation, associated with Gastropods and Pelecypods fragments.
- The lower and upper boundaries of the Gulneri Formation are unconformable contact.
- The planktic zone of *Rotalipora cushmani* is of the Late Cenomanian age recorded from Dokan Formation as a partial range and does not represent the whole late Cenomanian, and manifests a short-term gap that the latest Cenomanian. The *Whitenalla archaeocretacaea* zone of the early Turonian age is recorded from the Gulneri Formation with remarkable disappearances and indicated by the disappearances of *Dicareinella hangi*, combined with the predominance of the Heterohelcides, especially the *Heteohelix mormani*, where the lowermost Turonian time indicator disappears.
- The upper boundary with the Gulneri Formation is characterized by a minor gap, which is also combined by the disappearance of the total zone of *Whittenella creatacea* of the Early middle Turonian age, with remarkable enrichments of glauconite about 40 cm thick.
- The planktic foraminiferal shifts in the studied sections point to eustatic sea-level changes reflecting astronomical climatic changes, and short gaps which are equivalent to the pre-Aruma unconformity of the Arabian plate.

REFERENCES

Abawi, T.S. and Hammoudi, R.A., 1997. Foraminiferal Biostratigraphy of the Kometan and Gulneri Formations (Upper Cretaceous) in Kirkuk Area, North of Iraq. Jour. Geol. Soc. Iraq, Vol.30, No.2, p.139 – 146.

Abawi, T.S., Hammondi, R.A. and Al-Khafaf, A.O., 2006. Stratigraphy of the Gulneri Formation (Upper Cretaceous) in the Type Section, Dokan area, Northeastern Iraq. Iraqi Jour. Earth Sci., Vol.6, No.2, p. 33 – 42.

Abawi, T.S. and Mahmood Saad A. 2005. Biostratigraphy of the Kometan and Gulneri Formations (Upper Cretaceous) in Jambur well No. 46, Northern Iraq Iraqi Jour. Earth Sci., Vol.5, No.1, p.1 – 8.

Abawi, T.S., and Hammoudi, R.A., 2006. Foraminiferal biostratigraphy of the Turonian – Early Campanian depositional subcycle from selected oil wells in Iraq, Anuario do instituto Geociencias Jour. Earth Sci., Vol.29, 651pp.

Abawi, T.S. and Hammoudi, R.A., 2010. Stratigraphy of the Dokan Formation (Upper Cretaceous) Jebel Azmer-Sulaimaniya Area, Northeastern Iraq, Iraqi Journal of Earth Sciences, Vol.10, No.1, p.1 – 10.

Al-Khafaf, A.O., 2005. Stratigraphy of Kometan Formation (Upper Cretaceous) in Dokan Endezah Area, NE-Iraq. Unpublished M.Sc. Thesis. The University of Mosul, department of Geology, 79pp.

Al-Khafaf, A.O., 2014. Biostratigraphic contribution to the differentiation of the Lower-Middle Cretaceous units in the Imbricated Zone of Sulaimani Governorate, Kurdistan Region, NE Iraq, Ph.D. thesis, University of Sulaimani.

Al-Khatony, S.E., Al-Azzawi, N.K. and Lawa, F.A., 2019.Structural and Tectonic Study of Qara Sard Anticline and Choplagh Syncline, from Sulaimaniya Area, Kurdistan Region, North-eastern Iraq. Iraqi National Journal of Earth Science, Vol.19, No.1, p. 39 – 58.

Al-Sagri, K.E.A., 2015. Linking the Timing of Deposition and Organic Matter Richness of the Gulneri Formation of Northern Iraq to the Global Oceanic Anoxic Event 2 (OAE 2): Implications to better constrain the depositional models of Iraqi's oil source beds and their timing of deposition. Iraqi Journal of Science, Vol.56, No.3A, p. 2007 – 2023.

Al-Sheikhly S.S., Tamar-Agha, M.Y., Mahdi, M.M., 2015. The facies analysis of the Cenomanian – Turonian succession of Surdash – Shaqlawa area, NE. Iraq. Iraqi Journal of Science, Vol.56, No.1C, p. 767 – 773.

Ameen, F.A. and Gharib, H., 2014. Biostratigraphy of the Tethyan Cretaceous successions from northwestern Zagros fold-thrust belt, Kurdistan region, NE Iraq. Arab J Geosci, Vol.7, p. 2689 – 2710.

Aqrawi, A.A.M., Goff, J., C., Horbury, A.D. and Sadooni, F.N., 2010. The petroleum geology of Iraq. Scientific Press, Beaconsfield, 424pp.

Arthur, M.A., Schlanger, S.O. and Jenkyns, H.C., 1987. The Cenomanian-Turonian Oceanic anoxic Event, II. Palaeoceanographic controls on organic-matter production and preservation. Geological Society, London, Special Publications 1987, Vol.26, p. 401 – 420.

Baban, D.H. and Sarraj, R.H., 2007. Palynofacies analysis and hydrocarbon generation potential of Dokan and Gulneri Formations (Upper Cretaceous) from selected wells in Northern Iraqi Oil Fields. Journal of Kirkuk University, Vol.2, No.3, p. 17 – 34.

Barno J.M.B., 2014. Structural analysis of kosrat anticline and its tectonic implications, northeastern Iraq. Unpublished Ph.D. thesis. University of Baghdad, 217pp.

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

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

Buday, T. and Jassim, S.Z., 1987. The Regional Geology of Iraq: Tectonic Magmatism, and Metamorphism. I.I. Kassab and M.J. Abbas (Eds), Baghdad, 445pp

Caron, M., Dall'Agnolo, S., Accarie, H., Barrera, E., Kauffman, E.G., Amédro, F. and Robaszynski, F., 2006. High-resolution stratigraphy of the Cenomanian – Turonian boundary interval at Pueblo (USA) and Wadi Bahloul (Tunisia): stable isotope and bio-events correlation. Geobios, Vol.39, No.2, p. 171 – 200.

Caron, M., 1985. Cretaceous planktic foraminifera. In Plankton stratigraphy (eds Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K.), p. 17 – 86 (Cambridge University Press, Cambridge).

Cetean, C.G., Bălc1 R., Kaminski M.A., Filipescu S., 2008. Biostratigraphy of the Cenomanian – Turonian boundary in the Eastern Carpathians (Dâmboviţa Valley): preliminary observations. Studia Universitatis Babeş-Bolyai, Geologia, 2008, Vol.53, No.1, p. 11 – 23.

Gertsch, B., Keller, G. and Adatte, T., 2010. Cenomanian – Turonian transition in a shallow-water sequence of the Sinai, Egypt. Int J Earth Sci (Geol Rundsch) 99, p. 165 – 182.

Haddad, S.N.S. and Amin, M.A., 2007. Mid-Turonian -early Campanian sequence stratigraphy of northeast Iraq. GeoArabia (Middle East Petroleum Geosciences), Vol.12, No.2, p. 135 – 175.

Hammudi, R.A., 1995. Stratigraphy of Turonian-early Campanian secondary sedimentary cycle in selected wells from Iraq. Unpublished Ph.D. Thesis, College of Science, Mosul University (in Arabic).

Hardenbol, J., Thierry, J., Farley, M.B., Jacquin, T., de Graciansky, P.C. and Vail, P., 1998. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins. In: Graciansky, P.C., et al. (Ed.), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins: SEPM Special Publication, Vol.60, p. 3 – 13 (charts 1 – 8).

Hussain, S.A and AL-Sheikhly, S.S., 2015. Paleoecology of Albian – Santonian succession of Surdash to Shaqlawa area, NE Iraq. Iraqi Journal of Science, Vol.56, No.2A, p 1076 – 1097.

Jaff R.N.B, and Lawa, F.A.A., 2019. Biostratigraphy and Systematic Palaeontology of Late Cretaceous Heterohelicidae Foraminifera from Kurdistan Region North-eastern Iraq. Iraqi National Journal of Earth Sciences, Vol.20, No.2, p. 33 – 63.

Jassim, S.Z., and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague, and Moravian, Museum, Berno, Czech Republic, 341pp.

Keller, G., Pardo, A., 2004. Age and paleoenvironment of the Cenomanian–Turonian global stratotype section and point at Pueblo, Colorado. Mar Micropaleontol, Vol.51, p. 95 – 128.

Keller. G., Han Q., Adatte T., Burns S.J., 2001. Paleoenvironment of the Cenomanian – Turonian transition at Eastbourne, England. Cretac Res, Vol.22, p. 391 – 422.

Lanci, L., Muttoni, G. and Erba, E., 2010. Astronomical tuning of the Cenomanian Scaglia Bianca Formation at Furlo, Italy. Earth Planet. Sci. Lett., Vol.292, No. 1 – 2, p. 231 – 237.

Lawa, F.A., Koyi, H. and Ibrahim, A.O., 2013. Tectono-stratigraphic evolution of the Northwestern segment of Zagros fold-thrust belt, Kurdistan, NE Iraq. Journal of Petroleum Geology, Vol.36, No.1, p. 75 – 96.

Lawa, F.A., 2018. Late Campanian – Maastrichtian sequence stratigraphy from Kurdistan foreland basin, NE Iraq. Journal of Petroleum Exploration and Production Technology, Vol.8, p. 713 – 732.

Leckie, R.M., Yuretich, R.F., West, L.O.L., Finkelstein. D. and Schmidt, M., 1998. Paleoceanography of the southwestern Interior Sea during the time of the Cenomanian–Turonian boundary (late Cretaceous). Dean WE, Arthur MA (eds) Concepts in sedimentology and paleontology, Vol.6, p. 101 – 126.

Maâmouri, A.L., Zaghbib-Turki, D., Matmati, M.F., Chikhaoui, M. and Salaj, J., 1994. La formation Bahloul en Tunisie centro-septentrionale: variation latérales, nouvelle datation et nouvelle interprétation en terme de stratigraphie séquentielle. J. Afr. Earth Sci., Vol.18, No.1, p. 37 – 50.

Nishi, H., Takashima, r., Hatsugai, t., Saito, T., Moriya, K., Ennyu, A. and Sakai, T., 2003. Planktic foraminiferal zonation in the Cretaceous Yezo Group, Central Hokkaido, Japan, Journal of Asian Earth Sciences, Vol.21, No.8, p. 867 – 886.

Numan, N.M.S., 2000. Major Cretaceous tectonic events in Iraq. Rafidan Journal of Sciences, University of Mosul, Iraq, Vol.11, No.3, p. 32 – 52.

Numan, N.M.S., 2001. Cretaceous and Tertiary Alpine subduction history in Northern Iraq. Iraqi Journal of Earth Sciences, Vol.1, No.2, p. 59 – 74.

Nederbragt, A.J. and Fiorentino, A., 1999. Stratigraphy and paleoceanography of the Cenomanian – Turonian Boundary Event in Oued Mellegue, north-western Tunisia. Cretac. Res., Vol.20, p. 47 – 62.

Omar, A.A., Lawa F.A. and Sulaiman, S.H., 2015. Tectonostratigraphic and structural imprints from balanced sections across the north-western Zagros fold-thrust belt, Kurdistan region, NE Iraq. Arabian Journal of Geosciences, Vol.8, p. 8107 – 8129.

Peryt, D., 2004. Benthic foraminiferal response to the Cenomanian – Turonian, and Cretaceous – Paleogene boundary events. Przegla̜d Geologiczny, Vol.52, No.8/2, p. 827– 832.

Piori, K., 2005. The Trawne Member (Albian‑Cenomanian, PieninyKlippen Belt, Carpathians): a new insight into its foraminiferal assemblages and biostratigraphy. Studia Geologica Polonica, Vol.124, p. 237 – 248.

Scotes, C.R., 1997. Paleogeographic atlas, PALEOMAP Progress Report 90 – 0497, Department of Geology, the University of Texas at Arlington, Arlington, TEXAS, 37pp.

Scopelliti, G., Bellanca, A., Coccioni, R., Luciani, V., Neri, R., Baudin, F., Chiari, M., Marcucci, M., 2004. High-resolution geochemical and biotic records of the Tethyan 'Bonarelli Level' (OAE2, latest Cenomanian) from the Calabianca – Guidaloca composite section, northwestern Sicily, Italy. Paleogeography, Palaeoclimatology, Palaeoecology Vol.208, p. 293 – 317.

Sharland, P.R., Archer, R., Casey, D.M., Davies, R.B., Hall, S.H., Heward, A.P., Horbury, A.D. and Simmons, M.D., 2001. Arabian plate sequence stratigraphy, GeoArabia, Special publication 2, Gulf Petro Link, Bahrain, 372pp.

Sissakian, V.K. and Fouad, S.F. 2015. Geological Map of Iraq, Scale 1: 1000 000, 4th Edition. Iraqi Bulletin of Geology and Mining, Vol.11, p. 9 – 16.

Sliter, W.V., 1989. Biostratigraphic zonation for Cretaceous planktic foraminifers examined in thin section. Journal of Foraminiferal Research, Vol.19, p. 1 – 9.

Soua, M., 2005. Biostratigraphie de haute résolution des foraminifères planctoniques du passage Cénomanien Turonien et impact de l'événement anoxique EAO-2 sur ce groupe dans la marge sud de la Téthys, exemple régions de Jerissa et Bargou. Mémoire de Mastère, Univ., de Tunis El Manar, 169pp.

Stevanovic, Z. and Markovic, M.Y., 2003. Hydrogeology Of Northern Iraq. Un (FAO), Report No.1, 225pp, and 52 Maps.

Voigt, S., Erbacher, J., Mutterlose, J., Weiss, W., Westerhold, T., Wiese, F., Wilmsen, F. and WoniK, T., 2008. The Cenomanian – Turonian of the Wunstorf section – (North Germany): global stratigraphic reference section and new orbital time scale for Oceanic Anoxic Event 2. Newsletters on Stratigraphy, Vol.43/1, p. 65 – 89.

Wonders, A.A.H., 1992. Cretaceous planktic foraminiferal biostratigraphy, Leg 122, Exmouth Plateau, Australia. In Proceedings of the Ocean Drilling Program, Scientific Results (von Rad, U., Haq, B.U. et al., Eds.). Ocean Drilling Program, College Station, Vol.122, p. 587 – 599.

About the authors

Fadhil Ahmed Ameen Lawa graduated from the University of Sulimani, Kurdistan region. Iraq, in 1980 with B.Sc. in Geology (Ore geology). He got his M.Sc. degree from the University of Mosul in 1983, in Stratigraphy and Paleontology. He joined the University of Salahaddin in 1983 and was nominated as an assistant lecturer. In 1985 he joined the Iraqi geological survey. In 1992, He joined the University of Sulimani and got his Ph.D. in Stratigraphy (Sequence stratigraphy) in 2004. His main field of interest is regional geology and tectonostratigraphy of the Kurdistan region, Cretaceous and Cenozoic Bio, and sequence stratigraphy. He has about 100 unpublished geological reports in the Iraq geological Survey, FAO (UN) agency, and other sectors. He published about (76) papers in local and international Journals.

e-mail: Fadhil.ameen@univsul.edu.iq.
Mailing address: Iraq. Kurdistan region, Sulaymaniyah, University of Sulaimani. The new campus, Qelyasn.

Araz Omar Salih Al-Khafaf graduated from the University of Sulaimani Kurdistan region. Iraq, in 1981 with B.Sc. in Geology. In 1989 he joined Basra Oil Company. In 1993 he joined the Sulaimani cement factory. In 1997 he Joined the University of Sulaimani. In 2005 he got MSc in Micropaleontology from the university of Mosul and work as an assistant lecture in the department of geology. He got his Ph.D. in Micropaleontology from the university of Sulaimani in 2014 In. He published 10 articles about the biostratigraphy of Cretaceous successions in Iraq and the Kurdistan region.

e-mail: araz.salh@univsul.edu.iq.
Mailing address: Iraq. Kurdistan region, Sulaymaniyah, University of Sulaimani. The new campus, Qelyasn.