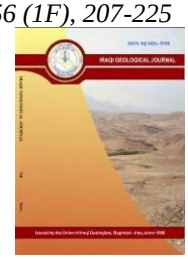
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Depositional Setting of the Shiranish Formation (Campanian-Maastrichtian) in Selected Sections from Northern Iraq

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Abstract

The Shiranish Formation (Campanian-Maastrichtian) was studied in two surface sections (Diana and Garuta) in Erbil Governorate. Both sections lie within the High Folded Zone of Zagros Fold-Thrust Belt in Iraq. Stratigraphically, the formation is divided into three lithostratigraphic units depending on the field characteristics with varied thicknesses of the formation in both sections. The lower unit (Unit A) consists of blue to grey well-bedded marly massive limestone, the middle unit (Unit B) is composed of blue to grey marl, marly limestone and stratified shale, and finally, the upper unit (Unit C) is composed of grey limestone and blue marly limestone. The lower contact of the formation is unconformable with the Bekhme Formation in the Diana section and conformable with the Kometan Formation in the Garuta section, while the upper contact is conformable with both Tanjero and Kolosh formations in Diana and Garuta sections respectively. X-ray diffraction analysis has revealed that calcite is the main mineralogical component with less of quartz and clay minerals as represented by chlorite and illite. Four lithofacies were distinguished (Marl facies (Sml), Shale facies (Ssl), Conglomerate limestone facies (Scl)) and red clay layers (Srl), whereas, three main microfacies were recognized; Fossiliferous Lime Mudstone Microfacies (Sml), Lime Wackestone Microfacies (Sw) and the Packstone Lime Microfacies (Sp), which in turn were subdivided into seven secondary facies, according to their components, which are; Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw1), Keeled Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw2), Calcispheres Lime Wackestone Submicrofacies (Sw3), Bioclastic Lime Wackestone Submicrofacies (Sw4), Benthonic Foraminiferal Lime Wackestone Submicrofacies (Sw5), Keeled Planktonic Foraminiferal lime Packstone Submicrofacies (Sp1) and Planktonic Foraminiferal Globular Chamber Packstone Submicrofacies (Sp2). Based on these facies, the formation was deposited in a relatively deep marine environment and within two secondary environments; the outer shelf and upper bathyal environments as a result of the widespread transgression in the beginning of the Campanian.

Keywords: Campanian-Maastrichtian; Shiranish; Depositional setting; Diana; Garuta; Northern Iraq

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1. Introduction

The Shiranish Formation (Campanian- Maastrichtian) is regarded as one of the widespread Upper Cretaceous units that cropped out in northern Iraq. It was deposited at the middle to end of the (AP9) Megasequnces of (Sharland, 2001) in the Campanian-Early Maastrichtian cycle. During this cycle, the ophiolite–radiolarites obduction between the Iranian plate and the Arabian Plates led to the creation Zagros foreland basin (NE Iraq) (Lawa, 2018), accompanied by with a large marine transgression in the whole of Iraq. These events led to the deposition of several sedimentary facies, including the Shiranish Formation which formed in the outer shelf deep environments (Jassim and Buday, 2006).

The first description of the formation was by Henson, 1940 close to the Shiranish Islam village, northeast of Zakho town, Iraqi Kurdistan Region in the High Folded Zone of Iraq (Bellen et al., 1959). It is situated at 161 and 177 km northeast of Diana and Garuta sections respectively. It consists of 228 m of thin bedded marly limestone in the lower part overlies by blue marl in the upperpart accompanied with dolomitic and marly limestone with prolific microfossils (Buday, 1980). It had a wide outcrop distribution in Iraqi Kurdistan within the High Folded Zone. The Shiranish Formation is reservoir and producing oil in all oil field in Iraq, and it was penetrated in several subsurface wells in central and southern Iraq such as, Kirkuk (K09, K116, 117), Chamchamal (2), Injana (5), Ain Zala (16), Jawan (2) and some wells of the Khana oilfield.

The formation has an economic consideration, because it regarded as oil reservoir in Kurdistan region and northwestern Iraq due to its highly fractures and joints in addition to secondary porosities (Ahmed, 1980; Awdal et al., 2013; Baban et al., 2020). There are several previous works conducted to the sedimentology, paleontology and stratigraphy of the studied formation without detailed study in the current studied outcrops. The most interested are the studies of (Ahmed, 1980; Abba Hussein, 1983; Al-Banna, 2010; Al-Jubouri, 2011; Al-Jubouri et al., 2016; Al-Hazaa et al., 2021, and Hassan, 2021). The current work aims to interpret the depositional setting of the Shiranish Formation in both Garuta and Diana sections from northeastern Iraq, through the field observations, mineralogy, petrography and microfacies analysis.

2. Geologic Setting

The studied area is situated in the Kurdistan region of northeastern Iraq. The studied sections are those that not previously investigated in addition to that, they are easily access and include complete succession of the formation. Tectonically, both sections are placed in the High Folded Zone of Iraq (Fig.1a). The first section is situated close to Diana village, northwest of Soran town in the northwest limb of Zozik anticline (36° 40' 35.88" N and 44°33' 40.55" E) (Fig.1b). The lower contact is sharp and unconformable with Bekhme Formation, Whereas the upper contact is conformable and gradational with Tanjero Formation. Whilst, the second section is situated near the Garuta village, 13 km southeast of Shaqlawa town and 5km east to Hiran town, close the main road between Shaqlawa and Hiran in the northern limb of Safin anticline at coordination's (lat. 36° 18' 37.7" N and long.44°26' 47.5" E) (Fig.1c). The lower boundary of the formation in this section is conformable with Kometan Formation, While, the upper boundary is gradational and conformable with Kolosh Formation.

3. Materials and Methods

A comprehensive field work was done in the two studied sections. It includes the lithological description, rock sampling, sedimentary structure and macrofossils. The sum of 102 samples (49 from Diana section and 53 from Garuta section) were collected from marly limestone and marl of Shiranish Formation. The collection of samples was based on the change in lithology or color (random sampling).

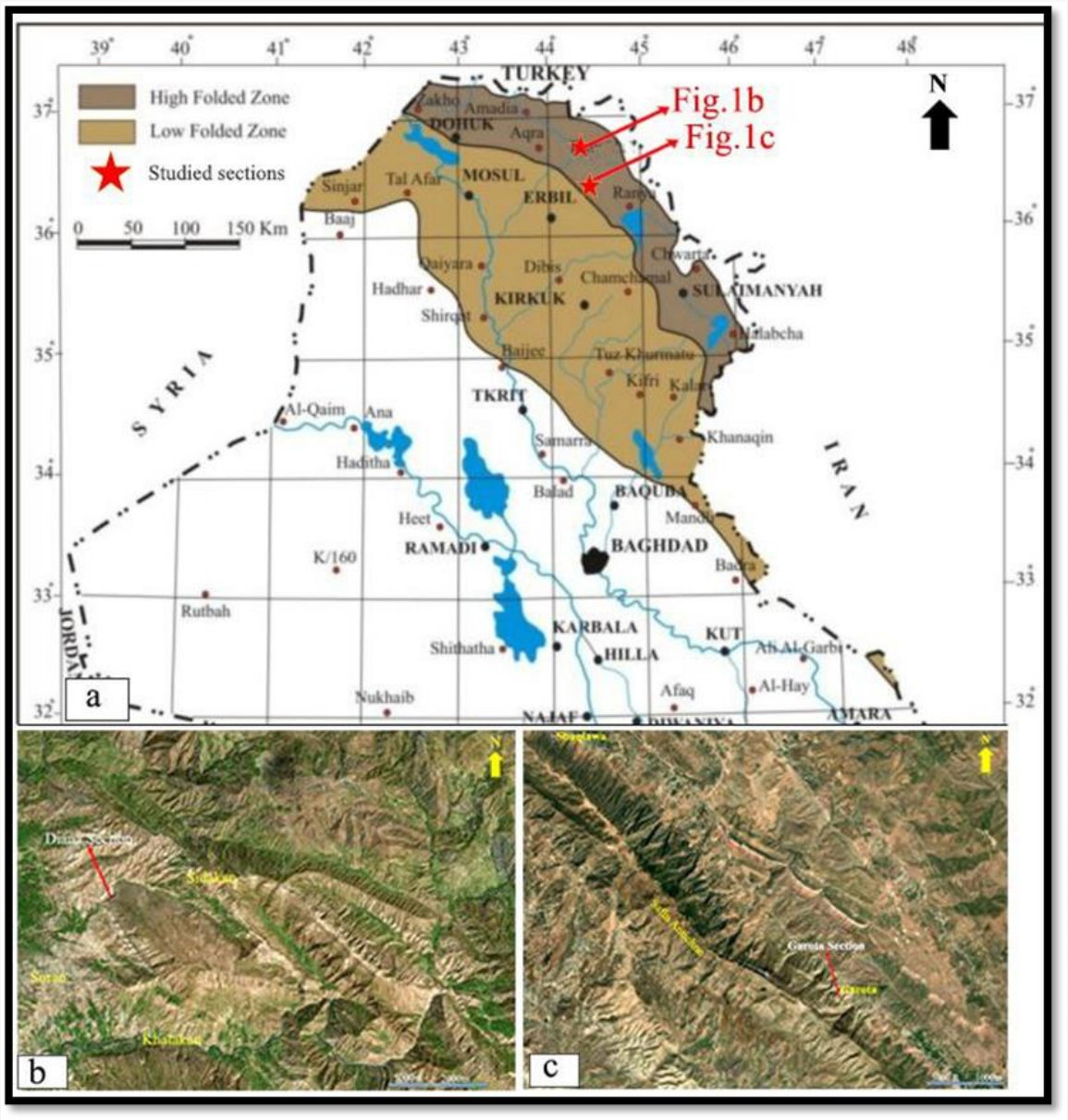


Fig.1. a) The location of the study area for the two sections of the Shiranish Formation according to (after Fouad, 2015). Satellite image of b) Diana and c) Garuta sections (from Bing Map)

Additionally, several samples were collected from both lower and upper boundaries in order check the position of these boundaries in the studied sections. The purpose of sampling is to provide a researcher with an assessment of the qualitative/quantitative nature of samples. Includes both field and laboratory analysis. The total 102 thin sections from the mentioned carbonate rocks were formed in the workshop of Geology Department, Mosul University. The thin sections also were stained with the Alizarin Red Solution (ARS) based on the Friedman (1959) procedure in order to discriminated between calcite and dolomite. Detailed petrographic and microfacies studies were done by using a polarized microscope depending on Dunham (1962) classification scheme. The total 8 samples (4 From Diana and 4 from Garuta) were used for X-ray diffraction (XRD) analysis. It performed at the Premier Laboratory in Houston, the U.S.A. on bulk rock samples using a Bruker D8 Advance XRD instrument. Mineral phase quantification in the bulk diffraction pattern is accomplished using the TOPAS software package.

4. Results

4.1. Lithostratigraphy

The total thickness of the Shiranish Formation is 73 and 93 m in both Diana and Garuta sections respectively. Depending on the field observations, the Shiranish Formation in the studied sections was divided into three informal lithostratigraphic units in ascending order (Figs.2, 9, and 10):

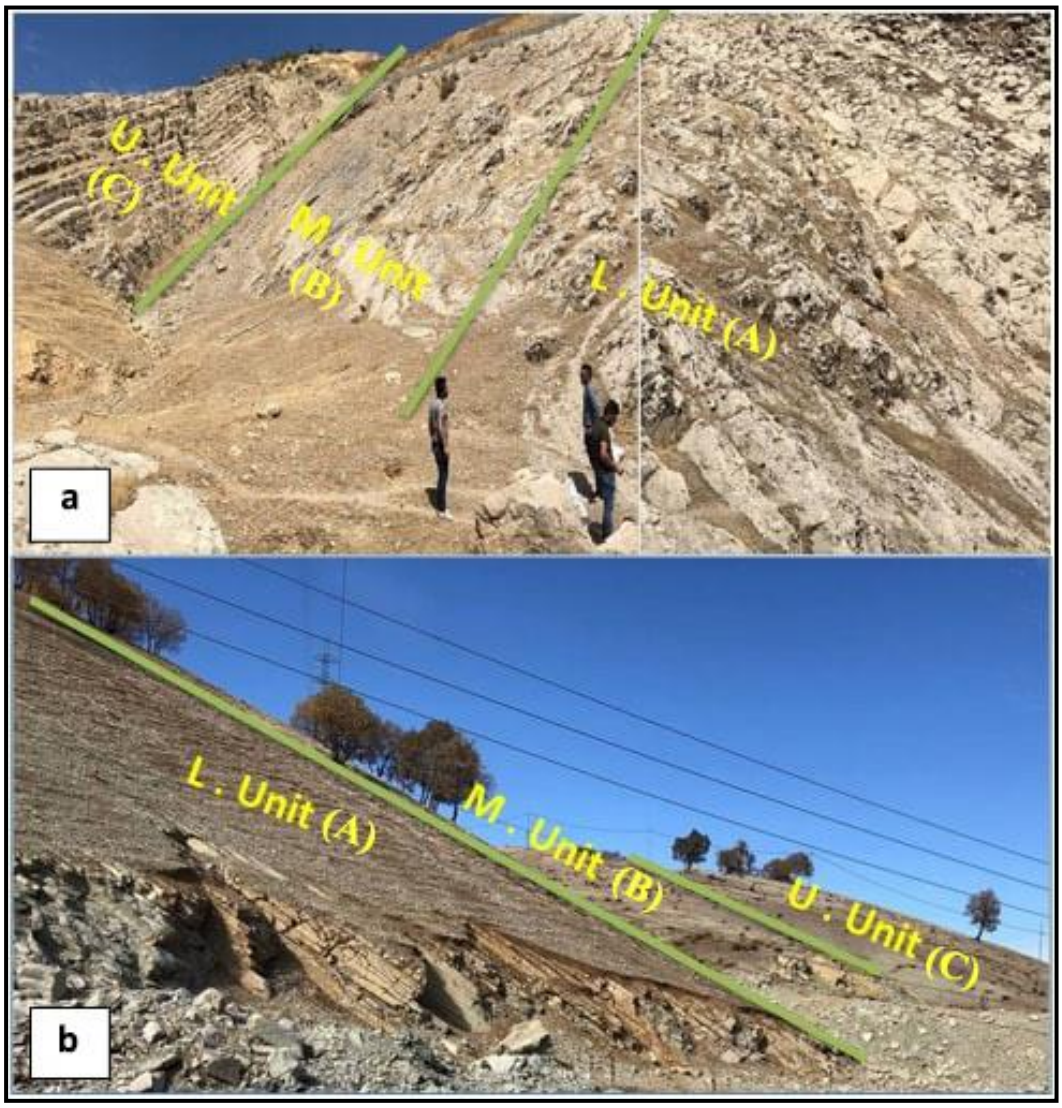


Fig.2. Field photographs showing the lithostratigraphic units of the Shiranish Formation in: a) Diana section and b) Garuta section

4.1.1. lower unit (Unit A)

This unit overlies the massive grey limestone beds of Bekhme Formation in Diana section. While, it overlies thin to medium bedded of white limestone of Kometan Formation in Garuta section. The thickness of this unit in both studied section is about 24m. It consists mainly of blue to grey bedded marly limestone and occasionally includes veins of calcite (Fig. 3a), iron oxides (Fig. 3b), bitumen shows (Fig. 3c) and joints (Fig. 3d).

4.1.2. Middle Unit (Unit B)

The thickness of the middle unit is about 19m and 27m in the Diana and Garuta sections respectively. It mainly consists of the marl and laminated shale containing iron oxides and affected by erosion, it also includes polygon structures, which is one of the distinctive features of the marl (Fig.4 a, b, c and d).



Fig.3. Field photographs shwoing**:** a) The veins of calcite in the limestone beds (arrows), lower unit (A) of Diana section. b) Iron oxides within the carbonate beds of the upper unit (C) of Diana section. c) Bed of marly limestone bearing bitumen shows (arrow), upper unit (C) of Garuta section. d) Well bedded marly limestone with joints (arrow) lower unit (A) of Garuta section

4.1.3. Upper Unit (Unit C)

This unit is overlying Unit B and underlain shale and marl of Tanjero Formation in Diana section and shale of Kolosh Formation in Garuta section. Its thickness reaches about 30m and 41m in Diana and Garuta sections respectively. It consists of light blue marly limestone and hard limestone interbedded with marl characterized by conchoidal structure (Fig. 5a). It also contains, iron oxides derived from oxidation of pyrite, calcite veins. The upper unit, in the Diana section contains a layer of conglomeratic limestone that is also mentioned by Kamil et al. (2021) as a result of continental slumping. This unit in

the Garuta section includes the Red Oceanic Bed (CROBs) in addition to joints (Fig. 5 a, b, c and d). This unit overlaid by the Tanjero Formation (Campanian-Late Maastrichtian) with a gradual change in color and lithology from bluish-yellow marly limestone of the Shiranish Formation to olive-green shale of the Tanjero Formation in Diana section, while it overlain by the Kolosh Formation in Garuta section by gradational and conformable contact.



Fig.4. Field photographs shows: a) A bed of brittle marl containing shale middle unit of Diana section. b) A bed of marly limestone containing pyrite lower unit of Diana section. c) Eroded marl which appears in the form of a valley in the middle unit of Diana section. d) The presence of the structures polygons marl, middle unit of Garuta section

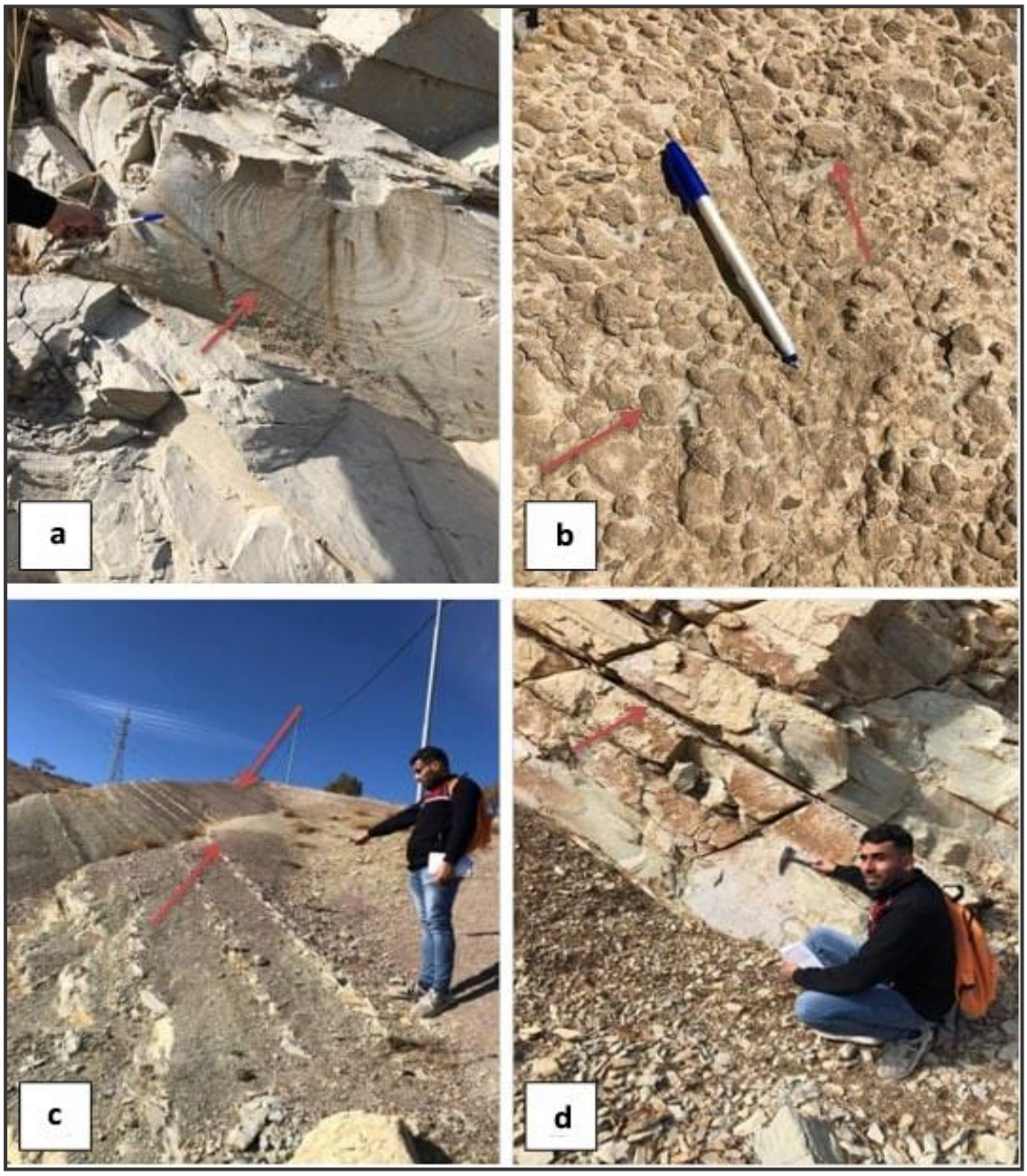


Fig.5. Field photographs displaying : a) Presence of chonchoidal fracture as a result of compression in the lower unit of Garuta section. B) Bed of conglomeratic limestone within the upper unit of the formation in Diana section. C) Color of the sediments changed to red in the upper unit of Garuta section. D) A bed of marly limestone containing calcite joints and veins in the upper unit of Garuta section

4.2. Mineralogy

The mineralogical study is one of the important clues in the sedimentary rocks that complement the petrographic and facies study in terms of identifying of the transported and deposited clay and non-clay minerals to give us an impression on the ancient climate and the sedimentary environment.

The XRD analysis shows that the non-clay minerals mainly are calcite with less amounts of quartz in both studied sections, whereas, clay minerals mainly include chlorite and illite (Figs. 6 and 7).The dominance of chlorite over illite in the Garuta section is clearly observed from the current XRD analysis (See Figs. 6 and 7). This may reflect the difference in paleoclimatic and paleoenvironmental conditions during deposition and the source of rocks from which these clay minerals were derived.

Basic igneous and metamorphic rocks rich in ferromagnesium minerals including elements such as Mg, Fe, and Ca are the main sources for chlorite (Millot, 1970), whereas, illite mostly is derived from weathering of rocks rich in muscovite, biotite, and k-feldspar (Hower et al., 1963). These rocks are dominated in the older ophiolitic complexes from Iraq and Turkey (Buday, 1980).On the hand, presence of chlorite commonly indicates prevailing cool/dry climatic conditions because it mostly survive in cool, moist environments, while illite prefers dry and hot climatic condition to survive in sediments (Chamley, 1989).

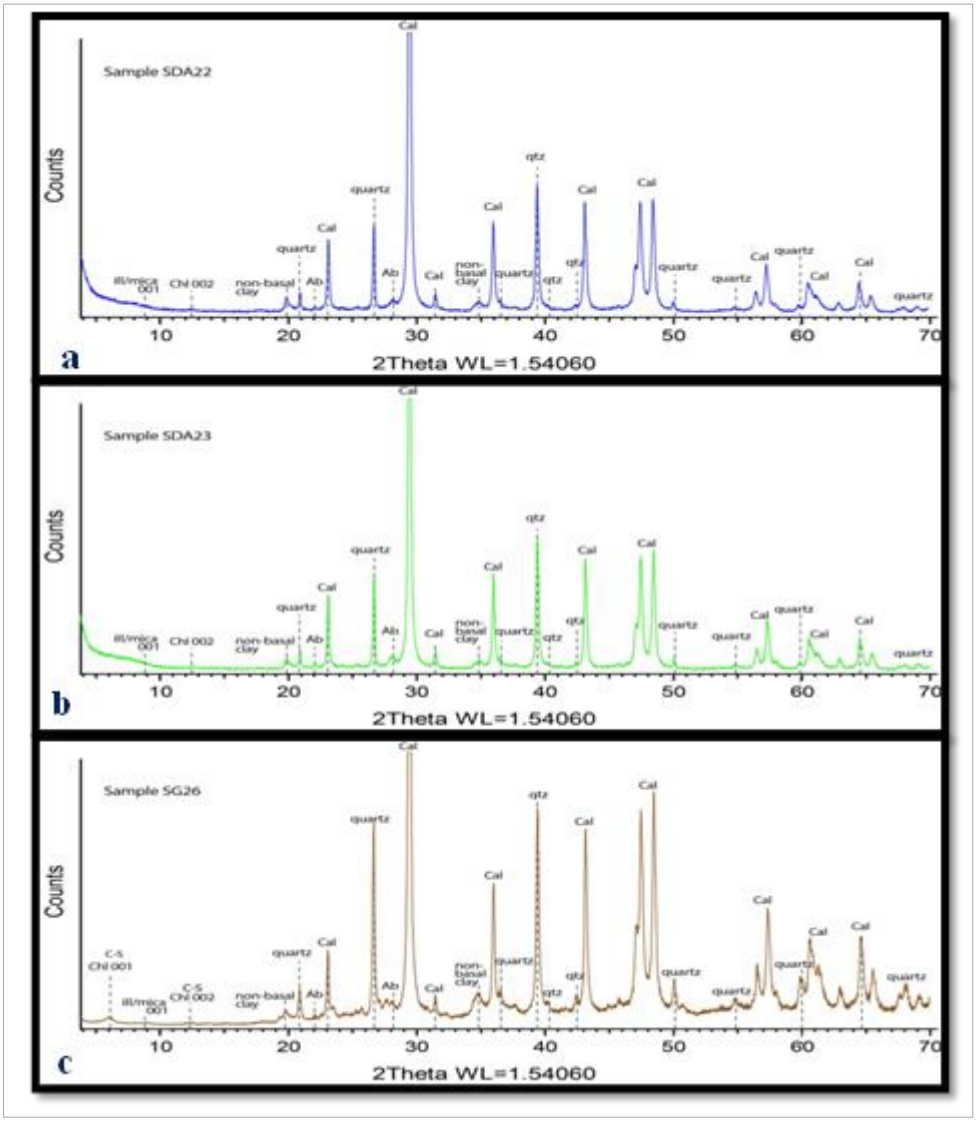


Fig.6. X-ray diffraction diagram (Bulk Samples) for selected samples from the two study sections of the Shiranish Formation. (a) sample 22 from Diana section. (b) sample 23 from Diana section. (c) sample 26 from Garuta section

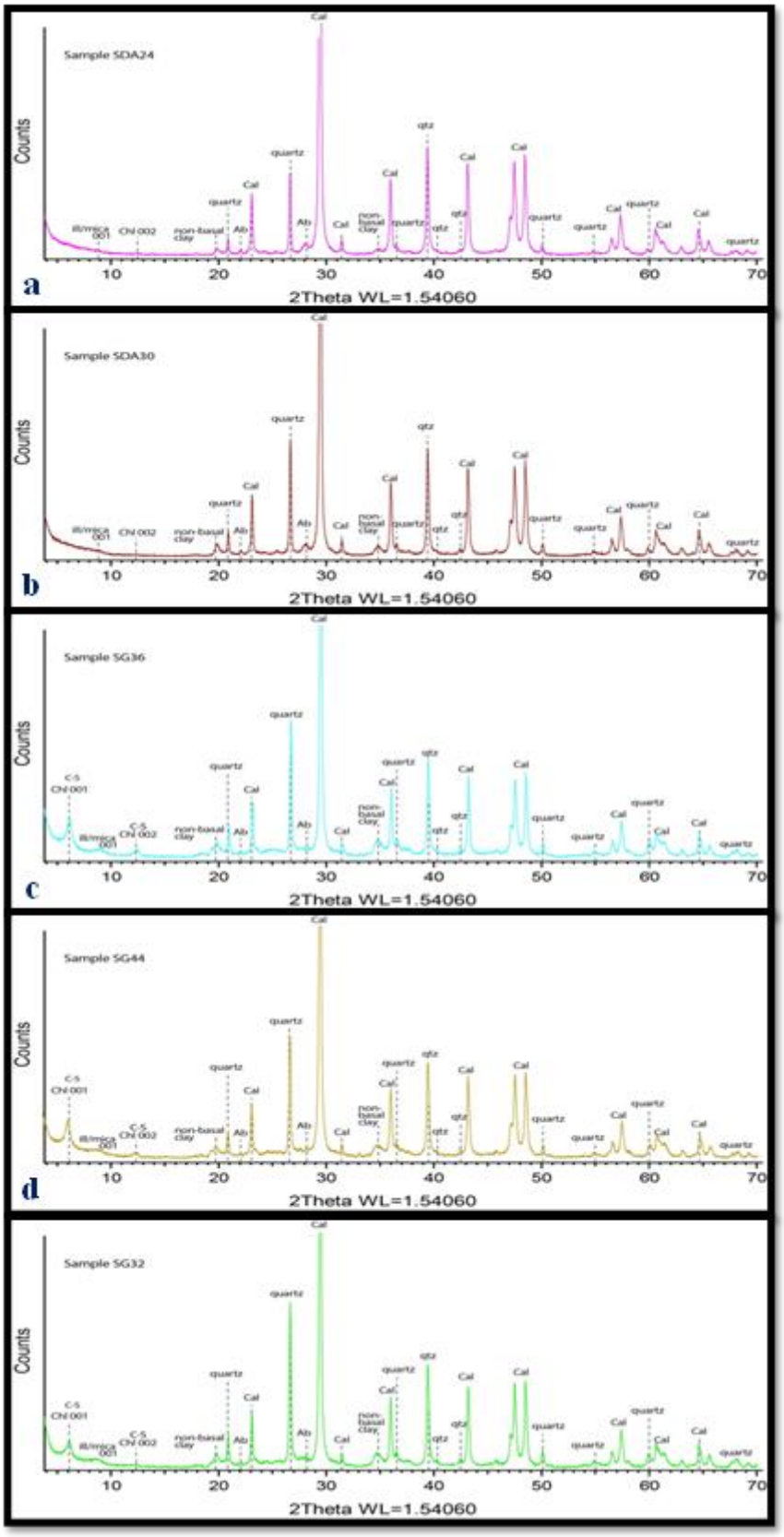


Fig.7. X-ray diffraction diagram (Bulk samples) for selected samples from the two studied sections of the Shiranish Formation. (a) Sample 24 from Diana section. (b) Sample 30 from Diana section. (c) Sample 36 from Garuta section. (d) Sample 44 from Garuta section. (e) Sample 32 from Garuta section

4.3. Facies Analysis

Field observations and petrographic analysis of the limestone and marl rocks of the Shiranish Formation, revealed that the formation could be divided into four lithofacies and three main microfacies.

4.3.1. Lithofacies

The following lithofacies were recognized in the Shiranish Formation in studied sections based on the field criteria:

- *Marl Lithofacies (Sml)*

This facies was found in the middle and upper units in the Shiranish Formation in both studied sections. It is characterized by their bluish-green colors and conchoidal fracture. Its rocks appear in the form of brittle layers that are clearly subjected to erosion processes, which sometimes make them appear in the form of groove structures. Its thickness varies between (50-120 cm). Additionally, it contains iron oxides and pyrite as well as polygon structure that is one of the distinguishing features of marl (Fig. 4 c).

- *Calcareous Shale Lithofacies (Ssl)*

This facies is identified in the middle unit of the Diana section. It is characterized by its dark bluish colors. Thin shale alternates with layers of marl and marly limestone, the thickness varies between 20-15cm. It also contains a lot of pyrite and iron oxides (Fig 4 a).

- *Intraformational Conglomerate Lithofacies (Scl)*

This facies was observed within the upper part (Unit-C) of the Shiranish Formation in Diana section with a thickness of 1m. It consists mainly of gravel with a size of (10-2cm) and characterized by medium to good sorting comprises of calcareous non-skeletal grains in muddy supported and sometimes grain supported matrix (Fig. 5 b).

- *Red Beds Lithofacies (Srl)*

This lithofacies is observed within most upper part of the Shiranish Formation in the Garuta section. It is about 7m thick (Fig. 5c). These red layers consist of marly limestone and clay with a red color containing a high percentage of iron oxides (Fe_2O_3). Ahmed et al. (2017) referred that the red color deposits belong to the red oceanic layers scattered in the upper Cretaceous period (CORBs) which have a global wide spread in the north of the Tethys Sea and are generally limited in northern Iraq.

4.3.2. Microfacies

Depending on the Dunham (1962) classification, three main microfacies were recognized in the limestone rocks of the Shiranish Formation in the studied sections. Each of them was subdivided into several sub-microfacies according to their significant fossils type (Figs. 9 and10):

- *Fossiliferous Lime Mudstone Microfacies (Sml)*

This facies includes less than 10% of grains embedded in micritic groundmass (Dunham, 1962). One submicrofacies was recognized in the carbonate rocks of the Shiranish Formation in the current study. This microfacies is observed in the upper part of the lower and middle units of the Diana and Garuta sections. It mainly involves very little skeletal grains with a percentage not exceeding (10%) embedded in a dark micrite groundmass (Fig. 8a). It also contains some calcispheres and bioclasts. This facies was subjected to diagenetic processes such as compaction, cementation and dissolution in addition to authigenic mineral such as pyrite and glauconite. This facies is equivalent to the standard microfacies (SMF3) of (Flügel, 1982) and deposited within the facies zone (FZ-3) of (Wilson, 1975) which represent an open deep shelf environment.

- *Lime Wackestone Microfacies (Sw)*

This microfacies is the most dominant facies in the Shiranish Formation in both studied sections. It characterized by containing grains range between 10-50 % in micritic groundmass (Dunham, 1962). It

mainly subdivided into five submicrofacies depending on the predominant grain type, which are as follow:

1. *Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw1)*

The common grains of this submicrofacies are planktonic foraminifera represented by the genera (*Hedbergella, Heterohelix Globotuncana,* and *Globigerinelloides*) (Fig. 8b), with few faunas of calcispheres and bioclasts. It common in the upper and lower units of the Shiranish Formation in two studied sections. It was affected by silicification, dolomitization and cementation, pyrite and glauconite authigenesis. This submicrofacies matches the (SMF3) of (Flügel, 1982) and (FZ2) of (Wilson, 1975) and deposited in an open deep shelf setting.

2. *Keeled Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw2)*

This facies was observed in the upper part of lower and middle units of both studied sections of the Shiranish Formation. It formed from skeletal grains about (15-25%) in the dark micritic groundmass and mainly consist of keeled planktonic foraminifera *(Globotruncanita, Globotruncana)* (Fig. 8c), with rare benthonic foraminifera due to containing organic and clay materials. The main diagenetic processes affected on this submicrofacies are granular cement, physical compaction, dissolution, fracturing and pyritization. It corresponds to SMF 3 of Flügel (1982) and FZ 2 of Wilson (1975) that was deposited in the upper bathyal environment (Al- Mutwali *et al.*, 2008).

3. *Calcispheres Lime Wackestone Submicrofacies (Sw3)*

This facies existed in different parts of both the studied sections, it is comprised of calcareous spherical grains (calcispheres) reaching about 65% among the skeletal grains (Fig. 8d) In addition to less numbers of benthonic foraminifera and bioclast within micrite groundmass. This facies are affected by several diagenetic processes, most notably are compression and cementation, as well as authigenic minerals include pyrite and glauconite. It is equivalent to SMF 3 of Flügel (1982) within FZ 3 of Wilson (1975) and was deposited in the outer shelf environment (Al- Haj, 2011).

4. *Bioclastic Lime Wackestone Submicrofacies (Sw4)*

This facies was recognized in the upper and lower units of the Shiranish Formation in Garuta and Diana sections. Its grains consist mainly of bioclasts (Fig. 8E), forming about (60%) of the total grains. The bioclasts are fragments of planktonic and benthic foraminifera, ostracods and echinoderms. The other grains are comprised of planktonic foraminifera (*Globigerinilloides* and *Heterohelix*), calcispheres and rare benthic foraminifera. It was subjected to several diagenetic processes involving fracturing, cementation and calcite veins in addition to compaction, cementation, dissolution and authigenic minerals such as pyrite (Fig. 8e). This facies correspond to the standard microfacies (SMF-9) of Flügel, 1982; and facies zone (FZ-2), (Wilson, 1975), which was deposited in the Outer Shelf environment. A distinguish (Al-Nasiri, 2003) has a microfauna similar to this one within the same environmental range.

5. *Benthonic Foraminiferal Lime Wackestone Submicrofacies (Sw5)*

This submicrofacies is found in the lower unit of the Shiranish Formation in both studied sections. The main grains of this facies are benthic foraminifera *(Lenticulina)* in addition to the presence of few planktonic foraminifera and echinoderms fragments. It was affected by recrystallization, dolomitization, silicification and dissolution diagenetic processes (Fig. 8 f). It matches to SMF 9 of Flügel (1982) and FZ 2 of Wilson (1975) which represents the outer shelf environment (Al-Jubouri et al., 2015).

- *Packstone Lime Microfacies (Sp)*

This microfacies was observed in the upper part of the upper unit of the Shiranish limestones in both Garuta and Diana sections. It is characterized by containing grains ranges between 50-90% in micritic groundmass (Dunham, 1962). This facies is subdivided into two submicrofacies:

1. Keeld Planktonic Foraminiferal lime Packstone Submicrofacies (Sp1)

The grains are mainly planktonic foraminifera reaches about (80%) of its total grains. The identified planktonic foraminifera include keeled genera e.g. *Globotruncanite* and *Globotruncana* (Fig. 8h) In comparison by genera *Hedbergella, Globigerinelloides* and *Heterohelix*. The other skeletal grains include less number of benthic foraminifera, calcispheres, and ostracods. The most predominant diagenetic processes affected on this submicrofacies are compaction of both types mechanical and chemical, as well as granular cement and dissolution which form vuggy porosity. Authigenic minerals (pyrite and glauconite) also present which mainly filled the pores and molds of the skeletal grains (Fig. 8g). This submicrofacies are observed in the upper unit of both studied sections. It is equivalent to SMF 2 of Flügel (1982), and FZ 3 of Wilson (1975) that was deposited in the upper bathyal setting.

2. Planktonic Foraminiferal Globular Chamber Packstone Submicrofacies (Sp2)

This submicrofacies was recognized in the upper unit of the Shiranish Formation in Garuta section. The proportion of their grains reaches to 85% and mainly is composed of planktonic foraminifera with globular chambers represented by genera *Hedbergella, Hetrohelix* and *Globogerinelloids* (Fig. 8i), with rare benthic foraminifera. The main diagenetic processes affected this facies are compaction, cementation, dolomitization and micritization. This facies is equivalent to SMF 3 and FZ 3 of Flügel (1982) and Wilson (1975) respectively and was deposited in the upper Bathyal environment (Al- Mutwali et al., 2008).

5. Discussion

5.1. Depositional Environment

The field description and facies analysis of the Shiranish Formation in Garuta and Diana sections showed that it was deposited in the pelagic (deep basin) environment (Figs 9 and 10). The recognized microfacies of the formation are mainly lime mudstone, wackestone and packstone and all predominant by micrite groundmass. They indicate a calm sea bottom suitable for accumulating lime mud (micrite), (Balaky et al., 2016). According to Wilson (1975) and Flügel (1982), these microfacies are equivalent to standard microfacies (SMF2, SMF3 and SMF9) within the facies zone (FZ-2 and FZ-3) which were deposited in an outer shelf and upper-bathyal environments (Koutosoukos, 1985) (Table, 1). The common bluish grey marly limestone and limestone with marl of the Shiranish Formation indicate outer shelf setting (Lawa, 2018).

Petrographically, the lower and upper units within the two studied section are dominant by planktonic foraminifera *Globigerinelloides, Heterohelix, Hedbergella* in association with rare benthonic foraminifera that indicate deposition in deep marine environment (Scholle, 1983). Echinoderms are common in normal marine, open-shelf deposits (Abid et al., 2022). Keeled planktonic foraminifera include *Globotruncanita and Globotruncana* genera which are more dominant in middle unit of both studied sections represent pelagic cold water deeper than 100m (Leckie, 1987). Calcispheres which are associated planktonic foraminifera in the studied sections and have unknown systematic affinity, are considered traces or remnants of planktonic organisms (Bein, 1977) and can be found in deposits of both shallow and deep water (Masters and Scott, 1978), but in the present study, the deep shelf origin of it is more acceptable due to their occurrence with pelagic fossils.

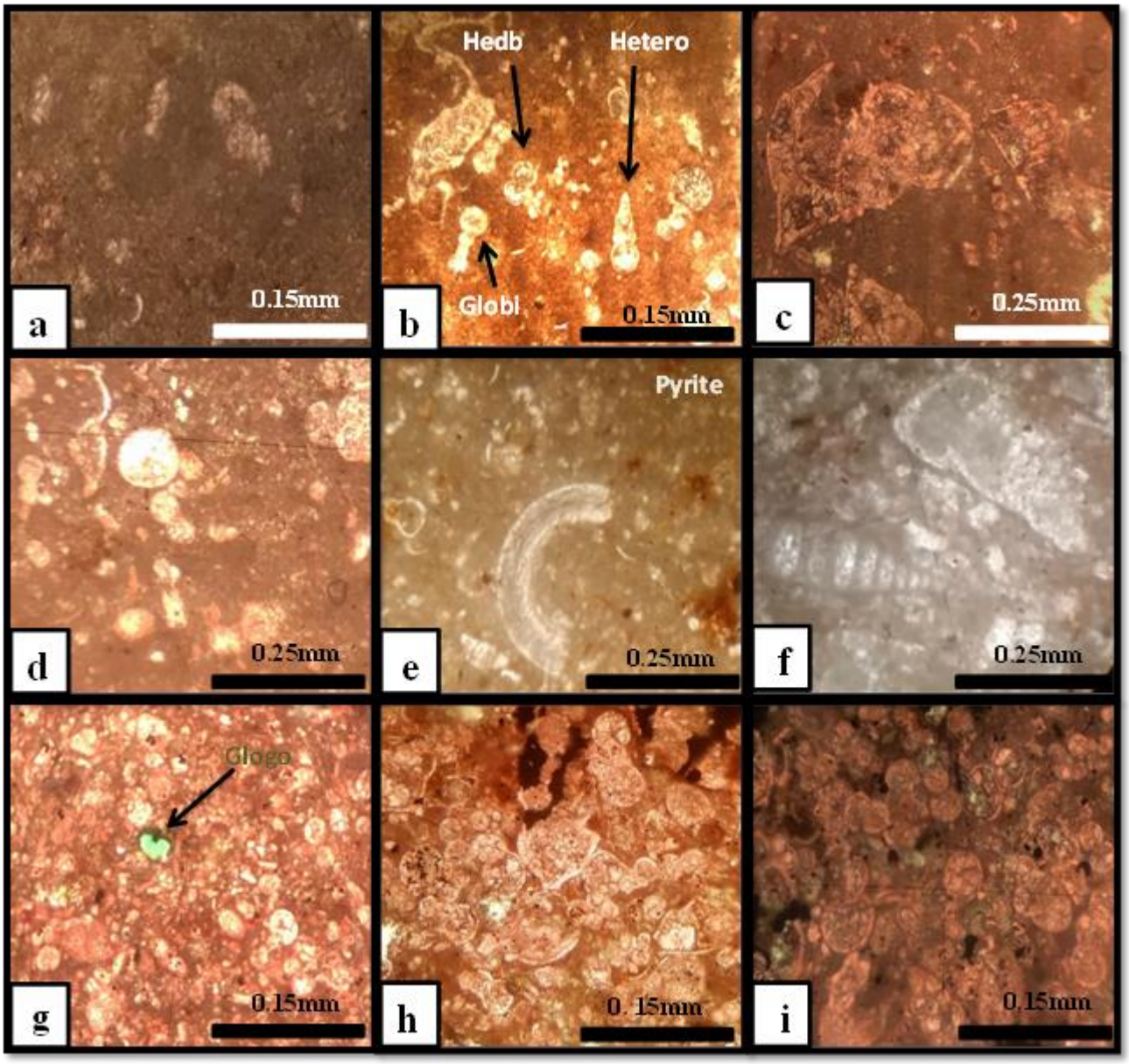


Fig. 8. Photomicrographs of Shiranish Formation: (a) submicrofacies lime mudstone bearing planktonic foraminifera in the lower unit of Diana sample 26. (b) Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw1), upper unit of Diana sample 39. (c) Keeled Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw2), middle unit of Diana sample 29. (d) Lime Wackestone Submicrofacies bearing calcispheres (Sw3), upper unit of Diana sample 33. (e) Bioclastic Lime Wackestone Submicrofacies (Sw4), upper unit of Garuta sample 40. (f) Benthonic Foraminiferal Lime Wackestone Submicrofacies (Sw5) lower unit of Garuta sample 9. (g) glauconite mineral. middle unit, Karuta section, lower unit of Diana sample 11. (h) Keeled Planktonic Foraminiferal lime Packstone Submicrofacies (Sp1), upper unit of Diana sample 44. (i) Planktonic Foraminiferal Globular Chamber Packstone Submicrofacies (Sp2), upper unit of Garuta sample 47.

The red beds of marly limestone which called Cretaceous Oceanic Red Beds and occur in the most upper part of the Shiranish Formation in Garuta section supposed to be deposited in the open marine ocean with oxic condition (Ahmed, 2017).

5.2. The Sedimentary Model of the Shiranish Formation

The results of the facies and environmental analysis of the Shiranish Formation in the studied sections have shown a kind of homogeneity in the distribution of facies between two sections with the present of slightly difference in some facies and this caused by different in paleo-oceanographic location of the studied section within the sedimentary basin. In general, the lower unit of the Shiranish Formation was deposited in outer shelf setting (100-200 m depth), upward deepening occurs in the middle unit where it was deposited in upper bathyal settings (200-600 m depth). In turn, the outer shelf deposition repeated in the lower part of the upper unit of the Shiranish Formation that grades into upper bathyal upward too. It is concluded that the deposition of the Shiranish Formation shows fluctuations in sea level mainly are progradational and may related to tectonic activities during Campanian- Maastrichtian (Buday and Jassim, 2006).

Table.1. Microfacies and facies zone of Shiranish Formation in studied sections.

Microfacies of Shiranish Formation	SMF of Flügel (1982) and FZ of Wilson (1975)			Environment Zone of Koutosoukos (1985)
	SMF	FZ	Location of SMF	
Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw1)	(SMF8)	(FZ-2)	Open Sea Shelf	Outer-Shelf (100-200m depth)
Calcispheres Lime Wackestone Submicrofacies (Sw3)	(SMF3)	(FZ-3)	Open Sea Shelf	
Bioclastic Lime Wackestone Submicrofacies (Sw4)	(SMF9)	(FZ-2)	Open Sea Shelf	
Benthonic Foraminiferal Lime Wackestone Submicrofacies (Sw5)	(SMF9)	(FZ-2)	Open Sea Shelf	
Fossiliferous Lime Mudstone Submicrofacies (Sm)	(SMF3)	(FZ-3)	Deep Shelf Margin	Upper Bathyal (200-600m depth)
Keeled Planktonic Foraminiferal Lime Wackestone Submicrofacies Sw2))	(SMF3)	(FZ-2)	Deep Shelf Margin	
Keeld Planktonic Foraminiferal lime Packstone Submicrofacies (Sp1)	(SMF10)	(FZ-2)	Deep Shelf Margin	
Globular Chamber planktonic Foraminiferal Packstone Submicrofacies (Sp2)	(SMF3)	(FZ-3)	Deep Shelf Margin	

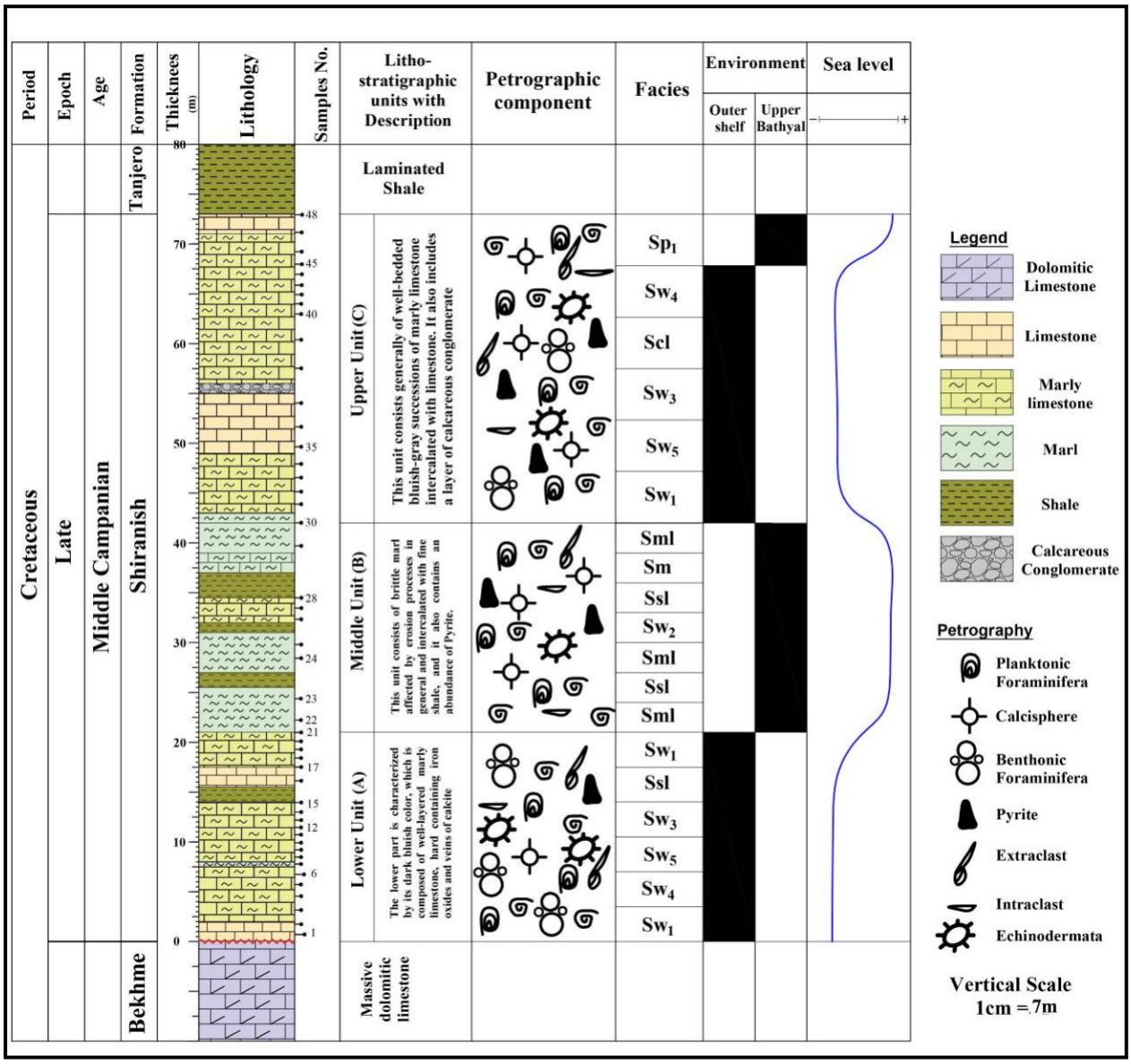


Fig.9. Columnar sections and depositional environments of the Shiranish Formation in Diana section.

Major transgression in passive margin foreland basins in Early Maastrichtian (Nichols, 1999) may play a role in deposition of the Shiranish succession. Numan (2001) and Znad et al. (2020) also referred that the foreland basins were separated into several sub-basins as a result of tectonic activities due to convergence of tectonic plates in the end of Cretaceous. These fluctuations in sea level are coincided with those mentioned by Gradstein et al. (2020). Based on all facies and palaeoecological proxies, a sedimentary model is proposed (Fig.11)

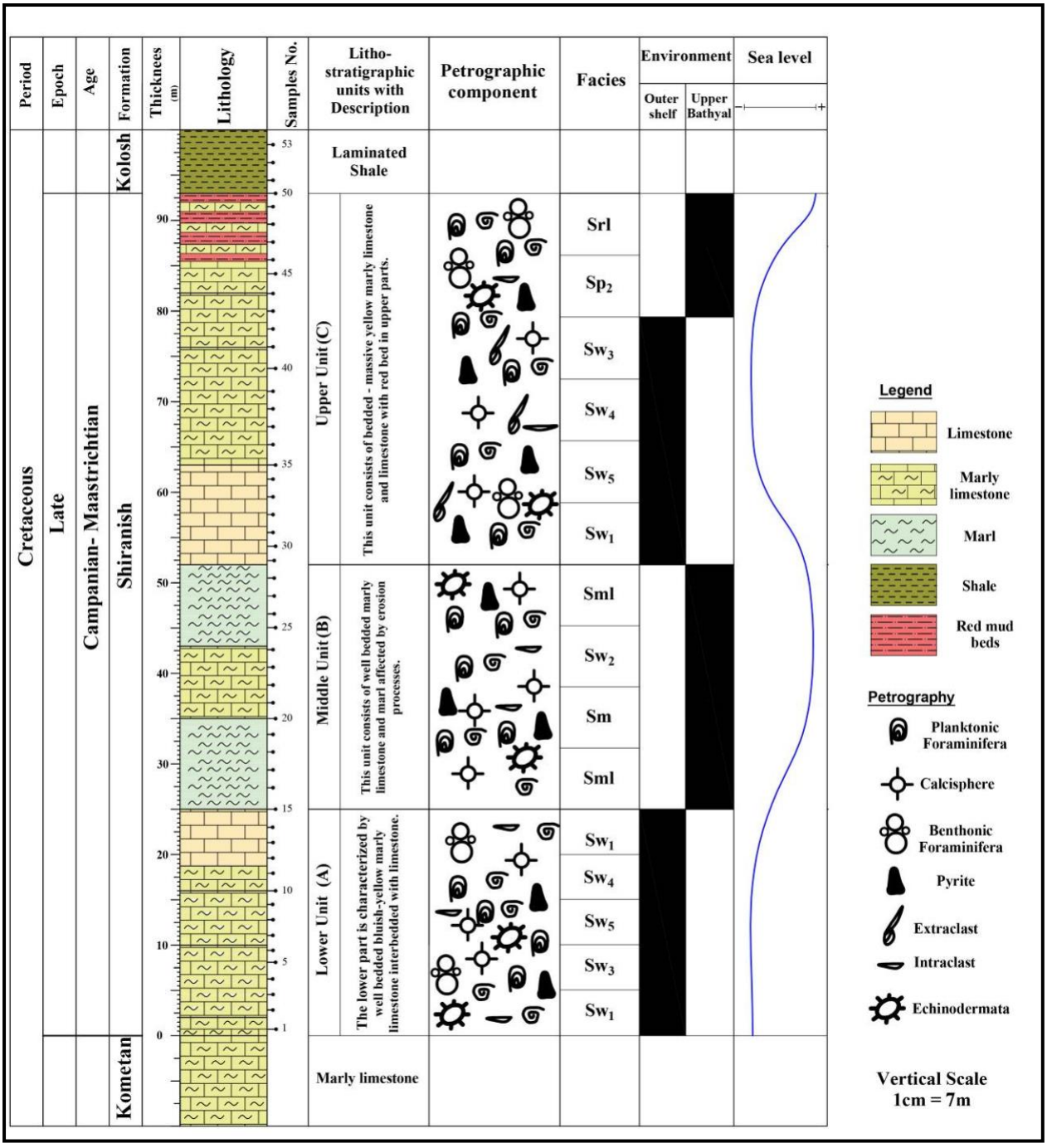


Fig.10. Columnar sections and depositional environments of the Shiranish Formation in Garuta section

6. Conclusions

The succession of the Shiranish Formation consists of marly limestone, marl and shale. The formation was divided into three lithostratigraphic units in both studied sections, the lower unit consists of marly limestone and semi-massive limestone, the middle unit consists of marl, marly limestone and shale, whereas, the upper unit is composed of bedded to semi-massive marly limestone. The lower contact of the formation is unconformable with the Bekhme Formation in the Diana section

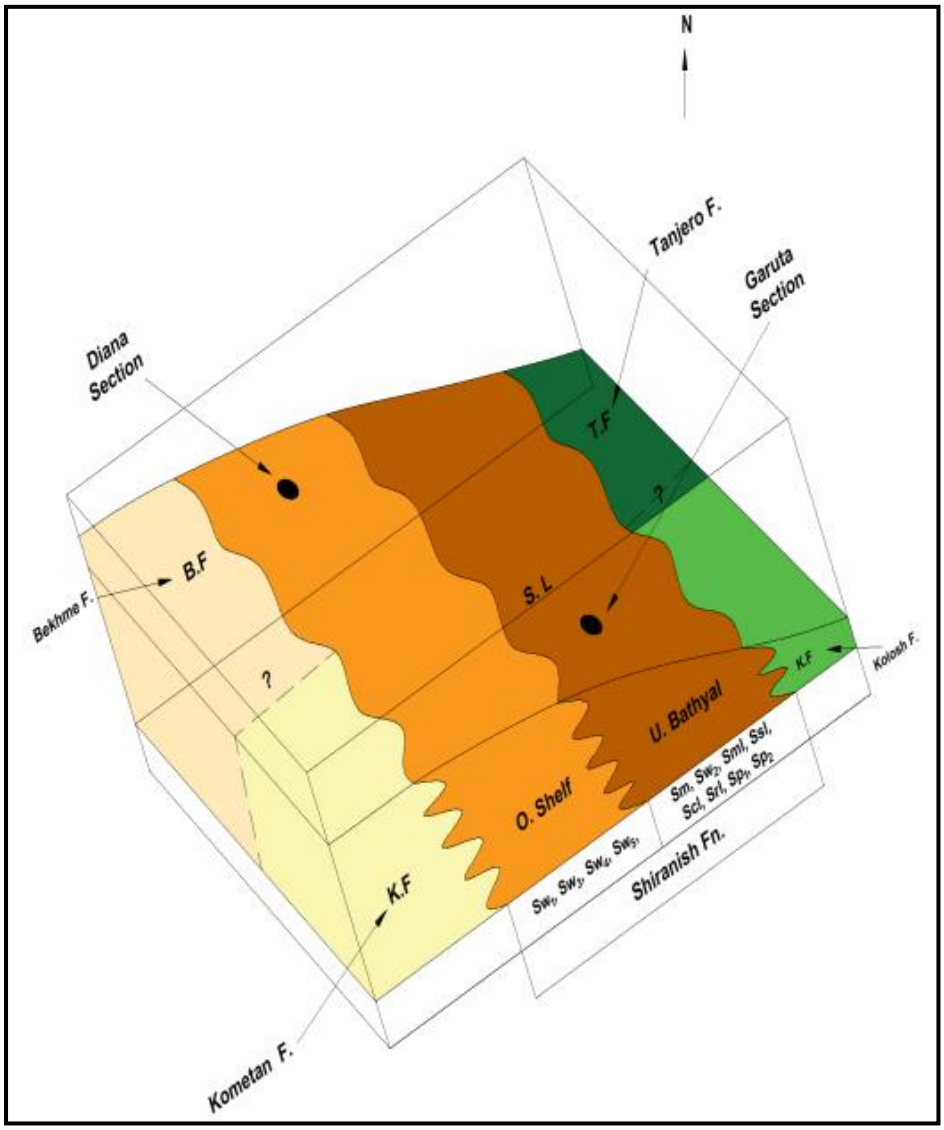


Fig.11. Sedimentary Model for of the Shiranish Formation

and conformable with the Kometan Formation in Garuta section, while the upper contact is conformable with both Tanjero and Kolosh formations in Diana and Garuta sections respectively.

X-ray diffraction study has revealed that the formation is composed mainly of calcite with less of quartz in addition to clay minerals that are represented by chlorite and illite. This may reflect the difference in paleoclimatic and paleoenvironmental conditions during deposition and the source of rocks from which these clay minerals were derived.

Four lithofacies: marl facies (Sml), shale facies (Ssl), conglomeratic limestone facies (Scl)) and red clay beds (Srl), in addition to three main microfacies (lime mudstone, wackestone and packstone) are recognized in the carbonate rocks of Shiranish Formation and later subdivided into seven submicrofacies, according to their significant grain components,

Comparing to Wilson (1975) and Flügel (1982, 2004), it was found that the Planktonic Foraminiferal Lime Wackestone Submicrofacies (Sw1), Calcispheres Lime Wackestone Submicrofacies (Sw3), Bioclastic Lime Wackestone Submicrofacies (Sw4) and Benthonic Foraminiferal Lime Wackestone Submicrofacies (Sw5) represent the outer shelf environment, while the Fossiliferous Lime Mudstone Microfacies (Sm), Keeled Planktonic Foraminiferal Lime Wackestone Submicrofacies Sw2), Keeld Planktonic Foraminiferal lime Packstone Submicrofacies (Sp1) and

Globular Chamber planktonic Foraminiferal Lime Packstone Submicrofacies (Sp2) were deposited in the upper bathyal environment.

The lateral facies variation between the two sections showed the presence of homogeneity between the facies and the sedimentary environments of the studied succession, while the vertical sequence revealed presence of fluctuations in the facies and the sedimentary environment. This variation may indicate fluctuations in sea level during the period of deposition of the Shiranish in the study area. This is characterized by presence of secondary basins and marine transgression compatible with the global oscillations during the Campanian - Maastrichtian period.

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References

Aba Hussein, A. A., 1983. Petrography and Geochemical study for selected sections of the formation of Shiranish in northern Iraq, M.Sc. Thesis, Baghdad University, Faculty of Science. 177.

Abid, A. A., Asaad, I. S., and Pasha, S. M., 2022. Foraminiferal assemblage, microfacies analysis, and depositional environment of Tanjero Formation (Late Cretaceous) in Hujran section, Northeast Erbil City, Kurdistan Region, Iraq. Arabian Journal of Geosciences, 15(3), 1-14.

Ahmed, M. J. and Tamar-Agha M.Y. and Alwan, Th. A., 2017. The Sedimentology and facies analysis of the Cretaceous oceanic red beds (CORBs) in the Shiranish Formation, Northern Iraq. Iraqi Journal of Science, 58 (3A),1220-1234.

Ahmed, W. M., 1980. Study and Comparison of the Sediments of the Upper Cretaceous Formation in Ain Zala Field-Northern Iraq, Unpublished Master's Thesis, University of Baghdad, College of Science, 87.

Al-Banna, N. Y., 2010. Sequence stratigraphy of Late Campanian – Early Maastrichtian Shiranish Formation, Jebel Sinjar, North western Iraq. GeoArabia, 15, (31-44).

Al-Haj, M.A. M., 2011. A study of the evolution of the sedimentary basin of the Cretaceous successions (Senomanian - Early Campanian) in northwestern Iraq, unpublished doctoral thesis, University of Mosul, College of Science, 246

Al-Hazaa, S. H., Jaff, R. B. N., Lawa, F. A. A., Mahanipour, A., and Al-Kahtany, K., 2021. Microfacies analysis, planktonic foraminifera, and calcareous nannofossil biostratigraphy in the Campanian sequences, Kurdistan region, NE Iraq. Arabian Journal of Geosciences, 14(2), 1-15.

Al-Jubouri, F. N. H., 2011.The biostratigraphy of the planktonic foraminifera, the sedimentary environment and the stratigraphy of the sequences upper Cretaceous-Middle Eocene selected wells from the Khabbaz oilfield, northeastern Iraq. Unpublished Ph.D. Thesis, University of Mosul, Iraq, 211.

Al-Jubouri, W.A, Al-Jubouri, F.N., AL-Taraf, A.M., 2016. Microfacies and the sedimentary environment of Sharanish formation within the Ain Zalah and Batma fields in northwestern Iraq, Kirkuk University Journal-Scientific Studies,11 (2), 438-463.

Al-Mutwali, M. M., Al-Banna, N. Y., and Al-Ghrear, J. S., 2008. Microfacies and sequence stratigraphy of the Late Campanian Bekhme Formation in the Dohuk area, north Iraq. GeoArabia, 13(1), 39-54.

Al-Nasiri, O.A., 2003. Stratification of the sequence of the cycle of the Upper Campanian - Maastrichtian in selected wells from the fields of Safia, Ain Zala, Batma, and Mount Qand Northwestern Iraq, an unpublished master's thesis, University of Mosul, College of Science, 88.

Awdal, A.H., Braathen,A., Wennberg, O.P., Sherwani, G.H., 2013. The characteristics of fracture networks in the Shiranish Formation of the Bina Bawi Anticline; comparison with the Taq Taq Field, Zagros, Kurdistan, NE Iraq. Petroleum Geoscience ,19 (2), 139–155.

Baban, D. H., Qadir, F. M., and Mohammed, A. R., 2020. Reservoir rock properties of the Upper Cretaceous Shiranish Formation in Taq Taq Oilfield, Iraqi Kurdistan Region. Journal of Zankoy Slemani, 22(1), 363-388.

Balaky, S.M., Asaad, I.S., Al-Juboury, A.I., 2016. Facies analysis and sequence stratigraphy of Kometan Formation (Upper Cretaceous) in the imbricated zone, northeastern Iraq. Arab Journal of Geosciences 9(20),1–17.

Bein, A., 1977. Shelf basin sedimentation: Mixing and diagenesis of pelagic and clastic Turonian carbonates, Israel. Journals of Sedimentary Petrology, 47(1), 382-391.

Bellen, van. R. C., Dunnington, H.V., Wetzel, R. and Morton, D. M.,1959. Lexique Stratigraphique International Asia, Fascicule,10a, Iraq, Central National deal Recherches Scientifique, Paris, 333.

Buday, T., 1980.The Regional Geology of Iraq: Tectonism, Magmatism and Metamorphism (Vol. 2). State Organization for Minerals, Directorate General for Geological Survey and Mineral Investigations.

Chamley, H., 1989. Clay Sedimentology. Springer-Verlag, Berlin, 623.

Dunham, R., J.,1962. Classification of carbonate rocks according to depositional textures. In Ham, W.E. (Eds) Classification of Carbonate Rocks, A symposium. AAPG. Bull. Publisher, Memoir 1. Tulsa.

Flügel, E., 1982. Microfacies of Limestone, Christenson, K. Springer-Verlag, Berlin: 633.

Fouad, S. F., 2015. Tectonic map of Iraq, scale 1: 1000 000, 2012. Iraqi Bulletin of Geology and Mining, 11(1), 1-7

Friedman, G.M.,1959. Identification of carbonate minerals by staining methods, Journal of Sedimentary and Petrography, 29 (2), 87-97

Gale, A. S., Mutterlose, J., Batenburg, S., Gradstein, F. M., Agterberg, F. P., Ogg, J. G., and Petrizzo, M. R., 2020. The cretaceous period. In Geologic time scale 2020, 1023-1086.

Hassan, Y. H. 2021. Biostratigraphy of Foraminiferal and Depositional Environment of Shiranish Formation in Sara Anticline in Dokan Area / Sulaymani, Northeastern Iraq. Unpublished M. Sc. Thesis. University of Mosul, Iraq.118.

Henson, F. R. S. 1940. Shiranish Formation (Cretaceous). Unpub. Report. In Bellen, R. C. van; Dunnington, H. V.; Watzel., and Morton, D. M.,1959. Lexique Stratigraique International, Asie.V.3, Fasc, 10a, Iraq, Paris 333.

Hower, J., Hurley, P.M., Pinson, W.H., Fairbairn, H.W.,1963. The dependence of k-Ar on the mineralogy of various particle size ranges in a shale. Geochim. et Cosmochim. Acta. 27, 405-410.

Jassim, S. Z., Buday, T., 2006. Late Turonian – Danian Megasequence Ap9. In: Jassim, S. Z. & Goff, J. C. (Eds.) Geology of Iraq, Published by Doline, Prague and Moravian Museum, Brno, 141– 154.

Kamil, A. I., Al-Dulaimi, S. I., Karim, K. H., 2021. Ammonites and Foraminifera of Shiranish Formation (Late Campanian-Maastrichtian) from Sulaimaniya and Erbil Governorates, Northern Iraq. Iraqi Journal of Science, 62 (12), 4712-4746.

Koutsoukos, E. A. M., 1985. Distribuiçao paleobatimetrica de foraminiferos bentonicos do Cenozoico: Margen continental atlantica. Brazil, Combase. Congresso Brasileiro de Geology, 2, 685-696.

Lawa, F. A., 2018. Late Campanian–Maastrichtian sequence stratigraphy from Kurdistan foreland basin, NE/Iraq. Journal of Petroleum Exploration and Production Technology, 8(30), 713-732.

Leckie, R. M.,1987. Paleoecology of Mid- Cretaceous planktic foraminifera: A comparison of open ocean and epicontinental sea assemblages. Micropaleontology,33 (2),164-176.

Masters, B.A. Scott, R.W., 1978. Microstructure affinities and systematics of Cretaceous calcispheres. Micropaleontology, 24 (2), 210-221.

Millot, G., 1970. Geology of Clays. Chapman and Hall, London, 429.

Nichols, G., 1999. Sedimentology and Stratigraphy Blackwell Publishing, 355.

Numan, N. M. S., 2001. Cretaceous and Tertiary Alpian Subduction History in northern Iraq, Iraqi Journal of Earth Sciences. 1, 59-74.

Rabeea, Kh. Znad, Saddam, E. Al-Khatony and Mahmood, A. H. Al-Sumaidaie., 2020. Effect of Tectonic setting on distribution of pelagic sediment unit (Shiranish Formation) In Zagros Foreland Basin, Iraqi Segment. Iraqi Geological Journal,53(2A), 105-119.

Scholle, P. A., Bebou, D. G., Moor, C. H., 1983. Carbonate Deposition Environments, A.A.P.G. Mem-33, Tulsa, Okla. 708.

Sharland, P. R., Archer, R., Casey, D.M., Davies, R.B., Hall, S.H., Heward, A.P., Horbury, A.D., Simmons, M.D., 2001. Arabian Plate Sequence Stratigraphy, Geo Arabia, Special publication 2. Gulf Petro Link. Bahrain. 372.

Wilson, J. L., 1975. Carbonate facies in geologic history Springer-Verlag. New York, 471.