DOI: https://doi.org/ 10.5281/zenodo.23270183



Purposeful scientific research as a pillar of sustainable development



Microfacies Analysis and Depositional Environment of the Late Cretaceous Shiranish Formation in the Selected Section, Safin Anticline, Northern Iraq

Irfan Sh. Asaad[1], Bzhar A. Delizy[2], Afnan M. Al-Zoubadi[3], Nasr R. Salih[1], Mustafa M. Ibrahim[1]

[1]Department of Earth Sciences and Petroleum, College of Science, Salahaddin University-Erbil, Erbil, Erbil, Kurdistan Region, Iraq

[2] Department of Petroleum Geosciences, Soran University, Erbil, Kurdistan Region, Iraq

[3]University of Diyala, College of Science, Department of Petroleum and Minerals Geology, Baqubah, Iraq

ABSTRACT

This study concerns microfacies and environmental environment of the Late Cretaceous Shiranish Formation in the Sulawki Saru section, Safin anticline, northern Kurdistan region, Iraq. Shiranish is lithologically composed of 81 m of thin to medium and fractured bedded grey to white limestone in the lower part and grey to blue bedded marly limestone characterised by joints in the upper part. Its lower boundary is conformable with massive dolomitic limestone of the Bekhme Formation, while upper boundary is not clear and covered by sedimentary material. The petrographic investigations of limestone with a microfacies analysis of carbonate rocks were based on (31) thin sections. The petrographic study revealed that the majority of matrix are micrite with occasional recrystallized microspar. The skeletal grains exhibit a diverse range of pelagic marine fauna, including planktonic foraminifera (*Rugoglobigerina*, *Heterohelix*, *Globotruncana*, *Globotruncanita*, *Hedbergella*, and *Oligostegina*), benthonic foraminifera (*Lenticulina*, *Rotalia*, and *Bolivionoides*), calcispheres, ostracods, echinoids, and bioclasts. Based on field investigations and petrographic examinations, two different lithological units were identified in the Shiranish Formation at the Sulawki Saru Section. They are arranged from older to younger: a-Fractured bedded limestone unit. b-Bedded marly limestone unit. Based on systematic microfacies study of limestones, two major microfacies and 9 submicrofacies are distinguished in the studied locality of the Shiranish Formation. Integrating all petrographic, facies, and textural evidences, it is concluded that the depositional environment of Shiranish Formation in the Sulawki Saru section was basinal environment (deep shelf) in lower part changed to outer shelf in the upper part with quiet, semi-reducing conditions.

Keywords: Cretaceous, Deep Shelf, Foraminifera, Shiranish, Sulawki Saru.

1. Introduction

DOI: https://doi.org/ 10.5281/zenodo.23270183

The Shiranish Formation, which is belong to the tectonostratigraphic AP 9 megasequences of Sharland et al. (2001), is regarded as the superior rock unit of the upper Cretaceous in northern Iraq. The formation which belongs to the upper Campanian-Maastrichtian, initially documented by Henson (1940 in Bellen et al., 1959) close to the Shiranish Islam village, northeast of Zakho town, in the High Folded Zone of the western Zagros Fold and Thrust belt. It is 228m thick consists of thin-bedded marly limestone in the lower part overlain by blue marl in the upper part, and occasionally dolomitized with dominance of microfossils (Buday, 1980). The formation geographically has widespread distribution inIraq and surrounded territories, cropping out within the High Folded Zone of Iraq and recognized in the northeastern part of Syria too (Buday, 1980; Litak et al., 1998). The thickness of the Shiranish Formation varies in the outcrops between 100 and 400 m, while the thickest subsurface section of the formation was recorded in Well Sasan-1, reaching 1500 m (Jassim and Goff, 2006).

However, several scholars have studied the Shiranish Formation since its first description by Bellen et al. (1959) from sedimentological, stratigraphical, and paleontological points of view, but no one covered the studied section previously. The most interested are El-Anbaawy and Sadek (1979), Abawi *et al*. (1982), Abdel-Kireem (1983 and 1986), Al-Qayim *et al*. (1986), Al-Shaibani *et al*. (1993) Kennedey and Lunn (2000), Jassim and Goff (2006), Sharbazhery (2008), Aqrawi et al., (2010), Al-Hadiedi (2010), Al-Badrani and Al-Asaaf (2010), Salih *et al*. (2012), Jaff (2015), Alzaidy (2017) and Al-Dulaimi *et al.* (2023). The facies variations from the southeast to northwest segments of the Safin anticline, together with the previously unstudied Sulawki Saru section, make this area of particular interest for the present study. The main objective of the current study is determining the depositional setting of the Shiranish Formation in the studied section, deduced from field description and microfacies analysis.

2. Geologic Setting

The Upper Campanian-Maastrichtian Cycle plays a significant role in Iraq's geological history. It was characterized by exhaustive tectonic activity, subsidence and folding in the foreland basin and quasiplatform of the Arabian passive margin (Numan, 2001). The cycle begins with an extensive transgression that nearly covered most of the country, occurring after the disruption resulted from Middle Cretaceous orogenies.Another uplift and regression are the characteristics of the ending of the cycle, which is originated from the paroxysmal phases of the orogeny near the Cretaceous-Tertiaryboundary called the Laramide orogeny (Buday, 1980). During the late Campanain-early Mastrichtian time, the ophiolites of Neo-Tethys were more thrusted over the Arabian Plate, raised above sea level, suddenly eroded and deposited again as flysch sediment (thickness up to 2000 m) stretching from southeastern Turkey to northeastern Iraq and southwestern Iran to Oman, in a narrow foredeep basin that runs along the northern and eastern margin of the Arabian Plate. Extensional basins characterized by strong subsidence over the Late Campanian-Maastrichtian period (Jassim and Goff, 2006). Karim and Taha (2010) divided the Upper Cretaceous tectonic history of the Arabian platform in the Iraqi Kurdistan region into four tectonic phases: Pre-drowning, syn-drowning, post-drowning and burial phases, which considered the Shiranish and Tanjero formations, belong to the latter phase, developed from the Arabian Platform's siliciclastic progradation, and are clastic influx related to the principal tectonic phase of the Zagros Fold–Thrust Belt, which developed as a result of the collision between the Arabian and Iranian continental plates.

The Sulawki Saru section is situated 45 km northeast of Erbil city, northeast of Sualawk Saru village, on the paved road of Safin Mountain (lat. 36° 18' 14" 14"N, long. 44° 25' 00" E) (Figure 1). In the high folded zone (Figure 1b), in the southern limb of the Safin anticline. Stratigraphic succussion of the southern limb of the Safin anticline in the studied area includes the Qamchqua, Bekhme, Shiranish, and Tanjero formations (Cretaceous) and the Kolosh Formation of Paleocene age.

DOI: https://doi.org/ 10.5281/zenodo.23270183

3. Methods and Materials

Comprehensive field work was conducted in the area around the section. It involves the study of main geology and structural conditions of the Cretaceous-Tertiary succession in around of the studied loclity. Moreover, the description and measuring of the outcrop in the study section in detail, recording lithology, mineralogy and grain size.

A total of 31 samples were obtained from the carbonates of the Shiranish Formation in addition to several samples from the underlying Bekhme Formation. This was in order to determine the position of the lower boundary in the studied outcrop. The upper boundary is obscured in the studied area. Generally, samples were collected where changes in lithology and/or color occurred, following a random sampling approach. All samples are chosen perpendicular to the bedding plane. Both upper and lower surfaces of each sample are also marked. In addition to performing a macroscopic study of samples by a hand lens and dilute HCl acid.

The total of 31 thin sections were produced in the workshop of the department of Earth Sciences and Petroleum, College of Science, University of Salahaddin. The prepared thin sections were orientated and impregnated with the Alizarin Red S Solution (ARS) according to the Friedman (1959) procedure for discriminating between calcite and dolomite. An extensive petrographic study and microfacies analysis were conducted on the thin sections. The petrographic investigation was based on the Dunham (1962) classification and was carried out using a polarizing microscope to identify the constituents.

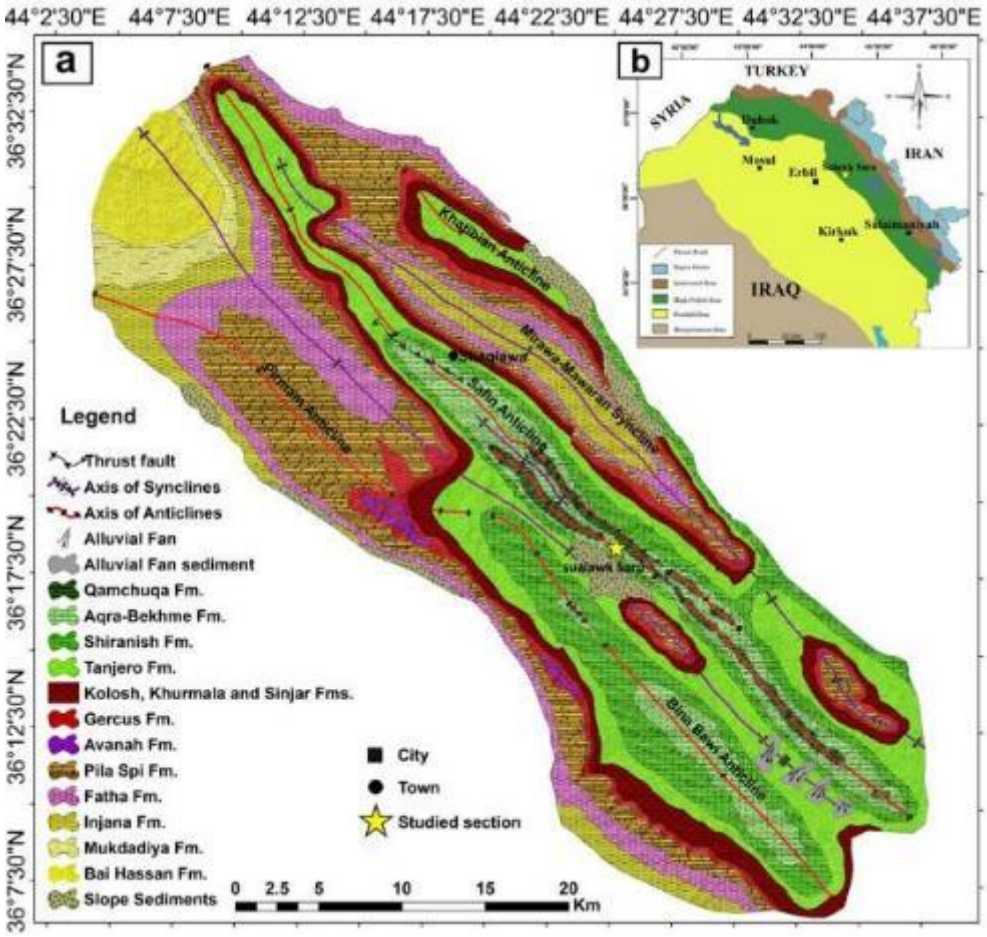


Fig. 1. a) Location of the Sulawki Saru section with tectonic zones of Iraq (after Jassim and Goff, 2006). b) Geological map of the Safin and Permam anticlines (after Sissakian and Fouad, 2014).

4. Results and Discussion

DOI: https://doi.org/ 10.5281/zenodo.23270183

4.1. Lithostratigraphy

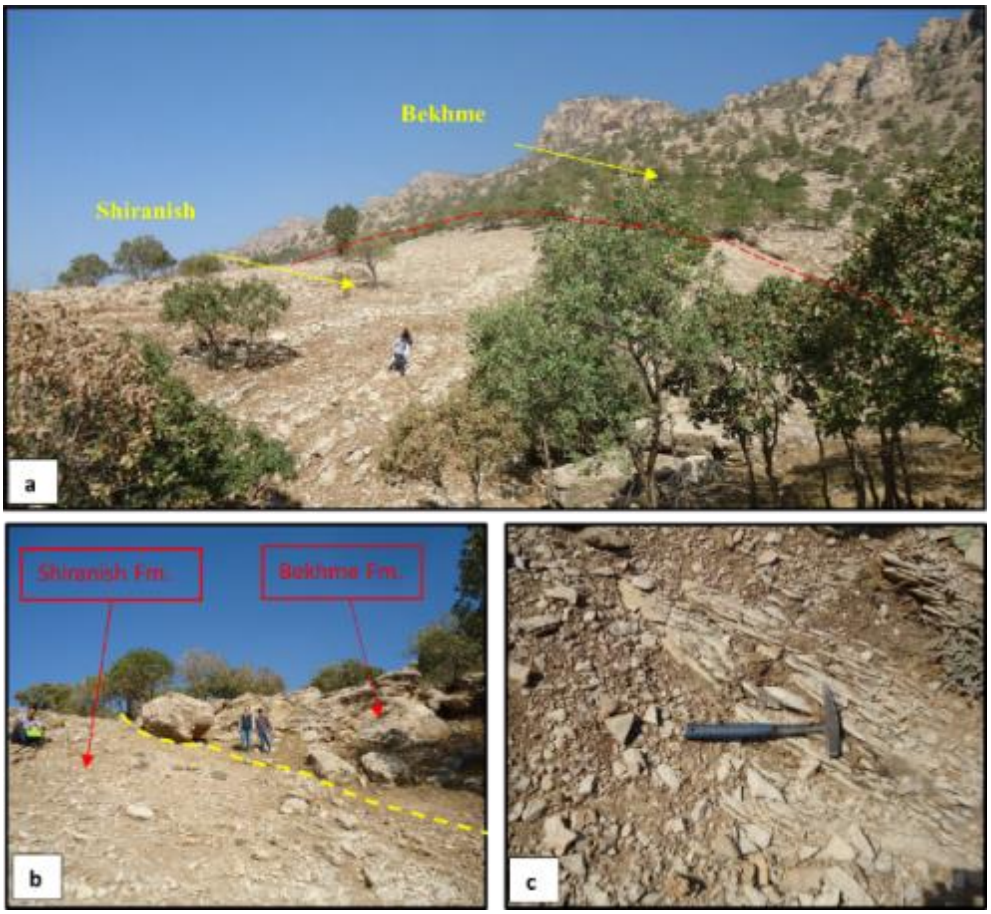
The overall thickness of the Shiranish Formation in the Sulawki Saru section is about 81 m (Figure 2a). The lower contact of the Shiranish Formation is conformable with the reefal grey dolomitic limestone of the Bekhme Formation (Figure 2b). While, the upper contact is covered by sedimentary materials and further away is overlain by the Tanjero Formation with conformable contact. Based on both detailed field descriptions, two lithologic units can be distinguished in the Shiranish Formation, as described below:

A-Fractured bedded limestone unit (Unit A)

This unit form the lower part of Shiranish Formation, overlying massive limestone of Bekhme Formation and underline bedded marly limestone unit. It is thickness 54 m consist of 11m of grey to white thin bedded (<10 cm) fractured limestone (Figure 2c). It overlain by 26 m composed of grey thin to medium fractured limestone (Figure 3a) and followed by 13 m of interbedding between medium bedded grey limestone with thin bedded fractured limestone. The last 4 m of this unit consist of 4m of fractured medium bedded limestone. The significant sedimentary structures within it are: thin horizontal laminations, groove marks (Figure 3b) and bioturbation (Fig.3c) observed in this unit. The calcite filled fractures also present in this unit (Figure 3d).

B- Bedded marly limestone unit (Unit B)

It overlies fractured bedded limestone unit and its upper part covered by sedimentary materials. The thickness of the unit is 27m composed of 13m of medium bedded light bluemarly limestone (Figure 3e) overlain by 14m of thin to mediumbedded light blue marly fractured limestone (Figure 3f). This unit is characterized by joints within their beds (Figure 3e).



DOI: https://doi.org/ 10.5281/zenodo.23270183

Fig. 2. Field photographs of Shiranish Formation in Sulawki Saru section showing: a) Shiranish Formation with underlying Bekhme Formation. b) Fractured bedded limestone unit overlaying massive limestone of Bekhme Formation. c) Thin bedded fractured limestone.



Fig. 3. Field photographs of Shiranish Formation in Sulawki Saru section showing: a) Thin bedded limestone interbedded with medium bedded limestone. b) Groove marks on the medium bedded limestone. c) Bioturbation on the surface bed of limestone. d) fractured filled by calcite (red arrow). e) Marly limestone unit characterized by joints (red arrow). f) Marly limestone unit covered by sedimentary materials.

4.2. Petrography

DOI: https://doi.org/ 10.5281/zenodo.23270183

The Shiranish limestone contain skeletal grains which mainly open marine derivative and subjected to neomorphism and pyritization. The main skeletal grains are Planktonic Foraminifera: *Globotruncana* (Figure 4b), *Globotruncanita* (Figure 4c), *Heterohelix* (Figure 5a), *Rugoglobigerina* (Figure 4a), and *Hedbergella* (Fig.4a). In addition to Oligostegina forams. While, Benthonic Foraminifera: *Lenticulina (*Figures 4c and d), *Rotalia* (Figure 5b) *and Bolivinoides* (Figure 5d). Other fossils are ostracods (Figure 5c), calcispheres (Figures 4and 5), echinoids (Figures 5d and f) and bioclasts (Figure 4e). Authigenic Minerals within the studied rocks are mainly pyrite which involves both spherical pyrite (Figure 4f) and moldic filled pyrite (filled the different fossils) (Figure 5b). The majority of groundmass is micrite (Figure 4a) that changed to microspar in some intervals (Figure 5e).

4.3. Microfacies types

Microfacies analysis of the present study were carried out depending on the classification of Dunham (1962). Later, the identifying facies were correlated to the Standard Microfacies (SMF) of Wilson (1975) and Facies Zone (FZ) of Flugel (1982) to to evaluate the analogy between the two sets. Two major microfacies types are identified in Shiranish limestone. Each was later subcategorized into several sub-microfacies, based on main fossil types (Table 1) (Figure 6). The following are the main microfacies within the Shiranish Formation:

4.3.1 Lime wackestone microfacies.

Its common within lower portion of studied section. It generally consists of micritic matrix with grains ranging between 10-50% (Dunham, 1962). It was subjected to different diagenetic processes. Based on the dominant of their grains, the facies were subdivided into following subdivisions:

4.3. 1.1 Planktonic foraminifera -calcispheres lime wackestone submicrofacies (Figure 4a)

This submicrofacies is common in the lower part of the fractured bedded limestoneunit.The common grains of this facies are *Rugoglobigerina* and Calcispheres. It subjected to neomorphism and pyritization diagenetic processes.

DOI: https://doi.org/ 10.5281/zenodo.23270183

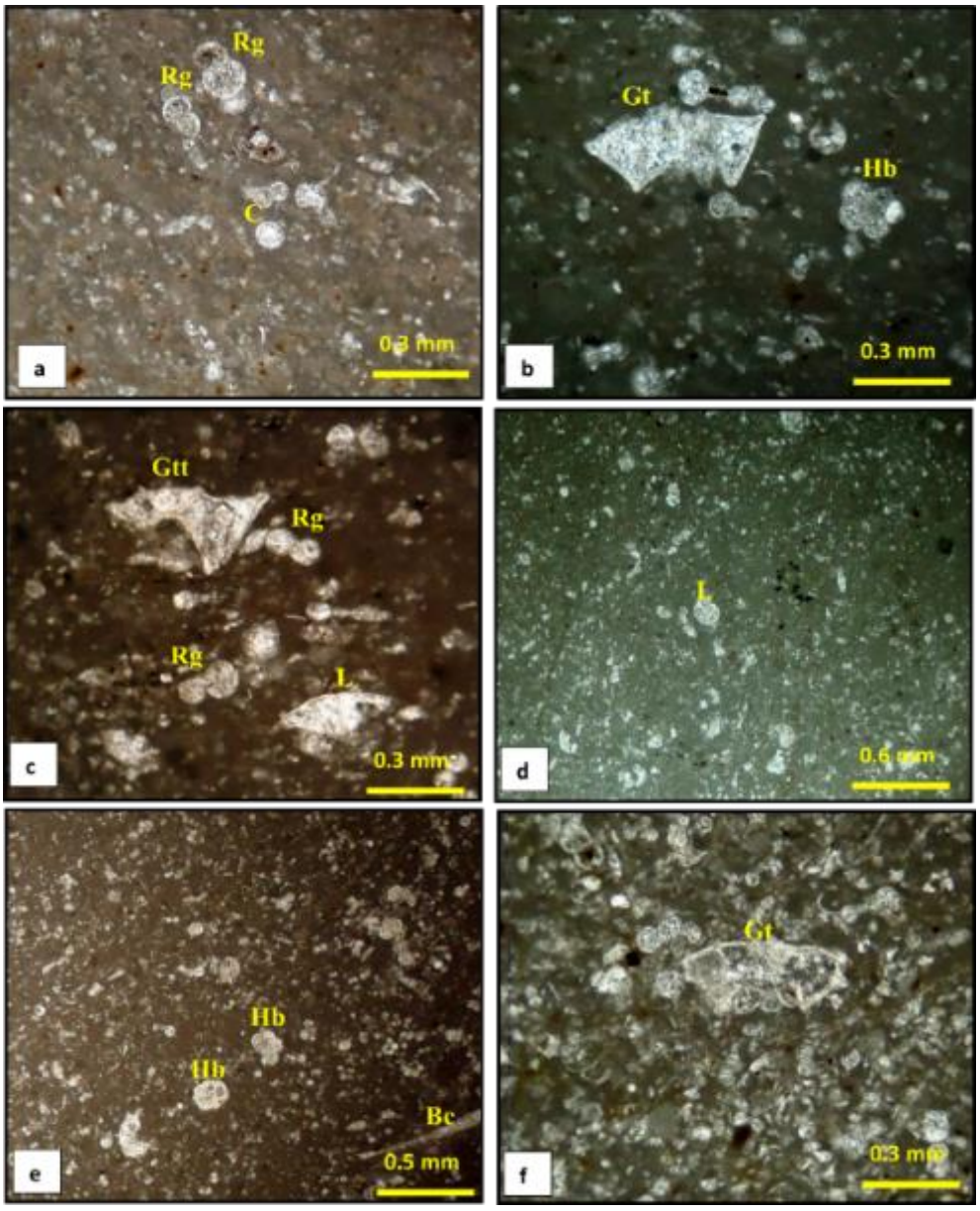


Fig. 4. Photomicrographs showing microfacies types of Shiranish Formation in Sulawki Saru section: a) Planktonic foraminifera (Rugoglobigerina (Rg) -Calcispheres (C) Lime wackestone submicrofacies. P.P., Sh.1. b) Planktonic foraminifera- lime wackestone submicrofacies including *Globotruncana* (Gt) and *Hedbergella* (Hb), P.P., Sh.2. c) Foraminiferal calcispheres Lime wackestone submicrofacies including *Globotruncanita* (Gtt), *Rugoglobigerina* (Rg) and *Lenticulina* (L). P.P., Sh.5. d) Foraminiferal calcispheres Lime wackestone submicrofacies including *Lenticulina* (L) surrounded by calcispheres. P.P., Sh.8. e) *Hedbergella* (Hb)- bioclastic (Bc) lime wackestone submicrofacies. P.P., Sh.10. f) Planktonic foraminifera-calcispheres lime packstone submicrofacies include Globoturuncana (Gt). P.P., Sh.13.
Key: Sh =Shiranish Formation, P.P.= plane-polarized light

DOI: https://doi.org/ 10.5281/zenodo.23270183

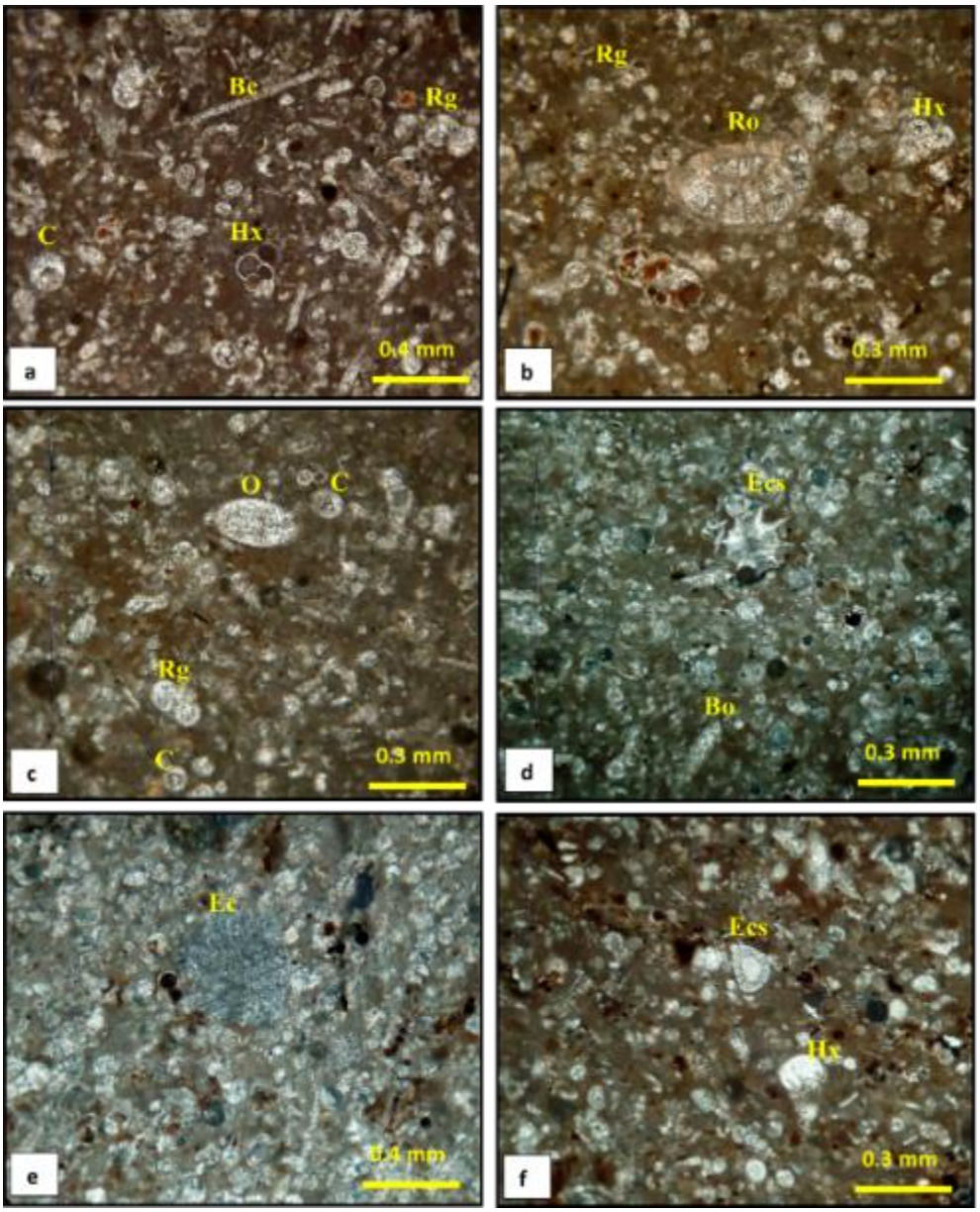


Fig. 5. Photomicrographs showing microfacies types of Shiranish Formation in Sulawki Saru section: a) Planktonic foraminifera (Hx=*Heterohelix* and Rg= *Rugoglobigerina*) -calcispheres (c)-bioclasts (Bc) lime packstone submicrofacies. P.P., Sh.12. b) Foraminifera lime packstone submicrofacies including *Rugoglobigerina* (Rg), *Heterohelix* (Hx), and *Rotalia* (Ro). P.P., Sh.16. c) Planktonic foraminifera (Rugoglobigerina (Rg)-calcispheres (C)- ostracoda (O)lime packstone submicrofacies. P.P., Sh.17 d) Foraminifera-calcispheres-echinoids lime packstone including echinoid spines (Ecs) and *Bolivinoides* (Bo). X.N., Sh.11. e) Foraminifera-calcispheres-echinoids lime packstone submicrofacies include echinoid fragments with syntaxial overgrowth cement (Ec). X.N., Sh.19. f) Foraminifera-calcispheres-echinoids lime packstone submicrofacies include echinoid spines (Ecs) and *Heterohelix* (Hx), P.P., Sh.22.
Key: Sh =Shiranish Formation, P.P.= plane-polarized light, X.N.= Crossed Nichols

DOI: https://doi.org/ 10.5281/zenodo.23270183

Table 1. Main microfacies and its subdivisions of Shiranish Formation

Main Microfacies Dunham (1962)	**Subdivision**	**Diagenetic features (Main skeletal grain +common diagenetic process)**	**SMF of Flugel (1982)**	**Facies Zone (Wilson,1975)**
Lime wackestone	Planktonic foraminifera - calcispheres lime wackestone	-*Rugoglobigerina*+ Calcispheres. Neomorphism and pyritization	**SMF3**	**FZ 2**
	Planktonic foraminifera- lime wackestone	-*Globotruncana*+ *Hedbergella* +*Rugoglobigerina* -Pyritization+ neomorphism+ cementation		
	Foraminiferal - calcispheres lime wackestone	-*Rugoglobigerina*+ *Globotruncanita*+ *Oligostegina*+ *Lenticulina* +Calcispheres -Pyritization + Neomorphism		
	Hedbergella- bioclastic lime wackestone	- Hedbergella + bioclasts -Pyritization+ Neomorphism		
Lime packstone	Planktonic foraminifera- calcispheres lime packstone	-*Globotruncana*+ *Rugoglobigerina*+ Calcispheres -Pyritization+ neomorphism		
	Planktonic foraminifera- calcispheres-bioclasts lime packstone	-*Heterohelix*+ *Rugoglobigerina*+ *Calcispheres*+ *bioclasts* -pyritization		**FZ 3**
	Foraminifera lime packstone	-*Rotalia*+ *Rugoglobigerina*+ *Heterohelix* -*Pyritization*+ *cementation*		
	Planktonic foraminifera- calcispheres- ostracoda lime packstone	-*Heterohelix*+ *Rugoglobigerina*+ calcispheres+ ostracods -Cementation+ neomorphism		
	Foraminifera-calcispheres-echinoids lime packstone	-*Heterohelix*+ *Rugoglobigerina*+ *Bolivinoides*+ Calcispheres + Echinoids spines and fragments -Cementation+ pyritization+ silicification		

DOI: https://doi.org/ 10.5281/zenodo.23270183

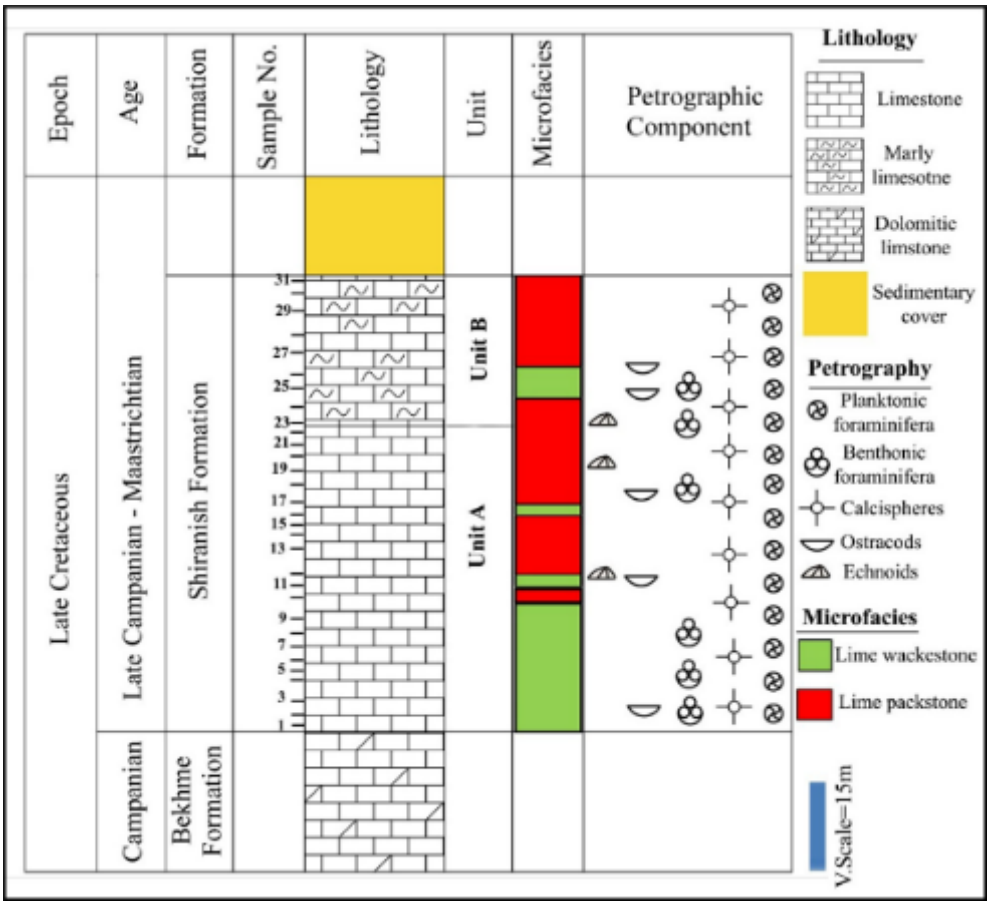


Fig. 6. Columnar section of Shiranish Formation in Sulawki Saru outcrop with microfacies.

4.3. 1.2 Planktonic foraminifera lime wackestone submicrofacies (Figure 4b)

It is common in the lowerpart of the Shiranish Formation within the fractured bedded limestone unit. It is dominated by *Globotruncana*, *Hedbergella* and *Rugoglobigerina*. Pyritization, neomorphism and cementation are diagenetic processes subjected to this submicrofacies.

4.3.1.3 Foraminiferal -calcispheres lime wackestone (Figures 4c and d)

This submicrofacies include planktonic foraminifera (e.g. *Rugoglobigerina, Globotruncanita* and *Oligostegina)* and benthonic foraminifera (*Lenticulina*) as major amount and calcispheres as minor amount. It observed within lower part of studied section and affected by pyritization and neomorphism.

4.3. 1.4 *Hedbergella*- bioclastic lime wackestone submicrofacies (Figure 4e)

This subdivision is occured within the upper portion of the fractured bedded limestone unit of Shiranish Formatoin in studied section. It dominated by planktonic foraminifera (*Hedbergella*) and bioclasts which are mostly remains of mollusks. The siginficant diagenetic processes affected it are pyritization and neomorphism.

4.3.2 Lime packstone microfacies

This facies is common in upper part of Shiranish carbonate in Sulauki Saru section. It characterized by consisting skeletal grains more than 50 % within micritic matrix (Dunham, 1962). The following submicrofacies are recognized:

4.3.2.1Planktonic foraminifera-calcispheres lime packstone submicrofacies (Figure 4f)

This microfacies is found in the upper part of fractured bedded limestone unit of the studied Formation. It is dominated by planktonic foraminifera (*Globotruncana* and *Rugoglobigerina*) and calcispheres. The common diagenetic processes affected this the submicrofacies are pyritization and neomorphism.

DOI: https://doi.org/ 10.5281/zenodo.23270183

4.3.2.2 Planktonic foraminifera-calcispheres-bioclasts lime packstone submicrofacies (Figure 5a)

This microfacies is occured within the upper portion of fractured bedded limestone unit of studied Formation. It is characterized by the predominance of planktonic foraminifera (e.g. *Heterohelix and Rugoglobigerina)* and calcispheres as well as bioclasts. Pyritization is common diagentic processes within the microfacies.

4.3.2.3 Foraminifera lime packstone submicrofacies (Figure 5b)

This subdivision is common in lower part of marly limestone unit of the Shiranish Formation. Its dominated by planktonic foraminifera (e.g. *Rugoglobigerina* and *Heterohelix*) in addition to benthonic foraminifera (Rotaliids). It characterized by highly affecting by pyritization and cementation diagenetic processes.

4.3.2.4 Planktonic foraminifera-calcispheres- ostracoda lime packstone submicrofacies (Figure 5c)

This facies is noticed within the upper portion of studied Formation. It characterizing by dominant of planktonic foraminifera (e.g. *Heterohelix* and Rugoglobigerina) in addition to calcispheres and ostracods. The microfacies affected by cementation and neomorphism diagenetic processes.

4.3.2.5 Foraminifera-calcispheres-echinoids lime packstone submicrofacies (Figures 5d and f)

This subdivision is occurred within the upper part of Shiranish Formation. It characterizing by dominant of planktonic foraminifera (e.g. *Heterohelix* and *Rugoglobigerina*) and benthonic foraminifera (*Bolivinoides*) in addition to calcispheres *as* well as Echinoids spines and fragments. The microfacies affected by cementation, pyritization and silicification diagenetic processes.

4.4. Facies associations

The Shiranish Formations depositional environment was analyzed and interpreted during the present study in Sulawki Saru section through microfacies and it is fossils contain. Accordingly, two facies' associations (FA) can be recognized which are deep shelf facies association (FA1) and outer shelf facies association (FA2).

4.4.1 deep shelf facies association (FA1)

This association is corresponding to standard facies zone 2 and standard microfacies 3 of Wilson (1975) and Flugel (1982) respectively. It comprises of light grey to white fractured bedded limestones bearing lime–wackestone and packstone microfacies in lower part. Carbonates of Shiranish contain microfaunas, which include, planktonic foraminifera particularly keeled types, small benthonic foraminifera, ostracods, calcispheres, and bioclasts.

4.4.2 outer shelf facies association (FA2)

This facies association is equivalent to FZ 3 of Wilson (1975) and SMF 3 of Flügel (1982). It occupied upper part of the studied formation and comprises of grey to blue bedded marly limestone bearing lime packstone with less wackestone and characterized by non-keeled planktonic foraminifera. Other fossils within this association are benthonic foraminifera, ostracods, calcispheres, echinoids spines and fragments in addition to bioclasts.

4.5. Environment of Shiranish Formation

The depositional environment of Shiranish Formation was elucidated depending on several indicators, which including facies, fossils and authigenic Mineral. The microscopic study of thin sections indicated the presence of various facies types; however, their lithological and biogenic contents displayed noticeable similarities among the studied sections. This indicates a consistency of facies and environment in these thin sections. While, according to the Dunham's (1962) terminology, it was observed that lime wackestone was the predominant facies in lower part followed by lime packstone. While in upper part the lime packstone is

DOI: https://doi.org/ 10.5281/zenodo.23270183

increased compared to lower part. Furthermore, the main matrix over all studied thin sections was micrite which occasionally changed microspar by diagenetic processes. The predominance of micrite reflects the stagnancy and calmness of the sea bottom during the accumulation of lime mud (Dunham, 1962). ased on the Standard Microfacies (SMF) and Facies Zone (FZ) schemes of Wilson (1975) and Flügel (1982), the microfacies of the Shiranish Formation correspond to SMF-3, representing FZ-2 (basinal–deep shelf) and FZ-3 (outer shelf) environments.

The predominance of micrite is refer to the quite nature of Shiranish basin, the dominant of planktonic foraminifera indicting to pelagic nature of its environment. The dominance of non-keeled planktonic foraminifera (e.g., Rugoglobigerina, Heterohelix, and Hedbergella), particularly in the middle and upper parts of the formation, indicates deposition in pelagic warm water at depths shallower than 100 m. In contrast, keeled planktonic foraminifera (e.g., Globotruncana and Globotruncanita), which occur mainly in the lower and middle parts, reflect pelagic cooler water at depths greater than 100 m (Leckie, 1987). Thus, the former assemblage is indicative of an outer shelf setting, whereas the latter points to a deep-shelf environment. Occurrence of benthic forams e.g. *Rotalia, Lencticulina, and Bolivionodes* regarded autochthonous benthic fossils in basinal environment (Wilson,1975; Flugel,2010) in both outer shelf and deep shelf settings. Calcispheres, which occur with planktonic foraminifera in the studied formation and possess an unknown systematic affinity, are regarded as traces of planktonic organisms (Andri, 1972 in Bein, 1977). They may be present in both shallow- and deep-water sediments (Masters and Scott, 1978); however, in the present study, a basinal origin for the Shiranish calcispheres is considered more plausible due to their association with pelagic organisms. Ostracods live in several environments, including marine, transitional, and freshwater settings, occurring at various depths from the seashore to the bathyal zone, and show a wide distribution from the equator to the polar seas (Haq and Boersma, 1998). Echinoid spines are common in normal marine, open-shelf setting (Abid et al., 2022). The integration of ostracods and echinoids with other pelagic faunas indicate basinal environment in both outer and deep shelf settings.

In contrast, the abundance of pyrite within the Shranish carbonates in studied section offer the evidence of deep marine environment, reducing conditions, low oxygen and very slow rates of sedimentation (Nichols, 2009). All petrographic, facies, textural evidences, concluded that the depositional environment Shiranish Formation is basinal environment (deep shelf in lower part changed to outer shelf toward upper part), quiet, semi reducing conditions. A drawn schematic block diagram shows all these interpretations (Figure 7). This figure illustrates the inferred paleoenvironmental conditions and elements of Upper Cretaceous Shiranish Formation in Iraqi Kurdistan region, Northern Iraq.

DOI: https://doi.org/ 10.5281/zenodo.23270183

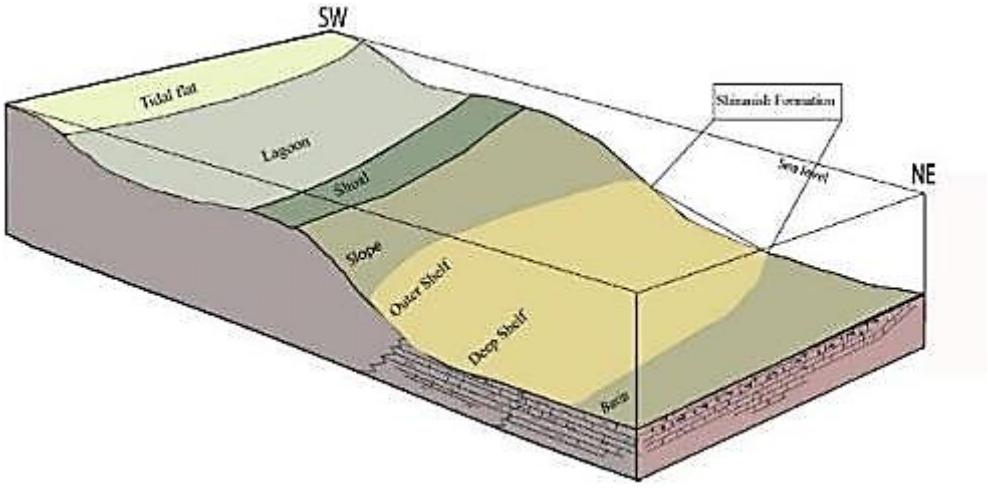


Fig. 7. Schematic model of Shiranish depositional environment in Sulawki Saru section.

5. Conclusions

The Shiranish Formation in Sulawki Saru section in Safin anticline, High folded zone, comprises of 81m of thin to medium and fractured bedded grey to white color limestone in lower part and grey to blue bedded marly limestone characterized by joints in upper part. Lower contact was conformable with massive dolomitic limestone of Bekhme Formation while upper contact is not clear and covered by sedimentary material. According to the field inspections and petrographic analysis, two different lithology units were identified in the Shiranish Formation at Sulawki Saru Section: Fractured bedded limestone unit (Unit A), and bedded marly limestone unit (Unit B). Moreover, petrographic study revealed that micrite is main matrix with occasional recrystallized microspar, and skeletal grains showing a variety of pelagic marine fauna which are, in order of dominance: Planktonic forams (*Rugoglobigerina, Heterohelix, Globotruncana, Globotruncanita, Hedbergella* and Oligostegina), benthonic forams (*Lenticulina, Rotalia* and *Bolivionoides*), Calcisphers, Ostracods, Echnoids and Bioclasts. In addition, based on classification of Dunham (1962), and depending on detailed microfacies study of limestone, two main microfacies and 9submicrofacies are recognized within the Sulawki Saru section of Shiranish Formation, which they are refer to basinal deep shelf and outer shelf environments of the formation. From the sum of all petrographic, facies, textural study, it concluded that the Shiranish Formation in Sulawki Saru section, deposited at basinal environment (deep shelf changed to outer shelf toward upper part) in quiet, semi reducing conditions.

Acknowledgments

Mr. Mario from the Department of Earth Sciences and Petroleum is gratefully acknowledged for providing computer facilities. Our colleague Muhammad Kaify is sincerely thanked for his assistance during the fieldwork.

Conflict of interests: The authors declared no conflicting interests.

Sources of funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Al-Dulaimi, A. M., Al-Haj, M. A., Asaad, I. S., Omar, N., & Zanoni, G. (2023). Depositional setting of the Shiranish Formation (Campanian-Maastrichtian) in elected sections from Northern Iraq. The Iraqi Geological Journal, 207-225.

DOI: https://doi.org/ 10.5281/zenodo.23270183

Abawi, T. S., Kireem, M. A., & Yousef, J. M. (1982). Planktonic foraminiferal stratigraphy of Shiranish formation, Sulaimaniah-Dokan region, northeastern Iraq. Revista Espanola de Micropaleontologia, 14(1), 153-164.

Abdel-Kireem, M. R. (1983). A study of the palaeoecology and bathymetry of the foraminiferal assemblages of the Shiranish Formation (Upper Cretaceous), northeastern Iraq. Palaeogeography, palaeoclimatology, palaeoecology, 43(1-2), 169-180.

Abdel-Kireem, M. R. (1997). Contribution to the stratigraphy of the Upper Cretaceous and the Lower Tertiary of the Sulaimaniah-Dokan region, northeastern Iraq; Contribution to the stratigraphy of the Upper Cretaceous and the Lower Tertiary of the Sulaimaniah-Dokan region, northeastern Iraq. Neues Jahrbuch fur Geologie und Palaontologie-Abhandlungen, 172(1), 121-139.

Abid, A. A., Asaad, I. S., & 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), 259.

Al-Badrani, O. A. (2011). Nannobiostratigrphy of Shiranish Formation in Balad Well No. 8, Northern Baghdad, Iraq. Iraqi National Journal of Earth Science, 11(2), 65-0.

Al-Banna, N. Y. (2010). Sequence stratigraphy of the Late Campanian–Early Maastrichtian Shiranish Formation, Jabal Sinjar, northwestern Iraq. GeoArabia, 15(1), 31-44.

Al-Qayim, B., Habib, H. R., & Al-Dyni, N. (1986). Petrology and geochemistry of Shiranish Formation (type section) towards sedimentary facies interpretation. Journal of the Geological Society of Iraq, 19(3), 123-136.

Al-Shaibani, S. K., Al-Hashimi, H. A. J., & Ghafour, I. M. (1993). Biostratigraphy of the Cretaceous-Tertiary boundary in well Tel Hajar no. 1, Sinjar area, northwest Iraq. Iraqi Geological Journal, 26(2), 77-97.

Al-Zaidy, A. A. H. (2017). Well log Sequence Stratigraphy and Petrophysical Properties of the Shiranish Formation in the Kirkuk Oil Field (K-260 and K-229). Diyala Journal For Pure Science, 13, 105-119.

Aqrawi, A. A., Goff, J. C., Horbury, A. D., & Sadooni, F. N. (2010). The petroleum geology of Iraq (Vol. 424). Beaconsfield, UK: Scientific press.

Bein, A. M. O. S. (1977). Shelf basin sedimentation; mixing and diagenesis of pelagic and clastic Turonian carbonates, Israel. Journal of Sedimentary Research, 47(1), 382-391.

Bellen, R. V., Dunnington, H. V., Wetzel, R., & Morton, D. M. (1959). Iraq: Lexique Stratigraphique International. Int. Geol. Congr. Comm. Stratigr, 3.

Buday, T. (1980). The Regional Geology of Iraq. Vol. 1, Stratigraphy and Paleogeography. Dar Al-Kutub Pub. Univ. of Mosul, Iraq, 445 p.

Dunham, R. J. (1962). Classification of Carbonate Rocks According to Depositional Texture. In: Ham, W.E., Ed., Classification of Carbonate Rocks. AAPG, 108–121.

El-Anbaawy, M. I. H., & Sadek, A. (1979). Paleoecology of the Shiranish Formation (Maestrichtian) in Northern Iraq by means of microfacies analysis and clay mineral investigation. Palaeogeography, Palaeoclimatology, Palaeoecology, 26, 173-180.

Flugel, E. (1982). Microfacies Analysis of Limestones, Springer – Verlag, Berlin, 633 p.

Flugel, E. (2010). Flügel, E., & Munnecke, A. (2010). Microfacies of carbonate rocks: analysis, interpretation and application (Vol. 976, p. 2004). Berlin: springer.

Friedman, G.M. (1959). Identification of carbonate minerals by staining methods. Jour. Sed. Pet., Vol.29, No. 2, pp. 87-97.

Haq, B. U., & Boersma, A. (Eds.). (1998). Introduction to marine micropaleontology. Elsevier, 376 p.

DOI: https://doi.org/ 10.5281/zenodo.23270183

Jassim, S.Z. and Goff, J.C. (2006). Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, Czech Republic. 341p.

Kamal, H. K., & Zardasht, A. (2009). Tectonical history of Arabian platform during Late Cretaceous An example from Kurdistan region, NE Iraq: 1-14.

Kennedy, W. J., & Lunn, G. (2000). Upper Campanian (Cretaceous) ammonites from the Shinarish Formation, Djebel Sinjar, northwest Iraq. Journal of paleontology, 74(3), 464-473.

Leckie, R. M. (1987). Paleoecology of mid-Cretaceous planktonic foraminifera: a comparison of open ocean and epicontinental sea assemblages. Micropaleontology, 164-176.

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

Nichols, G. (2009). Sedimentology and Stratigraphy. Wiley – Blackwell, UK. 419P.

Numan, N. M. (2001). Cretaceous and Tertiary Alpine subductional history in northern Iraq. Iraqi Journal of Earth Science, 1(2), 59-74.

Sissakian, V. K., & Fouad, S. F. (2014). Geological map of Sulaimaniyah Quadrangle, scale 1: 250 000. Iraq Geological Survey Publications, Baghdad, Iraq.

Sharbazhery, H. G.H. (2008). Sequence stratigraphy of the Qamchuqa, Dokan, Kometan, and Shiranish Formations from selected sections in Kurdistan Region. Unpublished M.Sc. thesis, University of Sulaimanyia, department of Geology.200pp.

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, Geo Arabia, Special publication 2, Gulf Petro Link, Bahrain, 372p.m Pet., Vol. 52, No. 4, pp. 1087-1100.

Wilson, J.L. (1975). Carbonate Facies in Geologic History. Springer-Verlag, Berlin. 471p.