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Sequence Stratigraphy and Sedimentary Environment of the Shiranish Formation, Duhok region, Northern Iraq

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Abstract

The Shiranish Formation is cropped out in several areas in northern Iraq. A stratigraphic and facies study was conducted within the Duhok region to determine the sedimentary environment. Three microfacies, reflecting the various subenvironments within different shelf parts of the deep sea, have been identified within the Shiranish Formation. Four depositional environments are identified: slope, the toe of slope, deep shelf, and deep-sea or cratonic deep basin. The Shiranish Formation in the Duhok region, Northern Iraq, was deposited in an open shelf carbonate platform. The Shiranish Formation sequence is divided into six third-order cycles in the study area. These asymmetrical cycles reflect an imbalance between the relative level of the sea and the production of carbonate, and each one reflects a rise in the sea level following a period of standstill. There is a two-sequence boundary type SB-2 that defines the surface. The Shiranish sequence developed in a high-subsidence area that played the main role in the evolution of the formation. It was deposited on a carbonate platform with high subsidence due to major transgression, wherever the successive sea-level rise and stillstand episodes persist.

Keywords: Sedimentary environment, Shiranish Formation, North Iraq, Duhok, Microfacies.

التتابع الطباقى والبيئة الرسوبية لتكوين الشيرانش بمنطقة دهوك شمال العراق

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الخلاصة

ينكشف تكوين الشيرانش في عدة مناطق شمال العراق. أجريت دراسة طباقية في منطقة دهوك لتحديد البيئة الرسوبية للتكوين. تم تحديد ثلاثة سحنات دقيقة، تعكس البيئات الثانوية المختلفة داخل أجزاء مختلفة من

الرف الى البحر العميق في منطقة الدراسة، تم تحديد أربع بيئات ترسيبية ضمن تكوين شيرانيش: المنحدر، إصبغ المنحدر (اسفل المنحدر)، الرف العميق، وأعماق البحار أو الحوض العميق. ترسيب تكوين شيرانيش في منطقة دهوك شمال العراق في منصة كاربونية مفتوحة الرف. وتم تقسيم تتابع تكوين شيرانيش إلى ست دورات من الدرجة الثالثة تعكس هذه الدورات غير المتماثلة عدم التوازن بين مستوى سطح البحر النسبي وإنتاج الكاربونات، وتعكس كل دورة ارتفاعاً في مستوى سطح البحر بعد فترة من ثبوت سطح البحر. هناك نوعان من حدود التتابع، حدود تتابع من النوع الأول والثاني تحد تتابع الشيرانيش من الاعلى والاسفل. نشأ التتابع في منطقة تجلس عالية لعبت الدور الرئيس في تطور التكوين. تم ترسيب تكوين الشيرانيش على منصة كربونية ذات تجلس عالٍ بسبب تقدم بحري كبير حيث استمرت النوبات المتتالية في ارتفاع مستوى سطح البحر واستقراره.

1. Introduction

The carbonates of the Shiranish Formation have been studied by several researchers in different areas of Iraq [1]; [2]; [3]; [4]; [5]; [6]. After converging between the Iranian and Arabian Plates (AP) continental crusts, the southern Neo-Tethys was obducted and closed throughout the Late Campanian to Maastrichtian periods [7]. The convergence caused the passive margin to turn into the active foreland basin at the beginning of the Zagros suture. The Shiranish Formation was deposited in active foreland during transgression with the Kometan Formation in the same sedimentary basin. The stress regime in the northeast of the AP developed two basins trending NW-SE and E-W [8].

In the L. Campanian - E. Maastrichtian period paleogeographic map, five depositional environment belts can be seen (Figure 1).

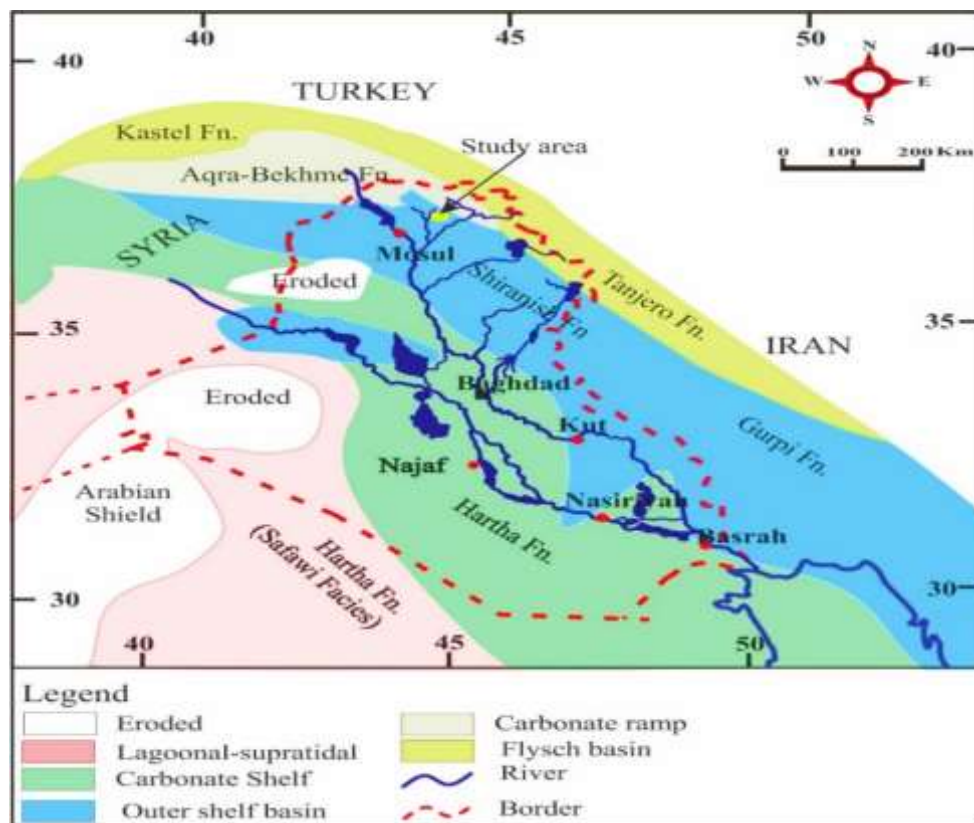


Figure-1 Paleogeography distribution of the L. Campanian to E. Maastrichtian rock unit, modified after [3]

These environments include 1) Hartha Formation lagoon and 2) Hartha Formation carbonate shoal. Both of them were deposited on a carbonate platform to the west of the open

sea, 3) The Shiranish Formation outer shelf basin environments, 4) The Bekhme Formation carbonate platform, and 5) Flysch facies of the Tanjero Formation, which formed as turbiditic flysch within the Balambo-Tanjero Zone [8].

2. Geological setting

[1] identified the Shiranish Formation for the first time in the Shiranish Islam Village, northeast of Zakho, Duhok Governorate, northwest of Iraq. It consists of 225 meters of shales, argillaceous to marly limestone and marl. [1] stated that the formation is conformably overlaid by the Bekhme Formation, which overlies a section composed of silty, rich shales and sandstones of the Kolosh Formation. Despite the Shiranish Formation being cropped out in the high folded zone of northern Iraq, the formation was also studied in several subsurface parts in various areas of Iraq when drilling wells reached the Upper Cretaceous layers [9].

In northeast Iraq, strong subsidence and basin filling (Tanjero Formation, consisting of thick flysch sediments derived from the northeast) characterize the Campanian- Maastrichtian sequence (Figures 1 and 2). The basin was separated from the unstable shelf by a ridge located in the folded zone in the Zakho-Dohuk-Aqra-Rawandoz-Ranya areas [8]. Over the ridge, the Tanjero flysch sediments (on the northeast side) are progressively replaced either by the Bekhme and Aqra formations (reef and shelf setting) or by the Shiranish Formation (deep-marine setting); the latter is generally developed with a relatively reduced thickness and intertongues with both the Aqra-Bekhme and Tanjero formations (Figures 1 and 2) [8].

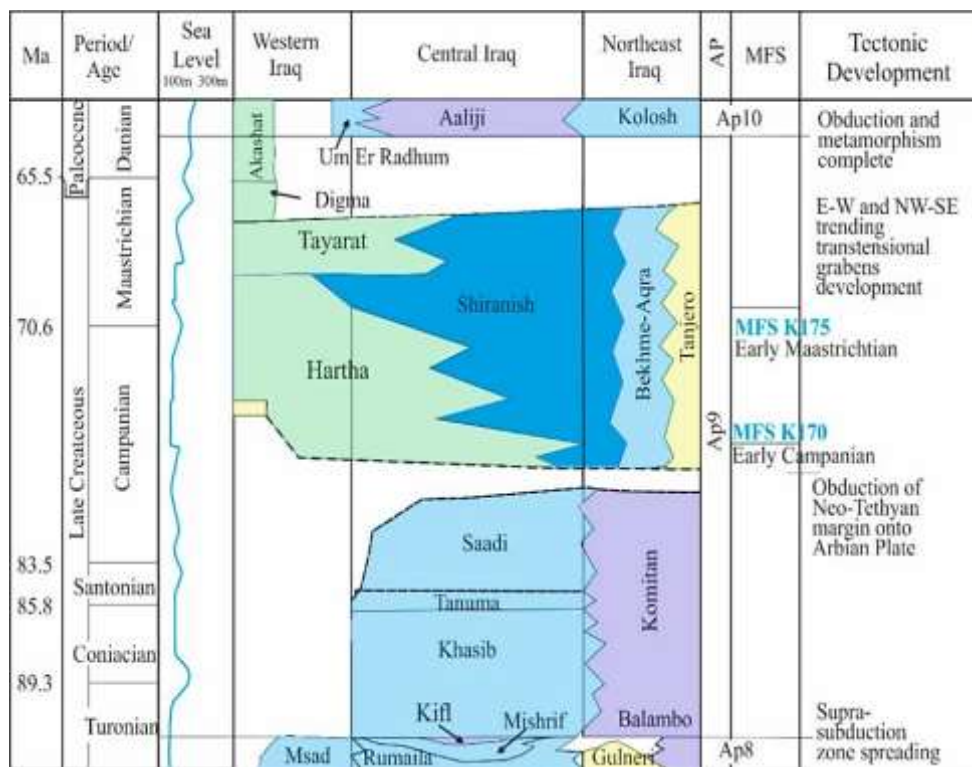


Figure 2: Stratigraphic correlation of formations of Turonian (Late Cretaceous) to Danian (Paleogene) age in northeastern, central and western Iraq [8]

This study aims to shed light on the sequence stratigraphy and depositional environment of the Shiranish Formation in the Duhok region.

3. Field work and Methodology

The fieldwork included one section of sampling located in northern Iraq in the Duhok area. The study section is situated on the southern limb of the Bekhair anticline, northern Duhok city, with a total thickness of 218 m. A detailed description and collection of samples were carried out on every noticeable change for the studied formation. One hundred thirty-two samples selected from this section were based on facies changes in lithology and color, hardness of the beds, and differences in other factors such as fossil content. Sixty-five thin sections are prepared in the laboratory of the applied geology department, College of Science, University of Babylon. The polarized microscope is used to study these thin sections to identify the fossils and lithological contents. The coordinates of the study area are 36°52'37" N and 43°05'38" E (Figure 1).

The lithology of the upper part of the Shiranish Formation comprises interchanging limestone, marl, and marly limestone layers (Figure 3A). The layer thickness of marly limestone and marl varies from about 15-45 cm to about 10-25 cm, respectively, with marl combined with limestone up to 10 cm thick. The intercalated limestone beds are yellowish to light gray. The middle part of the formation likewise forms marl and marly limestone (Figure 3B), and these beds are friable (Figure 4A).



Figure 3: A- The upper part of the Shiranish Formation shows alternating between marly limestone, marl and limestone beds. B- The middle part of the Shiranish Formation consists of marl and marly limestone

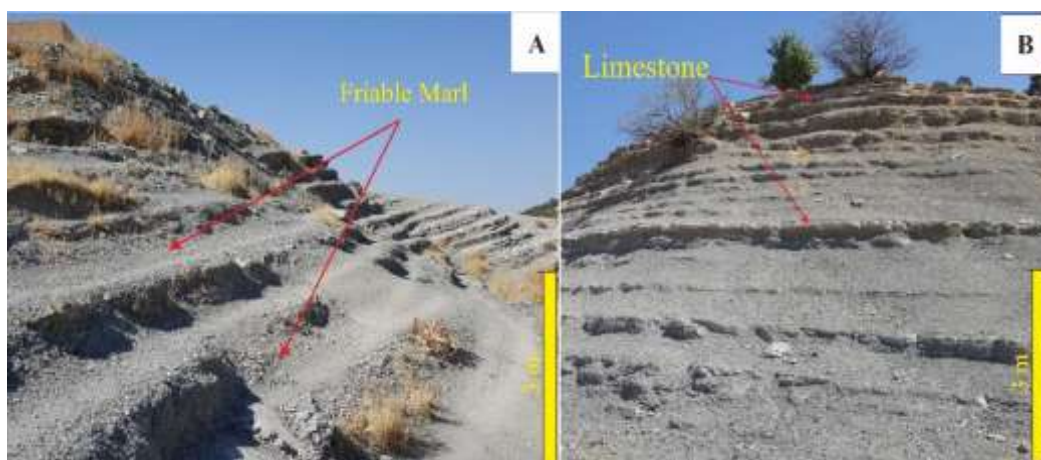


Figure 4: A- The friable marl in the middle part of the Shiranish Formation. B- The lower part of the Shiranish Formation consists of hard gray limestone marl and marly limestone

Marly limestone beds are gray to dark gray, with a thickness of about 25 to 35 cm of each layer. The lower portion of the formation consists of hard, thick, gray limestone and marly limestone (Figure 4B). The thickness of the marly limestone bed in this part is approximately 5-25 cm. The lower contact of the Shiranish Formation is conformable with Bekhme Formation in this section, distinguished by a very thick limestone bed for the Bekhme formation and the marly limestone bed Shiranish (Figure 5A).

The Shiranish Formation's upper contact is unconformable with the Paleogene deposited and taken at the base of the Kolosh Formation's sandstone or siltstone bed (Figure 5B). Any visible improvement is based on detailed petrography and facies analysis of samples. In this analysis, the Shiranish Formation reaches 218 m thick (Figure 8).

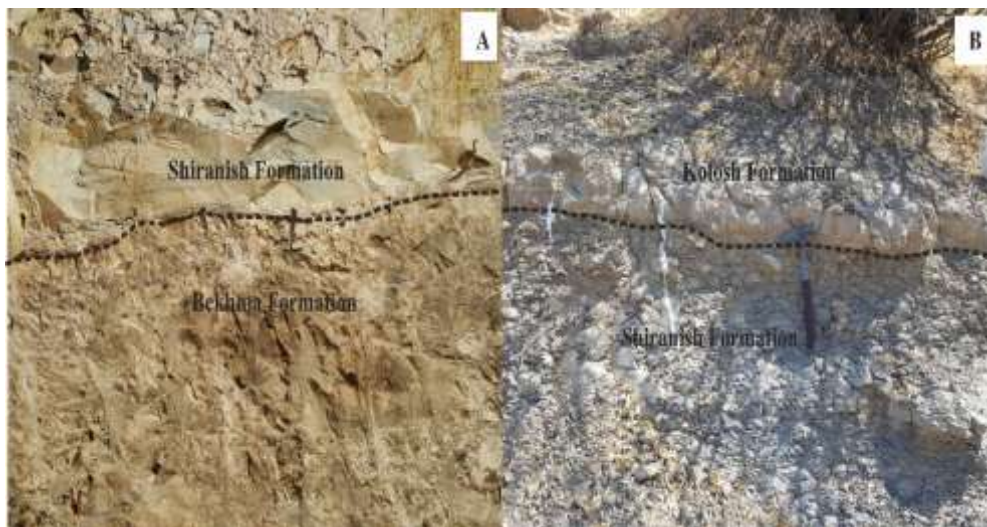


Figure 5: The lower and upper contact of the Shiranish Formation. A- Lower contact with the Bekhme Formation. B- Upper contact with the Kolosh Formation

Carbonates microfacies analysis and identification of certain fossils were accomplished by microscopic examination of thin sections. Biostratigraphy was used in addition to the depositional environmental analysis according to the type, density, and distribution of fauna and the nature of fauna bodies. An extensive petrographic investigation investigates the texture and types of carbonate grains. In the characterization of the carbonate rock classification, an expanded Dunham classification. [10] is used; Three microfacies and one lithofacies are distinguished within the studied section.

4. Results and Discussions

4.1 Facies and Microfacies

The facies and microfacies of the Shiranish Formation have been diagnosed, including three main microfacies and one lithofacies described below:

4.1.1. Planktonic Foraminiferal lime Mudstone microfacies (F1)

The planktonic mudstone's main skeletal components include predominantly the globular planktonic foraminifera defined by *Rugoglobigerina rugosa*, *Rugoglobigerina macrocephaly*, and *Globotruncana fornicate*. Micrite, rare calcispheres, and sponge spicules make up the matrix (Figure 6A). Compaction, micritization, cementation, and cement-filled fractures are common diagenetic processes.

The intraparticle has low porosity, and the microfacies are recorded in the lower part of the studied section. Compared to the standard microfacies types of [11], it belongs to the standard microfacies (SMF3) in FZ1.

4.1.2 Lime wackestone microfacies

Included:

- *Bioclastic plankton wackestone submicrofacies (F2)*

This submicrofacies is characterized by the predominance of bioclastic planktonic foraminifers, (*Globotruncanella* sp., *Rugoglobigerina rugosa*, *Rugoglobigerina hexacamerata* sp., *Heterohelix* and *Globigerinelloides* sp.). As well as a few pelecypod fragments and pyrite grains (Figure 6B) in addition to benthos fauna and unusual radiolarians are discovered. Diagenesis processes that affected these facies were cementation, compaction and dolomitization sequentially. According to [11], these facies are similar to the standard microfacies that distinguished the basinal environment.

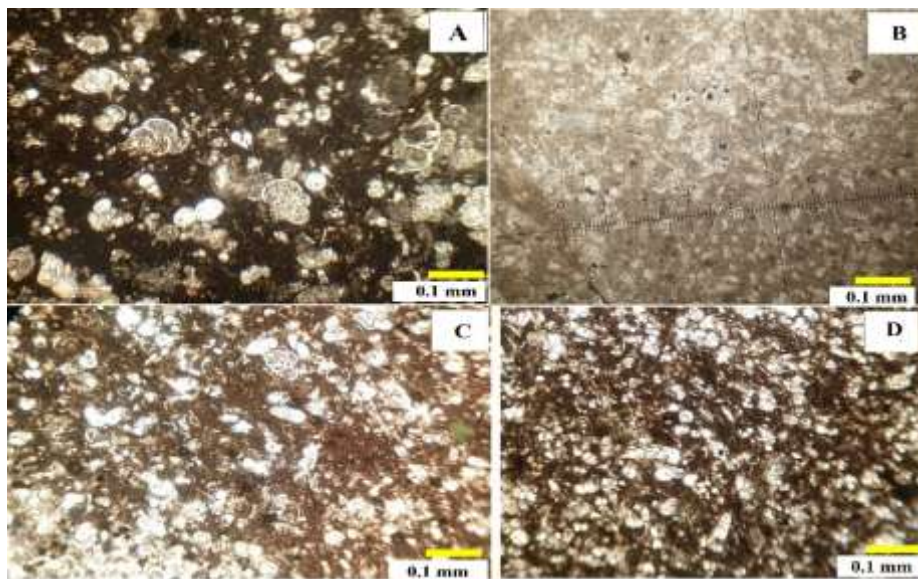


Figure 6: Photomicrographs of A- Planktonic Foraminiferal Mudstone; B- Bioclastic planktonic wackestone; C- Planktonic Foraminiferal Wackestone and D- Planktonic Foraminiferal packstone. where Py: pyrite, G: glauconite

The microfacies accumulated in the outer shelf to the upper portions of the upper bathyal environments ranges in depth from 100 m to 300 m, depending on the presence of benthic foraminifera and the percentage of planktonic forams [12]. It is possible to imagine a low-energy ecosystem underneath the wave base [13]. Active diagenetic features include compaction (plankton shell deformation), micritization, and cementation (fracture filling) (Figure 6C). Authigenic minerals such as glauconite and pyrite can be found in these facies. The microfacies represent the deposition in the deep shelf (SMF 8 of FZ.2).

- *Bioclastic Foraminiferal Wackestone submicrofacies (F5)*

Contain bioclast such as, benthic and planktonic organisms, Echinodermata particles and red algae (Figure 7A). Both are rooted in micrite cement, which has been patchily converted into spar calcite cement. The upper and middle sections of the study area are characterized by the presence in these submicrofacies.

The main diagenetic processes that affected these microfacies were cementation, neomorphism, dolomitization, and authigenic minerals. The regular microfacies (SMF-3) and

(FZ-3) that characterize a shallow open environment are identical to these microfacies (Toe of slope) [11].

4.1.3. Lime packstone microfacies

- *Planktonic Foraminiferal packstone submicrofacies (F4)*

It comprises of a variety of Upper Cretaceous planktonic foraminifera (*Rugoglobigerina rugosa* and *Heterohelix* sp.). Their participation rates range from 70% to 85%. (Figure 6D). The distribution of benthic foraminifera is low. The abundance of planktonic foraminifera and the diversity of benthic foraminifera indicate a middle bathyal environment, which corresponds to the microfacies' deepest portion ([14] and [15]).

The majority of evidence points to an upper to the middle bathyal environment with water depths ranging from 300 to 700 meters. These microfacies were found in the lower parts. Compaction and cementation and glauconite and pyrite-filled skeletal grains are diagenetic characteristics of these microfacies. These microfacies are close to the standard microfacies (SMF-2) and (FZ-2) that are found in the environment of the deep shelf [11].

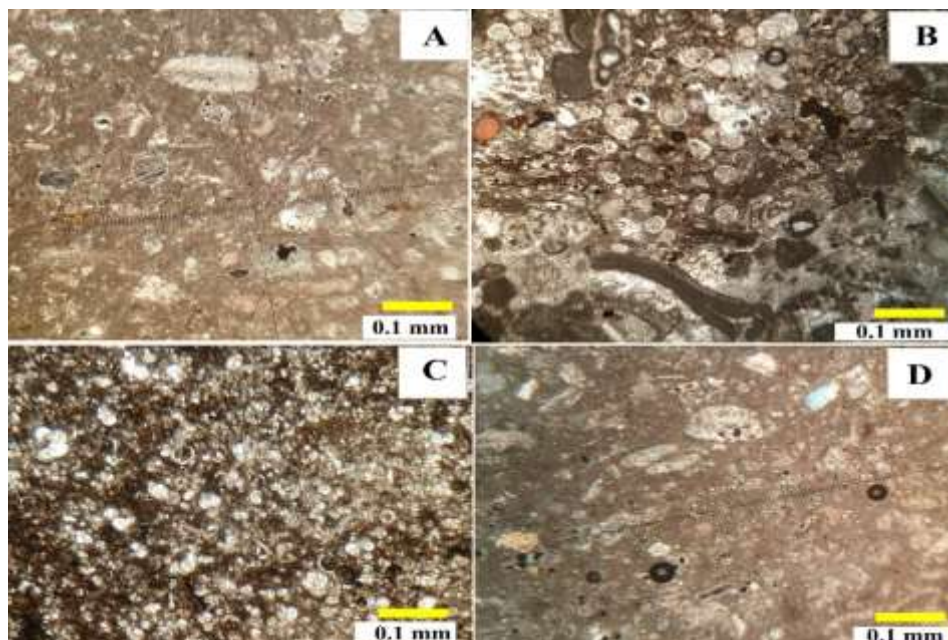


Figure 7: A- Bioclastic Foraminiferal wackestone. B- Bioclastic Foraminiferal packstone. C- Highly fossiliferous marl subfacies; D- Poorly fossiliferous marl subfacies.

- *Bioclastic Foraminiferal packstone submicrofacies (F6)*

This facies emerges in the Shiranish Formation's lower part as a thin bed. It consists of Mollusca shell fragments, algal plates, and Echinodermata fragments representing the abundance of reef-derived fossils with Planktons (Figure 7B). Some of these shell fragments were substituted by secondary calcite and deformed. These microfacies is identical to the standard microfacies (SMF5) and (FZ-4), describing (Slope) shallow open environment [11].

4.1.4. Marl lithofacies (F7)

These facies consist of thin layers of hard marly limestone surrounded by dark-gray to soft blue-gray marl. Because of the wide variety of allochem contents, these facies have been divided into two subfacies:

1. Highly Fossiliferous Marl sublithofacies, which have a significant content of planktonic foraminifera (*Rugoglobigerina*; *Globotruncanella* sp., *Macrocephala*; *Pseudotextularia*

elegans; *Globigerinelloides* sp., and *Hedbergella*) (Figure 7 C). The paleontological evidence indicates that these facies represented the outer shelf to middle bathyal environments [16].

2. Poorly Fossiliferous Marl sublithofacies, the thin soft marl subfacies consist of (*Rugoglobigerina macrocephala*, *Globigerinelloides* sp., *Pseudotextularia elegans* and *Pseudogumbelina* sp.) (Figure 7D). The paleontological and sedimentological of the subfacies refer to the moderate shelf environment [16].

4.2. Depositional Environments

According to [11] and [13], facies model proposals, the Shiranish Formation in Duhok was deposited in four environments: Deep Sea, Deep Shelf, Toe of Slope, and Slope (Figure 8). The Shiranish Formation successions represent the transgression process of the sediments during the Late Campanian-Maastrichtian period due to [8]. According to units of the tectonostratigraphic in the underfilled foreland basin stage, the depozone foredeep mid-unit (Pelagic) corresponds to the Shiranish Formation ([17]; [18] and [19]). The four different environments are discussed below.

4.2.1. Slope Environment

This ecosystem comprises a bioclastic foraminiferous packstone. It is rich in Mollusca shell fragments, algal plates and Echinodermata fragments, which appear as an abundance of reef-derived fossils with Planktons. This area is situated inside the slope zone according to the standard microfacies given in [11] and [13]. The slope sediments make up the lower part of the formation. It was predicated on the presence of reworked grains of reef-derived fossils in planktonic Foraminifera, Echinoderms, and Ostracod shells. Within these groups, there are species of large and small benthic foraminifera and a red algae [20] as in (Figure 8).

4.2.2. Toe of Slope Environment

This environment comprises a bioclastic foraminiferous wackestone rich in planktonic foraminiferous debris, benthic, and fewer Echinoderms concentrations. This environment belongs to the deep zone microfacies of the standard microfacies of [11] and [13]. It was built on the existence of reworked kaolinite minerals and grains linked to the shells of Echinoderms, planktonic foraminifera, and Ostracods. In addition, there are many species of small and large benthic foraminifera within these units. The existence of red alga indicates a low rate of deposition at the top of the slope [21] (Figure 8).

4.2.3. Deep Shelf Environment

Fine materials of this environment such as silicate particles, micrite, calcareous content and biological constituents are Cycle E begins with identified by the shells of planktonic species. The Shiranish Formation's depositional environment had sediment in deep marine zones, depending on the matrix and grain constituents. Furthermore, less benthic foraminifera and fine sediments with typical planktonic foraminifera represent pelagic conditions and show that the ecosystem is deep and quiet. *Rugoglobigerina rugosa* and *Heterohelix* sp. are planktonic foraminifera found in the Shiranish Formation facies and in the deep marine environment [22].

The presence of fossiliferous marl subfacies, which include thin *Rugoglobigerina macrocephala*, *Globigerinelloides* sp., *Pseudotextularia elegans*, and *Pseudogumbelina* sp., as well as pyrite and phosphate minerals within the planktonic foraminifera wackestone, is thought to be direct evidence of deep sedimentation.

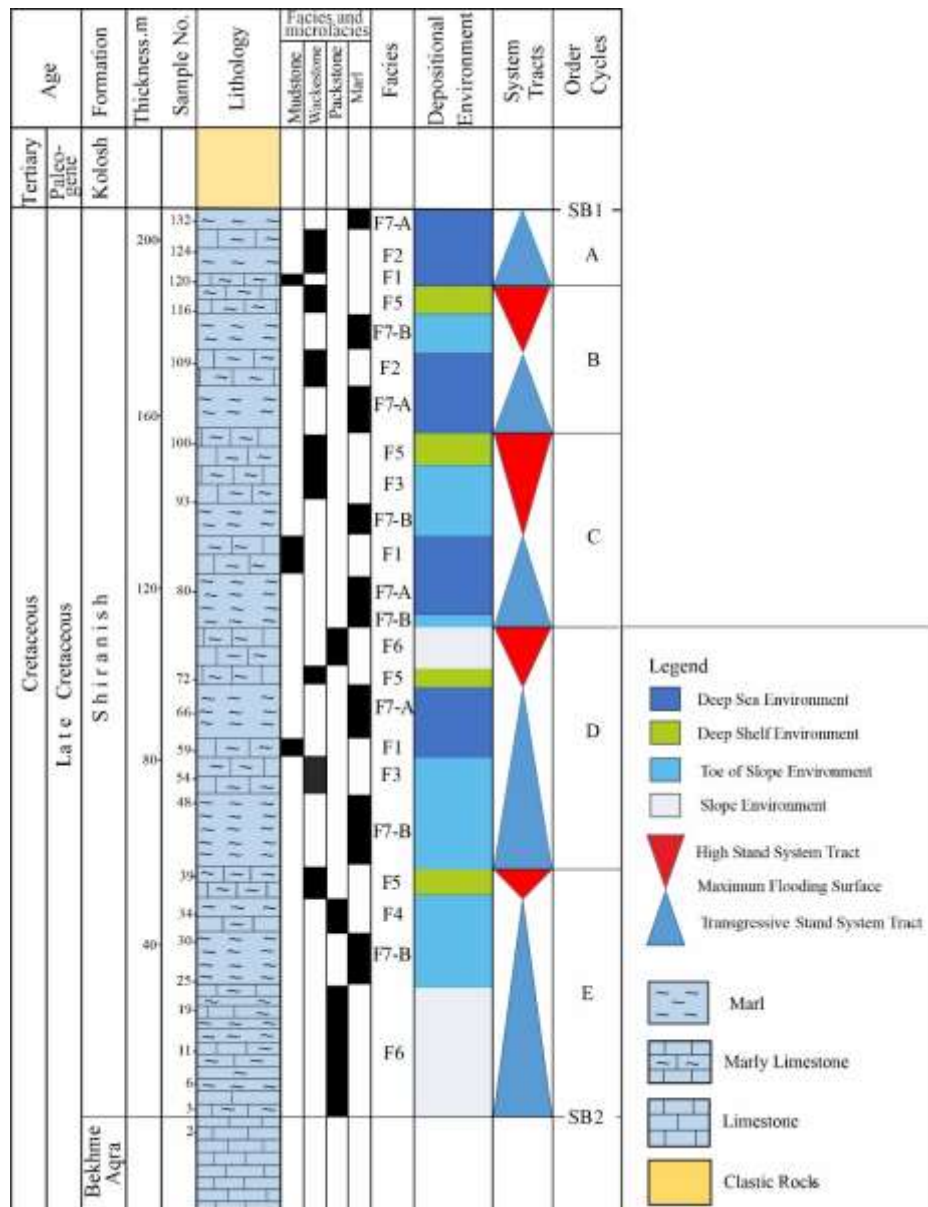


Figure 8: Sequence Stratigraphy subdivision of Shiranish Formation in the study area.

4.2.4. Deep Sea

The planktonic foraminiferal mudstone, bioclastic wackestone, and highly fossiliferous marl subfacies help identify the deep sea or cratonic deep basin environment [23]. The skeletal grains are the most similar between these microfacies and standard microfacies.

4.3. Sequence stratigraphic framework

The Late Cretaceous deposits (Shiranish Formations) sequence Stratigraphic study of the Duhok region interpreted five third-order cycles known as A, B, C, D and E (Figure 8).

Cycle E begins with alternating thin-bedded marly limestone rich in bioclastic. It consists of Mollusca shell fragments, algal plates and Echinodermata fragments showing an abundance of reef-derived fossils with Planktons (facies F6) represented by the Transgressive Stand System Tract (TST). It overlies the Bekhme Formation by a type two-sequence boundary (SB2), inferred by a brown limestone bed in the Bekhme Formation rich in benthonic foraminifera, biologic pores, and trails below the Shiranish Formation. The

Transgressive Stand System Tract (TST) is supplemented by marl and marly limestone (facies F7-B and F4) accompanied by increased planktonic foraminifera abundance and greater diversity. The Maximum Flooding Surface (MFS) is positioned in the lower of facies F5, where the High Stand System Tract (HST) of this Cycle (Figure 8).

Cycle D starts with the sedimentation of facies (F7-B, F3, F1, and F7-A). They show increased water depth upward, suggested by the increase of the percentage of planktonic foraminifera, and they represent the Transgressive System Tract (TST). The topmost portion of F7-A, followed by facies F5 and F6, all display shallowing upward setting, which indicate the cycle's High Stand System tract (HST) (Figure 8).

Cycle C begins with commences the sedimentation of F7-B, F7-A, and F1, which show a rise in water depth as the number of planktonic foraminifera increases upward. Transgressive System is represented by all facies (Tract TST). The MFS is located where the most planktonic foraminifera have been found. The upper portion of the Cycle, followed by facies F7-B, F3, and F5, defines the HST. Shallowing upward is referred to by all facies (Figure 8).

The deposition of facies F7-A and F2, which depicts a rise in water depth accompanied by an increase in the number of planktonic foraminifera, represent Cycle B. Transgressive System Tract was represented by both facies (TST). The upper part of the Cycle, followed by facies F7-B and F5, defines the High Stand System Tract (HST). Each facies refer to a shallowing upward movement. The Transgressive System Tract (TST) of Cycle A is indicated by facies F5, followed by facies F1, F2, and F7-A, displaying a deep upward environment. The upper SB is Type 1 beneath the bedded sandstone of the Kolosh Formation (Paleogene) (Figure 8).

5. Conclusions

In this study, the Shiranish Formation consists of marls interbedded with limestones and marly limestone. The lower contact with the Bekhme Formation is conformable. It occurs between the top of the Bekhme Formation's very thick limestone bed and the base of the Shiranish Formation's marly limestone. The Shiranish Formation's upper contact is unconformable with overlain Paleogene deposits and is found at the bottom of the Kolosh Formation's sandstone or siltstone bed.

The Shiranish Formation was mostly deposited in four facies zones: FZ1 (Deep Sea), FZ2 (Deep Shelf), FZ3 (Toe of Slope), and FZ5 (Slope). It reflects changes in the relative sea level and basin's paleotopography. The Shiranish Formation successions represent the sediments' transgression process during the Late Campanian-Maastrichtian period.

The asymmetry of these cycles reflects a mismatch between the relative sea level and carbonate production. Each cycle reflects the time it takes for sea levels to rise after a stillstand, because of a significant transgression, where successive episodes of sea-level rise and stillstands, the Shiranish Formation was deposited on a strong subsidence carbonate base. The two-sequence boundary is used to describe this surface (SB-2), the Shiranish succession develops in the study area in an area of high subsidence. The subsidence acts as the primary controlling factor in sequence growth.

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