Microfacies Analysis and Stratigraphic Development of the Shiranish Formation Late Cretaceous (Maastrichtian) in Mergasur Area, Northern Iraq

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Abstract

A petrographic and microfacies analysis was conducted to understand better the sequence development of Shiranish Formation in Mergasur area within Erbil governorate (Lailuk section), Northern Iraq. These analyses interpreted the depositional environment, an essential aspect of stratigraphic analysis. Shiranish Formation is overlying Bekhme Formation in Lailuk region, with an unconformable contact. Shiranish series consists of four main microfacies: lime mudstone, wackestone, packstone, and grainstone. These microfacies are further divided into seven sub-microfacies: planktonic foraminiferal lime mudstone, planktonic foraminiferal lime mudstone to wackestone, planktonic foraminiferal wackestone, bioclastic planktonic foraminiferal wackestone, bioclastic planktonic foraminiferal wackestone to packstone, planktonic foraminiferal packstone, and planktonic foraminiferal packstone to grainstone. The sub-facies are associated with four discrete depositional settings: profound shelf, abyssal or cratonic deep basin, incline, and the inclined base. The studied region, Shiranish Formation, contains three asymmetrical depositional sequences (A, B, and C). The sequence disparity suggests a correlation between sea level and carbonate production variation. Asymmetrical cycles represent a phase of increasing sea level after a calm period. Shiranish sequence was formed over a discontinuous surface, creating a clear distinction from the underlying Bekhme Formation. The surface is represented using a type two-sequence boundary (SB-2). The Shiranish succession in the research region is created in an area of high subsidence. A significant transgression caused by a series of sea level occurrences resulted in the formation of the Shiranish Formation on a carbonate platform with significant subsidence. A significant transgression that caused several periods of sea level rise and stillstand is responsible for the formation of the Shiranish Formation on a carbonate platform that has seen significant subsidence. The depositional sequence stratigraphy, Shiranish sequences A to C, is distinguished by three maximum flooding surfaces (MFS-165, MFS-170, and MFS-175). These sequences have a notable correlation with comparable stratigraphic patterns reported in Iraq and other regions of the Arabian plate.

Keywords: Sequence stratigraphy; Facies analysis; Shiranish Formation; Northern Iraq

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1. Introduction

The Late Campanian-Maastrichtian sequence is the important succession in the stratigraphic evolution of Iraq and the North Arabian Plate. This sequence begins with a widespread rise in sea level that almost covers the whole country, which occurred after the termination (Budy, 1980). The Southern Neo-Tethys Basin underwent closure and obduction in the Late Campanian and Maastrichtian epochs due to the collision of the Arabian and Iranian Plates' continental crusts. The Shiranish Formation was formed in a dynamic foreland basin during the early development of the Zagros belt, which occurred due to the shift from a passive edge (Jassim and Goff, 2006). The formation of the NW-SE and E-W interpolated extensional and trans tensional basins, which follow the NW-SE and E-W trends, respectively, was caused by the same stress regime on the northeastern Arabian Plate (Jassim and Goff, 2006).

The Shiranish Formation gets its name from the Islam Shiranish region of northwest Iraq by Henson (1940). It consists of argillaceous to marly limestone, marl, and thinly bedded shales with 225 m in thickness (Jassim and Goff, 2006). Alsultan et al., (2022) have discovered that the marly limestone bed of the Shiranish Formation and the relatively thick limestone bed of the Bekhme Formation provide evidence for the uninterrupted lower boundary between the Shiranish Formation and the Bekhme Formation. However, the Paleogene deposits could not conform to the Shiranish Formation's upper boundary.

The paleogeographic map of the Late Campanian-Early Maastrichtian period displays five separate bands representing different depositional settings (Fig. 1). The Balambo-Tanjero Zone experienced the development of various types of environments. These include carbonate shoal environments in the Hartha Formation, carbonate lagoon environments in the Hartha Formation, outer shelf to basinal environments in the Shiranish Formation, and carbonate platform in the Bekhme Formation (Buday and Jassim, 1987).

Al-Naqib (1959) observed that the tectonic activity throughout the Upper Cretaceous period impacted the properties, distribution, and thickness of the Shiranish Formation. The formation was separated into many subzones based on the composition of planktonic foraminifera (Al-Kassab, 1979). The periods of the Late Maastrichtian and Campanian.
The High Folded Zone contains the Shiranish Formation in the Sandor Villages (Dohuk Governorate) and Lailuk Town near Mergasur (Erbil Governorate). The study section is mostly composed of Cretaceous-aged carbonate-sedimentary rocks. The eroded cores and anticline limbs often exhibit visible strata. In the Mergasur area, the Shiranish Formation is situated below the Bekhme Formation and above the Tanjero Formation. In the Sandor area, it is positioned between the Kolosh Formation and the Bekhme Formation. Budy (1980) noticed that both the Bekhme and Aqra formations diminished quickly, resulting in narrow segments inside the Shiranish Formation (Fig. 2). The research region is situated in northern Iraq's high-folded zone (Fig 3). The structure in the examined area has a thickness of approximately 225 meters (Jassim and Goff, 2006; Tamar-Agha and Basi, 2021). The Shiranish Formation is a portion of a regional transgressive-regressive depositional series from the Upper Cretaceous (Campanian and Maastrichtian) that inundated almost the whole of Iraq (Dunnington, 1958; Chatton and Hart, 1961; Karim and Surdashy, 2005; Karim et al., 2008; Kent, 2010).

Fig. 2. Lithostratigraphy correlation of the Late Cretaceous succession in Iraq (after van Bellen et al., 1959; Jassim and Goff, 2006)

2. Materials and Methods

A total of 75 samples were taken from the Shiranish Formation at Mergasur within the Lailuk Village, Erbil Governorate, northern Iraq. The outcrop part is situated, between 36° 47' 41.83'' N and 44° 22' 38.49'' E (Fig. 3). The hardness of the beds, variations in fossil richness, and facies alterations in lithology and color were taken into consideration throughout the sampling selection process. Thin sections were analyzed in the applied geology department laboratories, College of Science, University of Babylon. Using a polarized microscope, thin sections were examined, and the microfacies approach was used following the Dunham (1962), Wilson (1975), and Flügel (2010) methods to ascertain the deposition environment.

The fieldwork revealed that the lithological description of the Shiranish Formation is divided into three portions in Mergasur, Erbil Governorates: the lower part is mostly composed of strong, thick, dark gray marl and marly limestone with 3.5 to 41 cm in thickness. In addition, there are layers of limestone and shale with a thickness of 5–30 cm in the lower part (Fig. 5). The middle part contains marl and marly limestone, despite the soft nature of these strata. The marly limestone is colored in shades of gray.
and dark gray with about 25 and 35 cm in thickness. While, limestone, marl, and marly limestone alternate in the upper part with varied thicknesses of the marl and marl limestone ranging between about 8–42 cm and about 12–23 cm, respectively. The contact between the Shiranish Formation and the Bekhme Formation is unconformable. The upper boundary of the Shiranish Formation is marked by the siltstone or sandstone layers of the Tanjero Formation (Fig. 4).

**Fig 3.** Location of the study area

This study aims to gain a deeper understanding of the geological changes and the process of sediment deposition in the Shiranish Formation within a specific area in northern Iraq. Bekhme Formation is unconformable. The upper boundary of the Shiranish Formation is marked by the siltstone or sandstone layers of the Tanjero Formation (Fig. 4).

**Fig 4.** Shiranish formation in Erbil-Soran (Lailuk Fig.5. Upper part contact is gradational between village) Blue marle and gray marly limestone. Shiranish and Tanjero formations
3. Results and Discussion

3.1. Depositional Microfacies

The Shiranish Formation carbonates were classified following Dunham (1962), Wilson (1975), and Flügel (2010) classification into mud or grain-supported textural types. Seven principal microfacies units are recognized, through all the studied samples depending on the present fossils and lithological characters as a basis for division. These seven principal microfacies include lime mudstone, lime mudstone to wackestone, wackestone, wackestone-packstone, packstone, packstone–grainstone, and marl microfacies which are subdivided into nine sub-microfacies as follows (Fig. 6):

3.1.1. Bioclastic planktonic foraminiferal wackestone sub microfacies (Sh1)

This microfacies, which is located in the middle and upper portions of the formation, is mostly composed of dark brown micrite that has been combined with iron and organic oxides, micrite with a small amount of quartz-rounded grains, and a small percentage of skeletal grains that are primarily made up of planktonic foraminifera. It is widely distributed among the middle and upper regions of the Shiranish Formation. Additionally, these skeletal grains consist predominantly of planktonic foraminifera. The matrix consists of micrite, uncommon calcispheres, and sponge spicules; it is less bioclastic than echinoderms and planktonic organisms. It is a member of the standard microfacies (SMF3) in FZ1, often referred to as the deep sea (Plate 1. a), in contrast to Wilson’s (1975) standard microfacies types.

3.1.2. Planktonic foraminiferal lime mudstone to wackestone microfacies(Sh2)

This microfacies is present throughout the Shiranish Formation, including in its lowest part. It consists of small, rounded quartz grains of external origin scattered within a matrix of brown micrite (Plate 1 b). Skeletal grains are primarily composed of planktonic foraminifera with circular forms, such as Globigerinelloides, and fewer echinoderms and bioclastic planktonic organisms. It is identical to the standard microfacies (SMF2) throughout the facies zone (FZ1, FZ2, and FZ3), which represents the basin environment.

Plate1: (a) Bioclastic planktonic foraminiferal wackestone microfacies, (b) Planktonic Foraminiferal lime mudstone to wackestone microfacies

3.1.3. Planktonic Foraminiferal Wackestone microfacies (Sh3)

One of the most prevalent facies of the Shiranish Formation in the study section, it contains more than 70% of the granular components in the planktonic foraminifera. These shells include groups of
foraminifera (such as *Globigerinelloides* sp., *Rugoglobigerina rugosa*, *Rugoglobigerina*, *Hexacamerata* sp., *Heterohelix*, and *Globotruncanella* sp.) and some benthonic foraminifera genera. Additionally, this facies is known to contain calcispher shells, authigenic minerals like pyrite, a spherical skeletal component with well-sorted skeletal components, and groundmass that is micrite and microsparite (Plate 2. a). The microfacies were present in the middle and upper sections of the Shiranish Formation. In comparison to Wilson's standard microfacies (1975), it is identical to the standard microfacies (SMF3) in FZ1, which represents the basin environment.

3.1.4. Bioclastic plankton foraminiferal wackestone microfacies (Sh4)

These submicrofacies were shown to be more frequently present in the middle than in the higher portions of the Shiranish Formation. It has a decreased Heterohelix content and skeletal grains composed mostly of planktonic Foraminifera (*Globotruncanana*). In addition to the bioclasts of foraminifera, the benthic foraminiferal grains and authigenic minerals include pyrite, iron oxides, and quartz grains. There were skeleton grains strewn across a richly organic, dark brown micrite ground. Included in the skeletal grains was the dark brown micrite matrix rich in organic substances. Plate 2. b, depicts the facies zone (FZ1) where this facies scales with the standard facies (SMF-3).

3.1.5. Bioclastic planktonic foraminiferal wackestone to packstone microfacies (Sh5)

This particular submicrofacies exhibits a wide distribution among the skeletal grains and is found predominantly in the middle and upper sections of the Shiranish Formation. The main components of this are spherical chambered planktonic foraminifera, such as those from the genus *Globigerina* sp., *Glotrenchana* sp., and *Globigerinelloides* sp., shells of *Heterohelix* sp., *Hedbergela* sp., and Calcispher. This microfacies contains spot pyrite, some iron oxides, and scattered skeletal grains within the microspar matrix (Plate 2. c). Within the recognized deep sea and cratonic deep facies zone (FZ1, FZ2), lies the standard facies of SMF1.

Plate 2: (a) Planktonic foraminiferal wackestone microfacies. (b) Bioclastic plankton foraminiferal lime wackestone microfacies. (C) Bioclastic planktonic foraminiferal lime wackestone to packstone microfacies. (d) Planktonic foraminiferal lime packstone. (e) Planktonic foraminiferal lime packstone to Grains tone.
3.1.6. Planktonic foraminiferal packstone microfacies (Sh6)

This microfacies is present in both the upper and lower parts of the Shiranish Formation and includes the skeletal details of planktonic foraminifera with spherical chambers, such as *Globigerina* sp. members, *Globigerinelloides* sp., and *Heterohelix* sp., and Calcispher shells. This microfacies has some iron oxides and spot pyrite scattered throughout the microspar matrix in addition to the skeletal grain (Plate 2.d). It was discovered on the standard facies (SMF-4) scale, within the facies zone (FZ3).

3.1.7. Planktonic foraminiferal packstone to Grainstone microfacies (Sh7)

The microfacies are found extensively in the lower sections of the Shiranish Formation. The majority of the composition is comprised of planktonic foraminifera, particularly those from the genera *Globigerina* sp., and *Globigerinelloides* sp. Additionally, it includes the distinctive shells of *Heterohelix* sp., and *Hedbergela* sp (Plate 2e). This microfacies, which was deposited inside the facies zone (FZ4), is found in the scale standard facies (SMF-5). It is composed of skeletal grains scattered throughout matrix microspar, together with some iron oxides, spot pyrite, and glauconite.

3.1.8. Highly Fossiliferous Marl Subfacies (Sh8-A)

A significant portion of the planktonic foraminifera (including *Globigerinelloides* sp., *Hedbergella* sp., *Pseudotextularia elegans*, and *Globotruncanella* sp.) are found in the hard portion of the Subfacies (Plate 2-a). According to paleontological data, this facies is located in the intermediate to outer bathyal habitats (Gibson, 1989).

3.1.9. Poorly fossiliferous marl subfacies (Sh8-B)

The thin *Rugoglobigerina macrocephala*, *Globigerinelloides* sp., *Pseudotextularia elegans*, and *Pseudogoumbelina* sp. make up this soft marl Subfacies (Plate 1-a). The sub-facies have a moderate shelf environment, according to Sedimentological and paleontological evidence (Gibson, 1989).

3.2. Depositional Environments

The Shiranish Formation’s successions show how sediments moved throughout the Late Campanian–Maastrichtian epoch. The depozone fore deep mid-unit (Pelagic) in the underfilled foreland basin stage 3 is a tectonostratigraphic unit that correlates with the Shiranish Formation. The four different settings are described as follows: A bioclastic foraminiferous packstone is one of the ecosystem's constituents in the slope habitat. It is widely distributed in Algal plates, Mollusca shells, and pieces of Echinodermata, all of which are fossils generated from reefs and seem to be teeming with plankton red algae, and based on a biostratigraphic zonation, containing certain kinds of both benthic and planktonic foraminifera. The formation was determined as Upper Campanian–Late Eocene age, and various sizes of benthic foraminifera are present (Abdallah and Al-Dulaimi, 2019; Alsultan and Awad, 2021). This site is inside the slope zone based on the conventional microfacies stated in Flügel (2010) and (Wilson, 1975). The lowest part of the formation is composed of slope sediments. The finding of fossilized grains associated with reefs in planktonic foraminifera, echinoderm, and ostracod shells served as its basis.

The toe of the slope is made up of a bioclastic foraminiferous wackestone with lower concentrations of echinoderms, benthic, and planktonic foraminiferous detritus. Reworked kaolinite grains and minerals associated with planktonic foraminifera, echinoderm, and ostracod shells formed their basis.
Furthermore, a range of small and large benthic foraminifer species are present in these units. Red alga indicates that the slope's deposition is occurring slowly (Mohammad and Alsultan, 2023). Biological components, micrite, silicate particles, calcareous content, and other fine materials are from the deep shelf habitat. The depositional environment of the Shiranish Formation comprises sedimentary material derived from deep marine zones, the deep marine environment contains skeletal grains consisting mainly of planktonic foraminifera. The bioclasts are mostly fine and unidentifiable, and coarser bioclasts of rudist and few benthic foraminifera with variations based on the grain character and matrix (Al-Dulaimi and Abdallah, 2019). The environment is characterized by its deep and quietness, which is indicative of pelagic conditions, as evidenced by the reduced presence of benthic foraminifera and the presence of fine sediments containing characteristic planktonic foraminifera. The Shiranish Formation facies and the deep ocean can contain planktonic foraminifera species, such as *Rugoglobigerina rugosa* and *Heterohelix* sp. (Alsultan et al., 2022).
3.3. Stratigraphic Development

Three depositional sequences—designated Shiranish sequences A to C were interpreted from Late Cretaceous deposits of the Shiranish Formation in Mergasur, Erbil Governorates. The series is characterized by sequence borders (SB), transgressive system tracts (TST), maximum flooding surfaces (mfs), and highstand system tracts (HST). The thickness of the sequence varies from 30 to 100 m (Fig. 6). The sequence A starts with planktonic foraminiferal packstone to grainstone submicrofacies, which are mainly made up of spherical-chambered planktonic foraminifera (Abdallah, 2019). It also includes the unusual *Heterohelix* sp. and *Hedbergela* sp. shells, which are rich in planktonic fossils derived from reefs. The alteration is from planktonic foraminiferal lime mudstone to wackestone, and the presence of extremely fossiliferous marl Subfacies suggests an increase in depth. The transgressive system tract (TST) is situated above the Bekhme Formation, separated by a type 2 sequence boundary (SB2). The transgressive and regressive cycle of Shiranish and Bekhme formations represent TST and HST, respectively. Wackestone submicrofacies of planktonic and bioclastic plankton foraminiferal reflect the High Stand System Tract (HST). The Maximum Flooding Surface (mfs) of this cycle is situated inside the central region of the very fossil-rich marl Subfacies.

There is evidence of a notable flood during the Early Campanian period in northern Iraq, as suggested by a "higher order" mfs (K165) according to (Sharland et al., 2001). According to Van Bellen et al., 1959, the upper portion of the Early Campanian Mushorah Formation in the Mushorah-1 well serves as the reference section for this Maximum Flooding Surface (mfs). The possibility of connecting the MFS of Shiranish Sequence A with the MFS K 165 is plausible because the K160 MFS, being of Middle Santonian age, is too old to have caused the floods in the Early Campanian. In sequence B, the facies Sh8-B, Sh8-A, Sh3, and Sh1 are deposited first, then the Poorly Fossiliferous Marl. As seen by the rising proportion of planktonic foraminifera, these facies signify the transgressive system tract (TST) of the sequence and reveal increasing sea depth upward. The percentage of Keeled planktonic foraminifera reaches its highest (33% in the facies) at the top of facies Sh8-A, which is designated as the MFS. A shallow environment pointing upward is shown by the upper portion of Sh8-A, the facies Sh2, Sh8-B, and Sh2, capped by the facies Sh6. This suggests the High Stand System Tract (HST) of the series. According to Wagner and Pehlivan, 1987, the mfs K170 is found in the basal carbonates of the Sayindere Formation in southeast Turkey. It has also been recorded from Syria, the species is located inside the intra-Erek Marl component of the Sawwanet Formation in the western outcrop and at the base Tayarat Formation shelf carbonates in southeast Euphrates Graben (Ponikarov, 1967; de Ruiter et al., 1995).

Moreover, the oligosteginal carbonates found at the foot of the Hartha Formation are situated in southern Iraq (Van Bellen et al., 1959; Buday, 1980; Sadooni, 1996; Alrashedi, 2013). It can also be found in the bottom of the Shiranish Formation at the Khabaz oil field, northwest of Kirkuk City, Northern Iraq (Al-Juboury, 2011). Therefore, there seems to be a correlation between the MFS (Maximum Flooding Surface) of Shiranish series B and the MFS of K170. The higher SB (Shiranish B) is classified as Type 2, and the series has a duration of fewer than 5.0 million years.

Sequence 3 commences with the deposition of Facies Sh8-A. The subsequent facies, Sh2 and Sh8-B, exhibit a progressive deepening of water and a notable augmentation in the abundance of planktonic foraminifera (Both faces symbolize TST. The MFS is located at the basal portion of the Sh2 facies, which coincides with the area exhibiting the greatest abundance of planktonic foraminifera. The HST is defined by the midline part of facies Sh2 followed by facies Sh6. Both facies indicate a transition to shallower depths. The upper sequence boundary (SB) of the Maastrichtian Tanjero Formation is composed of Type 2 bedded sandstone. Sadooni, 1996 and Sharland et al., 2001, have proposed a possibly important "higher order". 
The carbonate shelf systems in central Iraq during the Mid-to-Late Campanian period experienced temporary submergence due to the mfs event known as K175. The MFS (K175) was found in the Ahdab-1 well in Iraq, specifically around the base of the Hartha Formation (unit H6). It was determined to be from the Late Campanian period based on dating conducted by Van Bellen et al. (1959) and Al-Kassab (1979). Furthermore, this was found in northern Iraq at specific sites: the lower section of the Agra Formation (Agra sequence 1) in Gali Zanta Gorge, the middle section of the Shiranish Formation in the Bekhme area, and the upper section of the Shiranish Formation (Kz sequence 2) in the Khabaz oil field (Al-Juboury, 2011; Alrashedi, 2013; Malak and Al-Banna, 2014). It appears feasible to establish a correlation between the mfs (Mean Foraminiferal Size) of Shiranish Sequence C and mfs K-175 in this way.

4. Conclusions

Nine sub-microfacies comprise the seven main microfacies types in the Shiranish sequence, which are lime mudstone, lime mudstone to wackestone, wackestone, wackestone-packstone, packstone, packstone-grainstone, and marl microfacies. The Subfacies represent four different depositional settings: deep shelf, deep sea or cratonic deep basin, slope, and the toe of the slope.

Three distinct depositional sequences A, B, and C can be identified within the Shiranish Formation. The asymmetry of these sequences indicates an imbalance in the relationship between sea level and carbonate production. These asymmetrical cycles signify a rising sea level phase that follows a time of quietness. The Shiranish sequence was developed on an unconformable surface, which separates it from the underlain Bekhme Formation.

A type two-sequence boundary (SB-2) is used to represent this surface. Since high subsidence is the primary governing element in sequence development, the Shiranish succession in the research region is created in an area of high subsidence. A significant transgression caused by a series of sea level occurrences resulted in the formation of the Shiranish Formation on a carbonate platform with significant subsidence. A significant transgression that caused several periods of sea level rise and stillstand is responsible for the formation of the Shiranish Formation on a carbonate platform that has seen significant subsidence. With three maximum flooding surfaces (MFS 165, MFS 170, and MFS 175), this depositional sequence stratigraphy—designated Shiranish sequence A to C displays a strong link with those found in Iraq and other regions of the Arabian plate.

References


