Bulletin of the Geological Society of Malaysia, Volume 71, May 2021, pp. 47 - 55
DOI: https://doi.org/10.7186/bgsm71202104

Stratigraphic and microfacies study of Upper Campanian - Lower Maastrichtian succession (Shiranish Formation) in Bade village, Bekhere anticline, Kurdistan region, northern Iraq

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Abstracts: The Upper Cretaceous Shiranish Formation outcropped close to Bade village and Bekhere anticline, Kurdistan region at northern Iraq and consists of alternating mixed tough grey limestone, marly limestone, marl beds interpreted as a middle - outer shelf – upper bathyal environments (basinal) depositional environment. Fifteen thin sections were studied under a polarized microscope to find out the petrographic component, fauna content, and for microfacies analysis. The major petrographic constituents are fossils, bioclastic grains, micrite matrix, and extraclast (quartz grains). Planktic foraminifera and nannofossils are the major particles within wackestone and packstone microfacies types. The planktonic foraminifera biozones from previous study (such as *Globotruncana aegyptiaca, Gansserina gansseri, Racemiguembelina fructicosa, Plummerita hantkeninoides*) and the recorded calcareous nannofossils biozones of *Broinsonia parca, Reinhardtites levis, Arkhangelskiella cymbiformis,* suggest a late Campanian to late Maastrichtian age.

Keywords: Upper Cretaceous, Shiranish Formation, planktonic foraminifera, nannofossils, Kurdistan region, Iraq

INTRODUCTION

The Shiranish Formation was first described near the village of Shiranish Islam, northeast of Zakho, from the High Folded Zone of northern Iraq by Henson, 1940 (in Van Bellen *et al.,* 1959). In the type section, the Shiranish Formation consists of thin-bedded argillaceous limestones, dolomitic in the same interval of the formation and overlain by blue pelagic marls. Some conglomerates (carbonate gravels) occur locally in the formation, resulting from slumping in the Sinjar area at north-western Iraq (Al-Mutwali & Al-Juboury, 2005). The Shiranish Formation is about 225 m thick in the type section and the thickness varies in other outcrops from 100 to 400 m, reaching 1500 m subsurface especially in well Sasan-1. The Shiranish Formation has been described too by Al-Shaibani (1973) in Azmer area, north Sulaimani and he mentioned that the formation is consisting of blue and yellowish marls interbedded with layers of marly limestone. Kassab (1973) studied the formation in Shiranish area, northeast of Zakho city, and determined the age as Middle Campanian-Upper Maastrichtian.

Kaka (2010) studied the formation from an exposed section in the northern part of Erbil city and divided the formation into two microfacies, which reflected the depositional environments as marine deep shelf margin to the deeper basin.

Jan *et al*. (2012) studied the formation at Hijran village at northeastern Iraq and mentioned that the formation was deposited in a quiet deep marine environment. Bamerni (2010) stated that the formation was deposited from the outer shelf to middle bathyal depositional environments under tropical to subtropical climate conditions in Khanke well No. 1 at Duhok area, north Iraq. And based on Alsharafani (2013), the Shiranish Formation was deposited in deep marine (upper bathyal) to outer shelf setting in Dokan Dam and Rowanduz areas, northeastern Iraq.

According to Malak (2015), the Shiranish Formation is divided into five subzones that refer to the Late Campanian-Early Maastrichtian age, and the formation has been deposited in shallow-marine, middle-outer shelf and upper-middle bathyal depositional environments.

Al-Badrani (2012) investigated the lower part of the Shiranish Formation in Sinjar anticline and concluded that the section is Late Campanian in age. According to Al-Mutwali & AL-Doori (2012), the formation is middle Late Campanian to the latest Maastrichtian at the Duhok area, northern Iraq.

Ameen & Gharib (2014) recorded two planktonic foraminiferal zones and these are related to the *Globotruncana* (*fornicata, stuartiformis, elevata,* and *ventricosa*) assemblage zone, *Globotruncana calcarata* total range subzone, from the Shiranish Formation, in the Sulaimani area of lower Late Campanian, while the second zone is nominated as the *Globotruncana* (*arca, tricarinata, esnehensis*, and *bahijae*) assemblage zone, *Globotruncana gansseri* interval subzone, and *Globotruncana contusa* total range zone of the Late Campanian to basal middle Maastrichtian age.

Jaff *et al.* (2014) recorded these zones from Shiranish Formation in Sulaimani area, *Globotruncana aegyptiaca* (Late Campanian), *Gansserina gansseri* (latest Campanian–Early Maastrichtian), and *Contusotruncana contusa* (late Early Maastrichtian).

The Shiranish Formation in Shkawtua village of North Iraq consists of mixed siliciclastic and carbonate strata interpreted as an outer shelf open marine (basinal) depositional environment, and suggests an Upper Cretaceous age of the formation (Abdula *et al*., 2018). Al-Maamari & Al-Badrani (2019) studied the calcareous nannofossils of Shiranish Formation from well K-306 at northern Iraq and determined five biozones that refer to the upper Campanian Maastrichtian age.

The Shiranish Formation conformably overlies the Bekhme Formation at the type area. Whereas in Dokan area, the formation unconformably overlies the older Cretaceous formation namely the Kometan Formation (Malak, 2015; Lawa, 2018), the same contact appears to be gradational in the Chaq Chaq stream near Sulaimani City (Al-Badrani, 2012). In the Hijran area near Shaqlawa, the formation rests unconformably on the Upper Qamchuqa Formation (Yahya & Al-Shammary, 1993). The Shiranish Formation is underlain by the Bekhme Formation at the southern limb of Bekhair anticline, Dohuk area, northern Iraq (Al-Mutwali & AL-Doori, 2012). While at Hijran section, about 10 km west of Shaqlawa town, northeastern Iraq, the lower contact is conformable with the Bekhme Formation (Jan *et al*., 2012).

The formation is overlain unconformably by the Kolosh Formation at the southern limb of Bekhair anticline, Dohuk area, northern Iraq (Al-Mutwali & AL-Doori, 2012), and unconformable surface with the Aliji Formation (Jambour-46, 49, Pulkhana 1–7, Sarqala-1–2, Kirkuk-306, 106 wells) (Van Bellen *et al*., 1959; Buday 1980; Al Qayim *et al*., 2008; Jaff *et al*., 2014).

At Hijran section, the upper contact of the formation is conformable with the Aaliji Formation (Aba-Hussan, 1983), and also with Tanjero Formation in Sulaimani and Erbil areas and in the Shkawtua village near Mergasur town (Lawa, 2018: Abdula, 2018).

The age of the formation at the type locality is Late Campanian-Maastrichtian (Kassab, 1973). While in the Sinjar area the age may be extending to the Late Maastrichtian (Al-Mutwali & Al-Juboury, 2005), and extended from middle Late Campanian to the latest Maastrichtian at Khanki well no. 1, Duhok city (Bamerni, 2010) and at the southern limb of Bekhair anticline (Al-Mutwali & AL-Doori, 2012). The age may be further extended to the Paleocene based on the foraminifera in the Hijran area (Hammoudi, 2011).

Jaff *et al.* (2014) recorded the age of the Shiranish Formation to be of late Campanian to early Maastrichtian in the Sulaimani area.

This study aims is to describe the lithology, vertical and horizontal facies changes, petrophysical properties, in addition to record the calcareous nannofossils content and establish the biostratigraphic zones and correlate them with their equivalent biozones in and regional Iraq to determine the age of the studied section. Another goal of this study is to identify the microfacies and make a conclusion of the depositional environment of the formation.

The Shiranish Formation is a part of the Arabian plate Megasequence AP 9, which is exposed in the imbricate zone, high folded thrust zone and within subsurface sections of the low folded thrust zone (Kirkuk embayment) (Jassim & Goff, 2006; Aqrawi *et al.,* 2010; Sharland *et al*., 2001; Lawa *et al.,* 2013). The Shiranish Formation has a wide geographic portion in Iraq and the surrounding countries, having outcrops in several localities within the High Folded Zone (Buday, 1980).

The studied section crops out on the northern limb of Bekhair anticline, 8.5 km north-east of Duhok city, and about 1.27 km south western of Bade village. The predominant rock units in the studied area are carbonate-sedimentary rocks. The latitude of the location is approximately 36° 5307" N and the longitude is about 43° 0500" E (Figure 1).

The Shiranish Formation is about 58 m thick and unconformably overlies the Late Campanian Bekhme Formation (Al-Mutwali & Al-Haidary, 2012) and is unconformably overlain by the Early-Late Paleocene Kolosh Formation (AL–Wazan, 2007).

MATERIALS AND METHODS

The recent study is based on an accurate field lithological description. The thickness of the beds was measured and the physical properties of the formation rocks were recorded. Fifteen samples were collected for petrographic thin section analysis based on vertical changes in lithology. Dunham (1962) classification was used to classify and name the facies. The sedimentological and paleontological evidence were used to identify and determine the depositional environment and the age of the formation. The samples of Shiranish Formation were selected for studying the calcareous nannofossils using the thin section (under a transmitted-light microscope). The calcareous nannofossils were extracted using the method H (Armstrong & Brasier, 2005).

Lithofacies description

The Shiranish Formation at Bade village can be divided into two parts depending on the high abundance of marl: the lower part of this formation (23 m) thick, consists mainly of tough, pale grey limestone and marly limestone beds of 5 to 55 cm thick. While the upper part is 25 m thick, consisting generally of marl beds alternating with marly limestone beds. The marly limestone is grey to light grey in color (Figure 2a & b and Figure 4).

The marl beds are about 15 cm to 7 m thick, and the thickness of marly limestone is about 10 to 50 cm (Figure 2b). The lower and upper contacts of the formation are unconformable with Late Campanian Bekhme Formation (Al-Mutwali & Al-Haidary, 2012) and the Early Paleocene Kolosh Formation (AL–Wazan, 2007), respectively.

Microfacies analysis

The Shiranish Formation is composed of three main microfacies denoted as SH 1, SH 2 and SH 3, which reflects the depositional environments.

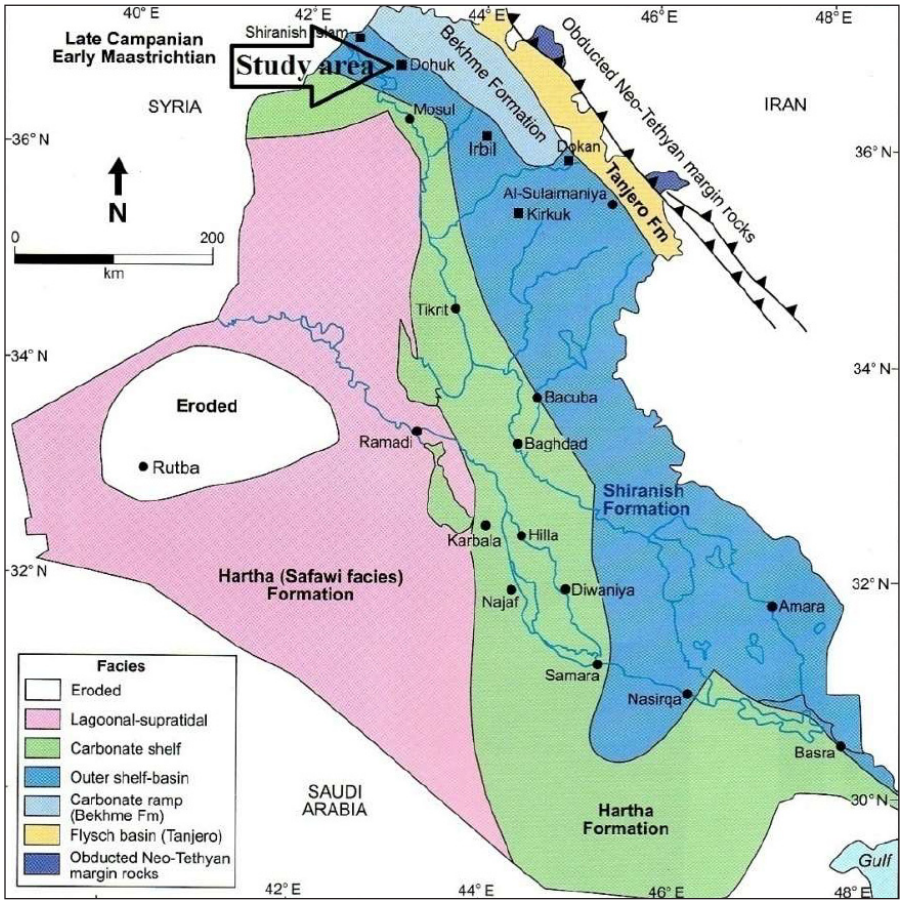

Figure 1: Location of the studied section (Dohuk City), northern Iraq (after Jassim & Goff, 2006).

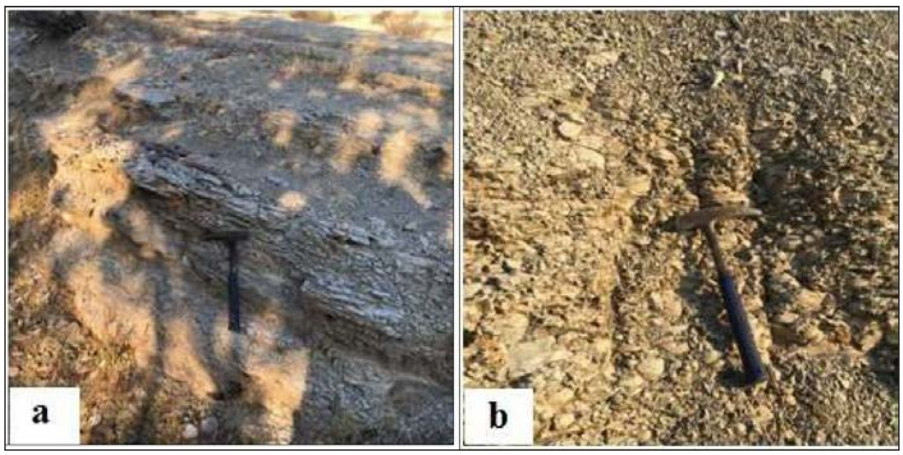

Figure 2: a) Grey marly limestone beds at the lower part, and b) marl beds at the upper part of the Shiranish Formation.

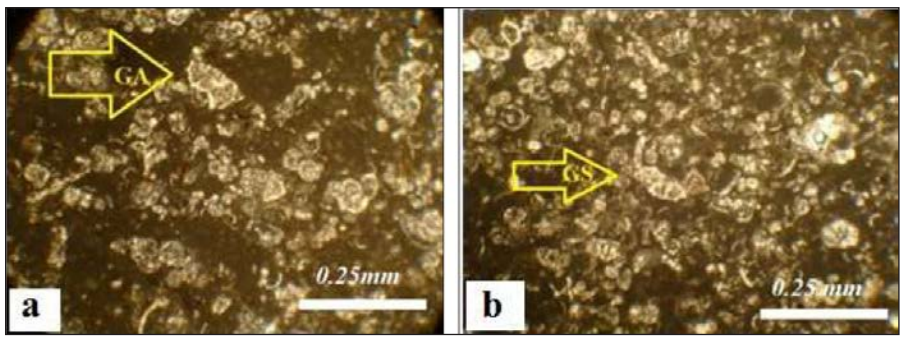

Figure 3: Images show planktonic foraminifera a) *Globotruncana aegyptiaca* (GA), b) *Globotruncanita stuarti* (GS).

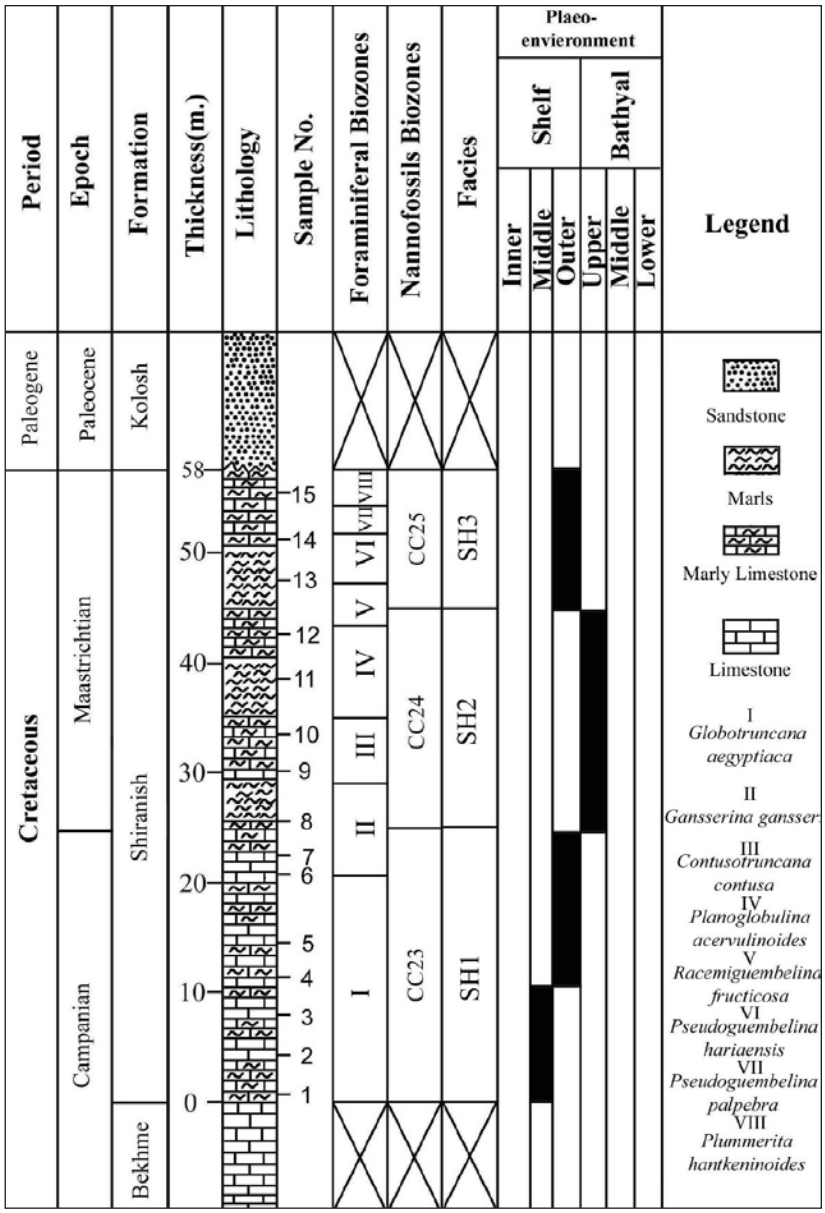

Figure 4: Lithological description, planktonic foraminiferal zones, nannofossils zones, microfacies and depositional environment of the Shiranish Formation in Bade section.

1 – Keeled foraminiferal lime wackestone – packestone microfacies (SH 1)

This microfacies is represented by grey marly limestone and limestone (25 m thick) that appear at the lower part of the formation, in which allochems make about 45-70% of the total content. The dominant keeled planktic foraminifera are *Globotruncana aegyptiaca* (Figure 3a-GA), *Globotruncana ventricosa, Globotruncana bulloides, Globotruncana rosetta*, *Globotruncanita stuarti* (Figure 3b-GS), and *Globotruncanita stuartiformis*. A small amount of benthic foraminifera is present as *Globorotalites* sp., *Gavelinella* sp., *Bolivinasp* and *Gyroidina* sp. These genera have a normal size and good preservation. Micrite forms most of the matrix of the microfacies. The facies are affected by dissolution that created vugs, intraparticle, and moldic porosity at some intervals of the sections.

2 – Foraminiferal lime packestone microfacies (SH 2)

These microfacies appear in the middle part of the formation and is about 20 m thick. The allochems of this microfacies range between 40–65% of the total microfacies content. The microfacies consists primarily of globular foraminifera species as: *Gansserina gansseri, Contusotruncana contuse, Planoglobulina acervulinoides, Heterohelix navarroensis, Planoglobulina carseyae, Globotruncana ventricosa. Globotruncana rosetta* (Figure 5a-Gr), *Globotruncanita conica* (Figure 5b-Gc), with few benthonic foraminifera

(*Gyroidinoides*, *Cibicidoides*, *Osangularia*, *Gavelinella*), and a secondary amount (25%) of bioclastic grains (plankton and benthonic foraminifera, echinoderm, Pelecypoda). The horizontal lamination of allochems (planktonic foraminifera tests) is present. Micrite forms most of the matrix of the facies and microsparite fills the chambers of some forams.

3 – Bioclastic lime packestone microfacies (SH 3)

This microfacies is recorded from the upper part of the formation (13 m thick). The allochems percentage is about 55 % of the total microfacies content, consisting of foraminiferal bioclasts in addition to pelecypods tests and no distinct benthonic foraminifera. A small amount of planktonic foraminifera are present as *Racemiguembelina fructicosa*, *Pseudoguembelina hariaensis*, *Pseudoguembelina palpebra*, *Plummerita hantkeninoides*, *Globotruncanita angulata*, *Heterohelix globulosa*, *Hedbergilla holmdelensis* (Figure 6a-H), and *Contusotruncana insignis* (Figure 6b-I). Extraclast (2%) of quartz grains is present. The paleontological evidence of this microfacies indicates to outer shelf environments of the facies (Gibson, 1989; Berggren & Miller, 1989).

Biostratigraphy and age determinations

Calcareous nannofossils biostratigraphy and age determination

Fifteen samples of limestone and marly limestone were selected for the study of the calcareous nannofossils using the thin section (under a transmitted- light microscope). The calcareous nannofossils were extracted using the method H (Armstrong & Brasier, 2005).

1 - Recorded species:

Arkhangelskiella cymbiformis Vekshina
Broinsonia parca(Stradner) Bukry
Ceratolithoides aculeus (Stradner) Prins and Sissingh in Sissingh
Chiastozygus platyrhethus Hill
Cyclagelosphaera argoensis Bown
Eiffellithuseximius (Stover) Perch-Nielsen
Eiffellithus turriseiffelli (Deflander and Fert) Reinhardt
Lithraphidites praequadratus Roth
Lithraphidites quadratus Bramlette and Martini
Micula murus (Martini) Bukry
Micula staurophora (Gardet) Stradner
Nannoconus sp.
Prediscosphaera sp.
Reinhardtitus levis Prins and Sissingh, in Sissingh
Watznaueria barnesae (Black and Barnes) Perch –Nielsen
Watznauria biporta Bukry

2 – Biostratigraphy:

Depending on the stratigraphic distribution of the recorded species, three biozones were identified by Murphy & Salvador, 1999 (Figure 7).

1) ***Broinsonia parca* Interval Biozone (CC 23) part**

Definition: Interval biozone of *Tranolithus phacelosus* Stover, 1966.

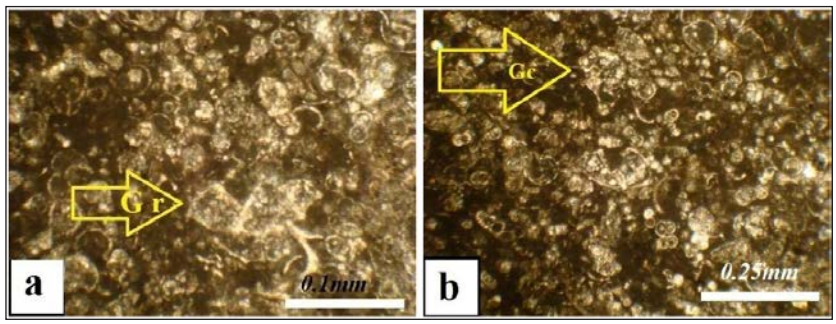

Figure 5: Images show planktonic foraminifera a) *Globotruncana rosetta* (Gr), b) *Globotruncanita conica* (Gc).

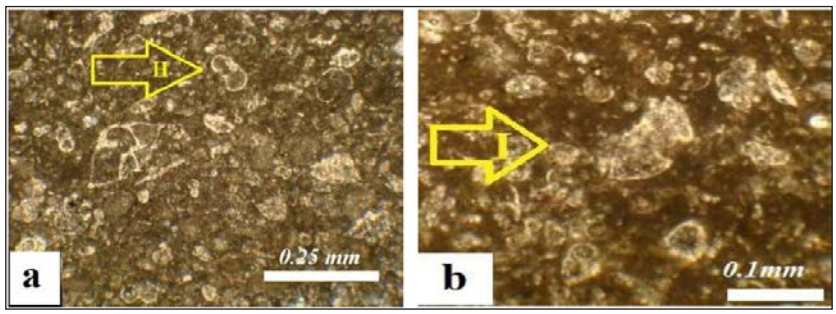

Figure 6: Images show planktonic foraminifera a) *Hedbergilla holmdelensis* (H), b) *Contusotruncana insignis* (I).

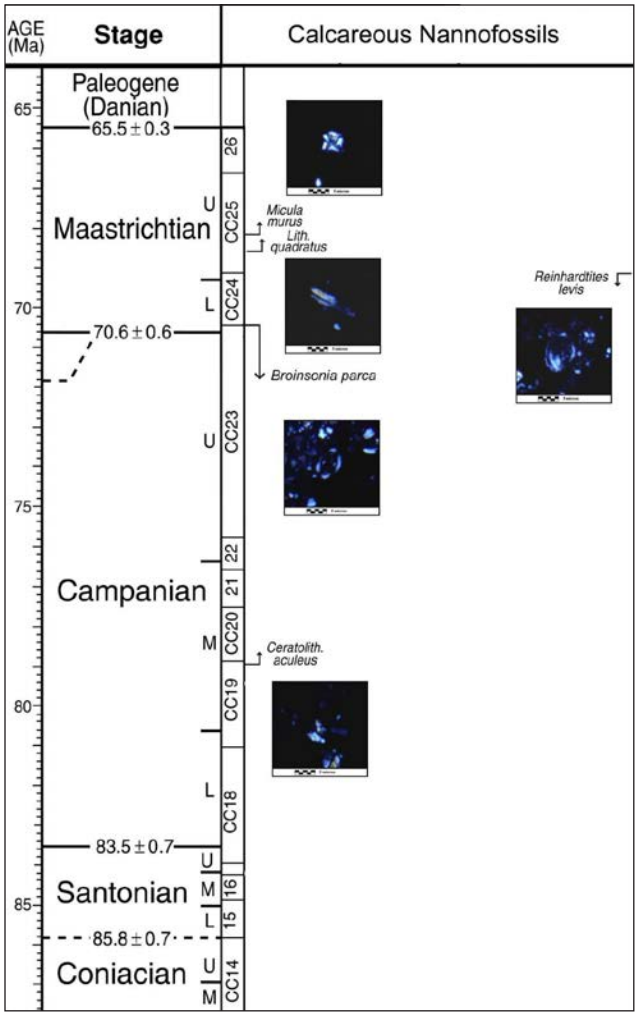

Figure 7: Age determination for the studied section.

Boundaries: Lower boundary of this biozone determinate by last occurrence *Eiffilithus eximus* (Stover, 1966) Perch- Nielsen, 1968 (not studied in this paper), to the last occurrence *Tranolithus phacelosus* Stover, 1966.

Thickness : 25 meter

Correlation and discussion: This biozone is correlated with CC23 (*Tranolithus phacelosus* biozone) which was studied by Sissingh (1977) with age of the late Campanian - early Maasterchtian, and correlated with UC16, UC17 biozone which was studied by Bown (1998), aged Campanian-early Maastrichtian age (Gradstein *et al*., 2012).

2) ***Reinhardites levis*** **Interval Biozone (CC24)**

Definition: Interval biozone of *Reinhardtites levis* Prins and Sissingh in Sissingh, 1977.

Boundaries: Lower boundary of this biozone determinate by Lastccurrence *Tranolithus phacelosus* Stover, (1966) to the Last occurrence *Reinhardtites levis* Prins and Sissingh in Sissingh, 1977.

Thickness: 20 meter

Correlation and discussion: This biozone is correlated with CC24 (*Reinhardtites levis* biozone) which was studied by Sissingh (1977) at the age of the late Campnian - early Maastrichtian, and correlated with UC18 biozone which is studied by Bown (1998) and aged Maastrichtian age (Gradstein *et al*., 2012).

3**) *Arkhangelskiella cymbiformis* Interval Biozone (CC25) part**

Definition: Interval biozone of *Arkhangelskiella cymbiformis* Vekshina, 1959

Boundaries: Lower boundary of this biozone was determinated by Last occurrence *Reinhardtites levis* Prins and Sissingh in Sissingh, (1977) to the first occurrence *Nephrolithus frequens* Górka, (1957) (Not studied in this paper).

Thickness: 13 meter

Correlation and discussion: This biozone is correlated with CC25 (*Arkhangelskiella cymbiformis* Biozone). Sissingh (1977) divided it into three subdivisions (CC25a, CC25b, CC25c) by the first appearance of the species *Arkhangelskiella cymbiformis* and the first appearance of species *Lithraphidites quadratus* at Maastrichtian age, and correlated with UC19 biozone which is studied by Bown (1998) which aged Late Maastrichtian age (Gradstein *et al*., 2012).

As mentioned above, the Shiranish Formation in Bade section consist of three biozones for calcareous nannofossils, these are from older to younger;

1. *Broinsonia parca* Interval Biozone (CC23) Part
2. *Rienhardtites lives* Interval Biozone (CC24)
3. *Arkhangelskilla cymbiformis* Interval Biozone (CC25) Part

For the studied section, these biozones are aged Late Campanian-Maastrichtian.

Plankton foraminifera biostratigraphy and age determination

The studied section was divided into eight zones according to Al-Mutwali & AL-Doori (2012). These are from older :

1. *Globotruncana aegyptiaca* Interval Zone (Part)
2. *Gansserina gansseri* Interval Zone
3. *Contusotruncana contuse* Interval Zone
4. *Planoglobulina acervulinoides* Partial range Zone
5. *Racemiguembelina fructicosa* Interval Zone
6. *Pseudoguembelina hariaensis* Interval Zone
7. *Pseudoguembelina palpebra* Partial range Zone
8. *Plummerita hantkeninoides* Total range Zone (Part)

The Shiranish Formation in Bade village is divided into eight zones. The distributions of faunal sequence and the correlation between these zones and other zonal schemes in and outside Iraq reveals a middle Late Companian age for the first zone and Late Campanian – Early Maastrichtian for the second zone, whereas the other six biozones extended from Early – Late Maastrichtian.

DEPOSITIONAL ENVIRONMENTS

The late Campanian – early Maastrichtian period assist a chain of earth movements leading to the advance of the Arabian plate towards the Iranian plates along the north and north-eastern boundaries (Numan, 1997; Aqrawi *et al.,* 2010; Lawa *et al.,* 2013). As a result of this convergent is the accompanying oceanic crust subduction under the Iranian plate, causing abrasion and eruption of the Neotethys ophiolite which rise to above the sea level and then was subjected to rapid erosion. The erosive sediments then deposited within a narrow basin called the Foredeep Basin as thick flysch deposit (2000 m) along the northern and eastern boundaries of the Arabian plate and northeastern parts of Turkey (Jassim & Buday in Jassim & Goff, 2006).

The insertion of ophiolite and the closing of southern Neotethys cradle to wide marine transgressive covered the north part of Iraq and the adjacent area like Iran, southern Turkey, and northern Syria. The deposits (Tanjero, Bekhme, Shiranish, and Hartha formations) distribute in a north west to southeast trend. During the Middle Maastrichtian period, the ophiolite obduction stopped and the flysch deposit decreased, and the Aqra Formation (*loftusia* bearing limestone, 800 m) deposited in shallow marine environments, resting on the Qamchoqa Formation.

The Shiranish Formation successions reflect the period of transgression during the late Campanian – Maastrichtian deposits (Jassim & Buday in Jassim & Goff, 2006). The tectonic load of accretionary prism and ophiolite obduction led to the formation of foredeep depozone within Zagros foreland basin at northern Iraq (Znad, 2013). According to the tectonostratigraphic units in the under filled foreland basin stage (Sinclair, 1997), the Shiranish Formation represents the middle unit of the trinity under filled lithofacies stage of Iraq Zagros foreland basin, that have been affected by the tectonics of the foreland basin and its depozones. Although the formation was deposited during the compressive phase (convergent plates) during the closure of Neo-Tethys, it was deposited in an extension environment both in the foredeep and in the back bulge, where the deposition of the formation is absent on the forebulge depozone in the area of Amadia extending to Aqra and Sheikhan. At the same time, there was a deposit in a back bulge depozone in the areas of Bekhere and Kali Dehi at the western plunge of Matin and Garah anticlines, this is the eastern edge of the descending basin of Sinjar-Abd el Aziz in westward direction.

The previous works in Iraq refer to the deep marine depositional environments of Shiranish Formation, and it is representing the deep shelf margin in the upper part from the formation, but it is open marine in the lower part from same area (Al-Banna, 2010). The age of the formation is estimated based on the recognized biostratigraphic zone using the index fossils determined from Upper Campanian to Middle Maastrichtian (Kaka, 2010). According to Al-Juboury (2011), the depositional environment of the formation in Khabaz field at northwestern Kirkuk city is the outer shelf to the upper bathyal, turbidite and submarine fans environment of the formation in Bekhme area (Al-Rashedi, 2013). The depositional environment of the Shiranish Formation extended from the middle shelf to middle bathyal environments in the Dokan area (Malak, 2015).

The study area witnessed during the Campanian period the occurrence of marine transgression following the deposition of the Bekhme Formation (Late Campanian). The effect of this transgression was evident through the sedimentation of the lower parts of the Shiranish Formation represented by the limestone and marly limestone rocks, where the microfacies analysis of these rocks (microfacies SH1) refers to the presence of much benthonic foraminifera such as *Gavelinella* sp, *Bolivina* sp, *Gyroidina* sp (Gibson, 1989). The depositional environment of this microfacies is interpreted as a middle – an outer-shelf environment with water depth ranging between 100–250 m. These limits are based on the diversity of plankton foraminifera and keeled/globular ratio, which increased or decreased upward depending on the transgressive or regressive development of the facies (Leckie, 1987; Koutsoukos & Hart, 1990).

The marine transgression continued during the Campanian, reaching the height of its greatness during the Lower Maastrichtian period, as this period witnessed the deposition of the central parts of the formation represented by the facies SH2 that refers to an outer shelf- upper bathyal depositional environment, with water depth ranging between 200–350 m (Berggren & Miller, 1989), indicated by the great species diversity and a high percentage of planktonic foraminifera and benthic foraminifera (*Gyroidinoides, Cibicidoides, Osangularia* and *Gavelinella)* which are common in these environments (Koutsoukos & Hart, 1990).

This was followed during the middle Maastrichtian period by a local marine retreat that left its clear imprint in the sediments of the upper part of the formation, where the microfacies SH3 were deposited, which indicate their deposition in environments less deep than the previous ones represented by outer shelf environments (Gibson, 1989; Berggren & Miller, 1989). Jaff & Lawa (2019) recorded shallowing upwards successions of the Shiranish Formation from the foraminiferal assemblages that are interpreted as representing outer shelf to middle slope environments, between 200 m to at least 600 m water depth, with maximum water depths in the Late Campanian, followed by shallowing into the Early Maastrichtian.

Elsewhere, the presence of lime mud as a template for all microfacies, a high percentage of planktonic foraminifera, and lack of sedimentary structure indicate a deep marine environment far away from marine waves and currents. Commonly, the depositional environment of the formation is comprehensive from the middle – outer shelf – upper bathyal and then returns to outer shelf environments. In the end, the deposits of the Shiranish Formation will be sealed with those of the Kolosh Formation deposits as a thick flysch succession.

CONCLUSIONS

The Shiranish Formation has major petrographic constituents of fossils (planktonic, benthic foraminifera and nannofossils) and bioclasts grains in the micrite matrix. The biozones of nannofossils refers to the Upper Cretaceous (Late Campanian –Late Maastrichtian) age. The integrated microfacies and paleontological indications point to middle – outer shelf and upper bathayal depositional environments .

ACKNOWLEDGEMENTS

The authors are very grateful to the University of Mosul/ College of Sciences for the provided facilities, which help to improve the quality of this work. Our gratitude is extended to the two anonymous reviewers for reviewing our manuscript.

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Manuscript received 13 July 2020
Revised manuscript received 19 September 2020
Manuscript accepted 13 October 2020