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Microfacies analysis and depositional environment of Pila Spi Formation (Middle - Late Eocene) in the Nerwa section, Berat anticline, High Folded Zone, Kurdistan Region, northern Iraq

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Abstract: Microfacies analysis and depositional environment of the Pila Spi Formation (Middle-Late Eocene) were studied in the Nerwa outcrop, Berat anticline, High Folded Zone in Iraqi Kurdistan Region. The total thickness of the formation is 13.5 m composed of medium to thick bedded yellow to white limestone and thick bedded grey to white dolomitic limestone. It is interbedded with thin beds of yellow marl in the lower part and have chert nodules in the upper part. The petrographic study of 17 thin sections of the Pila Spi carbonate showed that the majority of the carbonates are micritic mixed with some microspar. The skeletal grains involve benthonic foraminifera, ostracods, mollusca, dasycladacean green algae, pelecypods, gastropods, rare planktonic foraminifera and bioclasts. Non skeletal grain included peloids, intraclasts and extraclasts which is mainly monocrystalline quartz grain. Based on field observations and petrographic analysis, three different lithological units were distinguished in the Pila Spi Formation in the studied section. They are in ascending order: medium to thick bedded limestone interbedded with marl unit, thick bedded dolomitic limestone unit and, cherty limestone unit. Depending on detailed microfacies analysis of carbonate rocks, three main microfacies and twelve submicrofacies were recognized in the studied section of the Pila Spi Formation. From the sum of all petrographic, facies and textural analyses, it is here concluded that Pila Spi Formation in the Nerwa section was deposited at subtidal semi-restricted lagoon, in lower part gradually changed to open lagoon environment toward the upper part.

Keywords: Eocene, microfacies analysis, depositional environment, Pila Spi, Iraq

INTRODUCTION

The Pila Spi Formation is regarded as terminal lagoonal facies that belongs to the Middle to Upper Eocene sedimentary cycle of Northeast Iraq (Buday, 1980) and represents the upper part of AP10 (Early Paleocene-Late Eocene; 65.5-34 Ma) of tectonostratigraphic megasequence of the Arabian plate (Sharland *et al*., 2001). It has great importance because it exhibits a good reservoir where it has been karstified such as in Chemchemal, Taq Taq and Tawke oil fields (Aqrawi *et al.*, 2010). Lees (1930 in Bellen *et al.*, 1959) was the first one who recognized and described the formation in the Pila Spi area of the southern margins of the High Folded Zone. Later Wetzel (1947 in Bellen *et al.*, 1959) re-defined the formation in Derbendikhan area, Iraqi Kurdistan Region as 85 m thick comprised of well-bedded porous, bituminous, white chalky limestone in the lower part and well-bedded bituminous limestone, weathering white, chalky and crystalline limestone with bands of pale green marl or white chalky marl and chert nodules in the upper part.

Since the first description of the formation in Bellen *et al.* (1959), there are several works conducted with the Pila Spi Formation in sedimentology, stratigraphy and paleontology trends. Such as, Al-Hashimi & Amer (1985), Qadir (1989), Al-Sarky (1999), Jassim & Buday (2006), Al-Qayim & Othman (2010, 2012), Khanaqa (2011), Sattam (2015), Mahmud (2015), Kadhim & Hussein (2016) and Al-Mashaikie & Latif (2017). The main aim of the current study is to understand the depositional environment of Pila Spi Formation in Nerwa section by using a combination of field, petrographic observations and microfacies analysis.

GEOLOGIC SETTING

The Pila Spi Formation is very well exposed in the form of outstanding scarps in the High Folded Zone, Northern Iraq. As well as in some subsurface that drilled in the Low Folded Zone. Tectonically, the outcrops of the formation equipped the boundary between the High Folded and Low Folded zones (Sissakian & Al-Jiburi, 2014). The Pila Spi Formation formed during the final closure of Neo-Tethys Ocean by subduction of the Arabian Plate and Iranian micro plates during the Paleocene and Eocene (Jassim & Goff, 2006). In the Middle-Late Eocene period the sequence was deposited to the SW of an emergent uplift during the final phase of subduction and closure of the remnant Neo-Tethys Ocean (Jassim & Buday, 2006; Al-Banna *et al.*, 2015). At the end of the Mid Eocene, the clastic sediment supplies from the uplifted area to NE ceased and the basin was filled with lagoonal carbonates of the Pila Spi Formation (Jassim & Buday, 2006).

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The studied area is located in the High Folded Zone at the boundary with Low Folded Zone (Figure 1). The studied section which is not covered by any previous studies is situated about 700 m northeastern of Nerwa Village, at the outlet of the Nerwa valley on the southern limb of Berat anticline in the Akre area, 19 km east of Bjeel town and 6 km northwest of Qandil bridge in Duhok Governorate, approximately at Lat. 36°41'41" N and Long. 44°10'50" E. Structurally, the Nerwa outcrop is located in the western segment of the southern limb of Berat anticline which is characterized by E-W trends of anticline axis in the area while it has NW-SE trendings in the S and SE parts (Figure 2). The change of the trend of the axis of Berat anticline is associated with the collision and convergent zone along the Taurus–Zagros Mountain system (Al-Ma´amar & Obaidi, 2016). Stratigraphically, the Nerwa section involves a stratigraphic succession starting from Qamchuqa and Bekhme, and Shiranish formations (Cretaceous), the latter is overlain by Kolosh Formation (the first Tertiary unit that appeared in the section), which is overlain by Khurmala, Gercus, Avanah, Pila Spi, Fatha (Lower Fars), Injana (Upper Fars), and further away Mukdadiya (Lower Bakhtiari) and Bai Hassan (Upper Bakhtiari) formations of Tertiary (Figure 2). The nature of the Pila Spi Formation boundaries is gradational and conformable with underlying Gercus Formation and unconformable with overlying Fatha Formation due to the disappearance of Oligocene sediments and marked by the presence of chert nodules in upper carbonate beds of Pila Spi Formation (Mahmud, 2015).

MATERIALS AND METHODS

For the purpose of choosing a suitable section for this work, extensive fieldwork was carried out in the

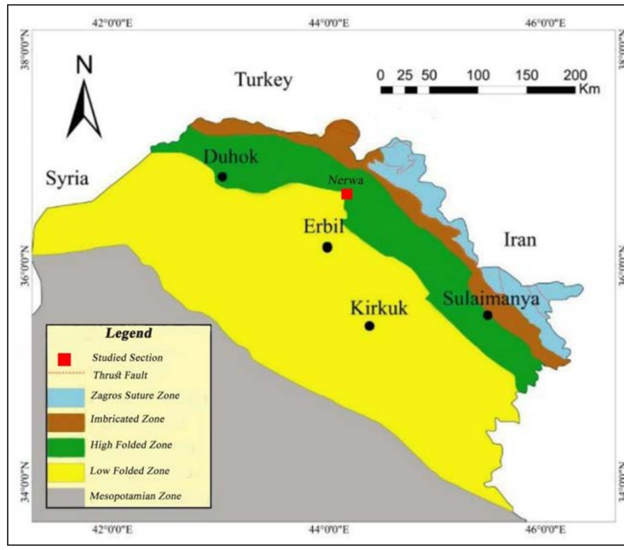

Figure 1: Location and tectonic map of studied area (after Jassim & Goff, 2006).

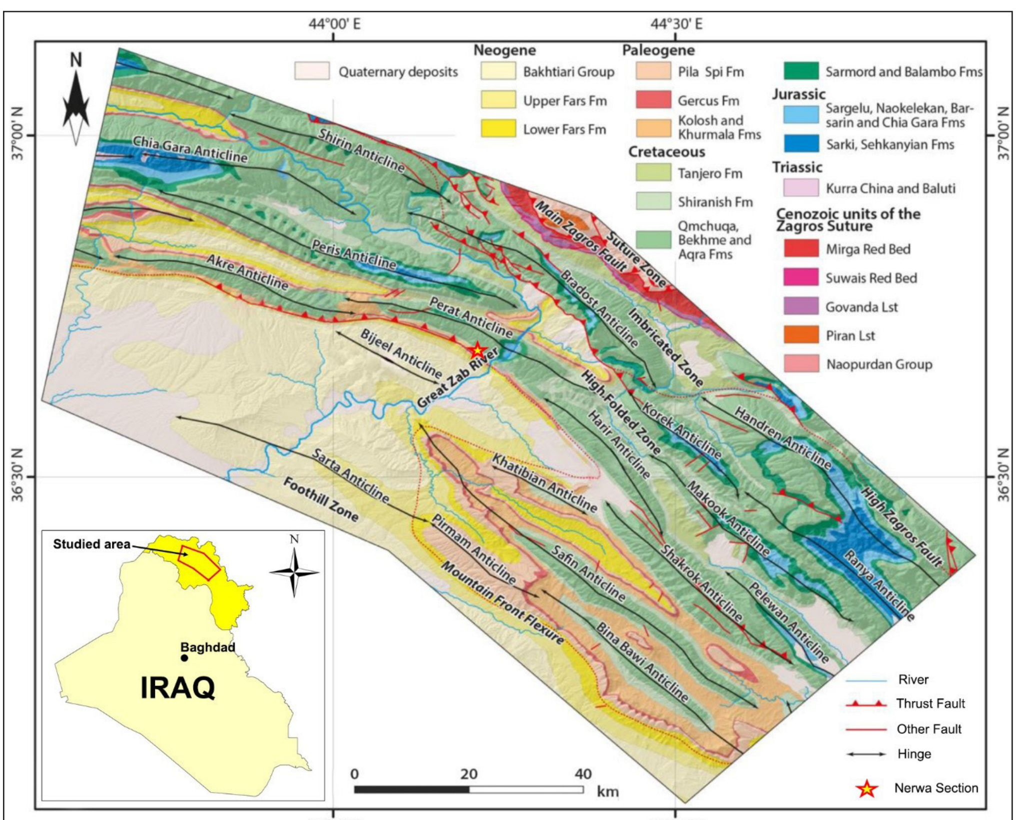

Figure 2: Geological and structural map of studied area (modified from Zebari *et al.*, 2019).

area around the section in Berat anticline in High Folded Zone. These studies included the general geology and structural relations of the Cretaceous-Tertiary succession in the surroundings of the studied area. At Newra section, the outcrop was described and measured in detail, logging the lithology, and studying the mineralogy, trace fossils, and sedimentary structures.

A total number of 17 samples of carbonate from Pila Spi Formation of the studied section were collected, besides, in addition to several samples across the underlying and overlying boundaries with the Gercus and Fatha formations respectively in order to check the nature and position of these boundaries in detail. Samples were usually collected at every change in lithology, and/or color. All samples were taken along a line perpendicular to the bedding plane. The upper and lower parts of each sample were also marked. Detailed description of samples (macroscopic study) using a hand lens and acid test using dilute HCL was performed.

The sum of 17 thin sections were prepared in the workshop of Earth Sciences and Petroleum Department, College of Science, Salahaddin University-Erbil. At least one thin section for each sample was prepared. These thin sections were oriented and stained with the Alizarin Red Solution (ARS) following the procedure of Friedman (1959) for detecting calcite and dolomite. Detailed petrographic study and microfacies analysis were performed. The petrographic description is based mainly on Dunham classification (1962) using the polarized microscope.

RESULTS

Lithostratigraphy

The total thickness of the Pila Spi Formation in Nerwa section is about 13.5 m (Figure 3). Depending on the integrations of the field observations and petrographic inspections, the Pila Spi Formation in the studied section can be divided into three informal lithostratigraphic units, which are in ascending order (Figure 4):

1. Medium to thick bedded limestone interbedded with marl unit

This unit is overlying the red mudstone of the Gercus Formation and is overlain by thick bedded dolomitic limestone unit. It is composed of 4.5 m of medium (30-50 cm) to thick (50-100 cm) bedded yellow weathered color and white fresh color limestone interbedded with yellow marl (Figure 5a) and characterized by macrostylolites (Figure 5b) and bioturbation (Figure 5c).

2. Thick bedded dolomitic limestone unit

This unit is overlaying medium to thick bedded limestone interbedded with marl unit and overlain by cherty limestone unit. It is composed of 5.5 m thick (50-100 cm) bedded dark grey to white dolomitic limestone (Figure 5d) characterized by groove structures (Figure 5e) and joints on their beds (Figure 5f).

3. Cherty limestone unit

This unit is overlaying thick bedded dolomitic limestone unit and overlain by mudstone of the Fatha Formation. It is composed of 3.5 m of medium (30-50 cm) to thick (50-100 cm) grey bedded limestone (Figure 6a) characterized by distributions of chert nodules along and perpendicular to bedding planes (Figure 6b).

Petrography

The petrographic study of 17 thin sections of the Pila Spi carbonates in Nerwa section reported that the rocks are subjected to severe diagenetic processes, therefore most fossils are obliterated and not diagnostic. The discriminated

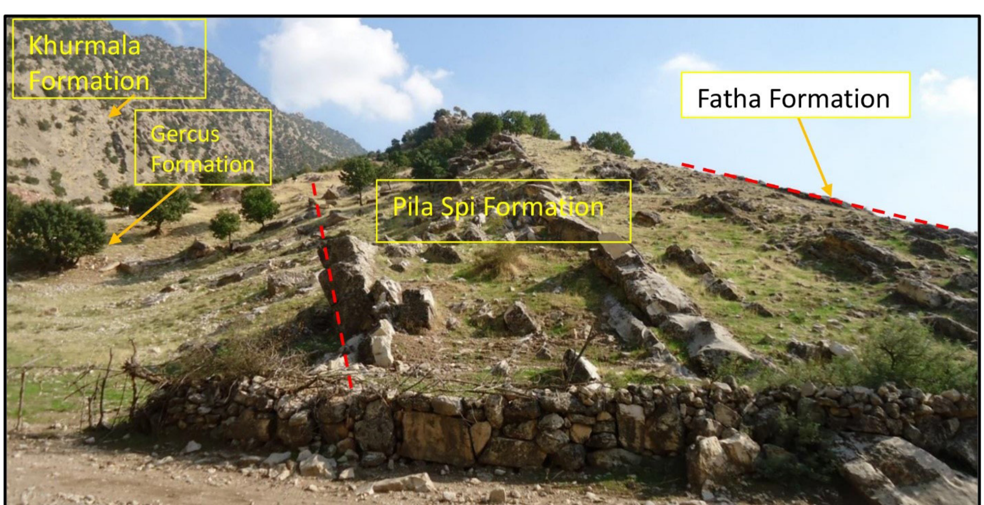

Figure 3: Field photograph representing Pila Spi Formation with underlying Gercus Formation, and overlying Fatha Formation in Nerwa section.

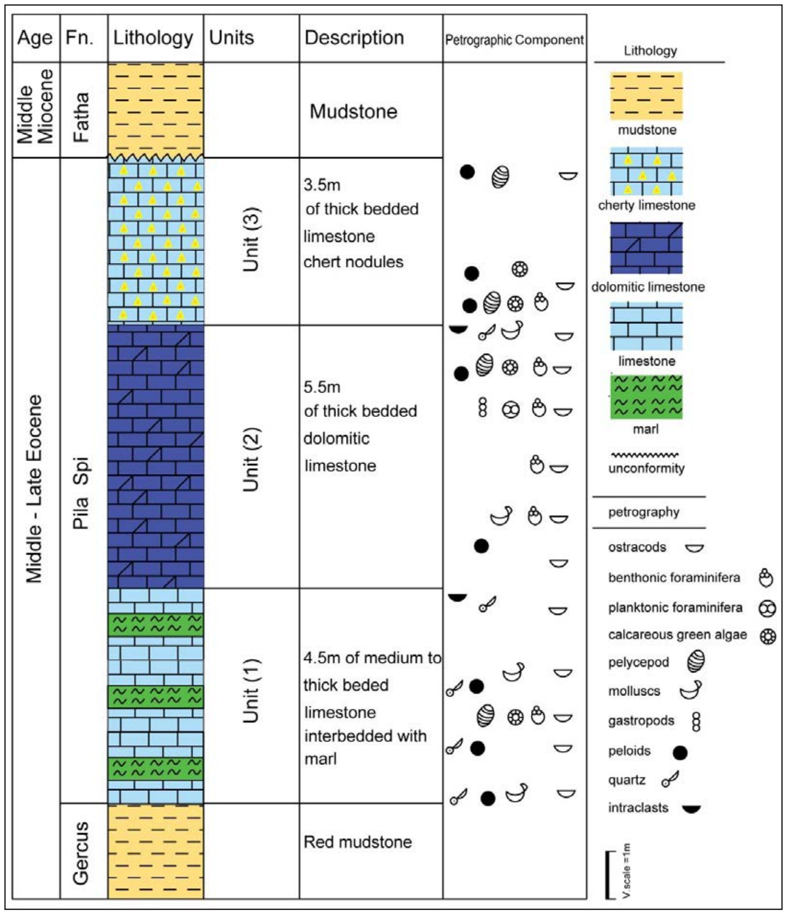

Figure 4: Columnar section of Pila Spi Formation in Nerwa section.

skeletal grains include benthonic foraminifera (Figure 7d), planktonic foraminifera (Figure 7f), ostracods (Figure 8c), mollusca (Figure 8 a), dasycladacean green algae (Figure 7c), pelecypods (Figure 8f), gastropods (Figure 7e) and bioclasts. Non-skeletal grains involve peloids (Figure 8a), intraclasts (Figure 8b) and extraclasts which is mainly monocrystalline quartz grain (Figure 7b). The major groundmass of the carbonate rocks of the Pila Spi Formation is lithified carbonate mud (micrite) which is severely subjected to dolomitization and changed to microspar by neomorphism.

Microfacies analysis

Three main microfacies types were identified in the studied carbonate samples of the Pila Spi Formation. Each was later subdivided into several submicrofacies, depending on the significant fossil type. Table 1 shows the main and submicrofacies recognized in the petrographic study of the formation.

1. Lime mudstone microfacies

This microfacies is most common in the studied section with a thickness 5.8 m. It is generally consisting only of micrite with rare (generally less than 10%) fossil content (Dunham, 1962). It can be divided into six submicrofacies:

Fenestral dolomitized lime mudstone submicrofacies

It is considered the characteristic microfacies of the Pila Spi Formation in the studied section due to highly dissolution diagenesis of the formation which forms a huge number of pores in the groundmass of the Pila Spi carbonate (Figure 7a). It is common in the lower part of the studied section and also subjected to neomorphism and dolomitization diagenetic processes.

Dolomitic sandy lime mudstone submicrofacies

It is mainly formed of micrite which is effected by dolomitization and includes less than 10% of monocrystalline quartz grains (Figure 7b). It is common in the lower part of the studied section and pyritization diagenesis also observed in this microfacies.

Dolomitic dasycladacean lime mudstone submicrofacies

It is common in the lower part and less common in the middle part of the studied section of the Pila Spi Formation. It includes mainly dasycladacean green algae in micritic groundmass (Figure 7c). The common diagenetic

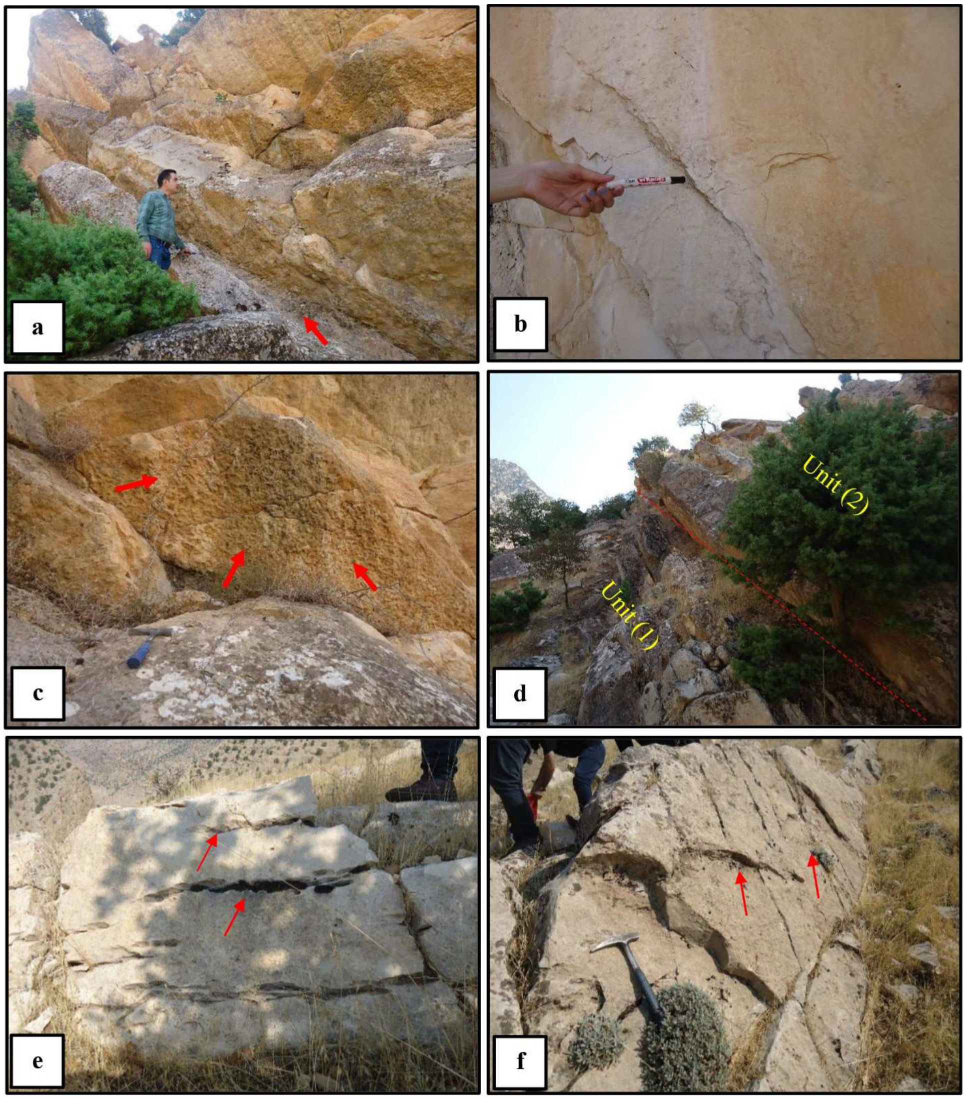

Figure 5: Field photographs show: **a)** Medium to thick bedded limestone interbedded with marl. **b)** Chemical compaction stylolites formed on the limestone beds of Pila Spi Formation. **c)** Bioturbation affected the limestone beds of the formation. **d)** Thick bedded dolomitic limestone overlain unit (1). **e)** Grooves on the dolomitic limestone beds. **f)** Joints on the beds of limestone.

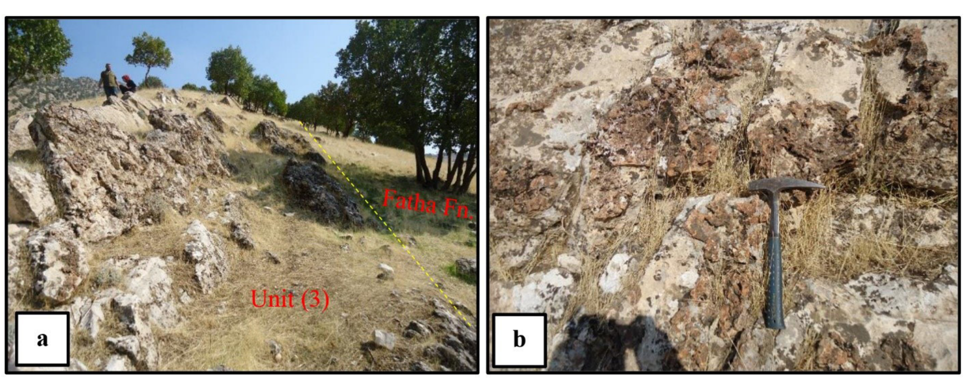

Figure 6: Field photographs show: **a)** Cherty limestone beds. **b)** Chert nodules on the limestone beds.

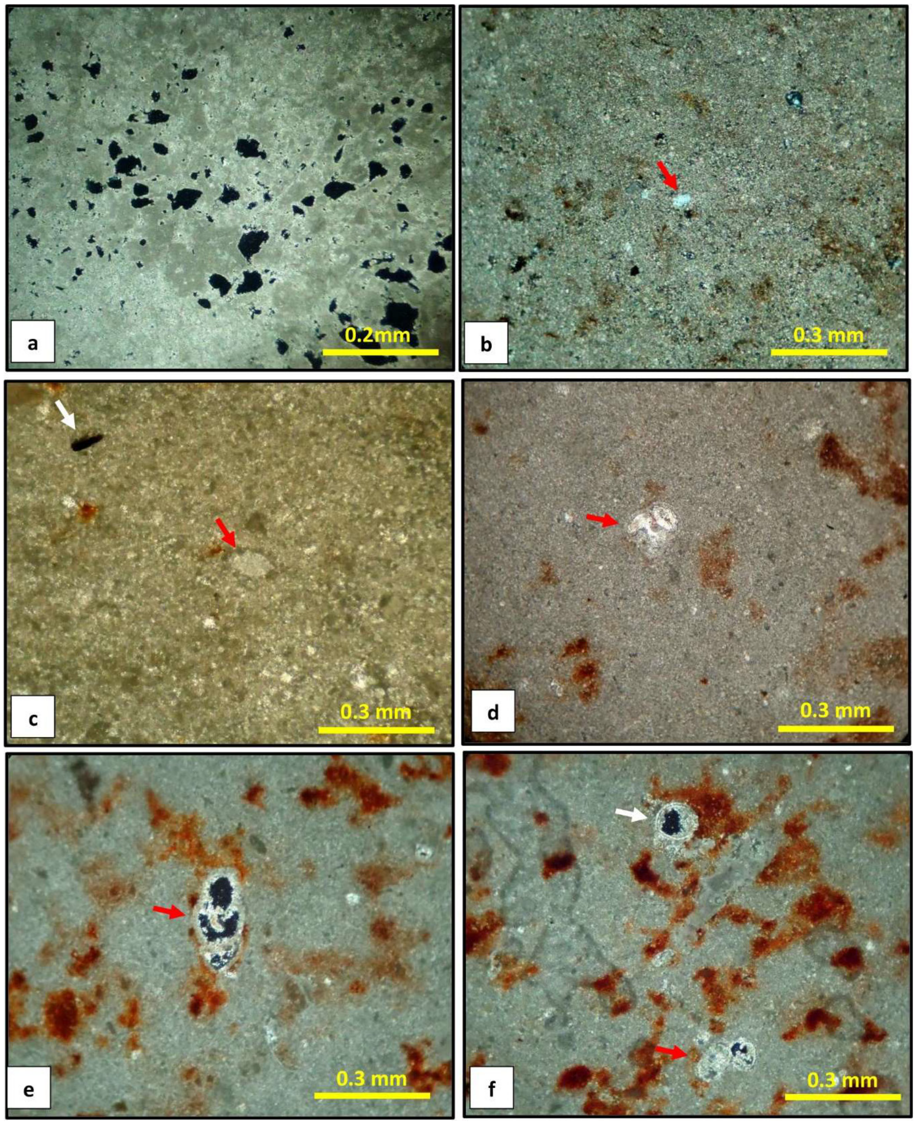

Figure 7: Photomicrographs of Pila Spi Formation showing microfacies types: **a)** Fenestral dolomitized mudstone submicrofacies. PN.11, X.N. **b)** Sandy (monocrystalline quartz (red arrow)) dolomitized mudstone submicrofacies. PN.1, X.N. **c)** Dasycladacean (red arrow) dolomitized mudstone submicrofacies affected by pyritization (white arrow). PN 3. P.P. **d)** Benthonic foraminifera (*Valvulina)* (red arrow)) mudstone submicrofacies. PN.10, P.P. **e)** Gastropoda (red arrow) lime mudstone submicrofacies. PN.9, X.N. **f)** Globigerinal (red arrow)-ostracoda (white arrow) dolomitized mudstone.PN.9, X.N. Key: PN: Pila Spi -Nerwa, P.P: Plane polarized light, X.N: Crossed nicoles.

processes observed in the submicrofacies are dolomitization and pyritization.

Benthonic foraminifera lime mudstone submicrofacies

This submicrofacies is common in the middle unit of the studied section. The main skeletal grains in this facies are benthonic foraminifera which includes *Valvulina* sp. (Figure 7d) and other undefined forams due to dissolution. Neomorphism and authigenic mineral (iron oxides) are the main diagenetic features of the facies.

Gastropoda lime mudstone submicrofacies

This mudstone microfacies is characterized by including the microgastropods as main skeletal grains (Figure 7e) and common in the middle part of the formation. The main diagenetic processes are dolomitization, iron oxides and dissolution.

Globigerinal-ostracoda lime mudstone submicrofacies

This submicrofacies is common in the middle unit of the studied section. It includes planktonic foraminifera (mainly *Globigerina*) and ostracods with rare bioclasts (Figure 7f). It is subjected to dolomitization, dissolution and iron oxidization diagenetic processes.

2. Lime wackestone microfacies

The wackestone facies characterized by having grains ranges between 10 – 50% in micrite matrix (Dunham, 1962).

Table 1: Microfacies of the Pila Spi Formation in Nerwa section.

Main microfacies Dunham (1962)	Subdivision of Dunham (1962)	Diagnostic features (main skeletal grain + common diagenetic process)	SMF Flugel (1982)	Facies Zone of Wilson (1975)
Lime Mudstone	Fenestral dolomitized lime mudstone	- Dissolution + Dolomitization -Nomorphism	21	8
	Dolomitic sandy lime mudstone	-Monocrystalline quartz -Dolomitization + Pyritization	23	
	Dolomitic dasycladacean lime mudstone	-Dasycladacean green algae -Dolomitizaton + Pyritization	8	
	Benthonic foraminifera lime mudstone	-*Valvulina* -Neomorphism + Iron oxide	9	
	Gastropoda lime mudstone	-Microgastropoda. -Dolomitization + Iron oxide +Dissolution	9	
	Globigerinal-ostracoda lime mudstone	-Globigerina + Ostracods - Dolomitization + Iron oxide + Dissolution	9	
Lime Wackestone	Molluscan - peloidal lime wackestone	-Mollusca + Peloids. -Dissolution + Dolomitization	9	
	Dolomitic intraclasts lime wackestone	-Intraclasts -Micritization + Dolomitization	8	
	Dolomitic Peloidal-ostracods lime wackestone	-Peloids + Ostracods -Dolomitization + Silicification Noemorphism + Dissolution	16	
	Dolomitic dasycladacean lime wackestone	-Dasycladacean green algae -Neomorphism + Dolomitization	8	
Lime Packstone	Peloidal lime packstone	- Peloids - Cementaion + Neomorphism	16	
	Pelecypods - bioclasts lime packstone	- Pelecypods + Bioclasts -Dissolution + Cementation	9	

The wackestone of the Pila Spi Formation is common in the middle and upper parts of the studied section and subjected to variable diagenetic processes. The total thickness of this microfacies reaches to 4.2 m. Depending on the grain composition, the wackestone is subdivided into the following submicrofacies:

Molluscan-peloidal lime wackestone submicrofacies

This subdivision is common in the unit (2) of the Pila Spi Formation. The common grains in it are mollusca and peloids (Figure 8a). The main diagenetic processes which passed through it were dissolution and dolomitization.

Dolomitic intraclasts lime wackestone submicrofacies

This submicrofacies is characterized by including intraclasts non- skeletal grains (Figure 8b) and common in the middle part and less common in the upper part of the studied section. It is subjected to micritization and dolomitization diagenetic processes.

Dolomitic peloidal-ostracods lime wackestone submicrofacies

It is common in the upper part of the studied section having ostracods and peloids as main grains (Figure 8c). The dolomitization, silicification, noemorphism and dissolution are the main diagenetic features.

Dolomitic dasycladacean lime wackestone submicrofacies

This subdivision was observed in the upper part of the studied samples of the formation. It includes dasycladacean grain algae subjected to dolomitization and neomorphism (Figure 8d).

3. Lime packstone microfacies

This microfacies is less common and is observed mainly in the upper part of the studied section of the Pila Spi Formation. It is thickness about 3.5m and it is characterized by increasing its skeletal grains up to 60% and leaving minor micrite between grains-supported limestones (Dunham, 1962). The observed submicrofacies of this type are the following:

Peloidal lime packstone submicrofacies

It is characterized by peloidal dominant texture (Figure 8e) and common in the upper part of the studied section. The cementation and neomorphism are the common observed diagenetic features.

Pelecypods-bioclasts lime packstone submicrofacies

This submicrofacies were observed in the unit (3) of the studied section of the Pila Spi Formation. It includes fossils and molds of bioclasts and pelecypods and is characterized by blocky calcite cement and dissolution (Figure 8f).

Facies associations

Two basic types of facies associations were identified from the integration of the recognized microfacies of Pila Spi Formation in Nerwa section, these are:

1. Subtidal semi-restricted lagoonal facies association (FA1)

This association is equivalent to standard facies zone 8 of Wilson (1975) and standard microfacies 8, 21 and 23 of Flügel (1982). It forms the lower unit of the formation and consists mainly of 4.5 m of medium to thick bedded yellow weathered color and white fresh color limestone rich lime-mudstone to wackestone. The bioturbation and chemical compaction stylolitization and fenestral texture are abundant in this association. The Pila Spi carbonates of this association show that the rare microfossils contain

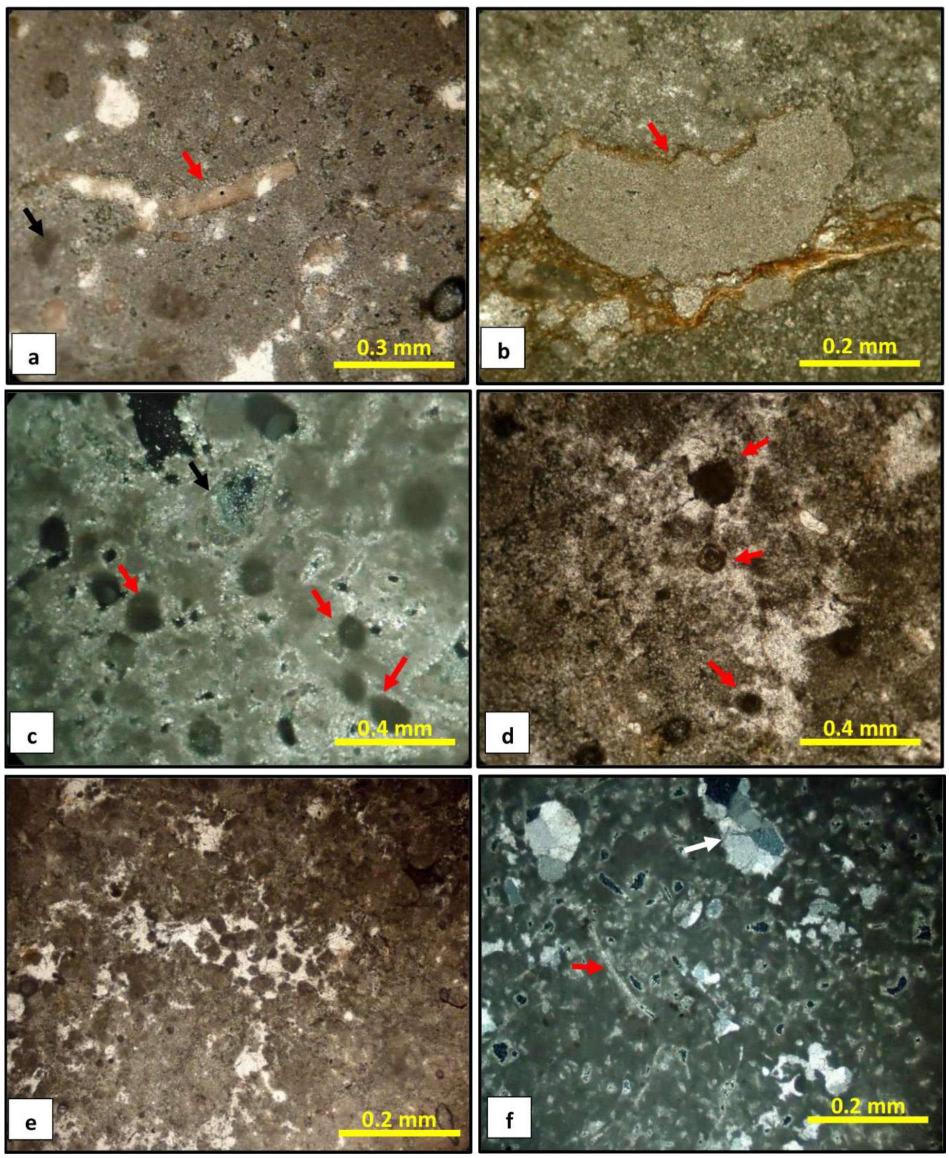

Figure 8: Photomicrographs of Pila Spi Formation showing microfacies types: **a)** Molluscan (red arrow)-peloids (black arrow) lime wackestone submicrofacies. PN. 14, P.P. **b)** Dolomitic intraclasts (red arrow) lime wackestone submicrofacies. PN.13, P.P. **c)** Dolomitic peloidal (red arrow)-ostracods (black arrow) lime wackestone submicrofacies. PN.14, X.N. **d)** Dolomitic dasycladacean lime wackestone submicrofacies. PN.15, P.P. **e)** Peloidal lime packstone submicrofacies. PN.15, P.P. **f)** Pelecypods (red arrow)-bioclasts lime packstone submicrofacies, blocky calcite cement filled bioclasts (white arrow). PN.17, X.N. Key: PN: Pila Spi-Nerwa, P.P: Plane polarized light, X.N: Crossed nicoles.

which include dasycladacean green algae, benthonic foraminifera, and rare ostracods which highly obliterated by diagenetic processes such as dolomitization, dissolution and neomorphism. Non-skeletal grains include mainly monocrystalline quartz and intraclasts.

Interpretation

The subtidal semi-restricted lagoon environment in the Nerwa section revealed different facies types which had obvious similarity in litho and bio content. This would indicate the homogeneity of both facies and the environment in this facies association. According to classification Dunham's (1962), it was found that mudstone is the most abundant facies followed by wackestone which both microfacies types were dominated by the micrite matrix. The dominance of micrite within these facies indicates that it deposited in a shallow setting with quite water condition (Ali & Mohamed, 2013). The fenestral fabric in FA1 is probably formed by burrowing in shallow subtidal settings (Grover & Read, 1978). The presence of calcareous green algae (Dasycladacean) indicates a shallow water environment of less than 10 m deep (Aguirre *et al.*, 2000). While the benthonic foraminifera inform the shallow marine environment of the facies (Hallock & Glenn, 1986). Monocrystalline quartz in lime mudstone microfacies supposed to be deposited in low energy, restricted intertidal, supratidal and subtidal environments (Wilmsen *et al.*, 2010; Bayet-Goll *et al.*, 2014; Nowrouzi *et al.*, 2015) and is associated with dasycladacean and benthonic foraminifera in tidal flats and restricted lagoons (Nikbakht *et al.*, 2019). Intraclasts found in all ramp settings and common in the middle ramp (Flügel, 2010) and in lime mudstone are supposed to be deposited in the high-energy subtidal environment (Yang *et al.*, 2010).

2. Open lagoon facies association (FA2)

This association is equivalent to standard facies zone 8 of Wilson (1975) and standard microfacies 9 and 16 of Flügel (1982). It equipped the middle and upper units of the formation and comprise of 5.5 m of thick bedded dark grey to white dolomitic limestone-rich lime mudstone and wackestone characterized by groove structures and joints on their beds overlain by 3.5m of medium to thick grey bedded limestone-rich lime mudstone, wackestone and packstone bearing chert nodules over their beds. The microfossils of this association include benthonic foraminifera (*Valvulina* sp), planktonic foraminifera (*Globigerina* sp.), micro gastropods, mollusca, ostracods and pelecypods. Non-skeletal grains include peloids and rare extraclasts.

Interpretation

The most abundant microfacies types in this facies association according to the terminology of Dunham (1962) was lime wackestone followed by lime mudstone and packstone. It is characterized by bearing planktonic foraminifera (*Globigerina*) which confirms that it connects with open seawater (Flügel, 2010; Ahmad *et al.*, 2020). Benthonic foraminifera mainly tend to deposit in the shallow marine environment (Murray, 2006). Ostracods found in marine, transitional and fresh water, found at various depths (Haq & Boersma, 1998). Pelecypods deposited in different environments from near- shore to off-shore environments (Clarkson, 1998; Balaky *et al.*, 2016) and it with gastropods are common in shallow lagoon with open circulation (Flügel, 2010). The peloidal packstone microfacies developed in protected lagoon environments with moderate water circulation (Flügel, 2010). The presence of chert nodules in the carbonates of the upper part of the Pila Spi Formation indicates a shallow marine environment with a land input source. As Laschet (1984) mentioned the input of silica from land is an important source in shallow-marine areas.

DISCUSSION

The facies association interpretation shows that the Pila Spi Formation in the studied section, deposited at the shallow marine environment, subtidal semi-restricted lagoon, in the lower part gradually changed to open lagoon environment toward the middle and upper parts. The concluded depositional model of the formation in the studied section was relatively concise to the findings of Mahmud (2015) in Bekhme section, 6.5 km southeast of Nerwa section which shows that it forms from dolomitized mudstone, miliolid mudstone and bioclastic wackestone in lower part and calcisphers, planktonic foraminifera and peloidal bearing wackestone to packstone in upper part which indicate semi-restricted and open lagoons depositional environments for the formation. The petrographic study of the Pila Spi Formation in Duhok and Bina Bawi areas which situated 105 km northwest and 49 km southeast to the studied section respectively, shows that the formation mainly comprises of mudstone and few beds of wackestone microfacies and most skeletal grains destroyed by diagentic processes but Ca/Mg and Sr/Ca ratios of the carbonate indicate that the formation was deposited at near shore of shallow marine environment (Kadhim & Hussein, 2016). These results correspond to the depositional setting of the Pila Spi Formation in studied section which relatively deposited in shallow marine, lagoonal environment. The recent study conducting to microfacies analysis of the formation in Shaqlawa section in Erbil governorate which is located 31 km southeast of Nerwa section and Zawita, and Sendor sections in Duhok governorate 95 and 102 km northwest to the studied section respectively, shows that the Pila Spi carbonate mainly comprised of lime mudstone, sandy lime mudstone, fossiliferous, bioclastic, peloidal and intraclasts bearing lime wackestone, packstone and floatstone microfacies which refers to back reef, lagoonal and intertidal setting (Mutar & Alsultan, 2020) and this improve that the depositional model of the formation in the whole Kurdistan region which is shallow marine lagoonal environment and emphasized in the present study.

To imply the facies associations interpretations and the updated vision of the Pila Spi environment in the Nerwa section, a schematic block diagram (Figure 9) was drawn which inferred the paleoenvironmental conditions of the Pila Spi Formation (Upper Eocene) in High Folded Zone in Northern Iraq.

CONCLUSIONS

1- The Pila Spi Formation in studied section consists of 13.5 m of medium to thick bedded yellow to white limestone and thick bedded grey to white dolomitic limestone interbedded with thin beds of yellow marl in the lower part and bearing chert nodules in the upper part. Lower contact was conformable and gradational with the Gercus Formation while upper contact was unconformable with the Fatha Formation.

2- Depending on field observations and petrographic analysis, three different litho units were recognized in the Pila Spi Formation at Nerwa section. They are in ascending order:

a - Medium to thick bedded limestone interbedded with marl unit.

b - Thick bedded dolomitic limestone unit.

c - Cherty limestone unit.

3- According to Dunham's (1962) classification, and based on detailed microfacies analysis of limestones, 3 main microfacies and 12 submicrofacies are distinguished in the studied section of the Pila Spi Formation. These facies were subdivided according to their environmental interpretation, into two basic types of facies associations: subtidal semi-restricted and open lagoonal environment.

4- From the sum of all petrographic, facies, textural analyses, it is here concluded that the Pila Spi Formation in Nerwa village, deposited at the shallow marine environment, subtidal semi-restricted lagoon, in lower part gradually changed to open lagoon environment toward the upper part.

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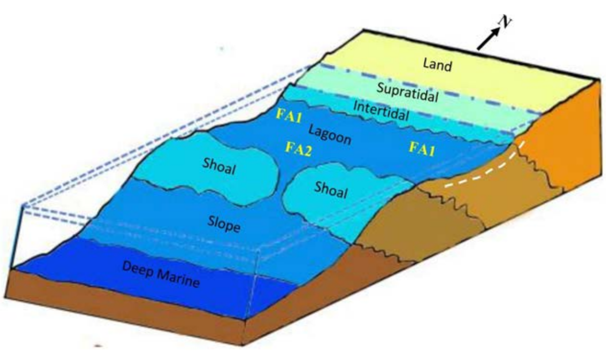

Figure 9: Schematic model of Pila Spi depositional environment (white dash line in Nerwa section). (FA1 = Subtidal semi- restricted lagoonal facies association, FA2 = Open lagoon facies association).

CONFLICT OF INTEREST

The author have no conflicts of interest to declare that are relevant to the content of this article.

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