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Microfacies Characterizations and Paleoenvironment of Upper Part of Qamchuqa Formation from Chwarqauran Section, Sulaimaniya Area, Kurdistan Region, Iraq

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Abstract

The Qamchuqa Formation was studied in Chwarqauran section, Sulaimanyia, Kurdistan region, Northeastern Iraq. The lithology of the formation contains limestone throughout the whole section except for one bed of dolomite at the Middle part. Twenty-four slides were prepared from 24 rock samples that were taken from this section to discriminate the petrography and fossil content. The petrographic study shows four main microfacies including lime mudstone, wackestone, packstone, and floatstone. Additionally, there are four sub microfacies: bioclast wackestone, miliolid wackestone, bioclast packstone and orbitolinid packstone. However, the fossil content shows the abundance of benthic foraminifera against the planktonic. All the microfacies indicate facies zone 7, 8 and 9A which reflect deposition in the platform interior between the tidal flat to the mid ramp and back reef environment.

Keywords: Qamchuqa Formation; Chwarqauran; Albian; Microfacies; Kurdistan; Iraq

1. Introduction

Wetzel (1950) was the first to describe the Qamchuqa Formation in the Qamchuqa gorge in the High Folded Zone in the north and northwestern city of Sulaimanyia, northeastern Iraq. Recent oil exploration in Kurdistan region (N Iraq) show that interest is increasing towards High Folded Thrust Zone (HFTZ), in oil production from those units (Lawa et al. 2020). The formation is underlined (in the type section) by the Sarmord Formation with conformable and gradation contact, while the upper contact with Kometan Formation is an erosional unconformity but without angular discordance (Bellen et al. 1959). Al-Sadooni (1978) studied the sedimentology and petroleum prospects of the Qamchuqa Group from Kirkuk, Bai Hassan and Jambur oil fields and compared the stratigraphy with outcrops at Safeen-Dagh and inferred that the deposition of the Qamchuqa Group is a rudist-algal-hydrozoans bank (not a reef), he also mentioned that the contact between the Mauddud Formation (The equivalent of the upper Qamchuqa Formation) and the overlying Dokan Formation is unconformable. Ameen (2008) studied the sedimentology and lithostratigraphy of the Qamchuqa Formation, along the outcrop section in northeastern Iraq and subdivided the formation into eight units based on the lithology and fossil content, concluding that the formation was deposited in low energy reef, back-reef, fore-reef and lagoon environments. Gharib (2009) recorded nine facies associations from the Cretaceous sequence of the

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Qamchuqa Formation that includes the inner, middle and outer ramp with supratidal facies associations to the outer ramp. The inner ramp consists of massive limestone at lime wackestone and lime packstone rich with benthonic foraminifera like *Orbitolina spp.*, *Pseudocyclammina spp.*, *Pseudochrysalidina spp.*, *Trocholina spp.*, *Cuneolina spp.*, *Textularia sp.*, *Ovalveolina* with pelecypod in the lower limestone unit in the Qamchuqa section. Miliolids also form the deposits within the inner ramp in the upper limestone unit in all sections at lime wackestone and lime packstone microfacies. Supra tidal that represents the stromatolite in the upper limestone unit in the Safin section also was within the inner ramp. The middle ramp consists of well-bedded limestone with interbedded thin marl in the middle limestone unit in the Qamchuqa and Smaqwy sections characterized by calcareous algae of green and red algae at lime wackestone to lime packstone microfacies, also other associations indicate the middle ramp consists of massive limestone, rich with rudist in the upper limestone unit in all sections at the lime rudstone microfacies while the outer ramp includes the massive limestone-rich with *Orbitolina* in the upper limestone unit in all sections at the lime wackestone and lime packstone microfacies. According to Al-Zaidy (2010), the Qamchuqa Formation is subdivided into six main paleoenvironments. These are the shallow restricted, shallow semi-restricted, shallow open marine, shoal, deep outer ramp and deep basinal environments. He also stated that the studied succession represents the deposition of four third order cycles.

Fig. 1. Location map of the study area (re-drawn from Jaff et al, 2014)

These cycles were deposited during successive episodes of relative sea-level rises and still stand. Lawa and Gharib (2014) studied the Tethyan Cretaceous successions from the northwestern Zagros fold-thrust belt in the Kurdistan region, NE Iraq and revealed eight benthonic zones from the Qamchuqa Formation (Barremian to Lower Early Cenomanian). Al-Bayati and Al-Banna (2015) studied the Qamchuqa Formation based on two surface sections in the Bekhme and Galala areas in the Kurdistan region, N-Iraq. They recognized that Qamchuqa rocks are characterized by their hard and high porosities and formed of dolostone, limestone and dolomitic limestone. The formation sequences are composed of lithofacies. Mamaseni et al. (2019) stated that Qamchuqa Formation at Duhok basin, northern Iraq, is represented by palynofacies six (PF.6), these facies are also a high percentage of phytoclasts content but more than PF.5, which the range is 48 – 85% with a moderate percentage of palynomorphs (12 – 43%) and a low percentage of amorphous organic matter (3 – 15%). The Qamchuqa Formation was deposited under proximal oxic shelf (III) condition. In the present study, the formation is of three main sedimentary facies. Limestone facies consist of four microfacies, dolostone microfacies are subdivided into five submicrofacies and lithofacies are subdivided into two studied in the Chwarqurna area, located with the Sulaimanyia, Kurdistan region, northeastern Iraq. This work aims to study the microfacies analysis and paleoenvironment of the only cropped out part of the Upper Qamchuqa Formation. The site of the work is located in northeastern Iraq, Sulaimanyia (Fig. 1). The coordinate of the section is 36° 12' 41'' N, 44° 50' 16'' E.

2. Materials and Methods

Twenty-four carbonate rock samples were collected from Chwarqauran section. The thickness of the section is 68.5 m and the distance between the samples is 1 to 5 m depending on the bed's characteristics. These samples were used to prepare twenty-four slides in the workshop of the Department of Petroleum Geology and Minerals, College of Science, University of Diyala. In the laboratory a petrographic study was done including microscopic examination of thin sections under a microscope, Leica PN: DM 500, to determine the petrographic characteristics and fossil contents. The slides were photographed using an Optika D9 camera. Finally, Arc GIS, Sedlog and Corel 9 were used to draw the maps, stratigraphic sections and plates.

3. Results

Rock bodies with specified characteristics are called facies. Ideally facies are a unit of discriminated rock that are deposited under special condition sedimentation and indicate a specific process of the environment (Reading, 1996). Sedimentary facies associations such as fining and coarsening-upward successions of facies, which indicate shifts in environmental conditions, and fossils which are useful indicators of salinity, temperature, water depths, water energy and turbidity of ancient oceans can be used to construct facies models for each major depositional environment (Boggs, 2009). The lithology, standard microfacies SMF, Facies zone FZ and depositional environment of the studied section are shown in Fig. 2. The depositional environments of the Upper Qamchuqa Formation have been interpreted based on the microfacies characterizations. The microfacies characteristics are clarified by texture, grain size and types (skeletal and non-skeletal). The modified carbonate rocks classification of Dunham (1962) by Embry and Klovan (1971) (Fig. 3) were adopted. The distribution of larger benthic foraminifera of the cretaceous by BouDagher-Fadel (2008) was also used to help discriminate the environment of deposition (Fig. 4). The identified microfacies were compared with the standard microfacies and depositional models of Flugel (2004). The most dominant component in the studied part of the Qamchuqa Formation are represented by the skeletal grains, among them the foraminifera, Ostracods and pelecypods shells are the most common.

Period	Formation	Thickness (m)	Sample no	& lithology	Facies type	SMF	Facies zone	Depositional environment
Early Cretaceous	Qamchuqa	60	24		miliolid packstone	8	7	Open sea shelf
			23		Lime Mudstone	23	8,9A	platform interior
			22		Bioclast peloid packstone	10	7	Open sea shelf
			21		Miliolid wackestone	8	7	Open sea shelf
		50	20					
			19					
			18					
			17		Bioclast wackestone.	10	7	Open sea shelf
		40	16					
			15					
			14		Bivalve floatstone	12-Bs	7	Platform margin
			13		Bioclast wackestone	10	7	Open sea shelf
		30	12					
			11					
			10		Lime Mudstone	23	8,9A	platform interior
			9					
		20	8		Orbitolina packstone	18-for	7	Back reef
			7					
			6					
			5		Bioclast wackestone	8	7	Shelf lagoon
		10	4					
			3		Lime Mudstone	23	8,9A	platform interior
			2					
			1		Orbitolina wackestone	8	7	Open sea shelf

Fig. 2. Standard microfacies SMF, facies zone FZ and paleoenvironment

3.1. Skeletal Grains

3.1.1. Foraminifera

Foraminifera are single-celled, protists where the cytoplasm is enclosed inside an organic or mineral shell called tests. The shells are composed of single or multi chambers (Sen Gupta, 1999). The result of microfacies is interpreting the depositional environment and they are common and widely distributed in present seas (Hemleben et al. 1989).

3.1.2. Benthonic Foraminifera

Benthonic Foraminifera are very abundant grains in the Qamchuqa Formation indicating a shallow open marine environment, and this abundance reflects shallow, well-lighted, temperate, little nutrition waters and suitable substrate with normal salinity Hottinger (Murray, 1991; O'Connell et al. 2012). There are many types of benthonic forams recognized in the studied sections. These are *Orbitolina spp.* (Plt.1-A), *Miliolids* (Plt.1-B), *Cuneolina sp.* (Plt.1-C) and *Nezzazata spp.* (Plt. 1-D).

Depositional texture recognizable					Depositional texture not recognizable	
Components not bound together during deposition						
Contains carbonate mud (clay / fine silt)			Lacks mud and is grain supported	Components were bound together during deposition		
Mud supported		Grain supported				
Less than 10% grains	More than 10% grains					
Mudstone	Wackestone	Packstone	Grainstone	Boundstone	Crystalline	
5 mm	5 mm	5 mm	5 mm	5 mm	5 mm	
	Floatstone (large grains)	Rudstone (large grains)		Framestone	1m	
	30 mm	30 mm	30 mm	Bindstone	100 mm	
				Bafflestone	100 mm	

Fig. 3. Modified classification of Dunham (1962) by Embry and Klovan, 1971

Fig. 4. Distribution of larger benthic foraminifera (BouDagher-Fadel, 2008)

3. 1. 3 Orbitolinids

Represent the most abundant skeletal grain in the studied section. The Orbitolinids are abundant in the outer platform in shallow deep water. Orbitolinids reproduced toward the open sea of the shallow water at depths of 30 to 80 m (Gräfe and Wendler, 2003).

3. 1. 4 Miliolids

They are tropical regions with 25°C shallow waters and indicate depths of about 33 meters and salinity of 30-50 ppt (Murray, 2006).

3.1.5. Planktonic Foraminifera

In present study it is represented by only *Globigerina sp.* (Plt. 1-E).

3.1.6. Bioclasts

Bioclast is the debris of organisms, resulting from the transmission and robbing of fossils. The bioclast as an expression is applied for fossils under microscope. Fossils are wracked (broken shells) or biomorph (bivalves), and skeletal grain is equivalent to bioclast (Flugel, 2010). The main component of the bioclasts found in this study are clasts of foraminifera, ostracods and shell fragments. The source of these shell bioclasts are due to either trituration by rapacious or operation after animals' death (Ginsburg, 1957; Trewin and Welsh, 1976; Vermeij, 1987), (Plt. 1-F).

3.1.7. Non- skeletal grains

These are the grains which are not related to the skeletal components of micro-organisms (Tucker and Wright, 1990). They are less abundant in the Qamchuqa Formation than skeletal grains and represented by peloids and intraclasts.

3.1.8. Peloids

Peloids are ovoid, spherical or rod shaped, composed of micrite, without internal structure (Boggs, 2009). Peloids are the most common non-skeletal grain in the Qamchuqa Formation. Their size ranges from silt to sand with ovoid or spherical shape and they are abundant in peri-tidal carbonates waters and deeper water. Peloids are scarce in the polar cooler water carbonates (Flugel, 2004), (Plt.1-G).

3.1.9. Intraclasts

Intraclasts are lime fragments of consolidated or partly consolidated particles which come from the denudation of closely penecontemporaneous sediment from intraclast, extracast, and lithoclasts of a basin and reprecipitated inside the same basin. They exist in sholy ecosystem but may move to inward water. The intraclasts are formed in shallow water environments which are distinct by high energy systems and tides which constantly rework lime sediments. Intraclasts are less common than peloids. They represent reworked grains of the Qamchuqa carbonates arising from current agitation. The differences in size, shape and orientation of the Intraclasts, indicate strong reworking of semi-lithified sediment (Flugel, 2010) (Plt.1-H).

3.2. Microfacies

Microfacies of present work are subdivided into four main carbonate microfacies and four submicrofacies (Fig. 2).

3.2.1 Non-fossiliferous lime mudstone microfacies m1

Characterized by non-laminated homogeneous micrite, these microfacies exist in the lower, middle and upper part of the Upper Qamchuqa Formation. They are equivalent to standard microfacies SMF 2, which are deposited within the facies zone FZ 8 that reflect tidal flats or evaporitic coasts FZ 9A, both of FZ 8 and 9A indicate saline or evaporative environments (Flugel, 2010) (Plt.1-I).

3.2.2. Wackestone microfacies

These contain two submicrofacies:

3.2.3. Bioclast wackestone submicrofacies M2

These contain skeletal and shell fragments consisting of more than 15 % of the total components of the facies. They are represented by small-size shell fragment, as well as a few benthic foraminifera and Ostracoda. All skeletal components fall into a gray-colored micrite; these microfacies exist in the lower and middle part of the Upper Qamchuqa Formation and compared with SMF 10 and deposition in the FZ 7 which represent inner and mid-ramp settings. (Wilson, 1975; Flugel, 2010) (Plt.1-J).

Scale bar: 1000 micron

Plate 1. (A) *Orbitolina* sp; (B) Miliolids; (C) *Cuneolina*; (D) *Nezzazata*; (E) *Globigerina*; (F) Shell fragments; (G) peloids; (H) intraclasts; (I) non-fossiliferous lime mudstone M1; (J) Bioclast wackestone submicrofacies M2; (K) Miliolid wackestone submicrofacies M3; (L) bioclast packstone submicrofacies M4; (M) *Orbitolina* packstone submicrofacies M5; (N) Bivalve floatstone microfacies M6.

3.2.4. *Miliolid wackestone submicrofacies M3*

Characterized by the presence of miliolid and other benthic and planktonic foraminifera (orbitolinids, miliolids) and Ostracoda, these microfacies are found in the upper part of the Upper Qamchuqa Formation and they can be compared with SMF 8 and FZ 7 which reflect shelf lagoon with circulation (Plt.1-K).

3.2.5. *Bioclast packstone submicrofacies M4*

These are characterized by skeletal and non-skeletal components in the rate of 50%, containing benthic foraminifera with coarse and fine peloids. These microfacies exist in the upper part of the Upper Qamchuqa Formation and can be compared with standard microfacies SMF 10 and deposition in the facies zone FZ- 7 which represent inner and mid-ramp settings. (Wilson, 1975; Flugel, 2010) (Plt.1-L).

3.2.6. *Orbitolina packstone submicrofacies M5*

Consisting of a high abundance of benthic foraminifera (*Orbitolina spp.*) and few shell fragments, these microfacies exist in the lower part of the Upper Qamchuqa Formation and can be compared with SMF (18-for) and deposition in FZ 7 which reflect lagoon environment (Wilson, 1975; Flugel, 2010) and also can be deposited in back reef environment according to the model of the special distribution of the Cretaceous larger benthic foraminifera along the shelf of Tethys (BouDagher-Fadel, 2008) (Plt.1-M).

3.2.7. *Bivalve floatstone microfacies M6*

Characterized by the dominance of non-attached bivalve shells arranged in a parallel pattern with micritic supported background, this microfacies exists in the middle part of the Upper Qamchuqa Formation and can be compared with the standard microfacies SMF (12-Bs) and deposition in the facies zone FZ 7 (Plt.1-N).

3.3. Paleoenvironment

Using the model of benthic forams of Cretaceous by BouDagher-Fadel (2008) which depends on index fossils (benthic forams) distribution (Fig. 4) found in the succession, some of these benthic forams prefer the platform ecosystem like *Orbitolina spp.*, which indicates back-reef towards the open sea. Miliolids reflect shallow shelf environment, *Cuneolina sp.*, and *Nezzazata spp.*, occupying the total shelf to the back-reef; all these benthic forams indicate a shallow open marine environment (Hottinger, 1983; Murray, 1991; O'Connell et al., 2012). The standard microfacies by Flugel (2010) and facies zones by Wilson (1975) which inferred from microfacies of the studied section discriminate shallow waters of the interior platform from the evaporitic or brackish water FZ 9A to back-reef FZ 7.

4. Conclusions

- Four main microfacies were found. These are non-fossiliferous lime mudstone M1, wackestone, packstone and floatstone M6 and four sub microfacies, bioclast wackestone M2, miliolid wackestone M3, bioclast packstone M4 and orbitolinid packstone M5, and these microfacies are sometimes repeated in the section. All microfacies and the fossil distribution reflect the facies zone 7, 8 and 9A.
- The Qamchuqa Formation in the present study was deposited in the platform interior between the tidal flat to the mid ramp and back reef environment.

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