Promote Scientific Research is Our Way to Serve the Community

Microfacies and Depositional Environment of the Lower Qamchuqa Formation in Bai-Hassan Oilfield / Northern Iraq

Sabir S. Shahab[1] , Lafta S. Kadhim[1] , Dler H. Baban[2]

[1] *Department of Applied Geology , College of Science , University of Tikrit , Tikrit , Iraq*
[2] *Geology Department , College of Science , University of Sulaymaniyah , Sulaymaniyah , Iraq*

ARTICLE INFO.

Keywords:
Lower Qamchuqa, Bai-Hassan Oilfield, microfacies, foraminifera.

Name: Sabir S. Shahab
E-mail:
Sabir.subhi@yahoo.com
Tel:

ABSTRACT

The Lower Qamchuqa (Shu'aiba) Formation with Aptian age is a shallow-marine carbonate that observed for the first time at the outcrop section in northern Iraq in Qamchuqa Gorge. For the present study, data of coring and cutting samples, thin section, and gamma ray log for the studied formation from the well BH-96 in Bai-Hassan Oilfield were used to determine the microfacies and sedimentary environment of the formation. The thickness of studied section was 49m from the upper part of the formation. The lithology of the studied section composed of shaly limestone with a 2m thick shale bed in the upper part of the studied section followed by successions of limestone and dolomitic limestone of thicknesses 19m and 11m respectively at the middle and lower part of the studied section. Three microfacies and six sub-microfacies types were identified in the formation which are the lime mudstone microfacies (subdivided to non-fossiliferous mudstone and fossiliferous mudstone sub-microfacies), the lime wackestone microfacies (subdivided to benthic foraminiferal wackestone, orbitolina wackestone, bioclasts wackestone sub-microfacies and pelloidal wackstone sub-microfacies), and the lime packstone microfacies. The identified microfacies were compared to the standard microfacies zones and appeared to be representing open marine and restricted platform environments.

Introduction

Bai Hassan Oilfield is located in Kirkuk Governorate and consists of an asymmetrical, longitudinal anticline of about 32km length and about 3km width. The oilfield considered as one of the several elongated asymmetrical anticline with double plunging which characterize Foothill Zone of the unstable shelf in North Eastern Iraq [1] (Fig.1A). The structure of the field consists of two domes namely Kithka and Dawood which separated by Shahl saddle (Fig.1B). The penetrated part of the Lower Qamchuqa Formation by the well BH-96 (which located at the NE flank of Kithka dome) is about 49m in which the total depth of the well reached. This penetrated thickness represents the upper part of the formation. The lithology of the formation appeared to be generally comprising of limestone with interbedded thin shale and dense dolomitization processes increasing within depth. In this study and through data gathered from the microscopic study of the prepared thin sections, calcimetry test, and gamma ray log the description of the formation lithology done in detail in addition to determining and paleo-depostional environment of the formation. The formation as documented by internal reports of Northern Oil Company (NOC) is overlained unconformably by the shale beds of Nahr Umr Formation and underlained conformably by Garagu Formation.

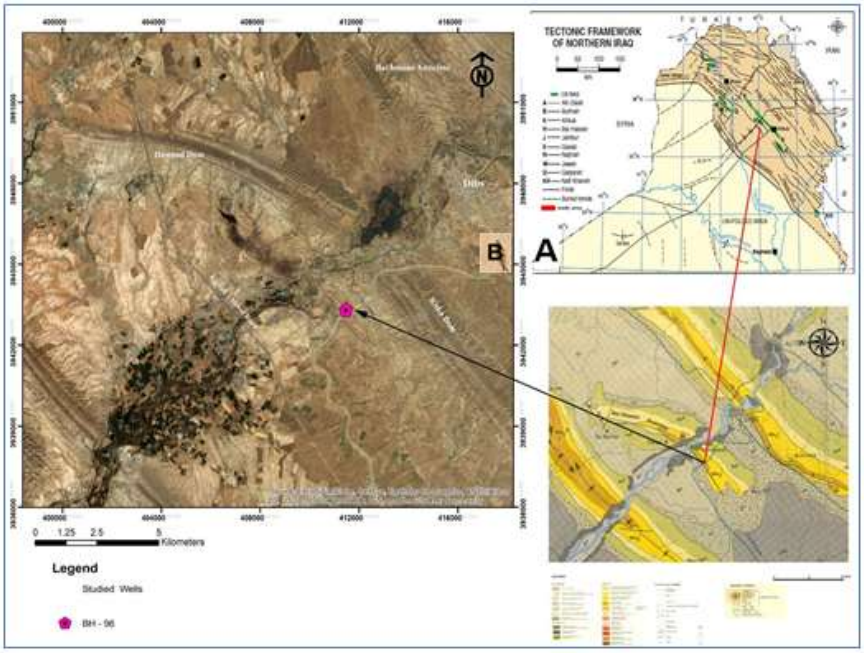


Figure 1: (A) Location of the studied field on the tectonic map of Iraq after [2], (B) location of the studied well on an aerial photo of Bai-Hassan structure.

Previous Works

Many studies by different authors done about Lower Qamchuqa Formation previously in Iraq [3-7] but only those which are exclusively about Lower Qamchuqa Formation and dealing with the microfacies and depositional environment (the topic of this research) are summarized below.

In an internal report by [8] mentioned that the Lower Qamchuqa (Shu'aiba) Formation in Bai-Hassan Oilfield comprises of three units. The upper and middle units consist of limestone dominant lithology and the lower unit which represents the major part of the formation consists of shaly limestone, limestone, and dolomite.

Lower Qamchuqa as a group studied by [9] in one of the fields situated in Kirkuk Governorate. They mentioned that Middle Sarmord Formation and the Lower Qamchuqa Formation are belonging to the MS I megasequence which corresponds to a regressive megasequence. They further subdivided the MS I to two mesosequences namely S1 and S2. The S2, which represented Lower Qamchuqa Formation, appeared to be composing entirely of carbonates and showing a regressive evolution and development of neritic dolomitic limestone.

During a sedimentology and lithostratigraphy study of Qamchuqa Formation in High Folded Zone; the facies analysis appeared that the formation deposited in a low energy environment which represented by reef, backreef, forereef and lagoonal environments [10].

Lower Qamchuqa Formation in Khabbaz Oilfield studied by [11] in which the formation which was of thickness between 180 and195 m subdivided into three lithological units. The upper 8-15 m named as unit A and consists of partly dolomitized marly limestones; and a middle unit B of 52 to 56 m thick consisting of vuggy dolomitic limestone and dolostone; whereas the lower C unit was of less than110 m thick and composed of shale-rich and dolomitic limestones. They also mentioned that the Limestone microfacies include shelfal bioclastic wackestones, *Orbitolina* bioclastic packstones, *Orbitolina* grainstones, and pelagic bioclastic wackestones.

Lithology of Lower Qamchuqa Formation

The lithology of the Lower Qamchuqa Formation determined visually from the study of the selected core and cutting rock samples and optically through the microscopic study of the prepared thin sections. The gamma ray log with the calcimetry analysis for a number of the rock samples supported the lithology determination for the studied formation. The data of the gamma ray showed a higher shale content of the upper part of the studied section in comparison to the lower part (from the depth 2010m and deeper) (Fig.2). A shale bed of about 2m thick also observed from the gamma ray log data between depths 2008 and 2010m and approved by the results of the calcimetry analysis (Table 1) were about 71% insoluble residue matter measured.

The integration study of the used tools showed that the depth between 1991m (top of the Lower Qamchuqa in the studied well) to the depth 2008m consists of dark to light gray colour shaly limestone followed by the mentioned 2m thick greenish gray shale bed. The middle part of the studied section (between depths 2010 and 2029m) appeared to be consisting of olive gray limestone, whereas the rest (lower) part of the formation till the total depth of the well at 2040m showed a pale yellowish brown to light olive colour dolomitic limestone.

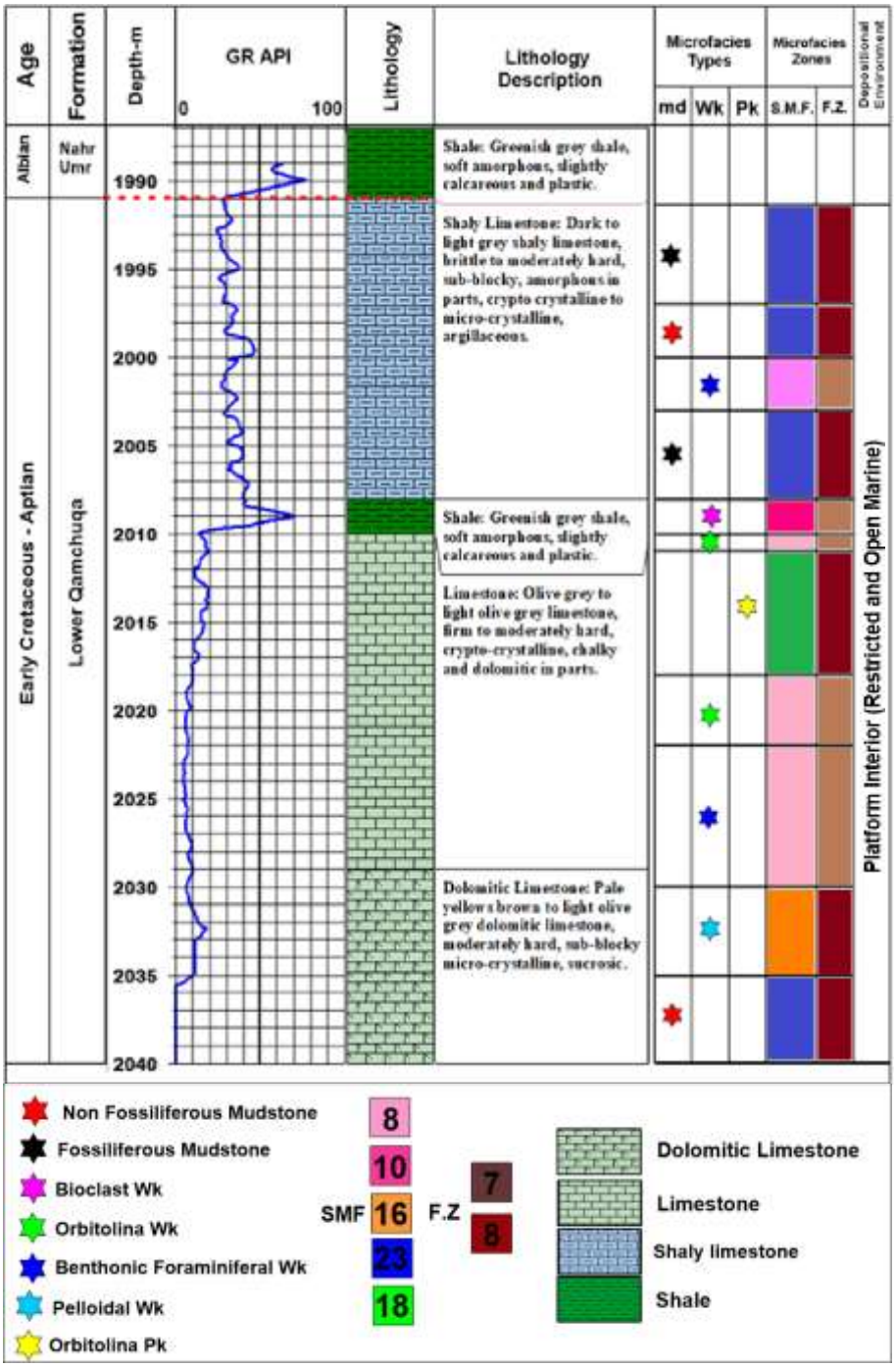


Figure 2: Stratigraphic column and microfacies of the Lower Qamchuqa Formation in the well BH-96.

The contact with the overlain Nahr Umr Formation characterized by a sudden increase in the gamma ray record indicating to existence of a possible unconformity surface between the two formations [8]. In fact, the unconformity condition between the two formations was documented by [8] in Bai Hassan Field.

Table 1: Concentration of Calcite ($CaCO_3$), Dolomite ($CaMg(CO_3)_2$) and Insoluble Residue for the Lower Qamchuqa Formation in the well BH-96.

BH-96 Interval Depth	Calcite $CaCo_3$	Dolomite $Mg(CaCo3)_2$	Total Carbonate	Insoluble Residue
	%	%	%	%
1991	82	2	84	16
1998	96	3	99	1
2010	23	6	29	71
2015	72	5	77	23
2023	92	4	96	4
2030	98	2	100	0
2036	76	12	88	12
2040	82	8	90	10
Avg.	77.63	5.25	82.88	17.13

Petrography

The petrographic study of carbonate rocks and associated deposits by using a polarized microscope is important approach to identify the nature of these rocks [12]. The present study includes the description of the major components of Lower Qamchuqa Formation which contains skeletal and non-skeletal grains. The skeletal grains commonly consist of benthonic foraminiferals represented by *Orbitolina, Textularia, Chofatella* and Meliollides, in addition Echinoderm, Bioclast, Sp onges and Algae. The non-skeletal grains represented by pellets and extraclasts.

Accordingly, three major types of microfacies have been described through optical study of the prepared 49 slides using polarized microscope and depending on classification of [13] (Fig. 3). The standard distribution of microfacies suggested by [14] was depended on, for determining the microfacies zones in order to detecting the paleo-depositional environment of the studied section of the Lower Qamchuqa Formation. Table 3 shows the depth interval; identified microfacies and sub-microfacies in this study, whereas more details for each identified microfacies can be seen below.

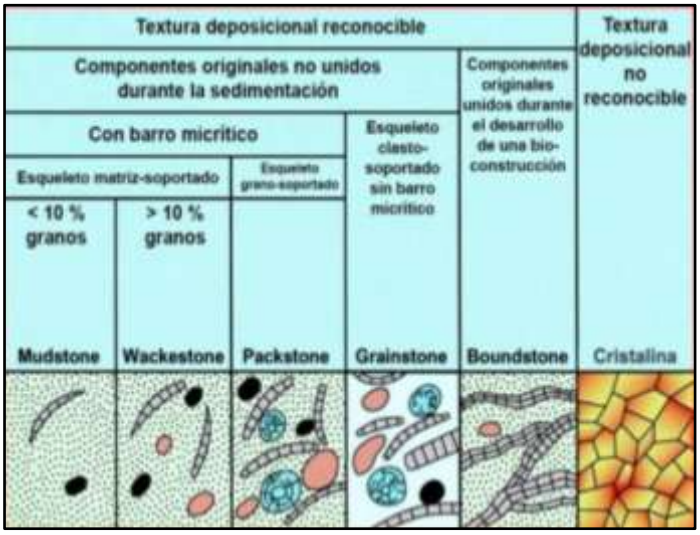


Figure 3: Classification of the carbonate rocks [13]

Table: 3 Microfacies and sub-microfacies types with depths interval in the well BH-96 for the Lower Qamchuqa Formation.

Depths Interval m	Microfacies Types	Sub-Microfacies Types
(1997-2000) and (2035-2040)	**Lime Mudstone Microfacies**	Non Fossiliferous Mudstone sub-microfacies
(1993-1997) and (2003-2008)		Fossiliferous Mudstone sub-microfacies
(2000-2003) and (2022-2030)	**Lime Wackestone Microfacies**	Benthonic Foraminifera Wackestone sub-microfacies
(2010-2011) and (2018-2022)		Orbitolina Wackestone sub-microfacies
(2008-2010)		Bioclast Wackestone sub-microfacies
2030-2035		Pelloidal Wackestone sub-microfacies
2011-2018	**Lime Packstone Microfacies**	----------

Mudstone Microfacies

This microfacies considered more distributed than the others within the Lower Qamchuqa Formation in the studied well BH-96, which content mainly <10% skeletal components according to the classification [13]. It is subdivided into two sub-microfacies depending on their components:

A- Non Fossiliferous Lime Mudstone sub-microfacies

This sub-facies is lithologically comprises dominantly of shaly limestone and dolomitic limestone with 8m thickness (Plt. 1-1). It was appeared in the upper and lower part of the formation. This sub-facies is similar to the standard microfacies

SMF 23 in the facies zone FZ-8 when compared with standard microfacies types [14].

B- Fossiliferous Lime Mudstone sub-microfacies

This sub-facies is lithologically comprises dominantly of shaly limestone observed only at the upper part of the formation with 9m thickness. The fossiliferous mudstone sub-microfacies contain less than 10% skeletal component represented by benthonic foraminiferals especially (*Chofatella*) as index fossil was detected and some bioclasts (Plt. 1-1). This sub-facies is similar to the standard microfacies SMF 23 in the facies zone FZ-8 when compared with standard microfacies types [14].

Wackestone Microfacies

This type of microfacies was commonly distributed on the middle and upper parts of the formation in the studied well BH-96. The skeletal components ranged between (10-40) % according to classification [13]. Also it was subdivided into four (secondary) sub-microfacies depending on their skeletal components:

A- B Benthonic Foraminiferals and *Orbitolina* Wackestone sub-microfacies

The both wackestone sub-microfacies benthonic foraminiferal and *Orbitolina* wackestones sub-microfacies are combined, because they were located at the same standard microfacies zone (SMF8 and FZ-7). The dominant lithology of both sub-microfacies were comprises of limestone, shaly limestone and dolomitic limestone. These sub-microfacies observed at the middle and lower part of the formation within 11m and 5m thickness (Plts. 1-3 and 1-4) respectively as shown in (Fig. 2). The skeletal components ranged between (10-40) percent according to classification [11] which represented by *Orbitolina, Textularia,* and Meliollides, in addition to the echinoderm, bioclast and sponge in parts. The extraclast as non-skeletal grain observed at the depth 2030m (Plt. 1-5). They were similar to the standard microfacies SMF 8 in the facies zone FZ-7 if compared with standard microfacies types [14].

C- Bioclast Wackestone sub-microfacies

It was composed dominantly of thin horizon of shale lithology. This was approximately observed at the middle part of the formation with 2m thickness.

This sub-microfacies characterized by existing of bioclasts more than 60 % with detecting some other skeletal components such as sponge and molluscs in part (Plt. 1-6). This sub-facies is belongs to the standard microfacies SMF 10 in the facies zone FZ-7 if compared with standard microfacies types [14].

D- Pelloidal Benthonic Foraminifera Wackestone sub-microfacies

It was composed dominantly of dolomitic limestone lithology within microspar and spary calcite in some parts. It is consists of micrite, which influenced by recrystallization. Moreover, some of micrite are recrystallized to micro-spar and spary calcite. The skeletal component represented by *Textularia,* and Meliollides (Plt. 2-1), whereas the non-skeletal grains represented by Pellets approximately about (10-15) %, which is detected at lower part of the formation with 5m thickness. This sub-facies is similar to the standard microfacies SMF16 in the facies zone FZ-8 if compared with standard microfacies types [14].

***Orbitolina* Packstone Microfacies**

This microfacies is composed dominantly of limestone lithology. It was detected at the middle part of the formation with 7m thickness. It was contain skeletal components about (60-90) % according to classification of [13], which considered contained *Orbitolina* fossils more than >60% with detecting each of bioclast, algae and sponge (Plt. 2-2). This sub-facies is similar to the standard microfacies SMF18 in the facies zone FZ-8 if compared with standard microfacies types [14].

Diagenetic Processes effecting on the Formation

The carbonate sediments diagenesis comprises all the processes that effect on the sediments after deposition till the realms of incipient metamorphism at high temperatures and pressures, which includes a physical, chemical, and biological process [15]. The dominant diagenetic processes that affecting on the Lower Qamchuqa formation commonly was represented by the physical compaction, chemical compaction, (stylolite), inversion, dolomitization, and cementation. The physical compaction was observed at the upper part of the formation at the same place the inversion was detected (Plt 2-3). At the middle part of the formation the chemical compactions was observed, which lead to resulted different types of stylolite (Plts. 2-4 and 2-5). In addition to the few cementations occurred, represented by granular (Plt 2-6), drusy (Plt 3-1) and blocky (Plt 3-2) cements at the lower part. The same lower part of the formation was exposed to the dolomitization processes that resulting dolomite floating texture rhombs (Plt 3-3), as well as the porosity appearance of low-medium proportion which represented by the intrafossils (Plt 3-4), channels (Plt 3-5), fractures (Plt 3-6), and cavern (Plt 3-7) porosities were detected. The authigenic mineral pyrite was scattering within the micritic matrix, and the presence of oil shows occurred.

Depositional environment Model

The depositional environment can be interpreted and detected depending upon microfacies contents and associated fossils. The each type of fossils reflected a suitable depositional environment after identified microfacies zones. The identified of the microfacies in the present study corresponds to the standards microfacies (SMF: 8, 10, 16 and 23) belonging to the standard zones FZ7 fluctuated to FZ8 if compared with standard microfacies types of Wilson's [14].

This reflecting restricted and open marine environments represented by platform interior paleo-depositional environment.

In the other side the depositional environment being detected by the skeletal components which represented dominantly by benthonic foraminiferals (*Orbitolina, Textularia* and Meliollides) that reflects

shallow environment with warm water, high salinity and moderate salinity [16, 17]. As [18] recorded that the occurrence of common *Orbitolina* corresponds to the carbonate microfacies of platform environment. The bioclasts presence of Lower Qamchuqa Formation indicates that it was deposited in a shallow-water carbonate platform [10, 11] it is the same that proved in this study. In addition the *Chofatella*, algae and echinoderms that indicated to shallow depth in open marine.

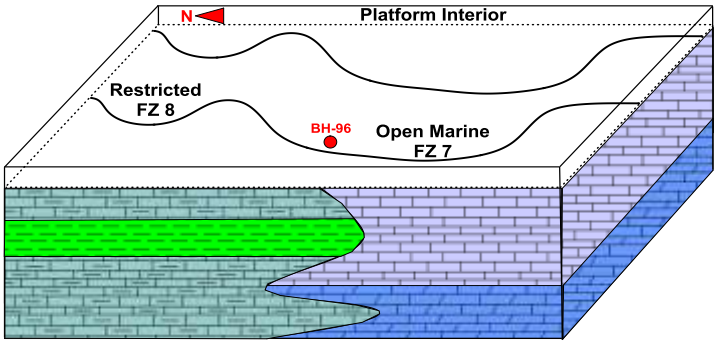


Figure 6: Depositional model of Lower Qamchuqa Formation for the studied well BH-96.

Conclusions

The main conclusions that this study came out with can be summarized in the following:

1. The lithology of the studied part from the Lower Qamchuqa Formation in the well BH-96 consists mainly of shaly limestone in its upper part and limestone in the middle part (separated with about 2m thick shale bed), and slightly dolomitized limestone at the lower part.
2. The carbonate rock of Lower Qamchuqa Formation in the well BH-96 consists of three main types of microfacies which can be subdivided to six sub-microfacies depending on the percentages of skeletal and non-skeletal components which consist mostly of benthonic foraminifera.
3. The studied upper part of the Lower Qamchuqa Formation in the location of the well BH-96 deposited in an open marine shallow environment and fluctuated in to a restricted marine environment.

Plate-1

1- Fossiliferous mudstone sub-microfacies detected at depth (1993) m, cutting sample, microscope polarizer x40

2- Non-Fossiliferous mudstone sub-microfacies, detected at depth (1997) m, core sample (C-7), microscope polarizer x40.

3- Benthonic foraminiferal wackestone sub-microfacies detected at depth (2022-2023) m, core sample (C-10), microscope polarizer x40.

4- *Orbitolina* wackestone sub-microfacies detected at depth (2010-2011) m, core sample (C-8), microscope polarizer x40.

5- Intraclast observed in benthonic foraminifera wackstone sub-microfacies at depth (2029-2030) m, core sample (C-10), microscope polarizer x40.

6- Bioclast wackestone sub-microfacies observed at depth (2009-2010) m, core sample (C-8), microscope polarizer x40.

Plate-1

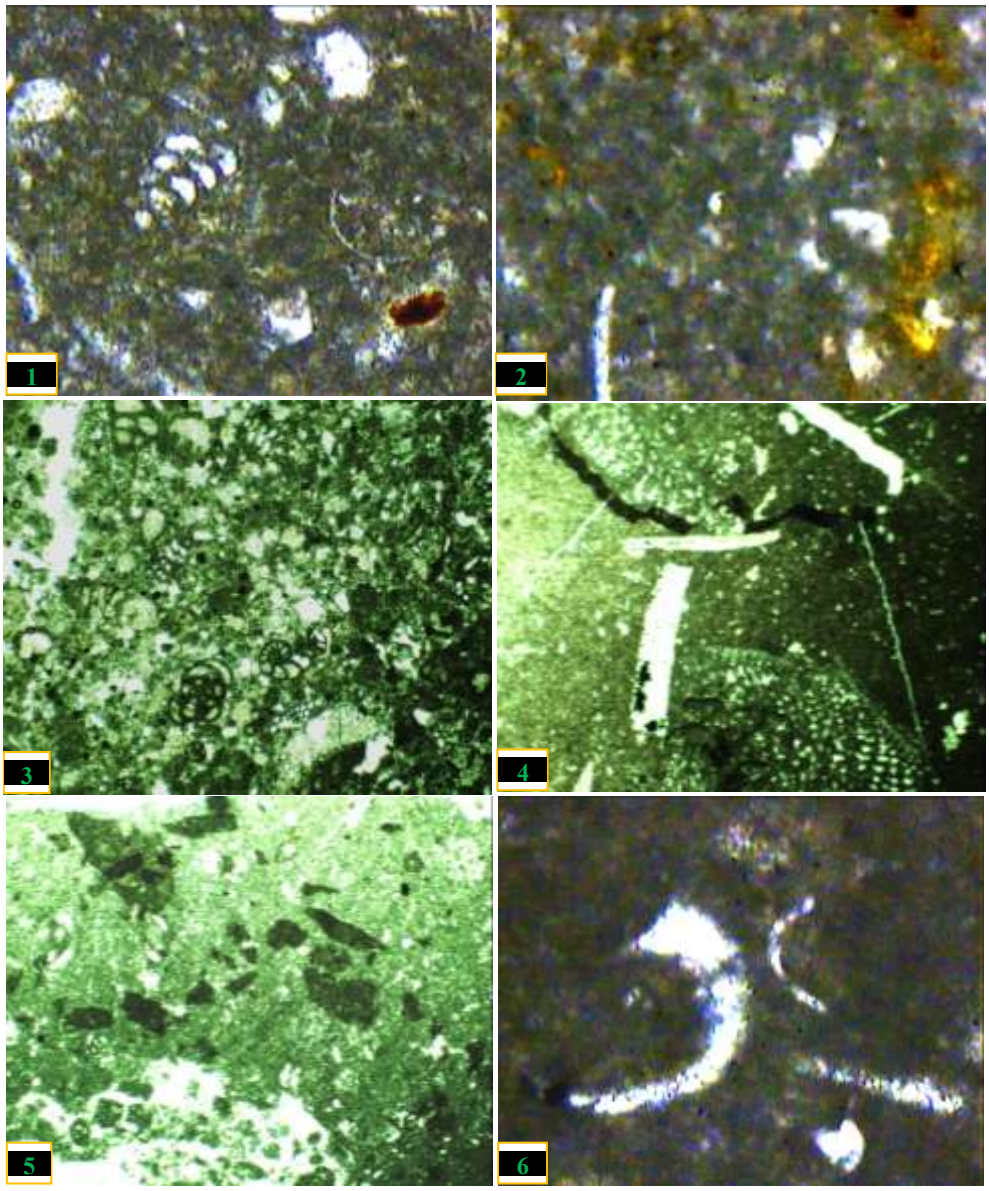


Plate-2

1- Pellets observed in wackestone sub-microfacies at depth (2030-2031) m, core sample (C-10), microscope polarizer x40.

2- *Orbitolina* packstone microfacies represented dominantly by *Orbitolina* detected at depth (2013-2014) m, core sample (C-9), microscope polarizer x40.

3- Physical compaction and isochemical diagenetic inversion are observed at depth (1995-1996) m, cutting sample, microscope polarizer x40.

4- Hummocky stylolite detected at depth (2025-2026) m, core sample (C-10), microscope polarizer x40.

5- Low implitude stylolite detected at depth (2029-2030) m, core sample (C-10), microscope polarizer x40.

6- Granular cement observed at depth (2018-2019) m, core sample (C-9), x40 microscope polarizer x40.

Plate-2

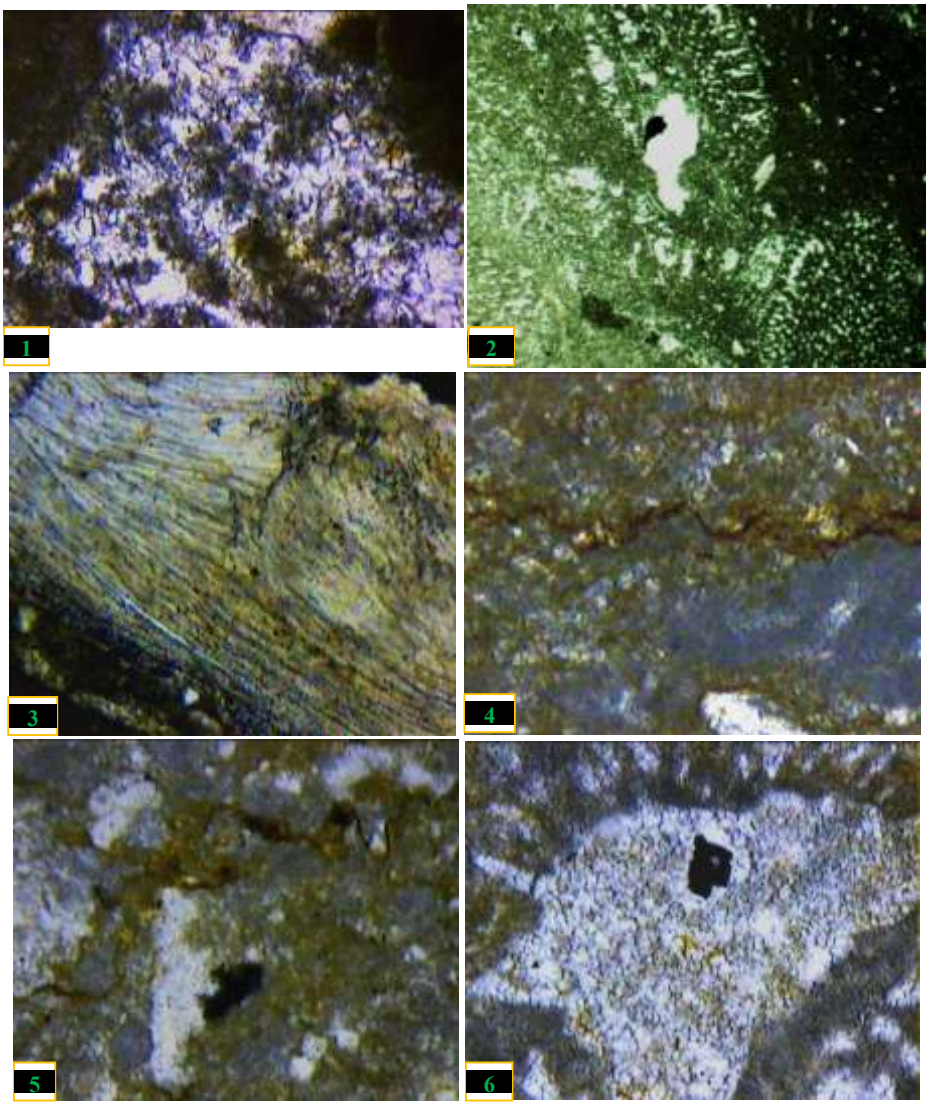
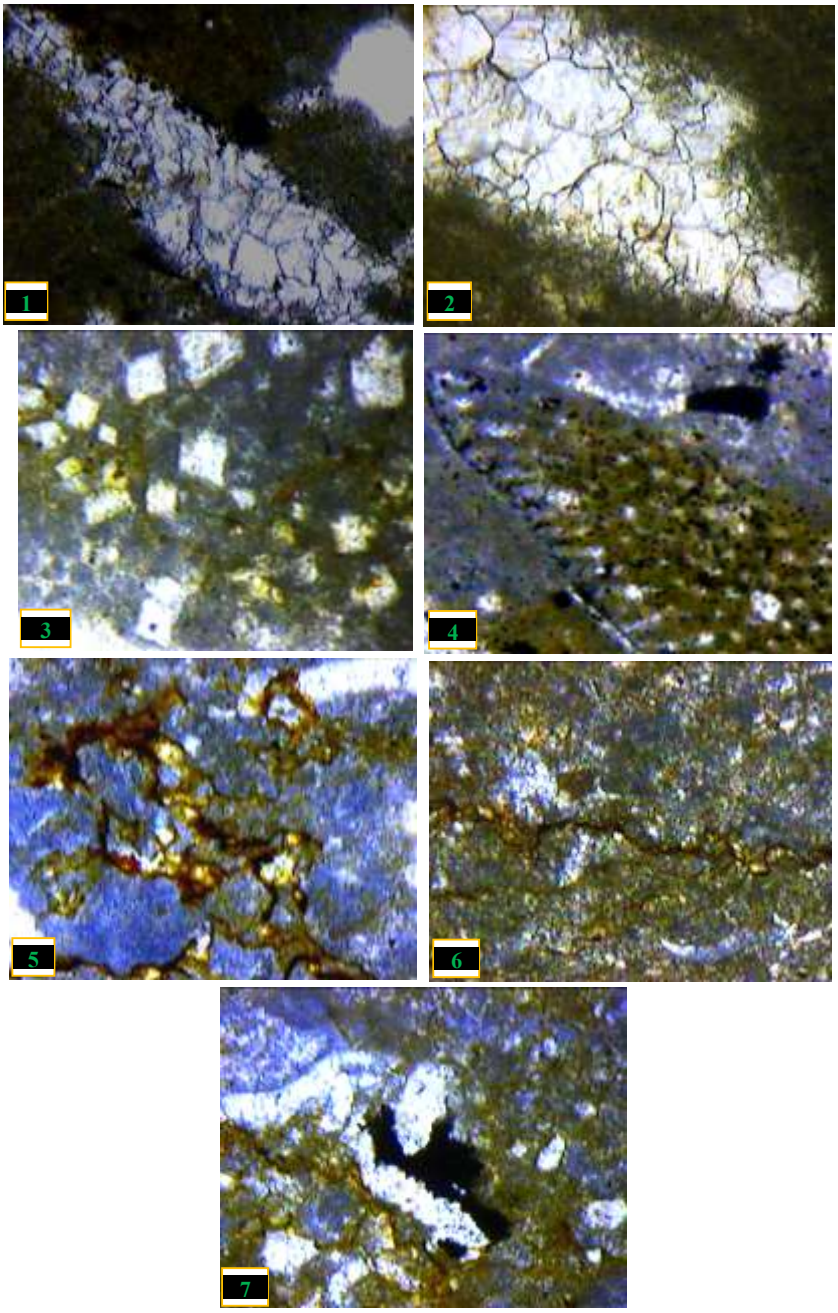


Plate-3

1- Drusy cement observed at depth (2024-2025) m, core sample (C-10), microscope polarizer x40.
2- Blocky calcite cement observed at depth (2035-2036) m, cutting samples, microscope polarizer x40.
3- Dolomitization processes the dolomite of the type floating rhomb texture, detected at depth (2035-2036) m, cutting samples, microscope polarizer x40.
4- Intrafossil porosity observed in *Orbitolina* fossil at depth (2024-2025) m, core sample (C-10), microscope polarizer x40.
5- Channel porosity observed at depth (2018-2019) m, core sample (C-9), microscope polarizer x40.
6- Fracture porosity observed at depth (2025-2026) m, core sample (C-10), microscope polarizer x40.
7- Cavern porosity formed by solution process observed at depth (2029-2030) m, core sample (C-10), microscope polarizer x40.

Plate-3



References

1- NOC, (1994). The annual report about the reservoirs for the year 1993, Northern Oil Company Kirkuk-Iraq.

2- Dunnington, H. V. (2005). Generation, migration, accumulation, and dissipation of oil in Northern Iraq. Geoarabia, **10 (2)**: 39-84.

3- Bellen, R.C., H.V. Dunnington, Wetzel, R. and Morton, D. (1959). Lexique stratigraphique international. Asie, Fasc 10 a, Iraq, Paris.

4- Buday, T., (1980). The Regional Geology of Iraq, Stratigraphy and Paleogeography. Publications of GEOSURV, Baghdad, **1**: 445pp.

5- Jassim, S. Z. and Goff, J. C., (2006). Geology of Iraq. Published by Dolin, Prague and Moravian Museum, Srno: 341pp.

6- Sharland, P. R., Archer, R., Casey, D. M., Davies, R.B., Hall, S.H., Heward, A.P., Horbury, A.D., Simmons, M. D., (2001). Arabian Plate Sequence Stratigraphy. Geoarabia, special publication, Gulf Petrol.

7- Aqrawi, A.A.M., Horbury, A.D., Goof, J.C. and Sadooni, F.N., (2010). The Petroleum Geology of Iraq. Scientifics Press Ltd, Great Britain: 424 pp.

8- NOC, (1992). A geological study of the Cretaceous reservoirs in Bai-Hassan Field, Northern Oil Company, Kirkuk, Internal report (in Arabic).

9- Al-Shdidi S., Thomas G., and Deluad2 J., (1995), Sedimentology, Diagenesis and Oil Habitat of Lower Cretaceous Group, Northern Iraq1, AAPG, **79 (5)**: 763-779.

10- Ameen, B. M., (2008). Sedimentology and Lithostratigraphy of Qamchuqa Formation from Kurdistan Region, NE-Iraq, Ph. D. Thesis (unpublished), University of Sulaymani: 143 pp.

11- Qader, F., & Al-Qayim, B. (2016). Petrophysical and Sedimentological Characterization of the Aptian Shu'aiba (lower Qamchuqa) Formation Reservoir at the Khabbaz Oilfield, Northern Iraq. Journal of Petroleum Geology, **39 (4)**: 375-392.

12- Flugel, E. (2004); Microfacies of Carbonate Rocks, Analysis, Interpretation and Application, Springer, Berlin, Heidelberg, New York: 966 pp.

13- Dunham, R. J., (1962). Classification of carbonate rocks according to depositional texture. In: Ham, W. E., (eds.), classification of carbonate rocks. AAPG, Mem.1, Tulsa Okala: 108-121.

14- Wilson, J.L., (1975). Carbonate facies in geological history. Berlin- Heidelberg. New York, Springer: 471 pp.

15- Flugel, E., (1982). Microfacies analysis of limestones. SpringerVerlag Berlin–Heidelberg, New York: 633 pp.

16- Douglass, R.C., (1960). The foraminideral genus orbitolina in North America, U.S. Geol. Survey, Prof: 333-52.

17- Brasier, M.D., (1980). Microfossils, George Allen and Urwin ltd. Boston: 193 pp.

18- Moulade, M. Peybemes, B., Rey, J., and Saint-Marc, P., (1985). Biostratigraphic interest and paleobiogeographic distribution of early and middle cretaceous Mesogean Orbitolina (foraminiferidal). Jour. of foraminiferal research, **15 (3)**: 149-158.

السحنات الدقيقة والبيئة الترسيبية لتكوين القمجوقة السفلى في حقل باي حسن شمالي العراق

صابر صبحي شهاب[1] ، لفتة كاظم سلمان[1] ، دلير حسين بابان[2]

[1]قسم علوم الارض التطبيقية ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

[2]قسم علوم الارض ، كلية العلوم ، جامعة السليمانية ، السليمانية ، العراق

الملخص

يعتبر تكوين القمجوقة السفلى (الشعيبة) بعمرفترة الابتيان من الصخور الكاربوناتية ذات اعماق بيئية ضحلة. اكتشف التكوين لاول مرة في شمال العراق في مضيق قمجوقة والذي يعد مقطعه المثالي. بالنسبة للدراسة الحالية تم استخدام البيانات لكل من نماذج اللباب والفتات مع مجس الكاما للجزء المخترق من التكوين و البالغ 49 مترا وذلك في البئر BH-96 في حقل باي حسن وبذلك تم تحديد السحنات الدقيقة واستنتجت البيئة الترسيبية القديمة للتكوين. فقد تم تقسيم التكوين صخاريا الى حجر جيري طيني متداخل مع طبقات رقيقة من السجيل بسماكات 7 و 2م على التوالي في الجزء الاعلى من المقطع الذي تم دراسته، وتليها تعاقب من حجر جيري مع حجر جيري دولومايتي باسماك 19 و 11م في جزئه الاسفل. شخصت ثلاث من السحنات الدقيقة الرئيسية وست من السحنات الدقيقة الثانوية في التكوين وهي; سحنة حجر جيري طيني الرئيسي (سحنة حجر طيني غير الحامل للمتحجرات وسحنة حجر طيني الحامل للمتحجرات)، حجر جيري واكي الرئيسي (حجر جيري واكي حامل للمتحجرات الاوربيتولينا، حجرجيري واكي حامل للفتاة الحياتي وحجر جيري واكي الدملقي) و حجر جيري المرصوص الرئيسي. عند مقارنة هذه السحنات مع الانطقة القياسية للسحنات الدقيقة الرئيسية والثانوية استنتجت البيئة الترسيبية القديمة للتكوين والتي تمثلت بالبيئة البحرية المفتوحة والبيئة المحدودة من الرصيف الداخلي.