Iraqi Journal of Science, 2019, Vol. 60, No.5, pp: 1104-1114
DOI: 10.24996/ijs.2019.60.5.19

ISSN: 0067-2904

Depositional Environment and Diagenesis processes impact on the carbonate rock quality: a case study, southeastern of Iraq

Afrah Hassan Saleh
Geology Department, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

Deposition environment and diagenesis processes are very important factors which affect and control the reservoir properties. The carbonate Mishrif Formation has been selected as a carbonate reservoir in selected wells from southeastern Iraq to understand the influence of the Deposition environment and diagenesis processes on the carbonate reservoir. A core examination of thin sections, shows that Mishrif Formation comprises of six depositional environments, these are: deep marine, lagoon, rudist biostrome, back shoal, and shallow open marine. These environments have effect by many diagenetic processes, including dolomitization, dissolution, micritization, cementation, recrystallization and Stylolite, some of these processes have improved the reservoir properties of the Mishrif reservoir, these are: dissolution, dolomitization and the stylolization. The others diagenetic processes have negative influence on the Petrophysical properties, such as cementation, compaction, and recrystallization processes, which damage the porosity and decrease the pore size. The reservoir properties are controlled by deposition environment, where lagoon environment is mostly compact with low porosity, shoal environment reflects a high energy and grain-supported environment and has good reservoir potential, deep-marine environments consist of mudstone to wackestone, which represents low energy level with low porosity and represents the non-reservoir environment.

Keywords: Depositional environments, Diagenetic processes, Carbonate rock quality, southeastern of Iraq.

البيئات الترسيبية والعمليات التحويرية وتاثيرها على خواص الصخور الجيرية، دراسة حالة، جنوب شرق العراق

افراح حسن صالح
قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تعد البيئات الترسيبية والعمليات التحويرية من العوامل الرئيسة المهمة والمتحكمة في الخواص البتروفيزيائية للصخور. تم اختيار تكوين المشرف كمكمن جيري في ابار مختارة من جنوب شرق العراق لمعرفة تأثير بيئات الترسيب والعمليات التحويرية على الصخور الجيرية. بينت فحص الشرائح الصخرية ان تكوين المشرف يتكون من ست بيئات رئيسة هي : البيئة البحرية العميقة (deep marine)، اللاكون (lagoon) ، الرودست (rudist biostrome)، الحيد (Shoal)، خلف الحيد (back shoal) والبيئة البحرية الضحلة المفتوحة (shallow open marine) هذه البيئات

*Email: d.afrah@yahoo.com

الترسيبية تأثرت بالعديد من العمليات التحويرية المهمة والمتمثلة بـ : الدلمتة، الاذابة، المكرتة، السمنتة، اعادة التبلور والاستايلولايت، بعض من هذه العمليات ساهمت في تحسين الخواص البتروفيزيائية لتكوين المشرف مثل: الاذابة، الدلمته والاستايلولايت. والبعض الاخر من العمليات التحويرية كانت لها تأثير سلبي على الخواص البتروفيزيائية مثل: السمنتة، الاحكام واعادة التبلور والتي كانت لها تأثير في تدمير المسامية وتقليل حجم المسام. البيئات الترسيبية متحكمة على الخواص البتروفيزيائية ، حيث ان بيئة اللاكون ذات مسامية قليلة، بيئة الحيد تمثل بيئة ذات طاقة عالية وخواص مكمنية جيدة، البيئة البحرية العميقة تتالف من الحجر الجيري الطيني الى الحجر الجيري الواكي وتمثل بيئة ذات طاقة قليلة وتمثل بيئة غير مكمنية.

1. Introduction

Diagenesis processes typically reduces porosity, redistributes the pore space, and alters permeability and capillary characteristics. Therefore, an understanding of diagenetic processes and the patterns of their products is essential for carbonate reservoir description and reservoir model construction[1].

To understand the impact of the diagenesis processes and depositional environment on the carbonate reservoir properties, Mishrif Formation has been chosen as a carbonate reservoir in selected wells from southeastern Iraq.

The Mishrif Formation, part of the Wasia Group, is a widespread Cenomanian—Turonian carbonate succession in the Arabian Gulf and surrounding areas [2].

The Mishrif represents a very complex sequence defined originally as complex of complex detrital limestones. This definition was given by Rabanit in 1952, who first described Mishrif Formation in the southern Iraq [3].

The Cenomanian Mishrif Formation is the main carbonate Cretaceous reservoir in southern Iraq [4].

Rudist buildups form the major oil-producing reservoirs in the Cretaceous carbonate strata of the Arabian Plate. They are the main components of the Mishrif Formation [5].

This study aims to clarify the impact of the diagenetic processes and depositional environment on the carbonate reservoir quality, the studied area is locating at southeastern Iraq in Missan province, to the southwestern of Amara city, which is surrounded by different oil fields, four oil-wells penetrate the Mishrif Formation, 2 wells from Noor field, 1 well from Amara field and 1 well from Halfayah field (Figure-1) have been selected for this study.

2. Geological setting

The study area is located tectonically in the Mesopotamian Basin and this setting has a direct effect on structural style, and depositional setting [6].

The Mishrif Formation belongs to the Cenomanian cycle, although this cycle probably ended during the early Turonian. In addition to the Mishrif, the cycle includes the Rutbah Sandstone Formation (mainly found in the Western Desert), the Ahmadi Formation, the Rumaila and Kifl formations (both in southern Iraq), and the Gir Bir, Dokan and Balambo formations (northern Iraq) [4].

The lower contact of Mishrif formation is conformable, where the Rumaila Formation is the underlying unit. The upper contact of the Mishrif Formation is marked by an unconformity of Khasib Formation [7].

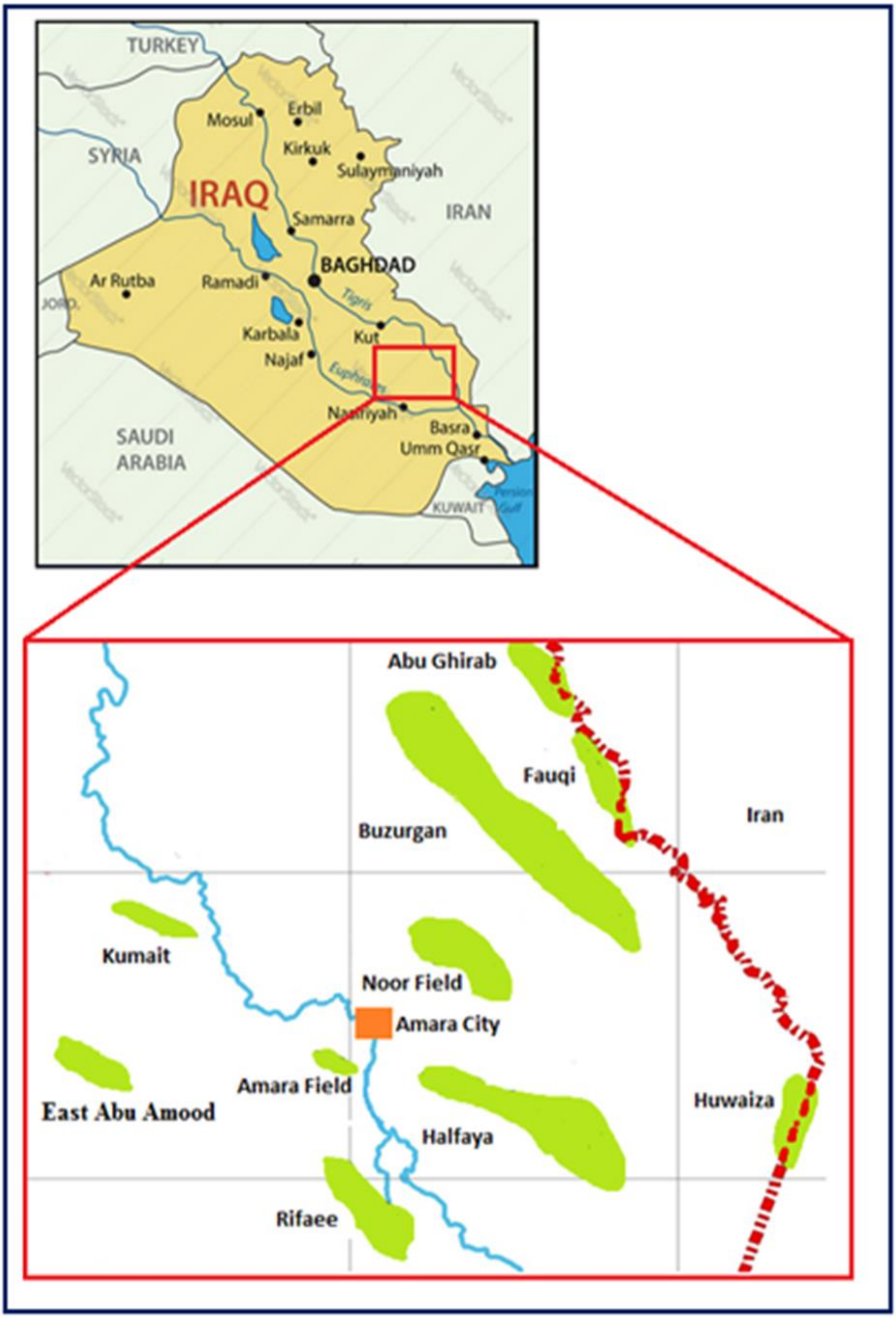

Figure 1-Location map showing the oil fields southeastern of Iraq.

3. Petrography

The petrographic of Mishrif Formation has been studied by examination and analysis the thin sections belong to wells (Halfayah -1, Noor-1, Noor-2, and Amara-1) in the Missan province in southeastern Iraq. The petrographic analysis shows that the Mishrif Formation is comprised of high percentage skeletal grains and low percentage non-skeletal grains.

3.1 skeletal grains

3.1.1 Foraminifera

Foraminifera are important skeletal grains in the Mishrif Formation that were found in the various facies. Two types of Foraminifera have been existed, both benthonic and planktonic Foraminifera. These Foraminifera indicate deep marine, lagoon, and shallow open marine environments. Planktonic Foraminifera (Plate 1-1) appeared clearly in the lower unit of the Mishrif Formation, which reflected the deep marine environment of the Rumaila Formation, serval type of the planktonic Foraminifera diagnosed within the Mishrif formation, like: *Hetrohelix*, *Hedbersgella*, and *Oligostiginids*.

Benthonic Foraminifera existed within Mishrif formation in different sizes and many types were diagnosed (Plate 1-2), such as: *Alveolinids*, *Miliolids*, *Nezzazata*, *Praealveolina* and many others.

3.1.2 Rudist

Rudist is very common within Cretaceous, and considered the major reservoir beds of the Mishrif Formation having large and small extensions. The large fossils (Plate 1-3) cover thin section, and most of these Rudist were found as debris, mostly in the middle part of the Formation with other components such as: corals, benthonic foraminifera.

3.1.3 Corals

In the Mishrif Formation, corals are common and important which were found with rudist, and identified in rudist biostrome environment as well as appearance as coral fragment connected with other organisms such as calcareous algae and benthonic Foraminifera, and were found as large and small fossil, covering the view of the thin section (Plate 1-5, 1-6).

3.1.4 Calcareous algae

Calcareous algae have been appeared in the Mishrif Formation in plentiful amount, and the major kind is green algae, which exists within middle and upper units of Mishrif Formation (Plate 1-7).

Calcareous algae presences within the Mishrif formation related to the secondary porosity due to the rapid dissolution of the aragonite nature of the algal structures, which reaction to the dissolution process and improve the porosity.

3.2 Non-skeletal grains

The non-skeleton grains included a peloids and Micrite, the peloids were found in the upper part and the size of these Peloids is between (0.02-1mm) (Plate 1-8).

Matrix (micrite) was found in most thin section of the Formation composing the matrix for all the facies kinds (Plate 2-1).

Plate -1-

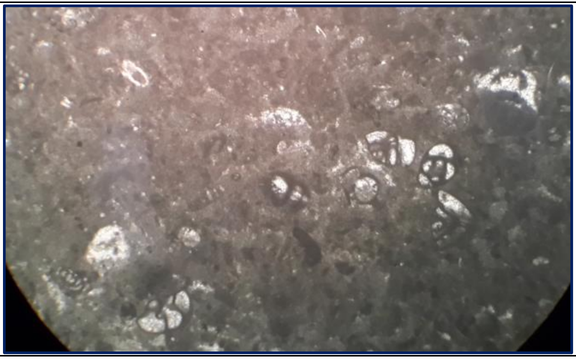

Plate 1 Planktonic Foraminifera
(Amara -1, depth 2034m, c-13 , ×35).

Plate 2 Benthonic Foraminifera
(No. 1, depth 3353.75 m, ×40).

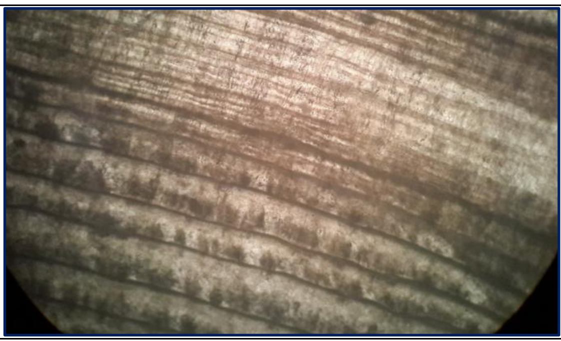

Plate 3 Rudist large fragments
(Amara -1, depth 2956.20 c-9)

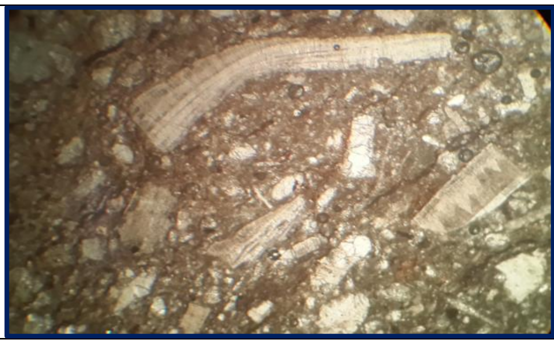

Plate 4 Rudist small fragments
(Amara -1, depth 3045 c-13 m ×35).

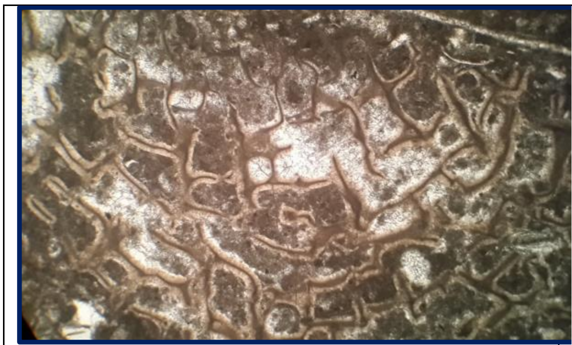

Plate 5 Coral as a complete fossil
(Halfayah -1, depth 2988 m c-9 × 40).

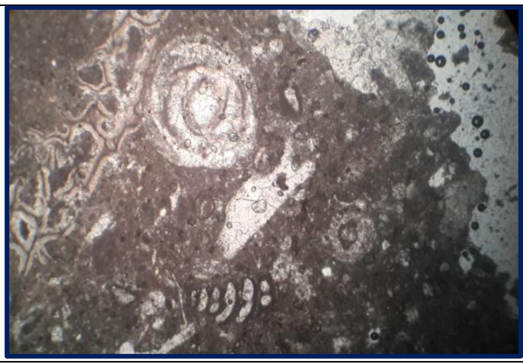

Plate 6 Coral fragment
(Amara -1, depth 3044 m c-13 × 40).

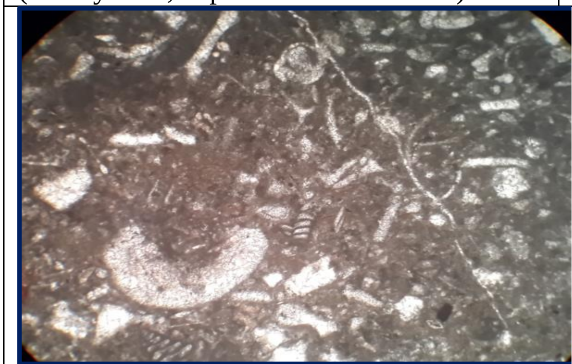

Plate 7 Calcareous algae
(Amara -1, depth 3044.30 m ×40).

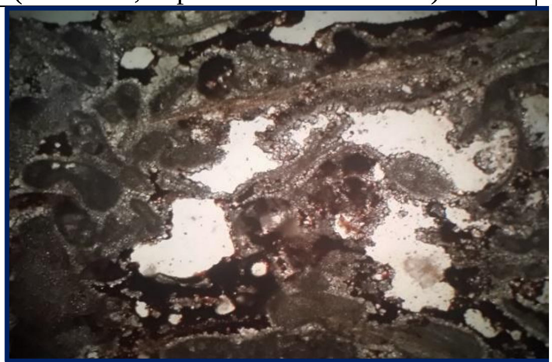

Plate 8 Pelloids
(Amara -1, depth 2891.40 m ×40).

4. Diagenetic Processes

There are many diagenetic processes which impact on Mishrif Formation, these diagenetic processes have a prevailing influence on the reservoir rock properties, whereas these processes improved the porosity of the formation.

4. 1 Dissolution

Dissolution process obviously was detected within Mishrif Formation (Plate 2-2), it is very significant and impact on petrophysical properties by growing the porosity (secondary porosity). This process is developed and enhanced the porosity in wells the Hf -1, Am-1 & more than wells No1 and No-2. Dissolution seams are well developed but often filled with dolomite. This process may affect the shoal and biostrome environments, and enhance the pre-existing porosity (intergranular porosity).

4.2 Dolomitization

Three dolomite textures were found in the studied wells (Plate 2-3), particularly in the wells (No-1 & No-2) which concentrated around the stylolites. This process was observed in the shoal and Rudist biostrome and in the shallow open marine environments, and not advanced enough to create a porosity, and its influence upon the reservoir is not exist. However, it increases the permeability significantly by opening the connections between the larger pores through the intercrystalline porosity.

4.3 Cementation

Two types of cementation were observed, granular cement and syntaxial rim cement (Plate 2-4, 2-5 and 2-6). The syntaxial rim cement expansion nearby grain, this process has been existing in deep marine and shallow open marine environments because of the typically high levels of supersaturating of marine waters. This process was observed more in the wells (No-1 & Noo-2) which effect on the porosity of these two wells.

The second kind (granular cement) was developed round grains and creating continuous crystals, this type of cement has observed in shoal and the shallow open marine environment. This type of cement effects on the petrophysical properties (porosity & permeability) of carbonate reservoir of the Mishrif formation, where damage the porosity, by fill pores with crystal.

4.4 Recrystallization

Recrystallization process changes in size or shape of crystals of a given mineral, without accompanying change in chemical composition or mineralogy [8].

In the Mishrif formation recrystallization is characterized by transformation (Plate 2-7) of micrite to the microsparite, this process may effect on the bioclasts such as Algae and corals and internal porosity may be destroyed, and it may be easy to diagnose and difficult to determine exactly how reduce the porosity in the reservoir bed. This process may be related to Stylolites and compaction.

4.5 Micritization

This is a process whereby bioclastic grains are altered on the seafloor or just below by bacteria, fungi and endolithic algae in quieter-water areas, leading to the formation of micritic envelops around bioclasts [9].

This process is represented by micrite (Plate 2-8), these envelopes are constant, especially in the high energy environment; made by algae and/or bacteria, and Pelecypod debris or Rudist, this process has been observed practically in the shallow open marine environment.

4.6 Stylolite (pressure solution)

Stylolites are most common in carbonate rocks and seam in limestone characterizing by concentrations of insoluble residues that may consist of clay minerals [8].

Stylolization has improved the reservoir properties of Mishrif Formation (P 3-1, 3-2), This process has been well observed in the No1 and No-2 wells due to it is developed particularly in lagoon, shallow open marine and deep marine environment which contain high amounts of micrite, in the shoal and Rudist environment the cement prevents the compaction, therefore the compaction is relatively low, therefore the shoal and Biostrome environments are free from Stylolites.

Plate -2-

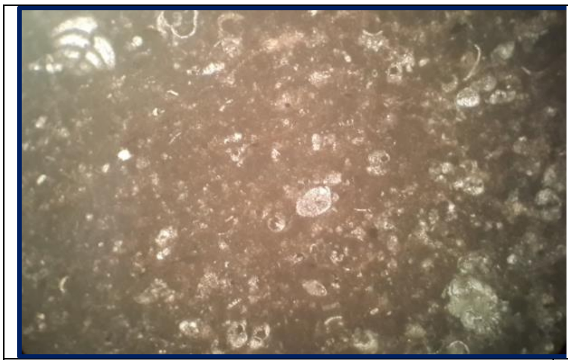

Plate 1 Matrix (micrite)
, (Halfayah -1, depth 2858 m, c-3)

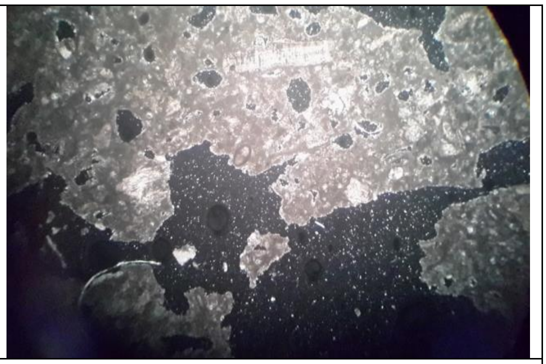

Plate 2 Dissolution,
(Amara -1, depth 3054.5 m C-14).

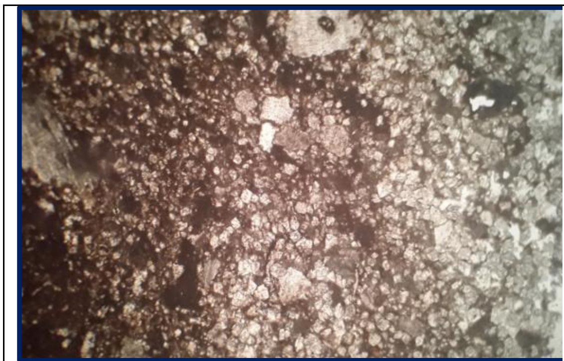

Plate 3 Dolomitization,
(Halfayah -1, depth 2986 m C-9).

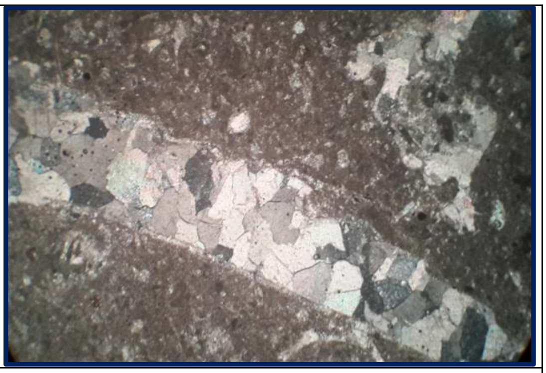

Plate 4 Granular (blocky) cement,
(Amara -1, depth 3044 C-13).

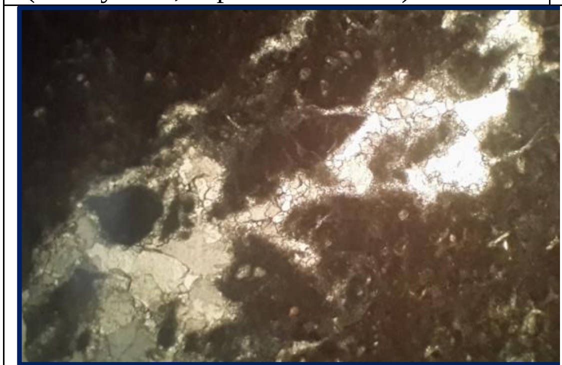

Plate 5 Granular (blocky) cement,
(Halfayah -1, depth 2920.50 C-5).

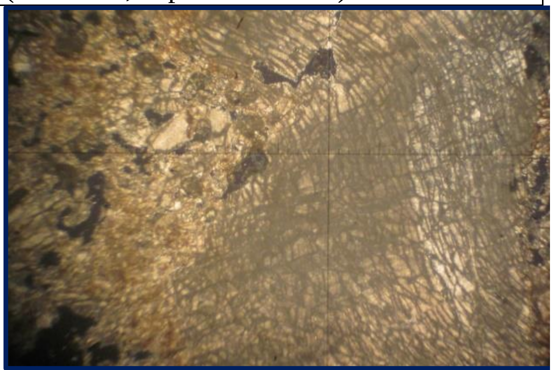

Plate 6 Syntaxial rim cement,
(Noor -2, depth 3887 m).

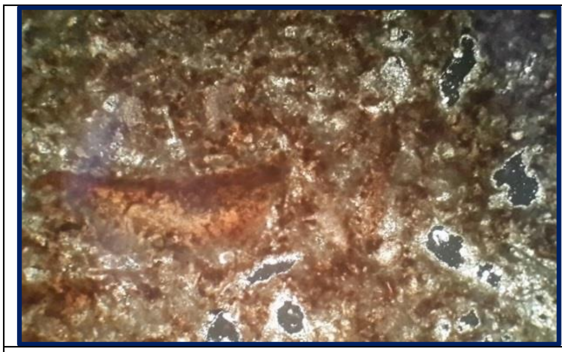

Plate 7 Recrystallization,
(Noor -1, depth 3413 m).

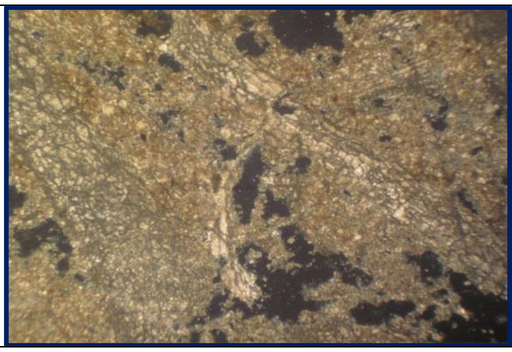

Plate 8 Micritization,
(Noor -2, depth 3881 m).

5. Microfacies Analysis of Mishrif Formation

The petrographic study shows six environments characterize the Mishrif formation, these are rudist biostrome, deep marine, shallow open marine, back shoal, lagoon and shoal, the details of these Microfacies as following: -

5.1 Lagoon environment

Lagoons are coastal bodies of water that have very limited connection to the open ocean, Seawater reaches a lagoon directly through a channel to the sea or via seepage through a barrier; fresh water is supplied by rainfall or by surface run-off from the adjacent coastal plain[10].

In middle and top units of Mishrif Formation, the lagoon environment has been existed, consist of benthonic foraminiferal (Plates 3-3), which are including miliolids, alviolinids, Nezzazata, and Textularia.

This environment is mostly compact, dense with low porosity and the joint and stylolites are common in this environment.

5.2 Back shoal environment

This environment considers a mixing zone between lagoon and shoal, consist from fine to very coarse grained bioclastic packstone, wackestone, and grainstone characterize this association[2].

Back shoal environment is mud-supported (Plates 3-4) and considers a moderate energy environmental, and the faunas in this environment are benthic Foraminifera, Chondrodonta, and bioclastic foraminiferal Facies.

5.3 Shoal environment

The shoal consider important environment in the Mishrif Formation, comprises of benthonic Foraminifera, Rudist, peloids, echinoderms, and calcareous algae (Plate 3-5). This environment is a grain-supported and represents high energy level, have good reservoir potential and good porosity which enhanced by dissolution, no argillaceous and Stylolites.

Shoal environment in the studied well shows very good porosity and considers the main reservoir environment and the main diagenesis process exist is dissolution which creates and enhanced the porosity, but the reservoir properties of this environment deteriorates when the cement and micrite were founded.

Plate -3-

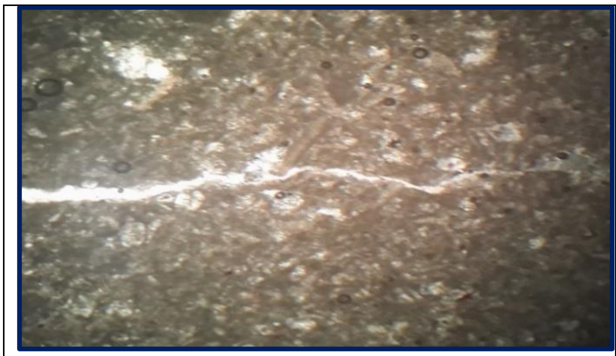		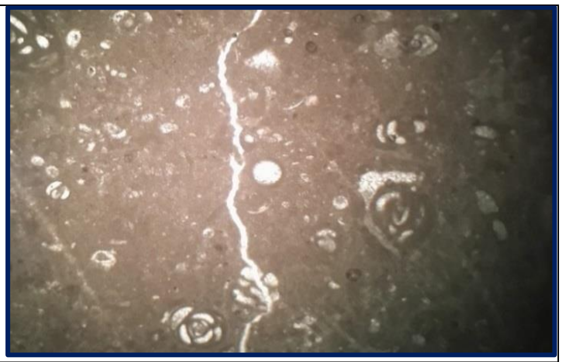
Plate 1 Stylolite, (Noor -2, depth 3416.3 m).		Plate 2 Stylolite, (Amara -1, 2870 m).
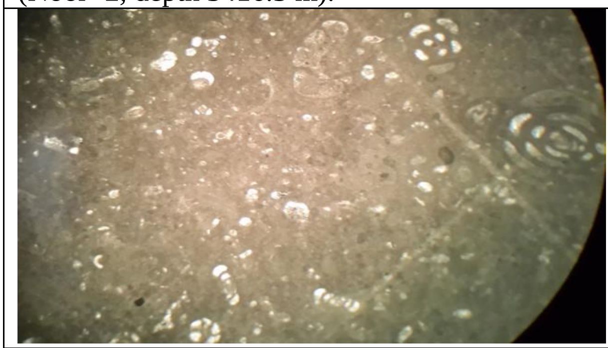		
Plate 3 Lagoon, (Amara -1, depth 2949 m, c-8).		Plate 4 Back shoal (Halfayah -1, depth 2902,30 c-3)

Plate 5 Shoal
(Amara -1, depth 2970.40 m, c-10).

Plate 6 Rudist Biostrome,
(Amara -1, depth 3036 m, c-13).

Plate 7 Shallow open marine,
(Halfayah -1, depth 3858 m c-3).

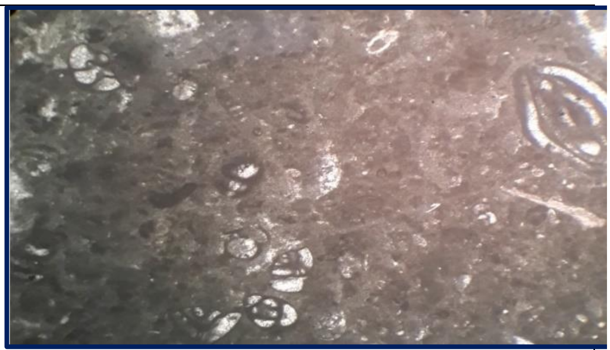

Plate 8 Deep marine
(Amara -1, depth 2034 m, c-13 ×35)

5.4 Rudist Biostrome environment

This environment is consisting from coarse grained, dominated by radiolitid and caprinid rudist with accessory monopluirds. The ostreiid Chondrodonta and small branching corals are locally common [2].

These Facies are consisted of coarse grained of Rudstone with Packstone/Grainstone facies (P 3-6), and debris of rudist, as well as sponge, coral and calcareous algae.

The rudist in this environment represent the major reservoir in the Mishrif Formation and has high petrophysical properties (porosity and permeability) due to the dissolution of the Rudistal shell which create secondary porosity.

5.5 Shallow open marine environment

This environment is common within Mishrif Formation, consist from benthonic and planktonic foraminifera, in addition to the, molluscs, sponge spicules, and echinoderms (Plate 3-7).

This environment exists in upper and middle units within Mishrif Formation The main diagenesis process existed are stylolites, dissolution and Micritization. This environment shows noticeable increase in the thickness in the studied wells.

5.6 Deep marine environment

Deep-marine environments represent the deeper area under a storm water wave and reflected low energy level, consist from small Bioclastic debris and planktonic Foraminifera like: Hedbergella (Plate 3-8).

These facies exist in lower unit of Mishrif, represent low energy level with low porosity and reflect the non-reservoir environment.

6. Discussion

The carbonates include the limestones, composed largely of calcite ($CaCO_3$), the effects of diagenesis are more marked in limestones than in sandstones. The effects of diagenetic processes are generally subordinate to primary porosity variations, which is seldom true of carbonate reservoirs[11].

The diagenetic processes impact the reservoir properties by changing the environment of the carbonate reservoir, whereas many diagenetic processes enhanced the reservoir properties, like

dolomitization, by create intercrystalline porosity and opening the connnection between the larger pores increases the permeability significantly, and the dissolution, which has a clear and effective effect in improving reservoir properties through increasing the secondary porosity, and the stylolization which has a very good effect to improve the reservoir properties.
Diagenesis usually follows more than one pathway in creating, enhancing, or reducing porosity, while diagenetic porosity and permeability are created or modified by post depositional processes, depositional porosity and permeability are formed at the time of deposition [12].

The diagenetic process has the negative influence and reduces the porosity in the carbonate Mishrif Formation,are the cementation process which reduces porosity by excess of cement and fills pores, and the recrystallization process which effect on the internal porosity and maybe destroy the porosity. Cementation and compaction process decrease the porosity and reduce pore size.

The impact of the depositional environment on the reservoir properties in carbonate is distinctly in shallow reservoirs.
The lagoon environment is mostly compact, dense with low porosity. Shoal environment reflected high energy and a grain-supported and represents high energy level, have good reservoir potential and good porosity which enhanced by dissolution, this environment in the studied well shows very good porosity and considers the main reservoir environment, and once the micrite and cement were founded the properties of this environment deteriorates.

Rudist Biostrome environment represent the major reservoir in the Mishrif formation, this environment has high Petrophysical properties (porosity and permeability) due to the dissolution of the Rudistal shell which create secondary porosity.

Deep-marine environments consist from mudstone to wackestone with small Bioclastic debris, which represents low energy level with low porosity and represents the non-reservoir environment.

7. Conclusion

1. The petrographic analysis shows that the Mishrif Formation consists of skeletal grains (Foraminifera, rudist, Corals and Calcareous algae), and non-skeletal grains (peloids and Micrite), with six depositional environments represent by deep marine, lagoon, rudist biostrome, back shoal, and shallow open marine.
2. There are many diagenetic processes impact the Mishrif Formation such as micritization, dissolution, dolomitization, cementation, recrystallization and stylolite processes.
3. The diagenetic processes impact on the reservoir properties by changing the environment of the carbonate reservoir, some diagenetic processes have been enhanced the reservoir properties, these are dolomitization, dissolution, and the Stylolization. The other diagenetic processes have a negative influence on the Petrophysical properties of the carbonate reservoir of the Mishrif formation, these are cementation, compaction, and recrystallization processes, which damage the porosity and decrease the pore size.
4. The reservoir properties were controlled by deposition environment, whereas Lagoon environment is mostly compact with low porosity, Shoal environment formed in a high-energy with a grain-supported and has a good reservoir property, deep-marine environments represents low energy with low porosity and represents the non-reservoir environment.
5. The porosity of the carbonate Mishrif Formation has been enhanced by diagenetic processes, these are dolomitization, dissolution and the stylolization, and the porosity decreasing by some diagenetic processes (cementation, compaction, micritization and recrystallization).

Acknowledgement

I am grateful to the Ministry of Oil for supporting my research by providing me the thin sections, data and references.

References

1. Lucia FJ. **2007.** *Carbonate reservoir characterization: an integrated approach*. 2nd ed. Berlin: Springer; 2007. doi: 10.1007/978-3-540-72742-2.
2. Burchette, T.P. **1993.** Mishrif Formation (Cenomanian-Turonian), southern Arabian Gulf: carbonate platform growth along a cratonic basin margin. In: Simo, J.A., Scott, R.W. and Masse, J-P (eds.), *Cretaceous Carbonate Platforms*. AAPG Memoir **56**: 185-199.

3. Buday, T. **1980.** *The Regional Geology of Iraq*. Vol.1: Stratigraphy and Paleogeography. Publications of GEOSURV, IRAQ, Baghdad.
4. Sadooni, F.N. **2005**. The nature and origin of Upper Cretaceous basin-margin rudist buildups of the Mesopotamian Basin, southern Iraq, with consideration of possible hydrocarbon stratigraphic entrapment, *Cretaceous Research*, **26** (2005): 213e224
5. Sadooni, Fadhil N. **2018**. Impact of the demise mechanisms of the Cretaceous rudist buildups in the Arabian Plate on their reservoir characteristics, Carbonates and Evaporites, DOI: 10.1007/s13146-017-0355-4.
6. Buday, T., and Jassim, S. Z. **1987.** *The regional geology of Iraq*, V.2, geological survey and mineral investigation, 352 P.
7. Jassim S. Z. and Goff J. C. **2006.** *Geology of Iraq. Dolin*, Prague and Moravian Museum, Brno. 341p.
8. Boggs, Jr, S. **2009.** *Petrology of Sedimentary Rocks*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511626487
9. Tucker, M.E. and Wright, V.P. **1990.** *Carbonate Sedimentology*. Blackwell, Oxford, doi.org /10. 1002 /9781444314175.
10. Gary Nichols, **2009.** *Sedimentology and Stratigraphy*, Blackwell Publishing, John Wiley & Sons Ltd. UK.
11. Richard, Selley C. and Stephen A. Sonnenberg, **2015.** *Elements of Petroleum Geology* (Third Edition), Academic Press, Elsevier BV, 526 p, doi.org/10.1016/B978-0-12-386031-6.00007-2.
12. Ahr, W.M. **2008.** *Geology of carbonate reservoirs: the identification, description, and characterization of hydrocarbon reservoirs in carbonate rocks*. Texas A&M University. 277p.