Petrography and mineralogy of the crystalline limestone of Fatha Formation from Mishraq area, Iraq

Falah A. Al-Miamary
Department of Geology, Mosul University, Mosul , Iraq
(Received 17 / 5 / 2009 , Accepted 5 / 1 /2010)

Abstract

The study deals with the secondary crystalline limestone in the Fatha Formation (Middle Miocene) in Mishraq area, south of Mosul City. It revealed that these rocks are very pure and cavernous. The main recognized diagenetic characters include ; crystalline calcite textures (such as blocky, the dominant)
in addition to fibrous and micritic textures. The study concluded that the studied rocks were deposited under hypersaline shallow-water conditions which were developed to phreatic environment.

Keyword: Fatha, crystalline limeston , diagenetic textures .

Introduction

The Middle Miocene age, Fatha Formation (formerly Lower Fars Formation) [1] is one of the most extensive and economically important formations in the entire Middle East region [2]. The formation covers a large area (approximately 1500 km x 300 km) and extends northwestward into Syria (there termed Lower Fars Formation) and southeastward into Iran (there termed upper part Gachsaran Formation) [3], (Figure 1). The Fatha Formation is a seal to numerous oil reservoirs in Iraq and Iran and, in certain areas, is a reservoir in its own right (e.g. Kirkuk, northern Iraq, [4]; [5]). In addition, the formation yields economically significant deposits of sulphur ([6]; [7]) as well as sulphate and salt .
The Fatha Formation is largely an evaporatic sequence. It consists of numerous shallowing-upward cycles of alternating mudrocks, limestones, gypsum, anhydrite and halite are present in the basin center [8]. The rich sulphur deposits are found in evaporite beds consisting mainly of gypsum and anhydrite, limestone, marl, and claystone [9]. The formation comprises a cyclic succession deposited in shallow marine, supra-tidal and continental environments([10];[11]).
The study of [12] established a scheme to identify this limestone occurrence as a marker beds for the purpose of detailed geological mapping in their area of study. They recognized five laterally persistent limestone marker beds within the Fatha Formation. Marker Beds 1 and 2 are located in the lower member while Marker Beds 3, 4 and 5 are located in the upper one. The entire marker beds are characterized by particular lithological properties: Marker Bed M1 is a marly limestone, partly dolomitic; Marker Bed M2 consists of two limestone horizons with gypsum or marl in between.

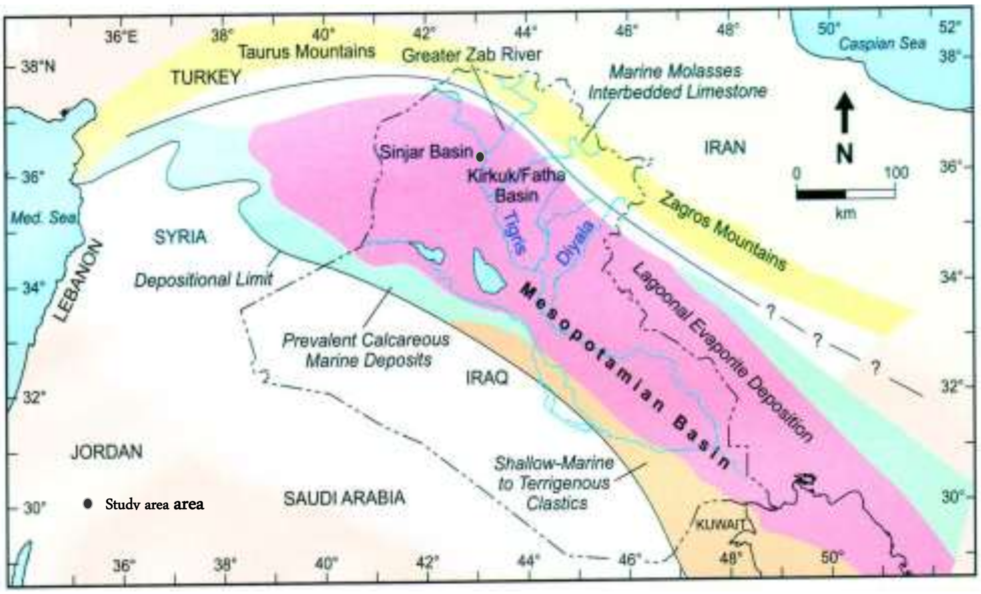

Figure (1): Map showing the Mesopotamian Basin in Iraq and simplified Middle Miocene lithofacies distribution map after ([8]) which is basically modified from ([4] ; [11] ; [13]; [14])

Marker Bed M3 is acrystalline limestone; Marker Bed M4 is an arenaceous and marly limestone; and Marker Bed M5 is a fossiliferous marly limestone.
The present work is focused primarily on the mineralogical and petrographic texture types of M3 (crystalline limestone) to give an idea about their diagenetic environment.

Geologic Setting

The Fatha Formation was deposited in a NW-SE-oriented basin which extended from NE Syria through N and NE Iraq into SW Iran (Figure 1). This Mesopotamian Basin is a foreland basin situated on the leading edge of the Arabian plate, attached to the African plate. Closure of the Tethys Ocean occurred in the late Cretaceous and resulted in the collision of the Arabian plate with the Iranian and Turkish plates to the NE and N [15].

The formation of the Zagros-Taurus mountain range led to the development of the Mesopotamian Basin as a result of crustal loading and flexure. Major orogeny also occurred in the late Miocene-Pliocene as a result of regional changes in the rates of plate motion, which produced a preferential northward movement of the Arabian plate relative to the Iranian-Turkish plates, and the collision of the Turkish-Iranian plates with the Eurasian plate to the north.

In the Late Cretaceous the Neo-Tethys Ocean began to close as evident by the obduction of ophiolites in Oman and elsewhere along the margin of the Arabian Plate (e.g. [16]; [17]). By the Late Miocene and Early Pliocene, the Neo-Tethys Ocean was closed by the collision of the Arabian and Eurasian plates (Central Iran and Turkey), and the Zagros and Taurus Mountain belts started to be uplifted ([18]; [15]). Between these two tectonic events, starting in the Late Eocene and continuing through the Middle Miocene, crustal loading and flexure of the eastern Arabian Plate formed the broad and shallow Mesopotamian Basin as a NW-oriented foreland basin ([19]; [20]). This 2,000-km-long basin extended from Bandar Abbas, in Iran, across Iraq and Syria to the Mediterranean Sea, and it was located southwest of the Zagros and Taurus Mountains (Figure 1) .

In the Mosul area in northern Iraq, an uplifted regional trend was likely to have structurally active during the deposition of the Fatha Formation (Mosul High) according to [21]; it affected the development of accommodation space and the distribution of sediments. This is evident by the decrease in thickness of the Fatha carbonates away from the high region, and their facies change from bioclastic limestone (with abundant oyster shell fragments) into dolomitized micrite. It is also evident from the increased thickness of the evaporites (and associated salt) towards Sinjar [22]. Evaporatic sequence forms the main facies of the Fatha basin showing cyclic character usually with limestone and claystones. Salt deposition occurs mainly in the center of the basin. Terrigenous admixtures and reduced evaporates dominated in the shorelines of the basin which is associated with red claystones and litharenites. The Red Beds basin probably received fine clastics in connection to the renewed uplifts and folding caused by the Styrian phase [13] .

Materials and Methods

Ten samples were selected from the crystalline lime beds in the upper part of the Fatha Formation in Sifena area (Figure 2). Detailed petrographic investigation was carried out using standard petrographic and scanning electron microscope to determine the main types and textural features in the lime samples.

All these analysis are achieved at laboratories of Bonn University, Germany.

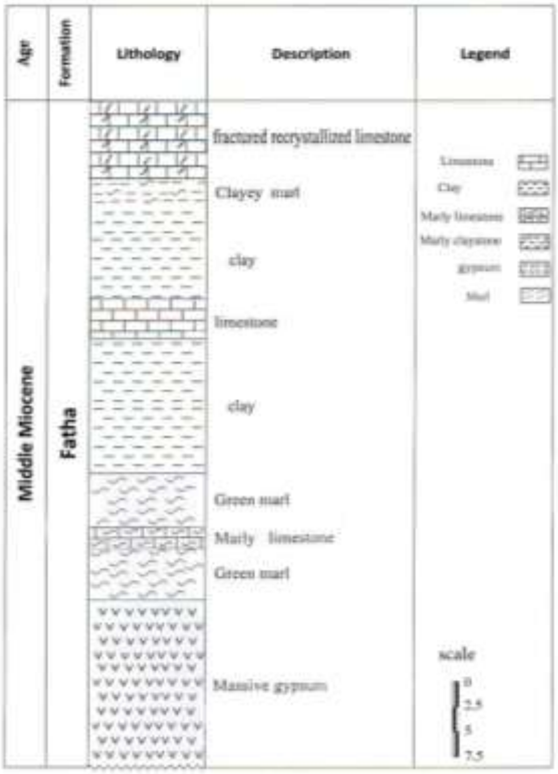

Figure (2) Lithologic section at Mishraq area (Sivena section) , Note that the study bed comprises the upper 7.5 meter of this section .

Results

In the field, the studied limestones (Figure 3) have (7-8) m in thickness (Figure 3 A) and these rocks are very hard, recrystalized with large crystal sizes (sugary type) (Figure 3 B, C) and mostly porous (Figure 3, D, E). The pores are formed by sulfate to limestone alteration due to difference in size [23] which may lead to fracturing and collapsing of rocks (Figure 3F).

Petrographically, various textures could be recognized in the studied limestone these include; blocky and mosaic calcite cements which is the most common one (Figure 4 A-B; 5A) followed by radial fibrous calcite cements that filling pores and formed mostly by dissolution of gypsum (Figure 4 C-D). These diagenetic calcite types commonly recrystallised in micritic matrix.

The micritic and sparitic cements are sporadically occur (Figure 4 E and F); these cements exist in intergranular pores and vugs left after selenite (gypsum) removal. This types is similar to cement type described by [24] in the Middle Miocene carbonates of Egypt.

Peloidal or oolitic-type calcite cements are also observed as concentric hemispheroid or ooid-like spheroids growing in situ (Figure 5 B-C) similar to those described by [25] in Poland.

Scanning electron photomicrographs (Figure 6) illustrates the common tight nature of these crystalline limestones with various scattered dolomite rhombs and presence of thin film of clayey (mostly illite) film covering calcite cement as in Figure (5 A).

The study rocks resemble sparstone type according to classification of limestone after [26].

In general, the studied limestone is diagenetic secondary limestone with various calcite cement textures. Regular and irregular pores after gypsum removal are abundant which reflect the evaporatic nature of the Fatha Formation. These pores are often partially occluded by calcite and/or selenite (Figure 5 D). These petrographic and mineralogic characteristics reflect the nature of deposition of the Fatha carbonates in barred hypersaline lagoonal environment.

Figure(3) Photographs showing the recrystalline limestone bed and various textures in the field. A; illustrates secondary limestone bed (the man for scale),B-C; sugary texture of the recrystalline bed (calcite crystals arrows ,pen for scale), D-E; vuggy and cavernous texture in the study limestone bed (arrows),F; illustrates the common brecciation and collapse phenomena in the study bed(arrows).

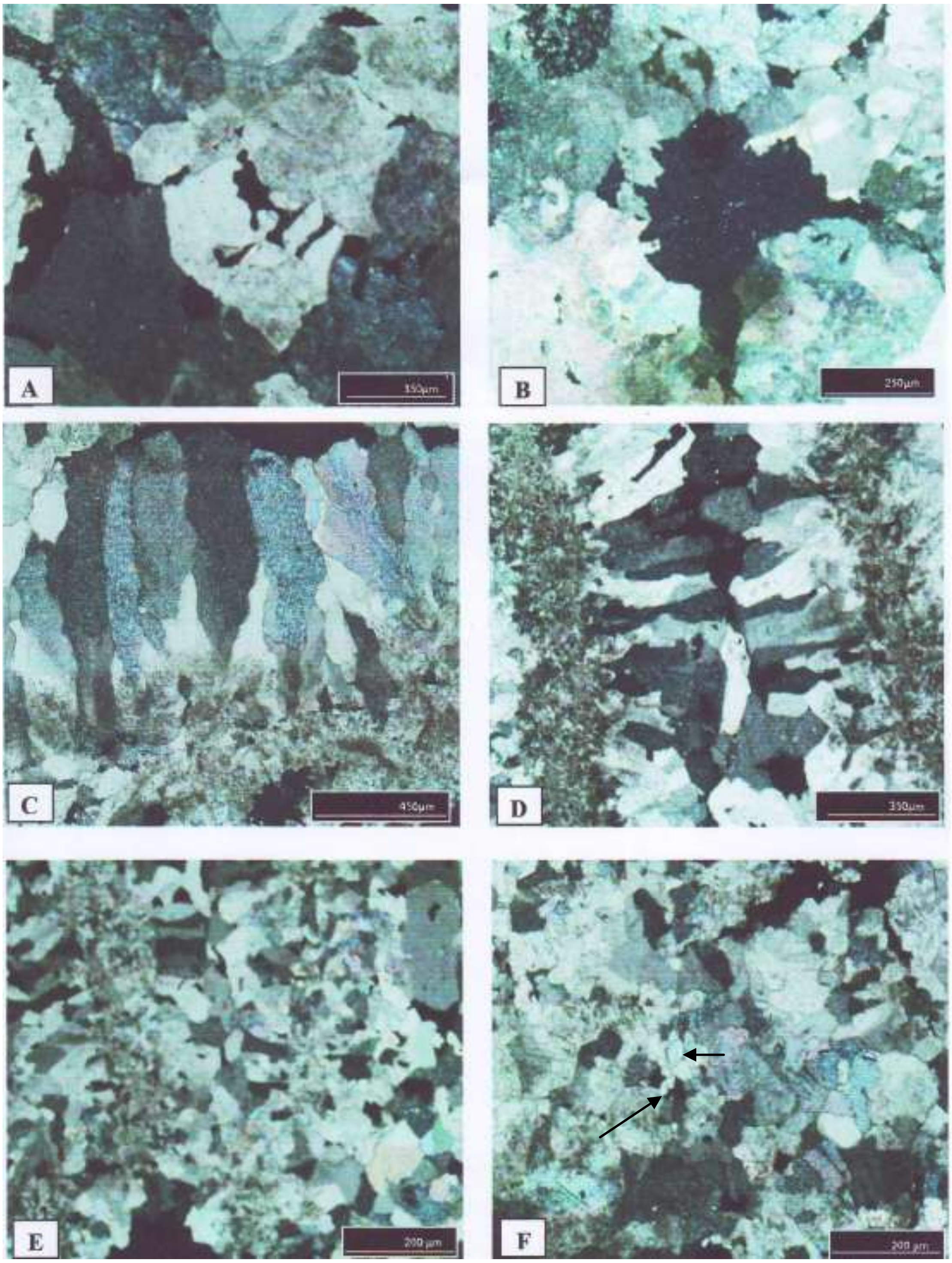

Figure (4) microphotographs showing; A-B, coarse crystalline blocky calcite cement, partly dissolved after gypsum dissolution . C-D ; fibrous radial calcites cement . E; fine micritic calcite cement which that coarsen toward pore center . F, sparitic-type calcite with few scattered dolomite rhombs (arrow).

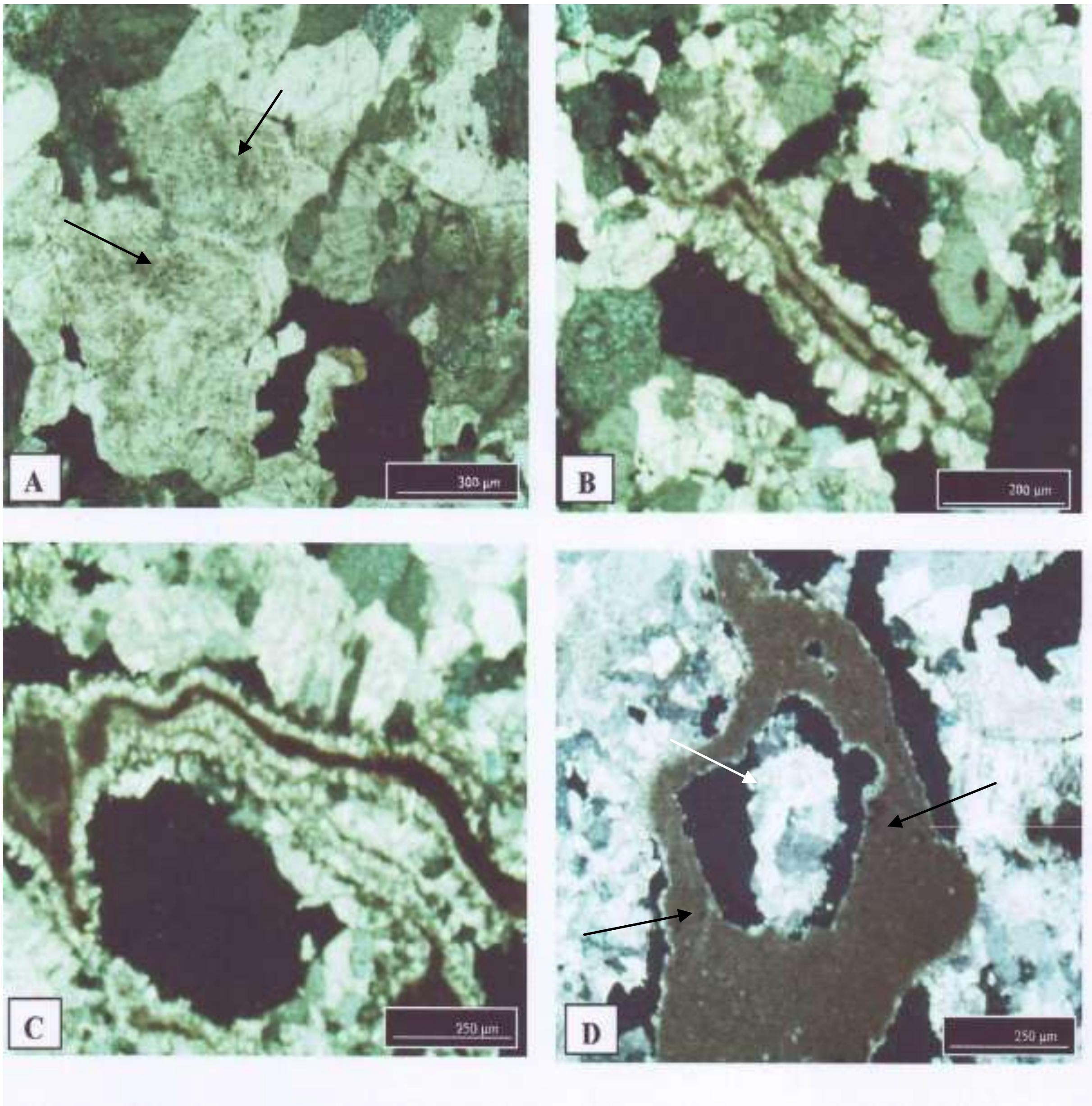

Figure (5) other petrographic textures under polarized microscope illustrating A; mosaic crystalline carbonate showing tight calcite with clay material cover (arrows). B-C; concentric hemispheroid or ooid-like spheroids growing in situ. D; micritic lime, cavernous with calcite cement(white arrow) occluding pore(black arrows).

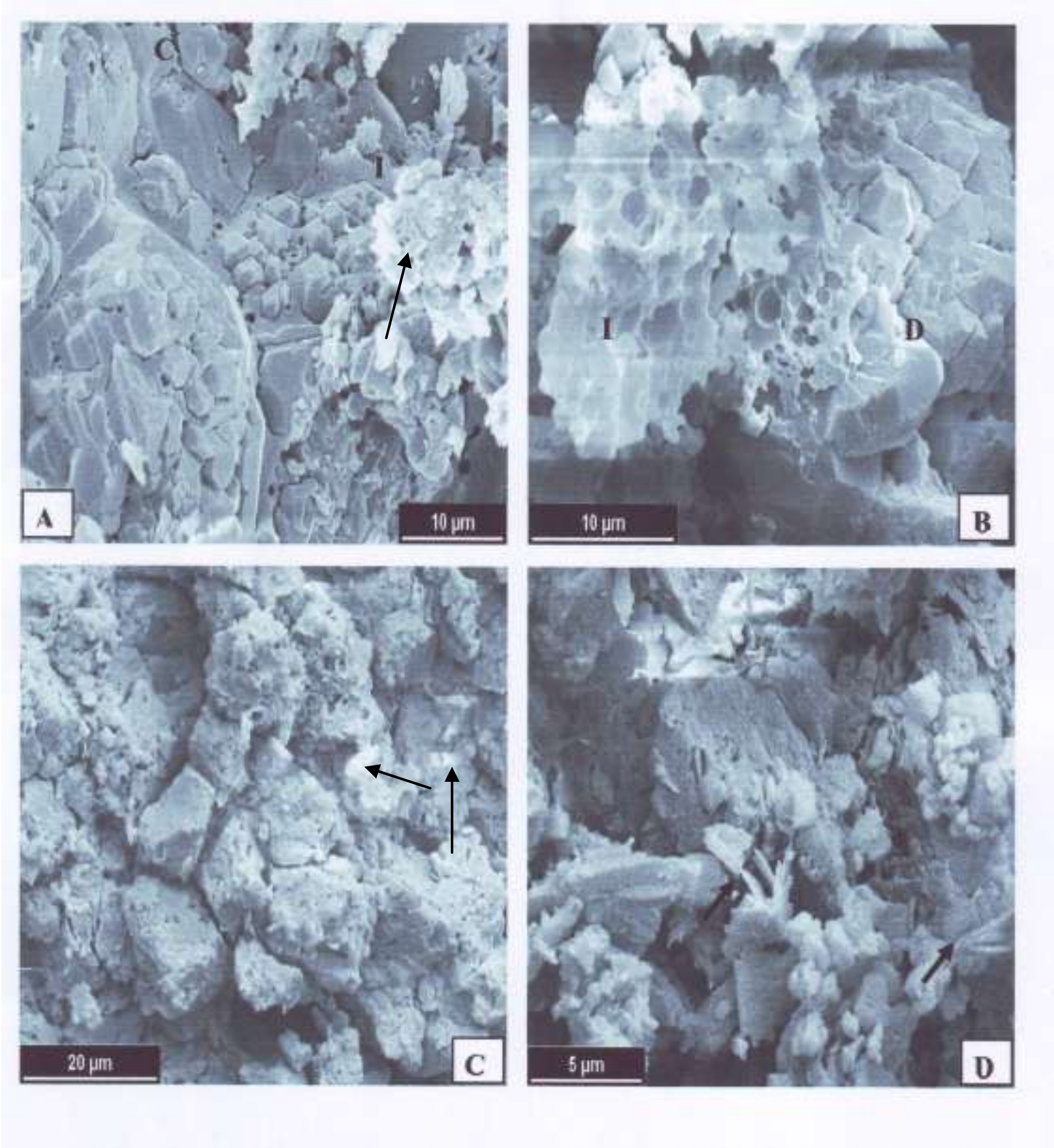

Figure (6) Scanning electron micrographs illustrating A-B: the presence of tightly crystalline limestone and dolomitic limestone with thin film of illitic clay minerals (I) (arrow), note C= calcite and D= dolomite rhomb. C: coarse crystalline limestone with scattered clayey materials (arrows). D: limestone with gypsum fibers (arrows).

Discussion and conclusions

The secondary limestone (resulted from replacement of evaporates) in the Fatha Formation and its textures and cement types (blocky, fibrous, sparite etc...) indicate their development in meteoric water conditions.

Under shallow water conditions, sulfate reduction took place in the presence of anaerobic bacteria and organic matter which liberates CO_2 and Ca ions and lead to formation of solutions saturated with $CaCO_3$ and H_2S ([27] ; [28]). Then $CaCO_3$ will precipitates as aragonite or high-Mg calcite [23].

Initially, the new formed limestone is composed of micritic groundmass and porous. When it contact with fresh water environment, micrite will change into microspar and then to pseudo-spar through authigenesis. . The unstable aragonite crystals altered to calcite and the high-Mg calcite into low-Mg calcite by leaching with fresh water,Calcite crystal then will grow in cavities and pores [29] . and may reach 600 micron or more in size.

Peloidal and micritic cements in the present work indicate their formation from shallow marine solutions enriched with $CaCO_3$ after sulfate reduction [30]. Whereas, sparry calcite cement forms under fresh water meteoric- phreatic conditions with deficiency of Mg ions which permits formation of calcite crystal with larger size toward pore center [31].

The blocky and radial fibrous cements developed in fresh water zones ([29] ; [30]).

In conclusion, the present limestone is a secondary type resulted from alteration of suphate to hard, dense, porous, and pure limestone including blocky, fibrous, sparry and less micritic cements.

They were developed diagenetically under meteoric water conditions. Calcite fills pores and cavities and recrystalizes to form sugary and high purity limestone. Due to such purity, the study recommend to a future research deal with its environment and industrial use .

References

[1] Al-Rawi, Y.T., Sayyab, A.S.; Al-Jassim, J.A.; Tamar-Agha, M.; Al-Sammarai, A.I.; Karim, S.A. ; Basi, M.A. ; Hagopian, D.; Hassan, K.M. ; Al-Mubarak, M.; Al-Badri, A.; Dhiab, S.H. ; Faris, F.M. and Anwar, F. (1993): New names for some of the Middle Miocene-Pliocene formations of Iraq (Fatha, Injana, Mukdadiya and Bai Hassan formations). Iraqi Geological Journal, v. 25, p. 1-17.

[2] Al-Juboury, A.I.; Al-Naqib, S.Q and Al-Juboury, A. M. (2001): Sedimentology, mineralogy and depositional environments of the clastic units, Fat'ha Formation (Middle Miocene), South of Mosul, Iraq. Dirasat, Pure Sciences, Jordan, v. 28, p. 80-105.

[3] Bellen, R.C. van, Dunnington, H.V. ; Wetzel, R. and Morton, D.(1959): Lexique Stratigraphique International. Asie, Fase, 10a, Iraq, Paris, 333p.

[4] Dunnington, H.V. (1958): Generation, accumulation and dissipation of oil in Northern Iraq. In, L.G. Weeks (Ed.) Habitat of Oil. American Association of Petroleum Geologists Bulletin , p. 1194-1251.

[5] Metwalli, M.H., Philip, G. and Moussly, M.M. (1974): Petroleum-bearing formations in northeastern Syria and Northern Iraq. American Association of Petroleum GeologistsBulletin ,vol. 58, p.1781-1796.

[6] Barker, J.M., Cochran, D.E. and Semrad, R.(1979): Economic geology of Mishraq native sulfur deposits, northern Iraq. Economic Geology, v. 74, p. 484-495.

[7] Jassim, S.Z., Raiswell, R. and Bottrell, S.H. (1999): Genesis of the Middle Miocene stratabound sulphur deposits of northern Iraq. Journal of the Geological Society, London, v. 156, p. 25-39.

[8] Al-Juboury, A.I and McCann,T.(2008): The Middle Miocene Fatha (Lower Fars) Formation Iraq .Geoarabia ,vol 13, p.141-174 .

[9] Al-Sawaf, F.D.S. (1977): Sulfate reduction and sulfur deposition in the Lower Fars Formation, Northern Iraq. Economic Geology , v. 72, p. 608-618.

[10] Shawkat, M.G. and Tucker, M.E. (1978): Stromatolites and sabkha cycles from the Lower Fars Formation (Miocene) of Iraq. Geologische Rundschau, v. 67, p. 1-14.

[11] Buday, T. (1980): The Regional Geology of Iraq. Stratigraphy and Palaeontology. Geological Survey and Mineralogical Investigations. Baghdad, Iraq, 445p.

[12] Ma'ala, K.A., Mahdi, A.H. Fouad, S.F. Lawa , F.A. Philip, W. and Al-Hassany, N. (1988) : Report on the Geological investigation for native sulfur in the northern sector of the Fatha mosul sulfur district. Directorate of Geological Survey and Minerals Investigation, 484p.

[13] Jassim, S.Z. and Karim, S.A. (1984): Final report on the regional geological survey of Iraq. Vol. 4, Paleogeography. State Organization for Minerals Library Reports, Baghdad, Iraq, 65p

[14] Jassim, S.Z. and Goff, J.C. (2006): Geology of Iraq. Dolin, Prague and Moravian Museum, Czech Republic, 395p.

[15] Al-Sharhan, A.S. and Nairn, A.E.M. (1997): Sedimentary Basins and Petroleum Geology of the Middle East, Elsevier (Amsterdam), 843p.

[16] Beydoun, Z.R. (1991): Arabian plate hydrocarbon geology and potential: Aplate tectonic approach. American Association Petroleum Geologists Bulletin ,studies in Geology vol. 33 ,p 1-77.

[17] Sharland ,P.R., Archer, R., Casey, D.M., Davies, R.B., Hall, S.H., Heward, A.P., Horbury, A.D. and Simmons, M.D. (2001): Arabian plate sequence stratigraphy. Geoarabia, special publication 2, Gulf Petrolink ,Bahrain ,371p.

[18] Buday, T. and Jassim S.Z., (1987): The Regional Geology of Iraq, Tectonism, Magmatism and Metamorphism. Publication of the Geological Survey of Iraq, 352p.

[19] Jordan, T.E. (1981): Thrust loads and foreland basin evolution, Cretaceous, western United States. American Association of Petroleum Geologists Bulletin, v. 65, p. 2506-2520.

[20] Allen, P.A.; Homewood, P. and Williams, G.D. (1986): Foreland basins: an introduction. In, Allen, P.A. and P. Homewood (Eds.) Foreland Basins. International Association of Sedimentologists, Special Publication, no. 8, p. 3-12.

[21] Numan, N.M.S.(1984): Basement controls of stratigraphic sequences and structural patterns in Iraq. Journal Geological Society, Iraq. v. 16, p. 8-24.

[22] Jassim, S.Z., Jibril A.S., and Numan, N.M.S. (1997): Gypsum Karstification in the Middle Miocene Fatha Formation, Mosul area, northern Iraq. Geomorphology, 18, p. 137-149.

[23] Berner ,R.A. (1971): Principle of chemical sedimentology : New York ,McGraw Hill Book company ,240p .

[24] Pierre, C. and Rouchy, JM (1988): Carbonate replacements after sulfate evaporates in the Middle Miocene of Egypt. Journal of Sedimentary Petrology ,vol. 58, p.446-456.

[25] Gasiewicz, A. (2000): Sedimentolgy and diagenesis of gypsum-ghost limestones and origin of polish native sulphur deposits. Prace panstwowego instytutu geologicznego ,Clxxii , p.1-144.

[26]Wright, V.P. (1992): A revised classification of limestone .sedimentary geology ,vol.76 ,p. 177-186 .

[27]Friedman ,G.M. (1972): Significance of Red sea in problem of evaporates and basinal limestone .American Association Petroleum Geologists Bulletin. vol.56, p.1072-1086.

[28] Spiro, B. (1977): Bacterial sulphate reduction and calcite precipitation in hypersaline deposition of bituminous shales .Nature ,vol. 269, p.235-237 .

[29] Folk, R.L. (1974): The natural history of crystalline calcium carbonate :effect of magnesium content and salinity . Journal of Sedimentary Petrology .vol. 44, p. 40-53.

[30] Flugel, E. (2004): Microfacies of Carbonate Rocks , Analysis, Interpretation and Application .Springer Berlin Heidelberg New York , 976p .

[31] Longman, M.W. (1980) : Carbonate diagenatic textures from nearsurface diagenatic environments. American Association Petroleum Geologists Bulletin. ,vol.64, p.461-487 .

بتروغرافية ومعدنية الحجر الجيري المتبلور لتكوين الفتحة من منطقة المشراق ، جنوب الموصل ، العراق

فلاح عبد المعماري

قسم علوم الأرض ، كلية العلوم ، جامعة الموصل ، الموصل ، العراق

(تاريخ الاستلام: ١٧ / ٥ / ٢٠٠٩ ، تاريخ القبول: ٥ / ١ / ٢٠١٠)

الملخص

تم دراسة الحجر الجيري المتبلور الثانوي المنشأ في تكوين الفتحة (المايوسين الأوسط) في منطقة المشراق ،جنوب الموصل، وتبين أن هذه الصخور هي صخور نقية جدا" وغنية بالفجوات . وأن من أهم المظاهر التحويرية التي تم تشخيصها في هذه الصخور هي أنسجة الكالسايت المتبلور مثل النسيج البلوكي (والذي يعتبر النسيج الأكثر شيوعا") إضافة إلى النسيج الليفي وغيرها. وهذه الصخور ترسبت تحت ظروف بيئة بحرية ضحلة عالية الملوحة ثم تطورت في بيئة المياه العذبة .

الكلمات الدالة : تكوين الفتحة ،الحجر الجيري المتبلور،الأنسجة التحويرية.