DOI: 10.24996/ijs.2023.64.10.19

ISSN: 0067-2904

Carbonate Ramp Facies and Porosity Recognition: Case Study of the Late Albian-Early Cenomanian Mauddud Formation in Ratawi Oilfield, Southern Iraq

Salah A. Hussain[1*], Yasamin K. Ibrahim[2]

[1]*Department of Petroleum Geology and Minerals, College of Science, University of Diyala. Diyala, Iraq*

[2] *Department of Geology, College of Science, University of Baghdad. Baghdad, Iraq*

Received: 5/8/2022 Accepted: 18/12/2022 Published: 30/10/2023

Abstract

The carbonate ramp facies of the Late Albian-Early Cenomanian Mauddud Formation were studied in the Ratawi Oilfield, Basra Governorate, south of Iraq using integrated borehole data set that included, core and cutting samples in three drilled wells to analyze the petrography of the Mauddud Formation, two hundred and eighty-one (281) thin sections were prepared and examined for the three selected wells. The results show that the formation is composed of light grey dolomitized limestone and pseudo-oolitic creamy limestone with green to bluish shale. The petrographic observations results show four facies' associations in the Mauddud Formation. These include: Mid–Ramp environment which is represented by Argillaceous mudstone microfacies, Argillaceous wackestone microfacies and orbitolinid wackestone microfacies; the shallow open marine environment which is assimilated by foraminiferal wackestone microfacies and foraminiferal packstone microfacies; a restricted marine environment that represented by bioclastic fossiliferous wackestone microfacies and miliolid wackestone microfacies and Shoal environment is represented by bioclastic packstone microfacies, bioclastic grainstone microfacies, peloidal foraminiferal pack-grainstone microfacies, and peloidal packstone-grainstone microfacies with diverse skeletal grains. The porosity includes Vuggy, Interparticle, Intraparticle and Fracture porosity.

Keywords: Early Cretaceous; Mauddud Formation; Foraminifera; Microfacies; Porosity; Basrah.

تمييز سحنات ومسامية المنصة الجيرية: دراسة حالة الالبيان المتأخر–السينومانيان المبكر لتكوين المودود في حقل رطاوي النفطي، جنوب العراق

صلاح علي حسين[1*] , ياسمين ابراهيم[2]

[1*] قسم جيولوجيا النفط والمعادن, كلية العلوم, جامعة ديالى, ديالى, العراق

[2] قسم علم الارض, كلية العلوم, جامعة بغداد, بغداد, العراق

الخلاصة

ان سحنات المنصة الجيرية للالبيان المتأخر–السينومانيان المبكر قد درست في حقل رطاوي النفطي, محافظة البصرة, جنوب العراق المعطيات المتكاملة لنماذج الابار متضمنة عينات اللباب والقطع الصخرية في

*Email: salahpgm@yahoo.com

ثلاث ابار محفورة من اجل تحليل السحنات الصخرية تحت المجهر لتكوين المودود, تم تحضير وفحص مئتان وواحد وثمانون (281) شريحة صخرية للابار الثلاثة المختارة. اظهرت النتائج ان التكوين يتكون من الحجرالجيري المتدلمت ذو اللون الرصاصي الفاتح والحجر الجيري ذو السرئيات الكاذبة ذات اللون الكريمي مع السجيل الاخضر المزرق. اظهرت نتائج الفحص المجهري اربعة مجاميع سحنية لتكوين المودود وتتضمن: بيئة منتصف المنصة وتمثلت بسحنات الحجر الوحلي الطيني والحجر الواكي الطيني وسحنة الحجر الواكي الاوربيتوليني، البيئة البحرية الضحلة المفتوحة والتي تمثلت بسحنة الحجرالواكي الحاوي على الفورامنيفرا وسحنة الحجر المرصوص الحاوي على الفورامنيفرا، البيئة البحرية المحصورة والتي نمثلت بسحنة الحجرالواكي ذو المكسرات الحياتية والغني بالمتحجرات وسحنة الحجر الواكي المليوليدي وبيئة الحواجز المتضحلة او الضحضاحات والتي تمثلت بسحنة الحجر المرصوص ذو المكسرات الحياتية وسحنة الحجر الحبيبي ذو المكسرات الحياتية وسحنة الحجر المرصوص–الحجر الحبيبي الحاوي على الدمالق والفورامنيفرا وسحنة الحجر المرصوص–الحجر الحبيبي الحاوي على الدمالق مع حبيبات هيكلية متنوعة. تضمنت المسامية بمسامية الاذابة ومسامية بين الحبيبات ومسامية داخل الحبيبات ومسامية التكسرات.

Introduction

The Mauddud Formation was first discriminated by [1] from the well Dukhan-1 in Qatar, as an organic detrital limestone creamy color. It depicted by [2] in the type area as light, and grey, sometimes pseudo-oolitic, cream in color limestones with occasional green or bluish shale streaks and they were considered the age of the formation as Albian according to the fossils. They believed that Mauddud Formation was extended to Cenomanian because that was a frequent occurrence of *Orbitolina concava*. [3] Described the upper contact of the Mauddud Formation with the Ahmadi Formation as unconformable. [4] Mentioned that Mauddud Formation was the equivalent to Upper Qamchuqa Formation in the North of Iraq, the depositional environment of the Upper Qamchuqa Formation is shallow waters of the interior platform from the evaporitic or brackish water FZ 9A to back-reef FZ 7 [5]. [6] Studied the microfacies analyses to distinguish the faunal and floral assemblages in the Mauddud Formation, which include the lamellibranchate Bryozoa, Gastropoda, and a large number of algal and foraminiferal species, genera, and subspecies. The Mauddud Formation is gradational with the underlying Nahr Umr, Lower Balambo, or Sarmord formations, while the upper contact of the formation is an unconformity in the North and North-East part of Iraq [7]. The microfacies of the Mauddud Formation that includes lime mudstone, wackestone, wackestone-packstone, packstone, packstone-grainstone, and dolostone were formed in a shallow warm marine environment with different salinities and energy levels [8]. [9] examined the stratigraphy, microfacies, and petroleum potential of the Mauddud Formation and hypothesized that the Orbitolina could be found in tropical to subtropical waters with temperatures as high as 15 to 25°C. [10] Studied the diagenetic processes overprint and pore types of the Mauddud Formation at Badra Oilfield in the Center of Iraq. [11] Study the microfacies interpretation and depositional environment of the Mauddud Formation in the Ratawi oil field. He said that the formation deposit through five main depositional environments, these are outer ramp, mid ramp, inner ramp, restricted and shoal. The dolomitization, micritization, cementation, recrystallization and dissolution are the diageneses processes that affected the Mauddud Formation. The present study is focused on facies analysis and depositional environment of the Mauddud Formation in selected wells of Ratawi Oilfield, southern Iraq (Figure 1).

Geologic setting

The Mauddud Formation in the type area (North of Sulaimaniyah) consists of prevalently of dolomite and it was replaced by neritic organic–detrital limestone. There are many differences were caused by different degrees of dolomitization, so some of its marly limestone. The Mauddud Formation overlies the Nahr–Umr Formation and it has gradational contact, but the upper contact is unconformable with Ahmadi Formation [6]. The lithology of the Mauddud Formation at the Khabbaz oil Field shows no significant variation and there is an interjection of limestone, dolostone, and dolomitic limestone with uncommon marl interjection [12]. The lithology of the Mauddud Formation in this work consists of limestone units with varying characteristics; an example of one of these units is shown in well Rt-23, where the limestone units of formation can be argillaceous bundles, fossiliferous, porous, compact, and stylolite.

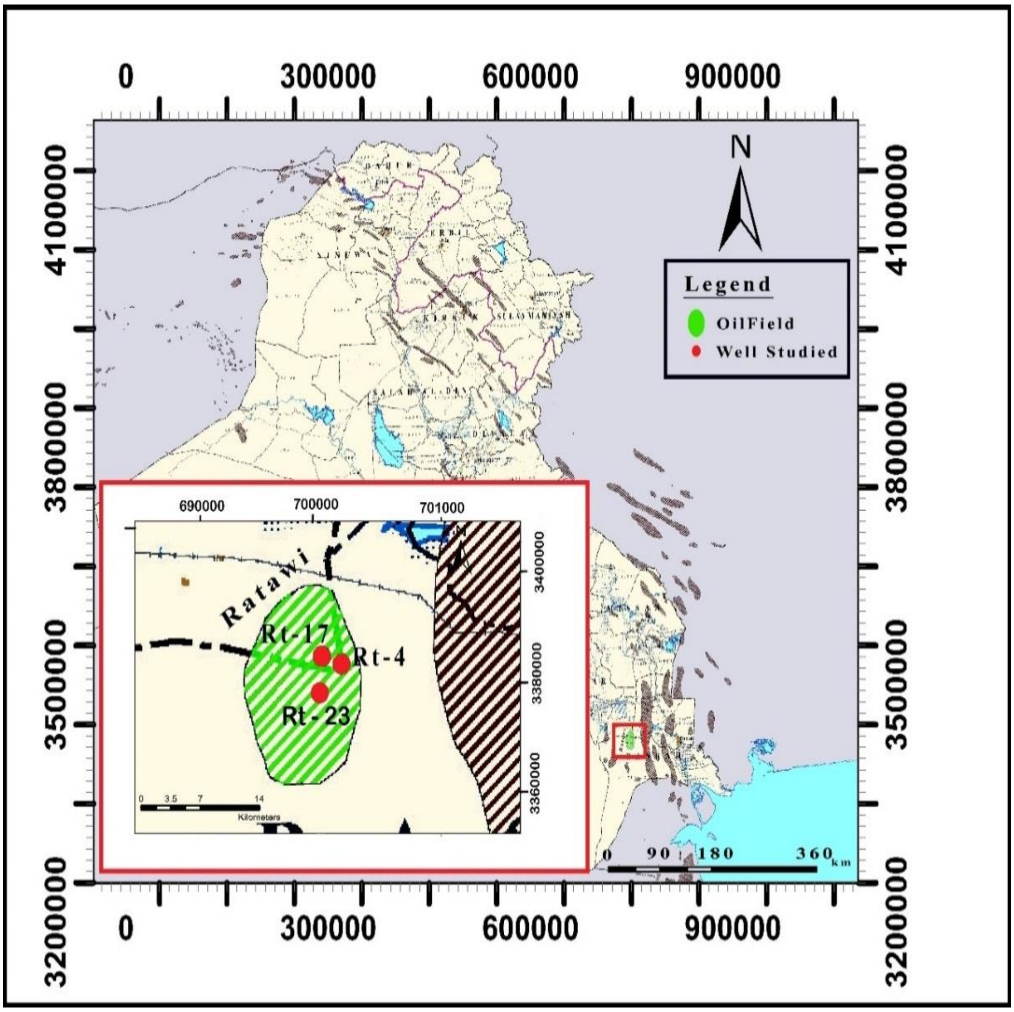

Figure 1: Location map of the study area, modified after [25].

From the tectonic view, the attitude of the Ratawi oil field on the Stable Shelf in the Mesopotamian zone at the Zubair Subzone. It is bounded in the north by the Takhadid-Qurna Transversal Fault and in the south by Al-Batin Transversal fault, in the Basra Block. It has a uniform structural style controlled by the underlying basement. It contains prominent N-S trending structures whose amplitudes increase with depth and reach 300m at lower cretaceous level [7].

Materials and Methods

The preparatory aspects of this work are studying the wells-final reports and reviewing the previous studies and then core samples were collected for the three wells Rt-4, Rt-17 and Rt-23, (Table 1), according to the changes in the lithology. Later, (281) thin sections were prepared in the workshop of the Department of Geology- College of Science-University of Baghdad and the workshop of the Department of Petroleum Geology and Minerals-College of Science-University of Diyala. The petrographic study includes a microscopic examination of thin sections under a standard petrographic microscope to determine the fossil's content.

Table 1: Situation and the top of Mauddud Formation in the study wells

Well No.	Depth (m)		Thickness	Number of thin sections	Coordinate	
	Top	Bottom			E	N
Rt-4	2554	2680	126	89	703900	3385100
Rt-17	2451	2582	131	94	701150	3385700
Rt-23	2481	2596	115	98	700100	3378700

Result

Facies are differentiated rock bodies with specific properties that are deposited under unique sedimentation conditions and serve as indicators of particular environmental processes [13]. Sedimentary facies associations, such as fining and coarsening-upward successions of facies, which indicate changes 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 create facies models for each major depositional environment [14]. The microfacies characterizations have been used to interpret the depositional environments of the Mauddud Formation. texture, grain size, and form all contribute to the microfacies characteristics (skeletal and non-skeletal). The microfacies classification in this study is based on [15] the distribution of larger benthic foraminifera which helps to distinguish the depositional conditions is based on [16]. The Identified microfacies were compared with Flagel’s standard microfacies and depositional models. Skeletal grains, such as foraminifera, ostracods, and pelecypods, are the most dominant component in the Mauddud Formation.

Skeletal Grains: Skeletal grains are the most dominant component within the Mauddud Formation, these include foraminifera and other bioclasts. Foraminifera in the Mauddud Formation represented by Orbitolinids (Pl.1-A), *Nezzazata simplex* (Pl.2-A) which indicates Middle Cenomanian [17]; *pseudotextularia* (Pl.2-B), and Milliolids (Pl.1-B). Orbitolinids are considered a significant constituent of the Iraq stratigraphic column which extends from the Barremian to the Maastrichtian. It was very abundant as a skeletal grain, *Nezzazata* was linked with miliolids and other benthic foraminifera. Miliolids are a suborder of foraminifera with calcareous, porcelaneous tests that are imperforate and commonly have a pseudochitinous lining. Tests are composed of randomly oriented calcite needles that have a high proportion of magnesium along with organic material. Tests lack pores and generally have multiple chambers [18]. Bioclasts are the debris left behind by organisms as a result of fossil transmission and robbing. Under a microscope, the term "bioclast" is used to describe wracked fossils (broken shells) or biomorph (bivalves) fossils are described, and skeletal grain is the same as bioclast (Pl.1- E).

Non-skeletal grains: Represented by peloids and intraclasts. Peloids are micritic grains that have rounded to sub-rounded, ovoid, rodlike shapes, The dimensions of the silt to fine sand-sized particles vary within a range of a few µm to a few mm, but most calcareous peloids are rarely larger than 500 µm, and commonly exhibit a diameter of < 200 µm [19]. Peloids are common in grain-supported microfacies of the Mauddud Formation (Pl.1- D). Intraclasts are typical large grains (several mm to several cm or more) with moderate to good rounding and multi-grained interior fabrics derived from a precursor deposit. They can form in a variety of environments, but they are most typically found in settings with high energy conditions [20]. Intraclasts are fragments of reworked carbonate rock created in the depositional basin (Pl.1- E).

Facies association

The Mauddud Formation has four main facies associations, they are Mid ramp, Shoal (inner ramp), Shallow open marine (inner ramp), and Restricted marine (inner ramp) (Figure 2), (Figure 3) and (Figure 4).

Facies association 1: Mid – Ramp environment

Bioclastic mudstone-wackestone dominates the Mid-Ramp facies association. Argillaceous mudstone, Argillaceous wackestone, and Orbitolined wackestone are the other significant microfacies. Nezzazata, rudist fragments, and pelecypods are the most common skeletal grains. These microfacies are similar to RMF-2 (Pl.1- F); this facies association is present at depths 2660-2680 in well Ratawi-4.

Facies association 2: Shallow open marine environment

The shallow open marine environment with open circulation is characterized by the abundance and diversity of fauna (Pl.1- G), and includes the following microfacies:

•Foraminiferal wackestone microfacies: These facies consist mainly of benthonic foraminifera like *Orbitolina concava* (Pl.2-C), *Neoiraqia* sp (Pl.2-D), and Miliolids as well as Echinoderms fragments, this microfacies is similar to RMF-13 and found at depth 2600-2610 in well Ratawi-4.

•Foraminiferal packstone microfacies: Orbitolina is the major component of these microfacies with about 45 % distributed in a micrite matrix, other fossils are Iraqi sp; Miliolids and Echinoderms with minor components of peloids and bioclasts, the abundance and diversity of fauna favors a shallow open marine condition. These microfacies are found at depth 2515 in well Ratawi-4; 2585 in well Ratawi-17 and at depth 2565 in well Ratawi-23.

Facies association 3: Restricted marine environment

The restricted environment is represented by variations from mud–supported to grain-supported fabrics. The microfacies are dominated by Milliolid, Nezzazata, small benthonic foraminifera with ostracods, gastropods (Pl.2-E) and algae (Pl.1-H), this environment is characterized also by the following microfacies:

•Bioclastic-fossiliferous wackestone microfacies: These microfacies are characterized by the abundance of bioclasts as well as miliolids and gastropods, this microfacies is corresponding to RMF-13. It has existed at depth 2495 in well Ratawi-4.

•Miliolid wackestone microfacies: The abundance of miliolids as major or only components in these microfacies indicates the restriction of the shallow marine environment, this microfacies is similar to RMF-18. It is found at depths 2500-2515 in well Ratawi-23.

Facies association 4: Shoal environment

The shoal environment is represented by Bioclastic packstone, Bioclastic grainstone, peloidal foraminiferal packstone-grainstone, and peloidal packstone-grainstone with diverse skeletal grains. Grain-supported texture distinguishes these microfacies. It consists of benthonic foraminifera (*Orbitolina*, miliolid, *Textularia*, and *Nezzazata*), Mollusca (pelecypods and gastropods), rudist fragments and peloids. (Pl.1- I). This facies is found at depths 2525-2540m in well Ratawi-4; 2585-2600 in well Ratawi-17, and at depths 2540-2565 in well Ratawi-23

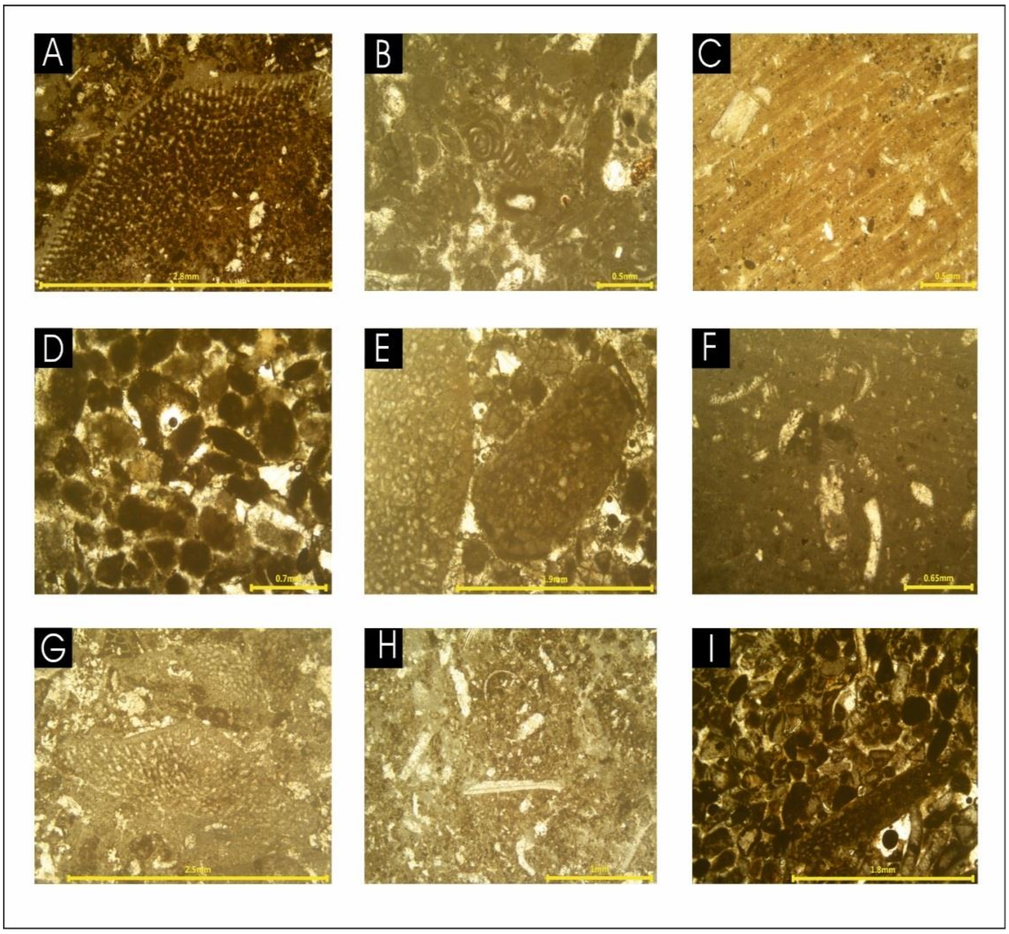

Plate- 1. (A) *Orbitolina* sp; (B) Miliolids; (C) Shell fragments; (D) peloids; (E) intraclasts; (F) Facies association mid – Ramp environment; (G) Facies association shallow open marine environment; (H) Facies association restricted marine environment; (I) Facies association Shoal environment.

Porosity types and distribution

The Mauddud Formation was affected by several diagenesis processes including dissolution which is the major control on pores formation and development, as noticed throughout this work, the dissolution affected both grains and matrix of the facies leading to a change in the pore volume of the carbonate rock, It depends on the solubility of minerals; for example, the solubility of calcium carbonate increases from low magnesium calcite to aragonite and high-magnesium calcite [20], the following pore types were recognized:

Vuggy porosity:

Vugs are pores with a diameter greater than 1/16 mm, and so are just visible to the naked eye. They are roughly equant in shape and consider non-fabric selective porosity [21]. It occurs in well Ratawi-17 at depths 2495.5, 2501, 2553 and 2558 (pl.2-F) and in well Ratawi-23 at depths 2518, 2537 and 2552 which means that the successions at these depths are affected by whole scale dissolution of parts of the rock or

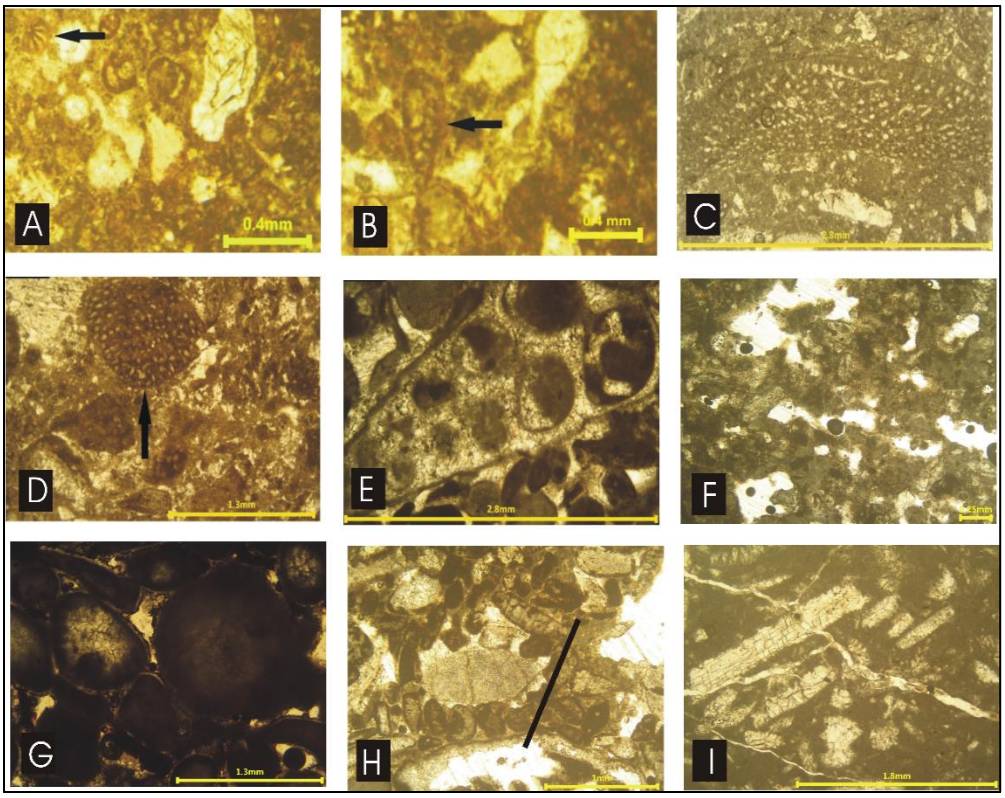

Plate- 2. (A) *Nezzazata simplex*, well Rt-4 at depth 2563m; (B) *Pseudotextularia*, well Rt-4 at depth 2562m; (C) *Orbitolina concava*, well Rt-4 at depth 2600 m; (D) *Neoiraqia* sp, well Rt-17 at depth 2541 m; (E) Gastropoda, well Rt-23 at depth 2571 m; (F) Vuggy porosity, well Rt-17 at depth 2495 m; (G) Interparticle porosity, well Rt-23 at depth 2552 m; (H) Intraparticle porosity, well Rt-17 at depth 2539 m; (I) Fracture porosity, well Rt-17 at depth 2513 m.

by dissolution enlargement of fabric-selective pores and the freshwater is the main cause of this type of pores, the expansion of dissolution and secondary porosity genesis are predominated by factors such as the freshwater acidity (e.g., rainwater filtered down through the soil zone becoming more acidic more than in locations where soils do not exist), [22]. Also, as a result of early and late diagenetic dissolution silt over the grains or cement boundaries and form small to large cavities (McNamara *et al*. 1992, Dehghani *et al*. 1999, in [19].

Interparticle:

Interparticle or intergranular pores occur in the spaces between the detrital grains that form the framework of sediment [23]. In carbonate rocks, the porosity between grains or particles is a result of primary porosity but also refers to secondary porosity (i.e. from the dissolution of the cortex of aragonitic ooids). The conservation of open intergranular porosity is enhanced by lacking water in the pores in arid climates, due to clay cap or by precocious oil placement [19]. It is existed in well Ratawi-17 at depth 2501 only and in well Ratawi-23 at depths 2518 and 2552 (Pl.2-G).

Intraparticale:

Intraparticle pores are voids within the skeletal material, which do not become filled with diagenetic cement. [24, 25, 26] defined the spaces of primary pores in the parts of the skeletons as intraskeletal porosity for example (chambers of foraminifera) or to open space formed by dispersal of weakly calcified internal structures [18] it’s found in well Ratawi-17 at depths 2510, 2539, 2558 and 2560 also occur in well Ratawi-23 at depths 2489 and 2537, (Pl.2-H).

Fracture:

This porosity can occur in a variety of ways and conditions. Tectonic movement can form fracture porosity in two ways. These are the tension over the crests of compressional anticlines and compaction drapes [27, 28]. Fracture porosity is also intimately associated with faulting and some oil fields show very close structural relations with individual fault systems [23] this type of porosity existed only in well Ratawi-17 at depths 2513 and 2529, (Pl.2-I), fracture porosity can cause by syn-depositional, post-depositional burial cracking of rocks or via brash fracture of shell or by increasing overload before cementation, folding and faulting [19].

Conclusions

1- The Mid–Ramp environment is represented by Argillaceous mudstone, Argillaceous wackestone, and Orbitolined wackestone, many types of fauna are present like *Orbitolina* sp., *Orbitolina concave*, *Neoiraqia convexa*, *spirploculina* sp.

2- Shallow open marine environment is represented by Foraminiferal wackestone microfacies and Foraminiferal packstone microfacies; the association fossils found are *O. (mesorbitolina) concave* and *spirploculina* sp.

3- Restricted marine environment is represented by Bioclastic fossiliferous wackestone microfacies and Miliolid wackestone microfacies, the fauna found in this zone are *Neoiraqia convexa*, *Biconava bentoni*, *Trocholina* sp. and *Nezazzata simplex*.

4- Shoal environment is represented by Bioclastic packstone, Bioclastic grainstone, peloidal foraminiferal packstone-grainstone, and peloidal packstone-grainstone with diverse skeletal grains, the association fossils found are *conicorbitolina conica*, *spirploculina* sp., *Neoiraqia convexa*.

5- Four types of porosity were found, these are Vuggy, Interparticle, Intraparticle and Fracture porosities.

Acknowledgements:

The authors would like to thank the Department of Geology-College of Science-University of Baghdad and the Department of Petroleum Geology and Minerals, College of Science, the University of Diyala for their help during this work. The authors acknowledge both unknown reviewers for their constructive suggestions and comments.

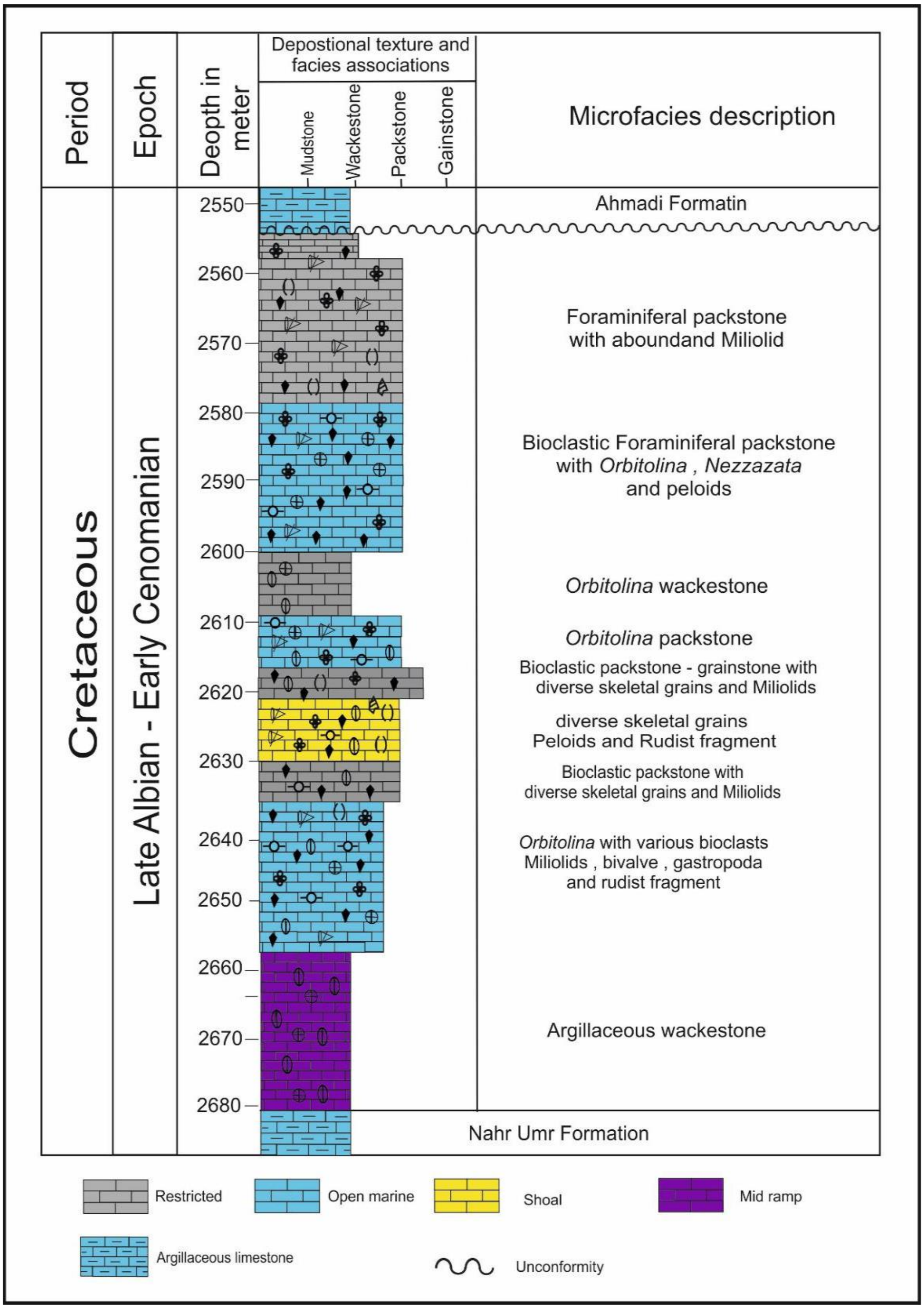

Figure 2: Microfacies succession and depositional environments of Mauddud Formation in Ratawi well –4.

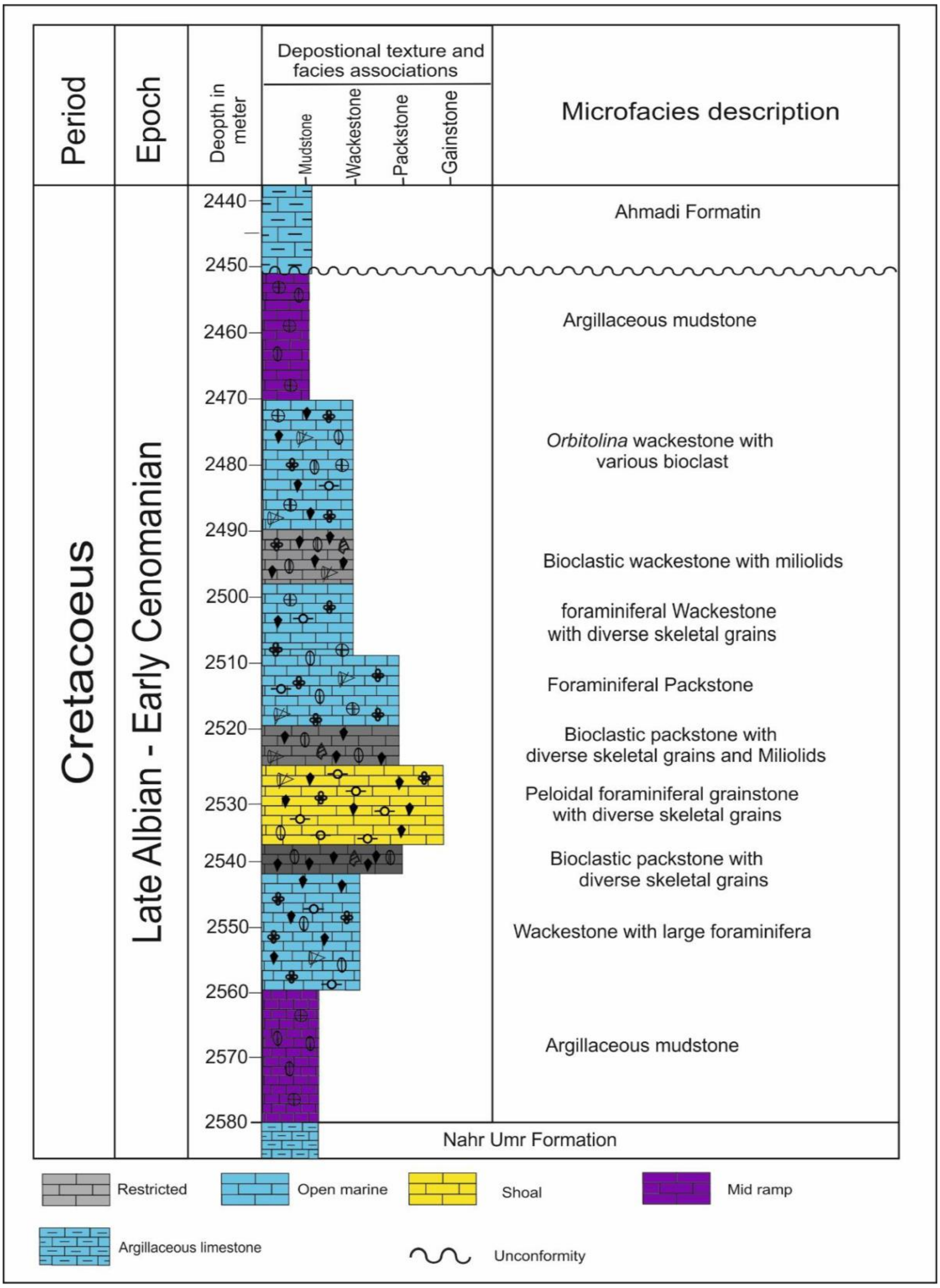

Figure 3: Microfacies succession and depositional environments of Mauddud Formation in Ratawi well – 17.

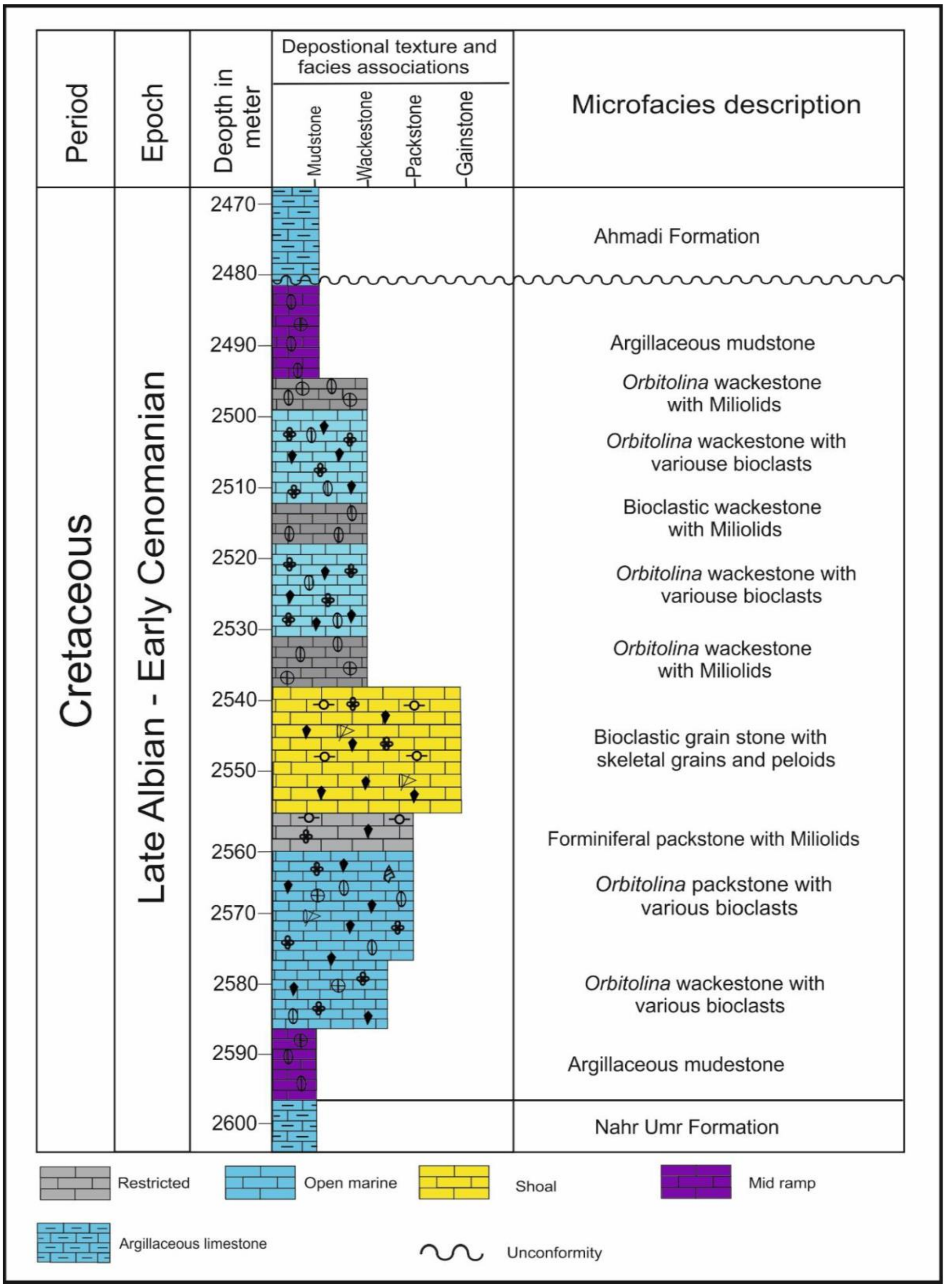

Figure 4: Microfacies succession and depositional environments of Mauddud Formation in Ratawi well – 23.

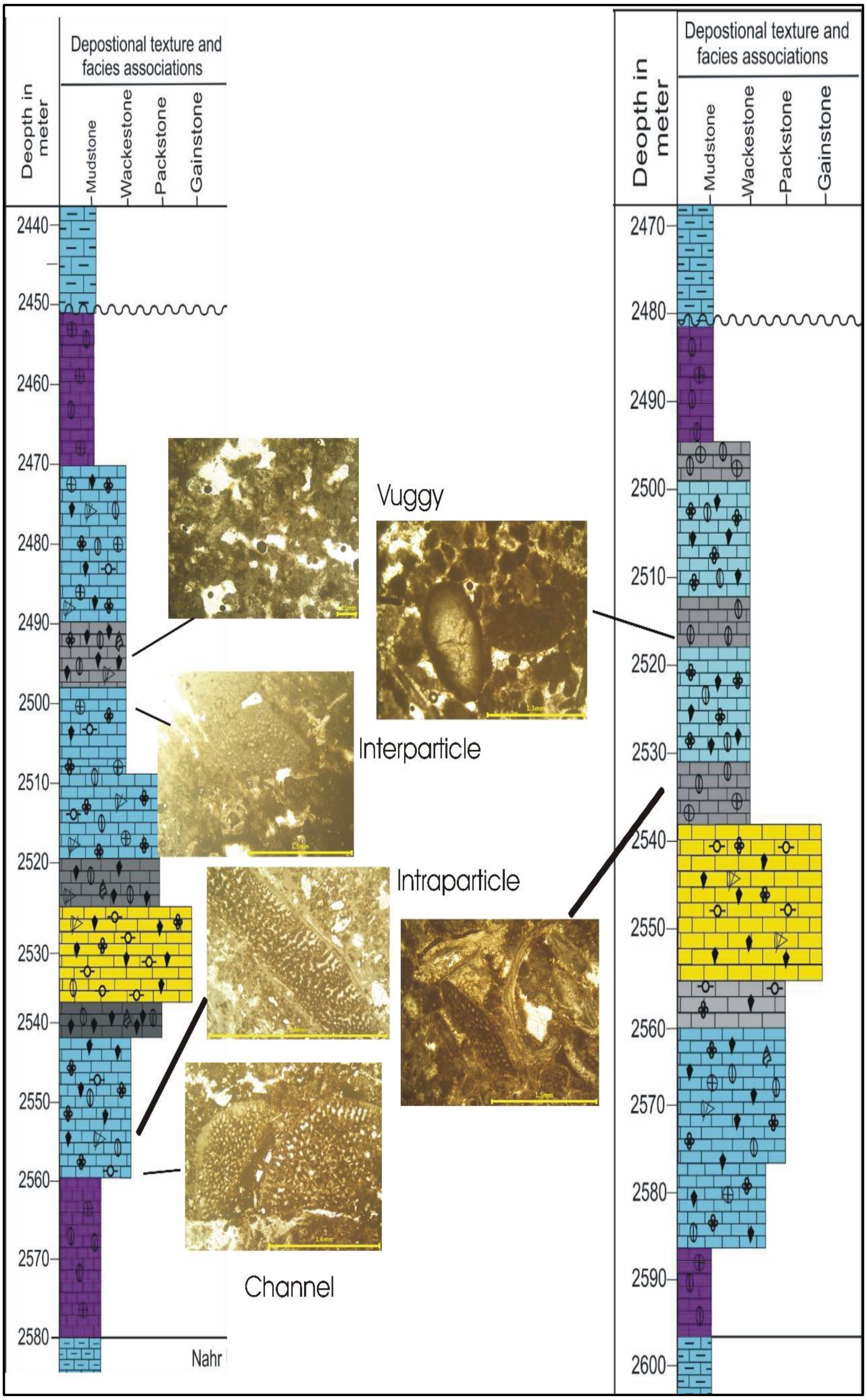

Figure 5: Porosity type distribution in well Rt-17 and Rt-23.

References

[1] Henson, F.R.S. “Oil occurrence in relation to regional geology of the Middle East”. *Geol. Soc. Tulsa, Digest.*, vol. 19, pp: 72-81, 1951.

[2] Bellen, V., Dunnington H.V., Wetzel R., & and Morton D. M. “Lexique Stratigraphique International, Asie, Iraq”. *Intern. Geol. Congr*., 1959.

[3] Al-Siddiki, A. A. “Subsurface geology of southreastern Iraq. 10 The Arbian Petroleum Cong”., *Tripoli, Paper*, vol. 141, no. B3, p. 47, 1978.

[4] Buday, T. *The regional geology of iraq. Stratigraphy and paleogeography. Published by State Organization for Minerals*, 459P, 1980.

[5] Hussain, S.A., Sahaab, A.M., Ahmad, K.I., Hussain, I.Q., Hashem, S.A. “Microfacies Characterizations and Paleoenvironment of Upper Part of Qamchuqa Formation from Chwarqauran Section, Sulaimaniyia Area, Kurdistan Region, Iraq”. *Iraqi Geological Journal.* vol.54, no. 1B, pp. 102-111, 2021.

[6] Sayyab, A.S., and Mohammed, M.U., “Biostratigraphic study of some subsurface sections of Mauddud Formation (south of Iraq)”. *Iraqi Journal of Science,* vol.26, pp. 45 – 67, 1985.

[7] Jassim, S.Z. and Goff, J.C, (Editors) *Geology of Iraq. Published by Dolin, Prague and Moravian Museum, Berno,* 341 p, 2006.

[8] Al-Dabbas, M., Jassim, A., & Qaradaghi, I. "Sedimentological and depositional environment studies of the mauddud formation, central and southern Iraq". *Arabian Journal of Geosciences*, vol. 5, no. 2, pp. 297–312, 2012.

[9] Sadooni, F. N., & Alsharhan, A. S. "Stratigraphy, microfacies, and petroleum potential of the Mauddud Formation (Albian-Cenomanian) in the Arabian Gulf basin". *American Association of Petroleum Geologists Bulletin*, vol. 87, no. 10, pp. 1653–1680, 2003.

[10] Faisal, M. & Mahdi, T. "Diagenetic Processes Overprint and Pore Types of Mauddud Formation, Badra Oil Field, Central Iraq". *Iraqi Journal of Science*, vol. 61, no. 6, pp. 1353–1361, 2020a.

[11] Hameed, H. Microfacies interpretation, petrophysical properties and 3Dgeological modeling for Mauddud Formation in selected wells of Ratawi oil field, South Iraq. University of Baghdad, 2021.

[12] Al-Qayim, B., Qadir, F. and Al-Biaty, F. "Dolomitization and porosity evaluation of the Cretaceous Upper Qamchuqa (Mauddud) Formation, Khabbaz oil field, Kirkuk area, northern Iraq". *GeoArabia*, vol. 15, no. 4, pp. 49-76, 2010.

[13] Reading, H. G., S*edimentary Environments: Processes, Facies and Stratigraphy. Third edition. Blackwell, Oxford*, 1996.

[14] Boggs, S. J. P*etrology of Sedimentary Rocks. Published in the United States of America by Cambrige University Press, Newyork*, 2009.

[16] Dunham, R. "Classification of carbonate rocks according to depositional texture". *American Association of Petroleum Geologists Memoir*, vol. 1, pp. 108–121, 1962.

[15] BouDagher-Fadel, M.K., *Evolution and geological significance of larger benthic foraminifera, Elsevier*, 571 p, 2008.

[17] Al-Dulaimy, S.I.M., Ibrahim, Y.k., Abdallah, F.T. "Biozonation (benthic foraminifera) of Mishrif Formation at Majnoon and Zubair oil fields, southern Iraq". *Bulletin of the Geological Society of Malaysia*, vol. 73, pp. 79 - 89, 2022.

[18] Loeblich, A. R., Tappan, H., & Moore, R. C. *Treatise on invertebrate paleontology, Part C, Protista 2. Geol. Soc. Am., Univ. Kansas Press, Lawrence,* 869 p, 1964.

[19] Flugel, E. *Microfacies of Carbonate Rocks, Analyasis Interpertation and Appliaction, 2nd edition*, 1006 p, 2010.

[20] Scholle, P. A., & Ulmer-Scholle, D. "A Color Guide to the Petrography of Carbonate Rocks: Grains, textures, porosity, diagenesis". *The American Association of Petroleum Geologists.,* 459 p, 2003.

[21] Choquette, P. W. and Pray, L. C. "Geologic nomenclature and classification of porosity in sedimentary carbonates", *The American Association of Petroleum Geologists,* vol. 54, no. 2, pp: 207–250, 1970.

[22] Mazzullo, S.J., and Chilingarian, G.V. Diagenesis and origin of porosity, in G.V. Chilingarian, S.J. Mazzullo, and H.H. Rieke, eds., Carbonate Reservoir Characterization: A Geologic-Engineering Analysis, Part I: Elsevier Pub. Co., Amsterdam, *Developments in Petroleum Science*, vol. 30, pp. 199-270,1992.

[23] Selley, R.C. *Applied sedimentology. second edition*, 474 p, 2000.

[24] Bachman, R. T. "Intratest porosity in foraminifera". *Journal of Sedimentary Research,* vol. 54, no. 1, pp. 257-262, 1984.

[25] OCHA, U. O. for the C. of H. A. *IRAQ* - Reference oilfield map (March), 2009.

[26] Faisal, M.J. and Mahdi, T.A., "Geological model of Mauddud Formation in Badra Oilfield". *The Iraqi Geological Journal,* pp.58-67, 2020b.

[27] Tareq, H., Al-Banna, A. and Al-Sharaa, G., "Lithological Study of Mishrif, Rumaila, Ahmadi and Mauddud Formations Using Vp/Vs Ratio, Acoustic Impedance and Well Logging at Amara Oil Field, Southern Iraq". *The Iraqi Geological Journal*, pp.39-58, 2021.

[28] Ahmed, R.A.H. and Hamd-Allah, S.M., "Geological Model for Mauddud Reservoir Khabaz Oil Field, Kirkuk, Northern Iraq". *The Iraqi Geological Journal*, pp.29-42, 2021.