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Microfacies Analysis and Diagenesis Processes of Mauddud Formation in Selected Wells from Ratawi Oil Field, Southern Iraq

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Abstract

Mauddud Formation was studied in Ratawi oil field, Southern Iraq to determine the depositional environment and effective diagenesis processes**.** The lithology of the formation is limestone in all studied wells (Rt-2, Rt-4, Rt-17 and Rt-19). lower contact of Mauddud Formation with Nahr Umr Formation is gradational, but the upper contact is unconformable with Ahmadi Formation.In this work, 114 thin sections were examined and shows four microfacies (wackestone, packstone, grainstone and argillaceous mudstone), which deposited in the Inner-Mid to Outer ramp environment. The most significant diagenesis processes were micritization, dissolution, cementation, compaction, and dolomitization, which had an impact on the texture and porosity of the Mauddud Formation.

Key Words: Mauddud Formation, Ratawi oilfield, Microfacies, Diagenesis processes.

تحليل السحنات الدقيقة والعمليات التحويرية لتكوين مودود في آبار مختارة من حقل رطاوي النفطي، جنوب العراق

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الخلاصة

تمت دراسة تكوين المودود في حقل رطاوي النفطي جنوب العراق وتمثلت صخارية التكوين في الحجر الجيري في جميع الآبارالمدروسة (Rt-2 ,Rt-4 , Rt-17and Rt-19) . يعتبر الحد السفلي لتكوين مودود مع تكوين نهر عمر متدرجا ، لكن الحد العلوي غير متوافق مع تكوين الأحمدي. في هذا العمل ، تم فحص (114) شريحة صخرية اظهرت أربعة سحنات دقيقة (الحجر الواكي ، الحجر المرصوص ، الحجر الحبيبي والحجرالطيني الجيري) ، والتي ترسبت في بيئة منحدر داخلي-متوسط إلى بيئة المنحدر الخارجي. كانت اهم العمليات التحويرية هي المكرته ، الاذابة,السمنتة, الانضغاط والدلمتة, والتي كان لها تاثير على نسيج ومسامية تكوين المودود.

الكلمات المفتاحية: تكوين المودود, حقل الرطاوي النفطي, السحنات الدقيقة, العمليات التحويرية.

Introduction

Ratawi Field is located 70 km northwest of Basrah city which was known for the first time by the gravity surveys at the beginning of the 1940, then a 2D seismic survey conducted during (1947-1948) by Basrah oil company resulted in appearance of asymmetrical 300 km^2 anticlinal structure [1]. The first exploration of Ratawi Oilfield was in well (Rt-1) which has been drilled in 1948. The drilling revealed existence of oil accumulations within upper cretaceous Mishrif Formation and lower cretaceous formations represented by Mauddud, Nahr Umr, Yammama, Zubair and Ratawi, and gas shows in Sulaiy Formation (Final geological report of the well (Rt-1)). There are significant hydrocarbon reservoirs in the Cretaceous carbonate succession in various Arabian Plate regions. In Southern Iraq, Mauddud Formation is widespread reservoir in many oilfields, [2]. The formation comprises an average (123) m of porous limestone with thin beds of argillaceous limestone deposited within shallow inner ramp environment [3].

Aims of the study

1. Microfacies analysis of Mauddud Formation.
2. Reconstruction of the paleoenvironment.
3. Estimating the diagenesis processes that have an impact on reservoir properties.

Location of the study area

Ratawi Oilfield is located about 70 km to the northwest of Basrah and 12 km to the northwest of North Rumaila oil field. A Surface map was drawn by ARC GIS Ver. 10.8, hows the field border and the locations of the studied wells (Table 1) and (Fig. 1). Four wells from Ratawi Oil Field (Rt-2, Rt-4, Rt-17, Rt-19) have been selected which penetrate Mauddud Formation. Table (1-2) show the coordinate of studied wells of the Mauddud Formation.

Table 1: Coordinates of the boundaries of the studied wells.

POINT	COORDINATES GEOGRAPHIC SYSTEM (DEG. MIN. SEC.)	
A	46°52'26.947"E	30°16'1.784"N
B	46°52'56.446"E	30°48'33.571"N
C	47°18'8.909"E	30°48'2.387"N
D	47°17'7.804"E	30°15'58.878"N

Table 2: Localities of Ratawi Oil Wells with the depth and thickness of Mauddud Formation.

Well Name	**Coordinates Geographic System (deg. min. sec.)**		Depth(m) RTKB	thickness
RT-2	**47°5'42.3468"E**	**30°30'39.94"N**	**2493-2612.5**	**119.5**
RT-4	**47°7'34.9122"E**	**30°34'51.8904"N**	**2554-2680.5**	**126.5**
RT-17	**47°5'52.188"E**	**30°35'13.1342"N**	**2456-2582**	**126**
RT-19	**47°4'52.2256"E**	**30°33'43.1906"N**	**2459-2580.5**	**121.5**

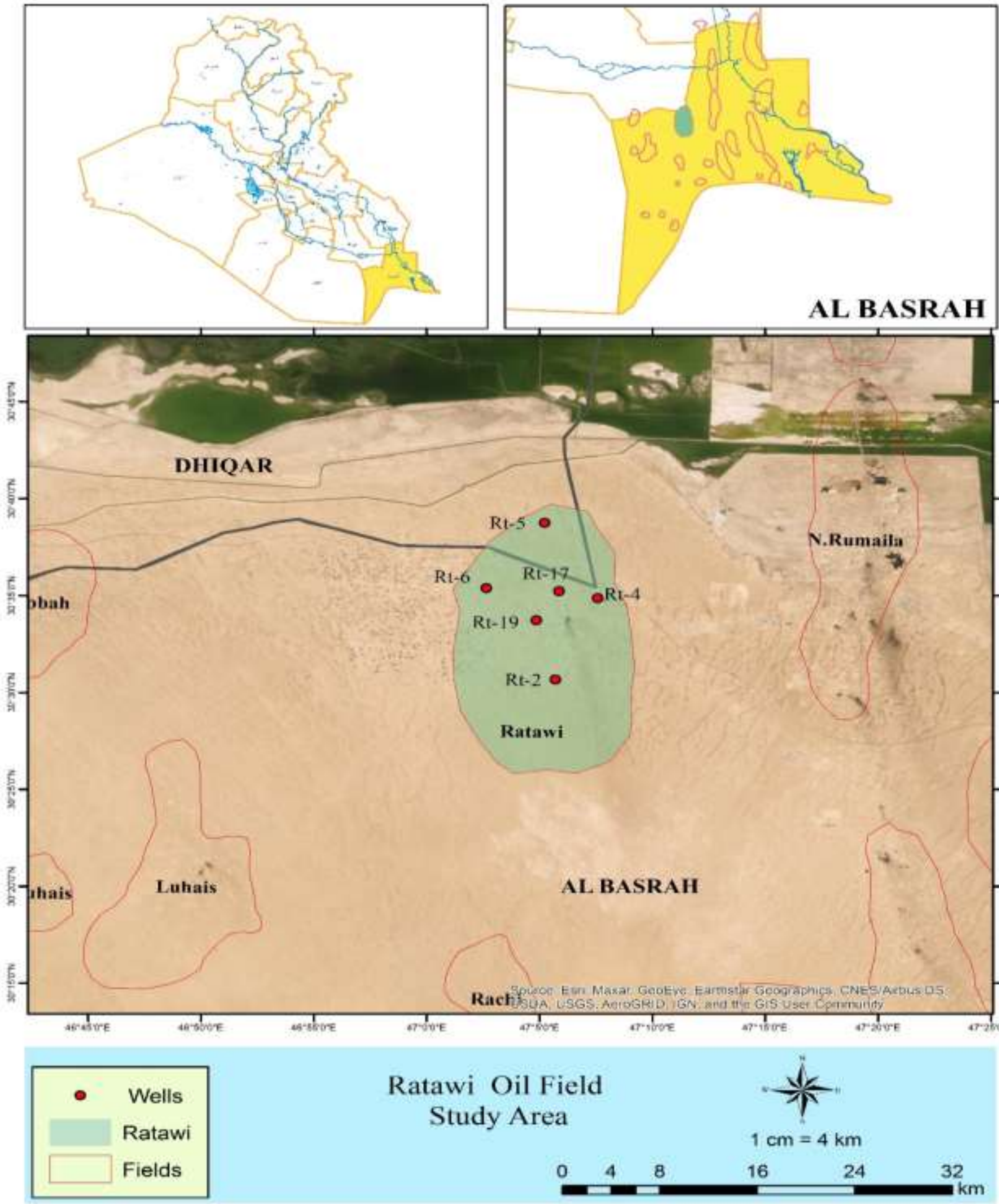

Figure 1: Location map of Ratawi Oilfield.

Materials & Methods

One hundred and fourteen slides were supplied by the laboratory department of the Oil Exploration Company for four wells within the Mauddud Formation (Rt-2, Rt-4, Rt-17 and Rt-19). A microscope (CETI) was used for diagnosing microfacies, diagenesis processes and interpret depositional environment. Microfacies were identified using the Dunham classification (Dunham, 1962). This classification categorizes rocks based on their texture and composition, allowing for the identification of different sedimentary environments. Diagenesis processes were identified such as cementation, dissolution, and recrystallization. The types of porosity in the formation were also identified using the Choquette and Pray classification.

Results

Facies association

A category of sedimentary facies used to discriminate a specific environment of sedimentation, [4]. In present study, the model of ramp microfacies (RMF) by [5] was used to interpret the environment of deposition.

Three main facies associations; inner ramp (includes various facies type), Mid ramp and Outer ramp shown in figures (2, 3, 4 and 5) are recognized as follow:

Inner ramp facies association

Wackestone, packstone and grainstone with the following components are characterized inner ramp facies. Foraminiferal wackestone is existed in all studied oil wells except well Rt-19, is containing textularia sp., miliolids and bioclast, which indicated by standard microfacies RMF 16 and reflects restricted inner ramp environment [5], (Pl.1-A). Orbitolina and bioclast packstone containing also miliolids, Trocholina sp., Pseudotextulariella sp. and bioclast of echinoderms that reflect RMF 13 and 14 according to [5] which deposited in the open inner ramp (Pl.1-B). Foraminiferal packstone with *Nezzazata*, *Valvulina*, miliolid and bioclast is characterized RMF 20 and present only in well Rt. 4, and indicates lagoon inner ramp environment (Pl.1-C). Peloidal and foraminiferal grainstone with various components include ooids, echinoderms, are existed in all studied oil wells except well Rt-19, which reflects RMF 26 and deposited in shoal inner ramp environment [5], (Pl.1-D).

Mid ramp facies association

Bioclast of echinoderms, peloidal, and foraminiferal Packstone and grainstone, which characterized mid ramp environment with the following description: RMF 7 that include echinoderms, *Orbitolina* and bioclast packstone (Pl.2-A); RMF 3 with peloids, *Orbitolina*, echinoderms, rudist packstone and this facies is not existed in well Rt-4 (Pl.2-B); RMF 9 containing bioclast and intraclast with foraminifera packstone (Pl.2-C), bioclast pack-grainstone with *Orbitolina* is characterized RMF 8, which found only in well Rt-19 (Pl.2-D). All the above facies are indicating mid ramp depositional environment according to [5].

Outer ramp facies association

The following RMF 2, 4 and 6 are characterized the outer ramp depositional environment, argillaceous mudstone RMF 2 (Pl.2-E) lacks any grains and existed only in well Rt-2. Peloidal packstone with bioclast and rare *Orbitolina* and echinoderms RMF 4 (Pl.2-F) is found only in wells Rt-2 and Rt-17, and peloidal grainstone RMF 6 (Pl.2-G) with bioclast and rare *Orbitolina*, which present only in well Rt. 19. The outer ramp facies is absent in well Rt-4, which indicates that the succession of Mauddud Formation in this well is deposited in the inner to mid ramp environment.

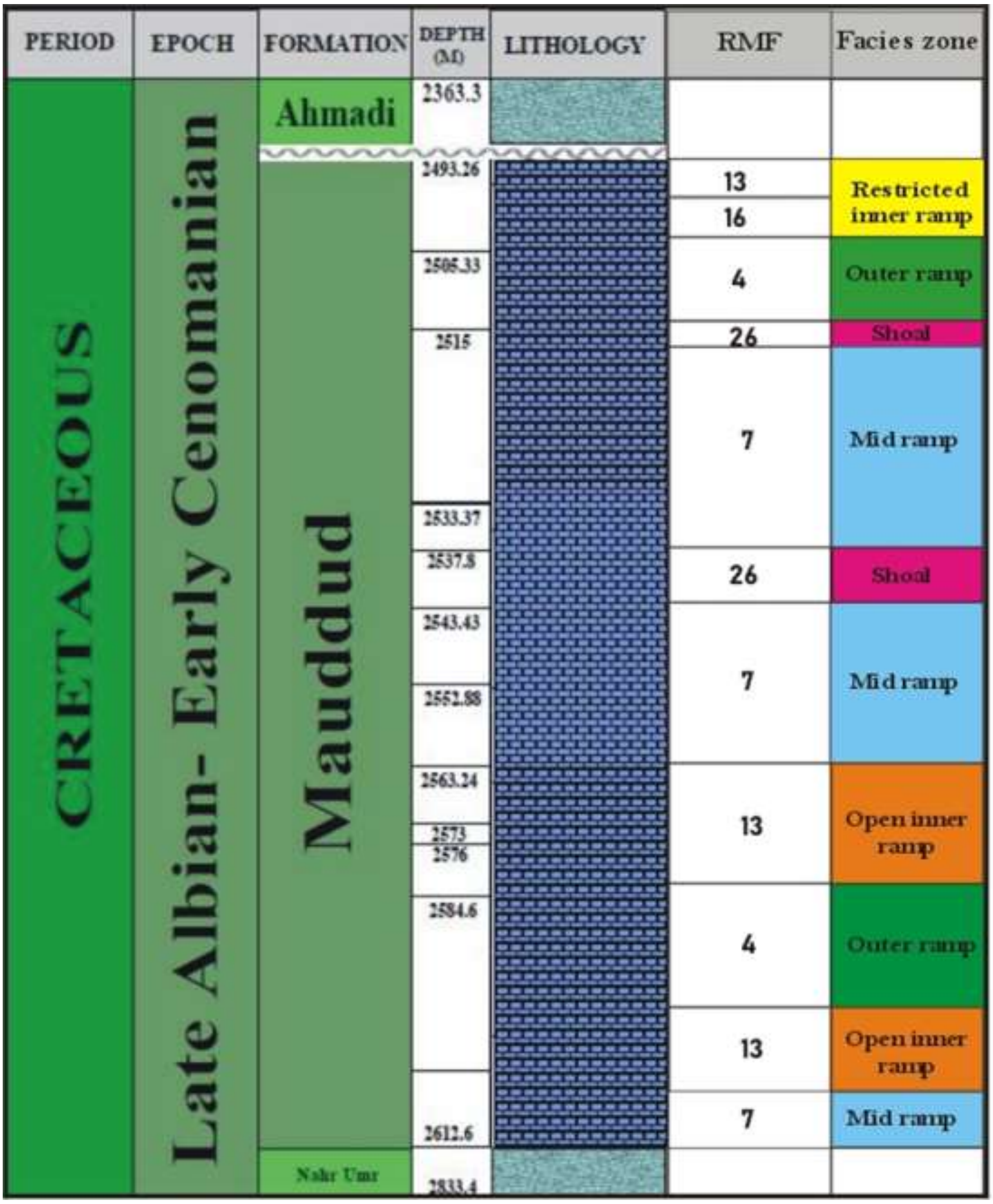

Figure 2: Microfacies (RMF) and facies zone of well **Rt-2**

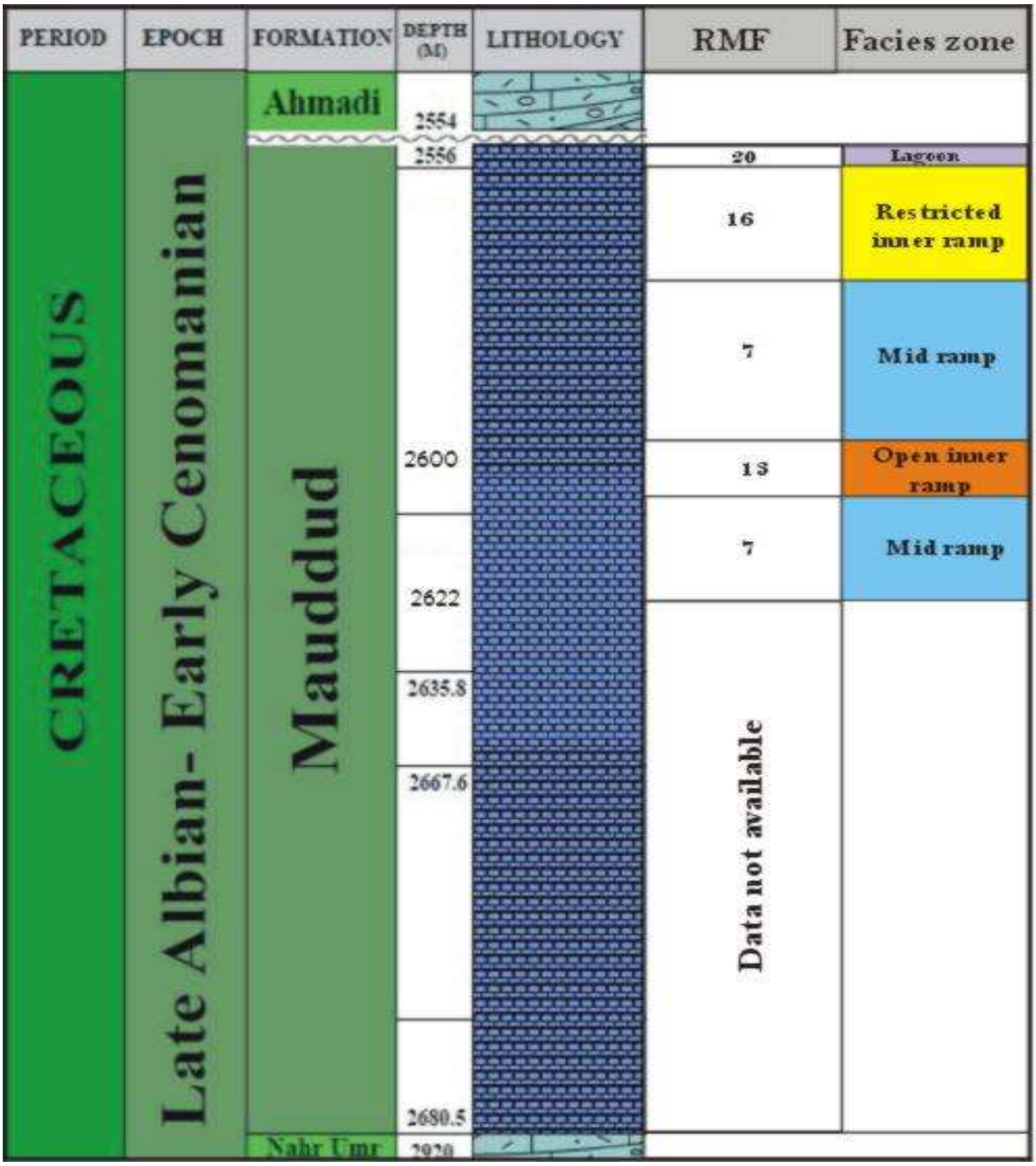

Figure 3: Microfacies (RMF) and facies zone of **well Rt-4**

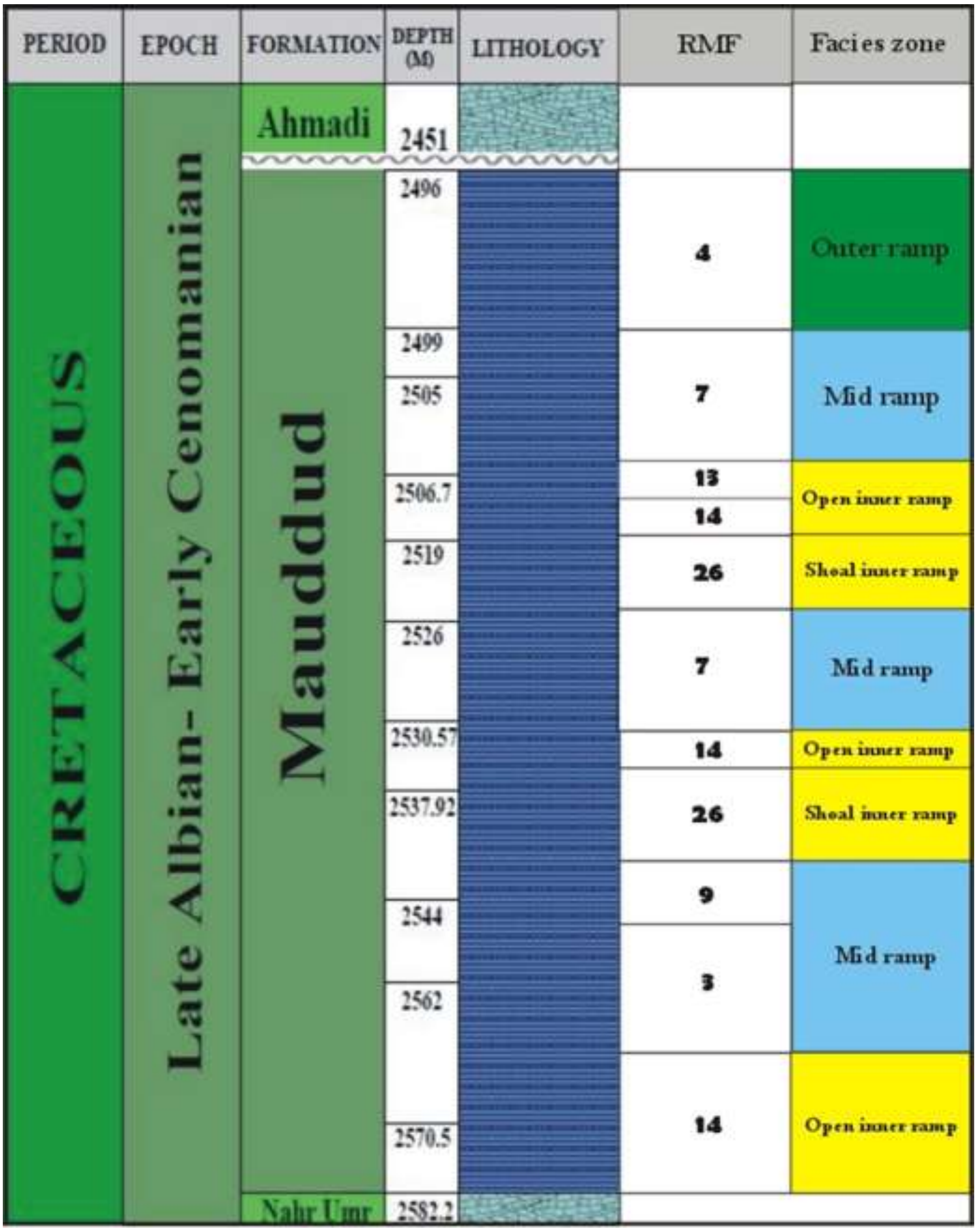

Figure 4: Microfacies (RMF) and facies zone of well **Rt-17**

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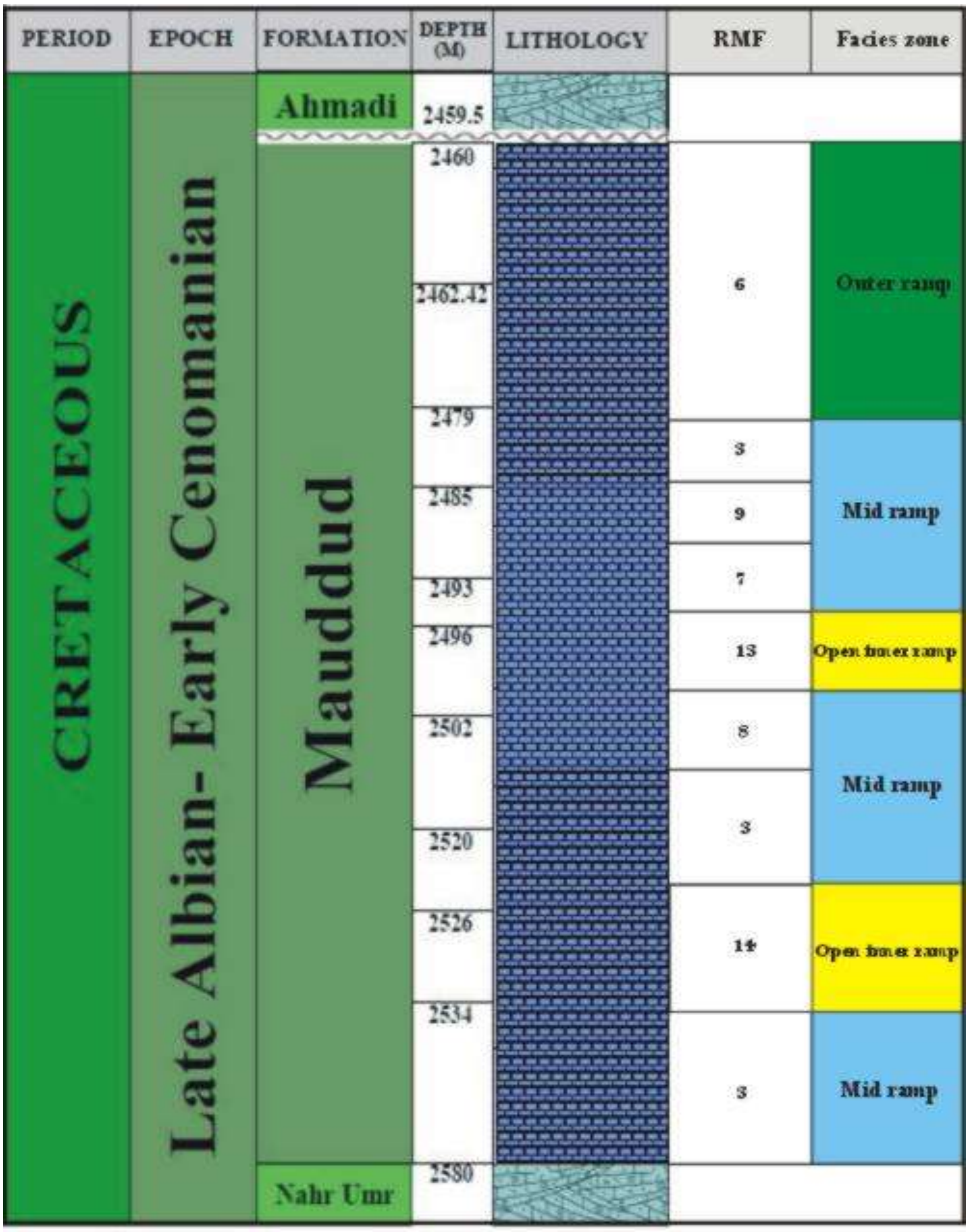

Figure 5: Microfacies (RMF) and facies zone of well **Rt-19**

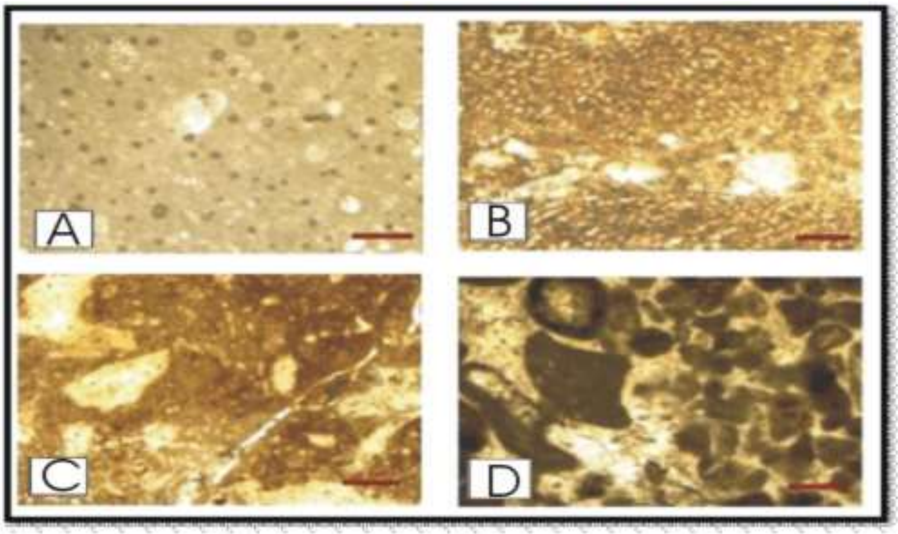

Plate 1

A- Foraminiferal wackestone microfacies, Well Rt-4, depth 2565.40 m. **B-** Orbitolina and bioclast packstone microfacies, Well Rt-2, depth 2590.75 m. **C-** Foraminiferal packstone microfacies, Well Rt-4, depth 2554.50 m. **D-** Peloidal foraminiferal grainstone. Well, Rt-2, depth 2536.10 m.

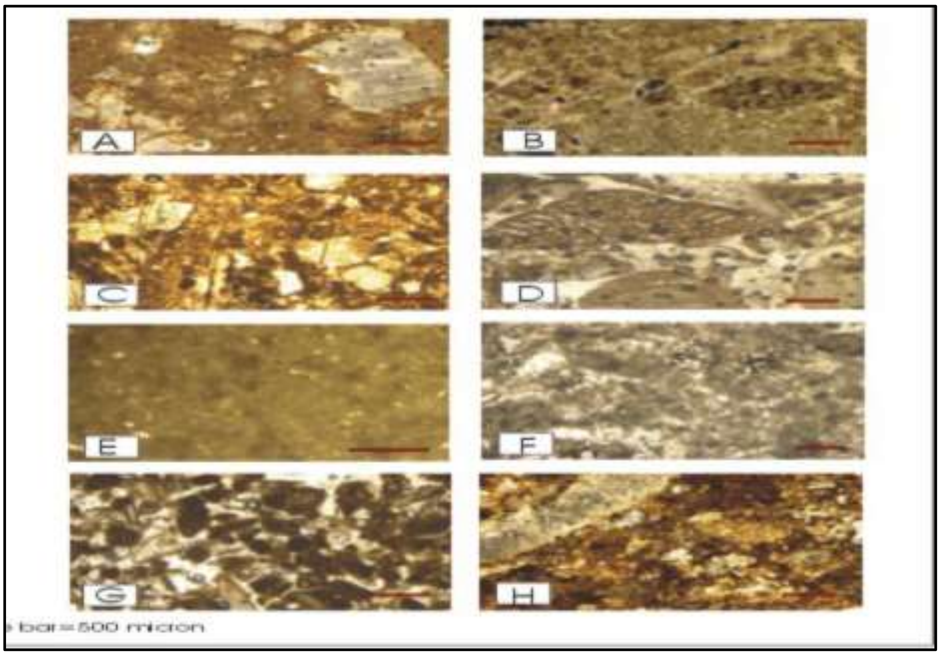

Plate 2

A- Bioclast packstone with echinoderm microfacies, Well Rt-19, depth 2489.04 m. B- Peloids-Orbitolina-echinoderms packstone microfacies, Well Rt-2, depth 2590.75 m. C- Bio-intraclast packstone microfacies, Well Rt-4, depth 2615.50 m. D- Orbitolina bioclast grainstone, Well Rt-19, depth 2503.60 m. E- Argillaceous mudstone microfacies, Well Rt-2, depth 2610.09 m. F- peloidal bioclast packstone microfacies, Well Rt-17, depth 2496.14 m. G- peloidal bioclast grainstone microfacies, Well Rt-19, depth 2464.30 m. H- Micritization of echinoderms fragment. Well, Rt-4, depth 2590.50 m.

Diageneses processes

Diagenesis is the process by which sediments change through time, starting at the time of deposition and continuing until the resulting materials (rocks) are either subjected to metamorphism or exposed to the effects of atmospheric weathering. [6]. Diagenesis refers to the physical, chemical and biological operations, which caused compaction, cementation, recrystallization and other modifications to the original sediment. They are important because they modify sediment by changing both its composition and texture [7]. [8]

Defined diagenesis as all alterations of the sediment's chemical constituents, shape, size, or crystalline structure. Carbonate rocks also undergo complex diagenesis due to their variable mineral composition and high elementary permeability, which make carbonate rocks susceptible to fluid transpiration [9].

Several diagenesis processes have been recognized in Mauddud Formation including: Micritization, Dissolution, Cementation, Dolomitization and Compaction.

1. **Micritization**

Microscopic algae and/or fungus that bore into sedimentary clasts of the size of sand or silt may transform them partially or completely into micrite-sized calcium carbonate [10]. The process especially occurs in the photic zone of the shallow water environment and it diminishing with the increasing of water depth [11]. In the present study, micrite is discriminated at the upper part of well Rt. 2 and the middle part of well Rt-4 (Pl.2-H).

2. **Dissolution**

Below a depth of roughly 4500 m, the carbonate sediments of the current oceans are mostly missing. High hydrostatic pressure, low water temperatures, and high CO_2 partial pressure all contribute to the disintegration of deep-sea sediments as well as significant variations in their carbonate preservation potential [5]. The disintegration of skeletal aragonite is one of the most prevalent diagenetic processes; at depth of several thousand meters, the bulk of aragonite shells entirely dissolve [9]. Dissolution is the most important diagenesis process that improves porosity and permeability and forms different kinds of pores, which can be isolated or connected [5]. In Mauddud Formation different types of porosity were recognized and classified according to [12], as following:

- Vugs pores: are pores that are larger than 1/16 mm in diameter and can be seen with the human eye. In terms of shape, they are roughly equant [12]. The addition of vuggy pore to interparticle pore changes the petrophysical features. The term "separate vugs" refers to pore space connected exclusively by the interparticle porosity. Touching vugs are pore spaces that link to form an intricate pore network without regard to the interparticle porosity [13]. In the present study , vuggy porosity is recognized in the middle part of well Rt-2 at depths 2541.40 m and 2554.18 m (Pl.3-A). Also it recognizes at the upper part of well Rt-4 at depth 2560.50 only, while in well Rt-17 it distributed at different depths, and at depth 2489.05 m in well Rt-19.

- Interparticle pores: [9] defines the interparticle or intergranular pores , which occured in the spaces between the grains that form the framework of a sediments. [13] defined it as pore spaces located among grains or crystals, but not significantly larger than the grains or crystals of the rock. They are discriminated near the upper and lower part of well Rt-2 and distributed in three depths (2571.9, 2592.5 and 2615.5 m) of well Rt-4 (Pl.3-B) and in well Rt. 17 the interparticle pores are common. Finally, they are present in depths 2480.40, 2500.29 and 2541.05 m.

-Intraparticle pores: are spaces within the skeletal grain, which do not become filled with diagenetic cement [4]. Primary porosity may exist inside the detrital grains of carbonate sediments, especially those of skeletal origin. This form of porosity is frequently reduced soon after deposition by micrite matrix infiltration. Additionally, due to the carbonate host grains' chemical instability, later modifications or destruction of their intraparticle pores may occur. [9]. In the Mauddud Formation, intraparticle porosity is distributed nearly at all depths of the studied wells, making it the most effective porosity. (Pl.3-C).

- Fracture pores: There are numerous circumstances and factors that might cause these pores. Two ways that tectonic movement can create crack porosity, these are the compressional anticlines and compactional drapes' tension above their crests. Additionally, faulting and fracture porosity are closely related, and certain oil fields have very strong structural relationships with specific fault systems [9]. In the Mauddud Formation, fracture porosity is the least occurring feature, present in all studied wells except for well Rt-19. (Pl.3-D).

3. Cementation

[7] is defined the cementation as the deposition of adequate amount of minerals within the pore spaces of sediment, while [9] defined it as a form of after depositional mineral growth that happens within the voids of sediment. In this study, several different forms of cementation have been recognized.

- Drusy cement: pore padding and underlay cement in inter-particle and intra-fossil pores, molds and fractures, identified by "equant to elongated, anhedral to subhedral non-ferroan calcite crystals, size is usually >10 μm and accessions toward the center of the void". It forms near surface meteoric as well as burial environments [5], drusy cement in present study is found in wells Rt-4, Rt-17 and 19 only (Pl.3-E).

- Blocky cement: [14] defined this type of cement as a large crystal of calcite, which reflects slow crystallization after the diagenetic process. Blocky cement represents environment of Deep burial [5]. It is existed in all studied wells (Pl.3-F).

- Granular cement: It is represented by equi-granular or anhidral and/or subhedral crystals [15]. It is found in all studied wells of the present study (Pl.3-G).

4. Compaction

"A compression process that re-orients and re-shapes the grains of sediment in response to the weight of overlying deposits" [16]. Compaction processes are classified as either mechanical or chemical [17]. The fractures (mechanical compaction) are found in all studied wells except well Rt-19.

According to [18] who proposed a classification of stylolite, which was then modified by [17]. The most common types of stylolites found in all studied wells except well Rt. 4 are low peaks.

5. Dolomitization

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Most dolomite present in sedimentary rocks is initially diagenetic, and it occurs as a replacement of calcite [19]. Dolomitization as a definition may aim that the process has replace the CaCo3 to the CaMg(CO3)2 or limestone replaces into (dolomitic limestone) [5]. Dolomitization is limited in studied wells and absent in well Rt-4.

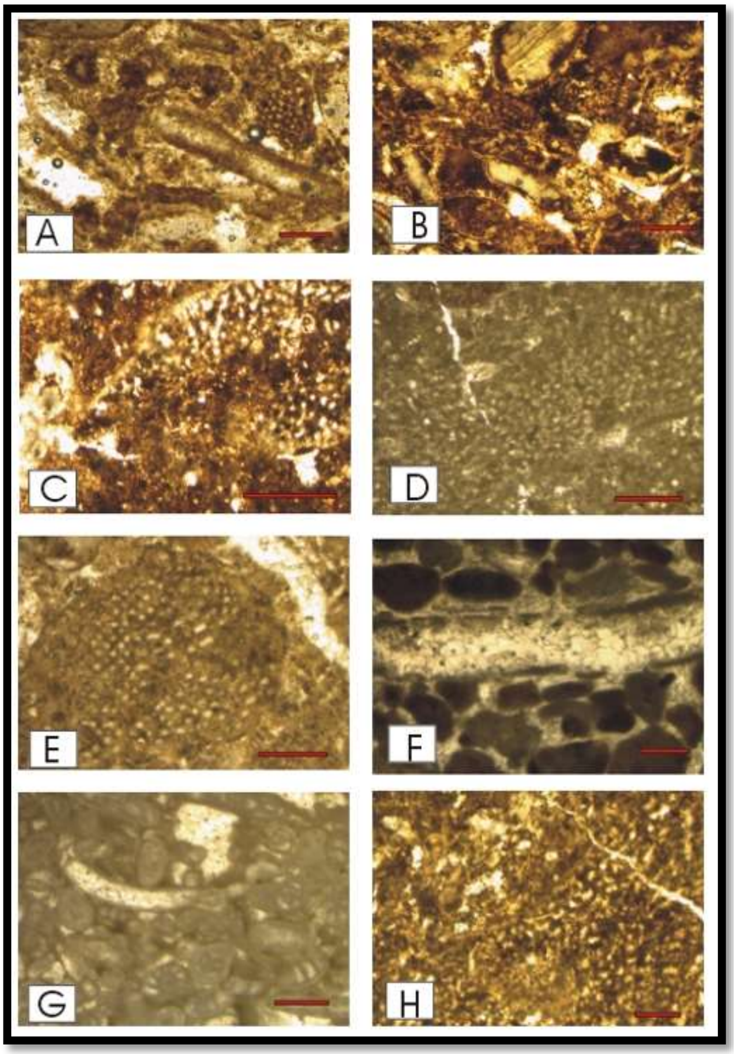

Plate 3

A- Vuggy porosity. Well, Rt-2, depth 2554.18 m. **B-** Interparticle porosity. Well, Rt-4, depth 2615.50 m. **C-** Intraparticle porosity. Well, Rt-17, depth 2566.80 m. **D-** Fracture porosity. Well, Rt-2, depth 2567.20 m. **E-** Drusy cement. Well, Rt-17, depth 2519.35 m. **F-** Blocky cement. Well, Rt-2, depth 2536.10 m. **G-** Granular cement. Well, Rt-4, depth 2571.90 m. **H-** Physical compaction (fracture). Well, Rt-2, depth 2577.25 m.

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Conclusions

1- Non-skeletal grains are less dominant compared to skeletal grains in the Mauddud Formation.

2- Petrographic study divided the formation into three facies association, these are:

-Inner ramp facies association characterized by Foraminiferal wackestone; Orbitolina and bioclast packstone; foraminiferal packstone with Nezzazata, Valvulina and Peloidal and foraminiferal grainstone.

-Mid ramp facies association characterized by echinoderms, Orbitolina and bioclast packstone; peloids, Orbitolina, echinoderms, rudist packstone; bioclast and intraclast with foraminifera packstone and bioclast pack-grainstone with Orbitolina.

- Outer ramp facies association characterized by argillaceous mudstone; Peloidal packstone with bioclast and rare Orbitolina and echinoderms and peloidal grainstone

3- Mauddud Formation was deposited in the Inner-Mid to outer ramp environment.

4- The diagenetic processes observed in the Mauddud Formation include:

- Micritization.
- Dissolution.
- Cementation.
- Compaction.
- Dolomitization.

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