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Diagenetic Processes Overprint and Pore Types of Mauddud Formation, Badra Oil Field, Central Iraq

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Abstract

Diagenetic processes and types of pores that control the reservoir properties are studied for Mauddud Formation in selected wells of Badra oil field, central Iraq. The microscopic study of the thin sections shows the effects of micritization, cementation, neomorphism, dissolution, dolomitization, compaction, and fracturing on Mauddud Formation carbonate microfacies. The decrease of porosity is resulted from cementation, compaction, and neomorphism. Different types of calcite cement occlude pore spaces such as drusy cement, syntaxial rim cement, and granular (blocky) cement. The neomorphism of micritic matrix and skeletal grains reduces porosity as indicated by development of microspar or pseudospar. Evidence of decreasing porosity by compaction includes closer packing of grains, which reduces interparticle porosity. Dissolution process has prominent effect in creating and increasing the effective porosity in different depositional textures of Mauddud Formation. Reservoir properties are increased in grain-supported microfacies, which have vuggy porosity or primary porosity, whose pore size differs depending on the size of the grains. The reservoir properties in the mud-supported microfacies are reduced due to the low occurrence of pores and their lack of connectivity if they exist.

Keywords: Badra oil field, Diagenetic process, Mauddud Formation, Pore types.

تأثير العمليات التحويريه على الخواص المكمنية لتكوين المودود في حقل بدرة النفطي

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الخلاصه

تم دراسة العمليات التحويرية وانواع المسامات التي تيسطرعلى الخواص المكمنية لتكوين المودود في آبارمختارة لحقل بدرة النفطي وسط العراق. الدراسة المجهرية للشرائح الرقيقة اوضحت تأثيرات عمليات المكرتة, السمنتة, أعادة التشكل, الأذابة, الدلمتة, الأحكام, و الكسورعلى السحنات المجهرية لتكوين المودود. النقصان في المسامية هو نتيجة لعمليات السمنتة والأحكام و أعادة التشكل. أنواع مختلفة من الكالسايت سمنت محتلة الفراغات مابين الفراغات مثل السمنت الدروزي, وsyntaxial rim cement, و السمنت الحبيبي. أعادة التشكل للمكرايت ماتركس و الحبيبات الهيكلية يقلل من المسامية كما يتضح من تحوله الى المايكروسبار. الدليل على تناقص المسامية بفعل الأحكام يشمل الرص بين الحبيبات والتي بدورها تقل المسامية مابين الحبيبات. تزداد الخواص المكمنية في السحنات ذات النسيج الحبيبي المتاثرة بالاذابة و التي تمتاز بمسامية

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هزيمية او مسامية اولية و التي يختلف حجم المسامات فيها اعتمادا على حجم الحبيبات. تقل الخواص المكمنية في السحنات ذات الاسناد الطيني بسبب قلة وجود المسامات و عدم اتصالها في حالة وجودها.

Introduction

Mauddud Formation includes important carbonate reservoirs in the Arabian plate region [1]. The formation has regional distribution and thickness all over the Arabian plate [2]. In central Iraq, Mauddud Formation produces oil in Badrd oil field from limestone units [3]. Mauddud Formation in Badra oil field consists of detrital limestone, stylolitic limestone, chalky limestone, limestone with thin layer of stylolitic dolomite and dolomite [4]. Abundant fossils support an Albian age. The formation was originally believed to extend into the Cenomanian because of the frequent occurrence of some species of the *Orbitolina concava* group [5]. The formation was deposited in neritic, sometimes shoal environment [5]. The Mauddud Formation is conformable and gradational in the lower contact with Nahr Umr, Lower Balambo and Lower Sarmod formations. The upper contact is marked by a break and is either nonsequential or unconformable; it is an unconformity in N Central, N and NE part of Iraq [6]. Clarifying the diagenetic overprint on depositional texture and porosity in this type of reservoir has implications for oil field development [7]. The aim of this study is to describe and interpret most important diagenetic processes that either destroy or enhance reservoir properties of Mauddud Formation in Badra oil field.

Geological setting

Badra oil field is located in central of Iraq, near the Iraqi-Iranian borderlines (Figure-1). Tectonically, it lies within two zones, Mesopotamian Zone (Tigirs subzone) and Foothill Zone (Himreen-Makhul subzone). The Mesopotamian zone is the easternmost unit of the Stable Shelf. The zone was probably uplifted during the Hercynian deformation but it subsided from the Late Permian time onwards. The zone contains buried faulted structures below the Quaternary cover, separated by broad synclines. The fold structures mainly trend NW-SE in eastern part and N-S in the southern part of zone, some NE-SW trending structures occur [6]. The Mesopotamian Zone is divided in three subzones: Zubair Subzone, Tigris Subzone and Euphrates Subzone.

The Tigris Subzone is the most extensive and mobile unit of the Mesopotamian Zone. It contains broad synclines and narrow anticline trending NW-SE accompanied by long normal faults. The zone contains two NW-SE trending groups of buried anticlines of low amplitude associated with longitudinal faults and an EW transversal trend.

The Foothill Zone is the part of the Unstable Shelf. The zone has the deepest Precambrian basement in Iraq (-13km) and very thick Miocene-Pliocene molasses sediments (-3000 m thick). The zone comprises two longitudinal units, the Makhul- Hemrin Subzone in the SW and the Butmah-Chemhemal Subzone in the NE.

The Makhul-Hemrin Subzone is the structurally deepest part of the Foothill Zone. The Subzone comprises long prominent NW-SE or E-W trending anticlines with decollement thrust faults. The anticlines of the Subzone are over 100 km long, [6]. The structure of Badra oil field is an asymmetrical anticline trending NW-SE with a steeply dipping SW flank and more gently NE flank [8]. Six wells have been selected in the study that is distributed along the anticline structure of Badra oil field (Figure-2). The main lithology of Mauddud Formation includes limestone units, which can be chalky, stylolitic, detrital, and dolomitic. The depositional setting of Mauddud Formation in the Arabian plate is represented by a ramp fringed by shoals and rudistbiostromes [1]. The reservoir rocks include a spectrum of biolastic and rudist-rich grainstone and packstone.

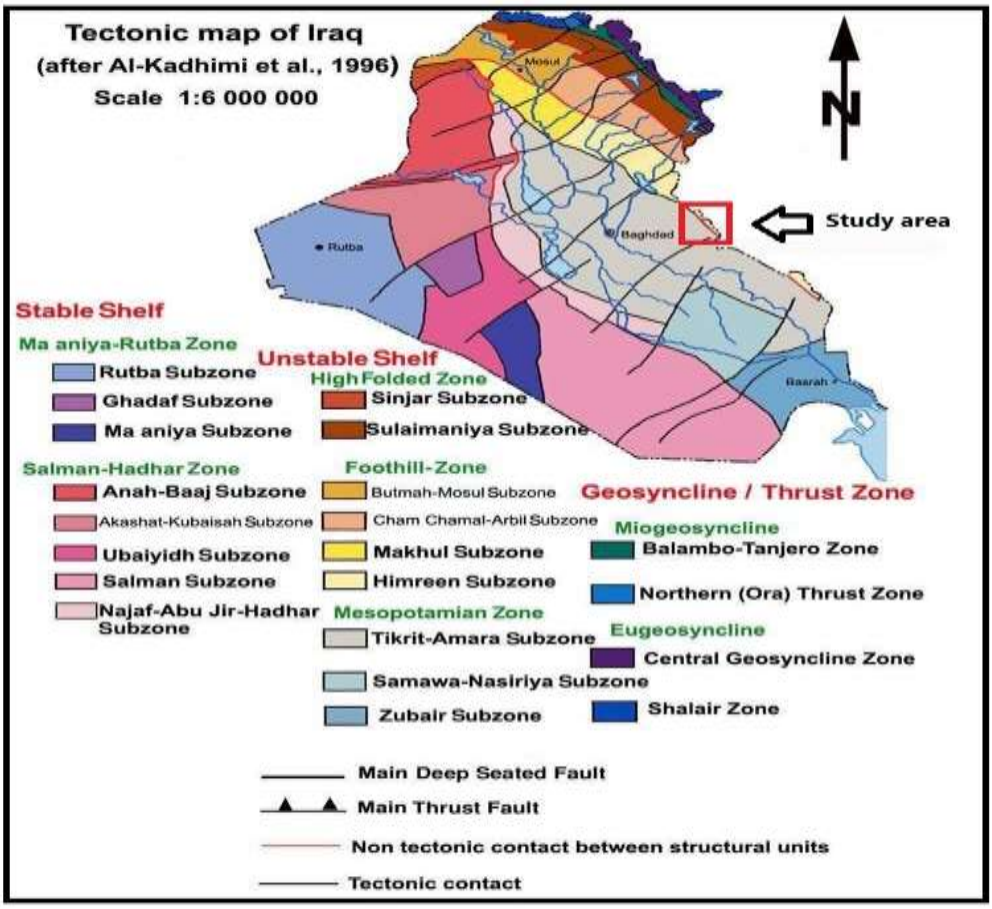


Figure 1-Tectonic map of Iraq after (AL-Kadhimi, 1996) with the location of the study area.

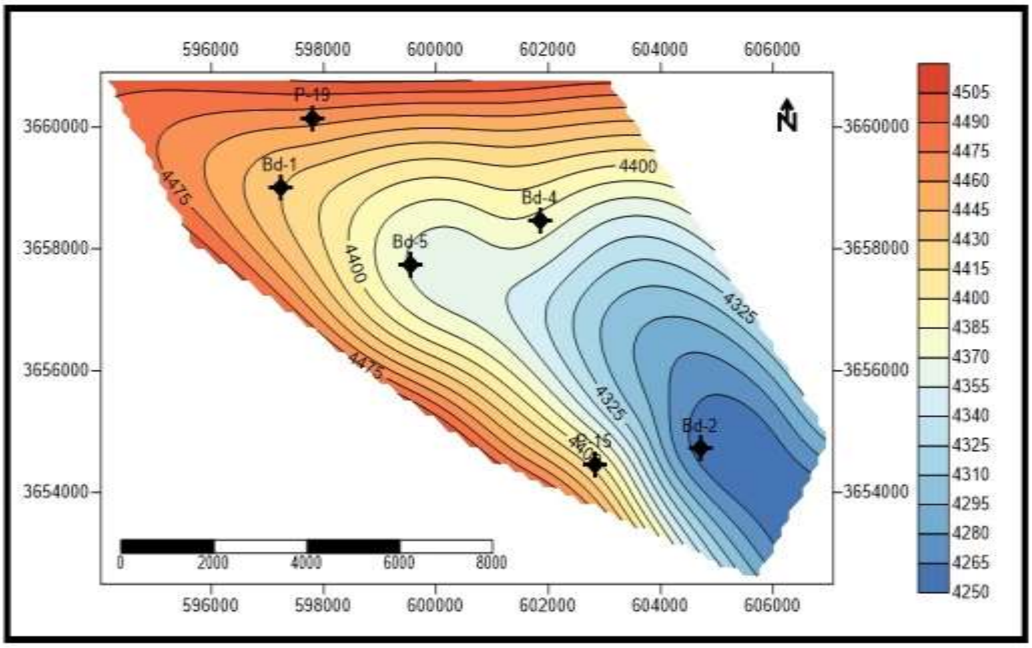


Figure 2-Structural contour map at the top of Mauddud Formation.

Methodology

The basic data of this study are generated by using polarized microscope, based on Dundam (1962) classification of carbonate rocks and Flugel (2004) classification of microfacies, with the aim of examination of thin sections to describe and interpret diagenetic processes and their effect on texture and pore types of Mauddud Formation microfacies. From cores and cutting samples recovered from six wells in Mauddud Formation, 500 standard thin sections were prepared from samples at 1-5 meter intervals.

Diagenesis Processes

Diagenesis refers to the physical, chemical and biological processes, which bring about compaction, cementation, recrystallization and other modifications. Diagenetic processes are important for several reasons. They can considerably modify sediment; both in terms of its composition and texture, and in rare cases, original structures are completely destroyed. Diagenetic events also affect sediment's porosity and permeability properties, which control sediment's potential as a reservoir for oil, gas or water [9].These processes may contribute to creating or occluding porosity. In Mauddud Formation there are several diagenesis processes include Neomorphism, Dissolution, Cementation, Micritazation, Dolomitization and Compaction.

Micritization

Micritization in Mauddud Formation started in early stage of deposition and affected the porosity. Is generally an early marine diagenetic process that encompasses algae, endolithic, bacteria and fungi boring into skeletal fragments [10].Complete micritizationof skeletal grains is common in microfacies of Mauddud Formation (Plate1-A). In addition, micritic envelopes are observed around echinoderm grains and shell fragments (Plate1-B).

Cementation

An important diagenetic process that reduces pores by filling cement between the primary and/or secondary porosity [11]. Calcite cement is the only type found in the Mauddud Formation. It occludes pores partly or totally.

The types of calcite cement have been recognized in Mauddud Formation include:

A-Drusy Cement

Drusy mosaic cement in the formation is characterized by pore filling calcite crystals increasing in size towards the center of interparticle pores or voids [12]. This type of cement is represented by anhedral and subhedral crystals filling moldic porosity of skeletal grains. The drusy cement reflects an early meteoric cementation process [11]. It is common in the microfacies of Mauddud Formation, and reduces remarkably the secondary porosity (Plate1-C).

B-Syntaxial Rim Cement

Syntaxial rim cement occurs in the Mauddud Formation microfacies when crystal develop around fragments of echinoderm plates creating optically continuous crystals. These crystals are composed either calcite or aragonite and it is of early diagenetic origin and indicating early fresh water phreatic cement [12]. This type of cement reduces the interparticle porosity, particularly in grain-supported microfacies (Plate1-D).

C-Granular (Blocky) Cement

This type of cement results from the late stages of the diagentic processes usually after the lithification of sediments, and exposure to pressure in the marine environment. Blocky cement is characterized by its transparency, anhedral or subhedral calcite crystals ranging 10-60 mm in size [13]. The large size of crystals indicates slow crystallization under saturated solution [12]. Such large crystals of cement are found in both mud-and grain-supported microfacies of Mauddud Formation (Plate1-E).

Neomorphism

A term introduced by [14] for aggrading neomorphism in which small crystals are converted to large ones by growth of a few large crystals in and replacing micritic matrix [15].Recrystallization occurs in both fossils and micrite of Mauddud Formation microfacies. Recrystallization of skeletal grains eliminates their original wall structure. Micrite is neomorphosed to microspar or pseudospar (Plate1-F). The degree of preservation shows that significant porosity was not developed in neomorphic skeletal grains nor in micrite.

Dissolution

Dissolution is the most important diagenesic process that improves porosity and permeability in Mauddud Formation. 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. Dissolution forms different types of pores such as: vuggy and moldic [16].These types are found in Mauddud Formation, and have different sizes (Plate1-G, H). Mauddud Formation is affected by major dissolution episodes as indicated by the extensive vugs and molds. Some skeletal grains are neither dissolved nor dolomitized such as echinoderms, and these have magnesium calcite composition [17].

Dolomitization

Dolomitization is a process that includes the conversion of lime mud completely or partly into dolomite by replacement of CaCO3 by magnesium carbonate through the action of Mg bearing water [12]. In Mauddud Formation, dolomitization is much more extensive and pervasive in mud-dominated microfacies where remnants skeletal grains of original microfacies can be preserved (Plate2-A).

Compaction

Compaction leads to reduction of porosity and rock volume resulting by the thickness of overburden sediments. Compaction processes are classified as either mechanical or chemical [18]. Mechanical compaction may begin soon after deposition and leads to a closer packing of grains (Plate2-C), flattening of elongate bioclasts toward the plane of the bedding and collapse of micrite envelopes. Chemical compaction is represented by stylolite that is produced by the combination of compaction and dissolution and is common in all carbonate rock textures [19]. Stylolites are the result of pressure solution, which involved solution around points of contacts between grains in response to pressure (Plate2-B).

Fracturing

Fractures in carbonate rocks are usually important secondary features formed by either compaction or develop in response to regional tectonic regime [13]. In Mauddud Formation, fracturing have a minor influence and it was mostly noticed in rudistid facies. They can be either open (Plate2-D) or filled with calcite cement.

Pore Types

The microfacies of Mauddud Formation show various pore types. They can be primary or secondary.

Following the classification of pore types by [16], different kinds of pores are distinguished in Mauddud Formation microfacies. They include:

1-Interparticle (Intergranular): these include the pores that occur between the grains (Plate3-A). The size of interparticle pores is large between Orbitolina grains (Plate3-B). Smaller pore sizes are observed between Peloids (Plate3-C).

2-Moldic: pores created through the dissolution of fossil fragments or rock fragments or grain. They are associated with interparticle pores (Plate3-D).

3-Cavernous: A pore system characterized by large openings or caverns. Although much cavernous porosity is of solution origin, the term is descriptive and not genetic. This type of pores is common in grain-supported microfacies (Plate3-E).

4-Vuggy: The vuggy pores have an irregular shape result from the dissolution of the original limestone elements such as allochems and intergranular sparry calcite cement [20]. The pores cut both matrix and grains, and they are common in mud-and grain-supported microfacies (Plate3-F).

5-Channel: A system of secondary pores in which the openings are markedly elongate and have developed independently of texture or fabric (Plate3-G).

6-Fracture: fractures are formed by tectonic stresses within the rock. Fracture pores can be open or filled with calcite cement (Plate3-H).

Conclusions

The study shows that the effect of diagenetic processes on the composition of the Mauddud Formation has various effects on the reservoir properties of the formation. The effect of the dissolution process is evident on the grain-supported microfacies, which have high porosity, leading to increased porosity, thus increasing reservoir quality. On the other hand, the reservoir properties of Mauddud Formation decrease by the effect of several diagenetic processes, the most prominent of which are cementation, compaction, and neomorphism. These processes have a variable effect on the microfacies. The negative effect of the cementation on the grain-supported microfacies is evident in reducing the porosity. Compaction and neomorphism have the same effect on the mud-supported microfacies. Their porosity is low, and therefore has poor reservoir quality.

Plate -1 Diagenesis

A-Micritization of skeletal grains with calcite cementation of pores between grains. P-15, 4540 m.

B-Micritic envelope surrounding a shell fragment. BD-5, 4585.66m.
C-Drusy mosaic cement between Orbitolina and shell fragments.BD-5, 4591.13m.
D-Syntaxial rim cement surrounding echinoderm grain. BD-5, 4585.66m.
E-Blocky calcite cement fills large moldic pore. BD-5, 4610m.
F-Neomorphism of matrix with scattered micritized and skeletal grains. BD-5, 4711.2m.
G-Large dissolution vugs of Peloidal-rudistid packstone microfacies. BD-4, 4695m.
H-Dissolution vugs associated with interparticle pores in Peloidal- rudisted grainstone microfacies. P-19, 4815.5m.

Plate-1 diagenesis

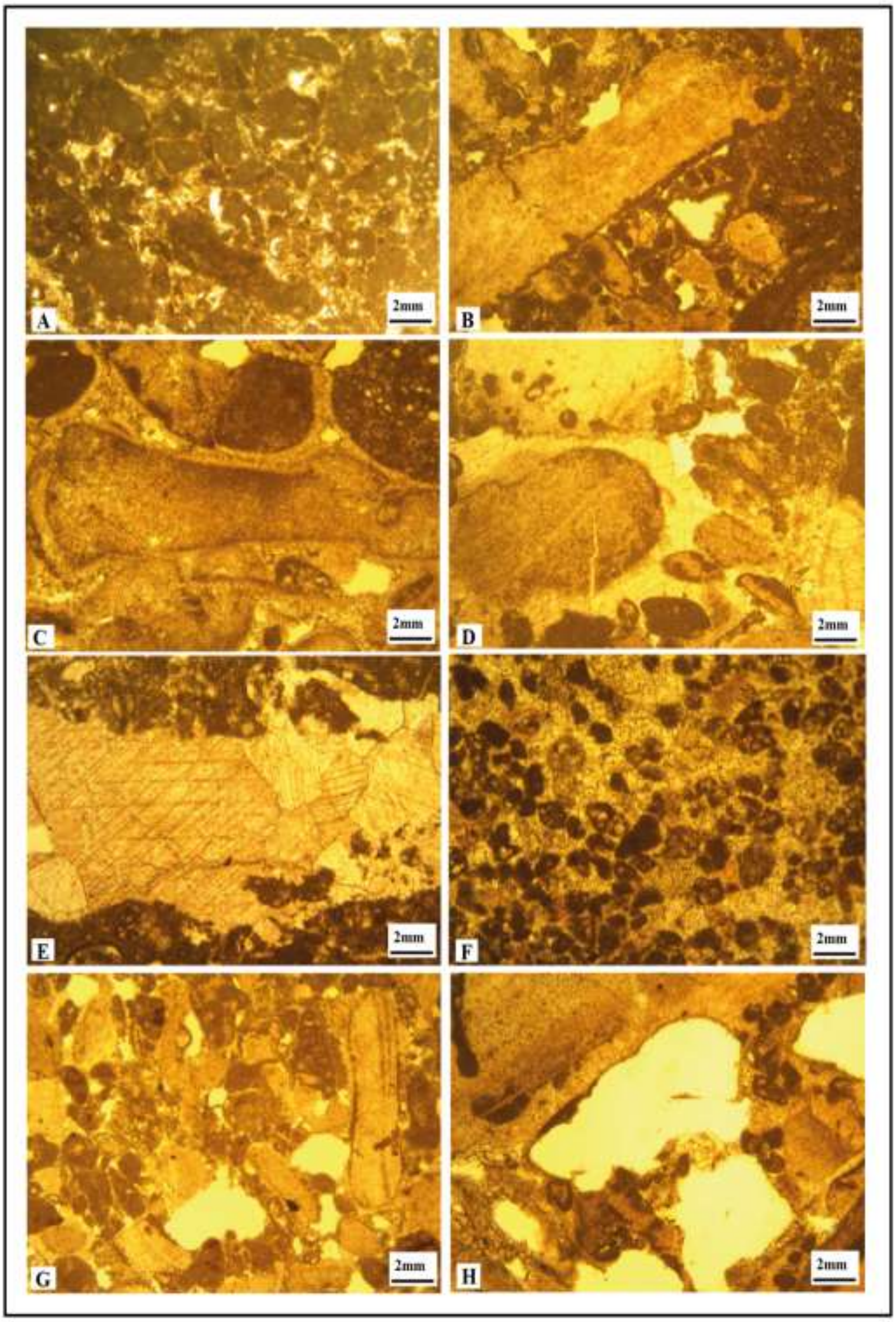


Plate-2 diagenesis
A-Scattered dolomitic rhombs in lime mudstone microfacies.BD-1, 4540m.
B-Compaction (Packing) of Oribitolina grains with calcite cementation of interparticle pores. BD-5, 4714.4m.
C-Stylolite in Echinoderm packstonemicrofacies.P-19,4690m.
D-Fracture cutting rudist fragment.P-15,4540m.
Plate-2 diagenesis

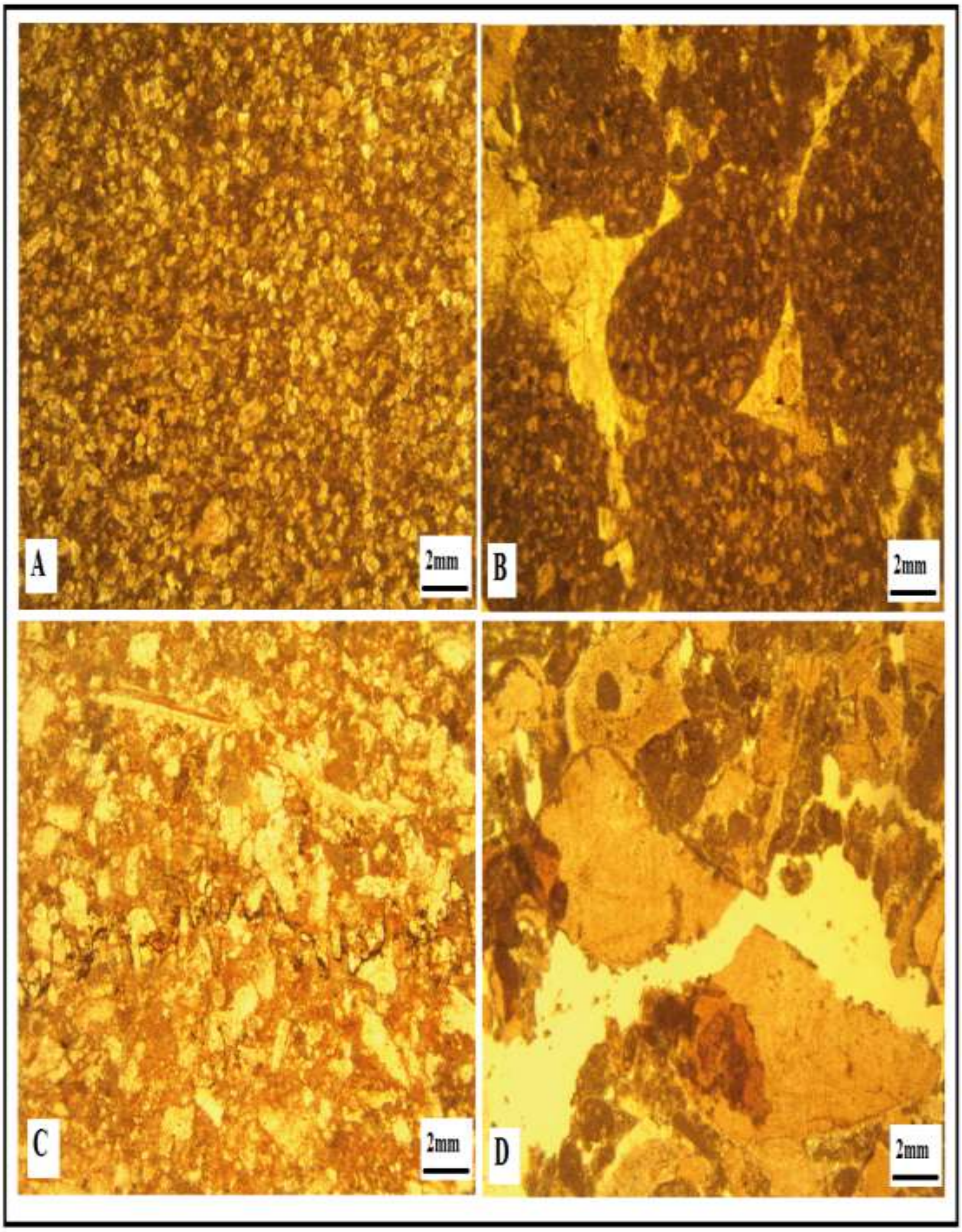
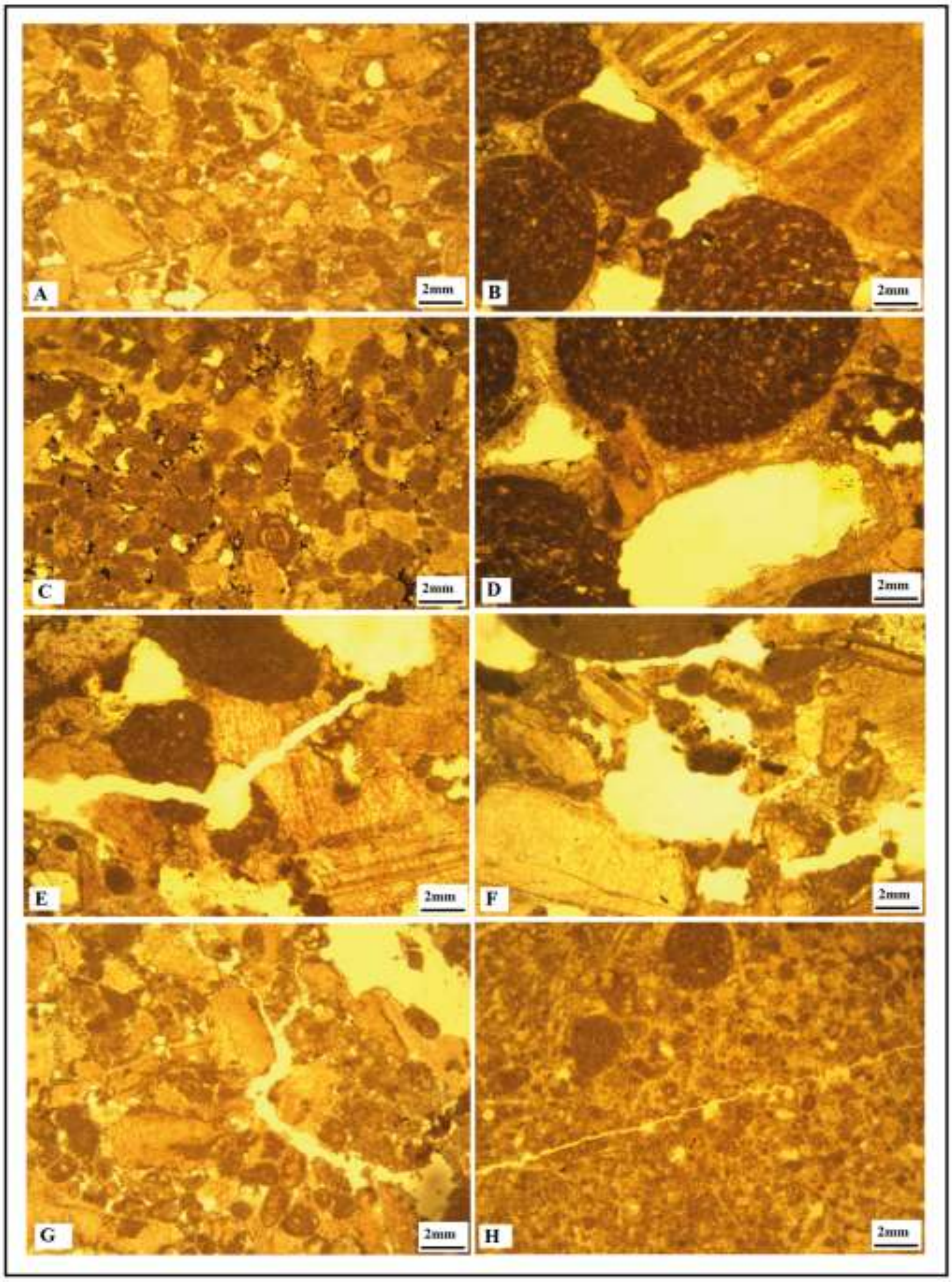


Plate-3 Pore types
A-Interparticle pores in peloidal-rudistid grainstone. P-15, 4633.5m.
B-Interparticle pores in Rudistid-orbitolina grainstone. BD-4, 4730.5m.
C-Interparticle pores filled with oil. Bd-5, 4715.83m.
D-Moldic and interparticle pores.BD-5, 4584.5m.
E-Cavernous pore in Orbitolina – rudistid grainstone.BD-2, 4500.5m.
F-Vuggy pores result in Peloidal-rudistid packstone. P-19, 4750m.
G-Channel pore in Peloidal- rudistid packstone- grainstone.BD-1, 4650m.
H-Fracture pore in Peloidal- foraminiferal grainstone. BD-5, 4715.85m.
Plate-3 Pore types



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