Süleyman Demirel Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
Cilt 22, Sayı 3, 1283-1295, 2018

Süleyman Demirel University
Journal of Natural and Applied Sciences
Volume 22, Issue 3, 1283-1295, 2018

DOI: 10.19113/sdufenbed.503923

Petrographical and Petrophysical Features of the Jeribe Formation at the Khabaz Oil Field, Kirkuk, Northern Iraq

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(Alınış / Received: 17.03.2018, Kabul / Accepted: 07.11.2018, Online Yayınlanma / Published Online: 27.12.2018)

Keywords
Iraq,
Jeribe Formation,
Khabaz field,
Kirkuk area,
Porosity,
Diagenesis

Abstract: The present study deals with the Jeribe Formation (Middle Miocene) in well Khabaz-17 (Long. 44° 11' 27" E ; Lat. 35° 25' 16" N) belonging to Khabaz oil field in Kirkuk area, northern Iraq. Generally, the lithology of Jeribe Formation is homogeneous and it consists of limestone, dolomite, dolomitic limestone, gypsum, and nodules of chert with a thickness of about 36 m at depth 645-681 m. Petrographically, 50 thin sections have been prepared and studied under polarized microscope. Based on this, they appeared to consists mainly of genus benthonic foraminifera (*Borelis melo curdica, Miliolids, Peneroplis, Nummulites and Rotalids*) where they characterized by the good keeping, large volume and the thickness of the wall. On the other hand, less common fauna included Gastropods, Pelecypods, Echinodermata fragments, Algae, Ostracods and many of bioclasts, as well as non-skeletal grains intraclasts and pisoids, while the ground mass mainly compose of a micrite and micro-sparite. Several diagentic processes affected the Jeribe formation which include mainly of dolomitization, cementation, micritization, dissolution, compaction, fracturing and other types of diagenetic such as neomorphism and bioturbation. Through the petrographic study the types of porosity were identified. While, the porosity ratios was determined from the density and the neutron logs. According to the results of these analyses, the porosity of Jeribe formation changes from 11.4% and 25.6%, with an average rate of 17.3%. These values are described as good porosity, and had probably been enhanced by some diagenetic processes by dolomitization and dissolution followed by secondary effects from tectonics activities.

Jeribe Formasyonunun Petrografik ve Petrofizik Özellikleri, Khabaz Petrol Sahası, Kerkük, Kuzey Irak

Anahtar Kelimeler
Irak,
Jeribe Formasyonu,
Khabaz sahası,
Kirkuk bölgesi,
Gözeneklilik,
Diyajenez

Özet: Bu çalışmada, Kuzey Irak, Kerkük bölgesinde yer alan, Khabaz petrol sahasında açılan Khabaz-17 kuyusunda (boylam 44° 11' 27" D, enlem 35° 25' 16" K), Orta Miyosen yaşlı Jeribe Formasyonunun petrografik ve petrofiziksel özellikleri incelenmiştir. Jeribe Formasyonunun litolojisi genellikle homojen olup, kireçtaşı, dolomit, dolomitik kireçtaşı, jips ve çört nödüllerinden oluşmaktadır. Jeribe Formasyonu Khabaz-17 kuyusunda 645-681 m derinlikte yer almakta olup, yaklaşık 36 m kalınlığı sahiptir. Bu formasyona ait karotlardan 50 ince kesit hazırlanmış olup, bu örnekler polarize mikroskop altında araştırılmıştır. İncelenen örnekler içinde saptanan genel fauna topluluğunu bentik foraminiferler oluşturur. En yaygın görülen fauna cinsleri, *Borelis melo curdica, Miliolids, Peneroplis, Nummulites ve Rotalidlerden* oluşur. Bu fauna türleri iyi korunmuş olup, büyük hacim ve duvar kalınlığına sahiptir. Bunların yanı sıra, daha düşük oranda olmak üzere, gastropod, pelecypod, Echinodermata, algl ve Ostracod kalıntıları olağan olarak bulunur. Diğer taraftan, bioklastlar ve iskeletsi yapıya sahip olmayan tanelerin yanı sıra, intraklast ve pisolidler, incelenen karbonat kayalar içinde bulunan diğer önemli allokemleri oluşturur. Allokemler arasını dolduran matriks daha çok mikrit ve spari-mikritten oluşmaktadır. Jeribe formasyonuna ait karbonat kayaları etkileyen belli başlı diyajenetik dönüşümleri, dolomitleşme, çimentolanma, mikritizasyon, çözünme, sıkışma, kırılma ve biyoturbasyon gibi

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neomorfik olaylar kapsamında değerlendirmek mümkündür. Çalışma alanında Jeribe Formasyonuna ait karbonat kayaların petrografik özelliklerine dayanılarak gözeneklilik türleri belirlenmiştir. Ancak gözeneklilik oranları, sondaj kuyusu içinde yapılan nötron ve yoğunluk logları vasıtasıyla saptanmıştır. Bu analiz sonuçlarına göre, Jeribe formasyonun gözenekliliği, %11.4 ile %25.6 arasında değişmekte olup, tüm formasyon için belirlenen ortalama gözeneklilik, %17.3 olarak bulunmuştur. Bu değerler, Jeribe Formasyonuna ait karbonat kayaların iyi sayılabilecek bir gözeneklilik oranına sahip olduğunu göstermesi bakımından önemlidir. Diğer taraftan, iyi sayılabilecek bu gözeneklilik yapısının daha çok dolomitleşme ve çözünme gibi diyajenetik proseslerin yanı sıra, tektonik kırılma faaliyetleri sonucunda geliştiğini belirtmek mümkündür.

1. Introduction

Carbonate rocks (limestone and dolomite) form approximately 50% of the world's oil and gas reserves [1]. The Lower-Middle Miocene Jeribe Formation in Kirkuk area is one of the most important productive reservoirs in northern Iraq, which giant oil and gas deposits in over 30 geological structures [2]. The Jeribe Formation was first described by Damensin, 1936 in [3]. Its type section lies near Jaddala village-Jabal sinjar, which belongs to low folded zone northeastern Iraq. This formation in the type locality comprises of 70 m of carbonate rocks. It is suggested that the age of Jeribe Formation is Middle Miocene [3 and 4]. The study area Khabaz field (Well-17) located between (Long. 44° 11' 27" E ; Lat. 35° 25' 16" N) (Figure 1). This study has several objectives. The main objective is to determine the petrographic constituents based on the study of carbonate rocks. The study also tries to define types of processes of diagenesis. Finally, the study tries to define types and proportion of porosity.

2. Material and Method

This study includes several stages starting with choosing the available well, which are Khabaz-17 with thickness 36 m at depth 645-681 m, selected from Khabaz oil field northern Iraq. The description of the lithology for Jeribe Formation and the sampling of the necessary intervals and 50 thin sections were prepared and examined by a polarizing microscope, with petrographical and petrophysical features (types and proportion of porosity) were studied as well as micro photos of thin section taken by the same microscope. The selected samples that represent the reservoir unit were based on oil shows detected in the logs. These thin sections were stained with Alizarin Red Solution (ARS) following [5]. procedure for identifying calcite and dolomite. Other used data were geologic reports and well logs for well Khabaz-17.

3. Geological Setting

The Khabaz oil field is represents a small subsurface asymmetrical anticline, and its northeast limb dipper than the southwest limb. The Khabaz structure is located between Jambur and Bai Hassan oil fields (Figure 1). This oil field located 23 km to the west to northwest of Kirkuk city northeast Iraq (Figure 1). As showing (Figure 2), the study area is located within the low folded zone in northern Iraq [6].

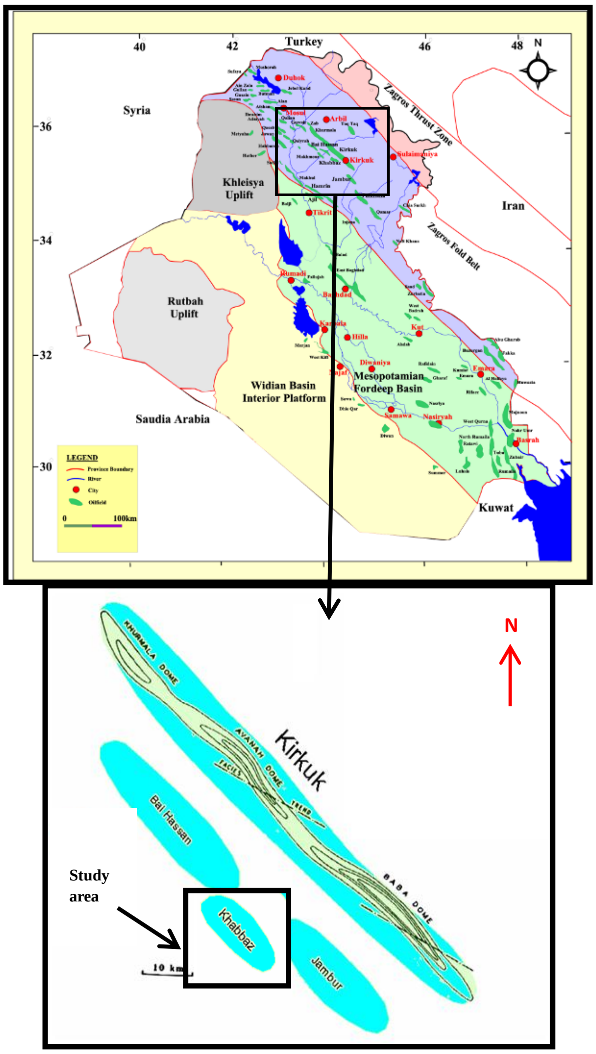

Figure 1. Major petroleum fields of Iraq and showing location of the study area, modified from [7].

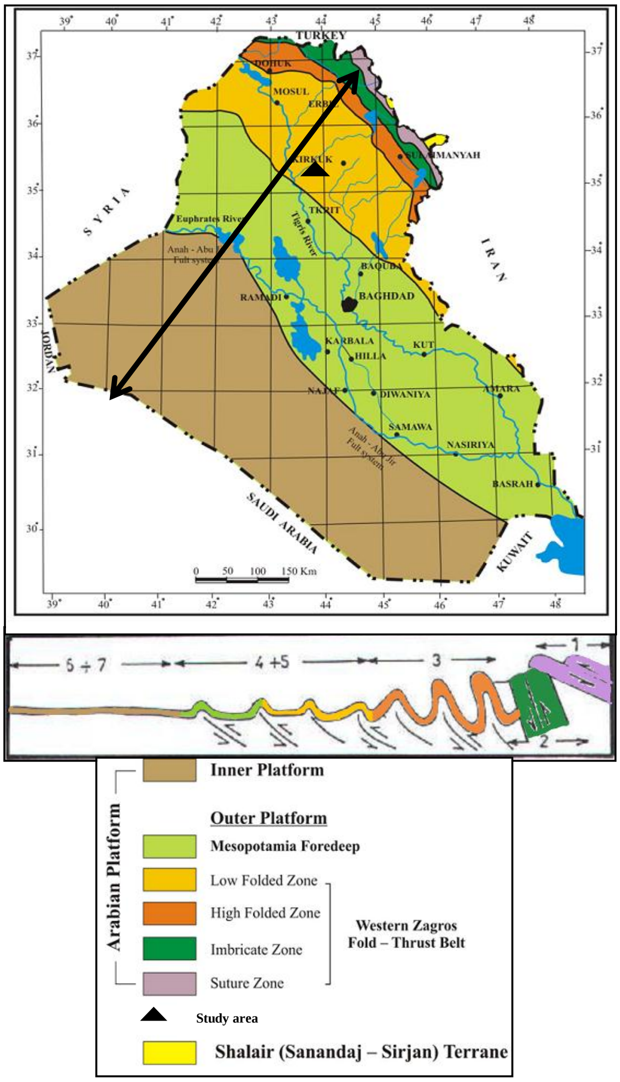

Figure 2. Simplified tectonic map of Iraq and showing location of the study area, modified from [6].

4. Stratigraphy

The present study the Jeribe Formation occurred in the Middle Miocene cycle [2]. The Middle Miocene cycle is an important cycle in the Tertiary Period rock units of northern Iraq, and includes reservoir basin which filled with sediments. During this cycle, most of the shelf transformed to basin or shallow marine where the deposits accumulated [3]. The collision between the Arabian plate with the Anatolian and Iranian plates led to a complete closure in Tethys sea and thus formed many phases from progression and regression [8]. These processes led to the deposition of Jeribe Formation [2] and [9].

The Jeribe Formation is not recognized in southern Iraq [3]. But it is widespread at the surface and in the northern oil fields of Iraq. Locally, from age Jeribe Formation is equivalent to the Gar Formation (southern Iraq) and the Kovand limestone formation (northern Iraq), from the facies the Jeribe formation is equivalent to Firat Formation (northern Iraq) [2] and [3]. Regionally, Jeribe Formation is equivalent to the Kalhur limestone formation and part of the upper Asmari formations in Iran through the age and facies, while in Turkey the formation is equivalent to Firat Formation (through age and facies) and Lice Formation (through age) [9]. Finally, the Jeribe Formation is equivalent (through age) to Gar Formation in Kuwait and Dam Formation in Saudi Arabia [10].

Generally the lithology of Jeribe Formation is homogenous, and consists of limestone, dolomite, dolomitic limestone, gypsum and nodules of chert. This formation, in the upper part of Jeribe formation here is described as a conformable zone with the Fatha Formation, but in the lower part of Jeribe Formation here is described as an unconformable zone with the Anah Formation (Figure 3) [2] and [9].

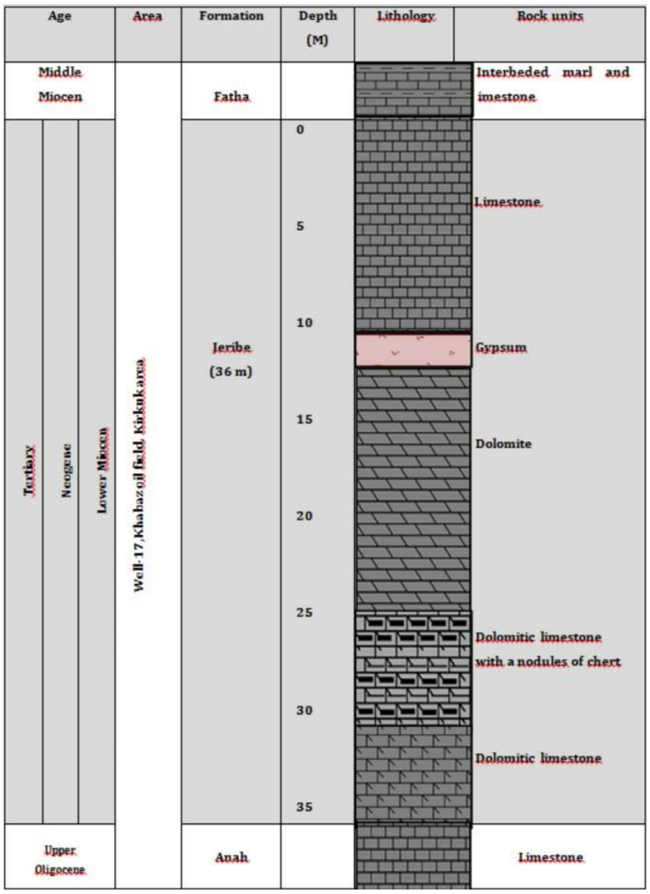

Figure 3: Lithostratigraphic columnar section of the Jeribe Formation in well-17, Khabaz oil field, Kirkuk area, northern Iraq.

6. Petrography

The following petrographic constituents according to [11] and [12] are observed within Jeribe formation.

6.1. Grains

Grain constituents in the Jeribe Formation consist mainly of a- skeletal grains and b- non-skeletal grains.

a. Skeletal grains

Skeletal grains were noticed to be common in the Jeribe Formation of this study area. These grains, appear completed as fossils or bioclasts in these formation that include: Benthonic foraminifera dominate within the rock units in this formation. Most of the foraminifera were subjected to leaching and recrystallization that made them hard to be identified, which are included in, *Milliolids* (Plate 1-A), *Peneroplis* (Plate 1-B), *Rotalids* (Plate 1-C), *Nummulites* (Plate 1-D) and *Borelis melo curdica* (Plate 1-E). All of fossil constituents indicate shallow marine and lagooner environment [13]. The study also identify other types of fossils prevalent in these sediments, Echinodermata fragments (Plate 1-F), Pelecypods (Plate 1-G) and Gastropods (Plate 1-H). The occurrence of Molluscs is mostly associated with shallow environments, Ostracods (Plate 2-A), Algae (Plate 2-B) and bioclasts (Plate 2-C). usually refers to the deposition in the shallow water (lagoon) environments [14].

b. Non-skeletal Grains

Non-skeletal grains are non-organic particles of carbonates with different sizes and shapes. They are very few in Jeribe Formation and include coated grains such as pisoids (Plate 2-D) and non-coated grains such as intraclast (Plate 2-E).

6.2. Groundmass (Matrix)

The microscopic study showed that the majority of the groundmass in the deposition of the Jeribe Formation are composed of micrite which crystals are between 1-4 micron (Plate 2-F), and only a few of them are made up of a micro-sparite which its crystals are between 5-10 micron (Plate 2-G).

7. Processes of Diagenesis

According to [14], The processes that affected Jeribe Formation according to their spread were classified as follows:

7.1. Dolomitization

According to the classification of [15], the textures of dolomite were recognized in the Jeribe Formation as follows:

a. Sieve mosaic texture saturated with bitumen: This type of texture is the most common in the present study (Plate 2-H). It is composed of coarse euhedral to subhedral crystals ranging between (0.25-0.3mm). The sieve mosaic texture refers to the intercrystalline porosity produced by dolomitization.

b. Contact rhomb texture saturated with bitumen: This type of texture consists of euhedral to subhedral crystals and they are connected with each other (Plate 3-A).

c. Floating rhomb texture: This texture is composed of crystal form with usually consist of euhedral to anhedral scattered within matrix, and there is no connection with each other (Plate 3-B).

d. Fogged mosaic texture saturated with bitumen: This texture is composed of dolomite crystals saturated with oil. This fabric is represented by dolomite crystals with cloudy center and clear rims (Plate 3-C). The crystal form is usually composed of euhedral to anhedral. This texture is worth attention due to being resulted from the packstone facies which reflect the increase in porosity caused by the growth of the rim of dolomite crystals by action of replacement and dissolution associated with increased porosity.

e. Suture mosaic texture saturated with bitumen: This texture is characterized by anhedral crystals, leaving behind little intercrystalline porosity (Plate 3-D).

f. Aphanotopic fabric: This texture is characterized by the small size which is less than 0.002 mm (Plate 3-E). As well as the observed crystals of dolomite formed within the skeletal grains as a result of the selective dolomitization (Plate 3-F).

7.1.1. Discussion of the Dolomite Mechanism

The different types of dolomite textures, within the rock units of Jeribe Formation were very useful for indicating porosity and exploring characteristic of reservoir rocks within the different recognized textures. The dolomitization process complete and selective affected most of the Jeribe Formation.

Several models have been developed for the interpretation of the dolomite origin. The results of the present study indicate a possibility for the dolomitization might have taken place by the seepage reflux-mixing zone model. High temperature in coastal lakes leads to increased salts in water, and the evaporite beds (Gypsum), commonly associated with dolomite in Jeribe formation, which gave evidence for supratidal-sabkha conditions that is significant for the seepage refluxion model. The mixing zone model is produced from mixed water, through mixing between marine and air water [1].

7.2. Cementation

According to [12], the important cement types in the present study included: Granular cement, which is composed of nearly equidimensional, anhedral to subhedral calcite crystals (Plate 3-G). Blocky cement, refers to medium-coarse grained crystals in which this cement crystals have almost the same diameter in all directions (Plate 3-H), and the drusy cement is composed of anhedral to subhedral calcite crystals and usually the crystal size increases toward the center of the void (Plate 4-A) [14].

7.3. Micritization

Many of the carbonate skeletal grains, which deposited in recent or old geologic ages, have micritic envelope around them [16]. In the present study, the micritization was abundant. As shown on (Plate 4-B), the outer zone of the some carbonate skeletal grains locally it was micritization.

7.4. Dissolution or Leaching

Dissolution is considered as responsible factor for the enhancement of the physical properties of the reservoir (increasing in porosity and permeability) in carbonate rocks [1] and [12]. The jeribe formation was very affected by the dissolution (Plate 4-C). More detail data will be given in below porosity section.

7.5. Compaction

According to [1] and [17], the compaction process can be classified into two types. These are chemical compaction and mechanical compaction. In the present study, the petrographic observation indicate that the effects of mechanical compaction in the Jeribe Formation was obvious through the following features packing of grains, breakage of grains, deformation of skeletal grains and veins penetrated of skeletal grains (Plate 4-D). As well as the chemical compaction, many sediments are subjected by pressure solution and the formation of stylolites (Plate 4-E) [12].

7.6. Fracturing

Fracturing is an important factor that affects reservoir quality, and it may create additional links in the permeability and porosity allowing increasing movement and extract of fluid in rocks [16]. The Jeribe Formation carbonate rocks were frequently observed to have fractures (Plate 4-F), in addition to other types of diagenesis processes, such as neomorphism (Plate 4-G) and bioturbation (Plate 4-H).

8. Reservoir Characterization

Porosity and permeability are most important petrophysical properties, thus widely used for the reservoir characterization. These properties are frequently enhanced by dolomitization, solution and fracturing. However they are destroyed by cementation that causes reduction in porosity and permeability [18]. In the study, thin sections and well logs are also used well to evaluate the reservoir properties for the Jeribe Formation.

8.1. Porosity from Thin Sections

According to the time of pore formation there are two main types of porosity which are: 1-Primary porosity (sedimentary porosity), and 2-Secondary porosity (diagenetic porosity). Estimating porosity typically come from various sources such as well logs, samples (cores and cuttings) and thin sections. The current study, deals with the porosity types, proportions and distribution within a carbonate reservoir (Jeribe Formation) that represent the dominant factor in the amount of oil production.

The petrographic study of Jeribe Formation had shown that both types of porosity (primary and secondary) are available. According to [19], the most common types of porosity recognized within Jeribe Formation were classified as follows:

A. Moldic porosity: This type is formed by a selective removal of primary constituents from sedimentary rocks and they are often partially or completely filled by calcite cement [20]. This type of porosity is observed in (Plate 5-A).

B. Interparticle porosity: Interparticle porosity is formed among individual grains (Plate 5-B). This porosity is considered the most important type due to the creation of the connection which enables the rock to occupy oil with gas and allow their movement [14].

C. Intraparticle porosity: This type of porosity corresponds to the space or voids within the grains especially skeletal grains of *the miliolids and rotalids* (Plate 5-C).

D. Vuggy porosity: Vugs are pores shaped as equant or elongated, and it is found abundant within the Jeribe Formation (Plate 5-D).

E. Fracture porosity: This porosity is resulted by fracturing which may originate from a collapse related to a compaction and tectonic deformation, This porosity is usually in a different shape and size (Plate 5-E), and can be a responsible factor for the reservoir existence [14].

8.2. Porosity from Well Logs

In the current study, the porosity values were calculated from the well logs, Density log (RHOB) and Neutron Compensated log (NPHI). From these logs, values of porosity (ØN) and bulk density (ρb) were calculated using the formula of [21]. shown below:

$$ØD = (\rho ma - \rho b) / (\rho ma - \rho f) \quad (1)$$

ØD, is calculated porosity. ρma, is matrix density. ρf, is fluid density. ρb, is bulk density. Neutron and Density logs are utilized for identifying lithologies depending on final reports of wells, in addition to total porosity (ØN.D) values which are calculated through the equation below:

$$ØN.D = (ØN + ØD)/2 \quad (2)$$

In study, the classification of porosity values identified according to the [22]. Total porosity values was determined from density and neutron logs as shown in (Table 1). According to the results of these analyses, the porosity of Jeribe formation changes from 11.4% in depth of 649 m and 25.6% in depth of 668.5 m, with an average rate of 17.3%. These values are described as good porosity, and had probably been enhanced by some diagenetic processes, particularly dolomitization and dissolution, followed by secondary effects from tectonics activities.

Tablo 1. Calculate the ØN, ØD and ØN.D values and their description from the Jeribe Formation.

Well name	Formation	Age	Depth (M)	ØD	ØN	Φ N.D	Description	Depth (M)	ØD	ØN	Φ N.D	Description	Depth (M)	ØD	ØN	Φ N.D	Description
Khabaz-17	Jeribe Formation	Middle Miocene	645	20.22	7.64	13.93	Fair	657	14.31	18.04	16.17	Good	669	26.72	8.02	17.37	Good
			645.5	15.75	15.2	15.5	Good	657.5	19.03	24.4	21.7	V. good	669.5	25.90	8.02	16.96	Good
			646	19.03	19.8	19.4	Good	658	13.56	22.59	18.08	Good	670	24.69	8.77	16.73	Good
			646.5	12.11	14.81	13.46	Fair	658.5	13.18	23.35	18.27	Good	671	26.31	8.02	17.16	Good
			647	14.73	16.90	15.82	Good	659	20.04	16.52	18.28	Good	671.5	25.90	8.02	16.96	Good
			647.5	14.95	13.30	14.13	Fair	659.5	18.96	24.0	21.5	V. good	672	25.90	8.02	16.96	Good
			648	30.54	1.8	16.2	Good	660	18.41	15.76	17.08	Good	672.5	23.06	9.15	16.11	Good
			648.5	13.69	17.1	15.4	Good	660.5	13.10	18.42	15.76	Good	673	29.15	7.64	18.40	Good
			649	20.27	2.6	11.4	Fair	661	12.93	27.0	20.0	V. good	673.5	26.72	7.26	16.99	Good
			649.5	11.80	23.2	17.5	Good	661.5	17.18	15.38	16.28	Good	674	20.04	13.86	16.95	Good
			650	18.43	7.41	12.92	Fair	662	20.04	13.86	16.95	Good	674.5	18.00	17.28	17.64	Good
			650.5	18.20	19.8	19.0	Good	662.5	13.68	36.2	24.9	V. good	675	27.12	7.26	17.19	Good
			651	15.76	9.53	12.64	Fair	663	18.41	16.52	17.46	Good	675.5	12.55	33.5	23.0	V. good
			651.5	11.04	27.0	19.0	Good	663.5	18.00	17.66	17.83	Good	676	5.34	25.63	15.49	Good
			652	13.68	25.5	19.6	Good	664	20.27	21.3	20.8	V. good	676.5	21.27	11.96	16.61	Good
			652.5	18.60	10.28	14.44	Fair	664.5	11.47	19.94	15.70	Good	677	21.85	8.77	15.31	Good
			653	16.98	10.28	13.63	Fair	665	21.27	14.24	17.75	Good	678	18.19	13.68	15.94	Good
			653.5	8.78	26.3	17.5	Good	665.5	31.36	19.8	25.6	V. good	678.5	13.10	18.42	15.76	Good
			654	17.79	8.77	13.28	Fair	666	20.86	13.48	17.17	Good	679	19.01	12.92	15.97	Good
			654.5	15.76	10.28	13.02	Fair	666.5	21.27	10.82	16.04	Good	679.5	19.63	12.34	15.99	Good
			655	18.58	19.8	19.2	Good	667	12.06	19.56	15.81	Good	680	8.97	23.87	16.42	Good
			655.5	21.60	16.3	19.0	Good	667.5	24.38	19.4	21.9	V. good	680.5	9.71	23.87	16.79	Good
			656	13.18	22.97	18.08	Good	668	21.44	11.79	16.62	Good	681	14.55	18.58	16.57	Good
			656.5	25.54	16.52	21.03	V. good	668.5	11.04	39.3	25.2	V. good					

4. Discussion and Conclusion

The present study revealed the following results:
1. Lithologically, the carbonate rocks of the Jeribe Formation are composed mainly of limestone, dolomite, dolomitic limestone, gypsum, and nodules of chert. The Jeribe Formation was deposited during the Middle Miocene age.
2. The petrographic study of the Jeribe Formation constituents has shown a diversity of foraminifera, *Miliolids, Peneroplis, Nummulites, Rotalids and Borelis melo curdica* the well-known index of Jeribe formation. Other less common fauna included Gastropods, Pelecypods, Echinodermata fragments, Algae, Ostracods and many of bioclasts as well as non-skeletal grains (intraclasts and pisoids). while the matrix of the Jeribe Formation was composed of micrite and micro-sparite.
3. Many of diagenetic processes had an influence on the Jeribe Formation, in order of significance which includes, dolomitization (floating rhomb, sieve mosaic, contact rhomb, fogged mosaic, sutured mosaic and aphanotopic texture), cementation (granular, blocky, and drusy cement), compaction (chemical and mechanical compaction), micritization, dissolution and fracturing. These processes were effective in late and early diagenetic stage.
4. According to microscopic study, the porosity included the following types: fracture, intercrystalline, vuggy and interparticle. While, the total porosity values was determined from density and neutron logs. According to the results of these analyses, the porosity of Jeribe formation changes from 11.4% and 25.6%, with an average rate of 17.3%. These values are described as good porosity, and had probably been enhanced by some diagenetic processes, particularly dolomitization and dissolution, followed by secondary effects from tectonics activities.

Acknowledgment

Our deepest thanks to the Northern Oil Company in Iraq for their generous support to this work. My deepest gratitude goes to Prof. Dr. Fuzuli YAĞMURLU for her sincere and patient guidance throughout the research and writing of the article.

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Appendices

PLATE 1

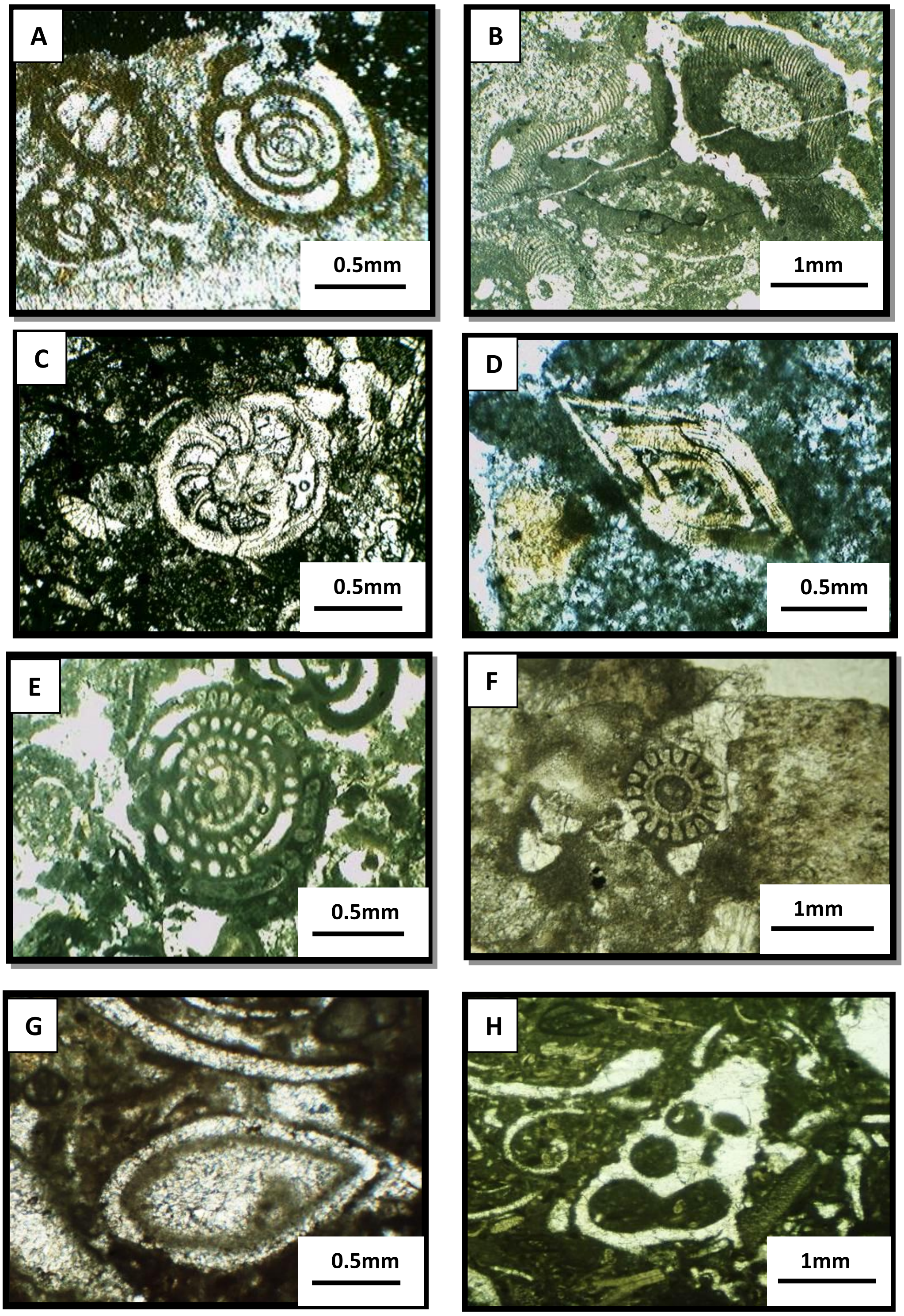

PLATE 1. Thin section photomicrographs: A) *Miliolids* ; B) *Peneroplis* ; C) *Rotalids*; D) *Nummulites* ; E) *Borelis melo var curdica*; F) Echinodermata; G) Pelecypod; H) Gastropoda.

PLATE 2

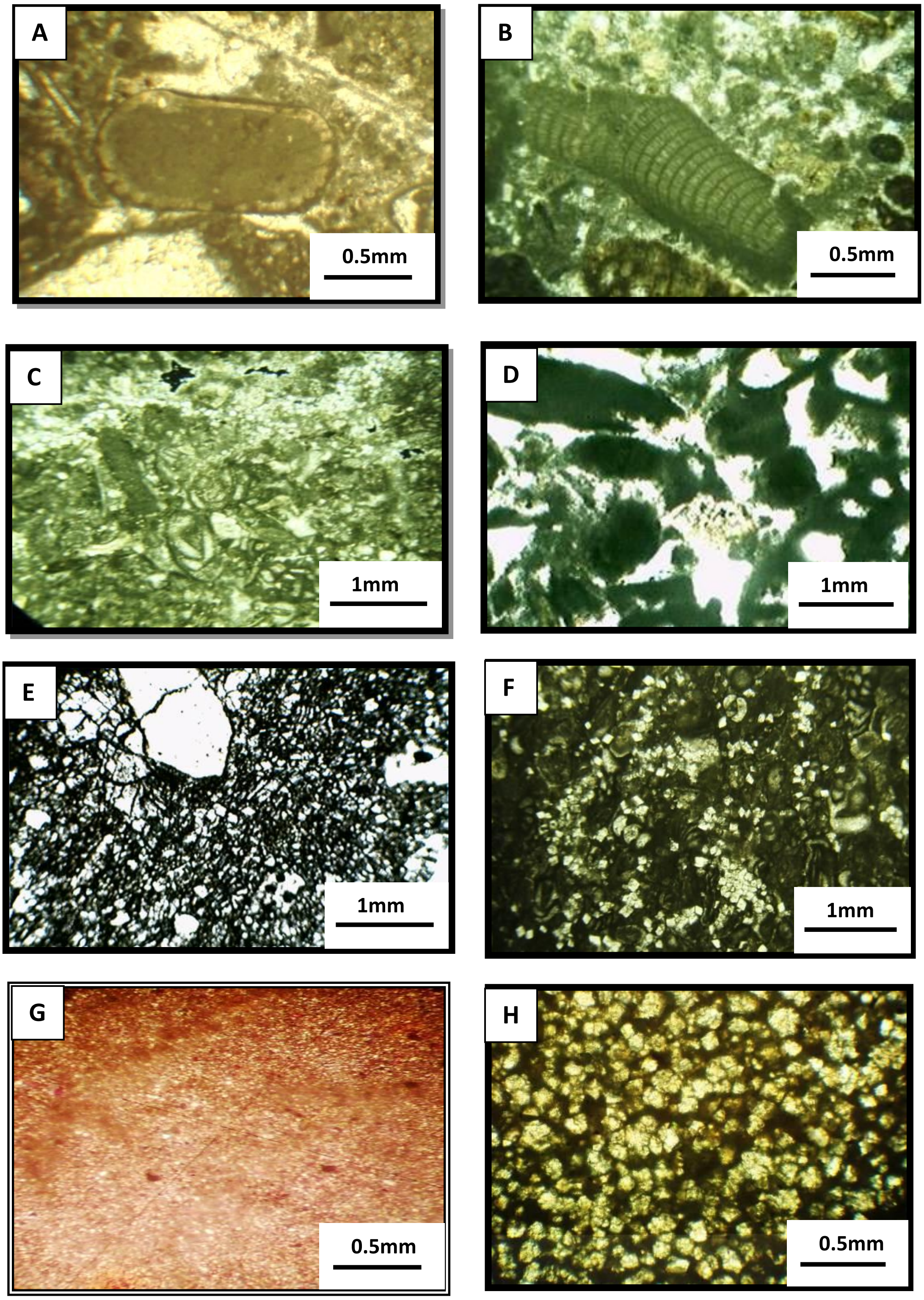

PLATE 2. Thin section photomicrographs: A) Ostracoda; B) Algae; C) Bioclast; D) Pisoids E); Intraclast; F) Micrite; G) Microsparite; H) Sieve mosaic fabric dolomite mineral with saturated bitumen.

PLATE 3

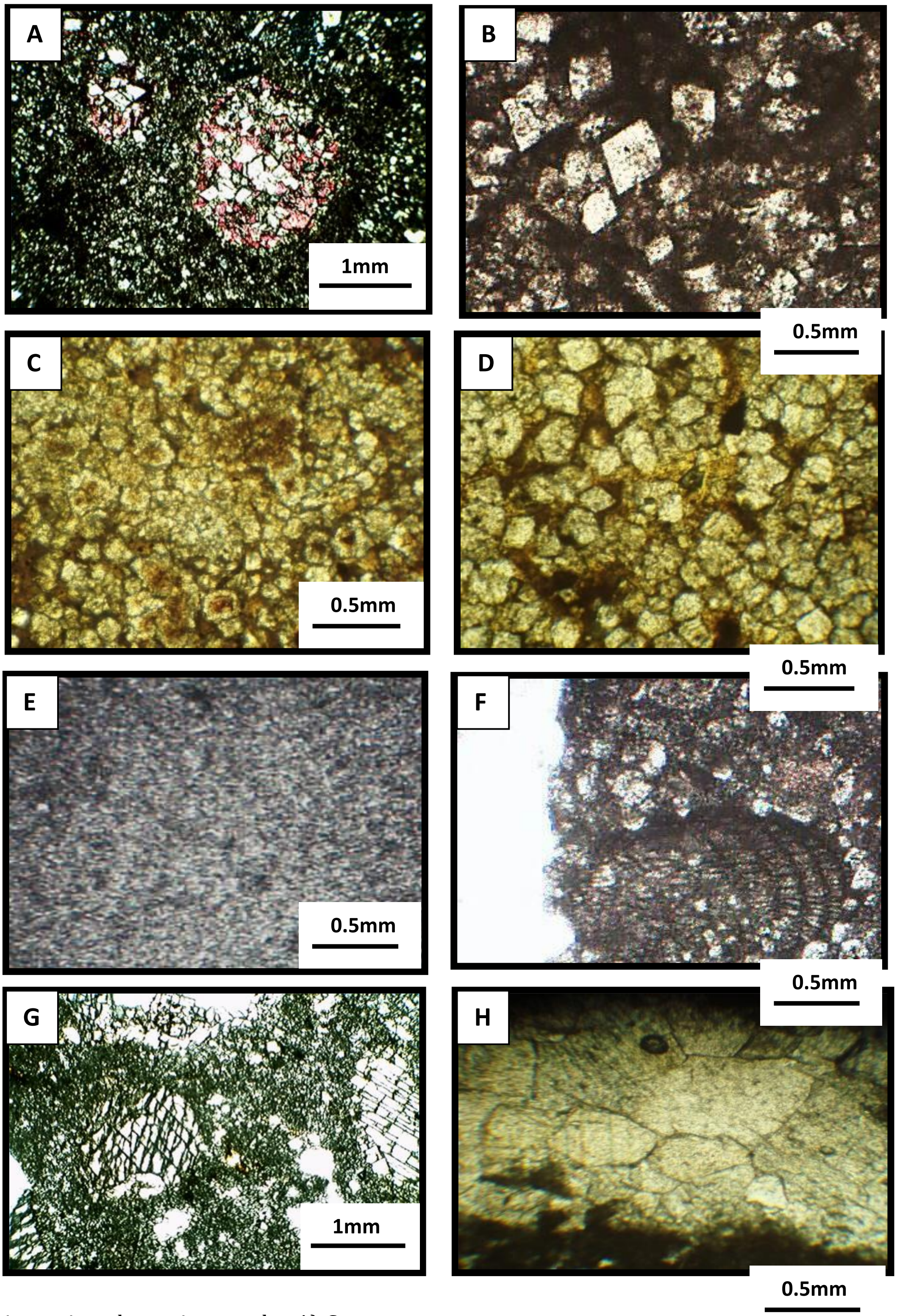

PLATE 3. Thin section photomicrographs: A) Contact rhomb texture dolomite mineral with saturated bitumen; B) Floating rhomb texture dolomite mineral; C) Fogged mosaic fabric dolomite mineral with saturated bitumen; D) Suture mosaic fabric dolomite mineral with saturated bitumen; E) Aphanotopic Fabric dolomite mineral; F) Selective dolomitization; G) Granular cement calcite mineral; H) Blocky cement calcite mineral.

PLATE 4

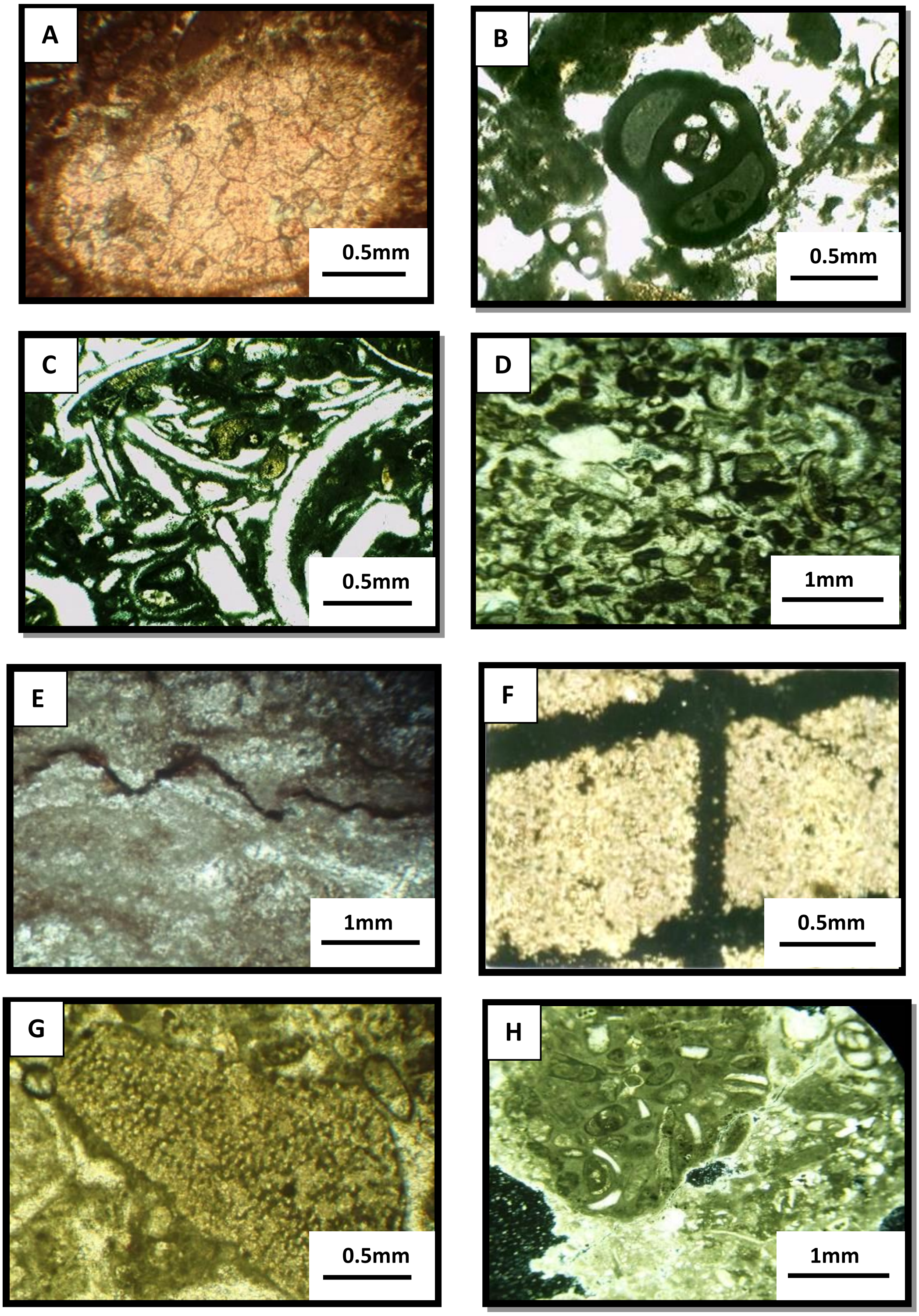

PLATE 4. Thin section photomicrographs: A) Drusy cement dolomite mineral; B) Micritization; C) Dissolution; D) Mechanical compaction; E) Chemical compaction (stylolites); F) Fracturing; G) Neomorphism; H) Bioturbation.

PLATE 5

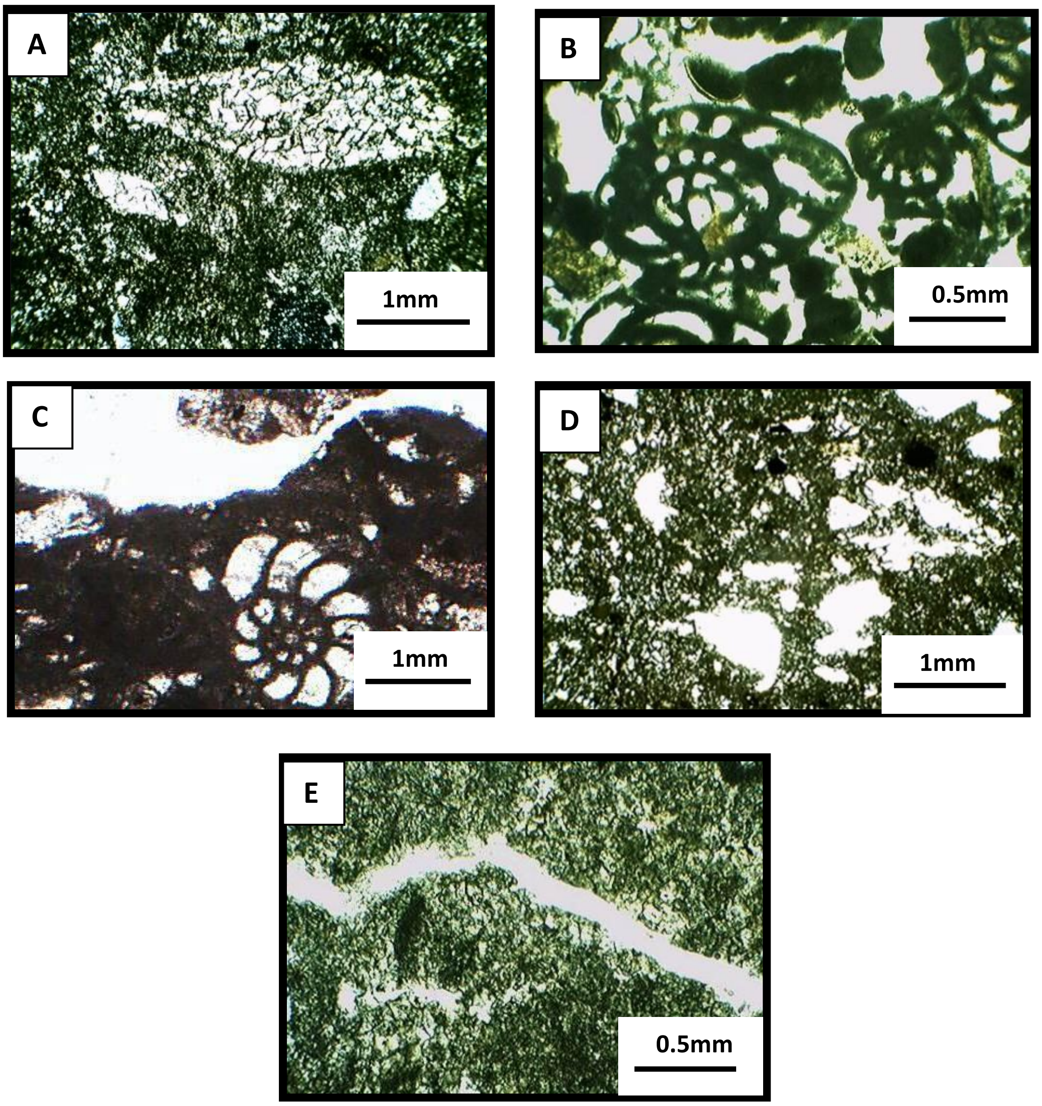

PLATE 5. Thin section photomicrographs: A) Moldic porosity; B) Interparticle porosity; C) Intraparticle porosity; D) Vuggy porosity; E) Fracture porosity.