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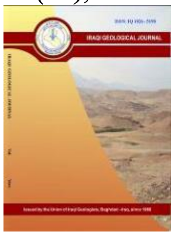

The Diagenesis Processes of the Hartha Formation in Majnoon Oil Field, Southern Iraq

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Abstract

The Hartha Formation is the shallowest of the major Majnoon oil field reservoirs. It is a 120 m thick carbonate platform deposit with an age of the Upper Campanian - Maastrichtian. It overlies the regional top of the Sa'di Formation unconformity and is in turn overlain by the Shiranish Formation. This research concentrated on diagenetic processes and petrophysical properties in the Hartha Formation in the Majnoon Oilfield, located in southern Iraq. The Hartha Formation was deposited on a carbonate ramp setting. It is subdivided into four main zones (A1, A2, B1, and B2), where A2 is the majority reservoir. Sixity of thin sections were made from several wells (MJ-29, MJ-47, MJ-88, MJ-91, MJ-92, and MJ-93). This formation was influenced by a number of digenetic processes, such as neomorphism, cementation, dolomitization, dissolution, and compaction. Dolomitization, dissolution, and cementation are the three main diagenetic processes in the current study. Detailed petrographic analysis of the dolomitization indicates that the dolomite formed is of two types (pervasive and selective) in the formation. The formation is affected by tectonic subsidence which is main controlling factor that achieved the paleogeography of the study area. This is produced different thicknesses of the formation along the structure, and the facies that formed the formation varied as a result of the variation of the relative sea level.This study aims to determine the extent of the impact of diagenetic processes on the porosity of the formation and thus impacts on the quality of the formation.

Keywords: Majnoon; Hartha ; Diagenesis; Dolomitization ; Dissolution

1. Introduction

The Basrah region, southern Iraq is well known for its giant oil fields. It is situated in what is known as the Mesopotamian Basin, near the eastern edge of the Arabian plate. The Majnoon oil field is a north-south anticlinal structure located in southern Iraq, about 60 km north of Basrah. The length of the structure is approximately 50 km, while its width is approximately 11 km (Fig.1). The Hartha Formation (Late Campanian-Maastrichtian) is one of the important formations of the Cretaceous period in central and southern Iraq. It has characteristics that make its subsurface sequences one of the most important reservoir rocks in the regions of central and southern Iraq. The sequences of this formation consist of successive layers of limestone, agglomerated limestone, dolomite, anhydrite/gypsum, and some shale. Such rocks are usually characterized by their extreme sensitivity to diagenesis processes, which in turn affect the reservoir properties of the formation, especially the petrophysical ones, and thus determine

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the quality of the reservoir. The formation has been studied by several authors Five depositional environments have been identified within the Hartha Formation: supratidal, deep marine, shallow open marine, basinal, and shallow restricted marine settings. The Hartha Formation was deposited within different sub-environments of the shallow carbonate platform, developed on a symmetric slope, and characterized by a relatively dense gradient.Abd Aoun and Mahdi (2019) provided several petrophysical models of the Hartha Formation. The modeling of facies presented the spreading of the depositional settings wherever the shallow, middle, and associated inside slopes covered the upper section of the formation, although the outer slope facies dominated the lower part of the formation. Abd Aoun and Mahdi (2019) described the Hartha Formation divisions Based on well logs analysis in the Majnoon oilfield This study divided the Hartha Formation into five reservoir units and distinguished four ancient environments (the outer, inner, middle, and coastal slope). Al-Joumaa and Al-Jawad (2019) estimated the calculating heterogeneity of the Majnoon field using the Dykstra Parsons method, and found that the value of the Dykstra Parsons` coefficient =0.799,9 which indicates a very heterogeneous reservoir, where the heterogeneity between (0 homo – 1 hetero). which proved that the Hartha reservoir in the Majnoon field is a very heterogeneous reservoir. Tamar-Agha and Basi (2020) clarified that the late Campanian-Maastrichtian sequence includes three different lithostratigraphic units: the Hartha, Shiranish, and Tayarat Formations. Many diagenetic changes affected the sequence, such as dissolution, replacement, neomorphic, sulfate development, and dolomitization. The objectives of this study are to determine diagenetic processing, the minerals present in the formation, the reservoir character of the Hartha units, and calculate the volume of shale

2. Geological Setting

The Majnoon oilfield is located within the stable shelf in the Mesopotamian Zone within the Zubair Subzone, according to the tectonic subdivision of Iraq as in clear Fig.1. The trend of the structures in this tectonic unit was influenced by the geometry of the underlying basement blocks and faults (Buday, 1980). The upper contact of the Hartha Formation is conformable with the Shiranish Formation, while the lower contact is unconformable with the Saadi Formation and is often marked by conglomeritic basal.

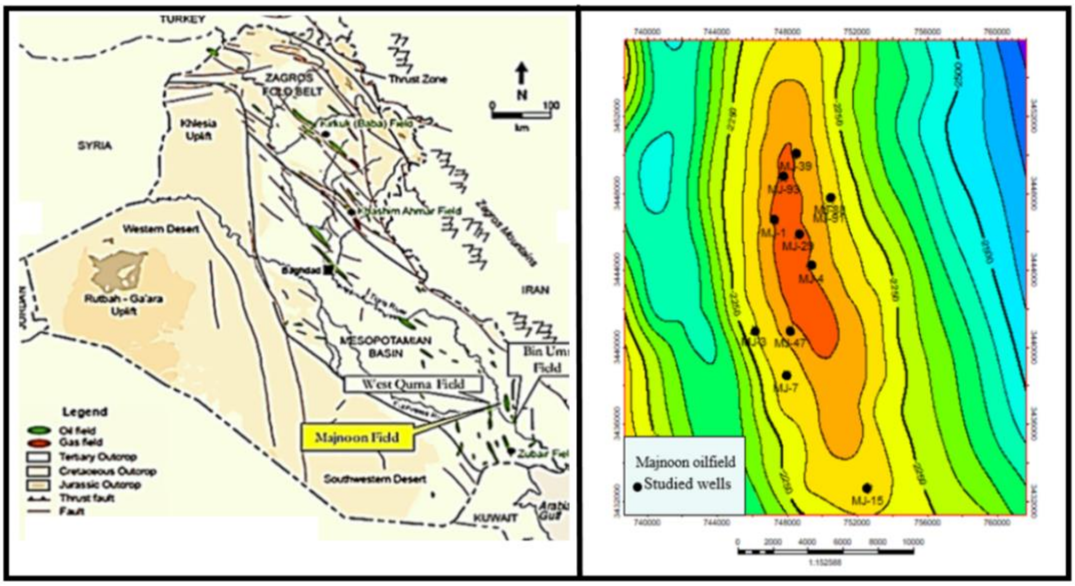

Fig 1. Location of the study area

3. Materials and Methods

The studied samples were taken from the wells of MJ-29, MJ-47, MJ-88, MJ-91, MJ-92, and MJ-93. Sixty thin-section analyses of the core were combined to identify porosity types and their related digenetic stages. Use well log data (gamma-ray, neutron, sonic, and density) for reconstructing not-cored intervals.

4. Results and Discussion

4. 1. Digenesis Development

The nature of limestone sediments is characterized by high sensitivity in sedimentary environments, unlike sediments of clastic rocks, so these rocks will vary in facies more than other rocks. The sedimentary environment is composed of a number of factors that participate in the production of limestone rocks (Al-Shawoosh, 2012). The major microfacies identified in the Hartha Formation are mudstone, wackestone, packstone, grainstone, bounstone, and crystalline dolomite microfacies. Each kind of it consists of several submicrofacies according to its components, which suffered from many diagenesis processes. Diagenesis processes are defined as all physical, chemical, and biological processes that collectively result in the transformation of sediment into sedimentary rocks (Rhymond, 1995). It may continue to function after the sediment solidifies a rock, altering the rock's texture and mineralogy. These processes are discussed in the following:

4.2. Constructive Diagenesis

4.2.1. Isocheimal

This process is not accompanied by any chemical change in the mineralization of the sediment, such as cementation and neomorphism (Myzban et al., 2022; Hassan et al., 2022)

4.2.2. Cementation

is defined as the diagenetic process of cavity filling or open-space filling through chemical precipitation of minerals from solution (Dabbagh, 2006). The process of cementation, which results in lithification, is the deposition and development of new carbonate crystals inside the void space. Many cementation types and minerals such as calcite, dolomite , and quartz cement are recognized in the study area at the Hartha Formation.

A. Calcite cement: Various types of calcite cement have been recognized in the Hartha Formation.

- Granular cement: The most common type of cement lacks a definite growth direction and has transparent crystals beneath subhedral to anhedral crystals. Different facies' pores, including veins, bio-molds, and vugs are filled with granular calcite cement (Plate 1. A). Typically the following compaction in deep-marine, subaerial, and under-sea environments (Bathurst,1985). From the analysis of the submicrofacies, appeared at depths of 2115m,2121.8m, 2124.5m, 2134.7m,2140.3m ,2141.6m ,2143.8m,2146.6m, and 2151.8m in MJ-29.

- Blocky cement :It is a calcite cement made of crystals with a medium to coarse grain size and no particular orientation.They are large calcite crystals that formed towards the late diagenetic process and indicate the gradual crystallization of an under-saturated solution (Plate1. B).This cement was identified throughout the succession under study as large crystals filling cracks, vugs, and inside skeletal grains resembling. From the analysis of the submicrofacies, appeared that depths of 2115.5m ,2121.0m,2124.5m,2150.3m, and 2154.58m in MJ-29.

- Syntaxial rim cement : The term "syntaxial" describes overgrowths that are in optical continuity with the underlying grains, resulting in the original crystal and the overgrowth forming a single bigger crystal with the same crystallographic axes optically continuous and epitaxial when crystals form around pieces of echinoderm plate, they produce optically continuous crystals (Plate 1.C), which is known as syntaxial rim cement in the microfacies of the Hartha Formation.

- Neospar cement: The presence of neospar cement on polycrystalline substrates (Skeletal grains, intraclasts, and lime mud) (Plate 1.D). It is common in limestones formed by brachiopods and bryozoans, where it may make up 85 to 95 % of the interparticle cement. Brown, isopachous neospar cement makes sharp contact with later equant cement. From the analysis of the submicrofacies, appeared that depth of 2147.8m in MJ-29.

B. Dolomite cement: Two types of dolomite cement can be recognised for filling vugs and fractures, medium to coarse-grained (0.109–0.327 mm) rhombohedral to subhedral crystalline dolomite crystals (Plate 1.E) and baroque dolomite is another name for saddle dolomite. It is distinguished by sweeping extinction, curved cleavage, and curved crystal faces.

C. Silica cement :it appeared that depth of 2136.8m in MJ-29(Plate 1F).

4.2.3. Neomorphism

It contains all diagenesis processes, such as recrystallization, crystal growth, and adjustments to the size, shape, and arrangement of crystals that occurred without a chemical change. The removal of the material's original depositional textures and components without changing its mineral chemistry, recrystallization processes occurring during burying diagenesis, and thermal history frequently change or destroy the original depositional microfacies and early diagenetic textures of limestone (Al Samarraie, 2011). Recrystallization in the Hartha Formation is an aggrading type, which is characterized by recrystallization processes in which coarse crystals develop from fine crystals. On the carbonates of the Hartha Formation, it can have a minor or significant impact including the neomorphism of limestone and the neomorphism of dolomite (Plates 2 A and B).

4.2.4. Allochemical

They are processes that are accompanied by a chemical change in the mineralization of the sediments, such as the process of dolomitization and pyritization.

1. Dolomitization : The Hartha Formation contains areas that are strongly dolomitized. Selective and pervasive dolomitization are the two distinct types of dolomitization (Plate2.E and F).When the limestone is attacked by selective dolomitization, dolomitic limestone is created, sometimes preserving the original depositional texture. When pervasive, it targets the primary sedimentary elements. Variable crystal sizes (0.18-0.604mm) (medium, coarse, and extremely coarse) and the presence of the majority of rhombohedral to subhedral crystals are evidence of actual dolomitization.

2. Pyritization : It is diagnosed in low-oxygen environments rich in aerobic bacteria. It is an indicator of a low oxygen percentage (Hassan et al.,2022). Pyrite is an authigenic mineral when H_2S is increased with an abundance of iron (Plate 2.H). Pyrite is a rare mineral to be found in the Hartha Formation. The

majority of the pyrite is found in various facies and exhibits frame boidal forms. Additionally, cubic crystals can be found in this formation.

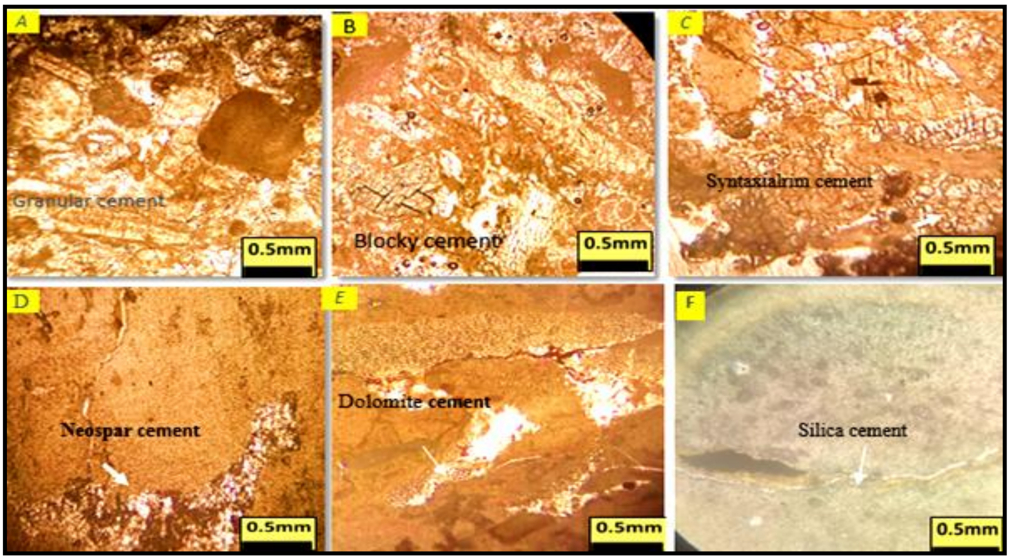

Plate 1. Type of cementation in MJ-29:A. Granular cement at depths of 2133.2m .B. Blocky cement at depths of 2122.5m.C. Syntaxial rim cement at depth of 2146.6m.D. Neospar cement at depth of 2133.24m .E. Dolomite cement at depths of 2140.3m .F. Silica cement at depth of 2136.8m.

4. 3. Destructive Diagenesis

4.3.1. Micritization

is the partial or complete conversion of sand or silt sized sedimentary particles to micrite-sized calcium carbonate, presumably because of tiny algae and/or fungi that bore into the sediment(Plate 2C).

4.3.2.Compaction and stylolization

The increased overburden pressure caused by burial results in compaction, a physical and chemical process (Al-Jaberi and Al-Jafar, 2020). Some textural consequences include grain penetration, grain deformation, grain breaking, and grain fracturing. The Hartha carbonate in the current study region is compacted chemically and physically. The preferred alignment of skeletal grains parallel to the bedding serves as the measurement tool for the impact of physical compaction.Chemical compaction is the subjecting of the granules to the dissolution of a pressure solution, resulting in stylolites and solution seams formed under burial conditions and vertical stress. Solution Seams (Parallel Stylolite), appeared at depths of 2120.8m, 2122.5m, 2133.2m, 2140.3m, and 2144.6m. In MJ-29, the types of compaction and stylolization are explained in Plates 2 F, G, and H.

4.3.3 Dissolution

It is found in ancient limestone. Some of these spaces remain empty, and others are filled with secondary materials (Plate 3 D and G). The voids are usually formed by the dissolution of aragonite, high and low magnesium calcite in natural waters. The resulting voids are mostly secondary porosity by the simple dissolution of skeletal fragments. The dissolution appears to be selective as some fossils are represented by biocasts or the molds are filled with cement. (Tamar-Agha and Basi,2021). This process is very dominant in many intervals in the Hartha Formation, causing vugs, moldic pores, fractures, veins, stylolite and other types of porosity. In some intervals, calcite cement filled these voids after dissolution.

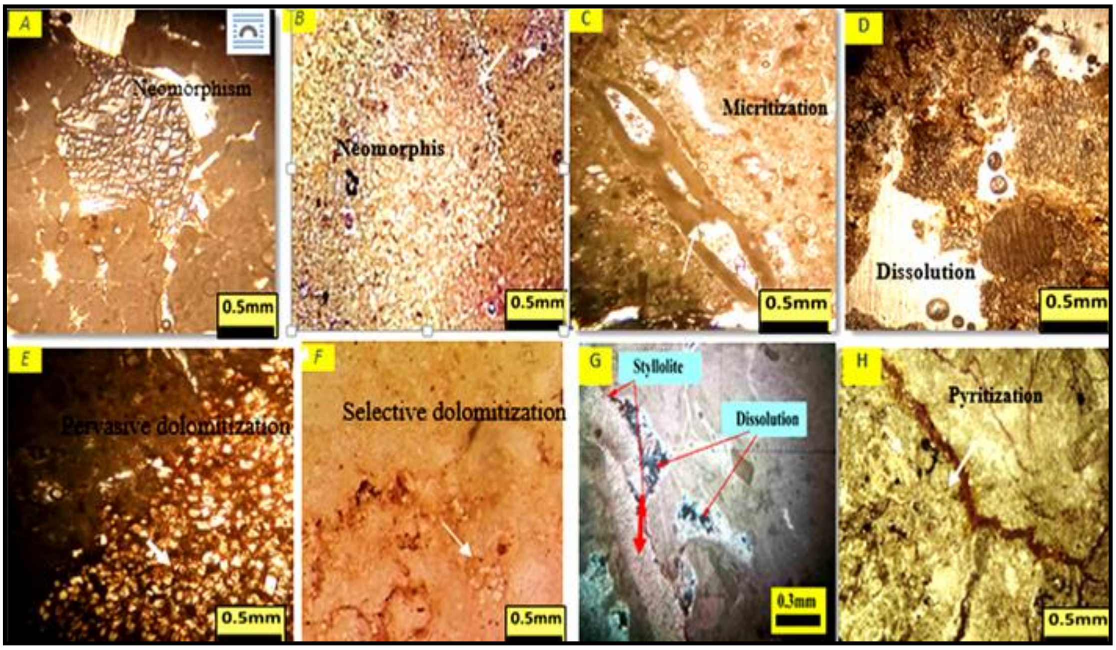

Plate 2. Digenesis processes in MJ-29 : A. Neomorphism of limestone at depths of 2124.5m. B. neomorphism of dolomite at depth of 2151.9m..C. micritization at depth of 2151.8 m.D. dissolution at depth 2144.6m.E. pervasive dolomitization at depth of 2152.5m F. selective dolomitization at depth of 2154.5m.G. compaction and stylization at depths of 2140.3m. H. pyritization and stylization at a depth of 2020.8 m.

4.4. Porosity

Many porosity types are categorized into fabric-selective and non-fabric-selective porosity and are defined as the ratio of the volume of pores to the entire bulk, whether isolated or touched.

4.4.1 Development of Porosity

Porosity is of two main types: primary and secondary (Selley, 1998). In the formation under study, the initial porosity was found either between the depositional allochems (intergranular) or within the skeletal framework of the bioclasts (intragranular), and it was destroyed by the deposition of sparry calcite cement. These diffuse cement effectively close the primary pores and reduce the porosity. Pores of secondary origin alone could be distinguished and microscopically identifiable in the Hartha Formation. These secondary pores appear to have resulted from diagenetic dissolution processes that affected the pre-fabrication of the rocks at various times during the post-depositional.

4.4.2.Fabric- selective pores

This is regulated by the original rock's component parts such as intraparticle, interparticle , moldic, intercrystal, and fenestral porosity.

- *Intraparticle porosity*

It is pore space within individual pellets, intraclasts, ooids, and other non-skeletal grains (Choquette and Pray, 1970). It appeared at depths of 2113.8m,and 2148.9m in well MJ-29(Plate 3.A).

- *Interparticle porosity*

It is generally of primary depositional origin, it has a weak effect in improving the reservoir properties because they are unconnected pores (Abd, 2017). From the analysis of the submicrofacies, this porosity appeared at depths of 2143.8, 2146.9, 2147.8, and 2148.9 in well MJ-29(Plate 3.B) .

- *Moldic porosity*

The dissolution of the shells and skeleton fragments produces this porosity, it appeared at depths of 2112.5m, 2130.4m, 2146.9m, and and2152.5m in well MJ-29 (Plate 3.C) .

- Fenestral porosity

Primary porosity in the rock framework is larger than grain supported interstices (Plate 3. D). Some features may be open pores or partially or completely filled with internal sediment and/or sparry cement. From the analysis of the submicrofacies, it appeared at depths of 2112.5m, 2124.5m, and 2148.9 m at well MJ-29.

- Pre-deposited framework porosity

This category of porosity is encompasses the primary pore space between reef formers as the biota builds a bioherm or boundstone clear (Plate 3.E).

- Intercrystal porosity

It is between crystals and nearly porous in carbonates, intercrystalline typically only occurs in carbonates similar to many porous dolomites (Plate 3 F), it appeared at depths 2143.8m, 2147.8m, 2150.3m,2151.8m, 2133.4m, 2137.3m, 2140.3m, and 2146.9m in well MJ-29.

4.4.3. Non –fabric selective pores

these pores develop independently of the original texture of the rock.

- Fractures and veins

These types of porosity are mostly found in mudstones and wackestones. Pressure solutions and tectonic movements are formed (Scholle, 1983). When the overburden pressure increased before the cementing, syndepositional or post depositional processes created the opening (Plate 4.A and D). It is appeared at depths of 2120.8m, 2121.8m, 2133.2m, 2135.4m, and2139.7m in MJ-29.

- Vugs

they are highly amorphous pores with no clear shape. It stands for the tissue-selective pore solution's expansion. it appeared at depths of 2120.8m, 2121.8m, 2122.5m, 2124.5m, 2137.3m, 2140.3m, 2147.8m, and2151.8m in MJ-29(Plate 4.B).

- Cavern porosity

large vuggy or large cavern refers to a large channel shape formed primarily by karstic solution processes (Flügel, 2010). This type of porosity was observed at depths of 2120.8m and 2124.5m in well MJ-29(Plate 4.C).

- Channel Porosity

it is the secondary porosity, noticeably longer and has grown without influence from the texture or fabric. From the analysis of the submicrofacies, it appeared at depths of 2120.8m, 2133.2m, and 2135.4m at Mj-29 (Plate 4.F).

4.4.4. Fabric selective pores or not

- Boring porosity

it is a pit formed by organisms that drill into relatively solid rock, shells, or other objects create (Plate 4.E). It occurs in the shallow marine environment. From the analysis of the submicrofacies, it appeared at depths of 2137.8 m, 2139.7m, and and2140.3m in Mj-29.

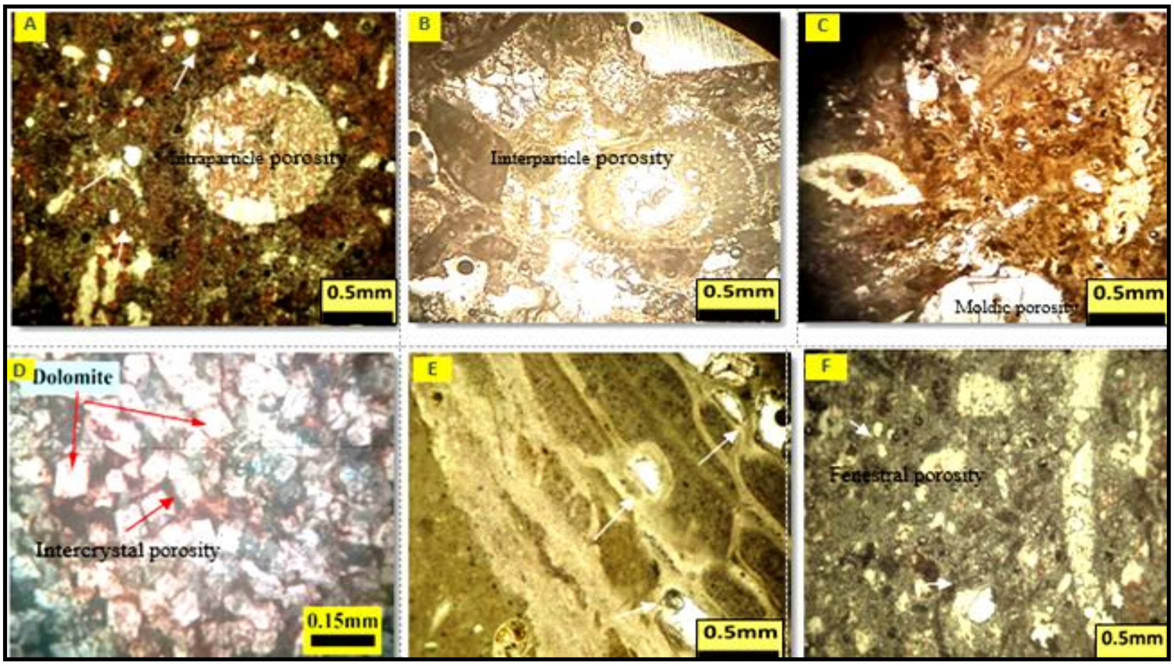

Plate3. Fabric- selective pores in Mj-29:A. Intraparticle porosity at depths of 2148.9 m.B. Interparticle porosity at depths of 2146.6m.C. moldic porosity at depths of 2151.8m. D. Intrecrystaline porosity at depths of 22130.4m. E. pre-deposited framework porosity at depths of 2113.8 m. .F. Fenestral porosity at depths of 2151.8m

4.5. Authigenic Minerals

authigenic minerals grow after sediment deposition during diagenesis (Flugel, 2004). The main recognized authigenic minerals are pyrite, quartz, gypsum, and anhydrite. From the analysis of the submicrofacies, it appeared at depths of 2120.8m, 2136.8m, 2152.5m, and 2154.6m (Plate 5).

- Pyrite : under reducing conditions, authentic pyrite frequently replaces organic material (Flugel, 2004).There is a different lithologic unit of the Hartha Formation containing cubic euhedral crystals of pyrite as shown in plate 5.A.

- Iron oxides : replacement typically involves two steps; dissolving the original material and filling the cavities with a different mineral (Tucker, 1981). Iron oxides frequently partially replace fossils, and

- they can be seen as cubic crystals inside the matrix in mudstones and wackestones. Magnetite and limonite are examples of iron oxides (Plate 5B).

- Quartz: the carbonate rock is replaced with idiomorphic quartz (Plate 5. C). Many carbonates that have been exposed to salty or hypersaline pore fluids include authigenic quartz crystals (Flugel, 2004).
- Sulphate development: the pore space represents the intraparticle voids, such as the spaces in the fossils, and the sulfates form as interlocking crystals of gypsum and anhydrite, sometimes even replacing parts of the pre-existing dolomite (Plate 5D).Gypsum typically occurs in the periphery, whereas anhydrite typically occurs in the center. Anhydrite is typically replaced by gypsum once the original fabric has been destroyed.

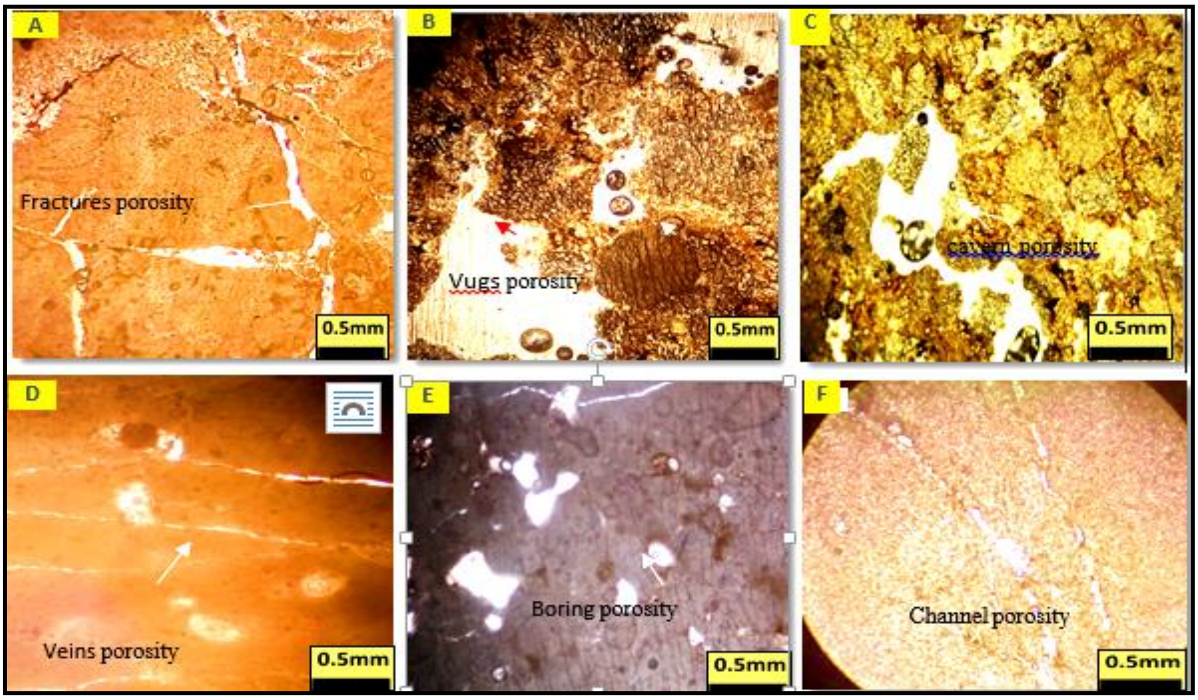

Plate 4. Non –fabric selective pores in Mj-29:A. Fractures porosity at depth of 2133.2 m .B. Vugs porosity at depth of 2144.6 m.C. cavern porosity at depths of 2144m D. veins at depth of 2136.8 m.E. Boring porosity at depth of 2137.7 m F. Channel Porosity at depth of2133.6m.

4.6. Hydrocarbon Evidence

Much oil evidence appeared in the studied sections of all the wells used in this study (Plate 5. E and f). The oil evidence was concentrated at the top and middle of the formation, especially at the two reservoir units (A2 and A3). This evidence appeared with the late diagenesis processes, especially the late dolomitization processes, dissolution, and fractures, which were found to accompany them in most of the depths. Most of the evidence is found in facies that refer to shallow areas with high porosity, low cementation, and wide-ranging biological components.

4.7. Digenetic Sequences

The Hartha Formation underwent morphological diversity over its digenetic history, which had an impact on the final sediments in the formation. Boring organisms and bacteria, whose effects start during sedimentation and after the sediments solidify, were responsible for the initial processes. If the algae were to penetrate the rocky and skeletal structures, filling them with micrite, which was symbolized by the phreatic marine water, they would do so. Increased water movement between granules causes seawater to fill the pores after limestone is deposited in a shallow maritime setting. As shown in table 1 from the petrographic investigation in the examined area, the diagenetic paragenesis of the Hartha

Formation is valid in this moderative range, which is known as the active marine phreatic zone.The severe breakdown of granules, particularly those composed of mollusca and high-magnesium calcite, because of the ingress of fresh water was typical of the second stage of the digenetic sequence, which was characterized by the development of the effects of the fresh environment. It resulted at the beginning of a new cementation phase, which is represented by granular, dry, and rim cement all around the echinoderms.The huge vuggy and melodic porosity that reflected the fresh environment of the vadose zone was formed because of ongoing granular disintegration and impact, as well as an increase in the amount of freshwater entering the system. A new phase of the digenetic phases, known as the mixed environment, has emerged because of the mixing of freshwater and saltwater. This environment represents the configuration of the dolomitization and increasing compression and pressure solutions.

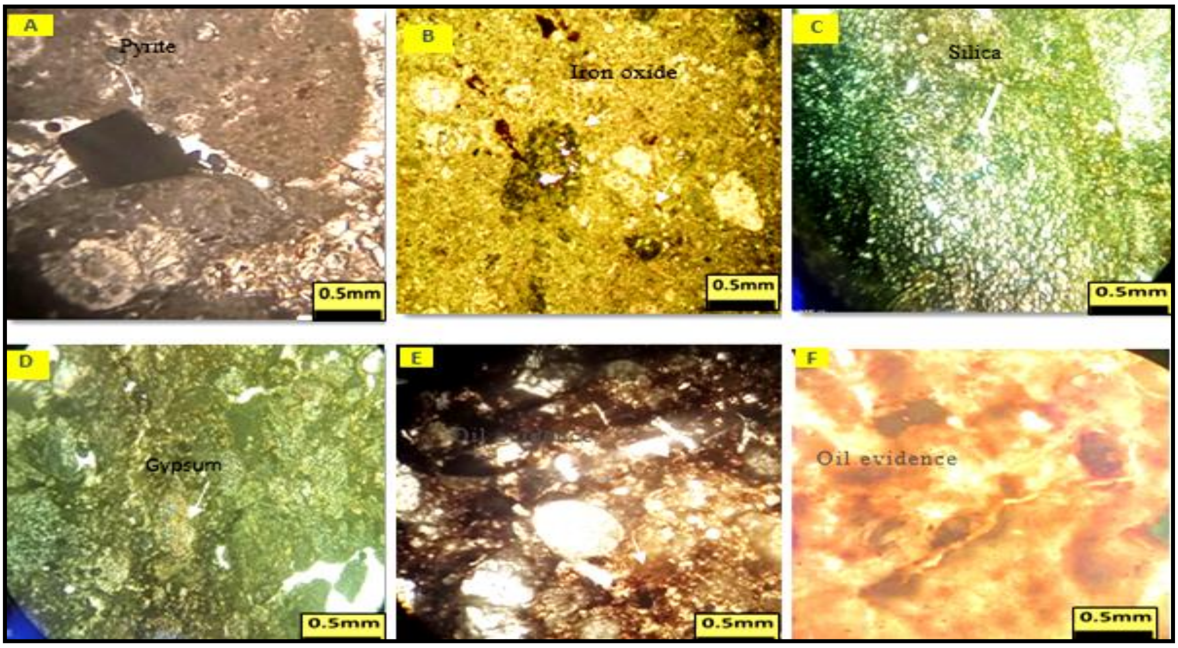

Plate 5. Authigenic minerals and Hydrocarbon evidence in MJ-29:A. Pyrite at depths of 2152.5m.B. Iron oxides at depth of 2154.6m.C. Quartz at depth of 2136.8m.D. Gypsum at depth of 2120.8m.E and F. oil evidence at depths of 2143.82m and 2120.8m respectively

4.8. Digenesis and Reservoir Quality

Diagenetic processes involved in the Hartha Formation caused the variation in reservoir quality, diagnostic phenomena have been divided into three categories based on how they affect reservoir quality; processes that increase, decrease, and have no impact. The following is a description of these procedures:

4.8.1. Processes enhancing reservoir quality

Fracturing: although fractures did not occur frequently over the studied interval, it appears that they improved reservoir quality by increasing porosity and permeability. Dissolution developed in a variety of porosities, including channel, melodic, and vuggy porosity. Dissolution thereby improved reservoir quality.By creating intercrystalline matrix porosity locally, dolomitization improved reservoir quality.

4.8.2. Processes decreasing reservoir quality

- Cementation: is the most important diagenetic feature, which reduced porosity. The largest detrimental impact on reservoir quality was caused by calcite cement in the form of sparry calcite. Almost all of the samples had a high sparry calcite cement distribution, which reduced or covered up various types of porosity such vuggy, fracture, and intraparticle porosity.

- Micritization: which results in decreased permeability and intraparticle and interparticle porosity, is the process of changing the original skeletal grain fabric to a cryptocrystalline texture by filling the micro-borings and chambers of fossils with micritic precipitates.

4.8.3. No or negligible effect on reservoir quality

Pyritization is a variety of digenetic characteristics that barely affect reservoir quality.

Table 1. Diagenetic paragenesis of the Hartha Formation.

Diagenetic environments	Diagenetic processes	Diagenetic fabrics	Diagenetic stages Early	Middle	Late
Marine phreatic	Micritization	Micritic envelope	■		
	Cementation	Syntaxial cement	■	■	
Mixing zone	Dolomitization	Dolomite	■	■	
Meteoric phreatic zone	Neomorphism	Recrystallzation	■	■	■
	Cementation	Syntaxial cement		■	■
Vadose zone Burial	Dissolution	Pores and Vugs			■
	Burial cementation	Blocky and granular			■
	Pressure solution	Stylolite			■
	Compaction	Fracture	■	■	■
	Dolomitization	Dolomite	■		■
	Authigenic	Pyrite	■		■
		Quartz, Sulphat	■		■

4.9. Hartha Formation Characteristics

The Hartha Formation is a carbonate that is around 120 meters thick. The Sa'di Formation is underlain by the Hartha; the Shiranish's regionally extensive argillaceous chalks are uniformly overlaid on top of it. The formation is divided into five units (A1, A2, A3, B1, and B2). Depending on the fact that each unit has its own characteristics that distinguish it from the others and determine the log's behavior towards it. The A1 sub-unit is characterized by negative values of SP and maximum GR logs, which are used to identify the top of Hartha Formation (Fig. 2). Comparison of the porosity resulting from the density and neutron logs with the SPI in the wells MJ-93, MJ-91, and MJ-29.

4.9.1. The reservoir character of the Hartha A2

Low density, high porosity, and abundant cyclicity are characteristics of the Hartha A2 sub-zone. At the base of A2, density increases, and porosity decreases. It is characterized by thin laminations of vug, some of which are centimeter scale, as seen in the core between depths of 2133 m and 2141 m.

In Hartha A2.1 based on resistivity and BHI log data, it shows the presence of thin beds (1–20 cm thick) within the Hartha A2. Vug packstone layers with moderate porosity and high permeability are observed in this interval, specifically in the bottom part of A2.1.

Log signatures indicate the thickest intervals in A2.2 reach 4 m, with a trend of increasing porosity to the top of the cycle. It is observed as being more bioturbated compared to A2.1. Porous and vug-layer intervals have been picked for A2.2 from the MJ-29 core photographs, BHI data, and legacy core interpretation. On the top of A2.2 included abundant intact (rudist) bivalves and pseudo stylolite fabrics.

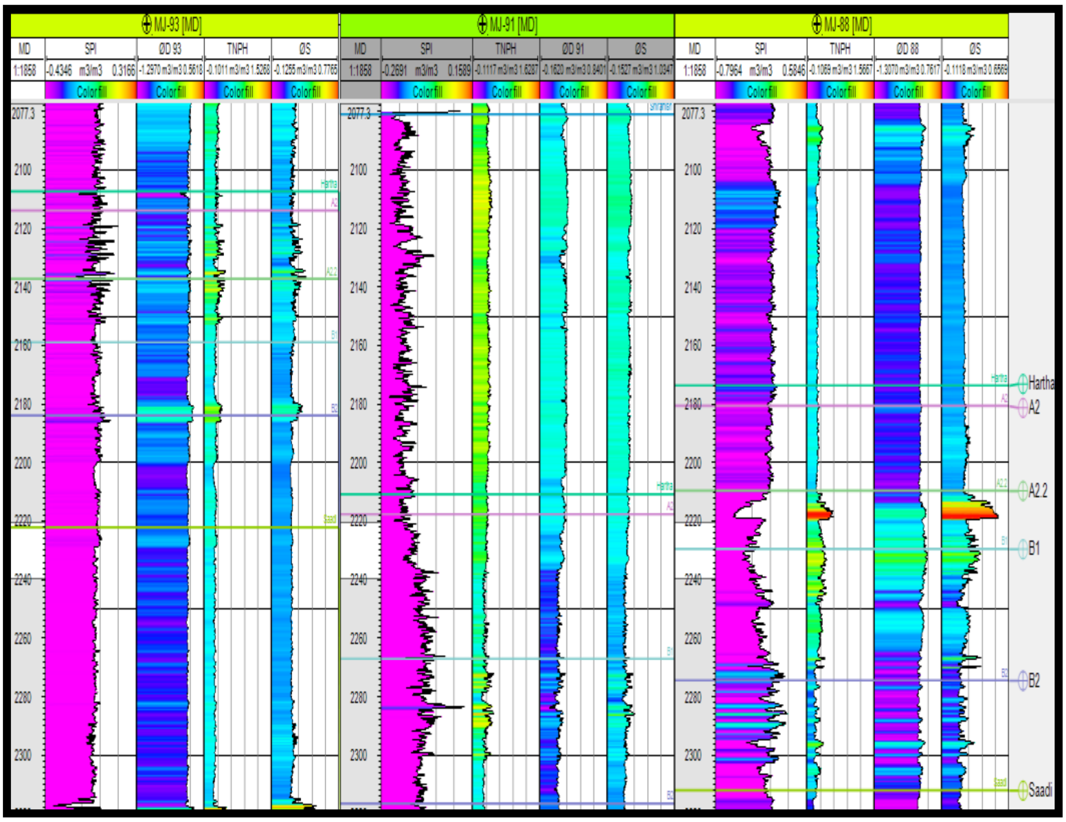

Fig. 2. The comparison of the porosity resulting from the neutron, density, and sonic logs with the secondary porosity(SPI) in the wells MJ-93, MJ-91,and MJ-88.

4.9.2.The character of the Hartha B1 and B2

The B1 and B2 subzones are characterized by lower porosity compared to A2. The top B1 sub-zone is picked at the base of the increasing density (deteriorating downward). Higher density and reduced porosity are characteristics of the B1 and B2 sub-zones. The carbonate mudstones predominate in the upper B2 subzone, which is identified by a rightward deflection of GR/SP. B1 and B2 are porous enough to hold water. These zones are characterized by carbonate mudstone and wackestone/foraminiferal packstone. They were deposited in a mid to outer ramp environment during the onset of sea level increase, culminating in the overlying Sa'di Formation, which is an open marine facies. B1 is likely to be associated with shallowing-upward that terminate with coarser packstone layers.

5. Conclusions

The most important diagenesis processes that affected the formation are the new transformation, cementation, dolomite, cementation and micritization, dissolution, pyritization, and recrystallization, in addition to the implicitly authigenic minerals.The diagenesis processes affected the destruction of the quality of the reservoir by mechanically and chemically compressing the granules (stylolite), which led to a decrease in the porosity, as well as the cementing process led to the destruction of the porosity of the reservoir.Dissolution, recrystallization, and partial dissolution improve the porosity of the reservoir.

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