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Microfacies Analysis and diagenesis process of Hartha Formation East Baghdad oilfield, center Iraq

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Received: 1 August 2023 **Accepted: 11 November 2023**

DOI: https://dx.doi.org/10.24237/ASJ.02.03.788B

Abstract

This study focused on interpreting the carbonate microfacies of Hartha Formation and the impact of diagenesis processes in selected wells of East Baghdad oil field. A total of 33 thin sections were examined from cutting and core samples. The study revealed distinct microfacies indicating different paleoenvironments. The outer-ramp environment is characterized by mudstone and wackestone microfacies dominated by planktonic foraminifera. Mid-ramp environment is distinguished by lime mudstone, bioclastic wackestone and foraminiferal-bioclastic wackestone. The inner ramp environment is subdivided into shoal, open marine, and restricted subenvironments. The shoal environment is only identified by rudistid grainstone microfacies. The open marine environment includes Benthic foraminifreal wackestone and Foraminiferal-echinoderm packstone. Restricted marine environment consists of mud-support microfacies such as Benthic foraminiferal-bioclastic wackestone and Rotalid wackestone Diagenetic processes affect the textural properties of Hartha Formation microfacies. They include dolomitization, cementation, compaction, and fracturing

Keywords: Hartha Formation, microfacies, diagenesis processes. East Baghdad oil field, Foraminifera.

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التحليل السحني و العمليات التحويرية لتكوين الهارثة , حقل شرقي بغداد النفطي, وسط العراق

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الخلاصة

ركزت هذه الدراسة على تفسير السحنات الجيرية المجهرية لتكوين الهارثة وتأثير العمليات التحويرية في آبار مختارة من حقل نفط شرق بغداد. تم فحص إجمالي ثلاث وثلاثون من الشرائح الرقيقة من عينات اللباب و الفتات. كشفت الدراسة عن السحنات الدقيقة المميزة التي تشير إلى بيئات قديمة مختلفة. تتميز بيئة المنحدر الخارجي بسحنات الحجر الجيري الطيني و الحجر الجيري الواكي التي تهيمن عليها الفورامنيفيرا الطافية. تتميز بيئة المنحدر الأوسط بسحنات الحجر الطيني، الحجر الواكي ذو المكسرات العضوية، و الحجر الواكي ذو المكسرات العضوية و الفورامينيفرا. وتنقسم بيئة المنحدر الداخلي إلى بيئة الحاجز المتضحل والبحرية المفتوحة و البحرية المحصورة. تم التعرف على بيئة الحاجز المتضحل فقط من خلال سحنة الحجر الحبيبي الروديستية. تشمل البيئة البحرية المفتوحة الحجر الواكي ذو الفورامينيفرا القاعية و الحجر المرصوص الحاوي على شوكيات الجلد و الفورامينيفيرا. تتكون البيئة البحرية المحصورة من السحنات ذات الاسناد الطيني مثل الحجر الواكي الحاوي على الكسرات العضوية و الفورامينيفيرا القاعية و الحجر الواكي الحاوي على الروتاليد تؤثر العمليات التحويرية على الخصائص النسيجية للسحنات الدقيقة لتكوين الهارثة. وهي تشمل الدلمتة ، والسمنتة ، والاحكام ، والكسور.

الكلمات المفتاحية: تكوين الهارثة, السحنات الدقيقة , العمليات التحويرية , حقل شرق بغداد النفطي , فورامنفرا.

Introduction

The Hartha Formation encompasses significant carbonate reservoirs that exhibit productivity in the central and southern regions of Iraq. Due to the petrophysical properties and the quantity of hydrocarbon present, it became significant [1]. The study area under consideration is situated within the East Baghdad oil field, which is recognized as one of the major oil fields in central Iraq. It was initially discovered by the National Oil Company through seismic survey interpretations conducted between 1974 and 1975 [2]. It hydrocarbons from Hartha Formation. The lithology of the formation consists mainly of limestones and argillaceous limestone in East Baghdad oilfield. In the eastern sections of the Mesopotamian Zone, where the formation transitions into the Shiranish Formation, argillaceous limestone becomes more prevalent [3].

The thickness of the Hartha Formation exhibits variations due to gradation and occasional overlap with the Shiranish Formation [4], Figure (1). In southern Iraq, the thickness ranges from 250 to 200 meters, while in northern Iraq, it averages around 350 meters [2]. Within the wells of the East Baghdad field, the Hartha Formation has depths ranging from 1874 to 2194 meters, with an average thickness of 289 meters [5]. The present study includes the examination of Hartha Formation microfacies with the objective of delineating the depositional environments. Additionally, the study seeks to identify and evaluate the diagenetic processes that modify textural properties of microfacies, and therefore change reservoir properties.

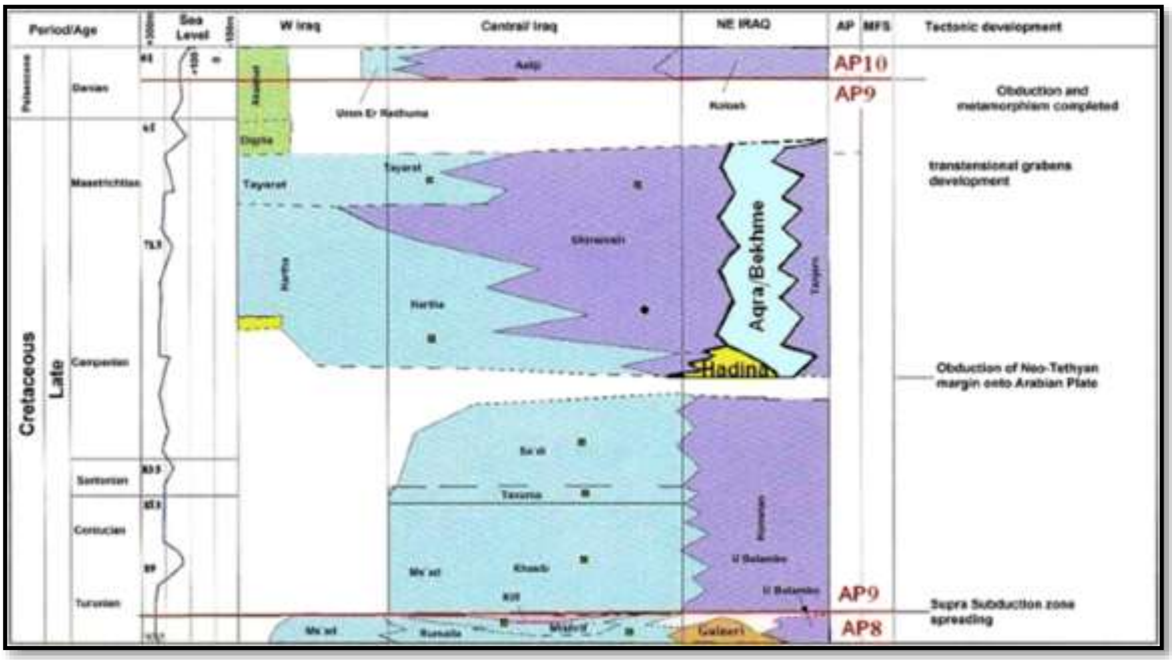

Figure 1: Stratigraphic correlation Early Turonian-Danian Megasequence [5].

Location of study area

The study area is located in the East Baghdad oil field, a significant oil field in central Iraq. It's situated 20 kilometers east of Baghdad's center [6]. Four wells are selected in this study included: EB-97 (in the Suwayra region), EB-93, EB-92, EB-102 (in Rashidiya) (Table, 1), as shown in Figure (2).

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Table 1: Geographic coordinates of study wells

WELL NO.	THICKNESS (M)	EASTING	NORTHING
EB-102	227	44°19'38"	33°29'27"
EB-97	254	44°50'26"	33°06'30"
EB-93	225	44°21'52"	33°28'19"
EB-92	266	44°19'31"	33°29'08"

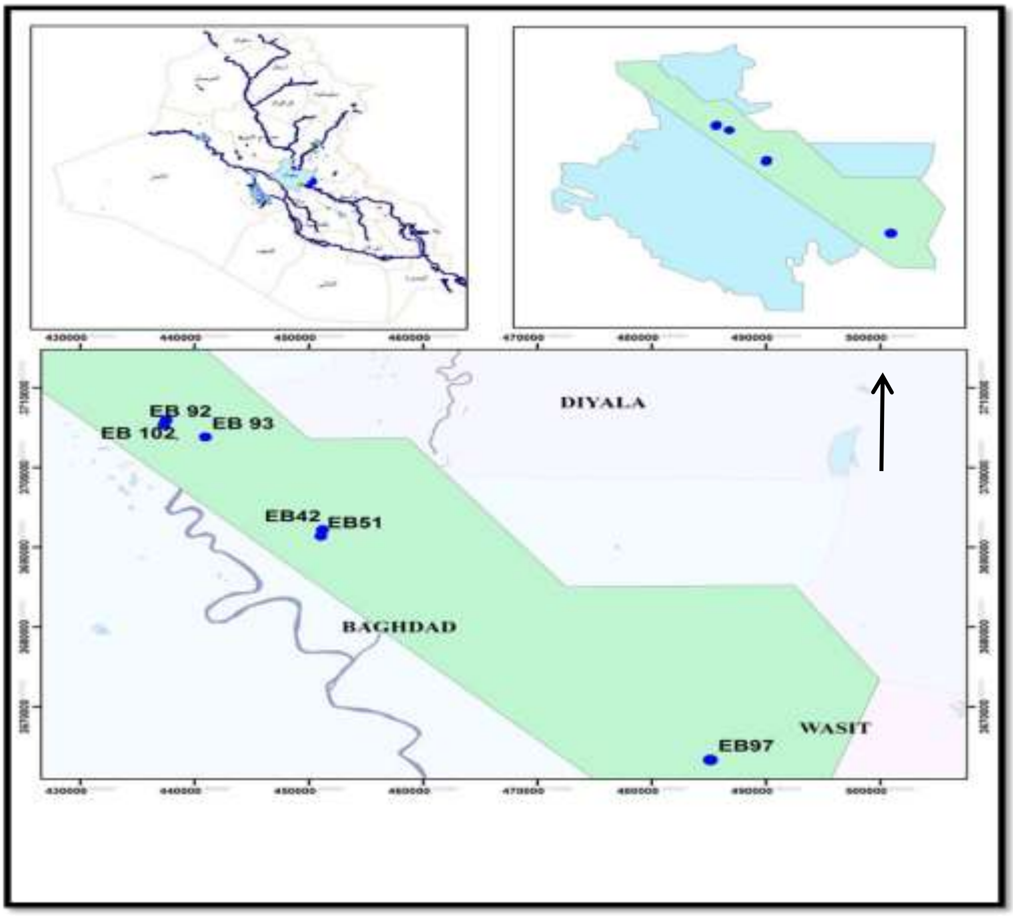

Figure 2: Location map of the studied wells

Materials and Methods

A total of 100 thin sections are prepared from cutting and core samples. These samples were taken at various distances to investigate the microfacies and diagenetic processes. The thin sections were examined using a polarized microscope, and visual documentation was conducted using a phone camera.

Results and Discussions

The interpretation of the paleoenvironment in which the Hartha Formation was deposited, along with the assessment of diagenetic processes that control the reservoir properties, led to the following findings**:**

Microfacies analysis

Accordance to [7] established classification of carbonate rocks, the limestone of Hartha Formation have been systematically classified into four distinctive microfacies: Mudstone, Wackestone, Packstone, and Grainstone. This comprehensive categorization encompasses not only the composition of carbonate grains.

Mudstone Microfacies

The mudstone microfacies, as defined in this study, refers to carbonate rocks with a significant proportion of fine-grained matrix and containing less than 10 percent grains, according to [7] classification. The presence of mudstone indicates a low-energy depositional environment characterized by calm water conditions and limited activity of grain-producing organisms. Furthermore, within the context of the current study, the mudstone microfacies has been further divided into sub-microfacies to provide a more detailed characterization.

Lime Mudstone

This particular microfacies exhibits a scarcity of Planktonic Foraminifera and is notable for the occurrence of clear dolomite crystals, figure (3 A). It corresponds to the standard microfacies (RMF 2) classification, which is indicative of a mid-ramp environment.

Planktonic Foraminiferal Mudstone

The microfacies under investigation revealed the presence of planktonic Foraminifera, as well as fragments of orbitoids, fine bioclastic material, and dolomite crystals, figure (3 B). This particular microfacies corresponds to the standard microfacies (RMF 5) classification, indicating its affiliation with an outer ramp environment.

Wackestone Microfacies

The wackestone microfacies of mud-supported carbonate rock, characterized by the presence of more than 10 percent grains, typically suggests calm water conditions and limited activity of grain-producing organisms, indicative of a low-energy depositional environment [7]. This microfacies is most common in Hartha Formation. It was subdivided into several submicrofacies, which are outlined as follows:

Bioclastic Wackestone

This microfacies include a diverse assemblage of skeletal grains, including planktonic foraminifera, and few benthic foraminifera (Rotalids), echinoderm, and fine-medium size bioclasts affected by neomorphism or cementation figure (3 D).The microfacies corresponds to the standard microfacies RMF 3, reflecting a mid-ramp environment [8].

Benthic Foraminifreal Wackestone

Benthic foraminifera are most common skeletal components in this microfacies, such as Orbitoids and Rotalids. The impact of physical compaction on the foraminifera is prominent through the breakage of foraminifer's tests figure (3 F). This microfacies is equivalent to standard microfacies RMF 13, which signifies the restricted- or open-marine environment [8].

Planktonic Foraminiferal Wackestone

Within this microfacies, the predominant component is planktonic foraminifera, and can be associated with sponge spicules and fine bioclasts figure (3 C). This microfacies corresponds to the standard microfacies RMF5, which indicates a mid-ramp to outer ramp environment [8].

Foraminiferal-Bioclastic Wackestone

Within this microfacies, planktonic and benthic foraminifera are associated with various bioclasts, such as echinoderm. Benthic foraminifera include Rotalids and Textularia figure (3 E). This microfacies corresponds to the standard microfacies RMF3 indicating mid-ramp environment [8].

Benthic foraminiferal-bioclastic wackestone

The main components of this microfacies include various bioclasts that are affected by cementation. The origin of bioclasts are algae and gastropod. Other important skeletal grains include benthic foraminifera such as Miliolids figure (4A). This microfacies is similar to standard microfacies RMF 20 indicating lagoonal environment [8].

Rotalid wackestone

Large Rotalid foraminifera is the major component in this microfacies and it is associated with minor occurrence of echinoderm. The tests of Rotalid can be wholly preserved or fragmented figure (4 B). This microfacies is equivalent to standard microfacies RMF 13, which indicates restricted- or open-marine environment [8].

Packstone Microfacies

This microfacies consist of various skeletal grains that embedded in packstone texture**.** It is subdivided into the following submicrofacies:

Foraminiferal Echinoderm Packstone

Foraminiferal- echinoderm packstone Echinoderm grains are very common in this microfacies, and rimed by syntaxics calcite cement. They are associated with benthic foraminifera, such Orbitoides and Ratalids. Secondary components can include peloids figure (4 C). The abundance of echinoderm suggests the similarity with the standard microfacies RMF 7, and their association with benthic foraminifera indicates open marine e environment [8].

Bioclastic Packstone

It is a grain-supported micorfacies, which is rich in bioclasts such as rudists, echinoderm, shell fragments, and foraminifera. Some bioclasts are difficult to be. Identified due to the effect of micritization or cementation. The packstone texture accomparted, with various bioclasts show the similarity figure (4D).With the standard microfacies RMF 14 indicating open marine environment [8].

Grainstone Microfacies

This particular microfacies is distinguished by the absence of lime mud [7]. It is affected by dissolution and cementation Grainstone microfacies have limited occurrence in Hartha Formation, and its subdivision is based on the occurrence of a single submicrofacies.

Rudist Grainstone

This submicrofacies is mainly composed of rudist bioclasts with limited occurence of peloids. Rudist bioclasts have different sizes, and affected by dissolution and later cementation. The groundmass of this microfacies is characterized by sparite. Rudist grainstone submicrofacies are common figure (4 E). In Cretaceous formations of Iraq and can indicates the deposition in shoal environment [9]. It has similar characteristics to the microfacies RMF 26.

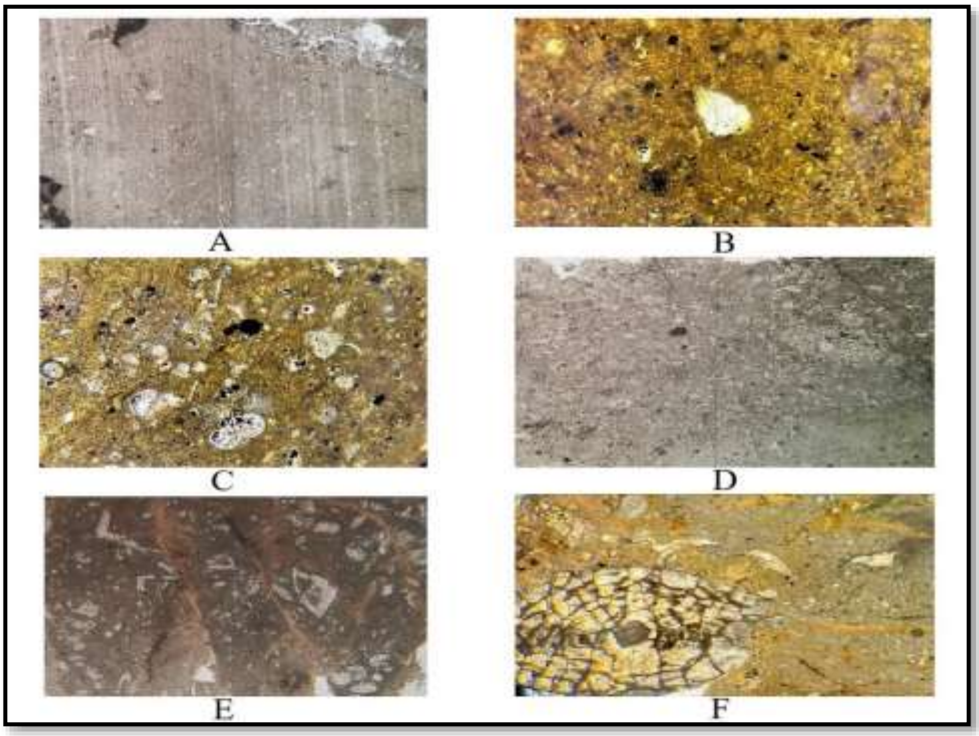

Plate 3: Submicrofacies of Hartha formation**:**

A: Lime mudstone EB 92 \ 1932m. - B: Planktonic foraminiferal mudstone EB 97 \ 2266m.
C: Planktonic Foraminiferal Wackestone EB 97 \ 2266m. - D: Bioclastic Wackestone EB 92 \ 1964m.
E: Foraminiferal-Bioclastic Wackestone EB 97 \ 2206m. - F: Benthic Foraminifreal Wackestone EB 102 \ 1716m.

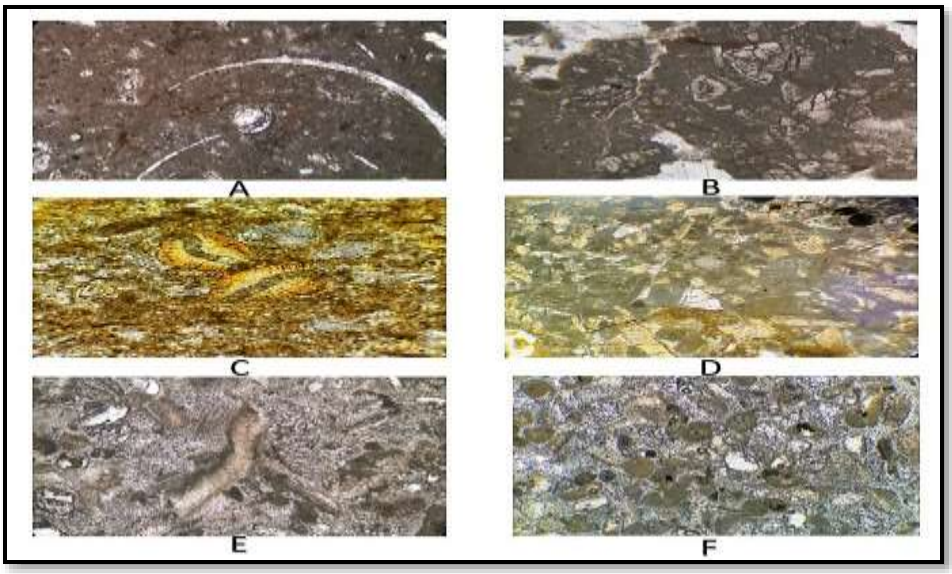

Plate 4: Submicrofacies of Hartha formation:

A: Benthic foraminiferal-bioclastic wackestone EB 97 \ 2079m. - B: Rotalid wackestone EB 92 \ 1898m.
C: Foraminiferal Echinoderm Packstone EB 97 \ 2261m. - D: Bioclastic Packstone EB 97 \ 2264m.
E: Rudist Grainstone EB 97 \ 2025m. - F: Peloids with rudist bioclast EB 97 \ 2025m.

Digenetic processes of Hartha Formation in East Baghdad oilfield

Diagenesis refers to the multitude of processes that occur within sedimentary rocks, resulting in alterations to their size, shape, volume, chemical composition, or crystalline structure subsequent to deposition and preceding metamorphism [10].

Diagenetic processes play a significant role in influencing the properties of oil reservoirs. These processes can either enhance or diminish the reservoir characteristics, making their understanding and evaluation crucial. The Hartha Formation consists of carbonate rocks that have undergone various diagenetic alterations. Several effective diagenetic processes significantly influence the reservoir characteristics of the Hartha Formation.

Dolomitization

Dolomitization is a geological process involving the transformation of limestone or its precursor sediment into dolomite through the replacement of original calcium carbonate

(CaCO3) by magnesium carbonate (MgCO3). This transformation occurs as a result of the interaction with magnesium-rich water over time [7]. The dolomitization observed in this study is characterized by the presence of small dolomite rhombic crystals scattering in lime mud matrix figure (5 A). Therefore, it has limited effect in enhancing porosity.

Cementation

Cementation refers to a chemical diagenetic process where minerals precipitate from saturated solutions within primary or secondary pore spaces [8]. In carbonate rocks, this process involves the filling of pores with carbonate crystals, which serve to bind the loose grains together [11]. Sediment cementation occurs during the early stages of diagenesis, immediately after deposition, and continues throughout the burial and lithification of sediments, extending into the late stages of diagenesis [12]. The cementation process occludes various types of pores, and play a significant role in the diagenetic evolution of Hartha Formation. Two main types of calcite cement are observed and identified in the studied wells. They include:

Granular Cement

Granular cement, characterized by the presence of uniformly sized calcite crystals with minimal development of faceted crystals, figure (5 C), is observed within the vadose and phreatic environments [13]. The granular cement grains typically range in size from 10 to 60 microns [14]. The occurrence of this type of cementation is common in Hartha Formation and it occludes interparticle, moldic and intraskeletal pores in mud- and grain-supported microfacies.

Syntaxial Rim Cement

Syntaxial Rim Cement is a type of cement that can be deposited during early diagenetic processes, either from fresh water in subaerial environments or from marine water. This cement typically forms around echinoderm fragment plates, exhibiting consistent optical properties and continuity [15]. It is commonly observed in limestones that have been formed in marine environments [8]. In the grain-dominated microfacies of the Hartha Formation figure (5 D), SRC plays a significant role in occluding interparticle porosity, contributing to the reduction of pore space within the rock.

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Compaction

Compaction has an impact on reservoir quality, which is more noticeable in muddy facies than grainy facies [16]. Mechanical compaction is resulted from sediment overburdening, and causes porosity reduction, dehydration, and decrease in sediment thickness. Its deformation fabric in Hartha Formation occurs as crushing of coarse skeletal grains, particularly large Orbitoid and Rotalid foraminifera.

Fracturing

Fractures are discrete cracks in rocks caused by stress; they comprise micro-fractures, joints and faults [17]. Veins are fractures filled with calcite or various epigenetic minerals [8] figure (5 B). Calcite veins occur in mud-support microfacies of Hartha Formation cross-cutting skeletal grains and matrix. They have a late diagenetic origin as indicated by their penetration of skeletal grains that are filled with calcite cement.

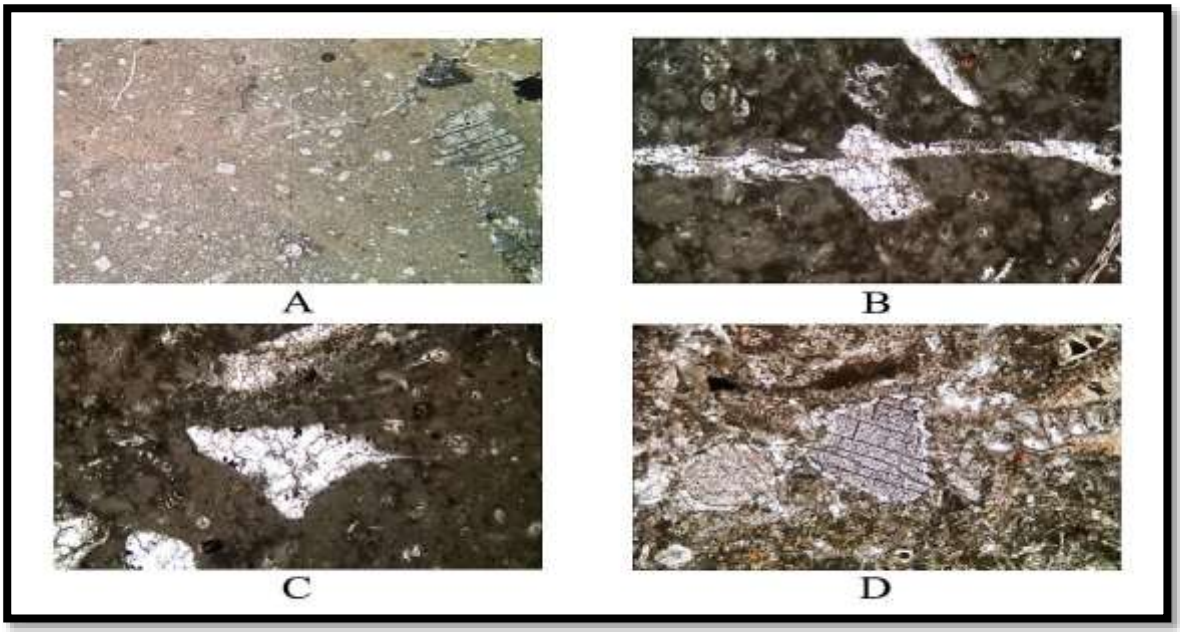

Plate 5: Digenetic processes of Hartha Formation:

A: Dolomite rhombs scattering in lime mud matrix EB92\1964m. - B:Calcite vein cross cut cemented bioclast.EB 97\2079m. - C: Moldic pore filled by granular cementEB 97\2079m. - D: Syntaxial Rim Cement in echinoderm grains EB 97\2261m.

Paleoenvironment of Hartha Formation

Previous studies based on the classification by [8], provided insights into the depositional characteristics of the Hartha Formation. It has been determined that the formation was predominantly deposited within the carbonate ramp setting [18] [19]. According to the previously outlined microfacies and their interpretation, the carbonate rocks of Hartha Formation were deposited in different paleoenvironments and along a ramp setting. This assumption is supported by the occurrence of similar microfacies to RMF2, RMF3. RMF5, RMF7, RMF13, RMF14, RMF20, and RMF26. The paleoenvironments of Hartha Formation in East Baghdad oil field are outer ramp, mid-ramp and inner ramp. In outer ramp environment, low-energy conditions prevailed, promoting the deposition of mud-support micro facies with occurrence of planktonic foraminifera. The transition from outer to mid-ramp is indicated by the increase of shallow marine fauna such as echinoderm and benthic foraminifera as they found in Bioclastic wackestone. Benthic foramini feral wackestone and foraminiferal-bioclastic wackestone microfacies at the inner ramp. Environmentally; high-energy conditions is responsible for the accumulation of rudist and other bioclasts with grainstone, which indicates the effect of wave action [20]. The effect of wave energy. Decreases toward open marine and restricted marine environments where benthic foraminiferal thrive, and be more common in wackstone and packstone microfacies.

Conclusion

This study elucidated the range of microfacies and paleoenvironments that related to the deposition of the Hartha Formation along a carbonate ramp. Based on the findings, it was determined that the depositional environment of the formation corresponds to the mid-ramp to restricted marine. The microfacies variations and diagenetic processes play a crucial role in shaping the reservoir properties. Reservoir properties are increased in packstone and grainstone microfacies, whereas wackestone and mudstone microfacies have lower reservoir properties. Cementation is the most prominent diagenetic process that reduced reservoir properties through occluding pores in mud- and grain-support microfacies.

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