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Microfacies Analysis and Diagenesis Processes of Yamama Formation in Selected Wells of Fihaa Oilfield, Southern Iraq

Ibtehag Hashim Sultan and Salah Ali Hussain*

Department of Petroleum Geology and Minerals–College of Science–University of Diyala

*salahpgm@yahoo.com

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Abstract

This study focused on explaining the carbonate microfacies of Yamama Formation and the impact of diagenesis processes in selected wells of Fiahaa oilfield in south Iraq. The study showed distinctive microfacies that indicate different paleoenvironments. The inner ramp environment is subdivided into shoal, open marine and restricted environments. The shoal environment microfacies include peloid packstone, bioclastic peloidal packstone and benthic foraminiferal peloidal packstone. Restricted marine environment microfacies include grainstone, mudstone, peloidal wackestone -packstone, packstone and lithoclast packstone. Open marine environment microfacies include the foraminiferal packstone and wackestone, bioclastic packstone and coral boundstone. Lagoon marine environment microfacies include bioclastic packstone and algae wackestone. Mid-ramp environment microfacies include foraminiferal peloidal packstone, bioclast packstone, bioclastic foraminiferal wackestone. Outer ramp environment is distinguished by foraminiferal peloid packstone, bioclastic packstone, peloid bioclastic pack stone and peloidal bioclastic wackestone. In the current study Yamama Formation Is affected by diagenetic processes which are classified into two major types: destructive diagenesis processes; such as compaction(chemical and physical in Fh-

2depth 4259m and Fh-2 depth 4054m), chemical dissolution in Fh-1 depth 4141m and Micrtization in Fh-2 depth 4131m,(Pl 2-A) and constructive diagenesis processes including cementation (Blocky in Fh-1depth 4100m, Drusy in Fh-1 depth 4090m, and Syntaxial rim in Fh-1 depth 4040m), Dolomitization in Fh-1 depth 4100m, Fractures in Fh-2 depth 4054m.

Keywords: Yamama Formation, microfacies, diagenesis processes. Faihaa oil field, Foraminifera.

Introduction

Yamama Formation was defined by Steinke and Bramkamp in 1952[11] from outcrops in Saudi Arabia, the Yamama Formation is one of the most significant oil production reservoirs in the Southern Mesopotamian zone. The "Yamama-Sulaiy" Formation was referred to as a 257m interval in Ratawi-1 by [24]. According to [21], the upper 203m of the Yamama Formation consist of 12m of specular and brown detrital limestone with thin shale beds overlain by 191m of micritic and oolitic limestone. The Mesopotamian Zone contains four separate depocentres that are roughly N-S and NW-SE orientated, as well as asmaller depocenter close Kirkuk. In the Euphrates region near Najaf, the formation can reach a thickness of 400 meters, while in southeast Iraq, it can reach a thickness of 360 meters. Several NW-SE trending depocentres have oolitic reservoir units [15]. According to [23], the comparable Minagish Formation in Kuwait was deposited as a transgressive unit in an inner shelf environment. According to [24], the formation is Berriasian-Valanginian in age. The Yamama Formation was formed in alternating habitats of oolitic shoal and deep inner shelf, possibly under the direction of modest structural highs within a carbonate ramp [21] The Formation is a subsurface unit made up of many types of limestone, including argillaceous limestone, fossiliferous limestone, and vuggy limestone. Sulaiy and Ratawi formations can be conformed to by the lower and higher contacts of the Yamama Formation, respectively [2]. Benthic foraminifer's fossils served as the primary source of information for biostratigraphic analyses of the Yamama Formation. Benthic foraminifera was utilized in the current biostratigraphic and age determination.

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Location of the study area

The Faihaa oil field is located in south of Basrah Governorate , in the southern part of Iraq . The east Husynian Iranian Field, west Nahr Umr Field, south Sindibad Field , and north Majnoon Oil Field. It is convex area of (2866 km). Table (1), Figure (1).

Table 1: The geographic coordinates of the studied wells

No	Well name	Coordinate	
		Easting	Northing
1	Faihaa-1	481`3.125״E	30˚56`2.658״N
2	Faihaa-2	48˚1`9.423״E	30˚59`33.036״N
3	Faihaa-3	48˚1`28.53״e	30˚52`44.074״N

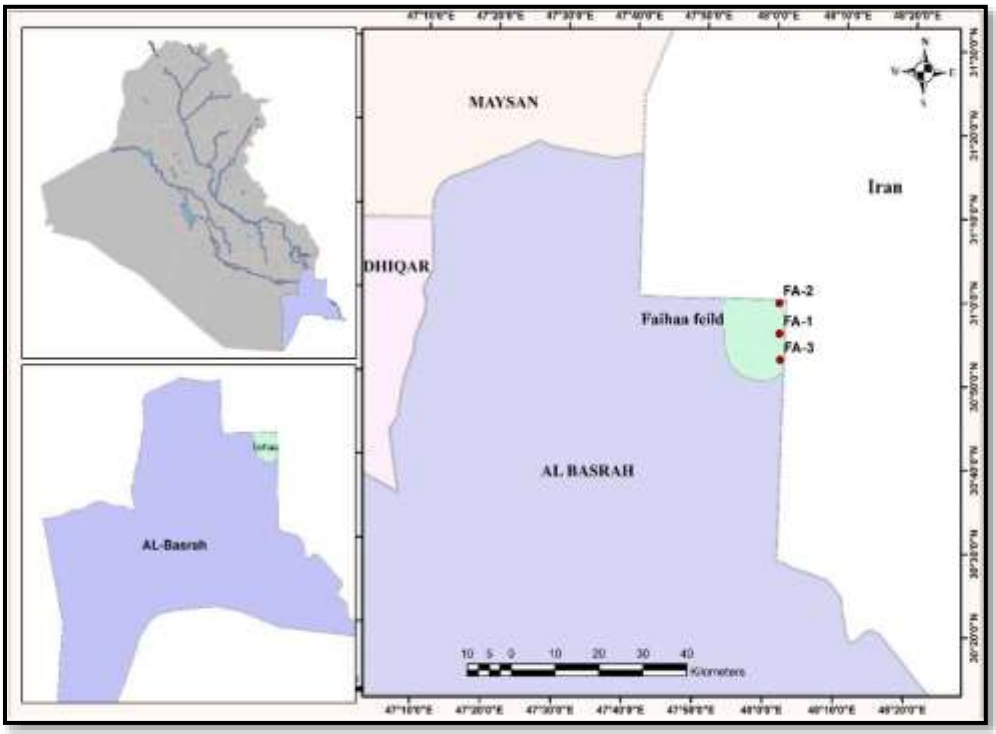

Figure 1: Location of the study area

Tectonic setting

The study area is located in the Zubair subzone of the stable shelf of the Mesopotamian, which represents a part of the south of Iraq. Two faults, one from the Al-batin fault zone and the other from the Najd fault system between the Ramadi-Musaiyib fault zone in the southwest and the Tikrit-Amara fault zone in the northeast, encircle this area. (Fig.2-3). Fig.2 Tectonic map o Iraq

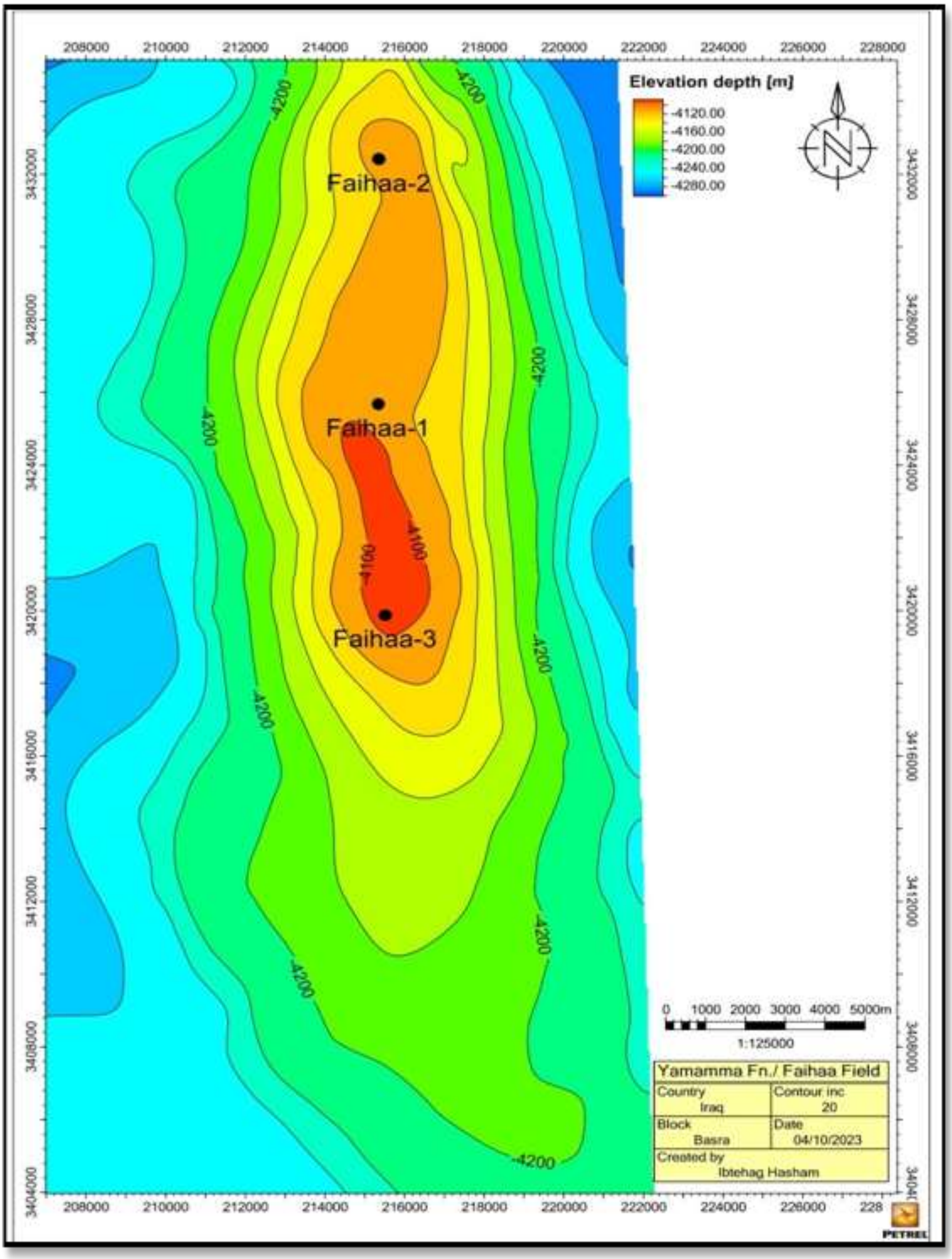

Figure 2: Structural contour map of Yamama Formation of Faihaa oilfield

Previous studies

- Bellen et al. (1959) characterized the combined Yamama/Sulaiy Formation as peloidal limestone underlain by the Ratawi Formation, hypothesized the existence of an unconformity between the early and late Berriassian, and divided the Yamama Formation into six units.

- Burn (1970) The Yamama Formation was studied and given a Valanginian age in well Suba-1.

- Ditmar et al. (1971) Yamama and Ratawi Formation's age was determined to be Tithonian-Late Berriassian.

- Fuloria (1976) Concluded and suggested that, generally, the Garagu zangor Sarmord (including Makhul), Karimia, and Chiagara Formations of the Musayyab-Falluja area correspond to the Upper Yamama, Lower Yamama, Upper Sulaiy, and Lower Sulaiy of the Basra area. He also concluded that all the argillaceous and carbonate rocks in the Yamama section.

- Siddiki (1977) Redescribed the Yamama Formation, and as a result, it was found that the top of Yamama was made of the clean limestone unit that was located underneath the argillaceous Limestone and shale of the Ratawi Formation.

- Buday (1980) According to its fossils, the Zangura Formation (Berriassian-Valanginian) and Garague Formation are thought to be comparable to the Yamama Formation (Late Berriassian – Valanginian).

Materials and Methods

Field work

Two stages comprise the field work: the first involves gathering basic information about the oil wells from the final geological reports and the structural map of the Yamama Formation in the Faihaa Oilfield; the second involves gathering thin sections from each well, provided by the Ministry of Oil's Department of Laboratories and Oil Exploration Company, and transferring these thin sections to the University of Diyala's Department of Petroleum Geology and Minerals laboratory to study and take pictures of the fossils and microfacies with their diagenesis processes.

Laboratory work

A thorough diagnosis of thin sections is made, with an emphasis on the relationships between the background (micrite or microspar) and the skeletal and non-skeletal (peloids or intraclast) grains. This allows for the discrimination of all standard microfacies using the classification of carbonate rocks [22] and the proposal of the paleo-depositional environment using [26] and [27]. The steps of diagenesis are thoroughly examined and categorized in accordance with [9,10,4,27]. Depending on how these operations affect the texture of the rock after deposition, these processes are divided into constructive and destructive categories. Each category includes a variety of processes like cementation, dissolution, dolomitization, and physical and chemical compaction. The diagenetic processes and all microfacies are covered in detail

Results and Discussions

The following conclusions were reached by interpreting the paleo environment in which the Yamama Formation was deposited and evaluating the diagenetic processes that regulate the reservoir properties:

Microfacies

According to [17], a microfacies is "a body of rock characterized by a particular combination of lithology, physical, and biological structures that bestow an aspect (facies) different from the body of rock above, below, and laterally adjacent." Previous research in southern Iraq pointed to the ramp model as a potential depositional environment for the Yamama Formation. As a result, this study uses the homoclinal ramp setting. According to [22], the depositional textures of the microfacies of the Yamama Formation are categorized. The limestone of Yamama Formation has been systematically classified into five distinctive microfacies: Mud stone, wackestone, packstone, grainstone and boundstone, Figure (3,4,5,6).

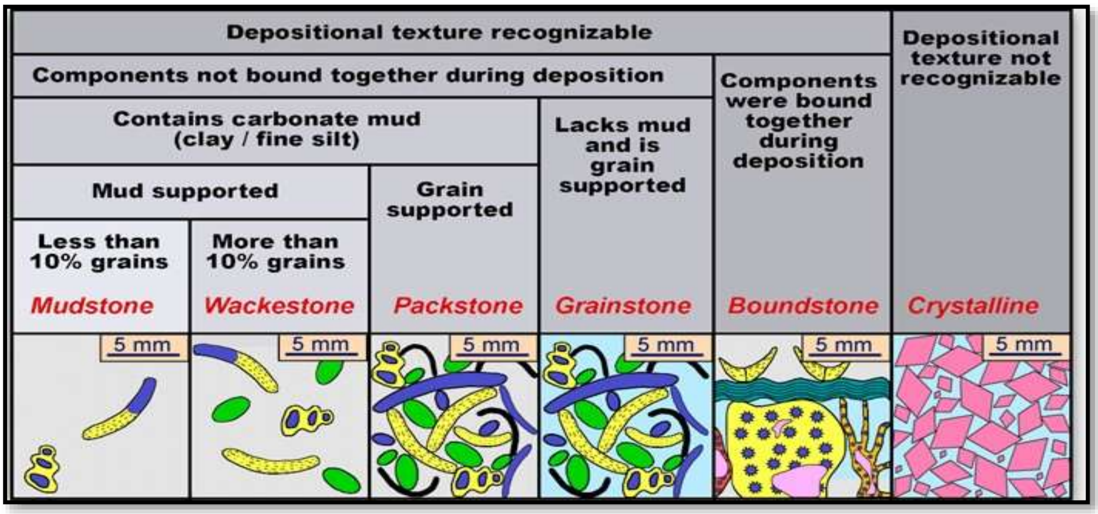

Figure 3: Dunham´s classification [22]for carbonate rocks.

1. **Mudstone**

Mudstone identical facies (SMF 3) located within zone (FZ-1) were found when this microfacies indicator—which indicates that the deposition occurred in quiet water and prevented the organisms from accumulating and produced from neomorphisum processes was compared to standard microfacies proposed by [26]. The two types of mudstone microfacies are lime Mudstone is mostly black, containing large volumes of siltstone and shale, and is distinguished by the presence of just micritic matrix rather than any fossils, and fossiliferous lime mudstone is distinguished by having fewer than 10% fossils in Fh-1 depth 4320m, (Pl 1-A).

2. **Wackestone to Peloid packstone**

Carbonate rock supported by mud that has more than 10% of grains [22]. Generally denotes a low-energy depositional situation with calm water and a restriction of organisms that produce grain. When grains are abnormally big, these carbonates were identified by [5] muddy carbonate rock supported by grains [22], in Fh-3 depth 4016 m, (Pl 1-D)

3. **Lithoclast packstone**

According to [11], this Yamama Formation microfacies has been characterized as fragmented limestone. There is a detrital limestone zone in the Formation, according to several researchers

[3,5]. There are differences in the sizes and shapes of these microfacies; some of the lithoclasts are actual interclasts and comprise typical Yamama lithologies, in Fh-1 depth 4028m, (Pl 1-B).

4. **Bioclastic wackestone**

This microfacies is made up of fragments of algae, mollusks, as well as a variety of lithoclasts that vary in size and shape. This mixture of organisms indicates an open marine environment without reefs or anything restricted to water circulation. From high-energy to low-energy environments, the particles have been moved. There is an open sea shelf (FZ 7) and a shelf lagoon with open circulation (FZ 2) that occurs. Often seen in mid - and inner-ramp environments [25], in Fh-1 depth 4028m, (Pl 1-C).

5. **Foraminiferal, wackestone to packstone**

High compaction is a defining characteristic of this microfacies, which can also often contain fragments of shell and algae. Large foraminifera thrive in shallow, normal marine environments, and in the case of a reef area, this facies may imply a transgression system tract [21], foraminiferal bioclastic wackestone [28] report that these microfacies are widely distributed and common in the majority of the wells under study, in Fh-2 depth 4139m, (Pl 1-G).

6. **Peloidal bioclastic packstone**

Because of the strong wave energy, these microfacies are distinguished by the excellent stored. Two methods are proposed to explain the genesis of these grains based on the diverse sizes, shapes, and sorts of peloids. The pellets developed in a protected setting with little energy [21]. It might correspond to Wilson's standard Microfacies Types (SMF 17) and (FZ 8) based on comparison with other microfacies within SMF 15 zone (FZ 6). [25] classification of standard facies zones indicates an inner ramp setting with restricted water circulation, in Fh-2 depth 4347m, (Pl 1-E).

7. **Grainstone**

According to Dunham's first definition, grainstone had to have less than 1% mud to fine-silt grade (<20 μm) sediment in it. The maximum quantity of carbonate mud that could be present

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in a grainstone was eliminated by [28]. Considering that grainstone facies are thought to have been formed in high-energy environments, it makes sense to exclude primary carbonate mud from this category, in Fh-3 depth 4023m (Pl 1-F).

8. Coral Boundstone

Good storage owing to high wave energy is what distinguishes these microfacies. There are two proposed methods for the genesis of these grains, based on the varying sizes, shapes, and sorts of peloids. According to [21], the pellets developed in a low-energy protected setting. Classification of standard facies zones [25], which denotes an inner ramp setting with restricted water circulation, suggests that the microfacies within SMF 15 zone (FZ 6) may correspond to Wilson's standard Microfacies Types (SMF 17) and (FZ 8),in Fh-2 depth 4076 m, (PL1-H).

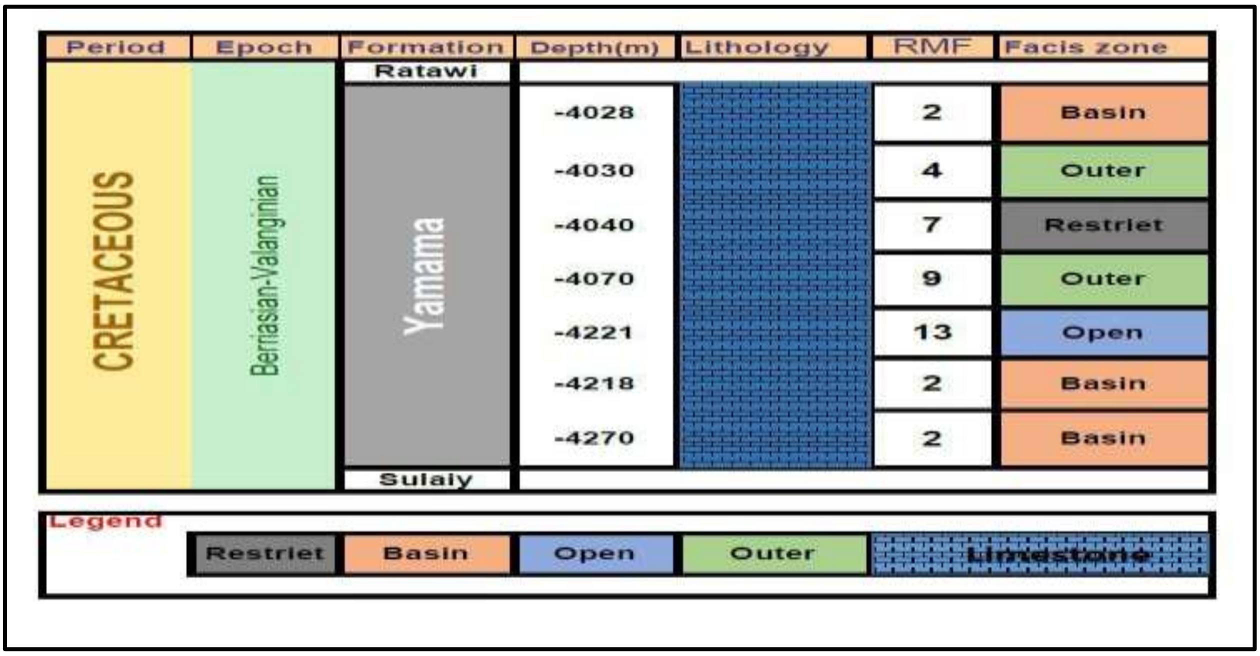

Figure 4: Microfacies description and paleoenvironment of Yamama Formation at well Fh-1

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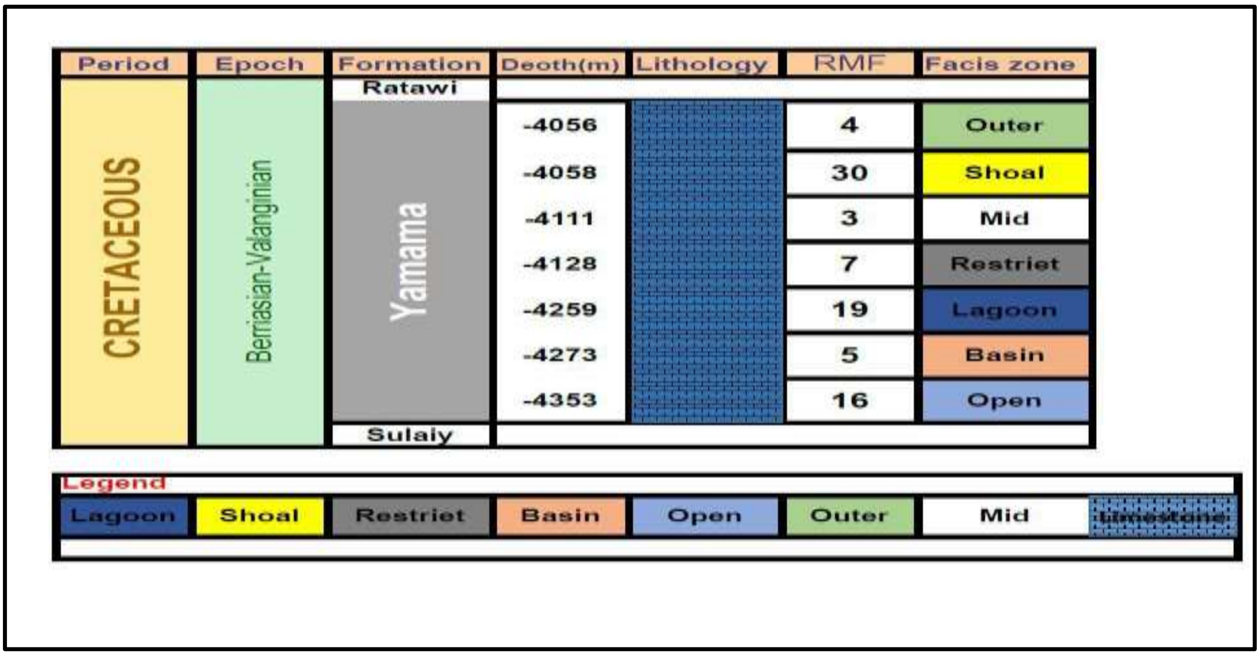

Figure 5: Microfacies description and paleoenvironment of Yamama Formation at well Fh-2

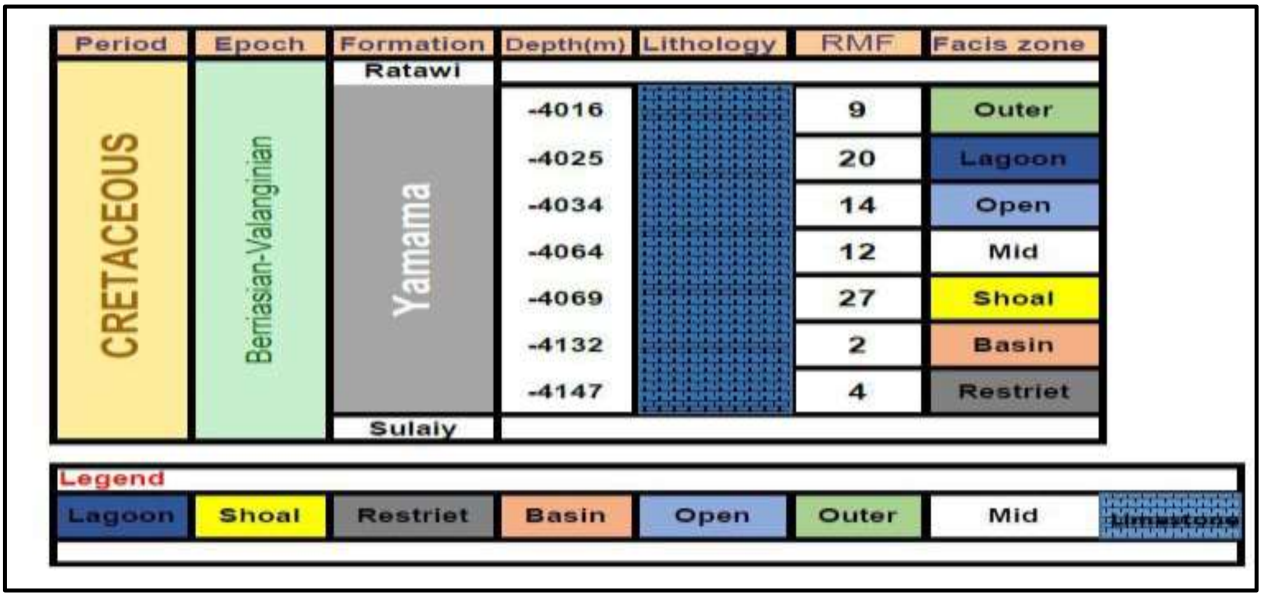

Figure 6: Microfacies description and paleoenvironment of Yamama Formation at well Fh-3

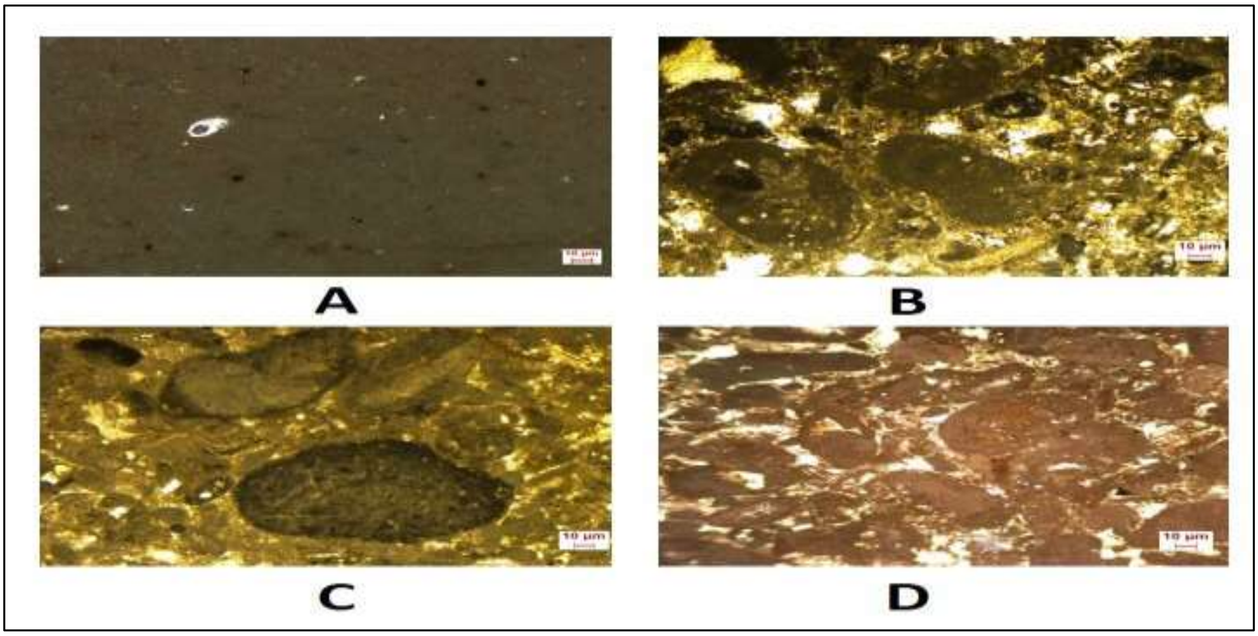

Plate 1: Microfacies of Yamama Formation.

Plate 1 :A: mudstone Fh-1 4320,B: lithoclast packstone Fh-1 4197,C: bioclast wackestoneFh-1 4028m,D: Wackestone to Peloid packstone 4016 in Fh-3

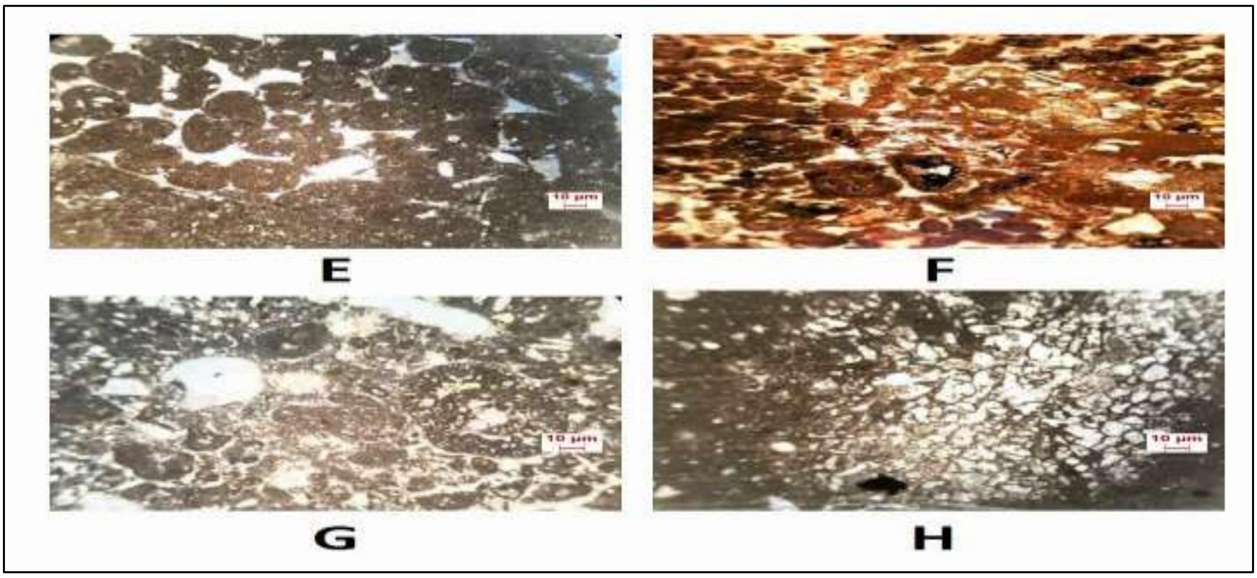

Plate1 E: peloid bioclast packstone Fh-2 4347m,**F**: Grinstone Fh-3 4023m,**G**: ForaminiferalPackstone to wackestone Fh-2 4139m ,**H**: Coral BoundstoneFh-2 4076m.

Diagenetic processes

Everything that occurs to sedimentary rocks that changes them into consolidated rock, such as cementation, compaction, recrystallization, and changes in the sediments during the time between deposition and metamorphism, as well as possible replacements like dolomite development [27].The diagenetic processes in Yamama Formation are classified into two major types:

Destructive diagenesis processes:

Destructive diagenesis processes occur without changing the chemical or mineralogical composition of the sediment and are represented by turbidity processes. Compaction, Chemical Dissolution, and Micritization.

1. **Micritization**

The term was coined by [16] micrite to describe syngenetic and early diagenetic changes affecting modern skeletal grains. It is a thin non-laminated coating of very fine micrite form that is formed around carbonate grains, skeletal grains, or ooids. The thickness of the micrite envelopes surrounding the grains varies between a few m and 500 m [27]. Longman [7] considers this process to be the earliest diagenetic process that forms in stagnant - quiet water environments, in Fh-2 depth 4131m, (Pl 2-A).

2. **Dissolution**

After mineral stabilization, dissolution can occur at any point in the carbonate sequence's burial history [8]. When the rock water system is out of (equilibrium), dissolution occurs, and the water is (under saturated) with respect to CaCO3. For example, meteoric water dissolves CaCO3 until water and rocks reach saturation equilibrium [27]. Non-fabric-selective dissolution will generally be observed, with the resulting pores cutting across all fabric elements such as grains, matrix, and cement [27].The effects of dissolution appear as vuggy pores and molding in Yamama Formation microfacies,in Fh-1 depth 4141m,(Pl 2-B).

3. **Compaction**

The diagenetic process of compaction takes place in the later stages of sedimentary evolution. It entails the mechanical forces that reduce the total volume of sediment, causing distortion and rearrangement of sedimentary components [15].Through agglutination, grain rearrangement, and reorientation, this process reduces the volume of grain particles. The loss of porosity and thinning of sedimentary beds are effects of compaction. Compaction in carbonate sediments can cause a loss of porosity of 50–60% of the original pore volume and a reduction in depositional thickness of up to 50% [12]. To understand the effects on the formation, the chemical and physical processes connected with sedimentation will be examined.

4. Physical compaction

The following characteristics serve as a representation of physical compaction in the present study Physical compaction is the process by which grains are broken and distorted under the influence of weight or external pressure. Micro-fractures are frequently seen as strong proof and indicators of physical:

5. Fractures

This porosity could be caused by a wide range of events and elements. Compressional anticlines and the tension of compactional drapes above their crests are two mechanisms by which tectonic movement can produce crack porosity. Additionally, there is a close connection between faulting and fracture porosity, and certain oil fields have very strong structural ties to particular fault systems [10], in Fh-2 depth 4054m, (Pl 2-C).

6. Chemical compaction

Stylolites and seams that dissolve under pressure are two distinguishing characteristics of this microfacies. When carbonate rocks dissolve along specific surfaces as a result of overburden or tectonic stress, this is referred to as chemical compaction. According to [20], stylolites are more frequently found in mud-supported rocks than in grainstones and packstones. The depth of burial, the stability of the minerals, the abundance of clay minerals, the composition of the water, the amount of organic matter, and the temperature all have an impact on the chemical compaction process [19]. All of these elements work together to contribute to the chemical compaction process in the investigated microfacies.

7. Stylolite

In limestone (or sandstone), stylolites are thin seams of clay and insoluble material that typically run parallel to bedding. They result from pressure solution, dissolution of limestone along

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planes as a result of overburden or tectonic pressure, and some are frequently sutured while others are less so [14],in Fh-2 depth 4259m, (Pl 2-D).

Constructive diagenesis processes:

There are two types of constructive transformational processes:

- **Cementation**

Defined as the process of space-filling crystal precipitation. Although other minerals such as evaporates and quartz occur locally, cement in carbonate sediments is made up of carbonates. Carbonates cement can form in a variety of environments [18]. Processes that cause mineral precipitation in primary or secondary pores necessitate pore fluid super saturation with respect to the mineral. Cement can be siliceous, calcitic, dolomitic, anhydritic, halitic, hematitic, or pyritic, according to [13].

Yamama was affected by this diagnostic process. Formation, in general, cementation leads to the overall deterioration of petrophysical properties because of its distinctive effect on it that causes destruction and reduces the porosities. The types of cement recognized are as follows:

1. **Blocky Cement**

Granular cement is explained by subhedral or anhedral calcite crystals with a preferred crystal orientation. Granular cement, by filling intergranular pores, fractures, and vuggys, occludes porosity in some grain-supported and mud-supported microfacies. The large size and appearance of the crystals are due to slow crystallization in saturated solution at late stages of the diagenetic history [7], in Fh-1 depth 4100m, (Pl 2-E).

2. **Drusy Cement**

Cement for void filling and pore lining in intergranular and intraskeletal pores, molds, and fractures, with equant to elongated, anhedral to subhedral calcite crystals. Size is usually greater than 10 pm. The size of the void increases toward the center. Displays a distinctive fabric. Both near-surface meteoric and burial environments were described by [25]. Drusy cement is found primarily in Algal, in Fh-1 depth 4090m, (Pl 2-F).

3. **Syntaxial rim cement**

This type of cement forms as a thin clear rim around echinoderm plates. It is very common in Yamama Formation packstone and grainstone microfacies where interparticle pores are filled

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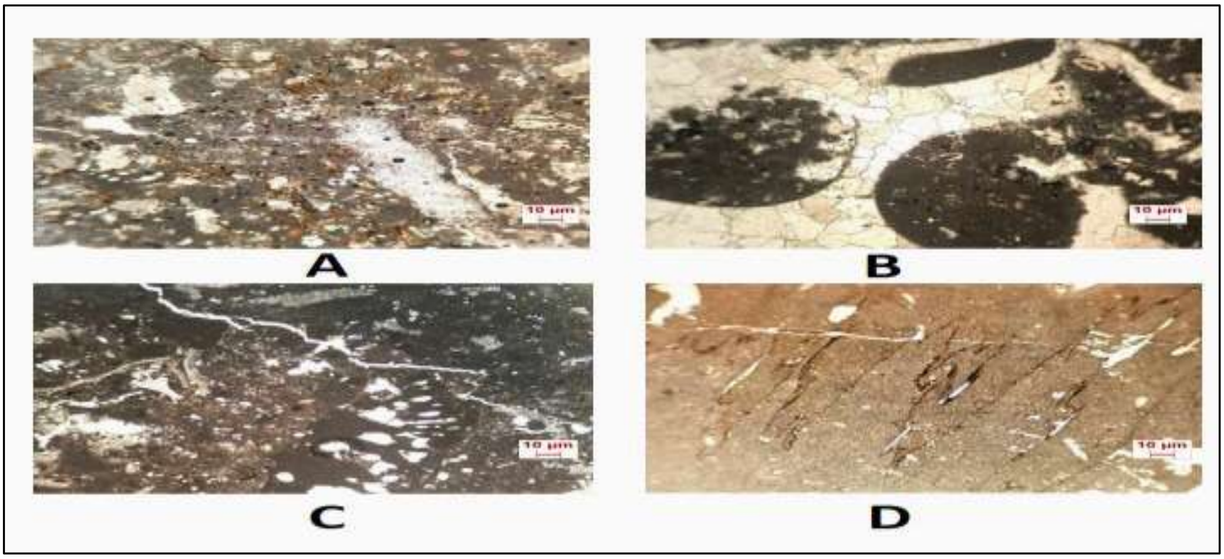
with cement. These crystals are made of aragonite or calcite, and they have an early diagenetic origin, indicating early fresh water phreatic cement [27], in Fh-1 depth 4040m, (Pl 2-G).

- **Dolomitization**

Dolomitization is the process by which limestone or its precursor sediments are completely or partially converted to dolomite by replacing original $CaCO_3$ with magnesium carbonate via the action of Mg bearing water. Porosity increases gradually in the early stages of dolomitization of limestones, but rapidly increases with increasing amounts of dolomite. At this stage, the dolomite has a sucrosic texture composed of equally-sized rhombohedra with intercrystalline porosity caused by associate calcite dissolution [25].

Has an impact on the Yamama Formation; at some intervals, the Dolomitization process attacks limestone, partially forming dolomitic limestone with the original depositional texture preserved,in Fh-1 depth 4100m, (Pl 2-H).



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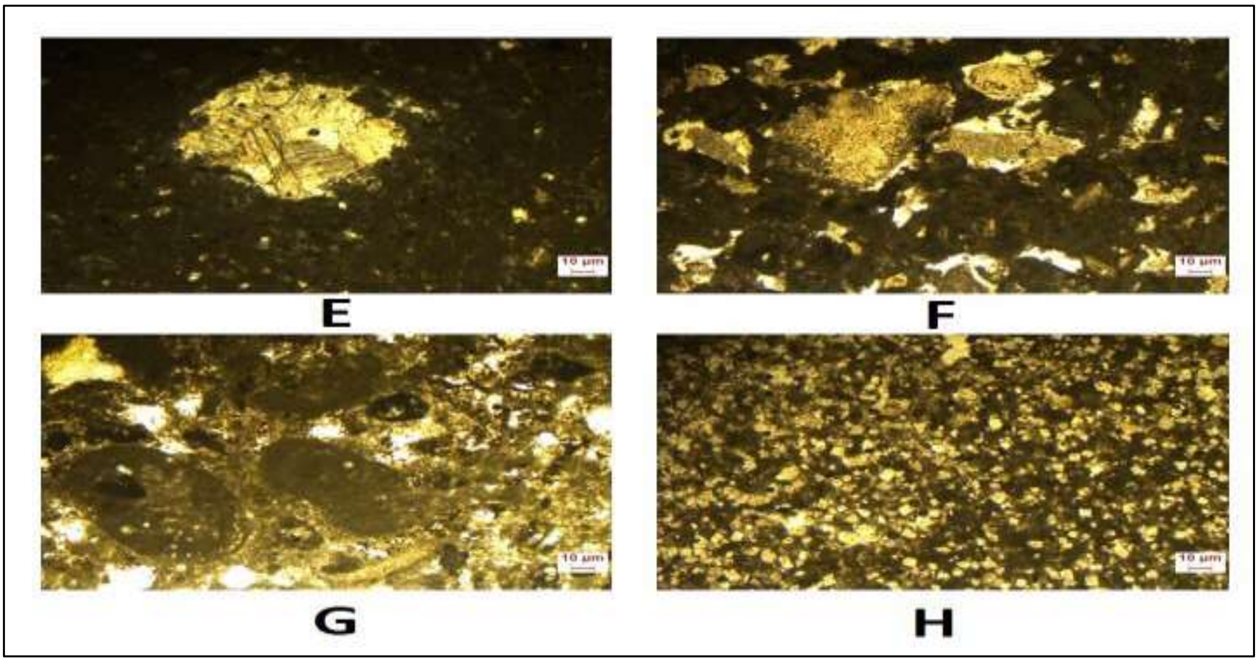

Plate 2: Diagenesis process of Yamama Formation

Plate 2-A: Micritization Fh-2 4131, **B: Dissolution** Fh-1 4141, **C: Fractures** Fh-2 4054, **D: Stylolite** Fh-2 4259**, E: Blocky Cement** Fh-1 4100**, F: Drusy cement** Fh-1 4090, **G: Syntaxial rim cement** Fh-1 4040, **H: dolomatization** Fh-1 4100.

Conclusions

1. Microfacies and Facies associations Foraminiferal wackestone to packstone, bioclastic packstone, peloidal bioclastic packstone, algal boundstone, packstone and wackestone, Grainstone and mudstone. The Facies associations mid ramp, Open Marine, Outer ramp, Restricted, Basin, and Shoal.
2. The diagenetic processes are classified into two major types; Destructive diagenesis processes: compaction (both physical and chemical), chemical dissolution and micritization, and Constructive diagenesis processes: cementation (blocky, drusy, syntaxial rim) and Dolomitization.

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