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Microfacies Analysis and Diagenesis Processes Development for Khasib Formation of East Baghdad Oil field, Iraq

Israa Qasem Hussain Tukkee, Salah Ali Hussain and Abdalratha Mohammed Sahaab

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

salahpgm@yahoo.com

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Abstract

Khasib Formation was studied in East Baghdad oilfield, Al-Rashdiya area in Baghdad Governorate. The lithology of the formation is limestone throughout the whole sequence in all studied wells (EB-83, EB-87, EB-92, and B94). It is bounded conformably from the top with Tanuma Formation and lower contact with Kifl Formation. The petrographic study shows three main microfacies (lime mudstone, non-laminated peloidal pack-grainstone, and laminated peloidal grainstone) and two submicrofacies (homogeneous non-fossiliferous lime mudstone, bioclast lime mudstone) the study shows the abundance of non-skeletal agains skeletal grains. All microfacies indicate facies zone (7, 8, and 9A) which reflect the platform interior between the open marine to the restricted and evaporitic or brackish water depositional environment. Several diagenesis processes have been distinguished that affected the texture and porosity of Khasib Formation, the most important of which were dissolution, cementation, dolomitization, compaction, micritization, and the porosity of a non-fabric selective type.

Keywords: Khasib Formation, East Baghdad oilfield, Microfacies, Diagenesis processes.

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التحليل السحني الدقيق وتطور العمليات التحويرية لتكوين الخصيب في حقل شرق بغداد النفطي، العراق

اسراء قاسم حسين تكي، صلاح علي حسين وعبد الرضا محمد سحاب

قسم جيولوجيا النفط والمعادن – كلية العلوم – جامعة ديالى

الخلاصة

تمت دراسة تكوين الخصيب في حقل شرق بغداد النفطي، منطقة الراشدية، محافظة بغداد. صخارية التكوين هي الحجر الجيري في جميع التتابعات العائدة للابار (EB-83, EB-87, EB-92, EB-94). يحده من الاعلى تكوين تنومة ويكون بحد توافقي معه، كذلك فان الحد الاسفل للتكوين يكون متوافقا مع تكوين الكفل. وبينت الدراسة الصخرية وجود ثلاثة انواع رئيسية من السحنات الدقيقة هي (الحجري الجيري الطيني، حجر المرصوص- الحبيبي، الحجر الحبيبي الحاوي على الدمالق) وسحنتين ثانويتين هما (الحجري الجيري الطيني المتجانس عديم المتحجرات والحجر الجيري الطيني ذو الفتات الاحيائي) اظهرت الدراسة سيادة المكونات غير الهيكلية على حساب المكونات الهيكلية. تشير جميع السحنات الدقيقة للانطقة السحنية (7, 8 و9) والتي تعكس بيئة ترسيبية محصورة المياه الخليطة وبيئة المتبخرات الى المنطقة المحصورة ضمن البيئة البحرية المفتوحة. تم تمييز عدد من العمليات التحويرية التي اثرت على نسيج ومسامية تكوين الخصيب التي كانت اهمها: الاذابة، السمنتة، الدلمتة، الانضغاط، المكرتة، ومسامية نوعها مسامية غير انتقائية النسيج.

الكلمات المفتاحية: تكوين الخصيب، حقل شرق بغداد النفطي، السحنات الدقيقة، العمليات التحويرية.

Introduction

Khasib Formation was first introduced by Owen and Naser (1958) in well Al-Zubair-3, which is located between the excavated depths (2146.3- 2196.3 m) and the thickness of 50 m. The upper part of 29 m is of dark fine-grained marly limestone, and the lower part of 21 m alternates dark and greenish shale and dark limestone (as in the upper part). In terms of fossils, the content includes *Globigerina* sp., *Gumbelina* spp., and *Oligostegina*. The age of the formation is Turonian – E. Campanian. Underlying Khasib Formation is Mishrif or Kifl Formation with disconformable boundary, between oligosteginal shale above and limonitic limestones with Charophyta below. The overlying formation is Tanuma Formation with a conformable boundary, in a change of black, fissile shales above to grey marly limestones below (Rabanit & Dunnington, 1952; in Bellen, 1959).

Aims of the study

1. Microfacies analysis of carbonate rock for Formation.
2. Paleoenvironment reconstruction.
3. Estimation of diagenesis processes that affects reservoir characteristics.

Location of the study area

The study area is located in the east Baghdad oil field. Its location in the Al-Rashdiya area in Baghdad governorate, the area for the east Baghdad field covers the portion north-west of Diyala River (Figure 1). As shown in (Figure 1), four wells were selected in the East Baghdad Oil Field / Midline Oil Company, (EB-83, EB-87, EB-92, and EB-94) as shown in (Figure 1). Table (1) shows the coordinates of the selected wells. The selected study wells from the East Baghdad oil field are located on an extended anticline fold structure NW-SE in the following order (EB-87, EB-92, EB-83, and EB-94)) as shown in the contour map in (Figure 2).

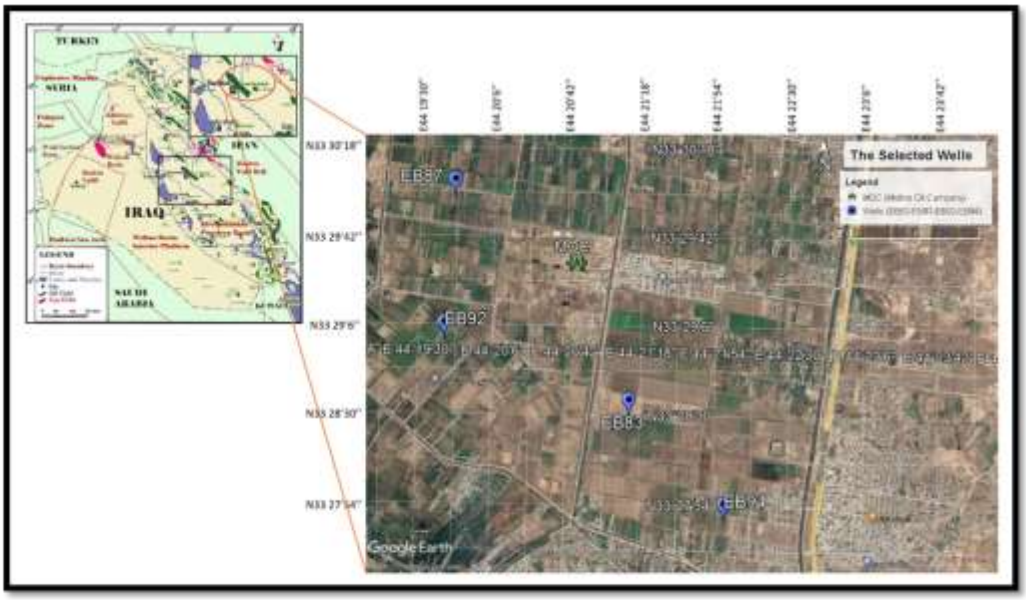


Figure 1: Satellite image of the study area.

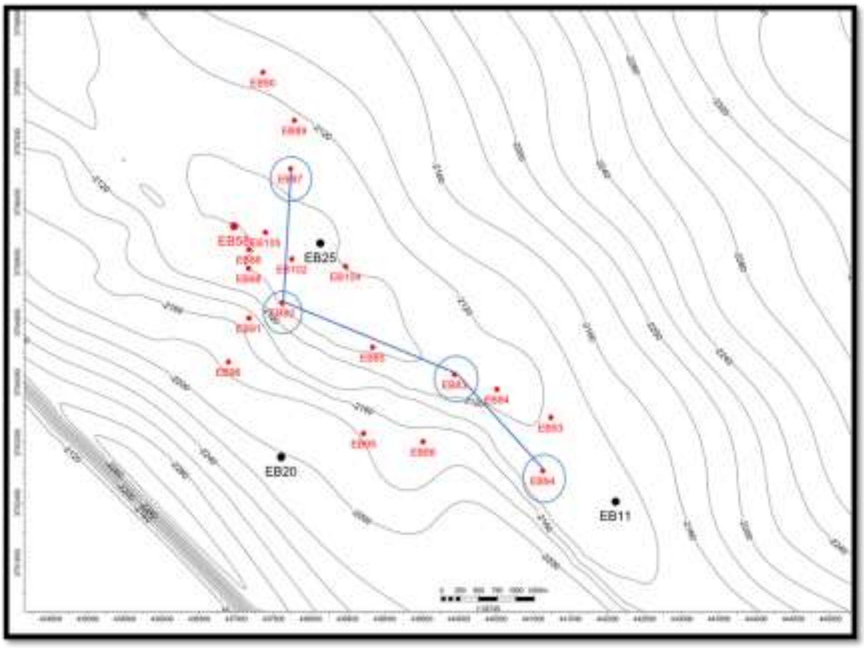


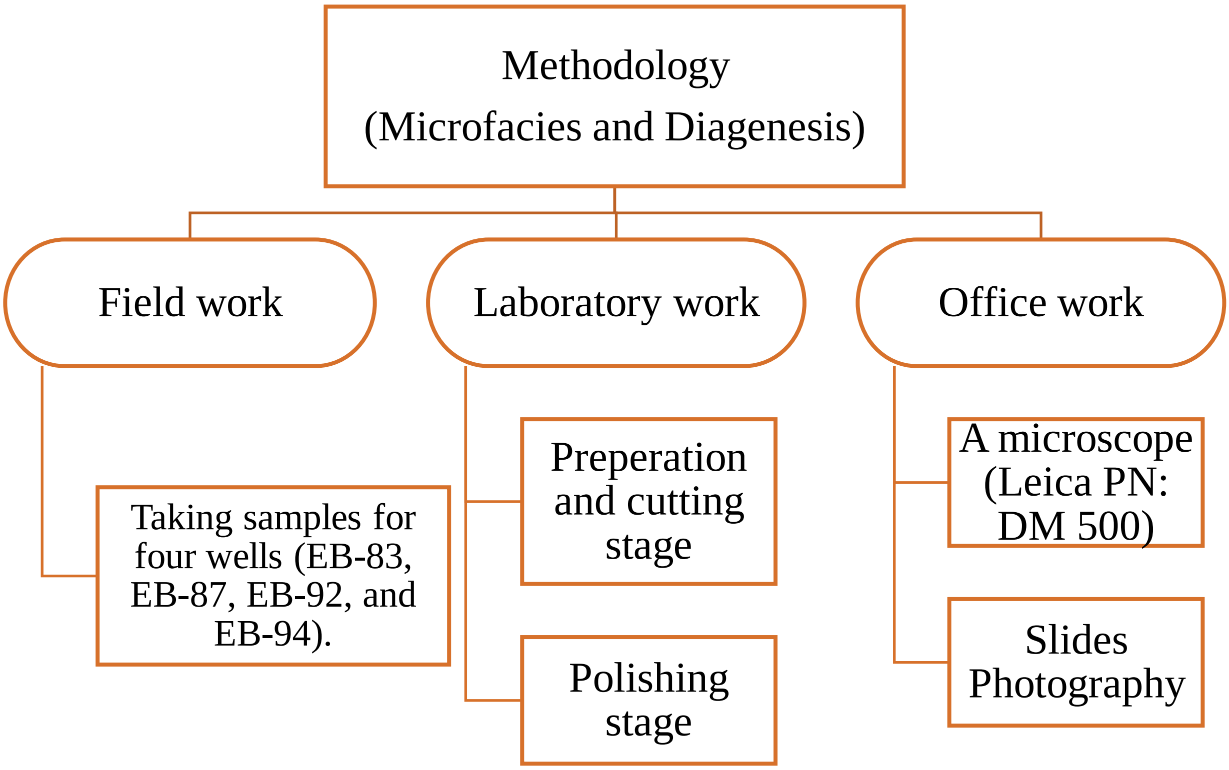
Figure 2: Contour map of the selected wells, the Khasib formation (from the Midline Oil Company).

Table 1: The coordinates of the study wells with the upper limit and the thickness of Khasib Formation.

Well NO.	Depth (m)	Thickness (m)	X	Y
EB-83	(2148_ 2252.5)	104.5	33 28’ 29.25’’	44 21’ 12.86’’
EB-87	(2151.39_ 2253.15)	101.76	33 29’ 57.78’’	44 19’ 46.69”
EB-92	(2139.5_ 2241.17)	101.67	33 28’ 59.78’’	44 19’ 42.74”
EB-94	(2165.49_ 2264.5)	99.01	33 27’ 47.86’’	44 21’ 59.27’’

Materials & Methods

Forty-nine samples of cutting were taken from four oil wells, these are: EB-83, EB-87, EB-92, and EB-94 in the East Baghdad Oilfield. Forty-nine slides were prepared in the workshop of the Department of Petroleum Geology and Minerals, College of Science, University of Diyala. Petrographic study including microscopic examination of thin sections under microscope type Leica PN: DM 500, to determine the petrographic characteristics, fossils content, and Diagenesis processes. A flowchart (1) will be explain the steps of methodology adopted in this study.



Flowchart 1: Microfacies and Diagenesis processes methodology.

Results

Microfacies

The facies characterized by (Boggs, 2006) is rock masses that have specific facies reflect the conditions under which they were framed. It is described by exceptional parts of the rocky, physical, and biological structures that give it a shape (facies) that varies from the encompassing rocks. In the classification of (Dunham, 1962) (Figure 3), three main facies were identified, represented by mudstone microfacies, pack-grainstone microfacies, and grainstone microfacies. Also, the mudstone facies were divided into two minor facies based on their petrographic components. The lithology, standard microfacies SMF, facies zone FZ, and environment of deposition of studied samples, are shown in (Figures 4, 5, 6, and 7).

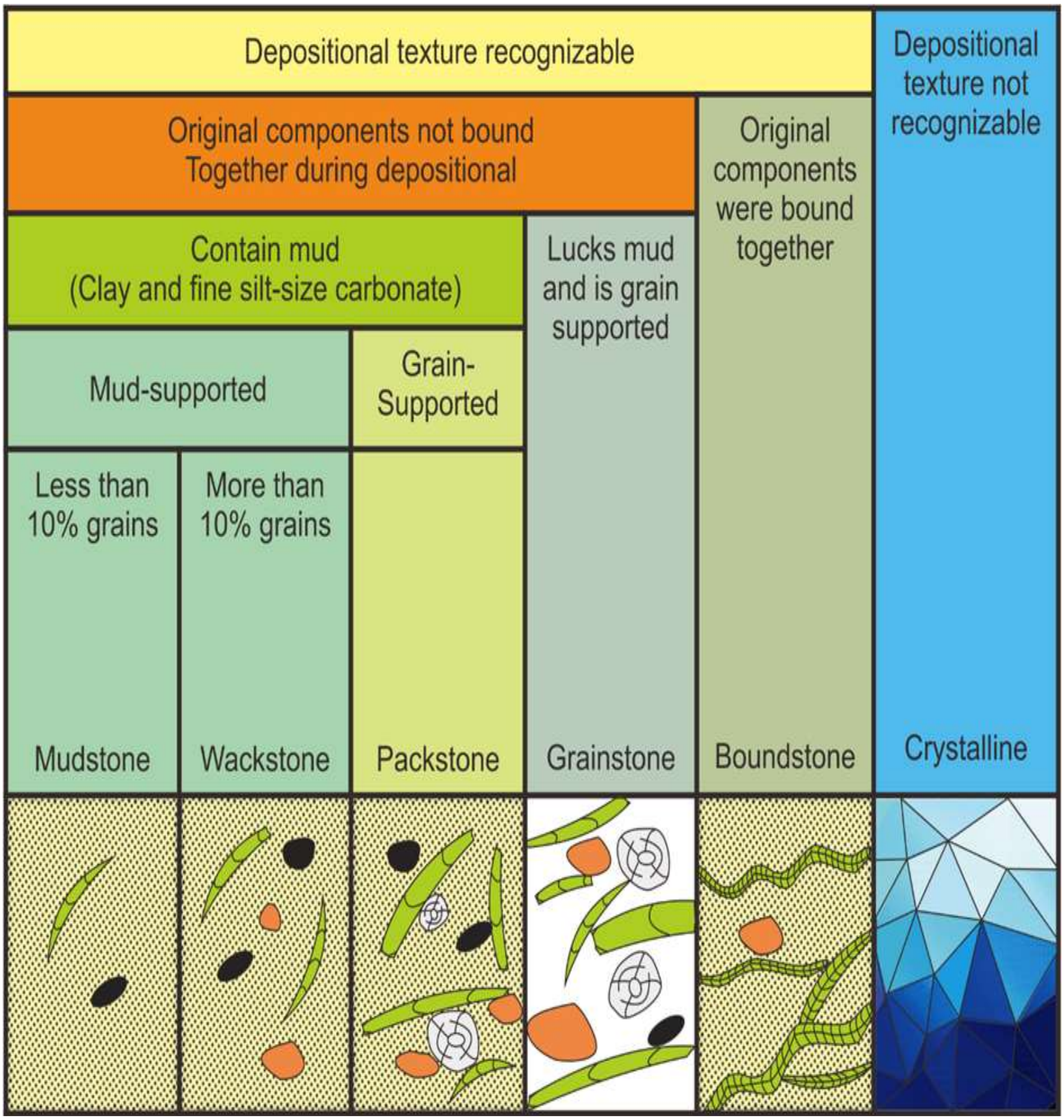


Figure 3: Classification of carbonate rocks (Dunham, 1962).

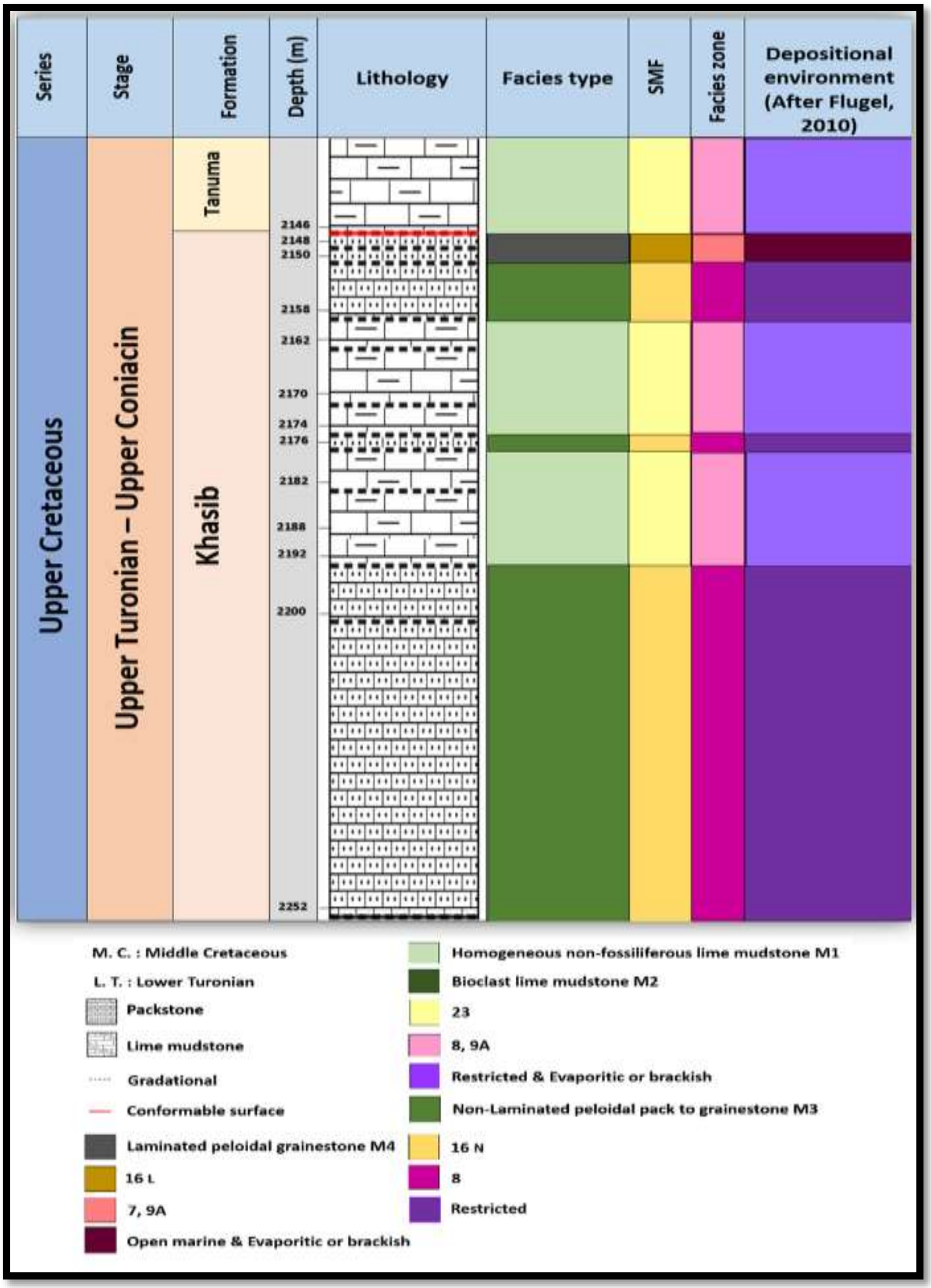


Figure 4: Shows the lithology, standard microfacies SMF, facies zone FZ, and depositional environment of well **EB-83**.

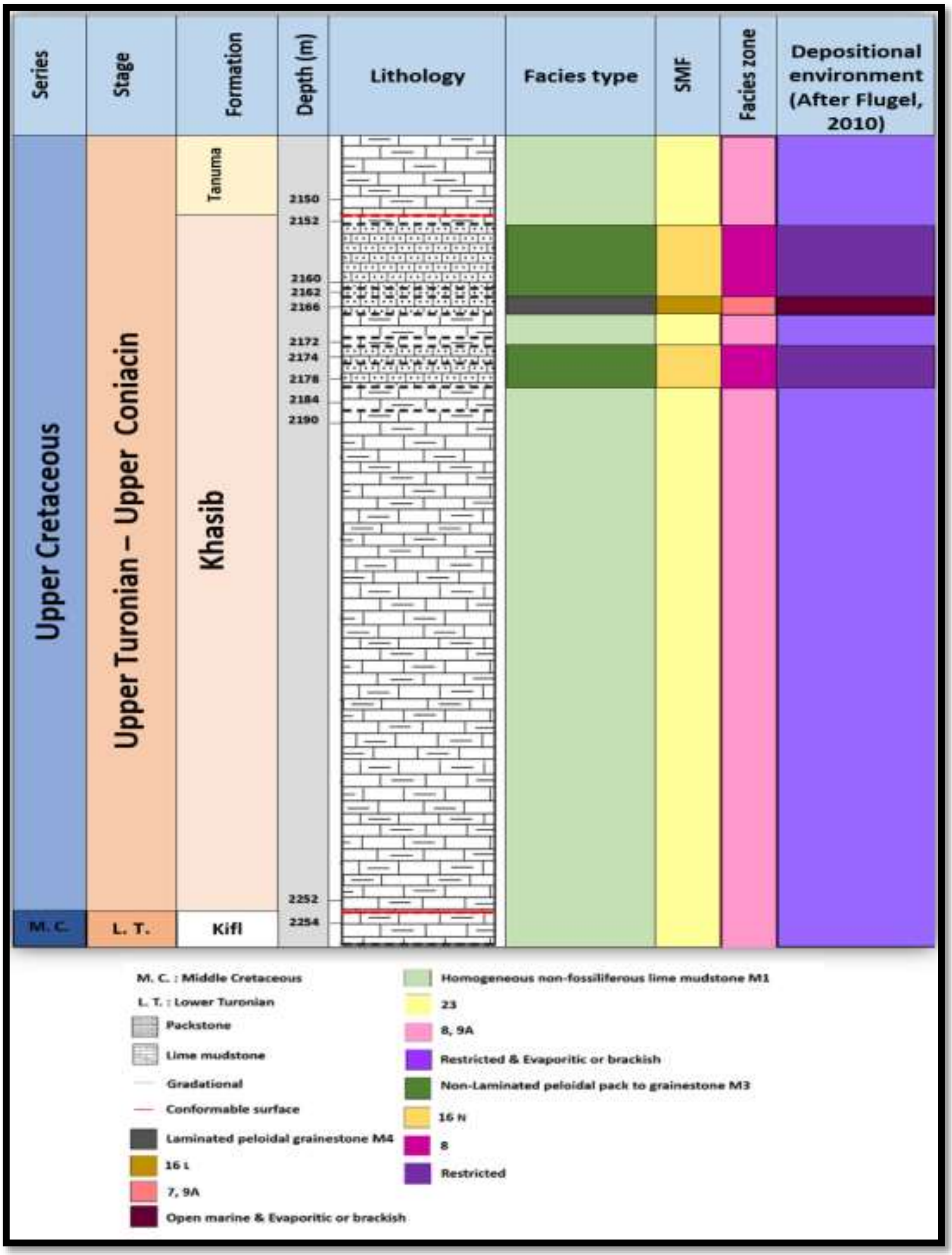


Figure 5: Shows the lithology, standard microfacies SMF, facies zone FZ, and depositional environment of well **EB-87**.

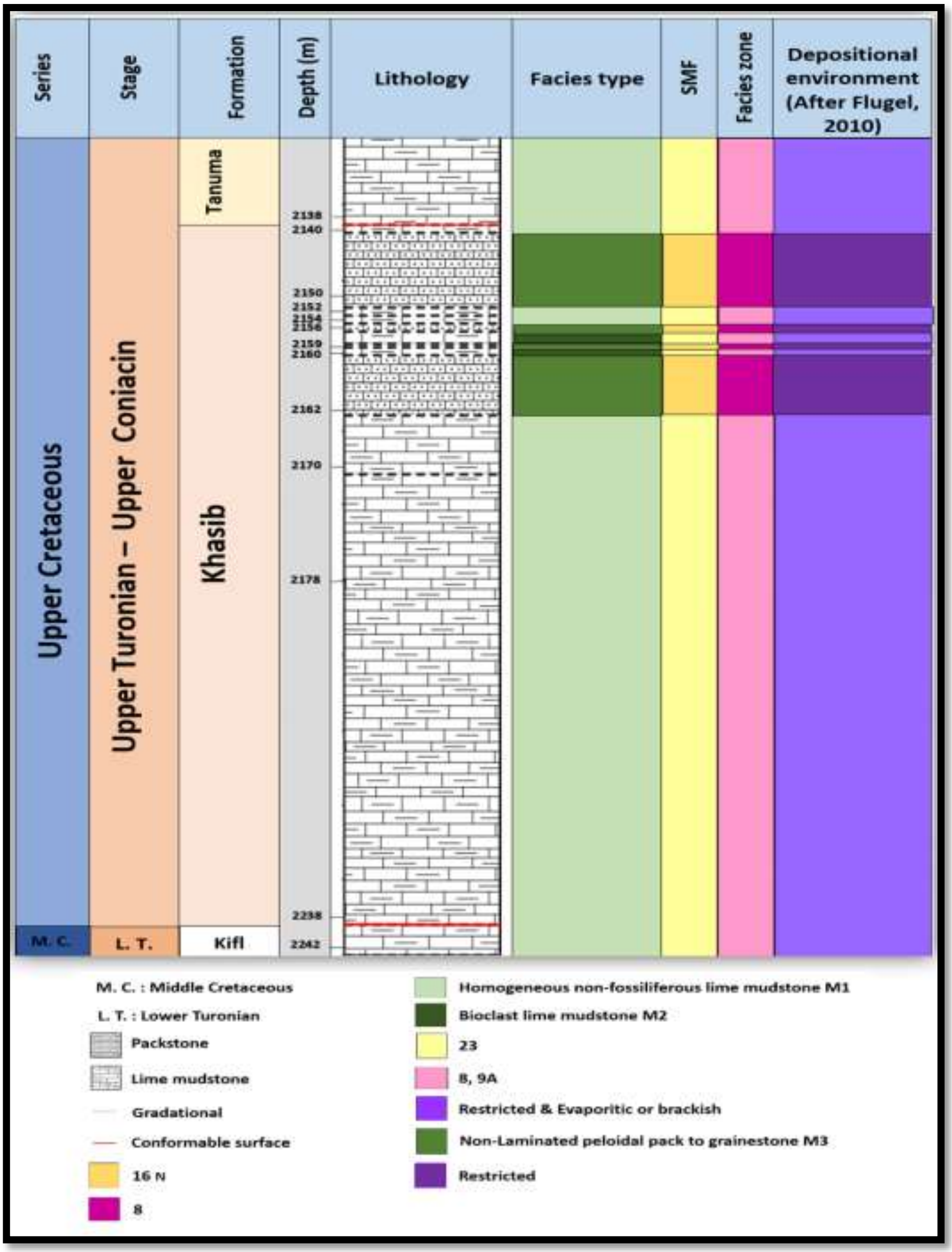


Figure 6: Shows the lithology, standard microfacies SMF, facies zone FZ, and depositional environment of well **EB-92**.

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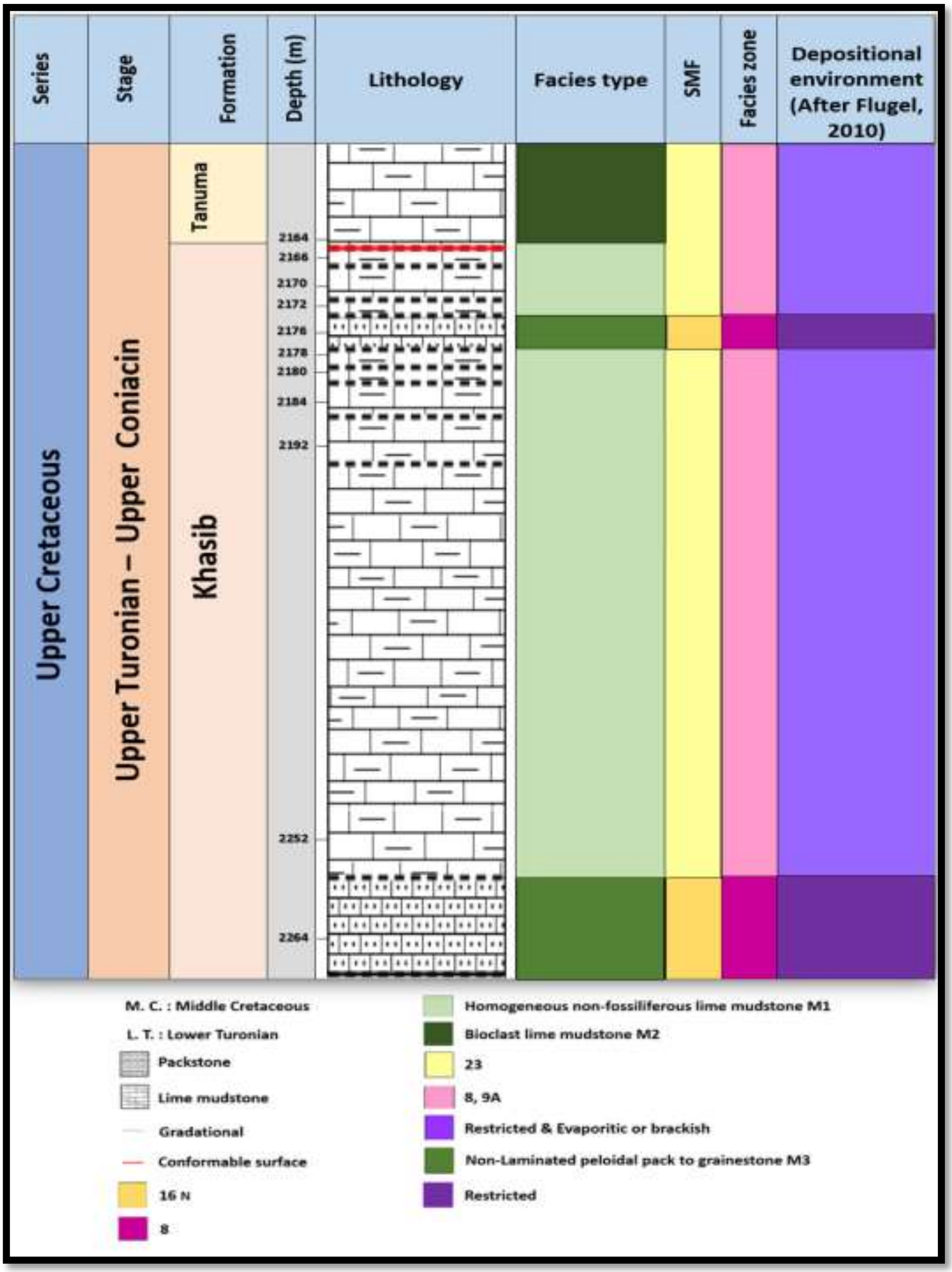

Figure 7: Shows the lithology, standard microfacies SMF, facies zone FZ, and depositional environment of well **EB-94**.

Lime mudstone microfacies

These facies were diagnosed in all wells within Khasib Formation, they were observed in the upper, middle, and lower parts of the formation, as well as in the lower part of the Tanuma Formation and the upper part of the Kifl Formation. These facies come in first place in terms of their prevalence in the composition. The most abundant presence of these facies is in the EB94 well. These contain two submicrofacies:

1. Homogeneous non-fossiliferous lime mudstone sub-microfacies M1

This facies does not contain skeletal or non-skeletal components, these microfacies are equivalent to standard microfacies (SMF 23) and deposited with the facies zone (FZ- 8, 9A) which represented the platform interior (restricted and evaporitic or brackish) (Flugel, 2010), as shows (Plt. 1 A).

2. Bioclastic lime mudstone sub-microfacies M2

It compared with the standard microfacies (SMF 23) and deposition in the facies zone (FZ-8, 9A) that represent interior platform (restricted and evaporitic or brackish) (Flugel, 2010), as shown (Plt. 1 B).

Non-laminated peloidal pack-grainstone microfacies M3

This facies is found in all studied wells in Khasib Formation, where it is located in the upper and lower parts of the formation. The peloid constitutes approximately 90% of the total non-skeletal grains. The most important Diagenesis processes affecting these facies are the process of dolomitization, cementation, and fractures. It can compare with the standard microfacies (SMF 16N) and deposition in the facies zone (FZ-8) that represent interior platform (restricted) (Flugel, 2010), as shown (Plt. 1 C fine peloidal pack-grainstone, 1 D Coarse peloidal packs-grainstone).

Laminated peloidal grainstone microfacies M4

This facies is found in two wells (EB83 and EB87) located in the upper part of the formation, with approximately thickness of 2 m, where the non-skeletal grains are present. The most important Diagenesis processes fractures and the micritization process have an impact on these facies. It can compare with the standard microfacies (SMF 16L) and deposition in the facies zone (FZ-7, 9A) that represent interior platform (open marine, evaporitic or brackish) (Flugel, 2010), as shown (Plt. 1E).

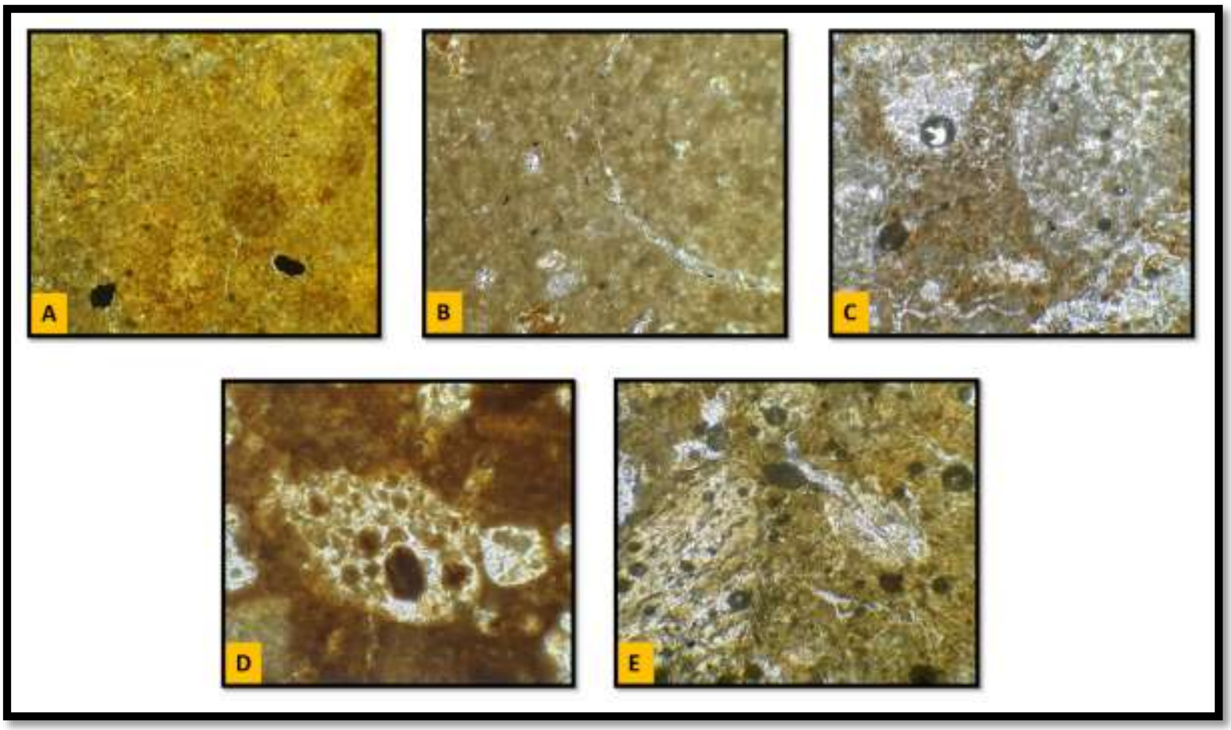

Plate 1

A. Homogeneous non-fossiliferous lime mudstone sub-microfacies M1: At the bottom of Tanuma Formation and the top (EB-83, EB-87, EB-94), middle (EB-83, EB-87, EB-92, EB-94), and bottom (EB-87, EB-92, EB-94) of Khasib Formation and at the top of Kifl Formation. **B.** Bioclastic lime mudstone sub-microfacies M2: At the top of Tanuma Formation and the top and bottom (EB-92) of Khasib Formation. **C.** Non-laminated peloidal pack-grainstone microfacies M3: At the top (EB-83, EB-87) and middle (EB-83, EB-87, EB-92, EB-94) and the top of Kifl Formation. **D.** Non-laminated peloidal pack-grainstone microfacies M3: In the middle (EB-83, EB-92). **E.** Laminated peloidal grainstone microfacies M4: At the top (EB-83, EB-87).

Paleoenvironment

We conclude that the large spread of peloids in the Khasib Formation indicates its deposition in platform interior environments (open marine, restricted, and evaporitic or brackish) depending on the standard facies of (Wilson, 1975; Flugel, 2010).

Lime mudstone facies are deposited in a restricted environment within a euphotic zone that is usually above the base of a mild weather wave, called a lagoon that is protected by sand shoals, islands, or reefs by the platform interior. As for non-laminated peloidal pack to grainstone, it indicates the depositional in a restricted environment and this causes large differences in salinity, temperature, and within the euphotic zone and less related to an open marine where skeletal organisms such as foraminifera. As for the last laminated peloidal grainstone, it indicates the deposition in an open marine or evaporite environment, it has an episodic influx for normal marine waters and a dry climate so that gypsum, anhydrite, and halite can deposit next to carbonate (Flugel, 2010).

Diagenesis processes

Diagenesis is all changes that may happened to sedimentary rocks after deposition and before metamorphism. All changes in size, shape, volume, chemical composition, or crystalline structure of a sedimentary rock after its detrital, biogenic, or crystalline constituents have been deposited (Ahr, 2008).

Most important Diagenesis processes:

1. Micritization

Micritization is one of the destructive diagenesis processes, defined by (Flugel, 1982) as the process of eroding and cracking the surfaces of the shells utilizing microscopic structures, then depositing as micrite within those eroded surfaces after organisms died, micritization process also occurs as a result of the influence of algae on the calcareous granules (Bathrust, 1975), plate (2A).

2. Dissolution

Dissolution is one of the destructive Diagenesis processes, defined by (Blatt *et al.*, 1980) as the process of forming voids within limestone rocks due to the dissolved carbonate minerals or decomposition and dissolution, either fully or partially to the limestone components represented by the ground and grains. (Milliman and Folk in 1974) indicated that the dissolution process leads to the formation of dissolving surfaces (stylolite) and secondary porosity, according to (Flugel, 1982), the dissolution process is positively affected by several factors, including low temperatures, high partial pressure of carbon dioxide (CO_2), low acidity function (PH), high hydrostatic pressure and rock fractures, plate (2B).

3. Dolomitization

Dolomitization is a process whereby limestone or its precursor sediment is totally or partially changed to dolomite by the substitution of the original $CaCO_3$ by magnesium carbonate, through the activity of Mg-bearing water (Flugel, 2010). Al-Dabbas *et al.* in 2010 refer that the process has changed $CaCo_3$ to $MgCo_3$or limestone changes into dolomitic limestone. The dolomitic process in the study area is a dolomitic process with small crystals. Dolomitization may increase porosity, but can also decrease from the porosity, plate (2C).

4. Compaction

This process usually leads to distortion of the sedimentary components and a reduction in the total volume of the sediments. Compaction, according to (Flugel, 1982), is mechanical, which led to a reduction in the volume of grain particles as a result of the agglutination, rearrangement, and orientation of the grains.

Chemical compaction

Chemical compression is one of the most important early diagenesis processes in deep environments, which in turn leads to the formation of melting surfaces (Friedman, 1975). Among the factors that affect the process of chemical compaction are the depth of burial, the stability of the present minerals, the abundance of clay minerals, the chemistry of the water, the content of organic matter, and the temperature (James & Choquette, 1986), plate (2D).

Stylolite

Chemical compaction is exemplified by pressure solution and result in stylolite and solution seams, formed under burial conditions. Stylolite are irregular, suture-like contacts, produced by differential vertical movement under pressure accompanied by solution (Flugel, 2010). Three different classes of stylolite have been identified in the sequences of Khasib Formation. According to (Logan and Semeniuk, 1976; Flugel, 1982), these classes are:

1. Low peak stylolite: It appears in the form of zigzag lines in its side section, and in this study, it was diagnosed in the parts plate (3A).
2. Irregular stylolite: Bedding-parallel irregular anastomosing sutured seams (microstylolite set) in lime mudstone, plate (3B1).
3. Hummocky stylolite: It appears in the form of zigzag and regular surfaces with small amplitude, plate (3B2 & C).

2. Physical compaction

Physical compaction is the process of crushing and distorting grains as a result of weight or overhead load. The most prominent evidence and indicators of the occurrence of physical compression are micro-fractures.

Fractures

Fractures are discrete breaks within a rock mass and comprise microfractures, joints, and faults. Fractures can raise the permeability of hydrocarbon reservoir rocks. Fracture systems in carbonate rocks can form during various stages of sedimentation and diagenesis (compaction load, freshwater dissolution) (Flugel, 2010), palte (3D).

Many limestones exhibit millimeter- to decimeter-sized calcite- or sediment-filled microfractures, commonly called calcite veins. Most calcite veins are due to brittle failure and tectonic fracturing of lithified carbonates caused by stress and shear displacement, extensional movements, or natural hydraulic fracturing (Flugel, 2010). In this study, Khasib Formation exhibits many types of microfractures. Each type of microfractures, represents a stage of diagenesis processes plate (4A & B).

5. Cementation

The cementing process was found in all wells where the cement has many types of minerals such as calcite, dolomite, and pyrite minerals. In the current study. The mineralogy of carbonate cement depends on the quality or composition of the solutions, that have passed through these rocks. The most important patterns of cement that were diagnosed in this study are:

1. Blocky cement

This type of cement contains high-magnesium calcite or low-magnesium calcite, it is found in subterranean environments (vadose and burial environment) and deep environments (Flugel, 2004). Blocky cement occurred accompanied by late diagenesis processes, plate (5 A, & B Blocky cement of calcite).

2. Granular cement

Granular cement consists of calcite crystals of equal size, without almost integral faceted crystals. this type of cement deposited within the vadose and ferrite environment (Flugel, 2004), and it has a size (of 10- 60) microns (Scholle & Ulmer-scholle, 2003), plate (5C).

3. Drusy cement

This type of cement characterized by the fact that the size of the crystals increases in size towards the center of the voids or the pores (Flugel, 2004). Drusy cement will precipitate in the vadose environment (Friedman, 1964). This type of cement is found in shallow and subsurface morphological environment saturated with groundwater (Flugel, 2004), plate (5D).

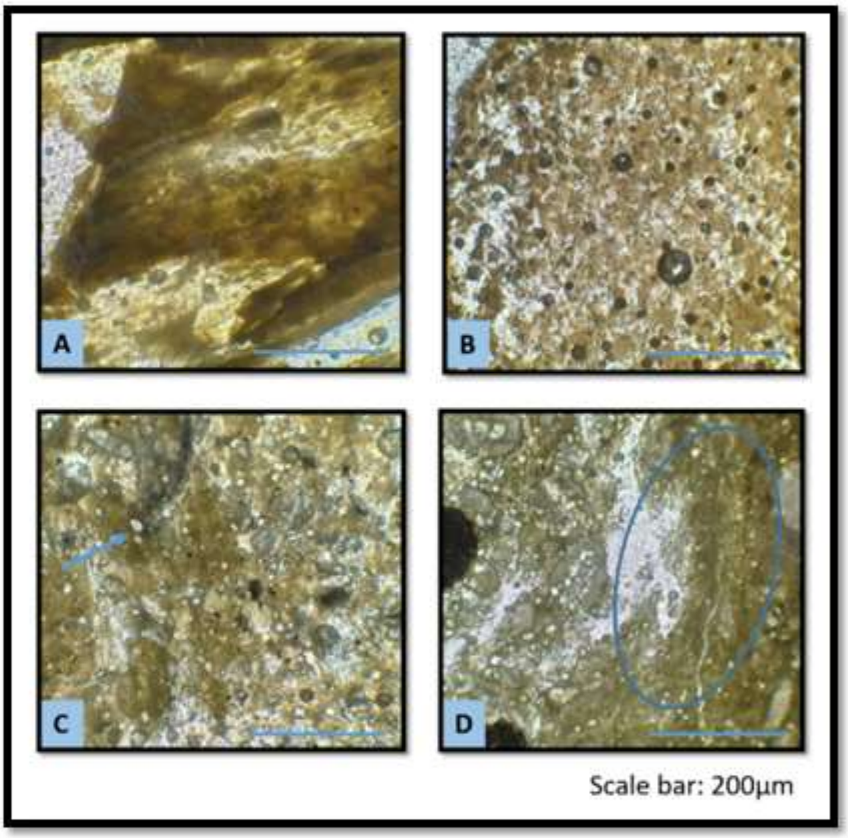

Plate 2

A. Micritization process exists during the depth from 2148 m to 2174 m in (EB-83), at the depth (2172m to 2174m) in (EB-87), and the depth (2152m to 2154m) in (EB-92), and in the depth (2170m to 2184m) in (EB-94) of Khasib Formation. **B.** Dissolution process exists in Khasib Formation and the bottom of Tanuma Formation in (EB-83, EB-87, and EB-94), and at the top and middle depth in (EB-92) and the top of Kifl Formation. **C.** Dolomitization process exists in the top of Khasib Formation in (EB-83, EB-92, and EB-94), at Khasib Formation in (EB-87), at the middle in (EB-92), and at the bottom of Tanuma Formation in (EB-83, EB-87, EB-92, and EB-94) and the top of Kifl Formation in (EB-92). **D.** Compaction process is seen at the depth (2170m) in (EB-92), and at the depth (2180m) in (EB-94) of Khasib Formation.

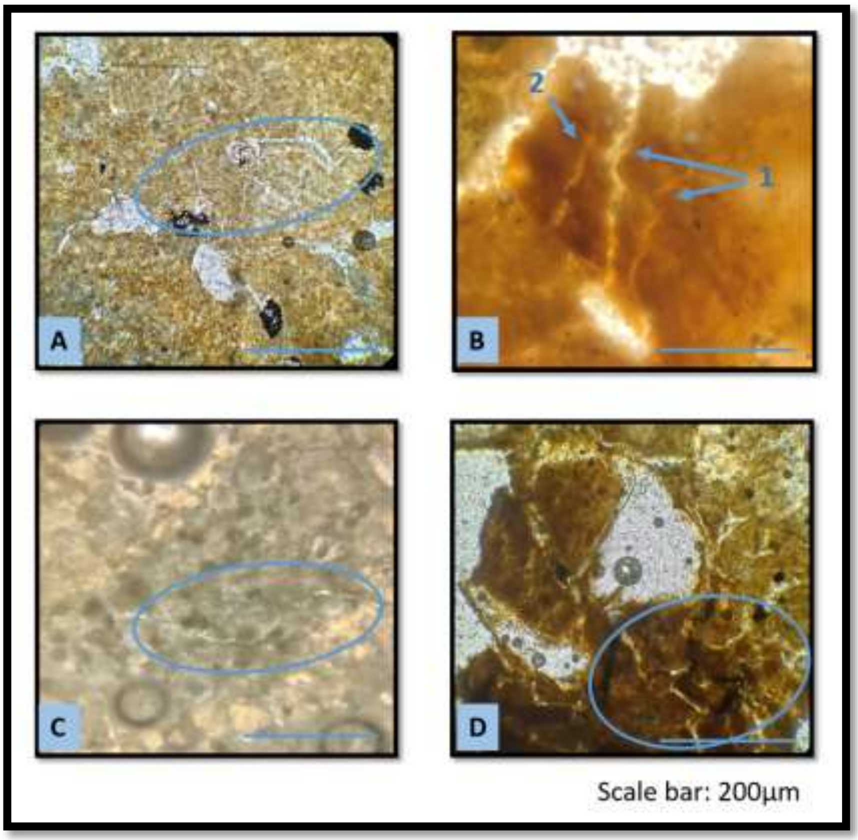

Plate 3

A. A stylolite peaks with low amplitude at the depth (2184m) in (EB-87) of Khasib Formation. **B.** 1; Irregular stylolite at the depth (2174m) in (EB-83 and EB-87), and the depth (2150m) in (EB-92) of Khasib Formation, 2; Hummocky stylolite at the depth (2188m) in (EB83) of Khasib Formation. **C.** Hummocky stylolite at the depth (2166m) in (EB-87) of Khasib Formation. **D.** Fractures at all Khasib Formation in (EB-83, EB-87, EB-92, and EB-94).

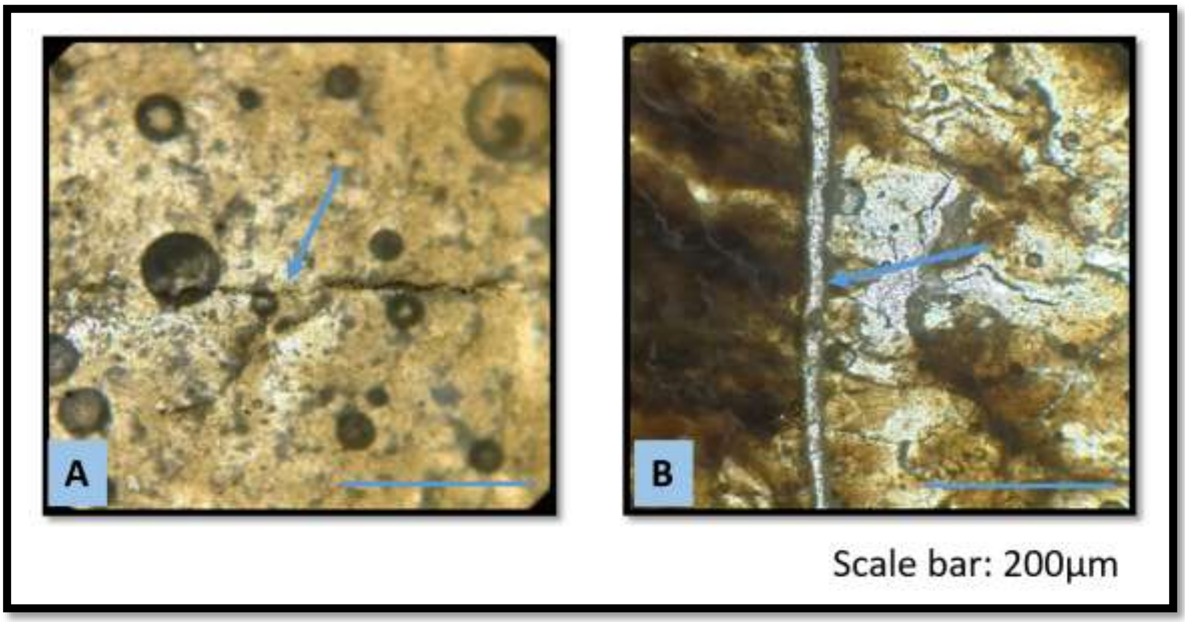

Plate 4

A. Fracture filled with pyrite at the depth (2148m) in (EB-83) of Khasib Formation. **B.** Calcite vein at the top in the depth (2254m) in (EB-87) and the depth (2242m) in (EB-92) of Kifl Formation.

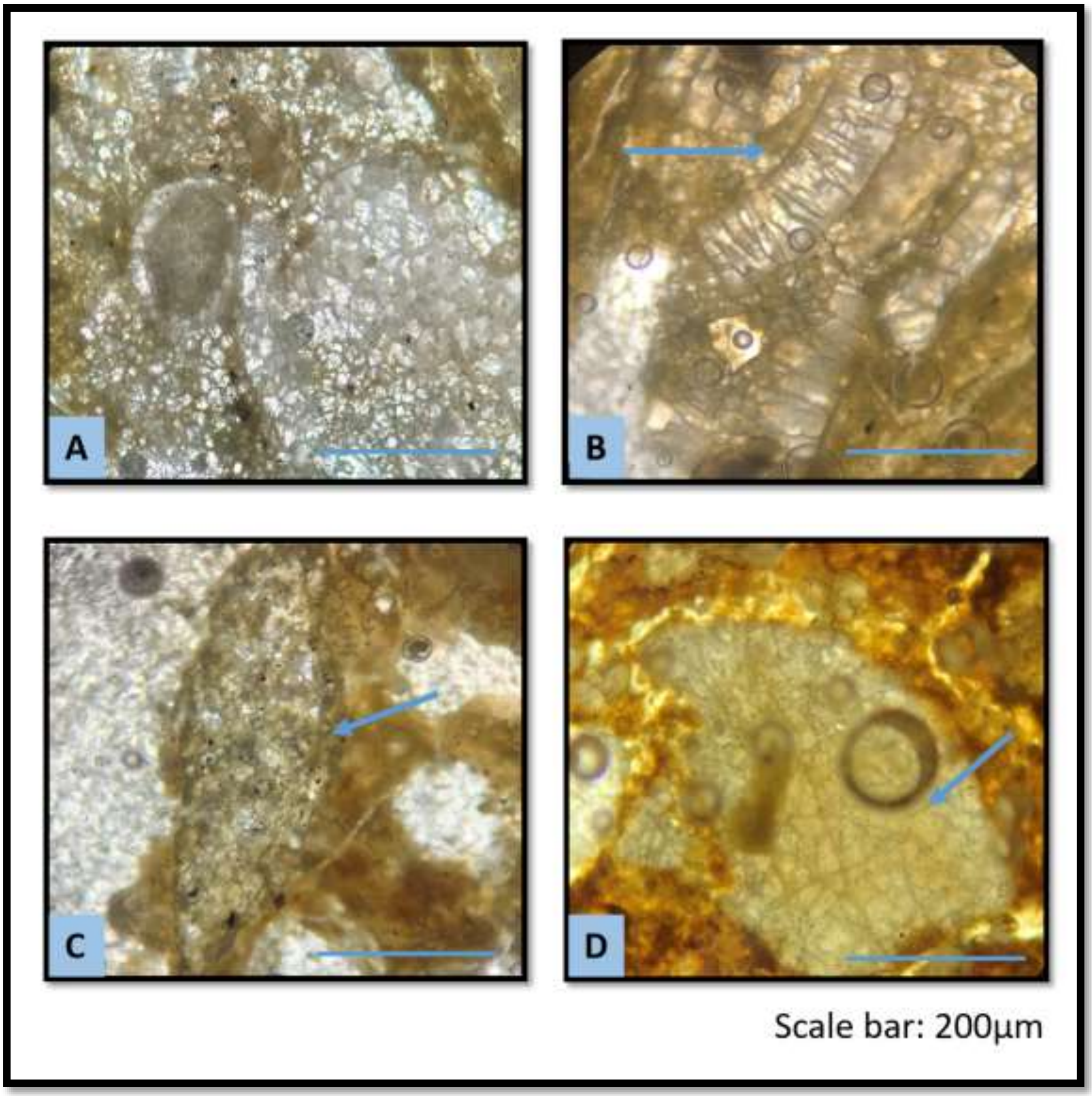

Plate 5

A & B. Blocky cement of calcite at the bottom of Tanuma Formation (EB-83 and EB-94), the top (EB-83 and EB-92), at the middle in (EB-83, EB-87, EB-92, and EB-94) of Khasib Formation, and the top of Kifl Formation. **C.** Granular cement of calcite at the top (EB-87), and the depth (2152m) in EB-92) of Khasib Formation. **D.** Drusy cement at the top and bottom in (EB-87), and the depth (2150m, 2178m) in (EB-92) of Khasib Formation.

Authigenic minerals

The process of forming localized minerals in the sediments is one of chemically asymmetric structural transformation processes, such minerals have several indications of a local cause of origin and are immovable, these minerals appear within the grains (structural and non-structural) molded in a vacuum (Flugel, 1982).

1. Pyrite mineral

Pyrite is one of the common local origin minerals in the fertile formation sequences. It consists of iron sulfides (FeS_2) in sedimentary rocks. The presence of this mineral is usually associated with organic and carbonate materials, especially in the anaerobic sulfide environment with an oxygen charge (Mahfouz, 2019).

Types of pyrite

Pyrite appears in Khasib formation sequences of three types:

a) Cubic pyrite, shown in the plate (6A).
b) Framboidal pyrite: this type of mineral has a scattered form and irregular shapes, completely or partially filling the gaps and visceral pores. Pyrite appears in the fertile formation sequences in the form of small spherical-shaped agglomerations that resemble clusters, so they are called framboids (Goldhaber, 2004), shown in the plate (6B).
c) Ribbon pyrite: It exists in the form of ribbons known as pyrite ribbons, shown in the plate (6C).

2. Glauconite

This mineral is the least prevalent in the sequences of Khasib formation, where it is found rarely. Glauconite is one of the clay minerals belonging to the mica group rich in silica, iron, and aluminum [K (Fe, Al) (Mg, Fe) (Si_2Al) O10 (OH)2]. It is indicated by (Bathurst, 1976; Berner, 1971) that the deposition of this mineral takes place under reducing conditions and in conjunction with the deposition of pyrite magnetron, plate (6D).

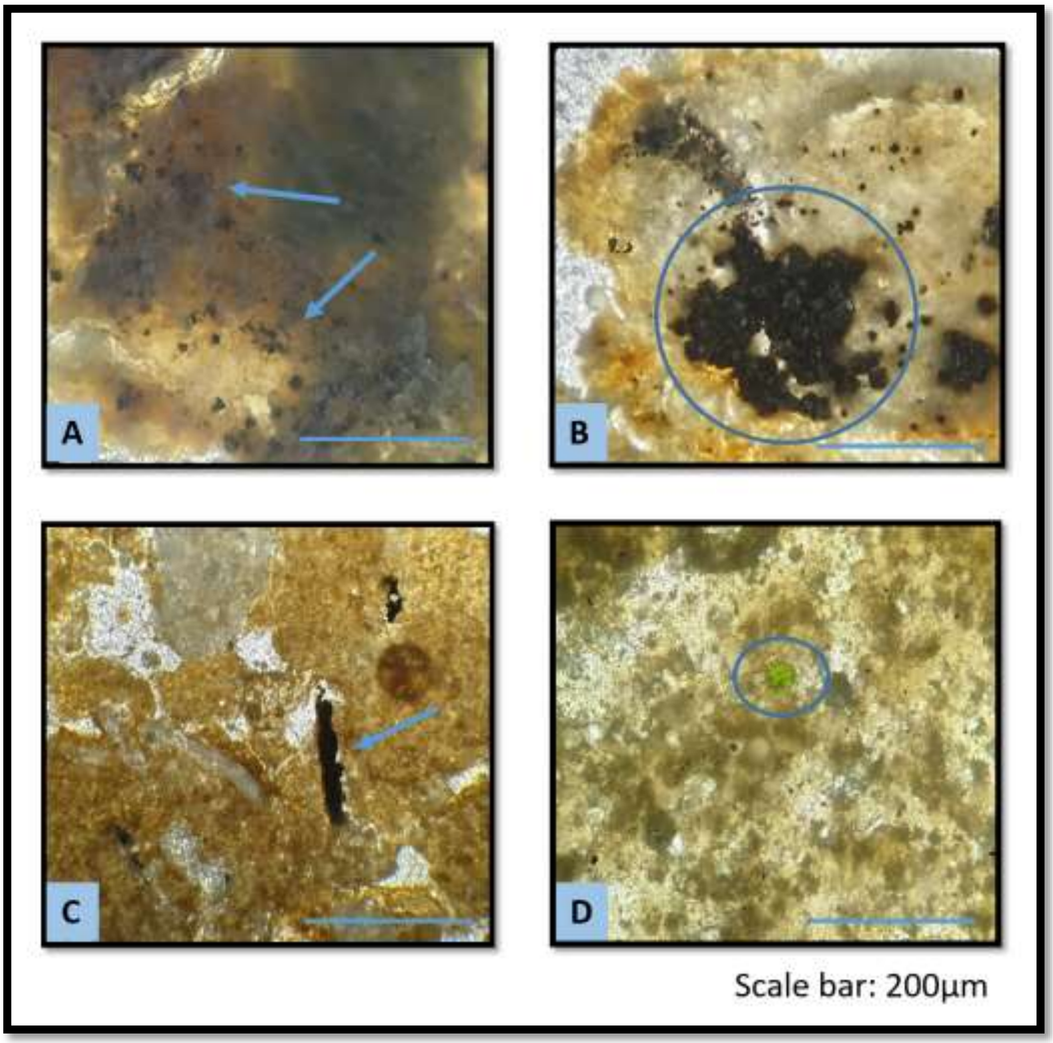

Plate 6

A. Cubic pyrite at the top in (EB-83, EB-87, and EB-92), the middle in (EB-92) of Khasib Formation, at the all Khasib Formation in (EB-94), the top of Kifl Formation in (EB-92), and the bottom of Tanuma Formation in (EB-94). **B.** Framboidal pyrite at the top in (EB-83), the depth (2166m) in (EB-87), the depth (2170m) in EB-92), and the depth (2172m) in (EB-94) of Khasib Formation, at the bottom of Tanuma Formation in (EB-87). **C.** Ribbon pyrite at the top (EB-83 and EB-87) and the bottom (EB-83), of Khasib Formation, and the bottom of Tanuma Formation (EB-94). **D.** Glauconite at the depth (2176m) in (EB-83) of Khasib Formation.

Porosity

The porosity of any rock is defined as the percentage of the total voids of the rock to its total volume (Selley, 1976). According to (Flugel, 2004) porosity is divided into two types: primary porosity: it is the pores that are formed during the process of deposition of sedimentary materials, and secondary porosity, which is formed after the process of deposition of sedimentary materials, due to some modification processes such as dissolution, fractures, and cracks in sedimentary rocks due to tectonic activities. There are many classification systems for porosity depending on the shape, size, and origin of the porosity. The current study was based on the classification (Choquette and Pray, 1970).

1. Vuggy porosity

Vuggy porosity is the second most abundant after fracture porosity in Khasib Formation in these selected wells. It is a type of second porosity produced by the irregular distribution in the early or late morphological processes as a result of the dissolution of the rock components plate (7A).

2. Channel porosity

In these selected wells, channel porosity is the least abundant relative to (fractures and vuggy porosity) in Khasib Formation. It is secondary porosity characterized by longitudinal or irregular holes with a clear elongation of one or two dimensions. Most of these pores are obtained by dissolution along the length of the fracture system or by lateral fusion of many holes, plate (7B).

3. Cavern porosity

Cavern porosity is the least abundant in Khasib Formation in these selected wells. It is secondary pore and it is the reason for the large openings of the channels and closed pores, which are produced by the dissolution processes that are found in the floor of the facies, plate (7C).

4. Fracture porosity

Fracture porosity is the most abundant in Khasib Formation in these selected wells. It is secondary porosity that results from the presence of voids that are produced by local sedimentation or as result of burial that occurs after the sedimentation process, which leads to a fracture in the rocks, plate (7D).

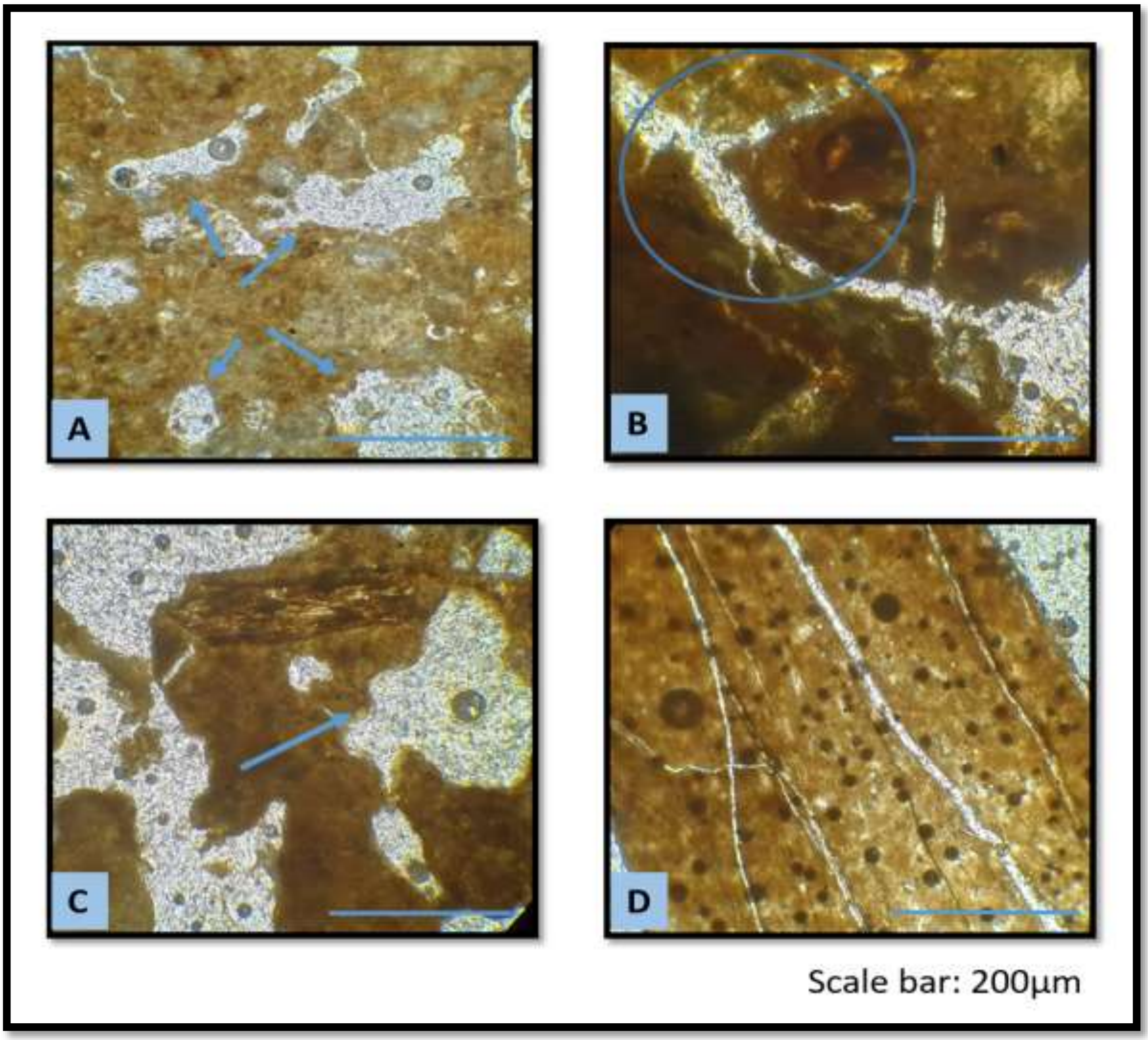

Plate 7

A. Vuggy porosity at all Khasib Formation in (EB-83 and EB-94), the top in (EB-87), the middle in (EB-92), of Khasib Formation, and the bottom of Tanuma Formation in (EB-94). **B.** Channel porosity at the depths (2150m, 2192m, and 2252m) of Khasib Formation in (EB-83), the bottom Tanuma Formation in (EB-83 and EB-87), the top in (EB-87 and EB-94), the middle in (EB-87) of Khasib Formation. **C.** Cavern porosity at the middle and the bottom (EB-83), the depth (2152m) in (EB-87), the depth (2140m) in (EB-92), the top in (EB-94), of Khasib Formation, and at the bottom of Tanuma Formation in (EB-94). **D.** Fracture porosity at all

Khasib Formation in (EB-87, EB-92, and EB-94), the top and the middle in (EB-83) of Khasib Formation, the bottom of Tanuma Formation in (EB-83, EB-87, EB-92, and EB-94), and the bottom of Kifl Formation in (EB-87 and EB-92).

Conclusions

1. Non-skeletal grains (Peloids) are very abundant than skeletal grains (very rare) in Khasib Formation in the studied wells.
2. Three main microfacies were found, these are: Lime mudstone, non-laminated peloidal pack-grainstone M3, laminated peloidal grainstone M4, and two submicrofacies, are homogeneous non-fossiliferous lime mudstone M1, bioclast lime mudstone M2.
3. The microfacies and the fossil distribution reflect the facies zone (7, 8, and 9A FZ).
4. Khasib Formation in the present study was deposited in the platform interior between open marine, restricted, and evaporitic or brackish environments.
5. Khasib Formation is affected by several diagenesis processes: dissolution, cementation, dolomitization, and chemical and physical kinds of compaction, formation of authigenic minerals, and affected by a lesser extent of the process.
6. Calcite and pyrite are the predominant minerals in the composition of all wells.
7. The formation is affected by several types of non-fabric porosity in all wells, the most important are: vuggy porosity, cavities porosity, fracture porosity, and channel porosity, which are greatly affected by the two pores (fracture and vuggy porosity).

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