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Purposeful scientific research is a basic pillar for the advancement of Iraq

Diagenesis of Qamchuqa Formation in Khalkan fold, northern Iraq

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ABSTRACT
The current study which associated with diagenitic effected of Qamchuqa formation in Khalkan fold, where collected about 43 sample treated with with red alizarin red beds to different between the dolomite and calcite facies. The important diagenitic processed which effects on formation represented by cementation, Dolomitization, dissolution, Compaction and Micritization.

1-Introdection

The formation consists of shallow-water carbonates, and lithology of formation consists from limestone, marly limestone and dolomite (figure 1), with a wide spread in the north and north-east of Iraq, the formation exposed in high folded zone, and represents a carapace for many mountains of the region, and subsurface it is located within low folded zone (figure 2). (Wetzel,1950 in Bellen *et al.* ,1959) defined the formation in Qamchuqa village to the northeast of Sulaimaniya city, northeastern Iraq, the upper and lower Qamchuqa Formations equivalent Mauddud and Shuaiba formations in south of Iraq (Jassim and Goff, 2006). The aim of the present study is to describe and identify diagenitic process of Qamchuqa Formation in Khalkan fold.

The study area is located on the southwestern flank of Khalkan Fold, near the village of Khadran in Dukan District, Sulaymaniyah Governorate, northern Iraq, at longitude (44 76 97.0 E) and latitude (36 12 02.3 N) according to the geographical divisions. The studied area tectonically located within the High Folded Zone of the Unstable Shelf, according to (Jassim and Buday,2006).

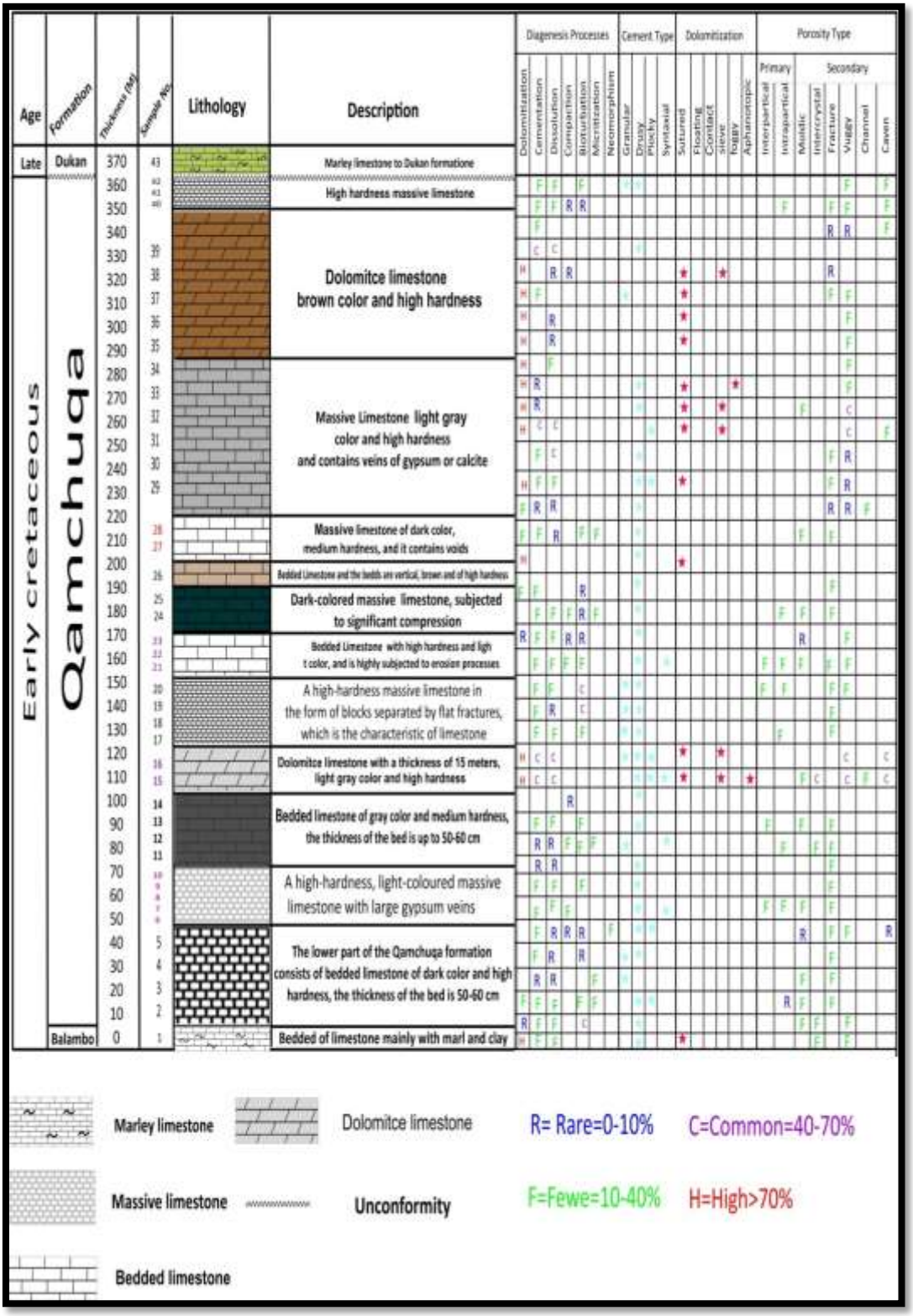


Fig. 1: lithology of Qamchuqa formation and percentage of diagenitic

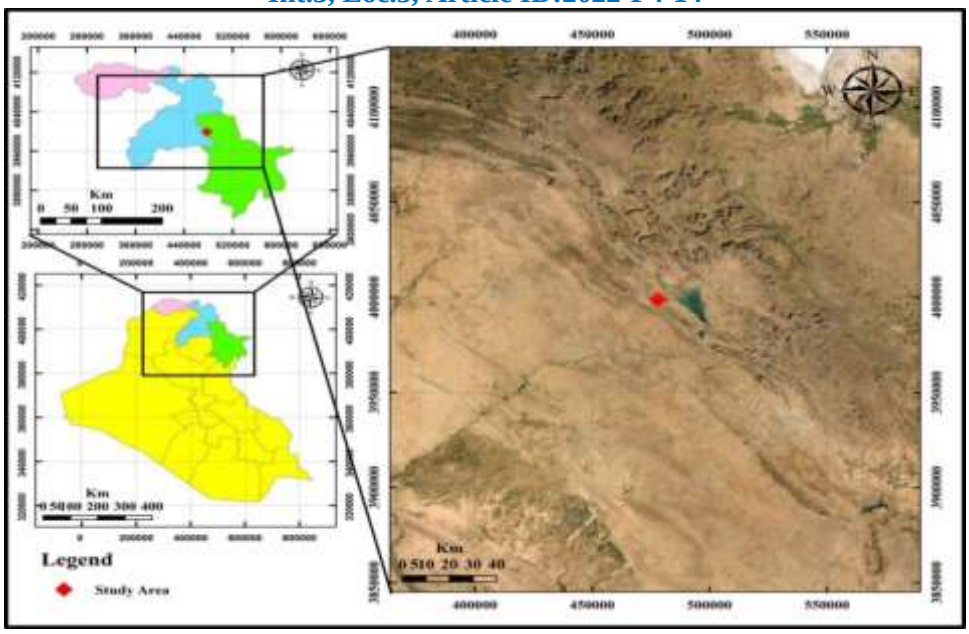


Fig. 2: Map of Iraq showing the location of the study section

2- Methodology

forty-three carbonate rock samples were collected from Khalkan fold. The thickness of the section is 370 m and the distance between the samples is 5 to 10 m depending on the bed's characteristics. These samples were used to made forty-three slides in the workshop of the Department of Geology, College of Science, University of Mosul .In the laboratory a petrographic study was done including microscopic examination of thin sections under a microscope, to determine the petrographic characteristics and fossil contents. The slides were photographed using an Mobile camera. Finally, Arc GIS and surfer were used to draw the maps, stratigraphic sections and plates.

3- Diagenetic

The diagenetic processes are representing by physical, chemical and biochemical changes which occurred during and after deposition at before the metamorphism process (Tucker, 1981) . The complexity of diagenetic processes in carbonate rocks is because of instability of their minerals and high primary permeability, which made these rocks were exposed to renewed active fluids (Selley,1976). After deposition carbonate sediments were effected to diagenetic processes, and caused change of it's porosity, mineralogy and chemistry (Boggs, 2006). There are many factors that influenced diagenetic processes such as temperature, burial velocity, pressure and tectonic activity (Friedman,1982). Diagenetic processes were classified in carbonate rocks by several researchers, one of these classifications by (Flugel, 1982) the Diagenetic are divided into two kinds: Constructive diagenesis and destructive Diagenesis, as follows:

3-1 Constructive diagenesis: These processes are divided into two parts Isochemical diagenesis and Allochemical Diagenesis.

3-1-1 Isochemical diagenesis:

These processes have not any change in the chemical and mineral composition of carbonate sediments, such as cementation and Neomorphism**.**

3-1-1-1 Neomorphism:

Neomorphism is isochemical diagenetic processe , it is the process of transforming a mineral to another mineral, which are similar in chemical composition and different in size, shape and crystal structure (Flugel, 2004). this process results to increase or a decrease in crystal size (Bathurst,1975). (Folk, 1965) pointed out that the process includes re-crystallization, which is an increase or decrease in the crystalline size of the mineral without any change in chemical composition, such as the transformation of the micrite to the more stable microspar. excluded the percentage of radioactive and rare elements (Larsen and Chillinger, 1979).(plt.1-A)

3-1-1-2 Cementation:

Cementation is isochemical diagenetic processe, it represents chemical deposition of minerals being completely or partially filling the fractures or pores and around or inter the particles or those resulting from dissolution (Scholle *et al*.,1989). Cement a crystallization material formed within the rock pores or it is a crystalline growth on the internal surface for different pores during of differents diagenetic processes (Blatt *et al*. , 1980). The most important types of cement in limestone are crystallized calcite include cement other in carbonate rocks include anhydrite, dolomite and silica, these are types a little existent (Selley ,1976). The most important factors controlling the cement process are the mineralology of sediments , their chemical composition and the concentration of the solutions inner them. According to (Flugel , 1982) , the cement is formed in the marine phreatic zones and fresh phreatic zones , at the relationship between the cement process and the

neomorphasim. In this study , we were observed, five types of cement in the studied section as follows :

A : Granular Calcite Cement : This type of cement is more common at the studied section, This type of cement is size is between (10-60) um, it's consists of calcite crystals of subhedral to anhedral , this cement is deposit within Phreatic and vadose zones (Flugel, 2004), it was observed within shells of fossils and fractures (plt.1-B).

B- Blocky cement: This type of cement is represented by larger crystal calcite and equal size, also that is have not a favorable direction in its growth and it is clearly and level bounders. This type of cement appears in the channels, pore and large cracks within matrix of the formation rocks, and this type of cement is formed in phreatic and vadose environments during late diagenetic process stages (Flugel, 1983: Heckle, 1982) (plt.1-C)

C-Drusy Calcite Cement : This type is consists of calcite crystals size larger than (10) um which euhedral to anhedral faces (Flugel , 1982) . This type is characterized by the size of the crystals increasing in size towards the center of the space (Flugel , 2004). It was formed through late diagenetic processes , found in shallow and deep marine environment (Longman , 1980) . Drusy is found to filled for some fractures. (plt.1-D)

D-Syntaxial Rim Cement: This type of cement is comprises of calcite crystals, and these crystals grow over the shells of skeletal grains, especially around the shells of echinoderms (Boggs,2009). It is found in deep burial environments. It is considered less common type of cement during the study sections and a person within different depths is (plt.1-E)

E- Dolomitic Cement: This type of cement is consist of pure dolomitic crystals, euhedral to anhedral faces with medium to coarse size and sharp borders, it is located within the spaces of the fossils or within the spaces between the fossils as a result of dissolution Shells and other gaps, it is appear within facies of formation which are intensity effected by dolomitic process, this type of cement is formed in burial diagenetic environments during late diagenetic stages (Flugel, 2004). (plt.1-F)

3-1-2 Allochemical Diagenetic:

3-1-2-1 Dolomitization

The Dolomitization is process of replacing the magnesium ion (Mg2) with the calcium ion (Ca2) in limestone deposits (Tucker, 1973). it is considered one of the very important diagenetic because its rocks represented more than 50 % of the carbonate rocks that reservoir hydrocarbons in the world, and the increase in the intensity of Dolomitization leads to an increase in the porosity as the process of replacing (Mg) with (Ca) leads to a decrease in the size of the crystals and thus the voids are formed, which in turn increases the porosity (Warren, 2000). (Greensmith,1981) summarized the preferred conditions for formation of Dolomitization associated with the sedimentation process, the important conditions are the availability of warm and shallow waters ranging in depth from (0-45 m), the presence of CO2, which causes the partial decomposition of limestone, and the possibility of chemical exchange with magnesium salts in sea water. Decrease or rise slowly in the sedimentation basin In order for the complete change from calcium carbonate to double calcium and magnesium carbonate, the water of the sedimentation basin must contain a high amount of magnesium versus calcium. (Selley, 1976) explained that the mineral dolomite is not similar to both calcite and aragonite because it does not create originally as a skeletal material. In the current study, the effect of dolmatization was very large on the formation, as most of the formation rocks were affected by dolmatization by up to 60% of the total formation rocks, Fore type of dolomite crystals were observed in current study, depending on the classification of (Randazzo and Zachos,1984):

A-Aphanotopic fabric: This fabric of dolomite is consist of dolomite crystal size less than (0.002 mm), for this cannot be distinguished the crystal boundaries by an ordinary microscope. It is formed by the homogeneous dolomitization of limestone rocks, (Randazzo and Zachos,1984). It is formed at the same time with sedimentation or in the early stages of diagenetic (Zenger, 1983). (plt.2-A)

B-Floating rhomb fabric: This fabric is consist of large and small single rhombic crystals that are distributed within the micritic or amorphous ground. It is euhedral to anhedral faces crystals that are formed during the early stages of the heterogeneous dolomitization process. (plt.2-B)

C-Contact rhomb fabric: is a rhombus that is contact with each other in a micritic ground, and this type represents a developed stage of dolomite tissue, as the number and size of its crystals increase so that they come into contact with each other. (plt.2-C)

D-Sutured Mosaic Fabric: This fabric is consist of dolomite crystals linked together, anhedral to subhedral faces, strongly agglutinated with few or no interfacial pores, and it represents the late stages of heterogeneous dolomitization. (plt.2-D)

3-2 destructive Diagenesis:

3-2-1 Compaction:

It is the process that leads to a decrease in the porosity and the total volume of the rocks as a result of the weight of the sedimentary cover (Flugel, 1982). This process is considered one of the important processes that lead to wide changes in the path of the diagenetic processes of the buried sediments (James and Choqutte, 1983). The degree of rock Compaction depends on the size of the grains ,as the fine grains respond more to Compaction than the coarse grains (Meyers and Hill 1983). According to (Flugel, 2004), the pressure leads to the convergence of the non-cemented carbonate grains and their compaction, and the continuation of mechanical Compaction in the rocks leads to occurrence of chemical Compaction, which leads to the formation of stylolite veins,

stylolite develop and become more frequent with the increasing depth of burial. The Compaction process was classified according to (Flugel, 1982) into two types:

3-2-1-1 Mechanical Compaction:

The sediments become lessening size due to the compaction, rearrangement and orientation of the grains, because subjected to mechanical Compaction.The current study indicates to some of the limestone rocks are affected by the process of Mechanical Compaction, By shattering the skeletons of the pelcypoda fossils (plt.2-E), this is one of the late diagenesis.

3-2-1-2 Chemical compaction:

Chemical compaction is one of the most important late diagenetic in deep environments, which leads to formation of stylolites (Friedman, 1975). The pressure solutions is a isochemical diagenesis process (Park and Schot , 1968) . The chemical compaction leads to increasing the porosity because of the rocks stop responding to the hydrostatic pressure which being on all sides .Thus , the rocks will start to dissolve forming the stylolites surfaces, these surfaces are on all parts of the layer, stylolites lead to increase porosity, but if it is cemented, the porosity is absent (Alluhaiby, 2018). clastic rocks are less responsive to the chemical compaction of the Carbonite rocks, because their minerals, Which are more stable than the carbonite rock minerals such as sandstone (Alluhaiby, 2018). At the present study depends on the classification of (Logan and Semniuk , 1976) for the purpose of identifying the types of stylolites that were showed in the sequences of formations , types of stylolites in the present study are :

A-Peaks High amplitude: This type of stylolite has a High peak (plt.3-A)

B- Irregular anastomosing stylolite: This type of stylolite is represented by the Crosse of a group of stylolite flakes that cohesion to each other and are irregular (plt.3-B)

C- Parallel sets: It is consist of parallel sets . (plt.3-C)

3-2-2 Dissolution:

represents the dissolution of rock components, either partially or completely, which leads to the formation of voids in the rocks that may later be filled with cement (Blatt *et al*., 1972). The dissolution process is represented by dissolving unstable minerals such as aragonite and calcite, this process depends on the stability and solubility of carbonate minerals, as the minerals aragonite and calcite rich in magnesium are less stable than the mineral calcite poor in magnesium and lead to dissolution it (Friedman, 1964). The most important factors controlling the dissolution process is represented by penetrating water temperature, the degree of saturation of the surrounding water with calcium carbonate, The stability of the mineral composition, hydrostatic pressure, the ratio of (CO) in the water, the percentage of fluid movement and (pH) (Milliman,1974: Longman, 1980). the dissolution process occurs in the vadose zone, and Probably it occur in the freshwater environment of the phreatic, result of its effect on the minerals aragonite and calcite, and the dissolution processes lead to the emergence of Intercrystalline porosity, Moldic Porosity and other porosity in the formation rocks under study, which is formed because dissolution of calcite in calcified rocks, or because the dolomitization process (Longman, 1980), we were observed this process in current study from dissolution of dolomitic rhomb (plt.3-C).

3-2-3 Micritization

The Micritization is considered one of the late destructive diagenetic process .(Flugel, 2004) point out that it is formed by microorganisms such as algae and fungi that eat the surfaces of living structures, followed by the deposition of micrite after the death of those organisms (figure 3). (Bathurst, 1975) mentioned that this process is consist on the outer edges of the fossils, where it works to surround it and preserve its external shape, forming the so-called micratic envelope, or it occurs completely, This leads to nonappearance any internal structure of the granules. (Boggs, 2009) point out that the Micritization process is form a barrier that preserves the skeletal granules from the effect of diagenesis such as dissolution and is resistant to them. (Wilson and Evans, 2002) indicated that it is formed in phreatic diagenetic environments and occurs in shallow water sediments. we were observed, five types of cement in the studied section we were observed, two types of micritization in the studied section, completely in Orbitalina fossils and partial (micratic envelope) in echinoderms fossils (plt.3-E), (plt.1-E).

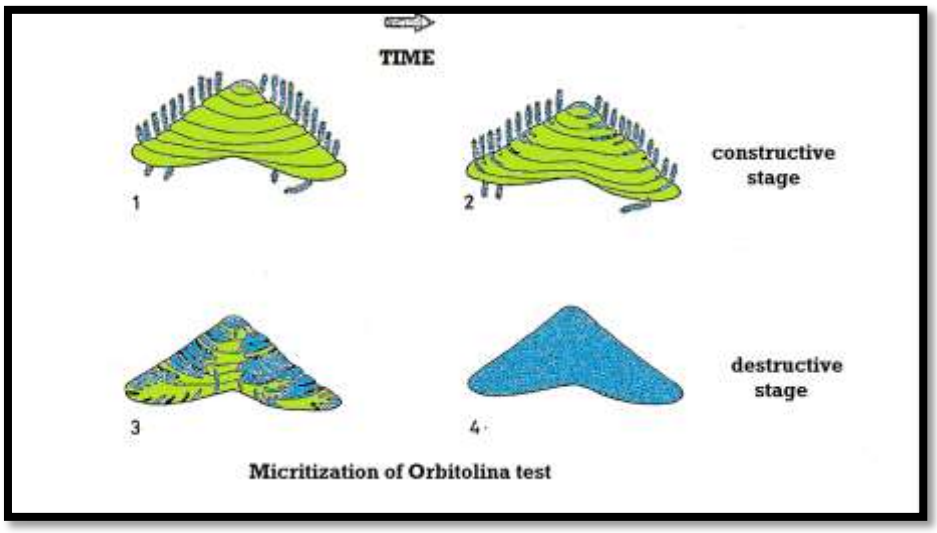


Fig. 3: represented the micritization process (Al-Sadooni,1978)

3-2-4 Bioturbation:

It is one of the destructive diagenetic processes, according to (Greensmith, 1971) It is traces of creep and boring of organism on sediment during and after their deposition, it is impact on the rocks completly through physical changes events of rocks or mineral composition in the end effect on it's reservoir properties, and common for bioturbation processes leads to increasing resrvoir properties of the rocks through it's effect on sorting of grains or removal some cement materials for it , also organic materials depleting of rocks may be work on decreasing from amportant as description as it which product rocks (AL - Juboury , 2003). (plt.3-F)

3-2-5 Porosity:

Porosity is defined as the percentage between the total size of the pores to the total volume of the rock (Selley, 1976), and this porosity may be connected or unconnected, which is then known as effective porosity. The porosity of carbonate rocks is divided into two main groups: primary porosity, which is formed during the sedimentation process, and secondary porosity, which is formed after the sedimentation process. Porosity is affected by diagenetic processes, and some of these processes reduce its percentage in rocks, such as compaction and Cementation, and some of the diagenetic processes increase the percentage of porosity, such as dolomite and dissolution. The dissolution process resulting from the embedded diagenetic processes leads to formed the porosity (Choqutte James, 1983). The porosity is more effected by Dolomitization, which is leads to increase in Porosity and permeability, and the process of replacing calcite with dolomite includes an increase in porosity by about (13%), (Chilingar and Terry, 1954 in Chilingar *et al*., 1979) The classification systems for the porosity of carbonate sediments depend on several bases, including: the type of pores and their mechanism of formation, the relationship between rock type and the type of pores and the nature of their geometry, and the relationship between porosity and modulatory effects. It was based on the classification of (Flugel, 1982). The axis is about a classification system (Choquett and Pray, 1970) (figure 4), as this classification contains (15) types of pores, and this system depends on whether the porosity is Fabric selective or non Fabric selective, as shown below:

3-2-5-1 Fabric selective porosity:

A-Interparticles Porosity, which are the pores that form between the grains. The importance of this porosity is that it is present in most sedimentary rocks (Selley, 1982), and (Boggs, 2009) indicated that this type of porosity is found between skeletal and non-skeletal grains. (plt.4-A)

B-Intraparticles Porosity: This is type of porosity is found within the grains (Flugel, 2010). This type always disappears or decreases relatively by filling these voids with Micrite after the end of the sedimentation process (Selley, 1982). (plt.4-B).

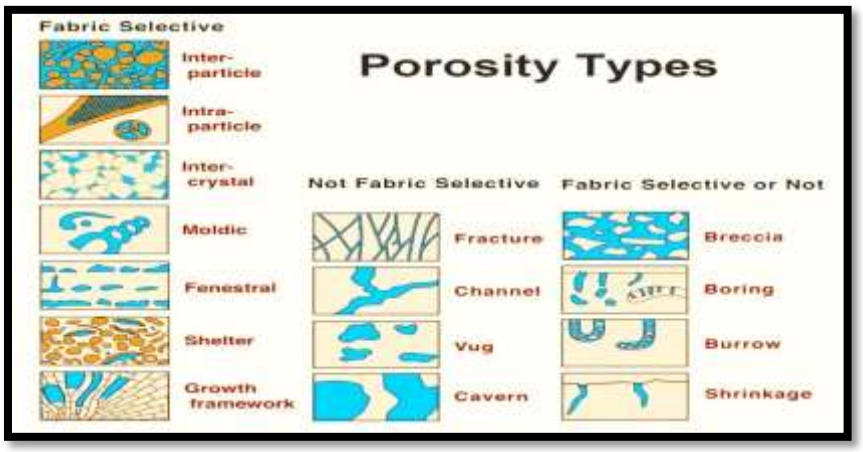


Fig. 4: Classification of porosity (Choquett and Pray, 1970)

C-Intercrystalline Porosity: This type of porosity is occur between crystals and are observed within dolomite rocks and limestone rocks subjected to the recrystallization process (Tucker and Wright, 1990: Flugel, 2010) and they are important if they present in dolomite rocks because these rocks are important because they may contain oil reservoirs (Selley, 1982), we observed it between the dolomite crystals in this study. (plt.4-C)

D-Moldic Porosity: This porosity is formed as a result of selective dissolution of skeletal and non-skeletal granules such as fossils and Ooids (Flugel, 2010). That is, the process of dissolving in the rock itself is specific to certain grains of one type. Which is selective dissolution of ooids or skeletal granules, This type of porosity, if it is found in rocks, differs in terms of geometric dimensions, effective porosity, or porosity, according to the type of dissolved grains (Selley, 1976). (plt.4-D)

3-2-5-2 Non Fabric selective porosity:

A-Vuggy Porosity: the porosity is forms from the irregular distribution of the early and late dissolving processes of the digenesis (Flugel, 2010). (plt.4-E)

B-Fracture Porosity: the porosity is formed as a result of tectonic movements or that is associated with the movement of cracks or as a result of surface weathering processes. We often find it at the surfaces of unconformity, and in this case it may expand and enlarge by the influence of solutions, especially in limestones (Selley, 1976). (plt.4-F)

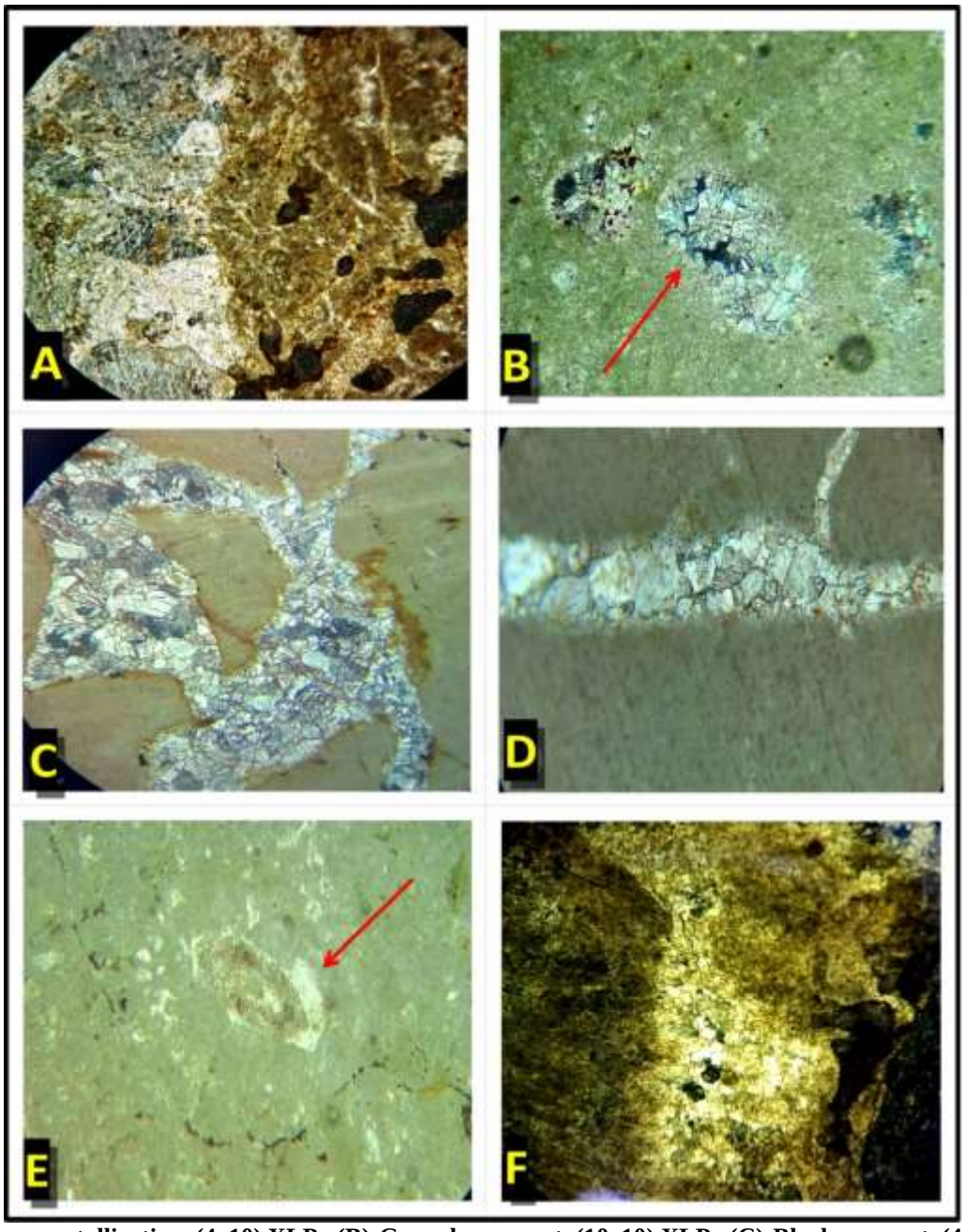
C-Channel Porosity: This Porosity is longitudinal gaps resulting from the influential diagenetic processes, often empty or filled with cement materials or hydrocarbons. (plt.4-G)

4-Conclusions

1-The important of digenetic process effected in formation rocks is Dolomitization, cementation, dissolution, Neomorphism, porosity, Micritization and compaction.

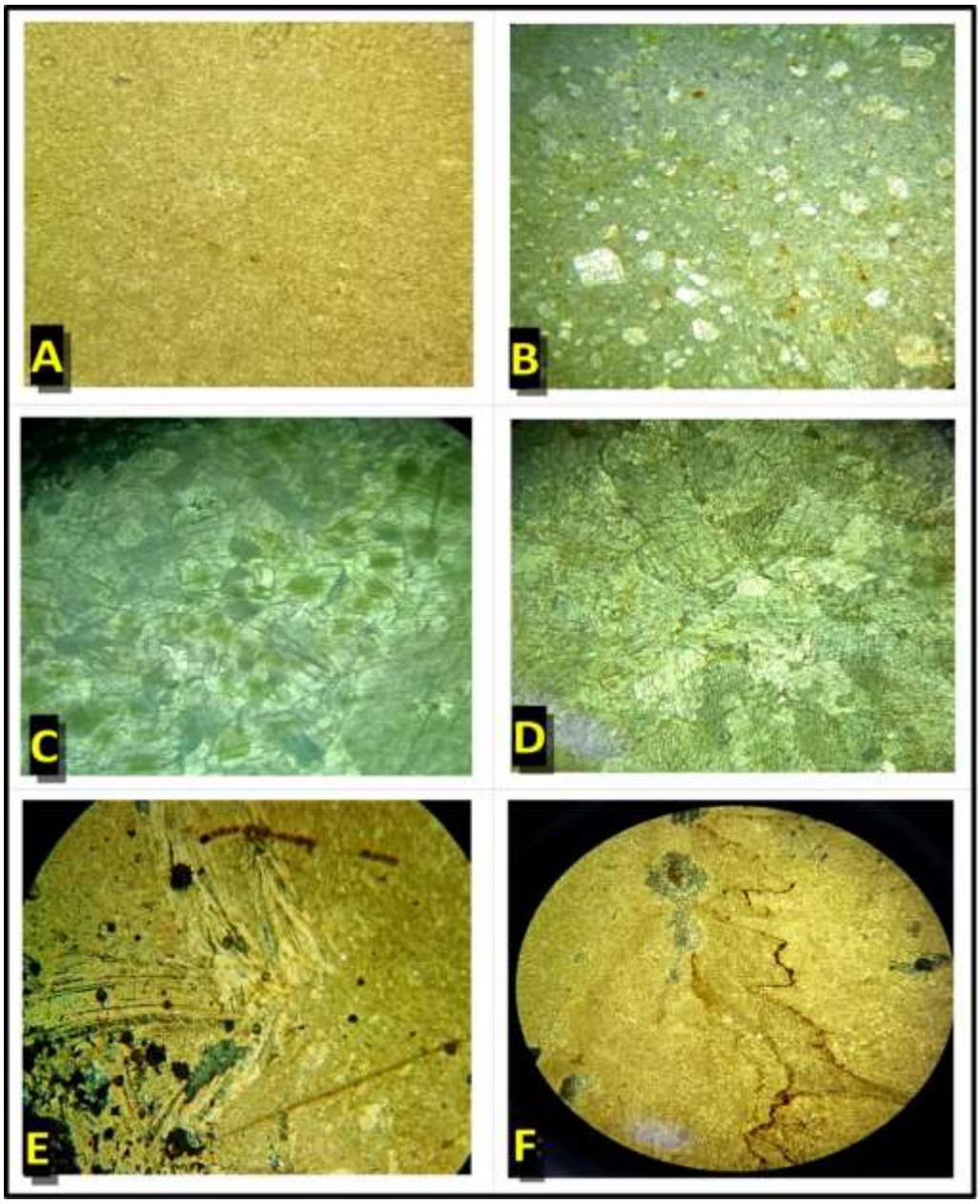
2-The diagenesis most affecting in formation rocks is Dolomitization, which led to the destruction of the skeletal grains, as well as making the texture foggy, which increased the undistinguished of the rock components accurately.

Plate-1



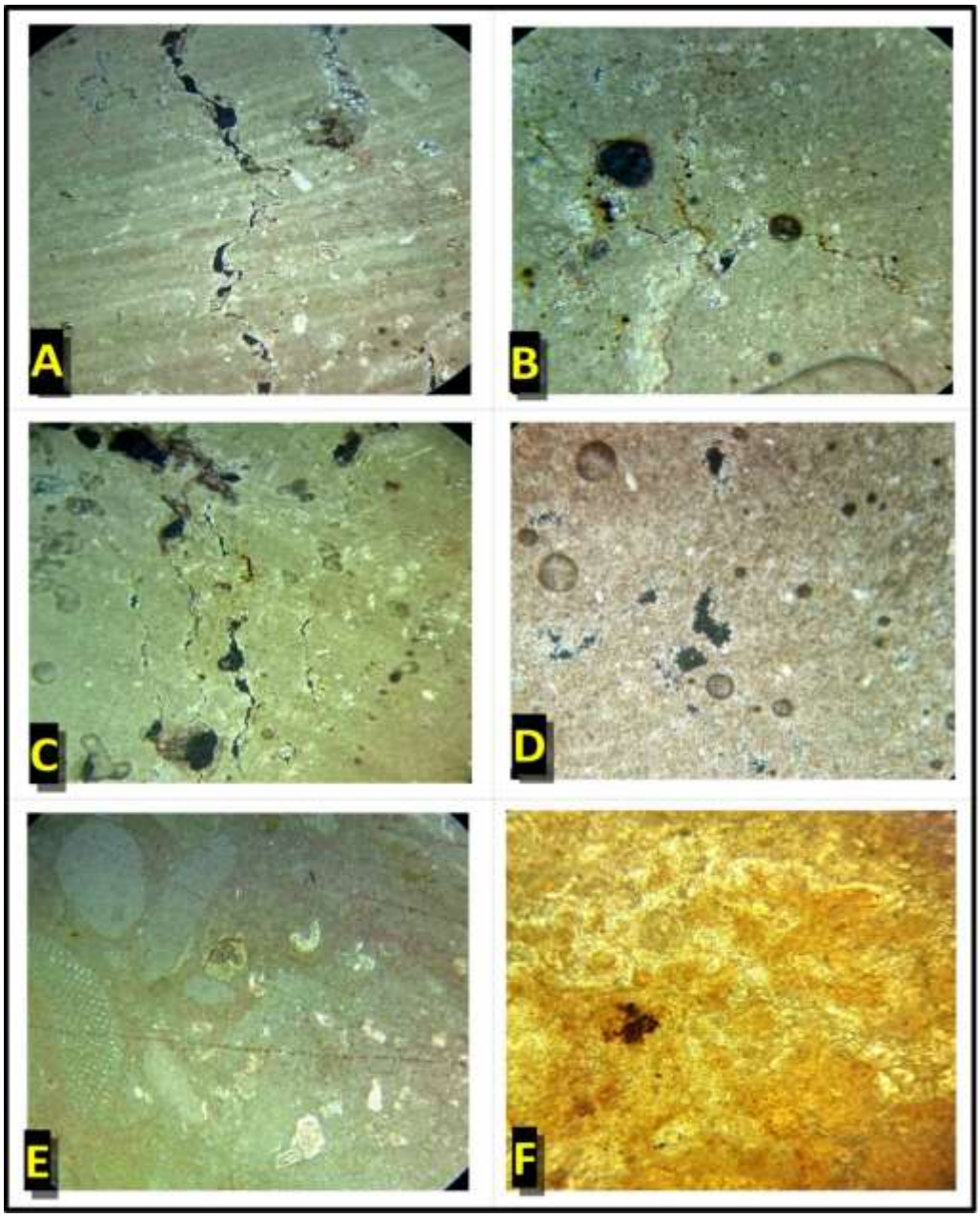
(A)-re-crystallization, (4x10) XLP.. (B)-Granular cement, (10x10) XLP.. (C)-Blocky cement, (4x10) XLP..(D)-Drusy mosaic cement, (4x10) XLP.. (E)- Syntaxial Rim Cement and Micritization of Ecanodime, (10X10) XLP..(F)- Dolomitic Cement, (4X10) XLP

Plate-2



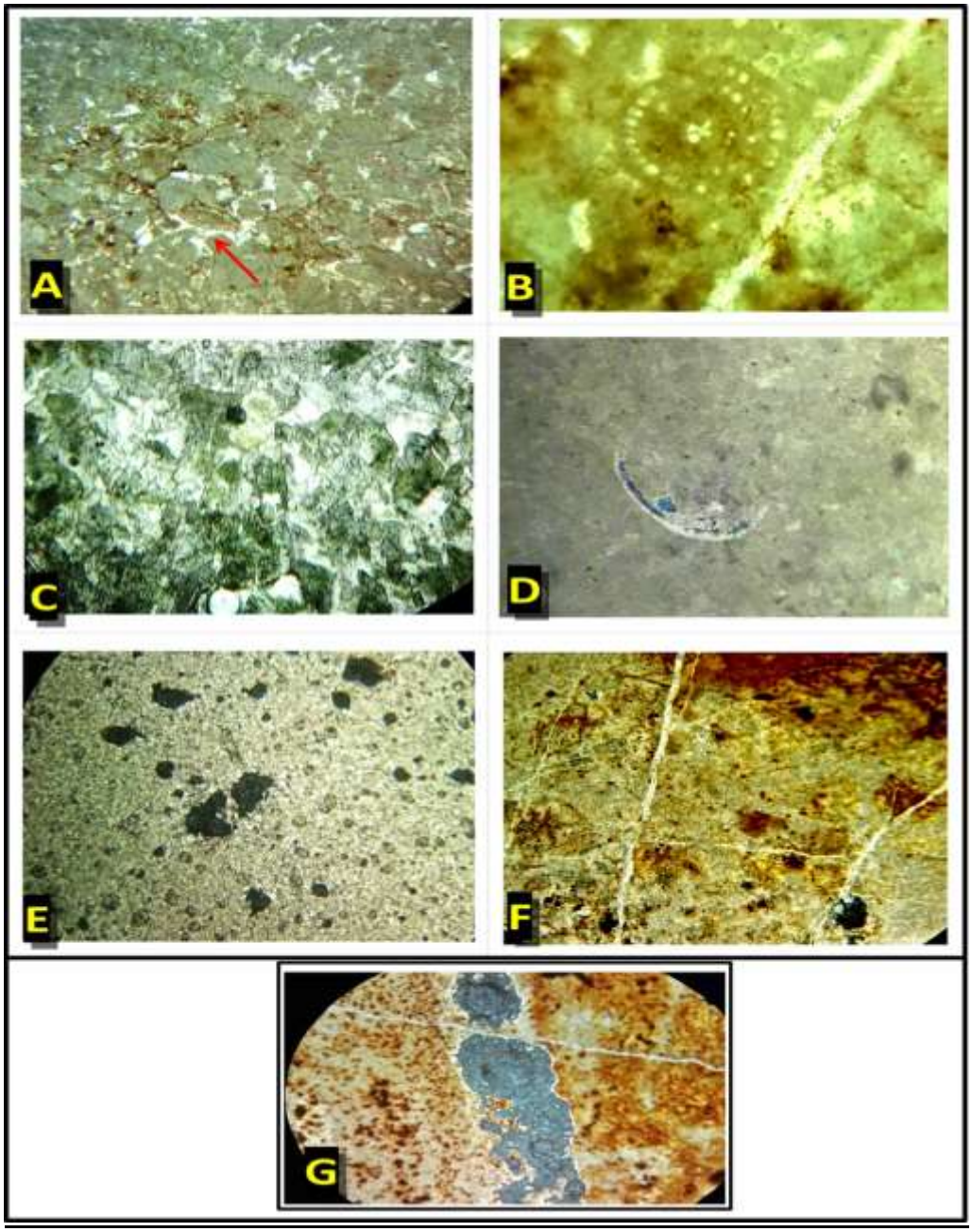
(A)- Aphanotopic fabric, (4X10) XLP.. (B)- Floating rhomb fabric(4X10) XLP.. (C)- Contact rhomb fabric, (4X10) XLP..(D)- Sutured Mosaic Fabric, (10X10) XLP..(E)- Mechanical Compaction, (4X10) XLP.. (F)-Chemical compaction, (4X10) XLP..

Plate-3



(A)- Peaks High amplitude stylolite,(4X10) XPL..(B)- Parallel sets stylolite, (4X10) XLP..(C)- Irregular anastomosing stylolite, (4X10) XLP..(D)- Dissolution, (4X10) XLP..(E)- Micritization for Orbitalina fossils, (4X10) XLP..(F)- Bioturbation (4X10) XLP..

Plate-4



(A)- Interparticles Porosity, (4X10) XLP..(B)- Intraparticles Porosity, (10X10) XLP (C)- Intercrystalline Porosity, (10X10) XLP..(D)- Moldic Porosity, (4X10) XLP (E)- Vuggy Porosity, (4X10) XLP..(F)- Fracture Porosity, (4X10) XLP.. (G)- Channel Porosity, (4X10) XLP..

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العمليات التحويرية لتكوين قمجوقة في طية خلكان، شمال العراق

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الملخص

اهتمت الدراسة الحالية بدراسة العمليات التحويرية المؤثرة في تكوين قمجوقة في طية خلكان، حيث جمعت حوالي 43 نموذج عولجت بصيغة الاليزرين الحمراء للتميز بين سحنات الدولوميت والكالسيت. اتضح من خلال الدراسة ان اهم العمليات المؤثرة في التكوين هي الدلمتة والسمنتة والاذابة والتضاغط الفيزيائي والكيميائي والمكرتة والمسامية والتشكل الجديد والتعكر الحياتي