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Journal of Educational
ISSN: 2011- 421X
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# مجلة التربوي

## مجلة علمية محكمة تصدر عن كلية التربية

## جامعة المرقب


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**يوليو 2023م**




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مجـلة الـتربـوي
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Arcif Q3
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العدد 23

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مجـلـة الـتربـوي
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ISSN: 2011- 421X
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معامل التأثير العربي 1.63
العدد 23

# Petrography of Abushyba Formation columnar-jointed sandstones (Triassic-Jurassic) from Jabal Nafusa- Gharian, NW-Libya

Ismail F. Shushan[1], Emad Eldin A. Dagdag[2] and Salah Eldin M. Elgarmadi[3]
[1,2,3]Geology Sec., Earth Sciences and Environment Dept., Fac. Sciences, Elmergib University
elforjismail@yahoo.com

## Abstract

A petrographic study is done on (15) samples cut from Abushyba Formation columnar sandstones deposited during the upper part of Late Triassic and the lower part of Early Jurassic periods from Jabal Nafusa that situated in Gharian Region, NW-Libya. About (20) thin sections were prepared at the Libyan Oil Research Institute in Tripoli. Ten (10) thin-sections were selected to characterize the columnar-jointed sandstones in the area of study which are subjected to petrographic studies using a polarized microscope at the Geology Department Laboratory in Al-Khoms City. Medium-grained, texturally mature, but chemically immature an arkosic arenite sandstone facies is found to characterize the studied samples which are thought to be deposited in riverine environments in which the sand grains were originated from granitic and gneissic outcrops. Clay and iron-oxide (and probably pyrite) rims and coatings around particles were evident and may form part of the cement. Euhedral quartz grains sometimes appeared with quartz overgrowth. Intergranular primary porosity as well Intragranular, fracture, stylolite and vug porosities were encountered. Deposition at increased depth of burial for the studied samples is proposed which was inferred from the presence of sutured, concavo-convex and elongated grain contact as well as the appearance of broken, over stacked and twisted or embayed and deformed grains where the porosity become reduced. In general, four (4) late diagenetic stages took place after deposition were found to characterize the studied samples: this include the "Redoxomorphic Stage": "at shallower depths remarked by iron-oxide, clay mineral and pyrite rims around grains as well as grain coatings, the " Locomorphic Stage" as depth of burial increased remarked by cement precipitation between grains which included clay material, iron-oxide and/or pyrite and silica (in the form of quartz overgrowth) cements, the " phyllomorphic Stage" at greater and increased depth of burial remarked by formation of mineralized material around grains (probably chlorite and micas)", the "Epi-diagenesis Stage" took place after the uplifting of the rock to shallower depths towards the surface and weathering agents activated lead to formation of many types of secondary porosities such as solution porosity, vuggy and moldic porosities as well fracture and stylolite porosities. The total porosity of Abu-Shaybah Formation columnar-jointed sandstones in Gharian area is enhanced through the last stage of diagenesis signifying the studied samples as having good reservoir quality for ground water (good water aquifer).

**الخلاصة :** تم عمل دراسة وصفية لعدد (15) عينة صخرية أخذت من مكشف للحجر الرملي العمداني الانفصال التابع لتكوين ابوشيبة التي ترسبت خلال الفترة الزمنية المتأخرة للترياسي العلوي والفترة الزمنية المبكرة للجوراسي السفلي بجبل نفوسة بمدينة غريان, شمال-غرب ليبيا. حوالي (20) شريحة زجاجية تم إنجازها بالمعهد الليبي للنفط بطرابلس. كما تم اختيار عدد (10) شرائح زجاجية وإخضاعها للدراسات الميكروسكوبية بواسطة المجهر المستقطب بمعامل قسم الجيولوجيا-كلية العلوم الخمس-جامعة المرقب وذلك لتشخيص العينات الصخرية بمنطقة الدراسة. من خلال الدراسة المجهرية, تم تصنيف عينات هذه الصخور على أساس أنها سحنة

حجر رملي الكوارتز أرينيت ذات حبيبات متوسطة الحجم تميزت بنضوج صخري نسيجي ولا تمتلك نضوج صخري كيميائي أو معدني. يعتقد أن سحنة الرمل هذه قد ترسبت بداخل بيئات نهرية قريبة من مكاشف صخرية للجرانيت والنيس. تم ملاحظة أغلفة من أكاسيد الحديد ومعادن الطين ولربما معدن البيرايت حول حبيبات الصخر حيث اعتبرت جزاء من اللاحم الصخري أيضا. بعض حبيبات الكوارتز الكاملة التبلور أظهرت نموا ثانويا والذي عزز من وجود اللاحم الصخري لعينات الصخر. تمثلت مسامية سحنة الحجر الرملي الكوارتز أرينيت في هذه الدراسة في ظهور كل من المسامية الاولية بين الحبيبات بالاضافة الى مسامية كل من داخل الحبيبات والمسامية القالبية والتجويفية ومسامية الشقوق والكسور والتي هي جزء من المسامية الثانوية. دلت طريقة التلامس ما بين الحبيبات لعينات الصخر على عمق الدفن الذي تدرج من العمق المتوسط فالعميق ثم السحيق حيث تنشط محاليل الضغط الذي صاحبه إنخفاض في المسامية. وبصفة عامة, تم تمييز (4) مراحل لعمليات النشأة المتأخرة التي أثرت على عينات الصخر بمنطقة الدراسة والتي أشتملت على كل من مرحلة التأكسد والاختزال عند أعماق الدفن الضحل تميزت بتغليف الحبيبات الصخرية بمعادن أكاسيد الحديد ومعادن الطين والبيرايت, مرحلة السمنته والالتحام عند أعماق من الدفن المتزايد تميزت بدخول لواحم أكاسيد الحديد ومعادن الطين والبيرايت والسليكا (ولواحم الكوارتز النامية), مرحلة ما بين حد عمليات النشأة المتأخرة والتحول المنخفض عند أعماق سحيقة من الدفن تميزت بنشوء معادن الكلوريت والميكا, وأخيرا مرحلة مابعد النشأة المتأخرة حيث قامت عمليات الرفع التكتونية برفع طبقات صخور أبوشيبة الى أعلى باتجاه السطح وتم نشوء أنواع مختلفة من المسامية الثانوية التي ساهمت في إرتفاع مسامية الصخر وأصبح بالتالي يمثل صخور خازنة ذات جودة عالية لتخزين المياه.

**Keywords: Keywords:** Abushyba Formation columnar-jointed sandstones, Sandstone petrography, Sandstone diagenesis, Arkozic aernite sandstone.

## Introduction

Christie, A. M., (1955) was the first who gave the name of Abu Shaybah Formation to the sandstone beds that cover a small limited areas in the north western parts of Al-Khoms City which then become covered to the south eastern parts by the carbonate rocks of Sidi Asaid Formation that deposited in Cretaceous. This formation has been also observed to outcrop in sporadic areas from Gharian Dome within central Jabal Nafusah in the NW Libya and parts from Tarhunah area located to the east of Jabal Nafusah. This formation has not been observed to outcrop toward the western part of Jabal Nafusah, specifically in Jadow and Jefern regions.

According to Fatmi, N. A. et al, (1980), Abu Shaybah Formation has been deposited during a geologic time ranged between the upper part of Upper Triassic and the lower part of Lower Jurassic periods. In general, the formation consists of intercalated sandstone, siltstone and claystone with pebbles of quartz and/ or feldspar (slightly conclomeratic). The thickness is varied between 150m to about 160m and showed cross bedding character that distinguish it from other types of sandstones (Mann, K., 1975). The mysterious columnar sandstone structures from Gharian area are not mentioned or documented by any of the authors who used to follow and document such alike these structures. For instance, Norbert Brügge, (Germany), Andras Zboray and Gabor Merkl , (Hungary) marked these structures of sandstone in Jebel Uweinat (the region between Libya-Eygpt-Sudan) and Jabal Arkenu. Similar another columnar sandstone structures is observed in many parts of the world (Ramon structure, Negev desert- Occupied Terrains-Palestine, Cerro Coi, Aregua, Paraguay, Island of Bute, Kilchattan bay, Scotland, Zittau Mountains "southeast corner of Germany", Bondi Beach, near Sydney, Australia and Columnar joints in Mesozoic Sandstone -India).

## Location of study area

Gharian is one of Libyan cities located on the north-western part and on the top of the so called "Western Jabal" of Gharian which forms the Central part of Jabal Nafusah. It

مجـلـة الـتربـوي
Journal of Educational
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Arcif Q3
معامل التأثير العربي 1.63
العدد 23

is situated about 75 km distant from southern Capital Tripoli. It is limited from north by the Aziziah City, Tarhunah and Mssalatah cities from the east, Jefern City from the west and Mizdah and Ben-Walid from the south (Fig.-1).

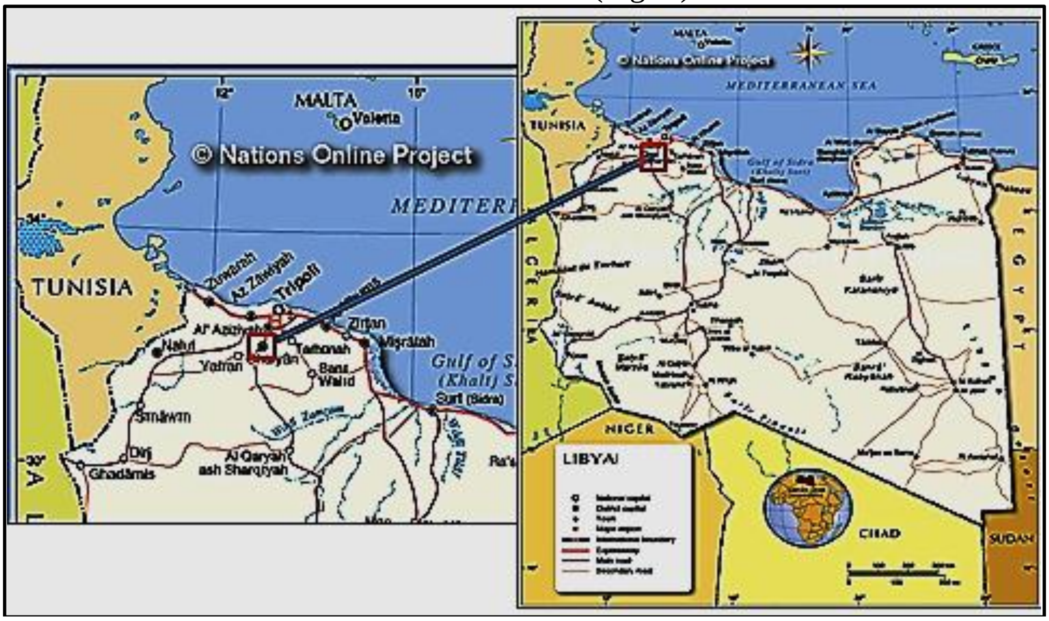


Figure-1: Location of the study area (the red squares)

**Aims of the study**

The principal scope and purpose of the present paper is to study the columnar-jointed sandstone of Abu Shaybah Formation petrographically. This including the identification of sandstone facies and to determine the different stages of digenesis that these sandstones have been subjected to after their burial. Documentation of this phenomena of columnar-jointed sandstones in Jabal Gharian through this study will be another scope.

**Methodology**

Samples collected from the outcrop (Fig.-2) were prepared for thin section study in laboratories belong to "Libyan Oil Research Centre- LORC" at Tripoli. Samples were impregnated in blue color agent solution for distinguishing porosity under microscope. A photo-camera polarized microscope is used to study and document the different petrographic characteristics of the columnar sandstone samples within the optical lab in Geology section at Earth Sciences & Environment Dept., Al-Khoms.

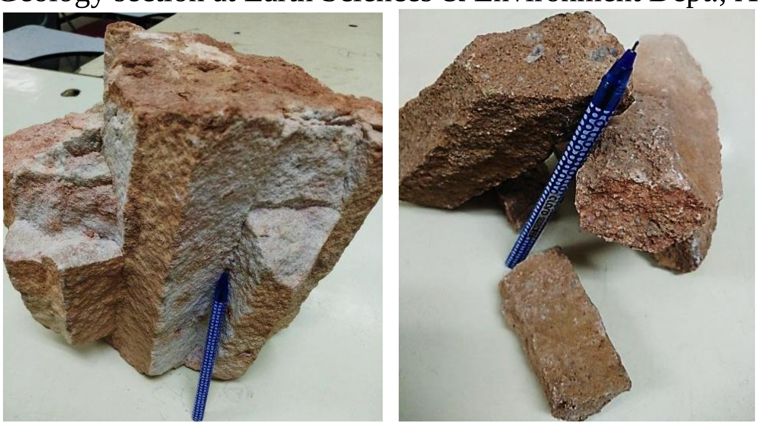

Figure-2: The columnar sandstone collected from enigmatic Abu Shaybah Formation columnar-jointed sandstone from Jabal Gharian, NW-Libya.

**Stratigraphic Succession of Study Area**

The area of the study is characterized by the deposition of Mesozoic rocks in the entire area of Jabal Nafusah which include Triassic, Jurassic and Cretaceous periods (Fatmi, N. A. et al, 1980 & Burollet, 1977 and Novovic,1977). This was summarized in (Fig.-3).

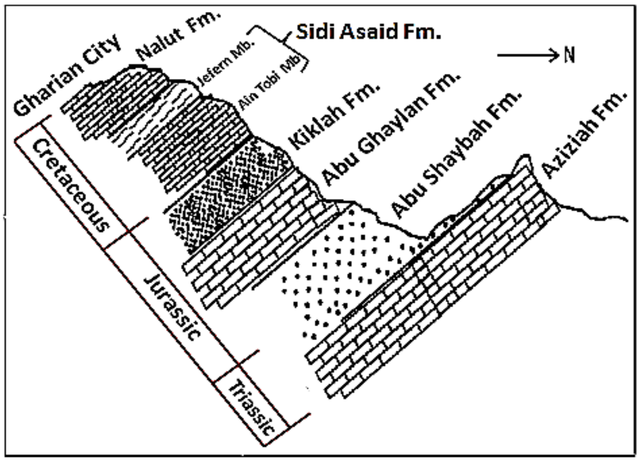


Figure-3: Summarizing the stratigraphic succession of the study area as a part of Jabal Nafusah (modified from Fatmi, A. N. et al. 1980).

**Petrographic studies of the Abu-Shaybah Formation columnar sandstones**

According to the microscopic characteristics of Abu Shaybah Formation columnar sandstones thin- sections examined in this current study, and according to Dot classification of sandstone (1964), the columnar sandstones are classified as "arkosic arenite". The samples contained less than 15% matrix material (M) which are commonly formed from clay-sized silica and clay minerals. Matrix materials are usually interring the basin of deposition either during sediment accumulation or are formed due to disintegration and weathering of the principal constituents of the rock after deposition and during diagenesis. The samples under study are formed of medium to coarse sand grains. Feldspars maintained about 70% from the whole composition of the rock compared with only 20% for quartz. In general, the shape of the grains is varied from sub-angular to sub-rounded and as a result, the rock samples examined here maintained medium to bad sorting of grains. Under crossed polarized light (XPL), feldspar particles appeared with colors varied from light brownish-red to light yellowish-orange and were almost altered. Quartz particles showed an irregular extinction with colors varied from bluish-grey to earthy-white. Under plain polarized light microscope (PPL), feldspar particles showed dark, dirty and rough surfaces, while quartz particles displayed lighter and smooth surfaces. The thin sections of Abu-Shaybah columnar sandstone displayed increased secondary porosity (blue color agent) which partially filled with the matrix material (M) and partially with the cement material (C) that probably belonged to iron oxide cement (dark and brownish black color) and/or to pyrite cement (black colored). Moreover, some anhedral quartz hexagonal crystals were coated with clay mineral matter and/or iron oxide and pyrite (Ir-Ox-r). Qz-overgrowth (Q-ovg ) was evident as well as varied sized lumps of iron oxide and/or pyrite were observed (Figures: 4, 5, 6 & 7).

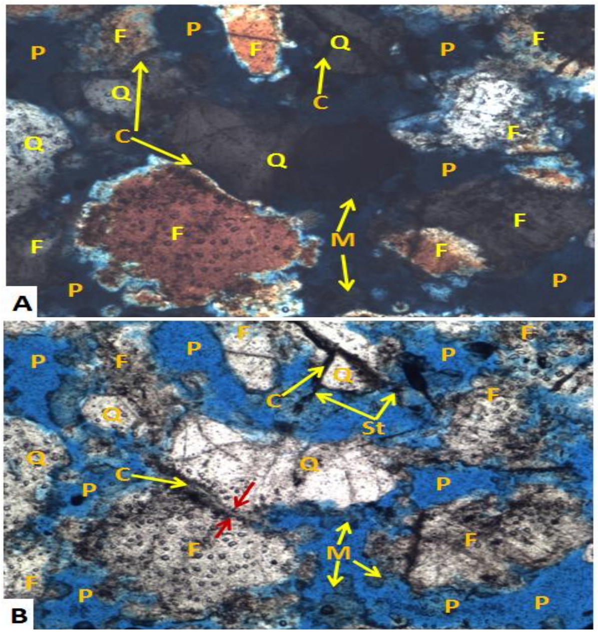


Figure-4: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. (A) is under crossed polarized light (XPL), (B) is under plain polarized light (PPL). Note the sub-angular to sub-rounded grooved and pitted quartz (Q) and feldspar (F) particles, the porosity (blue color- (P)), the matrix (M), and the cement (C).Also, note the infilling of stylolites (St) with clay materials and concavity and convexity of quartz and feldspar grains (red arrows in slide-B). Sample-1, (X10).

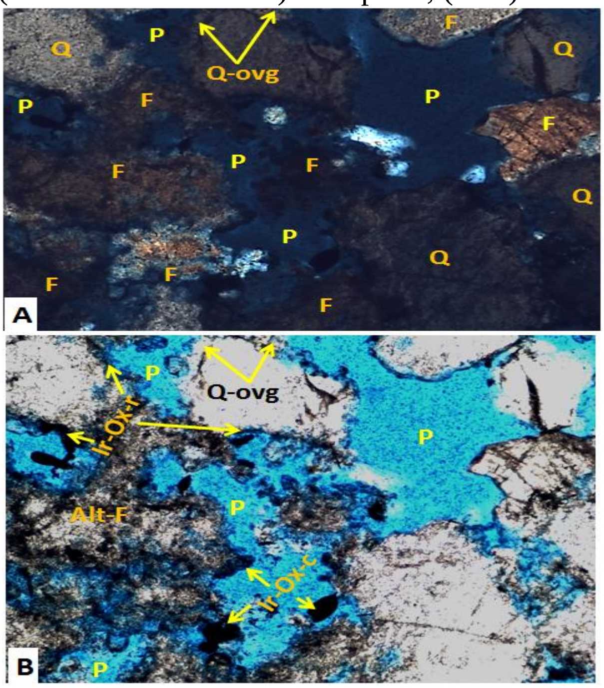


Figure-5: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. Note the altered feldspar particles (Alt-F), the coating of quartz particles (Q) with iron oxide coating (ir-OX-r) and iron oxide and/or pyrite clusters (ir-OX-c). Also note the high porosity (P). Slide (A) is under (XPL), slide (B) is under (PPL). Sample-2, (X10).

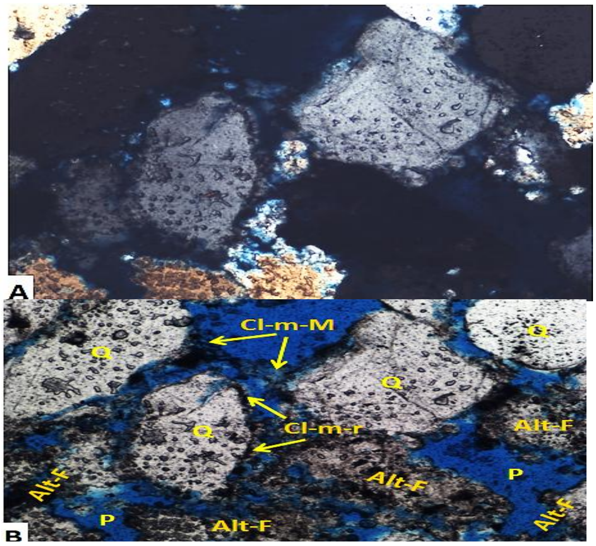


Figure-6: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. Note the altered feldspar (Alt-F) the grooved hexagonal anhedral crystals of quartz (Q) with clay mineral coating (Cl-m-r), the clay mineral matrix (Cl-m-M) and the intergranular porosity (P). Slide (A) is under (XPL), slide (B) is under (PPL). Sample-3, (X10).

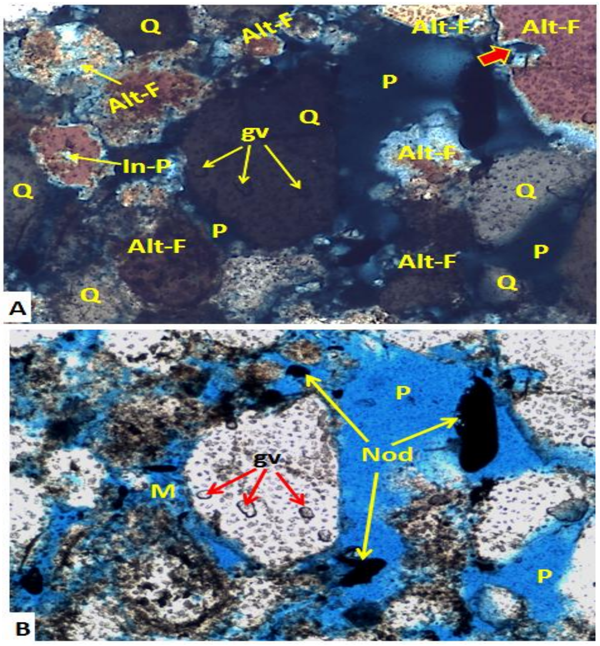


Figure-7: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. Note the extensive alteration of feldspars (Alt-F), the enlarged grooves on subrounded quartz particles (gv), the intergranular porosity (P), the intragranular porosity (In-P), the embayment of feldspar particle (upper right corner-red arrow), the matrix (M) and the dark-colored black nodules (iron oxides and/or pyrite nodules). Slide (A) is under (XPL), slide (B) is under (PPL). Sample-4, (X10).

**Late Digenesis and Porosity Development**

Several physical, chemical and biological diagenetic processes may affect sediments after deposition and during or after their lithification. As a result, the amount and distribution of porosity and permeability of sedimentary rocks become influenced. The diagenetic processes will control the texture, mineralogy and fluid properties of a given sedimentary rock (Worden, R.H. et. al., 2003). Diagenetic processes could destroy or preserve or/and enhance the porosity and permeability of sandstones (Baiyegunhi, C. et. al., 2017). Depositional environment and diagenetic processes were believed to have a great influence on the initial porosity and permeability of sandstones. Once, the processes and products of diagenesis become understood, the key aspect in the evolution of sedimentary basins may become revealed which may affect the destruction, preservation and generation of porosity (Sciscio, L., 2015). Through petrographic studies the types, timing and rate at which diagenetic processes affect porosity and permeability in sandstones become known (Ajdukiewicz, J.M. and Lander, R.H., 2010). Primary depositional factors (such as mineral composition, grain size, grain sorting etc.) and secondary diagenetic modifications may control the reservoir quality and heterogeneity of sandstones (Makeen, Y.M. et. al., 2016). Depositional factors in general tend to control the depositional porosity and permeability of sandstones which afterwards disturb types and extent of diagenetic alterations (Morad, S. et. al., 2010). Compaction and cementation may reduce the porosity and permeability of sandstones at greater burial depths, which then become enhanced by dissolution processes and later may preserved by grain coatings (Baiyegunhi, C. et. al., 2017, Zhang, L. 2016, Zhou, X. et. al., 2016). In general, Burial diagenesis processes have a significant impact on the clastic reservoir qualities including sandstones (Ajdukiewicz, J.M. and Lander, R.H., 2010).

**Physical or Mechanical Diagenetic Processes:**

This type of diagenesis is presented by process called "compaction" that resulted due to the pressure of overburden beds on Abu-Shaybah columnar sandstones after deposition. The following microscopic evidences that indicate the effect of compaction on the studied samples of Abu-Shaybah columnar sandstones in gharian area are as follows:

1- The appearance of broken-over stacked and twisted or embayed as well as deformed rock particles (Figure: 8, 9 & 10).

2- Generally, the grain contact of the particles is observed to be in more than one point. This involved the sutured grain contact, the concavo-convex contact and the elongated grain contact (Figure: 8, 9 & 10).

**Chemical Diagenetic Processes**

Chemical digenesis of Abu-Shaybah columnar sandstones within the study area were evident under microscope and involved the following phenomena:

1- The formation of silica cements in the form of quartz overgrowths as well as iron oxide (reddish brown) and pyrite (opaque) cements that crusted many of the grains of the samples (Figure: 11, 12 & 13).

مجلة التربوي
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معامل التأثير العربي 1.63
العدد 23

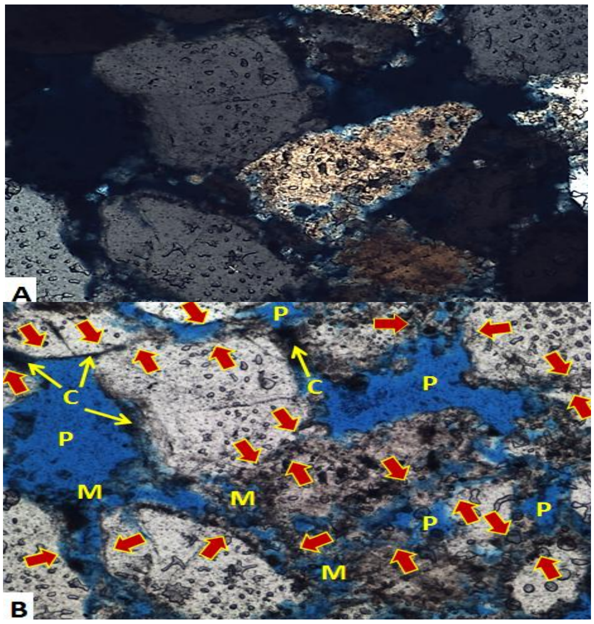


Figure-8: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. Note the different types of grain contact as a result of compaction (elongated and sutured). and the solution effect as well (the highly grooved surfaces of the grain could be the result of probably hot solutions. Slide (A) is under (XPL), slide (B) is under (PPL). Sample-5, (X10).

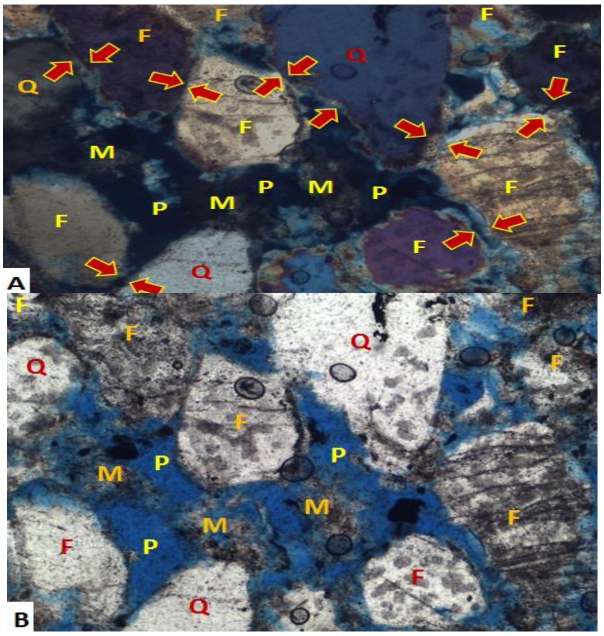


Figure-9: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. Note the different types of grain contact as a result of compaction. Slide (A) is under (XPL), slide (B) is under (PPL). Sample-6, (X10).

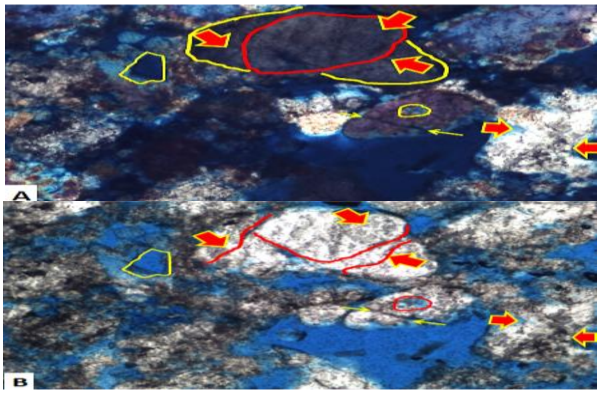


Figure-10: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. Note the overlapping grains, the embayment of grains, the fractured grains and hot solutions effect as well. Slide (A) is under (XPL), slide (B) is under (PPL). Sample-7, (X10).

2- The alteration of feldspar grains was also evident and may denote a late diagenetic process that took place through hydrolysis (a chemical weathering agent) and produced clay mineral material deposited as cement between grains, grain coating and matrix (Figure: 5, 6 & 7).

3- The observed secondary porosity within the rock samples is another late diagenetic phenomena resulted by chemical weathering of sandstones. This occurred when humic material-enriched ground waters and hydrothermal solutions raised from deep seated magma chambers through joints, fractures and faults and then pass through sandstones and dissolve cement material and other mineral crystals developing several types of secondary porosity such as moldic porosity, vug porosity and stylolites as well (Tucker, 1981). Actually, this type of porosity enhanced the total porosity of Abu-Shaybah columnar sandstones within the study area (Figure: 7, 10, 12 & 13).

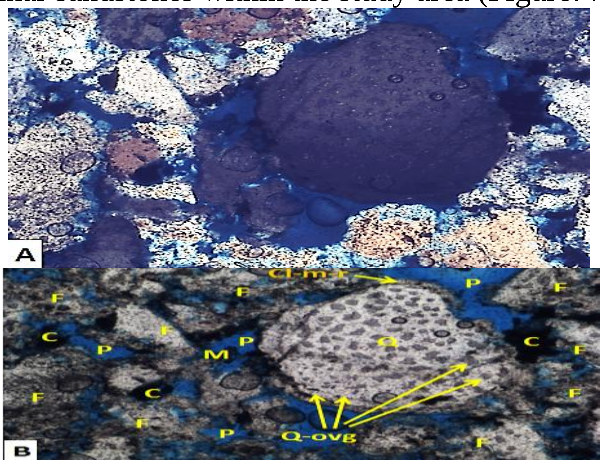


Figure-11: : Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. The late diagenesis produced by chemical processes. Note the overgrowth of quartz grain (Q-ovg), the clay material coating of quartz grain (the grey colored rim around quartz grain (Cl-m-r), the altered feldspar grains (F), the opaque (probably pyrite and iron oxide) cements (C) and the secondary porosity (P). Note the reddish brown aggregates or pellets in slide (A) could be of hematite. Slide (A) is under (XPL), slide (B) is under (PPL). Sample-8, (X10).

مجلة التربوي
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العدد 23

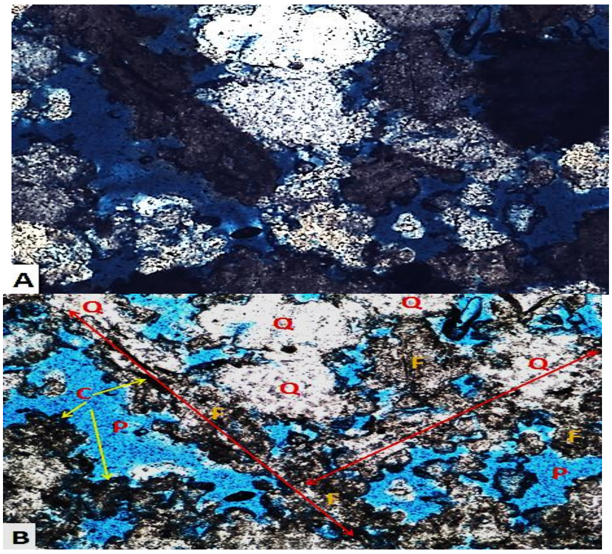


Figure-12: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. The late diagenesis produced by chemical processes. Note the coating of quartz grains by dark grey colored rims of clay and iron oxide and pyrite as well (C), the extensive dissolution (alteration) of feldspar and some quartz grains. Also note, the increased secondary porosity (P) and the development of an aligned stylolites (the red arrows in slide-B). Slide (A) is under (XPL), slide (B) is under (PPL). Sample-9, (X10).

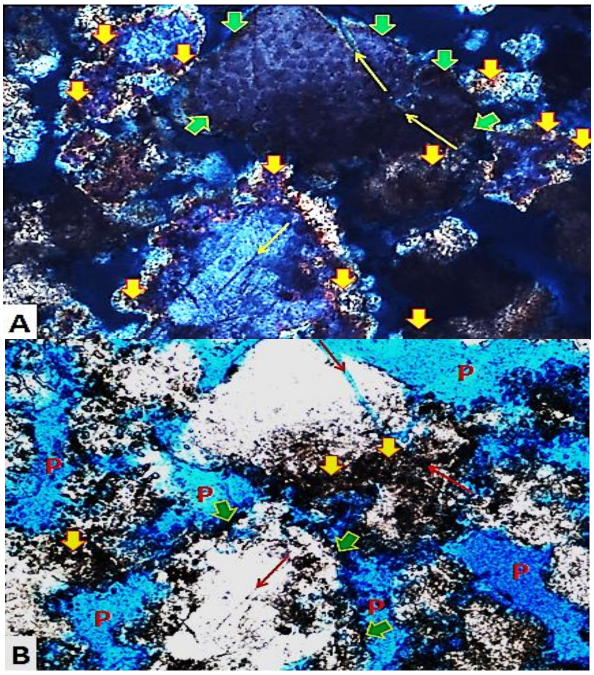


Figure-13: Arkosic arenite of Abu-Shaybah columnar sandstones, Gharian area. The late diagenesis produced by chemical processes. Note the iron oxide and/or pyrite nodules (thick yellow arrows) and the iron oxide and/or pyrite rims (thick green arrows) the coating mineral grains. Also note the altered feldspar and quartz grains and staylolite development (thin red and yellow arrows) and the increased secondary porosity (P). Slide (A) is under (XPL), slide (B) is under (PPL). Sample-10, (X10).

**Discussion**

Referring to the previous results of the petrographic study of columnar sandstones of Abu-Shaybah Formation within Gharian area documented by slides in figures: 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13, the following discussion will summarize this case of study.

1- The general appearance of grains that form the rock framework (which include quartz about 20%, feldspar about 70% with no lithic fragments and less than 15% matrix, "this were classified as arkosic arenite as discussed by Dott, 1964") appeared to be dramatically altered (especially feldspars). According to the maturity (Selley, 1976), this type of sandstone is considered texturally mature (as containing less than 15% matrix material) and is chemically immature (as containing more feldspar than quartz in other words it contains more unstable minerals than stable ones). This type of sandstones are thought to be deposited in riverine environments in which the sand grains were originated from granitic and gneissic outcrops (Greensmith, 1981, Blatt et.al, 1980, Pettijohn, 1975).

2- The studied rock samples showed evidences of late digenetic processes which was represented by both physical and chemical late changes. Blatt et. al (1980) stated that, the porosity of sandstones is dependent on many factors such as: grain size, grain roundness, grain packing and grain sorting. Other factors that may modify porosity of sandstones is the late diagenesis. The principles of Physical digenesis for clastic sedimentary rocks is discussed by Taylor (1950). In his studies, he stated that the number of grain contact points in the rock increasing as the burial depth of the rock increases. He then specified that "tangential contacts" between grains will prevail at shallow burial depths, "long contacts" will characterizing medium burial depths, " concavo-convex contacts" were found at greater depths, while "sutured contacts" formed at places where "pressure solutions" prevail (also refer to Sippel, 1968). Generally, these diagenesis could result in reducing the original porosity of the rock. In the present study, grain contacts of Abu-Shaybah columnar sandstone appeared as longitudinal, concavo-convex and sutured grain contacts which may denote their burial at medium to great depths that resulted in the reduction of their primary porosity.

6- Based on Dapples (1967) who studied the late diagenetic processes of sandstones and according to the petrographic characteristics of Abu-Shaybah columnar sandstones denoted in this current research, several chemical changes were detected in this current study which may denote subjection of these sandstones to at least (4) late diagenetic stages as follows:

a- The Redoxomorphic Stage: this include both oxidation and reduction processes which is usually take place after compaction processes where most of the pore waters released from sandstones. During this stage initial reactions between oxygen (O), iron (Fe), sulphur (S) and organic materials will take place in a regular way. Sandstones maintaining high porosity deposited above water table level will be subjected to oxidation reactions due to the aeration and passage of oxygenated ground waters through the available pore spaces. As a result, the organic material and sulphur compounds become oxidized and sulphate ions will transport in solution remaining only the oxidized iron (Ferric oxide) coating the sand particles and sometimes mixed with the clay matrix that forming the rock (rock will appear in red color) .

Unlikely, fine-grained, less porous argillaceous sandstones deposited below water table level where there is no free air, will undergo a remarkable reduction reactions. The existed organic matter may remain unchanged and formation of pyrite may took place (rock will appear in greenish-gray color). As a result of oxidation and reduction reactions through the Redoxomorphic stage, sandstones will lose their primary porosities.

b- The Locomorphic Stage: including the early process of cementation. Cement defined as the crystallized material that deposited (grown) within the pore spaces of the sediment after deposition. Silica solutions that invade the rock strata after deposition may led to the deposition of silica around the grains as a rim. This process can also take place through pressure solutions or pressure welds where at greater burial depths and when the number of grain contact points increases between grains, the edges of quartz crystals start to dissolve and re-precipitate directly around the quartz grains in the form of secondary quartz (Tucker, 1981). In a similar way, the iron-oxide-bearing solutions entering rock strata may deposit iron-oxide cement between grains and as grain coatings. In the present study hematite aggregates and/or pellets also found and acted as cement agent (this has been also reported by Chima, P., et.al., 2018). A study relating secondary silica, porosity and burial depth of sand sediments with pressure solution and pressure welding phenomena is made by Rittenhouse (1971b). He stated that as the degree of grain packing and grain incorporation of sandstone increases, silica dissolute at the grain-contact points and re-precipitate directly around the grains rapidly. The observed grain-contact types at great burial depths (also refer to Sippel, 1968) caused a reduction in columnar sandstones of Abu-Shaybah Formation.

c- The Phyllomorphic Stage: This is another expected phase in which the columnar sandstones of Abu-Shaybah Formation in Gharian area has been subjected to. This phase took place at the end of late diagenesis and beginning of low-grade metamorphism and where all the primary porosity of the rock has been lost through the "Locomorphic phase". During Phyllomorphic stage recrystallization of clay particles and other labile minerals (such as feldspar particles) that form the sandstone may took place and minerals like chlorite micas, biotite and muscovite could be formed. These changes may remark the beginning of transformation of sandstones to quartzite.

d- The Epi-diagenesis Phase or Stage (also referred to as " Secondary Porosity Formation Phase": Sandstone rocks could be subjected to tectonic movements at any time, causing them uplifted and as a result subjected to a sever and intensive both physical and chemical weathering processes on and near the earth's surface. This stage then will enhance the porosity of the rock (Hea, 1971). Secondary porosity is formed including "fracture porosity by physical means" and " solution porosity by chemical means through leaching that involve vuggy porosity, moldic porosity and stylolite porosity". A summary of the late diagenesis phases of sandstones is showed in figure-14.

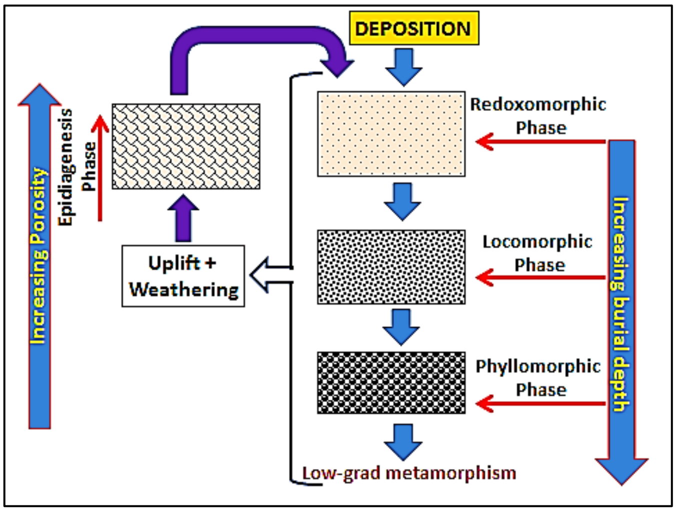


Figure-14: showing the relation between late diagenesis processes of sandstones and the development of their porosity (Modified from Selley, 1976).

## Conclusions

Conclusions that can be drown from the present petrographic study of Abu-Shaybah Formation columnar-jointed sandstones in Gharian area may be summarized as follows:

1- The examined rock samples are classified as arkosic arenite sandstone consisted principally of about 20% subangular to subrounded quartz grains with exceeded amounts of about 70% subrounded to rounded (and sometimes altered) feldspar grains. Matrix material were less than 15% and lithic fragments were absent. Medium to bad sorting of grains is observed with exceeded secondary porosity. Clay and iron-oxide (and probably pyrite) rims and coatings around particles were evident and may form part of the cement. Euhedral quartz grains sometimes appeared with quartz overgrowth. Intergranular primary porosity as well Intragranular and fracture and stylolite porosities were encountered.

2- Four late diagenetic stages took place after deposition were found to characterize the studied samples of Abu-Shaybah Formation columnar-jointed sandstones in Gharian area which include: " The Redoxomorphic Stage": "at shallower depths and is remarked by iron-oxide, clay mineral and pyrite rims around grains as well as grain coatings", The Locomorphic Stage": "as depth of burial increased and remarked by cement precipitation between grains which included clay material, iron-oxide, pyrite and silica (in the form of quartz overgrowth) cements", " The phyllomorphic Stage": "at greater and increased depth of burial and is remarked by formation of mineralized material around grains (could be chlorite and micas)", "The Epi-diagenesis Stage": " took place after the uplifting of the rock to shallower depths towards the surface and weathering agents activated lead to formation of many types of secondary porosities such as solution porosity, vuggy and moldic porosities as well fracture and stylolite porosities". This late stage of diagenesis enhanced the total porosity of the Abu-Shaybah Formation columnar sandstones in Gharian area and can be considered as having good reservoir quality for ground water (good water aquifer).

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