Mineralogy and Petrography of Fatha gypsum rocks in Zurbatiyah area, eastern Iraq

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Abstract

Gypsum rocks of Fatha Formation in Zurbatiyah area, eastern Iraq were studied in terms of mineralogy and petrography. Mineralogically, X-ray difractometry results reveal that gypsum rocks are predominantly composed of gypsum minerals with minor amounts of calcite, anhydrite, bassanite and dolomite minerals. Scanning electron microscopy has shown that gypsum rocks rich inclusion with (Mg) in some samples. Fatha gypsum rocks have higher thickness in the succession of formation with marl, clay and limestone forming multi cyclic deposition. The thickness of Fatha formation in the studied area reach to 525 m. Petrographical and textural analyses reveal the common petrographical texture types of gypsum, alabastrine, satinspar, selenite, porphyroblastic, blocky, and columnar gypsum texture reflect evolutionary alterations relationships such as crystallization and recrystallization of gypsum rocks. The secondary hydration of anhydrite to gypsum and other alteration changes refer to shallow marine, supra-tidal and continental environments to the Fatha Formation.

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Gypsum, texture, Fatha Formation, mineralogy, Zurbatiyah.

1. Introduction

This paper focuses on the mineralogy and petrography of Fatha gypsum rocks in Zurbatiyah area. Fatha Formation was first defined by Busk and Mayo 1918 as lower Fars Formation, without mentioning the type locality. [1 and 2] described the formation was Agha Jaari oil field of southwest Iran. Recently, the lower Fars Formation is abandoned in Iran and is renamed as Gachsaran Formation by [3] which is equivalent to Fatha Formation. The Fatha Formation previously described as the most important formation within middle Miocene period in this area, covered by some of the Stable Shelf and the entire Unstable Shelf with Injana Formation (Upper Fars) [4]. Gypsum rocks of Fatha Formation forms as a cap rocks for many oil reservoirs (in the center and south of Iraq). Gypsum rocks of Fatha Formation also used in the manufacture of gypsum plaster and most useful materials in the dental field [5], which have available an economic source quantities of sulfur deposits especially in Mishraq city, northern Ir. Evaporites form about 50 % of the total thickness of the middle Miocene Fatha Formation in Iraq. [6] the evaporites are wide spread thus It consists essentially of minerals such as gypsum, anhydrite and rock salt such as halite. Fatha Formation characterized by rhythmic nature [1, 7]. Each rhythm contains different lithologies were comosed of greenish to gray marl, limestone, gypsum (and or anhydrite) and redish mudstone. These cyclicity of Fahta Formation divided it into two members namely Lower and Upper members[7]. The Upper member stated with first appearance of the reddish brown mudstone [7]. Fatha Formation deposted in shallow marine, supra-tidal and lagoonal environments [6, 7].

M. O. Ali [8] focused on facies analysis of Miocene succession (Serikagni, Dhiban, Jeribe, Fatha, and Injana formations) showing microfacies and environmental deposition in their formations also study the clastic rocks are represented by three groups of successions :

1-sand dominated – mud dominated rocks of Injana Formation

2-Red mud dominated – Green shale dominated rocks of Fatha Formation

3-Marl – Gray shale of Serikagni Formation.

2. Location of the study area

The study area is located geographically along the Iraqi- Iranian International Borders within the Zurbatiyah area about 80 km of Wasit governorate East of Iraq and within the latitudes ranged from (N 33° 08′ 60″ - N 33° 23′ 57″) to longitudes (E 46° 02′ 60″ - E 45° 58′ 15″) (Fig.1).

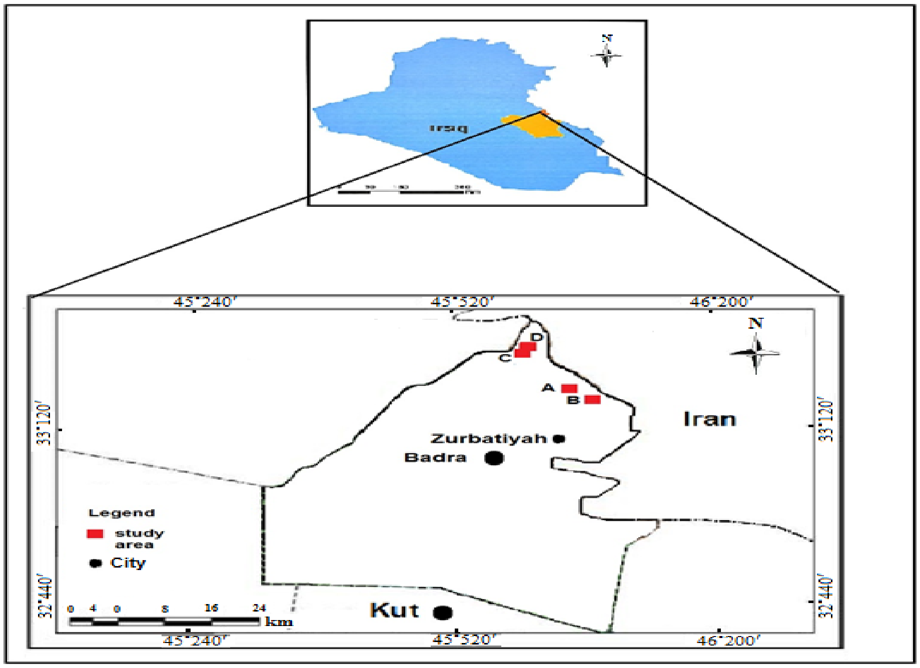


Fig.1: Location map of the studied area

3. Geological setting

The study area mainly included two zones , the eastern part of Mid –Mesopotamian Zone and the southwestern part foothill Zone - Makhul Sub - Zone represent the outer and central unit of the Unstable of the Nubio-Arabian platform. [9]. According to [10, 11], the study area located in the low folded zone of the western Zagros Fold-thrust Belt. (Fig.2). The Area is affected by late regional tectonic movements which caused severe distortions in geosyncline before Quaternary Period, the major structure within the study area is Hemrin anticline that extending parallel to the Iraqi-Iranian border, and have NW to SE trends, The most axis of Hemrin anicline is in Iran, while in Iraq includes the most southwestern limb and many secondary folds [12]. The present study focuses on Fatha Formation (middle Miocene age) deposited in closed lagoon of hypersaline conditions [13]. The good exposures of the formation allows the study of the cyclic nature. It is composed of repetition of gypsum, green marl, red claystone and limestone which indicate a closed basin –sabkha conditions during the middle Miocene stage [7].The formation was divided into two members (Lower and Upper memeber) [7], both members are exposed in study area repetition of lithology reflects the nature of depositional regime of Fatha Formation which was governed by alternating period of desiccation and influx of sea water [1]. On the other hand, the intermittent tectonic movement seems to be the most favorable mechanism to explain the cyclicity in Fatha formation deposits [7]. The Fatha Formation conformably overlies the lower Miocene Jerbie Formation which is exposed in the core of the anticline in Showshareen Valley. The Jerbie Formation consists of thick dolomitic limestone beds with darkish brown colour while the Upper Miocene Injana Formation lies up to Fatha Formation including variable lithology sandstone bedded and red to brown mudstone with thin gypsum bed further than calcareous sandstone, and rare limestone. They are deposit in sedimentary cycles of sandstone, siltstone, and mudstone. These cycles consist principally of repeated fining upwards succession nested above each other in general coarsening upwards in the sand [14].

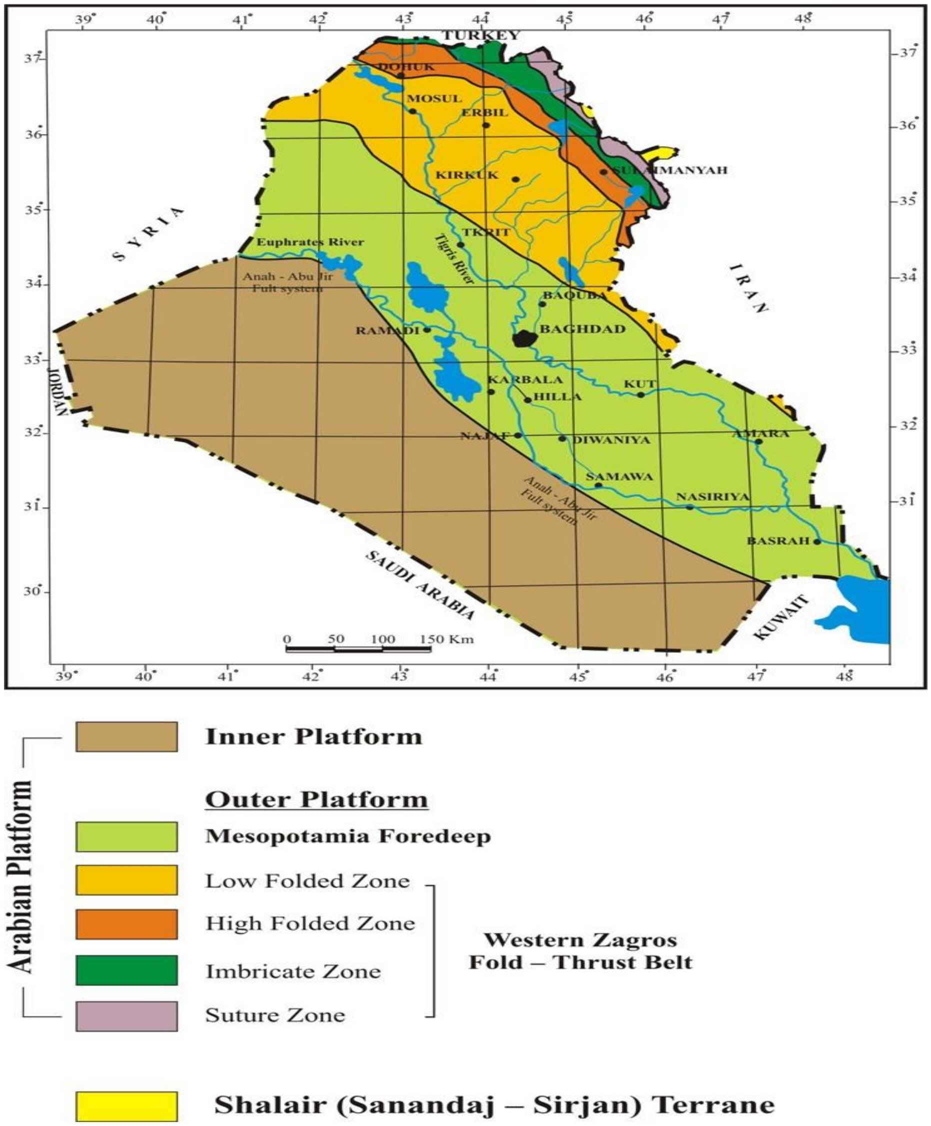


Fig.2: Tectonic Map of Iraq [10 and 11].

4. Materials and methods

Twenty five samples were collected from four selected sections A, and B (represent Al Jabal area) and C, and D (represent Al Hasheema area) in Zurbatiyah area as shown in Fig.1. The mineralogy of bulk samples were examined by using X-ray diffraction (XRD) techinques type. The instrument used is Bruker 2D Phaser in Department of Geology, College of Science, University of Baghdad. Twenty five thin sections of gypsum rocks were studied under polarized microscope, type Optica in Basrah Geology Laboratory. Scanning electron microscope - Energy dispersive X-ray spectroscopy (SEM- EDX) techniques Model ZEISS Gemini SEM 500 available in Amir Kabeer University Laboratory/ Mahshahr-Iran are used to examine the microstructures of gypsum samples.

5. Results and discussion

5.1 Lithology of gypsum rocks

The gypsum facies represents the mainly thick beds of the cyclic succession of Fatha Formation, the other components of cycles being greenish to gray marl, limestone, and redish to brown mudstone (Fig.3). The component of evaporite developed mostly thickly in the basinal area of Fatha Formation and extended southeast towards Iran International Border . The total maximum exposed thickness of Fatha Formation in the studied area about 525 m according to our field Observations. Field observations indicates the presence of massive and nodular gypsum, while the selenite type exist with bedding and fractures layers. The presence of black spots pitted or impurities in the gypsum may be refer to the mixing of different materials during primary sedimentary processes, or due to the secondary effects by solution, weathering and erosion (Fig. 4) [15]. Jerbie Formation (middle Miocene) is laying berneath of Fatha Formation which is exposed in the studied area composed of about more than 100 m gray limestone to dolomatic limestone, whereas Injana Formation is laying up to Fatha Formation composed of gray and brown sandstones interbedded witt brown claystone and brown siltstone.(Fig. 5). Fatha Formation was deposited in shallow marine to supra-tidal and continental environments [16], and the cyclicity of the Formation is due to tectonic factors, glacioeustatic sea- level changes, and autocyclic processes of sabkha/tidal-flat progradation [17]. The study area is affected by some thrust faults running parallel to the Iraqi-Iranian international borders.

Fig.3:Cyclic succession of beds in Fatha Formation

Fig.4: Nodular massive withchicken-wire texture

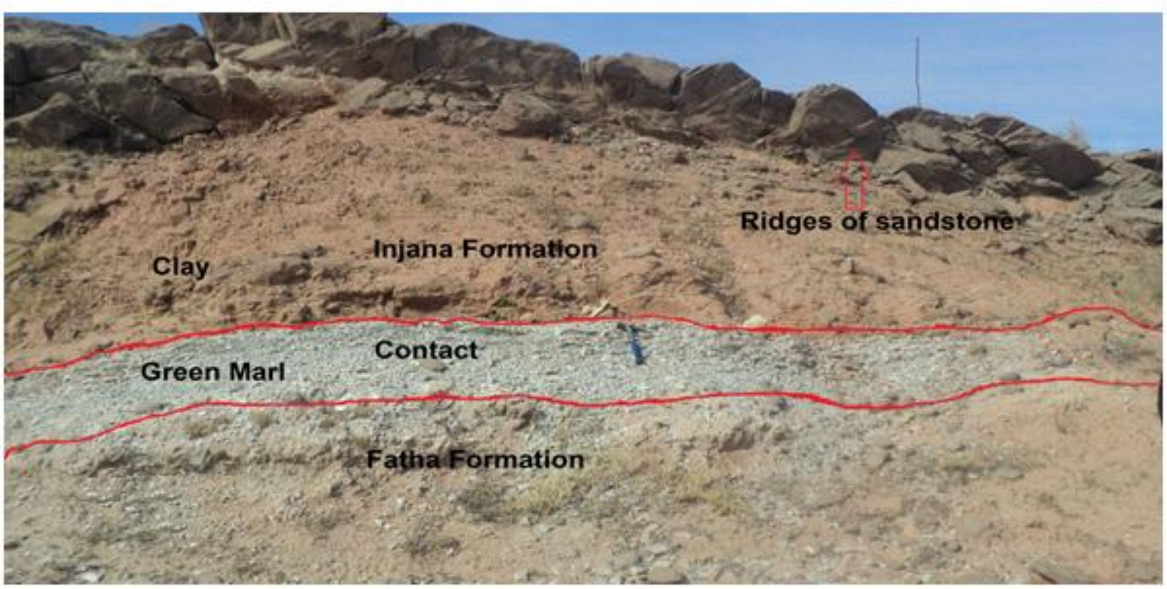


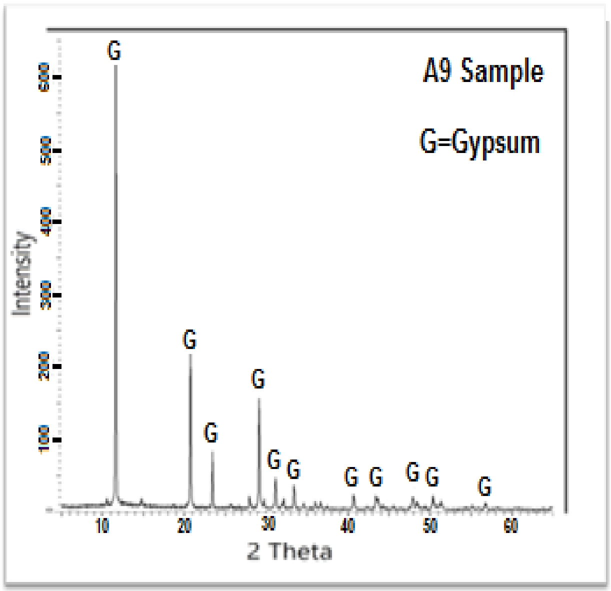
Fig.5: Contact between Injana and Fatha Formations

5.2 Mineralogy of gypsum rocks

The mineralogy of gypsum rocks were studied for the four sections A,B,C, and D choosed in the studied area to identify the mineralogy and to show the differences in textures and micro structures of gypsum rocks.

5.2.1 X-ray diffraction

The X-ray diffraction (XRD) results of eighteen gypsum samples show that all samples have high purity with minor amount of calcite, dolomite and Bassanite, where gypsum appears the predominant phases ranges between 70 % - 100 % of total constituents (Table.1) and (Fig.7). Bassanite phase represents the transformed phase of gypsum and anhydrite and the temperature required for transformation lies between (40-48°C) but may be lowered to (20-25 $^{\circ}$C) in the presence of sodium chloride [18]. Also XRD used to semi-quantify the mineralogical phases according to [19]. The mineralogical impurities associated with gypsum are calcite, dolomite, anhydrite and bassanite. These impurities may be mixed with gypsum because of primary sedimentary processes or present as a result of the secondary effect of solution, weathering and erosion [20]. Figure 7 shows the XRD pattern for gypsum A9 sample (section A, Al-Jabal area) and D6 sample(section D, Al Hasheema area). Table 1 is listed bulk semi - quantitative mineralogy of Fatha gypsum rocks samples according to [19].



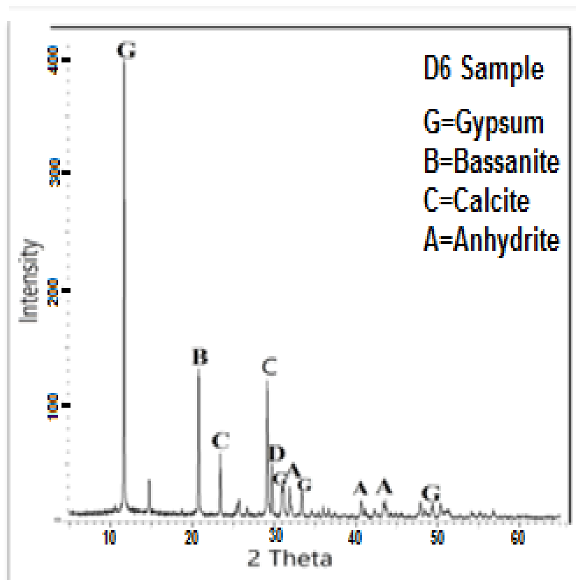


Fig. 7: The XRD diffraction for gypsum A9 sample (section A, Al-Jabal area) and D6 sample(section D, Al Hasheema area).

Table 1: Bulk semi - quantitative mineralogy of Fatha gypsum rocks samples according to [19].

Sample	Gypsum	Dolomite	Calcite	Anhydrite	Quartz	Bassanite
*A5	100	-	-	-	-	-
A9	100	-	-	-	-	-
A11	100	-	-	-	-	-
A12	100	-	-	-	-	-
A15	69.8	5.8	2.6	1.2	-	20.8
*B3	100	-	-	-	-	-
B6	100	-	-	-	-	-
*C1	100	-	-	-	-	-
C4	100	-	-	-	-	-
*D2	100	-	-	-	-	-
D6	100	-	-	-	-	-
D7	100	-	-	-	-	-
D9	100	-	-	-	-	-
D13	100	-	-	-	-	-
D14	100	-	-	-	-	-
D17	100	-	-	-	-	-
D20	100	-	-	-	-	-
D27	100	-	-	-	-	-

*A section A, *B section B, *C section C and *D section D

5.2.2 Scanning electron microscope

Scanning electron microscopic tests show deep focusing of various gypsum microstructures and structures such as dolomitic inclusion impurities (Fig. 9 A), these inclusion impurities remains of the primary precursor minerals (such as anhydrite in gypsum) can be appear in the gypsum crystal lattices. Particularly valuable are the inclusions in the primary minerals which can be liquid, solid, gaseous and alternated straight bands of dark and white folias in fibrous (selenitic) gypsum (Fig. 9 C). The EDX spectra recorded of the gypsum studied in Zurbatiyah area (Al Jabal and Al Hasheema area) indicates a clear enrichment of Ca and S whereas the other constituents Al, Mg, Si and O are inherited by different silicates, especially clay minerals and dolomite with scarce amounts in gypsum crystals lattice (Fig. 9 B and D). Gypsum crystals occur in different shapes and sizes such as euhedral lenticular, granular, hexagonal, columnar, rod-like, subhedral, , tabular, prismatic, etc. [21], and growth the nodules of gypsum reflect different diagenetic processes have affected on the gypsum rocks; these include: hydration, cementation, compaction, replacemnent and recrystalization. [22]. Most sulphates are very easily undergo the diagenetic processes, in which the dominant role is played by: hydration (gypsification) of anhydrite and dehydration (anhydritization) of gypsum; both processes are reversible[23], and the reaction takes place as follows:

$$CaSO_4 \cdot 2H_2O \rightleftarrows CaSO_4 + 2H_2O \text{ .... } 1$$

$$\text{gypsum} \rightleftarrows \text{anhydrite} + \text{water}$$

The conversion of gypsum to anhydrite and back to gypsum are common processes. The stability and solubility of gypsum and anhydrite are greatly affected by changes in the physical and chemical parameters that occur within common geologic environments. [24]. According to mineralogical, petrographical and Scanning electron microscopic study the purity of gypsum found in section A,B,C and D (Al-Jabal and Al Hasheema areas) varies due to its origin, the type and amount of impurites fully depend on the source location of the quarry or mine gypsum rocks which is the purity of mined natural rocks presents a variation between 80-96 %. [25]. (Henkels and Gaynor, 2005) while in the current study, the purity reach to 98 % reflect the importance of gypsum raw materials for product gypsumplasters in Zurbatiyah area.

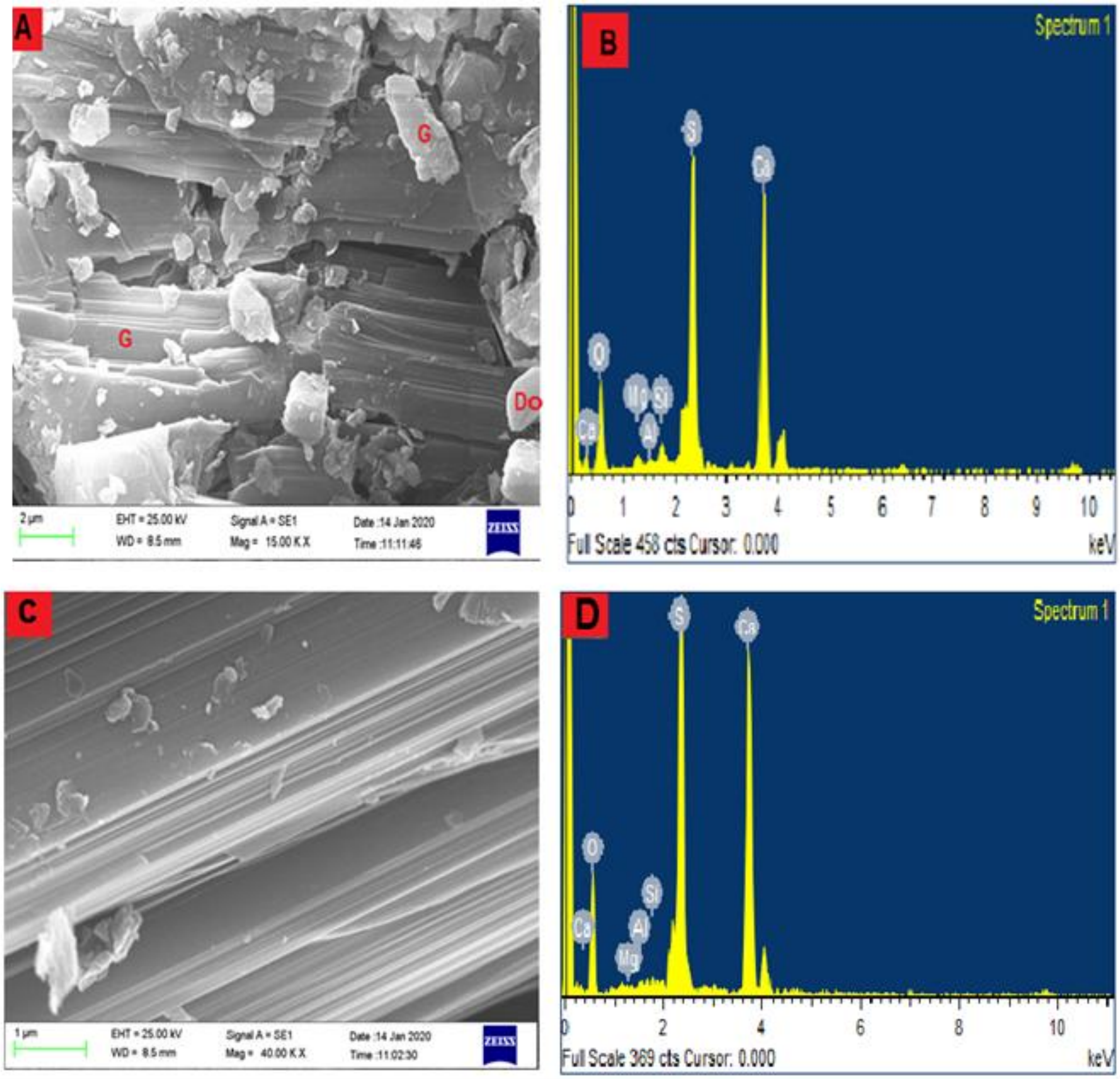


Fig. 9: SEM - EDX (A,B) image of (G) gypsum crystal, and (Do), dolomite rhomb crystal inclusion, (C,D) alternated straight bands of dark and white folias in fibrous gypsum (sample A1 section A (Al Jabal area)).

5.3 Petrography of gypsum rocks

Petrographic studies of evaporites especially gypssum are helpful to aid deciphering their origin, allowing to know the events that took place beyond deposition and determine gypsum types and their textures. Thus, petrographic studies have been done to understand and accomplish the goal of current study. Diagenetic processes have affected the studied rocks such as including hydration, dehydration, cementation, replacement and compaction reflects textures and their crystals growth which are depend on crystallization, saturation and ionic strength [26]. The crystal shapes within spherulitic pseudomorphs indicate formation as radiating clusters of platy crystals which were probably originally anhydrite. The tabular euhedral pseudomorphs initially crystallized as gypsum, whereas the acicular single crystal pseudomorphs have a shape which is most closely comparable with that of anhydrite [27]. The primary gypsum directly pricipitate from brines and preserve the original texture and have not any anhydrite relics [28] (Dronkert,1985) whereas the secondary gypsum formed due to the replacement of a precursor anhydrite or has been occurred during diagenesis [18].Two basic properties are considered by the present study in order to classify the evaporitic rocks, the structural terms are based on variations in external features of the evaporitic masses, while the external terms are based on the optical mineralogy and details of crystal fabric within the evaporitic masses.

5.2.1 Gypsum textures

The texture o f the gypsum varieties that are available in the outcrops of Fatha Formation as well as the structure and the morphology o f the outcrops belongs with repetition successions of layers cyclicity and other microtextures examined under polarized microscope. The following textures are identified in studied gypsum rocks.

5.2.1.1 Porphyroblastic texture

This type of texture is characterized by the presence of large gypsum crystals are embedded in a finely crystalline groundmass. The large crystals are composed of porphyroblast, generally up to 3 mm in size (Fig.6 A). In some gypsum crystals, secondary anhydrite microcrystals are observed and have formed a subcellular Poikilotopic texture (Fig. 7 A). This texture is characterized by the presence of inherited relicts of anhydrite and bassanite due to gypsum hydration or secondary hydration processes [29].

5.2.1.2 Alabastrine texture

This type of texture is very fine and also called microcrystalline gypsum with size less than 50 μm (Fig.6 B). The alabastrine gypsum texture is very common in gypsum samples that resulted from the secondary hydration of an anhydrite precursor which formed under various conditions [18]. Also The alabastrine gypsum texture recorded as circular, elongated, or irregular patches adjacent to, or within the porphyroblastic gypsum or cross linked gypsum crystals (Fig. 6 B). Gypsum crystals appear to be secondary and often observed as elongated, cross-linked crystals, producing alabasterine texture (Fig. 7 B).

5.2.1.3 Fibrous texture

This type of texture is found inside the fractures and cracks crystallized under pressure from water-filled veins, might be fine or coarse fibrous texture. Sometimes are developed as a lamella crystals union together forming felty texture, irregular and unoriented texture (Fig.6 C).

5.2.1.4 Granular texture

This type is composed of coarse crystals interlocking firmly. When the coarse crystals have a preferred orientation due to thick overburden load, then texture is called integrated granular texture (Fig.6 D).If the coarse crystals have randomly orientation the texture called unintegrated granular texture. These textures affected by tectonics effects reflect on thier texture that have been grouped in textures dynamic and Porphyroblast texture after hydration of anhydrite which is belongs to the first stage of diagenesis (early diagenesis) [30], surrounded by fine grained (alabastrine secondary gypsum). This texture as a results of tectonic activity spreaded in all studied area (Fig. 8). Formation of the dynamic texture in the secondary gypsum based on tectonic processes, These processes have different tectonic effects due to the type of gypsum texture [31].

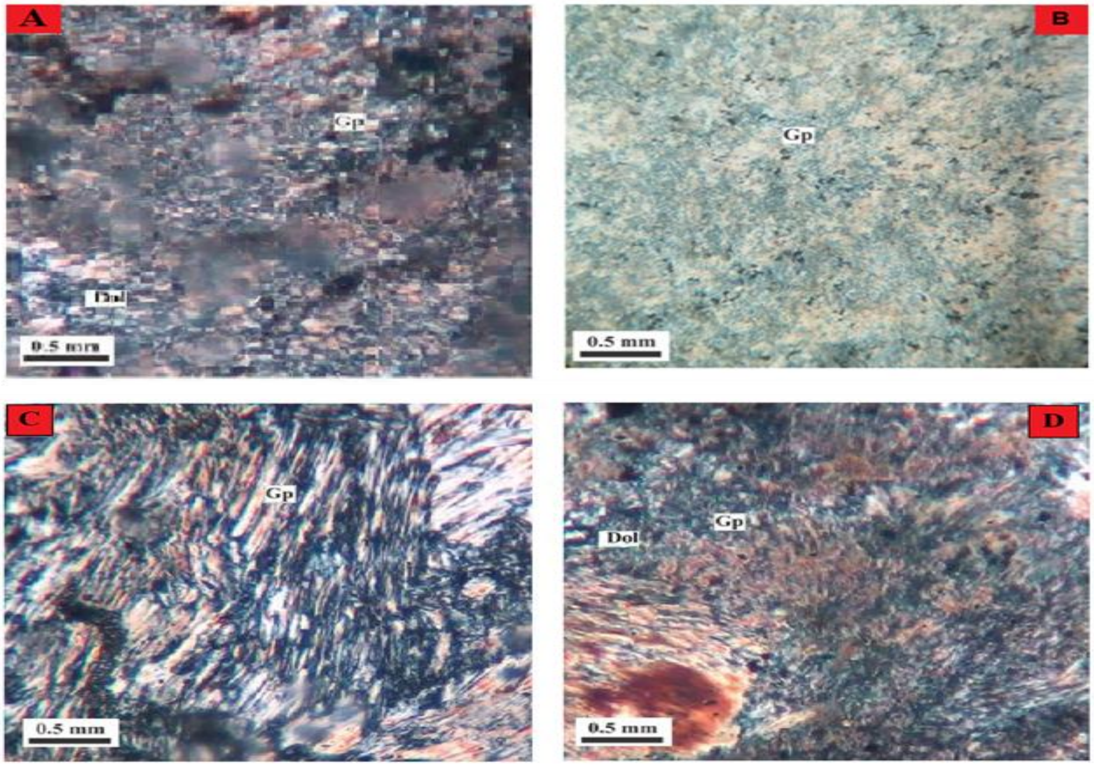


Fig.6: A porphyroblastic texture, B alabastrine texture, C cross linked gypsum crystals to fibrous gypsum, and D granular texture in cross polarized light (XPL).

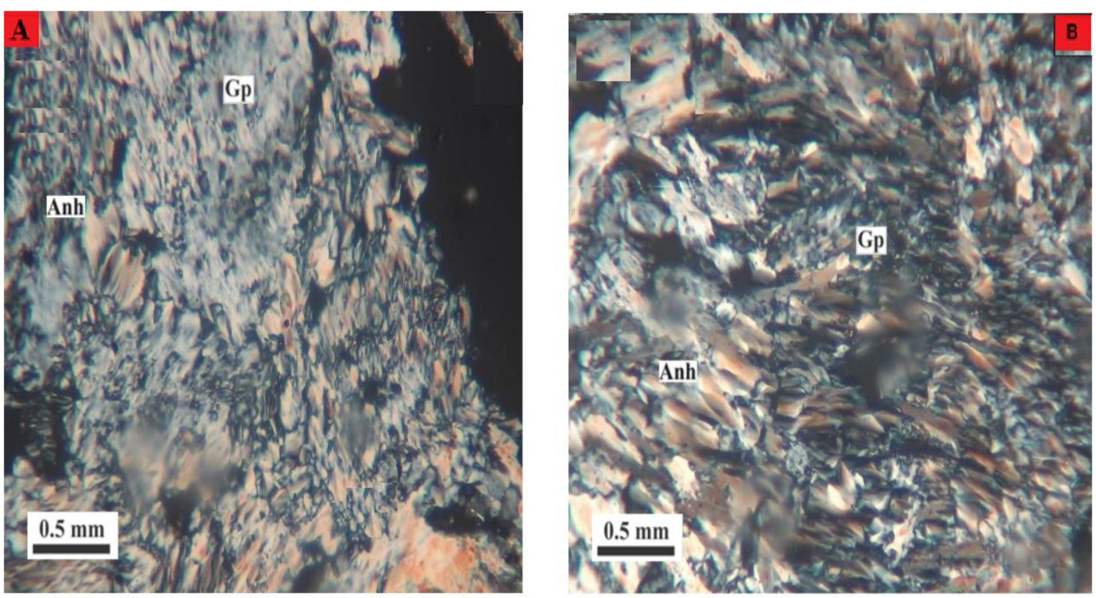


Fig.7: A Crystallization of parallel gypsum plates cross polarized light (XPL light), B An overview of porphyrotope gypsum with anhydrite fine crystalline residues cross polarized light (XPL light).

Fig.8: Tectonic activity in the studied area

5.4 Conclusions

The present study reached the conclusions mentioned below:

- Depending on field observations, mineralogy, and petrography of gypsum rocks in Zurbatiyah area reveals the primary gypsum in the most parts of the selected sections studied and the secondary gypsum covered some flat area with small thickness.
- The main component of gypsum rocks is gypsum mineral accompanied by calcite, dolomite, anhydrite, bassanite, and quartz as subsidiary minerals.
- The petrographic stydy indicated that the gypsum rocks are mainly having a nodular, fibrous, structure, and the main texture types are porphyroplastic, alabastrine, granular and fibrous fabric.
- According to petrographic and lithofacies studies, most diagenetic processes affected on the studied gypsum rocks are crystallization, recrystallization, replacement, hydration, dehydration, cementation and compaction.

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معدنية و بتروغرافية صخورتكوين الفتحة الجبسية في منطقة زرباطية, شرق العراق.

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المستخلص

تمت دراسة صخور الجبس معدنيا وبتروغرافيا في تكوين الفتحة في منطقة زرباطية, شرق العراق. واظهرت الدراسة المعدنية باستخدام تقنية الاشعة السينية الحائدة والمجهر الالكتروني الماسح بأن الصخور الجبسية تتكون في معظمها من معدن الجبس وكميات قليلة من معادن الكالسايت والانهيدرايت والبازانايت والدولومايت وبعض النماذج كانت غنية بمكتنفات الدولومايت.

وتميزت صخور هذا التكوين بسماكات عالية ضمن تتابع الدورات الرسوبية والطباقية في منطقة الدراسة ذات التتابع مارل, طين, حجر جيري و جبس حيث وصل سمك تكوين الفتحة في منطقة الدراسة الى 525 مترا. اظهرت الدراسة الصخارية والنسيجية تواجد معظم الانواع الشائعة للجبس وانسجته مثل الجبس الالباستري وساتنسبار والليفي (سيليناايت) والبروفيروبلاستي والمصمت والعمودي, وعكست هذه الانسجة العلاقات للتغيرلت التطورية للمعادن مثل التبلور واعادة التبلور للصخور الجبسية وكذلك عمليات التميؤ او التميؤ الثانوي و تحول الانهيدرايت للجبس والعديد من التغيرات الاخرى والتي تشير الى بيئة بحيرية ضحلة, فوق مدية وبيئة قارية.