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Petrology and Mineralogy of Jabal Sanam Carbonate Rocks, Basrah, Iraq

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Abstract

The field observation confirms the Sanam salt plug in southern Iraq composed essentially of successive sedimentary rocks interbedded with three igneous dikes and metamorphosed rocks. The tectonic and structural features of this Mountain are faults, minor folds and slickensides; In addition to several types of primary and secondary sedimentary structures. The exposed rocks capped and surroundings belong with the Dibdibba Formation (Pliocene - Pleistocene).

Petrographical and XRD analyses of (27) thin sections show that the investigated rocks consist dominantly of dolomite represents the dominant mineral with few to trace amount such as gypsum and quartz. Where A variety of dolomite rock units (carbonate breccias, stromatolite dolomite, dolomite and gypsiferous dolomite) of the Jabal Sanam plug have been identified and studied.

Dolomites of the Jabal Sanam are interpreted as stromatolitic bindstones which formed in intertidal to supratidal environment. Where this dolomites are similar to most dark gray dolomites are common in many salt plugs of the Arabian Gulf, Oman and Iran. They seem to be an essential and consistent part of the Hormuz Series. Severe tectonic movements during the exhumation phase led to the formation of the carbonate breccia at the uppermost part of the deposit. Streaks of organic matter probably result from oxygen-poor conditions during the Infra-Cambrian; Suggest that dolomitization could be an alternative dolomaitization model.

Dolomitization is believed to be related to a shallow setting and brine reflux. The Jabal Sanam dolomites experienced extensive recrystallization and sulfatiza during the emplacement of the salt dome.

Keywords: Hormuz Series, Sanam, Salt plug, Carbonate, Cambrian, Iraq

Introduction

Jabal Sanam is located in the extreme southern part of Iraq at the Iraq - Kuwait international borders, about (48 km) south of Basrah Governorate and (8 km) to the west of Safwan town. Based on the physiographic subdivision of Iraq presented by **[1],** Jabal Sanam occurs within the Dibdibba plain, whereas tectonically, it is located within platform of the foreland basin **[2].** It has coordinates of (30° 7' 00" to 30° 8' 00") latitude and (47° 37' 00" to 47° 38' 00") longitude (Figure 1) covered a total area of (1488484 m^2) about (1.5 km in diameter), and ranges in elevation between 60 to 150 m a.s.l. (125 m, above surrounding area).

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The mount body is comprised of a mixture of various lithologic compositions including sedimentary, igneous and metamorphic rocks **[1,3 &4].** Some of the dolostone beds in the intruded body include sedimentary iron, which is deposited due to hydrothermal fluids with high iron concentration. Where they believe that all those crushed rocks were raised from a depth of about (6 km) with the salt plug that underlies the intruded body **[3].** Dating of some dolerite rock fragments by K/Ar method revealed (570 - 580 Ma) dating of an Infracambrian or Cambrian age **[1].** Moreover, the negative gravity residuals associated with the structure strongly suggests that it is underlain by Infra- Cambrian salt **[5].** The rock successions of the Sanam Structure are belonging to Infra-cambrian, possibly in equivalent of the Hormuz Salt Series of the Arabian Gulf region **[5].** Therefore, these rocks could be considered as the oldest rocks in Iraq surrounded by Middle Miocene-Pliocene rocks and Quaternary sediments, which form the surrounding flat plains. The present study aims to make a detailed examination in the petrology and mineralogy of Jabal Sanam carbonate rocks in Iraq.

Figure 1: Satellite image shows the Jabal Sanam (the studied area) surrounded with the Dibdibba Plain.

Methodology

■ The field observation

In a field trip to Jabal Sanam by the authorands, about (27) rock samples were collected from the top and slopes of the structure; Systematic sampling for all representative rock units exposed in the area of study.

The field observation confirms the Sanam Structure composed essentially of successive sedimentary rocks interbedded with three igneous dikes. The lithological exposed in the Jabal Sanam are sedimentary rocks units (stromatolite carbonate, carbonate breccia, sandstone, mudstone, gypsum and gypsum breccia), igneous and metamorphic rock units. The tectonic and structural features of this Mountain are faults, minor folds and slickensides (Plate/ 1). Several types of primary and secondary sedimentary structures are observed to follow the classification of **[6],** (Plate/ 2).

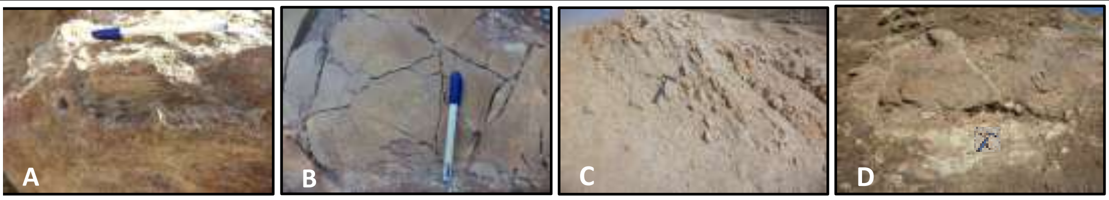
■ **Faults,** Several tens of faults are identified through the rock successions of Jabal Sanam from bottom to top and includes normal, reverse and thrust faults. The reverse and thrust faults are identified in the sides of the mountain, while the normal faults are identified inside the mountain (A, B & C). These faults are extended from one meter to several meters long.

■ **Minor folds,** Several folds are identified enclosed in the rock successions of Jabal Sanam from bottom to top and includes normal and recumbent folds. The large folds are mostly appearing in the sides of the mountain, while the small folds are identified inside the mountain (D & E). The injection of the salt diapers made a structure seems to be like a large anticline, but it is highly fractured and have broken blocks in sides of the mountain.

■ **Slickensides,** are a common structural feature recognized in the Jabal Sanam. It is recognized along the fault plain specially in the sides of the mountain (F).

Plate/ 1: Show different morphotectonic structures recognized in Jabal Sanam.

A) Thrust fault, **B)** Reverse fault, **C)** Normal fault, **D)** Normal fold, **E)** Reverse fold, **F)** Slickenside.



■ **Load casts,** are common structure observed in the rock successions. It is mostly associated with the carbonate breccia beds. The beds below the carbonate breccia are showing the load casts (Plate/ 2A). These casts are observed on the upper surface of carbonate and mudstone beds.

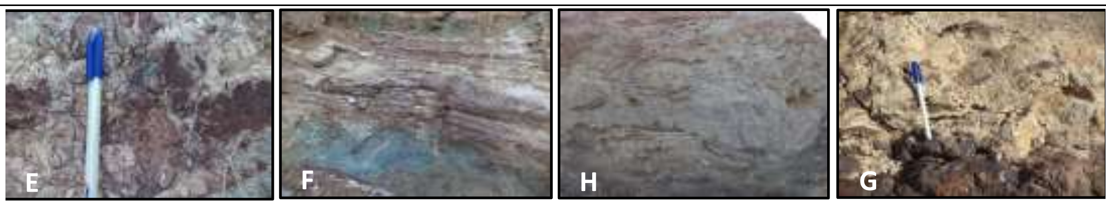
■ **Scour and fill structures,** are common structure observed with the load casts. It represents a scour hall depressions observed in the upper surface of the beds and filled with sediments of the above beds (Plate/ 2A). These structures are observed in the beds below the carbonate breccia.

■ **Groove casts,** are a observed in the upper surface of mudstone beds (Plate/ 2B). The groves are mostly parallel striations appear in the upper surface of the bed due to creep or slump of the overlying beds.

■ **Wedge beds,** are common feature in successive thin bedded carbonates, which are observed in the middle part of the successions (Plate/ 2C). It is observed as group of beds pinch out in a certain direction.

■ **Slump structures,** are common structure in the lower and middle parts of the rock successions in the mountain. It represent a slump of bed or bed set of the same or various lithologies to show disturbance in the internal features (Plate/ 2D).

■ **Slide structures,** are identified as a large mass of rocks sliding within another bed or bed set of different lithology (Plate/ 2D). This structure attains small and large sizes and recognized in the lower and middle parts of the rock successions.



■ **Disturbed and chaotic structure,** are mostly identified in the carbonate breccia units and chaotic fragmented beds of carbonate, gypsum and mudstones (Plate/ 2E). These beds are mostly associated with the slump and slide beds.

■ **Thin and thick beds,** are the most common structure in the Jabal Sanam. Most beds are thin and interbedded with thick and thin of various lithologies beds such as stromatolite dolomite, carbonate breccia, gypsum, sandstones and mudstones (Plate/ 2F).

■ **Convolute structures,** are identified in the lower part of the rock successions. It represents of as thin bedded mudstones creeped over a cohesive bed and convoluted due to shear stress (Plate/ 2G).

Plate/ 2: Show different sedimentary structures recognized in Jabal Sanam.

A) Load and scour casts, **B)** Groove casts, **C)** Wedge beds, **D)** Slump and slide structures, **E)** Disturbed and chaotic bed, **F)** Thin beds, **G)** Convolute beddings, **H)** Stromatolite laminations.

■ Laboratory Work

Twenty-seven (27) samples are selected for thin section slide preparation for petrographic examination followed the procedure listed in **[7]** to cut the sample perpendicular to the bedding plain to present all the mineralogical assemblages. The samples were prepared for thin sections in the workshop at the Iraqi Geological Survey. Twenty-seven (27) samples were selected for XRD analysis (Table 1) by crushing and pulverized using Herzog crushing machine to get powder of grain size (-75µ) at the Iraqi Geological Survey. XRD analysis was performed to identify the minerals difficult to determine under polarized microscope (especially tiny and very fine grains) in Iraqi-German labs in the department of geology, collage of sciences, university of Baghdad using German - Iraqi Geological laboratory of the Earth sciences Department, College Science, University of Baghdad. The condition of X-ray diffraction analysis is: SRD7000 Model 2009 / Japan, Cu-Ka tube 6/ Ka 5, Ni filter, Curt: 30m ANP VOT: 40 KV, Skann speed: 600 /minute, reproducibility: 0.00020. and the diffractograms were analyzed.

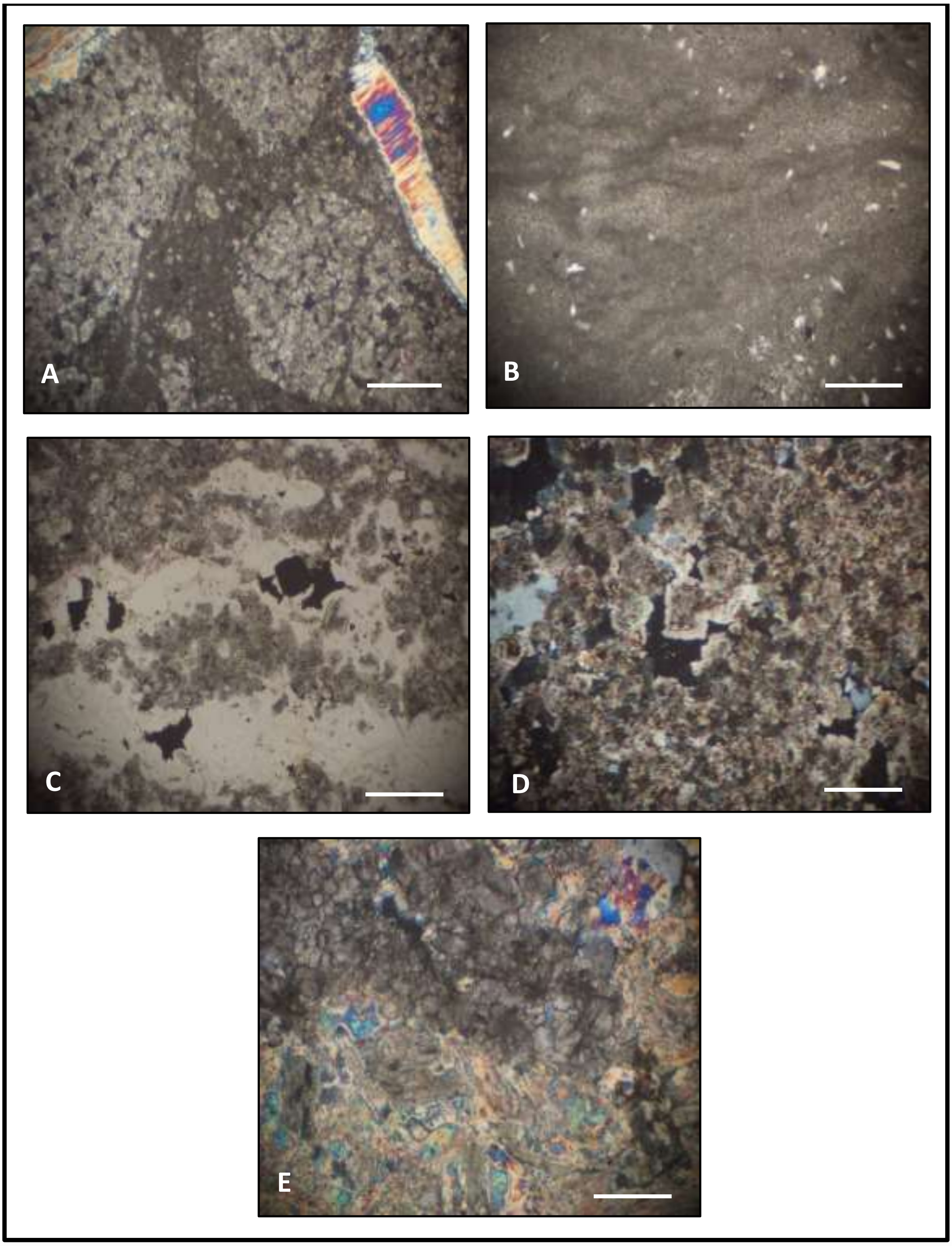
Table 1: Mineralogical assemblages of the studied rocks units identified by XRD analysis.

Sample no.	Minerals composition
JS1	Dolomite, Gypsum, Quartz, Chlorite.
JS2	Dolomite, Quartz, Muscovite, Gypsum.
JS3	Dolomite, Gypsum, Quartz.
JS4	Dolomite, Quartz.
JS5	Dolomite, Gypsum.
JS6	Dolomite, Quartz, Halite.
JS7	Dolomite, Quartz.
JS8	Dolomite, Quartz, Gypsum.
JS9	Dolomite, Gypsum, Quartz.
JS10	Dolomite, Quartz.
JS11	Dolomite, Quartz, Orthoclase.
JS12	Dolomite.
JS13	Dolomite, Gypsum, Barite, Quartz, Celestine, Anhydrite, Halite.
JS14	Dolomite, Gypsum, Quartz, Halite, Calcite.
JS15	Dolomite, Quartz, Halite.
JS16	Dolomite, Calcite, Gypsum, Quartz.
JS17	Dolomite, Quartz, Sanidine.
JS18	Dolomite, Muscovite, Halite, Quartz.
JS19	Dolomite, Gypsum, Quartz.
JS20	Dolomite, Gypsum, Quartz, Calcite.
JS21	Dolomite, Gypsum, Quartz, Goethite.
JS22	Dolomite, Gypsum, Halite, Quartz.
JS23	Dolomite, Quartz.
JS24	Dolomite, Microcline, Gypsum, Quartz, Calcite.
JS25	Dolomite, Gypsum, Quartz, Microcline.
JS26	Dolomite, Quartz, Gypsum, Iron oxide.
JS27	Dolomite, Feldspar, Quartz, Hematite.

Results (Petrology and Mineralogy)

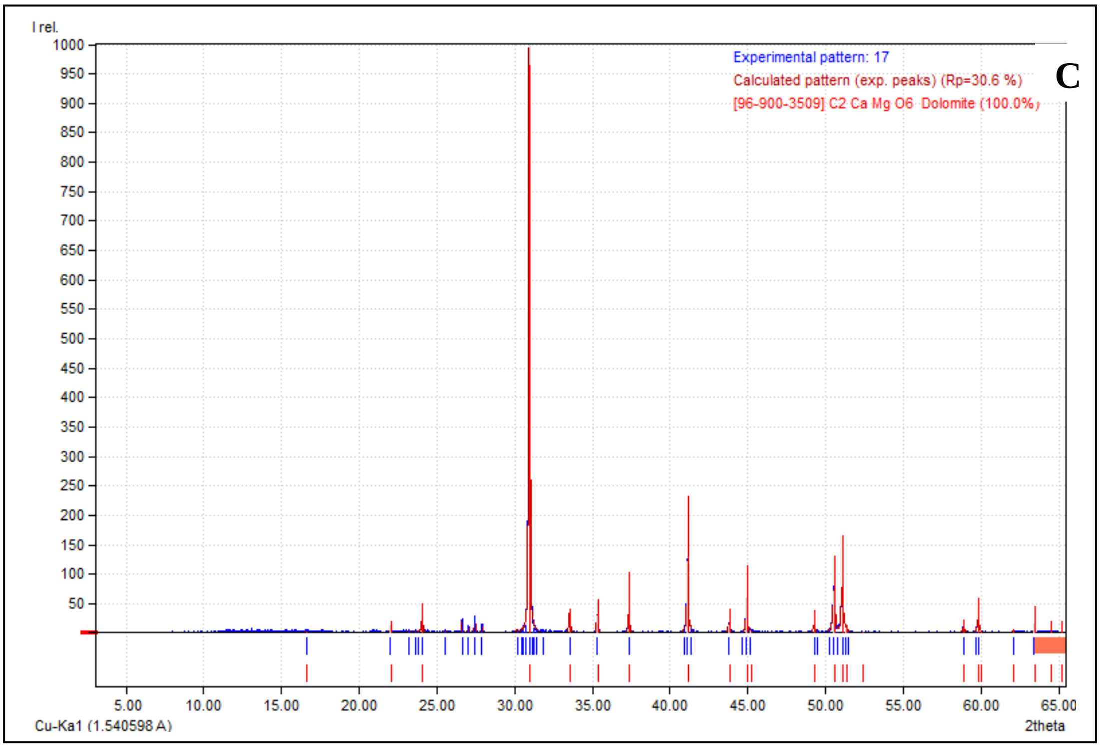
This study includes petrographic examination of thin-sections reveals mineralogical assemblages of the studied rocks and their crystal habits and textures as well as diagenesis and alterations if there; Using the general specifications of these minerals and described in global sources such as **[8, 9 &10].**The mineral composition is supported by XRD analysis (Table 1). According to the minerals assemblages identified by petrographic examination and XRD analysis, Several types of carbonate rock units are identified in the Jabal Sanam, these are:

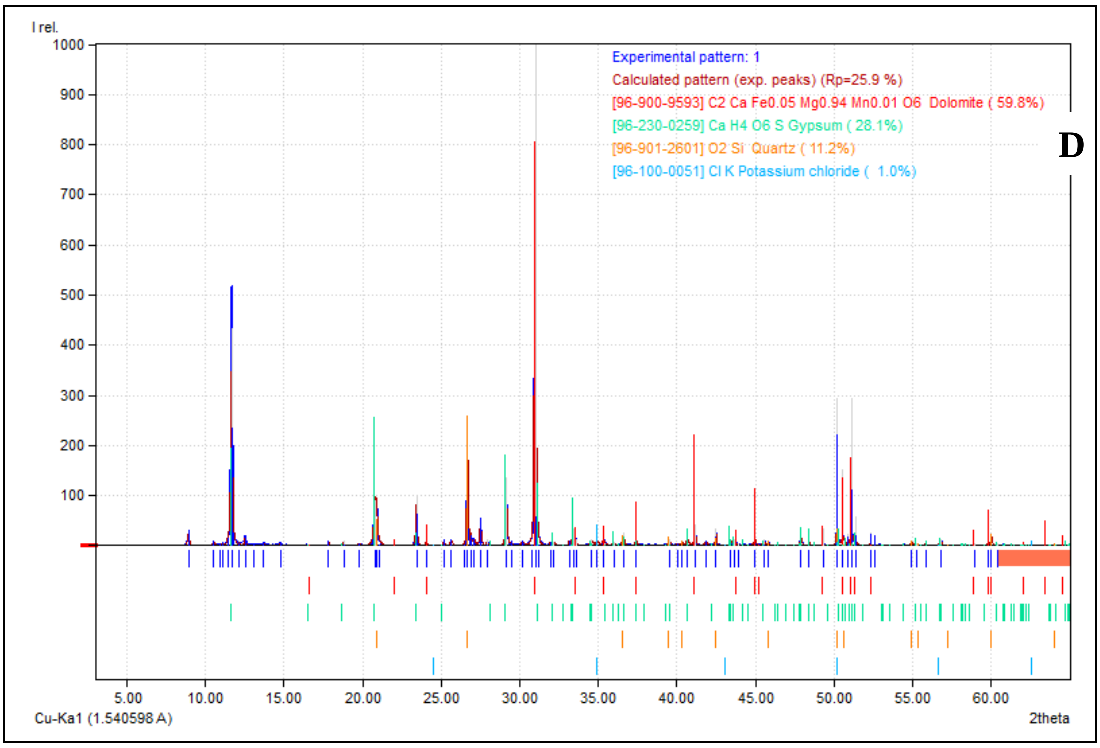
- **Carbonate breccias;** The most abundant and repeated type of carbonate rocks through the stratigraphic section is the carbonate breccia. Mineralogically, the carbonate breccia is composed basically of dolomite. The breccia is composed of dolomite fragments of different sizes and of angular shape. The pore spaces are filled partially with fine carbonate fragments and dolomicrite matrix (Plate/ 3A). The cementing materials of these rocks are of two types; the major is dolomite and the minor type is gypsum. XRD analysis of carbonate breccia shows that is composed of about 85% of dolomite, 8% gypsum and 7% quartz (Figure/ 2A).
- **Stromatolite dolomite;** This rocks are composed mainly of the dolomite of medium to coarse crystals size. It reveals characteristic stromatolite laminations of regular and irregular shape. These laminations are sometimes interbedded with crystals of gypsum laminae (Plate/ 3B & C). Mineralogically, the dolomite percent reaches up to 95% of the whole rock with accessory detrital monocrystalline quartz of angular to subrounded shape and very fine sand size grains. Some pore spaces are filled with quartz and iron oxides as authigenic minerals. XRD analysis of stromatolite dolomite shows that is composed of about 78% of dolomite and 22% of quartz (Figure/ 2B).
- **Dolomite;** The dolomite rocks composed basically of 100% of dolomite crystals (Plate/ 3D), (Figure/ 3C). Some beds have fine crystalline dolomite and/or dolomicrite, while others are of medium to coarse crystalline dolomites. The crystals are clear or dusty center with some scattered rhombohedral crystals and sometimes appears in crystalline patches.
- **Gypsiferous dolomite**; The gypsiferous dolomite composed basically of dolomite crystals of different sizes ranging between fine to coarse crystals. Gypsum is filled with relatively high percentages of porosity and fractures (Plate/ 3E). Organic matters are observed in some samples filling the pore spaces or as debris fragments, which that the pore spaces are filled partially. Iron oxides are present to fill some of the pore spaces. This rock is laminated stromatolite composed of dolomite lamina inter laminated with gypsum lamina with scattered detrital quartz grains (Figure/ 3D).



Plate/ 3: Show mineralogical constituents of various types of rock (Bar= 0.2 mm).
A) Dolomite breccia, **B & C)** Stromatolite dolomite, **D)** Dolomite, **E)** Gypsiferous dolomite.

Figure 2: Diffractograms of carbonate units show mineralogical composition.
A) Carbonate breccias. **B)** Stromatolite dolomite.





Figures 3: Diffractograms of carbonate units show mineralogical composition.
C) Massive dolomite. **D)** Gypsiferous dolomite.

Discussion

The petrographic study of the carbonate rocks indicates that the nearshore and shallow-marine sediments are relatively more affected by dolomitization **[11].** Where, diagenetic processes in the shallow burial realm are controlled strongly by early dolomitization which is either attributed to the shallow subtidal model **[11]** or triggered by reducing conditions induced from removal of ($SO4^{2-}$) by sulphate reducing bacteria**[12].** According to the shallow sub tidal model, dolomitization occures prior to replacement of connate water within permeable carbonates at the lagoon floor with hypersaline, moderate to highly lagoon brine **[13].** On the other hand, bacteria induced reducing conditions accompanied by metal enrichment additionally faciliate dolomite precipitation **[14].** These types of processes likely occured within organic-rich associated carbonate laminae.

The predominant dolomite/dolomicrite are likely to be related to burial dolomitization at temperatures exceeding (~50°C), **[15&16].** When evaporite successions reach depths of (2-3 km), temperature increases above (~ 60°C) which enables dolomitization by solutions with lower (Mg/Ca) ratios; Therefore residual evaporite brines or sea water can become dolomitizing solutions **[17].**

Formation of carbonate gypsum breccia subsequent to evaporite rehydration follows when an increased amount of gypsum is leached under the influence of meteoric. Gypsum dissolution processes control and facilitate dissolution of the associated dolomite, followed by calcite precipitation throughout a process described in the literature as gypsum-driven dedolomitization **[18].**

The precipitation of calcite removes dolomite-supply carbonate ion and gypsum-supply calcium ion from the solution, thereby causing further dolomite and gypsum dissolution; Finally, this type of process, together with tectonic movements resulted in the formation of carbonate gypsum breccia deposits. Laminated facies composed of millimeter to centimetre thick intercalations of dolostone sometimes bearing organic matter, pyrite, quartz, gypsum and/or halite were interpreted by **[19],** as having originated from sabkha or lagoon of the environment. Due to burial, the thickness of the overlying deposits increased (increasing lithostatic pressure and temperature).

Severe tectonic movements during the exhumation phase led to the formation of the carbonate-evaporite breccia; Exhumation processes were followed by widespread partial dedolomitization of the deposit. The dark colored carbonate rocks seem to be common in many salt plugs of the Arabian Gulf, Oman and Iran; Where they seem to be an essential and consistent part of the Hormuz Series. The dark color suggests formation in reducing environment. Some of the observed lamination of regular and irregular shape, observed in some dolomite samples studied may be compared to similar structures at Halul and Shraouh plugs noticed by **[20],** which they were attributed to stromatolitic bedding and algal mats; These may be considered evidence of formation in intertidal to supratidal environments supported by the very fine grained texture of the dolomite.

These dolomites might be earlier than or congruous with the evaporates of the Hormuz Series; They could have precipitated directly or in the early digenesis during the latest Precambrian transgressive phase (600 Ma), before the Early Cambrian regression, as marginal marine carbonates. Where as the evaporates occupied the center of the basins and continued to form longer time than the carbonates during the regressive and evaporitic stage.

Some carbonate samples contain calcitic and less affected by diagenetic modifications that may suggest them as by product of other rock alterations and/or direct precipitation from solution in continental environments. Where they have no fossils content and no impurities or structures that may point towards their origin in marine environment; They might be broken parts of epigenetic vein filling.

Conclusion

A variety of dolomite rock units at Jabal Sanam plug have been identified and studied; They are: Carbonate breccias, Stromatolite dolomite, Dolomite and Gypsiferous dolomite.

Infra-Cambrian carbonates of the Jabal Sanam, have been investigated with respect to depositional environment and diagenesis. Petrographical and XRD analyses show that the investigated rocks consist dominantly of dolomite and have formed in a reducing depositional environment. Laminated dolomites of the carbonate-evaporite cycles are interpreted as stromatolitic bindstones which formed in intertidal to supratidal environment; Where this dolomites are similar to most dark gray dolomites reported and described in association with the Hormuz Series salt of the Gulf region. Severe tectonic movements during the exhumation phase led to the formation of the carbonate-evaporate breccia. Streaks of organic matter probably result from oxygen-poor conditions during the Infra-Cambrian. Dolomitization is believed to be related to a shallow setting and brine reflux. The Infra-Cambrian age and the presence organic materials in the studied rocks; Suggest that dolomitization could be an alternative dolomaitization model.

CONFLICT OF INTERESTS.

There are non-conflicts of interest.

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الخلاصة

يعتبر جبل سنام واحدا من اكثر من مائتين من المقحمات الملحية التي تعود الى سلسلة هرمز في منطقة الخليج العربي والتي يقدر عمرها بتحت الكامبري, تؤكد الملاحظة الميدانية أن سد الملح "سنام" في جنوب العراق يتألف أساسا من صخور رسوبية متعاقبة متداخلة مع ثلاثة سدود نارية وصخور متحولة, تظهر الصفات التكتونية (الفوالق والطيات الصغيرة) والتركيبية لمنطقة الدراسة, بالإضافة إلى عدة أنواع من التراكيب الرسوبية الأولية والثانوية, وتغطي صخور تكوين دبدبة الصخور المنكشفة من جبل سنام والمناطق المحيطة به. تظهر التحليلات الصخرية و المعدنية ل (27) عينة من الصخور التي تم فحصها حيث تتكون من معدن الدولومايت الذي يمثل المعدن الرئيسي مع كميات قليلة من المعادن الثانوية مثل الجبس والكوارتز ..... إلخ. وتم تحديد ودراسة مجموعة متنوعة من وحدات صخور الدولومايت (carbonate breccias, stromatolite dolomite, dolomite and gypsiferous dolomite) في تركيب سنام.

بينت دراسة الدولومايت على وجود تراكيب شبيهة بالستروماتولايت ويعتقد انها ترسبت في بيئة بحرية على حافة الحوض الرسوبي؛ حيث تكون هذه الدولومايت مشابهة لمعظم الدولومايت الرمادي الداكن الشائع في العديد من سدادات الملح في الخليج العربي وعمان وإيران. أدت الحركات التكتونية الشديدة خلال عملية اختراق الصخور نحو السطح إلى تكوين الصخور الكاربونات المترهصة في الجزء العلوي من الترسيب .قد تنتج شرائط من المادة العضوية من الظروف السيئة للأكسجين خلال تحت الكامبري (Infra–Cambrian). تشير إلى أن الدلمتة يمكن أن يكون نموذج بديل الدلمتة وقد مرت صخور الدولومايت جبل سنام فترة إعادة بلورة موسعة أثناء واختراق قبة الملح, ويعتقد أن عملية الدلمتة مرتبطة بالوضع للضحلة وتدفق الأملاح.

الكلمات الدالة: سلسلة هرمز، جبل سنام، المقحمات الملحية، بتحت الكامبري، الكاربونيت، العراق.