MINERAL RESOURCES AND OCCURRANCES IN AL-JAZIRA AREA

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ABSTRACT

Al-Jazira Area is located at the northwestern part of Iraq, it is covered by Euphrates, Fatha and Injana formations of Miocene age. Oligocene is represented by Anah Formation that is exposed as narrow strip near Rawa town along Euphrates River. These formations consist of limestone, marl, claystone, gypsum, sandstone and siltstone. Gypcret, sand and gravels of Quaternary sediments are present as thin cover. Limestones of Anah and Euphrates formations are mostly exposed on both sides of Euphrates River with high purity of calcium carbonate and are present with an economic potential for cement, glass, sugar industries, building purposes and road construction. The surface exposures of gypsum of Fat'ha Formation, which cover wide parts of Al-Jazira Area, are partly altered to gypcret; it is of good quality suitable for high grade plaster industry. Although most of the claystones of Fat'ha Formation are of bad quality, but there are some claytones suitable for bricks manufacturing. Sandstones of Injana Formation mostly contain calcareous cementing materials or claystones, secondary gypsum is also present as cementing material in some places; therefore they are not suitable for building purposes. Pleistocene terraces exposed on the banks of the main valleys and near Euphrates River are suitable for building purposes. Salt pans are mostly related to fractures aided the percolation of ground waters, which dissolve the evaporites (gypsum and salt beds) of Fat'ha Formation, leading to karstification and subsidence. Sulphur is one of the mineral showings that has been exploited by the locals in the past, but with no economic importance now days, it is present in the gypsums of Fat'ha Formation near Rawa city.

الموارد والشواهد المعدنية في منطقة الجزيرة

رافع زائر جاسم

المستخلص

تتكشف في منطقة الجزيرة عدة تكوينات جيولوجية هي عنة والفرات والفتحة وانجانة ويظهر أقدمها على ضفاف نهر الفرات قرب مدينة راوة. تحتوي هذه التكوينات على الحجر الجيري والجبس والطفل والصخور الطينية والرملية والغرينية. ان ترسبات العصر الرباعي تمثلت في معظم المناطق بغطاء خفيف من الرمل والجبيكريت، كما يوجد بعض منها كمواد مالئة للوديان. يتكشف الحجر الجيري في تكويني عنة والفرات بالقرب من حوض الفرات وهو ذو قيمة اقتصادية عالية لكونه يتمتع بالنقاوة المطلوبة والسماكة الجيدة لغرض صناعة السمنت والزجاج والسكر ولأغراض البناء، أما في تكوين الفتحة فان طبقات الحجر الجيري تكون قليلة السمك. الجبس العائد لتكوين الفتحة يعد الأكثر تكشفا في منطقة الجزيرة ويغطي مساحات واسعة منها وهو ذو نوعية جيدة لصناعة الملاط الأبيض (البورك)، وفي اغلب الأحيان تحولت الطبقة العليا منه الى جبس ثانوي بفعل التجوية ولذلك فان هذا الجزء يكون صالحا لصناعة الملاط واطئ النوعية (الجص). توجد الأطيان ضمن تكوين الفتحة وانجانة وهي ليست ذات نوعية عالية في معظم الأحيان، إلا ان بعضهاا قد تكون صالحة لصناعة الطابوق. ينتشر الحجر الرملي بصورة أساسية في مناطق تكشف تكوين انجانة، إلا انه في كثير من الأحيان تكون المادة الرابطة فيه هي الكلس مع وجود الأطيان، وأحيانا يكون الجبس هو المادة الرابطة وبذلك لا يكون ذا فائدة لأغراض البناء.

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يوجد الحصى ضمن ترسبات المصطبات النهرية التي تعود الى عصر البلايستوسين التي توجد بالقرب من نهر الفرات وكذلك في حافات الوديان الرئيسية في منطقة الجزيرة وهي ملائمة لأغراض البناء. أما بالقرب من وادي الثرثار فتظهر في الوديان العميقة وقد احتوت على الشوائب كالأطيان والجبس إضافة الى احتوائها على الجبس الثانوي كمادة رابطة، وبذلك فإنها ليست ذات قيمة اقتصادية لعدم صلاحيتها لأغراض البناء.

من أهم المواد ذات القيمة الاقتصادية في منطقة الجزيرة هي الأملاح المترسبة في السباخ (بحيرات ملحية)، ربما تكونت نتيجة عاملين: الأول هو الفوالق والثاني هو إذابة الطبقات الملحية الموجودة في تكوين الفتحة وبالتالي تخسف المنطقة وامتلائها بالترسبات الحديثة التي ظهرت فيها عيون ملحية. يوجد الكبريت، الذي يعد من الشواهد المعدنية التي لا تمثل قيمة اقتصادية تذكر، مع الجبس الموجود في ترسبات تكوين الفتحة بالقرب من مدينة راوة وقد تم استخراجه من قبل السكان المحليين في الماضي.

INTRODUCTION

The Iraqi Jazira Area occupies the northwestern part of Iraq and covers about 29270 Km^2. It is bounded by Sinjar mountain from the north, Euphrates River from the south, Wadi Al-Tharthar from the east and the Iraqi – Syrian international borders from the west (Fig.1). The State Company of Geological Survey and Mining carried out in Al-Jazira Area extensive regional geological survey program in the period between 1971 and 1977. The economic potential and mineral occurrences of the area is reviewed hereinafter. The most important economic raw materials present in the area are limestone, gypsum and salt. The reserve estimation and chemical analysis of the raw materials and mineral occurrences are stated whenever mentioned in the references covered by this review.

PREVIOUS WORKS

Many works dealt with the geological mapping of different localities in Al-Jazira Area and some studies dealt with the salt pans and mineral investigation, the most conspicuous are:

- Al-Rawi (1968) studied the salt occurrences in the salt pans scattered in Al-Jazira Area. He mentioned their extensions and the approximate reserve of sodium chloride salt.
- Al-Mubarak (1971) studied the stratigraphy, structure, geomorphology, hydrogeology and economic geology of the area in the upper Euphrates Valley; from the Iraqi – Syrian borders in the west, to Anah and Rawa cities in the east (Fig.2, Area I). He mentioned that Anah Euphrates, Fat'ha and Injana formations are exposed in the area. Quaternary sediments are represented mainly by Pleistocene terraces, slope sediments possibly of Pleistocene – Holocene age and of river alluvium of Holocene age.
- Al-Rawi *et al*. (1973) studied the hydrogeology and economic potential of Bawara salt pan by analyzing more than sixty samples representing the salt crust, sediments and brines. They estimated the reserve to be about 706280 tons.
- Ibrahim and Sissakian (1975) studied the stratigraphy, structure, hydrogeology and economic geology of the area between Rawa – Baiji – Tikrit and Al-Baghdadi (Fig.2, Area II). They specified the raw materials present in the area (limestone, sandstone, gypsum and gravel) to be useful for industrial and/ or building purposes.
- CGG (1975) carried out aerospectrometric survey and revealed the presence of potassium anomalies in Jazira Area, most of them coincide with the location of the salt pans.
- Al-Bassam and Shehata (1975) carried out geochemical survey following up CGG (1975) results and concluded that most of the anomalies are due to potassium salts in Albu Gharis – Taweel Salt Pan, while others are related to the potassium incorporated in claystones.
- Mohi Ad-Din *et al*. (1976) carried out regional geological mapping of Bawara – Ash-Sha'abany area (Fig.2, Area III). They studied the stratigraphy, geomorphology, structure, hydrogeology, geochemistry and economic geology of the area and reported about the economic importance of limestone, dolostone, gypsum, mudstone, claystone and salt occurrences.

- Ma'ala (1976) carried out regional geological mapping of Al-Hadhr area (Fig.2, Area IV). He studied the stratigraphy, structure, hydrogeology and economic geology of the area (Iraqi – Syrian borders, from the west to Wadi Al-Tharthar to the east and the latitudes 35º 52' 30" N and 35º 22' 30" S). He specified the economic importance of limestone, gypsum, gravels, claystone and salt.
- Ma'ala (1977) carried out regional geological mapping of the area extended from Tel Afar to the Iraqi – Syrian borders to the west (Fig.2, Area VI). He studied the stratigraphy, structure, hydrogeology and economic geology of the area and specified the economic importance of limestone, gypsum, gravels, claystone and salt.
- Mohi Ad-Din *et al*. (1977) carried out regional geological mapping of the area covering the northeastern part of Al-Jazira Area (Fig.2, Area V). They studied the stratigraphy, geomorphology, structure, hydrogeology, geochemistry and economic geology of the area and specified the economic importance of limestone, gypsum, gravels, claystone and salt.
- Al-Badri *et al*. (1986) carried out mineral investigation and estimated the salt reserve in the major salt pans in the central part of Al-Jazira Area.
- Al-Hadithi *et al*. (1987) used the aerial photographs and Landsat images to construct maps of the salt pans in Al-Jazira Area. They estimated the coverage areas by the salt pans in winter and summer.
- Al-Badri and Mohammed (1988) studied the geochemistry and reserve estimation of the salt in Albu Gharis salt pan.
- Tobia (1996) studied the geology and hydrogeology of the salt pans in the central part of Al-Jazira Area. He studied the lithological column of the studied salt pans describing the presence of salt crust on top and clay layer with salt crystals beneath the black mud slurry. He considered underground origin for the salts, as the leached salts rise up to the surface through springs or seepages inside the salt pans. The salt minerals forming the salt crust are mainly halite with some gypsum.
- Jassim *et al*. (1999) re-evaluated the data mentioned by Tobia (1996) and interpreted that glauberite is present in the areas covered by the black mud slurry in the salt pans of the central part of Al-Jazira Area.
- Al-Bassam (2003) studied the salt crust of Albu Gharis Salt Pan and the sediments directly below the salt crust to evaluate their economic potential for potassium. The study revealed the presence of potassium in the old salt crust (in the center of the polygons) with a mean of 0.86% and in the new salt crust (at the edges of the polygons) and near the springs inside the salt pan with 1.85%.
- Abdul Ameer (2005) studied Snaisla Salt Pan in details and gave the lithological description for the sediments at different parts of the salt pan and the salt minerals present in the salt crust and sediments.
- Al-Sendy *et al*. (2006) analysed the salt crust of Albu Gharis – Taweel Salt Pan in order to use the salt in the preparation of aluminum slag collector.

MINEROGENIC STRATIGRAPHY OF AL-JAZIRA AREA

According to Parsons (1955), Al-Mubarak (1971), Ibrahim and Sissakian (1975), Mohi Ad-Din *et al*. (1976 and 1977), Ma'ala (1976 and 1977) and Jassim *et al*. (1984), the exposed formations in Al-Jazira Area are:

1- Anah Formation	Late Oligocene
2- Euphrates Formation	Early Miocene
3- Fatha Formation	Middle Miocene
4- Injana Formation	Late Miocene

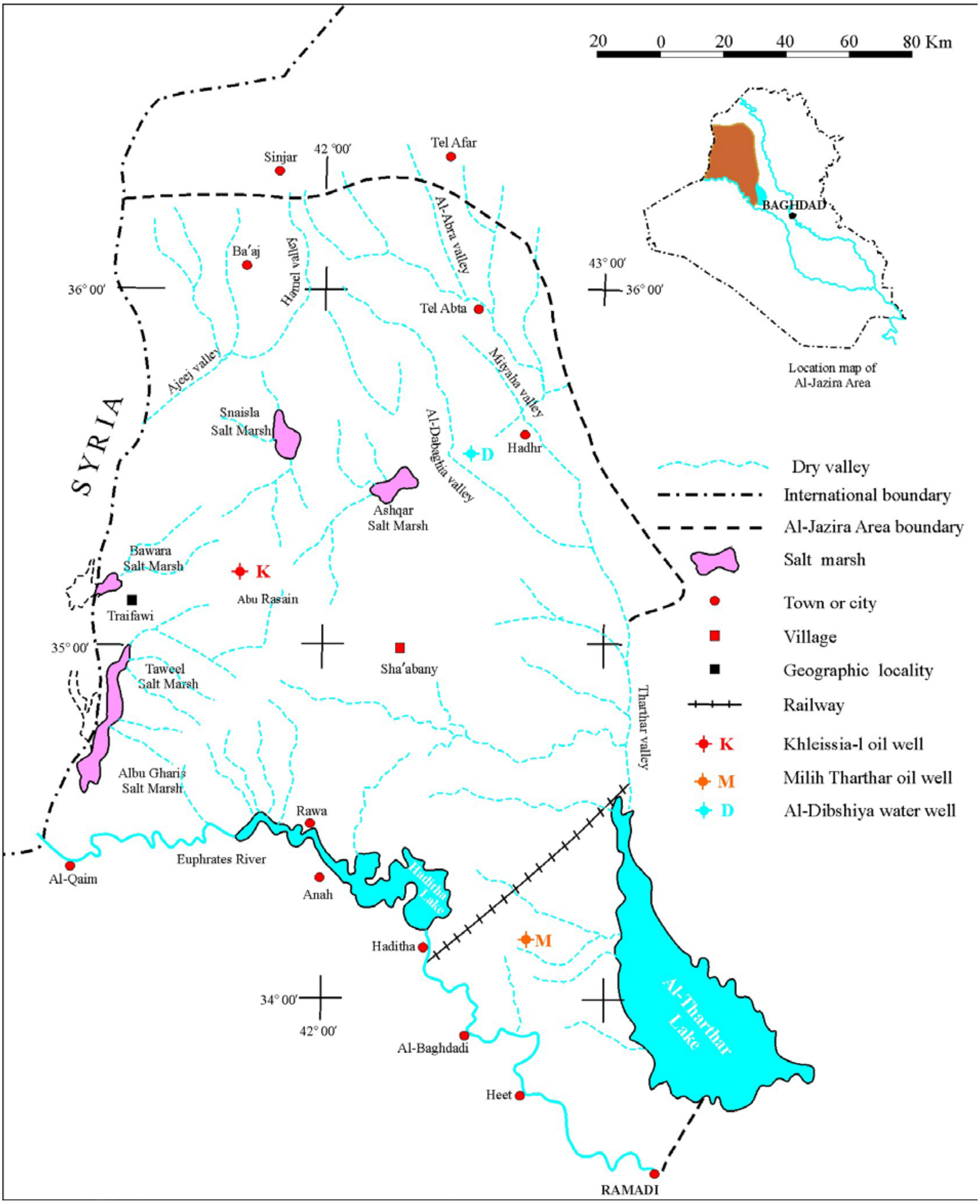

Fig.1: Location map of Al-Jazira Area

The oldest exposed rocks in Al-Jazira Area belong to Anah Formation (Late Oligocene); they are exposed on both banks of Euphrates River (Al-Mubarak, 1971), and composed of recrystallized massive and coralline limestone, generally cavernous. Miocene rocks are represented by Euphrates Formation (Early Miocene), composed basically of limestones with marl and breccias or brecciated marly limestone, Fat'ha Formation (Middle Miocene), composed of limestone, claystone and gypsum and by Injana Formation (Late Miocene), composed of sandstone, siltstone and claystone. Quaternary sediments are represented mainly by terraces, gypcrete and valley fill sediments.

The minerogenic stratigraphy of Al-Jazira Area is shown in table (1); the zones are shown in a special map that shows the distribution of the raw materials (Fig.2). For the purpose of this review, Al-Jazira Area is divided into six parts representing the areas covered by the GEOSURV teams during the regional geological mapping (Fig.3).

The economic occurrences of the raw materials and industrial rocks are mentioned hereinafter:

▪ **Limestone**

Limestones of Anah Formation (Late Oligocene) are exposed in several localities on the left bank of Euphrates River, around Rawa city, and at the opposite side of Alus island (Areas I and II) (Al-Mubarak, 1971 and Ibrahim and Sissakian, 1975, respectively). The limestones are gray to creamy white color, recrystallized, massive and coralline, generally cavernous, hard with compact crystalline texture. The maximum exposed thickness reaches up to 5 m and the geological reserve around Rawa city was described by Al-Mubarak (1971) as very high. The chemical analysis of the limestones is shown in table (2); it reveals that the limestones of Anah Formation are suitable for cement, sugar and glass industries and road construction (Al-Mubarak, 1971 and Ibrahim and Sissakian, 1975).

The limestones of Euphrates Formation are exposed along Euphrates River forming continuous belt along its left bank. They are mainly pure and sometimes dolomitic, recrystallized, marly and chalky. The chemical analysis of the limestones (Table 3) reveals that they could be used for cement industry. The reserve has not been calculated, but it was described as huge reserve by Ibrahim and Sissakian (1975).

Limestones and dolomitic limestone of Fat'ha Formation are exposed in vast areas over Al-Jazira Area. They are exposed at Al-Hadhr (Area IV) (Ma'ala, 1976) and Bowara – Ash-Sha'abany (Area III) (Mohi Ad-Din *et al*., 1976). The chemical analyses are shown in table (4). Their occurrences along Euphrates Valley (Areas I and II) are lithologically very variable, often dolomitic, conglomeratic and/ or brecciated and occur in beds of limited thickness (Al-Mubarak, 1971 and Ibrahim and Sissakian, 1975).

▪ **Gypsum and Gypcrete**

Gypsum is widespread in Al-Jazira Area, alternating with marl and limestone and belongs to Fat'ha Formation (Middle Miocene). The exposed thickness of gypsum beds is about 16 m in Area (I) (Al-Mubarak, 1971), (65 – 70) m in Area (II) (Ibrahim and Sissakian, 1975), (65 – 70) m in Area (III) (Mohi Ad-Din *et al*., 1976) and reaches up to 12 m (with an average of 3 m) east of Area (IV) near Hadhr (Ma'ala, 1977). The results of chemical analyses for gypsum from these areas are shown in table (5). The purity of gypsum ranges from (65 – 99) % with huge geological reserve as described by Ibrahim and Sissakian (1975), Mohi Ad-Din *et al*. (1977) and Ma'ala (1976) and is suitable for high grade plaster industry and building purposes. Gypcrete was found topping the gypsum in most exposure areas. It is suitable for low grade plaster (juss) industry.

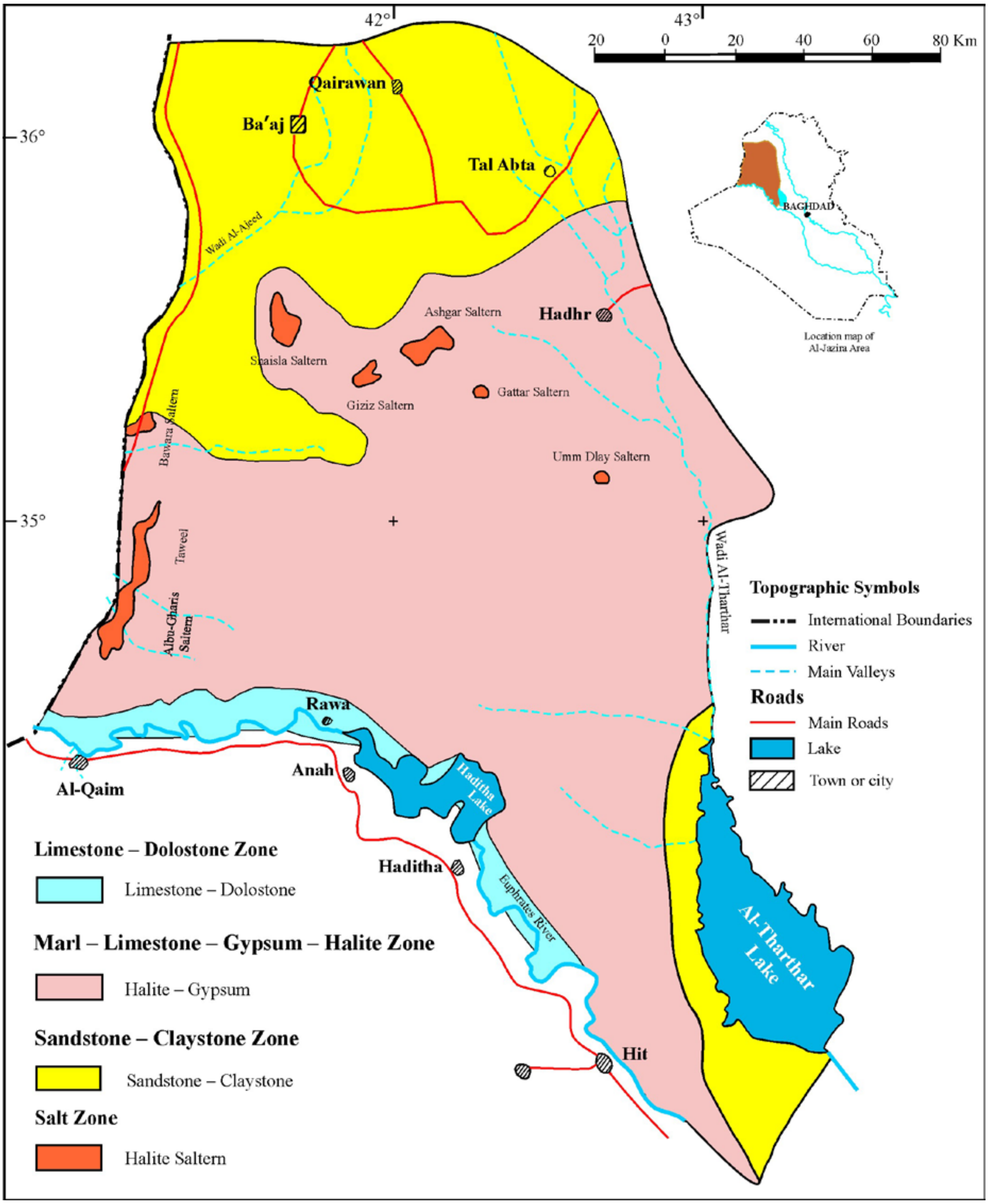

Fig.2: Distribution of the raw materials in Al-Jazira Area

Table 1: Minerogenic stratigraphy of Al-Jazira Area

Age	Geological unit	Raw materials
Quaternary	Sabkhas	**Salt**, suitable for domestic uses.
	Terraces and valley fill sediments	**Gravels and pebbles**, suitable for building purposes
	Gypcrete	**Secondary gypsum**, suitable for plaster (juss) industry
Late Miocene	Injana Formation	**Sandstone**, suitable for construction **Claystone***, suitable for brick industry
Middle Miocene	Fat'ha Formation	**Limestone**, suitable for cement industry and road construction **Gypsum**, suitable for plaster industry and building purposes **Claystone***, suitable for brick industry **Sulphur**, not economic
Early Miocene	Euphrates Formation	**Limestone**, suitable for cement industry and road construction
Late Oligocene	Anah Formation	**Limestone**, suitable for cement and glass industries; road construction and for building purposes

***** Except those beds which include gypsum veins

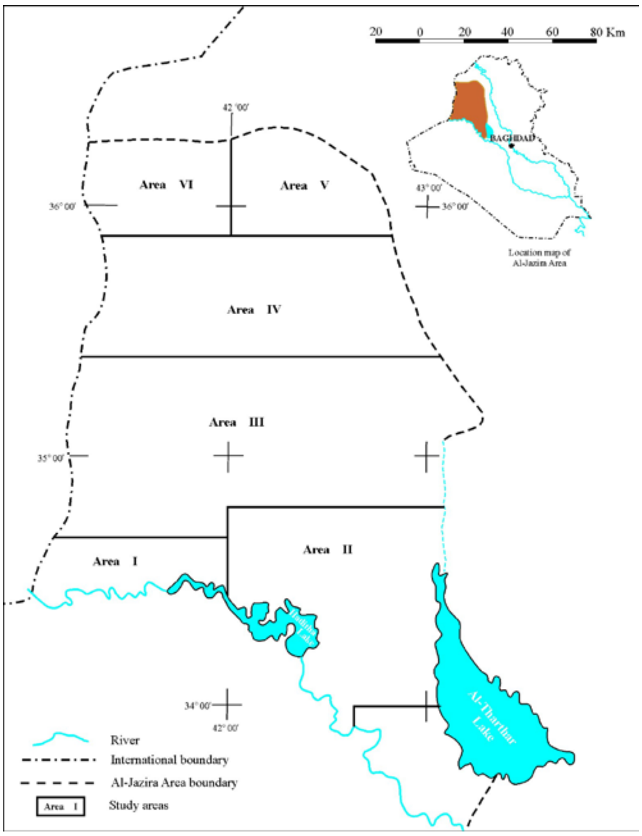

Fig.3: Location map of different regional geological mapping areas in Al-Jazira Area

Table 2: Chemical analysis of limestone of Anah Formation in Rawa area (Area I)
(After Al-Mubarak, 1971)

Component	Mean concentration (%)
CaO	53.2
MgO	0.4
Fe_2O_3	0.3
I.R.	0.5
$CaCO_3$	95

Note: The high quality limestone (CaO > 50%) is suitable for glass industry as mentioned by Lang (1976) in Al-Mubarak and Amin (1983).

Table 3: Chemical analysis of limestones of Euphrates Formation, east of Rawa city (Area II)
(After Ibrahim and Sissakian, 1975)

Component	Concentration (%)
CaO	37 – 53. 2
MgO	1.4 – 16
Fe_2O_3	0.03 – 0.6
I.R.	< 1.0
$CaCO_3$	66 – 95

Table 4: Chemical analysis of limestones of Fat'ha Formation in Bawara – Ash-Sha'abany area (Area III) (Mohi Ad-Din, 1976) and Hadhr area (Area IV) (Ma'ala, 1976)

Component (%)	Bawara – Ash-Sha'abany area (Area III)	Hadhr area (Area IV)
SiO_2	1.74 – 5.69	3.75 – 3.8
CaO	49.2 – 52.78	45.7 – 51.7
MgO	0.62 – 1.32	1.2 – 5.8
Al_2O_3	0.5 – 1.09	1.6 – 2.6
Fe_2O_3	0.15 – 1.09	0.4 – 0.8
SO_3	0.9 – 2.52	0.14 – 0.84
L.O.I.	40.06 – 41.46	40.4 – 40.8

Table 5: Chemical analysis of gypsum of Fat'ha Formation from different parts in Al-Jazira Area (Area II After Ibrahim and Sissakian, 1975; Area III after Mohi Ad-Din, 1976 and Area IV after Ma'ala, 1976)

Component (%)	Area I	Area II	Area III	Area IV
SiO_2	Not mentioned	12.46 – 37.1	0.46 – 12.1	0.17
CaO		21.73 – 34.3	32.39 – 41.37	40.94
MgO		1.17 – 3.49	0.04 – 1.43	0.14
Na_2O		Not analyzed	0.02 – 0.12	0.11
K_2O		Not analyzed	Not analyzed	0.04
L.O.I.		5.12 – 8.73	1.15 – 13.00	1.56
SO_3		18.62 – 42.19	32 – 54.6	57.37
Al_2O_3		3.45 – 8.07	0.4 – 3.04	0.27
Fe_2O_3		0.86 – 2.46	0.13 –1.19	0.12

▪ **Claystone and Mudstone**

The claystones of Injana Formation are exposed in Wadi Al-Tharthar (Areas II and IV) and in the areas located in the northwestern part of Al-Jazira Area (Area VI). In Wadi Al-Tharthar it is variable in color, fairly hard to soft, conchoidally fractured with veins of translucent gypsum (2 – 3 cm thick); in the lowermost part only. The thickness of the claystone beds ranges between (1 – 10) m, its economic importance has not been mentioned by Ibrahim and Sissakian (1975). In Area (III), the claystones or mudstones are red, pinkish, and brown to gray, yellow and light green in color, mostly soft, fractured, with high amount of secondary gypsum. Its thickness ranges between (1 – 15) m. The claystones or mudstones are of no economic importance (Mohi Ad-Din *et al*., 1976).

The mineralogical analysis by X.R.D shows that the claystones of Injana Formation in Area III are composed of quartz, calcite, dolomite and chlorite. Mica and palygorskite are sometimes present (Mohi Ad-Din *et al*., 1976). In Area (IV) the claystones of Fat'ha and Injana formations are massive, mostly accompanied by sandstone and siltstone; most of the beds are calcareous. The claystone of Fat'ha Formation contains gypsum nodules, fibrous gypsum and selenite filling the joints, while the claystone of Injana Formation contains few impurities, giving good possibilities to be used for bricks industry (Ma'ala, 1976). In Area (V) the claystones of Fat'ha Formation are red and brown in color, its thickness is (2 – 5) m and reaches up to 10 m. Its suitability for bricks industry has not been investigated (Mohi Ad-Din *et al*., 1977). The chemical analyses of claystone of Fat'ha Formation are shown in table (6).

Note: Claystones of Injana Formation in other places, outside Al-Jazira Area were found to be of economic importance for brick industry, but its suitability in Al-Jazira Area for such industry has not been investigated yet.

Table 6: Chemical analyses of claystones of Fat'ha Formation in Al-Jazira Area (Area III after Mohi Ad-Din, 1976; Area IV after Ma'ala, 1976 and Area V after Mohi Ad-Din *et al*., 1977)

Component (%)	Areas I and II	Area III	Area IV	Area V	Area VI
SiO_2	Not mentioned	40.89 – 48.6	46.87	34.82 – 41.44	Not mentioned
CaO		5.61 – 7.71	5.79	11.49 – 17.25	
MgO		10 – 13.4	12.2	6.5 – 9.03	
Al_2O_3		10.59 – 13.54	11.02	8.12 – 13.42	
Fe_2O_3		4.6 – 6.88	3.44	4.2 – 7.63	
$SO_3^{=}$		1.2 – 2.2	0.39	1.25 – 12.7	
TiO_2		0.36 – 0.88	0.51	0.47 – 0.7	

▪ **Sandstone**

The sandstone is found in areas covered by Injana Formation, it is brown to gray, well sorted. Sandstones are absent in the Areas (I and II), while present in Area (III) in form of lenses with thickness of (5 – 8) m, extending in length from 100 m to several Kilometers. They are well cemented and compacted; the cementing material is mostly calcareous or clayey and sometimes gypsified. It is not useful for concrete and building purposes (Mohi Ad-Din *et al*., 1977) the chemical analyses are shown in table (7).

Table 7: Chemical analyses of sandstones of Injana Formation in Al-Jazira Area (Area III and V after Mohi Ad-Din *et al*., 1976 and 1977, respectively)

Component (%)	Areas I and II	Area III	Area IV	Area V	Area VI
SiO_2	Absent	35.35 – 55.62	Not mentioned	48.25 – 52.76	Not mentioned
CaO		11.92 – 17.25		14.8 – 17.2	
MgO		1.87 – 5.30		1.48 – 3.23	
Al_2O_3		8.43 – 13.61		4.07 – 11.05	
Fe_2O_3		3.53 – 5.86		2.03 – 4.25	
$SO_3^{=}$		0.30 – 1.79		0.12 – 12.48	
Cl^-		0.03 – 0.80		0.08 – 0.260	
TSS		0.03 – 0.09		Not analyzed	
TiO_2		0.07 – 0.66		0.5 – 0.7	
Na_2O		1.08 – 2.08		Not analyzed	
L.O.I		13.37 – 18.46		0.18 – 16.3	

In Area (IV), the sandstone is rather porous but also partly cemented by secondary gypsum. Bedding ranges from very thick (15 m) to thinly bedded (few centimeters). It is not useful for building and construction purposes (Ma'ala, 1976).

In Area (V), the sandstone has low quartz content and shows an increase in the clay minerals and mica. It is fairly hard to hard with thickness ranging from few centimeters to more than 5 m. Hard varieties of sandstone are used locally as building stones (Mohi Ad-Din *et al*., 1977).

- **Gravels**

They are found in Area (I) as river terraces of Pleistocene age on the left bank of Euphrates River in two levels, 10 m and 25 m above the present level of the river with variable thicknesses (1 – 3 m). The gravels are composed of limestone, quartz and chert with rare igneous and metamorphic rocks, the size is up to 7 cm with silty or sandy gypsiferous matrix. The gravels are suitable for construction purposes (Al-Mubarak, 1971).

In Area (II), the gravels are present in the southern part, which represents, the area between Al-Tharthar Depression and Euphrates River. They are mainly covered by old deposits of sandy gravels (terraces) preserved in three levels and varies in thickness (0.5 – 5) m. The range of SO_3 and T.S.S. in the sand fraction of five samples were (0.61 – 2.54) % with an average of 1.32% and range of (0.27 – 3.5) %, with average of 2.43%, respectively. While for the coarse fraction (gravels) it is (nill – 0.6) % SO_3, with average of 0.24% and (trace – 1.07) % T.S.S., with average of 0.46%. The samples contain quartz and chert (> 50%), carbonates (10 – 30 %), rock fragments (10 – 15 %), clay (< 2%) and micas in trace amounts. Gypsum is the only secondary mineral present in the samples and concentrated in the fine fractions. The T.S.S.% and SO_3% of the studied samples show that all the gravels are of good quality for constructions, while the finer fractions (sand) vary in quality as they were found to be suitable for constructions in some localities and not in others (Hamza and Abd Al-Latif, 1975).

In Area (III), gravels were found in the northern part of on the northern limb of Abu Rassain anticline. The exposed thickness is unknown, but it is reported to be 18.5 m in the Khleissia-1 oil well (Mohi Ad-Din *et al*., 1976).

In Area (IV), the gravels are present either as isolated remnants of Pleistocene terraces of Wadi Al-Tharthar along its course, or locally restricted to the top of hills in distance from some hundred meters to 13 Km from the present course of the valleys (Ma'ala, 1976). The author believes that this position is due to uplifting of the area and meandering of the valleys. Gravels are also present as valley fillings. They were also found at the margins of depressions occupied by salt pans. The gravels are poorly sorted and composed of limestone, chert, flint and gypsum cemented by secondary gypsum. The maximum thickness is 2 m with average less than 1 m and their exposures extends for few meters. Most of these gavel deposits have no economic importance (Ma'ala, 1976).

In Areas (II) and (V) gravels were exposed in many large valleys, they are contaminated by gypsum fragments derived from Fat'ha Formation. They are not suitable for construction purposes (Ibrahim and Sissakian, 1975 and Mohi Ad-Din *et al*., 1976).

▪ **Salt Occurrences**

There are many salt pans (salt marshes) scattered throughout Al-Jazira Area occupying shallow depressions filled by recent sediments and salt. These salt pans are: Snaisla, Bawara, Albu Gharis – Taweel, Ashqar, Umm Dlay, Gattar, Geziz (Al-Hadithi *et al*., 1987) (Fig.1).

─ Snaisla Salt Pan

It is located about 74 Km west of Al-Hadhar town. The salt's cover is about 57 Km^2 out of 75 Km^2, which represents the total area of the salt pan (Al-Hadithi *et al*., 1987). The static water level is just below the surface and there are many springs supplying the salt pan by brine at the northern and northeastern parts of the depression.

The salt pan is surrounded by alternation of claystone, siltstone, limestone and gypsum of Fat'ha Formation. According to Al-Hadithi *et al*. (1987), the depression is shallow erosional depression, while Jassim *et al*. (1999) described the depression to be a result of fractures, indicated by the presence of lineaments on the surface that allowed the water to dissolve the salts from the salt beds in Fat'ha Formation, leading to subsidence of the area and formation of the depression.

The average sodium chloride concentration in the salt crust is about 80% (Table 8) (Al-Badri *et al.*, 1986). Minerals found by X.R.D. in the salt crust are: halite, gypsum, calcite glauberite and small quantities of polyhalite, bassanite, trona and sylvite. The minerals found in the sediments are: halite, gypsum, calcite, glauberite, quartz, dolomite, bassanite, polyhalite in addition to clays. The salt reserve was calculated to be 1895290 tons and similar amount was calculated to be present in the brines (Al-Badri *et al*., 1986). The salt of this salt pan could be used for industrial purposes.

This salt pan has been studied by Tobia (1996), he concluded that the origin of the salts is from underground as brines rising to the surface via conduits. Jassim *et al*. (1999) re-evaluated the data given by Tobia (1996); they concluded that glauberite is present in the area covered by the black mud slurry inside the salt pan. They suggested, from lineament analysis in the area, that the depressions were formed by subsidence of the area due to the dissolution of the salt beds of Fat'ha Formation.

─ Ashqar Salt Pan

It is located about 40 Km west southwest of Al-Hadhr town. The salt occupies about 60 Km^2 out of 64 Km^2, which represents the total area of the salt pan (Al-Hadithi *et al*., 1987). The salt crust layer is formed from the brines soaking the sediments, and appears about few centimeters below the salt surface.

The salt pan is surrounded by outcrops of Fat'ha Formation (Al-Hadithi *et al*., 1987). The average NaCl in the salt crust is about 90%, ranging between (42.46 ─ 99.58) % (table 9). The salt samples near the periphery comprise high I.R. content due to the effect of aeolian materials supplied by wind. The mineral constituents of the salt crust are: halite, gypsum and small quantities of polyhalite, bassanite, carnalite and glauberite. The salt reserve was calculated to be 2030410 tons and almost similar additional amount was calculated from the brines (Al-Badri *et al*., 1986).

─Umm Dlay Salt Pan

The salt pan is located about 50 Km southeast of Ashqar Salt Pan. The salt occupies about 4.5 Km^2 out of 7.5 Km^2 that represents the total area of the salt pan (Al-Hadithi *et al*., 1987). The salt crust is scattered and highly contaminated by aeolian sand and the NaCl concentration is only 58% (Al-Badri *et al*., 1986).

Salt minerals found in the salt crust by X.R.D are: halite and gypsum with minor quantities of polyhalite. Calcite and quartz were found to be associated with salt minerals in the salt crust and thought to be transported to the depression by wind. The salt pan is surrounded by gypsum, limestone and marl beds forming scarps. The salt reserve in this salt pan is 80124 tons and almost additional similar amount was calculated from the brines.

─Gattar Salt Pan

This salt pan is located about 14 Km southeast of Ashqar Salt Pan. Thin salt layer covers all the surface area of the salt pan, which is surrounded by marl, limestone and gypsum of Fat'ha Formation. The salt reserve is about 46472 tons and almost similar amount was calculated from the brines (Al-Badri *et al*., 1986 and Al-Hadithi *et al*., 1987).

─ Geziz Salt Pan

It is located about 1.5 Km southwest of Ashqar Salt Pan**,** the salt covers the eastern part, which is about 14 Km^2. The salt pan is surrounded by gypsum and marl of Fat'ha Formation. The salt reserve of the two parts is about 130749 ton and almost similar amount was calculated in the brine present between the sediments of the salt pan (Al-Badri *et al*., 1986 and Al-Hadithi *et al*., 1987).

─ Bawara Salt Pan

It is located along the Iraqi – Syrian borders that nearly bisect the pan. The salt crust occupies about 11.5 Km^2 out of 18.5 Km^2, which represents the Iraqi part of the pan. Many springs supply the pan by the brine, flowing along in the western part that is located in Syria.

The salt pan is surrounded by sandstone; siltstone, marl and gypsum beds of Fat'ha Formation (Al-Hadithi *et al*., 1987). The sediments underlying the salt crust include three layers. The first is about 4 m thick, composed of gypsum, carbonate and silicate grains, saturated with brine of chloride and sulphate type. The level of this brine is about 20 cm below the salt pan surface. The second layer is about 4 m thick, composed mainly of gypsum crystals, the groundwater being of calcium sulphate type. The third layer has almost the similar composition of the second layer, but the groundwater is of chloride rather than sulphate type and extends from depth of 8 m till the bottom of a drilled well (about 30 m deep) (Al-Rawi *et al*., 1973). The salt reserves were estimated to be about 2953119 tons (Al-Badri and Mohammed, 1988). The chemical analyses of the salt crust are shown in table (9).

─Albu Gharis – Taweel Salt Pan

It is located about 70 Km northwest of Rawa city close and parallel to the Iraqi – Syrian boundaries. It is an elongated depression about 40 Km long and 3 Km average width. The salt occupies about 70 Km^2 out of 88 Km^2, which represents the total area of the salt pan (Al-Hadithi *et al*., 1987). Al-Rawi (1968) studied the salt pan and noted that brines flow out from the upper part of Fat'ha Formation. Therefore, crystallization around these springs is continuous in the hot and dry seasons forming salt cones over the main salt layer. These cones and the salt crust are dissolved partly or completely by the accumulated rain water in the salt pan during rainy seasons. The salt pan sediments are topped by salt crust forming polygons with an old crust inside them and the new formed salts are added to the cracks bounding the polygons. The thickness of the salt crust is about few millimeters near the periphery and reaches about 20 cm in the interior of the salt pan. The results of chemical analyses and X.R.D. of the salt crust are shown in table (10). The studies revealed the presence of potassium in high concentration than other salt pans in the Al-Jazira Area (Al-Badri and Mohammad, 1988 and Al-Bassam, 2003). The salt crust generally, is underlain by about 30 cm thick black slurry rich in organic matter, followed by brown silty clay that contains gypsum and halite crystals of different sizes. This layer is mostly underlain by salt layer that reaches down to the digging depth, which is 170 cm. In the absence of the salt layer, green marl was found, while near the southern part of the salt pan, an anhydrite with gypsum layers were found. The salt pan is surrounded by marl, limestone and gypsum of Fat'ha Formation. (Al-Badri and Mohammad, 1988; Al-Bassam, 2003 and Al-Sendy *et al.*, 2006).

Table 8: The range and average of cations, anions and hypothetical salts in the salt crust of Ashqar and Snaisla Salt Pans (After Al-Badri *et al.*, 1986)

Elements and Components	**Snaisla Salt Pan**		**Ashqar Salt Pan**	
	Range	**Average**	**Range**	**Average**
	(%)			
I.R.	0.15 – 12.84	2.438	0.10 – 45.97	4.23
Cl^-	26.62 – 60.0	46.75	25.90 – 60.09	53.35
NaCl	43.78 – 89.90	80.15	42.46 – 99.58	90.058
$CaCO_3$	0.05 – 0.25	0.072	0.05 – 0.09	0.064
$CaSO_4$	0.49 – 37.47	14.68	0.55 – 22.33	3.439
KCl	0.052 – 0.38	0.104	0.03 – 0.28	0.114
Na^+	2.0 – 38.9	31.5	18.69 – 39.22	32.49
Ca^{+2}	0.20 – 11.6	4.312	0.20 – 6.6	0.972
Mg^{+2}	0.047 – 0.76	0.14	0.028 – 0.132	0.075
K^+	0.029 – 0.11	0.055	0.029 – 0.145	0.052
$SO_4^=$	0.36 – 34.2	13.13	0.35 – 0.45	3.402
$CO_3^=$	0.03 – 0.052	0.040	0.03 – 0.051	0.038
	Range	**Average**	**Range**	**Average**
	(ppm)			
As	–	–	–	<5
Zn	1 – 40	6.04	3 – 34	9.9
Sr	15 – 1643	537	3 – 583	132.2
Cd	2 – 4	3.6	5 – 8	6.1
Cu	3 – 52	7	2 – 22	7.2
Pb	4 – 19	13.9	3 – 25	11

Table 9: Chemical analyses of 49 samples from the salt crust of Bawara Salt Pan (After Al-Badri and Mohammad, 1988)

Element (%)	Minimum	Maximum	Mean
Na^+	2.42	37.32	7.86
K^+	0.05	0.49	0.26
Mg+2	0.024	0.34	0.134
Ca^{+2}	0.72	28.32	8.283
$SO_4^=$	1.89	48.5	25.26
Cl^-	2.44	57.57	11.15
I.R.	3.0	78.54	46.61

Table 10: The chemical analyses of the old and new salt crusts of Albu Gharis - Taweel Salt Pan (After Al-Bassam, 2003)

Components (%)	Old Salt Crust	New Salt Crust
Na^+	31.72	35.58
K^+	0.86	1.85
Mg^+2	0.41	0.66
Ca^{+2}	0.65	0.39
$SO_4^=$	2.05	0.94
Cl^-	50.48	58.67
I.R.	12.29	1.02
Mineral constituents (from X.R.D. analysis)	halite, sylvite, gypsum, quartz, calcite(tr)	halite, gypsum, calcite(tr), sylvite(vtr)

tr = trace; vtr = very trace

▪ **Sulphur**

Bolton (1954) reported the occurrence of sulphur about 8 Km north of Rawa city within the gypsum of Fat'ha Formation. It has been worked out in the past by the local people. Its occurrence is without any economic importance now days (Al-Mubarak, 1971).

DISCUSSION

Regional geological mapping projects in Al-Jazira Area were carried out by GEOSURV in the early seventies of the last century. Unfortunately, the rocks were not sufficiently analyzed and tested to find their economic importance by the previous authors and occasionally were considered of no economic value or not suitable for constructions and industries, except in few areas.

The author believes that the chemical analyses of the aforementioned industrial rocks and/ or raw materials may show their suitability for their economic importance, accordingly we could not evaluate their economic importance, hitherto. Although, some of them could be upgraded or purified in order to bring them to meet the industrial specifications; for example the claystones of Fat'ha and Injana formations.

CONCLUSIONS

- Limestones of Anah and Euphrates formations near the Euphrates River have huge geological reserve suitable for cement, glass and sugar industries and are suitable for building purposes.
- Gypsum of Fat'ha Formation is almost pure and suitable for plaster and cement industries and building purposes.
- Secondary gypsum (gypcrete) of the Quaternary sediments is suitable for low grade plaster (Juss) industry.
- The claystone of Fat'ha Formation locally contains high amounts of impurities, its suitability for brick industry was not examined at the time of survey, while that of Injana Formation has few impurities and therefore it might be suitable for the above mentioned purpose.
- The sandstone of Injana Formation is not suitable for building purposes in its natural occurrence due to the presence of calcareous cement and clay impurities. However, it might be suitable after treatments.
- Gravels of river terraces are suitable for building purposes.
- The deposited salts in the salt pans are attributed to the dissolved salt horizons (by means of water) that occur within the Fat'ha Formation at depth and migrate through fractures to the surface.
- Surface run-off water, after heavy rain showers bring sediments and solutes to the salt pans in addition to the seepages inside the salt pans, which yield the brines from depth.
- Albu Gharis Salt Pan has the highest potassium content among the other salt pans in the area.
- The total reserve of sodium chloride salt within the salt pans of Al-Jazira Area is about 8 million tons.
- The purity of the salt in the salt pans varies from (60 – 90) %, therefore needs purification before being used for human and industrial consumptions.
- The brines are very important source for sodium chloride salt.

RECOMMENDATIONS

1. Investigation for salts other than sodium chloride, like sodium sulphate and potassium chloride in the salt pans.
2. Investigation for the limestones quality and reserves of Anah and Euphrates formations and gypsum of Fat'ha Formation in Al-Jazira Area along Euphrates River.
3. Investigation for the claystones of Injana Formation in Wadi Al-Tharthar and the Areas III and V to study their suitability for brick industry.
4. The salt can be produced by pumping the brines to artificial basins and to be evaporated by solar heat.
5. Re-evaluation of the claystones for brick industry.
6. Re-evaluation of the Pleistocene and Quaternary terrace gravels for construction purposes by subjecting them to washing, sieving and fragmentation.

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