DISTRIBUTION OF CELESTITE IN KARBALA AND NAJAF AREA – CENTRAL SOUTHERN PART OF IRAQ

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ABSTRACT

A detailed geological survey in Karbla and Najaf area has been carried out by the authors and others including a lot of geological sections, traverses, document points and mapping, beside drilling boreholes, to investigate the origin and distribution of the celestite in the studied area. The work indicates that the main celestite deposit is concentrated as a narrow strip of about 200 m width along both Tar Al–Najaf and Tar Al–Sayyed, then decreases downwards within Karbala–Najaf Plateau. It is scattered along both tars (cliffs), either within certain areas, extending to many kilometers or within isolated sections, in very limited areas. Abu–Jir Fault is the main and the principle controlling factor on the distribution of the celestite, in the studied area in addition to the lithology, porosity and permeability.

The celestite has been found in the upper part of Injana Formation and the lower part of Dibdibba Formation within sandstone, siltstone or silty claystone beds, but more concentrated in the sandstone beds of Dibdibba Formation. It is differentiated in the field either by its heavy weight in a tough, cliff–forming siltstone or silty claystone beds or as colourless needle–shaped crystals in heavy, tough sandstone beds. Generally, three main horizons of celestite are present in different levels in both formations, but more horizons may be present in other areas. The celestite is formed from the combination of Sr from the deep ground water and the SO_3, which was supplied from the surrounding environment due to high ground water level and continuous evaporation. The thickness of the celestite–bearing beds ranges from (0.1–0.5) m. The Sr concentration is up to 34% whereas the celestite concentration is up to 74.8 %.

توزيع السلستايت في منطقة كربلاء و النجف – جنوب وسط العراق

كريم محمود حسن و أزهار علي غالب

المستخلص

قام الباحثان وآخرون بأجراء مسح جيولوجي تفصيلي لمنطقة كربلاء – النجف شمل العديد من المقاطع الجيولوجية، المسارات الحقلية، نقاط الوصف، وإعداد خرائط جيولوجية بمقياس1: 25000 و1: 50000 لغرض الاستكشاف المعدني لمعادن السلستايت، الفلدسبار، أطيان الاتابلغايت وغيرها إضافة إلى حفر بعض الآبار لدراسة توزيع السلستايت في منطقة الدراسة . أثبتت الدراسة أن تركيز السلستايت ينحصر في نطاق ضيق بعرض حوالي 200م حول طار النجف وطار السيد ويتناقص في العمق داخل هضبة كربلاء – النجف ، حيث يتواجد على طول الطارين ضمن مساحات معينة ويمتد ليضع كيلومترات أو على شكل نقاط أو مقاطع منفردة ضمن مساحة محدودة جدا" . تبين ان فالق ابو جير هو العامل الرئيسي والأساسي في تكوين وتوزيع السلستايت إضافة إلى الوضع الصخاري، المسامية والنفاذية. يتواجد السلستايت في الطبقات العليا لتكوين انجانه والأجزاء السفلى لتكوين الدبدبة ضمن صخور رملية، غرينية او غرينية طينية ولكن يتركز بصورة أكثر في الصخور الرملية لتكوين الدبدبة . يمكن تمييز السلستايت حقليا" أما بوزنه الثقيل ضمن الصخور الغرينية الطينية الصلبة ذات الحافة الجرفية (cliff– forming beds) أو كبلورات أبرية عديمة اللون، شفافة ثقيلة وصلبة . بصورة عامة هناك ثلاث انطقة رئيسية للسلستايت وعلى مستويات مختلفة ضمن تكويني انجانة ودبدبة ولكن قد تتواجد هناك انطقة ثانوية أكثر في بعض ألاماكن . يتكون السلستايت من اتحاد السترونتيوم المتكون من المياه الجوفية العميقة و ايون SO_3 الذي يتم تجهيزه من البيئة المحيطة بسبب ارتفاع مستوى المياه ألجوفيه والتبخير المستمر .

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INTRODUCTION

The studied area is cone–shaped, bound by Tar Al–Najaf, Tar Al–Sayyed and Karbala–Najaf road (Fig.1). It represents a plateau bound by two scarps, the western one called Tar Al–Sayyed and the southern one called Tar Al–Najaf. The surface of the plateau is flat covered by gypseous pebbly soil or gypcrete with some aeolian sand sheets or shrub dunes. The soil is underlain by sandstone or pebbly to gravely sandstone of Dibdibba Formation. This study is based on field work and laboratory studies, which were carried out by a team from the State Company of Geological Survey and Mining during 2001–2003. The study deals with the origin and distribution of the celestite in the area and the factors controlling its distribution.

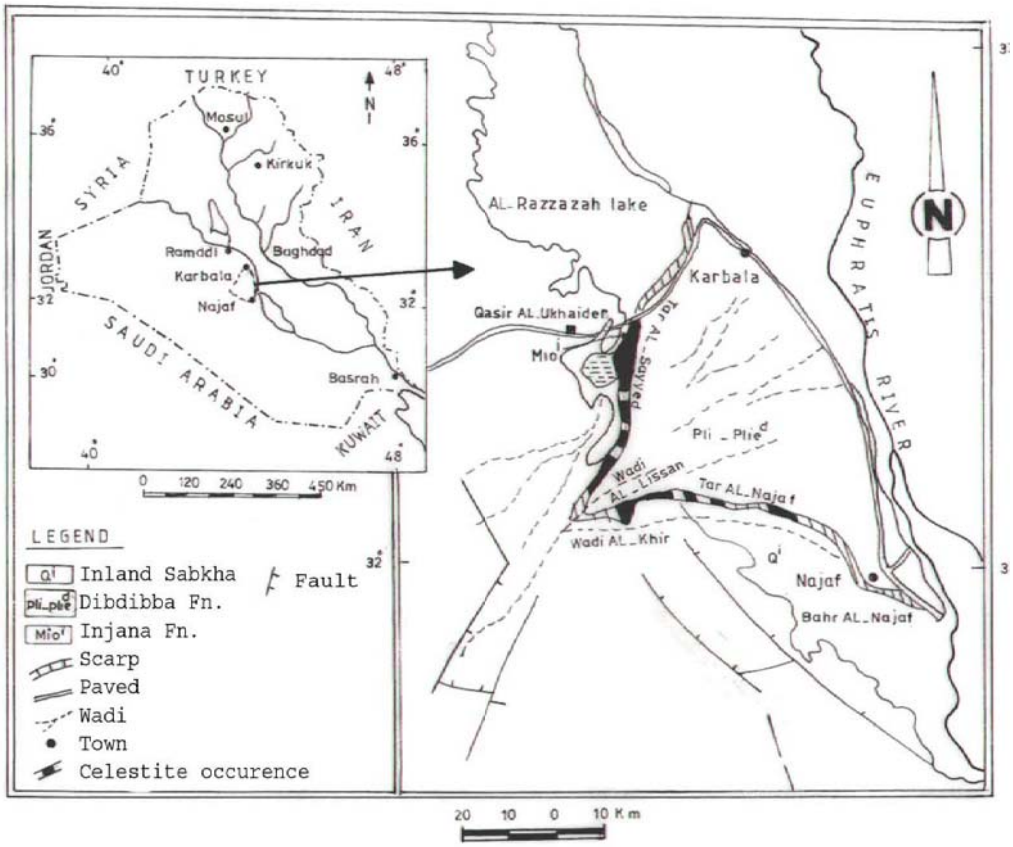

Fig. (1): Location and generalized geological map

PREVIOUS WORKS

*Al-Bassam (1994) mentioned that the celestite in siltstone of Injana Formation (Al–Najaf area) is formed by early diagenesis. He reported that the Sr was supplied from aragonite during the gradual change to calcite, it eliminate Sr, while the SO_3 was supplied from the surrounding environment due to high ground water level and continuous evaporation.

*Al-Bassam (1995) studied the mineralogy, geochemistry and genesis of celestite in Al–Najaf area. He mentioned that there is a remarkable siltstone bed in Injana Formation which contains up to 43 % of celestite ($SrSO_{4)}$. He recorded that the celestite seems to have formed by direct crystallization from saline solution as well as by replacement of aragonite and calcite under hot and arid climatic conditions. Strontium may have been supplied from several sources, including aragonite, feldspar, and deep ground water aquifer of oil–field origin, whereas the sulphate was supplied from near–surface ground water.

*Al-Baidary (1997) mentioned that the celestite is present in a tough calcareous bed in Injana Formation in Karbala–Najaf area and the celestite has been formed from strontium–sulphate rich solutions directly or from the combination of strontium ion resulted from changing of aragonite.

*Al-Khafaji and Al-Quaizi (1999) investigated the celestite on both Tar Al–Najaf and Tar Al–Sayyed and mentioned that the celestite was developed in some areas along both Tars.

* Polis and Al-Ka`aby (1998) stated that the mineralization of celestite is local and patchy. Mineralized from ground solutions containing considerable amounts of strontium and sulphate that precipitated within the pores of the original rock.

*Dawood (2000) studied the mineralogy, origin of celestite and the factors controlling its distribution in Tar Al–Najaf in a limited area extending 19 km northwest and 10 km southeast of Najaf city. He mentioned that celestite precipitated locally by mixing of groundwater rich in Sr^{++} and SO_4^{-2} ions in rock interstitial spaces. The major source of Sr^{++} ions is the deep oil–trap groundwater, in addition to Sr^{++} ions set by decomposition of feldspar as minor source. He mentioned that Sr^{++} was supplied from ground water due to the effect of Abu Jir Fault. Moreover, he listed the factors controlling the distribution of the celestite in the area to be porosity, permeability, difference in the chemical composition of water and the climate.

*Al-Khafaji and Al-Quaizi (2002) mentioned that the celestite occur in lenses within Injana and Dibdibba Formations, and the celestite bearing beds are characterized by their high permeability, which affected the movement of ground water and consequently on strontium concentration.

AIM

The present study deals with the distribution of celestite in Karbala–Najaf plateau along both Tar Al–Najaf and Tar Al–Sayyed, which extend laterally to about 170 km, and the factors controlling its distribution.

GEOLOGICAL SETTING

Structurally, the studied area is located between the Stable Shelf and the Unstable Shelf, the latter is represented by the Mesopotamian Zone. Abu Jir Fault Zone passes through the studied area and has a considerable effect on the topography of the area, particularly the configuration of the depressions and ridges as it was proved by (Hassan et al., 2000) in the neighboring areas. Stratigraphically, Nfayil (M. Miocene), Injana (U.Miocene) and Dibdibba (Pliocene–Pleistocene) Formations are exposed along the scarps of the plateau (Tar Al–Sayyed and Tar Al–Najaf) Fig. (1) (Hassan et al., 2000).

Nfayil Formation (Middle Miocene)

The formation is exposed at the base of the scarps. It is composed of alternation of marl and limestone in cyclic deposition. Two main cycles can be recognized in the studied area, each cycle consists of marl, yellow to yellowish green, friable, medium tough, slope–forming, overlain by limestone, grey, tough, cliff–forming. Oyster shells are dominant in the second cycle. The contact with the overlying Injana Formation is marked by the first appearance of brown to reddish brown clastic sediments (claystone or sandstone) of Injana Formation. The thickness of this formation is (2–15) m.

Injana Formation (Upper Miocene)

The formation represents the dominant rocks of both Tar Al–Najaf and Tar Al–Sayyed. Lithologically, Injana Formation is composed of brown to reddish brown clastic sediments; alternation of claystone, sandstone and siltstone with few (2–3) thin beds of marly limestone. The claystone is brown to reddish brown, medium tough, conchoidally fractured, occasionally silty and massive. The sandstone is grey to greenish grey, fine to medium grained, cross–bedded (planner cross–bedding) and micaceous. The siltstone is brown to reddish brown, clayey, massive, and medium tough, the thin limestone or marly limestone beds are greenish grey, tough to medium tough. The thickness of each bed reaches (15–20) cm, occasionally reaches 40 cm, this limestone devoid of any fauna (Fig. 2).

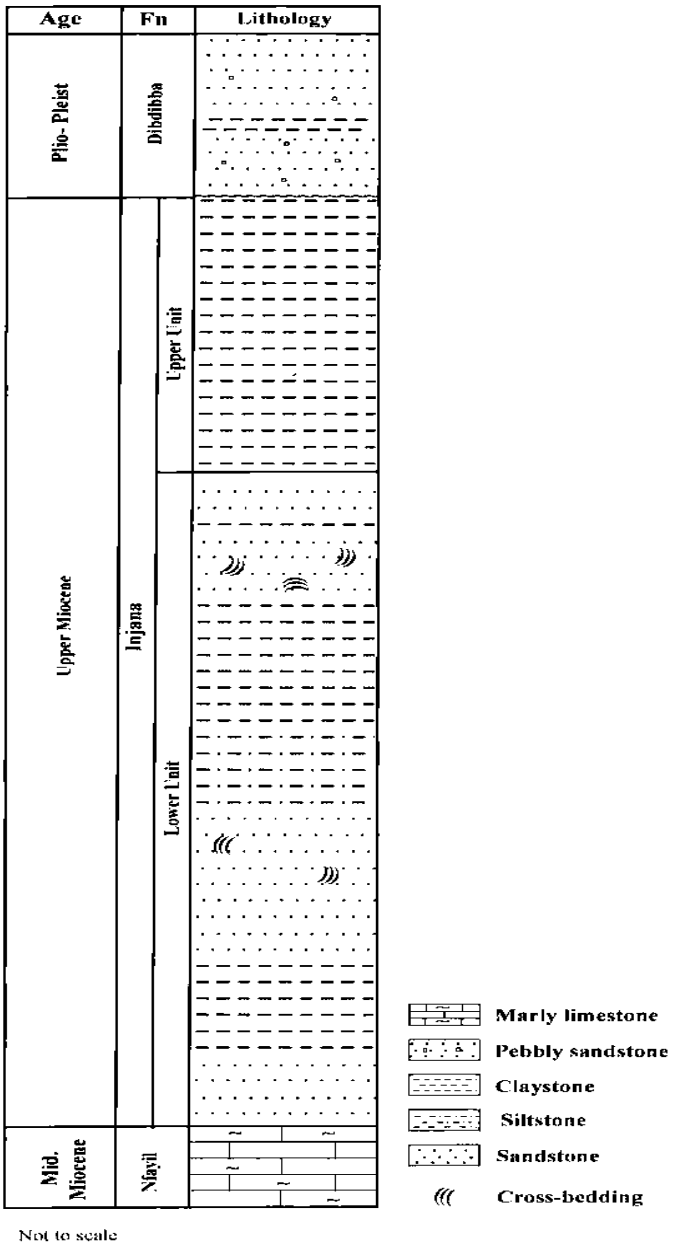

Fig. (2): Generalized columnar section of Injana and Dibdibba Formations

Dibdibba Formation (Pliocene–Pleistocene)

The formation is exposed in the upper part of both Tar Al–Najaf and Tar Al–Sayyed, it locally covers the surface of Dibdibba plateau. The formation is

composed mainly of sandstone, pebbly sandstone with some thin beds of siltstone or claystone. Some sandstone beds, particularly in the lower part are rich with celestite that is developed diagenetically making the rocks more tough (Fig.2). Quartz is the main component of the sandstone, in addition to the feldspar and rock fragments.

DISTRIBUTION OF CELESTITE IN THE STUDIED AREA

In the present work, the celestite has been found only along Tar Al–Najaf and Tar Al–Sayyed within Injana and Dibdibba Formations in different levels and horizons. Celestite is more concentrated within the sandstone beds, but it has been found also within the siltstone or silty claystone beds. It is differentiated in the field by its heavy weight within tough, cliff–forming beds, but in some beds, particularly the sandstone, celestite is characterized by its colorless, needle–shaped crystals within hard beds, and it is found in the upper part of Injana Formation and the lower part of Dibdibba Formation. It is either concentrated in certain areas along both Tar Al–Najaf and Tar Al–Sayyed or present in limited sections or isolated hills (Fig.1).

Celestite in Injana Formation

The celestite has been found in one horizon in Injana Formation within siltstone or silty claystone beds. It is difficult to be differentiated in the field as a mineral or crystals within the brown to reddish brown silty claystone beds, but it could be felt by its heavy weight in tough beds. Along Tar Al–Najaf, celestite is more concentrated in the eastern part just below Al–Najaf town or in the western part near the junction between Tar Al–Najaf and Tar Al–Sayyed. Along Tar Al–Sayyed, celestite is more concentrated in the southern part of the cliff and near the junction between the two tars (cliffs). In the area just below Al–Najaf town, the thickness of the celestite bearing beds ranges between (0.1–0.5)m, the overburden ranges from (5–15)m and the Sr concentration is (13.26–33.0)%, and the celestite concentration is (29.17–72.60) % (Table 1). In Tar Al–Sayyed the thickness of the celestite bearing bed ranges between (0.1–0.25)m and the concentration of Sr is (24.0 – 30.0)% (Table 2). In the junction area between Tar Al–Najaf and Tar Al–Sayyed, the thickness of the celestite bearing bed in Injana Formation ranges from (0.1–0.5)m, the overburden is (7.1–24.0)m, the Sr concentration is (17.0–30.0) % and the celestite concentration is (37.40–66.0) % (Table 3).

Celestite in Dibdibba Formation

The celestite is more dominant in Dibdibba Formation than in Injana Formation, it has been found in one or two horizons in this formation, particularly along Tar Al–Sayyed. Generally, the celestite has been found in the lower part of

Dibdibba Formation within brown to grayish brown sandstone bed (Hassan and Kadhum, 2002). Celestite is differentiated in the field by its colorless, needle–shaped crystals within heavy tough beds. In the area south of Al–Najaf town, the thickness of the celestite bearing beds ranges between (0.1–0.35)m, the overburden thickness is (0.5–14.5)m and the concentration of Sr is (8.0–33.0)% (Table 1). In Tar Al–Sayyed the thickness of the celestite bearing beds ranges between (0.1–0.3) m and the concentration of Sr is (16.0–30.0)% (Table 2). In the junction area, the thickness of the celestite bearing beds ranges between (0.1–0.5)m, the overburden thickness is (0–8)m and the concentration of Sr is (9.70–34.0)% (Table 3).

Table 1: Chemical analysis of celestite bearing beds in Injana and Dibdibba Formations along Tar Al–Najaf

Sample No.	SO_3 (%)	Sr (%)	Celestite (%)	Thickness (m)	Overburden thickness (m)
Injana Formation					
1	12.5	13.26	29.17	0.2	15
2	24.5	27.12	59.66	0.1	5
3	18.0	20.0	44.0	0.5	11
4	21.0	33.0	72.60	0.5	11
Dibdibba Formation					
5	18.5	25.0	55.0	0.35	14.5
6	14.0	19.0	41.8	0.1	0.5
7	16.75	10.0	22.0	0.2	5.5
8	20.0	30.0	66.0	0.3	2.2
9	21.5	28.0	61.6	0.15	9.25
10	6.0	8.0	17.0	0.3	5.25

Table 2: Chemical analysis of celestite bearing beds along Tar Al-Sayyed, Sheet No. (I–38–U–06), Scale 1:50 000

Sample No.	SO_3 (%)	Sr (%)	Celestite (%)	Thickness (m)
Injana Formation				
1	18.0	30.30	66.66	0.25
2	19.57	27.33	60.1	0.1
3	19.50	24.0	52.8	0.3
Dibdibba Formation				
4	13.25	27.0	59.4	0.2
5	13.25	22.0	48.4	0.2
6	15.5	27.0	59.4	0.1
7	22.0	18.0	39.6	0.15
8	8.75	20.0	44.0	0.3
9	12.75	22.0	48.4	0.2
10	15.75	30.0	66.0	0.2
11	10.0	17.0	37.4	0.2
12	13.50	16.0	35.2	0.3

Table 3: Chemical analysis of celestite bearing beds of Dibdibba and Injana Formations along Tar Al–Sayyed and Tar Al–Najaf, Sheet No.(I–38–T–08), Scale 1:50 000

Sample No.	SO_3 (%)	Sr (%)	Celestite (%)	Tickness (m)	Overburden thickness (m)
Dibdibba Formation					
1	20.0	26.0	57.2	0.20	4.8
2	22.50	31.0	68.2	0.20	3
3	19.0	27.0	59.4	0.35	2.75
4	7.0	12.70	27.9	0.25	1.75
5	11.50	9.70	21.34	0.20	1.8
6	22.50	32.0	70.4	0.10	8
7	23.50	33.70	74.14	0.25	6
8	21.50	33.0	72.6	0.25	8
9	20.0	31.0	68.2	0.20	4.5
10	21.50	31.0	68.2	0.35	0
11	24.50	30.0	66.0	0.5	3
12	13.50	18.0	39.6	0.3	4.5
13	23.0	32.0	70.4	0.50	0
14	18.75	34.0	74.80	0.20	4
15	21.50	31.7	69.74	0.30	0
16	21.0	12.1	26.62	0.10	0.4

… continue table 3

Sample No.	SO_3 (%)	Sr (%)	Celestite (%)	Tickness (m)	Overburden thickness (m)
Injana Formation					
17	18.0	30.0	66.0	0.5	7.1
18	23.0	25.0	55.0	0.5	22
19	16.0	17.0	37.4	0.1	24

FACTORS CONTROLLING THE CELESTITE DISTRIBUTION IN THE STUDIED AREA

The present study indicates that the factors controlling the distribution of the celestite are:

▪ Structural Setting

The authors believe that the structural setting is the main controlling factor for the distribution of the celestite. In the studied area, the depressions, ridges and the scarps (Tar Al–Najaf and Tar Al–Sayyed) were developed due to the effect of Abu Jir Fault (Hassan et al., 2004).

The celestite in the studied area is restricted mainly along the Abu Jir Fault Zone, particularly along the scarp of both Tar Al–Najaf and Tar Al–Sayyed. Six boreholes were drilled in the studied area above the Dibdibba plateau to show the extension of the celestite. These boreholes were drilled at different distances from the scarp (200–2000)m. The study indicates that the celestite is restricted to the scarps and extends in the plateau to a distance of less than 200 m only, where the chemical analysis indicate that the Sr^{++} content is very low in these bore holes. Samples have been collected from the Quaternary sediments in the depression of Bahr Al–Najaf along the fault zone. These samples indicate that the Sr^{++} content is more than that of Nfayil and Euphrates Formations, where it reaches 4300 ppm (Table 4). The presence of three celestite horizons in Injana and Dibdibba Formations may indicate the presence of three phase of reactivation along the fault zone for supplying Sr which combines with SO_3 to form celestite in the studied area.

▪ Porosity and Permeability

It is worth to mention that many samples have been collected from the limestone and marl of Nfayil and Euphrates Formations for chemical analysis to show the distribution of the celestite in these rocks. The study indicates that the Sr content doesn't exceed 257 ppm (Table 4). The celestite is concentrated mainly in the porous clastic sediments (sandstone, siltstone or silty claystone) of both Injana and Dibdibba Formations; with more concentration in the sandstone beds.

Table 4: Chemical analysis of samples from Nfayil and Euphrates Formations, and Quaternary sediments

Sample No.	SO_3 (%)	Sr (ppm)	Formation
1	1.6	257	**Nfayil**
2	<0.07	254	**Nfayil**
3	<0.07	219	**Nfayil**
4	0.11	<10	**Nfayil**
5	0.11	<10	**Nfayil**
6	0.53	<10	**Nfayil**
7	0.08	<10	**Nfayil**
1	<0.07	242	**Euphrates**
1	3.6	247	**Quaternary deposits**
2	24.5	4300	
3	12.4	2300	

The celestite is actually formed by diagenesis and disseminated through the permeable clastic sediments of Injana and Dibdibba Formations. It is rare in the carbonate rocks and in the marly rocks of Nfayil and Euphrates Formations, while in the recent sediments the concentration of the celestite is more than that of the rocks of Euphrates and Nfayil Formations.

DISCUSSION

Although a lot of previous works have dealt with the celestite occurrences in Karbala–Najaf area; the present work adds new results concerning the configurations of celestie in the studied area. Almost all the previous works were restricted to the exposed rocks along both Tar Al–Najaf and Tar Al–Sayyed. The present work included several boreholes at different distances from the tars (cliffs) within the plateau, which indicate that the celestite is restricted to both tars and decreases downwards in Karbala–Najaf Fan (Dibdibba Plateau).

Al-Bassam (1994 and 1995) reported that the celestite seems to have formed by direct crystallization from saline solution as well as by replacement of aragonite and calcite under hot arid climatic conditions, he mentioned that Sr may have been supplied from several sources, including aragonite, feldspar and deep ground water aquifer of oil–field origin. The authors believe that there is no effect of the eliminated Sr from aragonite during the gradual change to calcite; because just west and southwest of the studied area and on the other side of Abu Jir Fault Zone, where the main rocks are calcite and aragonite under the same conditions, but there is no indication for presence of the celestite.

Dawood (2000) studied a very limited area extending 19 km NW and 10 km SE of Al–Najaf city, but the present work dealt with both Tar Al–Najaf and Tar

Al–Sayyed for about 180 km distance. He referred through his thesis that the Sr was supplied from ground water due to the effect of Abu Jir Fault Zone, but he mentioned that the factors controlling the distribution of celestite in the studied area are (1) porosity and permeability (2) difference in the chemical composition of water and (3) climate. This means that the effect of Abu Jir Fault Zone is of minor importance, while the authors believe that Abu Jir Fault Zone is the main and principle factor on the distribution, because the celestite is concentrated only around the fault zone and decrease downwards away from the fault zone.

Al-Khafaji and Al-Quaizi (1999) did a good contribution to the celestite geology along Tar A–Najaf and Tar Al–Sayyed, but the present work dealt with new localities with higher celestite concentrations.

CONCLUSIONS

The present work dealt with a large area including both Tar Al–Najaf and Tar Al–Sayyed extending to about 180 km, it adds new localities for the celestite in the area and indicates that Abu Jir Fault Zone is the main principal controlling factor controlling the distribution of the celestite, which is concentrated just around the fault zones and decreases downwards in the plateau. It also provides new information on the stratigraphy and structural setting of the studied area.

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