Study of texture the Mazraeh celestite deposit from North Central Iran

Mohsen Ranjbaran[1]*, Seyed Javad Moghaddasi [2], Farzad Sotohian[3]

1- Schools of Geology, College of Science, University of Tehran, Tehran, Iran
2- Department of Geology, Payame Noor University, Tehran, Iran
3- Faculty of Natural Resources, Environmental Science Department, University of Guilan, Guilan, Iran.

* Corresponding Author: ranjbaran@khayam.ut.ac.ir

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Abstract

The Qom Formation, which hosts the Mazraeh celestite deposit, contains dominantly limestones, marl and subordinate evaporites deposited in shallow marine environments. Petrographic evidence indicates that the celestite deposits were formed by replacement of limestone. The presence of carbonate inclusions within celestite crystals as well as the pseudomorphic habits of some crystals suggests that celestite replaced preexisting carbonate. Based on petrographic evidences and celestite mineralization occurred as a late-diagenetic process during deposition of Qom Formation. Celestite occurs mostly at lower part of members of the Qom Formation as banded, rhythmic, massive, cavity and cave fillings. The layered, rhythmic and elongated lenticular celestite crystals are positioned parallel to the general bedding of the sequence and formed at early principal diagenetic stage. Relatively high strontium ion content of the Karadj Formation suggests a high probability of ion supply to form celestite from these formations.

Keywords: Rhythmic, Celestite, Oligo-Miocene, Iran, Mazraeh, Qom Formation.

1–Introduction

The strontianite ($SrCO_3$) and celestite ($SrSO_4$) are two minerals contain Sr at a level to make them profitably exploitable from mineral deposits. Celestite mineralization is also found in varied geological environments, including igneous, hydrothermal, and sedimentary deposits (Hanor, 2000; Dill, 2010). Nevertheless, the largest celestite deposits occur dominantly as epigenetic replacements and open-space fillings in coastal carbonate-evaporite sequences from Silurian to Pliocene ages (Hanor, 2004). Development of celestite in sedimentary carbonate depends heavily on the availability of sulphate ions (Yan and Carlson, 2003). Only two minerals, celestite ($SrSO_4$) and strontianite ($SrCO_3$) contain sufficient Sr to make it economically recoverable from mineral deposits in the world. Celestite is the main source of strontium in the world. In sedimentary carbonate, celestite occurs predominantly as: (1) primary precipitates under hypersaline conditions; (2) replacements of gypsum and anhydrite and (3) replacements of back reef, tidal and sabkha algally laminated limestones (or dolomites). The dolomitization of aragonite produces a greatly increased Sr concentration in the residual brine reflecting the higher Sr content of aragonite compared to dolomite and calcite (Kinsman, 1969): aragonite $CaCO_3$ 8,000 ppm Sr; dolomite $(Ca, Mg)CO_3$ 200-600 ppm Sr and calcite $CaCO_3$ 400 ppm Sr. The average of Strontium concentration in the earth's crust and seawater is 0.04% and 8 ppm respectively (MacMillan *et al*., 1994). The Iranian celestite deposits occur in Cenozoic carbonate-evaporite succession (Ehya *et al*., 2013). The other Iranian celestite deposits occur in the Zagros and

Alborz structural zones. A one of the largest celestite regions in the world located in the Qom Formation basin at Iran .The strontium deposits and occurrences in Iran occur mostly in the carbonate evaporite successions of Cenozoic age, through northern Iran, the Oligo-Miocene Asmari Formation, in Zagros Folded Belt, southern Iran, and the Qom Formation Oligo-Miocene, Central Iran. The Oligo-Miocene sequences characterize the celestite distribution in the carbonate sediments in the Central Iran (Bazargani-Guilani and Nekouvaght Tak, 2008; Bazargani-Guilani, and Rabbani, 2005). The Mazraeh celestite deposit is located in the Central Iran in the southeastern of Houz-e Soltan Lake (Fig. 1) and mineral has been commercially extracted from shallow pits in area. In this contribution, we present the geological setting, petrographic and mineralogical findings, to determine the natural occurrence Mazraeh celestite deposit. This paper aims at improving our knowledge on the genesis of celestite ore deposits based on texture in the Central Iran and is mainly based on field studies and petrographic investigations.

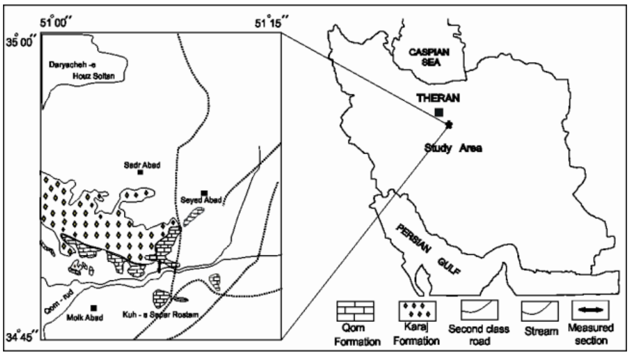

Figure1) Geological map of the study area (modified from Emami, 1995).

2– Material and methods

In this study, random samples were collected from limestone occurrences in the Oligocene-Miocene carbonate rock series. During the macroscopic observations of the celestite layers and their country rocks, a total of 28 celestite mineral and host rock samples were selected from different localities for petrographic investigations. Routine optical-mineral examinations were performed on thin sections from these samples using a polarizing microscope. Some celestites deposit are samples were chosen to study the micro textures using Scanning Electron Microscope (SEM). Micro structural investigations were performed using a scanning electron microscope (SEM; XL30-, Philips, Netherlands), operated at 17 kV accelerating potential, equipped with an energy-dispersive X-ray spectrometer (EDX) (Dolenec *et al*., 2005).

3– Geological setting

Tectonic setting Iran is divisible into eight geological provinces. The Central Iran is one of eight geological provinces (Heydari *et al*., 2003; Aghanabati, 2004). As a consequence, Central-Iranian paleogeography changed dramatically by the development of a volcanic arc which separated a fore arc from a back arc basin during Eocene times (Behforouzi and Safari, 2011; Fig. 2).

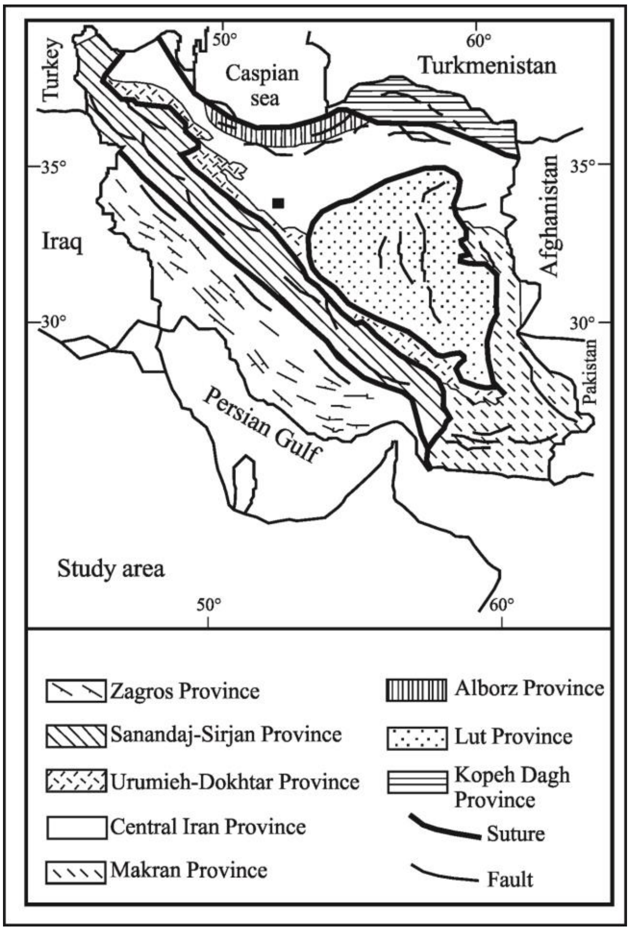

Figure 2) Tectonic setting Iran is divisible into eight geological provinces (Behforouzi and Safari , 2011).

Marine sedimentation of the Qom Formation began during the Oligocene and continued to the end of the Early Miocene in the Esfahan-Sirjan fore arc and in the Qom back arc basin (Schustr and Wielandt, 1999). The Qom Formation was deposited at the north-eastern coast of the Tethyan Seaway (Reuter *et al*. 2007; Fig. 3). The thickness of the Qom Formation varies from area to area. In the type area, the Qom Formation with 1,200 m thickness is laid on the gypsiferous and evaporitic red beds (LRF) conformably and overlaid conformably by evaporitic red beds of Middle-Late Miocene age (URF) (Reuter *et al*., 2007).

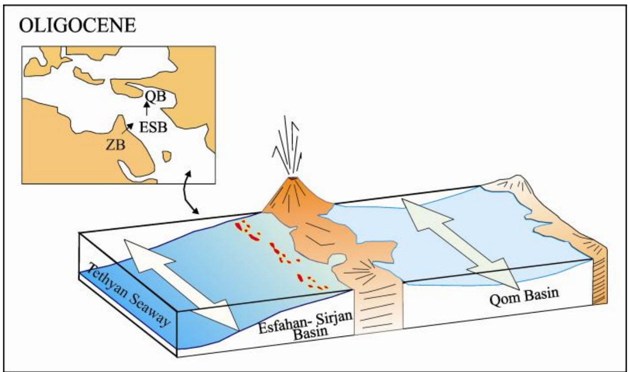

Figure 3) The modified Schematic block diagrams illustrating the development of the Esfahan-Sirjan Basin and Qom Basin from Late Oligocene to Early Miocene times (paleogeographic maps modified from Harzhauser and Piller, 2007). The black arrows in paleogeographic maps tag the positions of the Zagros Basin (ZB), Qom Basin (QB) and Esfahan- Sirjan Basin (ESB); white arrows in block diagrams show the permeability of gateways (Reuter et al., 2007).

This formation is divided up to 11 member type areas. These are named as: silty marl, sandstone, and limestone (a) basal limestone, (b) sandy marls, (c1) limestone and marls, (c2) red and gray shale, sandstone and gypsum, (c3) limestone, (c4) green to yellow marls (d) evaporates, (e) greenish gray marls, (f) Top limestone and Top evaporates (Aghanabati, 2004). Therefore, Qom Formation is divisible to its members only in a small area in Central Iran back-arc basin. In addition, deposition of the Qom Formation took place in back-arc and intra-arc basin environments behind and within the Central Iranian Volcanic Belt. The lower boundary of the Qom Formation is underlined by Eocene volcanic rocks, the LRF and other older rocks. The Qom Formation is overlain by the URF or alluvium in most areas. The Qom Formation in the study area and overlies mostly volcanic or pyroclastic rocks of the Karaj Formation, or red shales, sandstones and conglomerates of the Lower Red Formation (LRF) (Fig. 4).

Table 1) Petrographical description of Karaj tuffs (Yassaghi et al. 2005)

Rock type	Distribution(%)	Mineral composition
Crystalline tuff	20	Up to 45% feldspar, 20% Ferromagnesian Silicates like Pyroxene (mainly altered to Chlorite), 15% Carbonates (partly secondary minerals), 5% Serisit (alteration products), 5% Opaque minerals, and 10% Microcrystalline quartz as ground mass.
Vitric tuff	35	60% Silica, 20% Clay minerals, 10% Calcite, 10% Iron Oxide and other Opaque minerals.
Lithic tuff	45	45% Clay minerals, 30% Silica and fine grain Quartz (Silt), and 25% Carbonates.

Karaj Formation is a volcano-sedimentary unit that consists of the variety of tuffs. According to petrographical studies these tuffs could be classified into three main types that include crystalline, vitric, and lithic tuffs (Table 1). The Karaj Formation is mainly composed of tuff beds lava flows (mostly trachytic to andesitic compositions), as well as several tuffy limestone, limestone and shale horizons. The thickness of the Karaj Formation exceeds 500 m.

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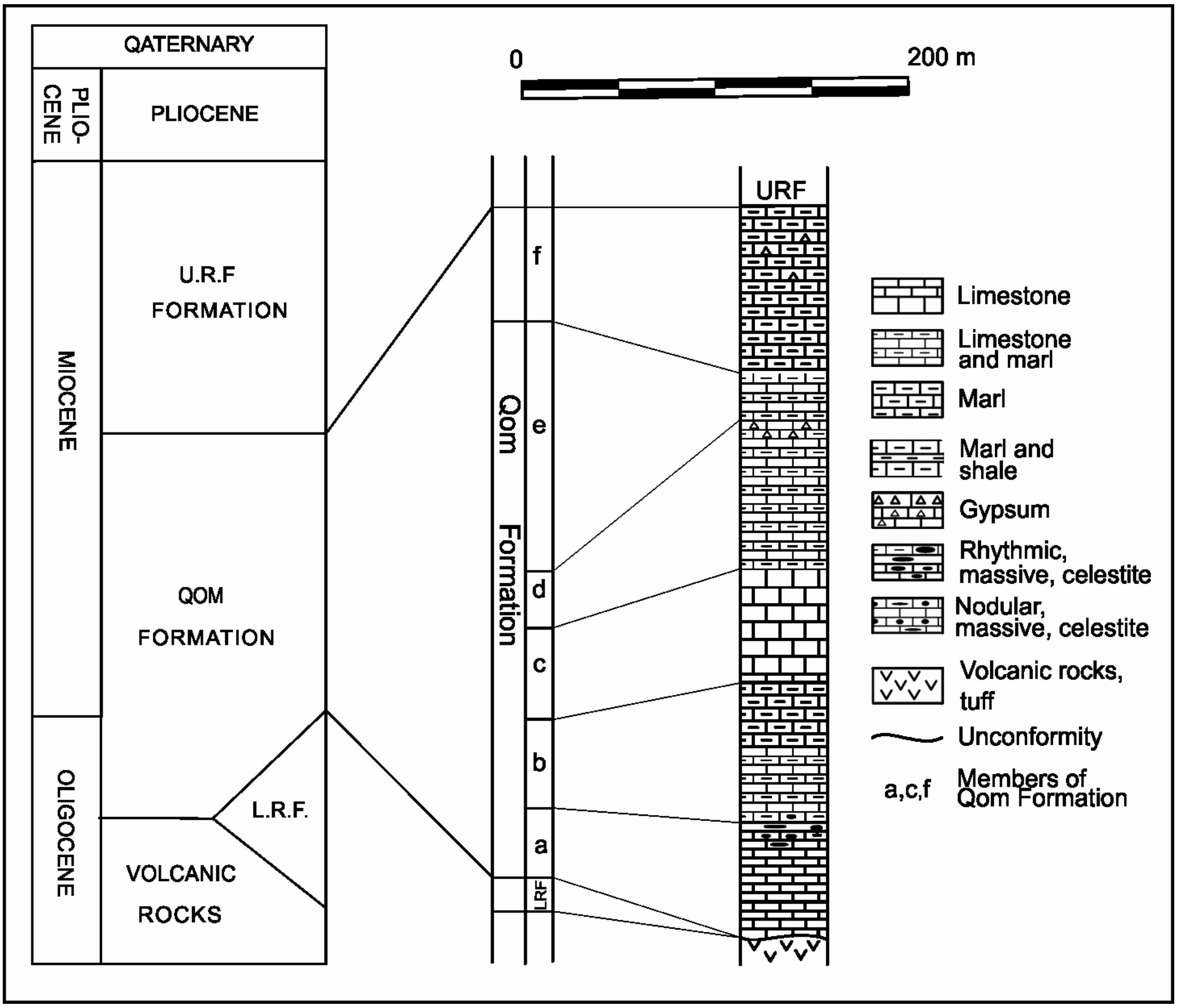

Figure 4) Stratigraphic distribution of celestite in the Qom Formation (modified from Bazargani-Guilani and Nekouvaght Tak, 2008; Okhravi ,1998).

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4– Celestite mineralization and Petrography

There are abundant cavities within the rock, filling in some places with fine, anhedral to euhedral celestite crystals. The limestone bed that parts the celestite beds is cream to white color. Under the microscope, this limestone bed is composed of biomicrite. Remobilization of strontium resulted in the crystallization of celestite in fractures and vugs of the limestone. In these cases, the celestite patches contain abundant carbonate inclusions. The celestite beds are texturally and mineralogically very similar. These beds are normally composed of cocolour to white, medium to coarse intergrown crystals of celestite. The first celestite generation is small size. The most important macroscopic feature of the celestite beds is their abundant geodes. These geodes range in size from a few millimeters to several decimeters.

The inner space of the geodes is occupied by large, tabular, and euhedral crystals of the second celestite generation. The colour of the celestite crystals filling the geodes displays a considerable variation, including colourless, milky white, pale blue, and rarely grayish blue. In this diagenetic structure, the radial aggregate of celestite has a fine-grained center, intermixed with carbonate materials. The large radial crystals of celestite that grown outward. The large celestite crystals are dominantly pale blue to grayish blue in these aggregates. Under the microscope, the overall feature of the celestite beds is that the celestite crystals embedded into a micritic to microsparitic carbonate matrix. The crystals also contain abundant carbonate inclusions.

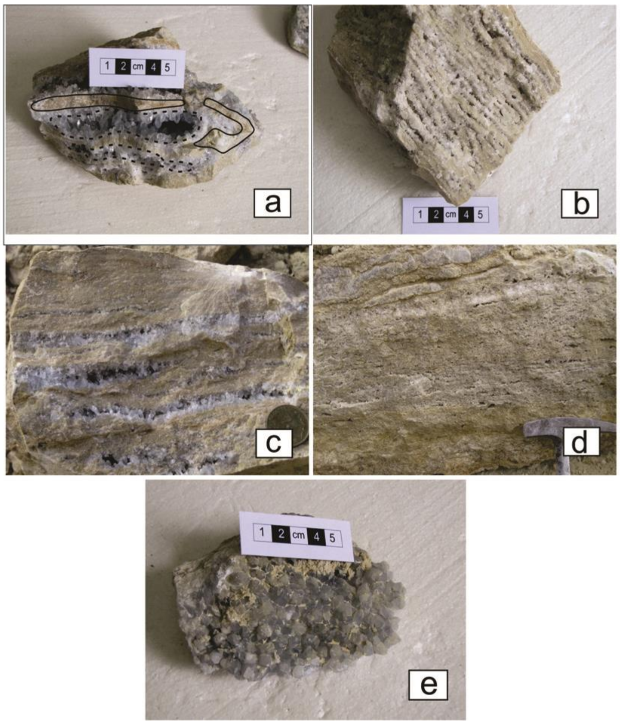


Figure 5) Hand specimens of celestite are. a) Large celestite crystals from the second generation grown in a geode. and massive celestite in hand specimen (full line) and vugs filled with celestite (dashed line), b) Illustrating laminated and rhythmic texture, Black colours is pore space, c) Massive celestite grading into drusy celestite ,d) Rhythmic, banded and massive celestite in the b member, and e) Aggregates of slender prisms of transparent celestite.

The morphology and the type of the inclusions reveal that some celestite crystals replaced the earlier calcite and late dolomite crystals. Celestite deposit of the Mazraeh mine, is present in the a and b and rarely other members of the Qom Formation, occurring as layered, rhythmic, massive and cavity filling (Fig. 4). The crystals observed in the pit range from pale blue to white and colourless. When first exposed, the larger ones are frequently bluish, sometimes quite deeply tinted, but after exposure to light and weather they become either white or colourless (Dill *et al*., 2009). The megascopical and microscopical classification of the studied celestite are as follows: (a) laminated, (b) layering and rhythmic, (c) massive, (d) nodular and (e) cave and cavity filling. Macro crystalline celestite from pale blue to white and colourless, were filled large open spaces (Fig. 5).

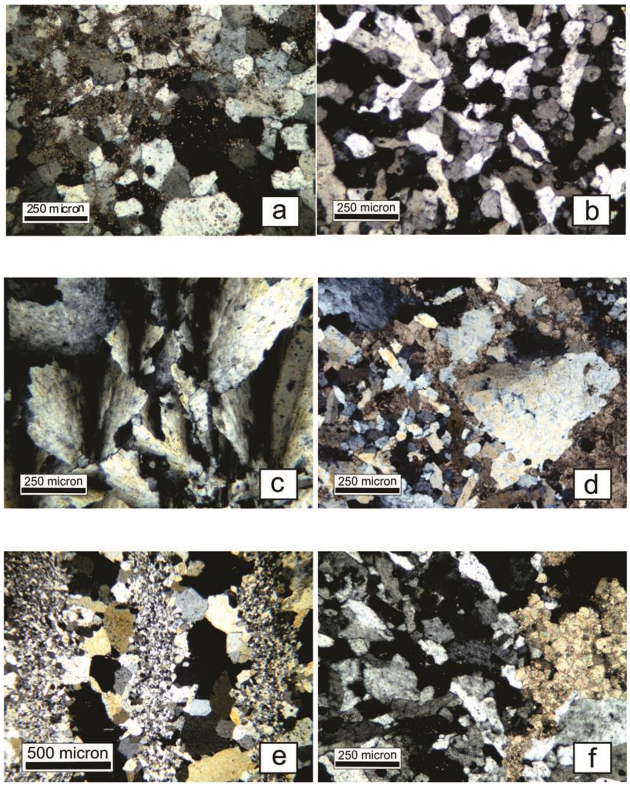


Figure 6) Different microscopic forms of celestite mineralization ,all photomicrographs are shown with crossed polars . (a) Photomicrograph of celestite crystals with granular texture.(xenomorphic to subautomorphic equal medium -grained crystalline celestite), (b) Prismatic to bladed celestite in a matrix composed of very fine-grained celestite , (c) acicular crystals of celestite developed as radial fans aggregates of growing celestite,(d) Poikilotopic celestite in the centre, surrounded by

celestite and rarely calcite crystal, (e) Layering of fine and coarse grained celestite and (f) Massive celestite revealing under the petrographic microscope a close intergrowth of calcite and celestite.

The celestite microscopic textures observed under the microscope are as follows: (a) equal grained, (b) lath and prismatic,(c) fan shape,d) porphyroid ,(e) banded and replaced fine celestite and (f) mixed fine grained celestite and calcite crystals (Fig. 6).

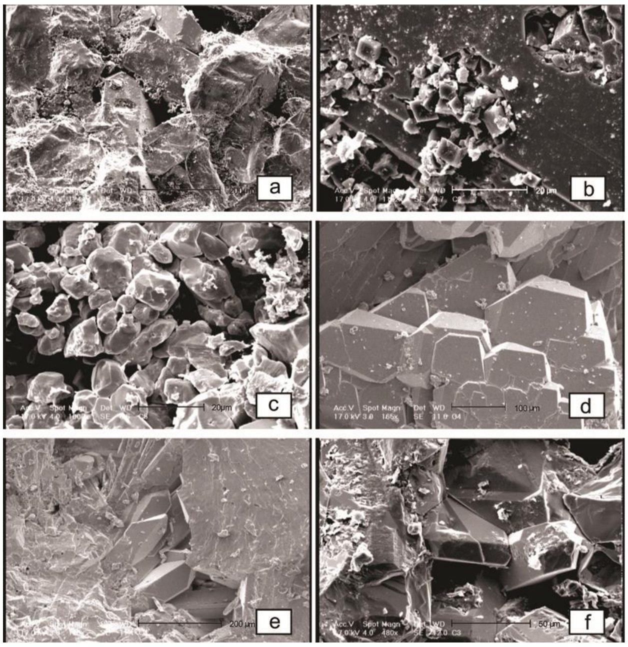
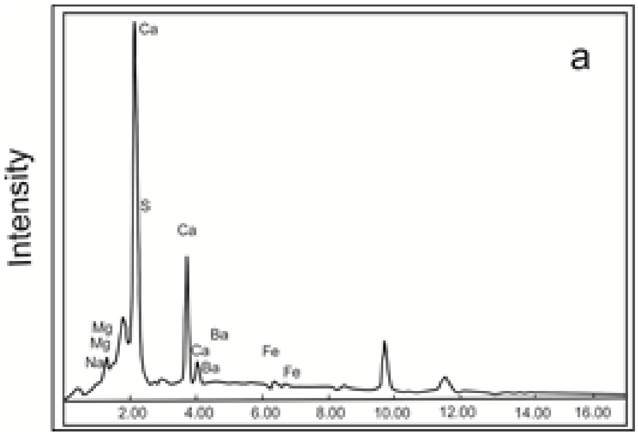


Figure 7) Celestite mineralization under the scanning electron microscope (SEM). a) SEM image of coarse, prismatic, euhedral celestite crystals of displacement type with oriented crystals , b) SEM Image rhomb-shaped crystals of dolomite Fe-bearing overgrowing celestite crystals ,c) SEM Image of anhedral celestite crystals developing in a microcrystalline 222 carbonate matrix , d) SEM photographs of celestite crystals from open vugs ,e) SEM image of coarse prismatic, bar-like, irregularly-freely growing celestite crystals with in a carbonate matrix texture together with euhedral calcite crystals and f) SEM image of a celestite cluster composed mostly of tabulated crystals.

Microstructural investigations were also performed using a scanning electron microscope (SEM; XL30-, Philips, Netherlands), operated at 17 kV accelerating potential, equipped with an energy-dispersive X-ray spectrometer (EDX). The celestite deposit demonstrated different kinds of crystals. They were petrographically classified into three main groups as follows: as follows : (a) coarse ,prismatic euhedral celestite crystals, (b) rhomb-shaped crystals of dolomite Fe-bearing overgrowing celestite crystals and (c) anhedral celestite crystals (Fig. 7).

The evidences such as the coarse-grained texture, euhedral crystals and the presence of and carbonate inclusions within the celestite grains demonstrate that celestite replaced the preexisting minerals, so the mineralization occurred most probably as a late-diagenetic process. (West *et al*., 1968 ; Carlson, 1987 ; Hanor, 2004). Interaction of groundwater with plagioclases feldspar in Karaj Formation tuff may produce relatively low $^{87}Sr/^{86}Sr$ values (Franklyn *et al*., 1991). The Low $^{87}Sr/^{86}Sr$ ratio is also reported from silicate rocks, containing low strontium concentrations and radiogenic strontium (Palmer *et al*., 1992). Five crystals of celestite crystals were selected for chemical analysis using EDA. Quantitative analyses carried out with the SEM-EDAX system revealed the following elemental contents in wt %: 4.19 to 11.67 % S, 86.45 to 93.05 % Sr, 3.9 to 4.7 % Ca 0 to 0.64 % Fe, 0 to 0.53 % Mg, and 0.0 to 0.74% Ba. It is interesting to note that Fe content was detected on dolomite found in the celestite are (Fig. 8).

The Mazraeh celestite deposit shows both with underlying volcanic rocks, where the breakdown of feldspars could liberate strontium during sedimentation of carbonates of the Qom Formation, indicates that volcanic rocks have supplied Sr of celestite. The volcaniclasts, as well as detrital minerals in the lower units of the Formation suggest that the trachytic to andesitic rocks have been source of Sr of celestite in the study area. The migrating of Sr within sulphate-bearing pore waters could precipitate celestite during synsedimentary to early diagenetic stages. Proposed that the celestites are the products of buried volcanic sources, which were active during the Latest Miocene to Pliocene. The formation of the celestite occurred in an environment enriched in Sr compared to Ba and Ca (Wood and Shaw, 1976).



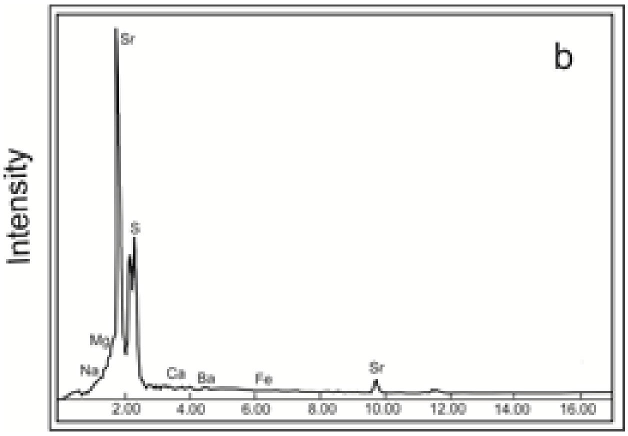


Figure 8) Energy Dispersive X-ray Spectroscopy (EDX) of celestite crystal (a) and dolomite crystal (b) The EDX diagrams indicate an evident difference in Fe content in dolomite.

5– Conclusions

The Oligocene-Miocene in the north Central Iran is marked by dominant shallow marine environments, accounting for formation of abundant synsedimentary-syndiagenetic sulphate minerals, especially celestite in the Qom Formation. The Mazraeh celestite deposit occurs mostly in the a and b, and rarely other members of the Qom Formation as bedded, rhythmic, massive, cavity and cave fillings. The celestite-bearing layers are composed of medium to coarse-grained celestite crystals of variable morphologies in a carbonate matrix. Petrographic investigations reveal that celestite replaced carbonate materials. According to lithofacies characteristics the host rocks, it is evident that they deposited in shallow marine environments. The petrographic findings document that celestite mineralization occurred as a late diagenetic process during the sedimentation of Qom Formation. This celestite mineralization in the region reflects an advanced stage of brine migration in the entire Qom Formation. The Sr derived from volcaniclastic rocks of the underlying Karaj Formation.

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