Celestite Ore Deposit and Occurrences of the Qom Formation, Oligo-Miocene, Central Iran

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Abstract: - A multidisciplinary study including field geology, petrography, geochemical and isotope analyses has been carried out on the celestite ore deposit and occurrences, hosted by the Oligo-Miocene Qom Formation in the Molkabad, Siah-Kuh and Davazdah-Emam regions, north Central Iran. The underlying Eocene Karaj Formation was studied as well, in order to trace the possible source of Sr and prevailing conditions during celestite precipitation. The Oligocene-Middle Miocene in the north Central Iran is marked by dominant shallow marine environments of an intertidal, subtidal and supratidal types, accounting for formation of abundant synsedimentary-syndiagenetic sulphate minerals, specially celestite in the the Qom Formation. Celestite occurs mostly in the a and b, and rarely other members (c, d, e, f) of the Qom Formation as layering, rhythmic, massive, cavity and cave filling, replacement of fossils, fossil filling, nodular and lens form. The vein and vein filling celestites are epigenetic in origin. The ^{87}Sr / ^{86}Sr ratio of celestite in the Molkabad ore deposit (0.708078 ± 0.000004) is lower than two other regions (0.708482), suggesting origination of Sr from the volcanic rocks of the underlying Karaj Formation through interaction of porewaters with plagioclase feldspars during deposition of the Qom Formation, and subsequent burial of the Formations. In the study area, the amount of Sr in the bulk rocks (KF) ranges from 219 to 490 ppm and the 1000×Sr/Ca molar ratio varies between 7.15 and 14.6 which is much higher than limestone. The calcareous environments had a strong impact on the fluid migration, leading to the celestite mineralization. In the study area, biostromal faciliated lateral migration of the basinal brines. The dissolved detrital materials, and trachytic to andesitic rocks of the underlying Eocene Karaj Formation are thought to have supplied necessary Sr for formation of celestite.

Key-Words: - Celestite, Oligo-Miocene, Molkabad, Siah-Kuh, Central Iran, Synsedimentary, Syndiagenetic, Sr Source

1 Introduction

Strontium averages 0.04% in the earth's crust [14] and 8 ppm in the seawater [11]. Celestite ($SrSO_4$) and to a lesser extent strontianite ($SrCO_3$) contain Sr in sufficient quantities to make them a mineral deposit.

Iran is exceptionally rich in evaporite deposits [13] which outcrop mostly within Cenozoic carbonate rocks. The strontium deposits and occurrences in Iran occur mostly in the carbonate-evaporite successions of Cenozoic age. These include for example the Upper Eocene Kond Formation, central Alborz, northern Iran [3], the Oligo-Miocene Asmari Formation, Zagros Folded Belt, southern Iran, and the Oligo-Miocene Qom Formation, Central Iran [2, 7, 9]. The Eocene-Miocene celectite deposits from Turkey [20] (Fig. 1a) and Spain [19] indicate development of celestite deposits in Cenozoic as well.

The Oligo-Miocene sequences characterize the celestite distribution in the carbonate sediments in the Central Iran, the Zagros Folded Belt, southern Iran and Sivas, Turkey. In the Central Iran, celestite is hosted by the Oligo-Miocene Qom Formation and has outcrops in the Molkabad, Siah-Kuh and Davazdah-Emam regions (Fig. 1b).

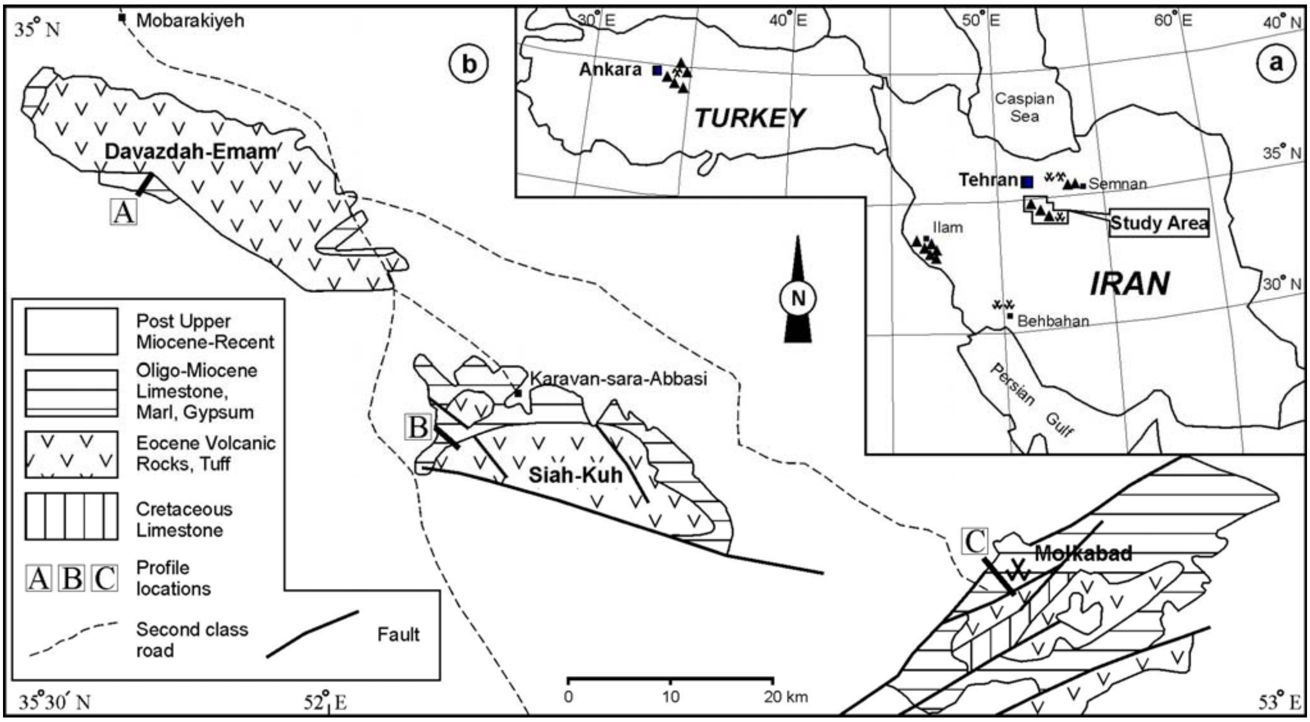

Fig.1 Sketch map illustrating a) celestite deposits (⚒, ⚒) and occurrences (▲) in the Eocene of western Semnan, Iran and Oligo-Miocene of Iran and Turkey; b) general geology of the study area, modified from Geological Map of Iran, scale 1:1000000, [22] and 1:250000 Aran Sheet [21].

The Molkabad ore deposit hosted by the Oligo-Miocene Qom Formation in Central Iran ranks the third large celestite ore deposit after Montevive in Spain and San Augustin in Mexico [18].

This paper aims at improving our knowledge of the genesis of celestite in the Central Iran and is based on field and analytical data, gathered on the Molkabad deposit, the Siah-Kuh and the Davazdah-Emam occurrences. In this regard, the stratigraphy and geochemical data of the Qom and underlying Karaj Formation (KF) in the Molkabad, Siah-Kuh and Davazdah-Emam regions have been presented, as well.

2 Geological and Stratigraphical Aspects

The structural geology of the study area is characterized by the Post-Cretaceous diastrophism, causing strong folding, magmatism and uplift [4]. The Laramide orogenic movements gave rise to folding of the Cretaceous strata which were subsequently overlained by the late Paleocene and Eocene rocks along prevalent angular unconformities [5]. In the Molkabad region, the late Cretaceous strata are overlain only by the Eocene Karaj Formation (KF) (Fig .1b).

Figure 2 shows the stratigraphic columns for the Molkabad, Siah-Kuh and Davazdah-Emam regions. Detailed field work revealed that the Oligo-Miocene Qom Formation (marine limestone, marl and gypsum) overlies unconformably and trasgressively the Eocene KF. The transgressive contact is occasionally marked by basal conglomerate and sandstone of the Lower Red Formation (LRF), which locally may rich a thickness of several hundred meters. The KF is mainly composed of lava flows (mostly trachytic to andesitic compositions), tuffaceous beds and ash layers in addition to several sandy limestone, limestone and sandstone horizons. The thickness of the KF exceeds 500 m and may reach as much as 1000 m. The lower contact of these volcanic rocks is exposed only in the Molkabad region, whilst their upper contact displays an angular unconformity underneath the Qom Formation (Fig. 2). Evidence of tectonic and fracturing is present as mud-filled cracks on the eroded surface of the volcanic rocks, and locally a few meters of agglomerates just below the Qom Formation. The upper part of the KF or volcanic rock column, is mainly strongly weathered and rock samples are very soft.

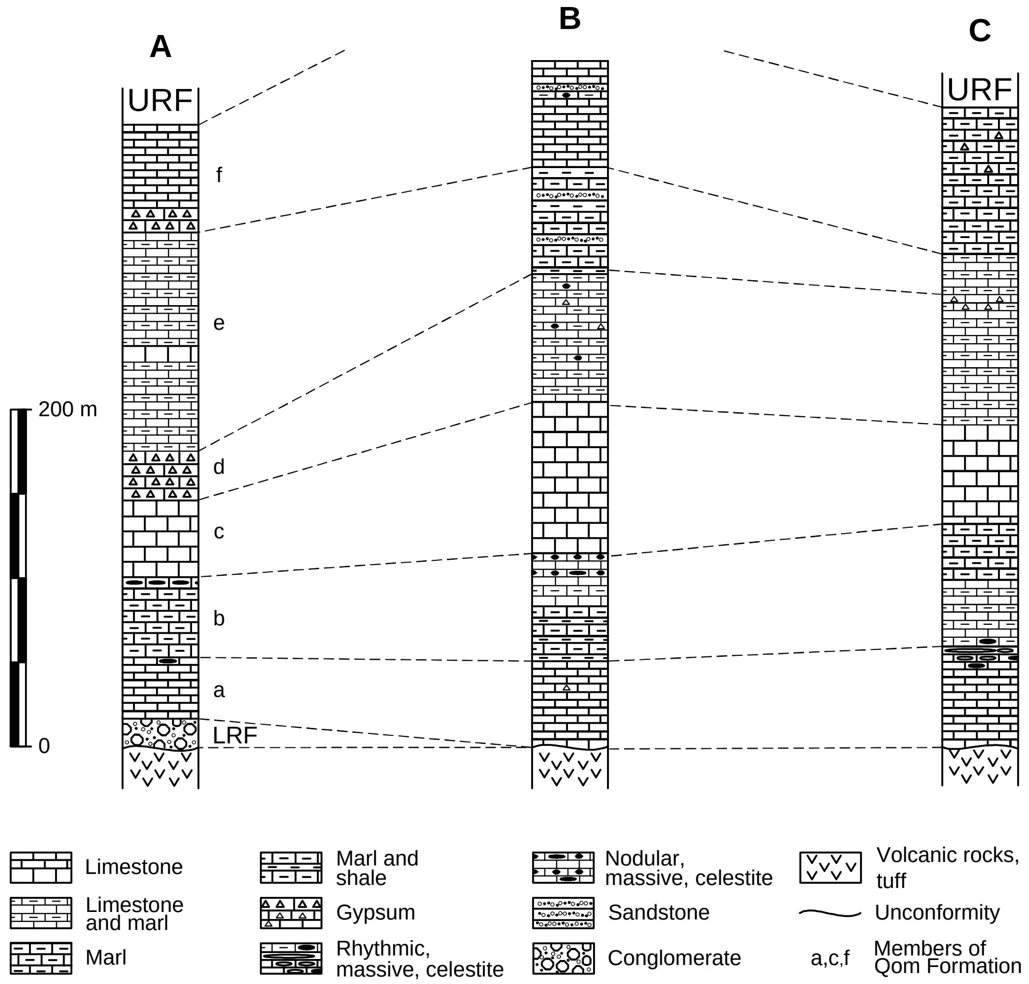

Fig.2 Stratigraphic columns section of the Davazdah-Emam (A), west Siah-Kuh (B) and Molkabad ore deposit (C). For profiles locations see Fig. 1.

In the study area, the Qom Formation includes 400-600 m interbedded of limestone, marl, gypsum, shale, sandstone, rhythmic and nodular celestite. Deposition took place in an intertidal, subtidal and supratidal environments with evaporitic conditions, evidenced by presence of gypsum and salt. According to Dill et al. [8], the celestite deposits in the Persian Gulf region were mainly concentrated also in supratidal to intertidal environments. Karstification and fluviatile channeling are minor features. The Qom Formation is believed to have been formed in an oxygen-rich sedimentary environment based on its white, orange to red colour and widespread enrichment in organic matter, algae, corals, gastropods and bryozoae (biostromal host rock environment of celestite). Fluid flow in a biostromal host environment has a strong lateral component and synsedimentary to syndiagenetic celestite mineralization is not succeeded by epigenetic celestite mineralization.

The rhythmic, layered and massive celestites are confined mainly to the lower limestone units (a and b members) in the Molkabad region, whilst in the Siah-Kuh region the nodular and patchy celestites occur in the lower marl and limestone units (b member) and sometimes in association to the evaporites or as cement of conglomerates (d member). The massive and layered celestite outcrop mostly in the lower marl units (b member) in the Davazdah-Emam region (Fig. 2).

2.1 Local Stratigraphy

The Qom Formation in the study area comprises fossiliferous limestone with interbeded marls and gypsiferous marls and overlies mostly volcanic or pyroclastic rocks of the KF, or red shales, sandstones and conglomerates of the LRF (Fig. 2). The unconformity is highly irregular and crosscuts bedding planes, suggesting a paleorelief differences in the stratigraphic level during the transgression of the Qom Sea. However, the lithologic changes are not very noticeable in the field. In this study, the Qom Formation has been formally subdivided into six members, denoted a to f (Fig. 2). The sedimentary basin during deposition of the entire Qom Formation became shallower from east to west. It must be noted that minor calcite, gypsum and celestite veins and veinlets appear in the limestone units of the Qom Formation throughout the study area. The Qom Formation is overlain by red sandstone, conglomerate, shale and evaporites of the Upper Red Formation (URF).

3 Material and Method

Geology of the study area including the Qom and underlying Karaj Formations were studied in detail to decipher source of strontium. The collected samples from three profiles and outcrops were used for analytical and petrographical experiments. The XRD analysis was done using Cu Kα at University of Tehran, Iran. The major and trace elements were analyzed by XRF methods in Geological Survey of Iran (GSI) and ICP in ACME Laboratories, Vancouver, Canada. The ratio of $^{87}Sr/^{86}Sr$ was determined for three celestite samples at Ruhr-University Bochum, Germany. Detailed petrographical study was performed at University of Tehran to determine textural and structural characteristics of the host rocks and celestite and their relationships.

4 Petrography

Figure 2 and previous comments clarify the different appearances of celestite in the study area. In the Molkabad ore deposit, celestite is present in the a and b and rarely other members of the Qom Formation, occurring as layering, rhythmic, massive, cavity and cave filling, vein and veinlet, replacement of fossils as well as fossil filling. In the Siah-Kuh region, it occurs as nodular, massive and patchy in limestone and replacment of the fossils in the a and b and to a lesser extent other members of the Qom Formation (Fig. 3). In the Davazdah-Emam region, celestite can be seen as massive and lens forms in the a and b members of the Qom Formation. The megascopical and microscopical classification of the studied celestites are as follows: a) laminated b) layering and rhythmic c) massive d) nodular e) cave and cavity filling f) vein filling. The celestit forms observed are: 1) equal grained 2) lath and prismatic 3) porphyroblastic 4) poycilotopic 5) replaced fine celestite 6) silicifeid celestite 7) fossil replacement and fossil filling (Fig. 4).

5 XRD data and Composition of Celestite

The XRD analyses of all the samples from the Qom Formation proved presence of large amounts of calcite, gypsum, quartz, feldspar, celestite, rarely dolomite and clay minerals.

Celestite pick intensity of 211 from powder diffraction (ASTM) is 100, but in the study area it is very low, exceeding mostly about 40. An increase of BaO contents (sample S40 and S50) coincides with increasing intensity of 002 peak of the XRD. The CaO contents of celestite from the study area are attributed to the gypsum and calcite inclusions. The $^{87}Sr/^{86}Sr$ ratios of samples from the Molkabad, Siah-Kuh and Davazdah-Emam regions are 0.708078 ± 0.000004, 0.708478 ± 0.000004 and 0.708489 ± 0.000004, respectively. These ratios indicate coincidence between samples of the Siah-Kuh (S100) and Davazdah-Emam (D120) regions with marine $^{87}Sr/^{86}Sr$ in Upper Oligocene and that they fit to the marine Sr-isotope curve [7, 12], interval of about 17-23 Ma (Aquitanian-Burdigalian). The lower ratio of Sr from the Molkabad region is related possibly to the underlayering volcanic rocks (plagioclase component). Interaction of groundwater with plagioclases feldspar may produce relatively low $^{87}Sr/^{86}Sr$ values [10]. The Low $^{87}Sr/^{86}Sr$ ratio are also reported from silicate rocks, containing low strontium concentrations and radiogenic strontium [16]. Bralower et al. [6] related the decrease of $^{87}Sr/^{86}Sr$ to a volcanic episode. The North Pacific sediments are variable mixture of continental material with high and volcanic material with low $^{87}Sr/^{86}Sr$ ratios [1].

6 Formation of the Celestite

The layered and laminated celestites of the Siah-Kuh and Davazdah-Emam regions show similar strontium isotope values with the coeval sea water. This fact together 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. In the study area, the bulk rock Sr (Sr of volcanics and tuffs) values range from 219 to 490 ppm and their 1000×Sr/Ca molar ratio varies between 7.15 and 14.6 [2]. These molar ratios are much more elevated than limestone (40 wt% Ca, 610 ppm Sr, and 1000×Sr/Ca molar ratio = 0.64; [15]).

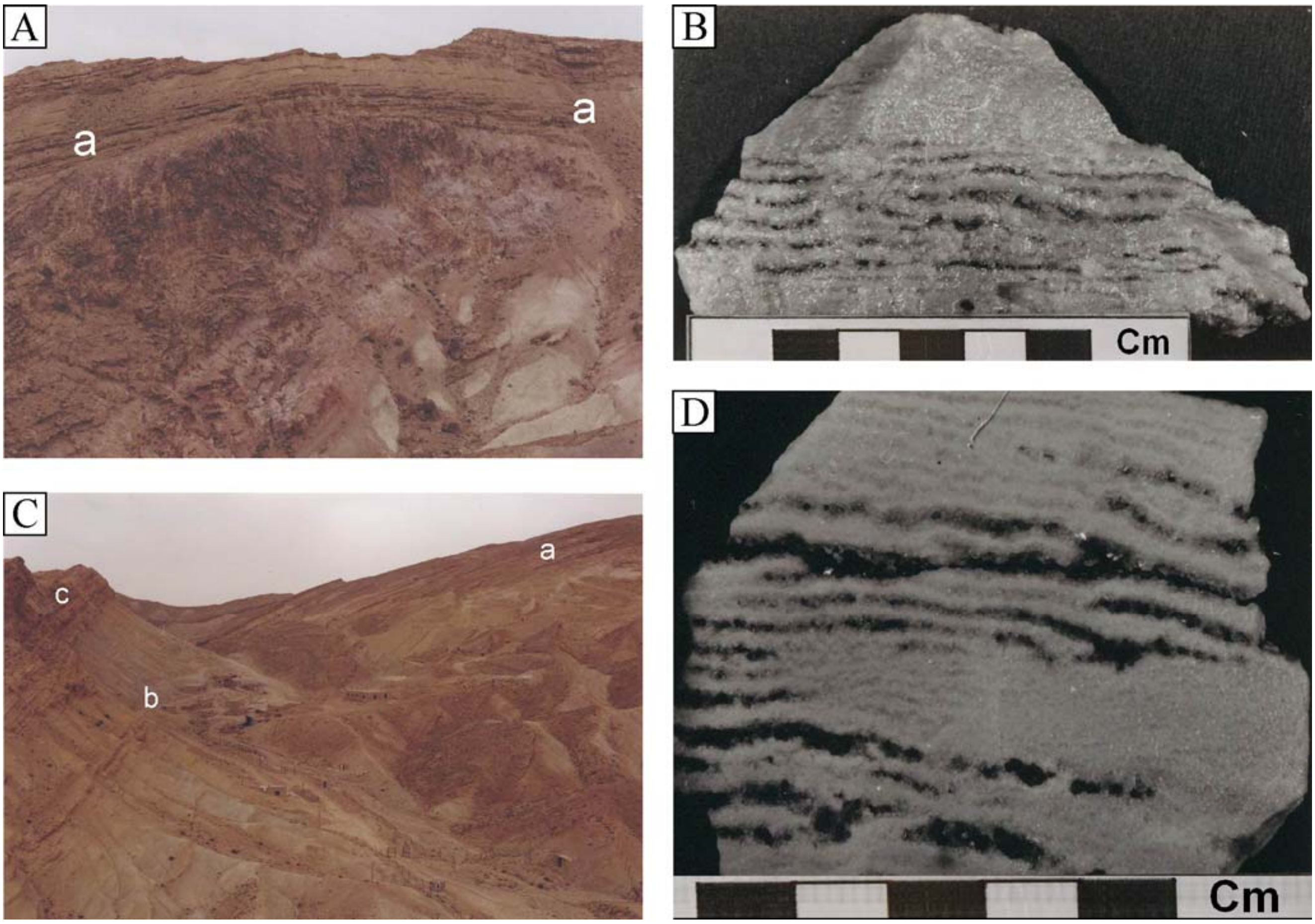

Fig.3 A) The lower limestone units of the Qom Formation (a member) with underlying Eocene volcanic rocks. In the upper part of the photo, the Molkabad anticline is obvious. Southern Molkabad deposit, view toward NE. B) Hand specimen of celestite, illustrating fine-layered and laminated (upper part) and layered and rhythmic texture (lower part). Black colors are pore space. Molkabad deposit, Sample: S201. C) General view of the Molkabad deposit. Limestone-marl (a), lower marl (b) which shows the location of infrastructure and middle medium to thick-bedded limestone (c). The mining activity is vivid in the upper and right side of the photo. D) Hand specimen illustrating layered celestite (upper part), rhythmic celestite (middle part) with pore spaces (black color). In the lower and right side of the photo fine layers have been changed to massive form. Molkabad deposit, Sample: S202.

The Pyroclasts, volcaniclasts, as well as detritial minerals in the lower units of the Qom Formation suggest that the trachytic to andesitic rocks have been source of Sr of celestite in the study area. The underlaying volcanic and tuff (KF) produced siliciclastic impurities within the lower units of the Qom Formation (a and b members). The mobility of Sr within sulphate-bearing porewaters could precipitate celestite during synsedimentry to early diagentic stages. On the contrary, vein and vein filling celestite postdate diagenesis of carbonate rock and suggest epigenetic origin.

7 Conclusion

During the Oligocene-Middle Miocene, the shallow marine environments including supratidal, subtidal and intertidal favored formation of significant synsedimentary-syndiagenetic sulphate minerals, particularly celestite in the Molkabad, Siah-Kuh and Davazdah-Emam regions, Central Iran. Detrital and dissolved matters in three depositional environments have been originated from trachytic to andesitic rocks of the underlying Eocene Karaj Formation. The prevailing environment in the study area was biostromal, justifying more lateral fluid flow, specially in the lower units of the Qom Formation.

Regression of the Qom Sea took place during the late Miocene, leading to an epigenetic mineralization in the Qom Formation. This epigenetic celestite mineralization in the region, reflects an advanced stage of brine migration in the entire Qom Formation during deposition of theUpper Red Formation (UPR) and younger sequences.

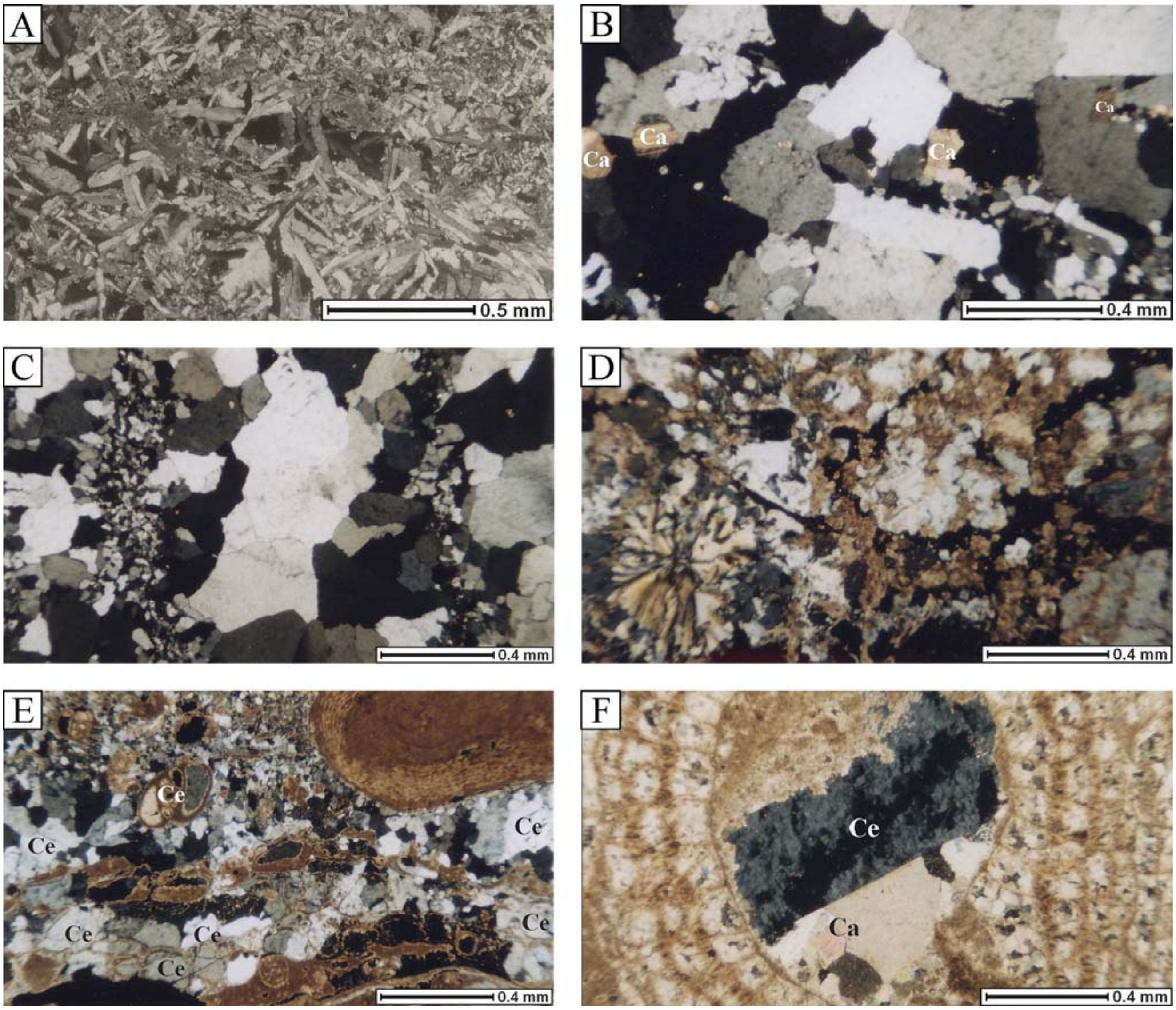

Fig.4 Different microscopic forms of celestite. A) Prismatic to bladed celestite in a matrix composed of very fine-grained celestite and minor calcite. XPL, Molkabad deposite, Sample: S40. B) Xenomorphic to subautomorphic coarse-grained celestite with minor calcite inclusions, XPL, Molkabad deposit, Sample: S54. C) Poikilotopic celestite in the centre, surrounded by celestite and rarely calcite. XPL, Molkabad deposit, Sample: S54. D) Strong silisification of celestite. XPL, Siah-Kuh region, Sample: S18. E) Replacement of foraminifer (upper part) and algae (lower part) by celestite. In the right side and upper corner of the photo, unreplaced brown algae is obvious. XPL. Siah-Kuh region, Sample: S104. F) Replacement of the core of algae by sparry calcite (Ca) and celestite (Ce). Micritic limestone is vivid right and left of the core. XPL, Siah-kuh region, Sample: S27.

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