Ore Mineralization at Qamsar Cobalt Deposit: Skarn and Metasomatism Evidences

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Abstract
Qamsar cobalt deposit is located 7 km northwest of Qamsar, in Urmieh-Dokhtar magmatic arc and in contact with a microdioritic subvolcanic body and limestone rocks of Qom Formation. Intrusive bodies in the area have middle to felsic composition and include diorite, tonalite, granodiorite and granite. Analytical data and studies on bodies in the area indicate that they are in calc-alkaline and per-alumina series. Ore mineralization in the deposit occurs as magnetite veins. Cobaltite as disseminated, diffusion, massive and veinlet textures accompanies magnetite. Cobaltite as euhedral and also with clastic texture is visible within magnetite and is sometimes hurtled by magnetite crystals. This shows that cobaltite crystallization occurred before magnetite crystallization in a sulfidic phase. Magnetite was crystallized in a subsequent oxidic phase.

Keywords: *Skarn, hydrothermal, alteration, cobaltite, erythrite, Urmieh-Dokhtar, Qamsar.*

Geology
The oldest outcropped units found in the area surrounding Qamsar cobalt deposit are Upper Eocene volcanics which are quite extended in the region. The Eocene eruptions have been of calc-alkaline type and submarine. These eruptions have been strongly sodic around the city of Kashan and appear as submarine lava and sometimes as continental dacite and andesite (Ghorbani 2002). In this area, deposits of Qom Formation begin with large thickness of Middle Oligocene gray coral limestones that gradually turn into Upper Oligocene micritic limestones (Radfar et al., 1993). In the northeast of Qamsar, deposits of Upper Oligocene are outcropped as gray to yellow limestone, green marl and gray sulfidiferous shale. An alternation of Lower Miocene pyroclastics and andesitic breccias, with calcareous sublayers, has been overlying these units (Fig. 1).

Intrusive bodies
Most intrusive bodies in the area have a monzogranite to granodiorite composition. The masses intruded the older rocks and caused contact metamorphism. Meinert et al. (2005) suggest that there is a parallel relationship between the sequence of emplacement, crystallization, alteration, and cooling of a pluton and the corresponding metamorphism, metasomatism, and retrograde alteration in the surrounding rocks. The youngest rocks affected by contact metamorphism of these masses are limestons of Qom Formation (Radfar et al., 1993). Therefore, time of magma intrusion should be younger than Lower or Middle Miocene.
Another igneous unit is the hypabyssal microdiorite to quartz-diorite body which intruded the volcanic rocks, Eocene pyroclastics, and Qom Formation limestones. Cobalt mineralization

has occurred in relation to this body. Hand specimens and outcrops have a dark green color, and under microscope show a microlitic porphyry texture. Sometimes plagioclase and pyroxene have been altered to uralite (Hajialilou 1989). Magnetite as disseminated texture is accompanied by microlitic context, while this case has not been seen in the vicinity of plagioclase or hornblende porphyrs (Fig. 2). Spatial relationship between microdioritic body, recrystallized limestone, and mineralization trend along the fault, are illustrated in Fig. 3.

Dacitic to rhyodacitic subvolcanic bodies, as sill and dyke intruded the volcanic rocks, microdioritic body, and Qom Formation limestone. The weakly altered rocks have yellowish white color and quartz, feldspar, and amphibole porphyrs. Many dykes with composition of diabase, rhyodacite, dacite to andesitic dacite have cut various units.

Tectonics

Most of major faults in the region, like Fin fault and Kashan fault, have NW-SE direction. The NW-SE direction of intrusive bodies (conforming to Urmieh-Dokhtar magmatic arc), more emphasizes role of the existing faults in the area in outcropping the bodies and related mineralization.

Mineralography and texture

The major content of ore mineralization in the deposit occurs as magnetite veins. Cobaltite, chalcopyrite, and pyrite as disseminated, diffusion, clastic, massive and veinlet textures accompany magnetite, or are seen within recrystallized limestone. The mineralization is mainly observed along a left lateral fault with N15E/60SE direction and about 200 m length but non-continuous and with several cm to 3 meters thickness. The fault moved some parts of the subvolcanic microdioritic body and recrystallized host limestones. Therefore, it is probably younger than or simultaneous with microdioritic body emplacement.

Magnetite

Magnetite is the main ore mineral existing in the deposit, generally accompanying by andradite, grossular, and pyroxene in contact between microdioritic body and Qom Formation limestones (Fig. 4). The ore is observed as disseminated, massive, vein-veinlet, replacement, and brecciated textures. The brecciated texture is subdivided into two forms: sometimes magnetite fills fractures of tectonic breccias of host rock, and sometimes hydrothermal high pressure fluid makes hydrothermal breccias. And a cement of magnetite surrounded fragments of host rock (Figs. 5 and 6). Also zonation can be seen in the magnetite that is common in contact metamorphism deposits (Ramdhor, 1982).

Cobaltite

In terms of economic value, cobaltite is the most valuable ore mineral. It is seen as silver color fine and euhedral crystals in hand specimen. Cobaltite as open space filling, disseminated, and diffusion textures is present in magnetite veins (Fig. 7). Under the microscope it is generally euhedral and has yellowish cream color and is similar to pyrite. Cobaltite as floated and also as clastic texture is visible within a cement of magnetite and is sometimes eaten by magnetite crystals (Fig. 7). This shows that cobaltite crystallization occurred before magnetite crystallization in a sulfidic phase. Due to suppression weathering erythrite, the secondary mineral of cobaltite, is formed on surface of the veins.

Chalcopyrite

Chalcopyrite is observed in yellow color and disseminated texture within magnetite veins. It is generally fractured and crashed. The fractures are filled with magnetite. Sometimes in the contact between chalcopyrite and cobaltite, chalcopyrite has eaten the margins of cobaltite and has entered the cobaltite.

Pyrite

Pyrite is usually euhedral and is accompanied by chalcopyrite. Abundance of pyrite is less than chalcopyrite.

Gangue minerals

In contact of microdioritic body and Qom Formation limestone, andradite, grossular, and pyroxene minerals have formed the skarn zone. The limestones are recrystallized. Other important minerals are hornblende, amphibole, epidote, actinolite, tremolite, chlorite, and quartz.

Alteration

Due to intrusion of bodies in the area and the influence of hydrothermal fluids resulted from final phases of the masses crystallization, different alterations have been created in the rocks. The most important types of alteration are argillic, silicification, actinolitization, propylitization, and hematitization.

Geochemistry

To determine and identify magmatic series, we used AFM, K_2O+Na_2O/SiO_2 and FeO^t/FeO^t+MgO vs SiO_2 diagrams. According to K_2O+Na_2O/SiO_2 diagram (Irvine and Baragar, 1971) intrusive rocks of the area are placed in the sub-alkaline field (Fig. 8a). According to AFM (Irvine and Baragar, 1971) and FeO^t/FeO^t+MgO (Miyashiro, 1974) diagrams, intrusive rocks of the area fall in the calc-alkaline field (Fig. 8b, c). The Ab-Or-An diagram (Irvine and Baragar, 1971) shows that the samples are placed in the sodic magmas field (Fig. 8d). In order to determine the tectonic setting of the intrusive in the area, the diagrams proposed by Pearce et al. (1984) were used. Using Nb, Ta, Yb and Rb contents, the granodioritic intrusions in the area fall into the field presenting subduction zone (Fig. 8e).

Conclusions

Based on this study, ore mineralization at the Qamsar cobalt deposit is in relationship with a microdioritic intrusive body that intruded the Qom Formation limestones and caused the recrystallization of these rocks, creating garnet and pyroxene skarn zones, and vein type ore mineralization. Faults as structural controllers have a determinant role in creating path for movement of the ore-bearing fluids and forming cobalt-bearing magnetite veins. Although the decision on how the Qamsar cobalt deposit was formed requires more data, but the following points should be considered:

In the contact between microdioritic body and limestones, magnetite has formed with skarn minerals. The acidic and porphyric subvolcanic masses are final products of magma differentiation and have carried the magmatic-hydrothermal fluids. During the emplacement of these young acidic subvolcanics such as dacite to porphyry dacite, large bulks of hydrothermal fluids have circulated in the area. The fluids have strongly altered skarn minerals and igneous rocks and formed hydrothermal mineralization.

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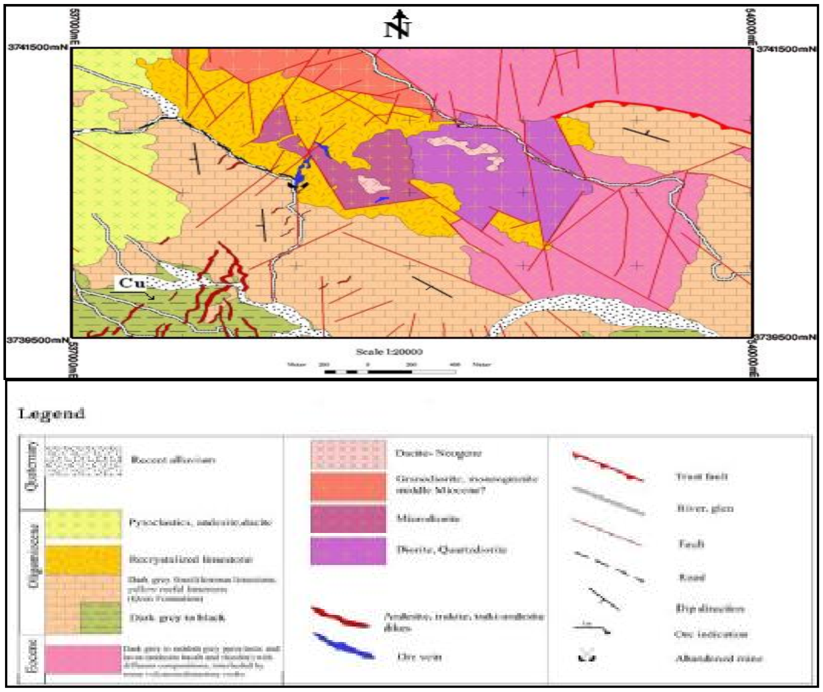

Fig. 1: geological map of the Qamsar cobaltdeposit. Scale 1:20000

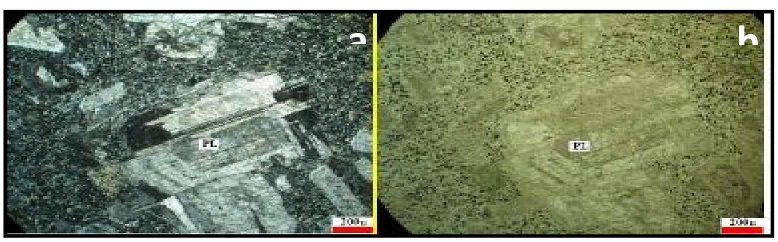

Fig. 2: Plagioclase phenocryst in microlitic context. . magnenite is accompanied bycontext. a) in XPL, and b) in PPl light.

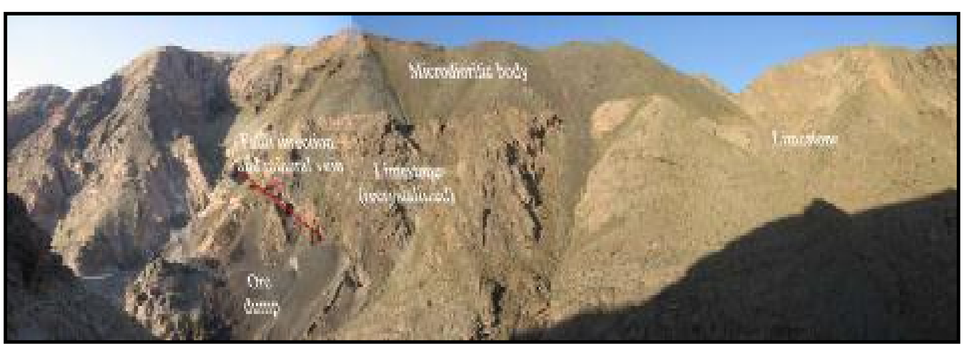

Fig. 3: View of Qamsar cobalt deposit. microdioritic hypabisal body is seen on top and as green color. The mineralization is observed along the fault with N15E/60SE trend.

Fig. 4: Formation of magnetite - Garnet vein in contact between body and limestone.

Fig. 5: Hydrothermal breccias. A cement of magnetite surrounded floated fragments of host rock.

Fig. 6: tectonic breccias. And filling the fractures by magnetite.

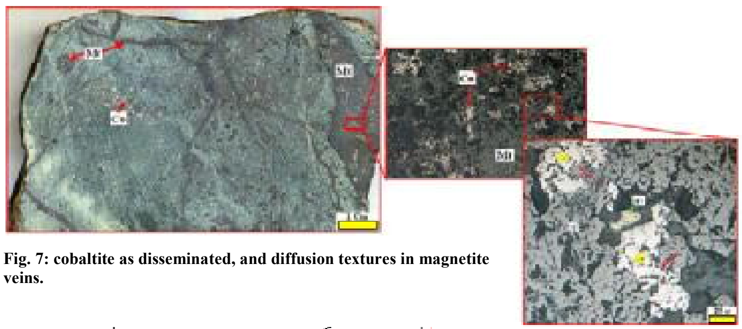

Fig. 7: cobaltite as disseminated, and diffusion textures in magnetite veins.

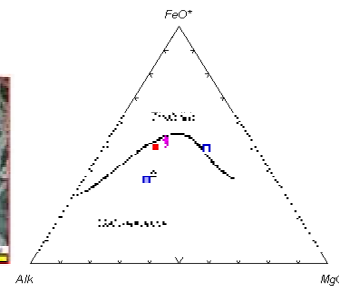

Fig. 8b: AFM diagram. The samples are placed in the calc-alkaline field (Irvine and Baragar, 1971).

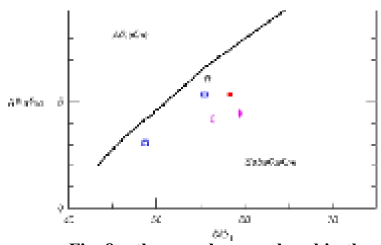

Fig. 8a: the samples are placed in the sub-alkaline field (Irvine and Baragar, 1971).

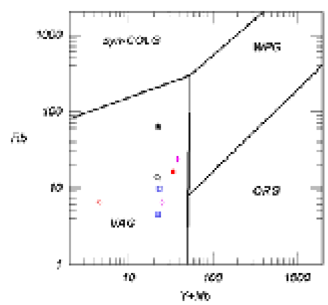

Fig. 8e: the granodioritic intrusions in the area fall into the field presenting subduction zone (Pearce et al 1984).

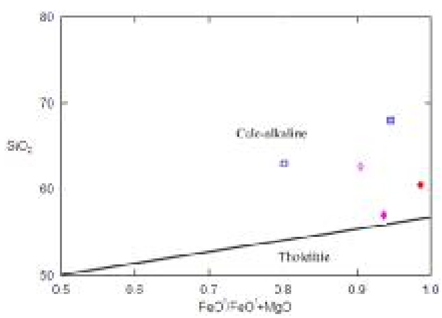

Fig. 8c: the samples are placed in the calc-alkaline field (Miyashiro, 1974).

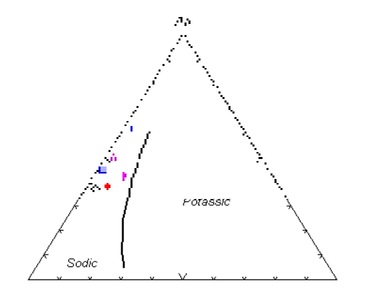

Fig. 8d: In the Ab-Or-An diagram (Irvine and Baragar, 1971) the samples are placed in the sodic magmas field.