Darhand copper occurrence: An example of Michigan-type native copper deposits in central Iran

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Abstract. The Darhand copper occurrence consists of disseminated, veinlet and pocket-shaped native copper mineralization in Late to Mid-Eocene basalt located 200 km south of Tehran, in the middle of the Orumieh-Dokhtar metallogenic belt, in central Iran. The submarine amygdaloidal spilitic basalt, which hosts the mineralization has undergone a propylitic alteration (chloritic, epidotic) as well as a low-grade metamorphism resulting in zeolites and prehnite-pumpellyite-quartz. The pockets, veinlets and amygdales of prehnite, epidote, chlorite and laumontite (zeolite), which fill the open spaces of basalt, host most of the copper mineralization. The Cu mineralization in veinlets, pockets and amygdales is composed of cuprite > native copper > malachite > tenorite > chrysocolla. The round and ellipsoidal grains of native copper and cuprite range up to 2cm in size. With the exception of rare scattered pyrite grains in the host rock, no sulfide minerals were observed in the mineralization. The Cu content of the ore reaches 3.5 % with rather high values of silver (6 ppm). Also the copper concentration in the submarine basalt is anomalously high with 250 ppm. The mineralization is bound to a definite basalt layer underlying the Oligo-Miocene limestone.

The Darhand copper mineralization shares some similarities with the Keweenawan native copper deposits in Michigan, USA. They both appear to be similar in the petrology and in the alteration of their host rocks as well as in their mineral association and ore characteristics. They differ only in the age of the host rocks.

Keywords. Michigan type copper deposits, amygdaloidal basalt, Darhand, Natanz, central Iran

1 Introduction

The Orumieh-Dokhtar metallogenic belt extends from the northwest to the southeast of Iran. Different types of copper deposits, including porphyry ones, are located in this belt. Not many of those deposits are reported to carry native copper. The Darhand copper occurrence was first recognized and investigated by the first author in 1999. The mineralization is hosted by Late to Mid Eocene amygdaloidal basalt and displays a type of metallogeny (high copper, elevated silver) and mineralogy (paucity of sulfide minerals) that is similar to the Michigan Keweenawan native copper deposits (Huber 1975; Wilson and Dyl 1992). This paper introduces the Darhand copper mineralization and compares it with the Keweenawan copper deposits. The stratabound nature of the occurrence may lead to the discovery of further deposits of this type in central Iran.

2 Geologic setting

The Darhand copper occurrence is located 200 km south of Tehran and 4.5 km east of Natanz, in the middle of the Orumieh-Dokhtar metallogenic belt, of central Iran. This belt is indeed part of Thethyan-Eurasian metallogenic belt (Jankovic 1977). The Orumieh-Dokhtar belt hosts most of the Iranian copper deposits, such as Cu-Mo porphyries, VHMS, stratiform deposits, skarn and vein type deposits that are mainly related to Tertiary volcanic activity. Although copper is dominant, other metal resources of lead, zinc, gold and manganese are found in this belt.

The important rock units of the study area are Cretaceous limestone, Late Eocene submarine amygdaloidal basalt, and ignimbritic tuff and breccia. Overlying these Tertiary formations is Oligo-Miocene limestone (Qom formation) with an unconformity (lack of Lower Red Formation). The amygdaloidal basalt trends NE-SW dipping east (N30E) lies below an ignimbritic tuff and breccia unit. The copper mineralization at Darhand is completely confined to this basalt and does not appear at all in adjacent formations.

3 Local geology

The Darhand copper mineralization is stratabound and covers an elongated area of 3 km^2. Cuttings for the construction of a highway through this area imply the continuation of the mineralization to a depth of at least 3m. Inspection of hand specimens indicates that amygdales are 0.1-2 cm in diameter. They are filled with calcite, chlorite, zeolite and prehnite. There are also veins, veinlets and pockets of the same material as long as 2m with N-S, E-W and NE-SW trends. Petrographic investigations carried out in this study show that the amygdaloidal layer is porphyritic basalt with open spaces filled by prehnite, carbonate, zeolite, chlorite, and some quartz. In some samples plagioclase and olivine have been converted to pumpellyite. The skeleton texture in the plagioclase crystals implies a fast cooling rate of the magma. In general, the rock shows the characteristics of spilitic basalts.

The most important alteration of the amygdaloidal basalt is propyllitic (chlorite, epidote), which is pervasive. Argillic and sericitic alterations are much less abundant. In addition to alteration, the rock has experienced a low-grade metamorphism to zeolites and prehnite-pumpellyite-quartz. According to XRD studies the zeolite is laumontite [$(CaAl)_2$ $Si4O_{12}$, $4H_2O$]. The presence of amygdales and pockets of prehnite, zeolite, calcite, chlorite and quartz makes the rock appear similar to Swiss cheese with filled holes.

4 Ore mineralogy and metal association

The mineral association in the Darhand occurrence includes native copper, cuprite, tenorite, malachite and chrysocolla which are disseminated in the pockets, veinlets and amygdales of prehnite, chlorite, zeolite, calcite and quartz in the form of round and ellipsoidal grains up to 2 cm. Malachite impregnation is seen in parts of the host rock where prehnite-carbonate increases in the rock. Cuprite grains are usually coated by tenorite. The aggregation of copper grains comprises 2-60 vol% of the pockets and amygdales. Also the host rock contains small grains of native copper. In the center of some small amygdales, malachite patches are visible.

Ore microscopy reveals the presence of native copper, cuprite, tenorite, malachite, and chrysocolla which have open space filling and dissemination textures. No sulfide mineral has been observed in the pockets. The only sulfide mineral is pyrite, which was rarely observed in the samples taken from host rock. The maximum copper content is 3.5% with about 6 ppm silver analyzed by ICP-MS. The other elements are not anomalous. The concentration of copper in the host rock is 250 ppm, which indicates a rather high anomaly.

5 Conclusions

According to its geologic setting, type of alteration and metamorphism, host rock petrography and ore paragenesis, the Darhand copper occurrence shows strong similarities to the native copper deposit located on the Keweenaw Peninsula, Michigan, USA. The most significant differences are the different ages of the host rocks, namely Precambrian for Michigan and Late-Mid Eocene for Darhand. The latter also lacks the presence of chalcocite.

There are some other similar deposits in Iran like the mineralization in the Tarom zone in northwest Iran, namely Qeshlaq (Bazin and Huebner 1969) and Ghebleh Boulagh (Behzadi 1994), all in Eocene volcanics. According to the characteristics of the Darhand occurrence and published data from Huber 1975, Wilson and Dyl 1992 and Behzadi 1994, the probable mineralization stages of this deposit are as follows:

- intrusion of a gas-rich basaltic magma in the sea floor;
- formation of open spaces and fractures in basalt due to the fast cooling of the magma; tectonic movements simultaneously caused a weak metamorphism in the rock;
- during metamorphism copper was liberated from the silicate minerals by the action of chloride containing hydrothermal fluids, heated by the hot core of the magma, and precipitated in the rock;
- egression of the volcanic body out of the water and oxidation of the mineralization.

If we apply the above-mentioned scenario to the Darhand occurrence, we can consider this mineralization as syn-genetic volcanogenic. Since the amygdaloidal basalt is vast and spread out not only in the area but over all of central Iran and the Orumieh-Dokhtar zone and due to the stratabound nature of the mineralization, it is highly likely that larger and more economical mineralizations of this type may be found. It is of interest to note that some ancient settlements and metallurgical workshops have been discovered in the vicinity of Natanz where native copper was formed by hammering (Hasanalian, personal communication). Although no trace of old mining was found in the area of Darhand yet, it is possible that further fieldwork may encounter them in the future.

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