



## Mineralogy, chemistry of magnetite and genesis of Korkora-1 iron deposit, east of Takab, NW Iran

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### Introduction

There is an iron mining complex called Shahrak 60 km east of Takab town, NW Iran. The exploration in the Shahrak deposit (general name for all iron deposits of the area) started in 1992 by Foolad Saba Noor Co. and continued in several periods until 2008. The Shahrak deposit comprising 10 ore deposits including Korkora-1, Korkora-2, Shahrak-1, Shahrak-2, Shahrak-3, Cheshmeh, Golezar, Sarab-1, Sarab-2, and Sarab-3 deposits (Sheikhi, 1995) with total 60 million tons of proved ore reserves. The Fe grade ranges from 45 to 65% (average 50%). The ore reserves of these deposits vary and the largest one is Korkora-1 with 15 million tons of 55% Fe and 0.64% S. The Korkora-1 ore deposit is located in western Azarbaijan and Urumieh-Dokhtar volcanic zone, at the latitude of 36°21.8', and longitude of 47°32'.

### Materials and methods

Six thin-polished sections were made on magnetite, garnet, and amphibole for EPMA (Electron Probe Micro Analysis). EPMA was performed using a JEOL JXA-733 electron microprobe at the University of New Brunswick, Canada, with wavelength-dispersive spectrometers.

### Results and discussion

Outcropped units of the area are calc-alkaline volcanics of rhyolite, andesite and dacite and carbonate rocks of Qom Formation in which intrusion of diorite to granodiorite and quartzdiorite caused contact metamorphism, alteration plus skarnization and formation of actinolite, talc, chlorite, phlogopite, quartz, calcite, epidote and marblization in the vicinity of the ore deposit.

Iron mineralization formed at the contacts of andesite and dacite with carbonates in Oligo-Miocene. The study area consists of skarn, metamorphic rocks, and iron ore zones. The shape of the deposit is lentoid to horizontal with some alteration halos. The ore occurred as replacement, massive, disseminated, open-space filling and breccia. The ore minerals of the deposit include low Ti-magnetite (0.04 to 0.2 wt % Ti), minor apatite, and sulfide minerals such as pyrite and chalcopyrite. Magnetite is the most important mineral and has 0.2 to 4 mm grain size and partly transformed into hematite, limonite and goethite. In some places, magnetite can be seen as euhedral grains in hand specimen. Supergene minerals such as chalcocite, malachite, azurite, and covellite are also present. Hematite formed as primary and secondary types in which primary type occurred in deeper parts of the ore body along with magnetite and has lamellar texture with up to 0.2 mm grain size. Meanwhile, secondary type of hematite formed from martitization along magnetite grain boundaries and fractures. In the surface area of the deposit, ore minerals strongly altered to mixtures of oxide and hydroxide minerals (ochre) like goethite, hematite, limonite and lepidochroite which changed the color of the ore body to yellow, deep orange, red and brown. Pyrite is the most important sulfide mineral and formed in three stages. In the first stage, pyrite occurred with magnetite and has 0.1 to 0.3 mm subhedral to anhedral grains which altered to oxide and hydroxide minerals. At the second stage, pyrite has 0.2 to 1 mm euhedral grains, occurred between the magnetite and gangue minerals and converting to chalcopyrite. At the third stage, pyrite with magnetite, calcite and quartz filled fractures as open-space fillings and are pretty unaltered.

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The skarn zone includes garnet, pyroxene, secondary calcite, epidote, and chlorite and the metamorphic zone includes marble. Sericitization, silicification, calcitization, chloritization-epidotization, argillitization, propylitization and actinolitization are the important alterations in the area from which chloritization-epidotization and calcitization in the ore and propylitic alteration in the volcanics are dominant.

The EPMA analytical results on 30 points on magnetite and hematite suggest that the amount of Ti and V (0.004 wt % and 0.002 wt % in average, respectively) are low in contrary to Mn and Al (0.33 wt % and 5.32 wt % in average, respectively). Therefore, it fits in the skarn ore deposit domain in Ni/(Cr + Mn) versus Ti + V and Ca + Al + Mn versus Ti + V discrimination diagrams of iron ore deposits (Beaudoin et al., 2007). High Mn in the rock samples of Korkora-1 can be resulted from substitution of  $\text{Fe}^{+2}$  by  $\text{Mn}^{+2}$  in magnetite structure that can be a sign of hydrothermal skarn. Titanium, Mn, V and Zn show a positive correlation and Al, Cu, Mg, P, Si, Ca, Ni and Cr show a negative correlation with Fe. According to the chemistry of magnetite and plotting them on  $\text{V}_2\text{O}_5$  versus  $\text{TiO}_2$  and  $\text{V}_2\text{O}_5$  versus  $\text{Cr}_2\text{O}_3$  diagrams, it can be recognized that the samples of Korkora-1 deposit resemble exoskarn magnetite of Goto deposit. The analysis of goethite of Korkora-1 show the amount of 2.5 to 4 wt %  $\text{SiO}_2$ , 76 wt % Fe, and Ni (110 ppm) without Ti and Cr in its structure. Mineralogical and geochemical evidence from ore, occurrence of iron in contact with carbonates and skarn mineralogy such as garnet, pyroxene, secondary calcite, epidote and chlorite suggest iron skarn genesis for Korkora-1 deposit. Fluids generated from intrusive bodies like diorite and quartz-diorite with variations in physicochemical conditions, produced skarn in contact with carbonates and volcanic rocks. The

heat from intrusive bodies caused recrystallization of carbonates and formed marbles in the footwall of the deposit. Meteoric water has also less important contribution in the ore-forming fluids. Fluid inclusion studies show existing of two types of fluids, a low salinity (10 wt % NaCl equiv.) and a medium salinity (25 to 30 wt % NaCl equiv.) fluid. Mixing magmatic and meteoric waters makes decreasing in the temperatures and deposition of ore fluids. The Korkora-1 deposit formed in four stages: 1) intruding the intrusive bodies, 2) entering Fe and  $\text{SiO}_2$  into Qom carbonates and forming calc-silicates, 3) mixing magmatic and meteoric fluids, hydrolysis of calc-silicates, consuming  $\text{H}^+$ , instability of Fe complexes and deposition of iron oxides, 4) retrograde alterations of hydrous and non-hydrous calc-silicates with low temperature and high  $\text{fO}_2$  fluids and forming chlorite, calcite, clay minerals and hematite.

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