



## Geological and geophysical (IP-Resistivity) studies of the Vajaro copper deposit, southwest of Shahrood

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### Extended Abstract

#### Summary

The Vajaro copper mineralization is located in 20 km west of Toroud village and southwest of Shahrood, situated within the Toroud–Chah Shirin metallogenic zone. The surficial oxide–sulfide copper mineralization occurs within Eocene volcanic host rocks. To determine the depth and extension of the mineralization, geophysical surveys using the geoelectrical induced polarization (IP) and resistivity methods employing the pole–dipole and dipole–dipole arrays were conducted along six survey lines in the area. The

results indicated the continuation of mineralization down to a depth of 50 meters, while drilling revealed mineralization extending to a depth of 185 meters.

Microscopic studies show that the host rocks of the mineralization consist of andesite and andesite–basalt, affected by extensive propylitic alteration and local sericitic–carbonated alteration, along with iron hydroxide alteration (restricted to the mineralized zones). The mineralization occurs as veins, veinlets, and disseminated and cavity filling forms. Thin calcite veinlets associated with ore minerals fill fractures and show a close relationship with the mineralization.

The mineralization formed in two stages: hypogene and supergene. In the hypogene stage, chalcocite, bornite, chalcopyrite, and magnetite formed together with epidote, chlorite, sericite, and calcite veinlets. In the supergene stage, secondary sulfide and oxide minerals including secondary chalcocite, covellite, malachite, azurite, and goethite developed within fractures and voids.

Fluid inclusion studies on calcite indicate homogenization temperatures between 121 and 200 °C and freezing temperatures between –1.1 and –5.8 °C. The calculated salinities range between 1.8 and 9.8 wt.% NaCl equivalent. Based on geological characteristics, mineralogy, ore textures and structures, and fluid inclusion data, the Vajaro copper mineralization is comparable to mantle-type (manto-type) deposits.

### Introduction

The study area is located in 20 km west of Toroud, southwest of Shahrood. The area is also located in the Toroud-Chah Shirin zone. The copper mineralization in the area has occurred in the forms of veins and veinlets in the Eocene volcanic host rocks. Detailed investigations in Vajaro mining area include preparing a geological map (in 1:5000 scale), geophysical studies using IP and resistivity methods, 6 exploration boreholes with depths of 47 to 185 meters (760 meters in total) and 70 chemical analyses by ICP-OES method. As a result, the lowest and highest amounts of copper in the mineralization area are determined as 0.01% and 4.2%, respectively. The purpose of this research is to investigate the characteristics of copper mineralization based on geology, mineralogy, alteration and fluid inclusion studies, and also, determination of the mineralization depth as a result of the geophysical work.

### Methodology and Approaches

For host rock, mineralogical and microthermometric studies, more than 35 thin and polish sections were prepared and examined. 7 samples were selected for microthermometric studies of fluid inclusion, and 4 samples were chosen for this analysis. The investigation of microthermometric studies using a heating and cooling plate, made by Linkam Company,

was carried out in the microthermobarometry laboratory of Shahrood University of Technology. The correctness of measurements for heating and cooling temperatures was  $\pm 2^{\circ}\text{C}$  and  $\pm 0.2^{\circ}\text{C}$ , respectively. Geophysical surveys using IP and resistivity methods were carried out to assess the lateral and vertical extents of mineralization. Inverse modeling of the acquired IP and resistivity data was made using RES2DINV software.

### **Results and Conclusions**

Microscopic data indicates that the host rocks of the mineralization are andesite and andesite-basalt of Eocene age, which undergoes extensive propylitic alteration and local sericitic-carbonated and iron hydroxide alterations. Mineralization occurs as scattered, veins and veinlets, and open space fillings. Calcite veins with small thicknesses along with minerals fill the fractures and open spaces and show a close relationship with mineralization. Mineralization is formed in two stages, hypogene and supergene. In the hypogene stage, chalcocite, bornite, chalcopyrite and magnetite, and during the supergene stage, oxide and sulfide minerals, including secondary chalcocite, covellite, malachite, azurite, and goethite are formed in the fractures and cavities of rocks. Microthermometric data show the homogenization temperature between 121 and 200  $^{\circ}\text{C}$ . The melting temperature of ice was measured on the samples that was obtained between -1.1 and -5.8  $^{\circ}\text{C}$ , and the obtained salinity was between 1.8 up to 8.9% wt.% NaCl.

For the IP and resistivity surveys, the dipole-dipole electrode configuration with an electrode separation of 10 m was employed along six survey lines, and as result, 700 IP and resistivity data measurements were totally made. As a result of modeling the data, the locations of the probable subsurface mineralization zones were determined by high chargeability and moderate to high values of resistivity in the modeling results. The estimated depth for mineralization was about 70 m, that was confirmed by the drilling data.

According to the fluid inclusion studies in the Vajaro region, the mineralization is the result of mixing hot and salty hydrothermal fluid with cold meteoric waters. The results indicate a fluid with high temperature and low salinity has been transformed into a fluid with low temperature and high salinity during the boiling process, and finally it has led to the sedimentation of mineralization in the region. Changes in the homogenization temperature in the range of 120 to 350  $^{\circ}\text{C}$  and salinities between 2 and 40% NaCl in fluid intermediates are the characteristics of this type of deposits. According to the type of host rock and the shape of the deposit, the mineralogical composition of the host rock of this deposit is very similar to manto type deposits in Chile. Manto type deposits are associated with chlorite, carbonate, sericite, albite and zeolitic alteration, and mineralization is often formed as scattered, veined and filling the holes of the host rock with pyrite, chalcopyrite, bornite, chalcocite, covellite, natural copper, hematite and some silver are included.

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