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Geology, geochemistry and fluid inclusion of Qarachilar Cu-Mo-Au quartz veins, northeast of Kharvana, East Azerbaijan

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Introduction

The Qarachilar Cu-Mo-Au occurrence is located in the Arasbaran ore zone (AZ), NW Iran, some 70 km north of Tabriz. The AZ is characterized by occurrence of different types of mineralization and hosts many Cu-Mo porphyry (PCD), Cu skarn, and epithermal Au deposits (Jamali et al., 2010; Jamali and Mehrabi, 2015). The main rock unit exposed in the area is Qaradagh batholith (QDB). A variety of porphyry and vein-type Cu–Mo–Au mineralization are associated with QDB. The most pronounced occurrences are in Qarachilar, Qara-Dareh, Zarli-Dareh, Aniq and Pirbolagh. This type of mineralization can be followed in other parts of northwest Iran, such as Masjed-Daghi porphyry Cu–Au deposit and Mivehrood vein-type Au mineralization in the southwest of the QDB, the Sungun PCD and the related skarn in its southeast, and Astamal Fe skarn deposit in the south of the QDB. To date, no detailed study has been undertaken to understand the characteristics of the Qarachilar occurrence and its mineralization type is controversial. The recent work by Simmonds and Moazzen (2015) also did not present relevant information for an understanding of the Qarachilar occurrence. The Re–Os age data obtained in their work were compared with similar events along the Urumieh-Dokhtar magmatic arc (UDMA) and southern Lesser Caucasus in order to elucidate the temporal pattern of mineralization across the whole QDB and the UDMA. The present paper provides an overview of the geological framework, the mineralization characteristics, and the results of geochemistry and fluid inclusion studies of the Qarachilar Cu-Mo-Au occurrence with an application to the ore genesis.

Materials and methods

More than 37 polished thin sections from Qarachilar host rocks and mineralized and altered zones were studied by conventional petrographic and mineralogic methods at the University of Zanjan. In addition, 9 samples from non-altered and altered host rocks and mineralized veins were analyzed by ICP-MS for trace elements and REE at the Zarazma Co., Tehran, Iran. Microthermometric data were performed on primary fluid inclusions using the Linkam THMS600 heating–freezing stage at the Iranian Mineral Processing Research Center (IMPRC), Tehran, Iran.

Results

The rock units exposed in the Qarachilar area are different sets of magmatic phases of QDB including granodiorite-quartz monzodiorite, porphyritic granite, quartz monzonite and acidic-intermediate dikes. Granodiorite-quartz monzodiorite is the dominant phase which hosts the Qarachilar quartz-sulfide veins. Mineralization at Qarachilar occurs as three quartz-sulfide veins. The veins reach up to 700-m in length and average 1-m in width, reaching a maximum of 2-m. They are generally steeply-dipping to the NE at 80°. The reported grades of Mo, Cu and Au range from 20 ppm to 3.6 wt%, 0.7 wt% to 5 wt%, and 0.23 to 37.2 g/t, respectively.

Four stages of mineralization can be distinguished at Qarachilar. Stage-1 is represented by quartz veins (ranging from centimeters up to ≤1-m width) that

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contain variable amounts of chalcopyrite and pyrite. Stage-2 is marked by <1-mm to 3-cm wide veins of quartz with molybdenite ±pyrite that usually cut Stage-1 mineralization, and, in turn, are cut by Stage-3 veins. The Stage-2 veins usually show a banded appearance. Disseminated texture is also observed in this stage. Molybdenite (0–5%) occurs as large flakes or aggregates of anhedral, tiny shredded crystals, rosettes, or plates, with variable sizes of 200-µm to 3-mm within the quartz veins-veinlets. Stage-3 is represented by 1 to 10-cm wide Au-bearing Fe-hydroxide quartz veinlets. Stage-4 is represented by individual or sets of late quartz-carbonate veinlets that usually cut previous stages. No sulfide minerals are recognized with Stage-4. The hydrothermal alteration assemblages at Qarachilar range from proximal quartz, sericite and carbonate to distal sericite, epidote and calcite (propylitic alteration). Potassic alteration occurs locally in 5-cm-wide, quartz-albite-secondary biotite veins within granodiorite-quartz monzodiorite pluton. The ore minerals composed of chalcopyrite, pyrite, molybdenite, galena and quartz, calcite and ankerite are present as gangue minerals. Chalcocite, covellite, malachite, azurite, ferimolybdite and goethite are formed during the supergene stage. The ore minerals show vein-veinlet, brecciated, disseminated, vug infill, replacement and relict textures.

The comparison of Chondrite normalized (Nakamura, 1974) REE patterns of non-altered and altered host granodiorite-quartz monzodiorite pluton and the mineralized samples at Qarachilar indicate that altered pluton and especially mineralized samples show lower concentrations of REE relative to non-altered plutonic host rocks. This signature indicates the mobility of REE by Cl and F-rich magmatic-hydrothermal fluids during alteration and mineralization processes. Homogenization temperatures (T_h) of two-phase inclusions within quartz varies from 182-532°C, and salinity varies from 9.2 to 23.5 wt% NaCl equiv. Three-phase halite-bearing type-1 (T_h>T_{m-h}) and type-2 (T_{m-h}>T_h) inclusions are homogenized in the range of 197-530°C and 203-375°C, respectively. They have a calculated bulk salinity of 29.5 to 55.1 and 32.4 to 45.6 wt% NaCl equiv., respectively. The variations in salinity and T_h could be explained by a combination of mixing and boiling hydrothermal fluids. These processes led to the deposition of Cu, Mo and Au in the veins. Geology, ore mineralogy, textures, geochemistry and microthermometric data of Qarachilar occurrence are comparable with vein-type Cu-Mo-Au mineralization related to Cu-Mo porphyry and intrusion related gold deposits.

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