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Cu-Mo-Au mineralization in Qarachilar area, Qaradagh batholith (NW Iran): Fluid inclusion and stable isotope studies and Re-Os dating

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The Qaradagh batholith is located in NW Iran, neighboring the Meghri–Ordubad granitoid in southern Armenia. This magmatic complex is emplaced in the northwestern part of the Urumieh-Dokhtar magmatic arc, which formed through north-eastward subduction of Neo-Tethyan oceanic crust beneath the central Iranian domain in the late-Mesozoic and early-Cenozoic and hosts most of the porphyry copper deposits and prospects in Iran, such as Sarcheshmeh and Sungun.

The Qaradagh batholith is comprised of Eocene-Oligocene intrusive rocks occurring as multi-episode stocks, where the dominant rock type is granodiorite. Hydrothermal alterations have also occurred in these rocks including potassic, phyllic-sericitic, argillic and propylitic alterations and silicification. These alterations are accompanied by vein-type and disseminated Cu, Mo and Au mineralization.

The Qarachilar area is located in the central part of the Qaradagh batholith, which hosts mono-mineralic and quartz-sulfide veins and veinlets (several mm to <1 m thick and 50–700 m long) and silicic zones containing Cu-Mo-Au-Ag ore minerals (mainly pyrite, chalcopyrite and molybdenite).

Microthermometric studies on the fluid inclusions of quartz-sulfide veins-veinlets show that the salinity ranges between 15-70 wt% NaCl, with the highest peak between 35-40 wt% NaCl. The homogenization temperature for primary 2-phase and multi-phase inclusions ranges between 220 and 540 ºC. Two-phase inclusions homogenizing by vapor disappearance have TH values between 280 and 440 ºC (mainly between 300 and 360 ºC). A few of them homogenize into vapor state with TH values of 440-540 ºC. Multi-phase inclusions show 3 types of homogenization. Most of them homogenize by simultaneous disappearance of vapor bubble and dissolution of halite daughter crystal, for which the TH value is 240-420 ºC (mostly between 260 and 340 ºC). Those homogenizing by halite dissolution show TH values about 220-360 ºC and a few homogenizing by vapor disappearance display TH values between 300 and 360 ºC.

The data-point trend in TH(L-V)-Salinity plot may signify boiling of low-salinity fluids and distillation by superficial fluids. Therefore, it can be concluded that the ore-forming magmatic-hydrothermal aqueous fluids have most likely experienced boiling and also mixed with low temperature and low salinity superficial fluids. Occurrence of boiling is also supported by the coexistence of liquid-rich and vapor-rich 2-phase inclusions as well as multi-phase halite-bearing inclusions which homogenize in a similar range of TH. The calculated minimum pressure at the time of entrapment is estimated about 50 to 120 bar, which is equal to the hydrostatic depth of 500-1100 m.

Stable isotope studies of O, H and S on the quartz and sulfide samples taken from quartz-sulfide veins-veinlets reveal a magmatic origin for the ore-bearing fluid and its sulfur content. The δ18O values for quartz and fluid are about 11.13-12.47 ‰ and 5.78-6.89 ‰ (SMOW), respectively, the δD values are about -93 and -50 ‰ and the δ34S values of sulfide minerals are about -1.37-0.49‰ (VCDT).

Re–Os model ages calculated for molybdenite samples range between 25.19±0.19 and 31.22±0.28 Ma, referring to middle-late Oligocene, contemporaneous with the third metallogenic epoch in the Lesser Caucasus (especially Kadjaran and Paragachai PCDs in South Armenian Block).