Hydrothermal copper mineralization in the Gyeongnam mineralized district, Korea

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Copper mineralization in the Gyeongnam district, which is located within the Cretaceous Gyeongsang basin, mainly occurs in hydrothermal polymetallic quartz and/or carbonate veins. These veins are all related to the Cretaceous Chindong granite. Generally, successive polymetallic ore mineralization in the district shows a simplified mineralogy progressing through: Fe-W-Mo, Cu, (Cu-)Zn-Pb with sulfosalts, and/or ferric mineralization. The early Gyeongnam hydrothermal system is characterized by high-salinity brine and/or CO_2-rich fluids. The vein mineralization initiated at high temperature (≈550℃) from fluids with high salinity (up to about 60 equiv. wt. % NaCl or NaCl+KCl) derived mainly from the granite source and/or CO_2-rich fluid by fluid unmixing coupled with boiling. The oxygen isotope data ($\delta^{18}O_{water}$ = 8.9 to 4.7‰ for the early mineralization) suggest that early hydrothermal fluids in the Gyeongnam hydrothermal system likely represent magmatic and/or meteoric water whose isotopic composition was controlled by exchange with a large volume of igneous (and metamorphic or sedimentary) rocks at near-magmatic temperatures. In the waning portion of the vein mineralization, the high-temperature, high-salinity fluids gave way to progressively cooler, more dilute fluids (down to ≈150℃ and ≈1 equiv. wt. % NaCl). There is a systematic decrease in calculated $\delta^{18}O_{water}$ values with decreasing temperature in the Gyeongnam hydrothermal system (from 5.0 to -9.9 ‰). These trends are interpreted to indicate progressive mixing of high-salinity, magmatic hydrothermal fluids with cooler and less saline meteoric groundwater. Equilibrium thermodynamic data combined with mineral paragenesis, and fiuid inclusion and isotope data indicate that copper minerals precipitated mainly within a temperature range of 350° to 250°C. During early copper mineralization at 350°C, significant amounts of copper (10^3 to 10^2 ppm) could be dissolved in weakly acid NaCl solutions. For late mineralization at 250°C, about 10^0 to 10^{-1} ppm copper could be dissolved. Equilibrium thermodynamic interpretation indicates that the copper in the Gyeongnam hydrothermal system could have been transported mainly as a chloride complex and the copper precipitation occurred as a result of cooling accompanied by changes in the geochemical environments (fs_2, fo_2, pH, etc.) resulting in decrease of solubility of copper chloride complexes.

Mineralogy and Geochemistry of the Yangyang IOA deposit, South Korea

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The Yangyang deposit is characterized by the occurrence of a distinctive type of iron oxide apatite (IOA) deposit such as a Kiruna-type deposit. Occurrence in iron mineralization is concordant to discordant layered, lenticular or massive, magnetite-biotite, magnetite-actinolite, and magnetite-apatite-biotite-pyrite ores, which are hosted by a stratum of metamorphosed subvolcanic-sedimentary unit enclosed within Paleoproterozoic gneiss complexes. The phosphorous content in the apatite-rich magnetite ore varies up to ca. 7.38 wt. % P_2O_5. However, the iron ores have about 40 to 90 wt. % Fe_2O_3 with significantly low titanium content (< 0.57 wt. % TiO_2) and V content (< 404 ppm V).

The dominant mineral constituents consist of magnetite, actinolite, biotite and fluorapatite with subordinate amounts of scapolite, albite, diopsidic pyroxene, pyrite and carbonates. Titanite, allanite, monazite and fluorite are distinctively found in a mineral accessory assemblage. Apatite grains contain Th-poor monazite, magnetite, and sulfide inclusions commonly, and exhibit patchy zoning in concentrations of REE and some trace elements such as Si, S, V, Zr, Y, Pb, Th, and U, suggesting that apatite undergoes hydrothermal overprint as observed in other IOA deposits of Kiruna area, Sweden, and Bafq district, Iran. Sulfides clearly overprint the oxide stage assemblages and consist of minor pyrite ± chaclcopyrite. Low Ti, V, Cr, Co and Ni contents in magnetite indicate that these magnetites are not magmatic origin (i.e., nelsonite). The halite-bearing fluid inclusion in apatite shows an evolving hydrothermal system from saline fluids. REE-rich fluorapatite and titanite in the Yangyang ore mean ages of 198±13 Ma and 226.1±5.3 Ma, respectively (U-Pb LA-ICPMS ages). The Yangyang iron deposit has been precipitated from iron oxide-volatile-rich magmatic-hydrothermal fluids, which is derived from slightly alkaline magma.