Geochemistry of a Te-bearing Au-Ag mineralization of the Yuryang mine: Fluid inclusion and stable isotope study

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Mesothermal, tellurium-bearing gold-silver vein mineralization of the Yuryang mine was formed in mineralogically complex quartz-sulfide veins that filled the fault fractures in Precambrian gneiss within Gyeonggi Massif. Ore grades average 179 g/ton gold with a gold/silver ratio of 1.5 : 1. Ore mineralization was deposited in single stage. Major ore mineralization can be divided into two mineralization phases with increasing paragenetic time: Fe-sulfide and base-metal mineralization phase → telluride mineralization phase. Fe-sulfide and base-metal mineralization phase occurs typically along vein margins and consists mineralogically of quartz, pyrite, sphalerite and galena with minor amounts of chlorite, rutile, chalcopyrite. Telluride mineralization phase is characterized by deposition of galena, pyrrhotite, electrum, and tellurides such as petzite, altaite, hessite, Bi-Te mineral. The occurrence of tellurides is characteristic feature of the late periods of vein mineralization, which suggests a distinct change in geochemical conditions (e.g., f_{Te2}, f_{S2}) of vein stage fluids with paragenetic time.

The vein quartz from the Yuryang gold deposit contains three types according to room temperature (25℃) phase behavior: type Ia, type Ib, and type IV inclusions. Two subtypes of type I fluid inclusions have been distinguished on the basis of their occurrence and compositional characteristics: type Ia (primary and/or pseudosecondary aqueous fluid inclusions showing the presence of a nucleated clathrate upon heating after cooling) and type Ib (aqueous inclusions). Type IV inclusions are subdivided into two types: type IVa (homogenized into aqueous phase) and type IVb (homogenized into carbonaceous phase) upon slight heating (up to about 30℃). Primary and pseudosecondary inclusions in vein quartz include CO_2-bearing, type Ia and IV inclusions. The wide range of fluid inclusion homogenization temperatures (205° to 344℃) in vein quartz reflects several hydrothermal episodes rather than one specific event, which is indicated by textural evidence of multiple opening and filling of the veins. The estimated mole percent of CH_4 in the nonaqueous part of type IV inclusions are 1 to 22 mole %. Isochores for type IV fluids (ρ = 0.60 to 0.82 g/cc) intersect the temperature planes of 253° to 326℃ at pressures of 0.7 to 1.5 kbars. The calculated mole fraction of the carbonaceous species (X_{CO2}) for type IV are 0.16 to 0.63. The CO_2-H_2O inclusions in vein stage quartz plot between the H_2O-CO_2-6.0 wt.% NaCl solvus at 2 kbar and H_2O-CO_2 solvus at 1kbar. The average salinities of CO_2-H_2O inclusions in vein stage quartz are 6.0 wt.% NaCl, therefore, slightly lower than 2 kbar.

The presence of pyrrhotite and the alteration assemblage quartz + sericite(± kaolinite) may indicate that sulfur in the Yuryang auriferous hydrothermal fluids was dominantly H_2S. Therefore, the $\delta^{34}S_{H2S}$ value of -0.1 to 4.2 (avg. = 2.0) per mil is a good approximation of the $\delta^{34}S_{\Sigma S}$ values of the fluids, indicating the derivation of sulfur mainly from an igneous source. Measured and calculated isotopic compositions of the mesothermal fluids [$\delta^{18}O_{water}$ = 5.0 to 9.7 ‰; δD_{water} = -52 to -77 ‰] may indicate that the mesothermal-type gold deposition in the Yuryang mine district has formed from magmatic waters. Also, the $\delta^{18}O_{water}$-δD_{water} data for the Yuryang gold deposits are compatible with deposition of the mesothermal-type quartz veins from deeply sourced homogeneous fluids generated during the Jurassic S-type felsic magmatism (the nearby granitoid intrusion). Other evidence for magmatic sources of Yuryang ore fluids is the common occurrence of liquid CO_2-bearing fluid inclusions in Korean granites exclusively of Jurassic age, possibly indicating a genetic association between the magmatic reservoirs and the mesothermal-type ore fluids (the Jurassic gold deposits in Korea are characterized by intermediate to high CO_2 contents). Korean Jurassic granites which are associated with the Daebo orogeny had been derived from the S-type magmas by dehydration of mica-rich metasedimentary rocks, therefore such crustal-derived magmas must have been so wet that could form significant amounts of auriferous hydrothermal fluids. Repeated fracturing and rehealing of the Yuryang veins, which is a typical of fault-hosted mesothermal-type veins, might have been associated with late-stage processes in orogenic belts. If uplift and unloading were accompanied during the mesothermal-type mineralization in the Yuryang district, meteoric waters could reach to the mineralizing sites during the late stages of vein mineralization. In fact, the variations in fluid inclusions types for the Yuryang veins indicate a pressure decrease during the mineralization, and furthermore the occurrence of aqueous type Ib inclusions in Yuryang mine is thought to represent the late stages showing involvement of deep-circulated meteoric waters. Furthermore, the occurrence of crack-seal-type veins in the Yuryang deposit may indicate relatively high P_{fluid} which could sustain the fluid movement over permeable fault systems in the Yuryang mining district. Repeated fractures of the veins were probably persistent enough at depth to act as high permeability conduits for the mesothermal-type mineralizing fluids of high P_{fluid}.

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