The genetic implication of gold-silver mineralization in the Suryun mine, Korea

Sang Joon Pak[1], Seon-Gyu Choi[1], Yun Sub Song[1] and Sang-Hoon Choi[2]

1. Introduction

The Suryun gold-silver mine is one of precious metal occurrences discovered in the Hapcheon mineralized district on which lies the western margin of the Cretaceous Gyeongsang Basin, Korea. The district hosts deposits that include the early to late Cretaceous (108 ~ 88 Ma) Au-Ag-bearing vein systems (So et al. 1989; Shelton et al. 1990). Rocks hosting the late Cretaceous Suryun mine (74 Ma) are mainly equivalent to the age unknown Goryeong granite and rare to the Cretaceous sediments of the Nakdong Formation. The Suryun mine exhibits characteristics that typical localities of gold occurrences (>2 g/t Au in ore) concentrates around the unconformity (> 100 m) between granite and sediments. Gold tonnage tent to be decreased toward lower level (< 100 m) from the unconformity, i.e., barren zone. In this study we provide a description of gold mineralization at the mine, establish a mineral paragenesis, and report the results of fluid inclusion, stable isotope, and thermochemical modeling studies. This study clearly shows that gold mineralization occurred in response to mixing and boiling of the hydrothermal fluid, and was triggered by the physico-chemical changes.

2. Alteration and Mineralization

Mineralized veins, the Main and West 1 vein, consist of cross-cutting, multi-stage quartz-calcite vein and breccia veins. Individual veins are slightly massive to crudely banded textures, and breccia veins consist of hydrothermally altered wallrock and/or vein fragments cemented by quartz and/or carbonate. Quartz is fine-grained and locally chalcedonic. Whereas, carbonate tends to be relatively coarse-grained and the latest calcite is marked by bladed textures. Ore mineralization occurs in six stages. Major gold-silver mineralization is bound up with early stages (stage I and II). The two stages show following features with increasing mineralization time: Au-rich electrum (77.4 ~ 49.5 atomic % Au), relatively Fe-rich sphalerite (2.45~1.54 mole % FeS) and base-metal sulfides Au-poor electrum (32.6 ~ 5.0 atomic % Au), Fe-poor

sphalerite (1.09~0.09 mole % FeS) and Ag-phases (i.e., native silver, argentite and hessite). On the basis

Key words: The Suryun mine, Gold-silver mineralization, Low sulfidation, Oxidized environment

[1] Dept. of Earth & Env. Sci., Korea Univ., Seoul 136-701, Korea (E-mail: electrum@korea.ac.kr)
[2] Dept. of Earth & Env. Sci., Chungbuk National Univ., Cheongju 361-763, Korea

of mineral assemblages, hydrothermal alteration nearby vein (i.e., early stages) is evidently classified as phyllic zone (i.e., sericite-dominant alteration). Far from the vein, propylitic zone (i.e., chlorite and/or epidote-dominant alteration) tends to prevail. Argillic zone (i.e., kaolinite-dominant alteration) occurs in minor and locally coexists with carbonate stockwork veins in the late stages. The large amount of hematite associated with alteration is widely precipitated in pre-mineralization stage throughout the deposit. Some of hematite as rhythmic bands co-precipitates with the banded quartz and carbonates in late stage. It implies that during the ore mineralization the Suryun mine was in oxidized environment.

3. Fluid chemistry and Ore forming conditions

Coexisting two types of fluid inclusions were observed in ore stage quartz and calcite according to room temperature phase behavior: liquid-rich (type I) and vapor-rich (type II) inclusions. Homogenization temperature and salinity ranges from 250° to 150°C and from 7.2 to 0.9 wt % eq. NaCl, respectively. It reflects fluids mixing that the homogenization temperature tends to decreases with the decrease of salinity. Measured and calculated isotopic compositions of the fluids [$\delta^{18}O_{water}$ = -4.2 to 2.0 ‰; δD_{water} = -65 to -111 ‰] may suggest that the Suryun mine has been contributed by meteoric waters and has been $^{18}O_{water}$ -enriched by interaction with wallrocks. The common sulfides and carbonates are characterized by a low sulfidation state during overall gold-silver mineralization. The alteration pattern marked by sericite also suggests ore forming conditions in a low sulfidation state. The mineralization in the early stage is represented by Au-rich electrum and Fe-rich sphalerite, and occurs over a temperature range of 270° to 240°C, which corresponds to log fs_2 values of -10.3 to -11.6. Ag-rich electrum and Fe-poor sphalerite can deduce the late mineralization condition that shifts to a lower temperature around range of 200° to 150°C, and logfs_2, -13.1 to -14.9. From the thermochemical modeling studies, the deposit was relatively low total sulfur system ranged form 10^{-3} to 10^{-4}. It is consistent with the weak sulfide mineralization throughout the ore deposition. Initial (~250°C) fluid pH and log fO_2 conditions are estimated at 4.5 to 5.3, and –34 to –36 bar, respectively. Proceeding ore deposition into lower temperature (at 200°C), sulfur fugacity are decreased and log fO_2 conditions are changed into –42 to –38 bar. Bisulfide gold complex i.e., $Au(HS)_2^-$ are dominant species in the fluid and the solubility of bisulfide gold complex drop down to precipitate gold as decreasing sulfur.

4. Result and Discussion

It harmonizes the occurrence of quartz-calcite hydrothermal breccias and bladed calcite with coexistence of type I and II inclusions (i.e., boiling). Deposition of chalcedonic quartz around upper level indicates rapid precipitation of silica, possibly due to the decreasing temperatures attending boiling. Gold mineralization was proceeded in relatively oxidized and fluctuation environment as dropping temperature.

It is evidenced by hematite-dominant alteration zone in pre- or ore stage. Also it suggests that reductant from sediments is not important to change fluid chemistry into reduced environment. Carbonate precipitated due to the increase in pH that accompanied boiling. Late stage sporadic argillic alteration requires a different fluid than that envisioned above, and reflects a slightly lower pH hydrothermal fluid that would be produced by gas condensation due to boiling. A weak gold and sulfide mineralization from the lower level indicates that hydrothermal fluid passed toward the upper level without physico-chemical changes. Whereas significant gold mineralization at the nearby unconformity occurred as controlled by mixing and the weak boiling. Our study is well explained why high gold tonnage concentrates on boundaries between granite and sediments, and barren zone is situated in lower level from unconformity.