Mineralogical characteristics of Se- and Te-bearing epithermal gold-silver deposits: Eunsan and Moisan veins

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1. Introduction

Epithermal deposits are an important class of hydrothermal deposits, that have recently seen an surge of exploration and research, principally as significant resources of gold and silver. Epithermal deposits form at shallow depths (surface to 1~2km) and temperatures less than 300°C (Hayba et al., 1985), and encompass a variety of low-sulfidation (near-neutral pH, reduced fluid; LS) and high-sulfidation (acidic and oxidized fluid; HS) deposits (Sillitoe, 1993; White and Hedenquist, 1995). In contrast to high-sulfidation epithermal deposits, magmatic signatures in low-sulfidation deposits are more elusive. Also, epithermal deposits are closely associated with subaerial, silicic volcanism or shallow intrusion in convergent margin settings, which generally forms in the late stages of arc evolution. The Eunsan and Moisan deposits, which occur in late Cretaceous volcanic rocks, are the most economically feasible gold-silver mineralization areas found in recent years in the Haenam-Jindo province, the southwestern Korea. An abundance of subvolcanic to volcanic rocks necessitates that much of the veins are hosted in lithologies of roughly equivalent age.

2. Geology and Ore Deposit

The Haenam basin in the southwestern Korea is situated within the Gwangju strike-slip fault system, and is filled with dominantly felsic pyroclastic rocks. The pyroclastic sequence in this basin can be divided into four litho-stratigraphic units in ascending order: the lower andesitic tuff with andesite intrusions and flows, the Uhangri formation, the Hwangsan tuff and the Jindo rhyolite(Chun and Chough, 1995). The general distribution of pyroclastic sequence suggests that the basin firmed as volcano-tectonic depressions related to continental rift within magmatic arcs or bark arc environment. Felsic volcanic and subvolcanic rocks are commonly spatially associated with mineralization as part of a bimodal suite of volcanic host rocks.

The Ag/Au ratios in the Eunsan veins exhibit a bimodal distribution with Se-rich type, whereas the Moisan veins show an intermediate normal distribution in Ag/Au ratios with Te-rich type (Fig. 1). The alteration, ore and gangue mineralogy of the Au-Ag-Se-Te deposits is typical of adularia-sericite-carbonate (low-sulfidation) class of volcanic-hosted epithermal deposits.

keywords: epithermal; gold-silver; mineralization; Te; Se; Eunsan; Moisan

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3. Vein Texture and Ore Mineralogy

The mineralogical differences between the Eunsan and Moisan deposits appear to reflect intrinsic geochemical characteristics.

The Eunsan and Moisan deposits occur as the colloform banded fissure veins and vein breccias that comprise predominantly chalcedony, fine comb quartz, bladed quartz and carbonate minerals such as calcite and dolomite with lesser illite-smectite mixed-layering clay, adularia and dark sulfide bands.

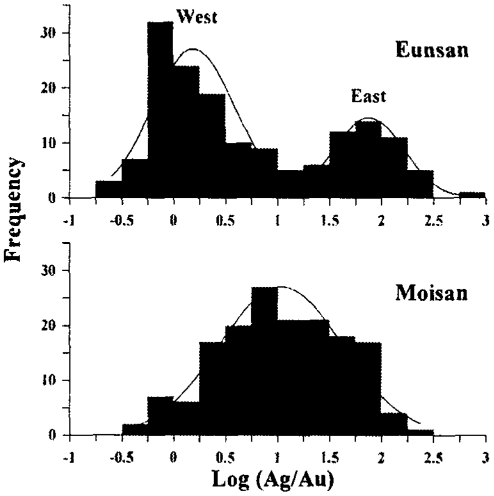

Figure 1. Ag/Au ratio in the Eunsan and Moisan deposits. The Eunsan deposit exhibit a bi-modal distribution, whereas the Moisan deposit shows an intermediate normal distribution.

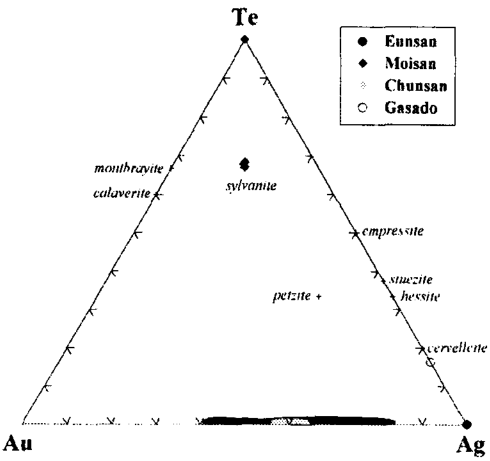

Figure 2. Au-Ag-Te ternary diagram for the Eunsan-Moisan mineralized area. Tellurides are found in the Moisan and Gasado deposits.

The ore minerals in the Eunsan veins (Se-type) are pyrite, sphalerite, chalcopyrite, galena, electrum, native silver, proustite, selenides (aguilarite and naumanite) and Se-bearing Ag minerals, such as argentite, pearceite, tetrahedrite, and stephanite. The ore minerals in the Moisan veins (Te-type) are pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, and tellurides (sylvanite, altite, tellurobismuthite, and native tellurium).

Gold in the Eunsan and Moisan deposits occur as electrum and sylvanite respectively (Fig. 2). Electrums are divided into three types; type Ⅰ) electrum in the electrum - pyrite - galena assemblage which approximates 16.77 to 36.45 atomic % Au is formed at early stage before Ag-sulfosalts mineralization and characterized in absence of sphalerite, type Ⅱ) electrum (46.61 to 57.52 atomic % Au) in the electrum - pyrite - sphalerite - argentite - chalcopyrite - galena assemblage is formed at middle (main) stage and occur as independent grain or filling cracks of pyrite, type Ⅲ) electrum in the electrum - argentite - tetrahedrite assemblage which subject to late stage shows low Au contents (20.92 to 38.77 atomic % Au) and contact gradually with argentite which coexist together native silver (Fig. 3). Au composition of sylvanite found only the Moisan deposit is ranged from 15.5 to 15.9 atomic % (Fig. 2).

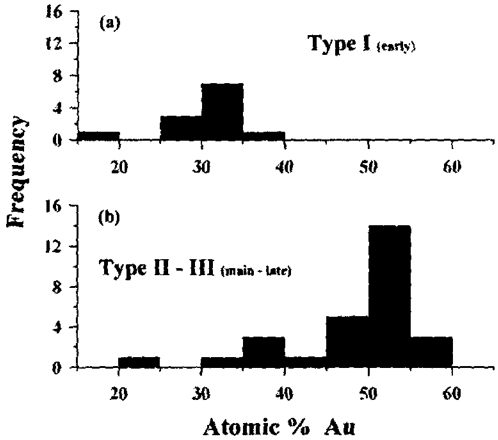

Figure 3. Histograms of the Au contents (Atomic %) of the electrum in the Eunsan deposit. a) electrum in pyrite as inclusion occurs with only pyrite and galena. b) electrum associated with Ag minerals occur as filling crack in pyrite or independent grain. Compositional zoning in single grain is indicated.

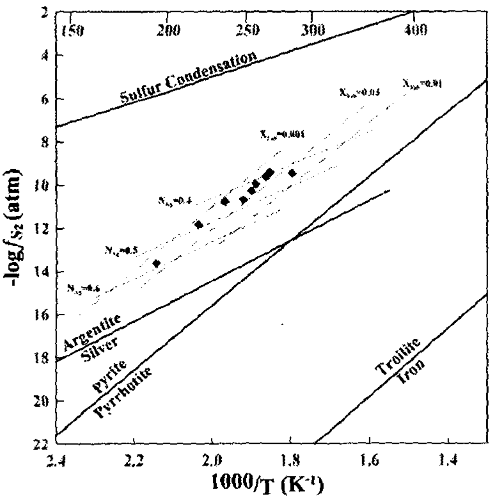

Figure 4. Fugacity of sulfur versus temperature diagram showing sulfidation reaction pertinent to the Eunsan deposit. N_{Ag} is the atomic fraction of Ag in electrum and X_{FeS} is the mole fraction of Fes in sphalerite.

Tetrahedrites from the Eunsan and Moisan deposits appear different Ag and Fe contents. The former is ranged from 22.63 to 37.15 wt. % Ag and 4.17~6.41 wt. % FeS and the later below 3.61 wt. % Ag and from 0.92 to 2.99 wt. % FeS.

4. Geological environment of ore deposition

Homogenization temperature and salinity with gold-silver mineralization of the Eunsan and Moisan deposits are ranged 113~298℃, 0~1.7 equiv. wt. % NaCl and 133~319℃, 0~1.7 equiv. wt. % NaCl (Lee et. al., 2001). Electrum-sphalerite geothermometer according to Fe-Zn-S and Au-Ag-S systems (Scott and Barns, 1971, Barton and Toulmin, 1964) indicates that the gold-silver mineralization temperature of the Eunsan deposit is ranged from 193 to 283℃ (Fig. 4). The hydrothermal systems of the deposits are characterized at very shallow depth by neutral pH fluids of low temperature and salinity (<300°C, <4 equiv. wt. % NaCl) but variable gas content (CO_2 and H_2S).

5. Discussion

The Eunsan (Se-type) and Moisan (Te-type) deposit formed in different parts of the same geothermal system, according to their alteration, ore and gangue mineralogy, vein morphology, geochemical signatures and stable isotope data. Mineralogical and geochemical differences in these deposits can be explained by variations of the physicochemical conditions that existed during gold-silver mineralization. The Se-type generally formed at shallower crustal levels and relatively lower temperature conditions than the Te-type. It suggest that the Moisan deposit display mineral association closer to the heat source than the Eunsan deposit. Adularia-sericite epithermal gold-silver deposits typically form within back-arc basins or rifts and are characterized by deep seated felsic intrusions around which are set up circulating hydrothermal systems dominated by meteoric waters. The gold-silver systems commonly display closer associations with volcano-tectonic depression and extensional structure than clear relations with intrusion source rocks, although subvolcanic acidic rocks of similar age may occur in the vicinity of some deposits (e.g. Moisan).

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