Copper-gold deposits in the Haman-Gunbuk metallogenic province: Magmatic hydrothermal system related to porphyry.

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1 Introduction

The Gyeongsang Basin contains a wide variety of ore deposit types, including precious- and base-metal veins, skarns, hydrothermal replacement ore, and breccia-pipe type deposits. Most Cu-Au mineralizations with base metals in the Gyeongsang Basin is concentrated on the Haman-Gunbuk metallogenic province. They are associated intimately with major periods of Cretaceous shallow magmatism initiated by paleo-Pacific plate motions. Several researchers insisted that the characteristics of these deposits show resemblance to porphyry copper deposits distributed along the Pacific Rim (Sillitoe, 1980). The base-metal vein deposits in the Haman-Gunbuk metallogenic province show contrasting styles on associated metals, mineral assemblage, ore fluid compositions and fluid evolution. In this study we document the age of ore mineralization and igneous activities in the Haman-Gunbuk area and the physical and chemical conditions of ore deposition. This study finally attempts to elucidate the area-wide mineralizing environment as well as to understand the base-metal mineralization of each deposit.

2 Local Geology

The Haman-Gunbuk province is situated in the southwestern margin of the Gyeongsang Basin. The Gyeongsang Basin is composed of three volcano-seidmentary groups: (1) The Lower Cretaceous Sindong Group contains sedimentary rocks (2) The Middle Cretaceous Hayang Group contains sedimentary rocks with pyroclastics (3) The Upper Cretaceous Yucheon Group mainly consist of volcanic rocks. The Jindong Formation distributed in the Haman-Gunbuk province represents the upper portion of the Hayang Group, and composed predominantly of dark gray shale, mudstone and sandstone. The Jindong Formation is intruded by a granodiorite phase of the Jindong granite. Sedimentary rocks adjacent to the granodiorite, in particular, shale and mudstone, are metamorphosed intensely to hornfels. The Yucheon Group in the province is characterized by the dominance of volcanic rocks in contrast to the unconformably

Key words: Cretaceous, Cu-Au, porphyry, magmatic hydrothermal

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underlying the Hayang Group. Andesite is found as small masses and intrusions (or extrusions) within sedimentary rocks of the Jindong Formation.
Sedimentation in the Gyeongsang Basin was initiated in the Hauterivian and continued into the Albian (130~100 Ma), whereas much of the magmatism occurred sporadically with a major episode between ca. 100 and 50 Ma.

3 Outline of Cu-Au and Pb-Zn-Ag Deposits

Mineralization in the Haman-Gunbuk province displays close relationships in time and space with subvolcanic granitoids. The Bulgugsa magmatism in the area such as Jindong, Masan, Hwawangsan granitoids ranges ca. 110~95 Ma whereas most mineralization in the province are consistently constrained to the period between ca. 89 and 81 Ma.
Base-metal mineralization in the Haman-Gunbuk province occurs mainly within quartz veins, which mainly formed along the NS and N20W trends. The veins showing multiple generations of quartz with base-metal sulphides occur in hornfels and sandstone of the Jindong formation, and partly in andesitic pyroclastics. The most common vein-related wall-rock alteration is potassium alteration. Potassium alteration is generally followed by sericitization and prophylitic alteration. Veins show textural evidence of open-space filling, extend several hundred meters along strike and vary in width. Ores in the veins generally are brecciated and banded. Base-metal veins in the province can be categorized into two types; Cu-Au deposits (e.g. the Jeilgunbuk, Ogok and Chilgok deposit) and Pb-Zn-Ag deposits (e.g. the Daejang and Yongjang deposit), based on their ore mineral abundances. Cu-Au veins consist mainly of tourmaline with Fe-oxides whereas Pb-Zn-Ag veins display base-metal sulfides, sulfosalts and carbonates with lesser tourmaline.

4 Ore Mineral and Paragenesis

Veins have similar mineralogies, but in detail show contrasting paragenesis. In Cu-Au deposits, generalized paragenesis is characterized by early stage assemblage showing high temperature minerals (tourmaline and actinolite) with Fe-oxides and Cu-Fe sulfides (e.g. magnetite and chalcopyrite, respectively). The early stage minerals are well harmonized with minerals occurred from porphyry-type copper deposit (Sillitoe, 1989). In contrast, Pb-Zn-Ag deposits are characterized by predominant base-metal sulfides (sphalerite and galena) with Ag-sulfide and Ag-sulfosalt. Fe-oxide with tourmaline and silicate minerals are dominant in Cu-Au veins of the province mainly occurs in or near the granodiorite, whereas the minerals in Pb-Zn-Ag veins decrease in abundance and sulfides and carbonates become dominant with increasing distance from the granodiorite (Park et al., 1985). Sphalerite occurred from Cu-Au mineralization shows high iron contents (20~15 mol % FeS), whereas one from Pb-Zn-Ag deposits have wide iron

contents ranging from 19 to 5 mol % FeS. The Au content of electrum cluster in similar and narrow range (43~32 atomic % Au).

5 Evolution of Ore-Forming Fluid

The hydrothermal fluid inclusions, principally obtained from vein stage minerals, are characterized by liquid rich, vapor rich and hihg salinity (halite-bearing). No liquid CO_2-bearing inclusions were observed, indicating that H_2O-NaCl fluid systems was predominat. The hydrothermal systems of Cu-Au vein deposits in the province are associated with ore-forming fluids of high to intermediate temperature (300°~500℃) with high salinity (30~55 equiv, wt.% NaCl). In contrst, the geothermal system of Pb-Zn-Ag deposits in the province are derived from a narrow range of intermediate temperature (200°~350℃) with relatively low salinity (10~20 equiv, wt.% NaCl). It may represent a mixed fluid of magmatic and meteoric waters. The $\delta^{18}O_{fluid}$ values of vein quartz ($\delta^{18}O_{fluid}$ = -5.9 ~ 11.1 ‰) in the province show a progressive shift from a magmatic-dominated hydrothermal system toward a meteoric-water dominated hydrothermal system, and are more close to magmatic water than those of Pb-Zn-Ag deposits.

6 Discussion

When the Haman-Gunbuk metallogenic province is compared with the world-class porphyry gold system, a close resemblance is noted, especially with regard of a spectrum of ore-deposit type (Corbett and Leach, 1998; Corbett, 2002). The spatial and temporal relationships of base-metal mineralization (Cu-Au and Pb-Zn-Ag deposits) to the late Cretaceous granites within the province imply proximity to a shallow magma source. The systematic mineralogy and variation of physicochemical conditions in Cu-Au and Pb-Zn-Ag deposits are, therefore, due to their positions relative to a magma source, which likely was genetically related to a low to intermediate-sulfdation porphyry system. Most of epithermal deposits in the southwestern portion in the Gyeongsang Basin may be removed when subduction of hot oceanic crust resulted in extreme uplift and subsequent erosion of the upper parts of the volcanic rocks. The close spatial and temporal association of mineralization with shallow-level graintoids and volcanic activity may be due to the change in subduction mode of the Izanagi plate during the Cretaceous time.

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