# Genesis of two contrasting metallogenic provinces in the Cretaceous Gyeongsang Basin, Korea

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The Cretaceous magmatism in the Gyeongsang Basin, which intruded into the upper crust or extruded throughout ENE-trending volcanic belts in southern Korea, led to the formation of two contrasting metallogeinic provinces: the Haman-Gunbug-Goseong and the Euiseong. The Haman-Gunbug-Goseong metallogenic province in the southwestern portion of the Gyeongsang Basin consists of dominantly nonmarine sedimentary rocks (e.g., the Sindong and Hayang groups) which are rarely intercalated with andesitic pyroclastics and flows. On the contrary, the Euiseong metallogenic province in the northwestern portion of the Basin is mainly composed of the Cretaceous volcanic sequence of the felsic pyroclastic rocks with andesites (e.g., the Yucheon Group). The occurrence of base-metal vein deposits in the Cretaceous Gyeongsang Basin, Korea, is reviewed to provide a better insight on hydrothermal mineralization. Our results indicate that the occurrence of base-metal vein deposits is causally linked to particular phases of basin evolution during the Cretaceous time.

The mineralization in the Haman-Gunbug-Goseong metallogenic province, which represents copper, gold and iron of porphyry-related type, displays close relationships in time and space with subvolcanic granitoids. The Bulgugsa magmatism in this area ranges ca. 112~100 Ma, whereas much of copper-gold-forming events are consistently constrained to the period between ca. 89 and 81 Ma. High-level veining and alteration that is broadly associated with volcanism commonly characterize the Euiseong metallogenic province, typical of polymetallic vein deposits transitional to deeper porphyry mineralization. The Bulgugsa magmatism in this area ranges ca.75~52 Ma with a major population between ca. 67 and 61 Ma, whereas much of base-metal-forming events are consistently constrained to a period of 78~60 Ma with a major population between ca. 70 and 65 Ma.

By using criteria of the alteration, ore and gangue mineralogy, host rock, fluid inclusion, stable isotope and geochemical data of the deposits, the base-metal vein deposits in the

Haman-Gunbug-Goseong and Euiseong mineralized provinces basin can be primarily distinguished as proximal and distal types. The hydrothermal systems of copper-gold vein deposits in the Haman-Gunbug-Goseong province are associated with ore-forming fluids of high to intermediate temperature (200°~550°C) with high salinity (18~55 equiv. wt.% NaCl). The ore-forming fluids become progressively more diluted by the incorporation of decreased quantities of magmatic water further from the nearby intrusion, suggesting significant input and fluid mixing of a meteoric water component to the magmatic fluids during the late stage of geothermal systems. Whereas, the geothermal system of polymetallic vein deposits in the Euiseong province are derived from a narrow range of intermediate temperature (200°~400°C) with relatively low salinity (1~7 equiv. wt.% NaCl). It may represent a mixed fluid of magmatic and meteoric waters. The $\delta^{18}O$ values of vein quartz in the northwestern portion are isotopically depleted relative to magmatic waters, indicating that magmatic water contributed little to ore-forming fluids. The $\delta^{18}O$-D values of fluids are consistent with meteoric-water dominance as fluid compositions approach those of unexchanged meteoric waters. It is attributed to significant input of a meteoric water component to the ore-forming fluids, indicating relatively shallow-level hydrothermal systems. The $\delta^{18}O_{H2O}$ values of vein quartz in the Haman-Gunbug-Goseong 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 in the Euiseong province.

The diverse physicochemical environment of hydrothermal systems may explain contrasts between the two mineralized provinces during the Late Cretaceous. During polymetallic mineralization in the Euiseong province, the presence of coeval volcanic activity and absence of subvolcanic granitoids may imply the development of shallow-level distal deposits. The base-metal vein deposits in the Haman-Gunbug-Goseong province formed in proximal environments of porphyry-style system under impermeable conditions (stratigraphic restriction) and deeper depth of ore formation than those in the Euiseong province, reflecting the deeper depth of ore formation.

The base-metal mineralization in the Gyeongsang Basin represents a close spatial and temporal distinction between the proximal environment derived from shallow-level granitoids in the southwestern Haman-Gunbug-Goseong province and the distal condition derived from volcanic environments in the northwestern Euiseong province. Polymetallic deposits of volcanic-dominant area in the northwestern portion of the Gyeongsang basin generally formed at relatively very shallower crustal levels and lower temperature conditions containing more amounts of meteoric or less-evolved circulating waters than those along the sediment-dominant area in the southwestern portion. Most of epithermal deposits in the southwestern portion of the Gyeongsang Basin might be removed when subduction of hot oceanic crust resulted in extreme uplift and subsequent erosion of the upper parts of the volcanic rocks. Comparisons and contrasts between the southwestern and northwestern portions of the Gyeongsang Basin in the Korean Peninsula provide a sophisticated understanding on spatial relationships between magmatism and associated mineralization. The close spatial and temporal association of mineralization with shallow-level graintoids and volcanic activity might be due to the change in subduction mode of the Izanagi plate during the Cretaceous time.