An Overview of Mesozoic Gold-Silver Deposits in Korea: Tectonic Implications

Choi Seon-Gyu[1)]*, Pak Sang Joon[1)], Oh Chang-Whan[2)] and Kim Sung-Won[2)]

1. Introduction

Mesozoic Au-Ag lode deposits are widespread in Korea, with more than 1,000 localities. Based on the fluid inclusion, stable isotope and radiometric age data, these deposits have been subdivided into three types (Shelton et al. 1988); mesothermal, intermediate Korean-type and epithermal deposits. Recently, there have been significant advances on the Mesozoic tectonic evolution of the Korean Peninsula and associated granitoid magmatism (Chough et al. 2000), so that the origin of the Mesozoic gold mineralization in Korea could be better understood.

2. Tectonic Frameworks

Recent metamorphic studies suggest that the Hongseong area of the Gyeonggi massifs the eastern extension of Late Paleozoic to Early Mesozoic Dabie-Sulu collisional belt between the South and North China blocks (Oh et al. 2004). The Mesozoic granitoids in Korea show a trimodal age distribution: Triassic (250-210 Ma), Jurassic (200-155 Ma) and Cretaceous to Early Tertiary (110-50 Ma) with a distinct magmatic quiescence in the Late Jurassic to Early Cretaceous. After this collisional event, orthogonal convergence has characterized the continental edge of the Eurasian Plate throughout much of the Jurassic, generating a NE-trending Daebo batholith belt of Korea. During this orthogonal subduction of the Izanagi Plate in Middle Jurassic, a lithospheric-scale, NE-striking right-lateral strike-slip Honam Shear Zone developed in the continental magmatic arcs presumably by slip partitioning. In the Late Jurassic to Early Cretaceous, the Izanagi Plate subducted roughly northward (oblique), resulting in left-lateral strike-slip displacement along a NNE-striking fault system. The period of this oblique subduction corresponds to the magmatic quiescence in the Late Jurassic to Early Cretaceous. During the Late Cretaceous, the Pacific Plate began to subduct northwestward (orthogonal) again along the East Asian continental margin, generating the Bulgugsa granitoids in Korea. Hornblende geobarometry data show that the emplacement pressures of Jurassic and Cretaceous plutons are 3.4 to 7.8 kbar and less than 2.8 kbar, respectively (Cho and Kwon 1994).

3. Mesozoic Gold-Silver Deposits

Keywords: Mesozoic, tectonic, porphyry-related, orogenic, gold-silver

1) Dept. of Earth and Environ. Sci., Korea University, Seoul, Korea (seongyu@korea.ac.kr).
2) Dept. of Earth and Environ. Sci., Chonbuk National University, Chonju, Korea.

The Au-Ag lode deposits are widely scattered in South Korea, and possess a variety of produced grade of silver and gold. Available K-Ar age data reveal that the Au-Ag mineralization can be divided mainly into two age groups: Jurassic and Cretaceous. The Jurassic deposits occur as gold-bearing simple quartz veins, whereas the Cretaceous ones as multistage Au-Ag quartz±carbonate veins (Choi et al. 2005b). The Au fineness values of precious-metal deposits in Korea show a limited range for the Jurassic ones and variable range for the Cretaceous ones. There are neither consistent spatial nor genetic relationships between the two deposit styles.

3.1. Orogenic Gold Deposits

The Au deposits occur in the NE-trending Jurassic granitoid belt and in basement gneisses adjacent to or within the Honam Shear Zone. The Jurassic gold deposits may be subdivided into batholith-related type and shear-zone type. The former is related to the Jurassic granitoids and associated pegmatites in the Gyeonggi massif, and the latter is present along the Honam Shear Zone in the Yeongnam Massif. The Jurassic auriferous deposits are commonly characterized by simple, massive (i.e., buck or ribbon) veins containing an early gold-bearing assemblage dominated by quartz with base-metal sulfides and a late carbonates. These deposits commonly show several characteristics: prominent association with pegmatite, low Ag/Au ratios in the ore, massive vein morphology and a distinctively simple mineralogy including Fe-rich sphalerite, galena, chalcopyrite, arsenopyrite, Au-rich electrum, Au-Ag-Bi tellurides, pyrrhotite or pyrite. The Jurassic deposits were formed at the high temperature (T_h 250° to 400°C) and deep-crustal level (2.5±0.5 kbar) from low-moderate saline and CO_2±CH_4- bearing fluids (calculated $^{18}O_{fluid}$ = 7.2±1.9 ‰; δD = -75±15 ‰). Most of O and H isotopic ratios for the ore-bearing fluids of the Jurassic deposits fall within the range of magmatic water. All these fluid inclusion and stable isotope data, and electrum-sphalerite geothermometry suggest that the dominant ore-forming mechanism of the Jurassic deposits is CO_2 effervescence and destabilization of bisulfide complexes by sulfidation reactions, indicating mesozonal environments.

3.2. Porphyry-related Gold-Silver Deposits

The Cretaceous deposits occur within or adjacent to Cretaceous pull-apart basins developed by left-lateral strike-slip shearing of NNE-striking fault systems such as the Gongju-Eumseong and Yeongdong-Gwangju ones. Most of the Cretaceous Au-Ag deposits commonly indicate that the ore-forming fluid filled the secondary extensional fractures of the major faults. The Cretaceous deposits appear to have resulted from multi-stage veins that are characterized by an earlier gold-bearing assemblage dominated by base-metal sulfides and a later assemblage composed of a variety of Ag-rich electrum, silver-bearing sulfides, sulfosalts, tellurides or selenides. The Cretaceous deposits are generally characterized by such features as complex vein morphology, medium to high Ag/Au ratios in the ore, and abundance of diverse ore minerals, as compared with the Jurassic ones. Hydrothermal fluids responsible for the formation of the Cretaceous deposits are characterized by variable but dominantly low salinities. Hydrothermal fluids indicate low to moderate temperatures (Th 150° to 350°C), neutral to slightly alkaline, variable (very low to high) salinity (<10 equiv. % NaCl), and/or partly CO_2-bearing (<10 mole %) solutions. The fluid inclusion data suggest that the Cretaceous Au-Ag mineralization may have been formed at about <1.0 kbar. ^{18}O and D values (calculated $^{18}O_{fluid}$ = -1.6±5.0 ‰; δD = -73±13 ‰) of ore-forming fluids show a mixing trend between magmatic water and meteoric water (Choi et al. 2005a), suggesting that the fluids originated from variable degrees of mixing (O-shift) between the two waters. Stable isotope data of mineralizing fluids from Cretaceous epithermal deposits are similar to modern meteoric and hot spring waters, indicating the predominance of meteoric water during Au-Ag mineralization. Gold precipitation from bisulfide complexes can be mainly caused either by a decrease in aH_2S or by an increase in pH and aO_2 due to a mixing and/or boiling mechanism. Most of the Cretaceous Au-Ag deposits are genetically related to low-sulfidation, epi- to meso-thermal type, transitional to deeper porphyry-related base-metal mineralization (Pak et al. 2004).

4. Discussions

Orogenic events in the Korean Peninsula are widely attributed to block movements in the Mesozoic associated with collision of the South-North China Blocks and subduction of the paleo-Pacific Plate. The temporal and spatial relationships of the Au-Ag lode deposits are related to changing plate motions. Relative orthogonal convergence has characterized the continental edge of the Asia throughout much of the Jurassic (Maruyama et al. 1997). The Daebo plutonism in the peninsula was most abundant 200 to 155 Ma, with distinct pulses at about 190~160 Ma. The main mineralization ages (ca. 165-145 Ma) of the Jurassic gold deposits correspond to the late stage of the Jurassic magmatism. It agrees with changing timing in far-field regional stress fields, such as from a compressional to transpressional regime of the Izanagi Plate into the eastern edge of the Asia. Extensional fractures along the NE-striking Honam Shear Zone system served as hosts for the Late Jurassic mineralization

The NNE-trending strike-slip fault systems, probably caused by the distal oblique (northward) subduction of the Izanagi Plate during Early Cretaceous, were accompanied commonly by the formation of pull-apart basins and subvolcanic activity. During Late Cretaceous, the mode of convergence of the Izanagi Plate was changed to northwestward so that orthogonal convergence occurred with magnetite-series calc-alkaline magmatism. Sedimentation in the basins was initiated in the Hauterivian and continued into the Albian, whereas much of the volcanism is constrained sporadically to a period of 110-50 Ma, with a major population between ca. 90 and 70 Ma. The mineralization ages (110-45 Ma) of the Cretaceous Au-Ag deposits tend to overlap with the whole stage of the Cretaceous magmatism, probably caused by the orthogonal subduction of the Izanagi Plate. The rarity of the mineralization in the Early Cretaceous coincides with the magmatic quiescence. Contrasts between two ore-forming styles of Korea during the Mesozoic can be explained by the difference in the depth of the pluton emplacement and associated extensional fractures that host ore. The formation depth of the Jurassic and Cretaceous deposits fits with the relative depth of intrusion for associated plutons. The reason why we observe the two deposit styles of different age at the present surface is due to a large amount of erosion during the Late Jurassic to Early Cretaceous times. The rapid uplift that caused the significant erosion might have been related to the Late Paleozoic to Early Mesozoic collision between the North and South China blocks (Songrim Orogeny) followed by Jurassic Daebo tectonic event representing a compressional deformation in a continental arc setting. The Mesozoic Au-Ag deposits of Korea formed in a continental arc setting and are related both temporally and spatially to magmatic intrusion. They represent an overlap between orogenic and porphyry-related systems that could be a unique type of gold deposits.

References

Cho D.R, Kwon S.T. (1994) Hornblende geobarometry of the Mesozoic granitoids in South Korea and the evolution of the crustal thickness. J. Geo. Soc. Korea 30: 41-61.

Choi S.-G., Ryu I.-C., Pak S.J., Wee S.M., Kim C.S., Park M.E. (2005a) Cretaceous epithermal gold-silver mineralization and geodynamic environment, Korea. Ore Geol. Rev. 26: 115-135.

Choi S.-G, Kwon S.T, Lee J.H, So C.S., Pak S.J. (2005b) Origin of Mesozoic gold in south Korea. Island Arc: in print.

Chough S.K., Kwon S.T., Lee J.H., Choi D.K. (2000) Tectonic and sedimentary evolution of the Korean Peninsula: A review and new view. Earth Sci. Rev. 52: 175-235.

Maruyama S., Isozaki Y., Kimura G., Terabayashi M. (1997) Paleo-geographic maps of the Japanese islands. Plate tectonic synthesis from 750 Ma to the present. Island Arc 6: 121-142.

Oh C.H., Kim S.W., Choi S.-G., Zhai M., Guo J., Krishnan S. (2004) First finding of eclogite facies metamorphic event in South Korea and its correlation with the Dabie-Sulu collision Belt in China. J. Geol. 113: in print.

Pak S.J., Choi S-G., Choi S.H. (2004) Systematic mineralogy and geochemistry of gold-silver vein deposits in the Taebaeksan district, Korea. Min. Mag. 68: 467-487.

Shelton K.L., So C.S., Chang J.S. (1988) Gold-rich mesothermal vein deposits of the Republic of Korea: Geochemical studies of the Jungwon gold area. Econ. Geol. 83: 1221-1237.