# Batholith-type Au deposits in the Gyeonggi massif: Genetic implication.

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## 1 Introduction

Orogenic gold occurrences are hosted within virtually metamorphosed terranes along the Pacific Rim (Goldfarb et al. 2001). Lode Au deposits in Korea tend to be distributed in the Precambrian Gyeonggi massif intruded by the huge Jurassic Daebo batholiths. Recent researches show that the southwestern part of the Gyeonggi massif experienced high-P/T metamorphism due to collision between the North and South China blocks during the Late Permian to Triassic (Oh et al. 2004a). Radiometric age data of lode Au deposits in the Gyeonggi massif, however, show that the deposits are more closely associated with Jurassic granitoids. This study attempts to document the nature of hydrothermal Au mineralization and origin of typical lode Au deposit, and elucidate the district-wide mineralizing environment.

## 2 Geological Setting

There are four major tectonic provinces in the southern part of the Korean Peninsula from north to south; the Gyeonggi massif, the Ogcheon belt, the Yeongnam massif, and the Gyeongsang basin. These tectonic provinces are bounded by tectonic lines trending NE-SW and NNE-SSW, the so-called Sinian direction. The two massifs are composed mainly of metamorphic rocks of the Late Archean to Neoproterozoic ages. The major U-Pb zircon and titanite ages and K-Ar biotite ages of Jurassic granitoids in central Korea have 175-167 Ma and 168-154 Ma, respectively (Cheong et al., 2003; Oh et al., 2004; So and Shelton, 1987). K-Ar muscovite ages (162~158 Ma) of pegmatite in Jurassic granitoids have similar ranges with K-Ar biotite ages of Jurassic granitoids, with the exception of a younger muscovite age from Ilbo pegmatite. Hornblende geobarometry indicate that the Jurassic Daebo granitoids in the area were emplaced at greater pressures (5.3~3.8 kb Cho and Kwon, 1994). Major elements of the Jurassic granitoids, except for peraluminous two-mica granites, mostly plot near the boundary between I- and S- type fields, and the Sr initial ratios are relatively high, suggesting a crustal origin (Chough et al. 2000).

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**Key words**: Jurassic, batholith-type, Orogenic, load Au deposits

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## 3 Features of Load Au Deposits

Most of the lode Au deposits in the Cheonan metallogenic province yield coeval late Jurassic formation ages (158~146 Ma). These lode Au deposits are closely related to muscovite-bearing pegmatite dykes, in terms of their formation age, and are typified by simple, massive veins and low Ag/Au ratios reflecting the paucity of silver phases. The lode deposits are located close to the boundary between Precambrian gneisses, comprising granitic and two-mica granite, and within Jurassic granitoids. Hydrothermal gold-quartz veins occur as fault-related fracture-fillings in Precambrian gneiss and Jurassic granitoids. The veins locally occur parallel to, and in gradational contact with, pegmatite dikes consisting of perthite, plagioclase and muscovite. The massive veins displays mosaic textures of quartz with grain boundary migration, implying that quartz grains were recrystallized at a deeper level.

## 4 Ore Mineral and Paragenesis

A pervasive alteration is restricted within very narrow zone in the deposit. In the wallrock alteration zone, biotite is converted directly to muscovite or sericite without chlorite, indicating the predominant potassic alteration. Subsequently, muscovite is converted to sericite. Hydrothermal quartz veins are composed of single or two stage veining, and ore minerals are quiet simple. Generalized assemblage from the load Au deposits in the area characterizes that early iron sulfide mineralization (e.g. pyrite and/or pyrrhotite) was followed by late Au-Ag(-Te)(-Bi)(-Sn) mineralization (e.g. electrum, argentite, hessite and canfieldite). Sphalerite occurred from early mineralization is closely associated with pyrrhotite and shows high iron contents (18~15 mol % FeS), indicating that sphalerite was precipitated at a considerable pressure. Some sphalerite grains related to late mineralization show relatively lower FeS contents. Telluride, bismuth and tin phases occur with electrum in central vein portions. The Au content of electrum is high, ranging from ca. 80~60 atomic % Au.

## 5 Evolution of Ore-Forming Fluids

Two types of the hydrothermal fluid inclusions, principally obtained from vein stage minerals, are characterized by the dominantly aqueous fluids of moderate salinity containing minor amounts of $CO_2$ and the mixed $CO_2$-$H_2O$ fluids of low salinity. Aqueous type inclusions tend to increase in salinity with decreasing temperature. Liquid $CO_2$-bearing inclusions have tendency of increasing salinity with decreases in temperature. The molar proportions of $CO_2$ in the $H_2O$-NaCl-$CO_2$ system from the Seolhwa and Yuryang deposits are clustered within the range of world-wide lode gold deposits with great formation depth. The estimated mol percent of $CH_4$ in fluid inclusions from the Seolhwa and Yuryang deposits show ~ 22 mol%.

The temperatures and $f_{S2}$ calculated from the electrum-sphalerite geothermometry range from 450° to 500℃ and $10^{-6}$ to $10^{-3}$, respectively. The compositions of sphalerite (17.0 mol % FeS ± 0.75) from the Yuryang deposit with hexagonal pyrrhotite correspond to about 2.1 ± 0.5 kb. The iron contents of sphalerite coexisting with pyrrhotite and pyrite ranged from 15 to 18 mol % FeS, which were in general agreement with the pressure-corrected values. The ranges of $\delta^{18}O$ values of quartz samples were as follows: 9.4 to 15.4 ‰. The calculated oxygen isotope compositions of the fluid varieds between 6.3 and 12.0 ‰. The inclusion fluids extracted from quartz samples have δD values of -52 to -143 ‰. The $\delta^{18}O$ values based on the pressure-corrected temperatures were clustered around the S-type magmatic water field, indicating that the ore-forming fluid is originated from S-type magmatic waters.

## 6 Discussion

The lode Au deposits in the Cheonan area resemble with the orogenic gold system, especially with regard to the type of deposits, mineralogy, host rocks, alteration patterns, and ore fluid system (Goldfarb et al. 2001). The veins associated with pegmatite and displaying interlocking networks of quartz, such as buck or ribbon texture, suggest that veining occurred in at a deeper level, equilibrating with the host rocks. The high temperature ore-forming fluid of the lode Au deposits originated from S-type magmatic water, indicating close association with abundant Jurassic S-type granitoids and two mica granites in the Cheonan area. The δD values of ore-forming fluid are more variable. However, in detail, the possibility of the regional metamorphic fluid component involving gold mineralization in load Au deposits is regarded as being minimal, because the Gyeonggi massif had already experienced peak metamorphism before the Neoproterozoic period (800 ~ 600 Ma).

The ore mineralogy and physicochemical conditions obtained from the lode Au deposits with Te-Bi-Sn mineralization are consistent with those of deposits that formed in an intrusion-related gold system at a deep depth (Lang et al. 2001). The Daebo igneous activities in the Cheonan area are constrained to the period ofca. 175 ~ 167 Ma and followed by pegmatite intrusion between 162 and 158 Ma. The timing of gold mineralization (158 ~ 146 Ma) in the area is well harmonized with the timing of pegmatite intrusion. The characteristics of ore-forming fluid such as high temperature and highly evolved water at the lode Au deposits, therefore, may reflect natures of Jurassic Daebo granitoids. In summary, the Jurassic lode Au deposits in the Cheonan metallogenic province are compatible with deposition of the mesozonal-type system from deeply sourced fluids generated by the Late Jurassic Daebo orogeny.

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