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Origin and Evolution of Ore Fluid in the Wang'ershan Gold Deposit, Jiaodong, China

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1 Geological Setting and Mineralization

The Jiaodong peninsula is situated in the southeastern of the north China craton, and it defines China's largest gold province (Deng et al., 2006; Yang et al., 2014). The Wang'ershan gold deposit, occuring in the largest goldfield of the peninsula, is hosted by the Late Jurassic Linglong type biotite granite. As Jiaodong's largest proven gold deposit which is controlled by second order Wang'ershan fault belt, it develops both disseminated-stockwork and and quartz vein styles of mineralization. The four main gold orebodies locate in the silicatized or sericited granite, No.1 and No.5 orebodies are controled by the faults F1 and F5, respectively, No.3 and No.23 orebodies are controled by the secondary fractures of F1 and F5.

Four mineralization stages have been identified on the basis of characteristics of alteration and mineralization, and crosscutting relationships observed in the field, and structure, texture and mineral assemblages by petrography and ore microscopy observation. They include a pyrite-quartz- sericite stage (I), a quartz-pyrite stage (II), a quartz- polysulfide stage (III) and a quartz-carbonate stage (IV).

2 Fluid Inclusions Microthermometry

Eight samples from all the four mineralization stages were collected for fluid inclusion microthermometry. Three types of primary fluid inclusions in quartzs were identified, which are type 1 H_2O-CO_2, type 2 aqueous and type 3 CO_2 fluid inclusions.

The quartzs of stage I contain just type 1 primary inclusions, while the quartzs of stage II and III contain a large number of type 1 and 2 inclusions and rare type 3 inclusions. Only type 2 inclusions can be find in the quartzs of stage IV. A combination of the type 1 and 2 fluid inclusions occurring together within the same growth feature in the quartzs of stage II and III, constituting a fluid inclusion assemblage. Total homogenization temperature occurs about 300-350°C, 220-300°C, 200-280°C and 140-190°C in the four stages respectively, while mean salinities reduce in turn from ca. 5.82, through 4.12 and 3.52, to 3.05 eq. wt% NaCl.

3 Hydrogen and Oxygen Isotope Analysis

We collected twenty-six samples which cover all the four mineralization stages, two ore types and four ore bodies. The $\delta^{18}O_{V\text{-}SMOW}$ and $\delta D_{V\text{-}SMOW}$ (δD for short) of quartz from the samples were analyzed. Oxygen isotopic compositions of hydrothermal waters ($\delta^{18}O_{W\text{-}SMOW,}$ $\delta^{18}O$ for short) in equilibrium with quartz were calculated using the water-rock interaction equation from Clayton et al. (1972) and the equilibrium temperature of four stages (350° C, 254° C, 240° C and 190° C, see below in discussion).

From stage I to IV, mean δD vary from -62.2‰, through -62.5‰ and -66.5‰, to -65.6‰; and $\delta^{18}O$ vary from 4.6‰, through 0.47‰ and -0.4‰, to -4.4‰, respectively. The disseminated- stockwork type and quartz vein type ores show δD= -62.9‰, $\delta^{18}O$= 3.5‰; δD= -64.4‰, $\delta^{18}O$= -0.8‰, respectively. No.1, No.3, No. 5 and No. 23 orebodies show δD from -63.0‰, through -67.7‰ and -62.0‰, to -63.9‰; $\delta^{18}O$ from 0.5‰, through 1.5‰ and 0.1‰, to 1.4‰, respectively.

4 Discussion and Conclusions

In stage II and III, it's common that type 1 and 2 inclusions occur together within the same growth feature and have a similar total homogenization tempurature. Fluid boiling could likely take place at the same time

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(Ramboz et al., 1982). Thus it is reasonable to estimate $\delta^{18}O$ by taking the highest homogenization temperature in stage I and IV (350° C and 190° C) and the mean homogenization temperature in stage II and III (254°C and 240°C) as the approximate equilibrium temperature.

Rather than comparing the hydrogen and oxygen isotopic composition of the ore-forming fluid to the empirical composition of the typical natural water of different origin, it would be more persuasive to compare the ore-forming fluid to the regional fluids. Jiaodong Mesozoic meteoric water (δD= -120 to -110‰, $\delta^{18}O$= -16.2 to -15.0‰), metamorphic fluid of Jiaodong Group (δD= -83 to -41‰, $\delta^{18}O$= 9.2 to 10.6‰) or magmatic fluid of Linglong granite (δD= -58 to -36‰, $\delta^{18}O$= 6.7 to 8.7‰) and Guojialing granodiorite (δD= -92 to -62‰, $\delta^{18}O$= 8.5 to 10.1‰) may be an origin of ore-forming fluid in the Wang'ershan gold deposit. Comparison results show that metamorphic fluid or magmatic fluid of Linglong granite mixed with meteoric water may more likely be associated with mineralization. However, ore-forming fluid often experience a long distance migration, hydrogen and oxygen isotopic composition reflect not only the original hydrogen and oxygen isotopic compositions of fluid, but also the water-rock isotope exchange evolution (Yang et al., 2013). Based on water-rock isotope exchange evolutional curves (calculated using the mass balance equation from Taylor, 1974), we conclude that the ore-forming fluids mainly came from metamorphic fluid, meteoric water mixed in ore-forming fluids during the III and IV stage of mineralization.

The δD values show a decrease trend in general from deep to shallow in the vertical, thus isotope dynamic fractionation may likely happen during fluid boiling (e.g., Yang et al., 2009; Wang et al., 2014). The $\delta^{18}O$ values' horizontal change has obvious negative correlation relationship with the proven scale of orebodies. It is likely to show that the F_1 and F_5 fault are the main channels for meteoric water with low $\delta^{18}O$ value to infiltrate, and the mixed fluids flow along F_1 and F_5 and into secondary fractures of F_1 and F_5 synchronously.

In conclusion, decreasing of temperature and salinity, water-rock isotope exchange between ore-forming fluids and Linglong type biotite granite and fluid boiling triggered by decompression dominate the ore-forming fluid evolution process.

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