Geochemistry and Metallogenic Model of Ailaoshan Cenozoic Orogenic Gold Belt in Yunnan Province, China

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ABSTRACT

Located in the suture zone between the Indochina block and the Yangtze block, Ailaoshan tectonic zone is one of the most important tectonic and magmatic zones in the world. Some large-scale gold mines, i.e. Laowangzhai, Mojiang, Daping and Changan, have been found in the area, that it is regarded as a Cenozoic gold belt related to Ailaoshan ophiolite belt and lamprophyre dykes, and attracted many researchers to investigate it. But a lot of disputations are still existing on its mineralizing era, source of ore-forming fluid, mineralizing mechanics, and especially the role of crust-mantle interaction in the mineralization. Based on detailed field investigation and geochemical analysis of Ailaoshan gold belt, the following major conclusions are reached in the dissertation:

1. Although with different host rocks, the Laowangzhai, Mojiang, Daping and Changan gold deposits share many common characteristics, such as ore-controlled tectonics, wall-rock alteration and mineralization style, thus they are probably formed in the same tectonic event.

2. Based on detailed geochemical analsyse of wall rocks and ores in Mojiang Au-Ni mine, it's proposed that the ultramafic intrusions are ophiolitic harzburgite-orthopyroxenite and Ni-bearing Mg-rich ultramafite. The chert of the Jingchang Formation and the Au-bearing altered chert was formed by hydrothermal exhalative sedimentation and mineralization. The auriferous

quartz veins were closely related to the ultramafic intrusions but not to the chert, and formed in the environment of high water/rock ratio.

3. Detailed geochemical analyses of the trace elements in scheelite, the alteration in diorite host rock and REE compositions in the gold ore in Daping gold deposit show that diorite and other host rocks are intensively mylonitized. The scheelites are enriched with Sr, Ba, and depleted with Mo, Bi, Sn, Nb and Ta, and possess MREE-enriched and dextral-inclined chondrite-normalied patterns and variable positive Eu anomalies. Thus, it is suggested that the ore-forming fluid was probably a deep-derived with relative high temperature, CO_2 and Na^+ enriched and reducing hydrothermal system. The diorite probably provided part ore-forming matters to early ore-forming fluid by the water/rock reactions. The auriferous quartz veins was related to the regional ductile shear activity and formed in the condition of low water/rock ratio.

4. The (PGE+Au) compositions of Au-Ni ores and ultramafic intrusions in Mojiang Au-Ni deposit indicate that most of PGE in the ores derived from the ultramafic intrusions, the Mojiang is a composite deposit composed mainly of early stage magma-type Ni ores and late stage hydrothermal type Au-Ni ores. The ultramafic intrusions were formed by different ratios partial melting of a depleted mantle, and the primary ultramafic magma was S saturated. In addition, the platinum group elements(PGE) compositions of various gold ores and around rocks in Daping and Changan gold deposit indicate that the gold mineralization was closely related to the mafic dykes such as the lamprophyre formed by upper mantle partial melting, and the ore-forming materials derived mainly from the mantle but not from the diorite or syenite dykes.

5. The platinum group elements(PGE) compositions of the lamprophyres involved in Daping and Changan gold deposit indicate that they were formed probably by mantle partial melting and the primary magma was S saturated. Besides, the PGE compositions of the Changan lamprophyre dykes show their primary magma had been polluted by the crustal materials, which was probably resulted from different intruded depth with the Daping gold deposit.

6. Based on comparison of PGE compositions among different gold

mines, it's proposed that regional intensive crust-mantle interaction might played an important role in the large-scale mineralization in Ailaoshan gold belt. Besides, the ophiolitic ultramafic intrusions probably provided partly metal origin to some gold mine, such as Mojiang.

7. The fluid inclusions in gold veins in Daping gold mine are dominated by liquid CO_2 inclusions and CO_2-H_2O inclusions with variable ratios of CO_2/H_2O, and a lot of gaseous CO_2 inclusions and N_2-CO_2 inclusions are also found by Laser Raman spectroscopy in the scheelite-bearing quartz veins of the early mineralizing stage. On the contrast, liquid CO_2 inclusions predominate in massive polymetallic sulphide type gold ores. Microthermometer measure indicates that the early stage ore-forming fluid possesses salinities of 6.37~14.64wt%NaCl, homogenization temperature of 299.4℃~423.7℃, and pressure of about 190～440Mpa, and salinities 3.70 ~14.64wt%NaCl, homogenization temperature 279.0℃~406.5℃ with peak 320℃~360℃, and pressure of 133.5~340.0Mpa in the major ore-forming stage. These characteristics indicate that the ore-forming fluid is high-CO_2 ($CO_2 \geqslant H_2O$) and low to moderately saline CO_2-H_2O-NaCl system. The Daping gold deposit is a mesothermal gold deposit controlled by the ductile shear zone, and the mineralization was a rapid deposition process under pressure-descending and boiling condition, gold deposition was mainly caused by the phase separation of the high CO_2 fluid due to rapid pressure decline.

8. Laser Raman spectroscopy analyses found plentiful graphites solid inclusions with 1~5μm in size in the auriferous quartz veins in Daping gold mine . Based on D:O peak intensity ratios, these graphite inclusions formed at granulite-facies metamorphic temperature. Therefore, it is convinced that the metamorphic fluid from granulite-facies lower crust was concerned with the mineralization.

9. The carbon isotopic compositions ($\delta^{13}C$) of the CO_2 in the fuild inclusions in the sheelite-bearing quartz veins in Daping gold mine are mostly -3~-6‰, suggesting that the primitive mineralizing fluid derived predominantly from the upper mantle. Sr-Nd isotopic composition of the scheelites indicates

the primitive mineralizing fluid derived predominantly from the lower crust, but interfusion of the mantle-derived fluid could not be excluded. The He-Ar, Ne and Xe noble gases isotopic compositions of fluid inclusions in scheelites indicate that the ore-forming fluid was composed mainly of mantle-derived magmatic fluid and CO_2, ^{40}Ar, ^{134}Xe, ^{136}Xe and ^{4}He-enriched crustal fluid, and air-saturated water was nearly absent. Re/Os ratios of the ore minerals are quite high, varying between 6.36 to 121.67, and $\gamma Os(t)$ are 290.21~810.24, averaging 492.92. Besides, $^{187}Os/^{188}Os(t)$ of the ore minerals are 0.495~1.154, which are much higher than the initial $^{187}Os/^{188}Os$ ratio of chondrite (0.12679) at the gold metallogenic age(33.55Ma), implying that crust-derived radiogenic ^{187}Os might have been added during gold mineralization. Based on above abundant evidences about Daping gold mine, it's proposed that the ore-forming fluid was a mixture of the mantle-derived fluids formed by the upper mantle degassing and the CO_2-riching fluids from the lower crust released by dehydration and roasting triggered by the rising hot mantle magma's heat. Thus, the Daping is a typical shear zone controlled mesothermal gold deposit.

10. $^{40}Ar/^{39}Ar$ dating was performed on hydrothermal sericite collected from mylonitized and sericitized diorite host rock of the Daping gold deposit, which yielded a set of age data, i.e., plateau age of 33.76 ±0.65 Ma, inverse and normal isochronal ages of 33.55 ±0.74 Ma and 33.57 ±0.74 Ma, respectively. These age data are very similar to that (33~34Ma) of the lamprophyre dykes.

11. Common metallogenic features of the different gold deposits in Ailaoshan gold belt are summaried: the ore-forming stages was closely related to the regional intensive crust-mantle interaction; The major mineralization took place within 30~50Ma just after the major collision between the Indochina Block and the Yangtze Block in early of the Cenozoic Era; The orebodies are localized in the brittle faults or fault brecciated zones which were probably closely associated with Honghe shear zone; The ore-forming fluids are low to moderately saline CO_2-H_2O-NaCl system with little N_2; The ore-forming

temperatures and pressures are regularly inclined from Daping to Mojiang to Laowangzhai and to Changan, and the corresponding gold mineralization type changes from quartz vein type to quartz vein + brecciated and altered rock type to brecciated and altered rock type.

12. A metallogenic model of Ailaoshan gold belt is proposed: in early of the Cenozoic Era, the collision between the Indochina Block and the Eurasian Block caused lateral extrusion, and then large-scale sinistral strike-slip shear movement took place along Honghe shear zone. Upwelling of Moho and partial melted upper mantle caused by crustal extension and strong ductile deformation resulted in formation and intrusion of large amounts of lamprophyre dykes. The mantle-derived fluids formed by the upper mantle degassing and the CO_2-riching fluids from the lower crust released by dehydration and roasting triggered by the rising hot mantle magma's heat mixed and migrated up along micro-fractures in the shear zone. In ductile-brittle transform belt at about 10km depth, the later brittle fault triggered CO_2 and H_2S gas phase separation because the rapid temperature and pressure decline, and led to the complex $Au(HS)_2^-$ disassembling and precipitation of Au^0, and finally formed Daping type depth-derived mesothermal gold lode. In brittle-ductile or brittle deformation belt, the ascending CO_2 -enriched fluid will be mixed with meteoric water and the mineral matters from the wall rocks, i.e. Ailaoshan ophiolite belt, and finally deposited the ore minerals in the brittle structures or brecciated structures of the shear zone because of water-rock interaction and temperature and pressure decline, and formed Mojiang, Laowangzhai and Changan gold mines.

Key Words: Cenozoic orogenic gold belt, ductile shear zone, ophiolite, platinum group elements(PGE), granulite-facies graphites inclusions, CO_2 enriched fluid inclusions, noble gas isotope, crust-mantle interaction, gold metallogenic model, Ailaoshan