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Mineral Geochemical Characteristics and Indication Significance of Biotite - Rutile in the Gabbro Intrusions in the Yinmin Iron-Copper District, Yunnan

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1 Introduction

After the Dongchuan Orogenic movement (Hudsonian Orogeny, ca. 1800 Ma±), the tectonic basement layer of the continental crust on the Yangtze massif could have been formed. And then tectonic-magmatic emplacement events of the mantle upwelling occurred in the early Mesoproterozoic age (1750±50 Ma), resulted in the Yangtze massif split. Yunnan-Sichuan Mesoproterozoic rifted basin domain formed, developing the Dongchuan, Luwu, Yimen and Yuanjiang sedimentary basins (Fang weixuan, 2014). Yinmin Iron-copper deposit was located in the middle of Dongchuan sedimentary basins, where the Luoxue- Yinmin composite fold-fault belts with multiple stages was formed, accompanied by the NE-trending, NW-trending and SN-trending fractures, which were the rocks-control structure, as well as the passageway and location for gabbro intrusions (Liu wenjian and Liu weiming, 2010; Du yulong et al., 2014; Nie tian et al., 2014). The gabbro intrusions were emplaced into the Late Archean- early Proterozoic Xiaoliukou Association, as well as all the formations of the Middle Proterozoic Dongchuan Group, in the forms of rock wall, rock bed, rock strain and dike. Mineralization of Ti, Fe, Co, and REE, closely related to Ti-Fe-rich gabbro intrusions, was discovered at the depth of Xiaoliukou Association in the Yinmin Iron-copper district. It was thought to be the mineralization of titanium -iron -oxide copper gold type deposits (Roberts, 1983; Hitzman,1992). According to the field observation and microscope identification with EPMA, the multiphase mineralization was intensively distributed in the Ti-Fe-rich gabbro intrusions, with uralitization, biotitization, albitization, iron-dolomitization, chloritization, and Ti-mineralization. It might be most favourable for metallogenesis of IOCG (Fang weixuan, 2013, Du yulong et al., 2014). Based on the tectonic lithofacies mapping, the research of mineral-geochemistry of biotite, rutile, chlorite, and dolomite from the Ti-Fe-rich gabbro intrusions at the depths of Yinmin Iron-copper deposit were conducted in the paper. Finally, the metallogenic physicochemical environment was discussed and analysed.

2 Mineral-geochemical characteristics

2.1 Rutile

The rutiles were croci, and occured as small scattered grains, generally granular, and columnar crystals, or slabby, strip, and irregular polycrystalline. There were four types of rutile according to their lithofacies characteristics. (1) Rutiles had a symbiotic relationship with biotites, or were distributed in the biotite vein. (2) ilmenites completely or partly altered into rutiles, distributed on the biotites. (3) Rutiles were distributed in triangle framework formed by albite, and exhibted as residual solitary crystal as the alteration by ankerite, indicating that ankerite was detrimental to rutiles. (4) Rutiles were distributed in the fissure vein, which were speculated to be formed from Ti-rich hydrothermal fluids. According to the iron concentrastions, rutiles were of both magmatic origin and alternation genesis while the rutiles in triangle framework were magmatic origin, but altered by ankerite in the later period (zack et al., 2004).

2.2 Biotite

Biotites were brown, pleochromatic, and occured as

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schistose and irregular crystals. It could be observed that femic-magnesian minerals, such as pyroxene, amphibole, were almost completely altered into biotites, which were distributed in the triangle framework, exhibited as metasomatic relict texture. Biotites also occurred as veinlet, net vein, or massive polycrystalline. There were some titanium minerals on the biotites, showing that the biotitization was characterized by stronger oxidization property. According to the classification of the biotite and $10\times TiO_2$-(FeO + MnO)- MgO diagram, biotites might be divided into magmatogene Ti-rich Mg-biotites, hydrothermal Mg-biotites and Fe-biotites (Foster, 1960; Nachit et al., 2005).

2.3 Chlorites

Chlorites were widely spread in the gabbro intrusions, which had weak pleochroism, light green and green. They occurred as schistose, net vein, and irregular, or were distributed in the fissure vein. According to the diagram of Si-Fe (Deer, 1962), chlorites mainly belonged to pycnochlorites, and slightly ripidolites and prochlorites, combining with the Al/(Al+Fe+Mg) value, indicatded that the chlorites might be mainly altered from biotites and uralite in the reducing environment (Laird, 1988; Zang, 1995).

3. Metallogenic physicochemical condition and significance

The IOCG ore body was mainly located in the Ti-Fe-rich gabbro intrusions, which was not only the mother rock, but also the wall rock. The ore minerals were titanium minerals, such as titanomagnetite, ilmenite, rutile, and rare-earth minerals, pyrite, as well as chalcopyrite. Uralitization, biotitization, albitization, iron-dolomitization, chloritization, titanium mineralization were strong and widely spread, which were most correlative to metallogenesis, as a consequence, the metallogenic physicochemical environment could be studied by the research on the mineral-geochemical characteristic and formation conditions of rutiles, biotites, chlorites and dolomite.

(1) According to the Waston's model (Waston, 2006), the formation temperature of the rutile ranged from 444 to 1082℃, with the mean value 627℃. Based on the origin of rutiles, crystallization temperature of rutiles ranged from 821 to 1082℃, and alteration temperature ranged from 444 to 730℃，suggesting that rutiles formed in the high temperature and strong oxidizing environment. In addition, from the biotitization facies to dolomitization facies, the Nb value of rutiles decreased, but the V value and V/Nb ratio increased, manifesting further that rutiles formed in the environment with high oxygen fugacity (Liu et al., 2014), but under the influence of dolomitization, the oxygen fugacity lowered.

(2) According to the empirical formula of Henry and diagram of log fO_2-T (Henry et al., 2005; Wones and Eugster, 1965), the crystallization temperature of the magmatogene Ti-rich Mg-biotites ranged from 653℃ to 750℃, and oxygen fugacity was -13.6~-13. The alteration temperature of hydrothermal Mg-biotite ranged from 525 to 619℃, oxygen fugacity was -14~-2.5. The alteration of temperature of hydrothermal Fe-biotite ranged from 551 to 577℃, oxygen fugacity was -15.2~-14.6. The oxygen fugacity was near Ni-NiO line, indicating that biotites formed in the environment with high oxygen fugacity， which is conducive to the rutile mineralization. Besides, Biotites were characterized by high Ti concentrations and low Al concentrations, indicating further that biotites formed in the high temperature and strong oxidizing environment (Buddington and Lindsley, 1965; Albuquerque, 1973).

(3) According to the chlorite geothermometer of Battaglia (Battaglia, 1999), the alteration temperature of chlorites ranged from 174 to 243℃. Moreover, based on the Walshe's formula (Walshe, 1986), the oxygen fugacity was -44.68～-51.42, and sulphur fugacity was -14.42～-19.76. Therefore, chlorites had formed in the medium- low temperature and strong reduction environment.

In conclusion, the rutile and the biotite in the study area had a symbiotic relationship, and some rutiles were altered from biotites and ilmenites. Biotitization may be most favorable for the rutile for its high oxygen fugacity. The formation conditions of biotites and rutiles suggest that the stages of magmatic crystallization and the early hydrothermal alteration might have been characterized by high temperature and strong oxidizing geochemical lithofacies. Chloritization and dolomitization might superimpose on the biotitization facies in the later stage of hydrothermal alteration. Chlorite facies may mainly altered from biotites and uralites in the medium temperature and strong reducing environment, which might be benefit for the formations of copper and iron sulfides. The superposition and evolution of physical-chemical conditions contributed to the mineralization of the iron oxide copper gold type deposit. In addition, it may also be indirectly proved the superimposed metallogenic characteristics of IOCG type deposits (Fang weixuan, 2012).

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