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Mineralogy and Metallogeny of the Shilu Co-Cu Ore Deposit in Hainan Province of South China

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1 Introduction

The Shilu Fe-Co-Cu ore district, located in western Hainan Province of South China, is famous for its high grade hematite-rich ores (up to 69% for FeO). It also contains cobalt (av. grade 0.31% for Co metal), copper (av. grade 1.1% for Cu metal) and other polymetallic mineral resources. For the past decades, many researches have been carried out on metallogenesis and enrichment mechanism of the Fe ores (Hou et al., 2007; Xu et al., 2013, 2014 and references therein). However, less attention was paid to genesis of the Co-Cu ores. Also, there has been in debate on that whether metals Co and Cu were deposited simultaneously with metal Fe, or of a magma-related hydrothermal origin, or of multiple sources (for a comprehensive review see Xu et al., 2013). In this paper, the mineral component, texture, and mineral chemistry were reported to constrain the metallogenesis of the Co-Cu ores.

2 Ore Geology

The Shilu Fe-Co-Cu ore district is mainly hosted within Neoproterozoic Shilu Group, a suite of neritic siliciclastic and carbonate sedimentary succession generally with greenschist facies metamorphism. This lithostratigraphic unit was divided into six sequences. Among these, the upper sixth sequence is subdivided into three segments. The Fe- and Co-Cu metals are hosted within the middle and lower segments, respectively.

Both the Fe-, and Co-Cu orebodies are stratiform, stratiform-like, and/or lentoid, and mainly occur in troughs or transitional zones from limbs to troughs of the synclinorium. Spacially, the Fe ore layers mostly lie on the Co-Cu ore layers generally with an interval of about 30-60m. Co is present mainly as isomorphism in the lattices

of cobaltiferous pyrite/ pyrrhotite, and Cu as chalcopyrite. The Co-Cu ores indicate massive and banded structures, subordinately with veinlet- stockwork, disseminated and brecciated structures. Cryptocrystalline to microcrystalline, fine to coarse-grained, subhedral-anhedral, and Cataclastic textures are present in the Co-Cu ores. Sulfide minerals include pyrite, pyrrhotite and chalcopyrite, with minor glaucodot, cobaltite, linnaeite, siegenite, pentlandite, millerite, sphalerite and galena. The gangue minerals are dominated by quartz, dolomite, tremolite, diopside and potash feldspar.

Based on occurrence and mineralogical assemblages, four Co-Cu mineralizing stages, i.e. primary diagenetic sedimentation, structural-induced metamorphic enrichment, and early- and late magma- related hydrothermal overprinting, can be identified in the Shilu deposit.

3 Mineralogy of Co-Cu Ores

3.1 Primary diagenetic sedimentation stage

Because of extensive structural and magmatic activities, primary diagenetic sedimentation can be rarely reserved. Fortunately, the relicts of framboid aggregates which comprise fine euhedral pyrite microcrystals with size of 5-25 μm were identified. EPMA analyses reveal that the diagenetic pyrite, i.e. the first generation (PyI), is high in Co (0.60-1.55%, av. 0.91%) but low in As (0.14-0.40%, av. 0.26%) and Ni (<0.35%) contents. The contents of Ti, Ag, and Cr are all less than 0.1%.

3.2 Structural-induced metamorphic enrichment stage

After deposition, Shilu area underwent two stages of structural deformation (Xu et al., 2013). D₁-deformation resulted in a NW-trending synclinorium, accompanying regional S₁ foliation and generally greenschist-facies (locally up to amphibolite-facies) metamorphism. This

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early deformation (D_1) likely induced recrystallization of diagenetic pyrite (PyI). As a result, this generation of pyrite (i.e. PyII) occurs as aggregates composed of 0.1-0.3 mm, euhedral crystals, and shows structural overprinting as indicated by presence as an alignment parallel to S_1 and a cataclastic texture. Chemically, PyII has higher but variable Co (0.23-2.39%, mainly 1-2%), As (0.22-0.66%, av. 0.40%) and Ni (0-1.23%, av. 0.37%) contents when Compared with PyI.

3.3 Early magmatic-hydrothermal overprinting stage

This stage led to large amounts of sulfide minerals which comprise cobaltiferous pyrite (the third generation, PyIII) / pyrrhotite, and chalcopyrite, with minor glaucodot, cobaltite, linnaeite, siegenite, pentlandite, and millerite. Pyrrhotite and chalcopyrite commonly occur as aggregates and intergrew with each other. They were filled in between quartz, dolomite, calcite, tremolite grains or in pyrite fissures, and sometimes distributed around quartz or dolomite/calcite breccias, showing interstitial texture. PyIII presences as euhedral to subhedral grain, and sometimes grew as the rim surrounding the core of glaucodot or cobaltite, indicating a concentration gradient for ore-forming hydrothermal fluids along with decreasing temperature. Pyrite formed in this stage has the highest Co and As contents, mainly ranging from 1.20-8.92% and 0.55-7.32% respectively, but low Ni content ($<0.5\%$). The Co content is also high in pyrrhotite (0.20-0.75%). The high Co/Ni ratios (3.09-654.71, av. 91.34) are similar to the feature of magma-related hydrothermal pyrites. Therefore, this stage likely was associated with the emplacement of the Indosinian to Early Yanshanian granites due to the closure of the Paleo-Tethyan Ocean, and is the main Co-Cu mineralizing stage in Shilu district.

3.4 Late magmatic-hydrothermal overprinting stage

This stage is characterized by occurrences of various pyrite-dominated veins, pyrite + pyrrhotite veins, pyrite+chalcopyrite veins, and lead-zinc veins, which generally cut across the earlier Fe- and Co-Cu orebodies. Mineral association includes pyrite (the fourth generation, PyIV),

chalcopyrite, galena, sphalerite, quartz, and calcite. PyIV occurs as subhedral to euhedral grains with little Co and Ni contents ($<0.1\%$). This mineralized stage was likely related to Late Yanshanian magmatic intrusion due to subduction of the paleo-Pacific plate.

4 Conclusion

Similar to Fe mineralization, Shilu Co-Cu ores also underwent multi-stage ore-forming process. The Shilu Fe-Co-Cu ore deposit is regarded as a polygenetic compound ore deposit reworked by structure and hydrothermal fluids.

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