Properties and Evolution of Ore-forming Fluid in Continental Sandstone-type Copper Deposit: a Case Study from Liuju and Haojiahe Deposits in Chuxiong Redbed basin in Yunnan Province, China

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1 Introduction

Liuju and Haojiahe copper deposits, which located in the Chuxiong Cretaceous red bed basin, Yunnan, China, are two typical continental sandstone-type deposits and attributable to the sedimentary-diagenesis-reworked type of deposits.

Orebodies of these two deposits, hosted in a set of medium- and fine-grained feldspar-quartz sandstone of Upper Cretaceous, are located in the interface between purple bed and grey bed, sandwiched between two purple silty mudstones. Besides, there coexist a horizontal metallic mineral zonation in this transitional zone from purple sandstone to grey sandstone: hematite, chalcocite, bornite, chalcopyrite and pyrite.

Two different types of ore occurred in both two deposits: disseminated or laminated ores and banded or veined ores. The ores with the former fabric were mainly located in the stratiform or stratoid orebodies within medium- and fine-grained sandstone in the flanks and core of folds(Fig. 1A). While, the latter fabric of ores were located in or nearby the the fractures or joints, and the grade of which is much higher than the former. The highest grade of veined ores at Haojiahe deposit even exceed 20%(Fig. 1B).

The two types of ore at Liuju and Haojiahe deposits respectively represent two typical mineralization process of sandstone-type copper deposits in this area, that was diagenesis period and tectonic-reworked period(Ran et al., 1998).

2 Fluid inclusion characteristics

Corresponding to the two mineralization process, fluid inclusions of two dominant periods were captured in the minerals of these two types of ore, which had recorded the special fluid properties and unique environmental conditions.

The fluid inclusions of diagenesis period in these two deposits, which can be observed in calcite and quartz

Fig. 1 Specimens of ores showing different mineralization periods at Liuju and Haojiahe deposits
A: Disseminated chalcocitization occurred in bedded orebody (Cu grade:0.9%). B: Veined ore occurred in fracture (Cu grade:23.3%).
cement and secondary enlargement of quartz from disseminated and laminated ores of bedded orebodies, were in the similar characteristics. There are mainly pure liquid inclusions, gas-liquid inclusions with rich liquid and some petroleum inclusions in this period. While, the fluid inclusions of tectonic-reworked period, mainly were pure liquid inclusions, gas-liquid inclusions with rich liquid and a few fluid inclusions of rich CO₂, were captured in quartz or calcite paragenetic with copper minerals from banded or veined ores. The features of petrographic observation above were confirmed by the laser raman spectroscopy test.

3 Ore-forming Fluid Properties

From diagenesis to tectonic-reworked period, the homogenization temperatures of both deposits were increasing changes; while the salinities went just opposite, both deposits of which decreased respectively. The homogenization temperatures of two periods were below 250°C, and the salinities never exceeded 20wt% NaCl eqv (Table 1). Generally, ore-forming fluid of two stages were basin brine with medium-low temperature and medium-low salinity. Besides, there were also some differences of the fluid components. The fluid evolution had experienced a trend as follows: gas components changed from reducing organic-rich end-member(CH₄) to relatively oxidizing end-member (CO₂) of N₂-CH₄-CO₂ triangular diagram; meanwhile, the ionic components changed from the rich SO₄²⁻-Ca²⁺-K⁺ type to the rich Cl⁻-Na⁺ type(Table 1). Ore-forming fluid with different properties played a different role in the mineralization process of bedded orebodies and veined orebodies.

4 Discussion on Ore-forming Fluid Evolution

From the studies we can see that, the evolution of ore-forming fluid during the diagenesis and reworked periods in both deposits have experienced increasing temperatures, decreasing salinities and an environmental change from reducing to relative oxidizing. In addition, this two deposits have similar characteristics of fluid inclusions of the diagenesis period, including homogenization temperatures, salinities and gas components. But for those in fluid inclusions of tectonic-reworked period, the homogenization temperatures at Haojiahe deposit are much higher than that at Liuju deposit (Table 1). Which was consistent with the geological facts that Haojiahe deposit had experienced more intensive tectonic reworked metallization than that at Liuju deposit and leaded to higher grade veined ores in the fracture.

The stratiform and stratoid orebodies occurred in the sandstone formed by movement of oxidized, copper-bearing fluids across a reduction front that resulted in the precipitation of copper sulfides (Hitzman et al., 2010). The alkaline oxidizing fluid in the purple sandstone and the acid reducing fluid from grey stone could form stable convection in the fluid migration channel of sandstone with high porosity and permeability. Under the control of pH and Eh, the metallic mineral zonation of hematite, chalcocite, bornite, chalcopyrite and pyrite formed in the sandstone strata from purple part to grey part. While the veined ores occurred in fracture were the coupling results of ore source, tectonic and ore-forming fluid in reworked period (Han et al., 2010). The tectonic reconstruction was the reson resulted in the mineralization of vein-type ore bodies in the faulting zone.

5 Conclusions

In conclusion, the metallogenic mechanism of sandstone-type of copper deposits in Chuxiong basin was

<table>
<thead>
<tr>
<th>Period</th>
<th>Diagenesis</th>
<th>T(h) Range(℃)</th>
<th>Salinity Range(wt% NaCl eqv)</th>
<th>Gas component</th>
<th>Redox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liuju</td>
<td>96~147</td>
<td>5.3~16.9</td>
<td>0.49~0.78</td>
<td>H₂O, CH₄</td>
<td>reducing</td>
</tr>
<tr>
<td>Haojiahe</td>
<td>84~162</td>
<td>3.3~14</td>
<td>—</td>
<td>H₂O, CH₄</td>
<td>reducing</td>
</tr>
<tr>
<td>T(c)</td>
<td>131</td>
<td>10.2</td>
<td>0.03~0.11</td>
<td>H₂O, CO₂, N₂</td>
<td>reducing</td>
</tr>
<tr>
<td></td>
<td>138</td>
<td>7.5</td>
<td>0.005~0.026</td>
<td>H₂O, CO₂</td>
<td>reducing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>oxidizing</td>
</tr>
</tbody>
</table>

Test equipments: T(h), salinity: Linkam THMSG600; Gas, Liquid component: Quadrupole Mass Spectrometer & Ion Chromatograph.
a evolutionary process from the diagenetic preconcentration to further enrichment in tectonic reworked period. The precipitation of copper sulfides at the interface between purple bed and grey bed was the result of the mixing action of the oxidizing, alkaline and copper-bearing fluids and the reducing, organic-rich and sulfur-bearing fluids in the sandstone stratum with high permeability, which formed the disseminated or laminated ores. while, the further evolution of reworked period formed the high-grade banded, veined ores, which is controlled by the orefield tectonic.

Acknowledgements

This research project was jointly funded by the Funds for main program of the NNSF (U1133602), Specialized Research Fund for the Doctoral Program of Higher Education (20115314110010), Special Exploration Program for National Crisis Mines (20089943), and Yunnan province and KMUST Innovation Team Project (2010, 2008).

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