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Fluid Inclusion and Stable Isotope Studies on Kangjiawan Pb-Zn-Au-Ag Deposit, Hunan Province, South China

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1 Introduction

The South China Block is composed of the Cathaysia plate in the southeast and the Yangtze plate in the northwest. Their junction zone, the Qinhang (or Shihang) belt, is an important W-Sn and Cu-Au-Pb-Zn-Ag metallogenic belt in South China (Mao et al, 2011). Kangjiawan Pb-Zn-Au-Ag deposit, as the fourth largest Pb-Zn deposit of China, is situated in the middle part of the Qinhang belt.

Kangjiawan Pb-Zn-Au-Ag deposit is a representative hydrothermal deposit. Previous researches mainly discussed its geologic features and deposit type (Liu, 1996; Xu et al, 2002). However, the ore-forming genesis and mineralization mechanism remain unclear. In this study, we focus on the ore-forming temperature, pressure, depth and ore-forming material and fluid source of the deposit by microthermometry of fluid inclusions and stable isotopic analyses.

2 Geological Setting and Deposit Geology

Kangjiawan Pb-Zn-Au-Ag deposit, located in the city of Changning, Hunan Province, South China, is an important part of Shuikoushan Pb-Zn polymetallic ore field. It has metal reserves with approximately 220, 000 tons Pb, 240,000 tons Zn, 750,000 tons sulfur, 2 tons Au and 15 tons Ag.

The exposed strata in this area are mainly a series of shallow marine clastic-carbonate sedimentary formation from Devonian to Cretaceous. NE- and NNE-trending faults and fold structures were well developed. The igneous rocks occurring in the ore field mainly include Shuikoushan granodiorite, Laomengshan rhyodacite, Xinmengshan dacite porphyry and Xianrenyan granodiorite porphyry, yielding zircon U-Pb ages between

152.0 Ma and 157.3 Ma (Fig. 1).

Ore bodies of Kangjiawan Pb-Zn-Au-Ag deposit occur in the silicified breccias between the Permian Dangchong Formation marlstone and Qixia Formation limestone in a thrust nappe fault. Ore minerals in this deposit are mainly galena, sphalerite and pyrite, with minor amounts of chalcopyrite, pyrrhotine, native gold and native silver. Gangue minerals in the ores are predominantly quartz and calcite, with trace amounts of chalcedony, fluorite and barite.

Based on the analyses of mineral assemblages and vein crosscut relationships, three stages of mineralization can be identified: pyrite-quartz stage (stage I), galena-sphalerite-quartz stage (stage II) and sulfide-carbonate stage (stage III).

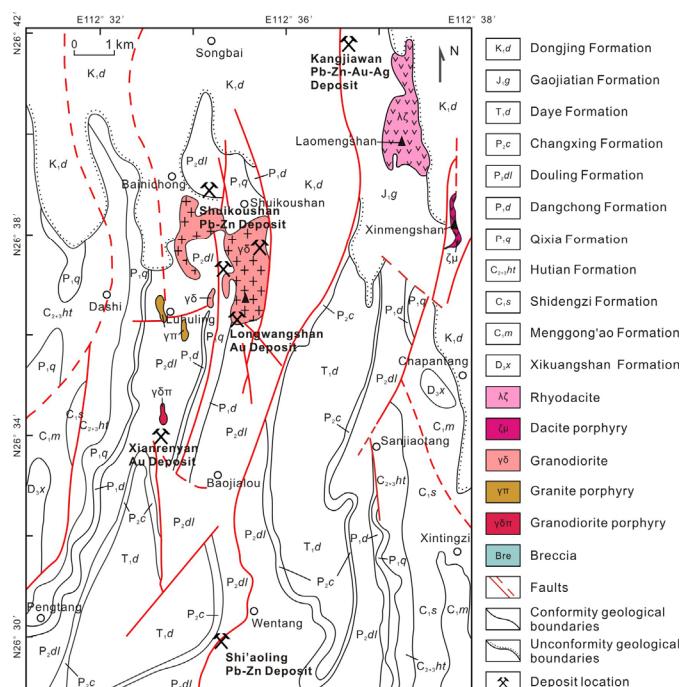


Fig. 1 Geological map of Shuikoushan Pb-Zn polymetallic ore field

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3 Results and Discussion

3.1 Fluid inclusion

Fluid inclusion data are obtained by analyses for quartz samples of the three stages collected from No.9, 11 and 12 sections. Homogenization temperatures (T_h) and temperatures of final ice melting were measured in 130 primary fluid inclusions from 21 thin sections.

Three types of fluid inclusions were observed in this study: liquid-rich two-phase inclusions consisting of liquid and a vapor bubble that occupied less than 30 % of the inclusion volume (the most abundant type), vapor-rich two-phase inclusions containing liquid and a vapor bubble occupying more than 50 % of the inclusion volume (trace amount) and three-phase inclusions containing liquid water, liquid CO₂ and vapor (rare). Absence of daughter mineral in any inclusions and rarity of vapor-rich two-phased inclusions indicates that the fluid “mixing” effect was dominant during the ore-forming process (Shepherd and Rankin, 1985).

The T_h peak values of the three stages are: stage I ranging from 300°C to 320°C, stage II within the temperature range of 120°C to 160°C and stage III from 100°C to 120°C, demonstrating the cooling of hydrothermal fluid with time.

Studies of the salinity of inclusions in quartz indicate that the salt contents of the ore solutions ranged erratically from 1 to 18 equivalent weight percent NaCl (%NaCl eq) during stage I, from 0 to 19 %NaCl eq during stage II and from 9 to 14 %NaCl eq during stage III.

Calculation of the pressure regime during ore precipitation based on the inclusion data indicate the mineralization depths of approximately 1,000 m below surface, implying that Kangjiawan deposit is an epithermal deposit.

3.2 Stable isotope

The δD values from inclusions in quartz range from -60 ‰ to -68 ‰, within the range of the magmatic water. The δ¹⁸O values range from -3.5 ‰ to -5.7 ‰, which are lower than that of the magmatic water, indicating that the ore-forming fluid was derived by mixing of magmatic hydrothermal fluid and meteoric water (Taylor, 1979).

The carbon isotope data on the hydrothermal calcite and limestone in Kangjiawan deposit show that the δ¹³C values of the hydrothermal fluids range from -10.5 ‰ to -17.8 ‰ and the limestone range from -13.8 ‰ to -18.7 ‰. The identical δ¹³C data are probably due to contribution of carbon from limestone to the hydrothermal fluids.

The δ³⁴S values of the sulfide minerals fall in a narrow range of -4.3 ‰ to 2.1 ‰ (averaging -0.81 ‰), suggesting a single sulfur source (Ohmoto and Rye, 1979). These

δ³⁴S values approximate to those of granitic rocks but distinctly different from sedimentary rocks (Hoefs, 1980), supporting sulfur of a granitic magma origin.

Pb isotopic data are obtained from galena, sphalerite and pyrite. The ²⁰⁶Pb/²⁰⁴Pb, ²⁰⁷Pb/²⁰⁴Pb and ²⁰⁸Pb/²⁰⁴Pb ratios are within the range of 18.427-18.573, 15.656-15.710 and 38.657-38.964 respectively, indicating the Pb of Kangjiawan was derived from the upper crust (Zartman and Doe, 1981).

4 Conclusions

Kangjiawan Pb-Zn-Au-Ag deposit is an epithermal deposit mineralizing at relatively low temperature at depths of approximately 1,000 m below surface. The metals and sulfur were most probably derived from a granitic magma, while the ore-forming solutions were derived by the mixing of magmatic hydrothermal fluid and meteoric water. The carbon was mainly derived from limestone. The mixing of the magmatic water and the meteoric precipitation was the predominant mineralization mechanism during the ore-forming process.

Acknowledgements

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