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The Evolution of Ore-forming Fluid of Maoping Lead-Zinc Deposit, Zhaotong in Northeast Yunnan: the Evidence of Sphalerite-hosted Fluid Inclusions

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1 Introduction

The Maoping zinc-lead deposit is one of the typical zinc-lead deposits in Northeast Yunnan District, located in the sagged Yunnan basin at the middle end of the Yangtze platform. This district has been the focus of extensive and intensive research for more than 40 years on its geology, geochemistry, geochronology, tectonics, ore-genesis and ore-prospecting. As ore-prospecting on deep orebody at recent years, the deposit has been a large-type one in this district.

Prior to this study, many papers have been published on ore-prospecting, geology, tectonics, fluid inclusion studies of the Maoping lead-zinc deposit (Zou et al., 2004; Han et al., 2007; Hu et al., 2003; Hu Bin, 2004; Wang et al., 2009; Shentu et al., 2011). The fluid inclusion study was restricted to quartz, dolomite and calcite which paragenetic with ore minerals (Han et al., 2007).

2 Outline of Geological Setting and Mineralogy of the Deposit

The Maoping lead-zinc deposit occurs in upper Devonian and lower-middle Carboniferous carbonate formation. The orebodies are strictly controlled by structure. The main ore minerals are sphalerite, pyrite, galena, and the gangue minerals include quartz, calcite, and dolomite. The ore structures are massive structure, disseminated structure, brecciated structure, mesh-vein structure. the texture of ore minerals are euhedralxeno-morphic granular , metasomatic texture, edge shared texture, intersertal texture. The No. I-6 orebody is the largest and is lenticular in shape, hosted by the upper Devonian carbonate formation.

Based on the observation of hand specimens and petrographic study, four main ore-forming stages and associated mineral assemblages have been identified at the deposit mainly depending on the grain size, texture, and paragenetic relationships. Four main stages include: (I) Pyrite-Sphalerite stage; (II) Sphalerite-Galena stage; (III) Galena-Sphalerite stage; (IV) Pyrite-Carbonate stage. Sphalerite is divided into three generations: (a) brown-red-brown sphalerite; (b) orange sphalerite; (c) light yellow sphalerite.

3 Fluid Inclusion Petrography

There are abundant fluid inclusions sphalerite-hosted used in this study on fluid-inclusion petrography. Based on the Roedder (1984), there were five types of fluid inclusions in sphalerite from the the deposit can be observed: a) pure gaseous inclusions, show a size variation from 1 to 8 μm, occurring in clusters, in isolation; b) pure liquid inclusions, are from 2 to 9 μm, occurring in clusters, in isolation, along growth zones; c) gas-liquid inclusions with liquid-rich, rang in size from 2 to 10 μm, occurring in clusters, in isolation; d) gas-liquid inclusions with gas-rich; and f) three-phase inclusion containing carbon dioxide, the length is 7 μm, occurring in isolation.

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4 Result

The homogenization temperatures of fluid inclusions in sphalerite ranges from 100℃ to 345℃, which have two change temperature sectors obviously, 150~200℃ and 250~345℃. The salinities of fluid inclusions range from 1.06 wt%$_{NaCleq}$ to 18.04 wt%$_{NaCleq}$, and have two change sectors, (1~13) wt%$_{NaCleq}$ and (13~20) wt%NaCleq. For calcite, homogenization temperature ranges from 164℃ to 221℃ and salinity ranges from 6.6 wt%$_{NaCleq}$ to 12 wt% $_{NaCleq}$.

1) Pyrite-Sphalerite stage: the distribution ranged between 169℃ and 351 ℃, with peak range from 200 ~ 215 ℃, and 260 ~ 300 ℃, showing the high temperature fluid characteristics, significantly different from the other stages of homogenization temperature unique features; salinity distribution in the variations from 4.4 wt%$_{NaCleq}$ to 18wt%$_{NaCleq}$, the peak from 9 wt%$_{NaCleq}$ to 11 wt%$_{NaCleq}$, with an average of 10.6 wt%$_{NaCleq}$, shown the features of moderate salinity and high-moderate homogenization fluid;

2) Sphalerite-Galena stage: the distribution of homogenization between 142℃ and 277 ℃, the main peak ranges from 170℃ to 185 ℃, with an average of 180.7 ℃; Salinity distribution range of (5.2~ 18) wt%$_{NaCleq}$, the main peak of (10 ~ 11.5) wt%$_{NaCleq}$, showed the features of moderate temperature and moderate salinity fluid.

3) Galena-Sphalerite stage: interval of homogenization is 104℃ to 173 ℃, the main peak of homogenization ranged from 140℃ to 165 ℃, with an average of 146 ℃; Salinity distribution ranges from 0.8 wt%$_{NaCleq}$ to 19.2wt% $_{NaCleq}$ with an obvious peak between 10 and 18 wt%$_{NaCleq}$, an average of 11.7 wt%$_{NaCleq}$; revealed low temperature and moderate-low salinity fluid properties.

4) Pyrite-Carbonate stage: the distribution of homogenization between 73℃ and 171℃, the main peak ranges from 100℃ to 125℃, with an average of 123℃; The interval of salinity ranged from 1.5 wt%$_{NaCleq}$ to 18.8 wt%$_{NaCleq}$, the main peak between 5 wt%$_{NaCleq}$ and 11 wt% $_{NaCleq}$, with an average of 9.1 wt%$_{NaCleq}$, uncovered that low temperature - low salinity fluid properties.

5 Discussion

The charactics of ore-forming fluid are: 1) The relationship between homogenization temperature and salinity of fluid inclusions sphalerite-hosted is that the early generations of sphalerite mainly from deep source fluid with moderate-high temperature and moderate salinity features; 2) the evlution of ore-forming fluid from the early generations to late generations in sphalerite is pure cooling (Fig 1); 3) the salinities have a multi-peak,

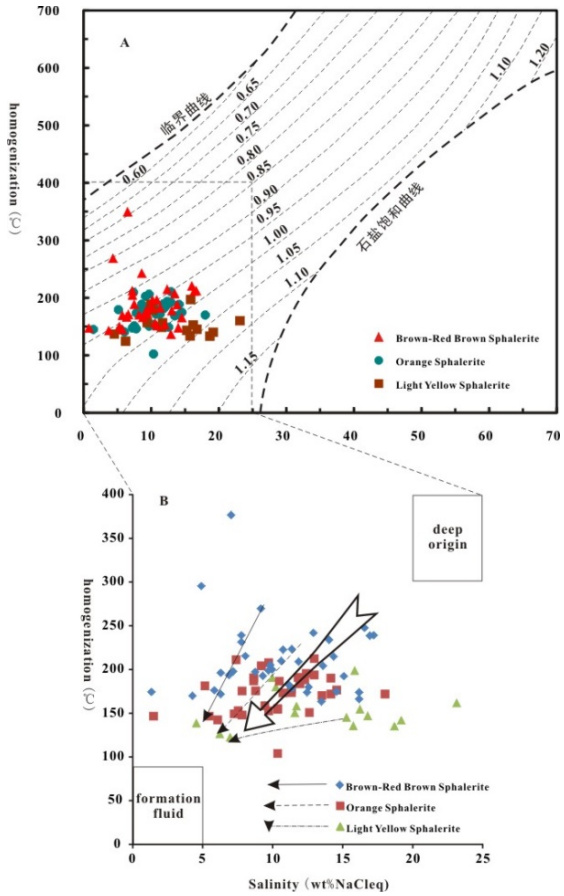

Fig.1 Scatter diagram of homogenization temperature and salinity of fluid inclusions sphalerite-hosted

when uniform homogenization near 150 ℃, showing that discrete distribution of salinities is an siginature of multiple sources of fluid mixed; 4) the densities are concentrated between 0.95 and 1.05 g/cm^3, most of them is below the density of water showed that low-density of fluid characteristics, especially hosted in the early generations sphalerite. Compare with gangue mineral, fluid inclusions in sphalerite contains more information of ore-forming fluid. The NIR (near-infrared light) micro-thermometric technique has provided an ideal method to study the ore-forming fluid of Zn-Pb deposit.

High concentration of Ca^{2+}- Na^+ - K^+ -Cl^-- SO_4^{2-} in fluid inclusion indicate that fluid could interact with Ca^{2+}- and K^+-rich fluids. The Na/K ratio ranges from 0.32 to 9.25, with an average of 4.52. It is higher than magmatic hydrothermal, but less than MVT lead-zinc deposits. The ratio of Ca^{2+}/Mg^{2+} vary 1.38 to 55.85 with an average of 29.34, which is higher than MVT lead-zinc deposits, indicated that ore-forming fluid is different from oilfield brines fluid system of MVT lead-zinc deposits. The average of Na^+/K^+ ratio in fluid inclusion of sphalerite, calcite, barite and quartz are 2.99, 5.02, 16.32 and 5.02 respectively. The average of Ca^{2+}/Mg^{2+} ratio in fluid inclusion of sphalerite, calcite, barite and quartz are 34.57,

28.73, 27.30 and 24.17 respectively. It shows that Ca increased and Na decreased in the ore-forming process.

In conclusion, the fluid system of the Maoping lead-zinc deposit was Ca^{2+}-Na^{+}-Cl^{-}-SO_4^{2-}, also controlled the alterration rocks cagateges in deposit. The metallogenic mechanism of Maoping deposit was accompanied the sulfide fluid reactive with the hosted rocks which was unique cooling, and unloaded under the weak acid- weak alkali environment.

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