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Characteristics of the ore-forming fluid in the Huayuan Pb-Zn ore filed, Northwest of Hunan Province, China

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1 Geological Setting

The Huayuan Pb-Zn ore field in Xiangxi is located in the southeastern margin of the Yangtze block and the mid-segment of the West Hunan-West Hubei metallogenic belt. The exposed stratum are the lower Cambrian Shipai Formation calcareous and silty shale, Qingxudong Formation dolomite(upper section) and limestone (lower section), the middle Cambrian Gaotai Formation argillaceous dolomite and the middle-upper Cambrian Loushanguan Formation dolarenite. The structure is mainly NE-NEE trending faults, such as the Huayuan-Zhangjiajie fault, the Lianghe-Changle fault and the Malichang fault, which are main rock-, ore- and facies-controlling structures (Peng, 1986).

Ore bodies in the Huayuan Pb-Zn ore files are hosted in algal limestone of the third submemeber, sand limestone of the fourth submemeber of the Lower Cambrian Qingxudong formation. The morphology of ore bodies is mainly layered and secondly veinlet. Mineral composition is simple, the metallic minerals are sphalerite, galena and little pyrite, the nonmetallic minerals are calcite, dolomite and a bit of barite, fluorite and asphalt. The ore textures are mainly subhedral to euhedral granular, and a small amount of metasomatic, inclusion and interstitial textures; the structures are mainly piebald, veinlet and disseminated secondarily. In addition, there are banded, spherulite, breccia and miarolitic structures. Hydrothermal-metallogenic period in the Huayuan Pb-Zn ore filed is divided into three stages: pyrite-sphalerite-dolomite-calcite-(fluorite) stage (I), pyrite-galena-sphalerite-calcite-barite-fluorite stage (II) and (sphalerite)-galena-calcite stage (III). The stage II is the main mineralizing event, followed by the stage I.

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2 Characteristics of Fluid Inclusions

2.1 Petrography

The primary fluid inclusions are not well developed, and most of them are two-phase type inclusions, which occur as isolated and random clustered in minerals. They are of ellipsoid and irregular shapes, and are 2 to 18 μm in size. According to the vapor-liquid ratios at room temperatures, primary two-phase inclusions can be generally divided into two subtypes: liquid-rich type (homogenization to a liquid phase with vapor commonly 15-35 vol.%) and vapor-rich type (homogenization to a vapor phase with vapor 55-85 vol.%).

2.2 Microthermometry

Stage I: fluid inclusions in sphalerite have homogenization temperatures from 187 to 256℃, mainly in 220 to 250℃, and salinities in the range of 15.0-18.5(wt.% NaCl), mainly in 16.5-18.5(wt.% NaCl); fluid inclusions in calcite have homogenization temperatures from 219 to 313℃, mainly in 220 to 250℃ and 270 to 300℃, and salinities in the range of 15.2-21.6(wt.% NaCl), mainly in 17.0-20.0(wt.% NaCl).

Stage II: fluid inclusions in sphalerite have homogenization temperatures from 158 to 239℃, mainly in 180 to 220℃, and salinities in the range of 13.8-17.2(wt.% NaCl), mainly in 15.0-16.5(wt.% NaCl); fluid inclusions in calcite, barite and fluorite have homogenization temperatures from 146 to 248℃, mainly in 180 to 230℃, and salinities in the range of 14.2-19.1(wt.% NaCl), mainly in 14.5-16.5(wt.% NaCl).

Stage III: fluid inclusions in sphalerite have homogenization temperatures from 94 to 192℃, mainly in 150 to 180℃, and salinities in the range of 10.9-14.0(wt.% NaCl), mainly in 11.0-13.0(wt.% NaCl); fluid inclusions in calcite have homogenization temperatures from 122 to 204℃, mainly in 150 to 180℃, and salinities in the range of 10.6-13.6 (wt.% NaCl), mainly in 11.0-12.5 (wt.% NaCl).

2.3 Laser Raman spectra

The testing results of Laser Raman indicate that, the vapor composition of stage I inclusions are mainly H_2O, small amounts of CH_4 and tiny amounts of H_2S. Stage II inclusions are dominated by H_2O, CH_4 and H_2S vapor component with tiny amounts of CO, N_2 and SO_2. Stage III inclusions are characterised by H_2O, and the CH_4 and H_2S are absent. The content of CH_4 and H_2S in the stage II inclusions are higher than that in the stage I, while the stage III inclusions almost do not contain CH_4, which indicated that the content of the reductive gas phase component in the ore-forming fluid increases first and then decreases.

3 REE Characteristics of Calcite

The total REE concentrations of calcites in stage I range from 1.73 to 10.94 ppm, average 4.77 ppm; the LREE/HREE ratios range from 6.21 to 10.19, average 7.96; δEu values range from 0.54 to 1.29, with no obvious abnormality; δCe values range from 0.61 to 1.05, average 0.87. The calcites in stage II have total REE contents ranging from 24.53 to 67.88 ppm (average 46.71 ppm), LREE/HREE ratios ranging from 11.19 to 19.85 (average 16.62), δEu values ranging from 0.46 to 0.84 (average 0.67), δCe values ranging from 1.05 to 1.09 (average 1.07). The total REE contents of calcites in stage I are similar with ores, wall rock and roof and floor stratas, less than stage II calcites, and significantly less than the stratas under the Qingxudong Formation.

4 Discussion and Conclusion

(1) The ore-forming fluids of the Huayuan ore field is a moderate-low-temperature, moderate-high salinity, weak reducing fluid system with multiple metallic cations and organics featured by CH_4, which is a $NaCl-MgCl_2-H_2O$ fluid system with $CaCl_2$ in stage I and II and a $NaCl-H_2O$ fluid system in stage III.

(2) The salinities of fluid inclusions decline with the decreasing homogenization temperatures from stage I to II, and they exhibit an obviously strong linear correlation, which indicative of fluid mixing (Wilkinson, 2001). The homogenization temperatures and salinities display a dramatic decline at the stage III, characterized by dispersed data points and a weaker correlation than the former stages, suggestting the ore-forming fluids might have meteoric water mixed in (Liu and Zheng, 2000).

(3) Calcites (I) have low total REE concentrations, which is similar to those of wall rock; calcites (II) have high total REE concentrations, which lie between those of wall rock and those of underlying stratas (Fig. 1). These suggest that the ore-forming fluids of stages I and II are mainly connate water in the ore-hosting strata, maybe with deep-source circular brine mixed in, and mainly deep-source circular brine, maybe with meteoric water mixed in, respectively.

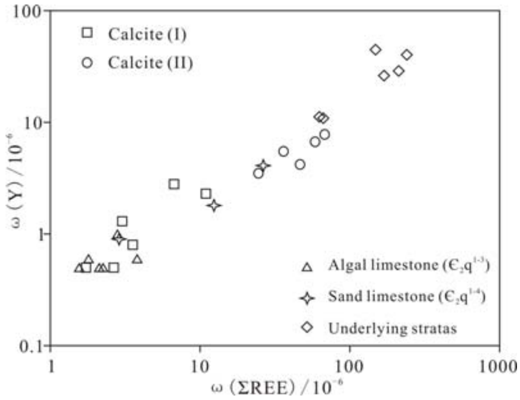

Fig. 1 Y versus ΣREE content from the Huayuan Pb-Zn ore filed

(4) Calcites (I) is featured by unremarkable anomaly of Eu and slightly negative anomaly of Ce have been observed. Calcites (II) is characterized by remarkable negative anomaly of Eu and slightly positive anomaly of Ce. These indicate that the ore-forming environment gets stronger reducibility at II compared with stage I, which is confirmed the laser Raman micro-analysis on the vapor phase composition of fluid inclusions.

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