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Isotope Geochemical Evidence of Ore-forming Sulfur Sources in the Laoyingqing Lead-Zinc Deposit Ore-hosted at Carbonaceous Slate in the Kunyang Group, Northeastern Yunnan

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The Northeastern Yunnan Zn-Pb Deposit Concentration District (NEYD), which is in the combination of the SN-trending Xiaojiang deep fault zone and the Zhaotong-Qujing concealed deep fault zone, and the NE-trending Mile-Shizong fault zone and the NW-teending Ziyun-Yadu fault zone, is located in the south-central part of the Sichuan-Yunnan-Guizhou Triangle area (SYGT) in the southwestern margin of the Yangtze Block. In recent years, many scholars have done no less research on ore materials and fluids origins, genesis, and metallogenic mechanism of lead-zinc deposits, and obtained important achievements, but there is still controversy in the ore sources. In this paper, based on the geological conditions of the Laoyingqing lead-zinc deposit, it has found that research on Zn-Pb deposits in SYGT ore-hosted in the Kunyang Group of the middle Proterozoic is less. So ore sources have been discussed by analyzing sulfur isotope characteristics of sphalerite in order to provide a scientific basis for in-depth study on the deposit genesis in NEYD.

1 Deposit geology

This deposit is close to the Xiaojiang fault and in the middle of the NNE-trending Dongchuan-Wuxing-Luozehe tectonic belt in NEYD. The structure in the mining area is dominated by the nearly SN-trending Wuxing anticline and secondary NE- and NW-trending faults. The ore-hosted faults F1 and F2 are reverse faults, and their occurrences are 60°∠63° and 115°∠86°.The exposed strata include the Huangcaoling Fm. and the Heishantou Fm. of the Kunyang Group in the Proterozoic, Sinian Dengying Fm. and Quaternary. The Huangcaoling Fm. is mainly silty sand and carbonaceous slate,and the Heishantou Fm. is mainly sandy phyllite,silty slate and siltstone,and the Sinian Dengying Fm. is mainly thick dolomite. The magmatic rocks include the Emeishan basalt and basic diabase veins in the Hercynian period.

V1 and V2 ore bodies are hosted in the fault (F1 and F2)zones in the carbonaceous slate at the lower part of the Huangcaoling Fm. of the Kunyang Group in the middle Proterozoic(Pt_2h^1), and their occurrences are consistent with the faults. These ore bodies are about 302–371m long, with a thickness of 3.10–3.56m and a grade of 4.92%–5.26%. The ore bodies are in irregular veins, partially expanded with good continuity. The ores minerals are mainly sphalerite and a small amount of galena and pyrite. The gangue minerals are mainly quartz and calcite, followed by mica, dolomite and Chlorite. The wall rock alterations are mainly silicification and carbonation.

2 Discussion for ore-forming Sulfur Sources

Sulfur isotopic composition was completed in Beijing Kehui Testing Technology Co., Ltd. The analysis results show that $\delta^{34}S_{V\text{-}CDT}$ of sphalerite samples is –1.38‰ ~ –2.62‰, with an average of –1.84‰, which are obviously different from the $\delta^{34}S$ values(+9.0‰～+28.6‰) (Kong et al., 2018)of most lead-zinc deposits in SYGT. Ohmoto (1979) pointed out that sulfur source of deposits must be concluded by the total sulfur isotope composition in the hydrothermal fluid during sulfide precipitation stage. According to Ohmoto's theory, in a low oxygen fugacity condition, the mineral association is pyrite, galena and sphalerite, and the $\delta^{34}S$ of minerals is approximately equal to the total sulfur isotope composition. Based on identifying mineral microscopy and selecting minerals, the sulfides in ores mainly include sphalerite, and galena and pyrite are very less, and there is no barite. The feature shows that the metallogenic hydrothermal fluid is under low oxygen fugacity. Therefore, the $\delta^{34}S$ of sphalerite can be approximately equal to the total sulfur value.

The deposit is mainly controlled by the branch ore-conducting structures of the regional Xiaojiang fault. Though sulfur sources in deposits hosted in the overlying marine strata mainly form reduced sulfur through TSR (Kong et al., 2018), the feature of mineral association of the deposit shows that the possibility of bacterial sulfur reduction (BSR) and thermochemical sulfur reduction (TSR) is less. The average $\delta^{34}S$ value of the sulfide is –1.84‰, which is abnormally low and is obviously different from the $\delta^{34}S$ value (+15.0‰～+35.0‰) of the evaporate in strata. Meanwhile, the Late Permian Emeishan basalt and the basic diabase due to being earlier than the mineralization period may not provide sulfur source. At present, no magmatism in the mineralization period has been found. Therefore, it is deduced that sulfur sources in ore-forming fluid may mainly come from deep sulfur risen along the Xiaojiang fault, and part sulfur

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formed from the pyrolysis of sulfur-containing organic matter in ore-hosted carbonaceous strata.

Keywords: S source, ore-hosted carbonaceous slate, Kunyang Group, Laoyingqing lead-zinc deposit, Northeastern Yunnan

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