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Genesis of the Wusihe Zn–Pb MVT Deposit, Dadu River Valley District, Sichuan Province, SW China

Suo-Fei Xiong,* Shao-Yong Jiang, and Yong-Jun Gong

State Key Laboratory of Geological Processes and Mineral Resources, Faculty of Earth Resources, and Collaborative Innovation Center for Exploration of Strategic Mineral Resources, Wuhan, China, *e-mail, sophie_0913@foxmail.com

The Sichuan-Yunnan-Guizhou triangle metallogenic province of the Yangtze Block in southwestern China is one of the most important Zn-Pb producers in China and contains more than 26 million tons (Mt) of Zn and Pb resources and reserves. Geochronological studies of these Zn-Pb deposits have revealed a Mesozoic (~200 Ma) mineralization event in province. The Dadu River Valley district in Sichuan Province hosts a number of carbonate-hosted Zn-Pb deposits that contain 10 Mt Zn and Pb. The Wusihe deposit, with 3.7 Mt Zn+Pb grading 8.6% Zn and 2.0% Pb, is the largest and the only one that is currently mined in the district.

Geological observations show that stratiform, banded, vein, and breccia type orebodies are mainly hosted in Neoproterozoic dolomites of the Dengying Formation, Lower Cambrian carbonaceous shales of the Qiongzusi Formation, and a breccia zone between the two formations. This deposit is characterized by four mineralization stages: (I) pyrite, (II) pyrite-pyrrhotite-galena-sphalerite-bitumen, (III) sphalerite-galena, and (IV) bitumen-calcite. Detailed fluid inclusion study reveals abundant aqueous-salt dominant inclusions and hydrocarbon-bearing inclusions in the sphalerite and gangue minerals. A Laser Raman spectroscopy study shows that the fluid inclusions contain measurable amounts of CH_4, H_2S, C_2H_6, C_2H_2, N_2, and NH_3. Microthermometric data exhibit salinities that are consistent at about 10 wt % NaCl equiv, but temperatures show a continuous decrease from early to late mineralization stages (203° to 291°C for stage I→168° to 269°C for stage II→133° to 229°C for stage III→102° to 199°C for stage IV). The six sphalerite samples collected from stage II ores within the Dengying Formation yield an isochron age of 411 ± 10 Ma (MSWD = 1.4), indicative of a Paleozoic Zn-Pb mineralization event. This age is much younger than the host ~540 Ma host rock. High precision in-situ lead isotope analyses indicate that the sulfides have different $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ ratios from the host dolomite rocks, and the sulfides from stage III show slightly more radiogenic values than stages I and II. Previous studies reported $\delta^{34}S$ values that span from +7.1 to +15.5‰ through conventional sulfur isotope analytical methods, whereas in-situ LA-MC-ICP-MS sulfur isotopic analyses of sphalerite, galena, and pyrite show highly variable $\delta^{34}S$ values that range from −12.5 to +21.5‰ for different ore types.

These geologic features, geochemical characteristics, and fluid inclusion data, together with the obtained Paleozoic (411 ± 10 Ma) mineralization age, suggest that the Wusihe deposit is an epigenetic Mississippi Valley-type deposit. Microscale sulfur isotopic compositions of sulfide minerals imply multiple sulfur sources and formation mechanisms for reduced sulfur. We propose that the Zn-Pb mineralization formed in a hydrothermal fluid system with abundant hydrocarbons, the regional migration of basinal brines that may have delivered the ore-forming materials, and where fluid mixing processed resulted in ore deposition.

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