American Mineralogist, Volume 105, pages 35–51, 2020

New insights into the evolution of Mississippi Valley-Type hydrothermal system: A case study of the Wusihe Pb-Zn deposit, South China, using quartz in-situ trace elements and sulfides in situ S-Pb isotopes

Kai Luo[1,2,4], Jia-Xi Zhou[1,3,4,*], Zhi-Long Huang[1], John Caulfield[4], Jian-Xin Zhao[4], Yue-Xing Feng[4], and Hegen Ouyang[4,5]

[1]State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550081, China
[2]University of Chinese Academy of Sciences, Beijing 100049, China
[3]School of Resource Environment and Earth Sciences, Yunnan University, Kunming 650500, China
[4]School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Queensland 4072, Australia
[5]Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China

Abstract

Unraveling the evolution of Mississippi Valley-type (MVT) hydrothermal system is crucial for understanding ore genesis and exploration. In this paper, we take the Wusihe Pb-Zn deposit in the western Yangtze Block (South China) as a case study, using detailed ore deposit geology, quartz in situ trace elements, and sulfides in situ S-Pb isotopes, to propose a new integrated model for the evolution of MVT hydrothermal system. Four hydrothermal stages were identified in the Wusihe ore district: (I) lamellar pyrite-sphalerite; (II) disseminated, stock-work, and brecciated sphalerite-galena; (III) massive galena, and (IV) veined calcite-bitumen. Within the most representative stage (stage II), Al concentrations in quartz (Q) increase from 8.46–354 ppm (mean 134 ppm) of Q1 to 171–3049 ppm (mean 1062 ppm) of Q2, and then decrease to 3.18–149 ppm (mean 25.4 ppm) of Q3. This trend indicates the role of acid-producing processes that resulted from sulfide precipitation and acid consumption by carbonate buffering. The occurrence of authigenic non-altered K-feldspar provides further evidence that the ore-forming fluids were weakly acidic with pH values of > ~5.5. Moreover, new bulk $\delta^{34}S$ values of sulfides (+1.8 to +14.3‰) are overall lower than those previously reported (+7.1 to +20.9‰), implying that in addition to thermochemical sulfate reduction (TSR), bacterial sulfate reduction (BSR) may play an important role in the formation of S^{2-}. In situ $\delta^{34}S$ values show a larger range (–4.3 to +26.6‰), and significantly, varies within single grains (up to +12.3‰), suggesting mixing of two isotopically distinct S^{2-} end-members produced by TSR and BSR. The diagenetic and hydrothermal early phase (stage I) sulfides were formed within a nearly closed system of BSR, whereas the formation of late phase (stage II and stage III) sulfides was caused by the input of hydrothermal fluids that promoted TSR. New galena in situ Pb isotopic ratios ($^{206}Pb/^{204}Pb$ = 18.02–18.19, $^{207}Pb/^{204}Pb$ = 15.66–15.69, and $^{208}Pb/^{204}Pb$ = 38.14–38.39) suggest that the sources of mineralizing metals in the Wusihe deposit are mainly Proterozoic basement rocks. Hence, a multi-process model (i.e., basin-mountain coupling, fluid mixing, local sulfate reduction, in situ acid-producing and involvement of black shales and carbonate sequences) was responsible for the formation of the Wusihe deposit, while S^{2-} was produced by both TSR and BSR, providing new insights into the evolution of MVT hydrothermal system.

Keywords: Quartz in situ trace elements, sulfides in situ S-Pb isotopes, MVT hydrothermal system evolution, Wusihe Pb-Zn deposit, South China