American Mineralogist, Volume 109, pages 408–421, 2024

Halogen fractionation during vapor-brine phase separation revealed by in situ Cl, Br, and I analysis of scapolite from the Yixingzhai gold deposit, North China Craton

Wen-Sheng Gao[1,2,†], Xiao-Dong Deng[1,*,‡], Lei Chen[3], Li-Zhong Zhang[1,2,4], Yu-Xiang Li[1], Tao Luo[1], and Jian-Wei Li[1,2]

[1]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China
[2]School of Earth Resources, China University of Geosciences, Wuhan 430074, China.
[3]MNR Key Laboratory for Exploration Theory & Technology of Critical Mineral Resources, China University of Geosciences Beijing, Beijing 100083, China
[4]Zijin Mining Group Co Mineral Exploration Institute, Xiamen 361006, China

Abstract

Halogens (Cl, Br, and I) are major complexing agents for metal ions, and their ratios (Br/Cl and I/Cl) have been used to determine the source and evolution of hydrothermal fluid. Halogen fractionation during hydrothermal fluid evolution, however, has been inferred from several studies, which poses problems in using halogen ratios as a fluid tracer. The Br/Cl and I/Cl ratios of scapolite are consistent with those ratios present in the coexisting fluid during scapolite formation, making this mineral particularly useful for understanding hydrothermal fluid evolution. To better understand halogen fractionation during vapor-brine phase separation, we conducted fluid inclusion microthermometry, major elements, and in situ halogens and Sr isotope analysis of scapolite formed from a high-salinity hydrothermal fluid during the vapor-brine phase separation at the Yixingzhai gold deposit, North China Craton. The studied scapolite has 1.84–3.41 wt% Cl, 389–806 ppm Br, 8.4–24.4 ppm I, and significantly high Br/Cl ($6.1–14.7 \times 10^{-3}$) and high I/Cl ($91–302 \times 10^{-6}$) molar ratios that likely result from the preferential incorporation of Br and I into the brine phase compared to Cl entering the vapor phase during fluid phase separation. Based on fluid inclusion microthermometry results, the Rayleigh fractionation simulation shows that the Br/Cl and I/Cl ratios of the brine are estimated to be up to 18×10^{-3} and 500×10^{-6} during the formation of scapolite. These results reveal halogen fractionation during the vapor-brine phase separation of hydrothermal fluids. This view has implications for interpreting the halogen systematics of scapolite and other minerals formed in similar environments, particularly when they are used as a fluid tracer.

Keywords: Scapolite, halogen fractionation, phase separation, hydrothermal fluid; Experimental Halogens in Honor of Jim Webster