American Mineralogist, Volume 109, pages 1443–1460, 2024

Chemical and boron isotopic composition of tourmaline from the Yixingzhai gold deposit, North China Craton: Proxies for ore fluids evolution and mineral exploration

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Abstract

Tourmaline is common in magmatic-hydrothermal deposits, and its composition and boron isotope geochemistry have been widely used to fingerprint the source and evolution of hydrothermal fluids and associated metals. However, whether these chemical or boron isotopic compositions or their combinations can be used as vectors for mineral exploration remains to be explored. In this study, we documented the major and trace element compositions and boron isotopic values of tourmaline along a vertical extension (i.e., 510, 830, 1230 m above sea level, a.s.l.) of the newly discovered porphyry Au mineralization in the Hewan feldspar quartz porphyry, Yixingzhai deposit, to shed light on the evolution of the ore-forming fluid, the mechanisms of Au deposition, and potential indicators for Au exploration. Field observations showed that tourmaline in the Hewan porphyry occurred mainly as orbicules or veins and intergrew with Au-bearing pyrite, hydrothermal quartz, and some clay minerals, indicating a magmatic-hydrothermal origin. Tourmaline sampled from 510 m a.s.l. showed $\delta^{11}B$ values (–11.5 to –9.3‰) consistent with those of the average continental crust and tourmaline in magmatic systems, which suggests that the ore-forming fluid was most likely exsolved from the host Hewan porphyry. The $\delta^{11}B$ values became heavier upward, reaching –9.9 to –1.5‰ at 830 m and –8.0 to +6.8‰ at 1230 m a.s.l. This boron isotopic variation, integrated with increasing Fe, Mg, Na, Ca, Li, Co, and Sr but decreasing Al, U, Th, REE, Zn, and Pb contents of the tourmaline samples from deep to shallow levels, implies that the initial magmatic fluids were gradually mixed with circulating meteoric water that contained materials leached from peripheral Archean metamorphic rocks and Mesoproterozoic marine sedimentary rocks. Considering the spatial distribution of the Au grade of the porphyry, we propose that a suitable mixing proportion of magmatic and meteoric fluids caused Au deposition and accumulation. We note that tourmaline samples collected from the economic Au zones had much lower and more concentrated $\delta^{11}B$ (–11.5 to –3.0‰), Co/(Pb+Zn) (<0.01), and Sr/(Pb+Zn) (0.27 to 1.07) values than those in low-grade or barren zones. Coeval plutons and breccia pipes, where tourmaline also occurs, are well developed inside and outside the Yixingzhai Au mine. We suggest that the obtained parameters can potentially be used as proxies for further Au exploration in this region. This study highlights the feasibility of using the chemical and isotopic compositions of tourmaline for mineral exploration.

Keywords: Tourmaline geochemistry, fluid evolution, mineral exploration, Yixingzhai Au deposit, North China Craton