American Mineralogist, Volume 106, pages 994–1008, 2021

Multiple generations of tourmaline from Yushishanxi leucogranite in South Qilian of western China record a complex formation history from B-rich melt to hydrothermal fluid

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ABSTRACT

One tourmaline-bearing leucogranite dike occurs in the Yushishanxi Nb-Ta mining area in the Yushishan district of the South Qilian orogenic belt in western China. Abundant tourmalines have been identified in the leucogranite, including disseminated, crosscutting quartz-tourmaline veins and tourmaline veinlets. Detailed petrological, geochemical, and boron isotopic studies indicate that these tourmalines have distinctive core-rim zoning signatures and significant chemical variations, which can be divided into four paragenetic generations. Generation-I tourmalines in the leucogranite have a magmatic origin and were followed by hydrothermal Generation-II, Generation-III, and Generation-IV. Tourmalines from all four generations belong to the alkali group and the schorl-dravite solid-solution series. The most notable features are the variations in Mg, Fe, and Ca contents. The variable Mg/(Mg+Fe) ratios in generations I to IV may be attributed to the multiple influx and/or interaction of initially magma-derived hydrothermal fluid with surrounding rocks, magma-derived Fe-rich hydrothermal fluid, and external metamorphic fluid. In situ B-isotope analyses of tourmaline yield a total range of $\delta^{11}B$ values from –11.7 to –6.0‰. The earliest Generation-I tourmalines have $\delta^{11}B$ values of –11.1 to –9.6‰, whereas Generation-II and Generation-III tourmalines record a higher $\delta^{11}B$ value of –9.5 to –6.0‰ and –9.3 to –6.9‰, respectively. Such an increase is mainly controlled by boron-isotope fractionation between melt-fluid and tourmaline-fluid, Rayleigh fractionation, and also, to some extent, by a hydrothermal recharge from the same magma source. Generation-IV tourmalines have the lightest B-isotope values (down to –11.7‰). This shift back to lighter B-isotopes in the Generation-IV cannot be explained by closed-system crystallization and isotope fractionation of known phases. Alternatively, a lighter source of boron via fluid circulation from the surrounding metamorphic rocks can explain this light boron isotope composition. Therefore, we propose that an isotopically light fluid may have derived from B release during mica breakdown within the surrounding metamorphic rocks.

Keywords: Tourmaline, geochemistry, boron isotope, magmatic-hydrothermal evolution, multiple generations, South Qilian