# Chemical and boron isotope compostions of tourmaline from Yushishan leucogranite, NW China: Implication for multiple stage formration from B-rich melts to hydrothermal fluids

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Tourmaline is abundant in the Yushishan leucogranite, NW China, with different modes of occurrence identified from field and petrographic observation: tourmalines hosted by leucogranite commonly occur as disseminated fine-grain tourmaline and medium-coarse zoned tourmaline segregations; tourmalines in veins occur as tourmaline-quartz vein, medium-grain and zoned tourmaline and fine tourmaline segregations in tourmaline veinlets. Four major growth generations (I to IV) are identified for these tourmalines.

Tourmalines all belong to the alkali group and are schorl-dravite series. The Mg/(Mg+Fe) ratios show an abrupt increase from Generation-I to Generation-II, then gradually decrease to Generation-III, and finally increase to Generation-IV again. The earliest Generation-I has $\delta^{11}B$ values of -11.1‰ to -9.6‰, but Generation-II records a shift to higher $\delta^{11}B$ values of -9.5‰ to -6.0‰. This increase in $\delta^{11}B$ is attributed to the fractionation between melt-fluid, tourmaline-fluid and Rayleigh fractionation. Generation-III tourmaline is characterized by similar B-isotope compositions of -9.3‰ to -6.9‰ with the Generation-II, but with higher Fe contents and lower Mg/(Mg+Fe) ratios, which indicates the hydrothermal fluid of Generation-III is strongly influenced by a recharge of the initial magmatic-derived hydrothermal fluid into the evolved fluid. Generation-IV tourmaline has the lowest B-isotope ratios (-11.7‰ to -9.8‰) with higher Mg/(Mg+Fe) ratios. This shift back to lighter B-isotope ratios in the Generation-IV cannot be explained by closed-system crystallization and isotope fractionation of known phases. Alternatively, a lighter source of boron as well as Mg via fluid circulation from the surrounding rocks can explain the light isotope compositions and Mg-rich nature measured in the Generation-IV tourmalines. Thus, we propose that these isotopically light fluids may derive from B release during mica breakdown within the surrounding rocks.