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Tourmaline as a tracer for Lithium mineralization in rare metal pegmatite: the case of Mufushan granitic batholith (South China)

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The Mufushan granitic batholith in South China represents a continuous fractional sequence of felsic magma from granite to rare metal pegmatite. The occurrence of tourmaline provides a valuable geochemical fingerprint for tracing magma evolution and lithium mineralization.

Tourmaline found in Li-poor pegmatite is characterized by black coloration and occurrences as isolated and/or segregation formations. It demonstrates symbiotic associations with muscovite, plagioclase, and quartz. In contrast, tourmaline discovered within Li-rich pegmatite displays either pink or zoning patterns consisting of a blue core surrounded by a pink rim. Its growth occurs both individually and as radiating clusters alongside lepidolite, petalite and microlite, indicating progressive evolution from an initial melt to one rich in lithium. Tourmaline growing at the contact zone exhibits high levels of Mg, Ca, Ti, and enriched concentrations of V, Co, Ni and REE contents. However, it shows negligible ^{Y}Al contents and low Li/Sr ratios, suggesting potential connections to early stages of fluid exsolution as well as contamination from mafic mineral originating in the host rock. Across the transition from Li-poor to Li-rich pegmatite, a significant increase in ^{Y}Al, (Li*+Mn) content, and $^{Y}Al/(Al+Fe)$ ratios is observed, aligning with expected patterns of magma fractional crystallization. The concentrations of Li, Be, Nb and Ta progressively increase and reach their peak during the crystallization of pink elbaite rim, indicating the saturation-driven formation of beryl, columbite group minerals and microlite prior to the formation of pink elbaite. The decrease in Li content can be attributed to the competitive precipitation of lepidolite as supported by the concurrent reduction in F content observed in elbaite, given that F is more likely to incorporate into lepidolite.

Furthermore, a gradual decrease in B isotopes of tourmaline is observed from Li-poor pegmatites (– 12.6‰ ~ – 14.8‰) to Li-rich pegmatites (– 14.0‰ ~ – 17.1‰), indicating that approximately 70% fractional crystallization contributes to the formation of highly evolved elbaite. These geochemical characteristics of tourmaline suggest that the process of fractional crystallization and fluid exsolution govern the formation of pegmatite and rare metal mineralization.