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Quartz-petalite intergrowths in the Yichun pegmatite: Formation from late-stage Li-rich melts and implications for Li mineralization in rare-metal granites

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We report a unique quartz-petalite intergrowth that occurs in the core zone of a zoned pegmatite sheet from the Yichun Li-Cs-Ta-Nb mine, China. Within this deposit, a rare-metal-mineralized granite underlies and partially intrudes into the earlier, zoned pegmatite, both of which have previously been interpreted to have originated from the same parental magma. The pegmatite core zone mostly comprises an early quartz generation that is fractured and free of mineral inclusions. A less abundant later quartz partially replaced the early quartz and is characterized by abundant globular to vermicular inclusions of petalite ($LiAlSi_4O_{10}$) and lesser K-feldspar (orthoclase/sanidine). These two types of sequentially crystallized quartz have $\delta^{18}O$ values (12.7–13.0‰) similar to magmatic graphic quartz in the pegmatite wall zone. Hydrothermal quartz in later veins has higher $\delta^{18}O$ (13.7–14.2‰). Titanium-in-quartz thermobarometry indicates similar crystallization temperatures (ca. 500 °C) for both quartz generations. Textural features and mass-balance calculations suggest that most petalite inclusions formed by exsolution from a magmatic quartz-petalite solid solution containing 1729–3135 ppm Li and >6649–12118 ppm Al, which resembles stuffed quartz observed in experiments involving the crystallization of Li-rich granitic melts. In addition, some petalite inclusions define growth patterns indicating co-precipitation with the host quartz and represent direct crystallization from the last aliquot of pegmatite melt containing ≤5000 ppm Li. Orthoclase/sanidine inclusions formed in early quartz crystals as co-precipitates with quartz (forming micrographic textures), and later via exsolution together with petalite. To attain ~2200 ppm Li in the core zone, 90% fractionation of an initial granitic melt containing ca. 300 ppm Li is sufficient. Although the rare-metal-mineralized granite at Yichun was suggested to have originated from a melt of similar compositions to the initial granitic melt that formed the pegmatite, the up to 1.2 wt% Li in the mineralized granite cannot be achieved through similar degrees of fractional crystallization. This highlights the indispensable role of metasomatism in the formation of economic-grade, granite-hosted Li mineralization at Yichun and, possibly, in analogous systems.