“Multi-Step Distillation” Anatexis as a Mechanism for Generating LCT Pegmatites

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Lithium-caesium-tantalum (LCT) pegmatites are an important subset of highly differentiated intrusions that retain geochemical signatures, implying that a component of recycling of Earth’s crust is required for their formation. Deposits of LCT pegmatites account for roughly half of global lithium output and the majority of global caesium and tantalum production. Despite their fundamental and growing importance to critical metal supplies, their petrogenesis remains debated.

Two main petrogenetic models have been proposed: (1) extreme fractionation of granitic intrusions, leading to a melt concentrated in incompatible elements, or (2) low-degree partial melting of host rocks during prograde metamorphism, enriching the anatectic component in incompatible elements. Although both models have been invoked empirically in different terranes, several pegmatite fields fail to fit either model.

Here, we present a novel method to quantitatively assess the fate of trace elements during anatexis to suggest a third petrogenetic model of economic pegmatite deposit formation, which we have termed “Multi-Step Distillation.” Through innovative petrological modelling, we show that water content and degree of partial melting significantly affects the lithium content of the melt component; however, a single step of melting is unable to generate economic grades. Alternatively, partial melting of leucosomes or leucogranites that were formed as part of an earlier melting event is highly effective at enriching the melting package in lithium, concentrating lithium into the melt by a factor of ~20.

Our models show that this mechanism is able to generate pegmatites of economic interest and may explain the petrogenesis of several pegmatite fields (such as the Maine pegmatite field and pegmatites of the St-Sylvestre complex) around the world.