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Evidence supporting the role of late-stage post-magmatic chaos in the formation of rare-metal pegmatitic ore systems

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Summary

Rare-metal (RM; e.g., Li, Ta, Nb, Sn) enrichment has long been considered a product, if not the hallmark, of unusually evolved magmatic systems, but the role *sensu stricto* of magmatic versus hydrothermal processes in pegmatite-hosted RM mineralized settings has long been debated. Recent studies on many such ore environments of varied age and setting, however, provide an increasing amount of evidence favoring a more substantive role for post-magmatic (i.e., subsolidus stage) metasomatic processes that overprint the already crystallized. Importantly and critical to both ore formation and exploration, this stage of chaos culminates in formation of RM enriched zones. The model argued is supported with several case studies using field observations, petrographic and imaging methods (SEM-EDS, CL), LA ICP-MS analysis of micas and fluid inclusions, $\delta^{18}O$- $\delta^{13}C$ isotopic data and fluid inclusion studies. The development of widespread, often irregular metasomatic zones occurs via CDP processes and gives rise to areas dominated by albite (i.e., saccharoidal or cleavelandite types) or mica; importantly, these zones often host substantial RM mineralization. That fluids in such settings are dilute, low-salinity aqueous or H_2O-CO_2 types depleted in RMs (e.g., LA ICP-MS data) precludes a link between primary RM enrichment and such fluids. Instead the RM enrichment is attributed to later ingress of even more evolved, volatile-charged low-viscosity melts and related generation of widespread zones metasomatism. However, that secondary micas in some cases are enriched in RM (1000s ppm) clearly indicates some fluid-mediated RM transport and upgrading occurs. In several cases a variety of data support an open-system model with exchange between host pegmatites and the wall rock, which may locally source some RM mineralization (e.g., Nb) or in some cases also the C in fluid inclusions (e.g., $\delta^{13}C$ analysis). In addition, $\delta^{18}O$(quartz, feldspar) and fluid inclusion data for quartz and metasomatic feldspars support ingress of externally sourced fluid reservoirs, including meteoric water in some cases (i.e., <1 wt.% equiv. NaCl), during the subsolidus transformation of the host pegmatite. Thus, the evidence presented here, in addition to supporting literature, is clear - RM mineralized zones in evolved pegmatite settings are in many cases co-spatial with areas that record substantial post-crystallization modification related to melt- and fluid-mediated metasomatism which leaves an imprint of chaotic textual development.