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Evaluation of rare element transfer into exomorphic halos, Cat Lake–Winnipeg River pegmatite field, Manitoba

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Critical elements are essential to the global economy. Some critical elements (e.g., Li) are associated with highly evolved igneous rocks (pegmatites) that form during the late stages of magma crystallization. Rare element pegmatite fields commonly contain multiple pegmatite groups with distinct trace element signatures, even when formed during a single tectonomagmatic episode. This diversity is typically attributed to variable magmatic fractionation and emplacement conditions. However, pegmatites commonly evolve through a magmatic to hydrothermal transition in which melt and fluid coexist. Late-stage pegmatite derived fluids can transfer elements into host rocks and form exomorphic halos. The extent to which this mass transfer modifies pegmatite compositions and apparent fertility remains poorly constrained.

Manitoba and Northwestern (NW) Ontario are endowed with large volumes of highly fractionated Li-rich granites and pegmatites. Here we investigate geochemical characteristics of the Cat Lake–Winnipeg River pegmatite field (southeastern Manitoba), hosted by Archean Rice Lake Group metavolcanic and metasedimentary rocks. Our dataset comprises 2,272 whole-rock ICP–MS analyses from 29 drill holes across four pegmatite groups (Eagle–Irgon, Rush Lake, Lac du Bonnet, Greer Lake). Rush Lake and Lac du Bonnet are P-enriched and show S-type signatures, whereas most other samples fall in an I-type field. Mg/Li vs La/Ta indicates dominant LCT affinities for Eagle–Irgon and Lac du Bonnet, while a P–Fe cross-plot distinguishes Greer Lake by systematically higher Fe/P, consistent with an NYF-like signature; Rush Lake spans compositions from weakly LCT-like to depleted in Li and shows only limited Ta enrichment.

Halo inventories show clear differences among pegmatite groups. Eagle–Irgon halos are most consistently enriched in Cs and Rb, Rush Lake shows the largest Li halo whereas Ta is largely retained in pegmatites. The inverse relationship between pegmatite enrichment and halo enrichment suggests late-stage metasomatic mass transfer contributes to within-field compositional variability. Halo magnitude varies among drill holes, indicating controls from structural permeability, host-rock lithology, and volatile enrichment, with implications for interpreting fractionation trends and for halo-based exploration targeting.