A tale of REE concentration, Strange Lake, Canada

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The Strange Lake pegmatites show extreme enrichment in the REE, Zr and Nb. This enrichment is spatially associated with the most altered rocks and expressed as secondary minerals, indicating that hydrothermal fluids played an important role in the concentration of these elements. The secondary minerals are so diverse and their textural relationships are so complex that it is difficult to unravel the mineral paragenesis. Here, we use the major and trace element composition of the evolving fluid (fluid inclusion analyses) to explain the progressive alteration of primary magmatic minerals and the precipitation of secondary minerals.

The fluid history started with exsolution of a high salinity, high pH, CH_4+H_2-saturated fluid at ~450°C. This fluid destroyed K-feldspar, releasing K, Al and Pb; the fluid was also enriched in LREE and Be. Cooling (to ~360°C) was accompanied by oxidation and a decrease in pH, which triggered alteration of arfvedsonite. Initially, the REE were transported as hydroxy-fluoride complexes but with cooling chloride complexes (MREE) became dominant. This caused precipitation of allanite-(Ce) and gadolinite-(Ce). At ~300°C, the fluid became CO_2-saturated, lowering pH, thereby decomposing elpidite and residual arfvedsonite. The resulting fluid was enriched in Ca, Zr, Fe, Li and Mn. Elpidite (HREE-rich), was replaced by HREE-rich zircon. The cooling to 300ºC also coincided with a change in the dominant REE complex to a fluorcarbonate species. Primary LREE silicates were altered to bästnasite-(Ce). The final stage of fluid evolution involved massive migration of CO_2 out of the pegmatites, destabilisation of fluorcarbonate complexes and precipitation of fluorite. This late, oxidised, low temperature (~150°C), CO_2-free fluid was enriched in the HREE, reflecting a return to the dominance of chloride complexes, particularly of the HREE. This lead to precipitation of gadolinite-(Y) and MREE-rich aegirine. Further cooling caused precipitation of HREE rims on the cores of MREE minerals, e.g., HREE-gadolinite on MREE-gadolinite.

In summary, a careful evaluation of the progressive evolution of the composition of the Strange Lake magmatic-hydrothermal system has allowed us to develop a robust mineral paragenesis for the deposit. This study underlines the importance of direct analyses of fluid chemistry to reconstruct the path of REE concentration in evolving hydrothermal systems.