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Evidence of remobilization of Light Rare Earth Elements during recrystallization of apatite in the Fen alkaline and carbonatite complex, Southern Norway

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Carbonatite and alkaline intrusions are crucial for the energy transition as they host important critical raw material resources. In this study, we use in-situ trace element and Sr isotope analyses in apatite to reconstruct the evolution of the Fen alkaline and carbonatite complex and track the behavior of Rare Earth Elements (REE) throughout its evolution.

Fen is a two-km-diameter circular intrusion, emplaced at 580 Ma, in Mesoproterozoic Sveconorwegian gneisses, in southern Norway. The Fe-dolomite carbonatite unit hosts the largest REE deposit in Europe, consisting of REE-fluorocarbonates and monazite. Carbonatites in Fen vary, west to east, from calcite carbonatite, dolomite carbonatite, to Fe-dolomite carbonatite, locally hematitized.

Apatite is found in all units and is most abundant in calcite and dolomite carbonatites. Apatite, in these, occurs as radial acicular crystal clusters or as individual subhedral crystals locally defining a flow banding. Apatite-rich veins cut all carbonatitic units and consist of apatite microcrystalline matrix containing variable proportions of subhedral apatite. Microcrystalline apatite can also be intergrown with fine-grained carbonates and chlorite. Magnetite, quartz, barite, fluorite, and thorite are accessory phases.

Preliminary results show that subhedral apatite and radial acicular apatite clusters in the calcite carbonatite have a distinctive trace element signature compared to the microcrystalline apatite. Subhedral and acicular apatite have REE patterns enriched in LREE compared to microcrystalline apatite, which is enriched in HREE ($(La/Yb)_N$=32-122 and 2-44, respectively). Subhedral and acicular apatite are enriched in Na (1300-2800 ppm) and Mn (175-455 ppm), but Sr concentrations remain below 6300 ppm, unlike for microcrystalline apatite (Na=200-800 ppm, Mn=32-300 ppm, Sr=3400-20000 ppm). In-situ Sr and oxygen isotopes show that euhedral and acicular crystals of apatite have a higher $\delta^{18}O$ and lower $(^{87}Sr/^{86}Sr)_i$ = 0.70293-0.70359, $\delta^{18}O_{VSMOW}$=+3.46 to +6.80 ‰) than microcrystalline apatite $(^{87}Sr/^{86}Sr)_i$ =0.70319-0.70407, $\delta^{18}O_{VSMOW=}$+1.94 to +5.97 ‰), although the datasets overlap. The data fall in the primary carbonatite field with some influence of high-temperature alteration with fluids of meteoric origin involved in the formation of microcrystalline apatite. The depletion in LREE in secondary apatite indicates that LREE are preferentially remobilized by these fluids, providing a potential source for additional LREE to form the REE deposit.