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Evidence for post-magmatic, rare-earth element mobilisation from a microgeochemical *in situ* ID-TIMS Sm–Nd isochron from a single magmatic eudialyte crystal, Norra Kärr alkaline complex

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The Norra Kärr alkaline complex is a small intrusion of peralkaline agpaitic nepheline syenites in southern Sweden. Eudialyte from the complex is rich in rare-earth elements [1] and constitutes mainland Europe's most promising potentially economic resource of heavy rare-earth elements. Textures and structures in Norra Kärr portray a convoluted history of geological events. Increasingly, there is clear evidence of a post-magmatic reworking of the rare-earth element deposit. It is likely that the post-magmatic event in part redistributed the rare-earth elements. From a geodynamic perspective, it is important to understand when these processes occurred, under what physical conditions, and the effect this had on the (economic) characteristics of the deposit.

Technical advances in Sm–Nd geochronology by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) allows smaller and smaller sample masses to be measured with high precision. At the Boston University TIMS facility, a method that produces routine high-precision isotope analyses of small Nd aliquots of 1–10 ng was developed [2]. This method—often applied to analyse garnet—provides an exciting prospect for microanalysis of minerals such as monazite, xenotime, bastnäsite, and eudialyte which, contrary to garnet, are rich in rare-earth elements. Sufficient Nd yields can be extracted from these minerals through sample sizes multiple orders of magnitude smaller than currently used in garnet Sm–Nd geochronology.

A single millimetre-sized eudialyte crystal in a polished rock slab from a crosscutting leucocratic vein from Norra Kärr was characterised by backscattered electron imaging and detailed *in situ* elemental analysis by laser ablation inductively coupled plasma mass spectrometry. The crystal displays euhedral magmatic sector and oscillatory zonation. Careful characterisation of this crystal by LA-ICP-MS analysis (10 µm spots) allowed calculation of the spread in $^{147}Sm/^{144}Nd$ ratios (0.162–0.193) and Nd concentrations (6654–7924 ppm). Thus, the required sample volume of eudialyte for a ~4 ng Nd aliquot corresponds to a semisphere with a diameter of the order of 50 µm. This facilitates *in situ* microsampling by microscope-guided micromilling, based on mineral textural domains, to produce enough material for full column chemistry and ID-TIMS analysis of Nd isotopes.

Six milled pits from a single zoned crystal of eudialyte produced a spread in the measured $^{147}Sm/^{144}Nd$ ratio of 0.141–0.185 and a robust Sm–Nd isochron with an age of 1040 ± 44 Ma (*n* = 5, MSWD = 1.7; one rejected sample from a texturally and chemically distinct domain). This is significantly younger than the age of magmatic intrusion at 1.49 ± 0.01 Ga [3], but matches the age of 1.1–0.94 Ga Sveconorwegian (Grenvillian) orogenic metamorphism to the west of Norra Kärr. The textural evidence combined with robust Sm–Nd geochronology implies post-magmatic remobilisation (potentially by partial remelting) of the alkaline rocks at temperatures significantly below 650 °C.

References:

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