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Apatite formation behaviour during metasomatism in the Bathtub Intrusion (Babbitt deposit, Duluth Complex, USA)

Sara Raič (1), Aberra Mogessie (1), Kurt Krenn (1), Christoph A. Hauzenberger (1), and Peter Tropper (2)

(1) University of Graz, Institute of Earth Sciences, Department of Petrology & Geochemistry, Graz, Austria (sara.raic@edu.uni-graz.at), (2) University of Innsbruck, Department of Minralogy & Petrography, Austria

The mineralized troctolitic Bathtub intrusion (Duluth Complex, NE-Minnesota) is known for its famous Cu-Ni-Sulfide±PGM Babbitt deposit, where platinum group minerals (PGMs) are either hosted by primary magmatic sulfides (base metal sulfides) or associated with hydrothermally altered portions. This secondary generation of PGMs is present in alteration patches and suggests the involvement of hydrothermal fluids in the mobilization of platinum-group elements (PGEs). Accessory fluorapatite in these samples reveals besides H_2O- and CO_2-rich primary fluid inclusions, textural and compositional variations that also record magmatic and metasomatic events. Based on detailed back-scattered electron imaging (BSE) and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICPMS), a primary magmatic origin is reflected by homogeneous or zoned grains, where zoning patterns are either concentric or oscillatory, with respect to LREE. Late magmatic to hydrothermal processes are indicated by grains with bright LREE-enriched rims or conversion textures with REE-enriched patches in the interior of the apatite. A metasomatic formation of monazite from apatite is documented by the presence of monazite inclusions in apatite and newly grown monazite at altered apatite rims. They formed by the release of REEs from the apatite during a fluid-induced alteration, based on the coupled substitution Ca2+ + P5+ = REE3+ + Si4+ (Rønsbo 1989; Rønsbo 2008). Samples with monazite inclusions in apatite further display occurrences of PGMs associated with hydrothermal alteration patches (chlorite + amphibole). The presence of H_2O- and CO_2-rich fluid inclusions in apatite, the metasomatically induced monazite growth, as well as the occurrence of PGMs in hydrothermally alteration zones, also suggest the involvement of aqueous chloride complexes in a H_2O dominated fluid in the transportation of LREE and redistribution of the second generation of PGEs.

Rønsbo, J.G. (1989): Coupled substitutions involving REEs and Na and Si in apatites in alkaline rocks from the Ilímaussaq intrusion, South Greenland, and the petrological implications. American Mineralogist 74, 896–901.
Rønsbo, J.G. (2008): Apatite in the Ilímaussaq alkaline complex: Occurrence, zonation and compositional variation. Lithos 106 (1–2), 71–82.