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Using apatite as a fluid probe for halogens to decipher fluid-rock interaction

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Apatite ($Ca5(PO4)3(OH,F,Cl)$) is the main host of halogens in magmatic and metamorphic rocks and plays a unique role during fluid-rock interaction as it incorporates halogens (i.e. F, Cl, Br, I) and OH from hydrothermal fluids to form a ternary solid solution of the endmembers F-Apatite, Cl-Apatite, and OH-Apatite. The distribution of halogens between fluid and apatite relies on a complex interplay of mainly compositional factors (i.e. activity of halogens, pH) and processes underlying the formation of hydrothermal apatite (i.e. replacement of precursor apatite, overgrowth, re-precipitation). We performed cold-seal-pressure-vessel experiments to constrain the distribution of all halogens (i.e. F, Cl, Br and I) between apatite and different geologically relevant fluids. Results of this study allow the calculation of halogen activities in natural hydrothermal fluids from the halogen concentrations of coexisting hydrothermal apatite.

Here, we present spatially resolved halogen data for different apatite generations of two metasomatized gabbro samples adjacent to shear zones from different localities (i.e. Bamble Sector, SE Norway and Krakeneset, Western Gneiss Complex, W Norway). We use these sample sets to constrain the fluid composition and a possible compositional evolution of the fluid as fluid-rock interaction proceeded. Samples of both localities represent alteration sequences with an increasing fluid influence going from unaltered gabbro (no fluid present) via pervasively altered gabbro (moderate fluid flux) to shear zone (high fluid flux).

Apatite from the Bamble sector shows a compositional evolution in F and Br, with relatively high F / low Br concentrations in samples close to the shear zone and low F / high Br in least altered gabbro samples. This observation can be explained by a compositional evolution of the hydrothermal highly saline fluid during ongoing fluid-rock interaction at mid-crustal conditions. The fluid lost F to the newly formed apatite and gained Br from dissolving magmatic apatite and desiccation reactions.

Apatite from Krakeneset metagabbro also shows a compositional evolution, but caused by interaction with a hydrous fluid at eclogite-facies conditions. Here, the newly formed hydrothermal apatite from the shear zone is highest in Cl and Br and lowest in F, whereas least altered gabbro contains low Cl / Br and high F apatite. Again, this behavior is a result of an evolving fluid. The infiltrating aqueous fluid is low in F, but relatively high in Cl and Br. During fluid-rock interaction magmatic F-apatite dissolved leading to an enrichment of F in the reacting fluid. Consequently, the newly formed hydrothermal apatite is lower in F, where the system is fluid dominated (shear zone), and successively higher in F, where the system becomes progressively rock dominated (metagabbro).

Both examples show the ability to use apatite as a fluid probe for halogens during fluid-rock interaction that can record compositional changes in hydrothermal fluids.