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Tracing multiple fluid events in the Bamble Sector, SE Norway: A halogen and chlorine isotope study

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Fluid-rock interaction causes element mobilisation and fractionation. It is related to the formation of economic mineral deposits and has consequences for the petrophysical properties of the affected rocks and the geodynamics of the related large-scale systems. Mineral reactions caused by metasomatism, i.e. the composition of the infiltrating fluid, are very common phenomena in many metamorphic settings. Lower crustal rocks from the Bamble area (SE Norway) show a manifold history of metamorphic and metasomatic events. Whereas the metamorphic history of this high-grade terrain is largely understood, the metasomatic part is still poorly constrained: What is the origin of the reacting fluid; how many fluid events caused the scapolitisation and albitisation in almost every rock in the Bamble area? We focus our study particularly on gabbro intrusions of sveconorvegian age ($\sim$1100 m.y.) which are affected by hydrothermal alteration due to interaction with high saline fluids.

Halogens (e.g. F, Cl, Br, I) as major anions in crustal fluids may allow deciphering the fluid source. These elements may be incorporated in newly forming or recrystallisating minerals such as biotite, amphibole, scapolite and apatite, as the fluid is reacting with the rock. Due to their hydophilicity halogens are thought to reflect source charactristics rather than fluid-solid fractionation effects; hence, the chlorine isotope ratio (δ^{37}Cl) combined with halogen concentrations likely offer the possibility to trace different fluid sources. We, therefore, analysed halogen concentrations and chlorine isotopes ratios of our sample set which represent a complete section from unaltered gabbro through amphibolised, scapolitised and albitised zones of a metagabbro towards an amphibolitic shear zone. Halogens were extracted through pyrohydrolysis [1] for the halogen-bearing phases scapolite, amphibole and biotite from each part of the section. Chlorine stable isotope ratios were measured using a ThermoElectron MAT253 gas-source MS; halogen concentrations were measured using Ion Chromatography (for Cl and F) and ICP-MS (for Br and I).

The δ^{37}Cl values for bulk rock and mineral separates show an overall increase from the unaltered gabbro (between -1.8 and -1.2‰) towards the shear zone (+1.2‰). The negative δ^{37}Cl values may indicate a depleted mantle origin of the unaltered gabbro ([2], which is progressively altered by a fluid enriched in ^{37}Cl. However, at least two different fluid events are distinguishable from δ^{37}Cl data as samples from the scapolite zone have lower δ^{37}Cl values (0‰) then samples from the amphibole zone (+0.6‰). This shift in δ^{37}Cl value can be explained by a change in the chemistry of the fluid and thereby a change of the fluid source. However, fractionation during formation and recrystallisation of the halogen-bearing phases could cause a similar shift. The latter interpretation is unlikely as halogen ratios and other bulk chemical data indicate an additional pulse of a fluid with a different composition. In particular fluid mobile elements (e.g. K, Rb, Cs, U) show a rapid increase at the transition from amphibole to scapolite zone. A third fluid event causing albitisation of the already scapolitised metagabbro can be inferred from changes in mineral composition. This albitising fluid has the same δ^{37}Cl value as the scapolitising fluid and is therefore likely to have a similar origin.

[1] Barnes, J.D. and Sharp Z. D. (2006) A chlorine isotope study of DSDP/ODP serpentinized ultramafic rocks: Insights into the serpentinization process. *Chemical Geology* **228**(4), 246-265

[2] John T., Layne G. D., Haase K. M., and Barnes J. D. (2010) Chlorine isotope evidence for crustal recycling into the Earth's mantle. *Earth and Planetary Science Letters* **298**(1-2), 175-182