Using Secondary Ion Mass Spectrometry to decipher fluid-rock interaction

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Secondary Ion Mass Spectrometry (SIMS) is a mature technique for quantitative analysis of isotopes with a high analytical performance even at the ppm level, and a high spatial resolution of 4-20μm. SIMS analysis can be obtained for nearly the whole periodic system. Examples of our SIMS related research on fluid-rock interactions are (1) deciphering the mechanisms of infiltration driven mineral reactions using O and C and (2) fluid composition during metamorphic reactions through the analysis of H_2O, Cl and F contents in hydrous minerals to estimate HCl°, HF°, and H_2O activities.

(1) The infiltration of igneous fluids into carbonate xenoliths in the Bergell and Adamello intrusions (Alps, Italy) produced spectacular olivine veins. Abundant C and O isotope disequilibrium between reactants and products are observed. Indeed, we measured $\delta^{18}O$ differences of up to ~15‰ over a distance of less than 30μm between recrystallized and crystallographically continuous rims on inherited dolomite crystals, using ca. 4μm analysis spot. The fact that only recrystallized or reacted minerals exchange isotopically with the fluid, confirms the need for coupled models of major element and isotope transport.

(2) It is well established that hydrous silicates can be used to track chlorine composition of coexisting fluids through the incorporation of Cl into the hydroxyl site. While some hydrous silicates have wt% level of chlorine, we found that biotite and muscovite have only 1-2000ppm in the studied contact aureoles. Hence, we have calibrated Cl measurements by SIMS, and extended the analytical procedure to include simultaneously H_2O and F content determination. With this procedure, we can estimate the oxy-component in the mica O(4) site. We found that there are significant differences in the O^{2-} to OH^- ratio, which we interpret to be partially due to water activity variations. We show that micas are retentive with respect to the hydroxyl composition, and its composition is thus a viable fluid monitor during mica crystallization.

These and other studies document the exciting new perspectives obtained through SIMS analysis for water-rock interaction. The high spatial resolution in-situ analytics combined with petrology is a powerful tool for fluid-rock interaction studies.