

Fluorine and chlorine as tracers of magma-fluid and magma-crust interactions

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Fluorine and chlorine are halogen elements present as minor or trace elements in basaltic magmas. During magma formation and evolution, they behave as incompatible volatile elements and preferentially partition into the melt or gas/fluid phases. Similar to H₂O, they are enriched in the outer layers on Earth (atmosphere, hydrosphere and crust) compared to the mantle. Unlike H₂O, however, they are mostly undegassed in basaltic systems. Thus halogens can be used to assess the nature of the source and magmatic interactions with crustal reservoirs and fluids. We will show examples from two contrasting tectonic settings: mid-ocean ridge spreading centers and subduction zones.

At oceanic spreading centers, rapid quenching and confining water pressure during submarine eruptions prevents most volatiles from degassing, allowing us to use Cl, F, H₂O and S contents dissolved in the glasses to study magma evolution. The Cl/Nb in submarine basalts is usually used as tracer for seawater contamination. We identify 4 out of 20 glass samples analyzed from the equatorial Mid-Atlantic ridge with high Cl/Nb, suggesting seawater contamination. These 4 samples are the most depleted of the area ((La/Sm)_N down to 0.27), indicating that depleted samples are more sensitive to contamination than enriched ones. These 4 samples are also characterized by more reduced iron oxidation stages (Fe³⁺/Fe_{total}=0.13±0.005) compared to the uncontaminated ones (Fe³⁺/Fe_{total}=0.16±0.01). Such characteristics cannot be generated by seawater contamination only. We suggest the participation of a seawater-derived depleted lithology either in the source or a secondary contaminant during magma evolution. The selective depletion of F compared to Cl could be used to differentiate the effect of seawater from the effect of other contaminants or variations in the mantle source.

In subduction zones, arc basalts are enriched in F and Cl compared to mid-oceanic ridge basalts (MORB), due to the input of H₂O-rich slab components to their mantle source. F/Cl ratios measured in melt inclusions can be used to identify the nature of the slab-derived components. We apply this approach to mafic lavas from Mt. Shasta (Cascades Arc, USA). The selective enrichment of the melt inclusions in Cl, F and other fluid-mobile elements as well as their contrasting δ¹¹B show the imprints of two distinct slab-derived components C1 and C2. Using trace element ratios, we modeled the compositions of these two H₂O-rich components (C1 with Cl/F of 1.1 is rich in both in high field strength elements and incompatible trace elements; whereas C2 with Cl/F of 4.0, is poorer in trace elements) and show that they represent a mixing between sediment melts and dehydration fluids from the altered oceanic crust.