Geochemical evolution of mafic enclaves during an arc eruption

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Many hazardous andesitic volcanic eruptions exhibit evidence for recharge by volatile-rich mafic magmas in the form of mafic enclaves in the host rocks, with this interaction ascribed as the eruption trigger. Mafic enclaves provide us with a snapshot of dynamic mixing processes in the shallow chamber as well as insight into deeper crustal processes. We examine geochemically the temporal evolution of mafic magma supply to a shallow magmatic system using the active Soufrière Hills Volcano (SHV), Montserrat as a case study and compare with similar magmatic systems.

At SHV, binary mixing between a mafic end member (48 wt % SiO_2) and up to 67 % host andesite (61 wt % SiO_2) can explain the range in mafic enclave major and trace element compositions (48–57 wt % SiO_2) for the phase 5 (2009-2010) erupted product, which is consistent with the observed high percentage (15–25%) of phenocrysts and rhyolitic melt incorporated into the evolved mafic enclaves from the SHV andesite. The range of mafic enclave compositions may reflect the sampling of a hybridised layer at the interface between the two magmas. However, systematic offsets in major and trace element compositions at SHV such as Fe, Mg, V and Sc, between the eruptive phases show that the mafic end-member composition progressively altered from the early phases 1 to 3, but was constant from the latter phases 3 to 5. This variability may reflect an evolving lower mafic layer linked to magnetite fractionation and/or a quasi-continuous heterogeneous mafic supply throughout the eruption.

We compare SHV with 3 other similar magmatic systems (Augustine Volcano, Mt. Lassen and Quizapu) and observe a similar geochemical variability in the mafic end member in particular in V and strong negative linear correlations for example between V, Fe, Sc and Ti. This suggests that magnetite fractionation may have an important role in generating geochemical variability in magma mixing systems.