

Constraining the evolving volatile and melt geochemistry of magma reservoirs using apatite

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A general model of magma evolution at subduction zones involves progressive fractionation of volatile-rich magmas in the deep to mid-crust, followed by ascent to storage regions in the shallow crust where further differentiation occurs. The deeper fractionation may involve crystallisation of mafic minerals such as pyroxene and amphibole from volatile-undersaturated magmas. In contrast, upper crustal magma storage conditions are commonly linked to active degassing following volatile saturation in frequently replenished magma reservoirs. Methods to evaluate the variability of trace element and volatile compositions of hydrous arc magmas are therefore critical to understanding the magmatic architecture in subduction zones.

We have been using the compositional record preserved in apatite to assess variations in melt and volatile geochemistry during magma storage and differentiation. Apatite crystallises relatively early in many magmas and is typically trapped as inclusions within phenocrysts, and can therefore preserve a temporal record of changing magmatic volatile contents in the lead-up to eruptions. New experiments and direct analysis of all the major volatile components (including C and OH) shows that apatite contains high CO₃²⁻ abundances and may therefore prove a sensitive means of tracking pre-eruptive magmatic CO₂ contents. Modelling suggests that apatite volatile compositions are particularly sensitive to the onset of volatile saturation in magmas, which is a great advantage over melt inclusion studies. We illustrate our results using case examples of eruptions from Campi Flegrei, Italy and Laacher See, Germany. At Campi Flegrei we find that volatile saturation occurred very late during magma storage and may have triggered eruptions due to pressurisation of the magma reservoir. Conversely, volatile saturation in the Laacher See magma occurred early in the magmatic history, during growth of the crystal load. Apatite chemistry therefore represents a useful new tool for investigating temporal variations in magmatic volatiles prior to eruption.