Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.11402

The apatite record of pre-eruptive magma mixing and mush disaggregation

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Fundamental problems in understanding pre-eruptive magmatic processes include the dynamics and timing of new magma injection and their links to remobilisation of stored magmas or crystal mushes. More information is needed about the volatile contents of new magmas entering the system, the physical mechanism(s) generating remobilisation, and the timing of any geophysically resolvable signals relative to subsequent eruptions. We also need a better understanding of the timing of magmatic volatile saturation. Here, we present new constraints on the pre-eruptive volatile histories of magmas, determined using apatite geochemistry. We consider variations in magmatic volatile chemistry, gas saturation state, and whether apatite crystals and melt could have been in equilibrium immediately prior to eruption. Combined with numerical forward modelling, we use constraints from apatite to highlight approaches to understanding mush reorganisation and eruption using the 12.9 ka Laacher See eruption, as well as other examples using data from the literature. We show that apatite inclusions and microphenocrysts can be used to investigate temporal variations in dissolved magmatic volatile contents and compositions, and to constrain the amount of pre-eruptive magmatic vapour released during eruptions. Considering the short timescales of apatite volatile re-equilibration, these data also bring temporal constraints on changes immediately preceding the eruption. We suggest that apatite may be a powerful way to track mush or magma storage and transport prior to volcanic eruptions.