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Arc magma differentiation via decompression-driven crystallisation: a mechanism to keep arc volcanics metaluminous?

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Arc magmatism is fundamental to the generation of new continental or island arc crust. However, the mechanisms that add to the chemical complexity of natural calc-alkaline magmas ranging from basaltic to rhyolitic compositions is strongly debated. Differentiation mechanisms under debate include magma mixing, assimilation, crustal melting, cannibalisation, or (fractional) crystallisation. In this contribution, the differentiation of arc magmas via decompression-driven crystallisation was investigated via comparing natural rock compositions with pre-existing and novel experimental data.

We performed a set of equilibrium crystallisation experiments at variable crustal pressures (200-800 MPa) on a hydrous high-Al basalt (3.5 wt.% of H_2O in the starting material) with run temperatures varying from near-liquidus conditions (1110°C) to 900 °C. Oxygen fugacity was buffered at moderately oxidising conditions close to the NNO equilibrium. Combining these novel experiments with polybaric fractional crystallisation experiments [1], we demonstrate the distinct effect of pressure (and additional parameters) on the crystallisation behaviour of calc-alkaline magmas. Different decompression trajectories illustrate crucial differences with respect to liquid and cumulate lines of descent, mineral chemistry, and the evolution of crystal/melt ratios. An important result is that decompression shifts the olivine-clinopyroxene cotectic curve towards melt compositions with higher normative clinopyroxene and increases the stabilisation of plagioclase, exerting a key control on the Al_2O_3 contents of residual liquids. We argue that the combined effects of elevated fO_2 and decompression keep liquids metaluminous, a characteristic signature of most arc magmas. We also show that the experimentally determined, pressure-dependent compositional variations of amphibole and clinopyroxene can be used as a proxy to monitor decompression paths of ascending natural arc magmas.

[1] Marxer F, Ulmer P & Müntener O (2022) Polybaric fractional crystallisation of arc magmas: an experimental study simulating trans-crustal magmatic systems. *Contributions to Mineralogy and Petrology* 177:3.