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Lithium and copper partitioning and mobility recorded by plagioclase at Augustine volcano, AK, USA

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Tracing the pre-, syn-, and post-eruptive mobility of volatile metals, e.g. Li, is important for understanding the behaviour of fluid phases in volcanic conduits, fluid-mineral-melt partitioning, and the formation of economic porphyry and epithermal metal deposits. Lithium diffuses rapidly and thus may reveal magmatic-hydrothermal processes operating on timescales of minutes to hours. We report detailed trace element data for plagioclase phenocrysts from the evolved, halogen-rich, magmatic system of Augustine volcano, AK.

Pumice-derived plagioclase crystals show essentially flat core-to-rim Li and Cu profiles, with limited variability (Figure 1, top panel). Relative to melt inclusion Li and Cu contents from the same phenocrysts, these concentrations are in accordance with experimentally determined equilibrium mineral/melt partitioning affinities for dacitic systems. The outermost rims of plagioclase crystals (<100 µm from crystal edges), however, are consistently enriched in Li and Cu.

Conversely, plagioclase sampled from effusive lava and vitrophyre deposits (Figure 1, bottom panel) show variable but elevated Li and Cu profiles. Both Li and Cu then markedly decrease close to the crystal-groundmass interface. Melt inclusions hosted by these crystals record Li concentrations in excess of 150 ppm.

Crystal cargoes from both deposit types have similarly complex zoning patterns and evidence of mafic recharge, indicating common storage histories prior to final ascent and eruption. Hence, we suggest that the systematic differences in Li and Cu profiles between effusive and explosive eruptions result from contrasting late-stage magma dynamics. For effusive samples, slower ascent rates and significantly slower post-eruptive cooling allow for greater extents of groundmass crystallisation (with an overall bulk $D_{Li}^{min/melt} < 1$), causing an increase in melt Li contents and subsequent diffusion into the plagioclase phenocrysts. In contrast, the more rapid ascent and quenching of pumice clasts, inhibited extensive groundmass crystallisation and lead to only minor Li enrichment in crystal rims. These results demonstrate the potential of Li profiles to trace both syn- and post-eruptive magmatic processes, but post-eruptive overprinting of original Li signatures in more slowly cooled volcanic deposits must be assessed [1, 2].

[1] Audétat et al. (2018). Geochimica et Cosmochimica Acta, 243; 99–115.
[2] Ellis et al. (2018). Nature Communications, 9; 3228.