Magma mixing and the assembly of complex eruption sequences

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Elemental diffusion in plagioclase and olivine [1, 2] can provide an integrated timescale of the sequence of magma mixing until eruption. For example, at Quizapu volcano (Chile) textural observations and Mg diffusion in plagioclase constrain a succession of magma recharge, mixing and eruption to a few days to three weeks [3]. One major caveat in using elemental diffusion, however, is the potential competing effect of crystal growth, which may lead to similar normal zoning patterns when magma mixes, cools and crystallizes with more evolved compositions.

In order to deconvolve crystal growth from diffusion, we have obtained by LA-ICPMS multi-element zoning patterns for olivines from the 1963-5 eruption of Irazu volcano (Costa Rica) for elements that span a wide range of diffusivities (Fe-Mg, Mn, Li, Ca, P, Sc, Ti V, Cr, Mn, Fe-Mg, Co, Ni, Zn). The 1963-65 eruption is characterized by phreatomagmatic deposits of basaltic andesites (54-57 wt% SiO_2, [4]). In three samples spanning a large sequence of the eruption we identify olivines of different origin (Fo70-91, crustal olivine cumulates and mantle-derived recharge olivines). Some olivines are dominated by growth signatures (primarily based on P profiles) and others record the timing of magma mixing through their diffusion profiles (Fe-Mg, Ni). The initial phase is dominated by mantle-melt derived olivines with a thin low Fo growth rim consistent with decompression growth over a few weeks in a mixed magma and a slightly normal zoned interior (Fo84-90) resulting from an extended time of diffusive exchange (months to years) at evolving but still mafic compositions. The later eruptive sequence shows much larger variety of olivines that records the syn-eruptive addition of distinct magmas that wax and wane through the eruption, though olivines still present from the early stage have much thicker growth rims indicating longer residence prior to eruption. Thus, multi-element zonation profiles record crystal growth during magma ascent and diffusive exchange during crystal storage, as an eruptive system evolves.

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A complex network analysis of growth and mixing dynamics in natural metal-silicate systems

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Core Formation in Partially Molten Planetesimals

The segregation of metallic cores from silicate mantles is one of the earliest, and most important, differentiation process involved in the evolution of terrestrial planetary bodies and reconciling our estimates of primary bulk silicate mantle with candidate planetary bulk compositions requires an understanding of the different regimes in which core forming material may have been mobile. This includes regimes that are dynamic and may result in transient states of high stress due to impact. Recent scenarios of core formation in planetesimals using calculations from extinct radionuclides (e.g. ^{26}Al, ^{60}Fe) call for segregation of a metal liquid (core) from partially molten silicate – a silicate mush matrix. This segregation scenario requires growth of molten core material into blebs large enough to overcome the strength of the mush matrix so that separation can occur. However, currently there is no satisfactory explanation as to how or why metallic liquid blebs in the presence of silicate melt actually grow. Experimental work has suggested deformation and shear can help coalesce metallic blebs. Here, we have developed an innovative approach that combines textures in experimental deformation experiments on a partially molten natural meteorite with complex network analyses. This approach can elucidate and quantify the growth of metallic blebs in regions where a silicate mush matrix is present and help predict separation.