The architecture of the intermediate-sized Quizapu magma system

PHILIPP RUPRECHT[1]*, GEORGE BERGANTZ[2], KARI COOPER[3] AND OLIVIER BACHMANN[4]

[1]LDEO of Columbia University, Palisades, NY, USA, (*correspondence: ruprecht@ldeo.columbia.edu)
[2]Dept. of Earth and Space Sciences, University of Washington, Seattle, WA, USA
[3]Dept. of Geology, University of California, Davis, CA, USA
[4]Inst. für Geochemie und Petrologie, ETH Zürich, Switzerland

While high melt fraction magma chambers may be transient features in the crust, magmatic mushes represent the long-lived counterparts of the crustal magmatic factory. Together they source largely variable andesitic to dacitic composite volcanic cones and stratovolcanoes and manifest the continuous presence of silicic magma in the crust above convergent margins. Silicic magmas are ultimately fed and their eruption triggered by magmas generated in the mantle. How intermediate-sized (tens of km^3) magmatic systems are assembled and what kind of crustal-scale architecture results from that assembly, requires an integrated approach of crystal-scale geochemistry, petrology, and fluid dynamics.

Utilizing such a combined approach provides tight constraints on the magmatic architecture beneath Volcán Quizapu (Chile), a magmatic system that produced two ~ $5km^3$ large historic eruptions. The shallowest part of the Quizapu system is dominated by high-melt fration dacites with minimal evidence for hybridization. This eruptible dacite lense is generated by crystal-melt separation from an andesitic mush of intermediate temperature. Hybridization – common for arc systems – is limited to the andesitic mush, while hot recharge magmas interact only in rare cases directly with the shallow dacite magma [1]. Such mafic recharge leads to mixing and eruption and diffusion modeling of elemental zonation in phenocrysts at Quizapu (e.g., Mg in plagioclase) suggests that recharge, mixing, and eruption occured within days to a few weeks [2]. Moreover, we consider the thermal effects on the mixing and eruption dynamics associated with hot mafic recharge and find (i) that overall mixing efficiency for the erupted volume is set early during the recharge events – limiting the extent of hybridization [1] – and (ii) that short-term reheating leads to significant viscosity reduction in the resident dacite magma. We argue that late-stage reheating may reduce the potential for Plinian eruptions as water-saturated dacites degas efficiently during ascent [3].

[1] Ruprecht *et al*. (2012), *J. of Petrology* **53**, 801-840. [2] Ruprecht & Cooper (2012), *J. Petrology* **53**, 841-870. [3] Ruprecht & Bachmann (2010), Geology **38**, 919–922.

Are long-lived stratovolcanos low-pass filters for magma transport?

PHILIPP RUPRECHT[1]* AND TERRY PLANK[1]

[1]LDEO of Columbia University, Palisades, NY, USA, (*correspondence: ruprecht@ldeo.columbia.edu)

Arc stratovolcanoes localize magmatic activity for 10s to 100s kyr, leading to self-cannibalization and the emergence of polybaric subvolcanic magma storage regions. Partial melts accumulate within mush zones and sills at various levels in the crust. Dense primitive mantle-derived magmas that ascend from mantle source regions encounter those density barriers on their way to the surface, leading to stalling and an evolution to more buoyant magmas through fractionation, mixing, and assimilation. It is therefore not surprising and well-known through geochemical and isotopic studies that primitive magma compositions typically do not reach the surface within voluminous arc magma systems. This view suggests that long-lived arc stratovolcanoes act as low-pass filters for primitive magmas from the mantle, where the frequency of magma addition from the mantle is converted in the crust to a slower integrated ascent rate as magmas stall, evolve and accumulate. Isotope and geochronology studies on crystal cargo provide evidence for such prolonged magma processing. While some stalling and processing in the crust is commonly agreed upon, magma transit times at middle to lower crustal levels are particularly unconstrained. A contrasting view is that magmas rise rapidly (potentially adiabatically), resorb any crystal cargo upon ascent, and crystallize at shallow depth.

Combining geochemical data from primitive crystals (e.g., Fo90), observations of upward earthquake migration beneath long-lived volcanic centers, and thermal constraints on magma transport in the crust, we show that slow processing (low-pass filtering) may not be as ubiquitous as it is assumed for large stratovolcanoes [1]. Instead, a second mode of fast magma transit from the mantle to the surface must coexist. Some phenocrysts in arc magmas record in their crystal zoning mixing eposides of primitive magmas at Moho depth (e.g., >1000 ppm Ni variations in olivines of constant Fo), and provide an upper limit on ascent rates of primitive magmas. In fact, thermal models for dike transport and trace element diffusion calculations for Ni zoning constrains integrated Moho-to-surface ascent rates for the fast mode to ~ 0.1-1 km/day, well in line with seismic observations from migrating earthquake swarms. Such ascent rates require primitive magmas to bypass or transit effectively most middle to lower crust magma storage regions.

[1] Ruprecht & Plank (2013, in press), Nature, doi: 10.1038/nature12342

DOI:10.1180/minmag.2013.077.5.18