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Tracing magma chambers beneath Lascar volcano with petrological, geochemical and geophysical methods

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Lascar is a 45ka calc-alkaline stratovolcano in the Central Volcanic Zone of the Andes (N Chile). Lascar's activity is characterized by lava flows, domes, and pyroclastic deposits (e.g. in 1993 and 2007). As for most subduction-related volcanic systems, depth, size and shape of magma chambers beneath active stratovolcanoes and the geometry of the magma feeders are poorly defined. We combine petrological, geochemical and geophysical results to constrain depth of and processes within the Lascar magma reservoir(s).

Erupted lavas range from basaltic andesites to dacites. Major element variations indicate alternating stages dominated by magma mixing and crystal fractionation. Glass inclusions are dacitic to rhyolitic in compositions with rather small concentrations of chlorine (200-1600ppm), fluorine and sulfur, suggesting that the trapped melts were evolved and largely degassed. Two pyroxene geo-thermo- and barometers constrain the magma storage conditions of the oldest (45 – 7 ka) to the most recent historic eruptions (1993 and 2007). A large temperature interval of crystallization from ∼850 to 1050°C is observed. For the oldest rocks, pressures range from ∼ 0.3 to 1.5 GPa, whereas significantly lower pressures from 0.3 to 0.5 GPa were calculated for the recent eruptions.

Phase equilibria for a natural basaltic andesite, (∼58wt% SiO_2 and ∼5wt% MgO) from Lascar were determined experimentally to constrain magmatic evolution by crystal fractionation or mixing using internally heated pressure-vessels. Experimental conditions ranged from temperatures of 900 to 1050°C and pressures of 0.3-0.5 GPa at a controlled fO_2, corresponding to the NNO+1 buffer (for H_2O-saturated conditions) and H_2O activities of ∼0.2-1.0. Compositional variations of the 1993 lava and older samples are reproduced experimentally and interpreted as products of crystal fractionation in a magma reservoir at ∼ 0.3-0.5 GPa pressure. Deeper magmas (∼ 1.3 ± 0.3 GPa) are dominated by magma mixing.

Long-period and broad-band magnetotelluric measurements conducted in the vicinity of Lascar volcano are interpreted within the context of regional measurements in the Central Andes. The broadband instruments were installed near Lascar while the long-period devices measured along a profile just south of Lascar. 3-D modeling and inversion did not resolve a magma chamber directly beneath Lascar volcano. Instead, two conductive zones extend to the south of Lascar, one extending immediately to the S-SE of the volcano, the other 10 km to the south. The depths of the anomalies extend to 2–3 km and 7–10 km, respectively.

Our combined data indicate that pre-eruptive storage depths of the youngest magmas are shallow (0.3 – 0.5 GPa). Differentiation processes in such reservoir(s) are controlled by fractional crystallization. Deeper magmas show clear evidence for magma mixing processes. Thus, magmatic processes (crystal fractionation vs. mixing) may differ in high pressure and low-pressure reservoirs, possibly related to their size. The absence of geophysical evidence for a large magma chamber indicates that the feeder system where shallow differentiation and mixing takes place is dominated by smaller reservoirs. Input of mafic andesite into the shallow Lascar magma system occurs from deeper (lower crustal levels) as exemplified by base-line magma compositions.