Investigating the rheological controls on the explosive-effusive transition at Tungurahua volcano

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Tungurahua volcano has been active since 1999 culminating in the voluminous August 2006 VEI-3 eruption, a series of explosive events terminated by the effusion of a lava flow. Understanding such a rapid shift in eruption style is crucial to eruption forecasting at andesitic arc volcanoes. Here, rheological changes occurring during magma ascent are invoked to explain eruptive style.

Erupted material from the August 2006 bimodal eruption is described as chemically homogeneous (bulk rock approx. 57 wt.% SiO_2) and texturally variable. The explosive phase showed a wide range of porosities (1-60%), crystallinities (20-30% phenocrysts), with an interstitial glass composition of 63-65 wt.% SiO_2. In comparison, the lava material is more crystalline (30-40% phenocrysts, high microlite content), less porous (1-5%) with an interstitial glass with 67 wt.% SiO_2. During fragmentation experiments, the pore overpressure required to achieve fragmentation of the explosive magma was 3MPa, whereas 6-10 times more pore pressure is required to fragment the lava.

Rheological behaviour of ascending magma (undergoing crystallization, volatile exsolution and chemical fractionation) is a chief determinant of eruptive style. A variety of experimental techniques were combined to map the rheological evolution of magma during ascent at Tungurahua. In the reservoir, the magma is envisaged as crystal poor with a composition similar to that of the bulk rock. The non-Arrhenian temperature dependence of the viscosity of the (dry) magma in the reservoir (from re-melted whole rock material) and the increase in melt viscosity due to initial (20 vol.%) crystallization were measured using a concentric cylinder. The end viscosities of the erupted products were elucidated using a uniaxial press and show apparent viscosities 5 orders of magnitude above the pure interstitial melt and 7-8 orders above the viscosity of the reservoir magma. The effusive material was more viscous and shear-thinning than the explosive material. Thus, the lava flow represents the late effusion of a more viscous (possibly related to ascent rate) magma with diminished stored energy to drive fragmentation.