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The Rheology of the 2006 Explosive/Effusive Eruption at Tungurahua Volcano, Ecuador

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The current eruptive activity at Tungurahua volcano commenced in 1999 and has displayed several episodes of explosive activity. Important events generated pyroclastic flows in July 2006, August 2006 and February 2008. The August 2006 eruption climaxed in a VEI 3 explosion with 10s of pyroclastic flows and notably terminated with the effusion of a 3-km long lava flow. This variability of eruptive scenarios represents an excellent opportunity to study the occurrence of multiple pulses of pyroclastic activity associated with near contemporaneous extrusion of lava flow from a single, central vent. Magma rheology is considered a chief determinant of eruptive style. During sub-Plinian-type eruptions, the transition from ductile to brittle behaviour is largely strain rate and also temperature dependent. While the rheology of single-phase silicate melts is well understood, the description of magma such as that at Tungurahua (i.e., bearing 30-50 % crystals and 10-35% bubbles) is relatively unknown. Our rheological investigations provide a unique snapshot into the development of the erupted magmas: from the effects of crystallisation in the magma reservoir and conduit to the effects of strain rate during ascent in the conduit up to the point of fragmentation.

To constrain pre-eruptive conditions at Tungurahua we attempt to apply geothermobarometry to the mineral assemblages in question. The two-pyroxene method has revealed temperatures ranging from 940-986°C and unreasonably high pressures (8-12.8 kbar), with a calculated equilibrium coefficient of 0.8. Application of the clinopyroxene-liquid geothermobarometer gives T = 1214-1469°C and P = 5 kbar. We remain unconvinced by these results, and we intend to complement our estimates using feldspar-glass relationships. We estimated the end temperature of the eruption at 976 °C, by determining the softening temperature (analogous to the glass transition temperature) using dilatometry.

Investigations with a concentric cylinder viscosimeter provide insight into the rheology of pre-erupted, crystal-free magmas at higher temperatures. We model the effects of crystallisation by comparing the obtained viscosity with that calculated [using Giordano et al., (2008) model applied to the chemical composition of the interstitial glass, measured via electron microprobe] for the interstitial melt of erupted products. The rheology of the magmas that produced the pyroclastic flows and the lava flow have been investigated using a Uniaxial deformation apparatus. This research yielded variable strain-rate and temperature dependent rheologies with the lava displaying higher viscosities at given strain rates. Combining several techniques in conjunction with one another, we are able to constrain the variations in magma rheology that may have occurred during the development of the recent eruptions at Tungurahua.

Using a combination of field observations and experimental analysis, we hope to constrain the factors controlling the observed explosive and effusive activity seen at Tungurahua. Initial results expose two differing magma rheologies interacting with one another in conduit and chamber. A more complete mixing was potentially impeded by the differing rheologies and ascent rates of the cogenetic magmas.