Does magma rheology control eruption style? The case of Fuego, Guatemala

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Volcán Fuego, Guatemala, is a basaltic andesitic stratovolcano that has been in semi-continuous eruption for more than 500 years. The past decade has been characterized by vulcanian explosions with minor ash emission, punctuated by strombolian episodes with extrusions of lava flows and rare larger eruptions with pyroclastic flows, most recently in September 2012. We have investigated 9 samples (4 lava flows, 1 air-cooled bomb, and 4 blocks transported in pyroclastic flows) erupted or deposited in 2003 and in 2008-9, and all collected from the Barranca Santa Teresa on Fuego's western flank, to see if the type of activity (lava flow vs pyroclastic flow generation) can be correlated with varying physical and chemical properties of the magma. In particular we test the hypothesis that magma rheology controls eruptive style, i.e. blocks and bombs should be more viscous than lava flows.

All the samples are highly crystalline, with similar basaltic andesite bulk compositions (52-53 wt.% SiO_2) comprising matrix glass of andesitic to dacitic composition (62-67 wt.% SiO_2) with abundant plagioclase, olivine and pyroxene phenocrysts together with minor Fe-Ti oxides. One lava flow "2003c" has a rhyolitic matrix glass ($\sim$74 wt.% SiO_2). Phenocryst compositions vary little, and show no systematic variation with eruption style. The matrix (dense-rock) density of the samples also varies little, from $\sim$2810-2850 kgm^{-3}), while bulk density varies from $\sim$1480 to $\sim$2680 kgm^{-3}, due to porosity. Lava flow samples contain 11-16 vol.% vesicles, while the bomb contains 16 vol.% and blocks range from 5 vol.% (dense) to 48 vol.% (vesicular). Water contents of matrix glasses vary from $\sim$0.25 wt.% (bomb) to less than 500 ppm (breadcrust block in a pyroclastic flow). The rheology of all samples was measured by uniaxial compression at $\sim$1020℃ and 1 atm. In all experiments, regardless of porosity, the viscosity increased from $\sim10^{10}$ to $\sim10^{12}$ Pa.s in a few hours, then increased only slightly for the next $\sim$80 hours. Lava flow sample 2003c has a slightly ($\sim$0.5 log unit) higher viscosity than other samples. These experiments never exceeded 2% total strain, and overall changes in porosity were negligible, but the proportion of isolated porosity increased during the experiment, which we attribute to early crack closure.

Despite large variations in vesicularity, and modest variations in matrix glass chemistry and dissolved water content, the rheology of blocks, bombs and lava flows is generally identical. We conclude that changes in eruption style do not reflect changes in magma properties. The most likely alternative controls are magma supply rate, and/or mechanisms related to how lava and hot erupted material accumulates near the summit region, and how this material may be remobilized as either lava or pyroclastic flows.