Rheology of Crystal- and Bubble-bearing Magmas: insights into volcanic conduit dynamics

Mattia Pistone[1], Luca Caricchi[2], Peter Ulmer[1]

[1]Department of Earth Sciences, ETH-Zurich, Zurich, Switzerland, [2]Department of Mineralogy, University of Geneva, Geneva, Switzerland

E-mail: Mattia.Pistone@bristol.ac.uk

Magmas are multiphase mixtures composed of crystals and gas bubbles suspended in a silicate melt. The relative proportions of these phases and their interaction control the rheological behavior, the modality of emplacement within the Earth's crust and the eruption of magmas. The rheology of crystal- and bubble-bearing magmas (ranging from dilute suspensions to crystal mushes) has been experimentally investigated. Hydrous haplogranitic magmas (1.6-2.6 wt% H2O) containing variable amounts of quartz crystals (24-65 vol%), and CO2-rich bubbles (9-12 vol%) were deformed in simple shear with a Paterson-type rock deformation apparatus at high temperature (823-1023 K) and high pressure (200 MPa), in strain-rate stepping (10-5 s-1 - 4*10-3 s-1) from low to high deformation rate. The rheological results show that three-phase suspensions are characterized by strain rate-dependent rheology (non-Newtonian behavior). Two kinds of non-Newtonian behaviors were observed: shear thinning (decrease of viscosity with increasing strain rate) and shear thickening (increase of viscosity with increasing strain rate). Microstructural observations suggest that: shear thinning dominantly occurs in crystal-rich magmas (55-65 vol% crystals) because of crystal size reduction and shear localization; shear thickening prevails in dilute suspensions (24-44 vol% crystals) due to outgassing promoted by bubble coalescence. To illustrate the impact of these new findings in magma rheology, we present two applications on volcanic conduits where magmas are characterized by shear thickening and shear thinning behavior. The two types of rheological behavior determine the modality of magma ascent in the volcanic conduit and, ultimately, the type of volcanic eruption.