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Mechanical constraints on the triggering of vulcanian explosions at Santiaguito volcano, Guatemala

Adrian Hornby (1), Yan Lavallée (1), Amy Collinson (2), Jurgen Neuberg (2), Silvio De Angelis (1), Jackie Kendrick (1), and Anthony Lamur (1)

(1) Department of Earth, Ocean and Environmental Sciences, University of Liverpool, Liverpool, L69 3GP, United Kingdom, (2) School of Earth and Environment, University of Leeds, Leeds, United Kingdom

Gas- and ash explosions at Santiaguito volcano occur at regular 20-200 minute intervals, exiting through arcuate fractures in the summit dome of the Caliente vent. Infrasound, ground deformation and seismic monitoring collected during a long term monitoring survey conducted by the University of Liverpool have constrained a stable, repeatable source for these explosions. The explosions maintain similar magnitudes and (low) erupted mass throughout examined period. Ground deformation reveals stable ∼25 minute inflation-deflation cycles, which culminate in either explosions or passive outgassing. Inversion of infrasound sources has revealed that faster inflation rates during the final minutes before peak inflation lead to explosions. These explosions fragment a consistently small-volume pressurized, gas-rich domain within magma located below a denser, lower permeability magma plug. Rapid decompression of this gas-rich domain occurs through fracturing and faulting, creating a highly permeable connection with atmospheric pressures near to the dome surface. We surmise that the dominant fracture mode at these shallow depths is tensile due to the volumetric strain exerted by a pressurising source below the magma plug, however a component of shear is also detected during explosive events. Fractures may either propagate downwards from the dome surface (due to greater magma stiffness and lower confining pressure) or upwards from the gas-rich domain (due to higher strain rates at the deformation source in the case of viscous deformation). In order to constrain the origin and evolution of these fractures we have conducted Brazilian tensile stress tests on lavas from the Caliente vent at strain rates from 10-3-10-5, porosities 3-30% and temperatures 20-800 °C. Across the expected conduit temperature range (750-800 °C) the dome material becomes highly sensitive to strain rate, showing a range of response from elastic failure to viscous flow. The total strain accommodated prior to failure shows a non-linear increase as viscous deformation becomes more important (i.e. temperature is increased or strain rate decreased). This allows us to constrain timescales for fracture propagation for given temperature-strain rate scenarios. We use these results, together with monitoring data and the results of numerical modelling to compare the probability of fractures propagating from the top-down or bottom-up prior to explosions at Santiaguito. Thus, we shed light on the triggers and signals leading to vulcanian explosions, which may be widely applicable to vulcanian explosions at active volcanoes.