Frictional control on spine growth at Mt. Unzen, Japan

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The 1991-1995 eruption at Mt. Unzen was characterised by the growth of 13 lava lobes. The onset (May 1991) and end (Oct. 1994) of the dome-building phase was punctuated by the extrusion of spines; the ultimate period of spine extrusion was accompanied by rhythmic seismic activity occurring as vigorous high-frequency swarms at <0.5km depth every 40-60 hours during the course of spine erection. Exogenic spine extrusion requires the seismogenic failure of magma and we infer the seismic swarms to represent discreet spine extrusion events, reaching up to metres of slip.

Frictional properties of magma ascent and spine growth were modelled through high-velocity rotary shear experiments on dome rocks from Mt. Unzen. These were conducted on a range of slip velocities (0.1-1.5m/s), axial load (0.4-5MPa) and slip distance (<20m). During slip at low axial load (<1Mpa) rock-rock friction took place, achieving a low friction coefficient in agreement with Byerlee's rule. Slip at higher axial load ($\geq$1MPa) induced melting at a mechanical work threshold; higher slip velocities led to increased melt productivity with a diminishing control on shear resistance at the slip zone. This relationship is accentuated with increasing load, which shows that the rheology of frictional melt induces slip dynamics which do not abide to Byerlee's rule. During frictional melting the characteristic mechanical response showed a progressive increase in shear resistance, peaking at a point when the melt layer extended across the slip zone. Lubrication of the frictional plane caused a decrease in shear stress to a steady state. We monitored heating up to 1800℃/s and stabilisation at ca.1200℃ during steady state. We note that the total slip required to undergo frictional melting diminishes with axial stress and slip velocity. The shear resistance of the frictional melt (at steady state) is proportional with the axial load, yet dependent on slip rate, which suggests that the rheological control on slip may be that of a non-Newtonian liquid.

This study concludes that frictional melting changes the mechanical properties of rocks at a fault surface and thus, the rheology driving dome extrusion may not be derived directly from the dome material itself. We envisage that seismogenic events during spine growth at Mt. Unzen may have been accompanied and controlled by frictional melting in the upper conduit.