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Friction in volcanic environments

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Volcanic landscapes are amongst the most dynamic on Earth and, as such, are particularly susceptible to failure and frictional processes. In rocks, damage accumulation is frequently accompanied by the release of seismic energy, which has been shown to accelerate in the approach to failure on both a field and laboratory scale. The point at which failure occurs is highly dependent upon strain-rate, which also dictates the slip-zone properties that pertain beyond failure, in scenarios such as sector collapse and pyroclastic flows as well as the ascent of viscous magma.

High-velocity rotary shear (HVR) experiments have provided new opportunities to overcome the grand challenge of understanding faulting processes during volcanic phenomena. Work on granular ash material demonstrates that at ambient temperatures, ash gouge behaves according to Byerlee's rule at low slip velocities, but is slip-weakening, becoming increasingly lubricating as slip ensues. In absence of ash along a slip plane, rock-rock friction induces cataclasis and heating which, if sufficient, may induce melting (producing pseudotachylyte) and importantly, vesiculation. The viscosity of the melt, so generated, controls the subsequent lubrication or resistance to slip along the fault plane thanks to non-Newtonian suspension rheology. The shear-thinning behaviour and viscoelasticity of frictional melts yield a tendency for extremely unstable slip, and occurrence of frictional melt fragmentation. This velocity-dependence acts as an important feedback mechanism on the slip plane, in addition to the bulk composition, mineralogy and glass content of the magma, that all influence frictional behaviour.

During sector collapse events and in pyroclastic density currents it is the frictional properties of the rocks and ash that, in-part, control the run-out distance and associated risk. In addition, friction plays an important role in the eruption of viscous magmas: In the conduit, the rheology of magma is integral to eruption behaviour and during ascent magma behaves in an increasingly rock-like manner as it degasses and crystallises. This character aids the development of shear zones in the conduit, producing fault surfaces that host gouge, cataclasite and pseudotachylyte and which control the last hundreds of meters of ascent by frictional slip. Recent work has shown that the occurrence of vesiculation of gas bubbles modifies the rheology of frictional melt and in extreme cases can trigger eruption style to switch from effusive to explosive activity. Hence it is of vital importance to recognise the frictional behaviour of volcanic rocks and magmas to understand the continuation of an eruption and associated hazards.