Simulation of Lava Dome Growth Considering shear thinning, thermal feedback and strain softening

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For a greater understanding of the flow properties of highly viscous crystalline-rich magma during ascent and in Peléean lava dome formation Finite Element Method (FEM) models have been developed. These models consider the fundamental controls on the eruption dynamics and the different growth styles (endogenous and exogenous). In endogenous dome growth the interior is a thermo-mechanically continuous structure, whilst for exogenous dome growth lava is extruded directly to the free surface due to the influence of faults. Transition between these two growth regimes are observed to occur for many lava domes and often denotes a significant change in the growth dynamics and a propensity for the dome to collapse.

The dome growth regime is governed by the rheology of the lava and the flow rate from the feeding conduit. At the lowest extrusion rates the extruded lava is highly crystalline and dome growth is predominantly exogenous, probably {\it via} the channeling of lava along structural discontinuities within the dome. This process is not understood quantitatively but it is thought to be due to shear planes, formed following brittle failure, originating at the conduit edge where the shear stresses experienced between new lava entering and existing lava is greatest. The development of these structural discontinuities ultimately governs the growth style and may also be responsible for shallow earthquake activity.

An axi-symmetrical FEM model has been developed for generic dome growth based on the parallelized finite element based PDE solver eScript/Finley (Davies, Gross and Muhlhaus, 2004). The lava viscosity is known to depend upon temperature, pressure, crystal content and water content and this is modelled using empirical data specific for the lava extruded from the Soufrière Hills Volcano. In our simulation we investigate the influence of thermal feedback due to shear (viscous) heating within the conduit and dome and its subsequence influence upon the flow profile. The models also consider the influence of the strain rate using a power-law viscosity (shear-thinning). Our model equations are formulated in an Eulerian framework and the evolution of the free surface of the lava dome is modeled using a level-set method (Tornberg and Enquist, 1999). We demonstrate that the formation of internal shear bands can be triggered by the inclusion of rate independent plastic deformations and strain softening.

1. Davies, M., Gross, L., Mühlhaus, H.–B., 2004, *Scripting High Performance Earth Systems Simulations on the SGI Altix 3700*, Proc. 7th Intl Conf. on High Performance Computing and Grid in Asia Pacific Region, 244-251.
2. Tornberg, A-K and Engquist, B (2000), A finite element based level-set method for multiphase flow applications. Comput. Visual Sci. 3, 93-101