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Computationally Modelling Lava Morphology in Crystal-rich Effusive Volcanic Eruptions.

A. Hale, H. Mühlhaus

Earth Systems Science Computational Centre (ESSCC), Australian Computational Earth Systems Simulator (ACcESS), Sir James Foots Building (47a), The University of Queensland, PO Box 6067, St Lucia, QLD 4072, Australia. (alinah@esscc.uq.edu.au / Phone: +61 7 3346 4110)

Extruded highly-viscous and crystal-rich lava has the characteristic that it can fracture and shear during deformation whilst still retaining some ductility. This property can lead to the formation of shear bands which are thought to originate in the upper conduit and determine the extruded lava growth regime. Endogenous growth occurs when the lava is extruded as a thermo-mechanically continuous structure, whilst exogenous growth occurs when the lava is extruded directly to the free surface due to shear bands. Transitions between the growth regimes often denote a significant change in the growth dynamics and a propensity for the lava mass/dome to collapse. Shear bands may also be responsible for the low-frequency shallow earthquake activity often observed prior to a collapse/eruption.

For a greater understanding of lava flow during ascent and its morphology in Peléean lava domes axi-symmetric Finite Element Method (FEM) models have been developed based on the parallelized finite element based PDE solver eScript/Finley. Lava viscosity depends upon temperature, pressure, crystal content and water content and this is modelled using empirical equations constrained to the lava extruded from the Soufrière Hills Volcano, Montserrat. Our simulations consider crystal growth, latent heat release and shear (viscous) heating within the conduit and dome. The formation of shear bands is modelled considering shear-localisation in a coupled conduit-dome model space and utilises a power-law strain-rate dependent orthotropic viscoplasticity. The model equations are formulated in an Eulerian framework and the evolution of the free surface of the lava dome is modelled (without displacing the model space) using a novel technique known as the level-set method. The dome growth regime is found

to be 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.