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The fluid-dynamics of bubble-bearing magmas

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The rheological properties of a fluid establish how the shear stress, τ, is related to the shear strain-rate, γ . The simplest constitutive equation is represented by the linear relationship $\tau = \mu\gamma$, where the viscosity parameter, μ, is independent of strain-rate and the velocity profile is parabolic. Fluids with such a flow curve are called Newtonian. Many fluids, though, exhibit non-Newtonian rheology, typically arising in magmas from the presence of a dispersed phase of either crystals or bubbles. In this case it is not possible to define a strain-rate-independent viscosity and the velocity profile is complex.
In this work we extend the 1D, steady, isothermal, multiphase non-homogeneous magma ascent model of Papale (2001) to 1.5D including the Non-Newtonian rheology of the bubble-bearing magma. We describe such rheology in terms of an apparent viscosity, η, which is the ratio of stress to strain-rate ($\eta = \tau/\gamma$) and varies with strain-rate across the conduit radius. In this way we calculate a depth-dependent Non-newtonian velocity profile across the radius along with shear strain-rate and viscosity distributions. The evolution of the velocity profile can now be studied in order to investigate processes which occur close to the conduit wall, such as fragmentation. Moreover, the model can quantify the effects of the Non-Newtonian rheology on conduit flow dynamics, in terms of flow variables (e.g. velocity, pressure).