A new model for bubble growth, deformation and coalescence in viscous magmas

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Exsolved volatiles provide the driving force for explosive eruptions. During the magma's ascent to the surface, the silicate melt becomes super-saturated with volatiles (mostly water), driving bubble nucleation and growth. The increasing vesicularity of the magma significantly affects its physical properties.

The general processes that govern the growth of a bubble in a decompressing melt are well established. Yet, the complexity of the non-linear processes that control the evolution of bubble suspensions during the ascent of magma to the surface has limited our current focus to highly idealized models. These models generally assume (1) a monodisperse array of equally spaced spherical bubbles, (2) an infinite medium (expansion is not confined by boundaries), (3) bubbles neither deform nor coalesce. These assumptions are challenged by observation of textures in pumices, where deformation, coalescence and polydispersed bubble size distributions are reported. The model we propose alleviates the three assumptions mentioned above and allows us to study the deformation and growth of bubbles in a suspension while bubble deform because of shear flow conditions and/or hydrodynamic interactions with neighbor bubbles or solid boundaries (conduit wall). The aim of this model is to provide a more accurate description of the effect of bubbles on ascending magmas as they reach high vesicularities, and ultimately, build bubble dynamics parameterizations for the inclusion of these processes as subgrid scale feature in conduit flow models.

After an introduction to the numerical model based on the lattice Boltzmann method for free surface flows, we present validations for the growth of a bubble by expansion (mechanical work) and diffusion (mass increase). We also show an application of interaction between bubbles of different sizes and validate our model with diffusion coarsening (Ostwald ripening), where a small bubble shrinks by exchanging mass with a larger one. Finally, we focus on the effect of hydrodynamic interactions between bubbles on the distribution of deformation and orientation of bubbles during simple shear calculations.