



Two-phase dynamics of volcanic eruptions: Acoustic-porosity waves and the conditions for choking

David Bercovici (1) and Chloé Michaut (2)

(1) Yale University, Geology & Geophysics, New Haven, CT, United States (david.bercovici@yale.edu), (2) Laboratoire de Géophysique Spatiale et Planétaire, IPG Paris, Université Paris Diderot, St Maur des Fossés, Paris, France (michaut@ipgp.jussieu.fr)

Volcanic eruptions involve turbulent, often super-sonic flows of gas and magma or ash mixtures. The mixture density is controlled by the different processes of particle matrix compaction and gas compression. Moreover, the separation of phases is governed by complex interaction forces; in particular inertia and turbulence appear as turbulent drag, virtual mass, and the Basset force. We present a model for two-phase, high Reynolds number flow of a compacting suspension of magma particles in a compressible gas. The model is used to examine acoustic-porosity wave propagation and the development of shocks or choking in a volcanic conduit. Standard pseudo-gas treatments of volcanic eruptions – wherein the phases are assumed to move with the same velocity – predict greatly reduced acoustic sound waves, and thus shock development at relatively low velocities. Sound waves in separable mixtures, however, are highly dispersive with fast waves propagating at the pure gas sound speed at small wavelengths and slow waves traveling at the pseudo-gas speed at long wavelengths (and complete wave attenuation at intermediate wavelengths). However, because shock development involves wave steepening, only the short wavelength limits apply; thus shocks should only occur when the eruption reaches the pure gas sound speed, and not at the pseudo-gas speed. Non-linear, finite-amplitude steady-state models of eruptions in a volcanic conduits show that compaction occurs over the magma particle gravitational deceleration height, and either suppresses gas expansion for fast eruptions, or isopycnally collapses the gas volume for slow eruptions. Once compaction ceases, the gas expands toward a shock structure or choking point, coincident with a rapid vent eruption. Turbulent drag between the gas and particles suppresses compaction effects but greatly sharpens the shock front at the choking point. The disparity between low pseudo-gas shock velocities and observations of high-velocity eruptions are usually attributed to variations in conduit width. However, the full two-phase theory predicts eruptions at the observed nearly sonic velocities, and thus requires no special conditions to explain the observations.