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Investigating disequilibrium effects in magma ascent dynamics with a new multiphase flow model

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Numerical and physical models have greatly enhanced our understanding of eruption dynamics. The multiphase non-equilibrium nature of magma inside a conduit, the development of gas overpressure, and the possibilities for open-system degassing are all recognized as controlling factors affecting changes in eruptive rate and style, yet models of magma ascent considering both distinct velocities and pressures for the different phases have not been deeply studied. The numerical model we present here considers a set of multiphase compressible equations governing magma movement through a subsurface pathway (e.g., from chamber to surface). This model represents a significant advance in its quantitative description of the magma system in that it: 1) is capable of treating both dilute and dense flow regimes; 2) describes flow above and below the fragmentation level in a coupled and consistent way; 3) quantifies the interaction between two phases forming the magmatic mixture with two distinct pressures and two velocities; 4) accounts for disequilibrium crystallization and degassing; and 5) allows for open-system degassing. Here we investigate, through a sensitivity analysis, the role of different disequilibrium processes, in particular those controlling overpressure increase and the retention of gas, in controlling vent conditions and transitions in eruptive style. We develop a reference case using conditions appropriate for the ongoing eruption of Soufrière Hills volcano. As an example, if an andesitic magma with a 5 wt% total water content (about 1.5 vol% of exsolved gas) decompresses to atmospheric pressure from 5km depth as a homogeneous mixture (single pressure and single velocity), the gas volume fraction at the vent should exceed 95 vol% if no further gas exsolution is considered, and 99 vol% with equilibrium exsolution. These values changes significantly when development of gas overpressure and open-system degassing are allowed and considered in the model, and thus affect eruption outcomes.