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1085 AD sub-Plinian eruptions at Sunset Crater: a numerical study through a 1D transient conduit model of magma ascent

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Volcanoes exhibit a wide range of eruption styles, from relatively slow effusion to intense explosions, in which very large volumes of volcanic gas and particles are ejected into the atmosphere. As magma rises through the conduit towards the surface, the confining pressure decreases, causing dissolved volatile species, such as water and carbon dioxide, to exsolve from the melt forming gas bubbles. Gas bubbles in the melt expand as the pressure decreases and the magma will fragment to generate explosive eruptions if and when a threshold gas volume fraction, bubble overpressure, or strain rate is exceeded. Ascent and fragmentation are influenced not only by the nucleation and growth of gas bubbles, but also by magma rheology and its behaviour under a wide range of strain rates. Here we employ a multiphase multicomponent 1D transient numerical model to better understand subsurface processes that controlled and characterized the 1085 AD sub-Plinian eruptions at Sunset Crater, Flagstaff, AZ. Specifically, we investigate the impacts of several model assumptions, such as isothermal conditions, instantaneous vs. finite-rate gas exsolution, and gas and melt coupling vs. decoupling, on numerical results. We focus our simulations on the dynamics associated with the sudden depressurization of an overpressured conduit sealed by a viscous, crystal-rich plug. Our numerical results show that, assuming perfect gas-melt coupling, the solution converges rapidly towards a steady-state explosive eruption, independently of whether the isothermal or instantaneous exsolution assumptions are made. As such, the isothermal and exsolution assumptions have little impact on fragmentation depth and mass eruption rate, and therefore appear to have limited bearing on simulated eruption style. However, when decoupling, due to permeable gas escape, is allowed between melt and gas, the solution does not reach steady-state. Our results, therefore, highlight the point that gas-melt decoupling is an important process that may control the eruption style and duration at explosive basaltic volcanoes.