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Role of rheology, ascent rate and outgassing on fragmentation: implications for basaltic lava fountains

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Basaltic volcanoes exhibit a wide range of eruptive styles, from relatively gentle effusive eruptions (producing lava flows and lava domes) to highly explosive activity (where pyroclastic materials are ejected from the vent as a jet or plume). The difference between explosive and effusive eruptions is dictated by the ability of magma to fragment during ascent. For lava fountains the distinction is unclear, as the liquid phase in the rising magma may remain continuous to the vent, fragment in the fountain, then re-weld on deposition to feed rheomorphic lava flows.

Here we use a magma ascent model to constrain the controls on basaltic eruption style, using Kilauea and Etna as case studies. Following our results, we suggest that lava fountaining is a distinct style, separate from effusive and explosive eruption styles, that is produced when magma ascends quickly and fragments above the vent, rather than within the conduit. Performing sensitivity analyses of Kilauea and Etna case studies we found that high lava fountains (> 50 m high) occur when the Reynolds number of the bubbly magma is greater than ~0.1, the bulk viscosity is less than 10^6 Pa s, and the gas is well-coupled to the melt. According to our results, explosive eruptions (Plinian and sub-Plinian) are expected over a wide region of parameter space for higher viscosity basalts, typical of Etna, but over a much narrower region of parameter space for lower viscosity basalts, typical of Kilauea. Numerical simulations indicate also that the magma that feeds high lava fountains ascends more quickly than the magma that feeds explosive eruptions, thanks to its lower viscosity. For the Kilauea case study, a decreasing ascent velocity is expected to produce a progressive evolution from high to weak fountaining, to ultimate effusion. For the Etna case study, instead, small changes in parameter values lead to transitions to and from explosive activity, indicating that eruption transitions may occur with little warning.