Transition between fragmentation and permeable degassing of low viscosity magmas

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Explosive eruption of magmas requires that the magma fragments into discrete parcels. Silicic magma can fragment through brittle failure or other processes that depend on the viscoelasticity of the melt. Owing to the low viscosity of basaltic magmas, the fragmentation mechanism must be different and will be governed by fluid mechanics alone. We perform a series of decompression experiments on bubbly Newtonian fluids with viscosities similar to those of basaltic magmas. For sufficiently rapid expansion, the bubbly fluid expands continuously and finally tears into several pieces. The fragmentation threshold is governed by a critical Reynolds number of O(1), indicating that it is the inertia of the expanding fluid that drives the continued expansion and ultimate breakup into discrete parcels. Experiments in which the fluid does not fragment allow us to determine the permeability of the bubbly fluid as the bubbles expand. Permeability remains small until the volume fraction of bubbles exceeds about 70%. We scale the results of the laboratory experiments to basaltic eruptions and find that the predicted fragmentation threshold is consistent with the exit velocities that characterize effusive and explosive (fire fountain) eruptions.