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An empirical scaling of shear-induced outgassing during magma ascent

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Outgassing, which changes the distribution of volcanic gases in magmas, is one of the most important processes to determine the eruption styles. Shear deformation of ascending bubbly magmas at the vicinity of the volcanic conduit wall has been considered as an efficient mechanism of outgassing. On the other hand, seismological observations of volcanic eruptions reveal the long-period (LP) earthquakes, suggesting the existence of a large void space in the conduit. However both, the quantitative features of shear-induced outgassing and a mechanism to make a large void space, has still remain unknown. Here I perform a series of model experiments simulating the shear deformation of bubbly magma ascending in a volcanic conduit. Syrup foam including CO_2 gas as an analogue of bubbly magma is deformed by using a timing belt. When the imposed shear strain is large enough, the height of the foam decreases indicating that outgassing occurs. Experiments also show that shear localization of syrup foam causes outgassing by making large bubbles or a crack-like void space, likely a LP earthquake source. Measured CO_2 concentration above the foam increases as an evidence that the gas is came from the inside bubbles. When there is an impermeable layer at the top of the foam, the gas accumulates beneath that layer. There is a critical strain, γ, above which outgassing occurs depending on the Capillary number, Ca, $\gamma > 1$ for Ca < 1 and $\gamma > \mathrm{Ca}^{-1}$ for Ca ≥ 1. The thickening rate of the region in which outgassing occurs is described as a function of $\gamma^{-0.54}\mathrm{Ca}^{1.2}$. Outgassing occurs efficiently at the very beginning of the deformation, suggesting that intermittent magma ascent causes effective outgassing such that the eruption style becomes effusive. This hypothesis is consistent with the fact that cyclic activity has been observed during effusive dome eruptions.