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Slug flow through a particle-rich plug, an analogue for Stromboli Volcano, Italy

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The persistent intermittent activity observed at Stromboli is generally explained as Taylor bubbles (gas slugs) rising to the surface of a basalt-filled conduit. The explosive rupture of the large bubbles at the surface ejects magma fragments that contain 40 – 55 vol% crystals, evidence of a crystal-rich layer near the surface. Such a high crystal content likely approaches the jamming transition, which indicates that the solids interact with each other, forming force chains that resist flow. In order to explore how crystal-crystal interactions influence flow in Strombolian magma during slug rise, we performed a series of analogue experiments. Taylor bubbles of different volumes ascend through a column, 25 mm in diameter and 1.4 m tall, composed of silicon oil surmounted by an oil-and-particle layer of $\sim$ 25, 75, and 150 mm thickness. The particle content of the layer was also varied up to the jamming transition. The vertical pressure gradient is scaled by reducing the pressure at the liquid surface with a vacuum pump. Pressure variations were measured at the top and bottom of the apparatus. When particle contents reached 80-90% of the random packing, a range of effects were observed including: substantially slowed slug rise velocity, bubble deformation and bubble splitting into several daughters. Occasionally, with particle concentrations at the random packing, the bubble was completely trapped beneath the particle-bearing layer, which thus acted as a rigid plug with strength greater than the buoyancy force generated by the gas. These complex dynamics at high particle fractions resulted in a longer, pulsating outgassing pattern in contrast to a single pulse in particle-free experiments, suggesting that crystals could cause temporal variations in Strombolian activity. Gas retention was also observed within the particle-rich layer. Extrapolating for sustained slug flow could, over time, accumulate a considerable gas reservoir near the surface, and thus contribute to passive degassing at Stromboli. There is strong evidence for crystalline magma at shallow levels that is ejected during eruptions of Stromboli Volcano. The analogue experiments suggest that these crystals modulate Strombolian eruption dynamics and could play an important role in explosive eruption patterns and non-explosive degassing.