Geophysical Research Abstracts
Vol. 19, EGU2017-9987-1, 2017
EGU General Assembly 2017

The viscous to brittle transition in eruptions of clay suspensions

Diana Schmid (1), Bettina Scheu (1), Fabian B. Wadsworth (1), Ben Kennedy (2), Art Jolly (3), and Donald B. Dingwell (1)

(1) Earth & Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Munich, Germany,, (danamia23@gmail.com), (2) University of Canterbury, Christchurch, New Zealand, (3) GNS Science, Lower Hutt, New Zealand

The research is motivated by the early 2013 activity of White Island, New Zealand, which was characterized by frequent small phreatic activity through a fine grained mud rich shallow crater lake. Field observations demonstrate that the small eruptions were driven by bubble-burst events. Additionally, during the ongoing eruption, water vigorously evaporated, causing a shift in rheology of the crater lake liquid-solid suspension. Yet, the effect of water content on the eruptive behaviour of clay-bearing liquid suspensions is poorly understood.

Here we investigate the influence of the solid to water ratio of the clay material erupted on the eruption characteristics. Kaolin was used as an analogue for the clay and was mixed with water in different proportions. We conducted experiments with different kaolin/water mixtures held at 120°C, in which they were decompressed from 2-4 bars to ambient conditions in a few milliseconds. During an experimental eruption, the velocity of the ejected material decreased, resulting in shifts in behaviour. Based on our experimental observations we established five different regimes that depend on the particle velocity relative to the gas velocity, and on the kaolin to water ratio of the mixture.

In all experiments and for all kaolin to water ratios, regime 1 is one in which particles are ejected rapidly in an expanding high velocity gas jet. In the liquid-dominated system (low kaolin to water ratios), the jet phase evolves to the ejection of elongate fluidal structures (regime 2) and then to discrete droplets (regime 3) as the ejection velocity wanes. Contrastingly, in the solid-dominated system, the jet phase (regime 1) transitions to a mixed solid-fluid structures (regime 4) and then to individual angular ejecta (regime 5). On the basis of high speed image analysis, we establish a phase diagram separating these regimes based on kaolin/water mixing rations and the ejecta velocities observed. The dominant transition between fluidal and solid-like behaviour is a viscous to brittle transition and occurs between a kaolin mass fraction of 0.48 and 0.65, which is consistent with previous observations of the liquid and plastic rheological limits, respectively.

We find that a Stokes' number balances the timescale of flow with the timescale of particle motion opposing flow. We suggest that the transition from regime 1 to regime 2 occurs when the relative velocity between the ejected material and the gas phase increases and the Stokes' number exceeds 1, leading to decoupling and shear-stresses at the ejected fluid interfaces. A capillary number characterizes the transition from elongated liquid structures (regime 2) to individual droplets (regime 3) in the liquid-dominated system when the relative velocity drops to a value at which surface tension can restore the droplets to spherical.

Our results emphasize that the different rheology of muddy material exhibit different characteristic eruption styles and offers a way to classify them.