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Morphology and dynamics of explosive vents through cohesive rock formations

Olivier Galland (1), Galen R. Gisler (1), and Øystein T. Haug (2)

(1) University of Oslo, Physics of Geological Processes (PGP), Oslo, Norway (olivier.galland@fys.uio.no), (2) GFZ German Research Centre for Geosciences, Helmholtz Centre Potsdam, Potsdam, Germany

Shallow explosive volcanic processes, such as kimberlite volcanism, phreatomagmatic and phreatic activity, produce volcanic vents exhibiting a wide variety of morphologies, including vertical pipes and V-shaped vents. In this study we report on experimental and numerical models designed to capture a range of vent morphologies in an eruptive system (Galland et al., 2014). Using dimensional analysis, we identified key governing dimensionless parameters, in particular the gravitational stress-to-fluid pressure ratio ($\Pi 2$=P/rho.g.h), and the fluid pressure-to-host rock strength ratio ($\Pi 3$=P/C). We used combined experimental and numerical models to test the effects of these parameters. The experiments were used to test the effect of $\Pi 2$ on vent morphology and dynamics. A phase diagram demonstrates a separation between two distinct morphologies, with vertical structures occurring at high values of $\Pi 2$, and diagonal ones at low values of $\Pi 2$. The numerical simulations were used to test the effect of $\Pi 3$ on vent morphology and dynamics. In the numerical models we see three distinct morphologies: vertical pipes are produced at high values of $\Pi 3$, diagonal pipes at low values of $\Pi 3$, while horizontal sills are produced for intermediate values of $\Pi 3$. Our results show that vertical pipes form by plasticity-dominated yielding for high-energy systems (high $\Pi 2$ and $\Pi 3$), whereas diagonal and horizontal vents dominantly form by fracturing for lower-energy systems (low $\Pi 2$ and $\Pi 3$). Although our models are 2-dimensionnal, they suggest that circular pipes result from plastic yielding of the host rock in a high-energy regime, whereas V-shaped volcanic vents result from fracturing of the host rock in lower-energy systems.

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