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Irregular vents – geometric effects on volcanic jet dynamics

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Explosive volcanic eruptions pose threat to health and infrastructure due to their highly energetic and dynamic nature. Gas overpressure derived from magmatic volatile exsolution is the driving force for magma fragmentation. The production of pyroclasts occurs primarily within the conduit, whereas the direct observation of eruptive processes is limited to processes above the vent. Thus, an enhanced quantitative understanding of volcanic eruptions must rely on laboratory experiments as well as analogue and numerical models.

Scaled rapid decompression experiments, employing four circular symmetrical vents, were conducted to investigate the influence of geometric features (e.g. conduit length, fragmentation depth and vent geometry) and physical parameters (e.g. particle load, particle size and temperature) on the dynamics of gas-particle jets. Previous experimental results reveal a paramount influence of tube length, particle load and vent geometry (Cigala et al., 2017). Natural volcanic vents 1) are less regular in geometry and 2) change on very short time-scales, as has been observed for example by repeated drone surveys.

In this study, six vents with bilateral symmetry (cylindrical and diverging inner geometry incorporating an inclined top plane at 5°, 15° or 30°) have been used to elucidate the dynamics of a) gas-only and b) gas-particle starting jets upon decompression.

Additionally, varying pressure ratio (8, 15 and 25 MPa) and particle size (monomodal particle size distributions with 125-250 μm, 0.5-1 mm and 1-2 mm diameter) were employed. Experiments were recorded with a high-speed camera at 10000 frames per second in order to examine gas and gas-particle jet dynamics and reveal both diversion and bending of the jets. Increasing the inclination of the top plane and the pressure ratio correlate positively with the degree of jet deviation, yet with a different jet direction for each of the inner vent geometries.

The production of fine particles was evaluated by comparing grain size distribution before and after each experiment. Particle size showed a negative correlation with particle spreading angle while particle exit velocity was positively correlated with overpressure. These results were compared to field data of explosive eruptions acquired at Stromboli volcano, Italy, by high-speed videos (1000 frames per second).

Such experiments, with complex vent geometry are bringing laboratory conditions a step closer to nature. Since vent geometry can easily and repeatedly be observed at high precision by drones, even during phases of elevated activity, increased knowledge about eruption dynamics based on vent geometry has the potential to improve the hazard assessment for explosive volcanoes.

References:

Cigala, V., U. Kueppers, J. J. Peña Fernández, J. Taddeucci, J. Sesterhenn, and D. B. Dingwell (2017), The dynamics of volcanic jets: Temporal evolution of particles exit velocity from shock-tube experiments, J. Geophys. Res. Solid Earth, 122, 6031–6045, doi: 10.1002/2017JB014149.