The significance of the opening angle of pyroclast ejection during explosive volcanic eruptions

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Explosive volcanic eruptions may occur with little or no warning. Assessing the related hazards has advanced greatly in the recent past through a multidisciplinary approach including fieldwork, laboratory experiments and numerical modelling. However, a comprehensive quantification of the physical processes affecting eruption style is still lacking.

Here we show results from laboratory experiments that help shed light on some of these to date, unobservable, processes. At ambient temperature, washed volcanic particles of varying mode (2 mm and smaller, monodisperse) and porosity (scoria and pumice) were filled into a cylindrical and vertical high-P autoclave (25 mm diameter) and pressurised to 5-15 MPa by Argon gas. Upon rapid decompression, the particles were accelerated vertically and ejected into a low-P section. The aim of this study was to constrain and explain the behaviour of particle-laden, underexpanded jets upon leaving a straight vent. We used three different initial configurations to allow for variable particle/gas-ratios and distance of sample surface from outlet: (1) 60 mm filling height, 300 mm distance from vent, (2) 240 mm filling height, 100 mm distance from vent and (3) 60 mm filling height, 100 mm distance from vent. The geometry of gas-particle-ejection was recorded with a high-speed video camera at 10.000 fps. After the experiments, particles were collected and checked for possible changes of grain-size distribution.

Expansion of the particle-laden jet takes place as long as the jet is overpressurised at the vent. More specifically, we find that: (i) the ejection speed of particles increased systematically with applied pressure and smaller distance of the sample surface from the vent (up to 200 m/s); (ii) the maximum opening angle of particle ejection is negatively correlated with the initial distance of the sample surface from the vent (larger distance = smaller opening angle); (iii) the opening angle is negatively correlated with sample density and grain size. In experiments of configuration (2), a clear development of the opening angle (from 30 °to vertical) could be observed during the course of each experiment. We also (iv) observed a considerable generation of fine ash, most likely due to decompression-induced fragmentation and particle-particle interaction. The high-speed videos have been modelled computationally to explain the observed Prandtl-Meyer expansion and ambient air ingestion.

Apart from conduit/vent geometries, these experiments highlight the strong influence of the conditions inside a volcanic conduit (overpressure, fragmentation depth) on the characteristics of particle ejection. As this is the first of only few directly observable features of particle ejection during explosive eruptions, the opening angle should be constrained during the monitoring of erupting volcanoes to gain a more complete view of the depth and efficiency of the physical processes ongoing.

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