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The temporal evolution of pyroclast ejection velocity and exit trajectory, a laboratory case study.

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Pyroclast ejection dynamics during explosive volcanic eruptions are highly variable. This variability is due to complex interaction among different parameters, which define the boundary conditions for a certain eruption. Scaled and controlled laboratory experiments come in hand to characterize the effect of specific physical parameters on the ejection dynamics.

We focus, in particular, on the dynamics of pyroclasts ejection in the region just above the vent, also called gas-thrust region, for the case of impulsively released gas-pyroclast mixtures (i.e. unsteady eruptions). In this study, gas-particle mixtures were released in a series of shock-tube experiments with varying 1) tube length, 2) vent geometry, 3) gas-particle ratio, 4) initial temperature and 5) particle size distribution. The tube length was varied by changing the starting sample load, resulting in a gas-particle ratio of 1, 2.5 and 8, respectively. Thereby, the initial distance of the sample from the exit varied between 320, 230 and 140 mm, respectively, allowing for variable time for accelerating (and possibly decelerating) the particles prior to exit. Moreover, four vent geometries were employed, a nozzle with converging walls (5°), a cylinder and two funnels with walls diverging at 15° and 30° respectively. All of them are characterized by a value h/D=1.07, where h is the length between the throat and the lip of the vent and D is throat diameter. The experiments were performed at both 500°C and room temperature using particles from 2 to 0.125 mm in diameter. In all experiments, initial pressure was 15 MPa.

High speed videos of the ejection behaviour were analyzed to obtain the temporal evolution of particle velocity and exit trajectory depending on boundary conditions. Max velocity of 300 m/s was observed together with a non-linear decay of exit velocity over time. The exit trajectories were found to deviate from the vertical by 5° to 45° and also display a non-linear evolution with time. Moreover, the velocity decay was used to investigate the accuracy of the empirical fragmentation depth model from Alatorre-Ibargüengoitia et al. (2011), when different gas-particle ratios are employed. This model is not reproducing all experimental constellations satisfactorily. Further experiments will help to develop this model further.

Vent geometry, particle size and temperature show the largest effect on ejection velocity and trajectory. In particular, we observed a positive correlation of velocity with 1) diverging vent walls and 2) temperature and a negative correlation with 1) starting tube length and 2) particle size. On the other hand, exit trajectories show negative correlation with 1) diverging walls, 2) starting tube length, 3) temperature and 4) particle size. Moreover, we found that gas-particle ratio additionally strongly affects the temporal evolution of particle ejection velocity and trajectory. These results highlight the importance of scaled and repeatable laboratory experiments for an enhanced understanding of natural volcanic phenomena that bear direct observability. A closer link will enhance volcanic hazard assessment.