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Vulcanian eruptions: Integrating fragmentation experiments with natural samples, theory and ballistic analysis

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Vulcanian eruptions are frequent, short-lived explosions that occur as a result of rapid decompression of pressurized magma. One of the most common hazards associated to this kind of eruptions are the ballistic projectiles. In order to improve hazard assessment, we need to understand the relationship between gas overpressure, ejection velocities and maximum range of the ballistic projectiles. There are several issues that have not been fully understood: 1) The influence of the fragmentation process itself on the dynamics (fragmentation energy, grain-size distribution); 2) If the common assumption that the gas-pyroclasts mixture behaves as a pseudo-gas in thermal equilibrium is valid in transient volcanic eruptions; 3) The influence of the vent geometry; and 4) How the drag force is reduced near the vent. Here we present the results of fragmentation experiments with natural samples at high temperature (850°C) at different pressures where we measured the maximum ejection speed of the resulting particles. We propose a model that is consistent with the experiments and takes into account the energy that is consumed during fragmentation. We also discuss the influence of the vent geometry (cylindrical conduit vs. radial geometry) and consider a drag-reduced zone in the calculation of the ballistic trajectories. Finally, we applied this model to different Vulcanian eruptions at Popocatépetl volcano, Mexico, and calibrate the model with the maximum range reached by the ballistic projectiles and their corresponding travel times measured from videos of the explosions. Our study relates the zones that could be affected by ballistic projectiles with the initial pressure, which can be estimated from seismic and geophysical monitoring, providing valuable information for more refined hazard assessment of active explosive volcanoes.