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Hazard assessment of volcanic ballistics: Integrating field observations, theory and fragmentation experiments

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During volcanic explosions, fragments following ballistic trajectories are frequently ejected. These fragments represent a threat to people, infrastructure, vegetation and aircraft due to their high temperatures and impact velocities. In order to improve hazard assessment, it is necessary to improve our understanding of the relationship between gas content, pressure, ejection velocity and trajectory of the ballistics and delimit their maximum range in explosive scenarios that can occur in a particular volcano. We present a model of Vulcanian eruptions that considers the energy balance in decompression of a pressurized magma below a caprock, followed by fragmentation and acceleration of pyroclasts. This model was tested via fragmentation experiments at magmatic conditions (850 °C and initial pressure <25 MPa) using a shock-tube apparatus. We measured the ejection velocity of the caprock propelled by the expansion of an underlying gas-particle mixture produced by in situ fragmentation by rapid decompression of natural samples. This model is used in concert with a ballistic model which considers drag coefficient data measured experimentally for volcanic particles. The coupled model was calibrated and validated with field and video observations of ballistics ejected during different Vulcanian eruptions at Popocatépetl volcano (Mexico). The maximum ranges expected for the ballistics in three different explosive scenarios defined for Popocatépetl volcano are presented in a ballistic hazard map. Our study relates the zones that could be affected by the impact of ballistic projectiles using the initial pressure that can be estimated from seismic and geophysical monitoring, providing valuable information for more refined short-term hazard assessment at active explosive volcanoes.