Understanding phreatic & hydrothermal explosion dynamics: insights into the energy conversion based on lab experiments

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Phreatic eruptions are amongst the most common and most diverse eruption types on earth. Often they are precursory to another type of volcanic activity but they can stand as well on their one. Phreatic explosions occur for instance when subsurface water or water on the surface is heated by magma, lava, hot rocks, or fresh volcanic deposits and result in craters, tuff rings and debris avalanches. Another wide and important field affected by steam explosions are hydrothermal areas; here hydrothermal explosions might occur every few months creating explosion craters and resemble a significant hazard to hydrothermal power plants as well as visitor parks. Despite of their hazard potential, phreatic explosions have so far been overlooked by the field of experimental volcanology. A part of their hazard potential in owned by the fact that phreatic explosions are hardly predictable in occurrence time and size as they have manifold triggers. The diversity of phreatic and hydrothermal eruptions arises from the variety of host rocks, ways to seal possible degassing pathways, and to alter this material depending on the composition of volcanic gases and the hydrothermal fluids.

We conduct rapid decompression experiments on a variety of natural samples from igneous rocks to sedimentary rocks; consolidated and unconsolidated. The setup used can be operated with gas and/or vapour overpressure of up to 20 MPa and in a temperature range from range from 20℃ to 400℃, further we vary the degree of water saturation of the samples. The experiments are monitored with a set of pressure and temperature sensors, synchronized to high-speed video recording of the particle ejection. The resulting particles are recovered and their grain size distribution are analysed. This together allows us to constrain the fragmentation behaviour and the efficiency of the fragmentation in phreatic explosions. We observe that the threshold for fragmentation is slightly lowered whereas the propagation speed of the fragmentation process through the sample is comparable to dry magmatic experiments. A clear contrast is seen for the ejection speed of the clasts: phreatic clasts can be ejected at almost double the speed as their magmatic counterparts under similar overpressure conditions. Further the ejection speed depends on the ratio of superheated water to vapour and argon gas. This ratio controls also the efficiency of fragmentation as well as the grain shapes.

Our experiments and results enable us to better understand the dynamics of phreatic and hydrothermal explosions and associated risks. Here we present insights into the energy conversion during phreatic eruptions, based on various starting scenarios. This will provide vital information for the hazard assessment of hydrothermally active areas.