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Revealing the process of fragmentation from high-speed video analysis of rapid decompression of magma.

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It is the fragmentation of magma which distinguishes explosive volcanic eruptions from the more quiet effusive form of volcanic activity. Hence the conditions leading to magma fragmentation as well as the fragmentation process itself are key points in order to better our understanding of the dynamics of volcanic eruptions. Better understanding of eruption dynamics will lead in return to improved hazard mitigation. So far, various models have been proposed for magma fragmentation, based on the investigation of deposits of explosive eruptions, theoretical constraints and laboratory experiments. The latter have been performed on a broad variety of natural magma and varying analogue materials, pointing out important correlations between magma properties and fragmentation behavior but also posed new questions.
We performed rapid decompression experiments of vesicular natural magma and monitored the fragmentation process with high-speed video recordings of the experiments and three pressure transducers along the sample. The coarse fraction of the generated pyroclasts was recovered and analyzed. The high-speed video recording allowed for the first time to scrutinize not only the result of fragmentation, but the fragmentation process itself for natural samples.

In the classical understanding of magmatic fragmentation one fragmentation wave travels through the magma causing “layer-by-layer” fragmentation. Our study shows that this model had to be revised: Within the investigated energy range the process of layer-by-layer fragmentation due to vesicle bursting is overriding, but it does not propagate as one fragmentation front through the sample, it rather occurs in several generations. The number of such generations depends in first order on the applied energy, but is also influenced by sample properties as i.e. permeability. The secondary internal fracturing of already fragmented parts occurs in the same manner as the primary fracture and could not be explained by previous models. We built a theoretical model to describe the experimental results, and show that it is capable of describing both, the primary sequence of fracturing, and the secondary intra-block fracturing. Further the model allows us to suggest a practical criterion for fragmentation events: firstly, the initial confining pressure must exceed the yield stress of the rock, and, secondly, the diffusion of the gas by porous flow must be sufficiently slow that a large excess pore pressure is built up. This will be the case if the rock permeability is small enough.