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Decompression Profiles During Magma Fragmentation

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The dynamics of magma fragmentation likely exert a strong influence on the explosive behavior and thus the eruptive style of a volcano. The speed of fragmentation for instance is directly affected by the pressure distribution within a volcanic conduit or dome. The fragmentation behavior may further be influenced by the gas permeability of the volcanic rocks, as it affects the speed by which a gas overpressure in vesicles is reduced in response to decompression. In case of very effective degassing, this may counteract the fragmentation process.

We use a shock-tube fragmentation apparatus to analyze the fragmentation behavior of samples covering a wide range of porosity. The results show that the speed of fragmentation depends (to the first order) on the potential energy available for the fragmentation process. This energy results from the gas volume within the open pore space of the sample and the applied pressure.

The pore structure (size, shape, and orientation) of the analyzed samples is another important factor governing the fragmentation behavior. For highly porous volcanic rocks the pore structure exerts the strongest influence on the permeability and thus the steepness of the pressure gradient, which builts up during rapid decompression. We observed that fast degassing of a sample (leading to a flat pressure gradient) shifts the fragmentation threshold to higher values. To elucidate the influence of this pressure gradient on the fragmentation behavior, we reconstructed the pressure profiles within different porous samples undergoing rapid decompression. Therefore, we performed a set of decompression experiments with a single sample shortened stepwise from 60 mm down to 1.8 mm. These experiments were conducted at a constant initial pressure value below the fragmentation threshold. The experimentally derived pressure profiles were compared to numerically modeled pressure profiles based on a 1D filtration code and showed good agreement.

We conducted further experiments above the fragmentation threshold to investigate the influence of the sample length on the speed of fragmentation. The results of differently porous samples of three different lengths (15 mm, 30 mm, and 60 mm with constant diameter of 25 mm) showed that the speed of the fragmentation wave seems to remain constant over the whole sample length.

We developed a numerical flow model taking account of the different properties of gas and matrix skeleton to reproduce the experimentally derived pressure drop curves. Our results represent a contribution towards a better understanding of the physical processes controlling the initiation, speed, and cessation of a fragmentation event.