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Determination of volcanic eruption explosivity from fractal analysis of experimentally generated pyroclasts

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Population growth in the proximal areas of active and highly dangerous volcanoes is substantial. Despite improvements resulting in increasingly reliable monitoring methods, prediction of volcanic eruptions, both in terms of timing and eruptive style remains subject to major uncertainties. In order to obtain further insights into the eruptive behaviour of explosive volcanoes, experimentally generated pyroclasts have been studied by fractal theory to investigate the relationship between eruption energy and grain size distribution. We investigated samples from Unzen (Japan) and Popocatépetl (Mexico) volcanoes with different porosities and textural characteristics originated from a variety of eruption styles. Unzen samples are from block-and-ash flow deposits generated from dome collapse events. Popocatépetl samples derive from ballistic blocks from Vulcanian eruptions, a pyroclastic flow deposit produced by a sub-Plinian eruption and from a lava flow. We performed rapid decompression experiments at well-controlled conditions of pressure and temperature using a shock tube apparatus and analyzed the grain-size distribution of the generated pyroclasts.

Fractal fragmentation theory was applied to each set of grain-size distribution by measuring the fractal dimension of fragmentation (Df). For each sample suite we observed a general linear increase of Df, i.e. the efficiency of fragmentation, with the energy for fragmentation (which depends on the applied pressure and sample porosity). Interestingly, the Df shows a positive linear correlation with the applied pressure for all the investigated samples irrespective of their origin, where the slope is related to the porosity of the sample. It emerges from this study that fractal dimension may be utilised as a proxy for estimating the explosivity of volcanic eruptions by analysing the fragment size distribution of the adjacent deposits. This may yield the opportunity to draw iso- Df or iso-explosivity contour maps based on fractal statistics. This possibility should be tested in the near future.