Calibrating volcanoes: Advances through a combination of scaled experiments and monitoring tools

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Volcanic eruptions, eruptive style and the related risks are difficult to be precisely forecast. Magmatic processes defy direct observation and impede their mechanistic and quantitative understanding. During explosive volcanic eruptions, pyroclasts of any size are generated and ejected from the crater(s) over variable time spans and at variable intensity. This ejection is a direct consequence of depth and efficiency of magma fragmentation and conduit geometry.

In an attempt to decipher more info from the observable features of explosive eruptions, we used a multi-disciplinary approach and combined experimental volcanology and volcano monitoring devices. During three campaigns, we performed over 50 field-based fragmentation experiments using natural volcanic clasts and cylindrical samples, drilled from natural volcanic rock samples. Decompression and particle ejection were monitored with (1) one Doppler Radar, (2) three high-speed and high-definition cameras, (3) one high-speed thermal camera, (4) acoustic and infrasound sensors and (5) pressure transducers along with (6) dynamic piezo-film transducers to record micro-seismic signals. The experiments were performed at controlled sample porosity (25 to 75 vol. %) and size (60 mm height and 25 mm and 60 mm diameter, respectively), confinement geometry, applied gas pressure (4 to 18 MPa) and temperature (25 and 850 ℃).

Our experiments allow for narrowing down the parameter range at which volcanic eruptions take place. We constrained ejection velocities through different approaches (high-speed videography and Doppler-spectrum analysis) and showed the effect of experimental conditions and sample characteristics. We show that both approaches successfully measured the pyroclast ejection, yielding consistent results of up to 130 m/s. Acoustic signals showed different features in dependence on the used set-ups, likely reflecting the variable length of the autoclaves (between 16 and 37 cm). The high-speed thermal videos of the 850 ℃ experiments showed plume temperatures of up to 400 ℃. We measured the fragmentation and removal speed of the pyroclasts using the pressure transducers. Together with known values of sample porosity and overpressure resistivity, we are able to constrain the conditions at the onset of fragmentation (eruption trigger). Close and high-resolution volcano monitoring, spiced with results from our experiments, will allow us to understand the language of volcanoes. Such an enhanced understanding of the pre-eruption state of a volcano is an essential factor in eruption energy estimation (probability of pyroclastic density currents, range of ballistics) and will contribute to adequate risk mitigation.