Experimental approach to constrain phreatic eruption processes on White Island, New Zealand

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White Island is New Zealand's most active volcano and primarily characterised by phreatic and phreatomagmatic eruptions. A phreatic eruption on August 2nd, 2012 ended an eleven year quiescence. More than 100 years of intense hydrothermal activity from magmatic fluids and groundwater has created a weak and unstable volcanic edifice highly susceptible to sector collapses and landslides. Here, we constrain the influence of alteration on phreatic eruption conditions and on the stability of an edifice subjected to an active hydrothermal system. A hydrothermally altered lava flow and four lithified pyroclastic rocks with different grades of alteration, together with unconsolidated material and sulfur- and iron-rich crusts from the crater-fill were sampled and investigated.

The lava flow is primarily composed of plagioclase, K-feldspar and pyroxene, but alteration has also lead to the presence of cristobalite, amorphous silica, gypsum and jarosite. The pyroclastic rocks do not contain any primary minerals or glass and consist instead of amorphous silica, alunite, jarosite, gypsum and kaolinite.

The lava flow with a low porosity (6.6-8%) was found to be moderately strong (110-140 MPa) when deformed in uniaxial compression tests, although we find that the presence of macroscopic fractures can lower the strength to 60 MPa. The altered pyroclastic rocks are more heterogeneous, porous (32-48%) and weaker, with unconfined compressive strengths ranging between 3 and 20 MPa. Our uniaxial experiments also show that the altered pyroclastic rocks are weakened when saturated with water.

Conditions for phreatic eruptions were constrained by fragmentation experiments on dry and water-saturated samples due to rapid decompression (from 9 MPa to atmospheric pressure) at temperatures of up to 300℃. This provided information about the energy threshold, fragmentation efficiency, the maximum speed and evolution of particle ejection velocities. The fragmentation threshold ranges between 5.1 MPa and 3.8 MPa for samples with a connected porosity of 32% to 48% , which is in agreement with the trend for pristine volcanic rocks. The fragmentation efficiency generally increases with higher applied energy but also if the sample is saturated. The particle ejection velocity after fragmentation increases with the applied pressure and porosity. For experiments on dry consolidated samples, where the fragmentation occurs at an argon gas overpressure of 6.5 MPa and 300℃, the ejection speed (45 m/s) is significantly lower than for fully water-saturated samples (145 m/s). Unconsolidated samples with connected porosities of 35% show a similar effect of sample saturation on the ejection.

Our study suggests that hydrothermal alteration and fluid-saturation associated with the presence of a hydrothermal system weakens the rocks (over a range of strain rates), which may result in slope destabilisation, lateral/sector collapse and further phreatic eruptions.