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Assessing volcanic flank instability using geomechanical properties: A case study from Pacaya volcano (Guatemala)

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Reliable estimates of mechanical properties of rocks, integral to volcanic processes such as inflation-deflation cycles and instability caused by magmatic intrusions, or gravitiational collapse caused by progressive loading are crucial for building accurate models of volcanic phenomena. Rock properties are often simplified or estimated because of a lack of data. However, targeted laboratory experiments can examine material properties, elucidating larger system behaviour. At Pacaya volcano (Guatemala) the scars of historical collapses are evident in the landscape, and in May 2010 a VEI-3 eruption led to slip of 10s of meters of the SW flank, which stalled and has since remained stationary. Here, we took lava samples from Pacaya with a range of porosities and measured the tensile strength (a threshold that must be exceeded to initiate failure and slip), wear-rate and frictional behaviour of the material during sliding. Tensile tests (UTS) using the Brazilian tensile test method showed a porosity-dependence of strength across the range measured (2-32% porosity), that scales to the uniaxial compressive strength (UCS) previously examined via a porosity-dependent ratio: UCS is between 12-20 times higher than UTS.

Rotary shear tests involved applying a defined axial load and slip rates of 0.1 to 1.5m/s, to simulate slip on a failure plane. We monitored evolution of the shear stress and wear rate during sliding for variably porous samples, with the target of understanding landslide initiation, runout and stalling. We found that the frictional properties are highly rate dependent, and that the porosity has a significant control on the rate of wear - offering clues to the progression of sector collapses in heterogenous volcanic edifices. Input of these process-specific rock behaviours into slope stability and deformation models influences the modelled instability. Strength controls the angle of the failure plane, while frictional behaviour controls the resultant instability, demonstrating that increased parameterisation of rock properties will improve accuracy of hazard assessment for collape-prone volcanoes.

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2. Schaefer, L. N., Kendrick, J. E., Lavallée, Y., Oommen, T. & Chigna, G. Frontiers in Earth Science 3 (2015).