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Evolution of mechanical properties of lava dome rocks across the Soufrière Hills eruption, and application in discrete element models

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Lava dome collapses pose a hazard to surrounding populations, but equally represent important processes for deciphering the eruptive history of a volcano. Models examining lava dome instability rely on accurate physical and mechanical properties of volcanic rocks. Here we focus on determining the physical and mechanical properties of a suite of temporally-constrained rocks from different phases of the 1995–2010 eruption at Soufrière Hills volcano in Montserrat. We determine the uniaxial compressive strength, tensile strength, density, porosity, permeability, and Young's modulus using laboratory measurements, complemented by Schmidt hammer testing in the field.

By viewing a snapshot of each phase, we find the highest tensile and compressive strengths in the samples attributed to Phase 4, corresponding to a lower permeability and an increasing proportion of isolated porosity. Samples from Phase 5 show lower compressive and tensile strengths, corresponding to the highest permeability and porosity of the tested materials. Overall, this demonstrates a reliance of mechanical properties primarily on porosity, however, a shift toward increasing prevalence of pore connectivity in weaker samples identified by microtextural analysis demonstrates that here pore connectivity also contributes to the strength and Young's Modulus, as well as controlling permeability. The range in UCS strengths are supported using Schmidt hammer field testing. We determine a narrow range in mineralogy across the sample suite, but identify a correlation between increasing crystallinity and increasing strength. We correlate these changes to residency-time in the growing lava dome during the eruption, where stronger rocks have undergone more crystallization. In addition, subsequent recrystallization of silica polymorphs from the glass phase may further strengthen the material.

We incorporate the variation in physical and mechanical rock properties shown within the Soufrière Hills eruptive into structural stability models of the remaining over-steepened dome on Montserrat, considering also the possible effect of upscaling on the edifice-scale rock properties, and the resultant dome stability.