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Experimental Compaction of Pumiceous Dome Lavas

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Lava dome stability is reliant on pore pressure, which varies according to the evolution of the permeable porous network. Here, we present experimental results of porosity and permeability evolution during compaction of aphiric (from Ngongotaha volcano) and crystal-bearing (from Tarawera volcano) pumiceous, rhyolitic lavas from Taupo Volcanic Zone, New Zealand. The Ngongotaha sample has 55 % porosity and is from the crystal-free dome carapace erupted ∼200 ka following caldera collapse at Rotorua Caldera. Two sample sets from Tarawera are crystalline, pumiceous clasts from a dome-collapse generated block and ash flow at Okataina Caldera ∼1314 AD, and contain 50 and 25 % pores.

This study tests the validity of the 'permeable foam' model by comparing properties of the experimentally compacted pumice to denser material seen in the exposed cores of Tarawera and Ngongotaha. Cylindrical samples were deformed under conditions similar to lava dome settings, under a constant, low axial stress of 2.8 MPa at 800-900oC (above the measured calorimetric glass transition temperatures). Deformation ensued to a total axial strain of 60% and the porosity and permeability of the samples were measured at strain increments of 10 %.

Samples display different resultant strains under the same applied stress and exhibit strain-hardening behaviour during compaction. The development of textures and microstructures is characterised using petrographic analysis and x-ray computed tomography. Porosity reduces steadily with increasing strain, but reaches a minimum of 20 % porosity at 40-50 % strain (irrespective of starting porosity or crystallinity), after which further strain is accommodated by barrelling of the sample. A rapid reduction in permeability along the primary axis occurs during the initial stage of compression and continues to decrease with increasing strain and densification of the lava. Permeability development differs between lava types due to the influence of crystallinity on the compaction process.

We infer that the incongruent development of porosity and permeability in pumiceous dome lavas can lead to a localised build-up of overpressures during volcanic eruptions, resulting in lava dome failure. In extreme cases compaction of pumiceous lava may form a volcanic plug in the upper conduit which can result in catastrophic explosive eruptions.