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Changes in elastic moduli and time-dependent brittle deformation of Etna basalt

M. Heap (1), S. Vinciguerra (2), P. Meredith (1) and P. Baud (3)

(1) Mineral, Ice and Rock Physics Laboratory, Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK, (2) Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma,Via di Vigna Murata 605, 00143, Rome, Italy, (3) Laboratoire de Physique des Roches, EOST, Strasbourg, France (m.heap@ucl.ac.uk)

Elastic moduli are crucial parameters for defining relationships between stress and strain. In volcanic areas, reliable estimates of mechanical properties and their degradation under multiple episodes of stressing is key to the accurate modelling of routinely monitored data such as ground deformation, and the calibration of damage-mechanics criteria for weakening of rocks forming volcanic edifices. During recent years, repeated episodes of major flank slip and intense surface fracturing at Mt. Etna have been observed to precede magma emplacement. Such repeated episodes of deformation can lead to an increase in the level of crack damage within the rocks of the edifice, and hence changes in their elastic moduli. Importantly, volcano monitoring techniques routinely running at Mt. Etna, such as seismic tomography and ground deformation modelling, rely on accurate knowledge of elastic moduli.

To this end, we report results of changes in elastic moduli from stress-cycling experiments on samples of extrusive basalt, the most representative lithology on Mt. Etna. The basalt contains an extensive pre-existing network of isotropic, interconnected microcracks caused by cooling. Both dry and water-saturated samples were initially loaded to 20 MPa at a constant rate and then unloaded to 8 MPa. Samples were then sequentially reloaded and unloaded at the same rate with the peak stress in each subsequent cycle increased by 10 MPa until failure. Results from both dry and wet samples showed an increasing reduction in sample stiffness with each increasing stress cycle, equating to a total decrease in Young's modulus of about 30% and an in-

crease in Poisson's by a factor of about 3. These changes are attributed to the growth of new cracks and the extension of pre-existing cracks during each stress cycle and, hence, an increase in the total crack density. This interpretation is supported by the observation of the Kaiser stress-memory effect, where cracking-associated microseismicity (acoustic emission) on any stress cycle only occurs when the maximum stress in any previous cycle has been exceeded.

Time-dependent weakening mechanisms, such as stress corrosion, that lead to the slow fracturing of volcanic edifices from the micro to the macro scale have been shown to be important during pre-eruptive patterns of flank failure at Mt. Etna. We therefore also report results from brittle creep experiments on water-saturated samples of Etna basalt under an effective confining pressure appropriate to volcano conditions (30 MPa). Crack damage evolution was monitored throughout each experiment by measuring the damage proxies of: axial strain, crack volume change and output of microseismic (acoustic emission) energy over creep strain rates in the range 10^{-6} to 10^{-9} s^{-1}.