Mt. Etna's flank instability, insights from rock deformation experiments.

Richard R Bakker[1], Philip M Benson[2], Sergio C Vinciguerra[3]

[1]ETH Zurich, Structural Geology and Tectonics, Rock Deformation Laboratory, Switzerland, [2]Rock Mechanics Laboratory, Dept. Earth and Environment, University of Portsmouth, United Kingdom, [3]Department of Geology, University of Leicester, United Kingdom

E-mail: richard.bakker@erdw.ethz.ch

Mt. Etna's (Italy) edifice is 1200 km2 wide and 3300 m high, made up of a succession of extruded lava flows above a thick sedimentary sequence. A number of flank eruptions have occurred in recent years, in all cases preceded by intense seismic activity and high rates of ground deformation, eventually leading to abrupt opening of eruptive fracture systems in the eastern flank. To better understand this deformation, the basaltic rocks of Mt. Etna volcano have been the subject of a number of experimental studies in recent years with the aim of better determining the mechanical parameters needed for ground deformation, and how these data might be rated to the seismicity for improved modelling.

Although the focus is often on these basalt units, sub-volcanic morphology show that only around 373 km3 of the bulk total volume of around 1400 km3 of the edifice at Mt. Etna and its substratum is comprised of volcanics. The rest comprises a laterally-extensive culmination of sedimentary rocks that reach a vertical thickness of about 2 km. An increase in instability, promoted by the thermal weakening of these sedimentary rocks has therefore been suggested as an important mechanism for the deformation of Mt. Etna. For this reason, a detailed understanding of the influence of high T on the mechanical properties of representative rock that forms the sub-volcanic basement of active volcanoes is essential.

Previous results carried out at high temperature and room (ambient) pressure on Comiso Limestone, a key lithology for the Etna's basement, provide evident of a predominantly brittle mode of deformation for temperatures to 760 C, together with a significant reduction in strength (Heap et al., 2013; Mollo et al., 2011). Here, we report new data on the rock mechanical properties of numerous rocks that for the edifice and basement of Mt. Etna, with particular focus on the key formation known as Comiso Lst.

Using an internally heated Paterson-type pressure vessel, we recreated conditions at 2-4 km depth together with high T, expected in this region of up to 600 C. We find the brittle to ductile transition occurs at a relatively low temperature of 300 C when confining pressure is applied, compared to no ductile behavior at unconfined experiments (Mollo et al., 2011). A significant decrease in strength occurs when the rock is exposed to temperatures exceeding 400 C. We note an increase in the yield-strength of the Comiso limestone when comparing samples that are drained as compared to undrained samples. We interpret this as due to the buildup of a pore pressure as a result of decarbonatization.

In conclusion: when compared to similar experiments on basalt, Comiso Lst. is significantly weaker, as expected, due a direct mechanical effect and as a result of decarbonatization. Magma intrusion-driven deformation could potentially increase edifice instability by activating shear zones or localizing sub-surface deformation at stresses much lower than expected.