Geophysical Research Abstracts
Vol. 13, EGU2011-4812-1, 2011
EGU General Assembly 2011

Chemical, physical and mechanical properties of tuffs from Campi Flegrei (Italy)

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Campi Flegrei caldera (Italy), 6km in diameter, poses great threat to densely-populated region in and surrounding Naples. The majority of erupted material at Campi Flegrei is in the form of tuff. However, only recently have studies started to investigate how fundamental physical properties of tuff can alter with depth and temperature for example (Vinciguerra, 2006; 2009). The need for these data has been recently highlighted by Manconi et al. (2010). Such properties may not only unravel key information on fluid and gas flow as well as seismic activity within the caldera, but they are essential parameters for ground deformation modelling and tomography used to monitor magma movement at depth. Here we present a comprehensive experimental dataset on how both the chemical, physical and mechanical properties of three representative tuffs from the Campi Flegrei caldera change with increasing thermal-stressing temperature (up to 1000°C). The tuffs are the grey Campanian Ignimbrite (CI), Neapolitan Yellow Tuff (NYT) and Piperno Tuff (PT).

Porosity change with increasing temperature is almost negligible in both CI and PT and is most likely to be due to their already impressive initial connected porosity (52.5 and 53.8%, respectively). NYT (initial porosity 45.6%) shows a decrease in porosity up to 750°C (of about 8%), before shrivelling and foaming at 1000°C. Thermo-gravimetric analysis shows that CI and PT lose about 2.5% of their mass during the heating process, whilst NYT loses about 18%. Measurements are accompanied by X-ray diffraction performed on natural state samples as well those heated up to 1000°C.

The permeabilities of the three tuffs were found to be very different. At 25°C and a 5 MPa effective pressure, the permeabilities are 1.0 x 10-14, 1.5 x 10-15 and 1.2 x 10-16 m2 for CI, PT and NYT, respectively. Interestingly, only NYT shows a decrease (of about an order of magnitude) in permeability with thermal stressing. CI and PT do not show any change. Uniaxial compressive strength tests (UCS) and tensile Brazilian strength tests echo these findings. CI and PT both show no reduction in strength with increasing thermal stressing temperature, whilst NYT shows a systematic decrease with each temperature increment. Appreciable AE was measured during the deformation of CI. However, both NYT and PT deformed, for the most part, aseismically. We also investigated how ultrasonic wave velocities and static and dynamic elastic moduli change with increasing thermal-stressing temperature for the three tuffs, including measurements at effective confining pressures up to 50 MPa. Results show that ultrasonic wave velocities increase within increasing confining pressure; however, as per the previous data, thermal-stressing was only seen to affect measurements on NYT.

The results of these investigations highlight that three tuffs from the same area can display very different chemical, physical and mechanical properties, and a very different response to thermal-stressing.