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How does temperature influence the physical and chemical properties of the deep carbonate basement and shallow lava flows at Mt. Etna volcano?

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The geology at Mt. Etna consists of a basaltic cover resting upon thick Mesozoic to Middle Pleistocene carbonate succession of limestone and dolomite, called the Hyblean Plateau. A detailed understanding of the influence of high temperatures, as a result of magma emplacement for example, on the physical and chemical properties of the rock that forms the deep sedimentary basement and the shallow volcanic cover at Mt Etna is a primary target for reliable volcanic hazard assessment. Here therefore we present experimental data on the influence of temperature on physical and chemical properties in both important carbonates of the deep Hyblean Plateau, and the most representative extrusive lava flow basalt forming the shallow volcanic cover.

Firstly, we show the output of acoustic emissions (AE) during heating (1°C/min to 1000°C) without load for each of the three rock types; in the case of the two limestones this is coupled with data of the mass loss during heating, by thermo-gravimetric (TG) analysis. We then show how the chemistry of the limestones changes with increasing temperature using X-ray powder diffraction (XRPD). Analyses show that, at about 600°C, the calcite in the sample starts to decompose releasing carbon dioxide – a reaction called decarbonation. At 800°C the calcite is fully dissociated and portlandite, a calcium hydroxide, is formed by the recombination of CaO with water-vapour.

Secondly, we demonstrate the influence of temperature (up to 900°C) on the deformation both the limestones and the basalt in constant strain rate (10-5 s-1) experiments. Our results show that there is an increase in strength in limestone prior to decarbonation. During and after decarbonation, strength is decreased significantly and the deformation behaviour is very ductile and almost aseismic. In contrast, the basalt remains very brittle despite the large increase in temperature; only at 950°C is there a noticeable softening of the sample during deformation. Finally, we show that, for the limestones, increasing the temperature results in an increase in porosity, CO2 release, Vp/Vs ratio and Poisson's ratio and a decrease in calcite content, Vp and Vs and Young's modulus.

Our experiments have demonstrated that high temperatures will strongly influence the chemical and physical properties of the limestones that form part of the Hyblean Plateau under Mt Etna. The basaltic cover will remain largely unaffected however. Although the limestones are at 5 km depth, and we performed uniaxial experiments, we can infer that the limestone that resides deep under Mt. Etna will be severely affected by the high temperatures generated by magma moving from depth, ponding and the intrusion of dykes. This weakening may provide potential new routes for magma to reach the surface and promote instability within the edifice. Furthermore, decarbonation of the sedimentary basement may help explain the anomalously high CO2 degassing seen at large faults at Etna volcano, such as the Pernicana fault.