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Permeability and Strength Development of Thermally Stressed Hyaloclastite in Krafla Geothermal Reservoir, Iceland

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During subglacial and subaqueous volcanic eruptions, hyaloclastite forms as a response to rapid quenching of effusive material. Predominantly basaltic hyaloclastite is commonly found in the relatively young volcanic complexes in Iceland, associated with recent glacial periods. As such, hyaloclastite forms in hot, water-rich environments where palagonitisation rapidly cements the basalt glass matrix, adding a substantial proportion of external water to the deposit. As hyaloclastite is buried under new deposits its mechanical and chemical properties are altered due to changes in the thermal and chemical environment. Eruptions and shallow intrusions may locally reheat the hyaloclastite, affecting properties such as water content, permeability, porosity and mechanical strength. Due to the high geotherms associated with volcanic centres, geothermal reservoirs are often partly composed of hyaloclastite. Krafla, North-East Iceland, provides a prominent example, where a 110 ka caldera is infilled with younger deposits, including a thick, volumetrically important hyaloclastite sequence. Within the caldera, an active magmatic system is utilized for geothermal energy production where previous drilling excursions have shown that hyaloclastite is common to >1 km depth in many parts of the reservoir. Here, the thermal and mechanical properties of hyaloclastite are constrained through a series of laboratory measurements.

Utilising surficial samples from the south-east rim of the Krafla caldera and drill core samples from borehole KH-6 (0, 70 and 556 mBGL) in the Krafla reservoir, change in porosity, permeability and compressive and tensile strength are analysed at a range of thermal stressing temperatures. Porosity and permeability measurements are determined using helium pycnometry and a classic hydrostatic cell, respectively. Thermal stressing temperatures were selected using simultaneous thermal gravimetry and differential scanning calorimetry in conjunction with thermomechanical analysis. Compressive strength measurements are determined using a triaxial press whilst tensile strength is derived from the Brazilian disc method using a uniaxial press.

Experimental results indicate the dominant dehydration reactions occur below 200 °C, well within the in-situ conditions experienced by the Krafla hyaloclastite. Further testing aims to quantify the resultant effect on the mechanical properties of thermally stressed samples. Subsequent thin section and XRD analysis will provide possible explanation to the extent of the chemical and mineralogical development associated with increasing depth and stressing temperature and possibly constrain the role of alteration within the system. This improved characterisation of hyaloclastite is useful for fluid flow and strength modelling with the Krafla geothermal reservoir and other hyaloclastite-bearing fields.