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Mechanical behaviour of the Krafla geothermal reservoir: Insight into an active magmatic hydrothermal system

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Krafla volcano, located in North-East Iceland, holds an active magmatic hydrothermal system. Since 1978, this system has been exploited for geothermal energy. Today it is exploited by Landsvirkjun National Power of Iceland and the system is generating ~60 MWg from 18 wells, tapping into fluids at 200-300°C. In order to meet further demands of environmentally sustainable energy, Landsvirkjun aims to drill deeper and source fluids in the super-heated, super high-enthalpy system which resides deeper (at 400-600°C). In relation to this, the first well of the Icelandic Deep Drilling Project (IDDP) was drilled in Krafla in 2009. Drilling stopped at a depth of 2.1 km, when the drill string penetrated a rhyolitic magma body, which could not be bypassed despite attempts to side-track the well. This pioneering effort demonstrated that the area close to magma had great energy potential. Here we seek a constraint on the mechanical properties of reservoir rocks overlying the magmatic systems to gain knowledge on these systems to improve energy extraction.

During two field surveys in 2015 and 2016, and through information gathered from drilling of geothermal wells, five main rock types were identified and sampled [and their porosities (i.e. storage capacities) where determined with a helium-pycnometer]: basalts (5-60% porosity), hyaloclastites (<35-45% porosity), obsidians (0.25-5% porosity), ignimbrites (13-18% porosity), and intrusive felsites and microgabbros (9-16% porosity). Samples are primarily from surface exposures, but selected samples were taken from cores drilled within the Krafla caldera, outside of the geothermal reservoir.

Uniaxial and triaxial compressive strength tests have been carried out, as well as indirect tensile strength tests using the Brazilian disc method, to measure the rock strengths. The results show that the rock strength is inversely proportional to the porosity and strongly affected by the abundance of microcracks; some of the rocks are unusually weak considering their porosities, especially at low effective pressure as constrained at Krafla. The results also show that the porous lithologies may undergo significant compaction at relatively low loads (i.e. depth).

Integration of the observed mechanical behaviour and associated permeability into future fluid flow simulations will aim to increase our understanding and exploitation of geothermal reservoirs.