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COTHERM: Geophysical Modeling of High Enthalpy Geothermal Systems

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In recent years geothermal heating and electricity generation have become an attractive alternative energy resource, especially natural high enthalpy geothermal systems such as in Iceland. However, the financial risk of installing and operating geothermal power plants is still high and more needs to be known about the geothermal processes and state of the reservoir in the subsurface.

A powerful tool for probing the underground system structure is provided by geophysical techniques, which are able to detect flow paths and fracture systems without drilling. It has been amply demonstrated that small-scale features can be well imaged at shallow depths, but only gross structures can be delineated for depths of several kilometers, where most high enthalpy systems are located. Therefore a major goal of our study is to improve geophysical mapping strategies by multi-method geophysical simulations and synthetic data inversions, to better resolve structures at greater depth, characterize the reservoir and monitor any changes within it.

The investigation forms part of project COTHERM – COmbined hydrological, geochemical and geophysical modeling of geoTHERMal systems – in which a holistic and synergistic approach is being adopted to achieve multidisciplinary cooperation and mutual benefit. The geophysical simulations are being performed in combination with hydrothermal fluid flow modeling and chemical fluid rock interaction modeling, to provide realistic constraints on lithology, pressure, temperature and fluid conditions of the subsurface. Two sites in Iceland have been selected for the study, Krafla and Reykjanes.

As a starting point for the geophysical modeling, we seek to establish petrophysical relations, connecting rock properties and reservoir conditions with geophysical parameters such as seismic wave speed, attenuation, electrical conductivity and magnetic susceptibility with a main focus on seismic properties. Therefore, we follow a comprehensive approach involving three components: (1) A literature study to find relevant, existing theoretical models, (2) laboratory determinations to confirm their validity for Icelandic rocks of interest and (3) a field campaign to obtain in-situ, shallow rock properties from seismic and resistivity tomography surveys over a fossilized and exhumed geothermal system. Theoretical models describing physical behavior for rocks with strong inhomogeneities, complex pore structure and complicated fluid-rock interaction mechanisms are often poorly constrained and require the knowledge about a wide range of parameters that are difficult to quantify. Therefore we calibrate the theoretical models by laboratory measurements on samples of rocks, forming magmatic geothermal reservoirs. Since the samples used in the laboratory are limited in size, and laboratory equipment operates at much higher frequency than the instruments used in the field, the results need to be up-scaled from the laboratory scale to field scale. This is not a simple process and entails many uncertainties.