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Thermomechanical effects of seasonal thermal energy storage in former subsurface mining structures

Mandy Duda (1), Ahrens Benedikt (1), Kroll Kristian (2), and Gilbert Jan Paul (2)

(1) Bochum University of Applied Sciences, International Geothermal Centre, Germany (mandy.duda@hs-bochum.de), (2) Ruhr-Universität Bochum, Institute for Geology, Mineralogy, and Geophysics, Germany

The successful implementation of renewable cascading and energy storage concepts is required to account for the increasing demand for sustainable energy supply. In this context, medium deep geothermal energy (MGE) reservoirs become increasingly important for seasonal thermal energy storage. Compared to deep geothermal reservoirs, the investment risk for the exploration of MGE reservoirs is significantly lower and their accessibility is usually higher.

Industrial waste heat and surplus heat from non-baseload energy sources can be used to enhance MGE systems through seasonal thermal energy storage in particular in metropolitan areas with a high heat demand. For example, the Ruhr area (Germany) has been and is subject to major structural changes associated with the end of (hard) coal mining and steel industry as well as accelerated urbanization. Abandoned coal mines bear considerable geothermal potential and may serve as underground reservoirs to seasonally store and produce thermal energy. At the same time, a comprehensive risk assessment of thermal mining is highly important in such densely populated regions, in particular with respect to surface movements and seismic potential. Therefore, a thorough subsurface characterization is required to derive the thermomechanical properties of geothermal reservoir rocks.

We determined the elastic and inelastic thermomechanical properties of two relevant rock types, a sandstone from said Ruhr area and a granodiorite from the Liquine fractured geothermal system (Chile), during conventional triaxial deformation at various temperatures and confining pressures covering the range of in situ conditions equivalent to depths of up to three kilometres. In addition, triaxial deformation experiments were conducted at different strain rates to investigate the deformation-rate dependence of the thermomechanical properties and to evaluate their temporal sensitivity. In cases, cyclic thermal stressing was applied at hydrostatic conditions to assess the effect of thermally induced cracks on the elastic properties. Results of laboratory experiments serve as limiting bound for the time and temperature dependence of elastic and inelastic properties of mechanically unaltered, intact rock mass and can be used as input parameters for thermomechanical modelling of subsurface structures contemplated as thermal energy storage.