Heating the subsurface: Thermomechanical characterization of subsurface seasonal thermal energy storage in the Ruhr metropolitan area

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Abstract

In recent decades, the Ruhr metropolitan area has been subject to structural changes associated with the ending of traditional coal mining and steel industry as well as accelerated urbanization. Considering effective climate changes, these processes pose local to global challenges for a post-fossil energy future. The successful implementation of renewable cascading and energy storage concepts is required to account for the increasing demand for sustainable energy supply.

The polycentric structure of the Ruhr area is particularly promising for the requirements imposed by the energy transition. Abandoned coal mines bear considerable geothermal potential and may serve as underground reservoirs to store seasonal surplus heat. Therefore, extensive subsurface reservoir characterization is required to derive the thermomechanical properties of the reservoir rocks. If direct information on in situ properties is limited or inaccessible, laboratory experiments can provide the basis for reservoir characterization and the prediction of the reservoir behaviour under in situ conditions during geothermal energy storage and provision.

In our experimental study we determined the thermomechanical properties of reservoir rocks during conventional triaxial deformation at various temperatures and confining pressures. Confining pressures and temperatures applied in the tests cover the range of in situ conditions equivalent to depths up to three kilometres. Cyclic thermal stressing was applied at hydrostatic conditions before triaxial deformation was commenced to characterize the interplay between pre-existing and thermally introduced cracks and their role on the mechanical rock properties. In addition, triaxial deformation experiments were conducted at various strain rates to investigate the deformation-rate dependence of the thermomechanical properties. Results of laboratory experiments serve as limiting bound for the strain- and temperature-dependence of elastic and inelastic properties of mechanically unaltered rock mass.