Geophysical Research Abstracts
Vol. 19, EGU2017-16677, 2017
EGU General Assembly 2017

Hydraulic properties of siliciclastic geothermal reservoir rocks under triaxial stress conditions, a multidisciplinary approach.

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Cretaceous Sandstone bodies in the subsurface of western Netherlands are already used for heating some of the greenhouses in that area. The reservoirs used are typically at depths between 1500 and 3000m, with temperatures generally <100 ˚C. For higher temperature applications deeper reservoirs are required. However, deeper reservoirs are subjected to higher effective pressures due to more overburden, which can lead to more compacted rocks, and thereby reduced permeability. We assess the effects of effective pressure on Triassic Buntsandstein, a formation targeted to act as a deep geothermal reservoir in the western Netherlands. Rock samples are acquired from laterally equivalent quarries and prepared for permeability measurements within a tri-axial apparatus. To determine anisotropy, cores are drilled both perpendicular and parallel to bedding. Experiments are conducted by maintaining hydrostatic confining pressure, stepwise increasing up to 700 bar (if still permeable enough for accurate measurements) and a pore pressure of 25 bar. At each step the permeability is assessed by imposing a number of constant flow rates and continuous measurement of the pore pressure difference between up and downstream reservoirs. Throughout the experiment the sample strain is measured in radial and axial directions, such that elastic constants can be determined and micromechanical mechanisms may be observed. In addition to measurements on in-tact rock samples, we also assess the effect of induced fracturing on permeability by similar measurements. First, rock samples are fractured within the tri-axial cell with normal jacketing to evaluate the stress conditions of failure. Secondly, the experiment is repeated using relatively strong jackets which remain sealing after sample failure, allowing for permeability measurements. Preliminary results show that an increase of confining pressure leads to a decrease of permeability by three orders of magnitude, from 1e-13 to 1e-16 m2. Anisotropy results in permeability parallel to bedding to be roughly one order of magnitude higher than perpendicular to it.

Based on the collected data, the validity of the available exponential permeability-porosity-stress relationship is assessed and the model parameters with the best fitting characteristic is chosen for the selected formation. The established relationship is then used as an input for field scale numerical simulation of cold fluid circulation in Buntsandstein formation to predict the reservoir behavior over longer term of fluid circulation. The Finite Element Method is used to evaluate the reservoir behaviour during injection/production of the cold/hot fluid in a fully coupled poro-thermo-elastic environment. Weighted residual method is used for deriving the weak formulation of the mass-, momentum- and energy balance equations. Consequently the standard Galerkin approach is used for spatial discretization of the weak formulas. Temporal discretization is also carried out in a fully implicit manner to avoid the time-stepping limitation. The preliminary results of this study show a promising capacity of heat extraction from the Buntsandstein formation as a geothermal reservoir within western Netherlands.