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Predicting Formation Damage in Aquifer Thermal Energy Storage Systems Utilizing a Coupled Hydraulic-Thermal-Chemical Reservoir Model

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In aquifer thermal energy storage (ATES) systems, large amounts of energy can be stored by injecting hot water into deep or intermediate aquifers. In a seasonal production-injection cycle, water is circulated through a system comprising the porous aquifer, a production well, a heat exchanger and an injection well. This process involves large temperature and pressure differences, which shift chemical equilibria and introduce or amplify mechanical processes. Rock-fluid interaction such as dissolution and precipitation or migration and deposition of fine particles will affect the hydraulic properties of the porous medium and may lead to irreversible formation damage. In consequence, these processes determine the long-term performance of the ATES system and need to be predicted to ensure the reliability of the system. However, high temperature and pressure gradients and dynamic feedback cycles pose challenges on predicting the influence of the relevant processes.

Within this study, a reservoir model comprising a coupled hydraulic-thermal-chemical simulation was developed based on an ATES demonstration project located in the city of Berlin, Germany. The structural model was created with Petrel, based on data available from seismic cross-sections and wellbores. The reservoir simulation was realized by combining the capabilities of multiple simulation tools. For the reactive transport model, COMSOL Multiphysics (hydraulic-thermal) and PHREEQC (chemical) were combined using the novel interface COMSOL_PHREEQC, developed by Wissmeier & Barry (2011). It provides a MATLAB-based coupling interface between both programs. Compared to using COMSOL's built-in reactive transport simulator, PHREEQC additionally calculates adsorption and reaction kinetics and allows the selection of different activity coefficient models in the database.

The presented simulation tool will be able to predict the most important aspects of hydraulic, thermal and chemical transport processes relevant to formation damage in ATES systems. We would like to present preliminary results of the structural reservoir model and the hydraulic-thermal-chemical coupling for the demonstration site.

Literature:
Wissmeier, L. and Barry, D.A., 2011. Simulation tool for variably saturated flow with comprehensive geochemical reactions in two- and three-dimensional domains. Environmental Modelling & Software 26, 210-218.