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Microtomographic quantification of hydraulic clay mineral displacement effects during a CO2 sequestration experiment in a saline sandstone aquifer

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Following the commitments made by the Kyoto Protocol, EU countries are challenged to reduce their emissions of CO_2. The mitigation option Carbon Capture and Storage (CCS) is the one that seems to have the most potential to achieve substantial CO_2 reductions at acceptable conditions over the next few decades. The idea of our investigation was to combine a non-invasive imaging with an invasive open-system fluid injection experiment and compare the results of the pre- and post-treated states of the studied reservoir sample. Main emphasis of this physical part of study was on the feasibility of permeability predictions with clay-rich sandstones on the pore-scale by a digitized rock analysis method comprising tomographic scanning, perfusion experiments, reprocessing the data and pore network analysis. A sandstone rock core sample was derived for this experiment from the 629 m deep saline sandstone aquifer of the Stuttgart Formation at the CCS research pilot plant Ketzin, Germany. Core flooding experiments have been performed in an open system laboratory injection device (FLECAS) under in-situ reservoir p/T-conditions. An open system was deemed more realistic of a CCS reservoir than the more common closed system setups. Supercritical carbon dioxide (CO_2) and artificial brine were injected at an average flow rate of 0.1 ml/min for 256 hours. X-ray computed microtomographic (μ-XCT) imaging was carried out before and after the coreflooding experiment at a spatial voxel resolution of 27 μm. The sample properties calculated from the tomographic images included open/closed porosity, pore size distribution (PSD), and the permeability tensor in x,y,z-direction. The major new observation was a clay particle migration and clogging effect along the z-direction obviously induced by the injected fluid hydrodynamics, while significant overall porosity changes due to geochemical dissolution/precipitation interactions could not be detected at the voxel resolution. The thus digitized rock data was taken as the direct real microstructure input for the GeoDict software package to simulate Navier-Stokes flow by a lattice Boltzmann equation (LBE) solver. This resulted ultimately in 3D pressure and flow velocity fields by which hydrodynamic variability due to the clay mobilization effect could be quantified on a sub-core scale.