Geophysical Research Abstracts
Vol. 13, EGU2011-2893-1, 2011
EGU General Assembly 2011

Petrophysical properties of sandstones exposed to supercritical carbon dioxide

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Within the framework of the BMBF funded project COMICOR variations of petrophysical, mineralogical and chemical properties were studied on bleached and unbleached sandstones. These untreated samples acted as a natural analogue for CO2-storage in deep seated saline aquifers. The petrophysical and compositional parameters porosity, permeability, electrical conductivity, mineralogical and chemical analysis as well as optical analysis were carefully performed on the untreated samples together with a detailed description of the geological setting. Thus we gained a reliable data base of these properties that control the storage volume and the flow conditions in a storage horizon. This was done on more than 200 plug samples. Porosities and permeabilities measured on plug samples coming from an heterogeneous and homogeneous lithostratic profile of two drillings exhibited variations from <0.08 up to >0.2 (fraction) in porosity and from <10-16 up to >10-13m^2 in permeability, variations of these properties were detected even in cm-scale. This implies, that all measurements have to be performed on the same sample to address changes of these quantities to be caused by CO2-flow.

In a second step of the project the samples were exposed in laboratory experiments to the pressure and temperature conditions (p: 12–20 MPa; T: 120-200°C) of a hypothetical deep seated saline aquifer. To simulate conditions close, and far away from an injection point, the plug samples were either partially or fully saturated with an artificial brine (3 M NaCl) and were then exposed to supercritical CO2 (scCO2). In the first case the scCO2 was in direct contact with the inner surface of the pore system (via the electrochemical double-layer, DL), thus causing a higher degree of interaction than in the case of fully saturated samples where the reaction kinetics are hindered due to the low solubility of scCO2 in the brine. The experiments lasted from some days up to more than 4 month, and if possible, the same samples were used repeatedly in subsequent experiments. Thus the reaction kinetics of e.g. permeability variations could be studied in great detail.

The optical analysis (microscope, microprobe) of slices and thin sections showed dissolution of detrial and precipitation of authogenic minerals in pores and along grain boundaries. The chemical analysis (XRF) exhibited mobilisation of aluminum, and calcium, thus the overall mineralogy (XRD, Rietveld) was changed. This was approved by the chemical analysis of the pore fluid where these elements were detected. Porosity was not altered by scCO2 treatment, while permeability increased up to more than 2.5 orders in magnitude on partially saturated samples, while fully saturated samples exhibited a much smaller permeability increase of less than one order in magnitude. As the hydraulic and the electrical charge transport are related to the same pore system, the permeability increase was confirmed by electrical conductivity measurements (IS) where an increase in bulk-conductivity was detected. This was caused by a higher degree of interconnection of the pore system, a finding that was validated independently on BSE-images (micro-probe). Solution of mineral phases at the inner surface was reflected qualitatively by a significant phase shift of the electrical low frequency signature performed by spectral induced polarisation (SIP).