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Experimental investigation of the CO_2 sealing efficiency of a regional cap rock in W Germany

J. Wollenweber, S. Alles, A. Busch, B.M. Krooss

Institute of Geology and Geochemistry of Petroleum and Coal, RWTH Aachen University, Germany (wollenweber@lek.rwth-aachen.de / Lochnerstr. 4-20, 52056 Aachen / Fax: +492418092152 / Phone: +492418095747)

The Upper Cretaceous “Emscher Mergel” (Emscher Marl) formation is a mudrock of wide regional distribution and a thickness of up to 1000m in the Münsterland basin of W Germany. It overlies a saline aquifer as well as deep, unminable Carboniferous coal seams which represent potential targets for subsurface storage of CO_2. In order to determine the top seal propeties and, in particular, the CO_2 sealing efficiency of this formation, fundamental petrophysical and mineralogical investigations have been performed on selected samples representing different stratigraphic layers.

These investigations comprise Helium and CO_2 gas breakthrough experiments under in-situ P/T conditions on initially fully water saturated cylindrical plugs of 10-20 mm thickness and 28.5 mm diameter. The experimental procedure has been described in detail by Hildenbrand et al. (2002). Repetitive gas-breakthrough experiments (three cycles) have been performed under elevated P/T conditions to test for reproducibility and petrophysical changes that might result from the interaction of the samples with CO_2. Between the different CO_2 tests, helium experiments under the same conditions have been conducted to compare the results with an inert (non-reactive) gas. Prior to each gas-breakthrough experiment, single phase permeability tests were performed with water.

In addition to the fluid-flow tests, CO_2 sorption experiments were conducted on “as received” powdered marl material at pressures up to 20 MPa and temperatures of 45˚C.

The repetitive CO_2 gas breakthrough experiments revealed irreversible changes of the petrophysical properties, possibly due to the interaction between the CO_2 and the sample. Absolute (water) permeability coefficients ranged between 6 and 70 nDarcy

(6-70·10^{-21} m^2). An increase in permeability was noted after the first CO_2 gas-breakthrough test while permeability remained constant after the follow-up tests.

Mass balance calculations of each gas-breakthrough experiment have been performed in order to determine the amount of CO_2 dissolved in the pore water and to quantify sorption processes and/or mineral reactions. This quantification revealed a significant CO_2 storage capacity of the "Emscher Mergel" during the first breakthrough experiment, whereas follow-up breakthrough tests did not show significant additional CO_2 fixation. The high storage capacity was verified by the volumetric sorption experiments on powdered samples. These yielded maximum excess sorption values of $\sim$0.25 mmol/g. From other studies these high values can be attributed to physical sorption on clay minerals and organic matter.

In order to obtain further information on mineral reactions (and sorption processes), XRD-, BET-, and Hg porosimetry measurements are presently being performed.

References:

Hildebrand et al., 2002. Gas breakthrough experiments on fine-grained sedimentary rocks. Geofluids (2002) 2, 3-23