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Changes of petrophysical properties of sandstones due to interaction with carbon dioxide, a laboratory study

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Changes of petrophysical, petrological, mineralogical, mechanical and chemical parameters were studied on sandstones from the Hessian depression and sandstones from Neidenbach (Eifel) before and after alteration with CO_2. The experiments were performed in a wide pressure and temperature range (p >10<20 MPa; T > 100<200°C) to cover the pressure and temperature conditions of most promising deep saline aquifers, with the consequence that CO_2 is above the critical point and thus in supercritical state ($scCO_2$). The experiments lasted from 10 days up to more than 6 month. In repeated experiments samples were analyzed after every 2 up to 6 weeks reaction time. Experiments were performed in two different setups, i) the pore volume was fully saturated with a CO_2-saturated artificial brine (3 M NaCl-solution) and ii) the pore volume was partially saturated with brine and in direct contact with wet CO_2.

Initial values of the untreated samples exhibit quartz to range from < 50% up to >85 weight %, density from 2.62 – 2.70 g/cm3, porosity from < 10% up to > 25% and permeability from < 10-17 up to 10-12 m^2. In both experimental setups porosity increased by less than 2 vol%. The increase in permeability was less than one order in magnitude for i) and more than 1.5 orders in magnitude for ii). The mineralogical composition was unchanged within the detection limit of powder X-Ray diffraction (XRD), while X-Ray Fluorescence Analysis (XRF) indicated mobilization of calcium, magnesium, aluminum and potassium. Dissolution was confirmed by the chemical analysis (ICP-OES-MS) of recovered artificial brines that showed an increase of the ionic species Ca, Mg, Al and K after the $scCO_2$-experiments. Partial solution of feldspar and clay was detected by optical inspection and scanning electron microprobe SEM-analysis. Low frequency electrical conductivity experiments (SIP, spectral induced polarization) exhibited both, a significant increase in conductivity that could be explained by dissolution at narrow pore throats thus causing a higher degree of interconnection of the pore system and a shift of the phase angle that indicates changes of the geometry of the pore surface area. The uniaxial compressive strength was measured before and after $scCO_2$-treatment on a set of homogeneous sandstones from Neidenbach. These data were compared with natural analogues, e.g. bleached and unbleached sandstones from the Hessian depression. The uniaxial compressive strength of untreated and $scCO_2$-treated samples were found to fit the range reported for sandstones.