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Mineral displacement and -dissolution processes and their relevance to rock porosity and permeability in Rotliegend sandstones of the Altmark natural gas field (central Germany) – results from CO_2 laboratory batch experiments

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The Rotliegend reservoir sandstones of the Altmark area (central Germany) comprise the second largest natural gas field of Europe. These sandstones were deposited on a playa-like continental platform with braided river systems, ephemeral lakes and aeolian dunes under semi-arid conditions. Some of the pristine, red coloured deposits suffered intensive late diagenetic alteration and are now preserved as bleached, high porous and permeable sandstones.
To evaluate the relevance of distinct fluids and their fluid-rock alteration reactions on such bleaching processes we performed laboratory static batch experiments on the Altmark sandstones. These 4-6 week lasting runs were conducted with CO_2 saturated synthetic brines under typical Altmark reservoir conditions (p= 20 MPa, T= 125°C). Thereby mineralogical, petrophysical and (hydro- and geo-) chemical rock features were maintained prior and after the experiments. Chemical data proved the dissolution of carbonate and sulphate minerals during the runs, whereas the variation in abundance of further elements was within the detection limit of analytical accuracy. However, FE-SEM investigations on used, evaporated brines reveal the presence of illite and chlorite minerals within a matrix of Ca-, Si-, Fe, Al-, Na- and S components (carbonate, anhydrite, albite and Fe-(hydr-) oxides ?).
By porosity and relative permeability measurements an increase in both rock features was observed after the runs, indicating that mineral dissolution and/or (clay) fine migration/detachment occurred during the experiments. Mineral dissolution, especially of pore-filling cements (e.g. carbonate-, sulphate minerals) is also deduced by BET analysis, in determining the specific surface of the sandstones. The size of these reactive surfaces increased after the experiments, suggesting that after the dissolution of pore-filling cements, formerly armoured grain rimming clay cutans were exposed to potential migrating fluids.
These findings are also supported by μ-CT investigations. Here, the achieved 3D modelling data indicate an increase in reactive surface areas exposed to the pore space (which is in accord to the BET observations), as well as an enhancement in rock porosity and permeability after the runs. Moreover, these simulations showed that a remarkable mass (mineral) transfer was induced by the experiments, which led to a displacement of the porosity and permeability distribution in the sandstones and therefore a change in the fluid flow characteristics within the rocks – a parameter most important for every fluid-rock process.
These observations are quite astonishing because they suggest that not only fluid velocity (e.g. during fluid flow experiments) might detach and transport grain rimming (clay) minerals, but also that physico-chemical reactions may enforce the release of such solids, even during almost static p-/T-/Xfluid conditions, as used in our experiments.