Forecast of reactive CO\textsubscript{2} injection into a carbonate formation, Middle East

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It is commonly accepted that subsurface CO\textsubscript{2} storage is required for controlling the greenhouse effect and climate change. This is especially important for countries in the Middle East, where producing and upgrading of large hydrocarbon resources from carbonate reservoirs cause a relatively large CO\textsubscript{2} footprint. Injection of CO\textsubscript{2} into saline carbonate formations would contribute to the desire of CO\textsubscript{2} neutrality in such operations. However, dissolution and dissociation of CO\textsubscript{2} in the brine causes lowering of the pH, which could affect the mineralogy of the host reservoir. Several studies have yet addressed this issue (e.g. [1-3]), although studies to carbonate reservoirs are less common than studies to other reservoirs. Carbonate minerals (e.g. calcite) are considered to be very reactive in response to pH changes. In addition, fractures and faults commonly occur in carbonate reservoirs and should be taken into account as they could act as a leakage pathway. The goal of this study was to assess the impact of CO\textsubscript{2} injection into a target carbonate reservoir in the Middle East. We computed the sensitivity of various model uncertainties to understand where model improvements should focus on.

We carried out reactive transport modelling (RTM) to study the long-term fate of CO\textsubscript{2} injection in a carbonate aquifer. RTM is becoming more recognized in the oil and gas industry due to increasing importance of production and injection of reactive fluids and gases. We used the in-house Shell reservoir simulator MoReS, which is coupled to the geochemical software PHREEQC (version 3) [4]. The software takes into account geochemical reactions based on the MSE framework [5], which we derived from the software OLI Stream Analyzer. The heterogeneous model is based on a geological model built in Petrel, contains faults, various rock types, and various porosity-permeability relationships. The mineralogy is dominated by calcite, but also contains anhydrite and dolomite. The formation water composition is assumed to be in equilibrium with these minerals. Up to 4.7 Mtonne of CO\textsubscript{2} is injected over a period of 30 years. The model contains more than 200,000 grid cells and uses grid refinement to accurately capture the flow pattern and reactive behavior.

The results show that CO\textsubscript{2} predominantly migrates along the high permeability zone at the top and the bottom of the formation where CO\textsubscript{2} is injected into. The formation is sandwiched between impermeable layers, which effectively block vertical migration. However, the plume reaches a conductive fault during the simulation, causing upward migration of dissolved CO\textsubscript{2} throughout the entire carbonate body. Variation of the injection well location relative to the fault locations demonstrate that this distance significantly influences the point in time when CO\textsubscript{2} breakthrough occurs in the faults. Migration of CO\textsubscript{2} in the faults also turned out to be sensitive to the fault conductivity, the relative permeability model, and different realisations of the Petrel geological model.

Lowering of the pH is buffered by dissolution of calcite and dolomite, which leads to oversaturation of anhydrite and hence precipitation. The mineral amounts that dissolved or precipitated are
relatively small and lead to an overall porosity increase up to 0.01% after 1,000 years. Comparable trends were also observed in other studies [2]. The porosity increase is a bit larger at the reservoir/fault interface, i.e. up to 0.04%, potentially due to accelerating transport of formation water and mineral dissolution into the high permeable faults.

The simulations demonstrate that it is important to accurately map the faults in the study area and choose the position of injection wells carefully with respect to such faults. This will give better control on CO₂ conformance during time. The overall geochemical impact of CO₂ injection into the carbonate reservoir is relatively low and therefore requires less attention.