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Simulating reactive transport processes induced by CO_2 injection in the nearly depleted Altmark natural gas reservoir, Germany

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In the framework of the CLEAN project, the nearly depleted natural gas field in the Altmark region was selected for a pilot project regarding Enhanced Gas Recovery (EGR) combined with geological storage of CO_2. A feasibility assessment must take into account all physical processes that could possibly impact its operational life and long term safety of disposed CO_2. The interactions of multiphase hydrodynamics, chemistry and heat transport occur at different spatial and temporal scales and yet are intimately related to each other. On the one hand, simulation results will be crucial to the engineering of the injection and for the reliability of the storage. On the other hand, such complexity introduces a high degree of difficulty in the theoretical representation of the underlying physics, and in the solution algorithm for the coupled numerical model.

Main features of the target reservoir are: Firstly, the CO_2 will be injected as gas that forms a mixture with the pre-existing N_2 and CH_4. An accurate set of equations of states (EOS), which reflects the density, viscosity, and mixing properties of the gas phase is thus required by the numerical models to calculate the distribution of different components in the same phase. Secondly, the injected CO_2 temperature is much lower than the reservoir temperature of 120 C. Therefore, the flow field of mixed gas phase can be greatly influenced when the reservoir is slowly cooling along with the injection. Non-isothermal scenarios must be modeled to reflect the response of porosity and permeability due to temperature change. Thirdly, the injected CO_2 will acidify the pore water, although water is actually present only in small amounts given the nature of the reservoir, nevertheless possibly inducing dissolution and precipitation of different minerals in the host rock. Reactive transport simulations are then needed to investigate whether such alternation will enhance the trapping of CO_2, and in which time span, or if at the contrary the reservoir or the sealing rock will be weakened by the acidic attack of the injected carbon dioxide.

The scientific software OpenGeoSys is actively being developed to tackle such challenges. It is capable of modelling coupled Thermal, Hydrological, and Mechanical (THM) processes in all kinds of porous media. Additionally, it has recently been coupled with chemical simulators PhreeqC and GEMIPM2K. The first is based on the Law of Mass Action (LMA) approach and the latter on the Gibbs Energy Minimization (GEM). Both of them will be employed to simulate the same geochemical system representing interactions between pore water and rock minerals.

Our study focuses on the following main directions: 1) For the nearly depleted gas reservoir, how does the injected fluid cool down the porous media, and to what speed and extent will the cooling effect influence the flow field. 2) Implementation of CO_2 solubility model in the aqueous phase and also the water saturation model in gas phase. Therefore, simulations can be made to investigate the dry-out effect in the vicinity of the injection well. 3) Two different reactive transport modules, PhreeqC and GEMIPM2K with their thermodynamical/kinetic databases, are calibrated using available data from field and lab experiments, including batch reactions and column flow-through tests. 4) Sensitivity analysis to the most relevant parameters in fully coupled THC simulations of the near field. A tentative assessment of the uncertainty associated with the models and the possible influence of heterogeneity are also discussed.