# Simulation study on trapping processes of $CO_2$ at Nagaoka pilot project

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Long term stability of $CO_2$ stored in reservoir is of intrinsic importance for ensuring the viability of geologic sequestration of carbon dioxide. Demonstrating the permanence of storage is an important task of pilot projects. In the Nagaoka project, Japan's first pilot-test of geological $CO_2$ sequestration that injected about 10,400 tonnes of $CO_2$ from 2003 to 2005, a stable containment of $CO_2$ in a reservoir has been successfully demonstrated by kept monitoring the $CO_2$ behavior even after the end of injection during about 10 years. Systematic and continuous data acquisition of time-lapse well loggings (e.g., resistivity, neutron, and sonic velocity) successfully illustrated the detailed nature of $CO_2$ migration at intra-reservoir resolution.
In this study, a three-dimensional reservoir model with sub-meter spatial resolution has been developed with comprehensively involving coupled process of two-phase fluid flow and geochemical transport. The model was history-matched against a set of monitoring data acquired during the post-injection period including pressure, well loggings, and fluid samplings. The calibration of a large model is computationally demanding, hence we newly developed a parallel version of coupled fluid flow and geochemistry TOUGHREACT V2.0/ECO2N with MPI parallelism, in-house. The new code also features hysteretic effect in relative permeability and capillarity which was not implemented in the original TOUGHREACT V2.0.
The detailed 3D history matching study reproduced the observed distribution of $CO_2$ saturation at sub-meter scale over time. From the lessons learnt through the history matching study, the following insights into the trapping processes of $CO_2$ at the project have been obtained.
- During the injection, free $CO_2$ migrated preferentially through higher permeable layers. The uneven arrival times of $CO_2$ to the well-depths are well explained by, and consistent with the non-uniform permeability distribution measured at wells.
- Pressure-driven-flow during the injection squeezed the formation water out of the reservoir, and consequently resulted in hydrodynamic dispersion of dissolved $CO_2$ into over- and under-lying lower permeable layers. This behavior is highly consistent with the resistivity changes observed by well loggings.
- In the post-injection period, negligible vertical migration of free $CO_2$ suggests that even a thin, intra-reservoir muddy-layer behaves like an impermeable flow barrier to trap $CO_2$, by a combined effect of lower vertical permeability and high capillarity to prevent the invasion of $CO_2$.

Keywords: Reservoir Simulation, CO2 trapping, Nagaoka, Parallel Computation, TOUGH2

 