

長岡サイトのCO₂挙動に対する岩相と不均質性の影響

Impact of lithofacies and reservoir heterogeneity on distribution of CO₂ at Nagaoka Pilot Site

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The Nagaoka pilot site is located in the onshore area of Nagaoka oil field in the Niigata plain of central Honshu on the Japan sea side of central Japan. The onshore deep saline aquifer utilized for the CO₂ storage project is located near the city of Nagaoka. The pilot site and the target formations were selected based on the geological information. The selected formation was the early Pleistocene Haizume Formation, around 60m thick and 1100m below the ground surface. Cores of the Haizume Formation at Nagaoka from well IW-1 show realistic reservoir characterization with litho-stratigraphic architecture.

To geological modeling and assess CO₂ distribution, 3D seismic schemes were applied in the Nagaoka site, which included 4D seismic monitoring. Seismic attributes analysis is a popular and important method to predict the distributions of reservoir rock properties such as lithofacies, porosity, density, and thickness. Although 3D seismic survey has been executed, the distribution of lithofacies and the heterogeneity in reservoir layers remain unclear across the Nagaoka site because there are only few wells drilled. Therefore, we described the geomodeling framework and simulation studies that were applied to micro and macro scale reservoir modeling with realistic litho-stratigraphic architecture at the Nagaoka site.

Lithofacies relations and much of the heterogeneity in Nagaoka aquifer reservoirs are related to the stacking of depositional sequences. To investigate the challenges of the spreading CO₂, a detailed reservoir heterogeneity model was set up based on analysis of 45 cores. The Haizume Formation consists of predominantly sandstone, alternating beds of siltstone and sandstone, siltstone, sandstone-argillaceous, and conglomerate. The marine deposits and consists of numerous thin shales (siltstone to mudstone) form the majority of heterogeneities in Haizume Formation. Heterogeneity is mainly controlled by the distribution of sandstones embedded in numerous alternated facies. The CO₂ reservoir formation in this site (ca. 20m thick) is divided into some independent zone layers with millimetric to decimetric laminations of sandstone, siltstone and mudstone, silts and sands alternate, conglomerate within sequences from metric to a few metrics. In such a heterogeneous formation, the connectivity of permeable rocks is clearly of major concern for predicting of CO₂ storage potential. The realistic modeling of these connectivities is thus required to plan future developments, to understand and predict CO₂ behaviors.

This paper presents the realistic modeling strategy that was applied to Nagaoka site. The modeling strategy is multi steps, with first a geologically constrained generation of facies distributions, and second, simulations of spreading CO₂ variations with the measured permeability within the facies distributions. These descriptions were incorporated into the model at a resolution, which ensured capture of the most significant heterogeneities. The detailed reservoir model matched well log and core performance in this site. The detailed reservoir model and results of simulation matched the monitoring data from well and field more closely than the previous large scale models. The modeling technique also allows accounting for larger scale constraints, such as field wide variations of facies frequencies and main directions of spatial continuity.