Numerical simulation of experimentally observed deformation behavior of mudstone due to the infiltration of non-wetting phase fluid

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It has been suggested that the pore pressure build-up due to the injection of carbon dioxide into geological formations may trigger slip on some preexisting faults, thereby deteriorating the sealing capacity of caprock (e.g., Zoback and Gorelick, 2012). To prevent the deterioration of the sealing capacity, it is necessary to understand the mechanical behavior of caprock due to the infiltration of carbon dioxide. This study aims to understand the deformation behavior of mudstone caused by the infiltration of non-wetting phase fluid through laboratory experiments and numerical simulations. In the experiment, compressed air was injected from the bottom of a water-saturated cylindrical mudstone sample under hydrostatic external stress condition. The mudstone sample was taken from the outcrop of the Umegase Formation of the Kazusa Group, and was shaped for the experiment. Axial and circumferential strains at half the height of the sample and discharge of water at the top were monitored during the experiment. Numerical simulations of the experiment were conducted using a simulator which can solve coupled two-phase fluid flow and deformation of porous media (Aichi, 2010). When using the capillary pressure curve based on the measured pore size distribution of the mudstone and the relative permeability curves based on those of mudstones of the Kazusa Group estimated by Tazaki (1988), the calculated strains and discharge were much greater than the measured ones. When the relative permeability to the non-wetting phase was set to about 1/1000 of the values obtained by Tazaki (1988), all the experimental results were reproduced well only for a few thousand seconds from the commencement of injection. In an experiment in which nitrogen was injected into a Umegase mudstone sample under similar pressure conditions, X-ray CT imaging showed a homogeneous infiltration of nitrogen near the inlet for about one hour from the commencement of injection, followed by a heterogeneous infiltration (Goto et al., in preparation). This observation suggests that in our experiments, air may have infiltrated into the sample heterogeneously except in the early stages. In the numerical simulation, the non-wetting phase moved upwards uniformly with very low non-wetting phase saturation because the flow obeyed the two-phase Darcy’s law. Therefore, the reason why the experimental results after a few thousand seconds were not reproduced by the numerical simulation is considered to be the difference in the flow pattern between the experiment and the simulation. It is suggested that modeling considering the heterogeneity of two-phase flow is necessary to explain the mechanical behavior of mudstone caused by the infiltration of non-wetting phase fluid.

References:
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