Numerical Study on the Effects of Contact Angle Change on Capillary trapping

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Abstract

For geological storage of CO2 in Japan, potential reservoirs are commonly found in from Tertiary to Quaternary sedimentary basins. They are often characterized by their moderate permeability and capillary pressure and being favorable for geochemical reactions. Igulauer et al. (2015) reviewed studies for the wettability (contact angle) of CO2-water-mineral systems and showed that some carbonate minerals have larger contact angle (that is, weak wettability) than quartz. It indicates that geochemical reaction caused by dissolved CO2 may result in weakening the wettability of geological formation and following reduction of capillary trapping. It will be a problem for long-term integrity of CO2 storage, especially in case that estimated initial capillary pressure is not so high. In this study, we will present simulation results of the reduction of capillary trapping due to contact angle change and its effects on the long-term behavior of injected CO2.

We built an axi-symmetrical model with a radius of 20 km and a vertical extent of 0.5 km for the simulation. A reservoir is located at 1,000 m below the seabed at 200-m water depth. A 100-m thick seal layer and a second aquifer overlay it. The reservoir and the seal layer have horizontal permeabilities of 100 mD and 0.1 mD, respectively. Vertical permeability is one tenth of the horizontal one for both formations. The reservoir is basically assumed to be a saline aquifer, however, methane is also present in some cases. We conducted numerical simulations on the long-term behavior of CO2 for 50 years of injection period and successive 450 years of shut-in. Simulations are carried out using the “STAR” reservoir simulation code with equation of state “SQSCO2”(three pore components: H2O, CO2 and NaCl) and/or “SQSGAS” (four pore components: H2O, CO2, CH4 and NaCl).

In the case studies, we changed simulation parameters such as the thickness of the reservoir (100 m or 200 m), the initial threshold pressure of the seal layer (0.5 MPa or 1.0 MPa), and the magnitude and timing of the contact angle change (from 15° to 75° and from 25 years to 100 years after the start of the injection). We also investigated the effects of reservoir condition and the composition of injected gas (CO2 and CH4).

In this study, the initial contact angle of water-CO2-rock system is assumed to be water-wet value at 0°. We assume that the contact angle $\theta$ changes at the above mentioned timing, and capillary pressure $P_c$ changes following Laplace’s equation; $P_c = 4\sigma \cos \theta d$. Capillary pressure was represented by van Genuchten type, and the threshold pressure ($P_{th}$) was given as the capillary pressure at the residual CO2 saturation.

Simulation results showed that i) given moderate permeability and capillary pressure of the seal layer, the contribution of residual gas trapping is significant to the CO2 storage in unchanged cases; ii) when capillary pressure is lowered due to change in contact angle, CO2 intrusion into the seal layer continues during shut-in period in some cases; iii) the existence of methane brings about higher gaseous saturation and mobility.
These results indicate that change in contact angle due to geochemical reaction can affect long-term seal capacity at CO$_2$ storage site.

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Reference: