Numerical Simulation of Two-Phase Flow for Heterogeneous Conglomerate Rock

Hyunjeong Jeon

Geologic Fluid Dynamics & Geofluids Lab.
Dept. of Earth System Sciences, Yonsei University

The geological carbon storage (GCS) in subsurface reservoirs is increasingly viewed as a solution for reducing greenhouse gas emissions. Recently, conglomerate rocks are targeted as potential CO_2 storage formations. The Janggi GCS projects in South Korea were launched to inject CO_2 at the Janggi conglomerate sedimentary formation, followed by collecting the conglomerate cores (i.e., JC-1 and JC-2). JC-1 and JC-2 represented the significant heterogeneity in distribution and morphology of clasts and matrix. In case of JC-1, large sized clasts were situated lopsidedly at the bottom whereas various sizes of clasts were evenly distributed within the whole core in JC-2. The goal of this study is to evaluate heterogeneous effects of clasts and matrix distribution on movement of CO_2 plume under reservoir conditions (10 MPa, 50 ℃) by simulating two-phase flow using ECO2N module and TOUGH2-MP simulator. To assess the heterogeneous effect quantitatively during the drainage process (supercritical CO_2 displacing water), the 2-D homogeneous matrix-only model (H-1) was additionally constructed with the equal geometry and dimension, and JC-1 and JC-2 were divided into fourteen sections with a uniform lateral interval so that thirteen different vertical profiles were formed. Distribution of CO_2 saturation, velocity of the CO_2 plume, and pressure difference between inlet and outlet were analyzed. As a result, the injected CO_2 plume flowed through the matrix in the cores while the clasts operated as an impermeable barrier. The time for the plume to breakthrough took longer in order of H-1, JC-1, and JC-2, which corresponds with order of high matrix ratio. The more heterogeneous the distribution of clasts, the more unstable frontal displacement of CO_2 plume. It can be also confirmed in breakthrough curves. Differences in the variance pattern of breakthrough curves were certainly distinguished between matrix-dominated regime and clast-supported regime. Several erratic patterns were resulted from disparity in velocity of CO_2 plume due to heterogeneous clast-matrix distribution. The arrival velocity (v_x) and cumulative v_x were estimated in JC-1 and JC-2, resulting in a correlation with clast-matrix ratio (C-M ratio). Heterogeneous throats to migrate for CO_2 plume due to various distribution of clasts cause sudden changes in v_x and cumulative v_x. Variance of the cumulative v_x at each boundary also dependent on the C-M ratio. The heterogeneous pressure difference was shown in three cores. Large fluctuation of pressure difference appeared in JC-2 whereas the largest increase to the peak appeared in JC-1. The results indicate that heterogeneity effects resulting from distribution of clast and matrix significantly affects the two-phase (CO_2-water) flow.