Carbon dioxide storage in a heterogeneous conglomerate formation: an experimental investigation at core-scale

Kue-Young Kim¹, Junho Oh², Weon Shik Han³, Kwon Gyu Park¹, Young-Jae Shinn¹

¹Korea Institute of Geoscience and Mineral Resources
²Kyungpook National University
³Yonsei University

Abstract

The availability of sufficient storage capacity of reservoir rocks is significant for successful geologic storage of carbon dioxide (CO₂). Research related to geologic CO₂ storage has until now focused on evaluating sandstone formations as they possess relatively high porosity and permeability, suggesting more economically viable than other types of rock formations. Although a number of CO₂ storage projects are being conducted worldwide, a need of more experience for verification of safe storage at various geological formations cannot be overemphasized.

The first onshore CO₂ storage project in South Korea is planned to inject CO₂ into a conglomerate formation (~1 km deep). Unlike sandstone formations that are generally considered for sequestration targets, the conglomerate reservoir showed significant heterogeneities in porosity and permeability. In this study, for the first time, we present the results of the core-flooding experiments for the highly heterogeneous conglomerate core obtained from the Janggi sedimentary formation. Heterogeneous distribution of clasts and matrix in the static core was identified through X-ray computed tomography (CT).

Multiphase flow experiments, including CO₂ injection (drainage) and water injection (imbibition) tests, were conducted with the conglomerate core sample. Real-time X-ray scanning system was used to capture the dynamic transport of CO₂ in the core. During the drainage test, CO₂ saturation at different locations showed logarithmic increases with pore volume (PV). It is interesting to note that the CO₂ saturation at the downstream side of the core was greater than one at the upstream side during the early stage (<1.0 PV). Spatial inversion of CO₂ saturation distribution is attributed to heterogeneous pore space along the conglomerate core including the presence of complex discontinuities in clasts. The dense network of discontinuities within the clasts served as well-connected pathways for CO₂ flow, which caused a rapid increase in CO₂ saturation.

Imbibition tests showed dynamic transition of CO₂ trapping. At the domain I where the matrix was dominant, CO₂ was distributed uniformly at the end of drainage test. Due to this reason, brine displacement also induced to uniform distribution of residually trapped CO₂ followed by dissolution at domain A. However, at domain II and III, the larger fraction of pores initially filled with CO₂, the more snap-off and trapping occurred as brine invaded the pore space. Three regimes of CO₂ trapping mechanisms were characterized as (i) immediate displacement of mobile CO₂ by the injected brine (R1), (ii) preservation of immobile CO₂ as residual trapping (R2), and (iii) gradual dissolution of residually trapped CO₂ into the fresh brine (R3). The core was equally divided into 50 subdomains and the amount of capillary trapped CO₂ was assessed with the Land model.
Based on the imbibition tests and initial-residual (IR) characteristic curve, capillary-trapping capacity was calculated. While the sandstones showed approximately linear increase in capacity with initial CO₂ saturation, the conglomerate showed considerable scatter due to its highly heterogeneous porosity distribution. The capacity of conglomerate ranged between 0.5 and 4.5% depending on the initial saturation. Considering that the initial saturation is 0.4, the capacity of conglomerate ranged 3-4%, whereas that of sandstones range was 4-7%. Despite the fact that the trapping analyses showed less capacity compared to homogeneous sandstone, the high porosity region in the conglomerate core showed similar capacity to the sandstones implying that the conglomerate formations can be an alternative CO₂ storage formation.