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Experimental Study on Carbon Mineralization in Fractured Basalt using X-ray CT imaging

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Carbon mineralization is a promising method of geological carbon storage since it enables safe storage on a short time scale, which typically requires a long time when supercritical CO2 is stored. Basalt is considered a potential host rock formation for carbon mineralization, as it is abundant globally and located at relatively shallow depths, providing advantages in terms of capacity and injectivity. Moreover, it contains a substantial amount of divalent cations, which allow rapid reaction kinetics. This study conducts two carbon mineralization tests by injecting a supersaturated and slightly alkaline solution into two fractured basalt cores at a flow rate of 1 and 5 mL/min. The saturation index and pH of the injected solution were approximately 0.4 and 7.2, respectively, representing the far-field condition where precipitation dominantly occurs. During the approximately 40 days of injection, several X-ray CT scanning and permeability tests were performed for both mineralization tests. X-ray CT imaging revealed that more calcite precipitated when applying high flow rate than low flow rate. This is because a greater amount of reactive solution was transported into the fracture for the same injection duration. For the high flow rate test, the calcite evenly precipitated along the entire fracture surfaces, whereas, under low flow rate, preferential precipitation was observed near the inlet. Preferential precipitation occurred because the low flow rate provided sufficient retention time relative to the reaction kinetic. Comparison to obtained relationship between permeability and porosity to the Kozeny grain-coating model indicates that the empirical parameters n ranges from 80 to 100 at the high flow rate, whereas it ranges from 100–120 for the low flow rate test. The difference means that the extent of permeability reduction was more significant for the same amount of precipitation due to local clogging. 1-D numerical solutions of advection-diffusion-reaction also reveal that a flow rate of 1 mL/min results in the local clogging for the condition similar to the flow tests. The results of this study imply that when a low flow rate is applied relative to the precipitation kinetics in actual carbon mineralization field, local clogging may occur, subsequently leading to a decrease in injectivity and capacity.

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References

Primary authors: JANG, Woojae (Korea Advanced Institute of Science and Technology (KAIST)); Prof. KWON, Tae-Hyuk (Korea Advanced Institute of Science and Technology (KAIST))

Co-authors: Dr HAN, Gyeol (Georgia Institue of Technology); Dr JOO, Hyun-Woo (University of Colorado Boulder); Mr ALCANTARA FUENTES, Marcopolo (Korea Advanced Institute of Science and Technology (KAIST)); Dr SEO, Jeonggyu (Korea National Oil Corporation); Mr PARK, Jaehan (Korea National Oil Corporation); Mr KIM, Jihyuk (Korea National Oil Corporation); Mr KIM, Hosang (Korea National Oil Corporation)

Presenter: JANG, Woojae (Korea Advanced Institute of Science and Technology (KAIST))

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