Geochemical Reaction of Well Cement in CO_2 Sequestration

KAZUHIKO NAKANO*1, SAEKO MITO[1], ZIQIU XUE[1]

[1]Research Institute of Innovative Technology for the Earth (RITE), 9-2 Kizugawadai, Kizugawa-shi, Kyoto, 619-0292, Japan; *Corresponding author: nakano@rite.or.jp

Evaluation of chemical degradation of well cement due to its exposure to supercritical CO_2 is a great important issue for ensuring the long-term safety of CO_2 sequestration because the chemical degradation of well cement is an affecting factor for creating of CO_2 leakage pathways. An ordinary Portland cement is thermodynamically unstable in CO_2-rich environments. When Portland cement is exposed to CO_2, portlandite ($Ca(OH)_2$) or C-S-H phase in the Portland cement is carbonated to form calcium carbonate ($CaCO_3$) at the cement surface by the following chemical reactions:

$$Ca(OH)_2 + H_2CO_3 \square CaCO_3 + 2H_2O$$

$$\text{C-S-H } (Ca_rSiO_{2+r}rH_2O) + yH_2CO_3 \square Ca_{r-y}SiO_{2+r-y}\ r\text{-}yH_2O + yCaCO_3 + 2yH_2O$$

In this study, we performed batch experiments using well composite samples consisting of casing, Portland cement, and sandstone in order to evaluate the chemical reaction of well cement in CO_2 sequestration.

After the batch experiment, cement a clear carbonation zone was observed along the cement-sandstone interface in the sample. However, the cement carbonation was limited at the cement surface. In addtition, the inner cement and the casing were in excellent condition. The predicted 30 years cement degradation estimated from our experimental results were consistent with the previous results of CO_2-enhanced oil recovery field samples that were collected from the wells exposed to CO_2 for over 30 years [1]. Our experimental result indicates that the cement carbonation provides an effective barrier to further CO_2 attack.

The crystalline phases in the carbonation zone were predominantly $CaCO_3$ (calcite, aragonite and vaterite) [2]. An interesting distribution of the three polymorphs of $CaCO_3$ in the carbonation zone was observed by micro-XRD and micro-Raman analysis; calcite was dominant at the side of the cement-sandstone interface, whereas aragonite and vaterite were dominant at the side of the inner cement.

[1] S. Mito et al. (2015) International Journal of Greenhouse Gas Control, 39, 420-431.

[2] K. Nakano et al. (2014) Energy Procedia, 63, 5754-5761.