8–10 Realistic Modeling of Tracer Migration in Rock Fracture

— Effects of Fine-Scale Surface Alterations on the Tracer Retention in Fractured Crystalline Rock —

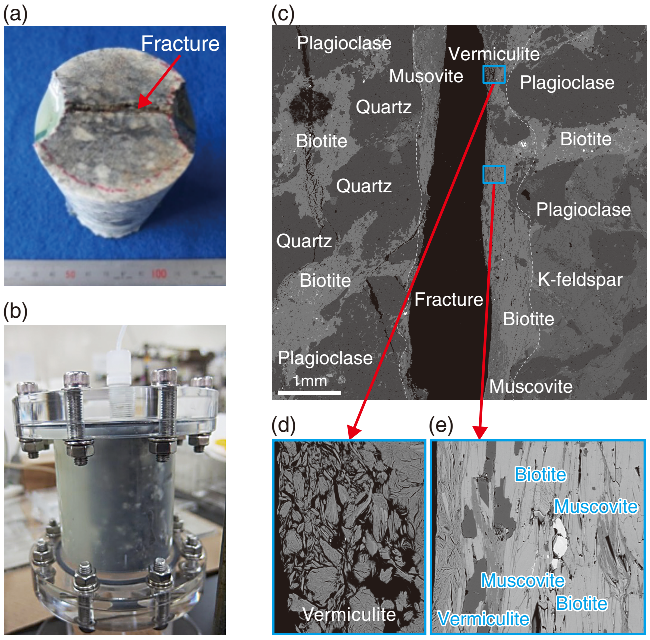

Fig.8-25 Experimental setup and EPMA observations
(a) Single-fracture sample from the GTS, (b) flow-through experimental setup, (c) heterogeneous mineral distribution around the fracture surface including the (d) weathered vermiculite and (e) foliated mica layer.

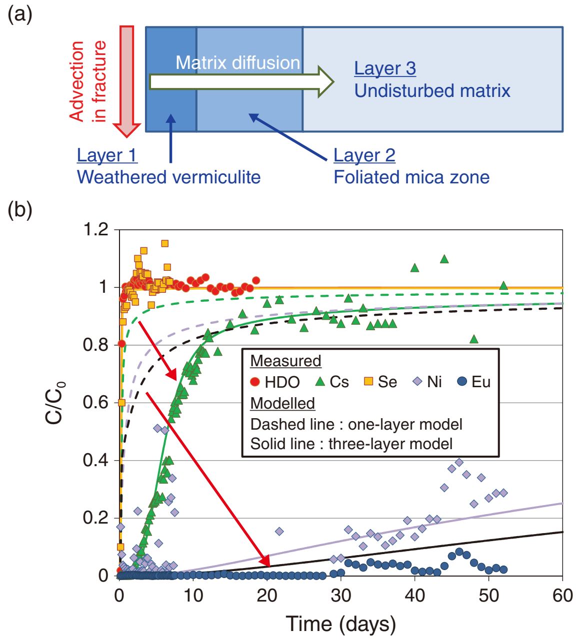

Fig.8-26 Measured and modeled breakthrough curves
(a) Conceptual transport model considering three layers at the fracture surface, (b) measured breakthrough curves and simulated results for one- and three-layer model.

Crystalline rocks such as granites have been investigated as potential host rocks for the geological disposal of radioactive waste in many countries. Radionuclide (RN) transport in fractured crystalline rocks can be conceptualized by a dual-porosity model where RNs are transported by advective water flow through a fracture and diffusion into the surrounding rock matrix. Fine-scale alterations found around fracture surfaces are key uncertainties that need to be considered when developing transport models for fractured crystalline rocks. This work therefore focused on developing a comprehensive approach coupling laboratory tests, microscopic observations, and modeling to understand and quantify tracer transport processes occurring in natural fracture surfaces, using a single-fractured granodiorite sample from the Grimsel Test Site (GTS) in Switzerland.

Laboratory tests coupling flow-through, through-diffusion, and batch sorption were conducted using synthetic groundwater including five tracers with different retention properties: HDO (deuterated water), Se, Cs, Ni and Eu. A flow-through tracer test was carried out at a constant flow rate using a granodiorite sample containing a single natural fracture (Figs.8-25(a) and (b)). Through-diffusion and batch sorption tests were also conducted using the same tracer solution for two different samples taken from a natural fracture surface and from a matrix part. These test results indicated that tracer retention was consistently in the sequence of HDO ≈ Se < Cs < Ni < Eu. Heterogeneities in the mineral and pore distribution around the fracture were clarified by coupling X-ray computed tomography (X-ray CT) and electron-probe microanalysis (EPMA). Heterogeneous mapping of the fracture apertures was visualized and evaluated using X-ray CT images. By comparing the elemental maps from EPMA and the chemical composition of primary minerals, heterogeneous mineral distributions were identified, indicating a foliated mica-rich zone near the fracture surface and a weathered vermiculite zone at the outermost surface (Figs.8-25(c)–(e)).

Based on these microscopic observations, a three-layer model including weathered vermiculite, foliated mica, and undisturbed matrix layers (Fig.8-26(a)) and their properties such as thickness, porosity, sorption, and diffusion parameters, obtained from laboratory tests, provided a better interpretation of the breakthrough curves of all tracers, measured in flow-through tests, than either a one-layer model assuming only an undisturbed matrix corresponding to a traditional dual-porosity model (Fig.8-26(b)). Mechanistic understanding and detailed modeling considering the effects of fine-scale surface alteration around a natural fracture will improve the safety assessment of fractured crystalline rocks.

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Reference

Tachi, Y. et al., Effects of Fine-Scale Surface Alterations on Tracer Retention in a Fractured Crystalline Rock from the Grimsel Test Site, Water Resources Research, vol.54, issue 11, 2018, p.9287–9305.