# Modelling Transport of Radionuclides Observed in In-Situ Tracer Tests Based on Microstructure Characterization

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## 1. Background

The SKB Task Force is a forum for the international organizations supporting the Äspö Hard Rock Laboratory (HRL), Sweden, in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. The 9th task of this forum was intended to increase realism in modelling of solute transport for the respective in-situ tracer tests performed at the Äspö HRL and the ONKALO underground rock characterization facility (URCF) in Finland. For the 2nd and 3rd steps of this task (called Task 9B and 9C), in particular, the inverse and predictive modelling works have been carried out based on the experimental data and results from the LTDE-SD test and the TDE test, respectively.

## 2. The in-situ tracer tests

### *2.1 The LTDE-SD test*

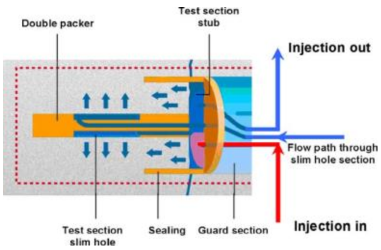


Fig. 1. The schematic diagram of the LTDE-SD test.

The LTDE-SD test was performed in a borehole installed at the Äspö HRL during 198 days. The fracture surface and the slimhole wall within the experimental section of the borehole were simultaneously exposed to the cocktail mixed with 22 radioactive tracers (Fig. 1). One of the main results from this test was the penetration profiles of $^{137}Cs$ having two slopes. In particular, the flat slope of tail in the profiles implies that the sorbing tracer migrated much deeper into the rock matrix than that expected from assuming homogeneous diffusion. The objective of Task 9B was to reproduce this anomalous observation from this test and to reinterpret its mechanisms.

### *2.2 The TDE test*

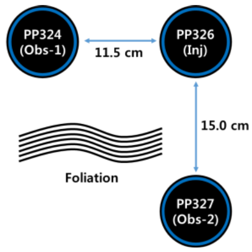


Fig. 2. The schematic diagram of the TDE test.

As a part of the REPRO project performed at the ONKALO URCF, this in-situ tracer test is still ongoing. Three parallel boreholes were installed as a right-angled triangle (Fig. 2): one injection borehole (PP326) and two observation boreholes (PP324 and PP327). Each pair of them is placed along or across the foliation existing in the bedrock and changes in concentrations of tracers injected have been monitored in each borehole. Thus, this test is to understand the migration of radionuclides depending on the foliation in rock matrix. The Task 9C aims at prediction of experimental results from this test.

## 3. Modelling procedure

We presumed that rock heterogeneity would be the most probable reason for the experimental results from both the in-situ tests. To prove this, it was incorporated into the model domains based on the microstructure characterization on the rock samples taken from the respective test sites, using mineral staining technique and $^{14}C$-PMMA autoradiography (Fig. 3). In particular, for the LTDE-SD test, planar or linear types of model components were delineated along the geometries of mineral grains and micropores characterized with both the techniques. For the TDE test, due to the highly complicated geometries of minerals and micropores in the rock sample, a mapping technique for raster images was applied to incorporate them into the model.

For both the tests, it was assumed that the transport of radionuclides occurred in rock matrix were governed by diffusion along and sorption on its microstructures. In particular, the selective sorption of Cs on the biotite and the micropore network composed of porous minerals, vein, and microfractures were considered. For the LTDE-SD test, considering disturbance near the fracture surface or borehole wall, increased porosity and sorption capacity were assumed to the minerals located at the rock surface.

For the LTDE-SD test, the transport parameters for the respective microstructures were determined for the experimental results of $^{137}Cs$ and $^{22}Na$ through the curve-fitting procedures. For the TDE test, the concentration change of non- or sorbing tracers in the injection and observation boreholes for 10 years were predicted. To focus on effects of foliation, the distances from the injection borehole to each observation borehole were assumed to be identical in the modelling.

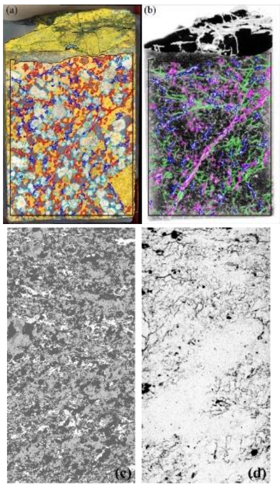


Fig. 3. Microstructure characterization on the LTDE-SD (a, b) and the TDE (c, d) rock samples: using mineral staining (a, c) and $^{14}C$-PMMA autoradiography (b, d).

## 4. Results and discussion

For the LTDE-SD test, the determined parameters well reproduced the penetration profiles and the concentration changes of $^{137}Cs$ and $^{22}Na$ in tracer cocktail observed in this test. Sensitivity analysis demonstrates the effects of the respective microstructures on the migration of tracers occurred during this test. These results show that the strong sorption of Cs on the disturbed biotite grains located at the rock surface would lead to the peak and the drastic decrease in concentration of the profiles. They also show that through the vein and microfractures the sorbing tracers would migrate into the biotite grains located in deep region of rock matrix and, as a result, such long tails seem to be created.

The foliation existing in the rock sample from the TDE test site was observed as the arranged biotite grains through the mineral staining image, while was not shown clearly in the $^{14}C$-PMMA autoradiograph. Therefore, its effects predicted for this test would be the results from the selective sorption of tracers on such arrangement of biotite grains. As a result, the concentration changes of non-sorbing tracers in the boreholes seem to be irrelevant to the direction of foliation. When the distribution coefficient of a tracer on biotite was assumed to 0.01 $m^3/kg$, however, the concentration in observation borehole placed parallel to the foliation increased more rapidly than that in the vertical one.

## 5. Conclusion

Understanding retention mechanisms of radionuclides in bedrock must be important for safety and performance assessment of a geological repository. However, the experimental results from the in-situ tests have shown that with only conventional approaches it is difficult to account for the realistic transport of radionuclides in rock matrix and, as a result, its safety and performance cannot be assessed appropriately. From the modelling results shown here, it is concluded that the experimental results from the in-situ tracer tests may result from the interactions among various microstructures existing in the rock matrix, or rock heterogeneity. This conclusion highlight the importance of considering roles of microstructures in transport of radionuclides in rock matrix. In other words, a careful characterization of rock microstructures needs to precede in estimation of retention parameters of bedrock in a repository for safety and performance assessments.

## Acknowledgement

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