Diffusion of Cs, I, and HDO in a Pre-Neogene Sedimentary Rock

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Abstract: To investigate the barrier performance of a pre-Neogene sedimentary rock for deep geological disposal of high-level radioactive waste (HLW), the heterogeneity of the rock matrices and the diffusion behaviors of cesium, iodine, and HDO were examined. The structures of the rock samples examined by X-ray Computed Tomography (X-ray CT) are used to interpret the diffusion behaviors of the ions and HDO. The research reveals that the rock's heterogeneity significantly influences radionuclide diffusion, challenging traditional models and underscoring the need for advanced modeling.

Keywords: deep geological disposal, host rock, pre-Neogene sedimentary rock, diffusion

1. Introduction

This study focuses on a pre-Neogene sedimentary rock, a geological formation known for its block-in matrix structure, which occupies a large part of Japanese basement rock. It is considered a host rock of a HLW repository [1]. Considering its lithofacies, vein patterns, and fracture characteristics, understanding the diffusion behavior of radionuclides like Cs^+ and I^- in such rock is crucial. This research incorporates through-diffusion experiments and X-ray CT to provide insights into the barrier performance of pre-Neogene sedimentary rock for long-term waste containment.

2. Materials and methods

The core samples (φ116mm × 25m length) were drilled from the Chichibu belt, Jurassic and Cretaceous accretionary prism [2]. Three segments were selected for further analysis, hereafter named 1-3, 1-12, and 2-3. They were characterized by X-ray Fluorescence (XRF), X-ray Diffraction (XRD), and Scanning Electron Microscopy with Energy Dispersive X-Ray Analysis (SEM-EDX). The core samples are made into disks (φ 20 mm × 5 mm thick). Through-diffusion experiments were conducted with the disk samples at room temperature with simulated groundwater according to the reference [3]. Tracer solutions containing 1×10^{-5} M Cs^+, 1×10^{-4} M I^- and 5 wt% D_2O were introduced. The disk samples underwent X-ray CT featuring 3600 projections, with a voxel size of 16 μm.

3. Result and discussion

The characterization showed 1-3 and 1-12 were mélange-type rocks with block-in-matrix structures. The dominant matrix of 2-3 was sandstone, which was a coherent type. In most of the diffusion results, the concentration of tracer relative to the original tracer concentration of the ions and HDO ranges from 1×10^{-4} to 4×10^{-3} and without delay, indicating less sorption, suggesting a scenario where either microfracture facilitates transport or diffusion is primarily governed by lithofacies with higher porosity. The variation in the slope of the breakthrough curve suggests that the fracture within the rock might not be confined to a single channel. From the X-ray CT analyses, the fractures and veins can be visualized, which had a great influence on diffusion behavior, not only on matrix diffusion but also on fracture transport, and we will discuss the details in the conference.

4. Conclusion

In this study, the pre-Neogene sedimentary rock was characterized, and the diffusion behavior of Cs, I, and HDO was investigated, which could not be described by traditional diffusion models and attempted to be interpreted in conjunction with X-ray CT.

References

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