Large-scale transport parameters inferred from profiles of natural tracers in pore water of Jurassic argillaceous rocks (Benken, Switzerland)

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Claystones and marls are worldwide considered as potential host rocks for the disposal of radioactive or other toxic waste, because they typically exhibit very low permeabilities. In Switzerland, the Opalinus Clay formation, which is part of an extended low-permeability sequence of Jurassic rocks, has been investigated in detail within this context.

Characterising the transport properties of a clay rock at large spatial and temporal scales is a difficult task. At Benken (north-eastern Switzerland), a deep borehole was drilled across the Jurassic low-permeability formations, which are located at depth of about 400 to 700 m (Nagra, 2001). We determined the concentrations of stable isotopes of water, chloride, and chlorine isotopes within the pore water by various methods from core samples of the deep borehole. The low-permeability formations are delimited at Benken by two aquifers (in the Malm and Keuper lithologies, respectively), from which water samples could be directly obtained. The pore water profiles in the low-permeability zone between these aquifers show clear trends that hint at diffusion-dominated transport processes.

We aimed at answering the following questions: (i) What is the maximum "age" of signatures in the tracers that we can expect to observe in the given pore water profiles? (ii) Can we infer large-scale transport parameters from the measured signatures? The first question was addressed by calculating penetration distances of periodic disturbances at the boundary. These calculations showed that it is unlikely to observe distinct signatures of events that happened considerably more than 10 Ma ago. Next, in order to evaluate the large-scale transport properties of the formation, we derived the palaeo-hydrogeology for the Benken site, performed a series of advective-dispersive model calculations and compared them with the experimental data. In accordance with the hydrogeological history, we varied initial and boundary conditions, as well as model parameters. The main results of these model calculations can be summarized as follows: (i), molecular diffusion to the underlying aquifer can explain the general features of the isotope profiles, (ii), no signatures of advective flow could be detected, (iii), the evolution time is in the order of 0.5 to 1 Ma (relying on laboratory diffusion coefficients) with a possible range of about 0.2 to 2 Ma, which is geologically plausible, and, (iv), parameters measured on small scales (centimetres or meters, months) are also plausible at the formation scale (tens of meters, millions of years) for the sediments investigated.

REFERENCE

Nagra (2001): Sondierbohrung Benken, Untersuchungsbericht. Nagra Technical Report NTB 00-01, Nagra, Wettingen, Switzerland.