Characterisation of matrix pore water in crystalline rocks (Olkiluoto, Finland)

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Crystalline rocks are characterised by two different hydraulic regimes. The first regime includes the water-conducting zones related to regional or local fracture networks. The second regime includes the bedrock mass of low permeability between the water-conducting zones. Solute transport is by advection in the water-conducting fractures whereas it might be predominantly by diffusion in the low-permeability bedrock mass. Depending on the residence time of formation groundwater in the water-conducting zones, interaction with water present in the pore space of the low permeable bedrock might become significant. Under knowledge of the pore water composition such interaction can be quantified as a function of time and space. In addition, it allows to characterise the transport properties of the low-permeability bedrock over larger scales (tens of metres). Within the framework of underground disposal of radioactive waste this is of importance due to the potential retardation of radionuclides by matrix diffusion and the interaction over time between pore water and the repository barrier material (e.g. bentonite; canister), because repository construction will be restricted largely to bedrock of low permeability. It is therefore important to know the composition of such pore water and its evolution over recent geological time, certainly during the last thousands to hundreds of thousands of years in accordance with the expected lifespan of a deep repository.

Pore water in a rock of low permeability cannot be sampled by conventional groundwater sampling techniques and has to be assessed by indirect methods based on drillcore material. A prerequisite for such investigations is the preservation of the water-saturated state of the rock samples until their conditioning for the various experiments in the laboratory. Pore-water composition and evolution can then be assessed by combining the information gained from individual samples taken along a profile within the low-permeability bedrock and the chemical and isotopic data of formation groundwater circulating in the adjacent fracture zones.

Investigations of pore water in Precambrian rocks have been successfully conducted on core material of borehole KR-39 drilled at the Olkiluoto site, Finland. The metamorphic rocks encountered by the borehole include fine-grained migmatitic gneiss, fine-grained, biotite-rich mica gneiss, and middle- to fine-grained granitic pegmatite. All rocks are void of recent weathering alteration phenomena such as e.g. oxidation. Whereas the gneissic rocks display a well developed foliation and thus a distinct anisotropy in transport properties, the granitic pegmatite is more isotropic in texture.

The water-accessible porosity of the rocks was determined independently by drying to stable weight conditions and the isotope diffusive-exchange method. This allowed to identify perturbations induced on the core samples by drilling and/or stress release effects. The general agreement between these methods suggest that such effects did not modify the measured water-accessible porosity significantly and that it is

representative for *in-situ* conditions. The water-accessible porosity is generally low and varies between 0.37 and 1.34 Vol.% in migmatitic gneiss and between 0.55 and 0.80 in granitic pegmatite. Within the samet rock type it decreases with increasing depth.

Chloride- concentrations of pore water where obtained from out-diffusion experiments taking the water-accessible porosity in account. They show a specific distribution with depth that is independent of the individual lithology. Pore-water chloride concentrations range between about 0.1 and 2 g/kg H_2O and can be correlated to the distances between sample and adjacent water conducting fractures and their corresponding transmissivities. The comparison of chloride concentrations in the pore water with those in the fracture groundwater near-by indicates steady state conditions between pore water and fracture groundwater in the highly fractured bedrock at shallow depths. At greater depth with a lower fracture frequency the pore-water chloride concentrations are lower than those in the fracture groundwater.

The chemical composition of the out-diffusion experiment solution shows large variation in ion-ion ratios as well as total mineralization. These variations reflect to a certain degree differences in chemical type and composition of the *in situ* pore water because the components induced to the solutions by mineral dissolution during the experiment are similar for the same rock type. As for chloride, the chemical types compare to those of the fracture groundwater at shallower depth and differ more at greater depth.

The same general trend between pore water and fracture groundwater is also obtained for the oxygen and hydrogen isotopic signature of the different water types. Pore-water $\delta^{18}O$ and δ^2H values vary in zones with high fracture frequencies and high transmissivities and are almost constant in the unfractured bedrock at greater depth. The pore-water isotope composition plots to the right of the Global Meteoric Water Line (GMWL) and is similar to that of the fracture groundwater over the entire borehole lenghts.

For the large-scale samples (1 kg) used in the out-diffusion experiments, diffusion is identified as the dominant transport process based on Cl-time series measurements. Calculated pore-diffusion coefficients for chloride vary between $5*10^{-11} m^2/s$ and $8.5*10^{-11} m^2/s$ depending on lithological effects, i.e. variations in grain size and anisotropy (foliation). As for the water content measurements, the evaluation of the chloride out-diffusion time series reveals only minor influence of disturbing effects induced by drilling and/or stress release. The calculated diffusion coefficients therefore appear to be representative for *in-situ* conditions.

The investigations show that the pore-water chemical composition and the transport properties of low-permeability rocks can be successfully characterised by applying various complementary indirect methods.