Coupled Palaehydrogeological Microbial and Geochemical Reactive Transport Model of the Olkiluoto Site (Finland)

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Abstract

In safety assessment studies for deep geological repositories understanding the past processes and events is key to reliably predict the future evolution of the site. Olkiluoto at Eurajoki has been selected as a repository site for final disposal of spent nuclear waste produced on Finland. As a result of land uplift, this island begun to emerge from the Baltic Sea about 3000-2500 years ago (Eronen & Lehtinen 1996). These complex geomorphologic changes have highly influenced the flow and geochemical conditions of the site resulting in a stratified hydrochemical system at least in the water-conducting fractures and deformation zones. Here, we present a palaehydrogeological reactive transport model that aims at shedding light on field evidence that can only be explained in the light of past regional changes in the boundary conditions. The hydrodynamic functioning of the simulated system has been defined based on the geometrical configuration of an existing regional-scale hydrogeological model (FEFTRA model, Löfman & Karvonen, 2012). Thus, density driven-flow and reactive transport have been simulated over the network of deformation zones of the aforementioned FEFTRA model (see Fig. 1) and key biotic and abiotic reactions have been included to study the potential for sulphide generation (sulphide is a detrimental agent for the stability of the repository) and to get insight into those key buffering reactions that may control sulphate reduction. The simulation time frame spans 2000 years: from 0AD to present.

The palaehydrogeological reactive transport simulations have been carried out using COMSOL Multiphysics® and PHREEQC (Nardi et al., 2012). The boundary conditions and the buoyancy fields at different simulation times have been borrowed from the FEFTRA model, and dual porosity processes have been included to mimic exchange of mass between the mobile zones and the matrix.

The coupled model has been shown to be able to integrate the information provided by a complex hydrological model with a number of nonlinear biotic and abiotic reactions and to capture the influence of the geomorphological changes on the hydrochemical conditions of the site. The preliminary results (e.g. Fig. 2) show that all processes (e.g. the land uplift and the

related infiltration processes, mineral dissolution and precipitation and bacterial-mediated sulphate reduction) are indissolubly connected and thus, need to be properly represented in a coupled framework.

In this modelling work, a coupled framework has been used to study the past hydrochemical evolution of the Olkiluoto island. The hydrodynamic changes of the site have been represented based on the results of an existing regional-scale model (FEFTRA). The resulting model is able to capture the mutual interdependence between these different processes: the geomorphological changes due to the land uplift and the related changes in the hydrodynamic functioning of the site, the hydrodynamic stratification of the water-conducting zones and the possible sulphate reduction processes that might explain some current field observations of sulphide-rich water. Overall, the COMSOL Multiphysics®-PHREEQC model demonstrates great potential to evaluate the buffering capacity of the geological medium.

Reference

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Parkhurst, D. L., & C. A. J. Appelo (1999), User’s guide to PHREEQC (version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations, U.S. Geol. Surv. Water Resour. Invest.,Rep. 99-4259.

Figures used in the abstract

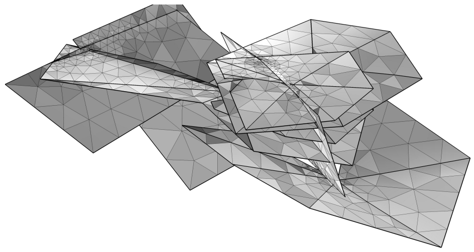

Figure 1: Ensemble of deformation zones of the well characterized area taken from the FEFTRA model and imported into COMSOL Multiphysics®

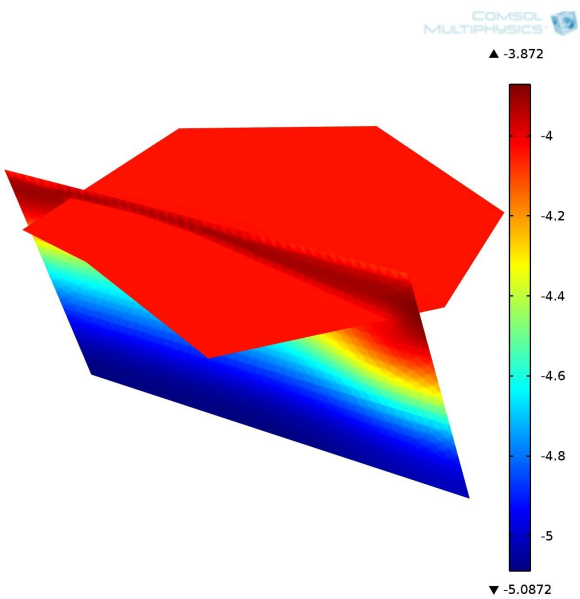

Figure 2: Preliminary results of the COMSOL Multiphysics®-PHREEQC simulations. Distribution of pe over deformation zones BFZ100 and HZ19C at the end of the simulated period