Modelling of groundwater flow and radionuclide migration in fractures and granitic rock matrix

Libor Gvoždík(1)*, M. Milický(1), V. Havlová(2), M. Zuna(2), K. Sosna(3), J. Smutek(4), L. Staš(5)

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1. Introduction

Crystalline rocks are considered as potential host rocks for radioactive waste deep geological repository (DGR) in many European countries, so as in Czech republic. The main transport mechanism in the crystalline rock is advection, however migration processes from fracture through fracture coating into unaltered rock has also to be studied. The conceptual model of the rock matrix is based on the presumption that non-advective migration is driven by diffusion into both altered mineral layers and undisturbed rock matrix, adjacent to water bearing fissures.

2. Project concept

Radionuclide migration in fractured crystalline rock environment is intended to be studied using different scale rock samples and in-situ activities within Czech project: **Transfer of migration parameters of crystalline rock from microscale towards real scale (PAMIRE).**

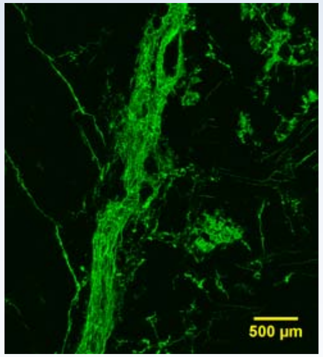
Aims of the project:

- Application of migration, electromigration experiments and computed tomography on samples of cm and dm scale
- Use of radioactive tracers in laboratory and in in-situ experiments
- Transfer of transport parameters from small scale to mid and in-situ scale

Objectives of the project:

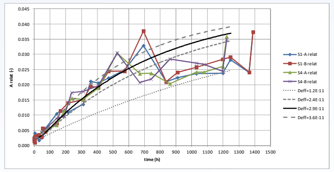
- Through diffusion laboratory experiments on cm/dm scale using radioactive tracers (3H, 36Cl, 125I), electromigration, porosity determination
- Micro-CT application, Hg porosimetry, confocal laser scanning microscopy for determination of pore frequency, connectivity and size
- In-situ experiments with a view of potential use of radioactive tracers in the Josef Underground Research Centre (URC; https://ceg.fsv.cvut.cz/en) to study advective and diffusive transport processes in fractured rock matrix and develop methodologies that would be used for such a purpose

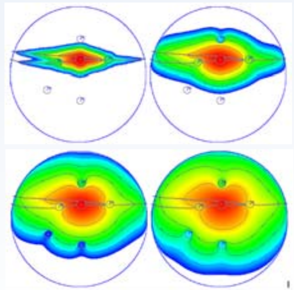
4. Laboratory studies



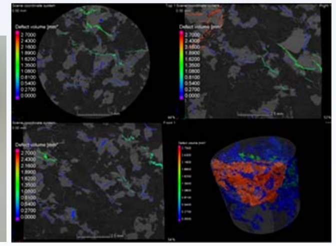
- Microfracture network visualised by CLSM - matrix impregnated with resin

- Through diffusion and outleaching experiments for the determination of effective diffusion coefficient D_e - cm and dm scale samples (Ø 5, 12, 29 cm)
- Tracers (HTO, I) activity measured in the inlet borehole and output reservoir → MT3DMS inverse modelling – in the 1st step homogeneous matrix with preferential zone ≈ closed fracture with filling (calcite, fluorite)





- Preliminary results: $D_e(^3H)$ = 1.5×10^{-11} m^2/s (fractured samples), ≈ 1.0×10^{-13} m^2/s (fresh samples)
- Porosity determination (gravimetric water saturation method): fresh rock matrix = 0.19 – 0.23 %, fractured matrix = 0.61 %

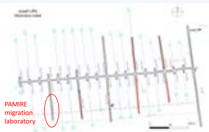


- RTG micro-CT scanner used for 3D reconstruction of rock volume (quartz, feldspar grains) and open pore space
- rock samples about 1 cm^3, pores filled with Hg

3. Site characterisation

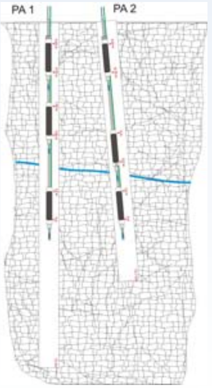
PA-1 (15 m), PA-2 (10 m) boreholes were drilled in the JP57 niche in Mokrsko part of the Josef Regional Underground Research Centre

- Host rock: amphibolite-biotite granodiorite
- On the basis of drilling, single/double packer water injection tests and single borehole NaCl tracer tests potential communicating fractured zones were identified
- In both boreholes multipacker systems with 3 open intervals were installed:
  1) disturbed rock close to the excavation face
  2) water conductive fracture (in distance 2.7-3.0 m)
  3) rock matrix



Location of migration lab and PAMIRE experiment

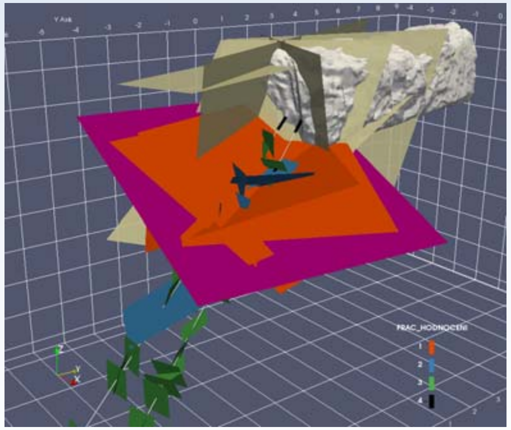
HRTV installation in the PA-1 borehole



5. In-situ studies

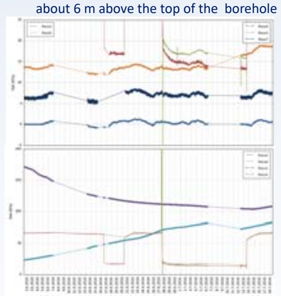
Site descriptive model construction was based on the following precursor:

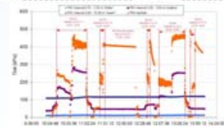
- Development of detailed fracture system model is one of the important step ahead any tracer test.
- Allocation of fractures and alteration zones in PA-1, PA-2 boreholes was based on detailed geological description of the core.
- HRTV (High Resolution Acoustic Televiewer) resulted in the fracture location and identification of their orientation in PA-1, PA-2.
- Optic visualisation of borehole walls (OPTV) enabled to adjust and re-examine the uncertainty in permeable zone identification.
- Site descriptive model construction was based on the above mentioned information from PA-1 and PA-2. The fracture connectivity is being studied using pressure measurement in multipacker.
- Simulation codes MODFLOW and NAPSAC (continuous porous medium and discrete fracture network models) is used for the evaluation of flow through the granite samples and in the granite host rock. Inverse modelling was utilised in order to calibrate fracture transmissivity.
- PA1, PA2 borehole natural outflow ≈ 2-4 ml/s (≈ inflow into fracture)
- Permeable fracture transmissivity ≈ 5×10^{-7} m^2/s (preliminary modeling results), probably connected with the niche surface



Visualization of the geometric model – adit JP-57 with boreholes PA-1 and PA-2 and fracture system (subhorizontal permeable fracture in red)

Pressure measurements in multipackers: hydraulic head in fracture (packed interval) about 6 m above the top of the borehole





Water injection tests in PA-1

(1) Progeo, spol. s r.o., Tiché údolí 113, Roztoky u Prahy, progeo@1progeo.cz
(2) ÚJV Řež, a.s., Hlavní 130, 250 68 Husinec-Řež
(3) Arcadis CZ a.s., Geologická 4, Praha 5
(4) Centre of Experimental Geotechnics, Czech Technical University, Thákurova 7, Praha 6
(5) Institute of Geonics AS CR, v.v.i., Studentská 1768, Ostrava-Poruba, Czech Republic

6. Conclusions, acknowledgement

Intensive activities are ongoing in order to characterize the site for tracer experiments in URC Josef, including construction of detailed site descriptive model, HG flow field description and determination of fracture connectivity. The activities in-situ are supported by laboratory programme, including diffusion and tracer experiments on cm and dm scale samples.

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