Development of tools for studying contaminant transport in fractured rock environment: laboratory migration experiments in physical models with artificial and natural fractures

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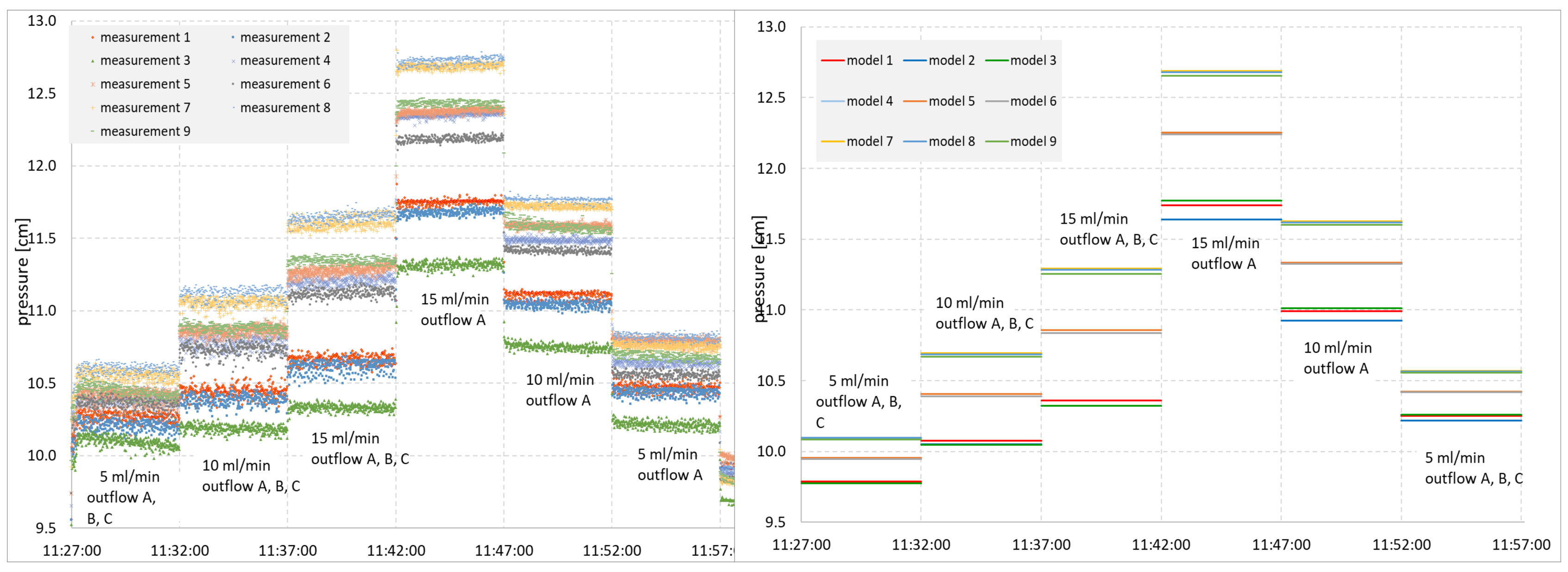
Objectives

Contaminant migration in crystalline rock environment is driven mainly by advective process in fracture network. The main goal of our project is to develop tools for evaluation of migration and retention of potential contaminants (radionuclides, heavy metals, nanoparticles) in the crystalline single fracture physical models.

Migration experiments on physical model with artificial fracture (MS1, MS2)

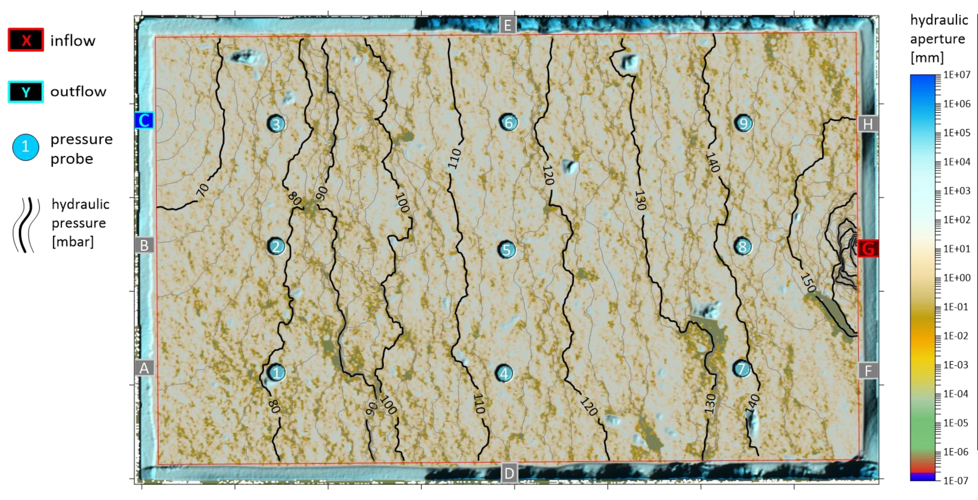
Pressure field

- Model fracture transmissivity derived from the hydraulic aperture using cubic law: $T = \frac{W\rho g e^3}{12\mu}$
- Hydraulic aperture calibration based on minimalization of simulated and measured pressure field differences

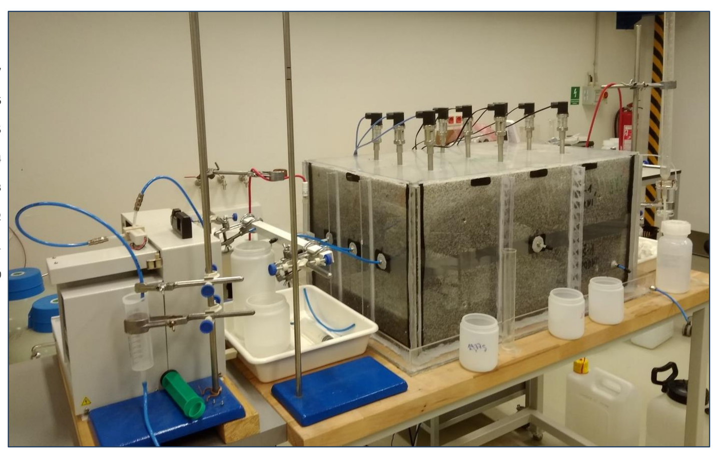


Measured vs. simulated pressure through the fracture of MS2 block

- Mean hydraulic aperture: MS1: **213 µm** x MS2: **386 µm**
- Calibrated hydraulic aperture is lower compared to the directly measured aperture



Transmissivity of the calibrated fracture with corresponding pressure field distribution

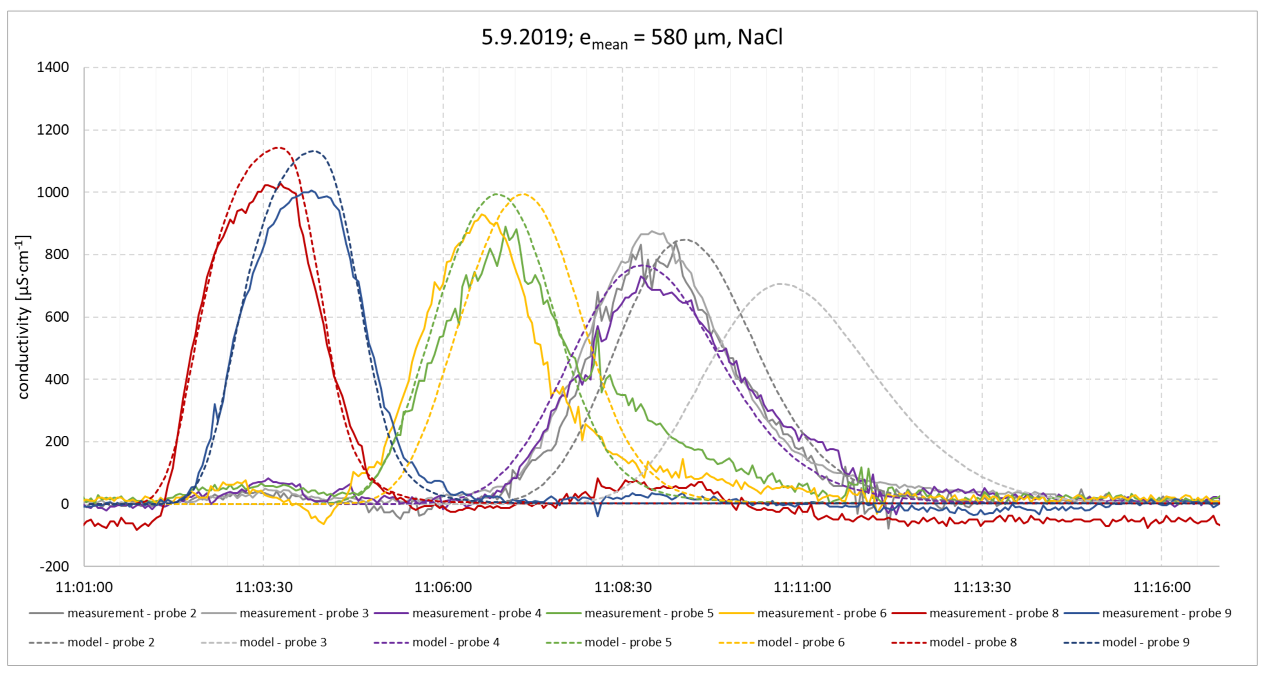


Instrumented block MS1 during KI tracer experiment (with pressure sensors)

- Block model dimensions (MS1, MS2): 80 x 50 x 40 cm

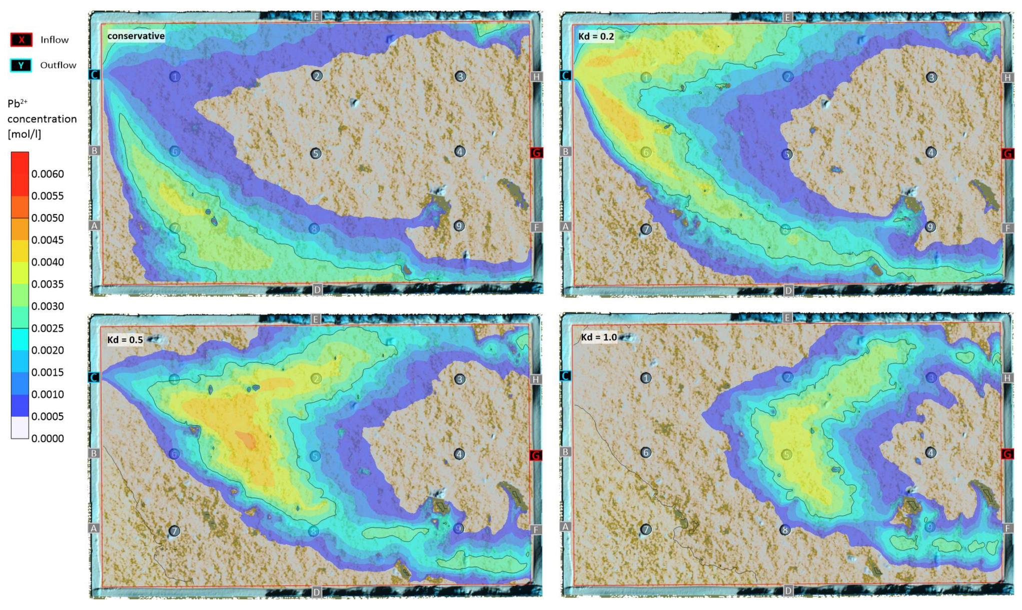
Tracer transport

- Calibration of the transport aperture is based on conformity of simulated and measured breakthrough curves
- Conservative: **NaCl, KCl, KI, HTO** X Reactive tracers: **$Pb(ClO_4)_2$**

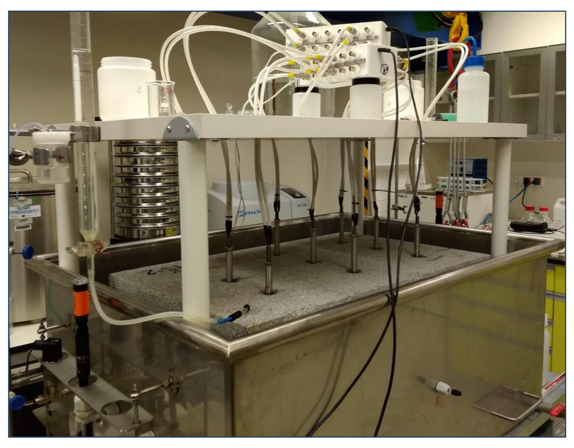


Measured vs. simulated breakthrough curves of NaCl tracer in MS2 fracture

- Mean transport aperture: MS1: **325 µm** x MS2: **580 µm**
- Transport aperture is greater compared to hydraulic
- Calibrated dispersivity: cca **7.5 mm longitudal / 5 mm transverse**
- Intensive sorption of tracer **Pb^{2+}** on the granite fracture surface



Simulated Pb^{2+} concentrations with various partition ratio parameter in timestamp 1000 s after tracer injection (MODFLOW+MT3D)

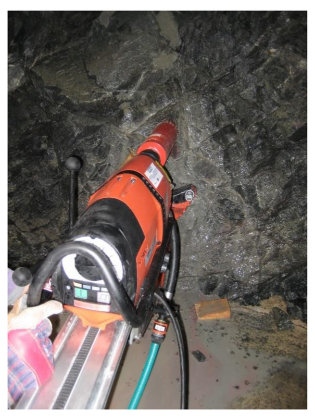


Instrumented block MS2 during NaCl tracer experiment (with conductivity sensors)

Migration experiments on physical model with natural fracture

Sample preparation

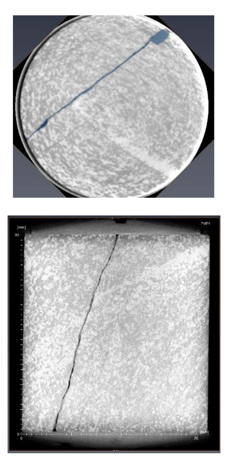
- Core sample drilling (URL Bukov)
- Sample resized and embeded with resin
- One inlet / one outlet

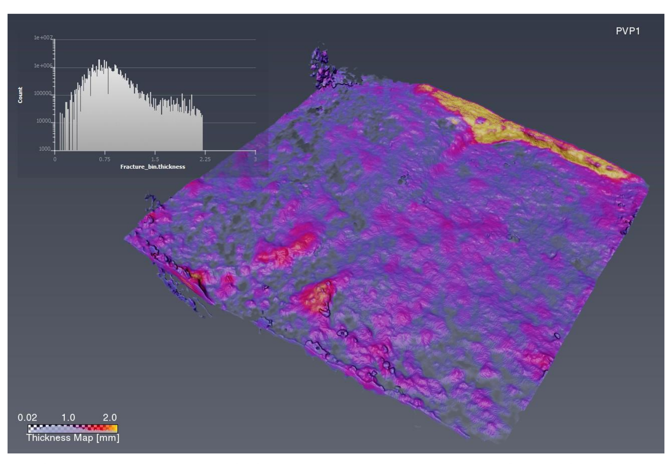


Core sample dimensions: 7,8 x 9 cm

3D fracture characterisation (HZDR, Leipzig)

- µCT density mapping of core samples
- Spatial rsolution: 50 µm
- Fracture segmentattion
- Aperture determination



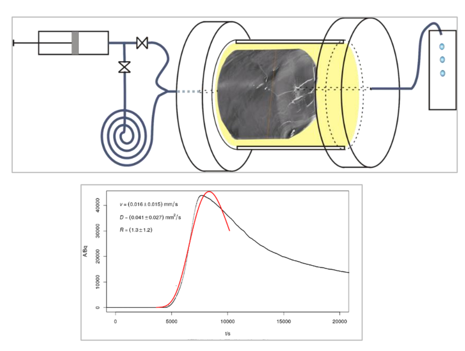


Segmented fracture grid for transport simulations

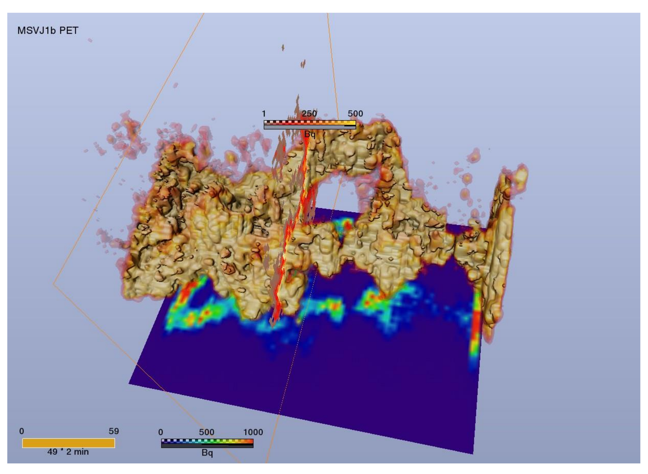
GeoPET experiments (HZDR, Leipzig)

- Tracer: [^{18}F]KF (100 MBq)
- Spatial resolution: 1 mm
- Flow rate: 1 ml/h
- Activity and flow velocity field
- Heterogenous migration pathways

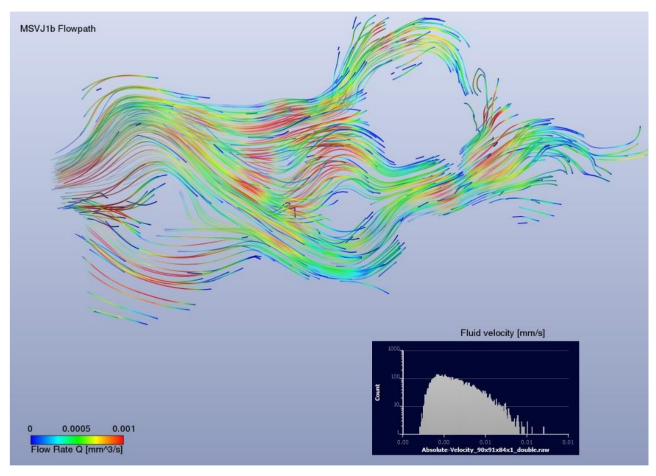
GeoPET setup



Flow through experiment with BTC at the outlet



Heterogenous activity map



Heterogenous flow velocity map

Conclusion

- Systematically higher transport aperture compared to hydraulic; advective transport affected by friction.
- Approximately the same ratio of transport to hydraulic aperture regardless of the sample.
- First results indicate possibility of using PET-µCT techniques for reactive transport analysis.

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