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Supplement of

Transport in tight material enlightened by process tomography

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Transport in tight material enlightened by process tomography

safe ND
Interdisciplinary research symposium on the safety of nuclear disposal practices

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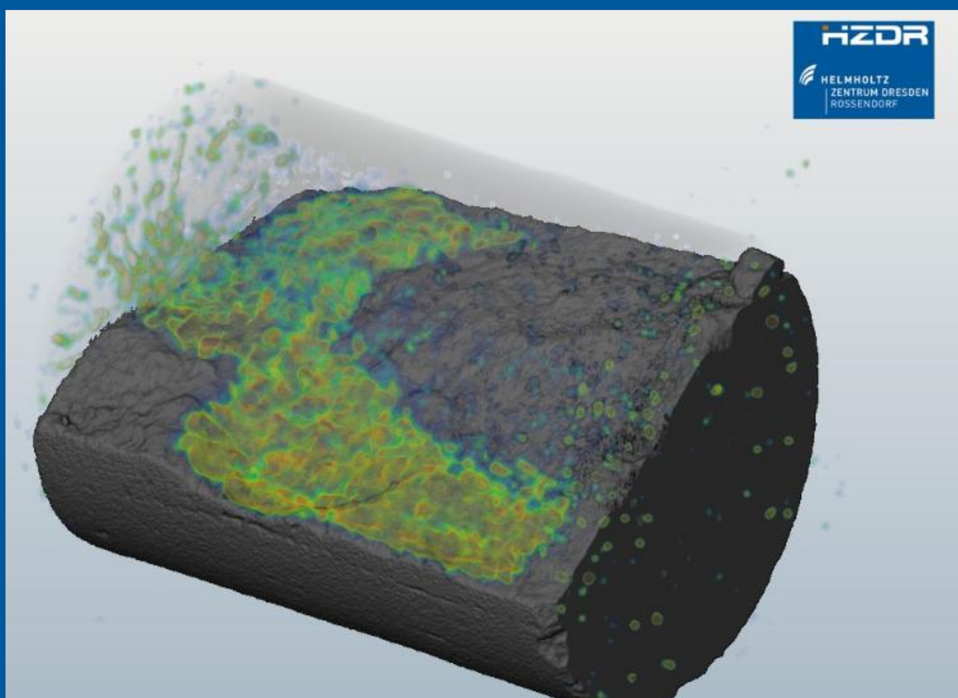

Partner von DRESDEN concept exzellenz-dresden.de

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Relevance of laboratory results

Reliable and robust data basis,

but discrepancies to large scale.

Questions to be asked:

Permeability frequently increases with scale, why?

Is the experimental time scale appropriate?

Do we understand the processes on the pore scale?

Impact of heterogeneity

Transport in tight materials

Input-Output tests (Permeability, diffusion cells, BTCs)	Process tomography (PET-µCT)
Duration of tests	
Stability? Time expenses	Spatiotemporally resolved snapshots Prove of stability by observation Optimization of test procedure Instationary tests without signal at outlet
Spatial Representativity	
Intact samples preferred (biased selection of samples) Small samples preferred (plugs)	Applicabillity on disturbed samples - including heterogeneities and fractures Tomography on complete drill cores Information on REV size Identification of connected transport paths
Process understanding, modelling	
Bias by test method	Identification of process (advection, diffusion, interactions with matrix)

Benefits of Process Tomography

Illuminate spatiotemporal internal properties during the process

- Heterogeneity (e.g. preferential transport, reactive zones)
- Retention and storage
- Velocity or rate distributions

Downside:

- Experimental limitations
- Expensive (work and costs)

Principle of Process Tomography with GeoPET

Requisites

Fotos:
Künzelmann (HZDR)

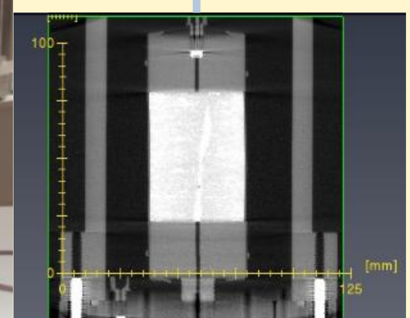
Plastic pressure vessel
or cast in epoxy

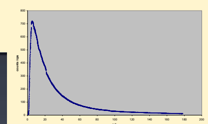
Transparent for
PET and CT
max. p_c: 10 bar

Sample dimensions:
d: 30..100 mm
l: < 100 mm

Injection of tracer pulse
into continuous flow of
carrier solution.

constant flow: 1 µL/min ..1 mL/min





BTC from
flow-through counter

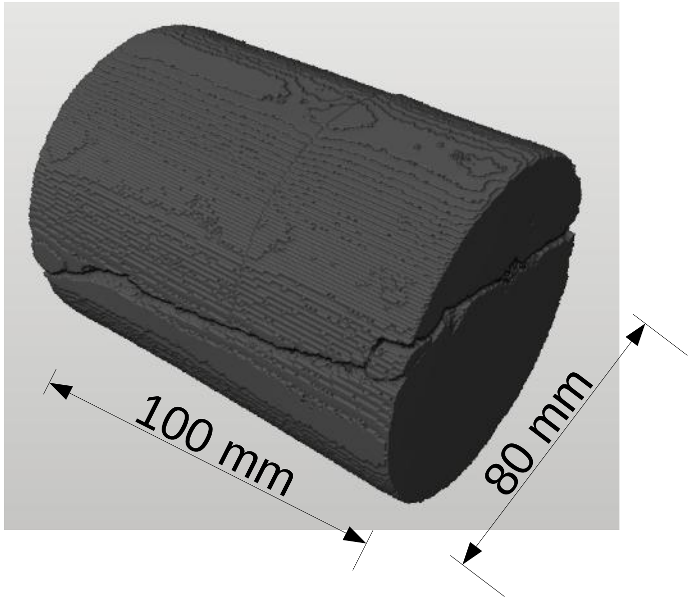
Data:
suite of PET frames
(minimum frame rate 1 min,
acquisition time hours to months)
plus µCT image

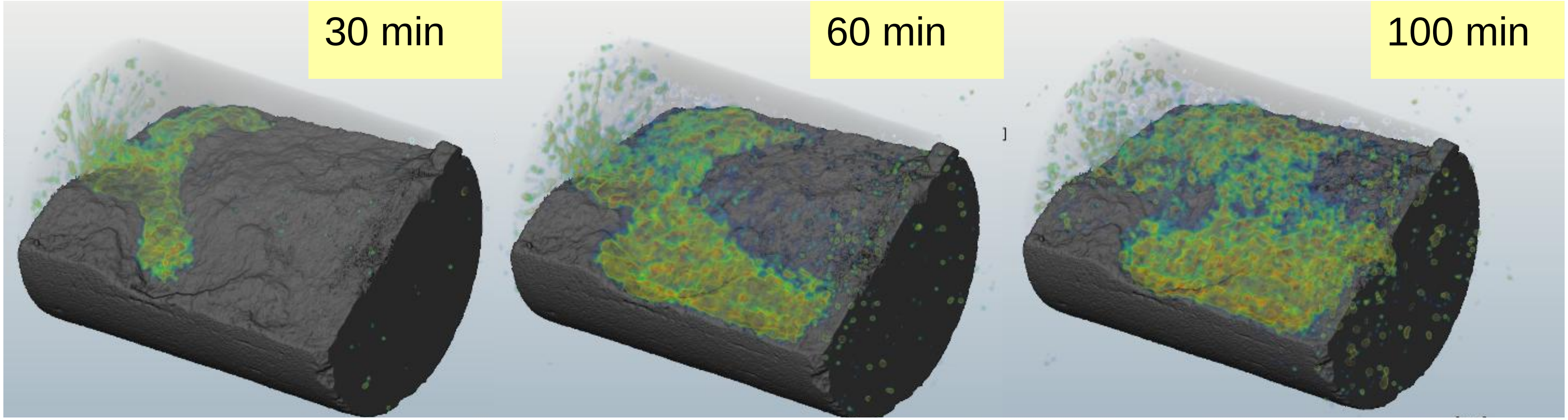
tomographic reconstruction
4D image processing
parameterization

Example for flow experiments

Bukov granite
with fracture

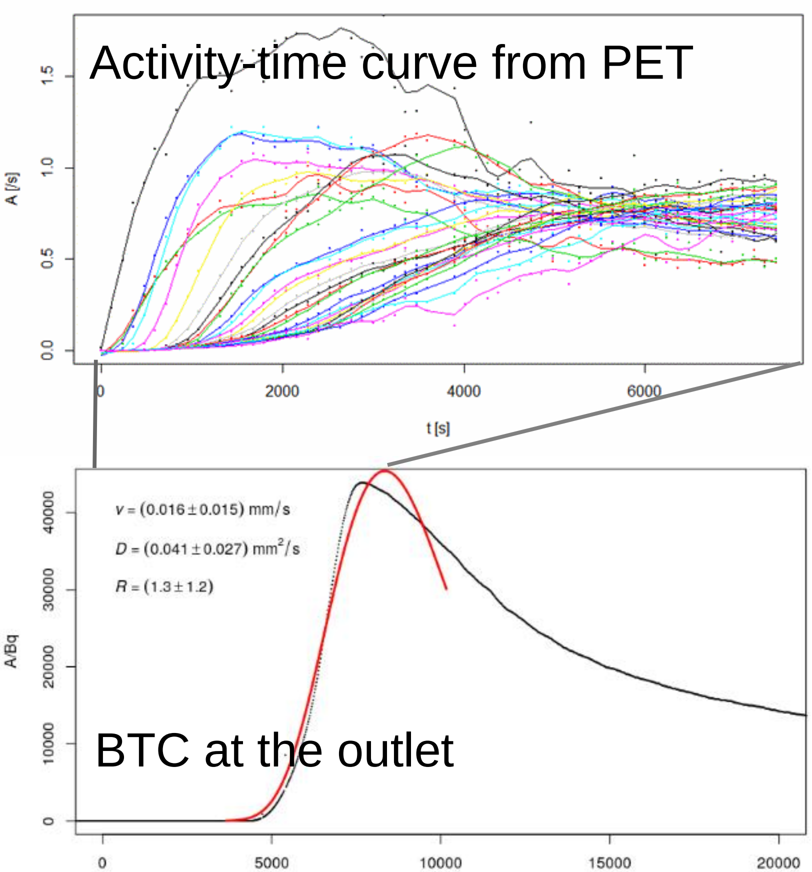
Flow rate: 0.1 mL/min
Carrier solution: 1 mMol KF
Tracer: 1 mL [^{18}F]KF

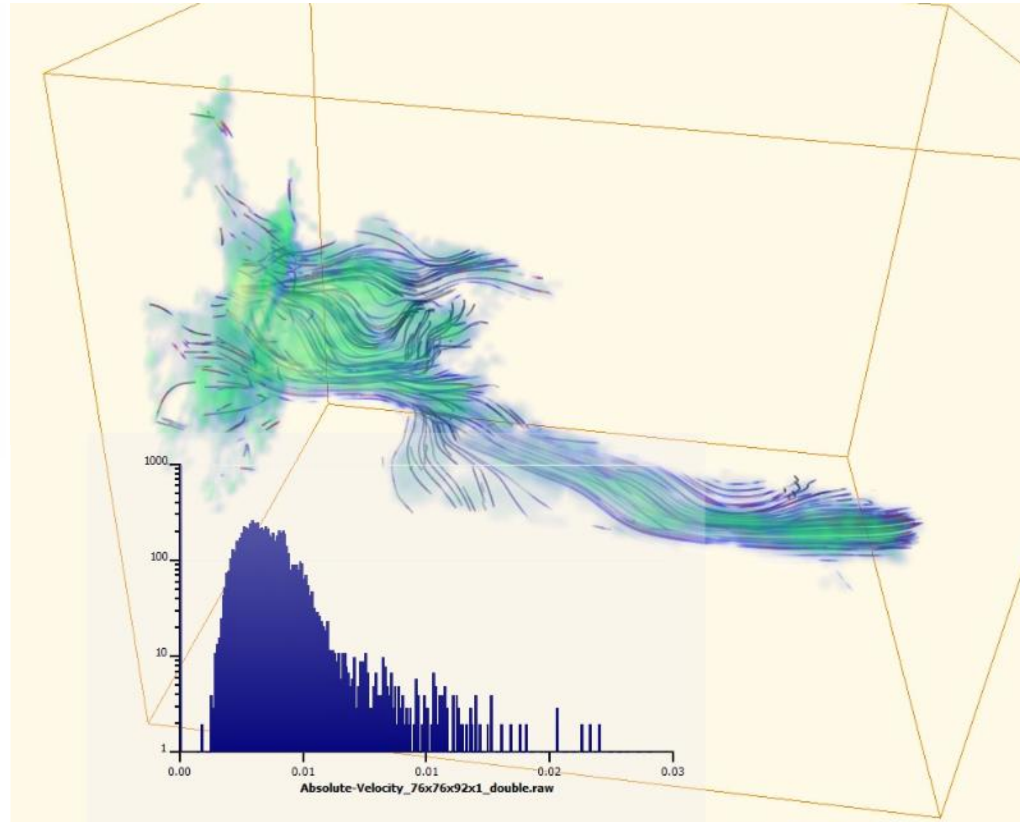




Kulenkampff, J.: Geophysical Research Abstracts, Vol. 20, EGU2018-8813-1, 2018.
Fischer, C. et al.: Geophysical Research Abstracts, Vol. 21, EGU2019-13965, 2019.

Results from Flow Experiment

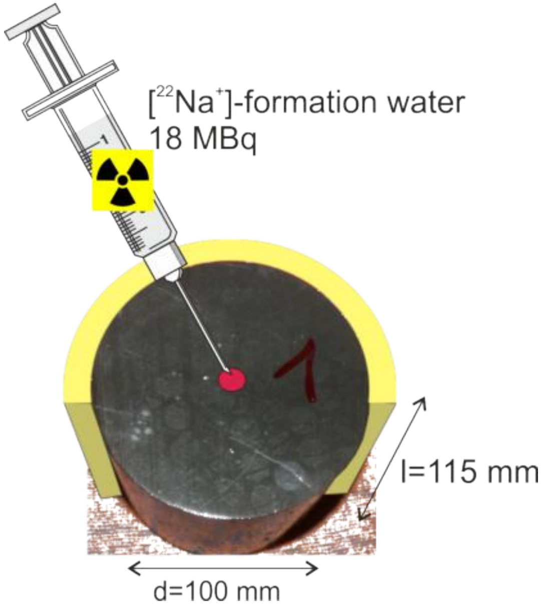




Internal and external BTCs
Small scale dispersion
Information on retardation

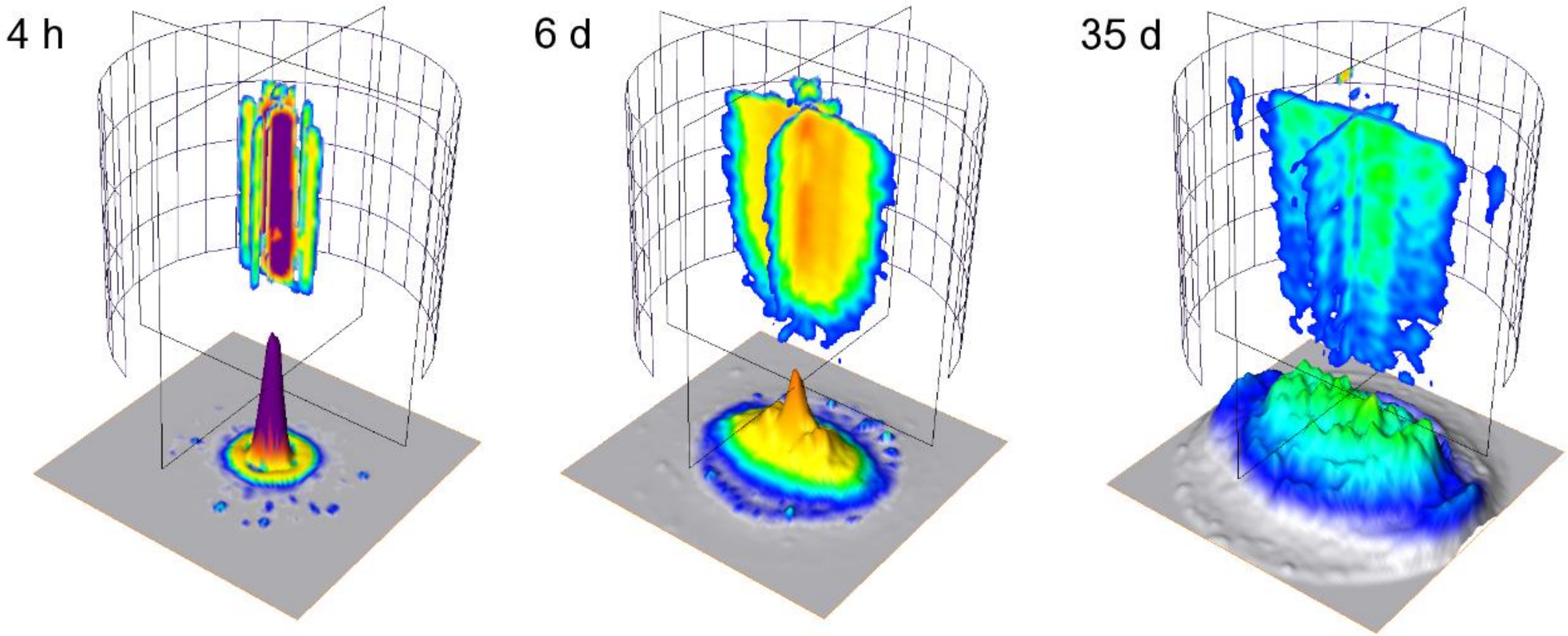
Flow path distribution
Velocity histogram
Effective volume

Examples for diffusion



Opalinus clay

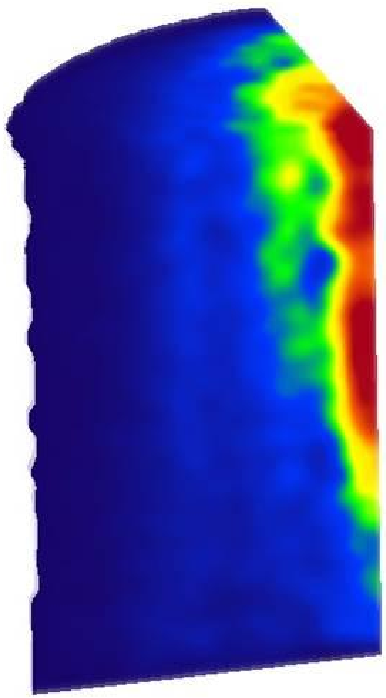
Completely cast in epoxy
Axial drill hole filled with
[^{22}Na] synthetic OPA-water
19 PET-frames over 1 year



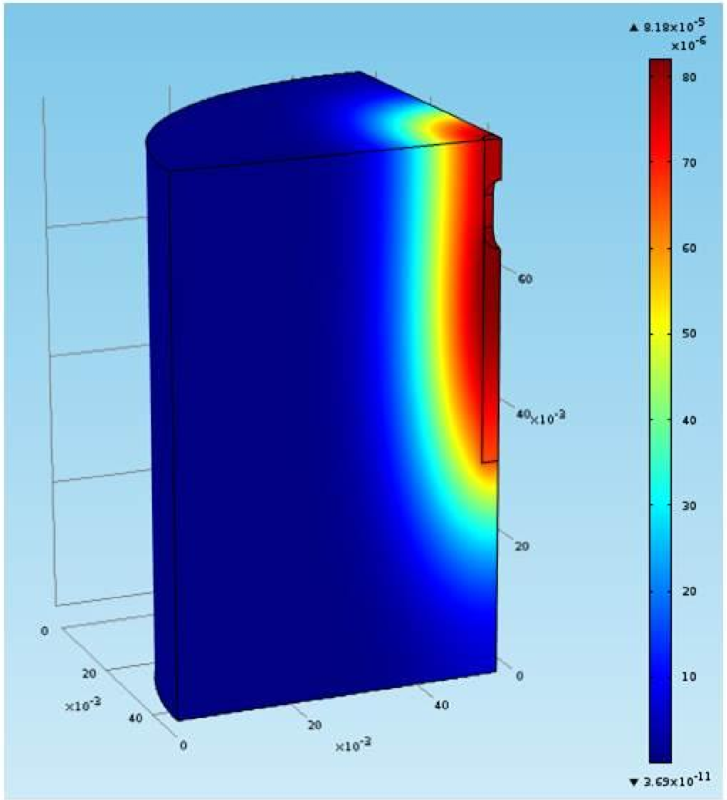
Kulenkampff, J. et al.: Solid Earth 7, 1207-1215, 2016.

Diffusion Results

PET data



COMSOL best fit



Best fit to FEM yields

Diffusion tensor
(axisymmetric)
Anisotropy
Heterogeneity

Lippmann-Pipke, J. et al.: Computers and Geosciences, 101, 21-27, 2017

Achievements

- process identification and understanding
- images (affirmative or puzzling)
- permeability or diffusion coefficient (eventually as tensors)
- dispersivity
- internal propagation curve
- transport pathways
- velocity distribution
- effective volume
- heterogeneity
- scaling from mm to cm

Questions

- applicability for safety case
- how to parameterize (e.g. heterogeneity parameter)
- how to apply for upscaling

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Cebama

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