Direct Observation of Preferential Transport by Means of GeoPET

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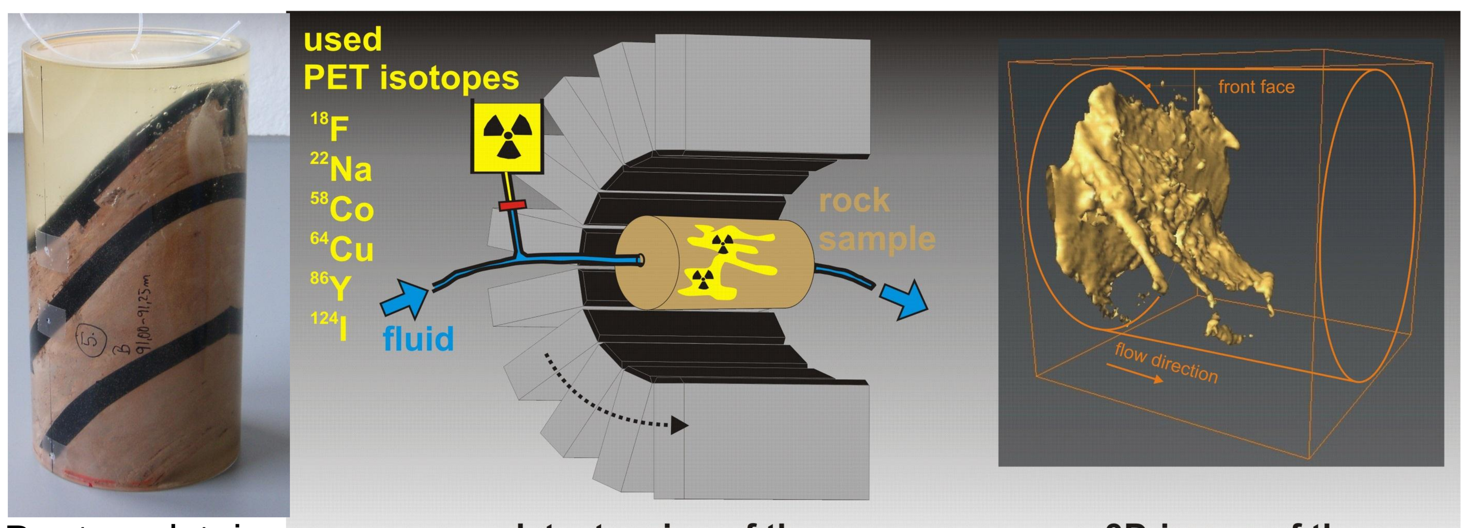
AIMS

• Transport process visualization in geological media by means of positron emission tomography (PET).
• Evaluation of observed transport processes in heterogeneously structured and strongly localized zones.
• Similarity studies with transport simulations on various scales. (in progress)
• Quantification of effective transport parameters by aligning observations with model results. (in progress)
• Derivation of parameter distribution functions. (in progress)
• Developing strategies for the *smart-simplification* of the 3D process reality (experimental results) into 2- or 1D - based on sensitivity studies. (To Do)

GeoPET-METHOD

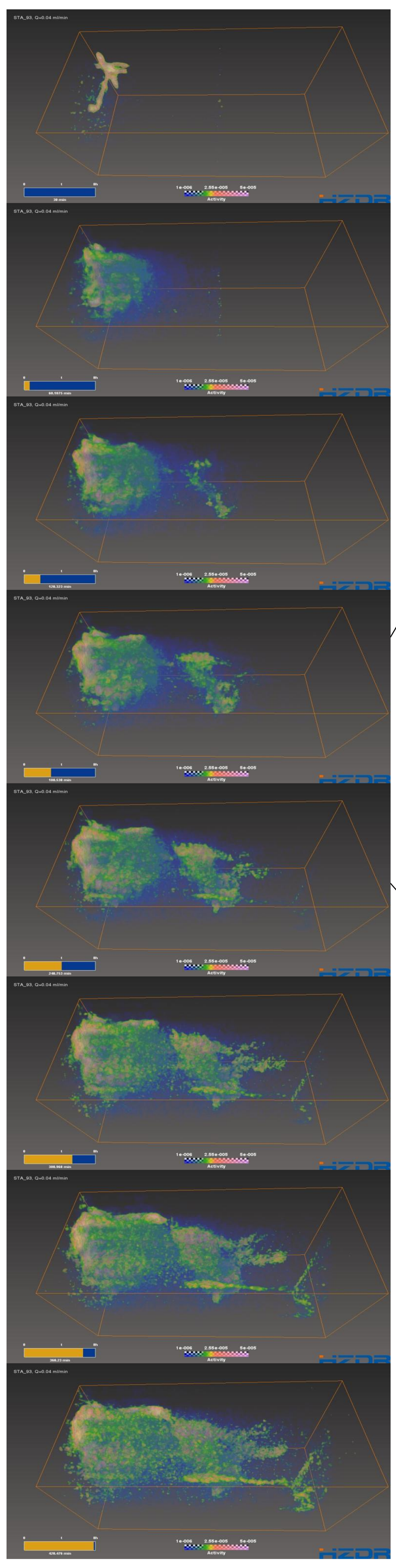
• Application of a high-resolution PET-scanner
• Resolution 1 mm, sample size 10 cm (drill cores)
• 3D observation of tracer concentrations
• Highest sensitivity (picomoles / voxel)
• PET nuclides (2h < $T_{1/2}$ < some years)
• Joint experiments with actinides from 2015 on

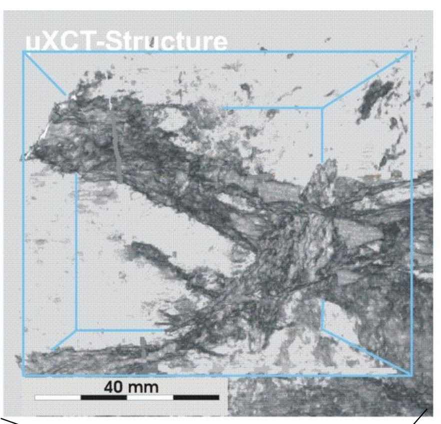


Buntsandstein (Staßfurt)

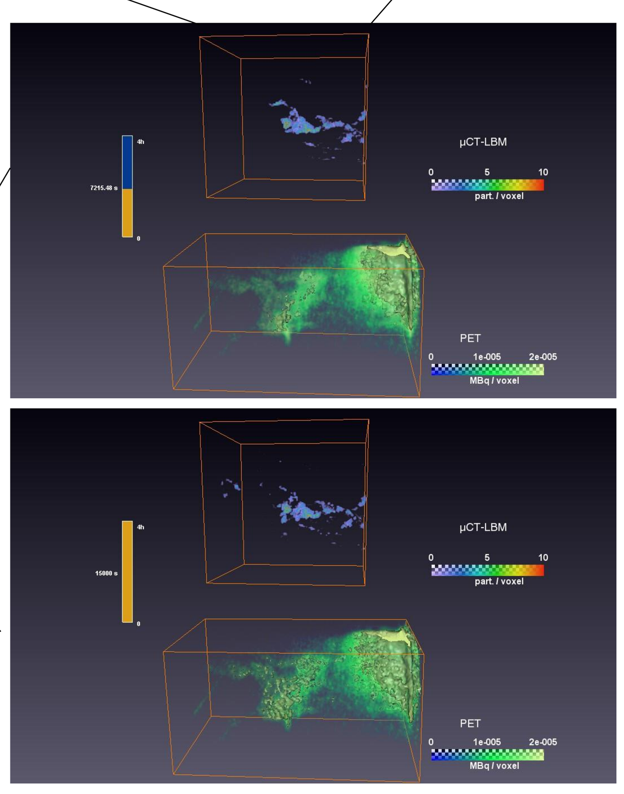
detector ring of the positron emission tomograph

3D-image of the tracer distribution





µCT (BAM Berlin) processed in Mainz



Lattice-Boltzmann-Simulation based on the µXCT-derived structural model vs. direct PET observation => General similarity in space and time, but significant discrepancies in details.

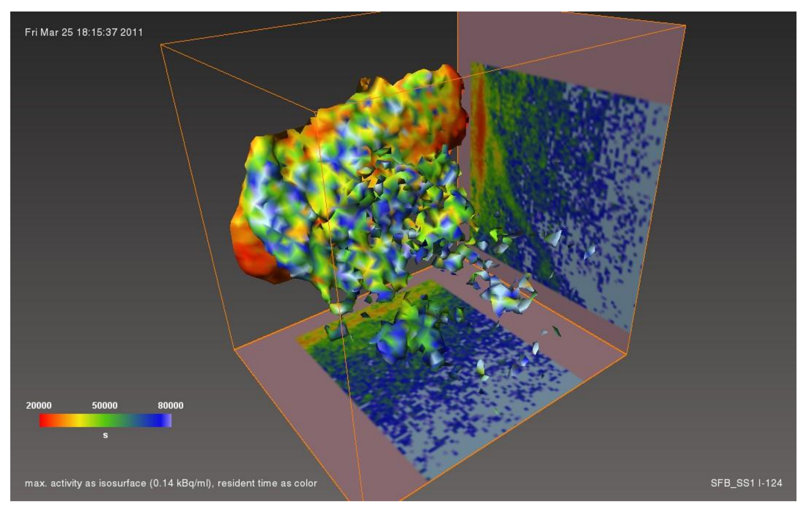
Halite core (Staßfurt), diameter 10 cm
Q-solution, flow rate 0.04 ml/min, for 8 h
Tracer pulse:
1 ml, 84 MBq [^{18}F]Q-solution at t=0

ADVECTION ON PREFERENTIAL PATHWAYS

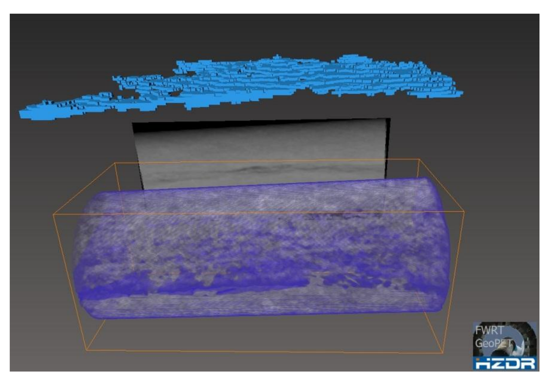
A PET-tracer is added to the carrier solution, which is continuously injected into the sample. Subsequent PET-images are showing the tracer propagation and yield the distribution of pathways and spatially resolved BTCs.

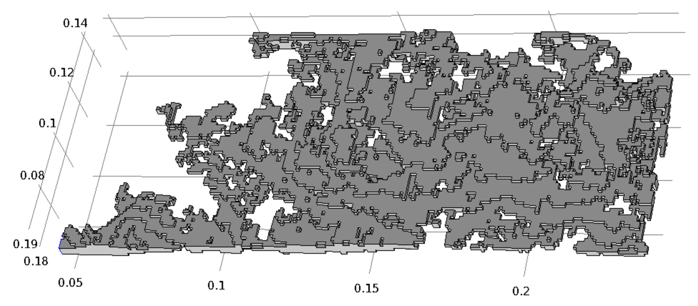
Frequently, we observe that the propagation pathways in fractures or fracture zones is strongly localized. Therefore, the effective transport volume and the effective internal surface area are much smaller than suggestions from bulk parameters.

color: passage times

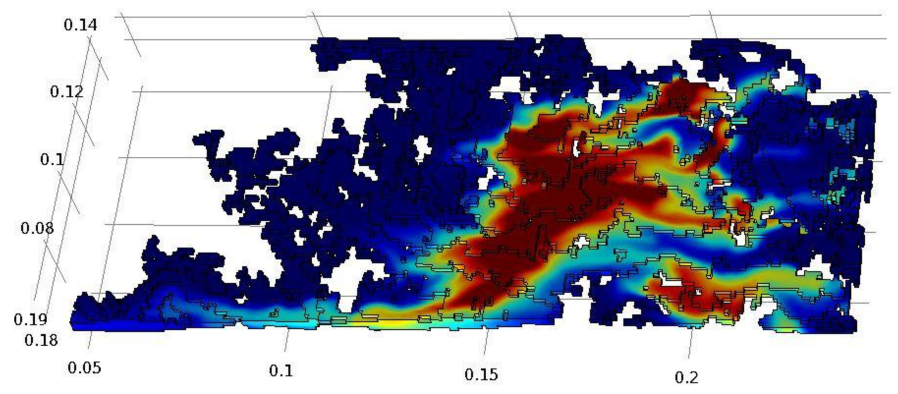


Injection of diluted [^{18}F]Q-solution into Buntsandstein from Staßfurt
After fast and strongly localized passage of a fracture (0 to 5 cm) the tracer spreads into bulk material (local activity below background).





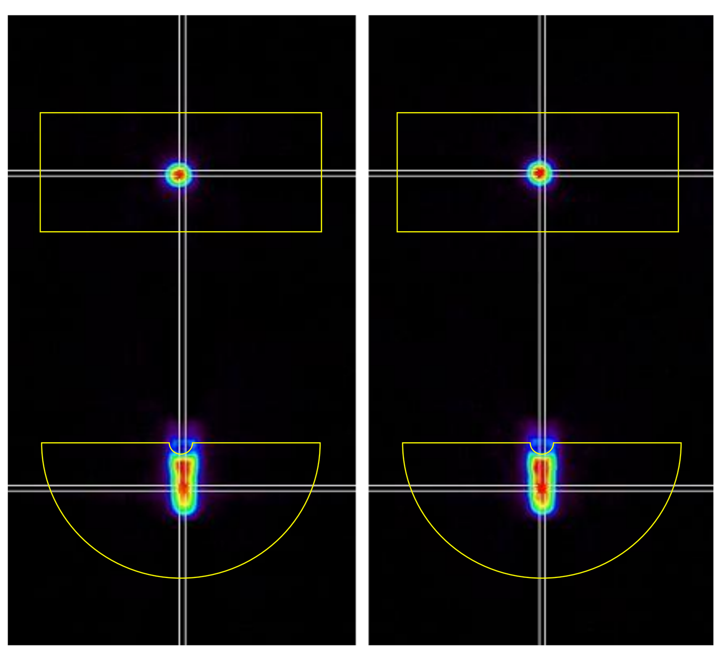
Laminar flow based model simulations (COMSOL Multiphysics) of transport in a fracture only reflects *degree of reality* of geometry extracted from CT.



DIFFUSION IN MACROSCOPIC SALT AND CLAY SAMPLES

In contrast to small-scale applications of diffusion cells, we charge complete drill cores with a central blind hole with solution. By labelling this with a longer-living PET-nuclide we aim at quantifying the diffusion tensor.

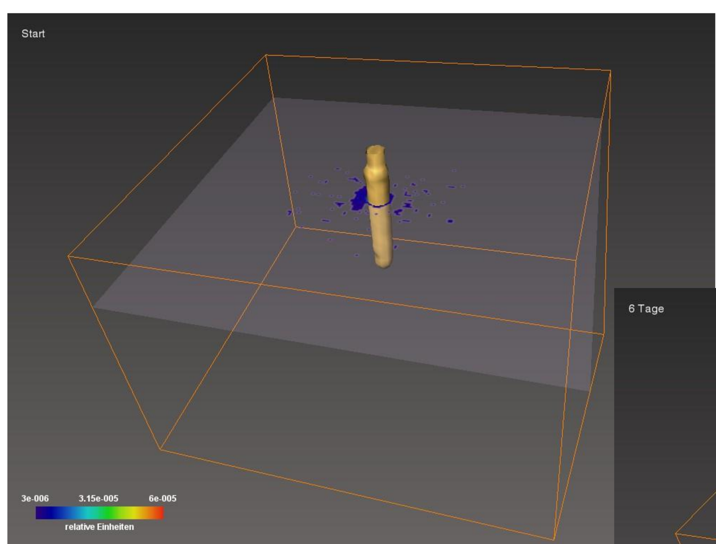
5 days



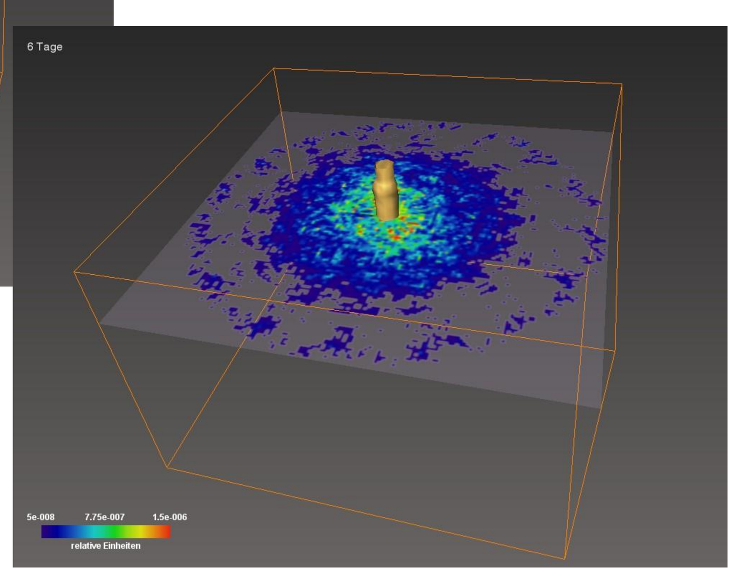
19 days

Halite half cylinder (Staßfurt), diameter 10 cm
charged with 0.5 ml [^{124}I]Q-solution:
no indication for diffusional transport during observation period of 19 days - as expected for undisturbed rock salt.

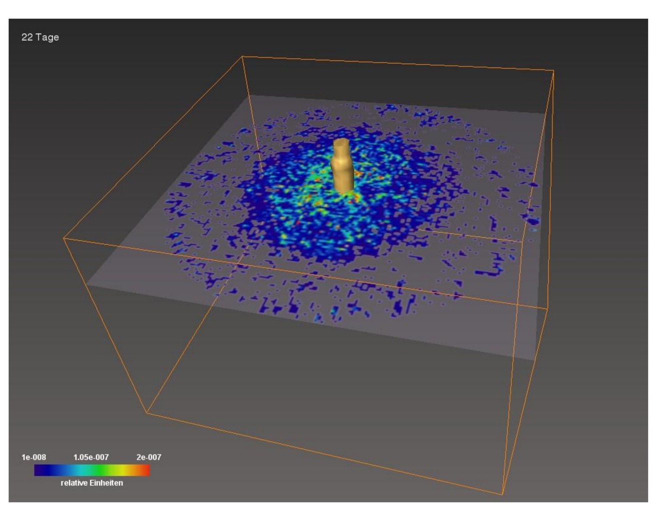
Opalinus clay core (altered by storage and drying), diameter 10 cm charged with 1.0 ml [^{124}I]-synthetic OPA-water:
fast and inhomogeneous spreading of the tracer, indications for local advective transport caused by suction during observation period of 22 days.



Start



6 days



22 days

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