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Spatiotemporal observation of transport in fractured rocks

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A number of injection experiments in different rocks types have been conducted with positron emission-process-tomography using a high-resolution "small-animal" PET-scanner (ClearPET by Raytest, Straubenhardt) for the monitoring of transport processes. The fluids are labelled with positron-emitting isotopes like e.g. $^{18}F^{-}$, $^{124}I^{-}$ or dissolvable complexes like $K_3[^{58}Co(CN)_6]$, without affecting their physico-chemical properties. The annihilation radiation from individual decaying tracer atoms is detected with high sensitivity, and the tomographic reconstruction of the recorded events yields quantitative 3D-images of the tracer distribution. Sequential tomograms during and after tracer injection are used for the spatiotemporal observation of the fluid transport.

Raw data is corrected with respect to background radiation (randoms) and Compton scattering, which turns out to be much more significant in rocks than in common biomedical applications. Although in principle these effects are exactly known, we developed and apply simplified and fast correction methods. Deficiencies of these correction algorithms generate some artefacts, that cause the lower limit of the tracer concentration in the order of 1 kBq/μl or about 10^7 atoms/μl, still outranging other methods (e.g. NMR or resistivity tomography) by many orders of magnitude.

New 3D-visualizations of the process-tomograms in fractured rocks show strongly localized and complex flow paths and in parts unexpected deviations from the fracture structures as deduced from μCT-images. Such results demonstrate the potential of large discrepancies between μCT-derived parameters like pore volume and specific surface area and the hydraulic effective parameters as derived by means of the PET-process-tomography. We conclude that such discrepancies and the complexity of the transport process in natural heterogeneous porous media illustrates the limits of parameter determination methods from model simulations based on structural pore-space models – in particular as long as the simulations are not verified by experimental data.