Geophysical Research Abstracts,
Vol. 11, EGU2009-12218, 2009
EGU General Assembly 2009
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Unsaturated flow patterns observed in mine soils with embedded porous fragments using neutron radiography

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Mine soils represent a typical dual-porosity medium characterized by porous fragments (e.g., lignitic or clayey clods) that are embedded in a coarser-textured sand-dust matrix. Effects of heterogeneously-distributed embedded fragments of various sizes and shapes on flow are largely unknown. The objective of this study is to identify water flow paths using neutron radiography and imaging techniques.

Experiments were carried out at the Swiss Spallation Neutron Source SINQ (PSI, Villigen). Neutron radiography (at the NEUTRA instrument) was used to observe unsaturated water movement under different flow conditions. For 2D-steady-state flow experiments, we used a double-membrane setup to infiltrate water (H2O) in slap-type undisturbed soil samples. Before the experiments, most of the water that was initially present in the samples has been exchanged by deuterium oxide (D2O). The 2D radiography series' show the dynamics of the spatial changes in water contents during the unsaturated flow process at defined matric potentials. In addition, we conducted multistep in- and outflow experiments to observe the 3D spatial distribution of the water content during the stationary phases at different steps of imposed pressure heads. Two minature tensiometers, one in the sandy matrix and the other in lignitic fragments, monitored the equilibration of soil water matric potentials in the dual-porosity medium.

Our observations basically confirm that flow patterns are strongly related to the local-scale structures and that a more continuous pore region exists in the vicinity of fragments for the imposed moisture conditions. This continuous pore domain allows for preferential flow within a relatively small fraction of the otherwise coarse-textured porous medium. The geometries and hydraulic properties of the porous fragments are additionally modifying the flow patterns.