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Quantification of trapped gas redistribution in dual-porosity media with continuous and discontinuous domains

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Nonwetting phase (residual air) is trapped in the porous media at water contents close to the saturation. Trapped gas phase resides in pores in form of bubbles, blobs or cluster forming residual gas saturation. In homogeneous soil media trapped gas is relatively stable until it is released upon porous media drainage. If porous media remain saturated, trapped gas can slowly dissolve in response to changed air solubility of surrounding water. In heterogeneous media, relatively rapid change in the trapped gas distribution can be observed soon after the gas is initially trapped during infiltration. It has been recently shown that the mass transfer of gas is directed from regions of fine porosity to regions of coarse porosity. The mass transfer was quantified by means of neutron tomography for the case of dual porosity sample under steady state flow. However the underlying mechanism of the gas mass transfer is still not clear. Based on the robust experience of visualization of the flow within heterogeneous samples, it seems that due to the huge local (microscopic) pressure gradients between contrasting pore radii the portion of faster flowing water becomes attracted into small pores of high capillary pressure. The process depends on the initial distribution of entrapped air which has to be considered as random in dependence on the history and circumstances of wetting/drying.

In this study, the redistribution of trapped gas was quantitatively studied by 3D neutron imaging on samples composed of fine porous ceramic and coarse sand. The redistribution of water was studied under no-flow and steady state flow conditions. Two different inner geometries of the samples were developed. In the first case the low permeability regions (ceramics) were disconnected, while in the second structure, the fine porosity material was continuous from the top to the bottom of the sample. Quantitative 3D neutron tomography imaging revealed similar redistribution process in both cases of interconnected and disconnected fine pore systems. The rate of the redistribution was significantly higher in the case of steady state flow condition in comparison to no-flow conditions. The transfer from fine to large pores led to reduced hydraulic conductivity of the sample.