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Bussod, G.Y., Svyatskiy, D., Zyvoloski, G., Boitnott, G.N., Lichtner, P.C., and Moulton, J. D. (2009) "Upscaling of Heterogeneous Porous Rocks Using High-Resolution Hydrogeophysical Scanning Measurements" Trans. Amer. Geophys. Union, Fall Meeting 2009, H43C-1041.

Abstract

This research is part of a DOE SBIR project that combines physical properties measurements on consolidated and unconsolidated subsurface lithologies, with numerical and effective media models that describe subsurface contaminant flow and transport. This paper presents results from an application of a new high-resolution methodology for the laboratory characterization of hydrogeophysical properties on core and field samples. The methodology is used to constrain contaminant flow and transport models for both unsaturated and saturated subsurface conditions. Spatially integrated fine-scale scanning (mm-cm resolution) of permeabilities, ultrasonic velocities and electrical conductivities on core and field samples are used to quantify heterogeneities at the smallest continuum scale. Through application of numerical and effective medium upscaling techniques, the scans provide a means to assign hydrogeophysical properties and model parameters at scales more appropriate to field applications, while preserving the physical influence of fine scale heterogeneities that cannot be explicitly modeled.

The methodology is being applied to several contaminated DOE sites at LANL, NM, Hanford, WA and Rifle, CO. We illustrate that fine- and meso- scale heterogeneities (mm-m) can cause significant saturation dependent anisotropy in hydrogeophysical properties (e.g., electrical conductivity and relative permeability). These effects are captured in our upscaling methodology to provide more accurate model parameters used in representation of the contaminated subsurface. Through a series of examples, we show how quantification of the fine scale heterogeneities of a particular flow unit can be used to constrain upscaled model properties at the meter scale. We show that as a result of these heterogeneities, the change in scale from centimeters to meters requires a change in character of the capillary pressure / relative permeability relationships. As an example, we find that after applying standard core measurement-based models of capillary pressure and permeability at the fine scale (e.g. Thomeer,1983; and Corey, 1954), the effect of typical fine and meso-scale heterogeneities (laminae, cross beds, etc.) leads to fundamentally different capillary pressure / relative permeability relationships at meter scale.

Interestingly, in many cases we find that this upscaling methodology predicts meter scale relative permeabilites and capillary pressures consistent with the commonly applied model of van Genuchten (1980). This suggests that fine to meso-scale heterogeneities reflecting common sedimentary structures may play a significant role in explaining the physical meaning of the van Genuchten parameters and relationships. We also discuss predicted deviations from the van Genuchten relationships, particularly with regard to saturation dependent anisotropy in relative permeabilities.

Contact NER for more information.