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Boitnott, G.N., G. Y. Bussod (2009) “Using High Resolution Complex Electrical Conductivity Measurements of Heterogeneous Rocks” Trans. Amer. Geophys. Union, Fall Meeting 2009, NS31B-1173.

Abstract

The complex electrical resistivity of a slab of Berea sandstone was measured using a four electrode probe in the frequency range of 1 Hz to 1 kHz. The measurements were made in the context of the development of a new high resolution methodology for the laboratory characterization of hydro-geophysical properties on core and field samples. Electrical conductivity maps with millimeter-scale resolution and measured at different pore fluid salinities are used to constrain dual conduction models (e.g. Waxman-Smits, 1968) that allow us to separate the contribution of electrical conduction through the pore fluid from surface conduction along mineral grain surfaces. Measured resistivity variations are observed to be structured in distinct layers at the scale of millimeters to centimeters and are well correlated with fine scale layering observed in thin section. The data is analyzed in conjunction with petrophysical maps of permeability and velocity variations.

The maps of permeability, resistivity, and velocity all indicate that Berea sandstone contains measurable structural anisotropy at a variety of scales. The heterogeneities in petrophysical properties are in general rather weak, with permeability varying by a factor of 3 and velocity and resistivity varying by 7% and 19% respectively. Analyzed collectively, the data provides insights into the physical causes of the observed resistivity anomalies and allows us to interpret them as due to localized pore-scale variations in grain size, pore structure, and mineralogy. Correlations among these petrographic variables lead to the discovery that surface conductivity of the rock is negatively correlated with the conductivity due to the free electrolyte.

Using this integrated petrophysical data-set, we build a predictive model of the meter-scale petrophysical properties that honors the intrinsic heterogeneity of the sample. The data and models are used as the foundation for a physically-based upscaling approach for understanding how petrophysical properties relate to flow and transport processes at scales difficult to measure in the laboratory. Through application of effective media and numerical models we show that the observed small-scale heterogeneity leads to anisotropy in electrical properties that correlates with anisotropy in relative permeability. The anisotropy is found to be a complex function of scale, salinity, and saturation.

Contact NER for more information.