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Linking hydraulic and electrical transport in porous rock: An integrated evaluation of several scaling models against original experimental data.

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Both permeability (k) and specific electrical conductivity (s) are important rock transport properties whose precise determination is of uppermost interest in all areas where the characterization of fluid flow within a pore space is the key issue. Both parameters are measured as bulk properties but are in fact defined by the individual pore structure of a rock. Compared to permeability, electrical rock conductivity is significantly easier to measure both in the lab and in situ. Thus, not least for practical reasons, it is desirable to establish a link between both transport properties and to couple both parameters through microstructure-related length scales. Approaches to this problem have been made repeatedly during the last five decades. The purpose of this investigation was to test some of the most prominent scaling models against original experimental and microstructural data. We first measured the effective pressure dependence of both permeability and specific electrical conductivity of three different types of sandstones. The experiments were performed in a HPT-permeameter at a maximum confining- and pore pressure of 50 MPa and 45 MPa, respectively and a constant temperature of 40°C. 0.1 molar NaCl-brine was used as the pore fluid. The experiments were then complemented with 2D image analysis and mercury porosimetry to derive the specific inner pore surfaces and the pore radius distributions of the samples. Finally, the experimental and microstructural results were used to relate both transport properties through different length scales and to test existing scaling models based on the hydraulic radius (1), statistics and percolation (2) and mercury porosimetry

(3). It is demonstrated that morphological differences can have profound effects on the systematic relationship between permeability, conductivity and porosity. It will be shown that the scaling models tested in this study have limitations in adequately reproducing the experimentally derived transport properties through coupling to only one microstructurally defined length scale. On the other hand, empirical permeability-conductivity relationships can deliver precise results but the related parameters have to be adjusted for each rock. In this context it is implied that, despite mathematical similarity, such relationships should not be confused with analytical or statistical scaling models as they include length scales with no true microstructural or physical meaning and thus give no insight into the real transport process. We finally conclude that the introduction of poroelastic concepts into the microstructure related equations for both permeability and conductivity is necessary if one aims on avoiding the use of empirical k-s relationships at effective pressures other than zero.

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