Digital Core Laboratory: Estimation of Transport Properties from Pore-Scale Images

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Estimating rock properties is of great interest in a wide variety of fields, including earth science and engineering. Quantitative prediction of the transport properties for porous media, such as sedimentary rocks, frequently employs representative microscopic models of the pore space as input. Recently digital imaging techniques such as microtomography have been used to provide void space images at the resolution of a few microns. Three-dimensional digital rock image at the pore-scale can be used to predict various static and dynamic properties. Porosity is the most fundamental properties of porous media and is predicted through image analysis of the rock sample. In some of rock samples such as carbonates, however, the presence of pores at scales below the image resolution leads to a broad spread in the low density signal from the microtomography device making it difficult to differentiate the pore from the microporous and solid mineral phases. The special segmentation process on the images - phase separation of the resolvable pore phase, intermediate microporous phase and the matrix phase, is applied for such complicated rocks. The binarized images after the segmentation process can be directly used for various simulations to predict rock properties. Transport properties such as permeability, relative permeability and capillary pressure functions define the flow behavior of porous media. These properties critically depend on the geometry and topology of the pore space, the physical relationship between rock grains and the fluids, and the conditions imposed by the flow process. Digital pore structural information gives us fluid flow properties through numerical approaches such as the lattice-Boltzmann method (LBM) and the network model. The LBM is used as a single-phase flow simulator since the method provides a good approximation to solutions of the Navier-Stokes equations that readily accommodates complex boundaries, as encountered in porous media. It is, however, not realistic to use the LBM for multiphase flow due to the large computational time. Therefore, the multiphase flow properties are estimated by the pore-scale network model. The networks are generated from the pore space images based on the guiding idea, which the pore space can be naturally discretised into subvolumes separated at the locally narrowest constrictions. The subvolumes and the constrictions can be identified with the nodes (pore bodies) and links (pore throats) of a network. The advancement of the fluid-fluid interface through a link or node in the network is governed by the relationship between the capillary pressure, the material wettability and the local channel cross-section geometry. Network representations provide valuable information to quantify the topological properties of the pore space and they are the key input to the pore network simulation to predict relative permeability. The numerically estimated results are in good agreement with experimentally measured values. Three-dimensional imaging and analysis of rock material at the pore scale can provide a basis for more accurate models; narrow the range of uncertainty in estimates of rock.