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Pore-scale modeling of transport properties based on X-ray microtomography data: introducing the concept of under-resolution porosity

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Pore structure is one of the main factors defining reservoir properties of rocks. Conventional estimations of such properties using only limited 2D data from thin sections using different approximations are usually inaccurate. In recent decades different numerical methods were developed to quantify flow and other physical properties on micro-scale. Each method has its own advantages and drawbacks, so utilization of more than one approache is reasonable, depending on the case study. Recent progress in X-ray micro-tomography and some other techniques allow precise determination of three-dimensional structure of rocks, however, a trade-off between resolution and sample size is usually unavoidable. Some amount of porosity (we call it "under-resolution") is usually not visible on X-ray scans or thin-section low resolution images. It may play an important role in resistivity, capillary curve shape and other properties.

The main aim of this contribution is to verify petrophysical modeling approach on a collection of sandstone samples with wide range of pore space configurations. At first, our method for obtaining 3D structure using X-ray microtomography is justified via detailed laboratory vs. tomography porosity measurements comparison. Next, permeability is determined for all samples using network-model extracted from 3D structure scans. Calculated formation factors and capillary curves in many cases deviated from experimental values, especially for samples with high under-resolution porosity. The influence of invisible porosity is also supported by coordination number correlations with other physical properties for samples within the same group (same reservoir type). To account for under-resolution pores invisible on X-ray scans different approaches can be utilized based on artificial addition of under-resolution porosity into numerical sample: NMR measurements, mercury porosimetry, or stochastic reconstructions from high resolution 2D cuts.

Adequacy of pore space information obtained using high-resolution microtomography is shown to be sufficient for pore-scale modeling of filtration properties of most reservoir rocks. Based on rigorous analysis of large collections of different porous materials influence of invisible porosity on modeling of physical properties was studied in detail. The developed concept of under-resolution can be successfully used for its incorporation into pore-network models and improvement of simulation results. For this purpose invisible porosity can be generated in addition to pore space extracted from micro-CT images.