Validation of the Digital Rock Models with Capillary Pressure Data in Late Carboniferous Sandstones

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Abstract

The Pore Throat Size Distribution (PTSD) is an important topological characteristic of the pore structure in complex sandstones, as it influences pore-scale fluid distribution and flow behavior. The PTSD is commonly derived from mercury injection capillary pressure (MICP) measurements, recently also using Digital Rock Physics (DRP) analysis via imaging of the rocks with 3D X-ray Micro Computed Tomography (MicroCT) and numerical modeling. Lab MICP data are used as control points for calibration and verification of the DRP algorithms. The pore sizes that can be characterized with DRP depending on the resolution of the imaging. In this work, the pore systems of the late Carboniferous Juwayl Formation were studied utilizing DRP and MICP analyses.

Ten 1.5” sandstone plugs from core were scanned using MicroCT at 25 microns resolution scans, then smaller variable size sub-plugs (out of the original plug) were taken to be scanned by the MIcroCT at 0.5 microns resolution. The sizes of the sub-plugs were determined based on the MICP analysis of the corresponding end trims in a way to represent the majority of the small pores within the resolution of the scan. The physical limitations of the DRP technology did not support the evaluation of the smallest sub-resolution pores in these sandstones. MICP data provided the PTSD down to 0.01 microns. On the other end, MICP is not applicable to pore throats larger than ~200 microns. However, DRP analysis resolved these larger pores and complemented MICP data. The capillary pressure and the PTSD were calculated from the rock tomograms using the immiscible multiphase Lattice-Boltzmann model with segmented 3D volumes. Uniform wetting conditions for the primary drainage were assumed in the simulation. As a result, the complete pore size distribution was characterized.

Once the pores were digitally reconstructed by combining DRP and MICP data, the pore network was modeled to define reservoir properties, including pores geometry characteristics and absolute permeability in different axis. In this study, absolute permeability was computed by applying pressure boundary conditions at inlet and outlet of the digital samples. At the side-walls no-slip boundary conditions were applied. The flow rate and absolute permeability were modeled using the Stokes-Brinkman equation. The DRP absolute permeability matched with conventional plug helium permeability measurements data within tolerance expected of inter-lab comparisons on similar plugs. By comparing digital MICP PTSD with the PTSD results from plug lab measurements, we ensure that the pore structure generated from the digital rock analysis is representative. This information supports building reliable DRP models and simulating the flow properties within the pore network for the study area sandstones. The study has improved understanding the reservoir rock pore networks and enhanced digital rock analysis algorithms.