Multi-scale Imaging Process for Computations of Porosity and Permeability on Carbonate Rocks

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Reservoir rock material collected during drilling is one of the main sources used to derive reservoir fluid transport and rock mechanics properties. Carbonate reservoir may have heterogeneities that create multi porosity/permeability systems that are very difficult to describe, and to determine their flow properties. They may contain micritic, sparic, and much larger grain and pore structures, all in one reservoir and in close proximity. Conventional methods use laboratory procedures to perform experiments that yield directly or indirectly required rock properties. Some of these procedures, such as the determination of relative permeabilities, may take several months to perform.

Yet, as reservoir characterization is becoming ever more important for oil and gas production, a much larger portion of reservoir rocks, from cuttings to full cores, will need to be analyzed than what are currently evaluated. This paper offers an example of the use of digital rock physics to determine porosity, permeability, and relative permeabilities for a carbonate sample using multi-scale imaging. Digital rock physics using the Lattice Boltzmann (LBM) for fluid dynamic calculations is at a point where for a proper digital pore space the resulting flow properties calculated are reasonably correct. The main issue facing digital rock physics is the need to up scale the computed properties to the scale of the core.

The process presented in this paper includes sample preparation, imaging, image processing, property computations, and property integration to the core scale. The sample is subjected to a descending scale of x-ray CT imaging, along with physical sub-sampling of the core. The descending size of scanning leads to increased resolution of the three-dimensional digital core, keeping the sample volumes registered in place. The resulting digital rocks are segmented and the pore structure is determined on the x-ray CT grid system. The resulting three-dimensional pore structure, that is the same as the actual pore structure subjected to resolution limits, is used as the input grid system for direct fluid dynamic computations that are second order accurate representation of the Navier-Stokes fluid flow equations. These computations yield porosity, absolute permeability, relative permeabilities, and capillary pressure. In this paper we focus only on porosity and permeabilities.