Physics-Based Reconstruction of Sedimentary Rocks

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RESEARCH OBJECTIVES

The relative permeability and capillary pressure functions define how much oil can be recovered from a reservoir. These parameters are the key input data for any reservoir simulation. The objective of this project is to develop methods of estimating the absolute permeability, capillary pressure, and relative permeability functions by analyzing 3-D images of the rock.

APPROACH

High-resolution images of rock are obtained both by electron-scanning microscopy of cores and by physics-based computer simulation of the sedimentary-rock formation process [Jin et al., 2003]. In either case, the geometry of the pore space is studied by applying methods of mathematical morphology to the digital images [Silin and Patzek, 2003; Silin et al., 2003].

ACCOMPLISHMENTS

A general approach for process-based reconstruction of sedimentary rocks has been developed [Jin et al., 2003]. The procedure includes dynamic grain sedimentation and compaction, followed by diagenesis. The results are confirmed by statistical comparison of computer-generated and natural images of sandstone cores. The mechanical properties of the natural rock, such as stress-strain curve, are also well reproduced in the computer-generated rock. Computer simulations provide an insight into rock-damage propagation as a system of coalescing microcracks.

A new, robust approach to studying the pore-space morphology of rocks from their 3-D digital images has been developed. An efficient and stable algorithm, which distinguishes between the pore bodies and pore throats and establishes their respective volumes and connectivity, has been proposed and tested. The output of this algorithm has been used to compute a dimensionless drainage-capillary-pressure curve, which simulates mercury injection. This curve is a robust descriptor of the pore-space geometry that can be used to determine the quality of natural-rock computer reconstruction (see Figure 1). An appropriate scaling of this image-analysis-based curve should enable prediction of the rock capillary pressure.

SIGNIFICANCE OF FINDINGS

Our approach provides a practical, inexpensive, and fast alternative to tedious core-flood experiments and allows the investigator to run many "what-if" scenarios. The predictive capability of the pore-scale calculations is especially important for imbibition experiments in mixed-wet rocks and in multiple drainage-imbibition cycles with two or three fluids present. For unconsolidated reservoir rock, analysis of computer-generated images, based on the known grain-size distribution, is virtually the only way to get insight into rock transport properties.

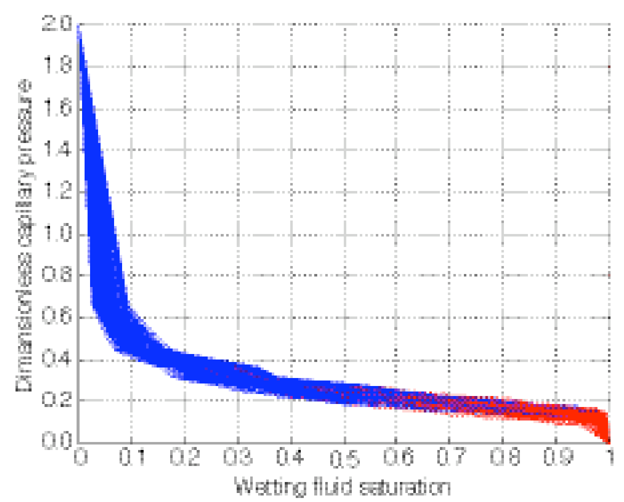

Figure 1. These 800+ dimensionless capillary pressurecurves have been obtained for images of Fontainebleau sandstone. The porosity of the imaged rock samples varies between 11% and 22%.

RELATED PUBLICATIONS

Jin, G., T. Patzek, and D. Silin. Physics-based reconstruction of sedimentary rocks. SPE Paper 83587 presented at SPE Western Regional/AAPG Pacific Section Joint Meeting. Long Beach, California, 2003; Berkeley Lab Report LBNL-52966, 2003.

Silin, D., and T. Patzek, An object-oriented cluster search algorithm. Berkeley Lab Report LBNL-51599, 2003.

Silin, D., G. Jin, and T. Patzek, Robust determination of the pore-space morphology in sedimentary rocks. SPE Paper 84296 presented at SPE Annual Technical Conference and Exhibition, Denver, Colorado, 2003; Berkeley Lab Report LBNL-52942, 2003.

ACKNOWLEDGMENTS

This research was supported by the Assistant Secretary for Fossil Energy, Office of Natural Gas and Petroleum Technology, through the National Petroleum Technology Office, Natural Gas and Oil Technology Partnership, under U.S. Department of Energy Contract No. DE-AC03-76SF00098. Partial support was also provided by gifts from ChevronTexaco and ConocoPhillips to UC Oil, Berkeley. Synchrotron images of Fontainebleau sandstone were provided by Schlumberger.