Integrated, Multi-Scale Characterization of Imbibition and Wettability Phenomena Using Magnetic Resonance and Wide-Band Dielectric Measurements

DE-FC26-04NT15518

Goal

The objectives of the project are to develop methods for obtaining realistic configurations of two immiscible fluids as a function of wettability and geologic characteristics, and to use these fluid configurations as a basis for predicting and explaining macroscopic (core-scale) behavior, including the relationships among relative permeability, wettability, and laboratory and log measurements of nuclear magnetic resonance (NMR) and broadband dielectric response. The ultimate objective is to measure dielectric and NMR responses in a range of sedimentary rocks and to use state-of-the-art multi-scale modeling to interpret these measurements to quantify wettability and relative permeability at the core and log scales.

Performers

University of Texas-Austin
Austin, TX

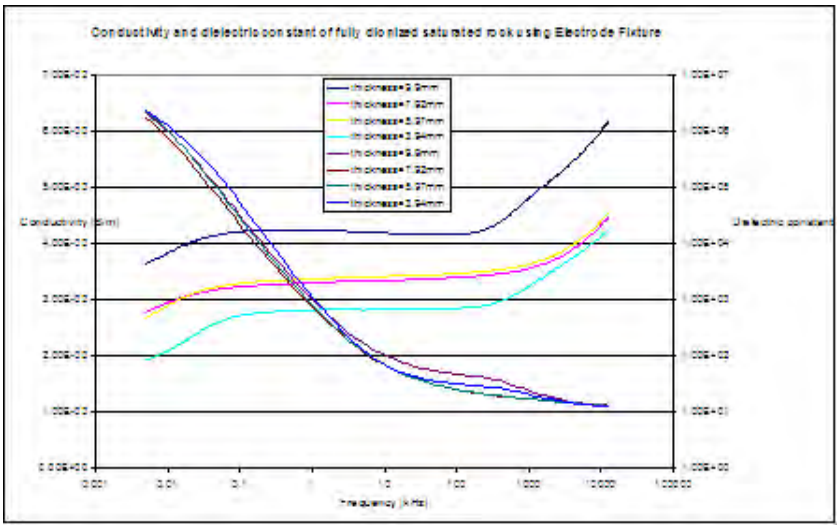
Rice University
Houston TX

Results

A draft of a thesis was completed that summarizes the results from the wide-band dielectric measurements (complex conductivity and permittivity). This thesis presents complex permittivity spectra for different rock samples as a function of grain size, salinity, and water saturation. In addition, six different measurement techniques are evaluated and results presented.

A PhD dissertation summarizing pore-scale numerical simulations of NMR and DC electrical resistivity in clastic rocks was completed. Results from the dissertation are planned to be presented at upcoming SPE meetings.

Rice University completed NMR measurements on different core plugs to compare with the dielectric measurements made at UT. An effort to combine these two sets of measurements is currently underway.



Conductivity and dielectric constant of fully water-saturated Berea sandstone with varying core sample thickness.

Benefits

This project brings together several advanced technologies for better interpretations of laboratory and wireline data to obtain petrophysical properties. New NMR techniques and dielectric measurements results in more accurate and less uncertain estimates of hydrocarbon saturations and rock flow properties. Advanced modeling of NMR and dielectric response for the first time brings a microscopic justification for the effective-medium response of complex rock formations. This effective-medium response provides new ways to quantify types of fluids and their saturation in complex pore structures. Finally, the project performers will interpret laboratory and field measurements in terms of physically representative models of the processes that form sedimentary rocks. The latter, recently demonstrated, approach offers an unprecedented capability method for quantitatively and predictively linking grain-scale geometry and surface chemistry to core-scale behavior.

Background

The project was initiated in 2004 as a joint effort between the University of Texas and Rice University. A lack of measurements and pore-scale understanding and the opportunity of combining two measurements, NMR and dielectric response of rocks, led to the formation of this team.

Summary

Project researchers have:

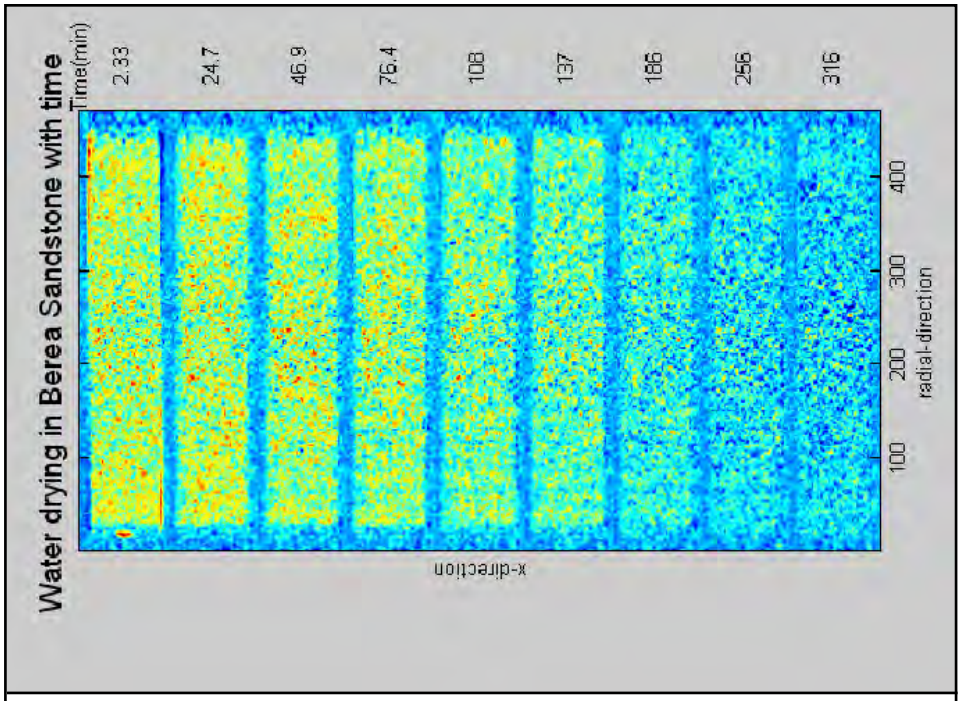
- Completed an MS thesis that presents new data on the dielectric properties of rocks. It also details six different measurement techniques for dielectric measurements on brine-saturated rocks.
- Completed a PhD dissertation that presents a general method to compute the electrical and NMR response of porous media, given the pore structure and wettability (fluid distribution).
- Made NMR measurements on core samples
- Undertook an ongoing effort to combine NMR results with dielectric measurements.

Current Status (December 2006)

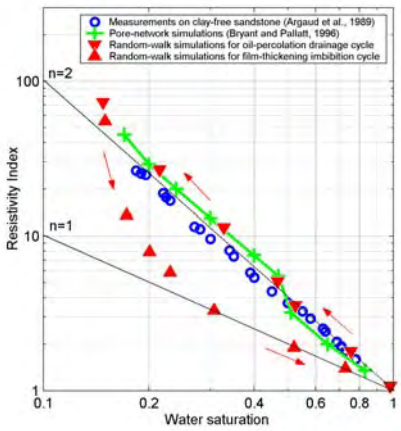
The project was initiated in October 2004 and is in its third year (of a 3-year project).

Funding

This project was selected in response to DOE's Oil Exploration and Production, Reservoir Efficiency Processes, Solicitation DE-PS26-04NT15450-3A, February 2, 2004.



CT scan of Berea sample saturation profile.



Evolution of resistivity index during primary drainage on a 20 p.u. clean water-rock rock: measurements performed on clay-free sandstones, pore-network simulation results with cemented Finney pack neglecting thin-film conduction, and random-walk simulation results carried out on the same ideal pack but allowing thin-film conduction. The imbibition cycle simulated for this pack also exhibits hysteresis.

Publications

Toumelin, E., and Torres-Verdín, C., "Influence of oil saturation and wettability on rock resistivity measurements: a uniform pore-scale approach" (expanded abstract), Society of Petrophysicists and Well Log Analysts 46th Annual Logging Symposium, New Orleans, LA, June 26-29, 2005.

Toumelin, E.l. Torres-Verdín, C., and Bona, N., "A new pore-scale framework for the simulation and interpretation of wide-band dielectric measurements (Expanded Abstract): Society of Core Analysts 19th International Symposium, Toronto, Canada, August 21-25, 2005.

Toumelin, E., Torres-Verdín, C., and Bona, N., "Improving the petrophysical assessment of rock-fluid systems with wide-band electromagnetic measurements" (expanded abstract), Society of Petroleum Engineers 2005 Annual International Meeting, Dallas, TX, October 9-12, 2005.

Project Start: October 1, 2004
Project End: September 30, 2007

Anticipated DOE Contribution: $797,685
Performer Contribution: $395,626 (33 percent of total)

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