Multiphase Fracture-Matrix Interactions Under Stress Changes

DE-FC26-01BC15355

Program
This project was selected in response to DOE Oil Exploration and Production solicitation DE-PS26-04NT15450-3B, with a focus on Enhanced Oil Recovery. One goal of the solicitation was to promote understanding of fractures and methods for increasing oil recovery

Project Goal
The main objective of this project is to quantify the changes in fracture porosity and structure and multi-phase transport properties, including fracture-matrix interactions, as a function of confining stress. Extensional and shear fractures are considered.

Performer
Pennsylvania State University
University Park, PA

Project Results
The project achieved the ability to map in three dimensions the distribution of oil and water in a fracture and relate that distribution to effective permeability at various fractional flows—including hysteresis effects—and to fracture-matrix interaction.

Benefits
The results provide new understanding of two-phase flow in fractures, including fracture-matrix interactions, and should improve modeling of fluid transport in fractured formations.

Background
The main driver for the project is the great need to accurately model and optimize transport in fractured systems, in order to improve industry's limited understanding of the detailed physics of these transport phenomena.

Project Summary
Among the project's achievements:

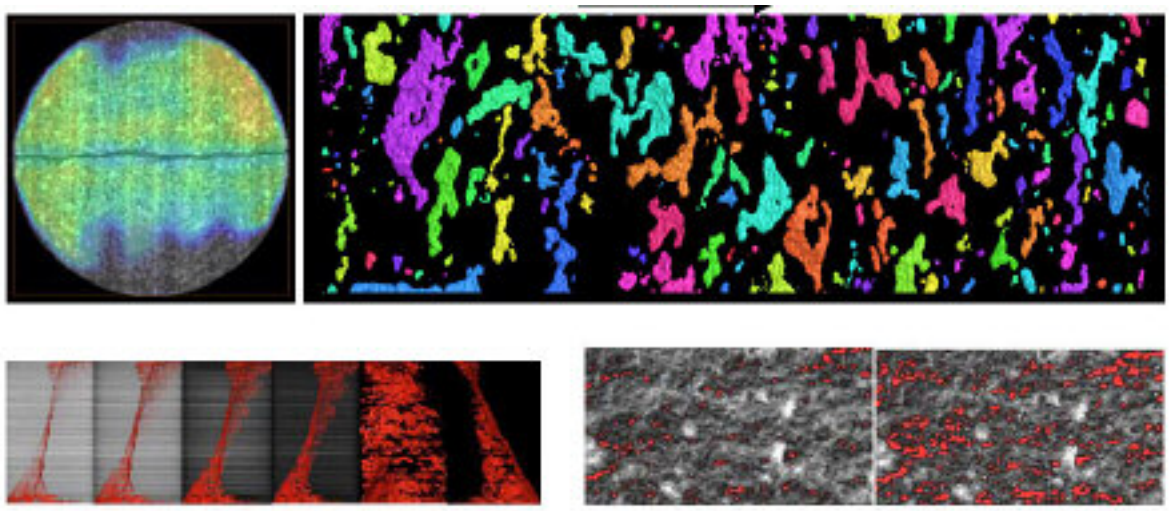
- Fracture topoplogy was obtained using x-ray computed tomography (CT) to include fracture surfaces, fracture volume, and structural relation to the matrix.

- Oil and water occupancy in the fracture was measured by CT and related to effective permeabilities of the two phases.

- Counter-current imbibition between the fracture and the matrix was documented and quantified and shown to be significant and rapid.

- Effects of changing confining stress on fracture properties have been quantified, including the changes in occupancy and transport of oil and water. Significant differences in oil-water occupancies in shear fractures parallel and perpendicular to bedding were observed.

Current Status (August 2005)
The project is proceeding under a 1 year, no-cost extension and will be completed by Sept. 20, 2005.



Water imbibing from fracture, top left. Disconnected oil globs within the fracture at residual oil saturation, top right. Three-dimensional renditions of a shear fracture in a layered sample, bottom. Fracture asperities (red) at 500 psig (left) and 2,500 psig (right).

Publications

Seven semi-annual reports to DOE. Two MSc and two PhD theses.

Karpyn, Z., Alajmi, A., Parada, C., Grader, A., Halleck, P., and Karacan, O., Mapping Fracture Apertures Using Micro-Computed Tomography, The Society of Core Analysis 2003 International Symposium, Pau-France. SCA2003-50, p. 575-580.

Nazridoust, K., Ahmadi, G., Karpyn, Z., Grader, A., Halleck, P., Mazaheri, A., and Smith, D., Single-Phase and Multi-Phase Fluid Flow through an Artificially Induced, CT-Scanned Fracture, 15th International Conference on Computational Methods in Water Resources, June 13-17, 2004, Chapel Hill, NC.

Karpyn, Z., Alajmi, A., Radaelli, F., Halleck, P.M., and Grader, A.S., A Correlation between Fracture Apertures and Properties of the Surrounding Layered Sandstone Matrix, 32nd International Geological Congress, Aug. 20-28, 2004, Florence, Italy.

Mohammed, N., Al Enezi, S., Halleck, P. M., Elsworth, D., and Grader, A. S., Effects of Bedding Plane Orientations on Two-Phase Flow in Shear Fractures. Eos Trans. AGU, 85(47), Fall Meeting Supplement, Abstract H11B-0300, 2004.

Karpyn, Z., Halleck, P. M., Grader, A. S., and Elsworth, D., Dynamic Micro-CT Study of Fracture-Matrix Flow during Capillary Imbibition in Layered Berea Sandstone. Eos Trans. AGU, 85(47), Fall Meeting Supplement, Abstract H11B-0297, 2004.

Karpyn, Z. T., Grader, A. S., and Halleck, P.M., Characterization of two-phase fluid residence inside a fracture with variable aperture, in preparation for GRL, 2005.

Karpyn, Z. T., Halleck, P.M., and Grader, A.S., Fracture-matrix transport dominated by capillary-driven flow in layered sandstone, Water Resources Research, submitted for review (2005WR004371), 2005.

Project Start: September 21, 2001
Project End: September 20, 2005

Anticipated DOE Contribution: $439,887
Performer Contribution: $110,154 (25% of total)

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