Geomechanics for Reservoir Management

FEW 4365

Program

This project was funded through DOE's Natural Gas and Oil Technology Partnership Program. The Partnership Program establishes alliances that combine the resources and experience of the nation's petroleum industry with the capabilities of the national laboratories to expedite research, development, and demonstration of advanced technologies for improved natural gas and oil recovery.

Project Goal

The project goal is to develop an improved understanding and tools for the management of reservoirs. The geomechanics approach to the characterization, stimulation, and production of oil reservoirs involves the characterization of natural fracture systems, the measurement of in situ stress, the development of an understanding of the evolution of stress state with reservoir production, and the determination of the mechanical and transport properties of reservoir rocks and fracture systems and how those properties change with the evolving stress state.

Performers

Sandia National Laboratories
Albuquerque, NM

Project Results

The major results from this project are in three areas:

- New methods were created for characterizing fracture systems and understanding their effect on reservoir production.

- Through the development and exploitation of new experimental techniques for imaging pores in rock, researchers developed computational methods to simulate how fluids (single-phase, and multi-phase) move through the pore network (or are trapped in pores).

- Project performers discovered and demonstrated the potential effect of localized compaction zones on reservoir production resulting from changes in stress as the reservoir is produced.

Benefits

The benefits resulting from this work are many. It has resulted in several partnerships with industry (most notably, with BP, Phillips, ExxonMobil, BHP, Chevron, Conoco, Halliburton, and Unocal) to support the development and implementation of methods that have significantly reduced drilling and production costs in the Gulf of Mexico. The project efforts also have resulted in the elucidation of phenomena, such as the formation of compaction bands, that can be demonstrated to have potentially significant effects on long-term reservoir production, if not addressed through careful production planning and management. This fundamental work also has spawned numerous research efforts at technical institutions and universities across the country to better understand the conditions leading to the formation of heterogeneous compaction or shear states. Related efforts to assist production companies in the Gulf of Mexico has led to drill hole stabilization methods saving millions of dollars.

Background

Reservoirs are dynamic systems that are constantly changing during their production history. Primary hydrocarbon production of a reservoir will reduce the pore pressure, increase the effective stresses and alter the formation permeability and fracture flow characteristics. Improving reservoir management requires the characterization of reservoir fracture networks, meaningful mechanical property and permeability data that are obtained under realistic reservoir conditions, and an improved capability to integrate coupled mechanical-fluid flow effects into reservoir production models.

The key elements in the application of this geomechanics approach to the characterization, stimulation, and production of oil reservoirs are the characterization of natural fracture systems, the measurement of in situ stress, an understanding of the evolution of stress state with reservoir production, and the determination of the mechanical and transport properties of reservoir rocks and fracture systems and how those properties change with the evolving stress state.

Field example of localized deformation preventing fluid movement.

Project Summary

Recent work entails:

- The development of methods to better characterize and understand the effects of fracture systems on production. These include the modeling of stresses and resulting fractures within sinuous reservoirs, comparison of the model results with the empirical field observations, and an assessment of the optimum methods of exploiting the anisotropic drainage caused by fracturing within such reservoirs; and the comparison of outcrop fault and fracture patterns with recently acquired seismic data over the Teapot Dome, as well as the construction of a model predicting spatial variations in fracture orientations and intensities around such structures.

- New experimental techniques to image and model fluid flow through rock pores, such as 3-D imaging and geometry analysis using newly developed laser confocal microscopy (a complete model of the solid and pore space in a small cube of rock at 1 micron resolution can be created); algorithms to artificially generate 3-D porous media based on observed and/or contrived pore geometries; and modeling of flow through highly detailed model materials using multiphase flow theory and Lattice Boltzmann algorithms, revealing details of the effects of pore geometry on effective permeability and flow.

- Elucidation and demonstration of the formation of heterogeneous compaction (compaction bands) in porous rock and the potential effects on reservoir production. Specifically, researchers performed extensive assessments of the mechanical properties (porosity, modulus, cementation) and the boundary conditions (stress magnitudes

and anisotropy, pore pressures) that can lead to the formation of compaction bands. Formation of compaction bands could lead to destructive compartmentalization of reservoirs. If such conditions and properties can be identified and successfully predicted, such reservoir conditions can be avoided.

Current Status (June 2005)

Althought the project was completed, related industry research on compaction bonding continues.

Laboratory experiment replicated field conditions and formation of compaction zones.

Publications

Cooper, S.P., Lorenz, J.C., and Goodwin, L.B., Lithologic and structural controls on natural fracture characteristics-Teapot Dome, Wyoming, Sandia National Laboratories Technical Report, SAND2001-1786, 2001.

DiGiovanni, A. A., Fredrich, J. T., Holcomb, D. J., and Olsson, W. A., Micromechanics of Compaction in an Analogue Reservoir Sandstone, Pacific Rocks 2000, Girard, Lieberman, Breeds and Doe (eds), Balkema, Rotterdam, pp. 1153, 2000.

Lorenz, J.C., Sterling, J.L., Schecter, D.S., Whigham, C.L., Jensen, J.L., Natural Fractures in the Spraberry Formation, Midland Basin, TX: The Effects of Mechanical Stratigraphy on Fracture Variability and Reservoir Behavior, American Association of Petroleum Geologists Bulletin, v. 86, p. 505-524, 2002.

Lorenz, J.C., and Cooper, S.P., Interpreting Fracture Patterns in Sandstones Interbedded with Ductile Strata at the Salt Valley Anticline, Arches National Park, Utah, Sandia National Laboratories Technical Report, SAND2001-3517, 2001.

Olsson, W. A., and Holcomb, D.J., Compaction localization in porous rock, Geophysical Research Letters, v. 27, 3537-3540, 2000

Olsson, W. A., Theoretical and experimental investigation of compaction bands in porous rock, J. Geophys. Res., 104, 7219-7228, 1999

Olsson, W. A., Quasistatic propagation of compaction fronts in porous rock, Mechanics of Materials, 33, 659-668, 2001.

Holcomb, D. J., and Olsson, W. A., Compaction localization and fluid flow, J. Geophys. Res., 2002.

Olsson, W. A., Origin of Luders bands in deformed rock, J. Geophys. Res., v. 105, pp. 5931-5938, 2000.

Olsson, W. A., Lorenz, J.C., and Cooper, S.P., A Mechanical Model for Multiply Oriented Conjugate Deformation Bands, J. Structural Geology, v. 26, 325-338, 2004.

Project Start: October 1, 1991
Project End: April 15, 2004

Anticipated DOE Contribution: $3,660,000
Performer Contribution: $340,000 (8.5% of total)

Contact Information

NETL – Paul West (paul.west@netl.doe.gov or 918-699-2035)
SNL – Laurence Costin (lscosti@sandia.gov or 505-844-3367)