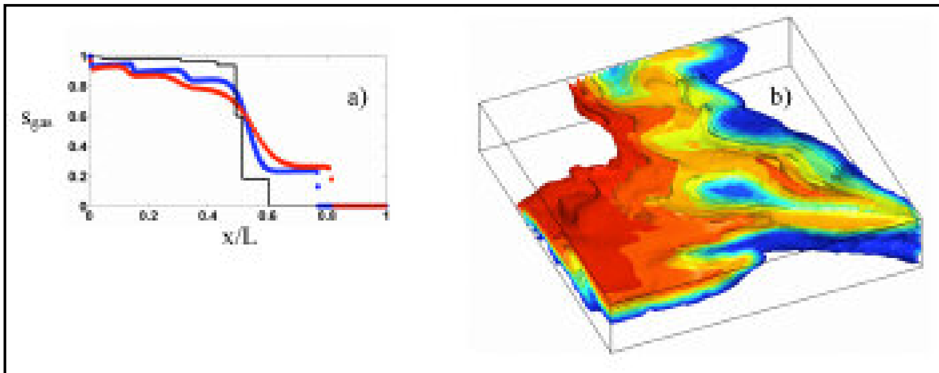
High Resolution Production of Gas Injection Process Performance for Heterogeneous Reservoirs

DE-FC26-00BC15319



Shown are a) 1-D accuracy for transport along streamlines and b) 3-D multicomponent displacement calculation.

Program
This project was selected in response to DOE's Oil Exploration and Production solicitation DE-PS26-01NT41048 (focus area: Gas Flooding). The goal was to improve understanding of three-phase flow and demonstrate improved methods to predict the performance of gas injection processes in heterogeneous reservoirs.

Project Goal
The objectives of the research were to develop a new set of ultra-fast reservoir simulation tools for the prediction of interactions of phase behavior of complex oil and gas mixtures with flow in heterogeneous reservoirs.

Performer
Stanford University
Stanford, CA

Project Results
A three-dimensional (3-D), streamline-based compositional simulator was developed. It allows assessment of the performance of gas displacement processes using numerical or analytical solutions for multicomponent displacement along a streamline in combination with high-resolution representation of heterogeneities in the calculation of streamline locations. The resulting predictions of process performance are more accurate than conventional finite-difference compositional simulations and can be obtained in a fraction of the computation time. There is still much work to be done to make compositional streamline methods a fully functional reservoir simulation tool.

Benefits
The computational technique developed allows accurate analysis of gas injection processes at field scale. Conventional compositional simulation is too slow to allow such analysis at field scale; hence the results of this project make possible detailed process performance predictions that could not be done before.

Background
High-pressure gas can displace oil and gas relatively efficiently in subsurface formations if displacement conditions are selected appropriately. The projects fundamental objective was to understand the physical mechanisms that control displacement performance in gas injection processes and to use that understanding to develop efficient and accurate computational tools for prediction of project performance at field scale.

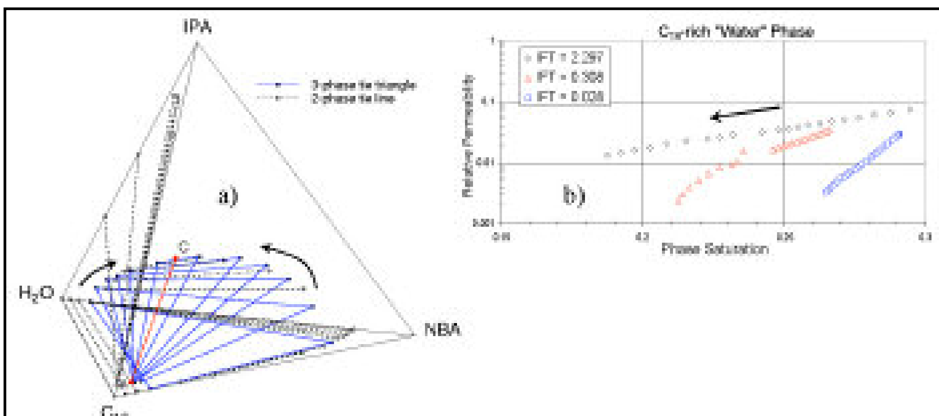
Project Summary
The project entailed four main lines of research: 1) efficient compositional streamline methods for 3-D flow, 2) analytical methods for one-dimensional displacements, 3) physics of multiphase flow, and 4) limitations of streamline methods.

In the first area, results were reported that show how the streamline simulation approach can be applied to simulation of gas injection processes that include significant effects of transfer of components between phases. In the second area, the one-dimensional theory of multicomponent gas injection processes was extended to include the effects of volume change as components change phase and an automatic solution algorithm was developed.

In the third area an extensive experimental investigation of three-phase flow was performed. The experimental results demonstrate the impact on displacement performance of the low interfacial tensions between the gas and oil phases that can arise in multi-contact miscible or near-miscible displacement processes. In the fourth area, the limitations of the streamline approach were explored.

The results establish that it is possible to use the compositional streamline approach in many reservoir settings to predict performance of gas injection processes. When that approach can be used, it requires substantially less (often by orders of magnitude) computation time than does conventional finite-difference compositional simulation.

Current Status (October 2005)
The results of this project are being applied in current research to investigate storage of carbon dioxide emissions in aquifers and



Shown are a) three-phase analog system for determination of relative permeability and b) interfacial tension variation and relative permeability.

coal beds. Building on the expertise gained in this project, project performers now are designing a high-performance industrial compositional streamline simulator (CSLS). The development of a CSLS is being supported by a new DOE cooperative agreement (NT15530).

Publications

"High-Resolution Prediction of Gas Injection Process Performance for Heterogeneous Reservoirs," Prepared for the U.S Department of Energy Under Grant No. DE-FC26-00BC15319. Principal Investigator: Franklin M. Orr Jr., Department of Petroleum Engineering, Stanford University.

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Jessen, K., Stenby, E.H. and Orr, F.M. Jr., "Interplay of Phase Behavior and Numerical Dispersion in Finite Difference Compositional Simulation," SPE Journal, 9(2), pp. 193-201, (2004).

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Berenblyum, R.A., Shapiro, A.A., Jessen, K., Stenby, E.H., and Orr, F.M. Jr.:,"Black Oil Streamline Simulator with Capillary Effects", SPE 84037, SPE ATCE, October 5-8, 2003, Denver, CO.

Project Start: September 1, 2000
Project End: February 29, 2004

Anticipated DOE Contribution: $1,107,062
Performer Contribution: $276,765 (20% of total)

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