Origin of Scale-Dependent Dispersivity and Its Implications for Miscible Gas Flooding

DE-FC26-03NT15534

Goal

The objectives of this project are to perform a novel fundamental study of the mechanism of dispersion, to develop an improved multiscale statistical model of dispersion, and to use this advance in understanding to optimize field-scale displacements.

Performers

University of Texas-Austin
Austin, TX

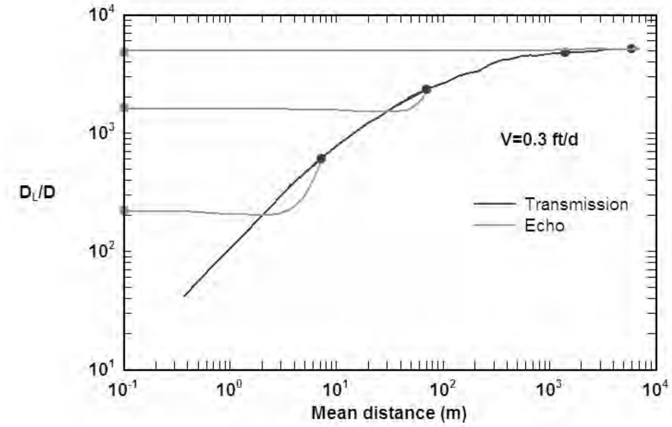
University of California
Merced, CA

Results

The simulation studies show that the echo test in parallel layers is scale-dependent when there is transverse flow between layers. Local transverse mixing decreases with distance in the flow direction until it reaches a constant value. The initial transverse dispersion value is influenced by the injection source, and transverse dispersion becomes approximately constant as traveled distance increases. In the case of zero diffusion in pore-scale simulations, local mixing would be reversible when flow is at a low Reynolds number. 3-D simulation of dispersion in porous media shows that measured dispersivity is greater than 2-D under the same condition because of greater surface contact between fluid and grains in 3-D simulation. Particle tracking simulations of tracer dispersion in layered flow shows that diffusion, aided by convection, results in enhanced levels of spreading. Pure convection can also cause such spreading, but it can be distinguished from dispersive mixing by observing the change in spreading on flow reversal. Purely convective spreading is completely reversible, whereas dispersive spreading is not.

Benefits

This project is developing improved models and simulators to establish a better grasp of the parameters that control optimal performance in miscible and near-miscible displacements. This capability will also enable better translation of laboratory results to field projects.



Evolution of normalized dispersion coefficient with mean distance travelled in transmission(forward flow) and echo (reverse flow) directions for tracer injected in a layered flow field. Disperison coefficient slowly increases and reaches an asymptotic limit at which spreading is irreversible. Reversed flow (Echo) dispersion values increase with penetration distance. Diffusion coefficient (D) is 1E-9 m2/s.

Background

The ultimate oil recovery efficiency from carbon dioxide (CO_2) injection is low. The CO_2 utilization rate—the amount of CO_2 injected to recover a barrel of oil—is high. The performance of a CO_2 process is strongly influenced by hydrodynamic dispersion, but the appropriate level of dispersivity to use at the scale of reservoir simulation is largely unknown. That ispersivity increases with scale (travel distance) has been known for more than 30 years. There is substantial ambiguity about what causes the scale dependence. Part of the work being proposed here is to investigate the scale dependence downward—from the core or column scale to the pore scale—as opposed to upward, as has been done previously. This approach has never been tried as part of an effort to understand the fundamental mechanism of dispersion.

Summary

Based on the laboratory scale dispersivity data and the knowledge of numerical simulation and reservoir heterogeneity, the project performers plan to upscale dispersivity from laboratory scale to reservoir simulation scale. Understanding the nature of spreading is necessary to correctly represent transport in mathematical modeling. Flow reversal (Echo) tests performed at the field scale would indicate actual levels of dispersive mixing.

The project researchers:

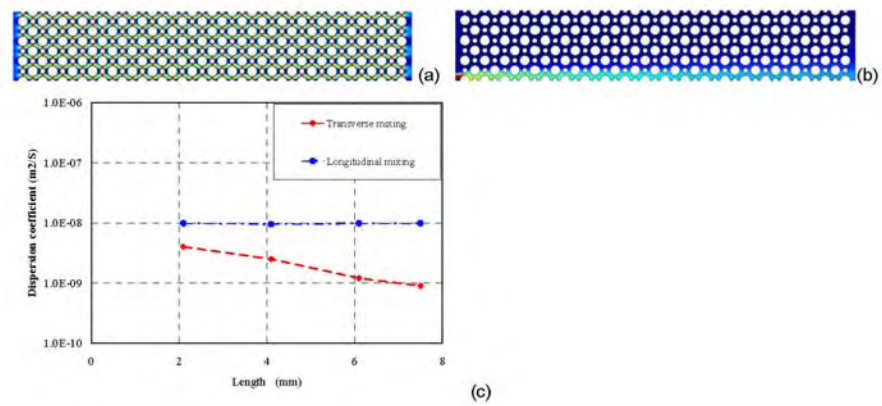
- Demonstrated the difference between convective and dispersive spreading by means of particle tracking simulations and the use of flow reversal (echo) tests to identify the nature of transport.
- Found that dispersivity is a scale-dependent property when transverse flow exists between layers in layered porous media.
- Found via pore-scale simulations that solute transport through porous media is irreversible for high Reynolds numbers

Current Status (February 2007)

The project is midway through the third year. Milestones have been met as scheduled.

Funding

This project was selected in response to DOE's Office of Fossil Energy Research and Development solicitation DE-PS2604NT15450-3F.



Shown are the a) velocity profile b) concentration profile, and c) calculated transverse and longitudinal dispersion for 2-D homogeneous porous media. Transverse mixing decreases as moving forward in the flow direction until it reaches to a constant value.

Publications

Jha, R.K., John, A.K., et al. (2006). Flow reversal and mixing. 2006 SPE Annual Technical Conference and Exhibition. San Antonio, Texas, U.S.A, Society of Petroleum Engineers.

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

DOE Contribution: $800,000
Performer Contribution: $200,000 (20 percent of total)

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