Saturations of Migrating Buoyant Fluids from Invasion Percolation Flow Simulation Using Small-Scale, High-Resolution Geologic Models With Realistic Heterogeneity*

Timothy A. Meckel†, Luca Trevisan‡, and Prasanna Krishnamurthy§

Search and Discovery Article #51409 (2017)**
Posted August 7, 2017

*Adapted from oral presentation given at AAPG 2017 Annual Convention and Exhibition, Houston, Texas, April 2-5, 2017
**Datapages © 2017 Serial rights given by author. For all other rights contact author directly.

1Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, United States (tip.meckel@beg.utexas.edu)
2Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, United States
3Center for Petroleum and Geosystems Engineering, The University of Texas at Austin, Austin, Texas, United States

Abstract

This study addresses the influence of lithologic heterogeneity at the sub-meter scale on the flow of buoyant fluids for different types of clastic sedimentary architectures from representative depositional environments. To adequately represent 3D heterogeneity, we present innovative techniques for generating digital models that combine a well-documented deterministic and descriptive bedform architecture component mimicking realistic crossbedding geometries with stochastic variability of petrophysical properties. One advantage of this approach is that it allows consideration of domain sizes larger than whole core and core plugs typically used for laboratory flow experiments, where small sizes may not fully capture depositional architecture. The main contribution of this study is the development of a predictive model for saturation estimation based on a comprehensive, yet simplified, set of geological models resembling a range of well-characterized and documented fluvial clastic facies. Basic geological features such as grain size distribution and sedimentary bedform architecture can be used to predict the fluid saturation during capillary/buoyancy-dominated flow conditions. These models are unique in regard to their geological realism and permit evaluation of the impact of sub-meter scale capillary heterogeneity on buoyant fluid flow scenarios that are relevant to petroleum migration, residual saturations (ROZ), and CO₂ flow. The digital models themselves expand characterization opportunities using a number of methods, including upscaling, connectivity, and bulk property anisotropy. Saturation results from simulations of small-scale domains can be used to benchmark expected values in larger reservoir scale domains.

Selected References


Saturations of Migrating Buoyant Fluids From Invasion Percolation Flow Simulation Using Small-Scale, High-Resolution Geologic Models With Realistic Heterogeneity

Tip Meckel, Luca Trevisan, Prasanna Krishnamurthy
The University of Texas at Austin

Acknowledgement is made to Landmark Software and Services, a Halliburton Company, for access to Permedia software.
• Understand the processes of capillary/buoyancy-dominated flow.
  • Hydrocarbon secondary migration; CO₂ injection; ROZ.
• Quantify the influence of meso-scale clastic heterogeneity on saturation.
• Predict saturations based on fundamental properties of geology and fluids.
  • Grain size distribution, sedimentary architecture, fluid density contrast
Presenter’s notes: Forces controlling flow – triangle
High inertia = high reynold’s number, non-laminar flow, Navier-Stokes approximations.
Bottom of triangle represents tow end members of viscosity and capillary dominated flow.
Transition from capillary to viscous around Ca ~ E-04 (England, 1987) – have more to say about Ca in next slide.
Go through two formalisms: different conceptualizations of important factors controlling flow at different scales – differ in importance put on capillary forces.
England cutoff: At E-04, capillary forces to viscous forces are 10,000:1; what is behind this cutoff??
For this reason, IP thought of as only representing ‘slow’ (i.e. migration) behavior.
Realistically, this flow can take place quite quickly as has been demonstrated in lab experiments.
Geologic Models with Realistic Heterogeneity

1) Generate 3D fabrics & Convert to 3D cellular cubes (binary).

2) Assign facies: $P_{th}$ distributions from facies ‘library’

3) 3D IP flow simulation:

Thousands of models simulate efficiently to define range of characteristic saturations.

Threshold pressure range: 6.1 kPa - 8.9 kPa

Physical model results

P$_{th}$ Distributions
54 textural classes - 25 facies combinations

Poorer grain sorting
decreasing grain size
Impact of capillary heterogeneity and bedform architecture on fluid saturation

Presenter’s notes: Now I’m going to show simulation results of 7 cases with different textural contrasts for the same sedimentary model
Impact of 3D capillary heterogeneity and bedform architecture at the sub-meter scale on CO2 saturation for buoyant flow in clastic aquifers

L. Trevisan\textsuperscript{a,}\textsuperscript{*}, P.G. Krishnamurthy\textsuperscript{b}, T.A. Meckel\textsuperscript{a}

\textsuperscript{a}Gulf Coast Carbon Center, Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA
\textsuperscript{b}Petroleum and Geosystems Engineering Department, The University of Texas at Austin, Austin, TX, USA

\[ 8 \times 40 \times 200 = 64,000 \text{ simulations} \]
Meter-scale sand tank visualizations

1st injection

homogeneous

heterogeneous
IP model of large heterogeneous sand tank

Hydrophilic silica sand: Granusil (angular)

Threshold pressure, kPa

0.05  1.5  2.1

#16  #20  #30

#50  #70  #110
IP model of large heterogeneous sand tank
IP model of large heterogeneous sand tank

Charge sequence

Capillary pressure, kPa

Early

Late

0.2

0.45
Ongoing work


Related poster: Beckham et al., Theme 7, Tuesday Morning


• Meckel, T.A., Krishnamurthy, P.G., Trevisan, L. A method to generate small scale, high-resolution 3D sedimentary bedform architecture models representing realistic geologic facies (under review).


Questions?

tip.meckel@beg.utexas.edu