Sandia National Laboratories

Flow Visualization and Processes Laboratory

Overview

The Flow Visualization and Processes Laboratory, or "Flow Lab," has developed over the past eight years at Sandia National Laboratory in response to the nation's need for solutions to applied problems in the subsurface environment. Located in Albuquerque, NM, it is a specially designed facility where Sandians and partners from universities, industry and other national labs apply unique capabilities to answer fundamental questions of flow and transport in porous and fractured media. In context of this collaboration, the Flow Lab supports an integrated basic research program that incorporates both experimentation in the field and laboratory with a variety of basic to applied modeling approaches that spans multiple applied problems, processes, media, and scales.

Multiple Applied Problems

- Flow and contaminant transport analysis, characterization and prediction
- Waste repository performance assessment and design
- Oil and gas reservoir stimulation and secondary/tertiary recovery
- Contaminated zone remediation
- Design of surface and subsurface barriers

Multiple Processes

- Single to multiphase (liquids, gases) flow/transport
- Multi-component (solutes, colloids, energy) flow/transport
- Bioturbation and microbial transport/attachment

Multiple Media

Field

- Fractured glacial till
- Alluvial deposits
- Fractured rock

Laboratory

- Large undisturbed field samples and core
- Engineered granular porous media
- Individual fractures and fracture networks
- Micromodels

5000 Square-Foot High Bay Lab

Sandia is a multiprogram laboratory operated by Sandia corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

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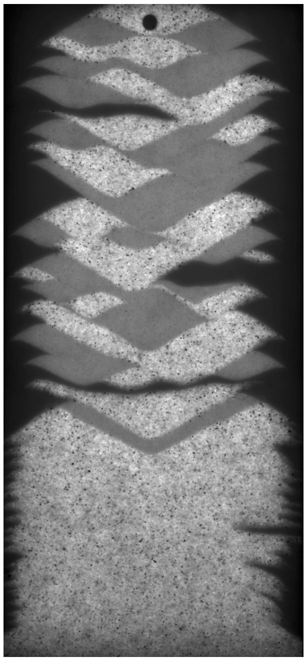
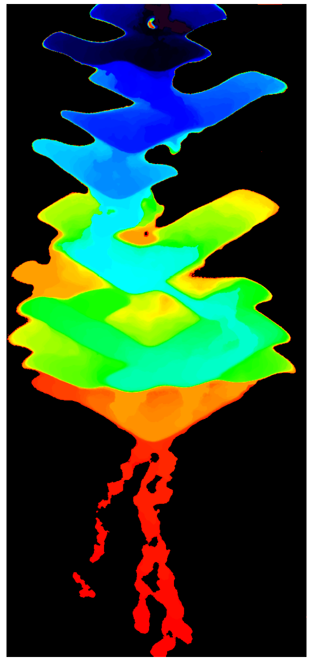


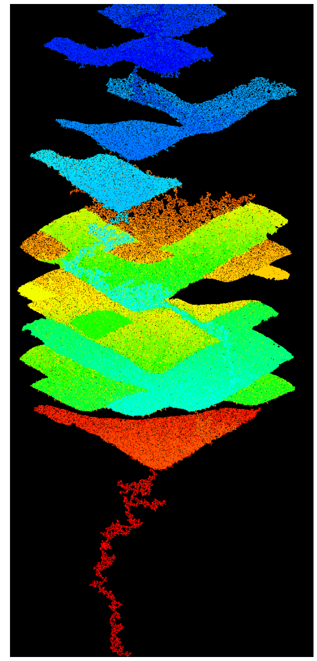
HETEROGENEOUS DESIGNED MEDIA

Thin sand slab (30x60x1cm thick) is packed using a computer controlled apparatus to yield a reproducible and controlled heterogeneity structure.



PHYSICAL EXPERIMENT

Transmitted Light Imaging is used to measure TCE invasion in time (blue-green-yellow-red sequence depicts invasion in time).



NUMERICAL SIMULATION

TCE invasion is predicted using an upscaled invasion percolation model (UIP). UIP requires only estimates of unit invasion pressures obtained from unit pore size distributions.

Research Approach

Across a wide variety of problems, researchers couple experimentation and conceptual modeling to develop flow and transport process understanding. Unique experimental capabilities at the Flow Lab span from "full field" energy transmission techniques that yield 2-D images of phase saturation and concentration fields during experiments to multiple sensor arrays for measurement of state variables at hundreds of points in field tests. Modeling capabilities span from traditional continuum models to Invasion Percolation and Lattice Gas Automata approaches. An example of the research approach is our study of Dense Non-Aqueous Phase Liquid (DNAPL) migration in heterogeneous porous media (see above). For this problem, traditional models based on continnum mechanics applied to conditions of two-phase flow are both parameter and computationally intensive. However, an entirely different appoach to modeling based on modifications of Invasion Percolation Theory developed at the Flow Lab shows successful prediction of experimental results. This Upscaled Invasion Percolation model or UIP is currently being applied at the field scale and integrated into an optimal approach for characterizing subsurface DNAPL contamination in the field - one of the most important contaminant problems of the industrial world.

Recent DOE Sponsors

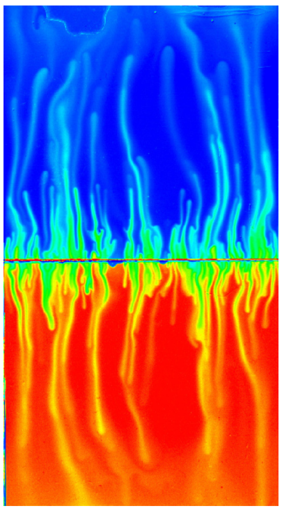
- Basic Energy Sciences (BES)
- Environmental Management Science Program (EMSP)
- Yucca Mountain Project (YMP)
- Waste Isolation Pilot Plant (WIPP)
- International Program of the Office of Civilian Radioactive Waste Management (IP-OCRWM)
- Sandia Laboratory Directed Research and Development (LDRD)
- Sandia Environmental Restoration Program (ER)
- Uranium in Soils Integrated Demonstration Project (UID)
- Oil and Gas Partnership Program (OGP)
- EPSCoR Traineeship Program (EPSCoR)

The Flow Lab Group

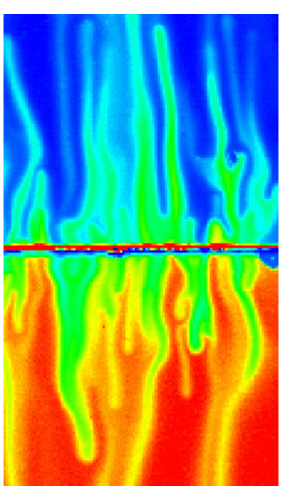
Intrinsic to the effective operation of the Flow Lab is the blending of students, technicians, and researchers from a variety of institutions to create a fertile, highly creative, research environment. High school and undergraduate students (15-20) from both local institutions (University of New Mexico and New Mexico Tech) as well as from National Fellowship programs funded by the DOE, participate in Flow Lab research throughout the year. Graduate students (5-10) from both local universities and from across the country conduct research leading to advanced degrees (MS and PhD) with researchers at the Flow Lab. A core group of technicians (4) work full time to support the facility and continue development of new measurement techniques and capabilities.

Sandians include: Robert Glass, Vincent Tidwell, Stephen Conrad, Will Peplinski, Bob Holt, Scott Pringle, Mehdi Eliassi, Lee Orear, Craig Boney, Jim Brainard, Kristine Smith, Lucy Meigs, David Alumbaugh, Christopher Rautman, Harlan Stockman, Lane Yarrington, Susan Altman, Steve Webb, and Eric Webb.

Flow Lab Collaborators include: John Wilson, Alan Gutjahr (NMTech); Scott Tyler, Clay Cooper, Stephen Wheatcraft (DRI/UNR); Michael Nicholl (OSU); Hari Rajaram, Russ Detwiler, Hartmut Spetzler (UC); Jim Yeh, Douglas LaBrecque (UA); Bruce Thompson, Michael Campana (UNM); Robert Burlage (ORNL); John Gale (U of Newfoundland); Mark Parker (Halliburton); Alex Mayer, Lirong Zhong (Michigan Tech); Jiamin Wan, Tetsu Tokunaga (LBL); Linda Abriola (U of Michigan); Ann Carey (U of Alabama); Jim McCord (DBS); Karsten Jensen (Technical University of Denmark).



Multicomponent convection in a 10x20cm Hele-Shaw cell imaged with the Transmitted Light Imaging System. The gravity stabilized case of a lighter solution (blue) overlying a denser (red) solution develops fingers because the solute in the top fluid has a smaller diffusion coefficient than the solute in the bottom fluid. A blowup of a region of the cell is shown below.



Laboratory Capabilities

- Experimental design with systematic variation of system parameters, boundary, and initial conditions and system length scales from centimeters to several meters
- Fabrication of controlled property analog media, micromodels, fractures
- High spatial and temporal resolution state variable measurement for phase saturation, solute concentration, temperature, and pressure
- High spatial resolution property field measurement and estimation of fracture aperture fields, porous media porosity fields, and permeability and capillary property fields
- Standard and very low permeability single and two-phase flow property measurement
- Automated experimental control and data acquisition

Field Capabilities

- Large multiplexed arrays of sensors for measurement of moisture content (TDR), temperature (thermocouples), pressure/tension (transducers) and solute concentration (TDR)
- Crosshole ground penetrating radar (GPR)
- 3-D electrical resistence tomography (ERT)
- Standard Neutron and Gamma logging
- Photovotaic systems for remote tests
- Standard vadose zone property measurement
- Portable weather stations

Numerical Simulation Capabilities

- Standard single/multiphase flow and transport
- Massively parallel single/multiphase flow and transport
- 2-D hysteretic unsaturated flow
- Standard and unique geological simulation (geostatistical to process)
- Unique 3-D modified Invasion Percolation for application from pore to formation scales
- Lattice Gas (Cellular Automata) for single and two-phase flow/transport

Lab Facilities

A 15,000 square-foot facility with:

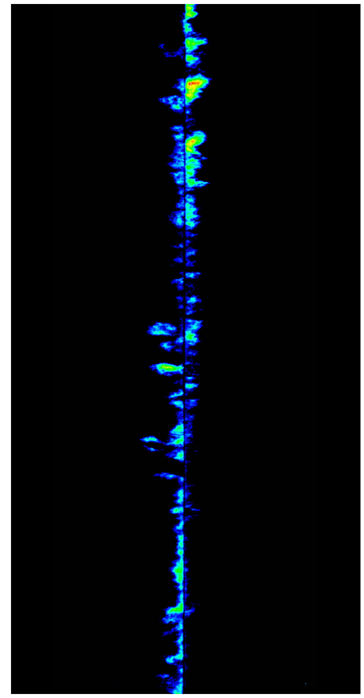
- Computational/data visualization lab
- Sample preparation and wet lab
- Standard saturated and unsaturated and low permeability single and two-phase hydraulic properties measurement lab
- Fracture flow and transport lab
- Heterogeneous porous slab single/multiphase flow and solute transport lab
- DNAPL and other hazardous chemical transport lab
- X-ray flow /transport visualization lab
- Field support/staging area
- Controlled sample storage
- Shop, Darkroom and Offices

Field Facilities

- Tijeras Arroyo Vadose Zone Facility (Alluvial Fan deposits)
- SNL/NMTech Vadose Zone Facility (Ancestral Rio Grande Alluvial Deposits)

Recent Research Projects, Sponsors, and Investigators

- Large-Scale Transport Pathway Process Delineation within Unsaturated Heterogeneous Alluvial Sediments (ER) *Glass, Brainard, and McCord*; Fractured Glacial Till (UID) *Glass, Roepke, and Brainard*; and Fractured Tuff (YMP) *Glass and Nicholl*
- Multi-Component Convection in Porous Media and Fractures (BES, EPSCoR) *Glass, Tyler, Stockman, Cooper, and Pringle*
- Multi-component Diffusion in Porous Media(EPSCoR) *Carey, Glass, and Wheatcraft*
- Processes Affecting Removal of Propping Fluid after Hydro-fracturing Tight Gas Reservoirs (OGP) *Tidwell and Parker*
- Phase Evolution/Solution and Air Invasion Near Drift in Regionally Saturated Fractured Rock (IP-OCRWM) *Glass, Nicholl, and Gale*
- DNAPL Movement Through Water Saturated, Heterogeneous Porous Media (LDRD) *Conrad, Glass, and Peplinski*
- Physics of DNAPL Migration and Remediation in the Presence of Heterogeneities (EMSP) *Conrad, Glass, and Peplinski*
- Up-Scaling Percolation Models (pore to facies scale) for Immiscible Displacements (air, water, NAPLS) in Alluvial Deposits and Fractured Rock Formations (BES, YMP, LDRD) *Glass, Yarrington, and Conrad*
- Gravity-driven Fingering in Porous Media and Fractures (BES, YMP) *Glass, Eliassi, and Nicholl*
- Scaling of Rock Matrix Permeability (BES) *Tidwell and Wilson*
- Single and Two-phase Flow and Transport Through Fractures and Fracture Networks (BES, YMP) *Glass, Rajaram, and Nicholl*
- Matrix Diffusion Effects in Fractured Dolomite (WIPP) *Tidwell, Meigs, and Altman*
- Fluid and Solute Transfer Between Fractures and Matrix Under Saturated/Unsaturated Conditions (YMP) *Tidwell and Glass*
- Non-isothermal Flow in Saturated/ Unsaturated Porous Media (YMP, LDRD) *Glass, Martinez, and Eaton*
- A Hybrid Hydrologic - Geophysical Inverse Technique for the Characterization, Monitoring, and Risk Assessment of Leachates in the Vadose Zone (EMSP) *Alumbaugh, Glass, McCord, Yeh, LaBrecque, and Rautman*
- New Permeameters for *in situ* Characterization of Unsaturated Heterogeneous Permeability: Development, Design, Testing, and Application(ESMP) *Holt, Wilson, and Glass*
- Measurement of Single and Two-phase Flow Properties of Low Permeability Media (WIPP) *Davies*



Solute diffusion from a flowing fracture into the surrounding porous matrix. The experimental system is formed by mating two 60x15x25cm slabs of volcanic tuff imaged with the X-Ray Absorption Imaging System.

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