Geophysical Research Abstracts
Vol. 16, EGU2014-8153, 2014
EGU General Assembly 2014

Dynamic Imaging of Fluid Flow in Sandstones by Nuclear Emission Tomography

Ronny Pini (1), Sally Benson (2), Jenny Druhan (2), Ferdinand Hingerl (2), James P. O'Neil (3), and Nicholas T. Vandehey (3)

(1) Colorado School of Mines, Golden, United States (rpini@mines.edu), (2) Stanford University, Stanford, United States, (3) Lawrence Berkeley National Lab, Berkeley, United States

The heterogeneity of geological formations varies over a wide range of length-scales and represents a major challenge for predicting the movement of fluids in the subsurface. Millimeters to cm-scale features that are commonly observed in sedimentary rocks have been shown to greatly influence fluid transport over much larger observational scales. From a practical perspective, these features give rise to capillary phenomena that affect process-relevant parameters, such as sweep or trapping efficiencies.

Measurements on core samples represent a major input for field-scale flow models and the latter adopt multistage up-scaling approaches to link the core-scale to the size of a grid-block. The lack of access to information about rock property heterogeneity at the sub-core scale has restricted the ability to fully take advantage of these methods; in fact, properties derived from the latter are inherently "effective", their spatial resolution being limited to a minimum of several centimeters by the measurement or sampling technique. However, making accurate predictions of multiphase flows and dispersion coefficients for single phase flow requires making measurements at the full range of relevant spatial scales, thus referring to the internal structure of the sample and the small-scale features described above. Essential components in this description include continuum properties that are related to the rock (porosity and permeability), to the fluids (saturation) and to both of them (capillary pressure-saturation relationship); the ability to create a link among all these properties is key to a physically-sound description of these naturally complex systems. One way to accomplish this is by adopting an integrated approach that combines displacement experiments in naturally heterogeneous core-samples with the simultaneous imaging of flow as well as with the support of detailed numerical simulations.

In this paper, nuclear emission tomography is applied to visualize fluid flow through a Berea Sandstone sample. Positron emission tomography (PET) is used to obtain near real-time dynamic 3D images of concentrations, while simultaneously measuring effluent profiles of a radioactive tracer that is injected into the core-sample through both delta- and step-like functions. The combination of these two data sets provides unparalleled insights about the effects of heterogeneity on tracer flows. It is shown that even for the homogeneous Berea Sandstone the effect of small-scale heterogeneity is significant. Numerical simulations in TOUGH2 of tracer flow in a medium with non-uniform porosity and permeability are carried out to support the experimental observations. Breakthrough curves are compared to those expected based on 3D permeability maps that have been previously obtained for the same core upon application of an independent technique based on multiphase flows. The potential is analyzed of combining various imaging techniques to visualize and quantify fluid flow in laboratory rock samples.