Breaking the 'Black Box':
Using 3D X-ray Imaging to Understand and
Optimize Multiphase Fluid Transport in Porous Materials

Abstract

Significant research efforts have been devoted to understanding fluid transport in porous media, spanning back to the 1800's and the days of Henry Darcy, but early understanding of flow processes was limited by the inability to directly observe fluid-fluid-solid interactions in opaque systems. Due to these constraints, a huge body of work has been developed based on a "black box" model: system parameters such as fluid flow rates, volumes, and pressures were measured at the inlet and outlet of porous media cores, and constitutive relationships were measured and used to infer the internal interactions between fluid phases and the solid architecture.

Recent advances in X-ray computed tomographic (CT) imaging and experimental technologies have enabled direct, high-resolution, internal 3D visualization of otherwise opaque samples; revealing that our established conceptual models and inferences of fluid flow behaviour are, in many cases, incorrect or incomplete. This talk will introduce multiple aspects of two-phase fluid flow physics that have recently been updated, thanks to new information from pore-scale 3D X-ray CT imaging - including: nonwetting fluid invasion patterns and snap-off during drainage, pressure signatures of fluid phases, and the importance of fluid topology to fluid trapping and mobilization.

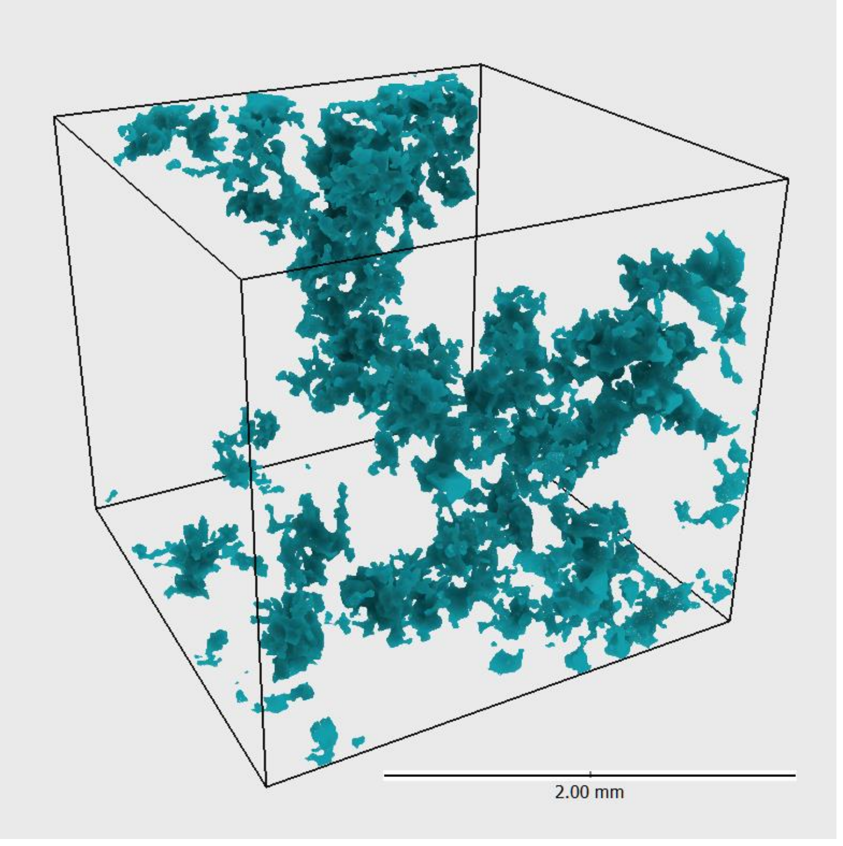

Figure: Cubic subset from a tomographic dataset showing the 3D morphology of nonwetting phase during injection into a sandstone core originally saturated with brine.