PoreLab – Porous Media Laboratory

Centre of Excellence (SFF)

Carl Fredrik Berg, IGP, NTNU

PoreLab

NTNU-UiO Porous Media Laboratory

Norwegian University of Science and Technology

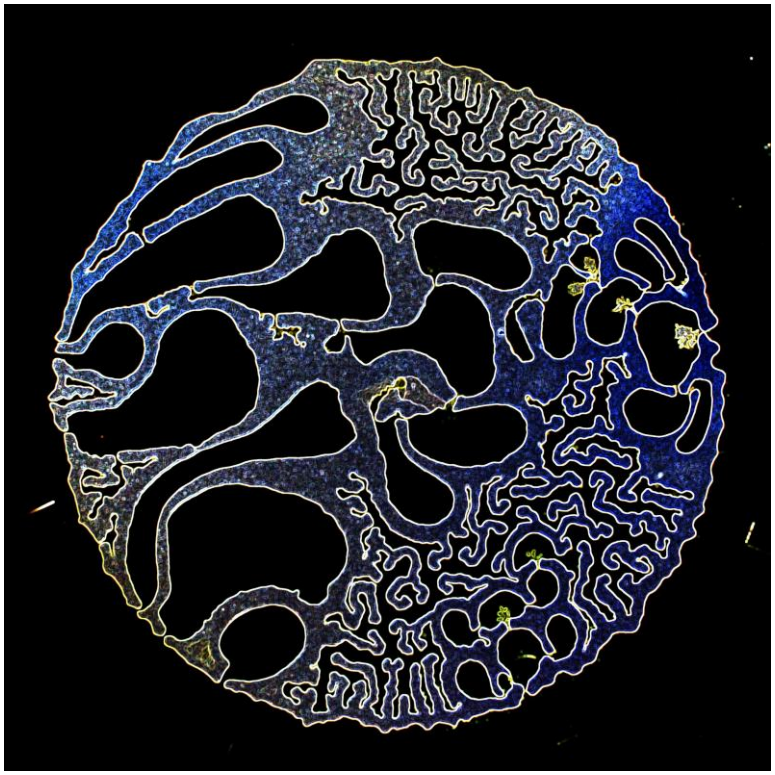
2017: Elected Center of Excellence

The Research Council concludes "… *The biggest asset here is the team - it is an extraordinary assembly of real leaders in the field, based on individual track records,* ***any of the proposed work packages could revolutionize the field of porous media***".

About PoreLab

PoreLab
NTNU-UiO Porous Media Laboratory

- Situated at NTNU and UiO
- Aim: From a sound basis in physics advance the understanding of flow in porous media that range from geological to biological and technological



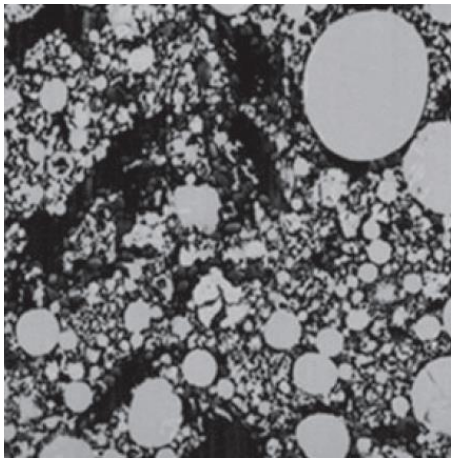
- 22 PhDs and 12 PostDocs from base funding
- ~70MY from additional funding

Pore structures

Batteries

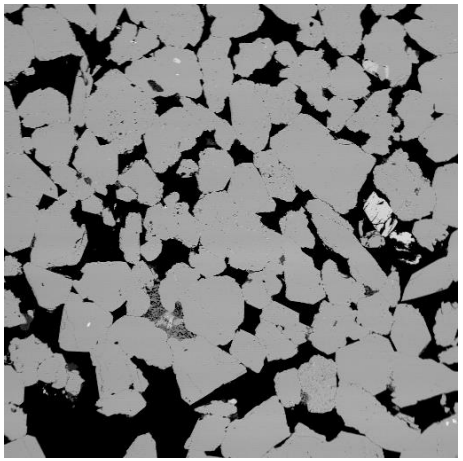
Liu et. al., 2015

Fuel cells



Holzer et. al., 2013

Hydrocarbon Reservoirs



Berg et. al., 2017

Research

- 7 main research areas:
  - WP 1: Thermodynamics of flow in porous media
  - WP 2: Deformable porous media
  - WP 3: Steady-state properties of flow in porous media
  - WP 4: Transient immiscible two-phase flow
  - WP 5: Thermodynamic driving forces
  - WP 6: Microfluidics and field studies
  - WP 7: Porous transport layers for PEM fuel cell and thermoelectric cells

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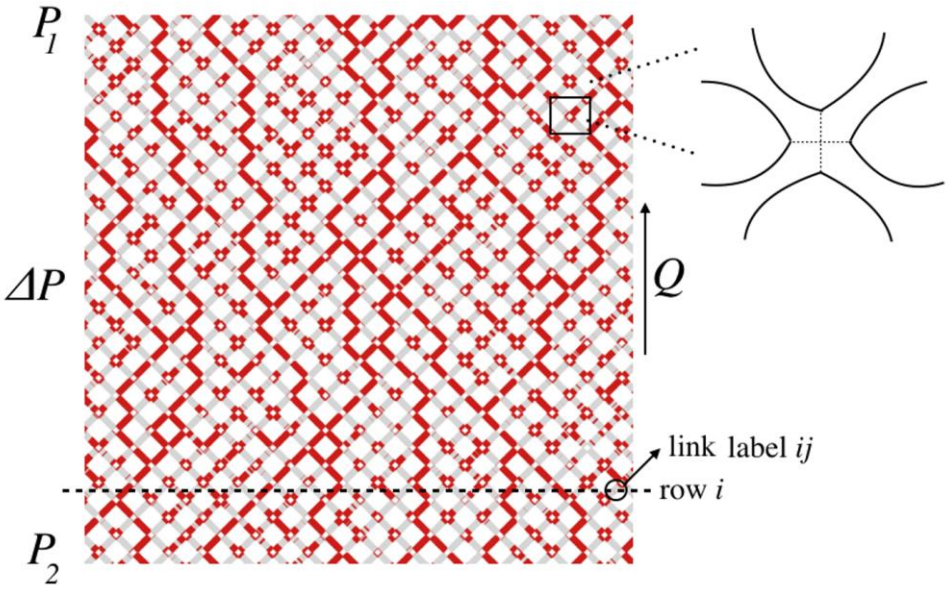
WP 1: Thermodynamics of flow in porous media

- **Objective:** To provide a set of equations and relations for immiscible two-phase flow in porous media connecting the physics at the pore scale with the macroscopic level where the porous medium may be described as a homogeneous continuum.



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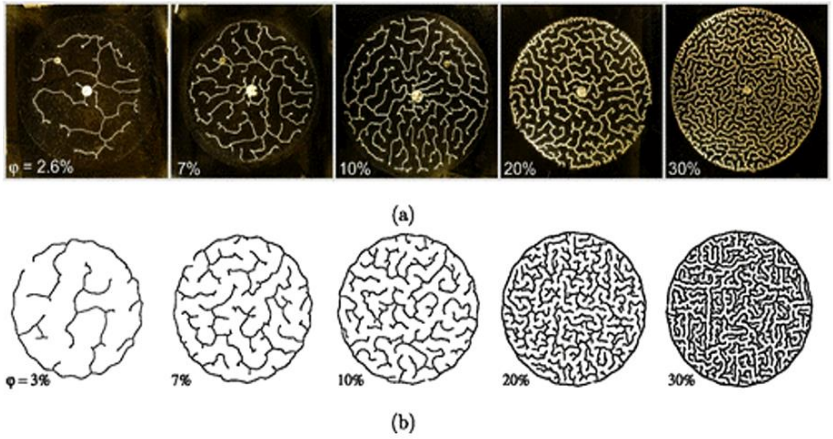
WP 2: Deformable porous media

- **Objective:** Understand the variety of patterns that form under the combined action of Coulomb friction, capillary- and viscous forces and make contact with non-equilibrium statistical mechanics on the theoretical and field observations on the empirical side, as well as hydrofracture processes where the solid matrix breaks down locally.



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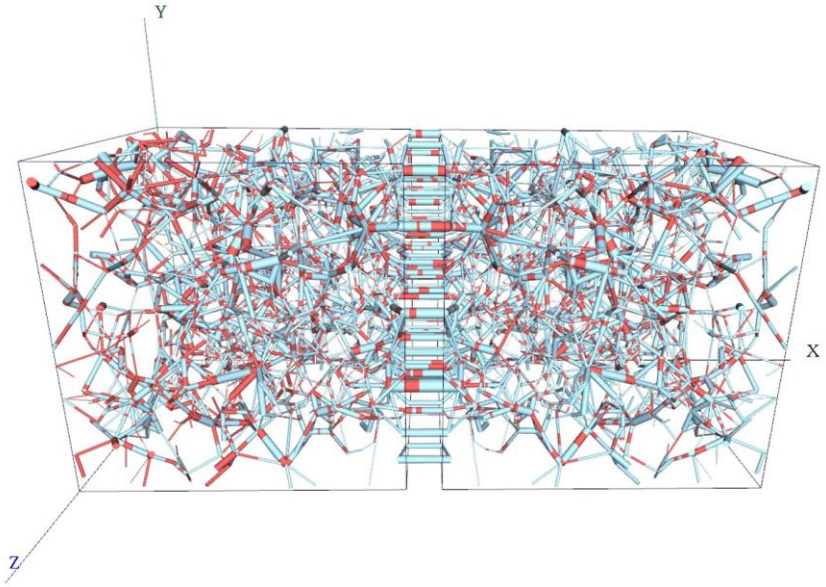
NTNU

WP 3: Steady-state properties of flow in porous media

- **Objective:** Establish a phase diagram for steady-state two-phase flow. Verify experimentally the equations based on non-equilibrium thermodynamics developed under WP1. Establish an experimental basis for introducing osmotic driving forces as described in WP5.



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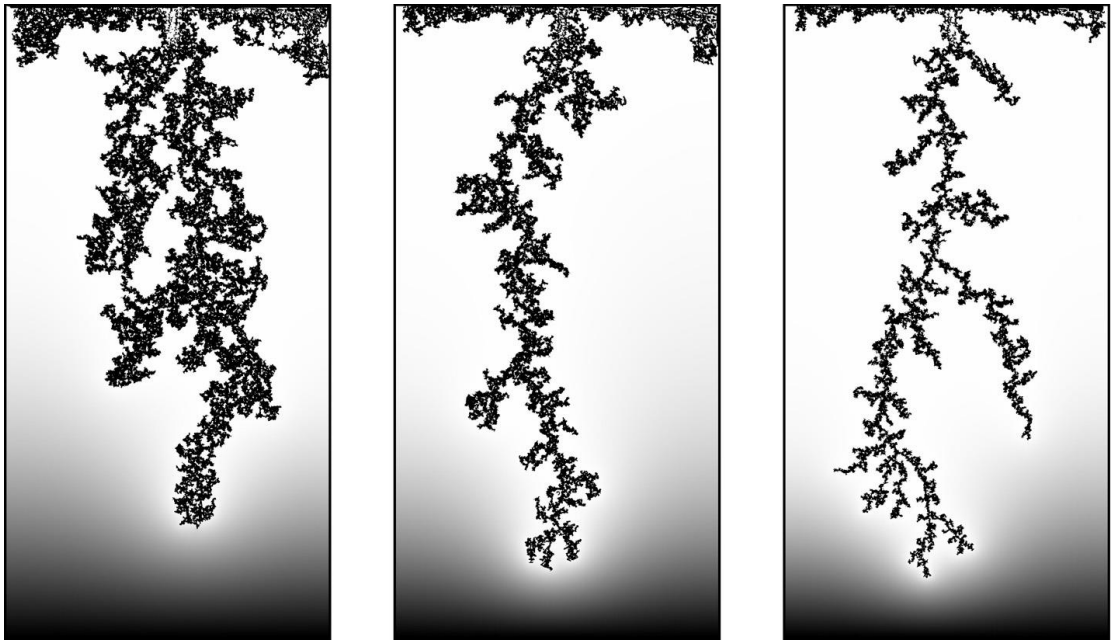
WP 4: Transient immiscible two-phase flow

- We study transient phenomena in porous media, particularly the relaxation behavior before the system reaches a steady-state and the crossover length and times associated with the different forces involved.



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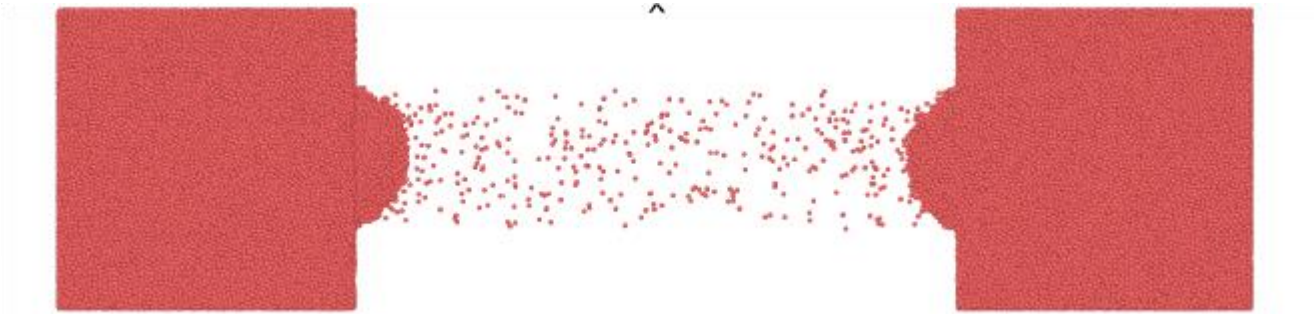
WP 5: Thermodynamic Driving Forces

- **Objective:** Extend the non-equilibrium thermodynamic description of immiscible two-phase flow to include gravitational, osmotic, chemical and thermal driving forces with the aim to construct a consistent and general description of immiscible two-phase flow.



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WP 6: Microfluidics and field studies

- **Objective:** Establish a new method for determination of wettability in porous media by using micromodels and micro-CT.
- Characterize multiphase flow in various wetting states and relations to trapping.
- Establish experimental support for the ensemble probability distribution by micro-CT scanning of flow in rocks.

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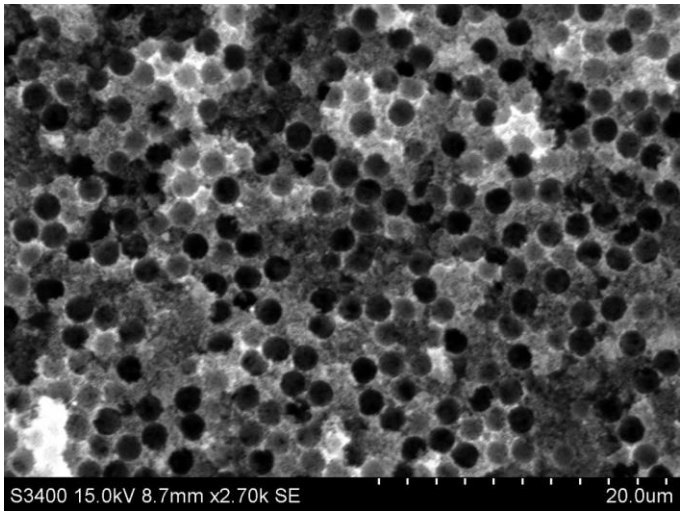
WP 7: Porous Transport Layers for PEM Fuel Cell and Thermoelectric Cells

- Objective: The objective is to apply knowledge from WPs 1-6 to:
  - Design more energy-efficient electrochemical systems tailoring their porous transport layer
  - Describe the role of buoyancy in CO2 sequestration in reservoirs
  - Predict hydraulic fracturing in three dimensions



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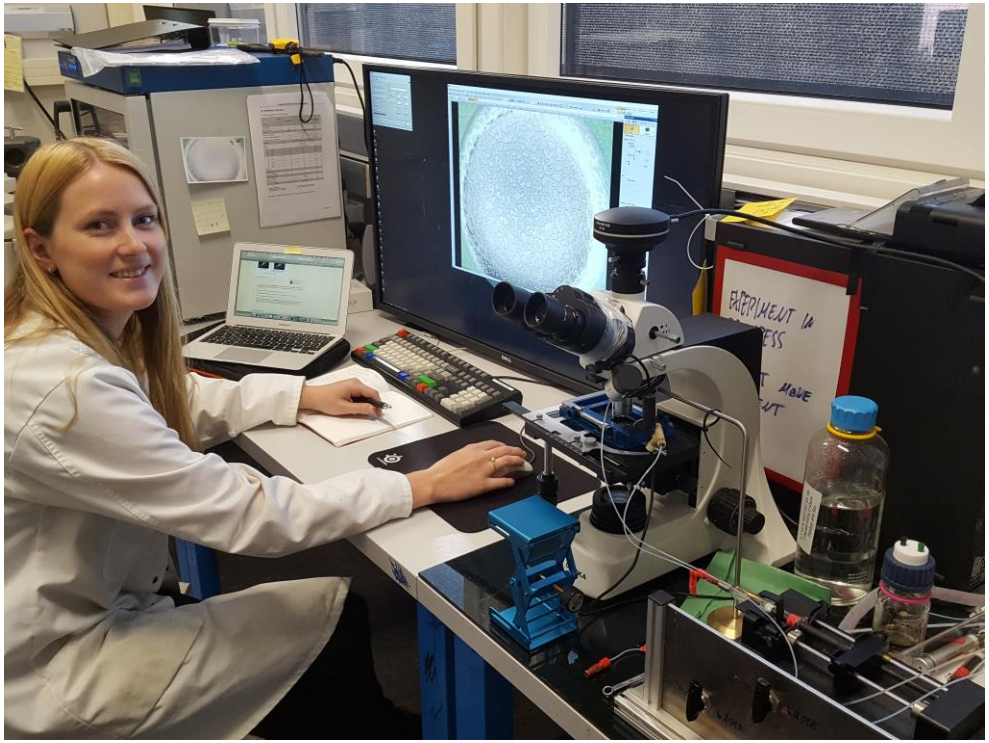
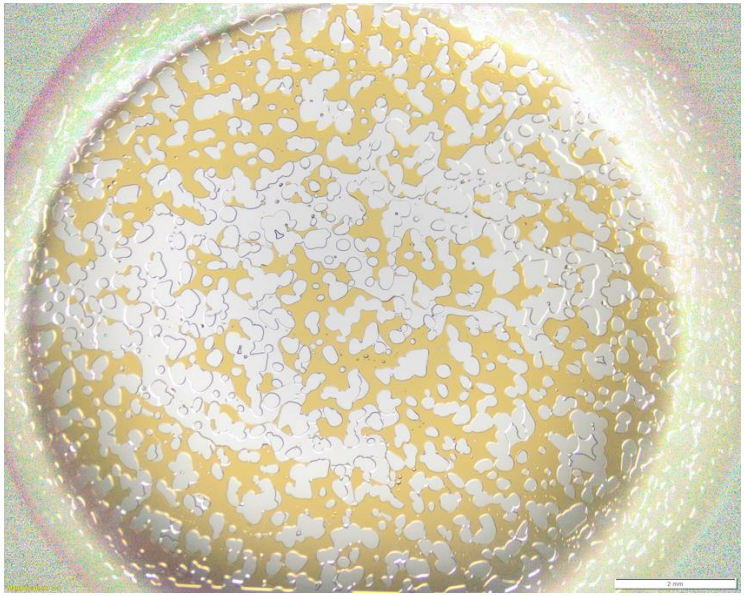
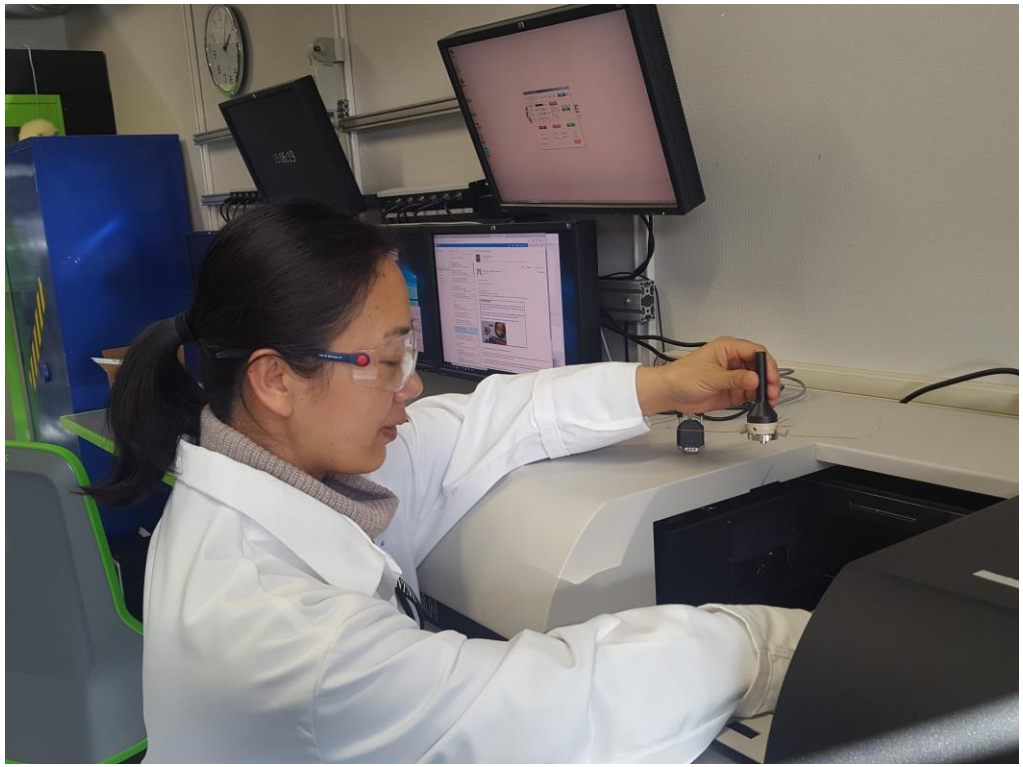
PoreLab research at IGP

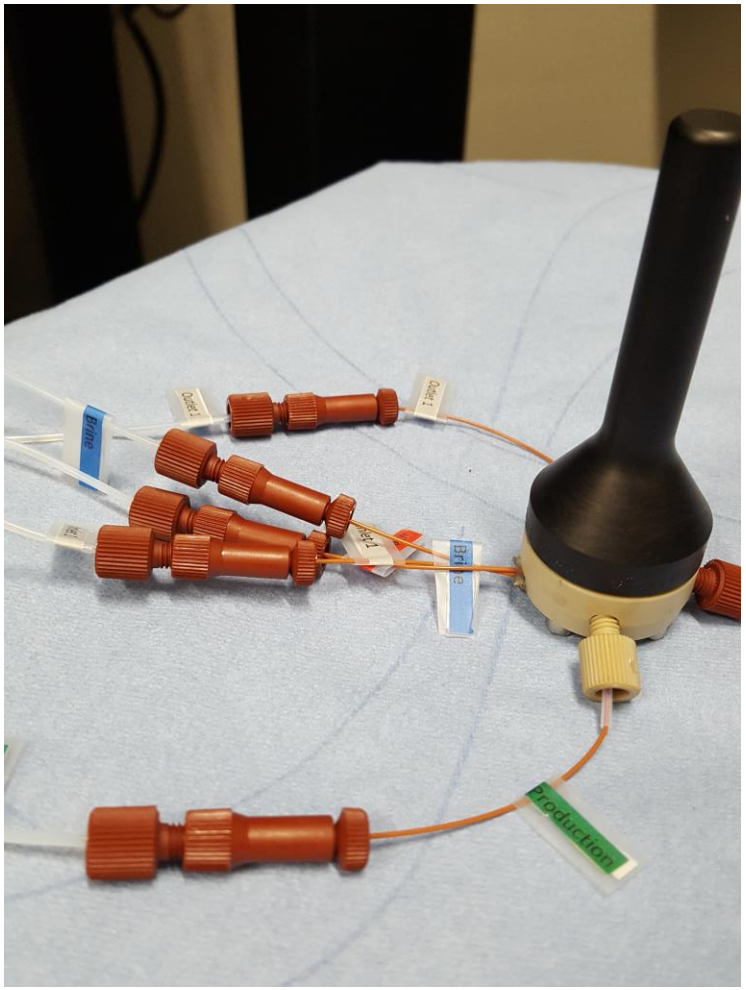
Imaging of multiphase fluid distribution: Micro-fluidics





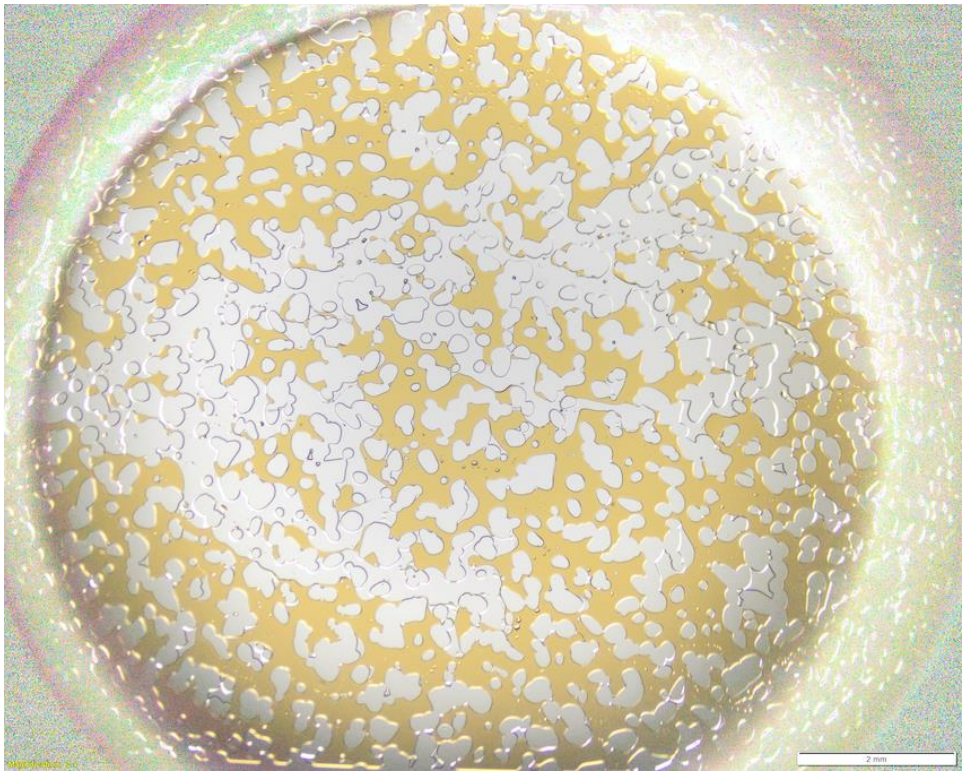
Imaging of multiphase fluid distribution: Micro-CT



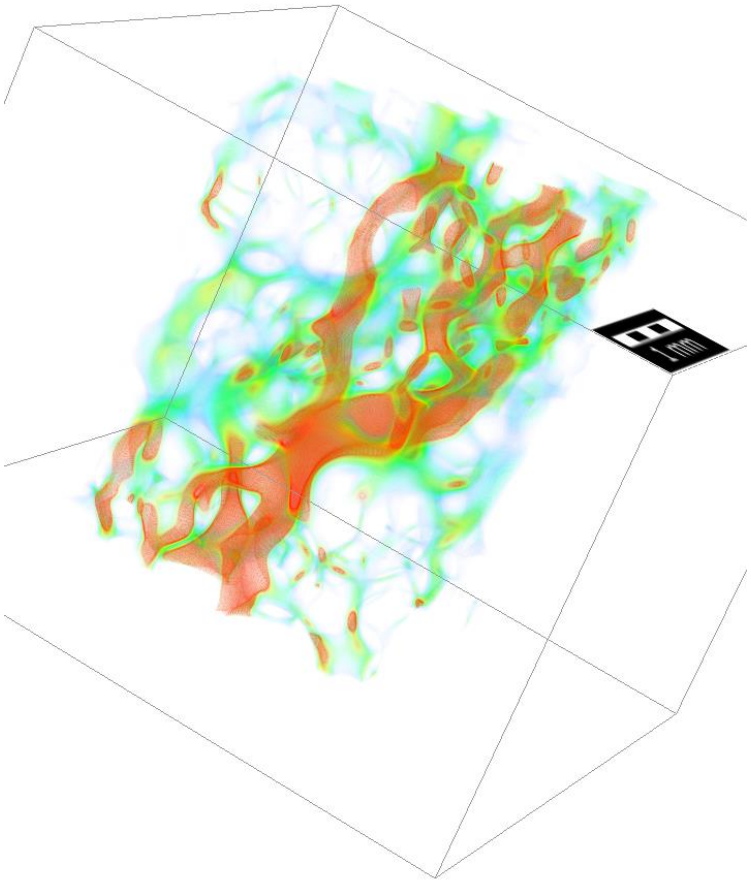


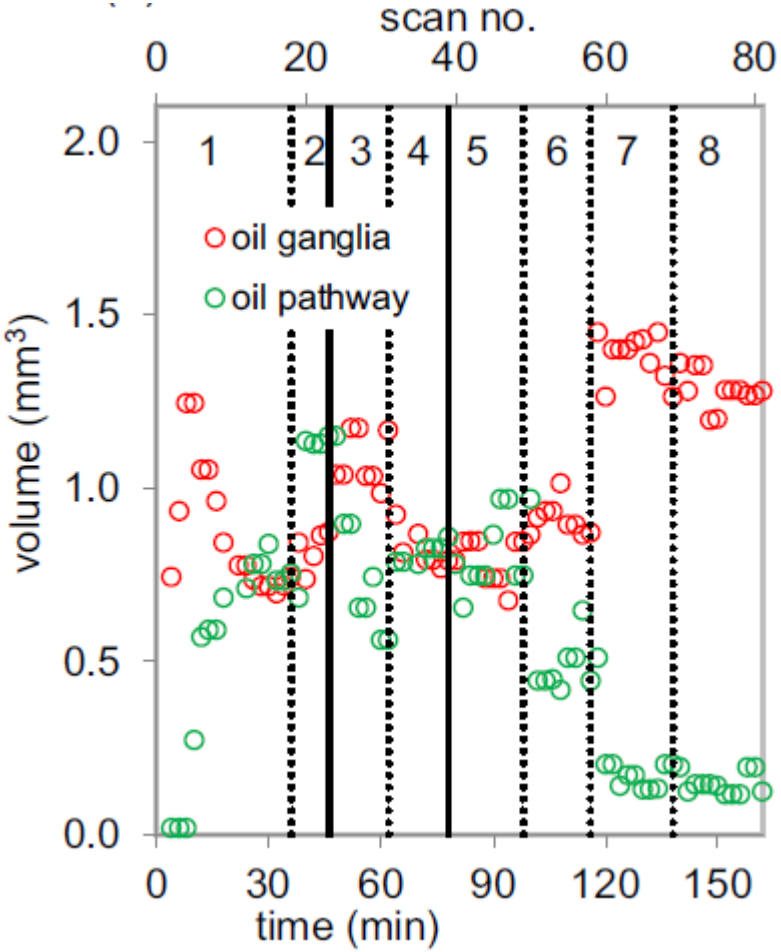
EOR effects of nano-fluids

- Screening residual oil after flooding with different nano-fluids
- Micro-model experiments and core flooding



Fluid distribution during flooding

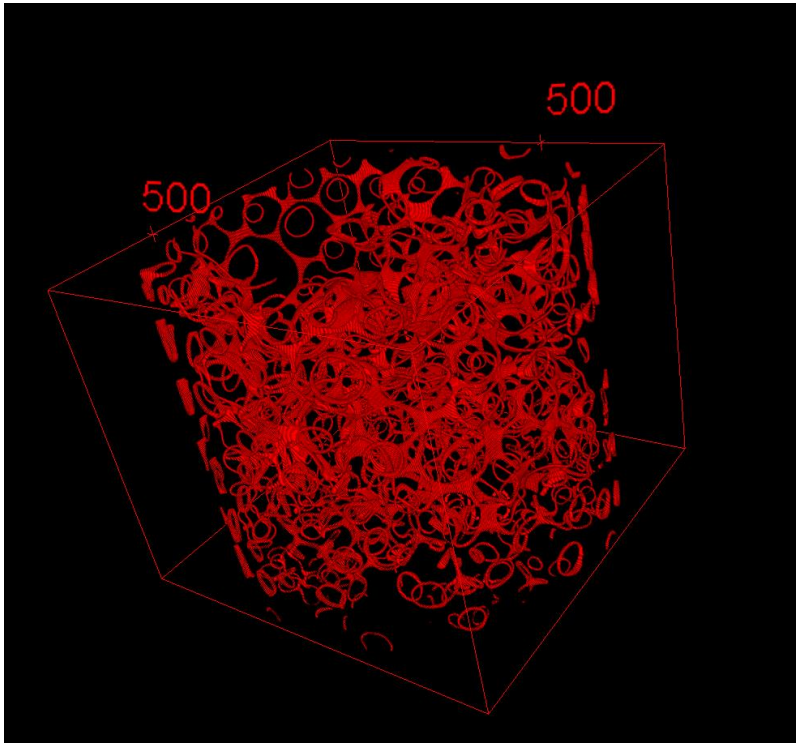




Khanamiri et. al., 2017

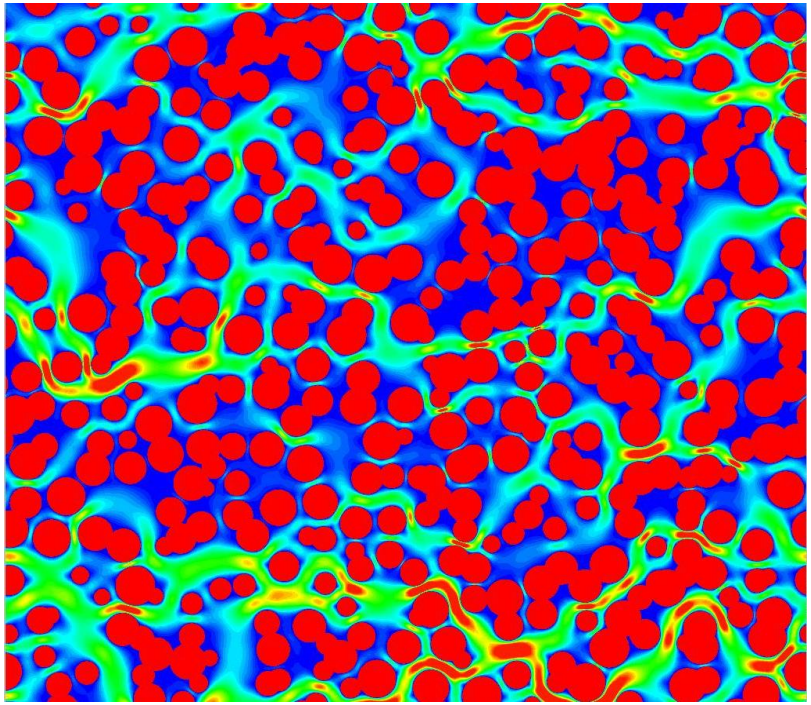
Thermodynamic description of fluid distribution

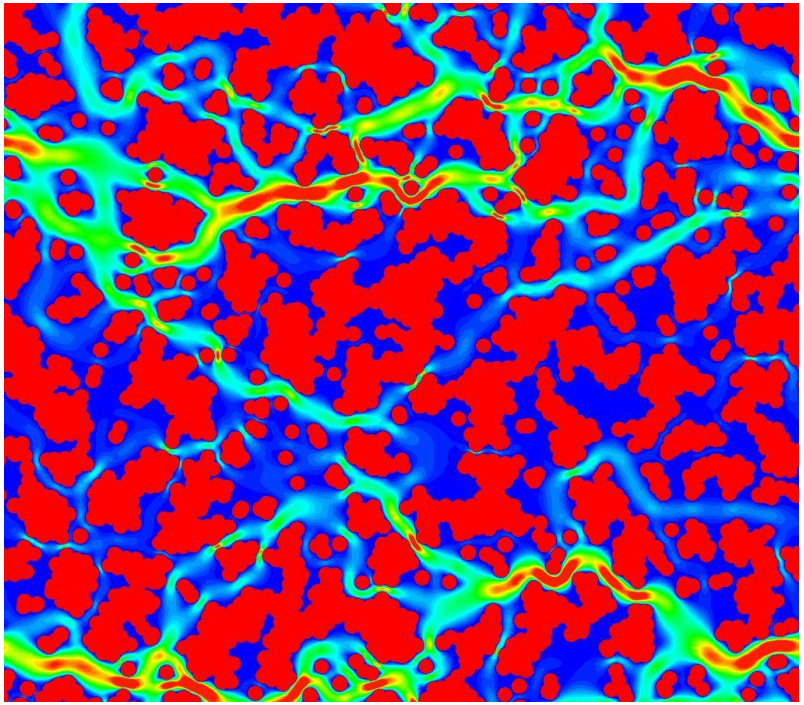
- Associate energy to volumes, surfaces and contact lines
- Linking added energy to changes in geometry of fluids
- Both quasi-static and during flooding



Pore structure and single phase flow

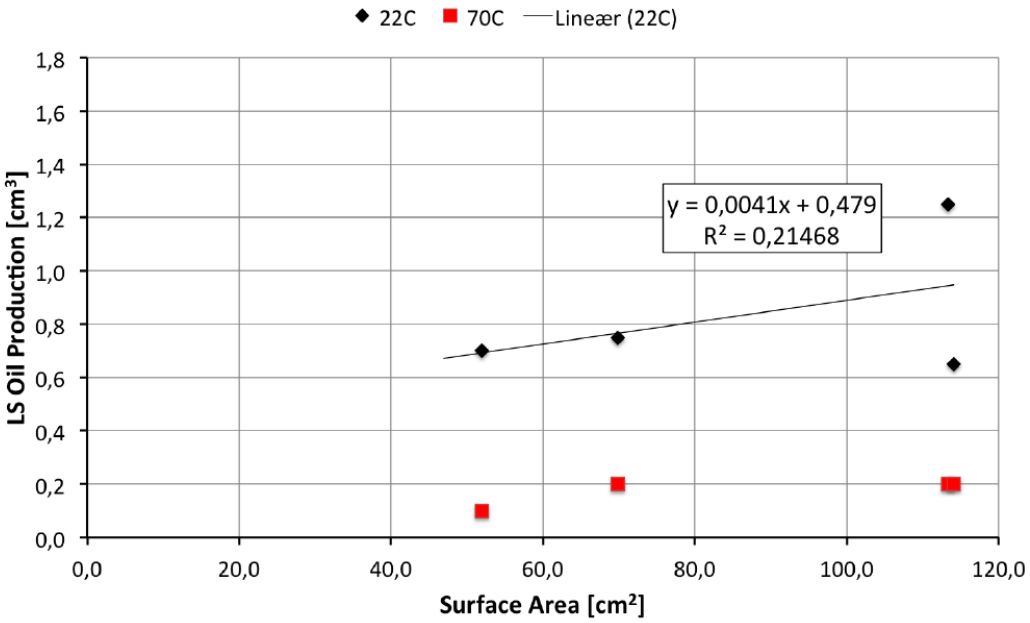
- Linking Minkowsky functionals to fluid flow





Osmosis

- Experiments showing oil production due to osmosis
- Lattice-Boltzmann modeling starting



Pollen, 2017

Future work: Wettability characterization

- Using pore scale imaging and modeling to refine current wettability characterization
  - Amott-index assumed to simple