Pore-scale imaging and analysis of surfactant flooding (tertiary recovery experiment)

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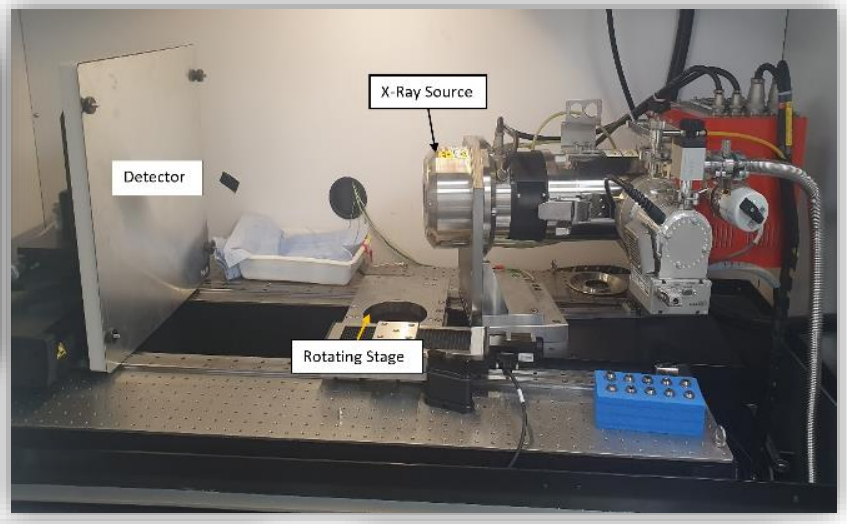
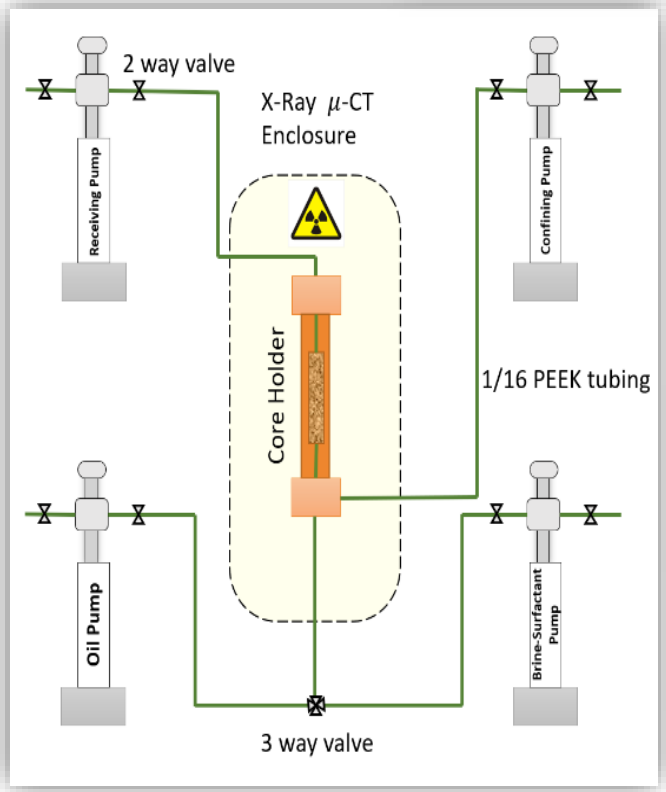
Project objectives

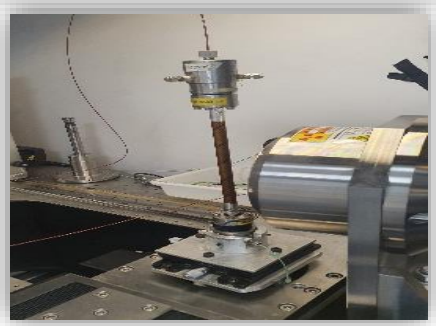
- Understand the mechanisms of oil recovery at the pore scale when using cationic surfactant flooding in carbonate reservoirs.
- Interpretation of fluid displacement, oil recovery, and quantification of in situ changes in wettability.
- Is recovery for this surfactant due to principally emulsion formation or wettability alteration?

- Three-dimensional pore-scale high-resolution X-Ray imaging and analysis were applied.
- An experimental approach is used to investigate the oil recovery mechanisms.

Experimental Design and Methodology



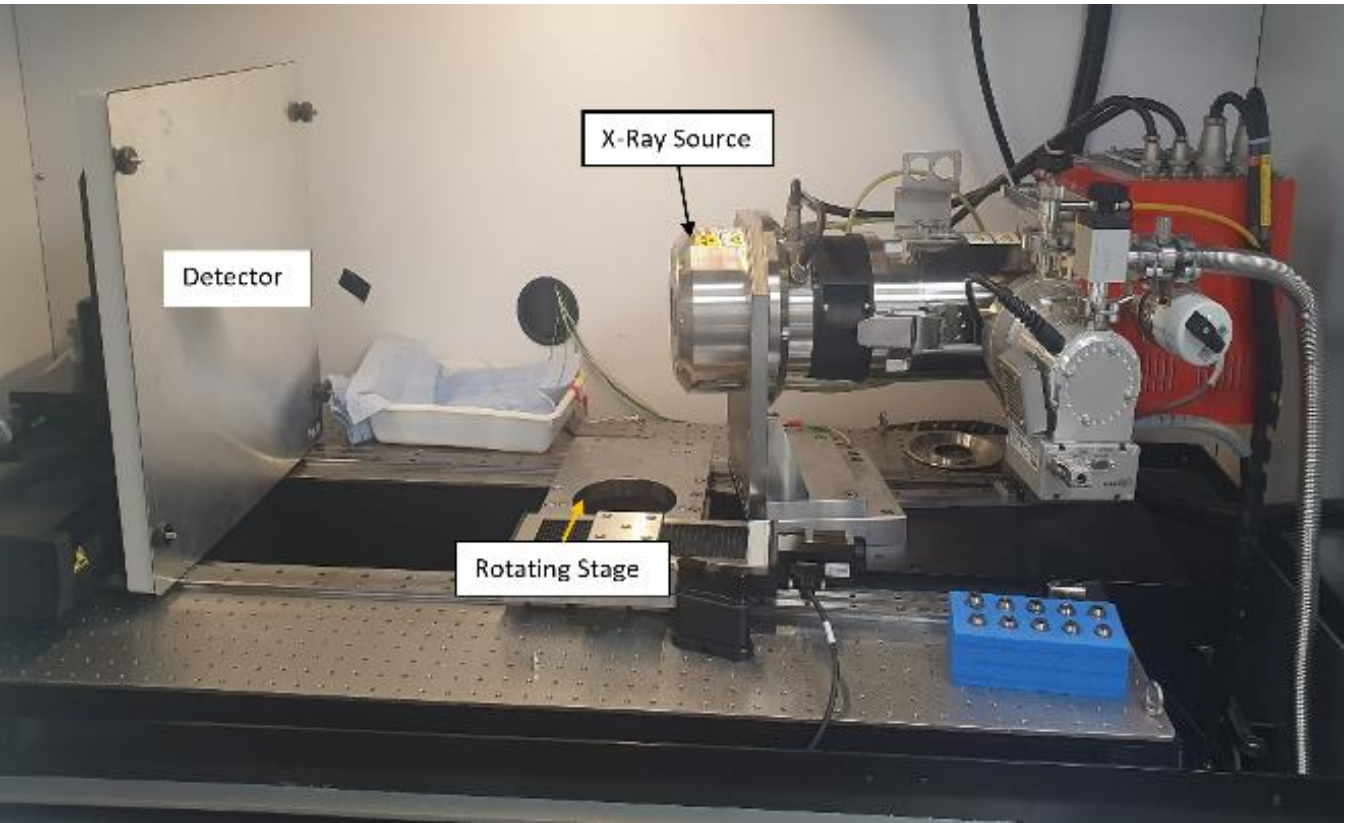


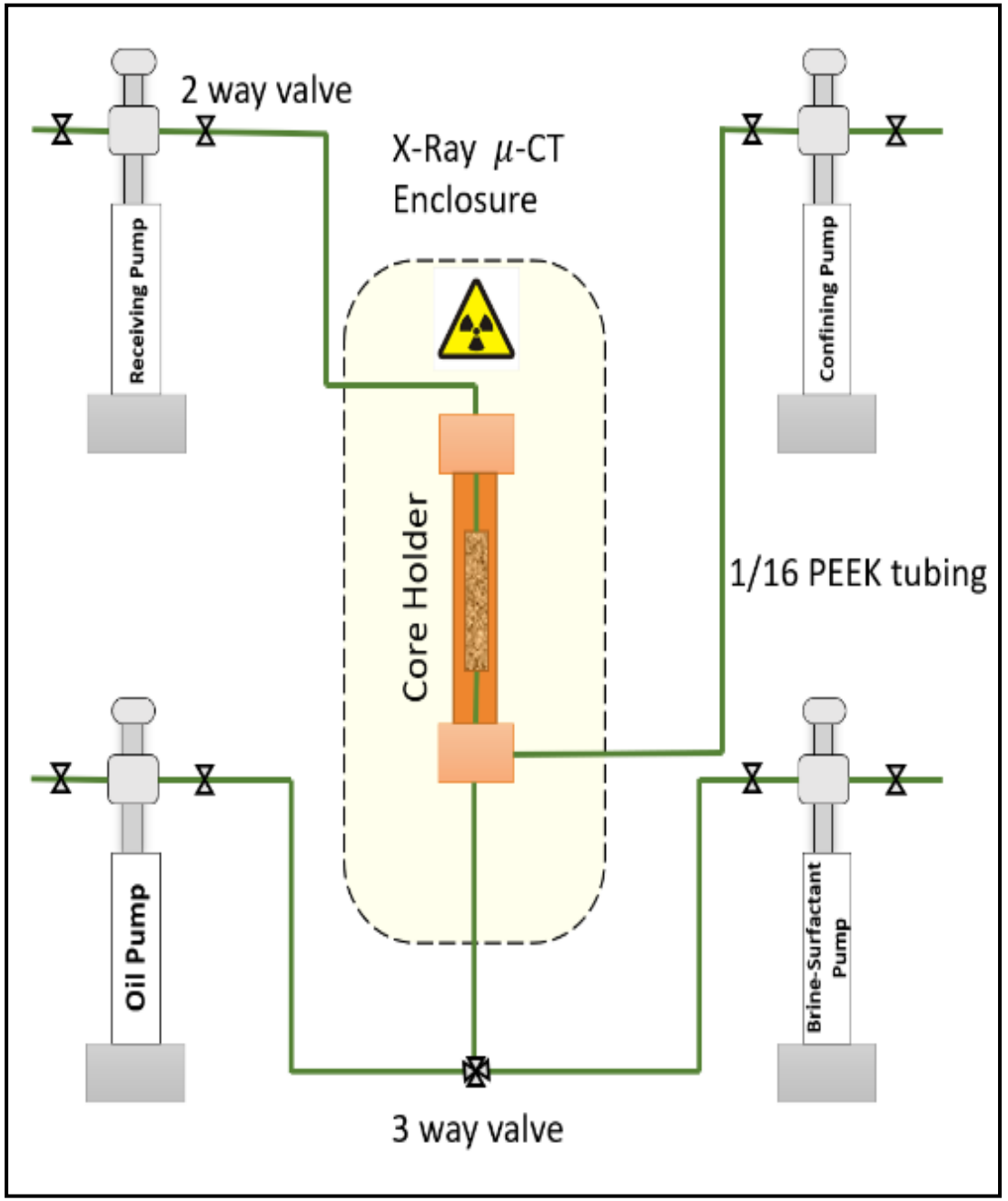


MATERIALS

Experimental apparatus

- Syringe pumps
- Hassler type core holder
- FEI Heliscan micro-CT scanner





Experimental Procedure

Sample Preparation

- Clean vacuum and dry the rock sample.
- Dry scan imaging.
- Saturate the sample with formation brine.

Drainag

- Inject crude oil to reach S_{wi}.

Ageing

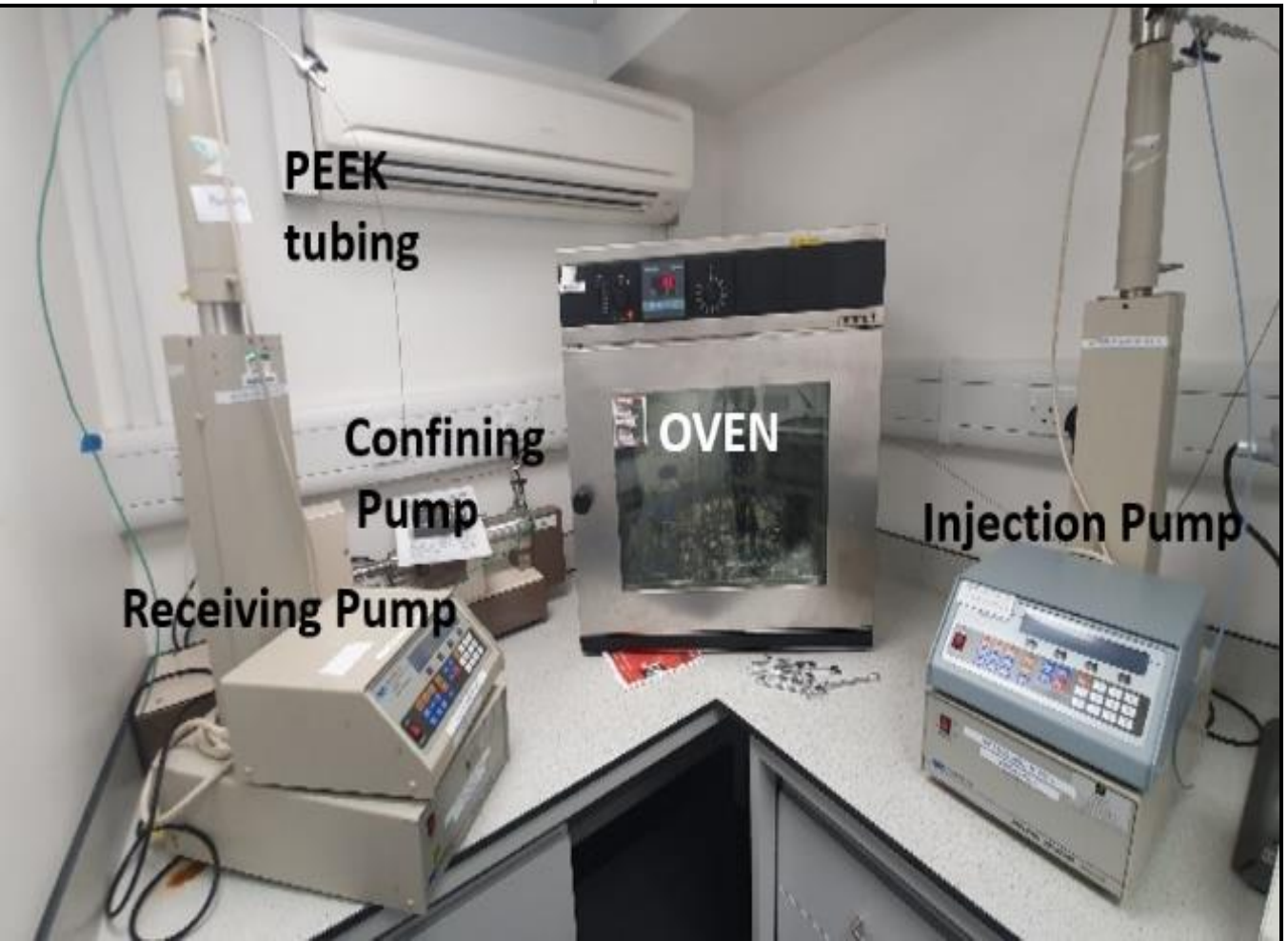
- Continuously inject crude oil at a low rate and high temperature of 80 °C.
- Reverse the flow direction half-way through the ageing process.

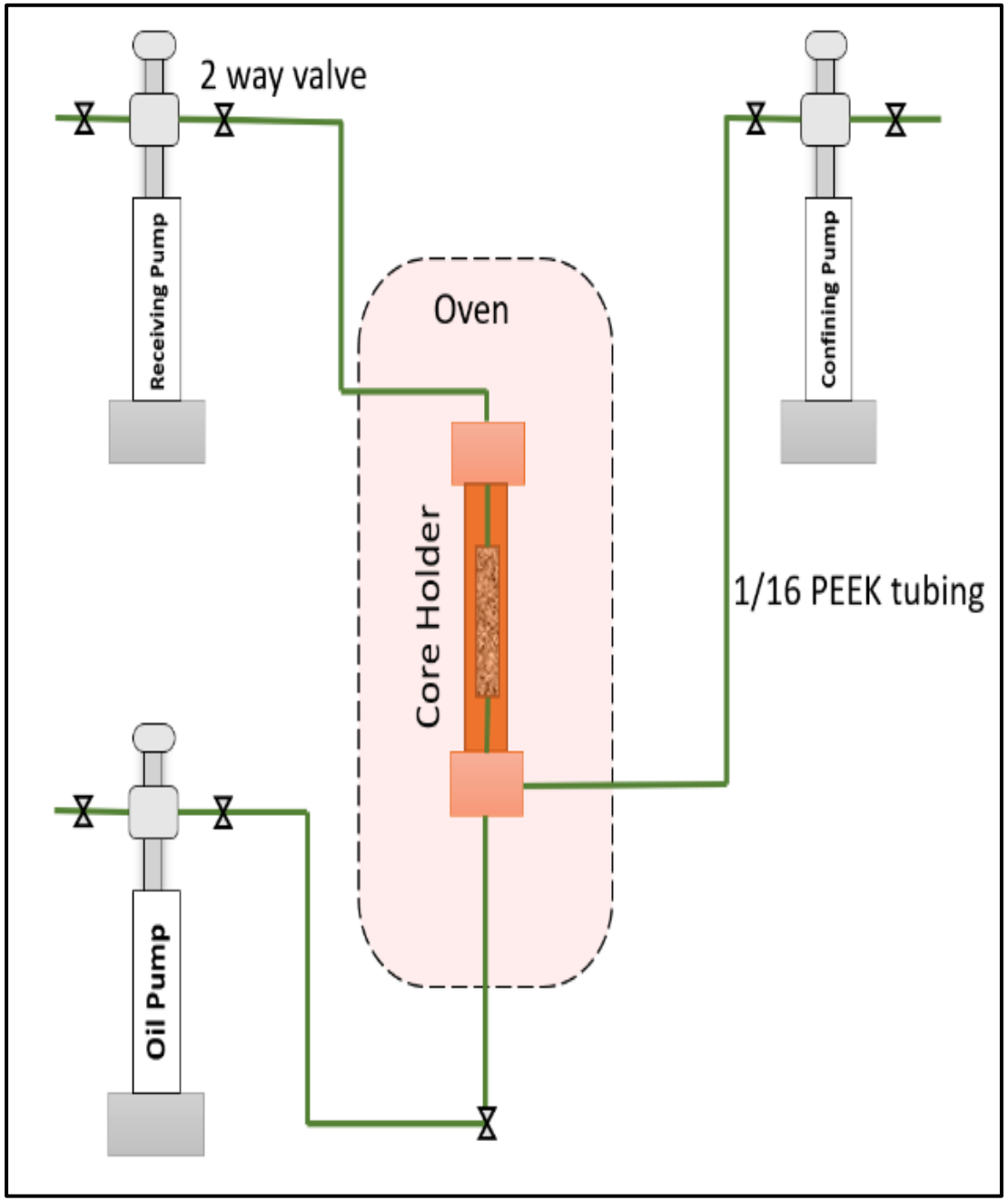
Secondary and tertiary flooding

- Flood the sample with 5 PV of brine as secondary recovery.
- Followed by 3 PV of surfactant as tertiary recovery.

Sample Ageing apparatus

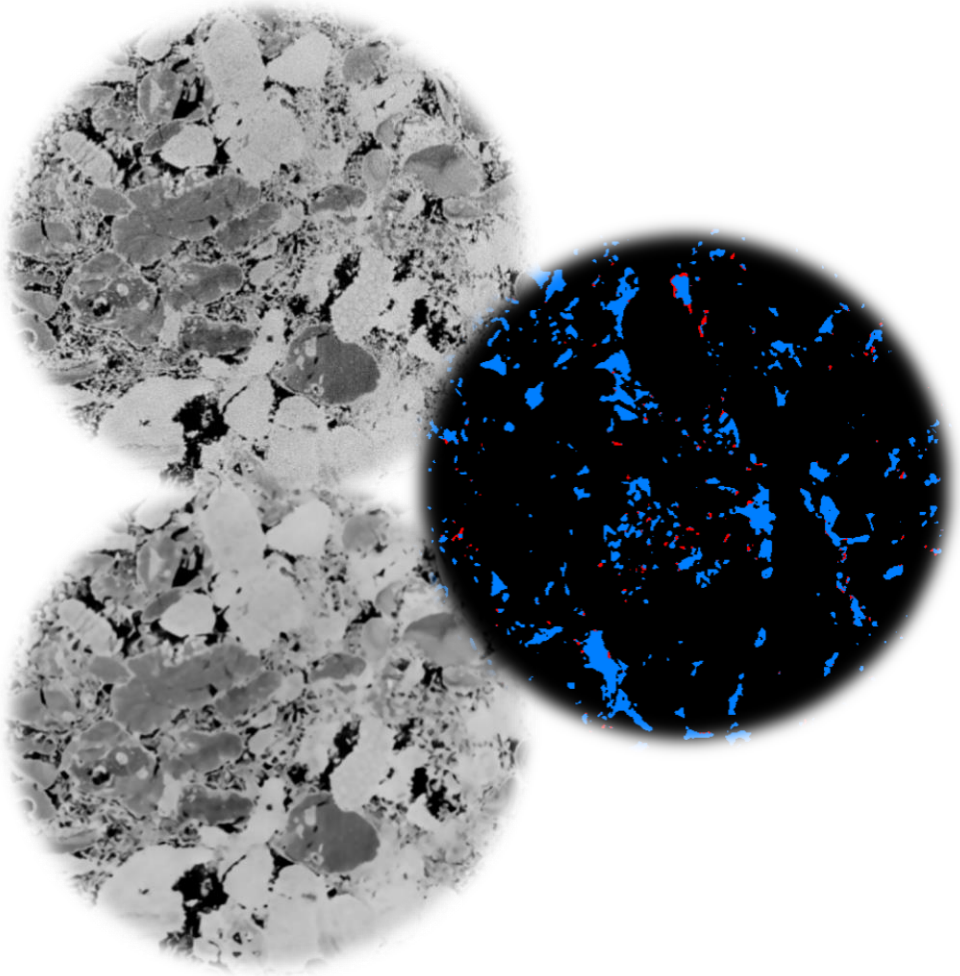
- Syringe pumps
- Hassler type core holder





Core Flooding and Micro-CT Imaging Process

Image Processing and Analysis



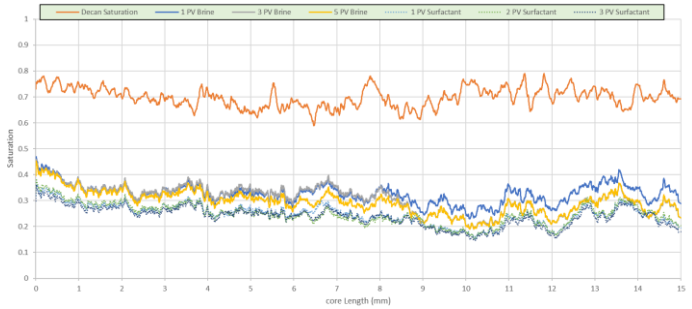
Processing

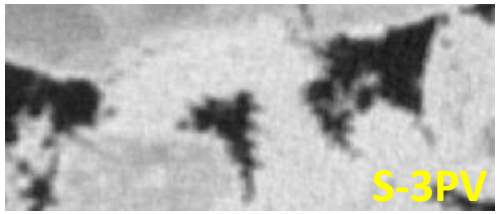
- Grey-scale normalization
- Stitching
- Registration
- Filtration
- Segmentation

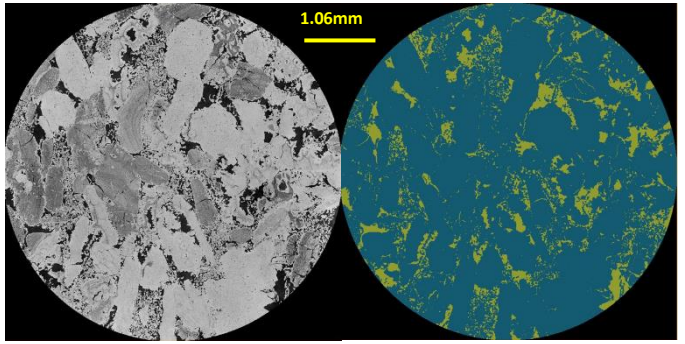
Analysis

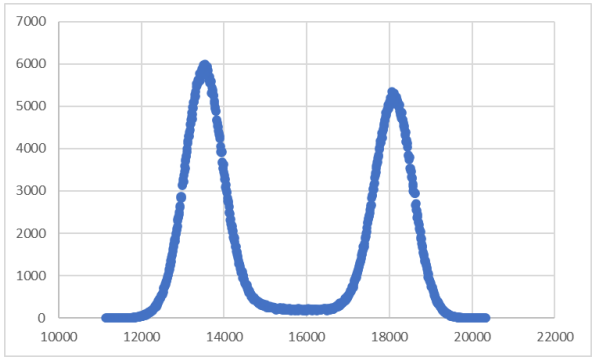
- Fluid saturation
- Recovery calculation
- Pore occupancy mapping
- Contact angle and curvature

RESULTS

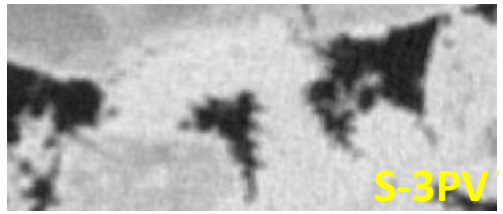

Decan Saturation
1 PV Brine
3 PV Brine
5 PV Brine
1 PV Surfactant
2 PV Surfactant
3 PV Surfactant
Saturation
core Length (mm)


S-3PV

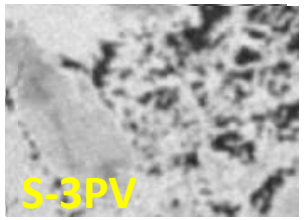

1.06mm


7000
6000
5000
4000
3000
2000
1000
0
10000
12000
14000
16000
18000
20000
22000

Observations of Displacement Processes: a Wettability Change?



300µm



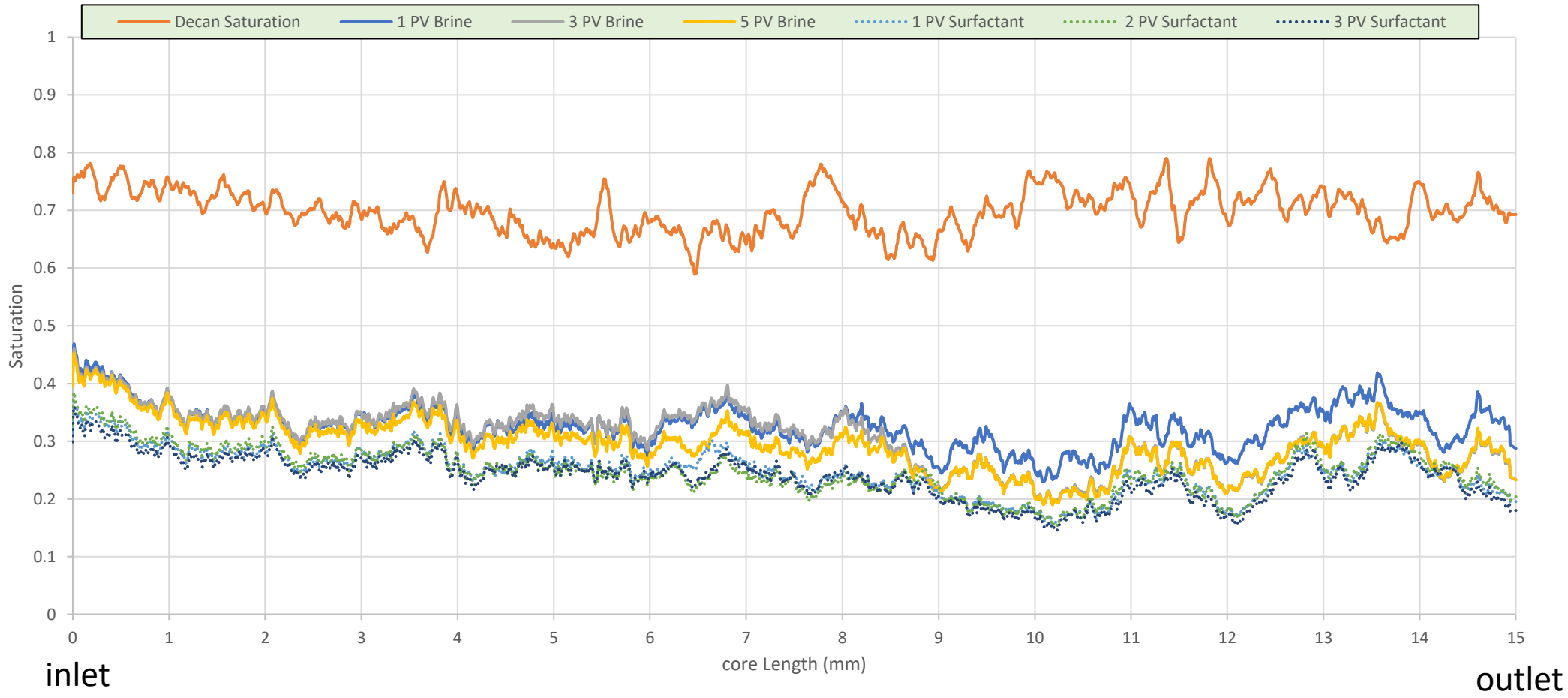
300µm

175µm

Decane Displacement Processes observed during tertiary recovery are:

- Decane displaced from the corners of large pores.
- Decane displaced from small pores
- Decane filled big pores and then was displaced.

Decane Saturation: Surfactant Flooding Leads to Incremental Recovery



Future Work

- Perform the remaining analysis (pore occupancy mapping and contact angle).
- Relate what we see to reveal the pore-scale mechanism of recovery: formation of emulsions/wettability alteration. Little or no emulsion seen, so maybe incremental recovery is more due to wettability alteration.
- Secondary Recovery with the same high concentration of surfactant.
- Surfactant flooding experiment at lower CMC concentration (Secondary and Tertiary Recovery).