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Primary Drainage and Waterflood Capillary Pressures and Fluid Displacement in a Microporous Reservoir Carbonate

Guanglei Zhang, Martin Blunt and Branko Bijeljic

Imperial College London

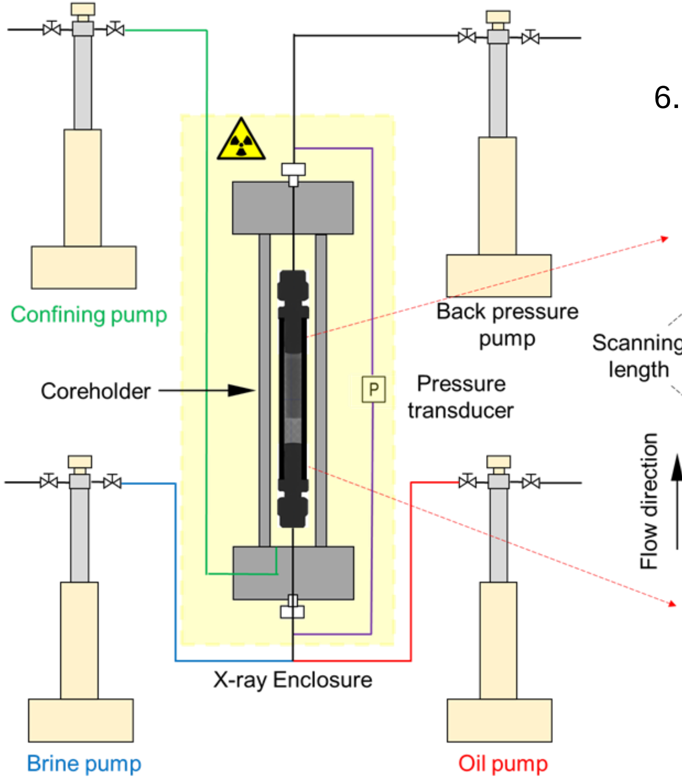
Objectives

The objective of this experiment is to use a Differential Imaging Porous Plate (DIPP) method to:

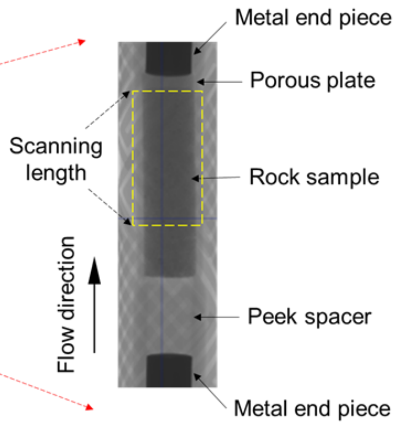
a) characterize primary drainage and waterflood capillary pressures and fluid displacement in a microporous reservoir carbonate, and

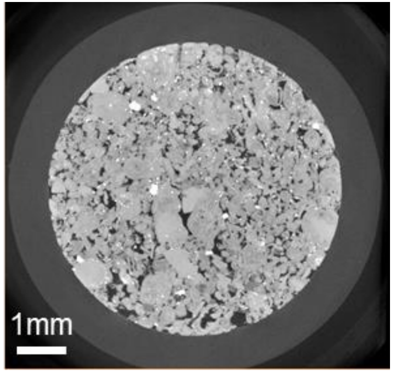
b) provide measurements for validation and calibration of our generalized network model (GNM)

Sample and experimental protocol for primary drainage, imbibition and waterflooding experiments



Sample size:
6.1 mm × 21.5 mm





- He Porosity: 0.190 ± 0.003
- Measured permeability: 88 ± 2 mD

1) Confining pressure: 1500 kPa; Back pressure: 500 kPa

2) Dry scan and 30%KI brine scan

3) **Primary drainage**: Inject decane at 8 capillary pressures from ~10 to ~1000 kPa with a water-wet porous plate

4) **Dynamic ageing** with crude oil for 3 weeks

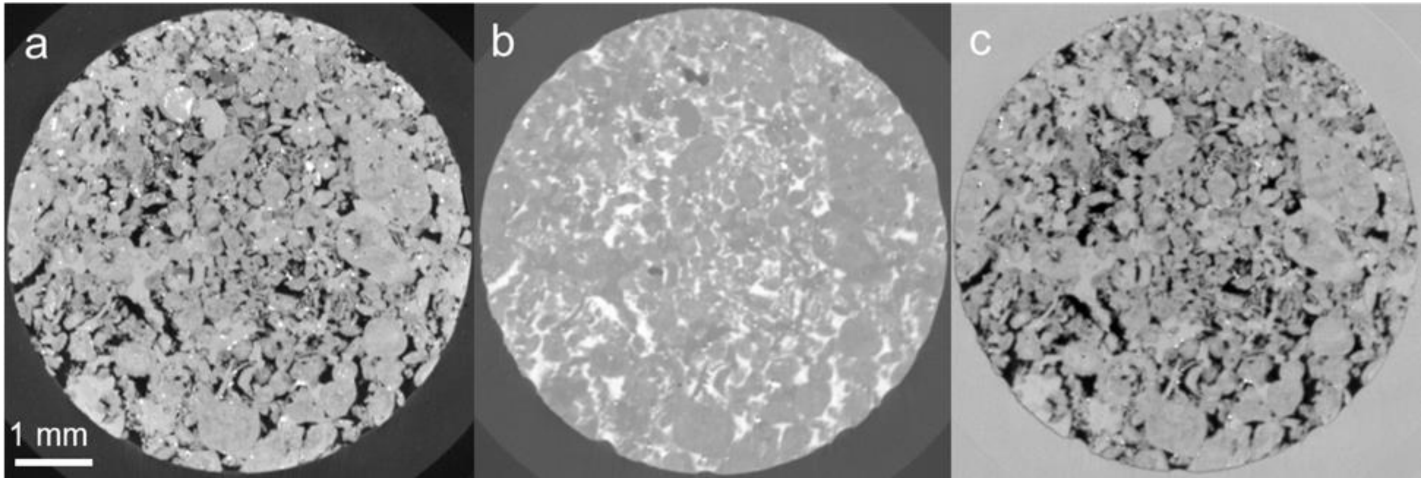
5) **Imbibition**: put the bottom end into 30%KI brine for one week

6) **Waterflooding**: Inject 30%KI brine at 8 capillary pressures from ~ -25 to ~ -1000 kPa with an oil-wet porous plate

CT imaging

Three high resolution scans (3.58 μm) for top 14.2 mm of the sample

Greyscale-based differential imaging to compute porosity



dry scan | brine scan | dry-brine+15000

$\overline{CT} = CT_{rock}(1-\phi) + CT_{air}\phi$

$\phi = (\overline{CT} - CT_{rock}) / (CT_{air} - CT_{rock})$

Differential imaging

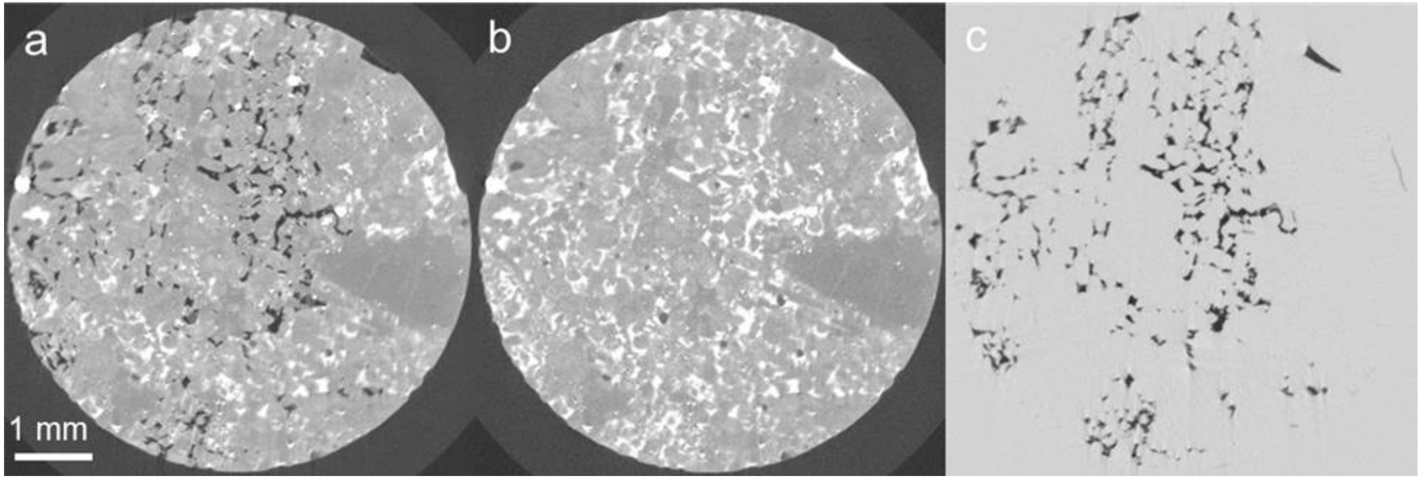
dry − brine

$CT_{rock}=0$

$\rightarrow \phi = \overline{CT} / CT_{air}$

Differential imaging → fewer parameters → lower uncertainty

Greyscale-based differential imaging to compute saturation



partially-saturated image
oil: black; brine: white

brine scan

dry-brine+15000

$\overline{CT} = CT_{rock}(1-\phi) + CT_o\phi S_o + CT_w\phi(1-S_o)$

$S_o = \dfrac{\overline{CT} - CT_{rock}(1-\phi) - CT_w\phi}{(CT_o - CT_w)\phi}$

Differential imaging

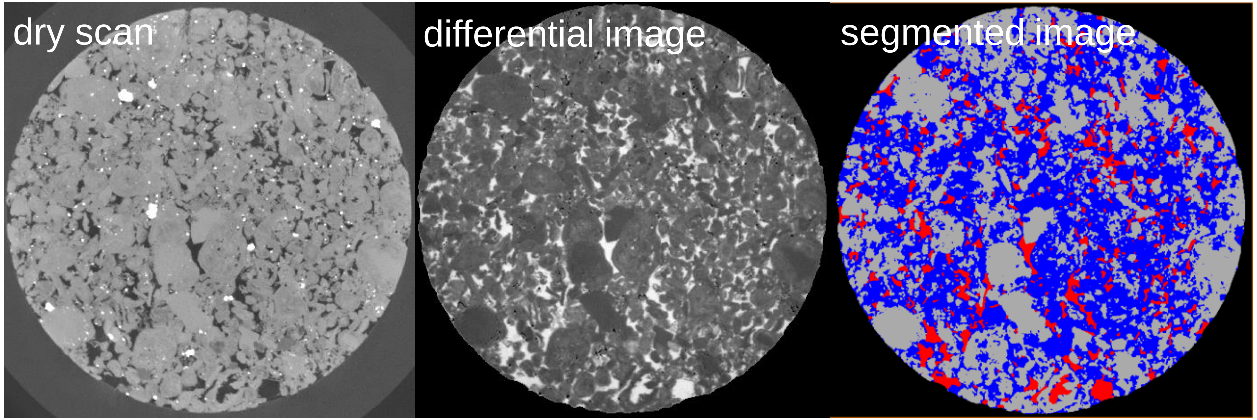
partially-saturated image − brine

$CT_{rock} = CT_w = 0$

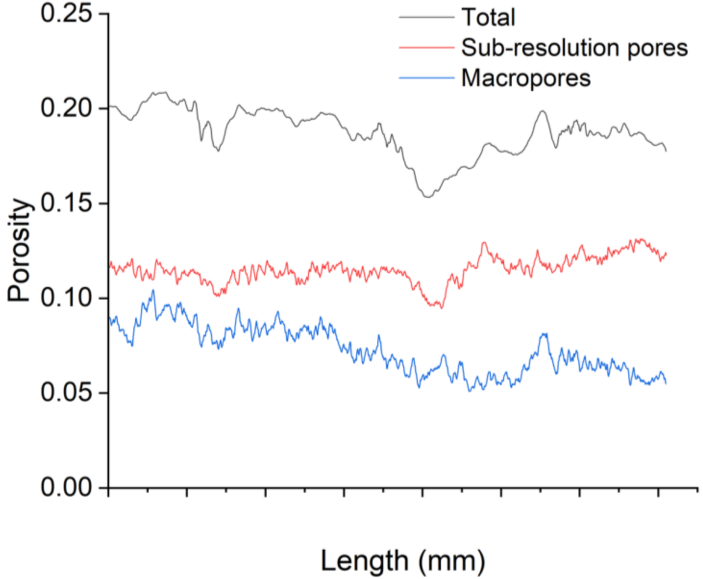
$\rightarrow S_o = \overline{CT} / CT_o\phi$

Differential imaging → fewer parameters → lower uncertainty

Watershed segmentation for grain, macropore and sub-resolution pores



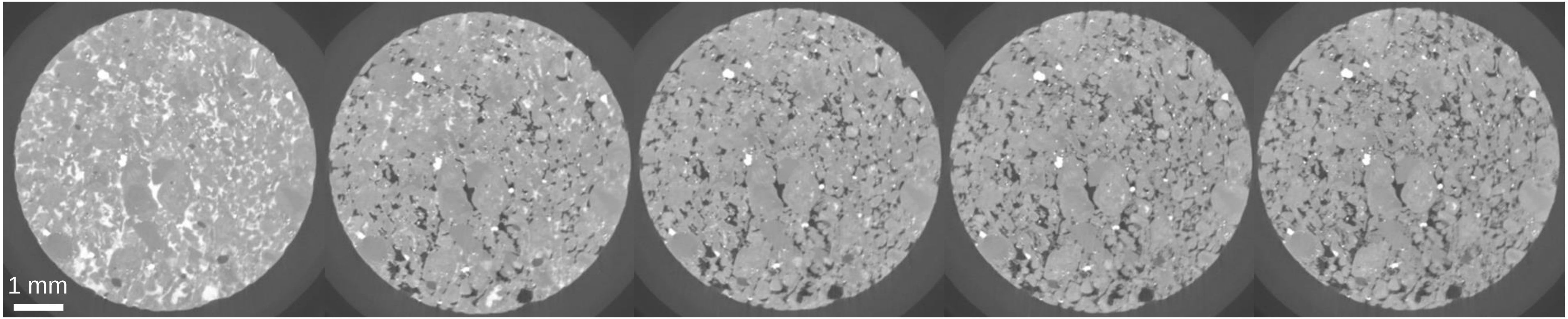
Grain: grey
Sub-resolution pores: blue
Macropores: red



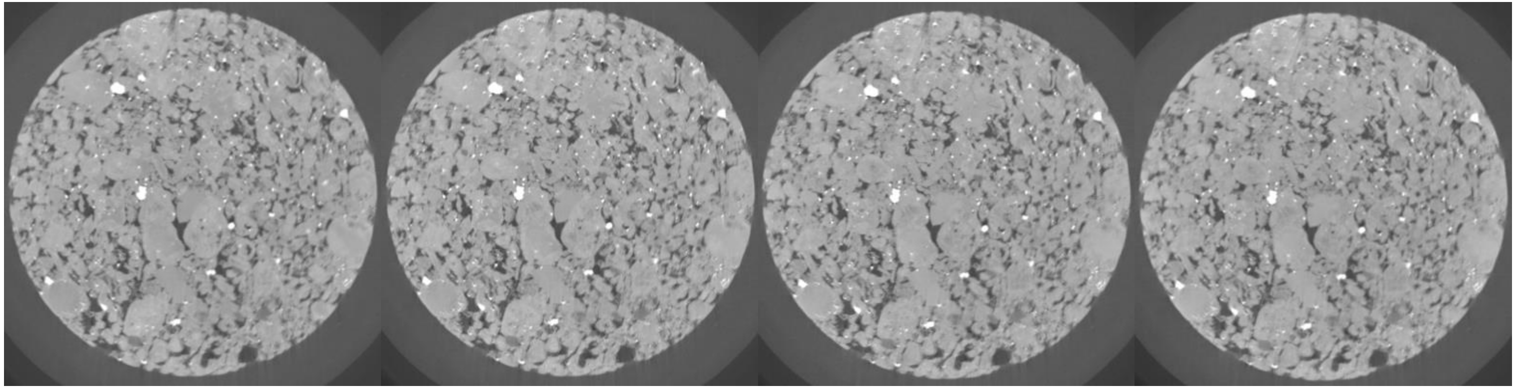
Total porosity	0.188 ± 0.010
Macropore	0.073 ± 0.005
Sub-resolution pores	0.115 ± 0.005

Helium Porosity: 0.190 ± 0.003

Greyscale images for primary drainage experiments

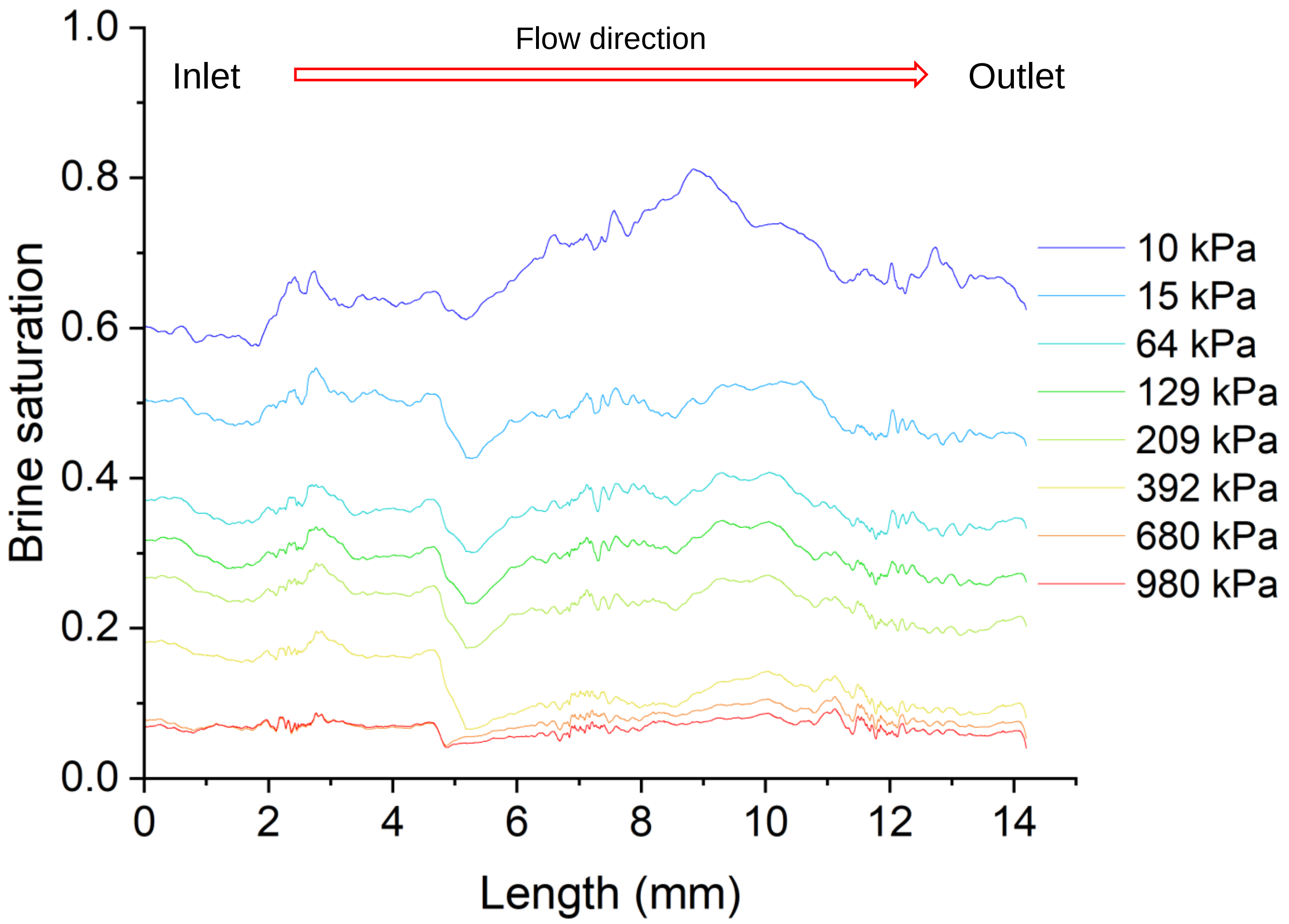


Brine scan | 10 kPa | 15 kPa | 64 kPa | 129 kPa

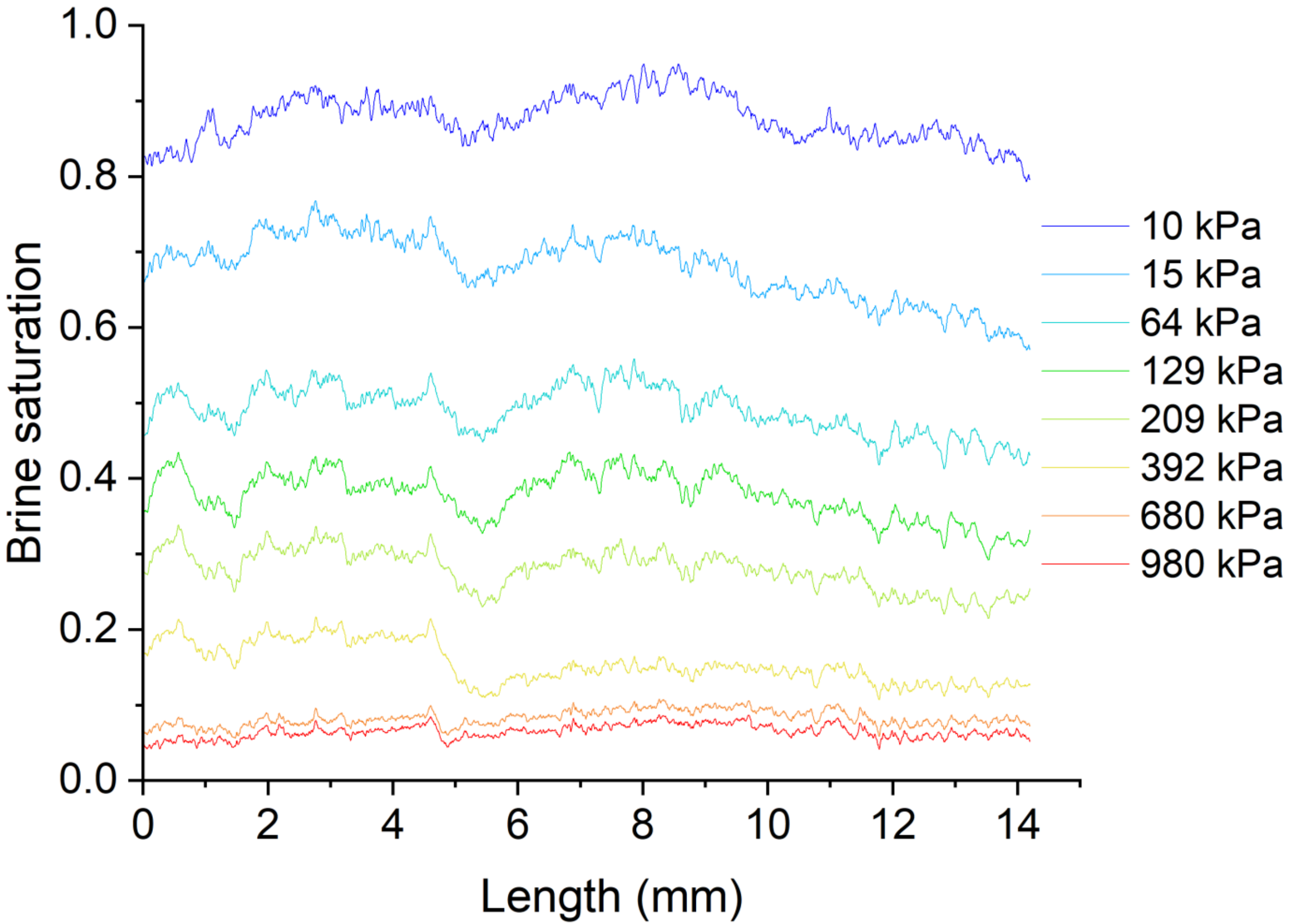


209 kPa | 392 kPa | 680 kPa | 980 kPa

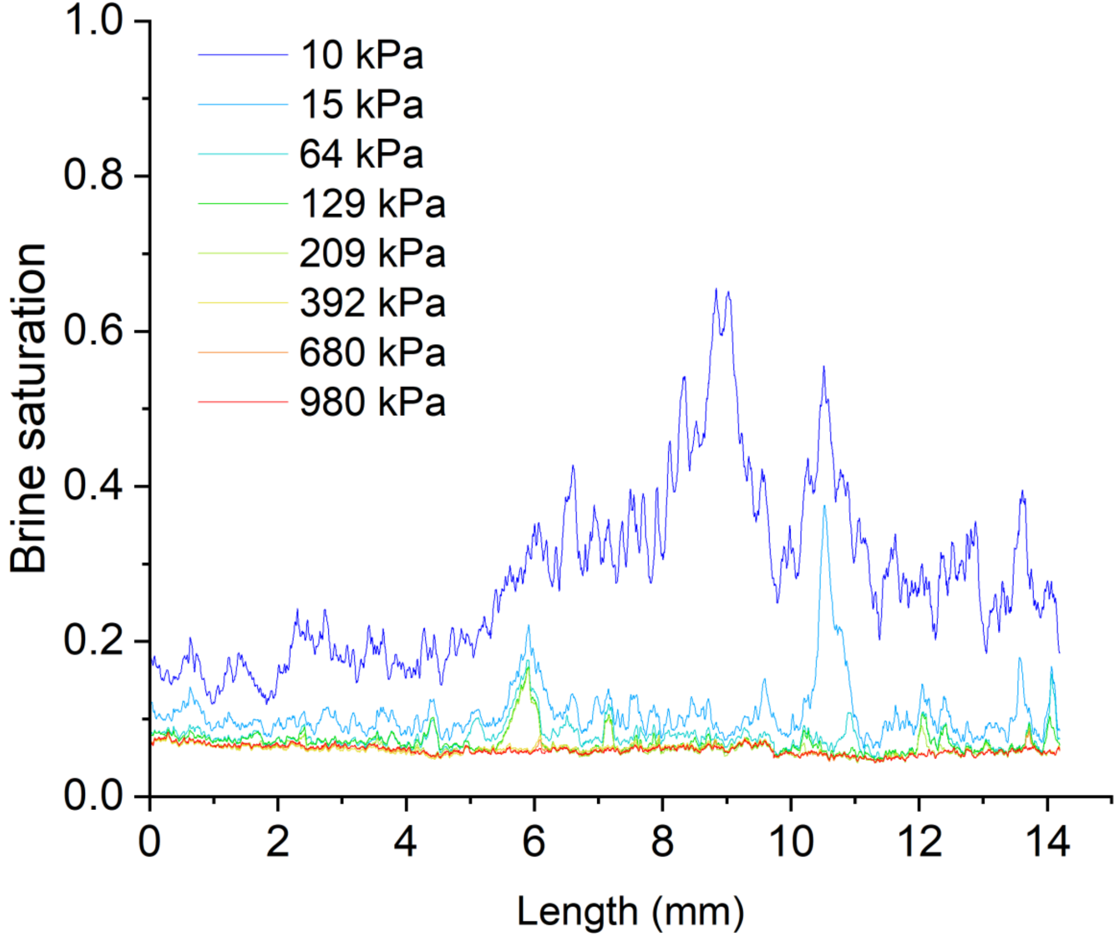
Total brine saturation during primary drainage



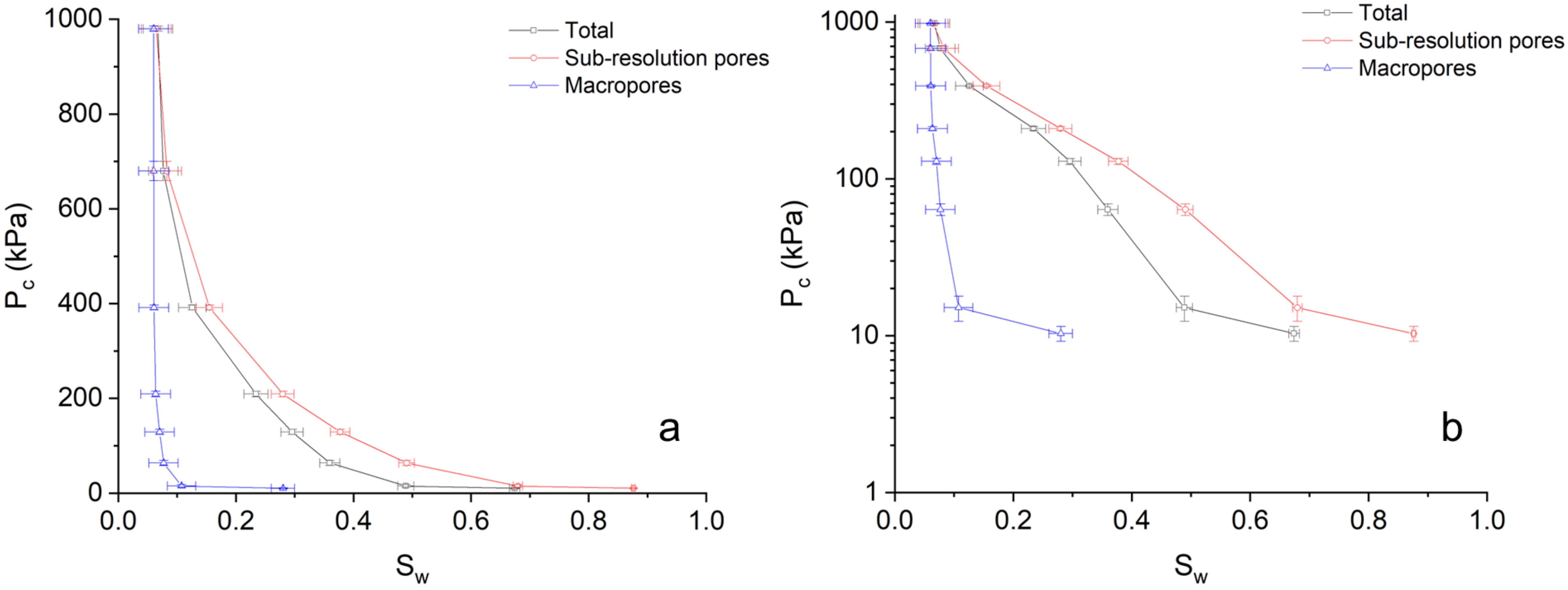
Brine saturation in microporosity during primary drainage



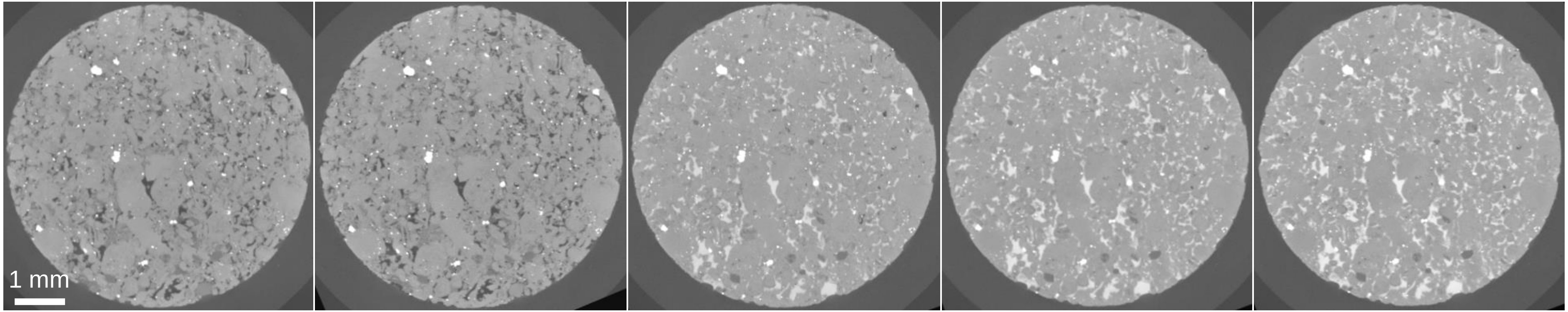
Brine saturation in macropores during primary drainage



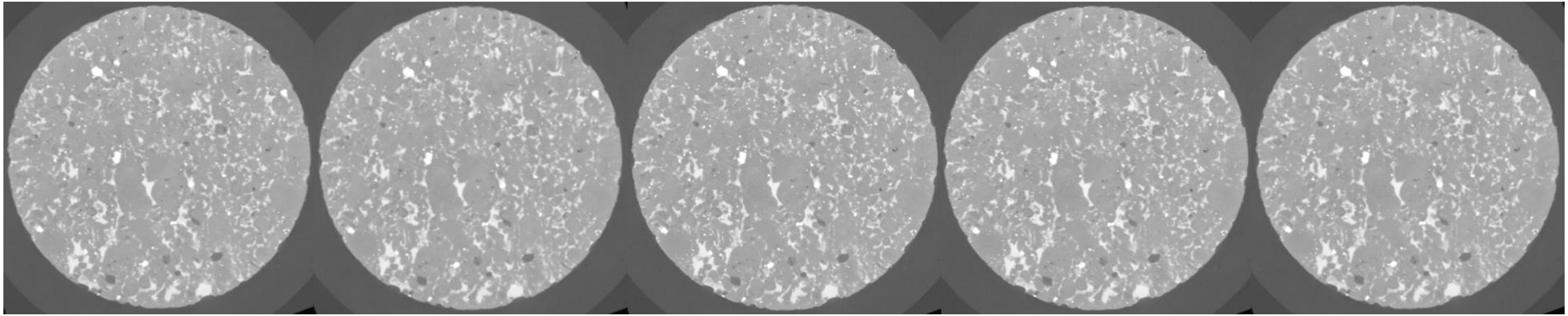
Capillary pressures vs S_w during primary drainage



Greyscale images for waterflooding experiments

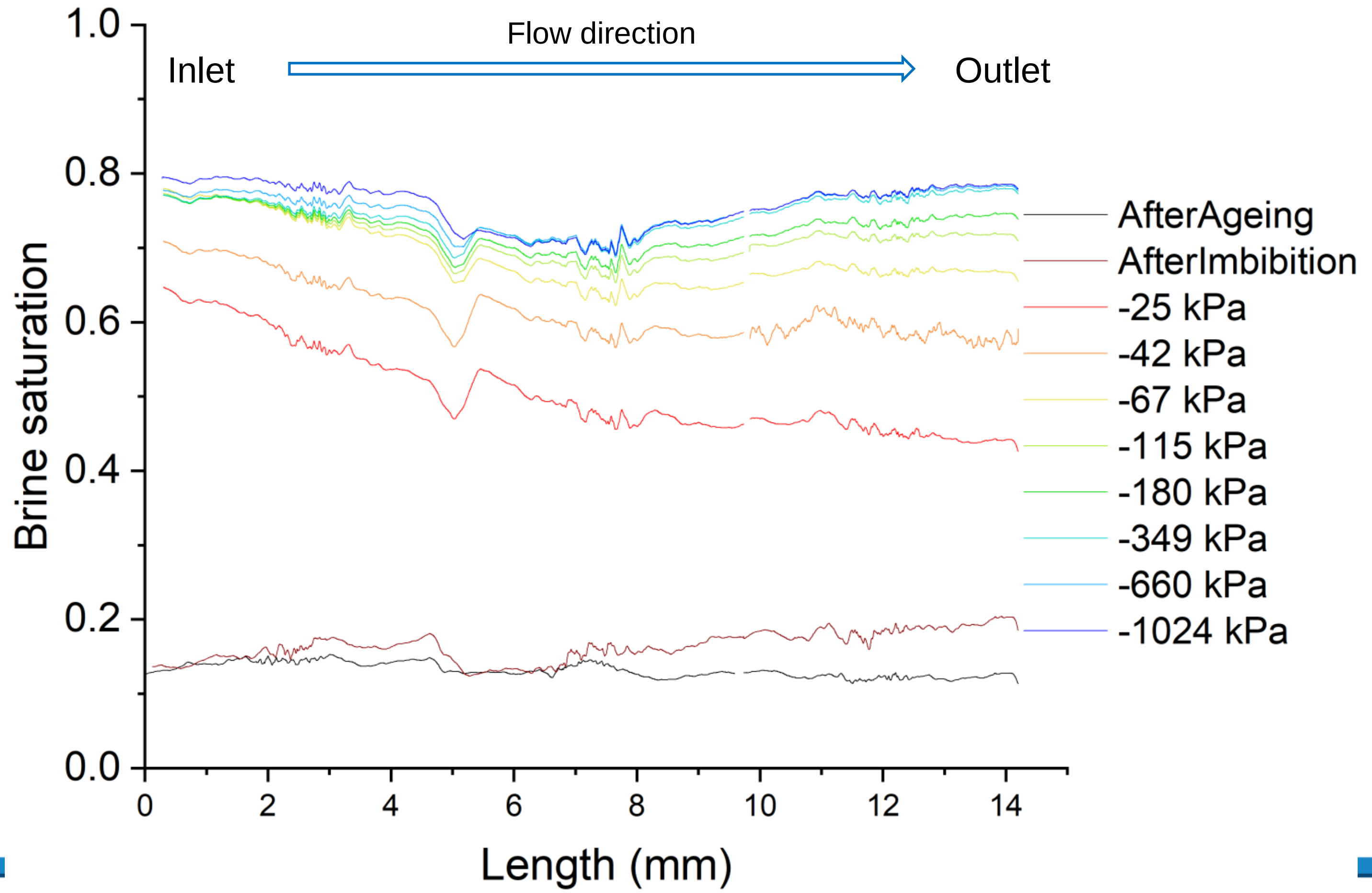


AfterAgeing | AfterImbibition | -25 kPa | -42 kPa | -67 kPa

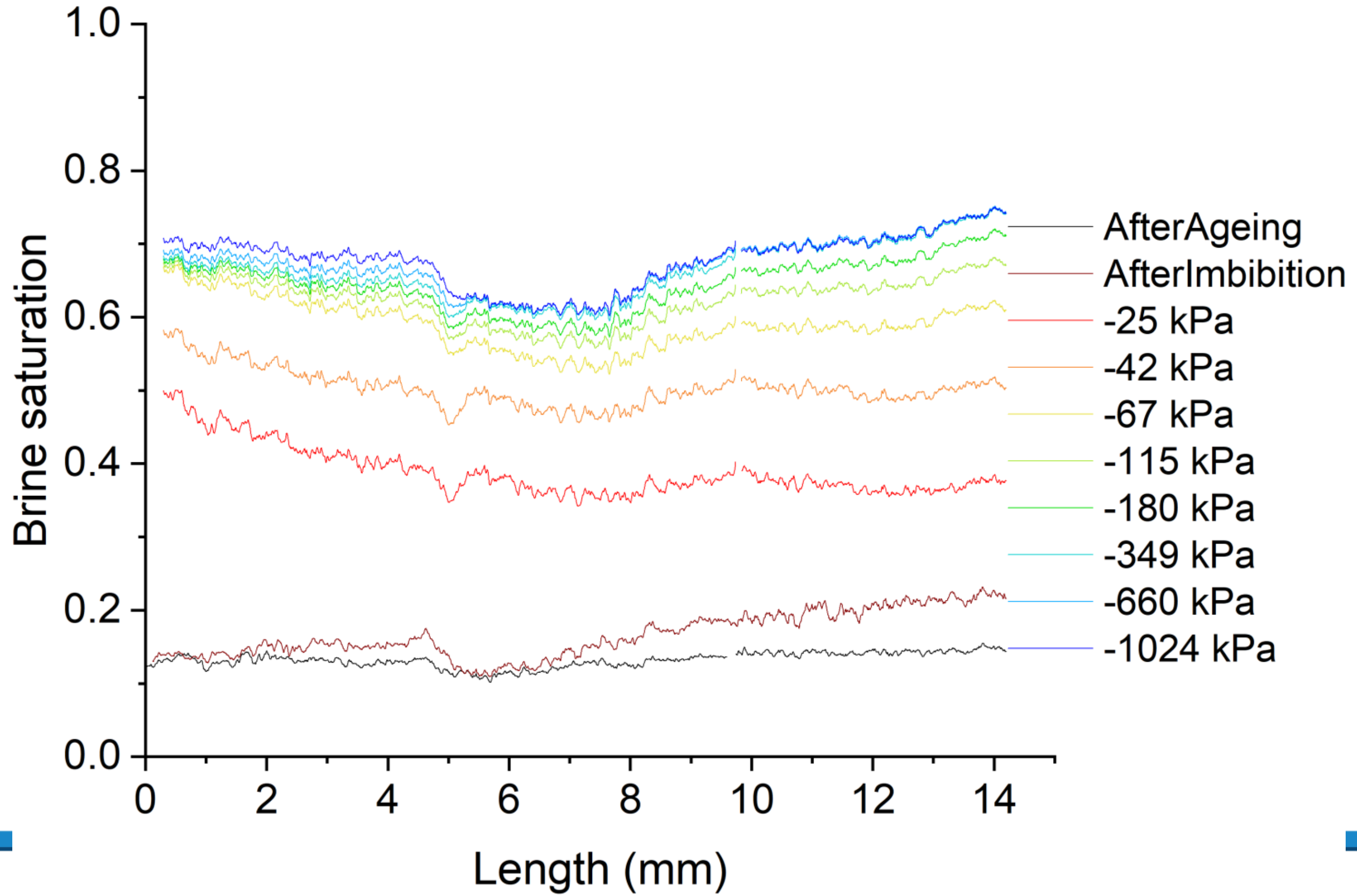


-115 kPa | -180 kPa | -349 kPa | -660 kPa | -1024 kPa

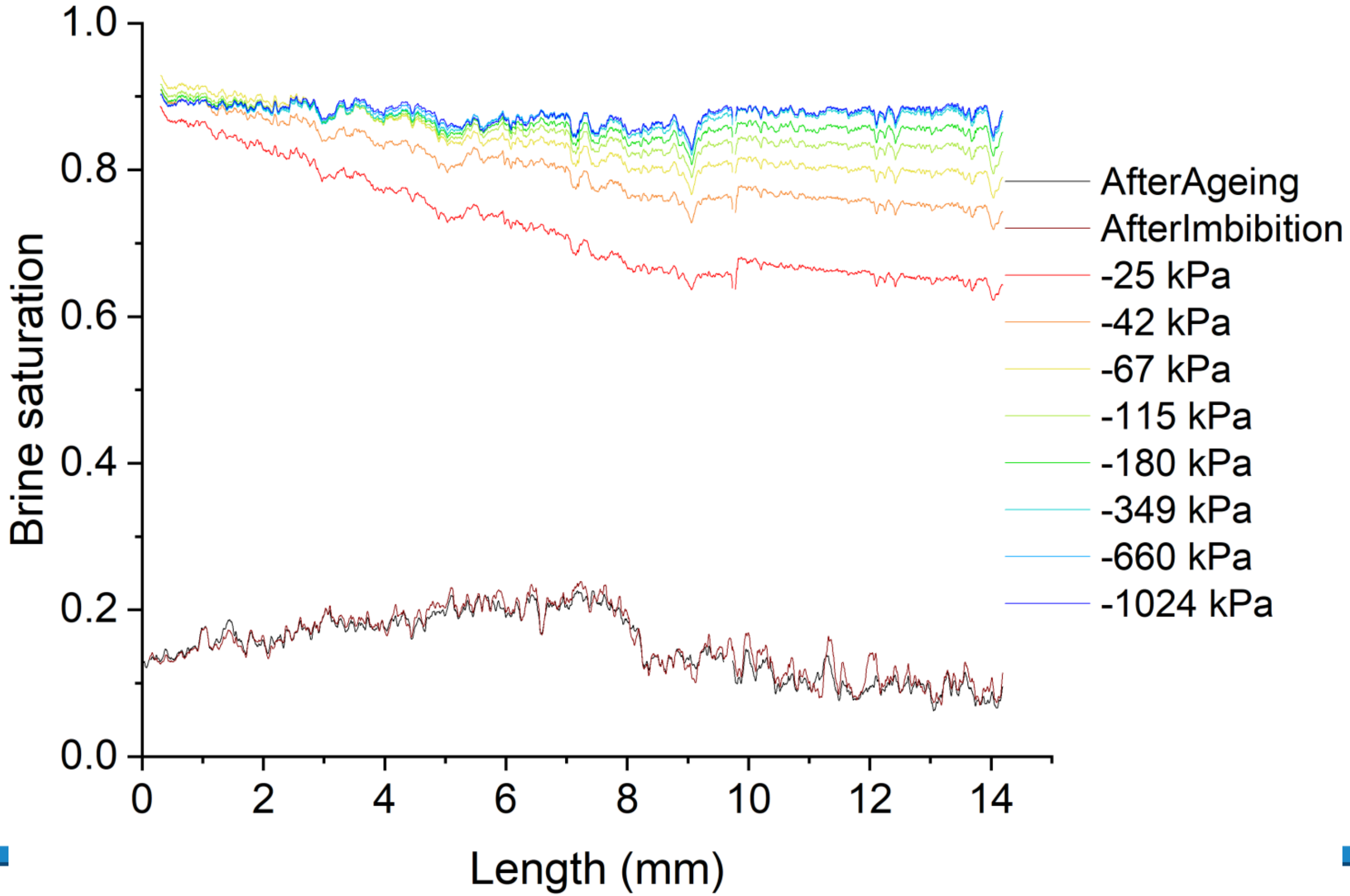
Total brine saturation during waterflooding



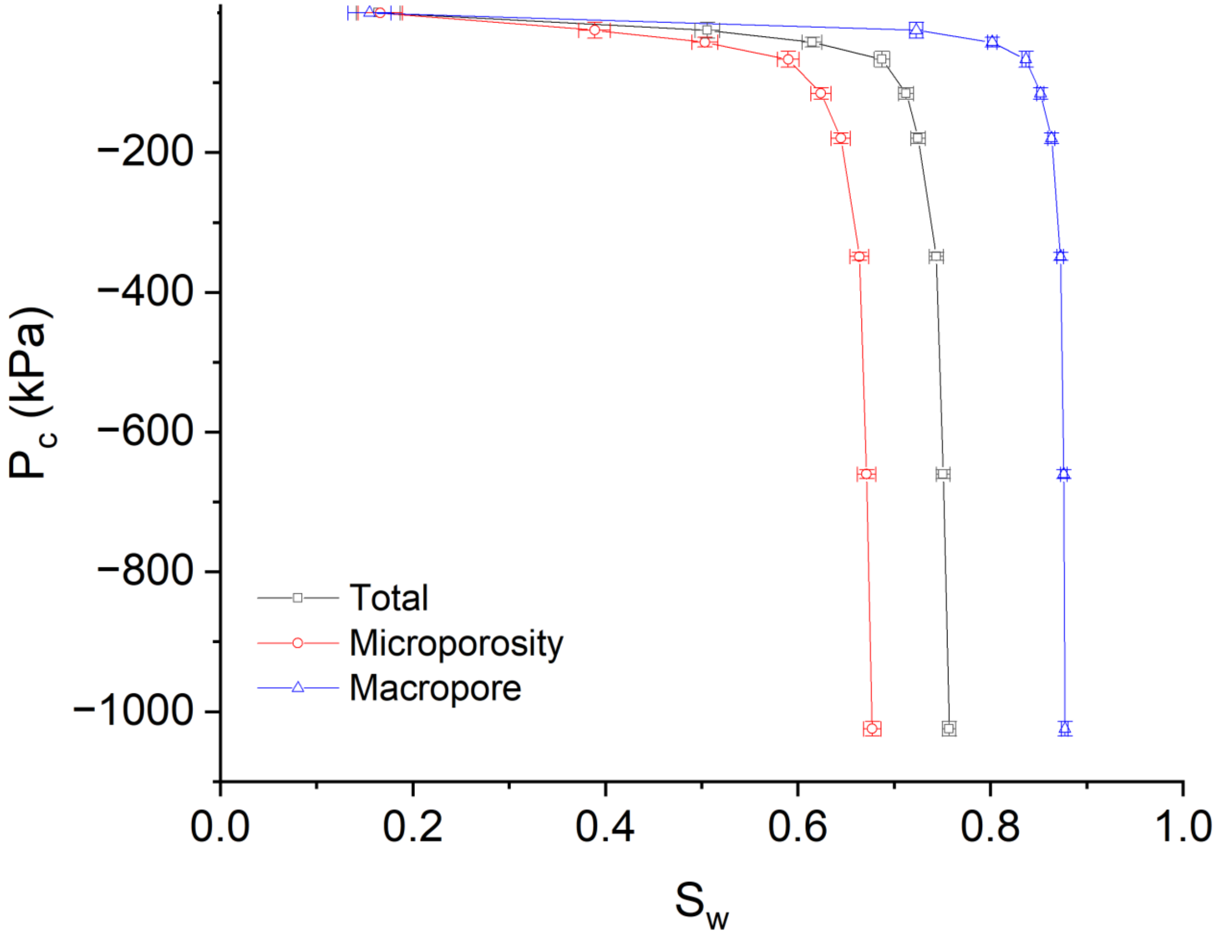
Brine saturation in sub-resolution pores during waterflooding



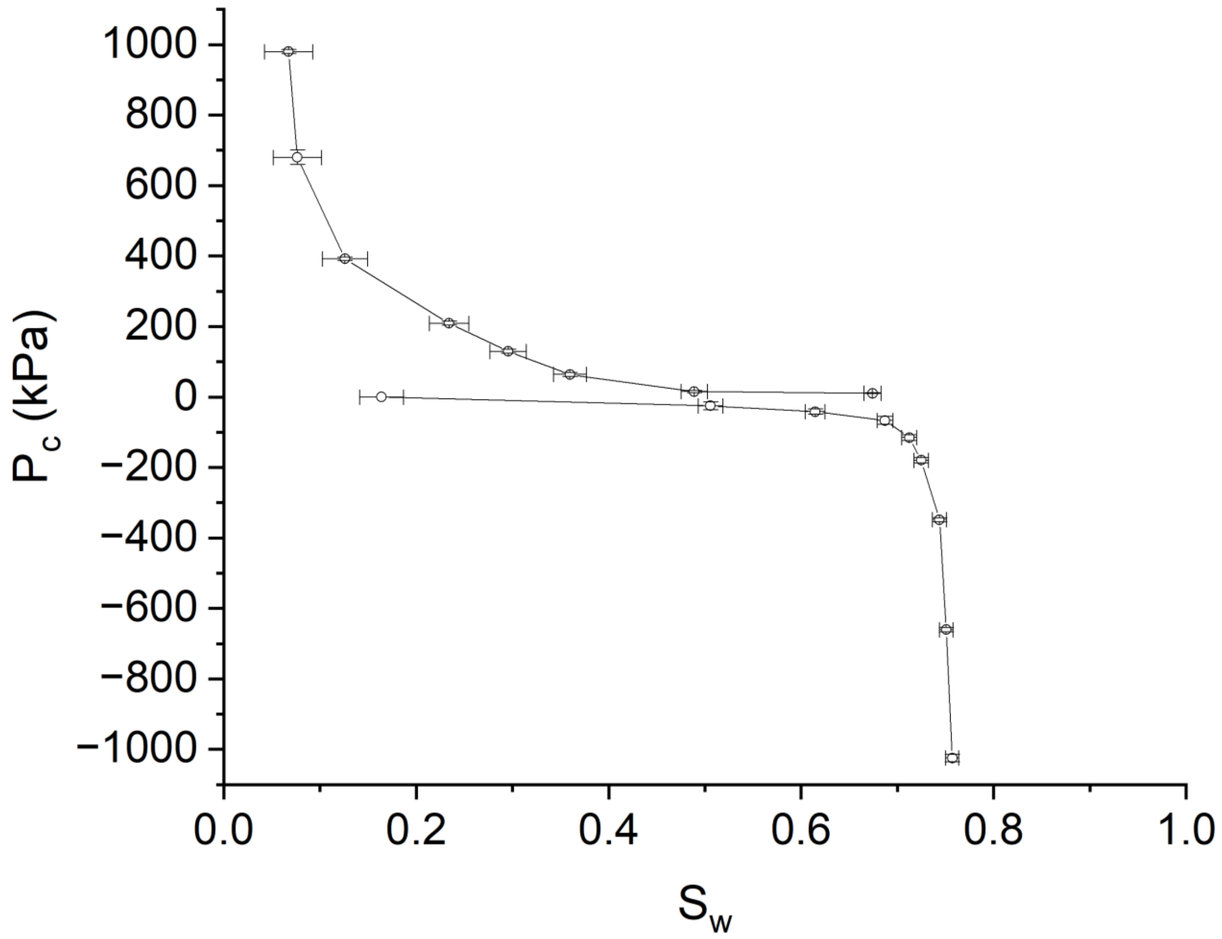
Brine saturation in macropores during waterflooding



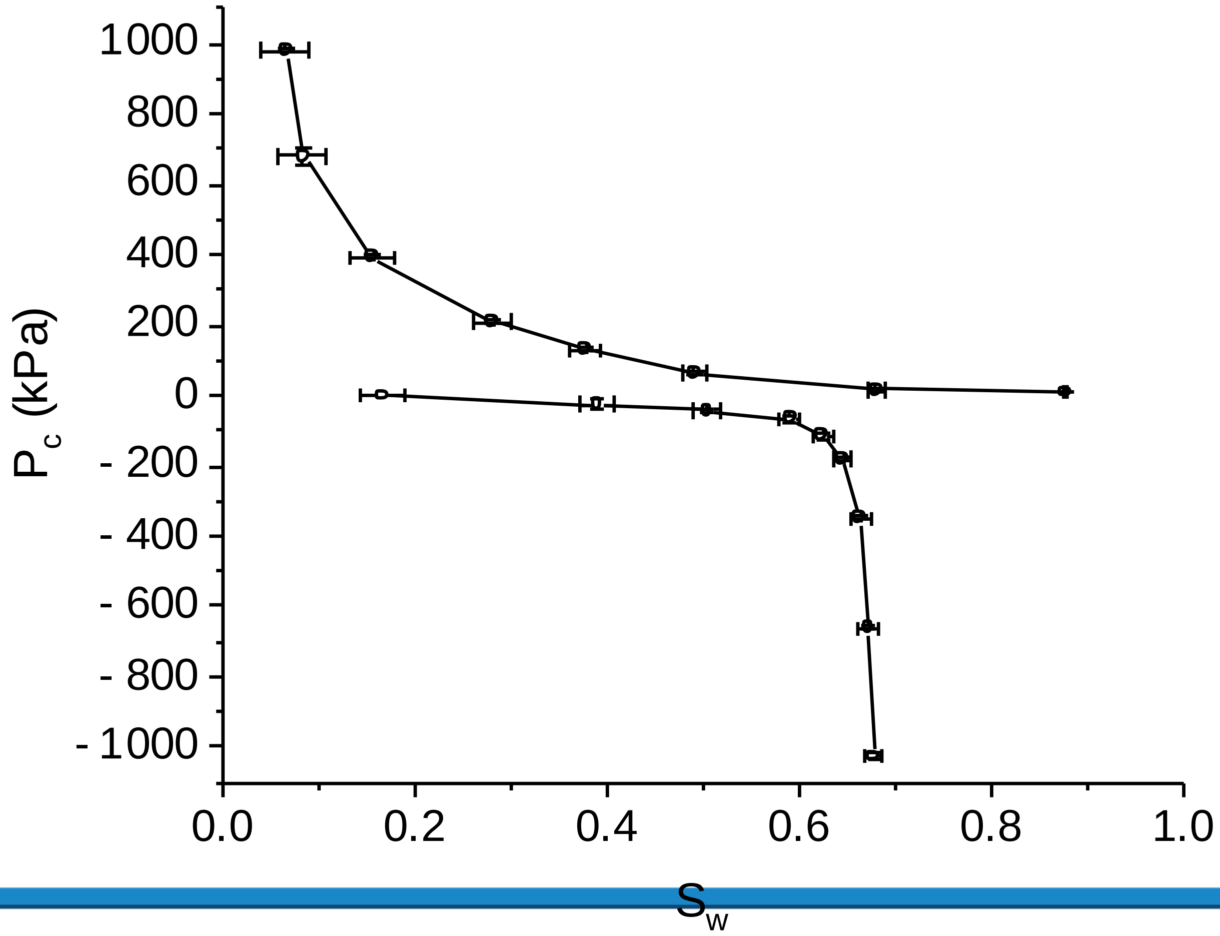
Capillary pressures vs S_w for waterflooding



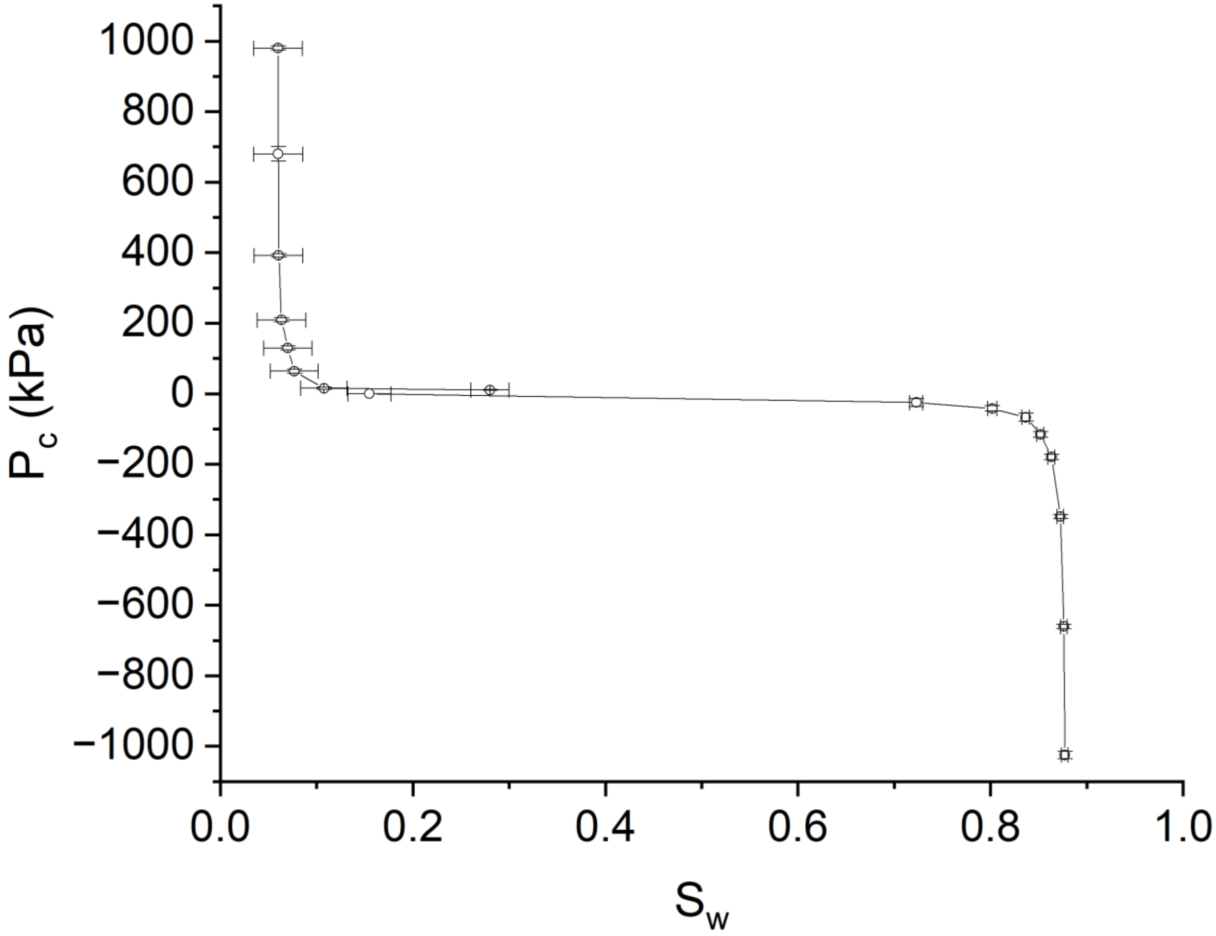
Capillary pressures vs S_w for drainage and waterflooding



Capillary pressures vs S_w in sub-resolution pores for drainage and waterflooding



Capillary pressures vs S_w in macropores for drainage and waterflooding



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Conclusions

- Developed an experimental methodology to measure capillary pressure during primary drainage and subsequent waterflooding using a porous-plate technique.

- Can accurately impose capillary pressure and a homogeneous equilibrium saturation distribution.

- Applied the method to a micro-porous carbonate.

- Can distinguish capillary pressure in resolvable macropores and micro-porosity.

- Benchmark experiments for multiscale pore-scale modelling.

Any questions ?

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