

# Applying Digital Rock Physics in Reservoir Engineering

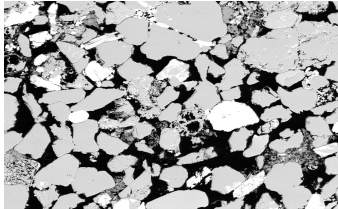
Gilbert Scott

DEVEX September 2020

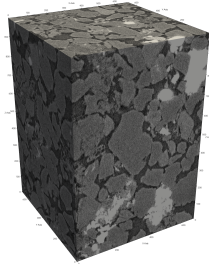
# Digital Rock Physics

- Pore scale imaging and modelling => rock properties

SEM



X-ray  $\mu$ CT



- Porosity
- Permeability
- Relative permeability
- Capillary pressure

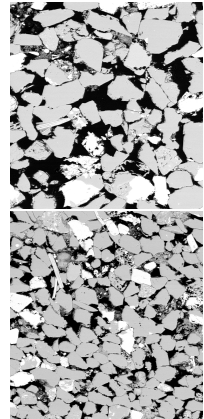
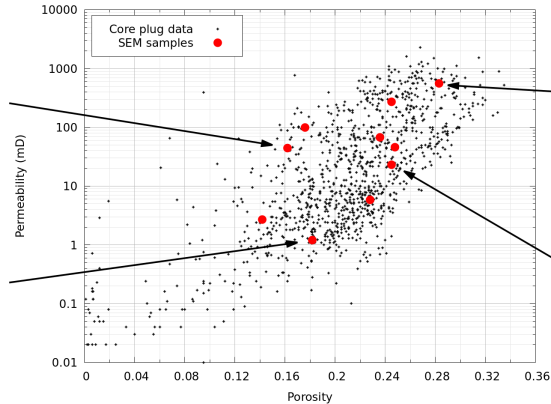
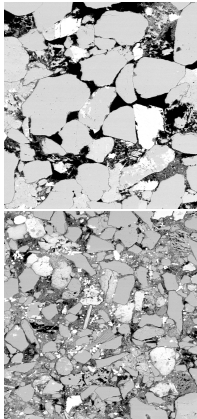
# SEM vs $\mu$ CT

	SEM 2D	$\mu$ CT 3D
Resolution	0.1 $\mu$ m	1 $\mu$ m
Image Size	30,000 <sup>2</sup> pixels	1000 <sup>3</sup> voxels
Field of View	9 mm <sup>2</sup>	1 mm <sup>3</sup>
Signal/Noise Ratio	High	Low
Acquisition Time	3 hours	24 hours
Cost Factor	1	10

- SEM images are significantly better quality, higher resolution and cheaper than  $\mu$ CT but only 2D

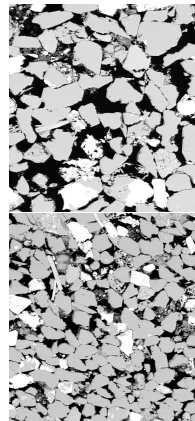
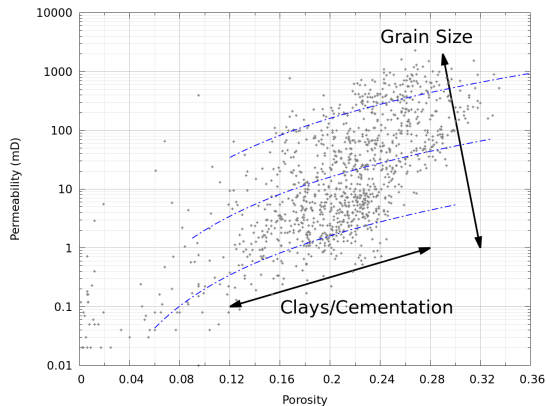
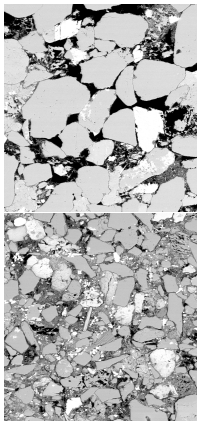
# SEM Imaging

- North Sea Jurassic sandstone oil reservoir



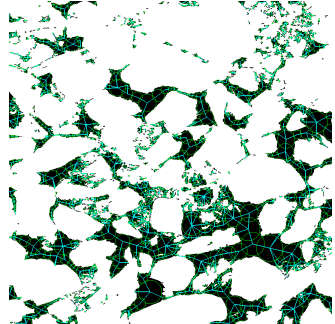
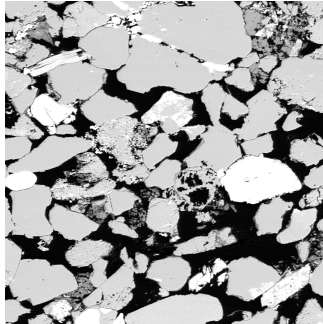
# SEM Imaging

- Poro/perm controlled by grain size and clays/cementation



# Workflow

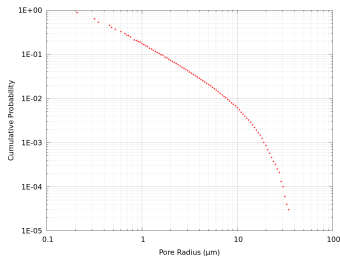
- 1 SEM Imaging
- 2 Segmentation
- 3 Statistical Analysis
- 4 Stochastic Network
- 5 Pore Network Modelling
- 6 Relative Permeability and Capillary Pressure



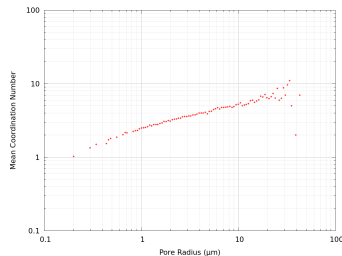
# Workflow

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Pore Size Distribution

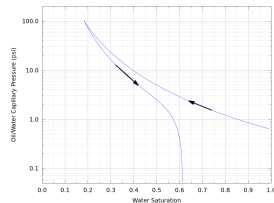
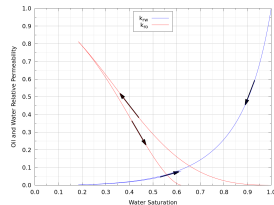
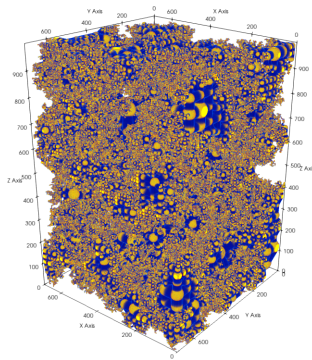


Pore Coordination



# Workflow

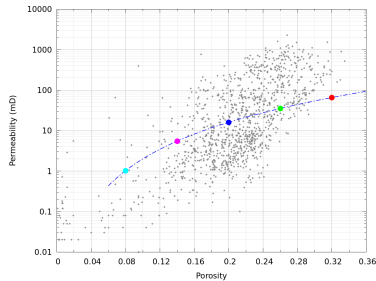
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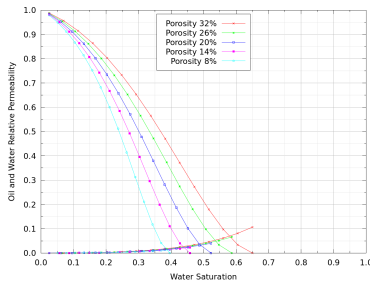


# Relative Permeability

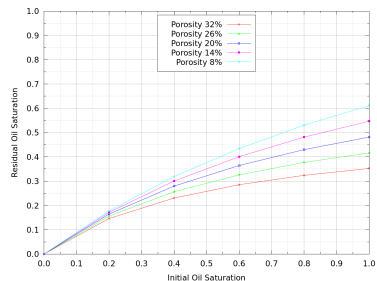
5 models with a range of cementation



Imbibition  
relative permeability  
water wet conditions



Trapping curves

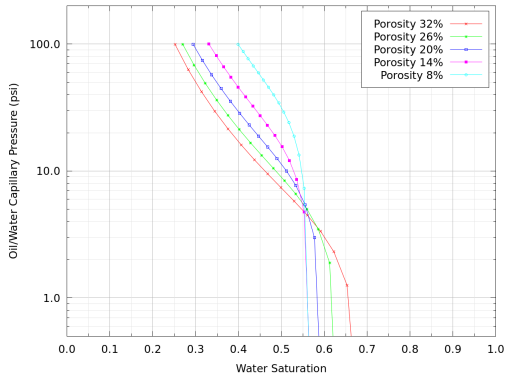


- Higher residual oil saturation at low porosity

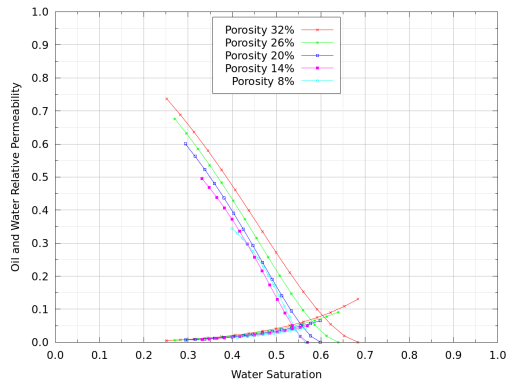
# Water Wet Conditions

- Drainage to a fixed capillary pressure

Imbibition Capillary Pressure



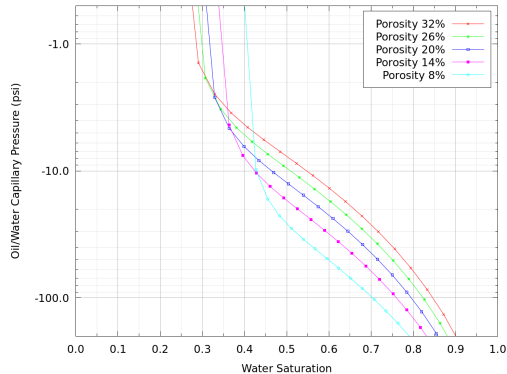
Imbibition Relative Permeability



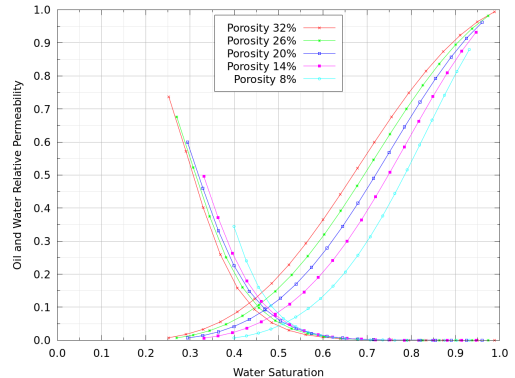
# Oil Wet Conditions

- Drainage to a fixed capillary pressure

Imbibition Capillary Pressure

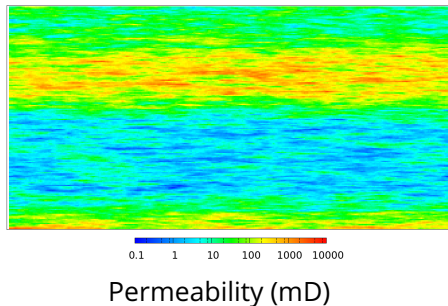


Imbibition Relative Permeability

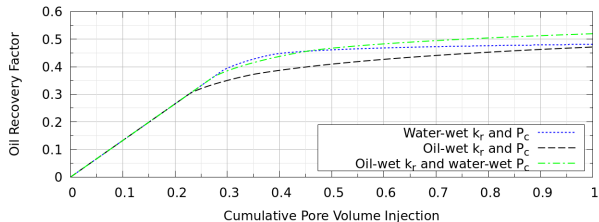
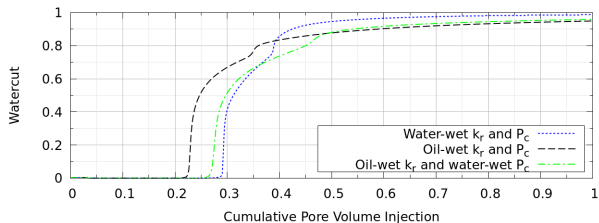


# Reservoir Modelling

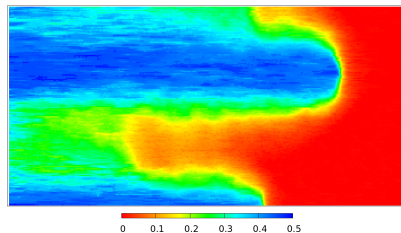
- Heterogeneous reservoir model
- Data from North Sea Jurassic oil reservoir
- 2D cross-section
- 1 Producer and 1 water injector
- Oil:water viscosity ratio = 2:1



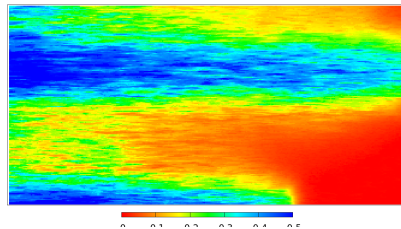
# Reservoir Model Results



Water-Wet  $k_r$  and  $P_c - \Delta S_w$  at 0.25 PVI



Oil-Wet  $k_r$  and  $P_c - \Delta S_w$  at 0.25 PVI



# Conclusions

- Digital rock physics is a valuable tool for reservoir engineering
- Pore network models can be generated from high resolution 2D SEM imaging
- Imbibition capillary pressure is important in finely gridded simulation models
- Knowledge of the rock wettability is important for waterflood modelling