Why do you need CT in the oil and gas industry?

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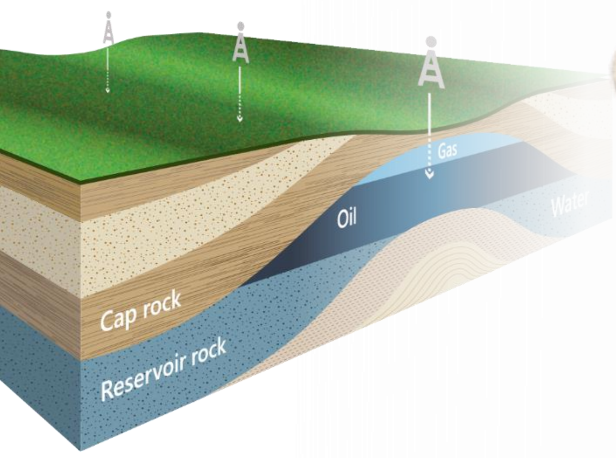
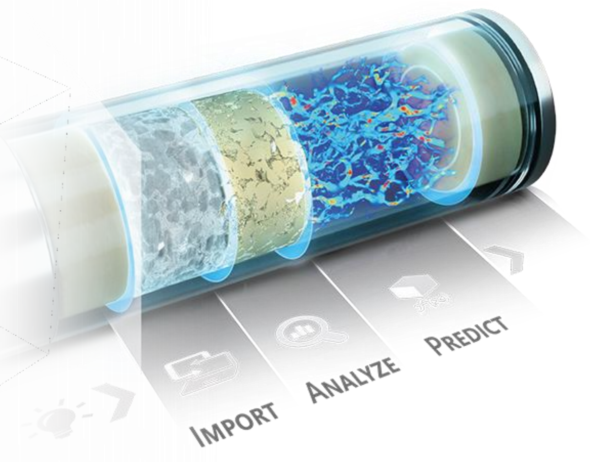
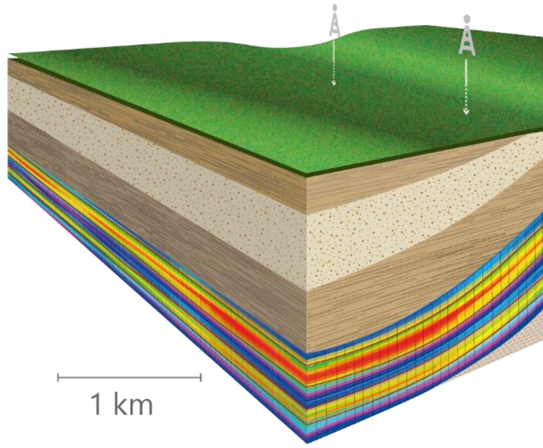
Motivation and Workflow

GeoDict

Oil&Gas Reservoir »	Sampling »	Imaging »	GeoDict »	Reservoir Simulator







Goal	Requirement	Imaging device	Digital Core Analysis	Reservoir simulator
Understand reservoir properties to **optimize oil & gas extraction**	Obtain and prepare rock samples (cores, plugs, cuttings)	Obtain 3D gray value scans of digital rocks (e.g., micro-CT device)	Segment 3D scan, characterize geometry, predict pore-scale digital rock properties	Feeding GeoDict results into simulations at the reservoir scale

→ Digital Core Analysis improves understanding of reservoir properties

→ DRP digitalizes (Special) Core Analysis and **saves time & costs in comparison to SCAL experiments**

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Polling Question #1

At what stage is CT used in the development and production process of oil and gas reservoirs?

At what stage is CT used in the development and production process of oil and gas reservoirs?

GeoDict

Upstream Sector

- Exploration and production (**E&P**)
  a) Finding crude **oil** and natural **gas** deposits
  b) Producing them

- Typically requires drill cores (*cuttings*)
- Upstream Sector (Exploration & Production):
  Improved well placement
  Reservoir characterization (porosity, permeability,…)
  Primary Production, Secondary Production, Tertiary/Enhanced Oil Recovery (EOR) Production
  Data input for reservoir simulators
  Predictions for management decisions
  → *Results taken from CT lead to more efficient and effective exploration and production activities.*
- Research & Development (R&D):
  Refine methods for CT & DRP (e.g., calibration)
  Develop new workflows
  Gain new insights on rock properties

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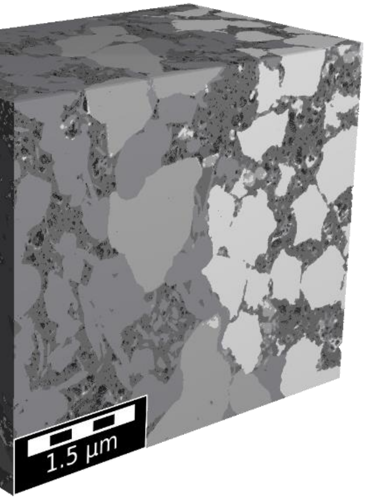
How do you scale the CT analysis results to guide decision-making applied to km-size reservoirs?

Digital Rock Physics – Scales

From nano-pore system to reservoir scale

Nano resolution »



Andrew (2018)

nm resolution

DRP in nano pores

DRP in Shales, sub-micron carbonate pore systems, …

Plug scale »

Andrae et al. (2013)

~1 µm resolution

DRP in micron pores

DRP in sandstones, resolved carbonate pores, …

Whole core scale »

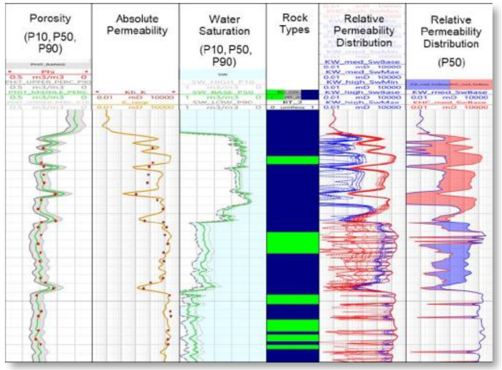
Victor et al. (2017)

50-500 µm resolution

DRP → whole core

Upscaling from DRP in resolved pore systems to lab-scale cores

Well log scale »



Burmester et al. (2022)

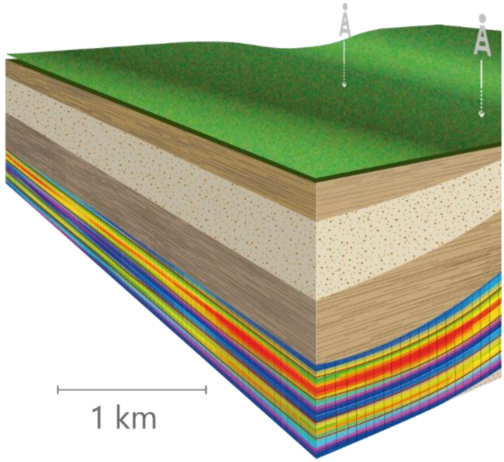
meter-scale

DRP → log scale

Integrated upscaling of

lab-SCAL,
digital-SCAL,
database modelling,
log interpretation

Reservoir scale

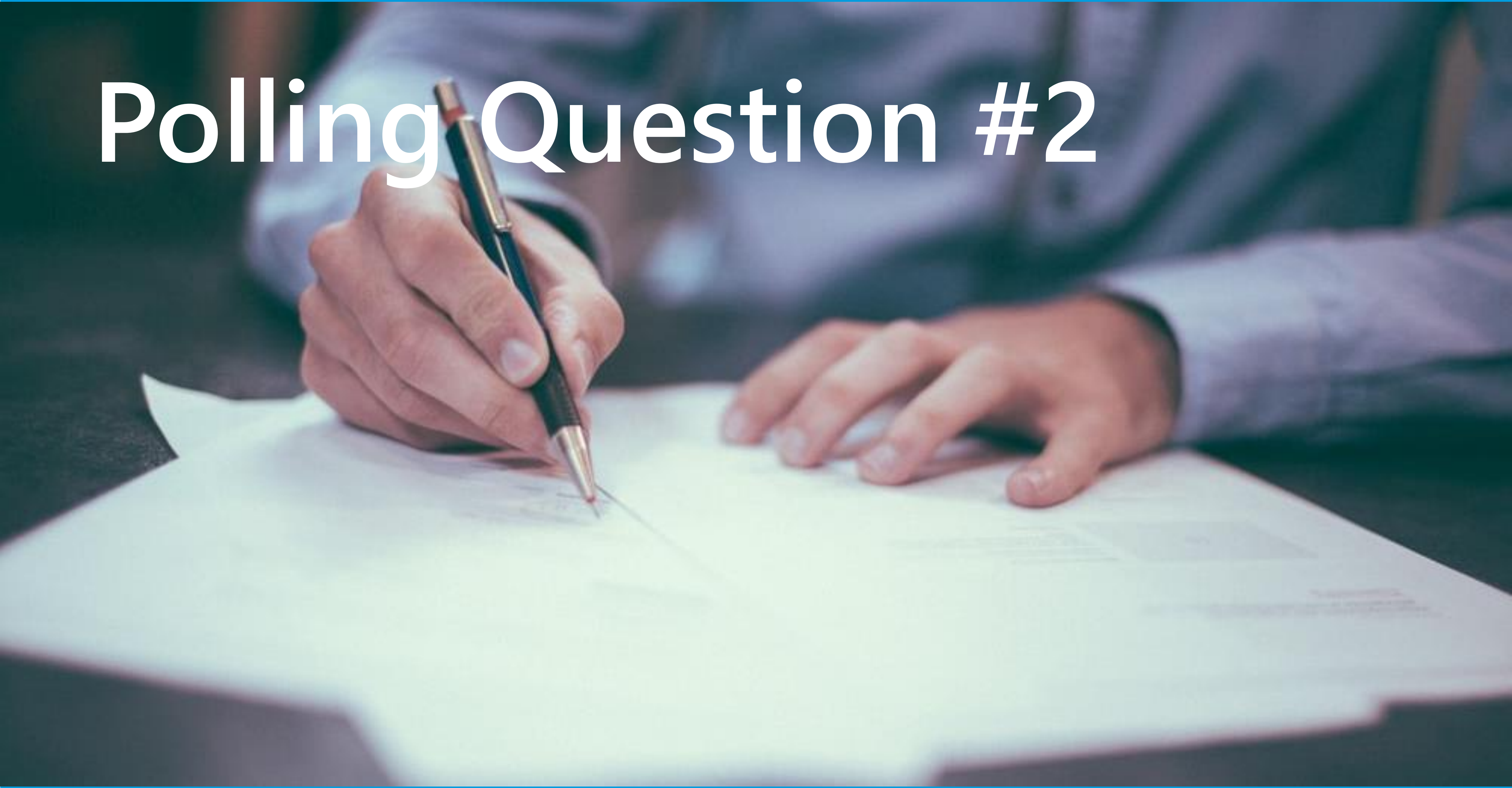


km-scale

DRP → reservoir simulator

Integration of DRP results to field-scale simulations

Polling Question #2



Lightning Round

When should we use digital rock physics and when should we use experiments?

When should we use digital rock physics and when should we use experiments?

GeoDict

Simulations:

Pros

- Non-destructive
- Can model complex processes that are difficult or impossible to measure directly
- Can be easily repeated and modified
- Can be used to optimize production and reduce costs
- Scalability

Experiments:

Pros

- Necessary if high resolution images of the sample are not available
- Provides direct measurements and data
- Can validate theoretical models and simulations

Example: Sandstone with high clay content

- Clay contents are usually not resolved by µCT resolution

Example: High sample throughput

- Digital simulation not limited by lab equipment

→ Best results are achieved by complementing both approaches

How do you correlate the simulation and experiments?

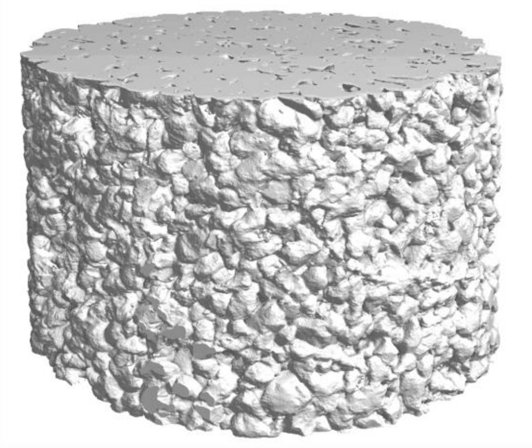
Mercury Intrusion Capillary Pressure (MICP)

GeoDict

SatuDict Hidden Porosity

Tackling the unresolved porosity in CT images

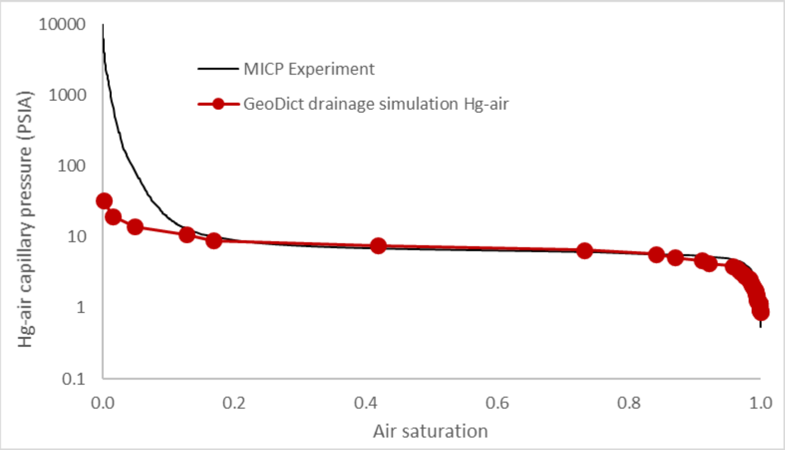
- A key finding for comparing lab MICP with DRP results
- Recommended for Digital Core Analysis workflows



Gildehauser sandstone

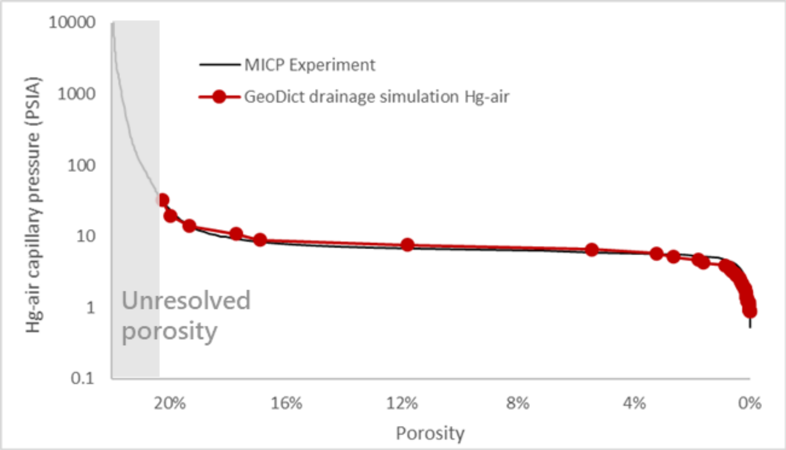
Berg et al. (2016)

GeoDict MICP
RAM usage: 7 GB
runtime: 0.5 h



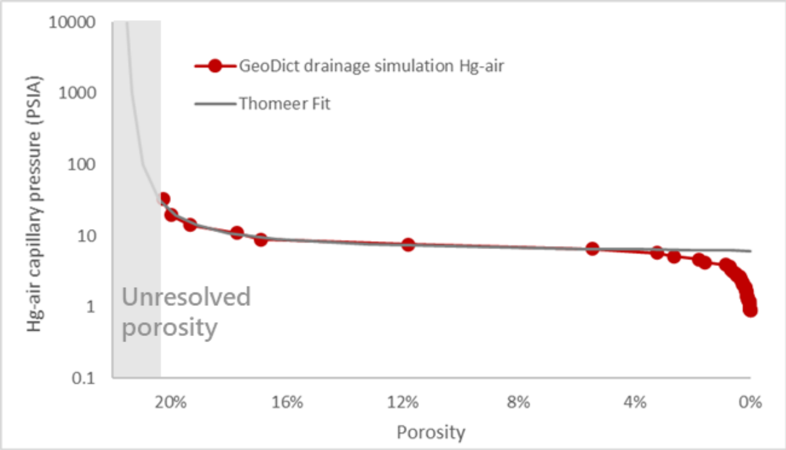
Issue:
Mismatch in published MICP data

Experimental versus digital MICP results as published by Berg et al. (2016)



Solution:
MICP sees higher porosity than µCT

Plot porosity on X-axis to consider the unresolved porosity



Advanced workflow:
Predict the unresolved porosity

Estimation of unresolved porosity via Thomeer model from digital MICP by Linden & Wiegmann (2023)

Berg et al., Connected pathway relative permeability from pore-scale imaging of imbibition, (2016) https://doi.org/10.1016/j.advwatres.2016.01.010

Linden & Wiegmann, Quantification of the hidden porosity in 3D digital scans of rocks, (2023), in preparation.

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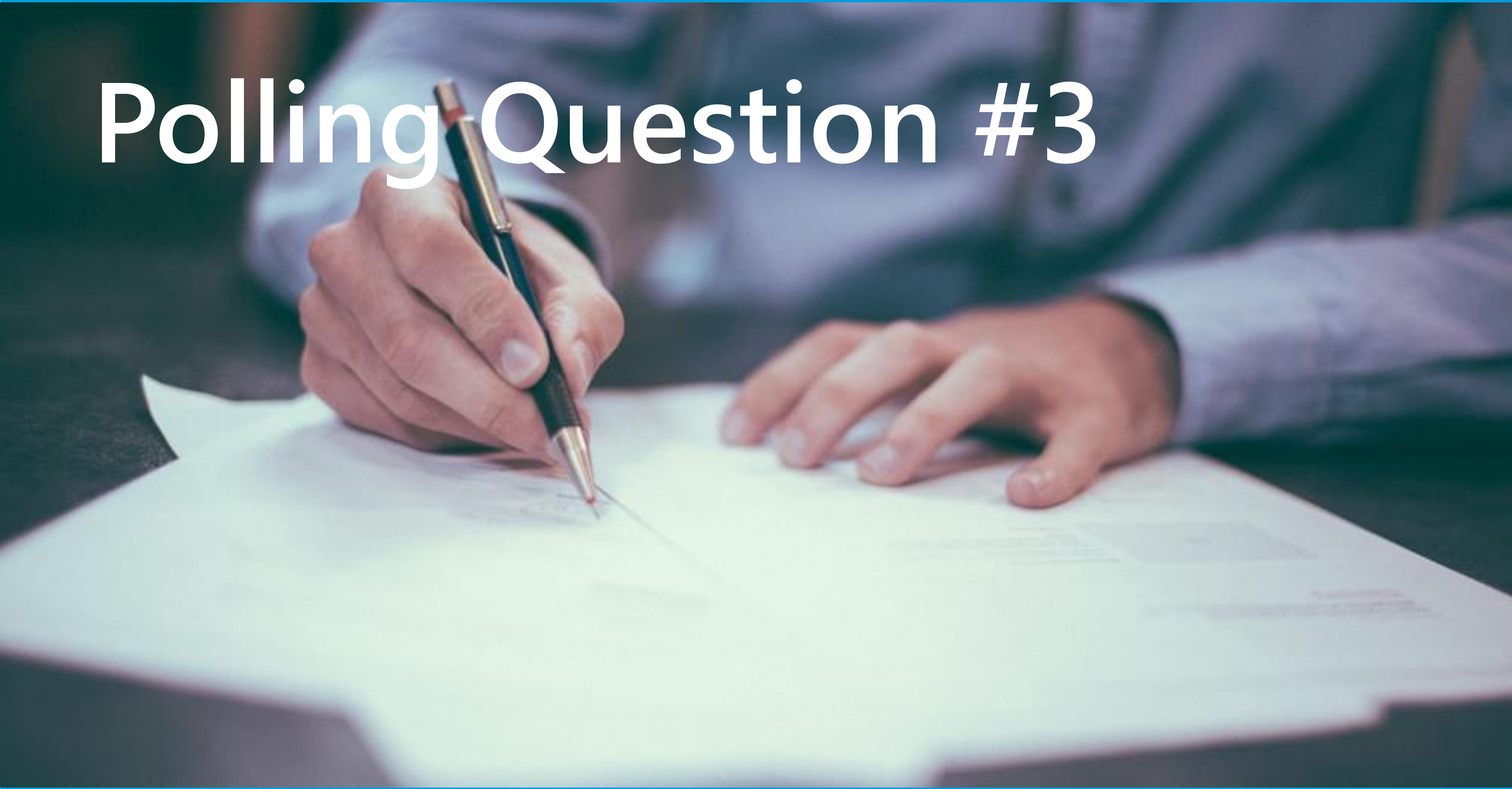
Polling Question #3

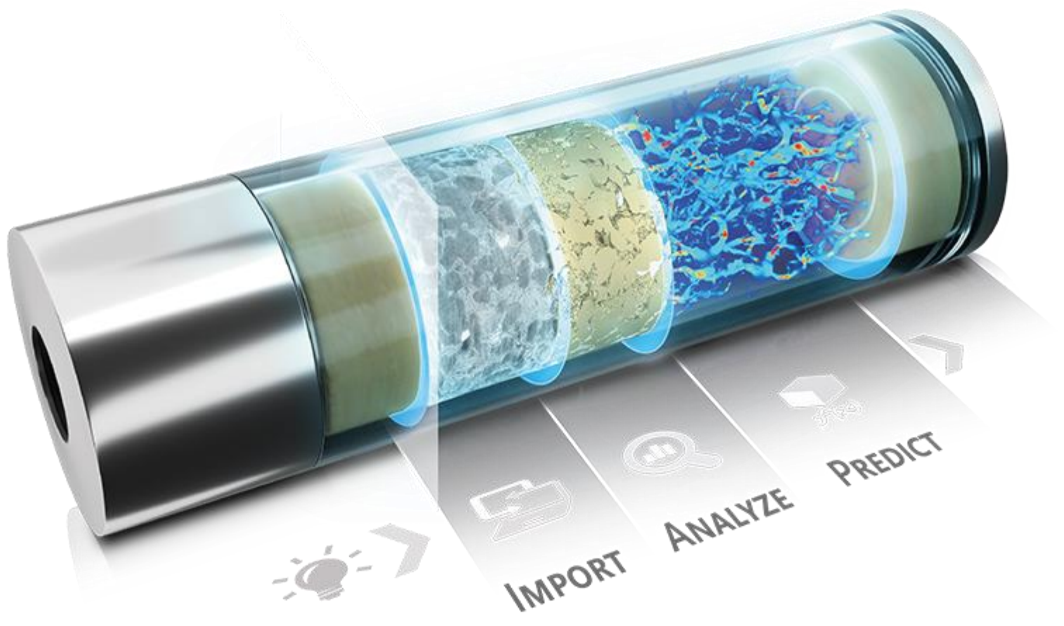


What are the challenges you see in applying digital rock physics to a practical decision-making process?

What are the challenges you see in applying digital rock physics to a practical decision-making process?

GeoDict

- **Data availability:** High-quality input data, such as micro-CT images.
- **Computational resources:** Digital rock physics models require efficient algorithms to work cost & time efficient
- **Upscaling:** Integration of DRP results to well and field scale
- **Validation:** Company-specific validation workflows
- **Automation:** Integration of proofed workflows into the production environment

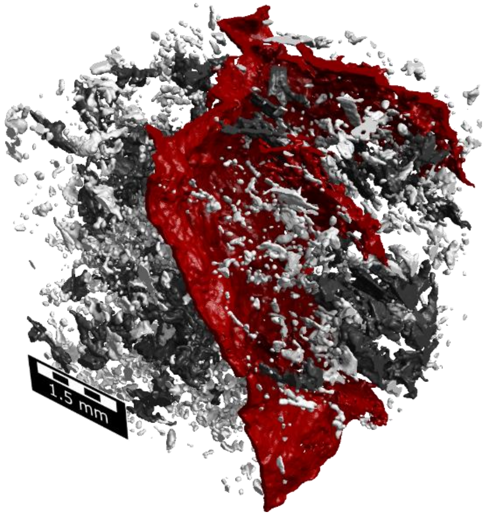


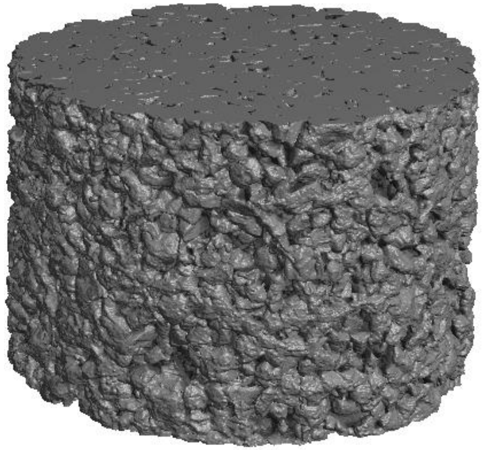
Math 2 Market

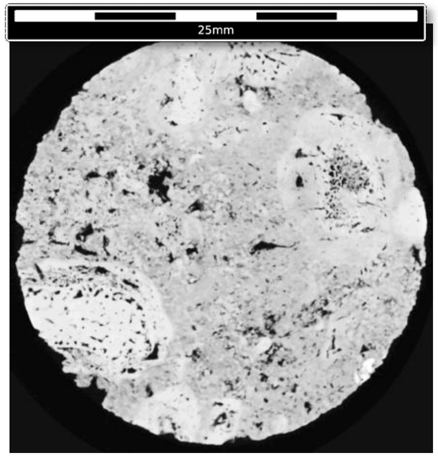
What is the difference between regions that can produce oil effectively and the ones that can't?

What is the difference between regions that can produce oil effectively and the ones that can't?

- Quality of transport properties of the oil-bearing formation
  - Permeability
  - Porosity
  - Pore connectivity
- Properties of oil and associated fluids
- Favorable trapping conditions
- Abundance and preservation of organic-rich sedimentary rocks (source rock)
- Favorable history of burial and deformation of rocks







Portfolio: GeoDict® for DRP

Image Processing and Image Analysis

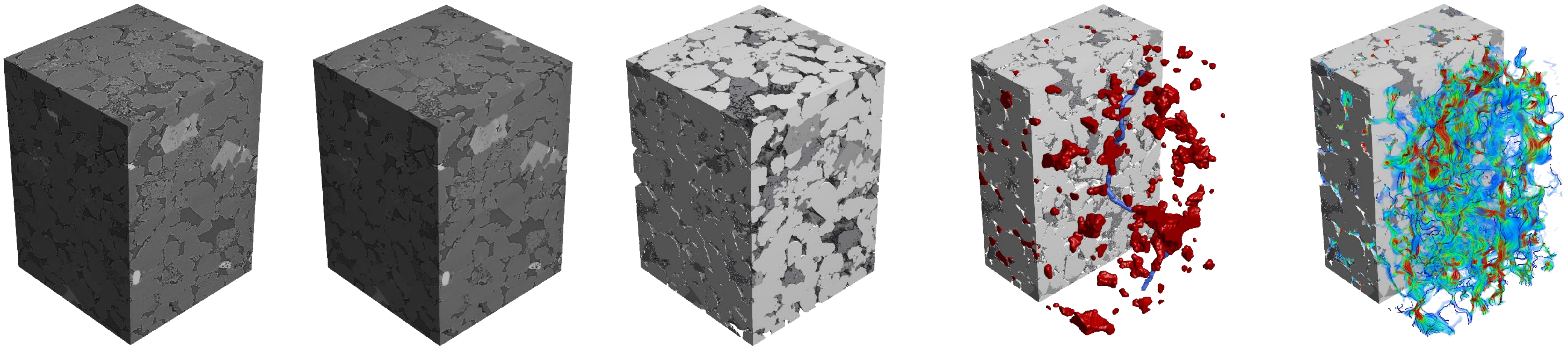


Image Import

- µCT scans
- Core CT scans
- Synchrotron CT scans
- FIB-SEM images
- Data from other imaging techniques

Image Processing

- Image operations: Rescale, Rotate, Crop, …
- Remove image artifacts (e.g., ring-artifacts)
- Reduce noise (e.g., NLM)
- AI image quality enhancement

Image Segmentation

- Single-multiple thresholds
- Auto-segmentation via Otsu method
- AI segmentation
- Watershed-based segmentation

Image Analysis & Generation

- Porosity (total and accessible)
- Pore size distribution
- Percolation and Tortuosity
- Grain, pore, frac identification with related statistics
- Advanced structure generation

Property simulations

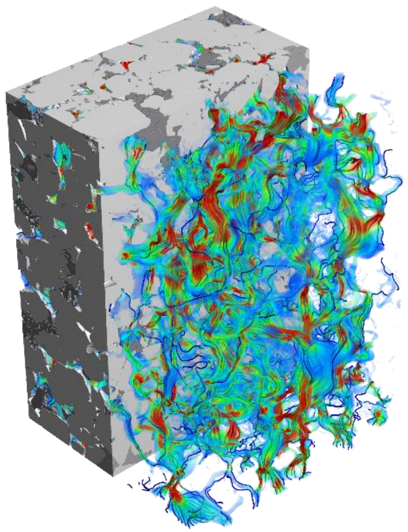
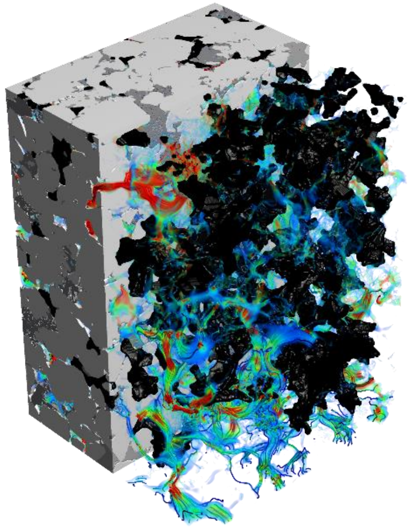
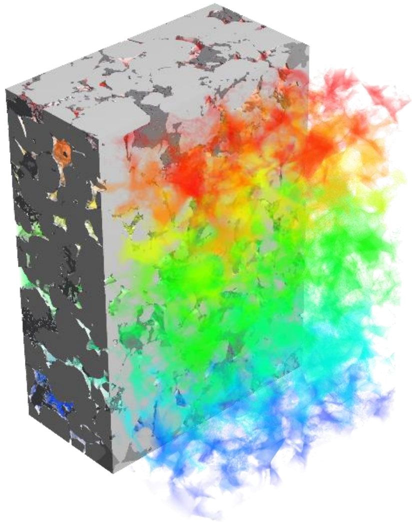
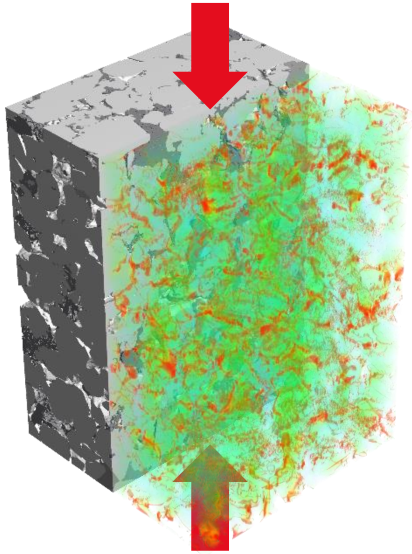
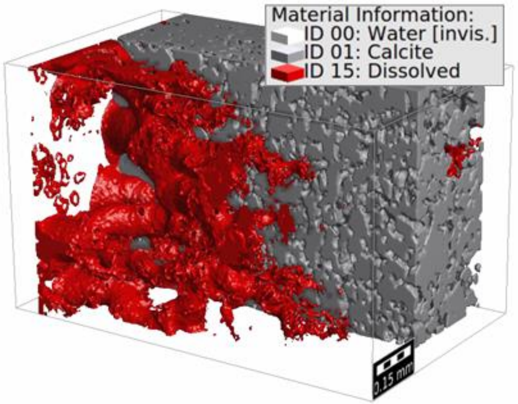
- Flow properties
- Electrical properties
- Thermal properties
- Mechanical properties
- Particle Transport

… and many more features

Portfolio: GeoDict® for DRP

Rock Property Simulations

GeoDict

1-phase Flow Properties	**2-phase Flow** Properties	**Electrical & Thermal** Properties	**Mechanical** Properties	Particle & Molecule **Transport**
▪ Absolute permeability	▪ Pore Morphology Method	▪ Electrical Conductivity	▪ Young's modulus	▪ Transport and deposition
▪ Navier Stokes-Brinkman	▪ Capillary pressure curve	▪ Formation factor	▪ Poisson's ratio	▪ Fines migration
▪ Darcy flow	▪ Relative permeability	▪ Resistivity index	▪ Bulk & Shear modulus	▪ Breakthrough curves
▪ Upscaling of Flow	▪ Mixed wettability systems	▪ Saturation exponent	▪ Stiffness	▪ Reactive Flow
▪ Structures $>4000^3$		▪ Cementation exponent	▪ In-Situ conditions	▪ CO2 sequestration
		▪ Thermal Conductivity	▪ Poroelasticity	▪ NMR T2 curve

… and many more features

MATH 2 MARKET

NEXT ON ASK THE EXPERT

Filtration Simulation – How to Make the R&D Cycle More Efficient

With Dr. Philipp Eichheimer

Wednesday, June 14, at 1 PM CDT