Oil & Gas (5): Digital Rock

ADVANCED MODELLING & SIMULATION – AMS –

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Digital Rock

PORE-SCALE DIRECT NUMERICAL SIMULATION (DNS) OF MULTIPHASE FLOW

- Fluid flow in porous media arise in many fields of science and engineering, and are critical in petroleum engineering.
- Multi-phase flow in porous media is a common phenomenon in hydrocarbon reservoirs.
- Fifty percent or more of the oil is left in a typical reservoir. Various methods are used to **enhance oil recovery (EOR)**.
- Petro-physical properties, such as porosity, relative permeability, saturation and capillarity pressure, are required for estimating productivity of hydrocarbon reservoirs.
- Advanced simulation capability will help engineering teams make more informed decisions on wells, production facilities and resource progression, including EOR.

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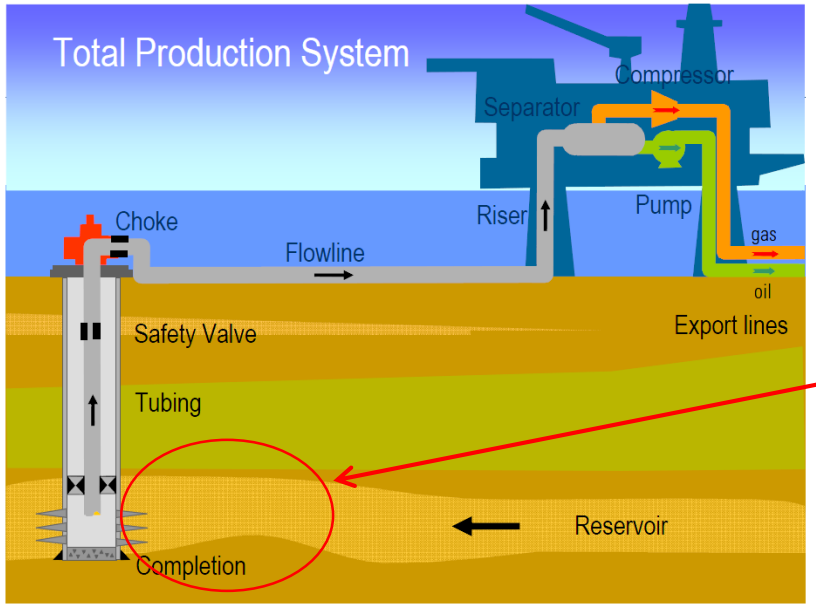
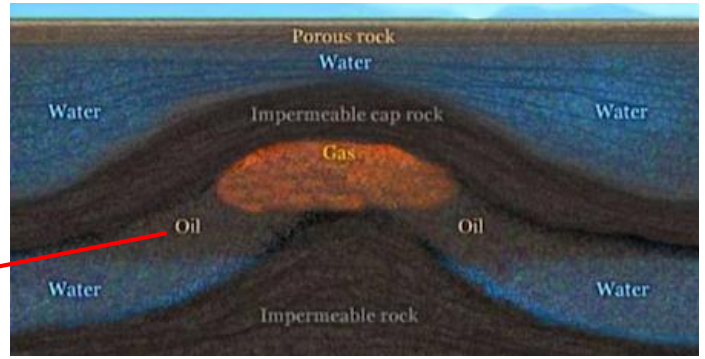
Towards Digital-Rock Technology

PUSHING PRESENT SIMULATION RESOURCES FURTHER





Today detailed knowledge of the hydrodynamics of the hydrocarbon (oil, gas) and injected fluids (e.g. water, polymers, steam, CO_2) in the reservoir is key for estimating well productivity, predicting its production time-scale, or taking decisions as to investing in EOR of depleted wells.

Modern advanced fluid flow simulation put in parallel with state-of-the-art bulk-flow-simulation can make the difference.

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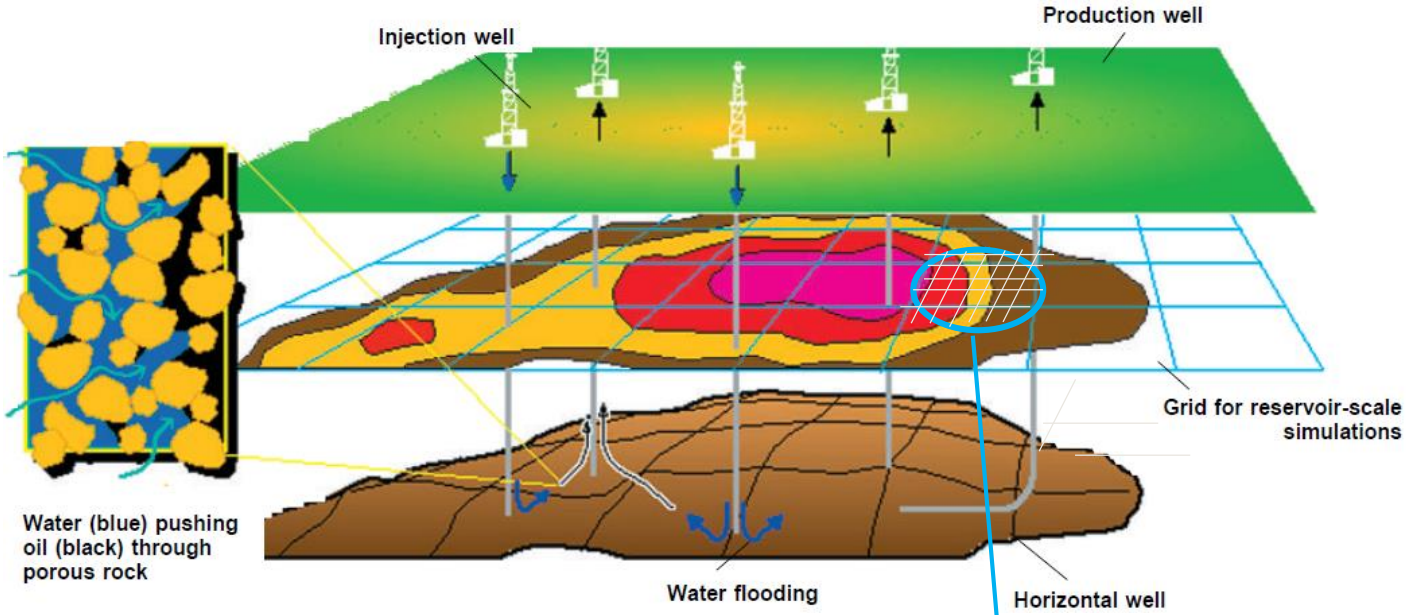
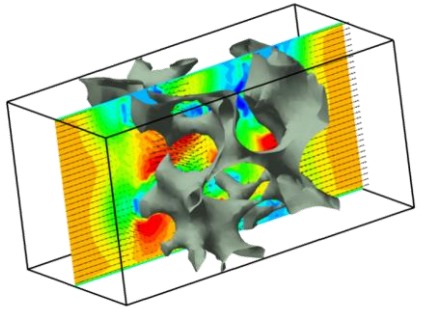
Towards Digital-Rock Technology

TREATING THE MULTISCALE ISSUE IN AN INTELLIGENT WAY



Sub-grid for pore-scale DNS



Reservoir-scale (bulk flow) simulations of reservoir-flow performance are important in the decision of whether to invest in major recovery projects.

Improved prediction of bulk-flow parameters through understanding the physics at the pore scale is the goal of the pore-scale direct numerical simulation (DNS) simulations of multiphase flow (Digital Rock).

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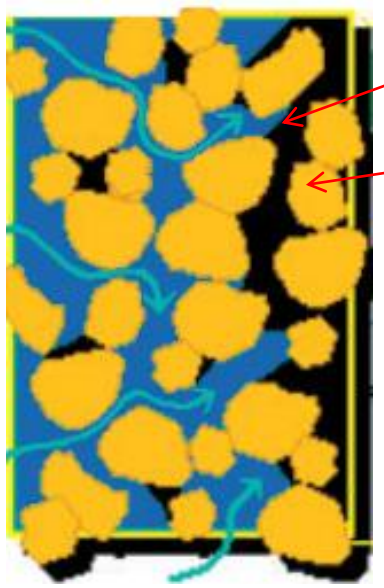
Digital-Rock workflow

FROM PORE-SCALE TO BULK-SCALE



Water (blue) injected under pressure into the reservoir is displacing oil (black). Wetting and capillary forces control the interfacial flow.

1- Interface Tracking for oil-water surface (DNS of interfacial flows)

2- Immersed surfaces (using tomography data: digital scan of a rock sample) for rock-pores digitalization.

3- Perform DNS simulations

4- Estimate parameters for bulk flow simulations: porosity, relative permeability, wettability, capillary pressure, water saturation

5- Back to reservoir-scale models

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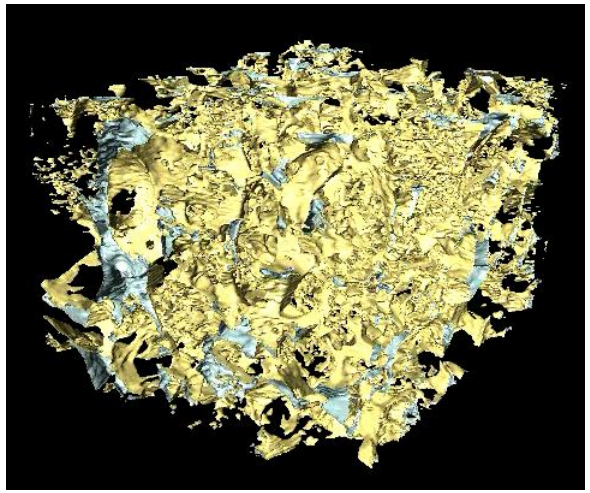
Digital-Rock workflow: Tomography data needed

PRESENT TOMOGRAPHY TECHNOLOGY ALLOWS RESOLUTIONS OF THE MM SCALE



Pore network by image segmentation, 1.384 μm voxels

5th generation CT Machine (*Universal HD-525r)*

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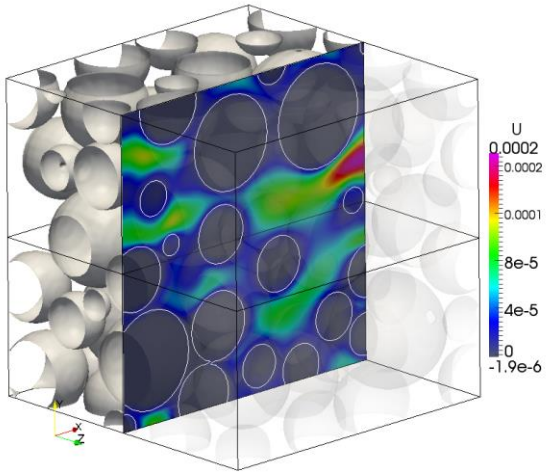
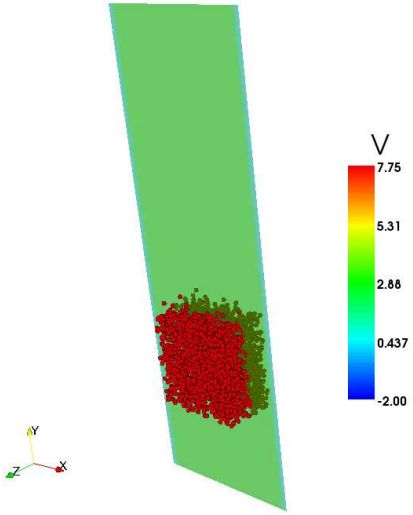
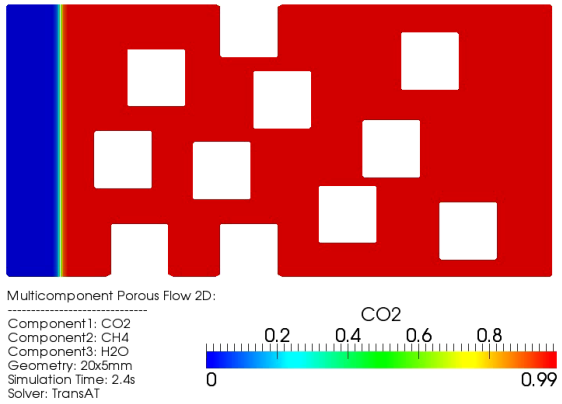
Digital-Rock workflow: Examples of simulation with TransAT

POSSIBILITIES TO REPRESENT PORE DATA IN TRANSAT: SINGLE- & MULTI-PHASE FLOWS







Digital-Rock workflow: Issues with real-field problems

MAIN ISSUE IS RELATED TO THE DIGITAL CAD FILE UNDER FORMAT STL

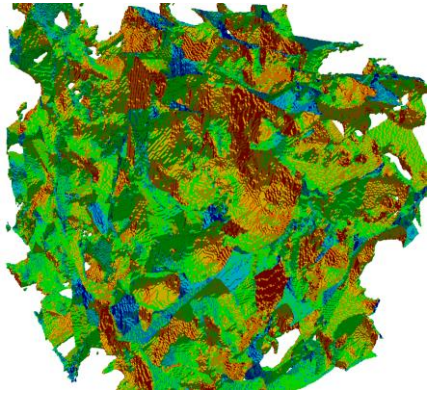
Creation of STL from RAW data
Post-processing tools can be used, but the resulting data are

Not necessarily closed
With many closed objects
And staircase approximation

1000^3 files are large

STL files are quite large

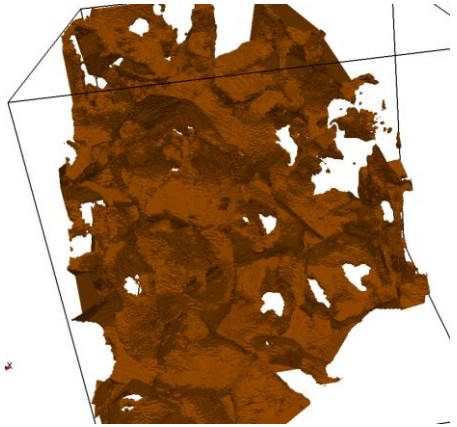
STL file created using Paraview



Issues

- Create closed STL
- Create accurate (not staircase) geometry
- Ability to split geometry into
  - Supergrid, and
  - Subgrid representations

Closed surface



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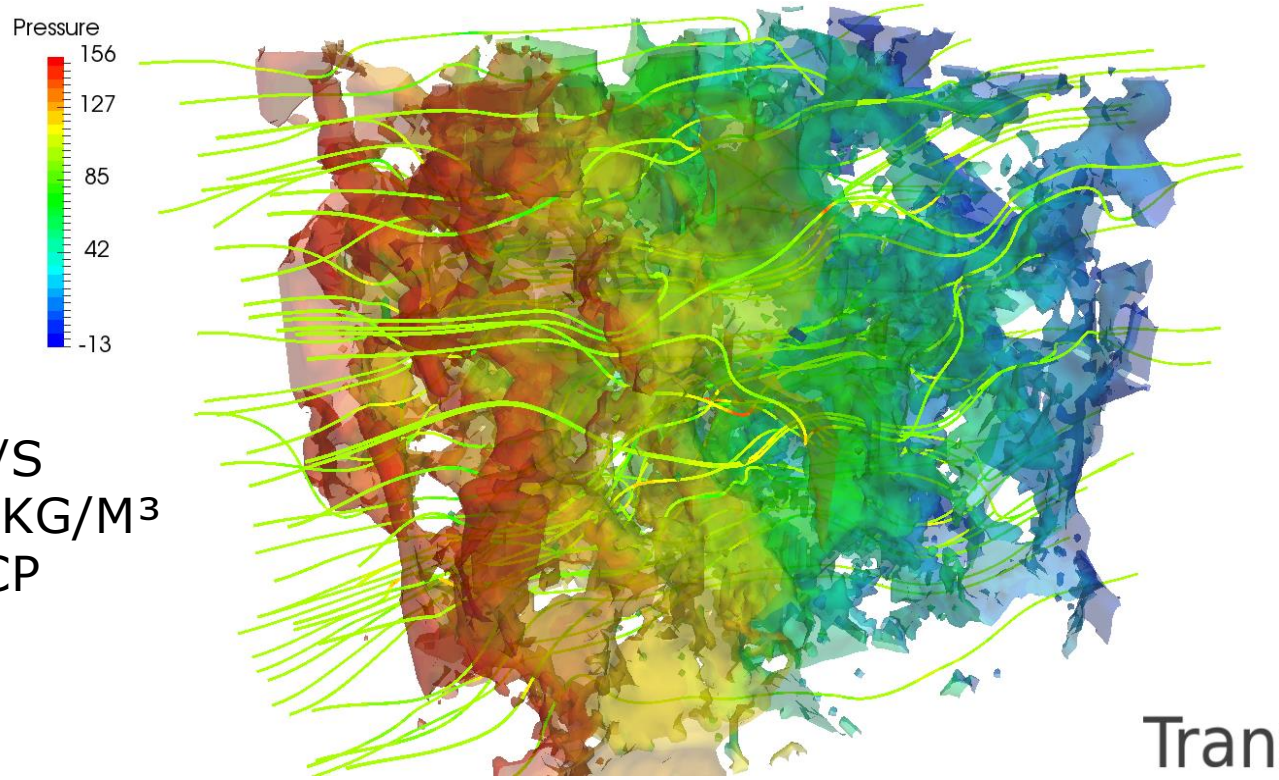
Simulation with TransAT

S5 SANDSTONE: SINGLE-PHASE



U = 1 CM/S
P = 1000 KG/M³
N = 100 CP

TransAT

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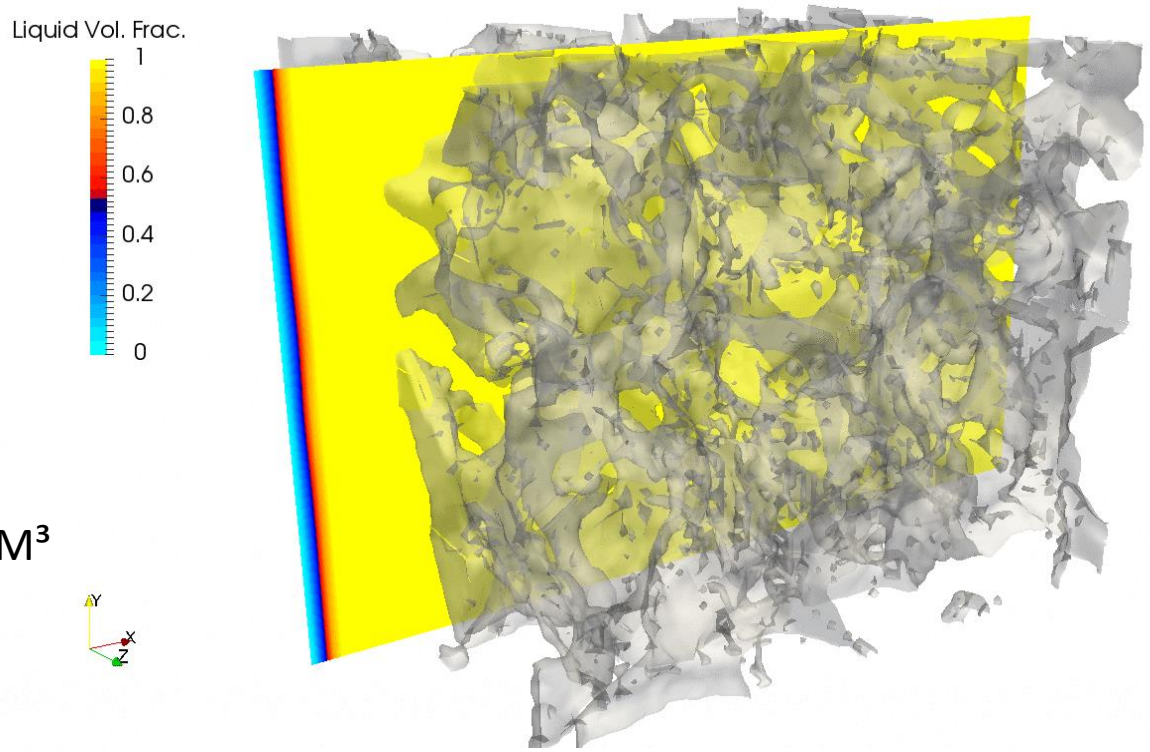
Simulation with TransAT

S5 SANDSTONE: TWO-PHASE



LIQUID
U = 1 CM/S
P = 1000 KG/M³
N = 100 CP
GAS
P = 50 KG/M³
N = 1.5E-5 PA.S

TransAT

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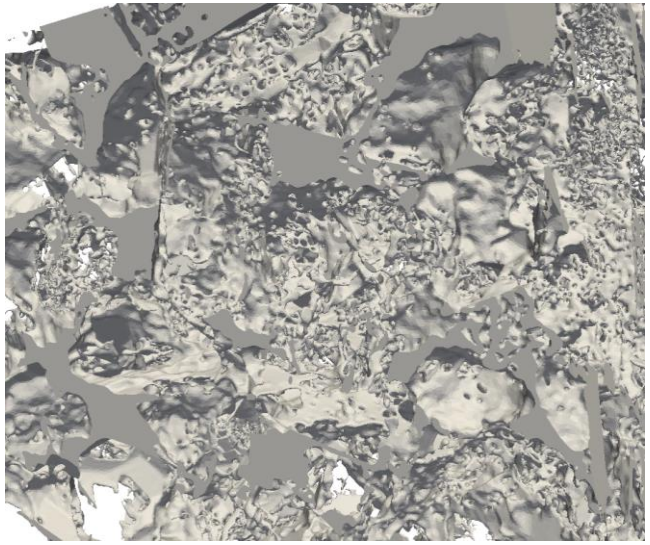
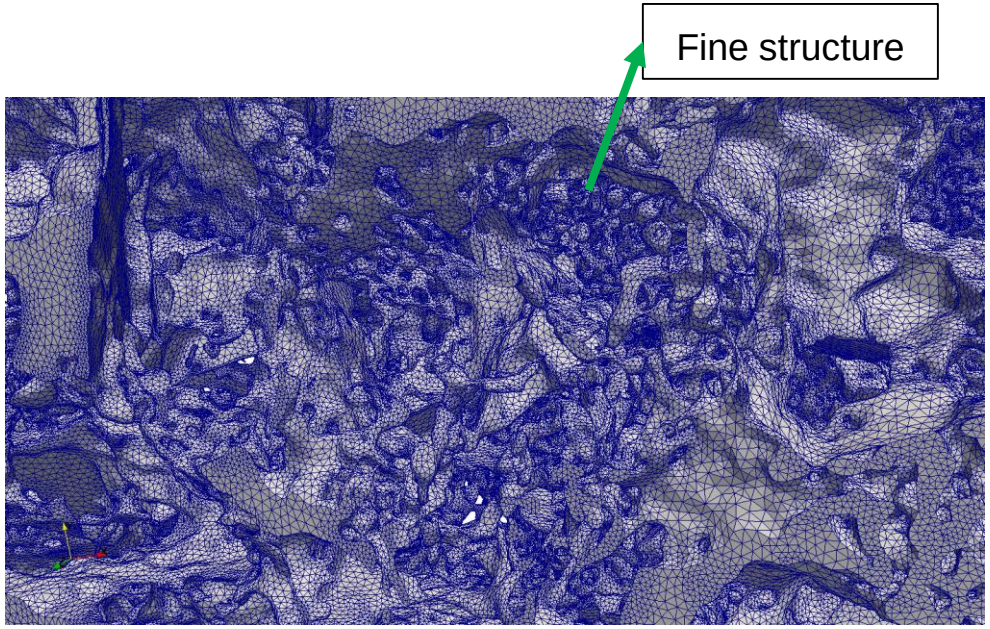
Simulation with TransAT

4A OIL-SATURATED BEREA SANDSTONE: SINGLE-PHASE





- VERY HIGH QUALITY STL
- NO STAIRCASE PATTERN LIKE S5 CASE
- TRANSAT CAN WORK WITH THIS FILE
- GEOMETRY WAS SCALED DOWN BY 100
- SINGLE-PHASE SIMULATION WAS DONE

- Mesh size 30 µm
- Mesh 128^3
- Inlet velocity = 1 m/s
- Density = 1000 kg/m^3
- Viscosity = 1 cP

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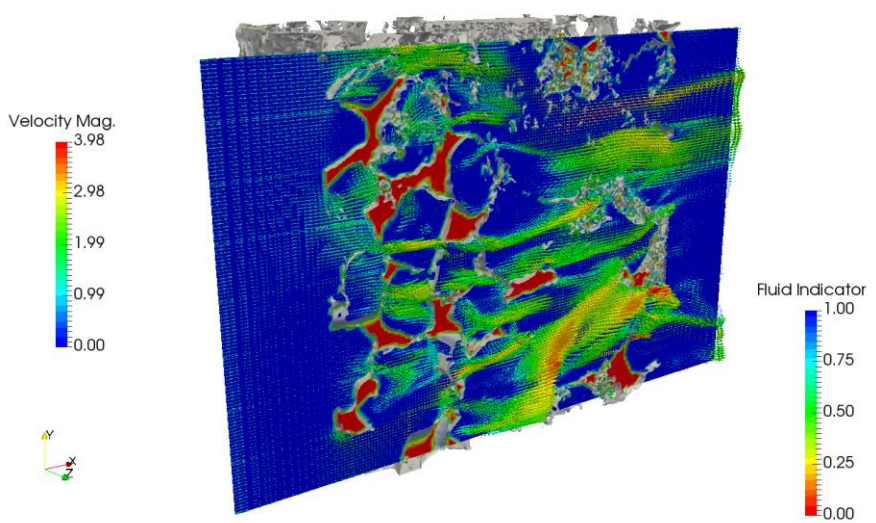
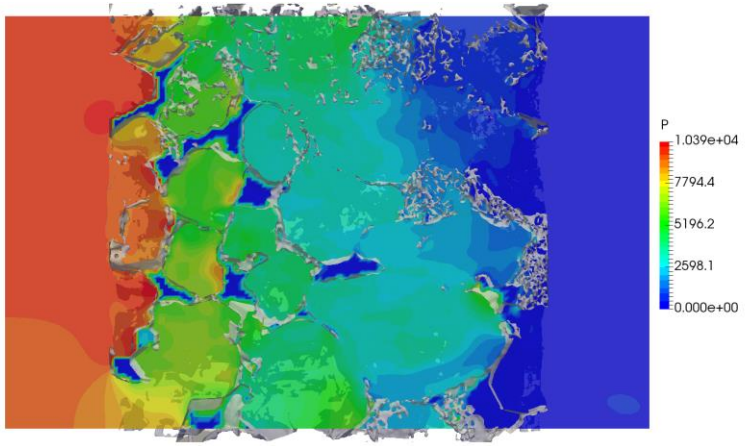
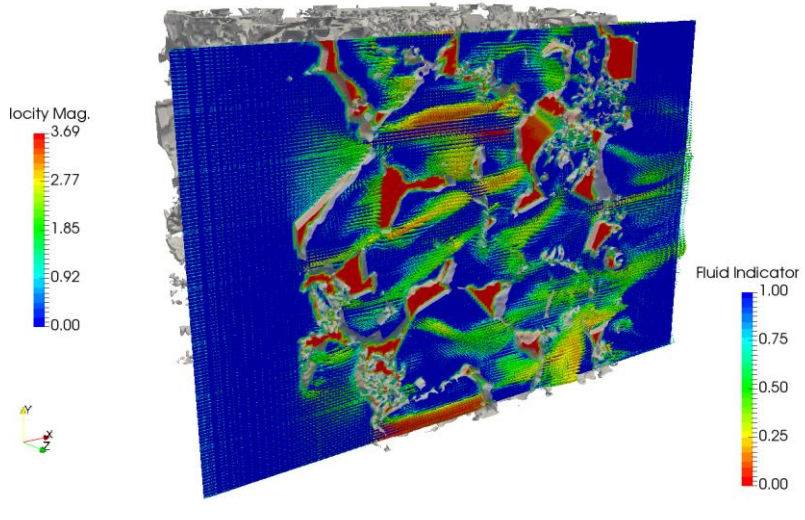
Simulation with TransAT

4A OIL-SATURATED BEREA SANDSTONE: SINGLE-PHASE

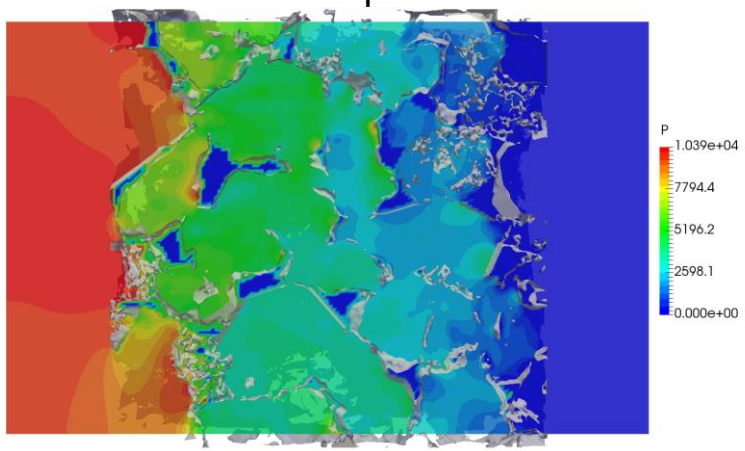


z-mid-plane





z-front-plane



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