Multi scale method for Micro-scale simulation: An effective approach to understand and quantify the impact of micro-scale heterogeneity for improved and enhanced oil recovery

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Agenda

- The necessity of focusing on the real heterogeneity of our reservoir
  - Case of sub-log heterogeneities
- Impact of grid size on our flow simulations while preserving heterogeneities
- The SPC approach: an innovative methodology to quantify micro-porosity in a microporous reservoir
- The multiscale method: Time-efficient simulation methodology while preserving heterogeneities
  - Simulation on the case of sub-log heterogeneities
- Workflow for implementing findings of field scale

Is my reservoir model suitable?

How to model reservoir heterogeneity, which has significant impact on recovery ?

- Traditional approach for reservoir model: use the upscaled model provided by the geomodeller
  - Built from open-hole logs
  - K derived using phi/K transform

- Can this model fullfill the requirements of capturing reservoir heterogeneity, which has significant impact on water flooding?
  - MOST LIKELY NOT !

- WHY? because Heterogeneities are what define flow pattern in our reservoirs
  - Open-hole logs CAN NOT show heterogeneities below 2ft

What is the reality behind our simplified porosity grids?

GR   PHIE

20 p.u.

Cell: 2ft x 50m x 50m

PHIE resolution ~ 3 ft

Upscaled grid
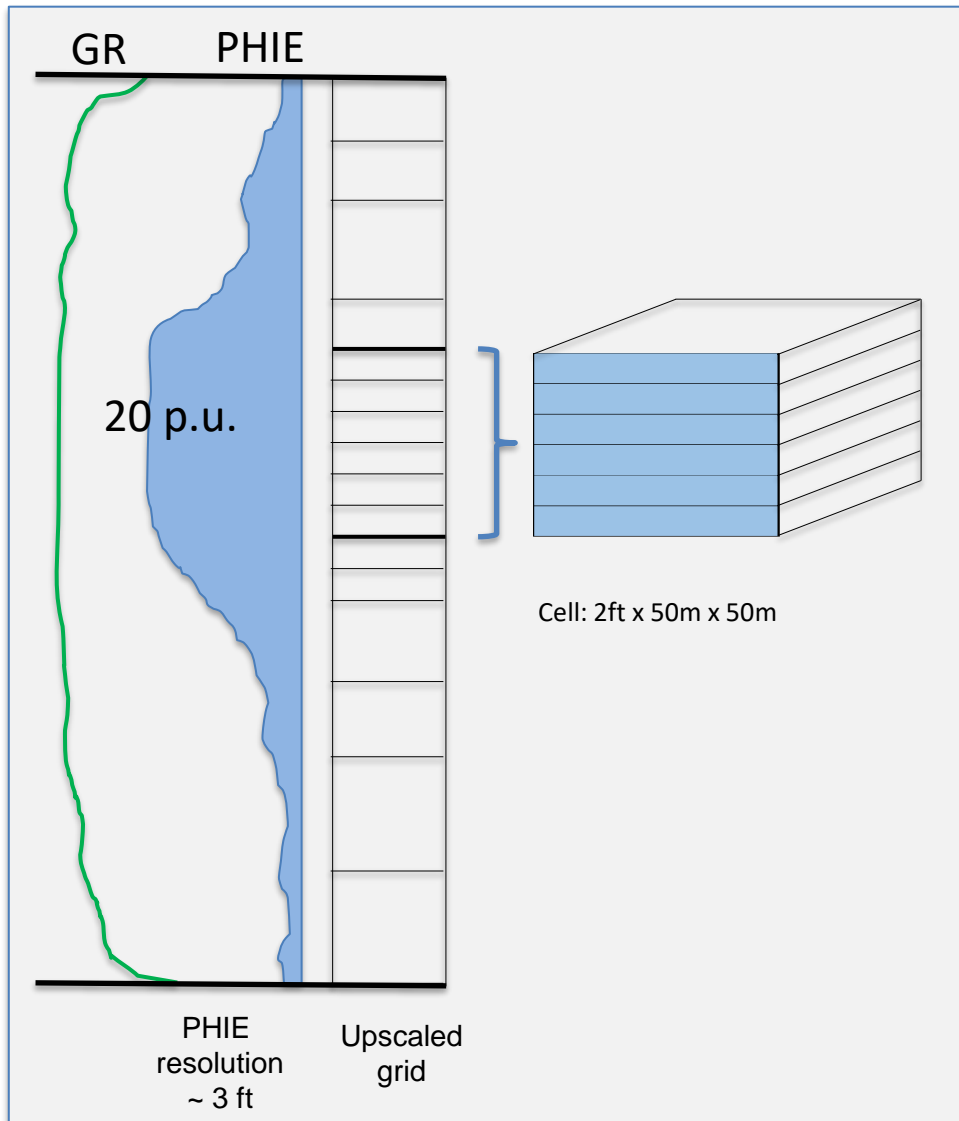
Three different realistic scenarios honoring 20 % log porosity over 2 ft vertical window
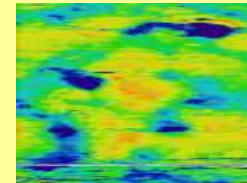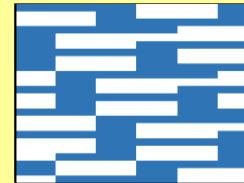
	30
	20
	10
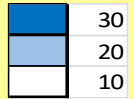
Tabular heterogeneity
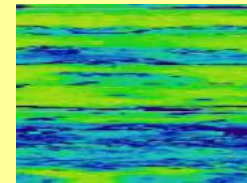
Commonly observed in carbonate platform top facies

Typical oil bearing facies

Nodular heterogeneity

Commonly observed in carbonate bioturbated facies

Typical transition facies

Random heterogeneity
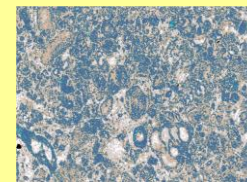
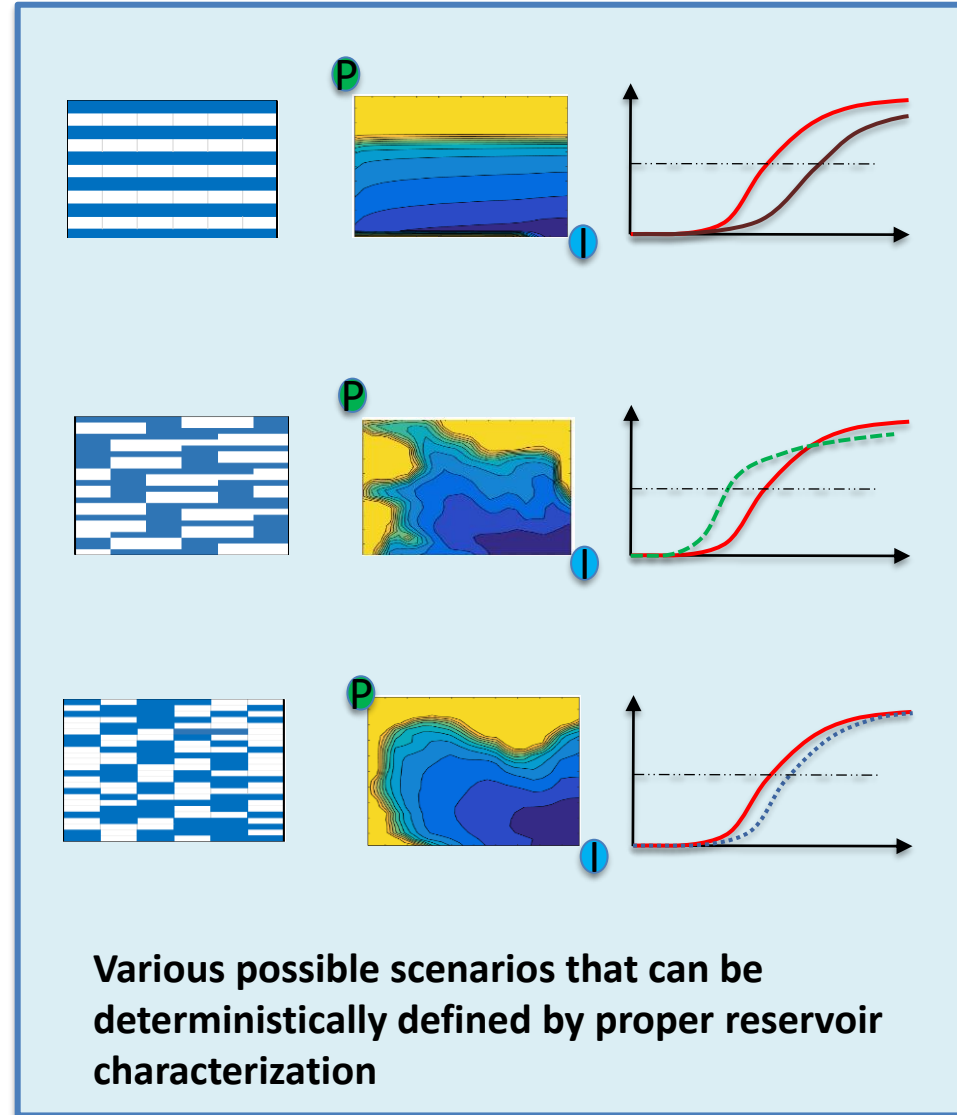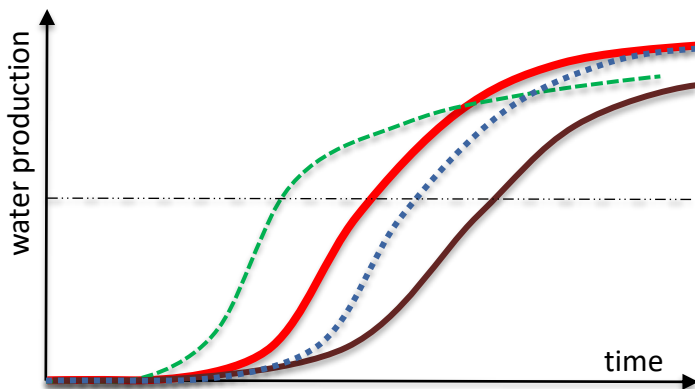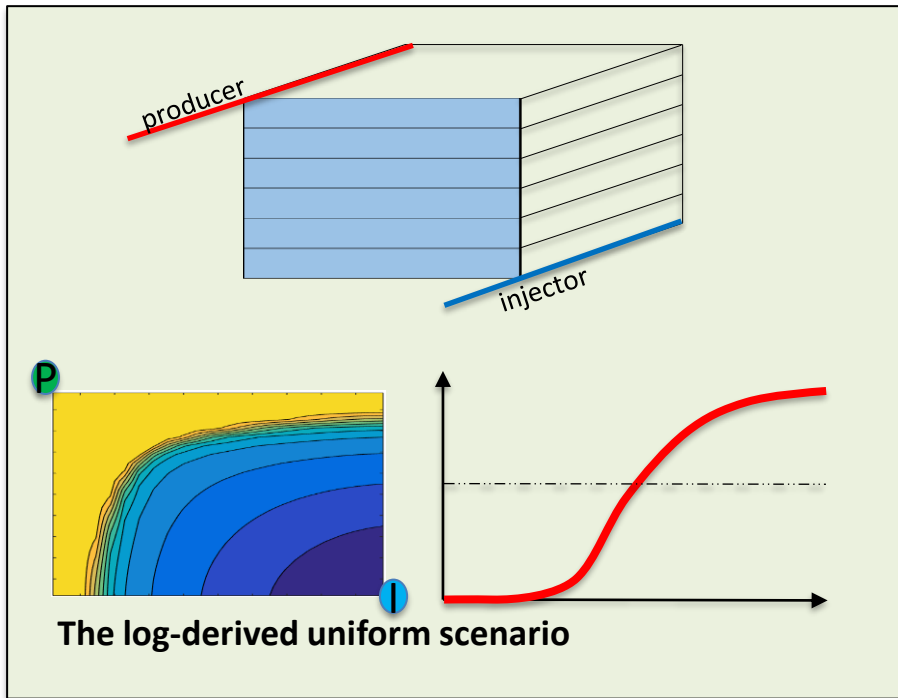Commonly observed at thin section scale

Typical micrograinstone microporous facies

All these textures can be described in a geostatistical sense, and implemented and tested in a box model.
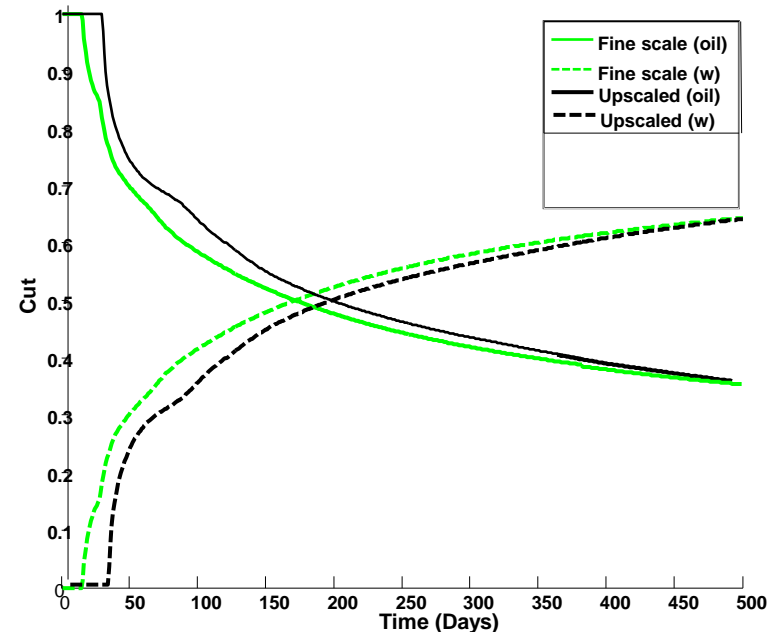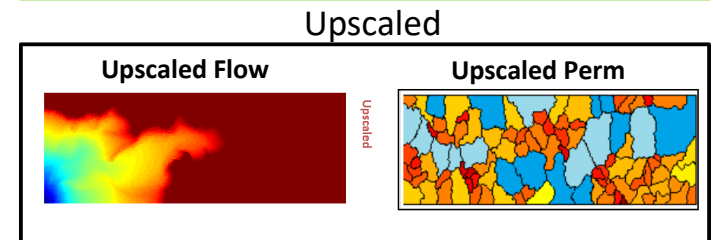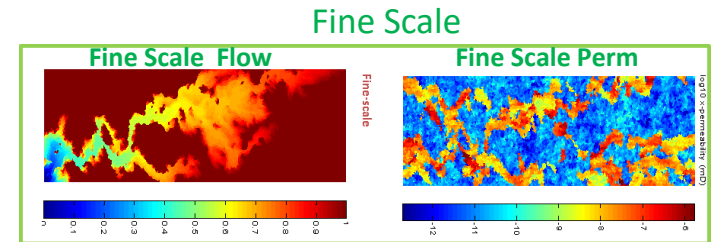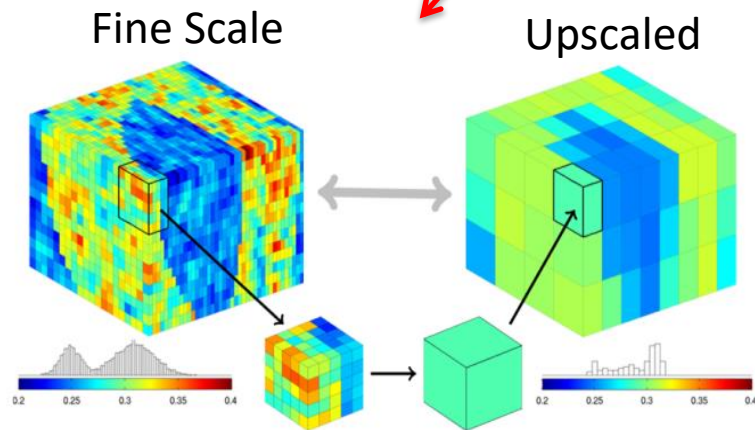
Impact of heterogeneities on production

The log-derived uniform scenario

Various possible scenarios that can be deterministically defined by proper reservoir characterization

Impact of heterogeneities on production

The log-derived uniform scenario
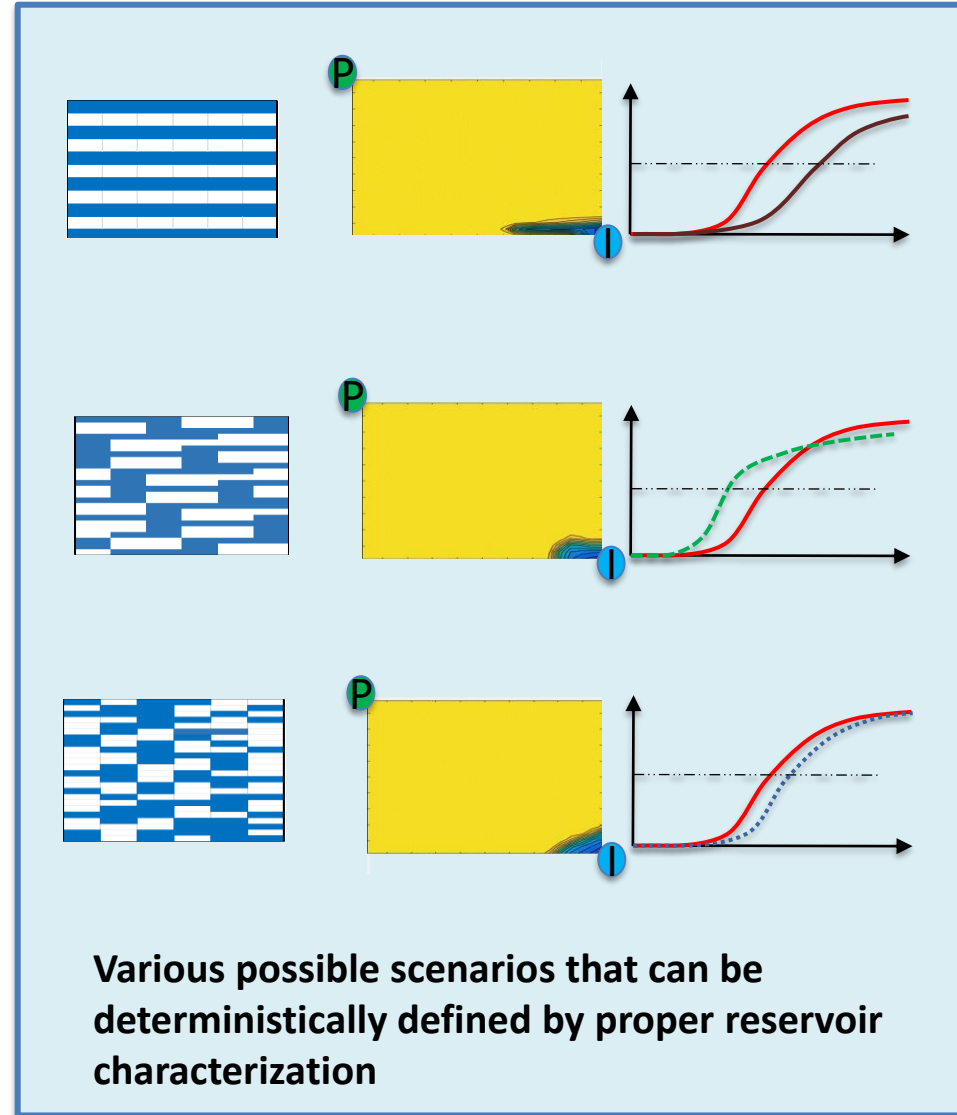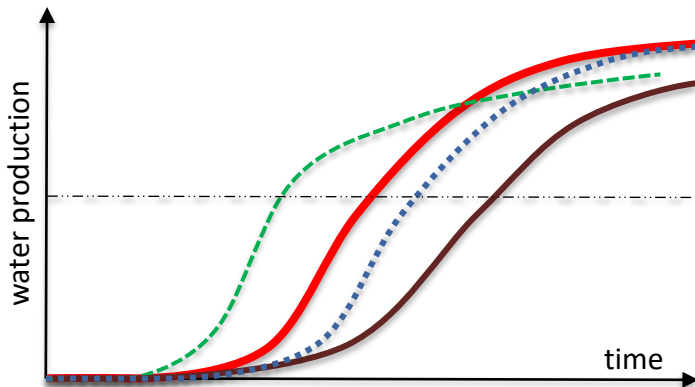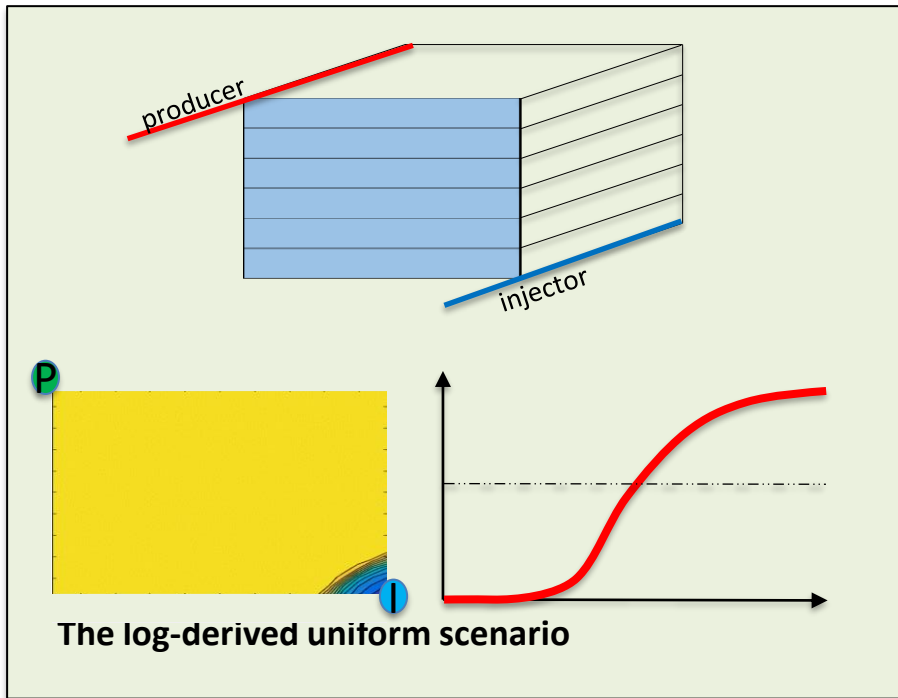
Various possible scenarios that can be deterministically defined by proper reservoir characterization
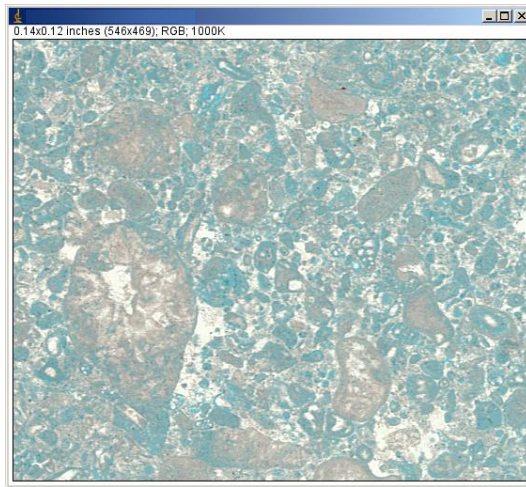
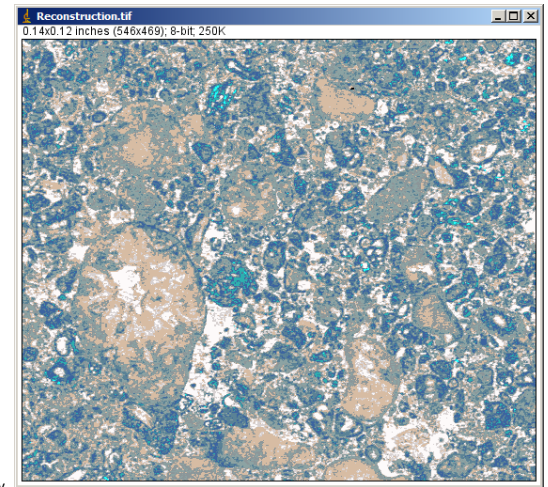# How to preserve water flooding accuracy for heterogeneous Reservoirs and impact of upscaling ?
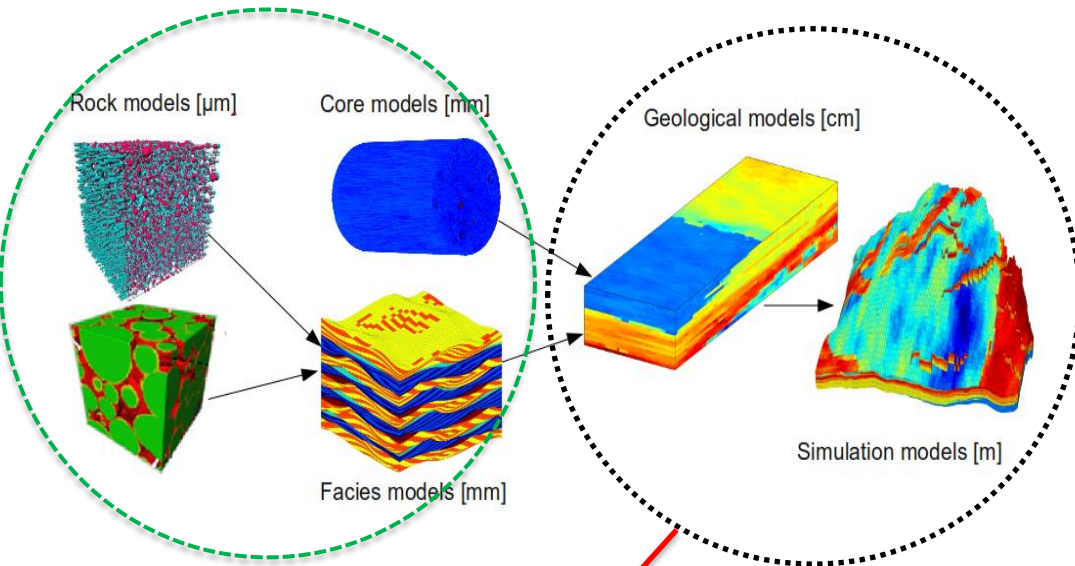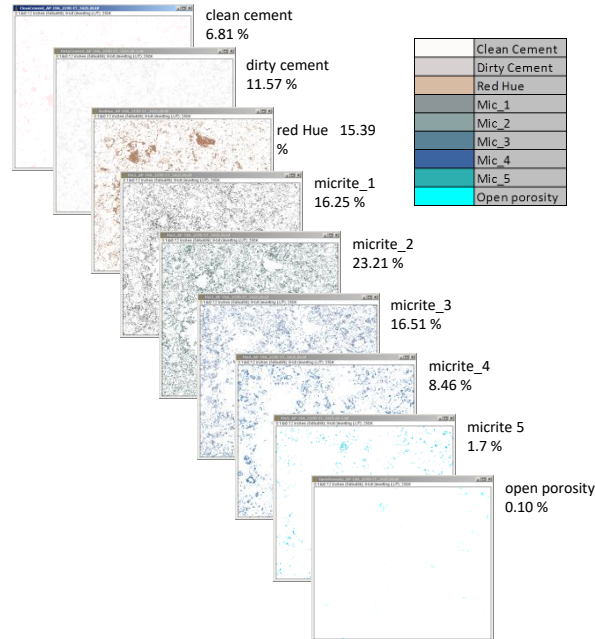
Discretization of thin section image into SPC's

- Thin section discretized into 9 colour Classes
- we show next the colour Classes can then be attributed to a Specific Porosity
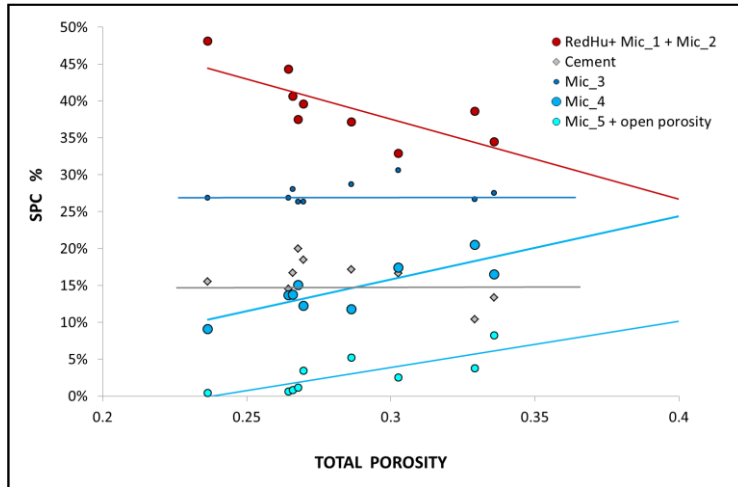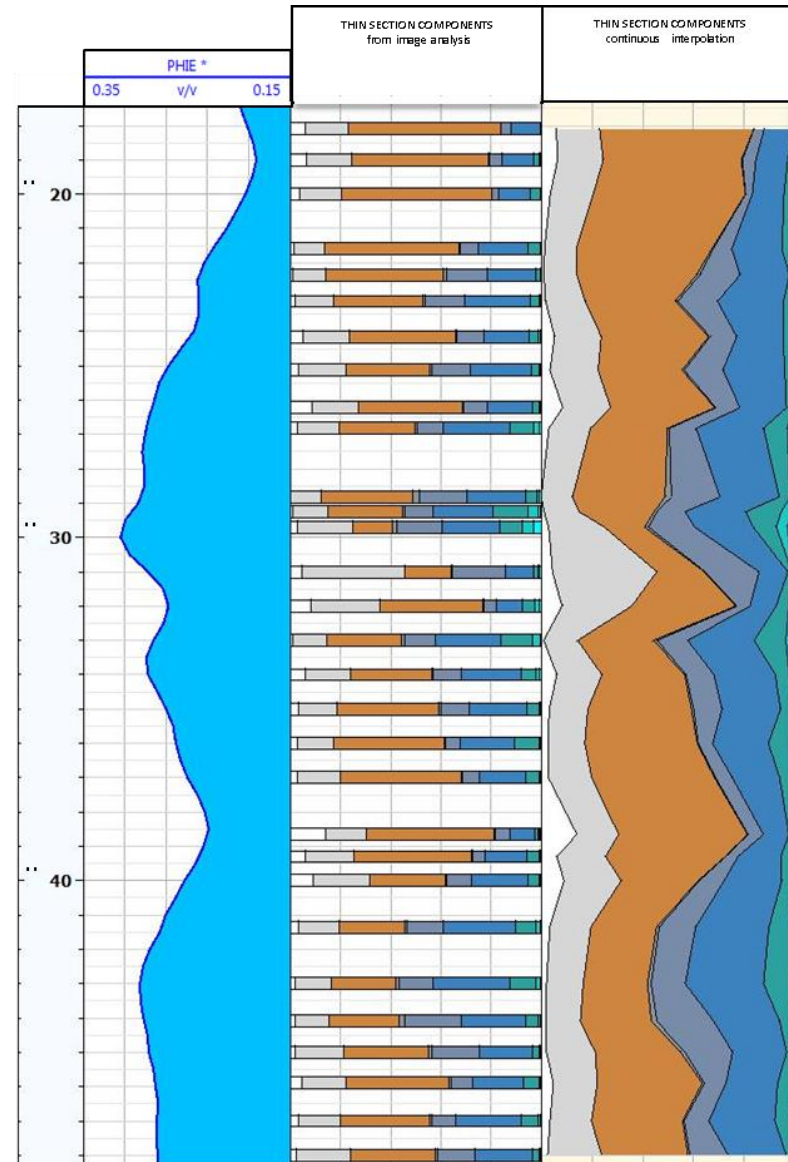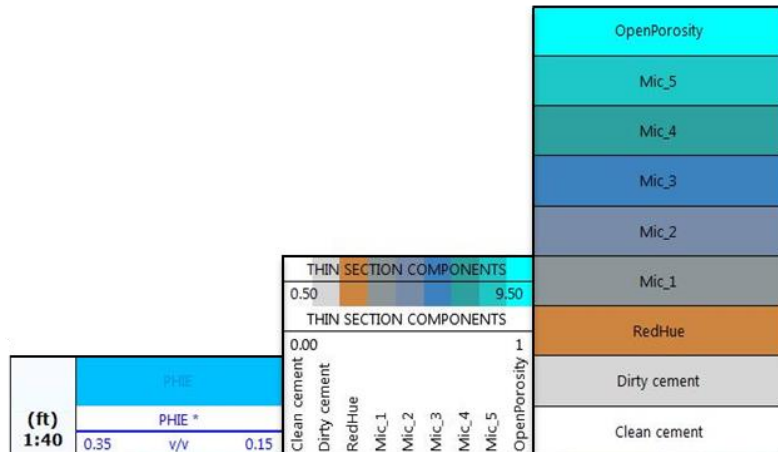- SPC: Specific Porosity Class

Initial thin section scan

clean cement 6.81 %

dirty cement 11.57 %

red Hue 15.39 %

micrite_1 16.25 %

micrite_2 23.21 %

micrite_3 16.51 %

micrite_4 8.46 %

micrite 5 1.7 %

open porosity 0.10 %

Clean Cement
Dirty Cement
Red Hue
Mic_1
Mic_2
Mic_3
Mic_4
Mic_5
Open porosity

reconstructed thin section

tight micrite   loose micrite   open porosity

blue saturation

Representation of the Thin section SPC distribution

* See IPTC – 1375 for Details

Example of SPC distribution on a cored well
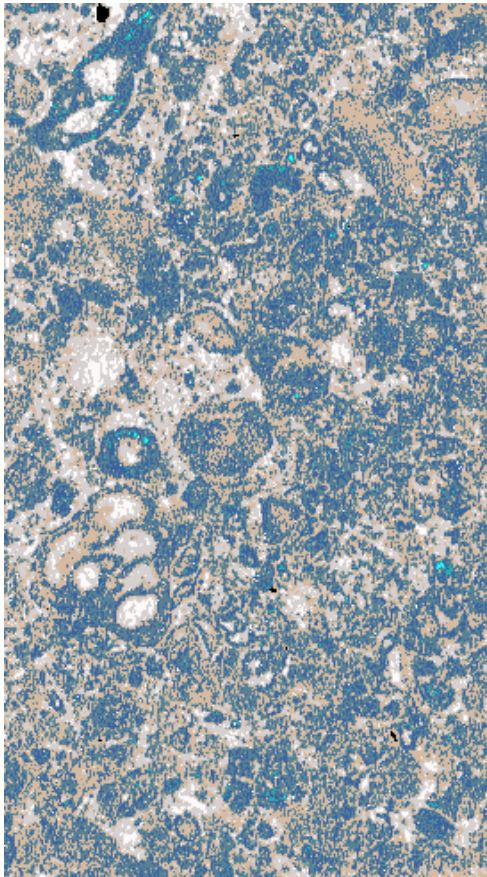

SPC control on porosity

Computing specific porosity and permeability

- Each SPC Component distribution relate to log porosity
- Each component has specific porosity SPC
- Permeability of each SPC is described by Kozeny's permeability model
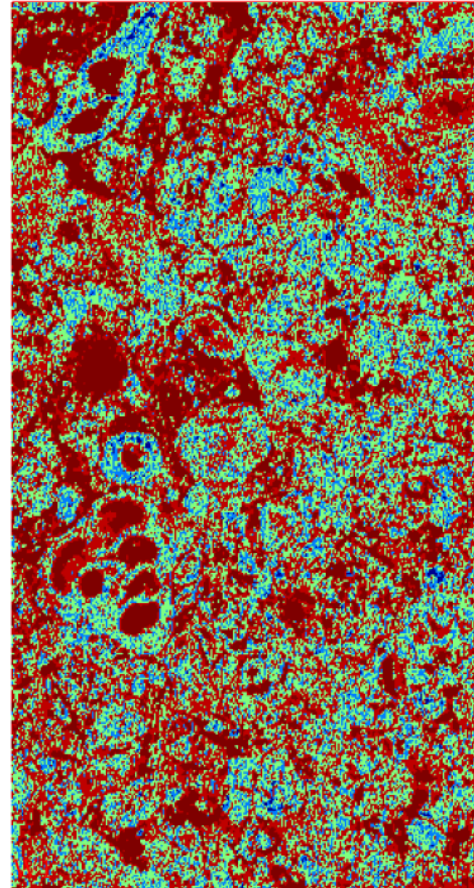- Reasonable fit between plug (Φ, K) and thin section-derived (Φ, K)

* See IPTC – 1375 for Details
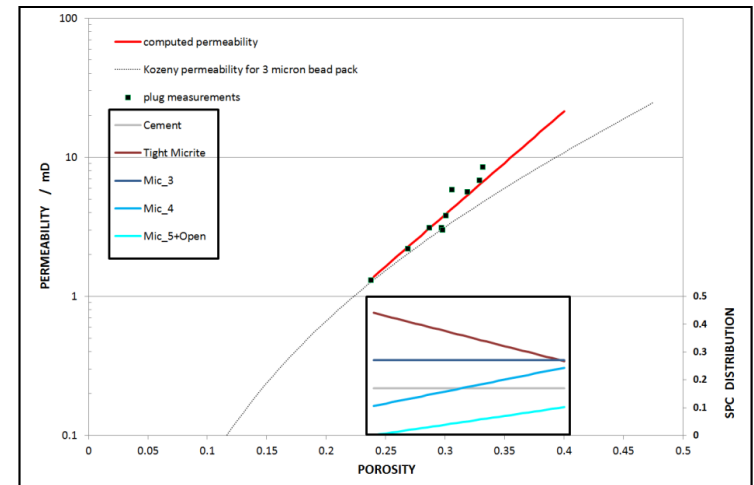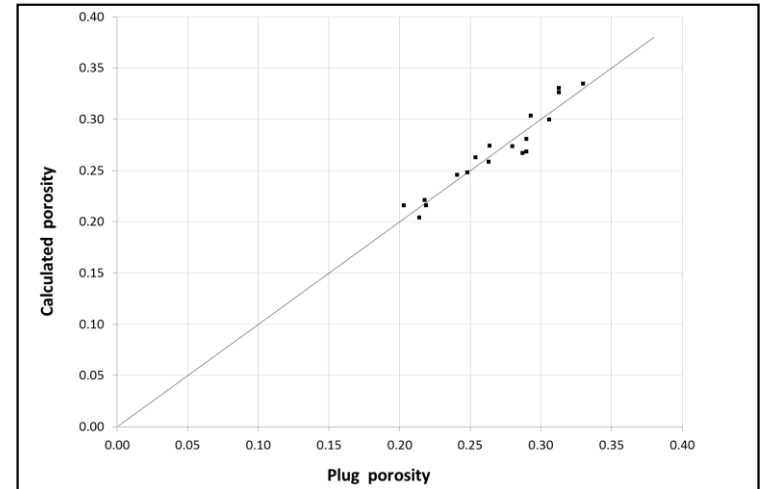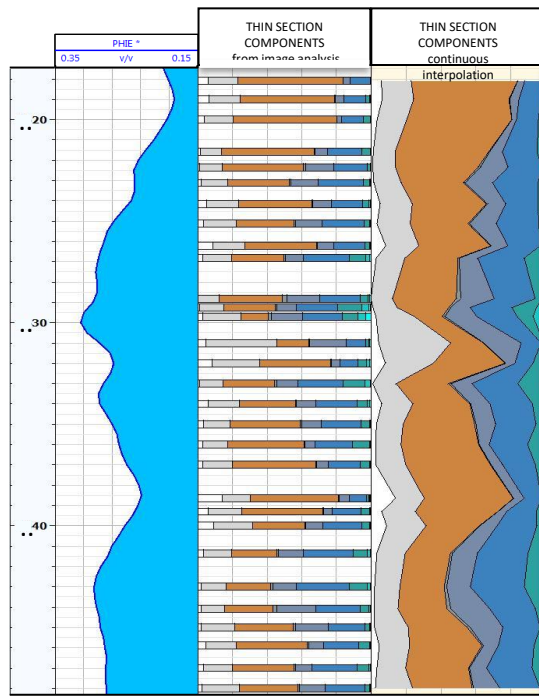
Computing specific porosity and permeability of a Highly Heterogeneous Sample
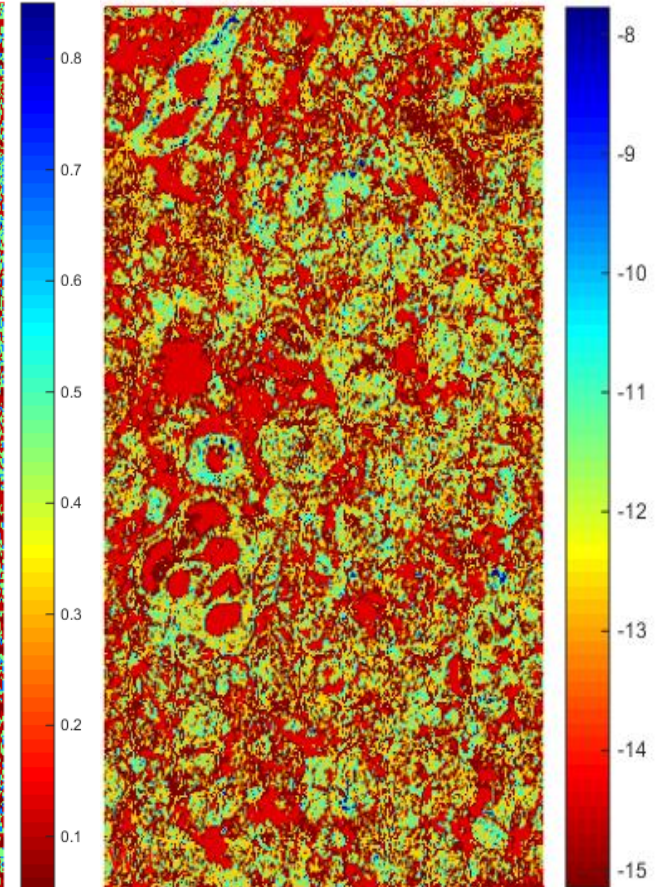
Thin Section dsicretized into SPC

W2 Porosity

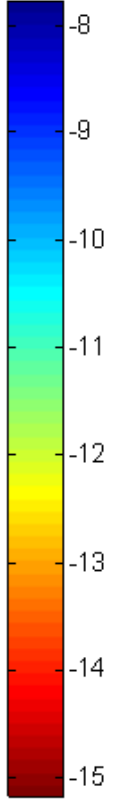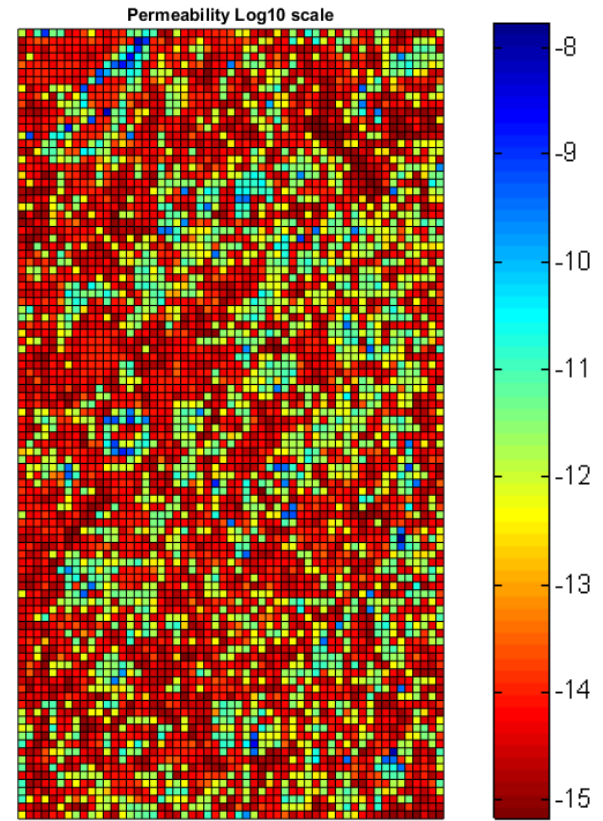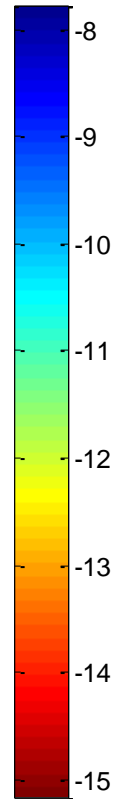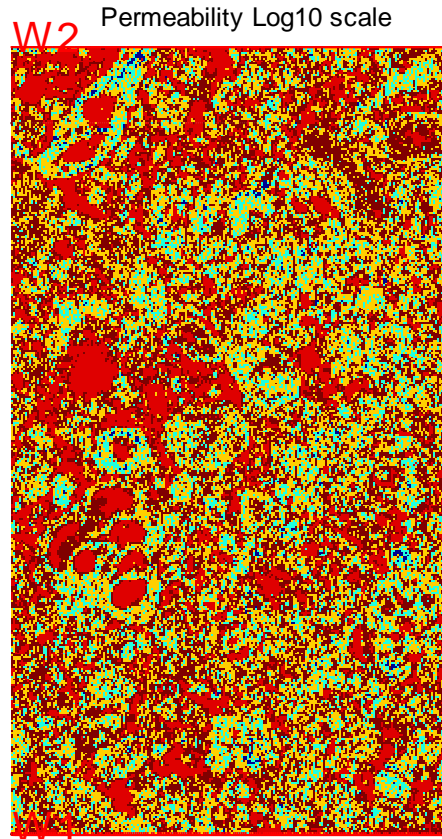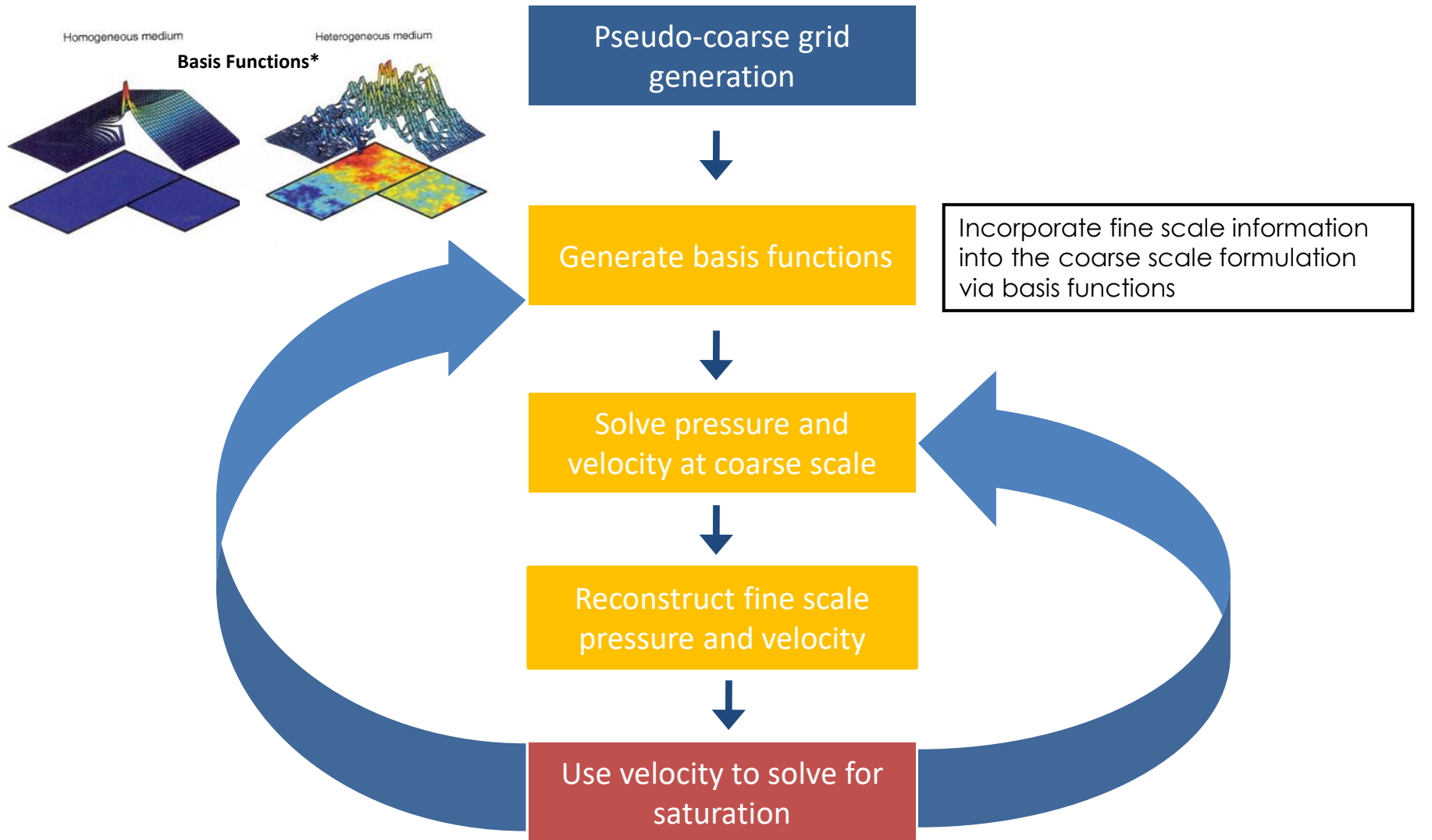W2 Permeability Log10 scale

# Impact of Upscaling on the permeability of a Highly Heterogeneous Sample in a Simulation Grid

275x500x1

55x100x1

Multiscale Method Workflow

Homogeneous medium   Heterogeneous medium

Basis Functions*

Pseudo-coarse grid generation

↓

Generate basis functions

Incorporate fine scale information into the coarse scale formulation via basis functions

↓

Solve pressure and velocity at coarse scale

↓

Reconstruct fine scale pressure and velocity

↓

Use velocity to solve for saturation

*Lie et al.,2010

Applying the workflow on a very Heterogeneous sample

Simulation on a heterogeneous rock sample

Capillary Pressure Curves P_c
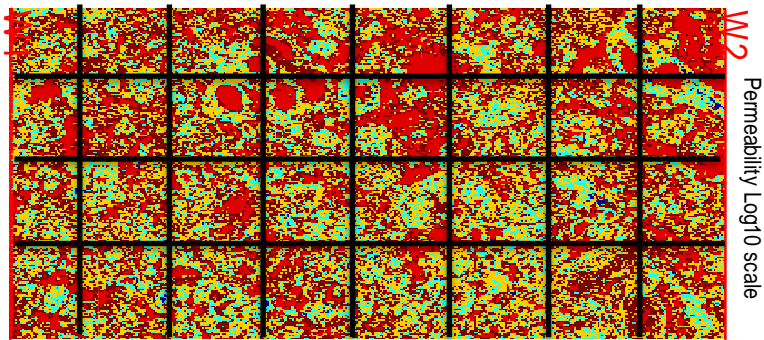
Relative Permeability Curves K_ro

Thin Section

W2 Porosity

W2 Permeability Log10 scale
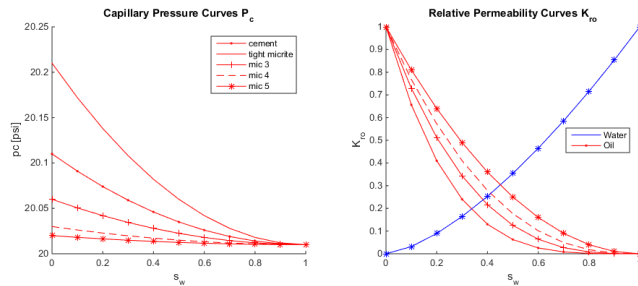
	n_water	n_oil
Cement	1.5	2.0
Tight Micrite	1.5	2.0
Mic 3	1.5	6.0
Mic 4	1.5	6.5
Mic 5	1.5	7.0

$\vec{v}.\vec{n} = 0$

$\vec{v}.\vec{n} = 0$

W1

W2

Q
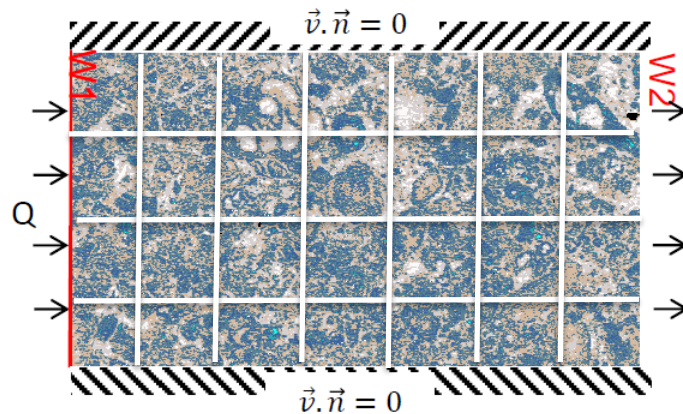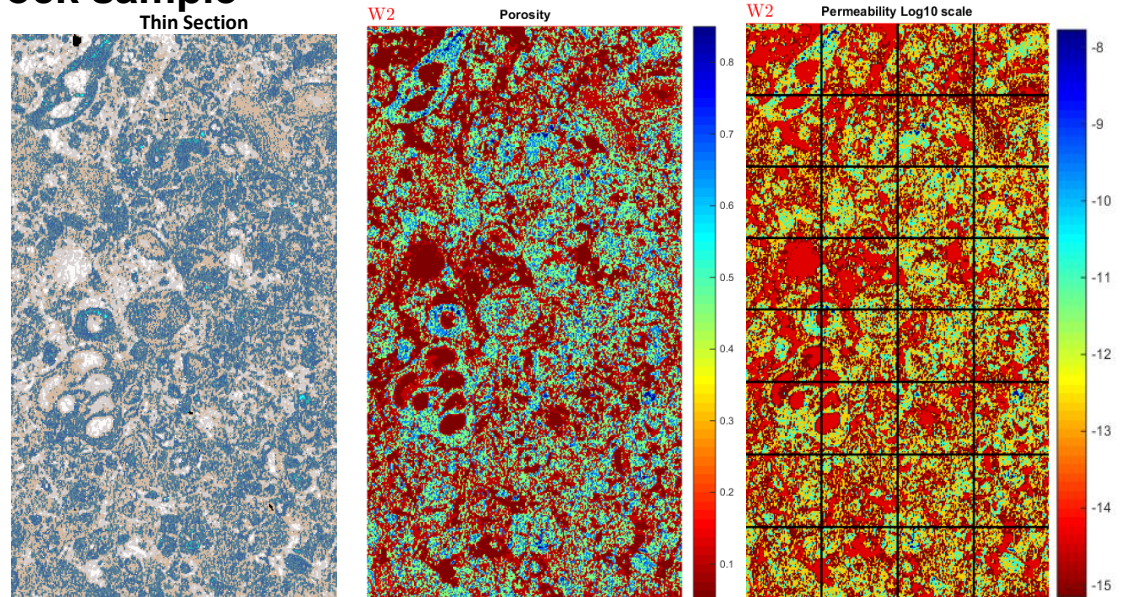
* See IPTC – 1375 and SPE 163626-MS, 163669-MS for Details

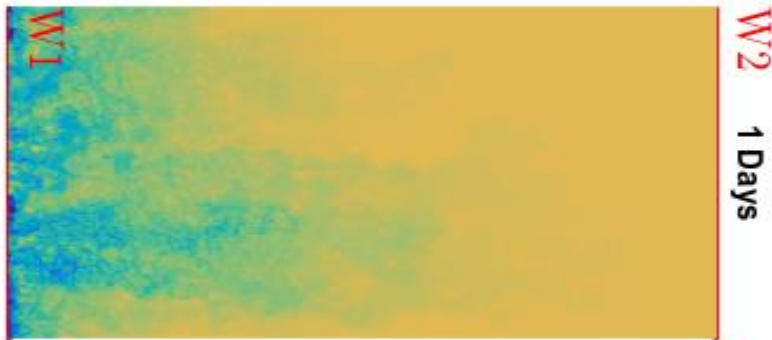# Simulation - 10 Days

Multi-scale

Upscaled

Permeability Log10 scale

Permeability Log10 scale
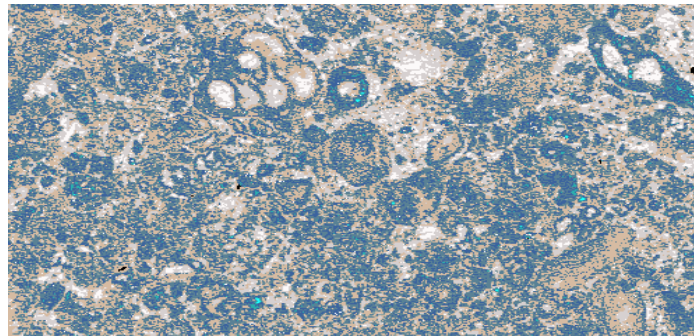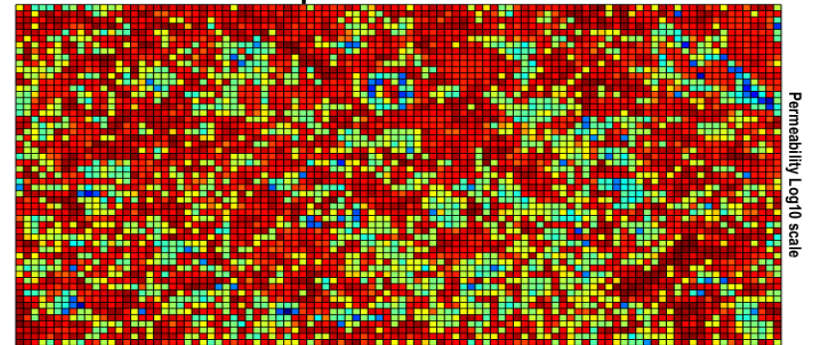
Simulation - 1 Day

Multi-scale

Upscaled

Simulation - 2 Day

Simulation - 3 Day
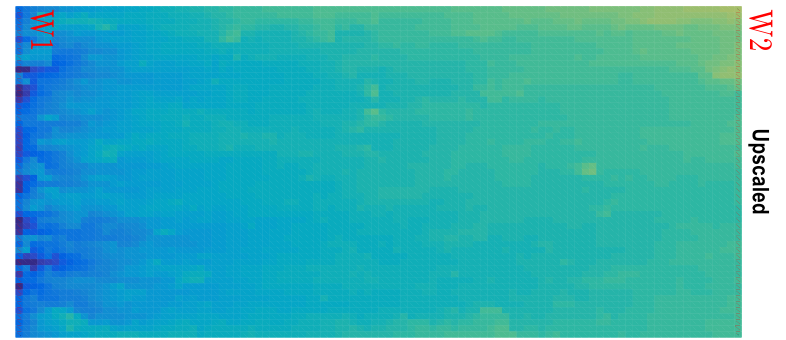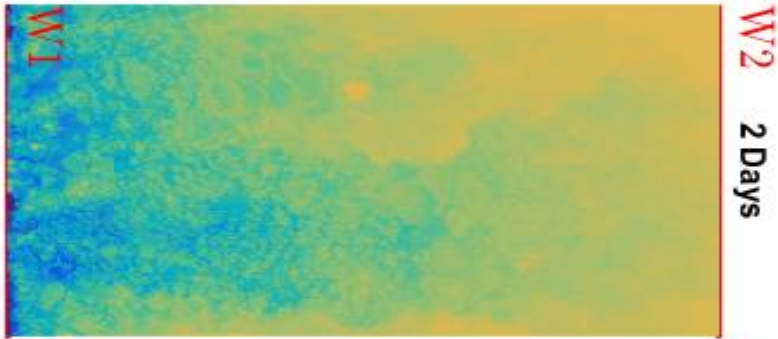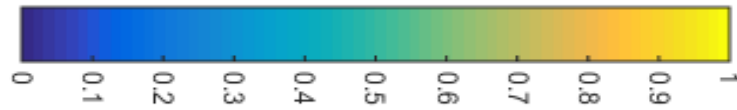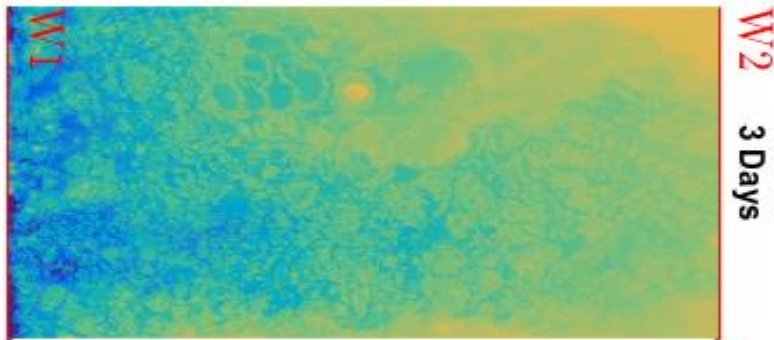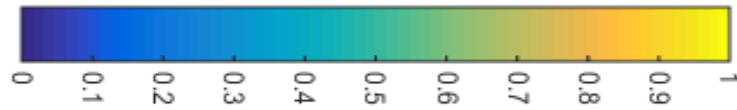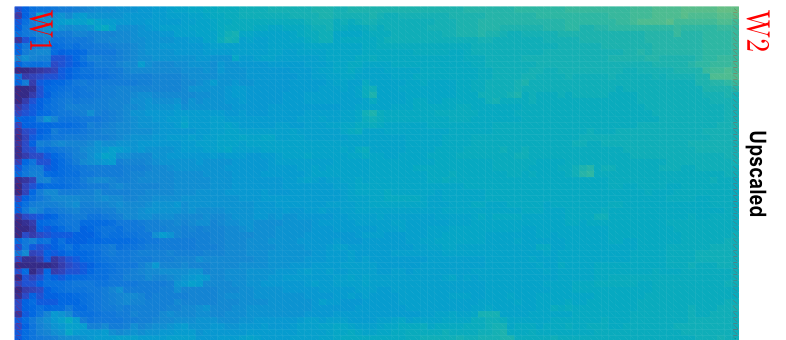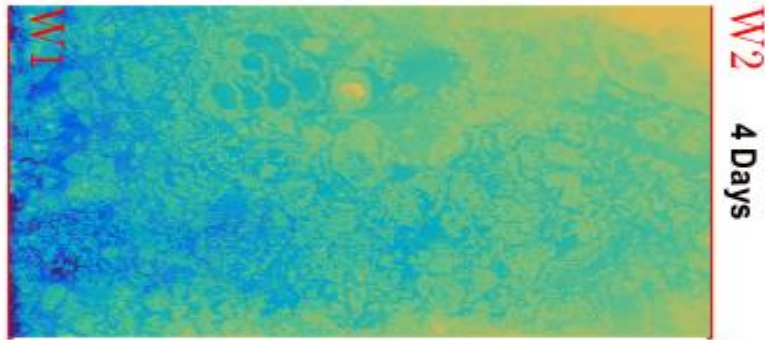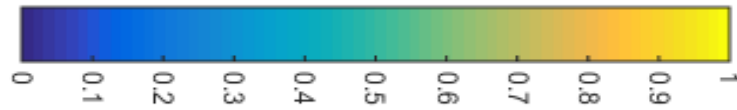
Multi-scale

Upscaled

Simulation - 4 Day

Multi-scale

Upscaled

Simulation - 5 Day

Multi-scale

Upscaled

Simulation - 7 Day

Multi-scale
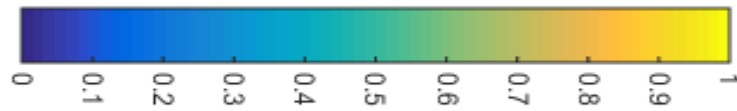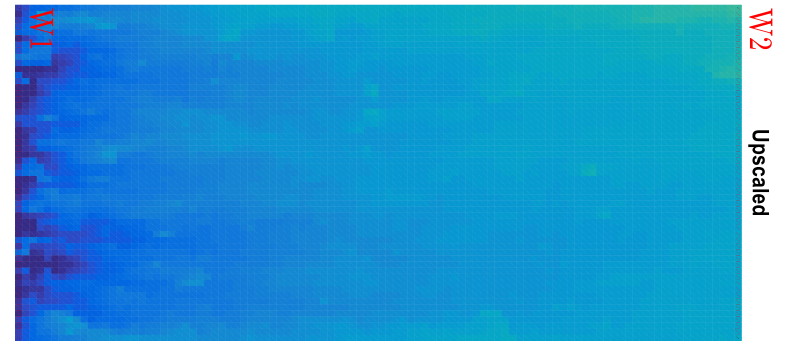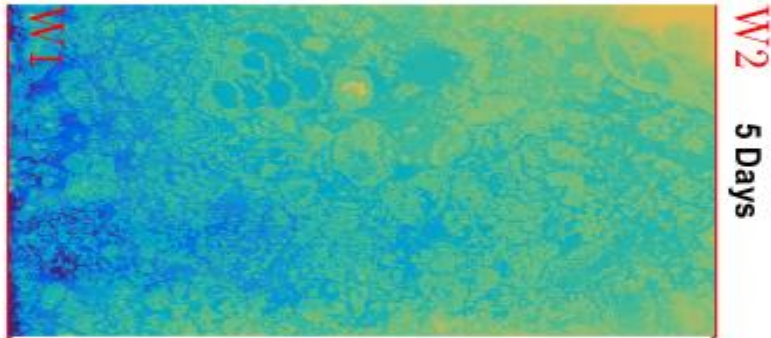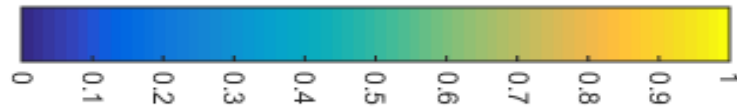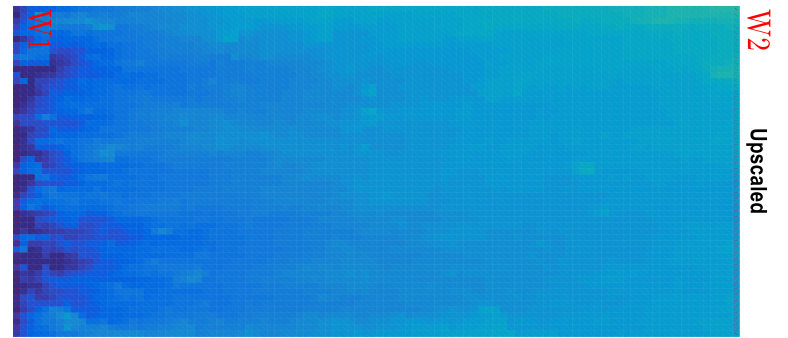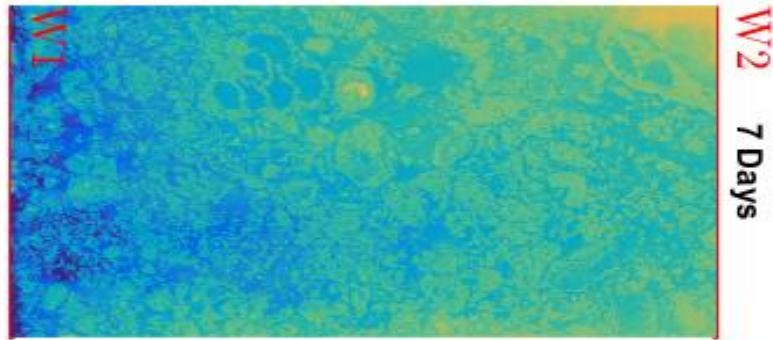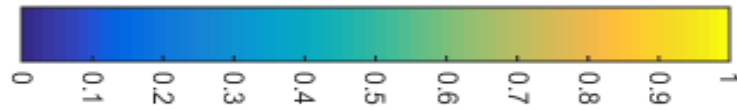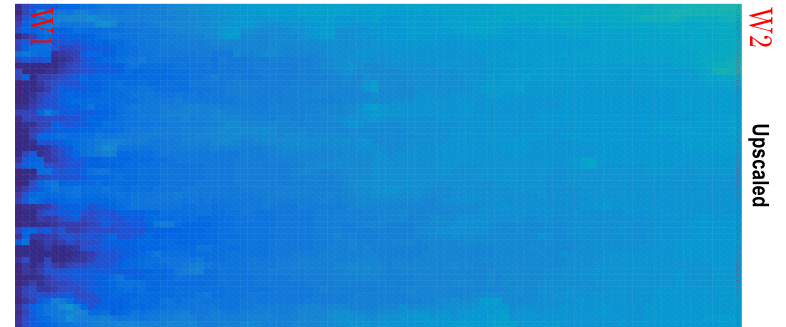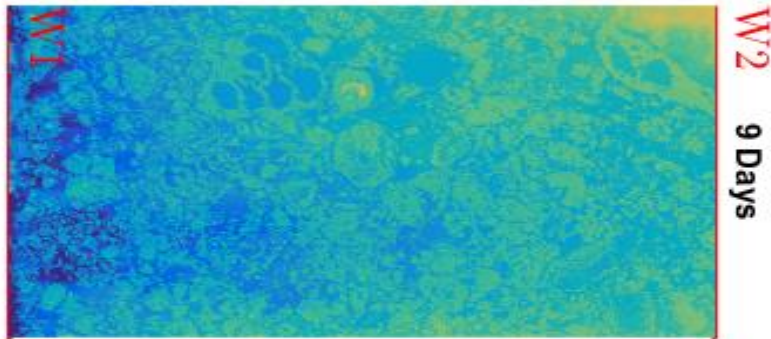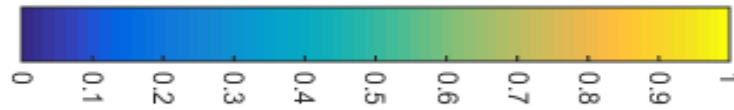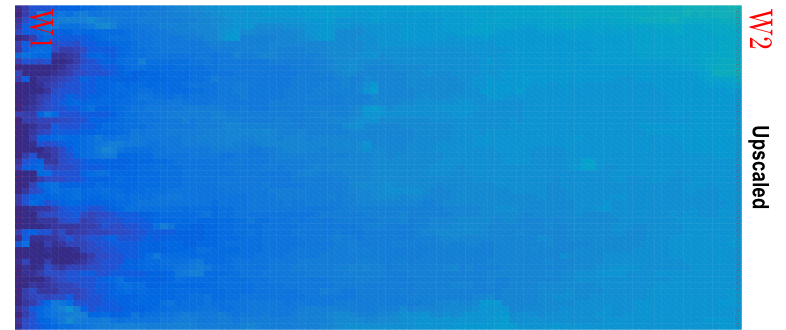

Upscaled
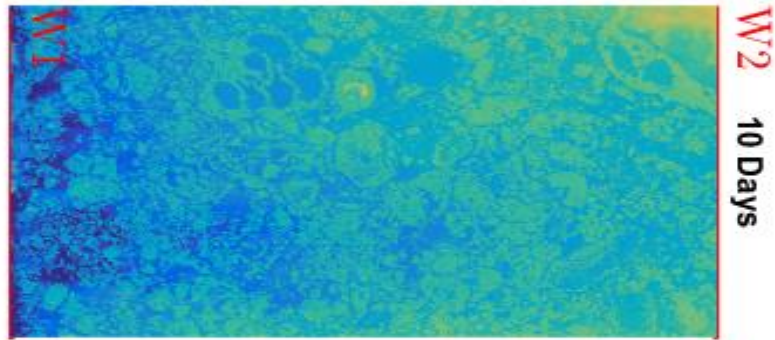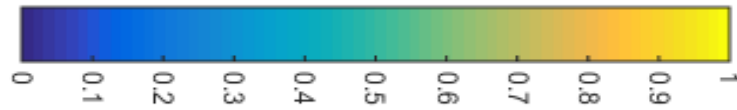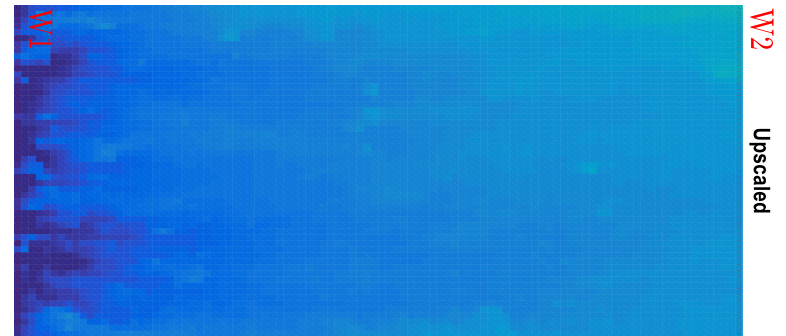
Simulation - 9 Day

Multi-scale

Upscaled

# Simulation - 10 Day

Multi-scale

Upscaled

Heterogeneity description, quantification, and choice of right simulation scale

- Who is doing it?
- Core is the main material available to observe / quantify sublog heterogeneities
  - High resolution image tool can do the job (cm resolution in good conditions)
- As long as the heterogeneities are not defined, we don't know if the flow experiments on core samples are representative of the flow response implemented in the model.
  - Full-core sample is not the solution either as long as the heterogeneity is not understood
  - REV
- A strategy should be agreed between petro-physicists / Geologist and RE's for the core sampling
  - BE INNOVATIVE ! Don't follow the books
  - RE's can before hand evaluate the impact of possible heterogeneities
    - Use mini-models or box models with representative elementary volume (REV)
  - Geologist can anticipate the distribution of heterogeneities that are often constrained by facies and depositional environments
  - Petro-physicists need to adapt their plugging and sampling strategy accordingly
    - a 'statistical' (every foot) sampling might not help in characterizing the heterogeneities
    - Prefer a deterministic sampling towards a statistical sampling

Porous Media Property Porosity/Permeability

Approximate REV

Model or Grid Block Size
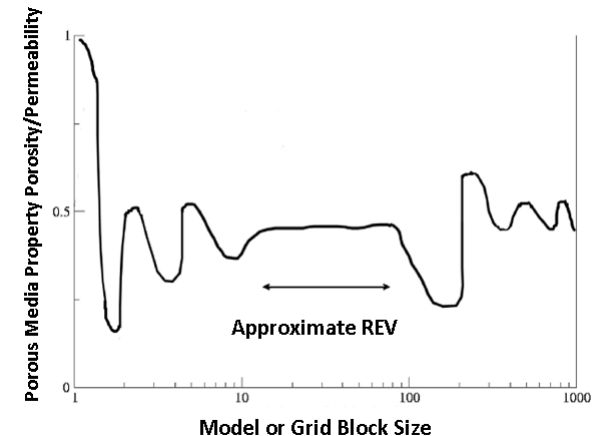
Summary

Workflow for quantifying impact of heterogeneity on IOR/EOR	

Step 1
- Heterogeneity Scale Identification

Step 2
- Heterogeneity Quantification

Step 3
- Box modelling at Relevant Heterogeneity Scale

Step 4
- Quantify Impact, honoring constraints, at reservoir grid scale

Step 5
- Implement findings on field scale