Evaluation of CO_2 Storage Capacity and its Uncertainty From Seismic and Well Data

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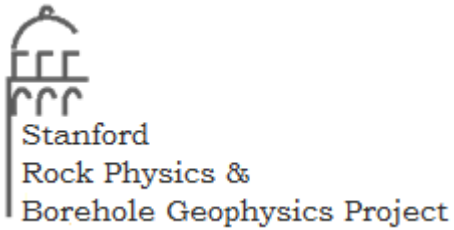
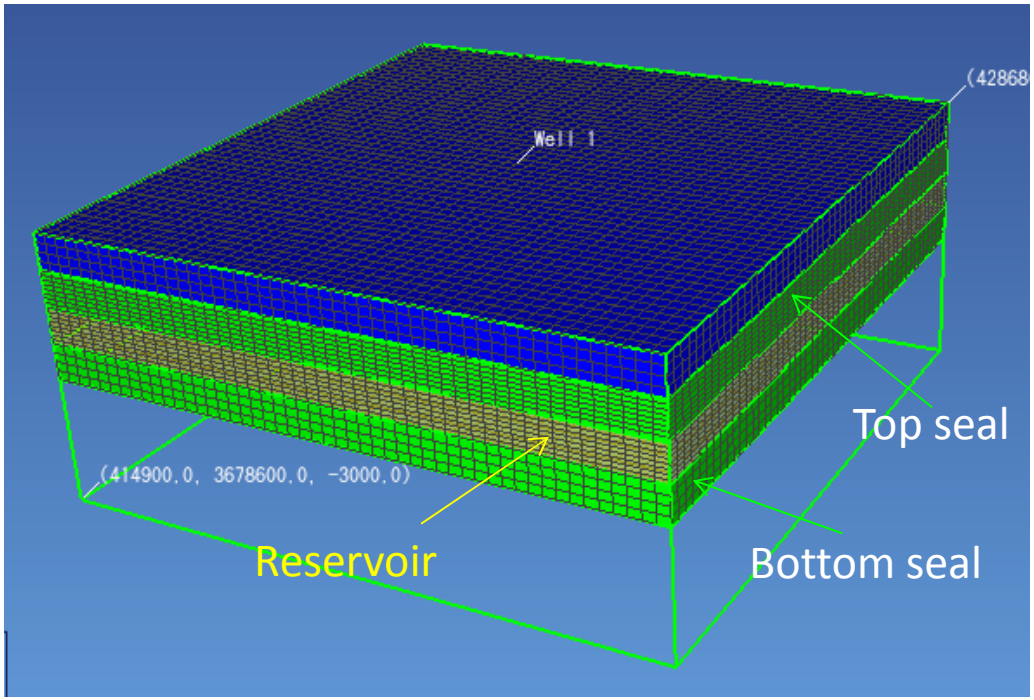
Paper G2
Meeting 2014



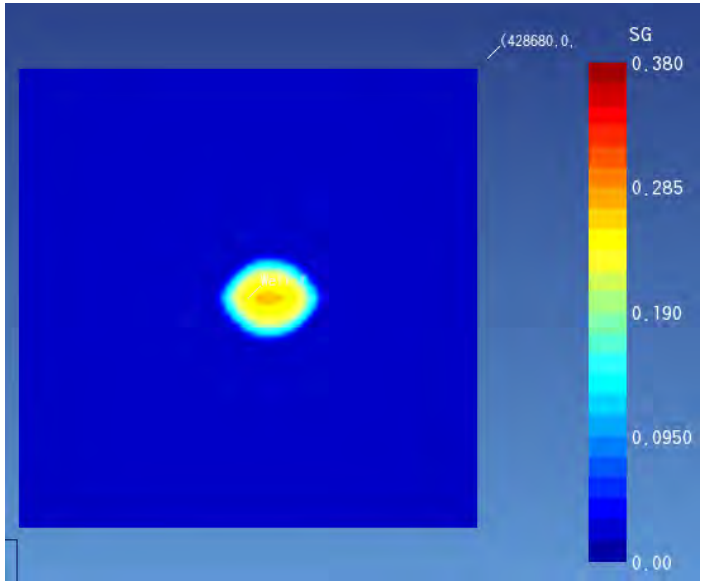
Problem

- Numerical flow simulation (e.g. TOUGH2) is important to predict CO_2 storage capacity. However, heterogeneities of the reservoir and of the seal are sometimes ignored.



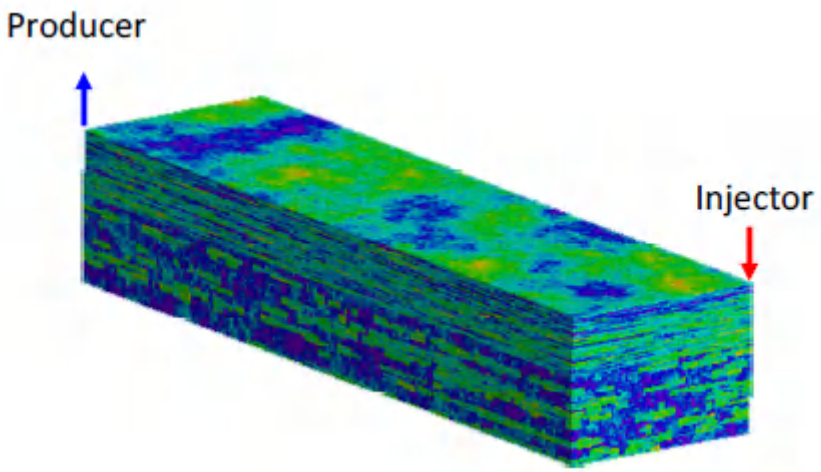
A homogeneous model

CO_2 saturation (plan view)



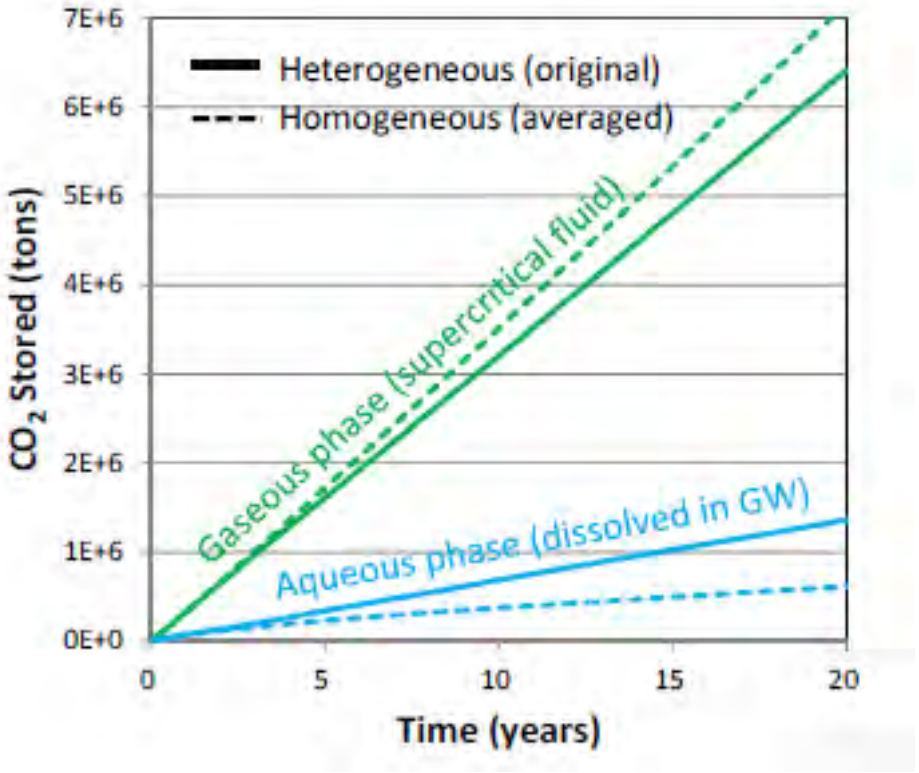
A previous study

Different results by homogeneous and heterogeneous models.



Heterogeneous model
(Porosity distribution)

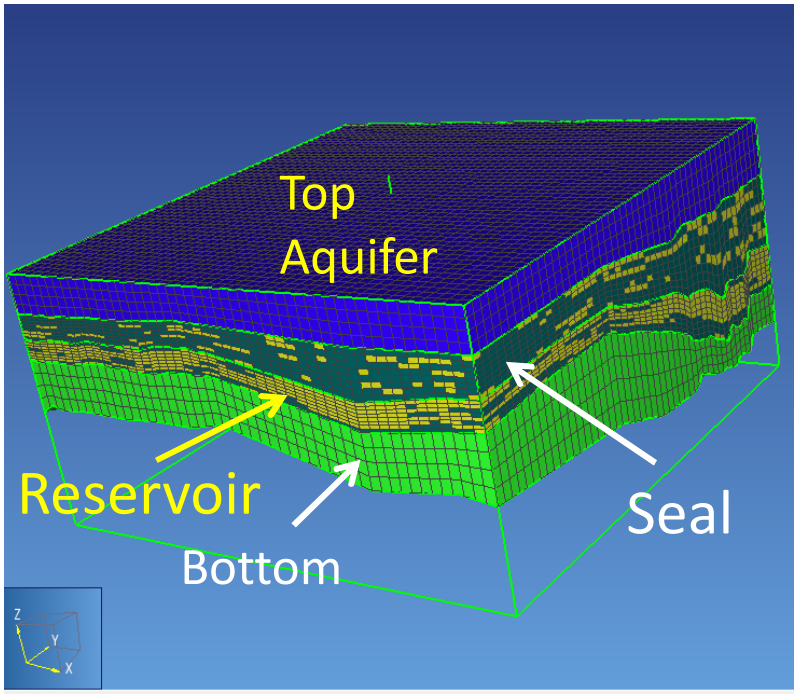
60x220x85 grid cells

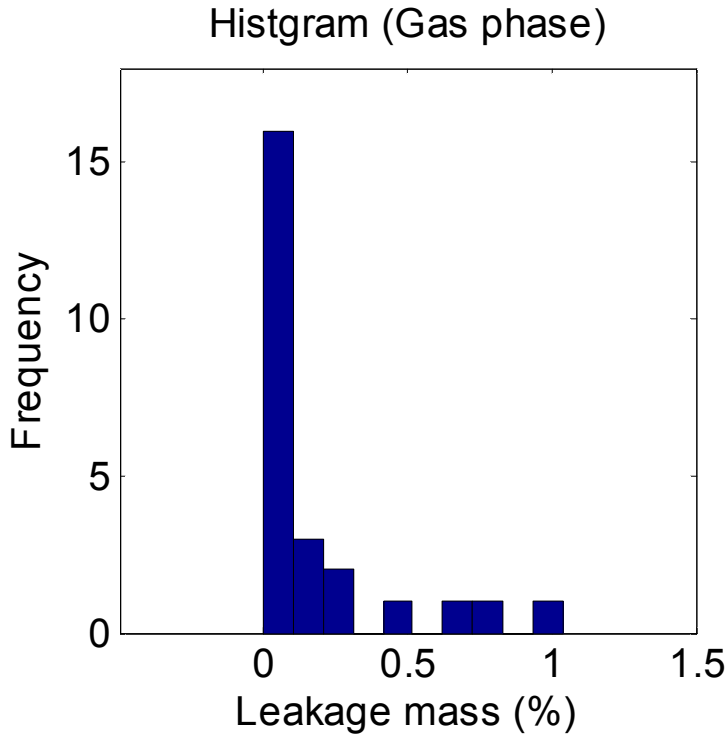


(Yamamoto et al., 2013)

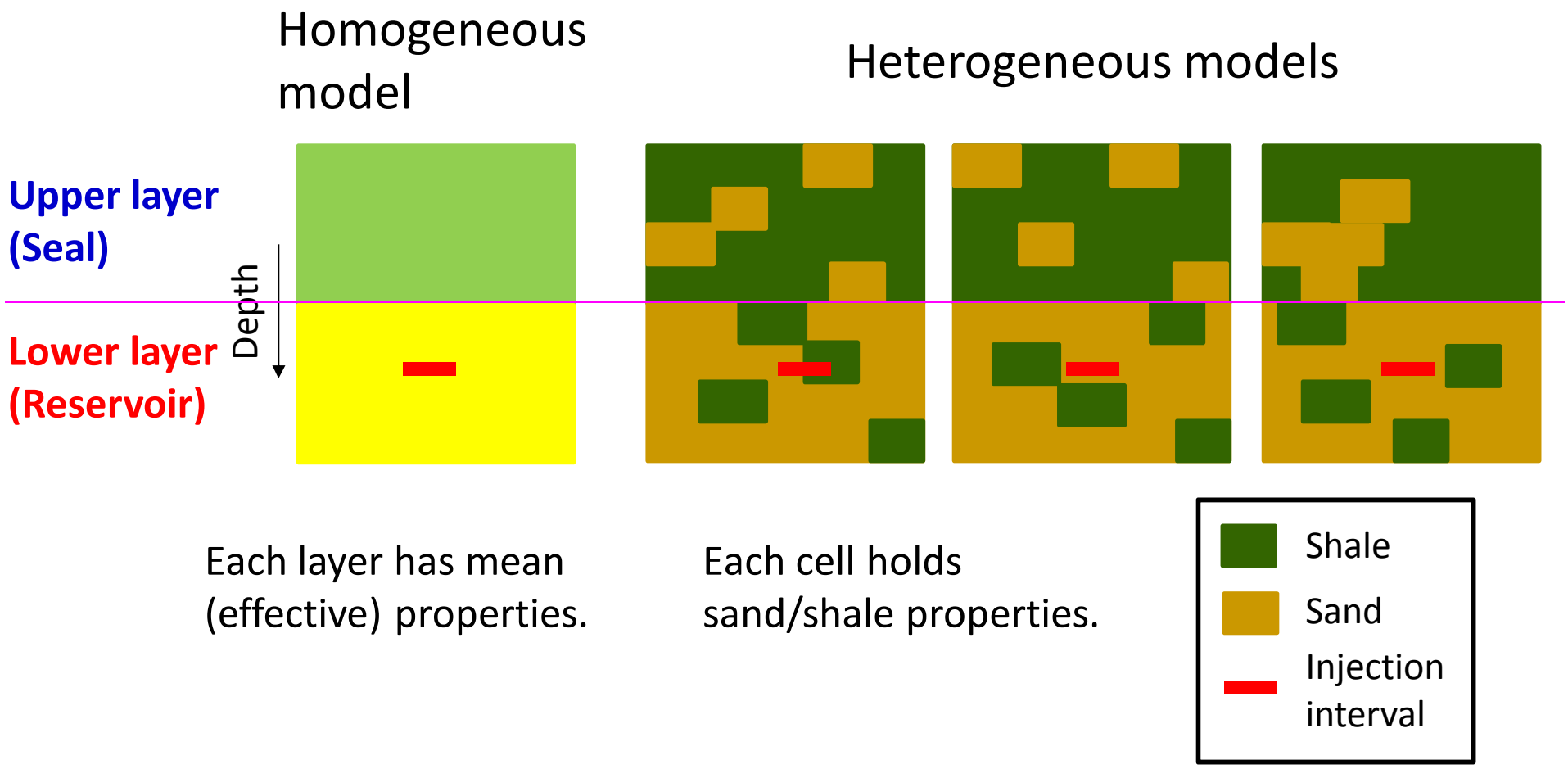
Purposes of this study

1. Include spatial heterogeneity with aids of seismic, well data, and stochastic modeling.
2. Evaluate the uncertainty of the CO_2 storage capacity and the risk of the leakage



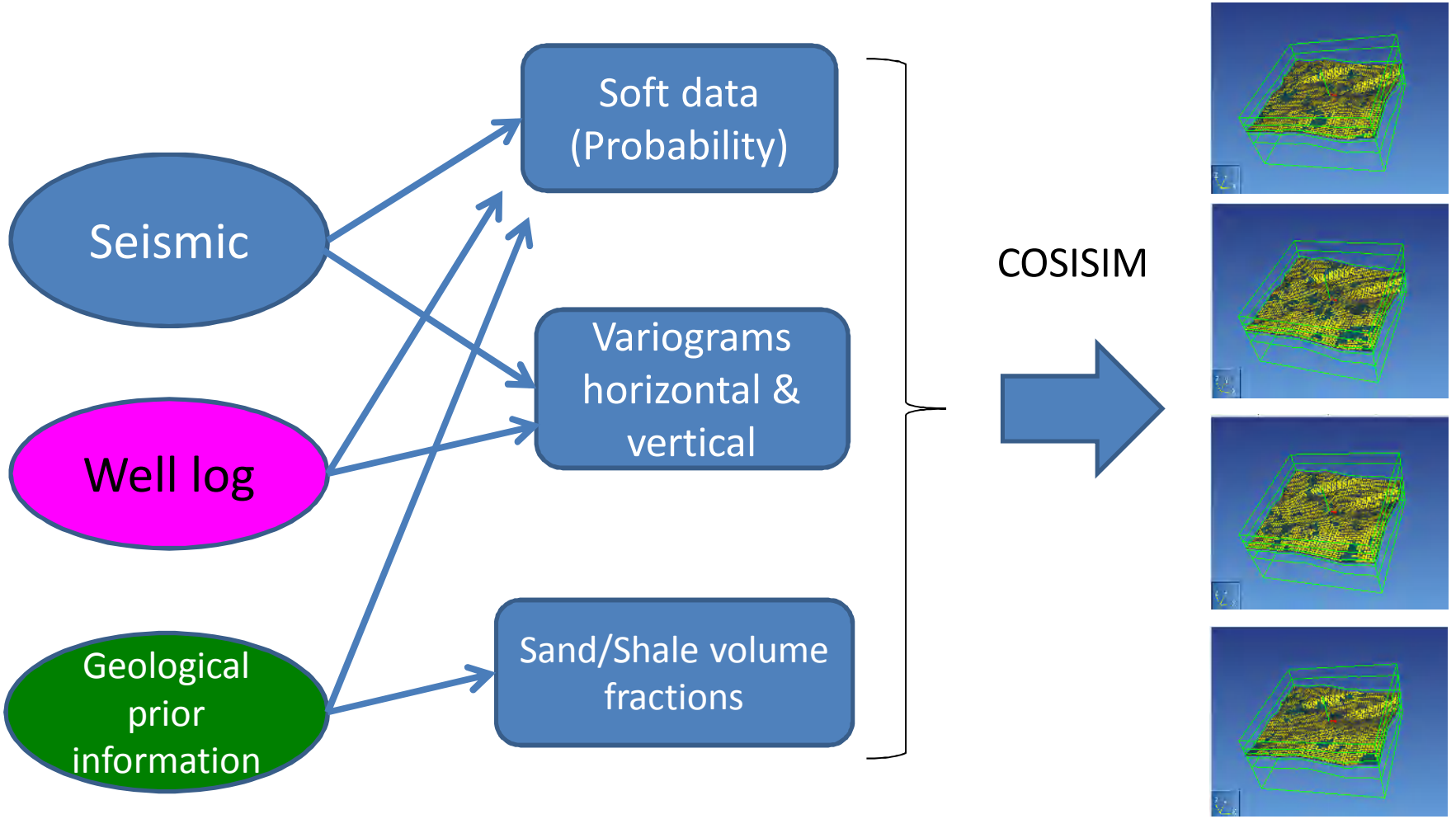


Spatial heterogeneity (binary mixture)

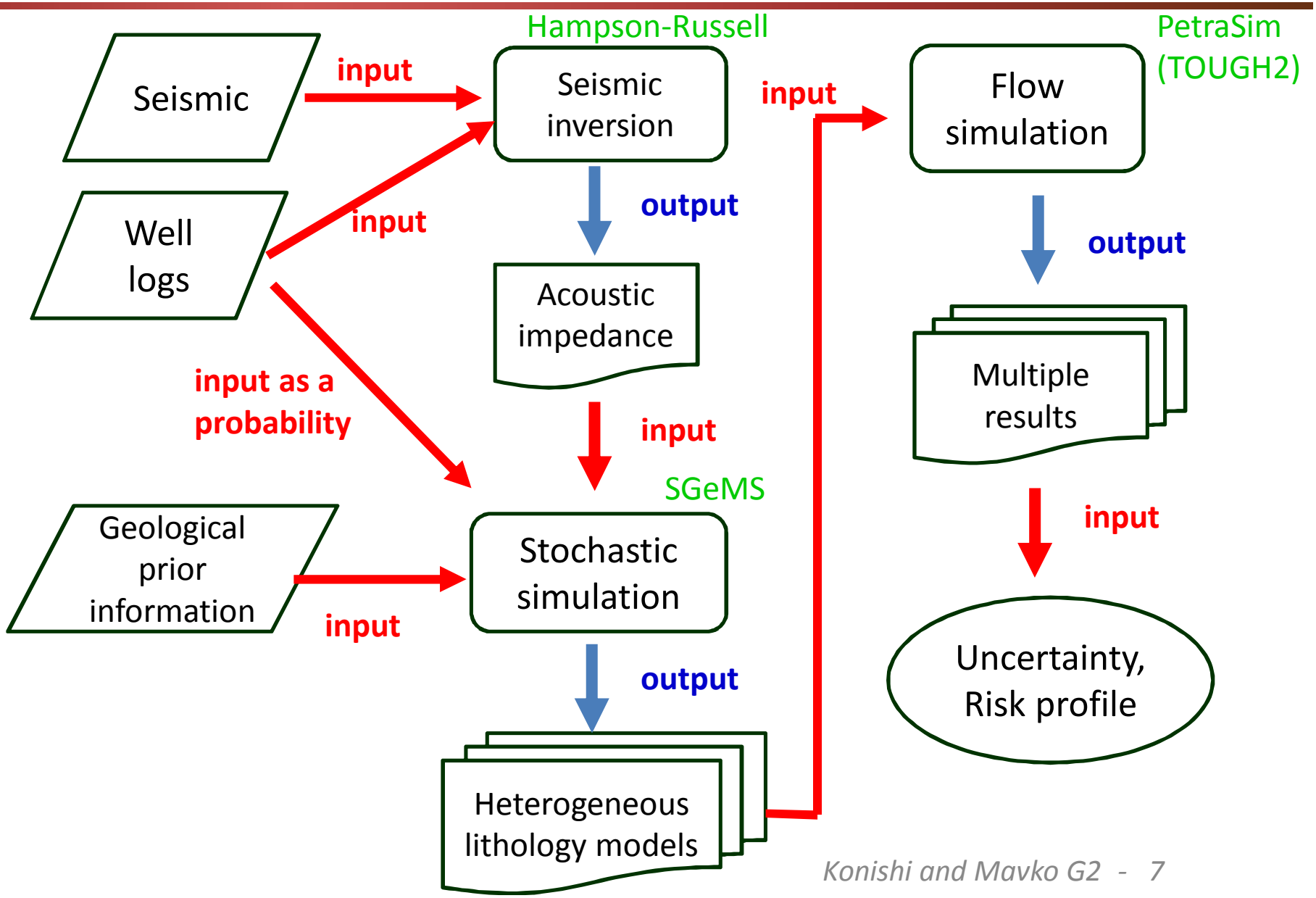


Procedure to build heterogeneous models

COSISIM (Sequential Indicator co-simulation)



Workflow


Hampson-Russell
PetraSim
(TOUGH2)
Seismic
input
Seismic inversion
input
Flow simulation
output
Well logs
input
output
Acoustic impedance
Multiple results
input as a probability
input
SGeMS
input
Geological prior information
Stochastic simulation
input
output
Uncertainty, Risk profile
Heterogeneous lithology models

Case study

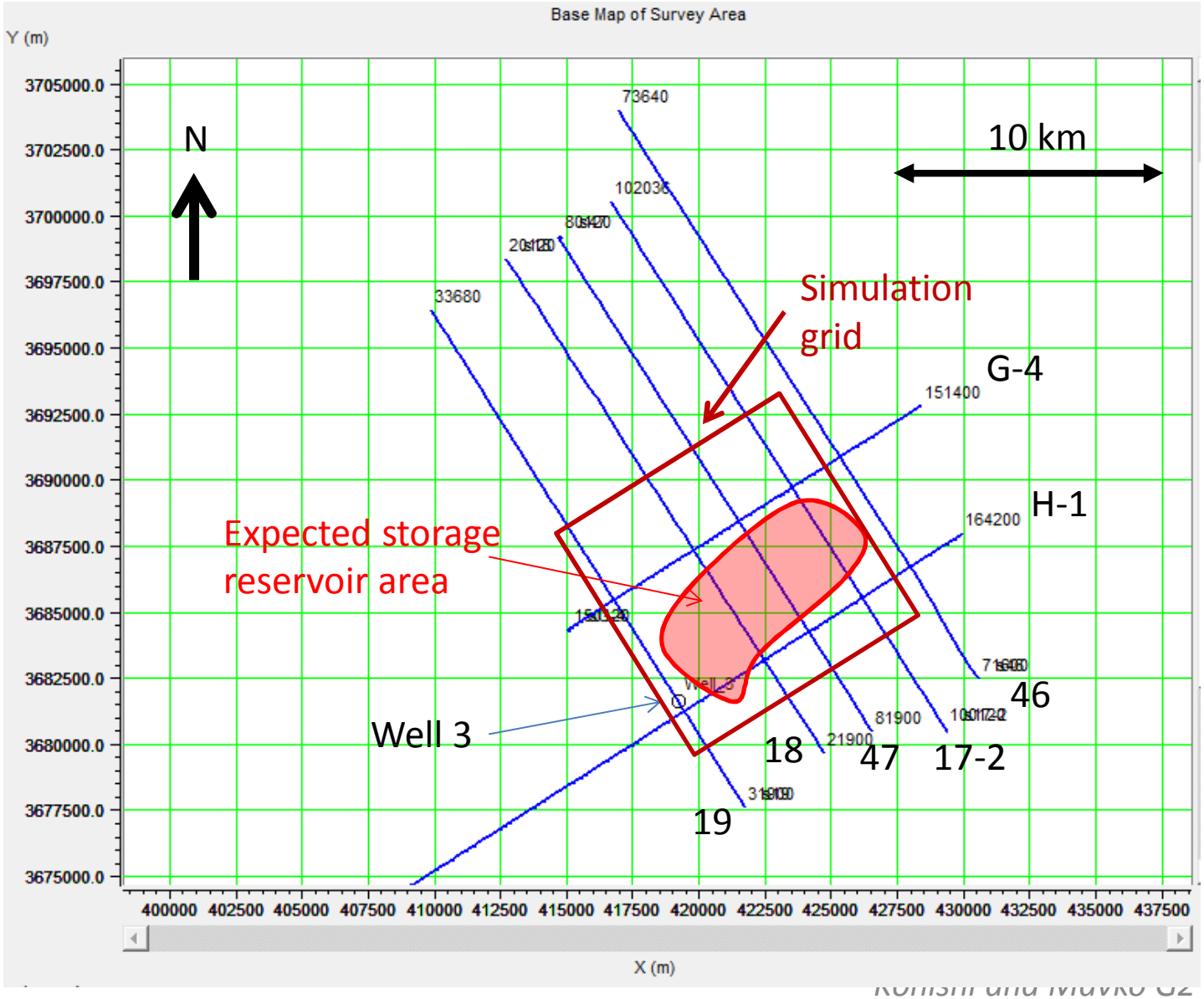
[Available data & information]

- Multiple 2D seismic sections (post stack)
- 1 well (well log & core measurements)
- Geological prior information
  - Major direction of faults (North-south)
  - Volume fraction of sand/shale

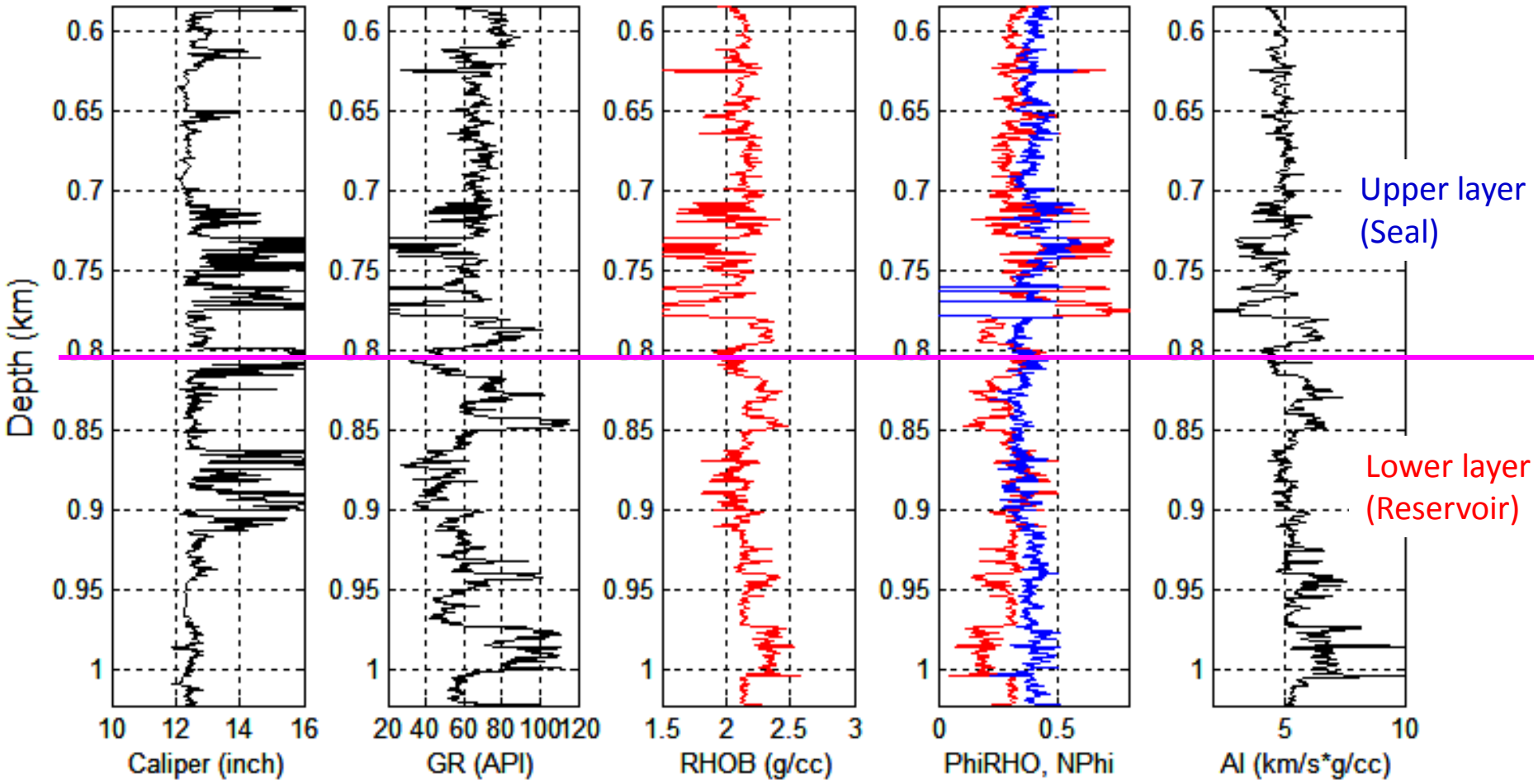
[Flow simulation]

- 25 heterogeneous models & 1 homo. model
- 1 Mt/year (32kg/s) injection for 30 years

The investigation area

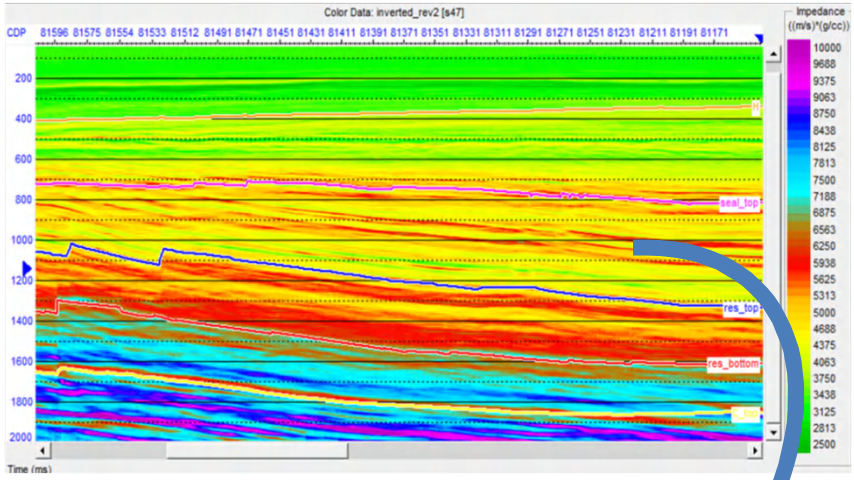


Well log


Depth (km)
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
10 12 14 16
Caliper (inch)
20 40 60 80 100120
GR (API)
1.5 2 2.5 3
RHOB (g/cc)
0 0.5
PhiRHO, NPhi
5 10
AI (km/s*g/cc)
Upper layer
(Seal)
Lower layer
(Reservoir)

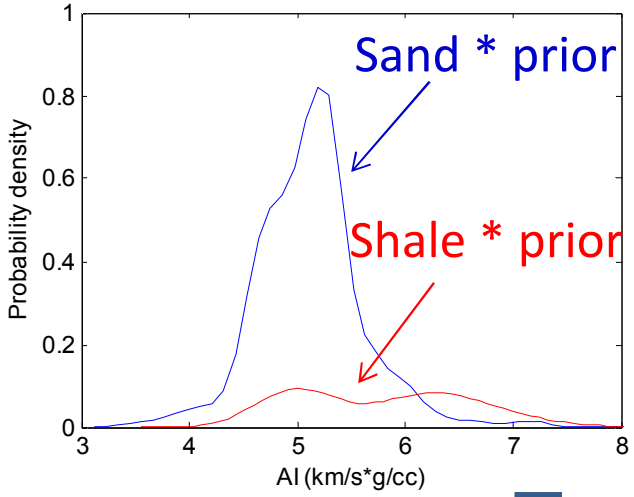
Sand/shale probabilities from seismic and well log

From seismic

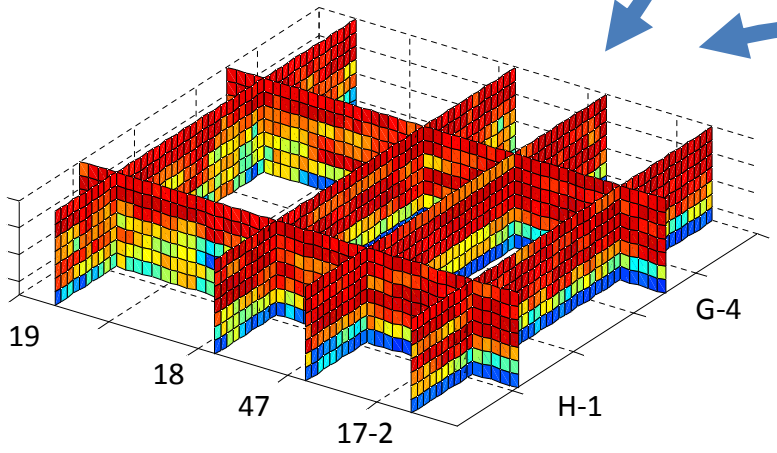


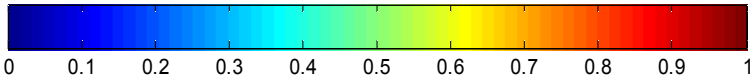
Acoustic impedance section

From well log

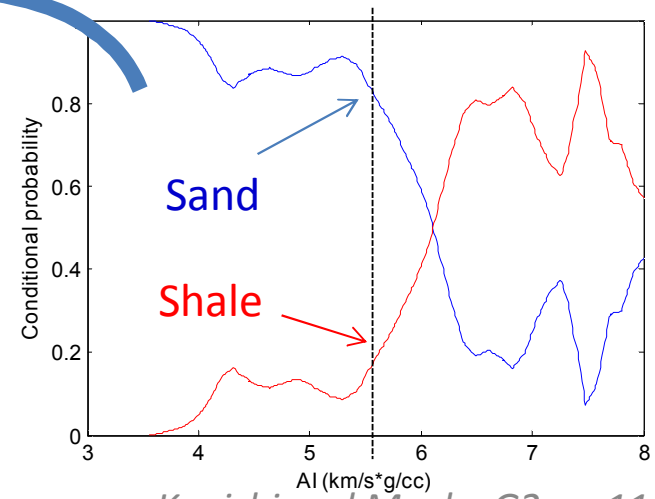


$$P(c_j|x) \propto P(x|c_j)P(c_j)$$

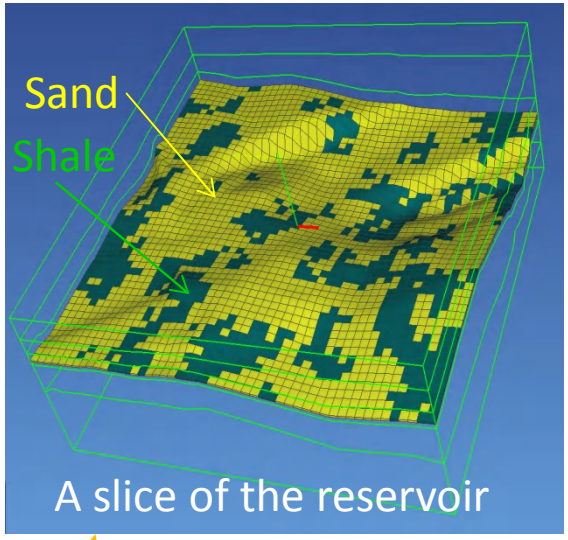


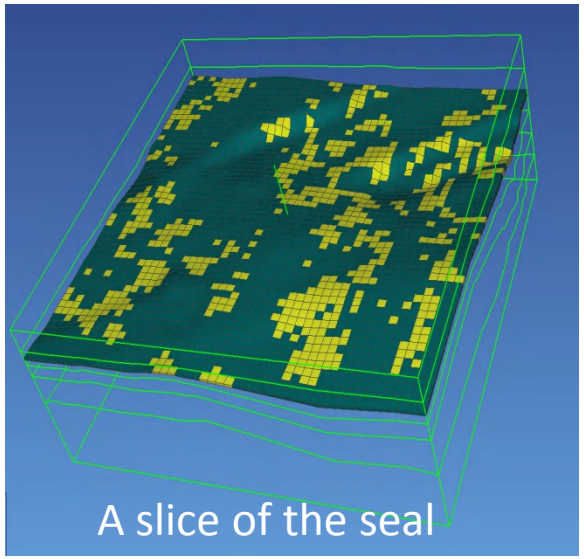


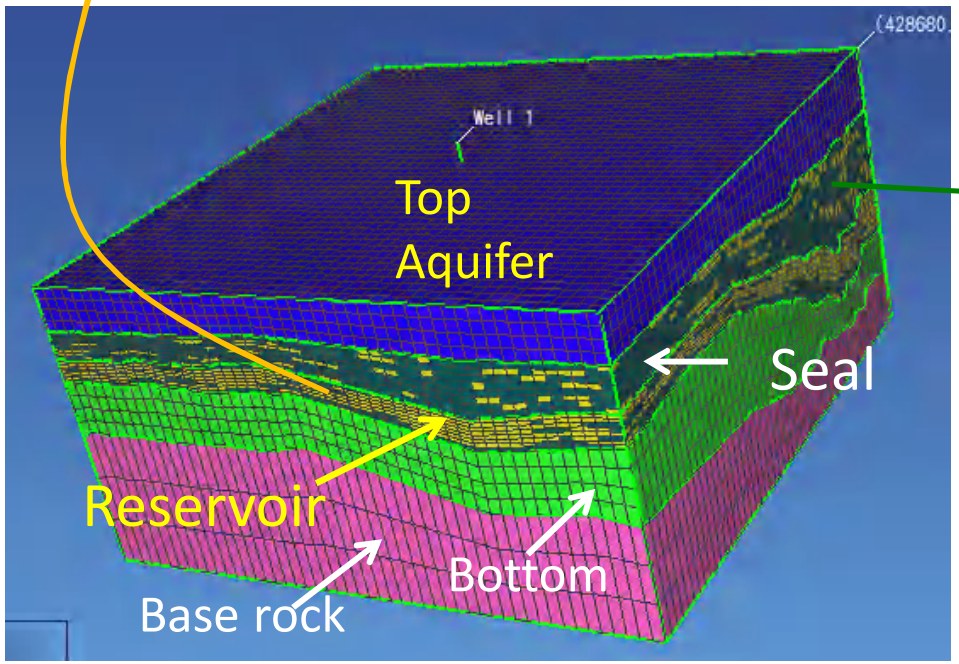
Sand Probability



An example of heterogeneous earth models



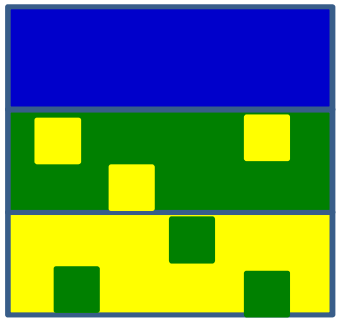




50 x 50 x 27 cells

1 cell size is
200m horizontally,
varies vertically

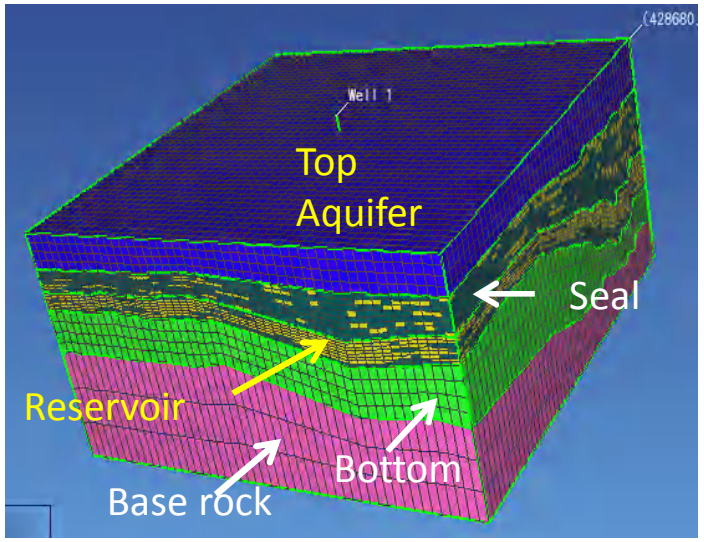
Properties of each rock type



Top aquifer

Upper (Seal)

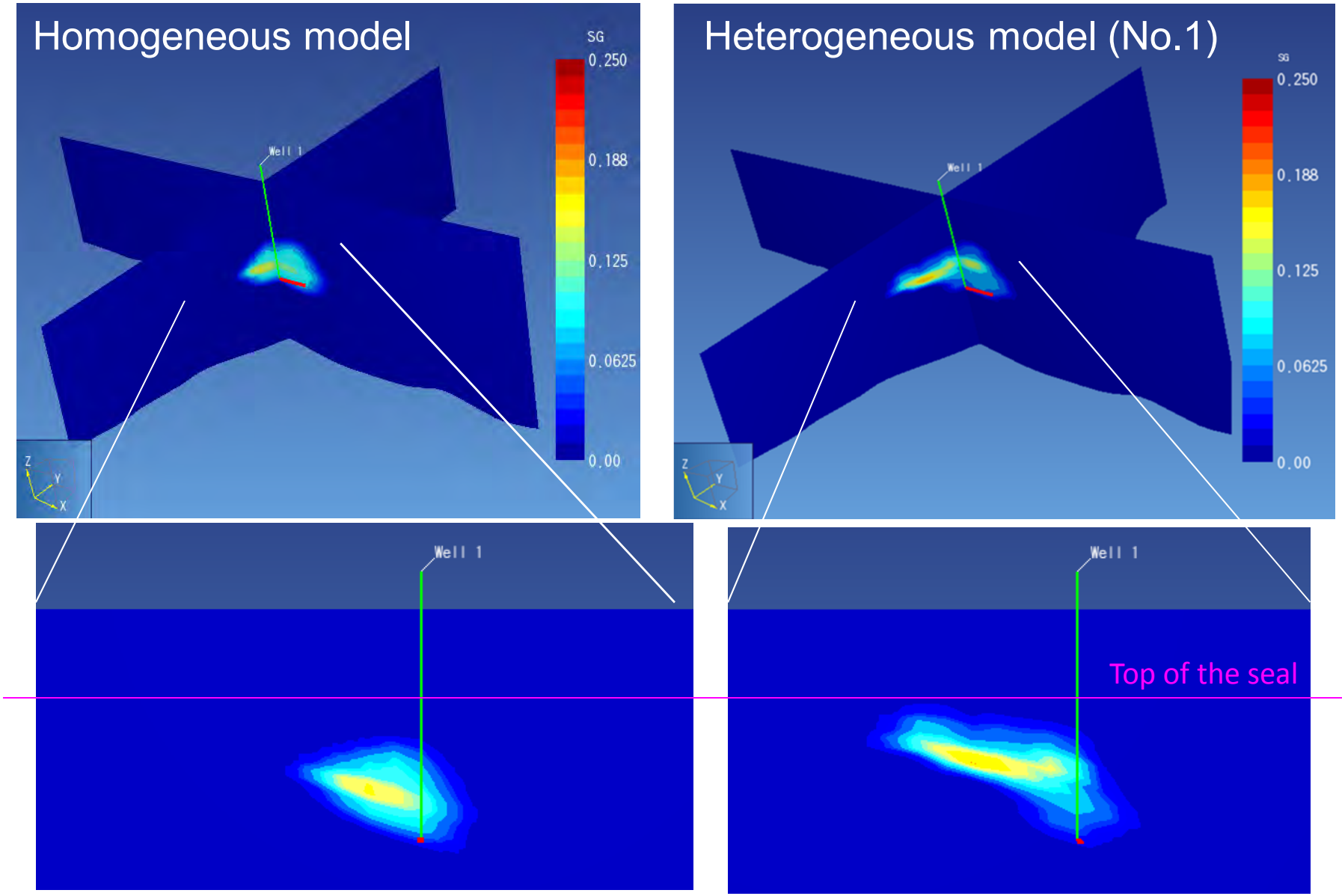
Lower (Reservoir)



[Properties of each rock type]

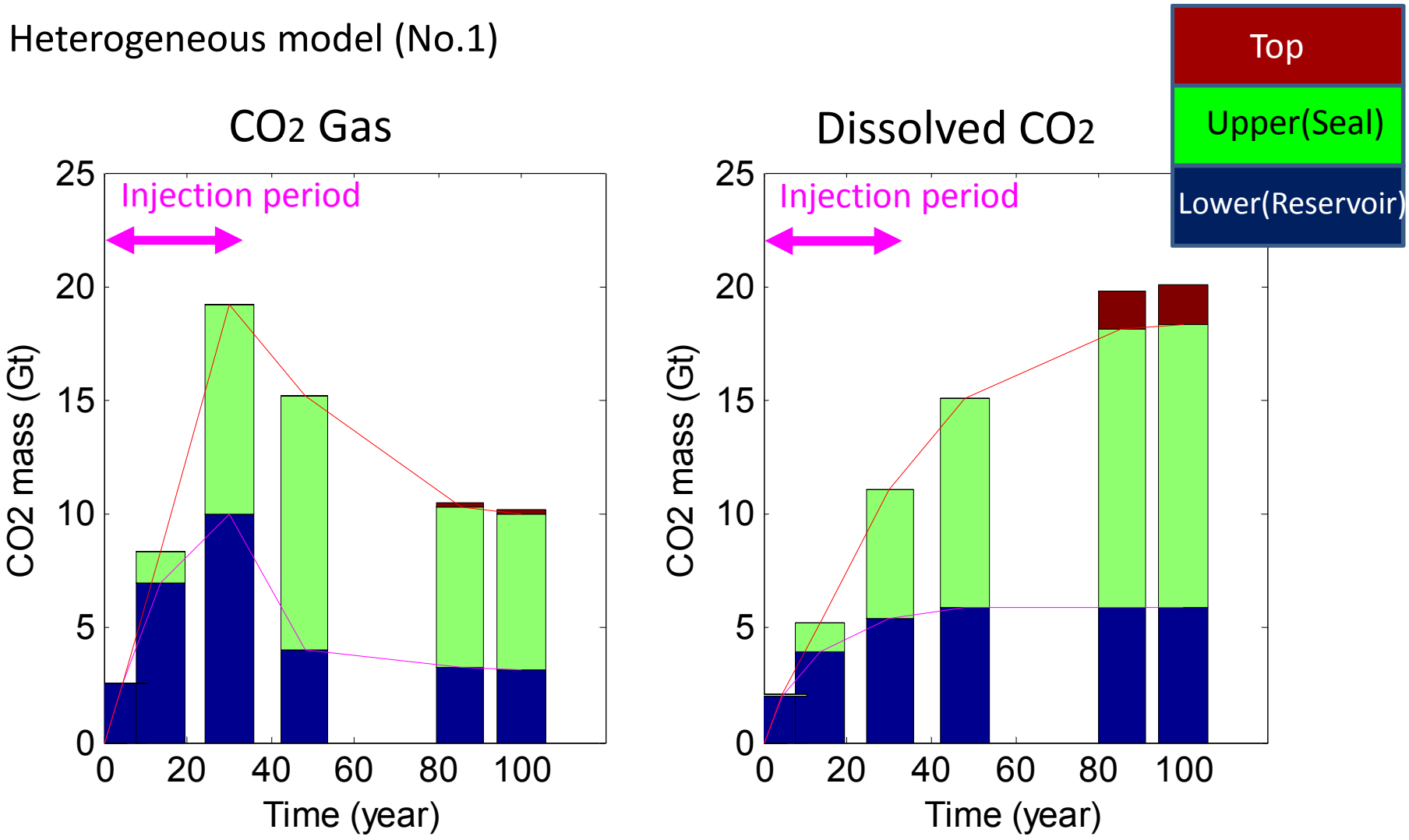
Rock type	Porosity	Permeability (md)	irreducible water saturation	Entry pressure (kPa)
Aquifer sand	0.3	100	0.3	4.2
Sand	0.3	54	0.5	5.6
Shale	0.25	1	0.8	31.8

Difference in CO_2 saturation profiles

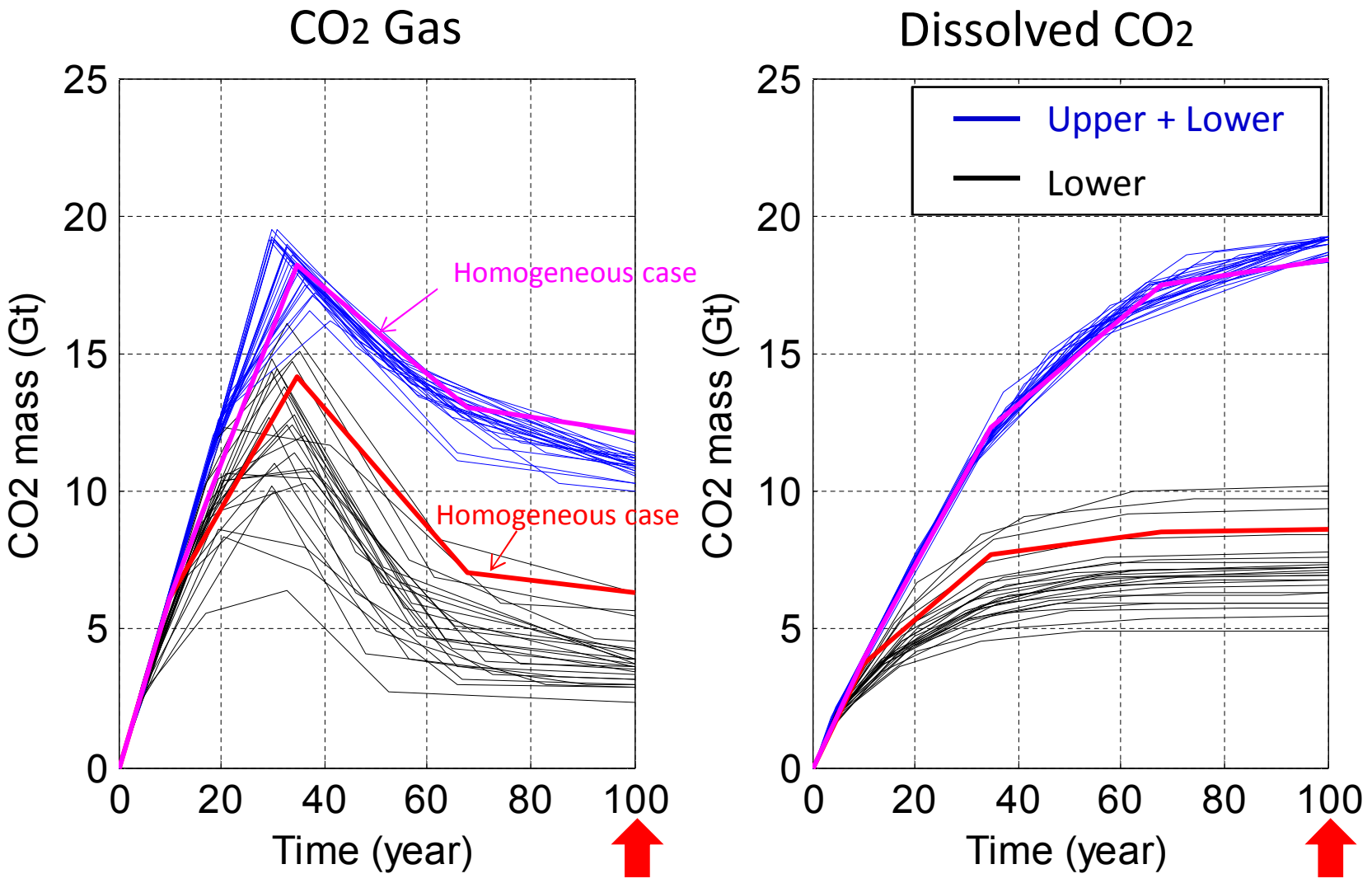


CO_2 mass in each layer with time

Heterogeneous model (No.1)

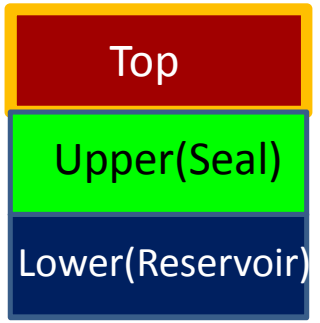


Time evolution of CO_2 mass for all models

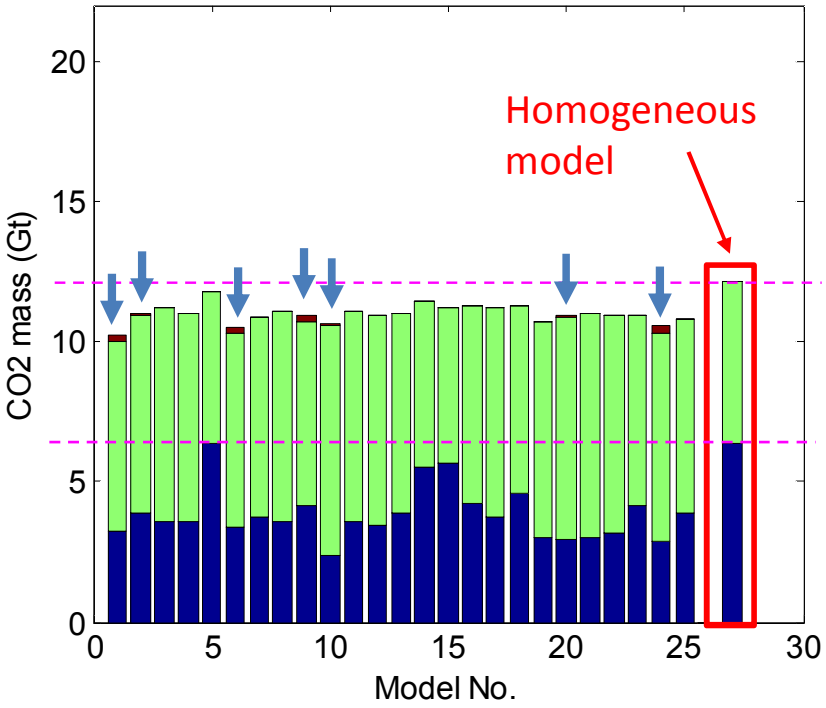


The leaked CO_2 mass at 100 years

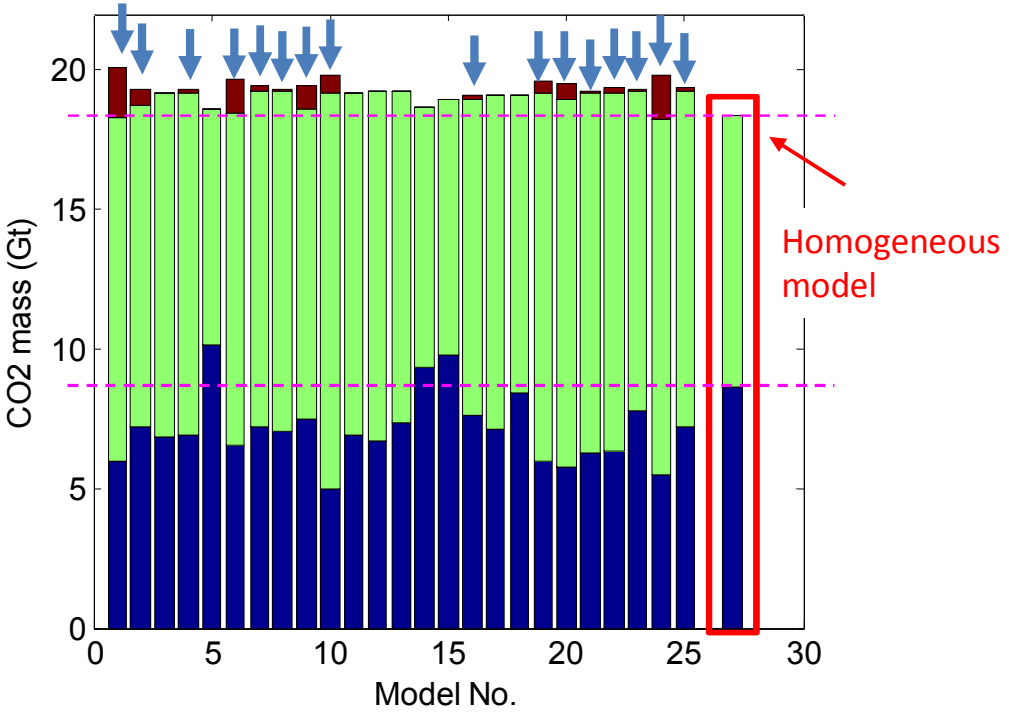
CO_2 mass in Top layer is defined as leaked CO_2



CO_2 Gas

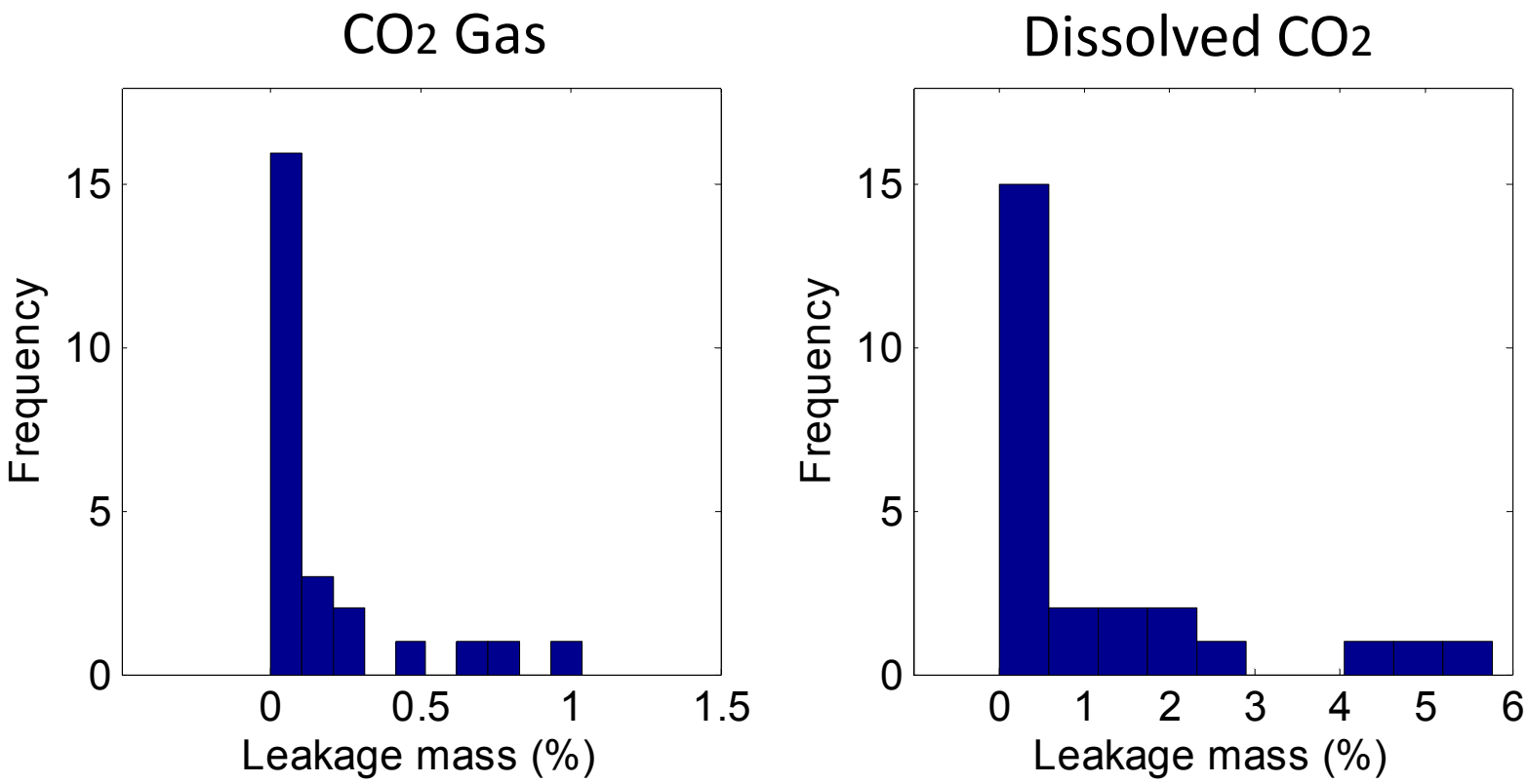


Dissolved CO_2



Histograms of the leakage mass ratio

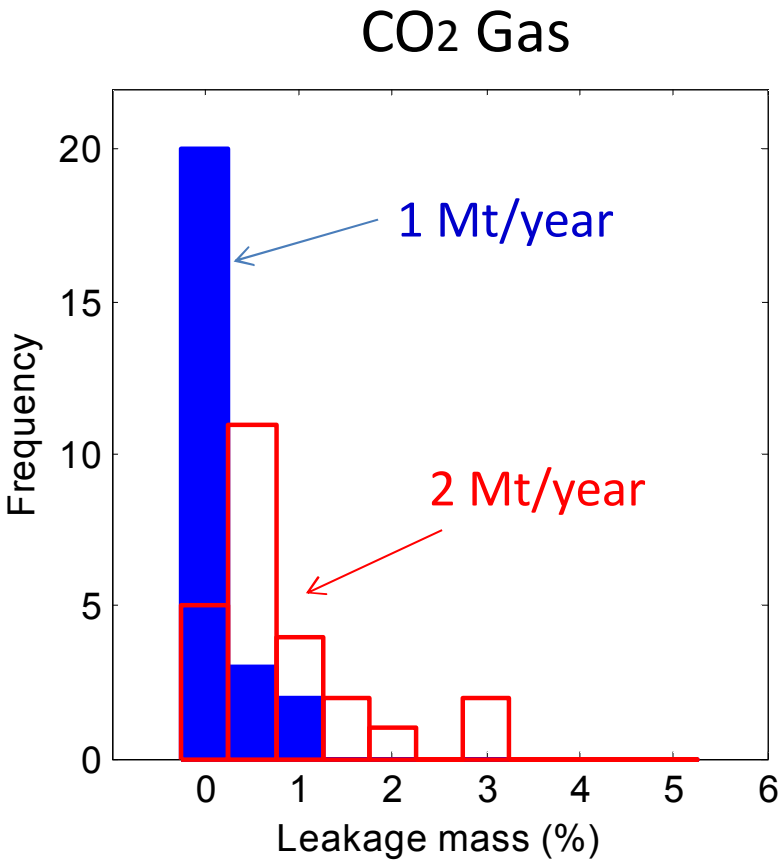
Leakage mass ratio = (CO_2 mass in Top) / (Total injected CO_2)

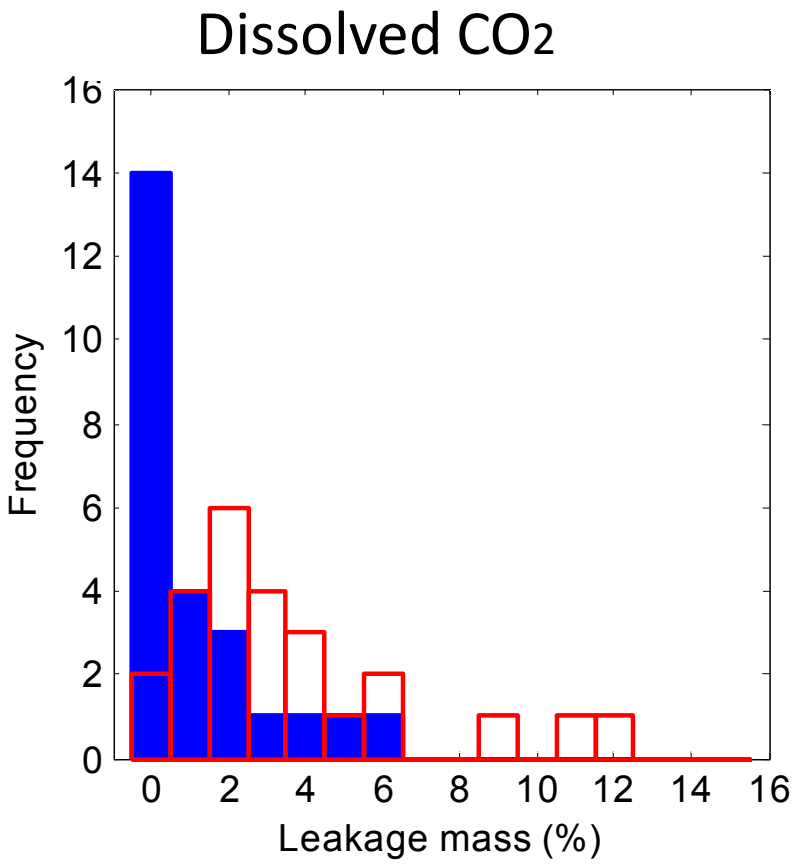


Risk Profile

Risk increases with a high injection rate

When injection rate is doubled, leakage mass ratio is increased.





Conclusions

- Homogeneous model does not provide the mean response for CO_2 storage capacity.
- A risk profile can be obtained from a distribution of the leakage mass.
- This methodology is simple but is helpful to evaluate proposed sites at an early stage of CO_2 projects.

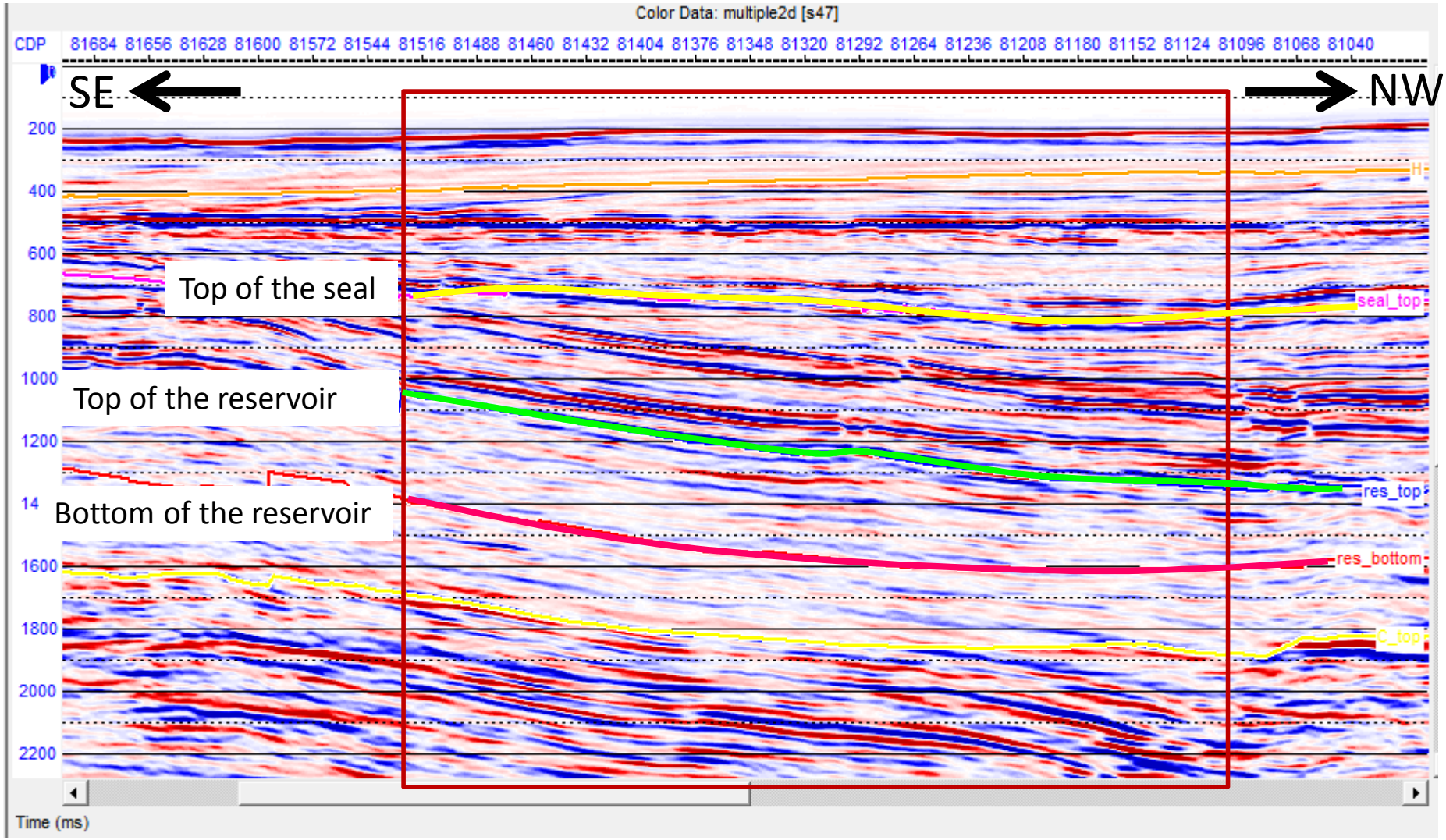
Acknowledgements

- RITE (Research Institute of Innovative Technology for the Earth)
- OYO Corporation
- SRB group
- Stéphanie Vialle in LBNL
- Seiich Ikeda in OYO

Thank you very much.

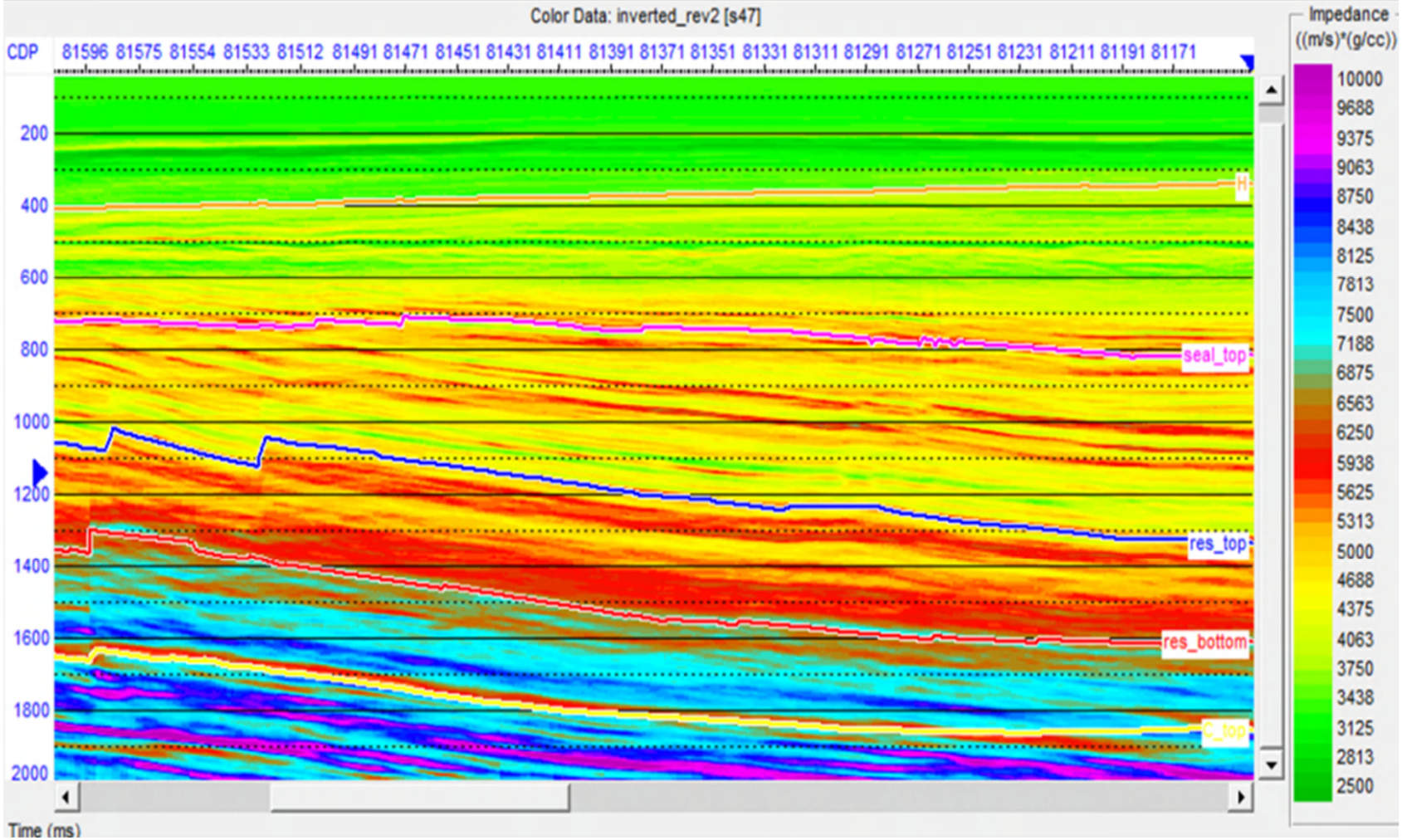
backup

Seismic section

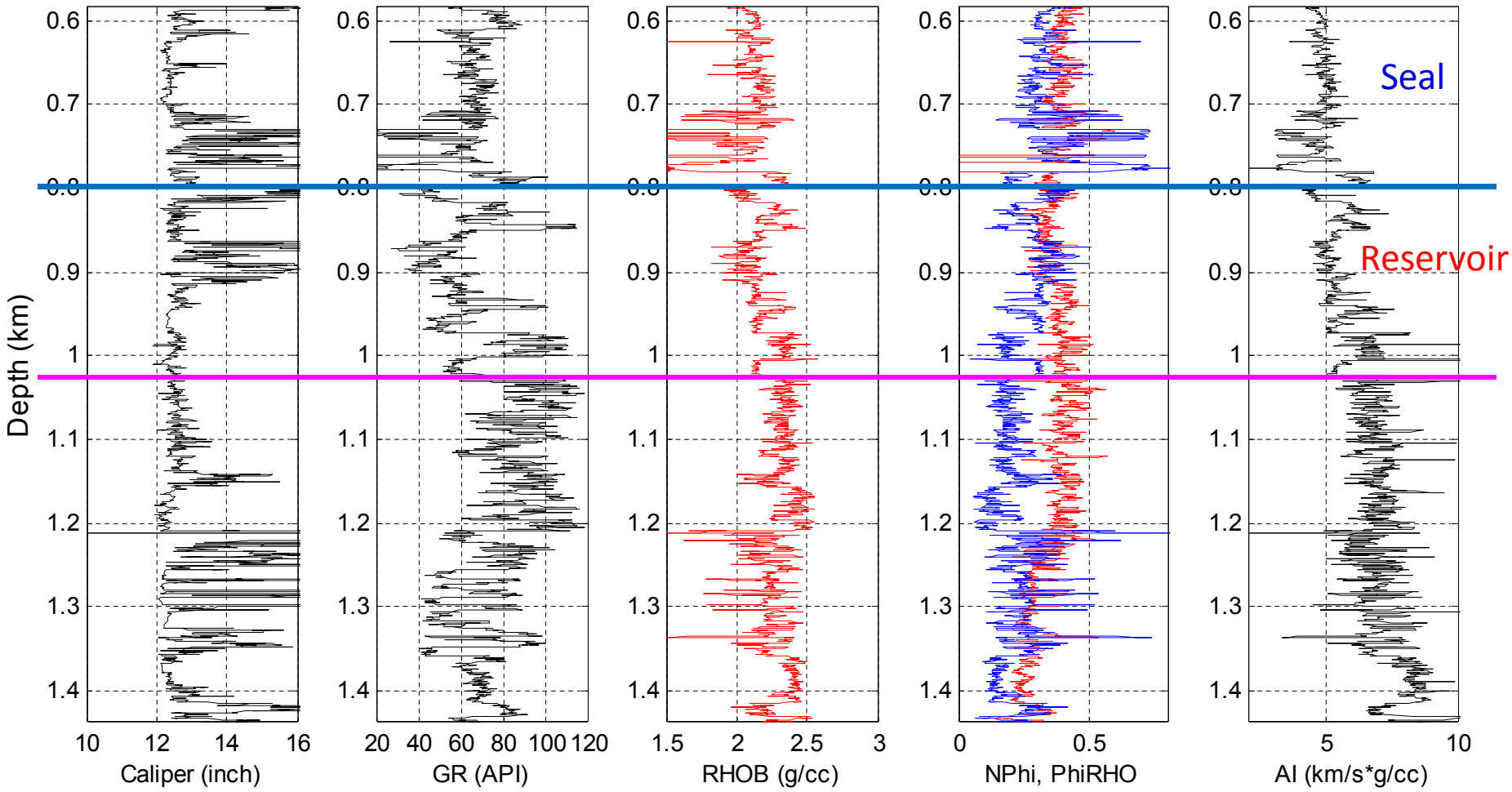


Inverted section (Acoustic impedance)

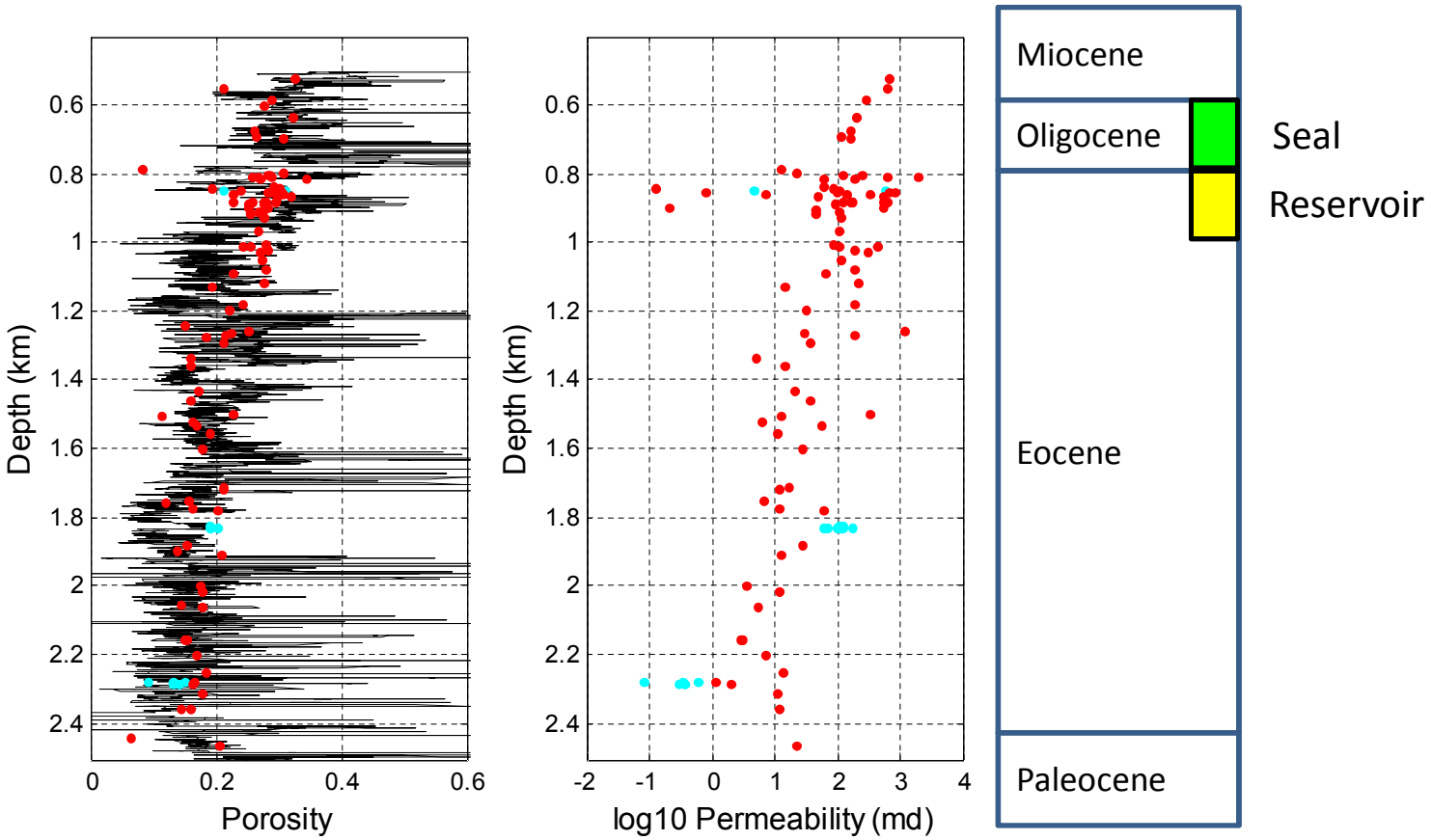
AI (m/s g/cc)



Well logs

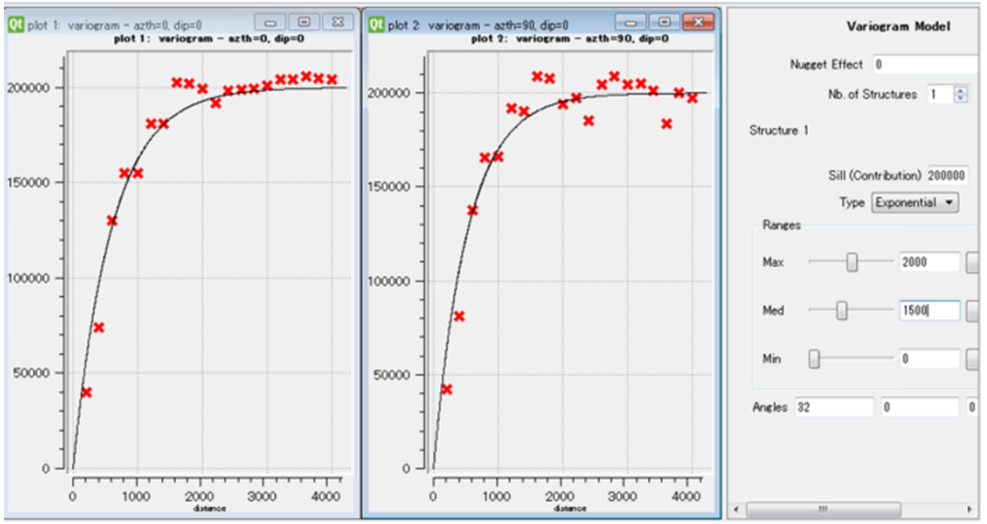

Depth (km)
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
10 12 14 16
Caliper (inch)
20 40 60 80 100 120
GR (API)
1.5 2 2.5 3
RHOB (g/cc)
0 0.5
NPhi, PhiRHO
5 10
AI (km/s*g/cc)
Seal
Reservoir

Core measurements

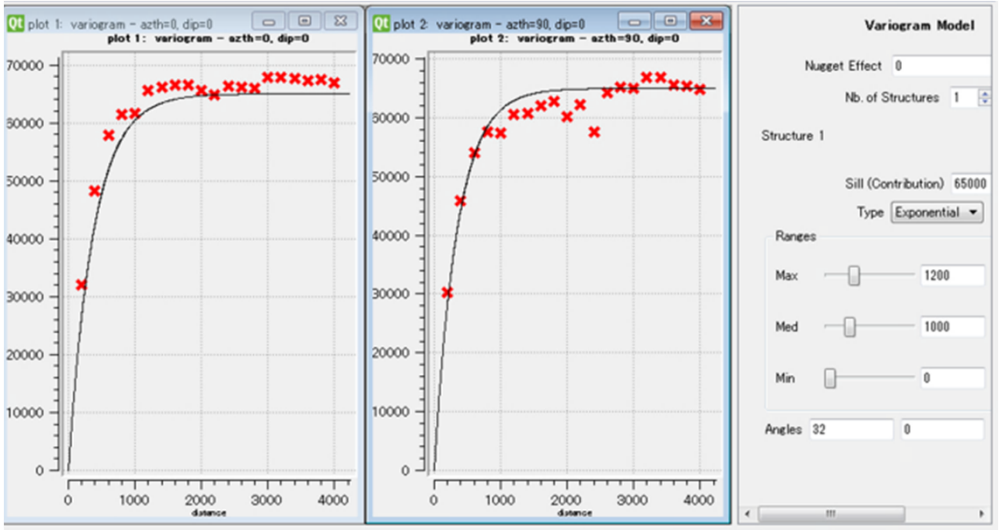


Variograms (Horizontal)

Reservoir

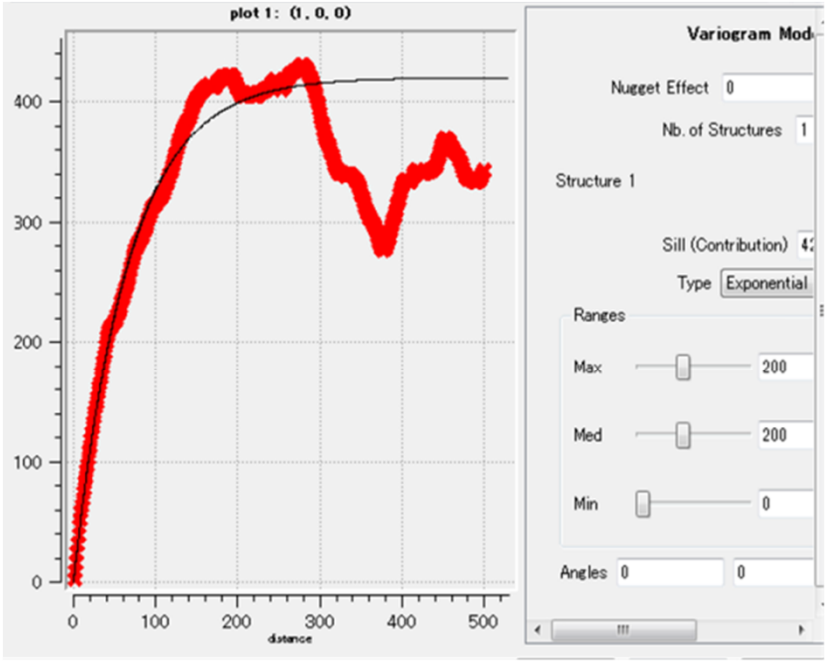


Seal



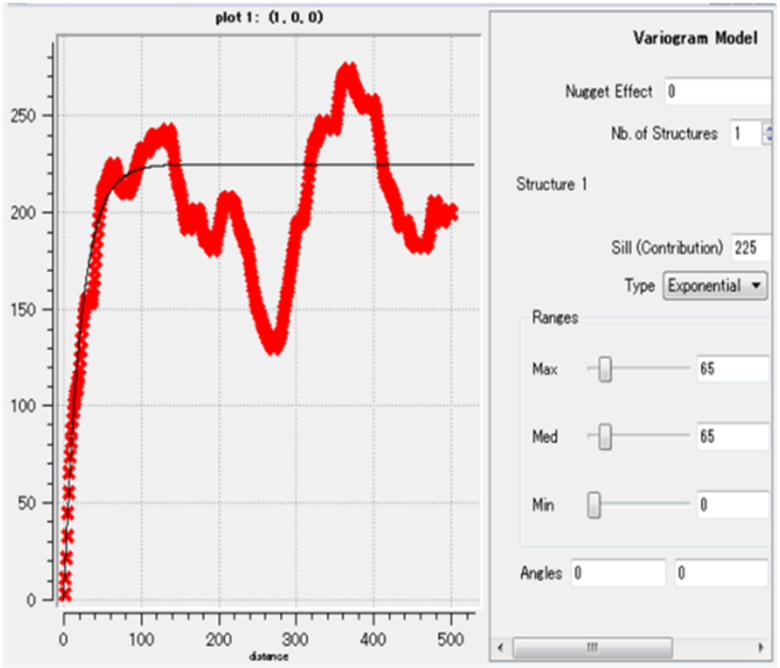
Variograms (Vertical)

Reservoir



Distance (samples)

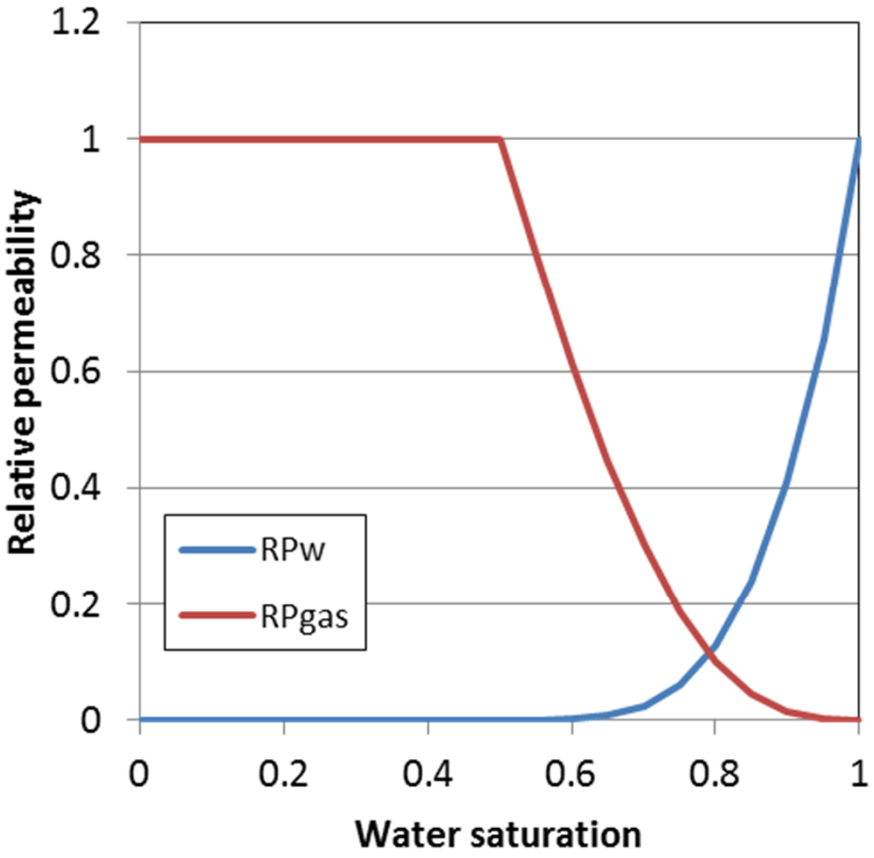
Seal



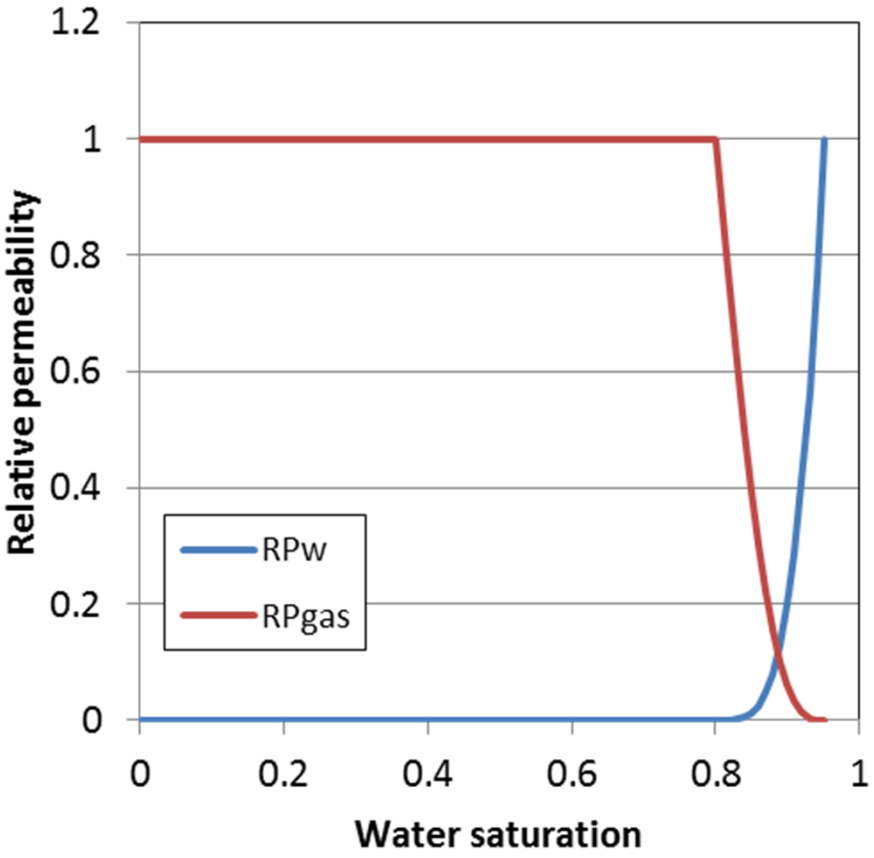
Distance (samples)

Relative permeability

Sand



Shale



Capillary pressure curves