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COPENHAGEN | DENMARK

Complex Construction vs. Simple Deconstruction: Alternative Workflows and the Role of 'Ultimate Truth' Models

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11-14 JUNE 2018
WWW.EAGEANNUAL2018.ORG

Complex models

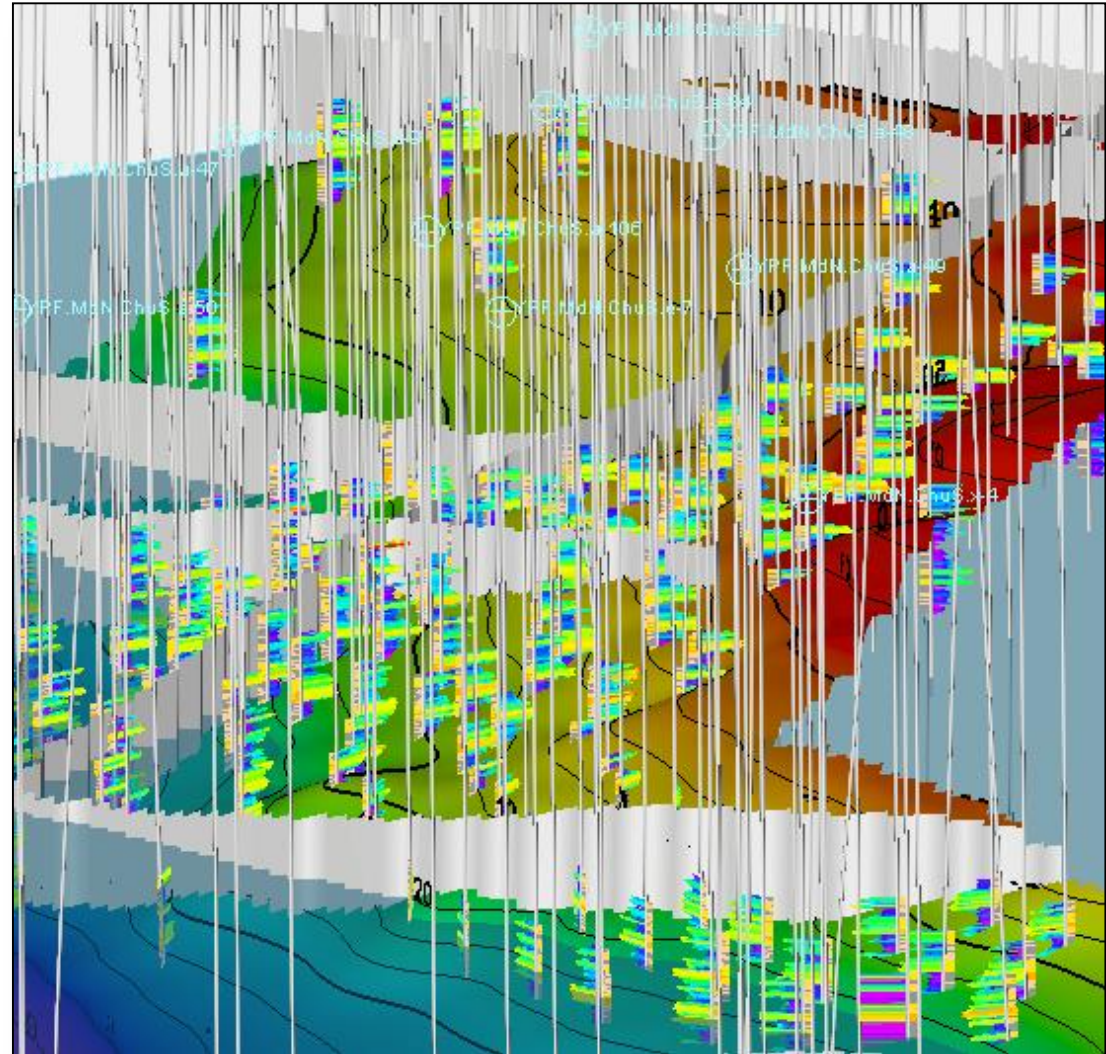
We have a complex problem

We had one thing we didn't understand

so ...

Now we have two

We build a complex model

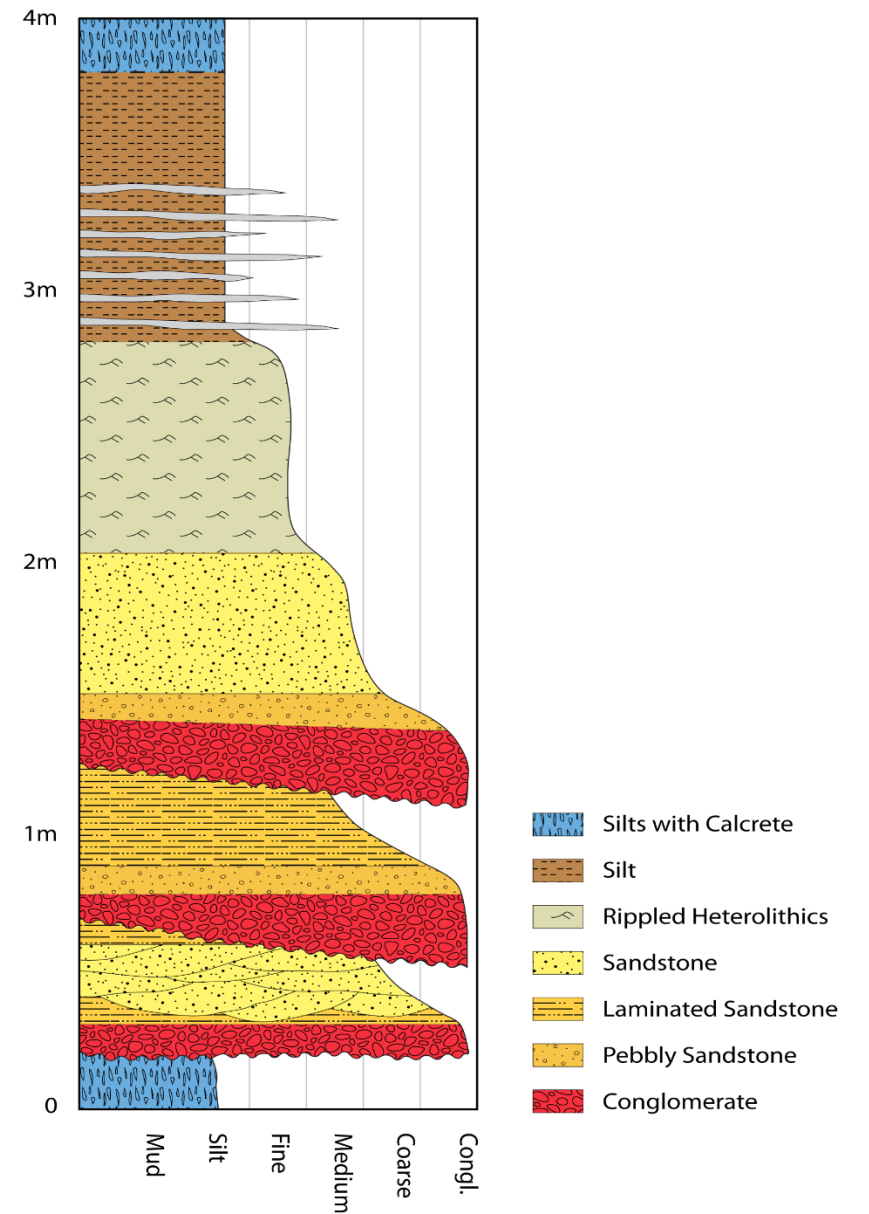
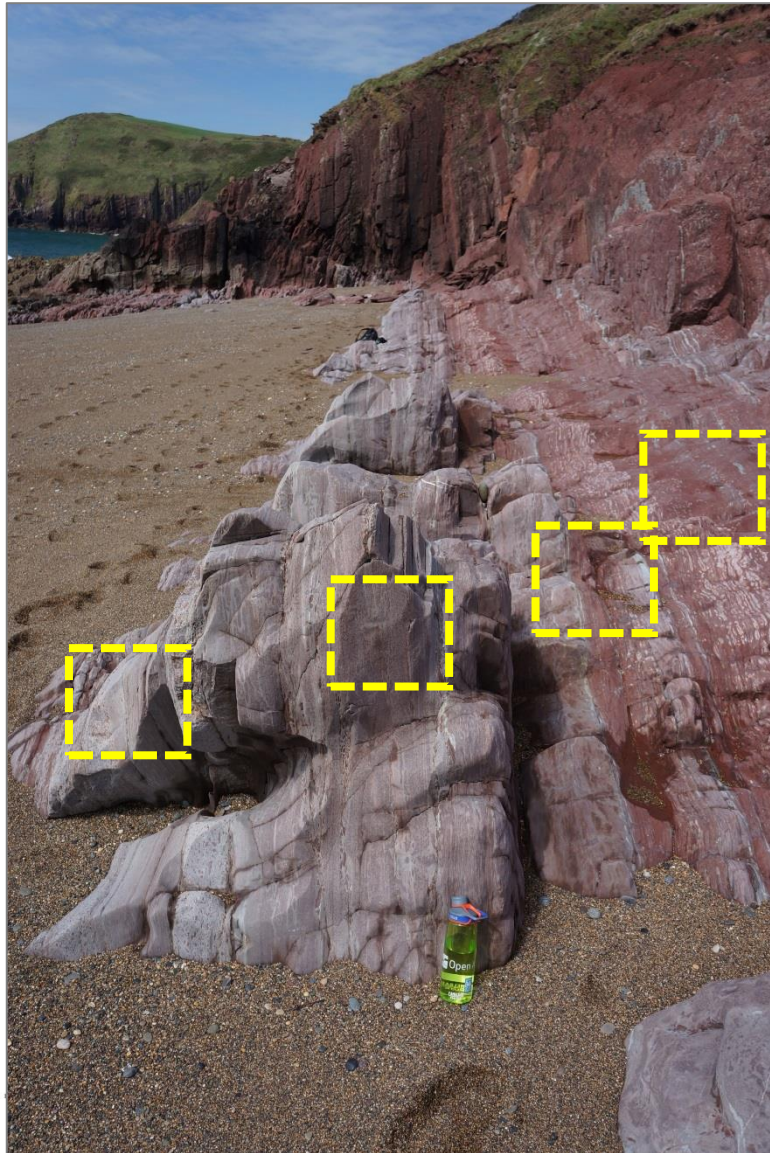




50m x 50m x 3m

25m x 25m x 1m

Understand one heterogeneous bed

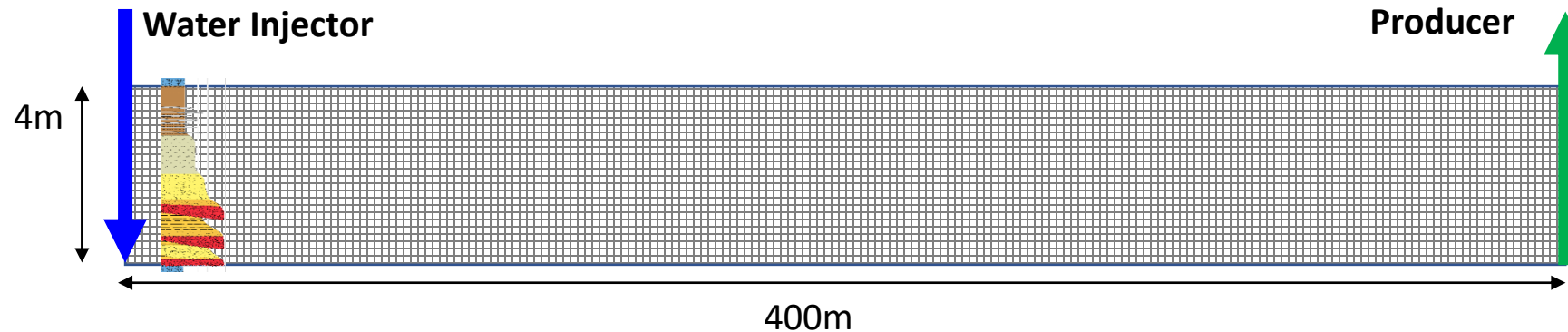
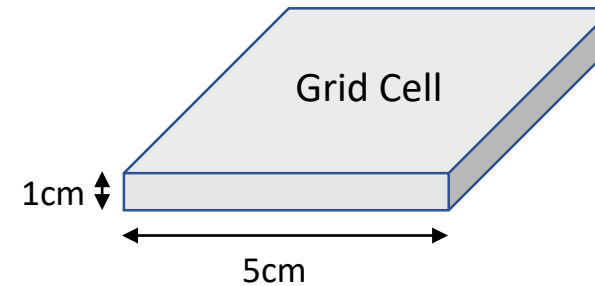
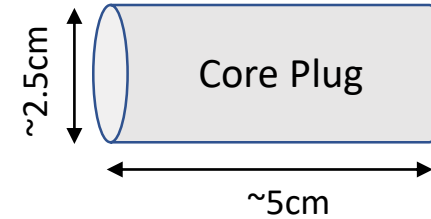


'Ultimate Truth' (... almost)

2D cross-sectional model

Typical offshore well spacing

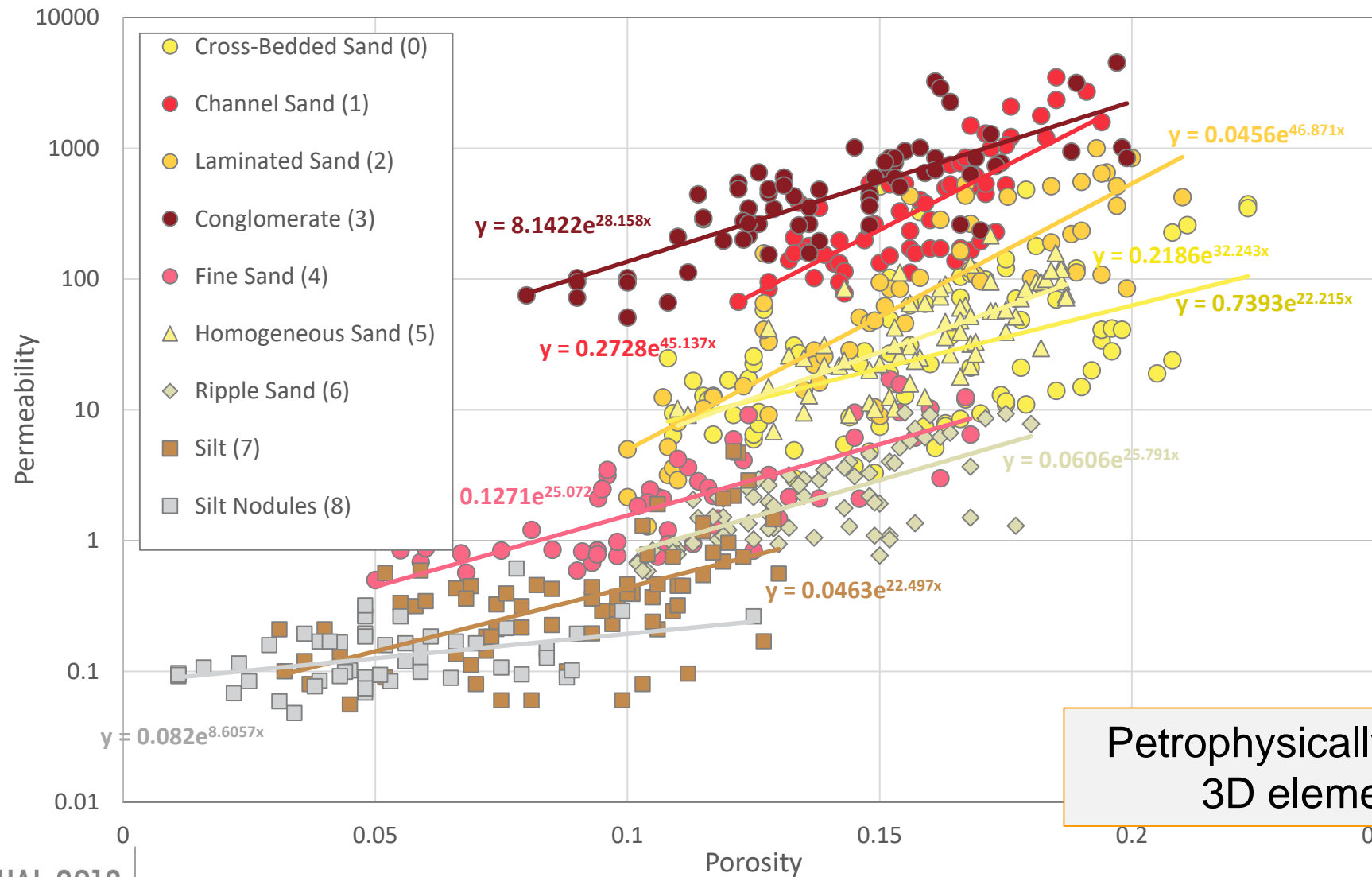
Cell resolution close to the scale of the input data (SCAL)



3.2 million static cells

320,000 dynamic cells

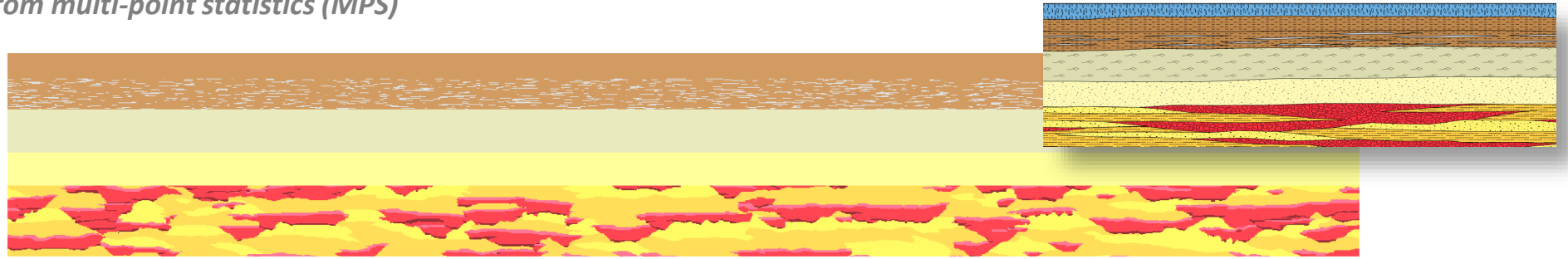
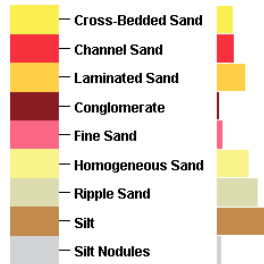
Model elements



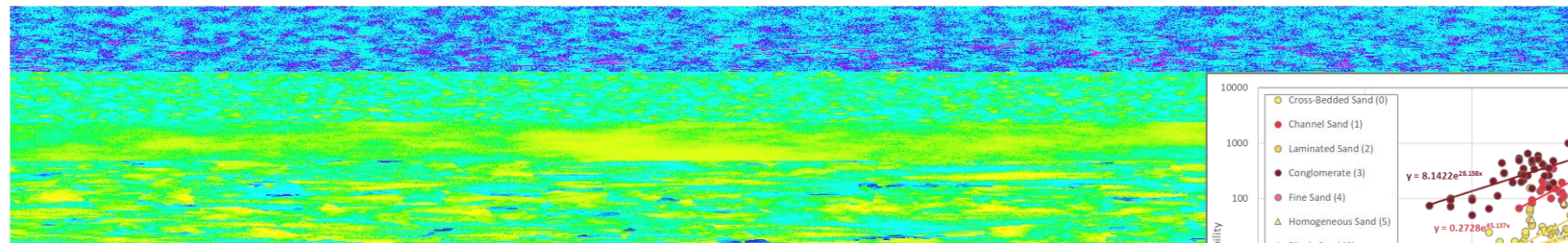
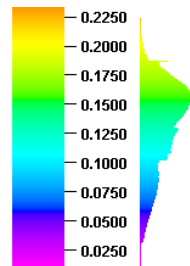
Petrophysically distinct
3D elements

Static model

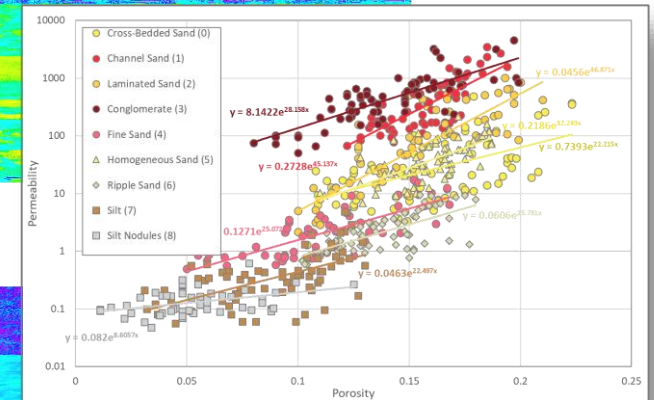
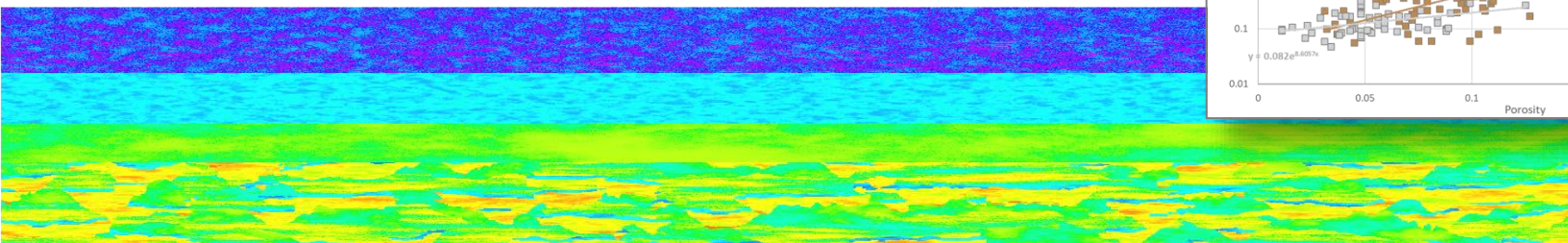
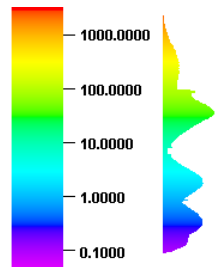
Model elements from multi-point statistics (MPS)



Porosity (frac)



Permeability (mD)

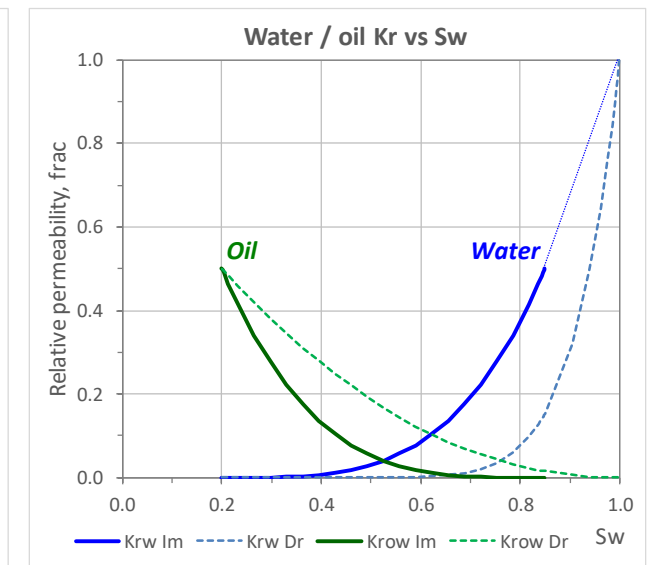
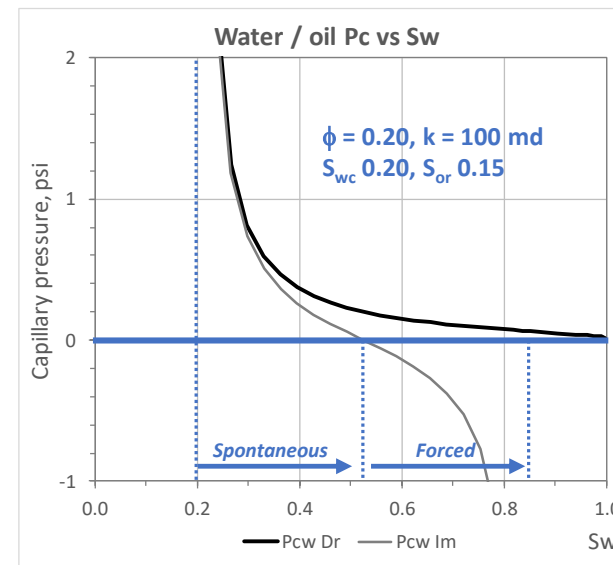


Dynamic model build

FLUID
Light oil (35 API), undersaturated



SATURATION
Mixed wet (I_w 0.5)



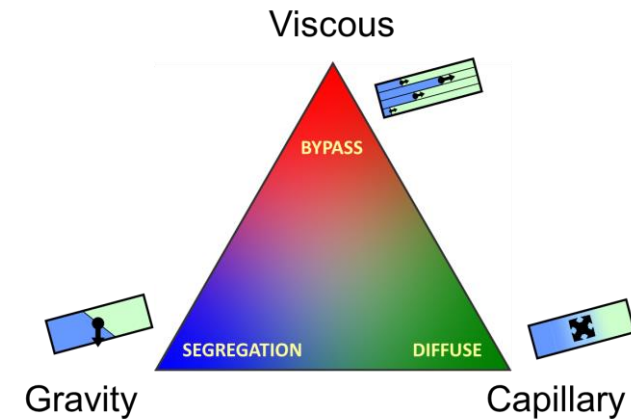
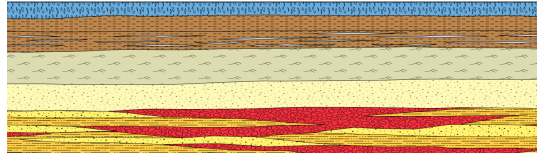
Model performance – how wrong can we be?

Impact of heterogeneity

Impact of viscosity

Need for 'full physics'

UNDERSTANDING
THE PRODUCING
SYSTEM



effective net

effects of imbibition

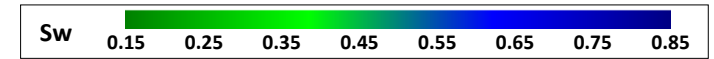
wettability

locating remaining oil

Viewing the floodfront

Water saturation (S_w)

T = 700 d



Saturation

Water relperm (K_{rw})

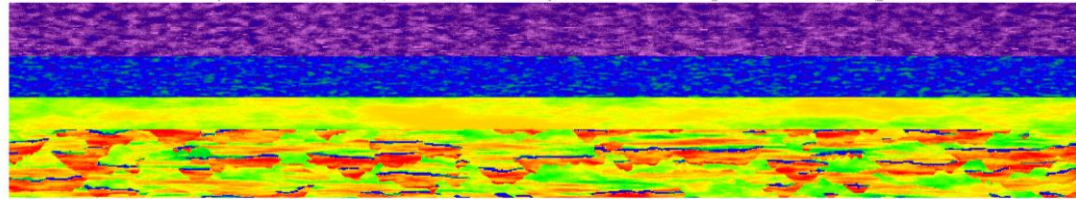
T = 700 d



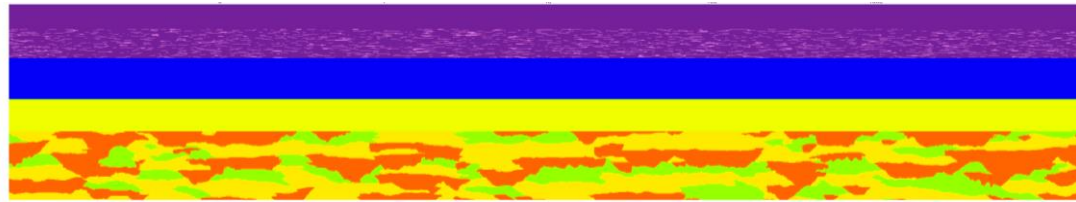
Relative permeability

Heterogeneity and sweep

'Truth'



Homogeneous bodies



4 layers



2 layers

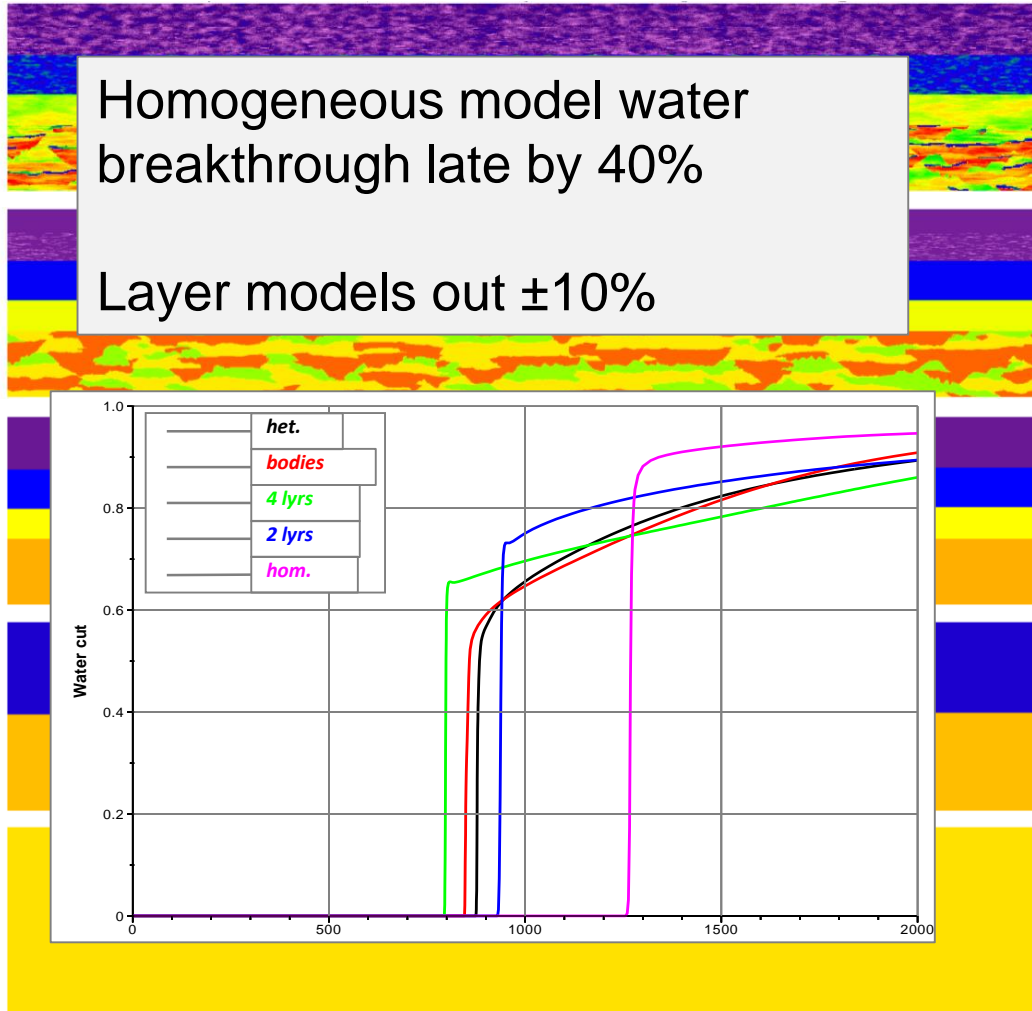


1 layer

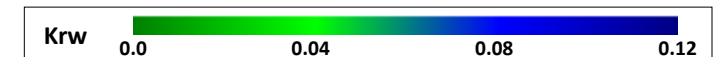
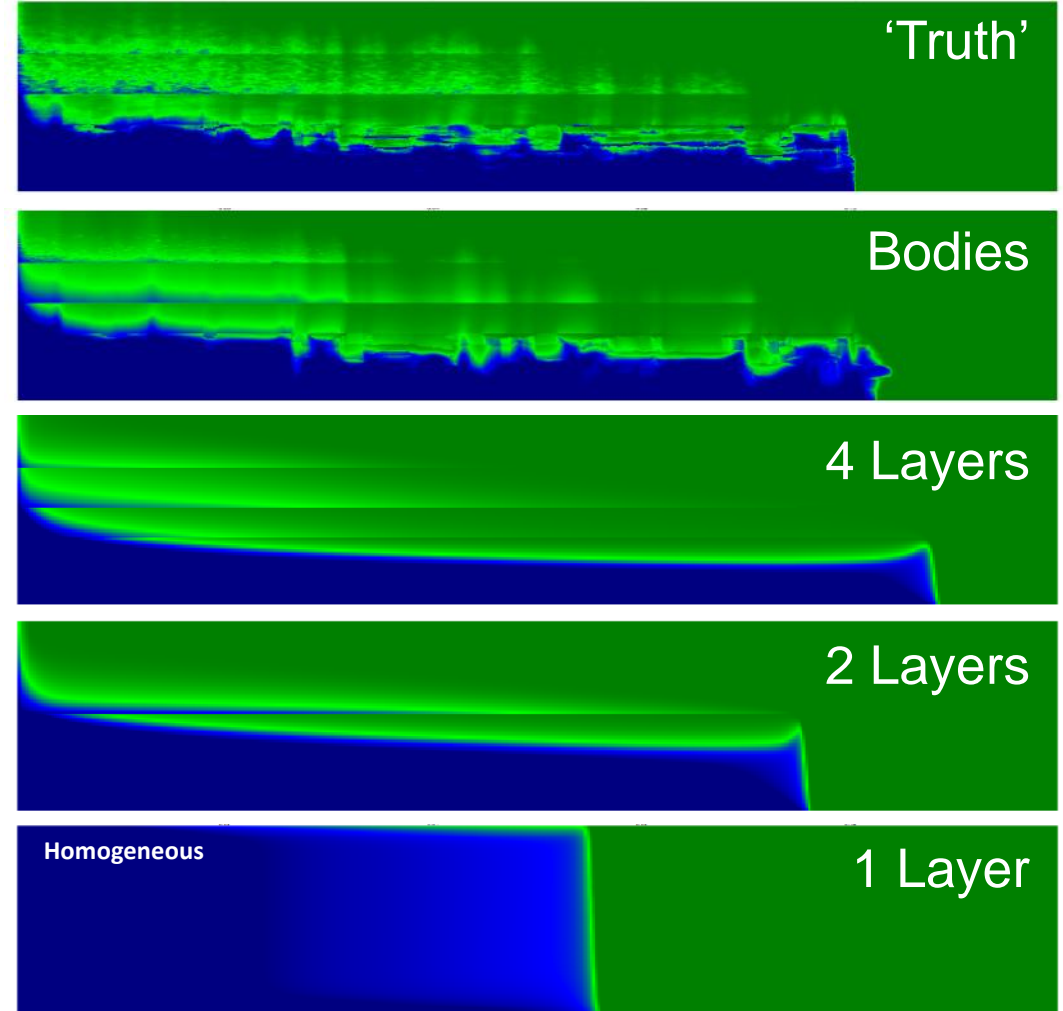


Heterogeneity and sweep

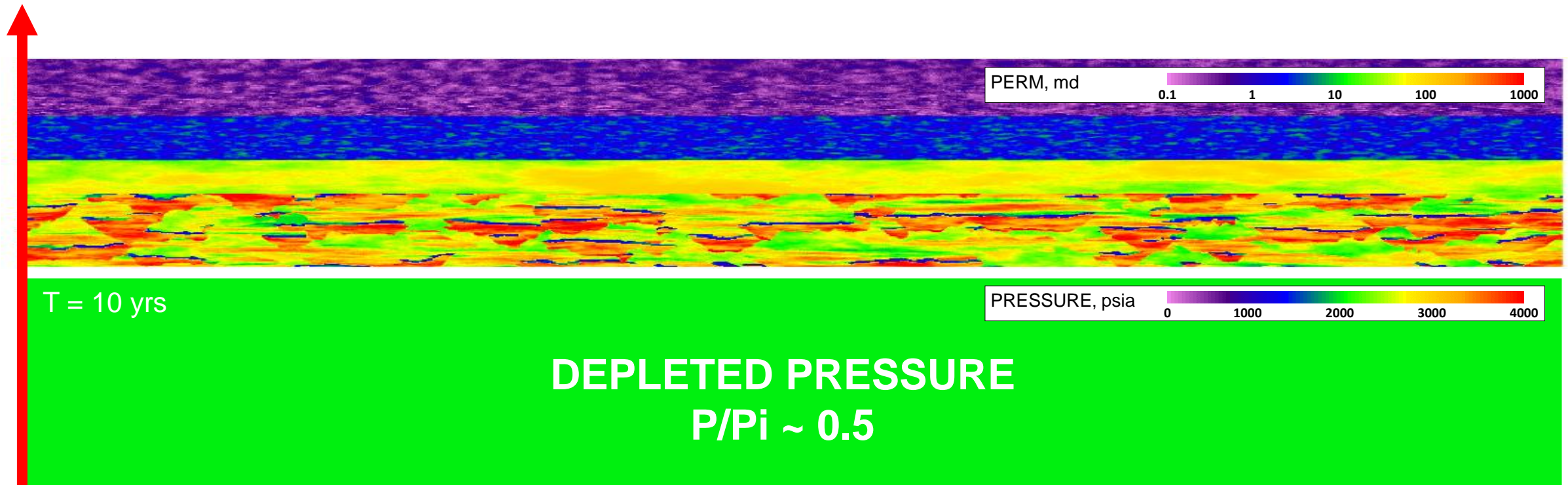
Permeability



Krw @ 700d



Impact of viscosity 1: gas

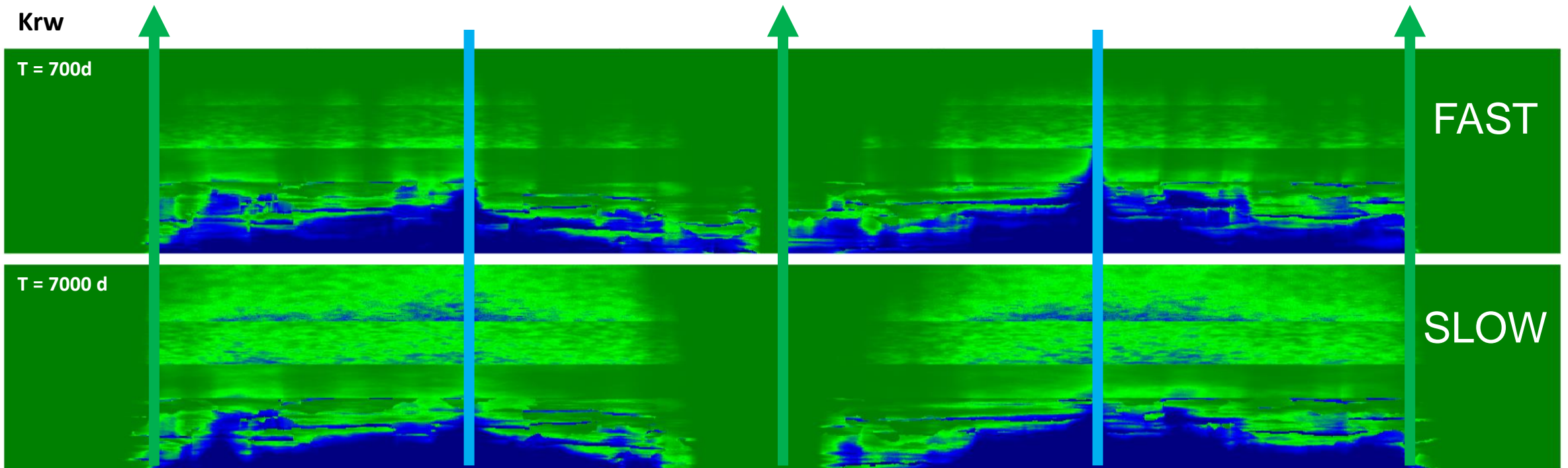


Gas doesn't 'see' the heterogeneity

Impact of viscosity 2: viscous oil

Viscous oil, 5 cp, unfavourable mobility ratio

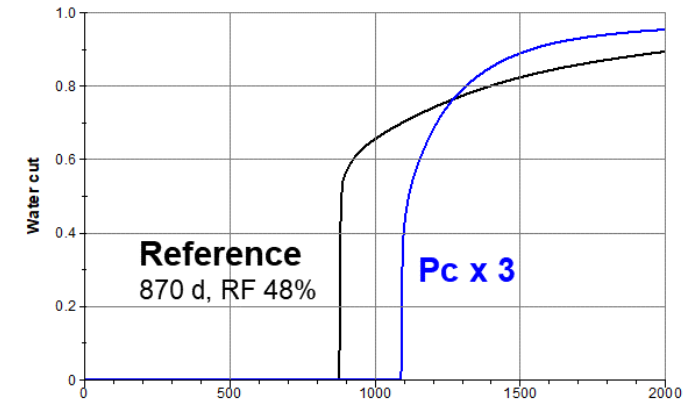
Contrasting fast vs. slow injection (15% vs. 1.5% PV/yr)



Understanding 1 - the impact of capillary forces

Increased P_c shows significant recovery from upper units

Delays WBT by ~ 25%, increased RF ~ 5%



Krw @ 700d

Reference case Htr ~ 10 ft @ 100 md

Pc x 3 case, Htr ~ 30 ft @ 100 md

'Truth' reference case

'Truth' with stronger Pc



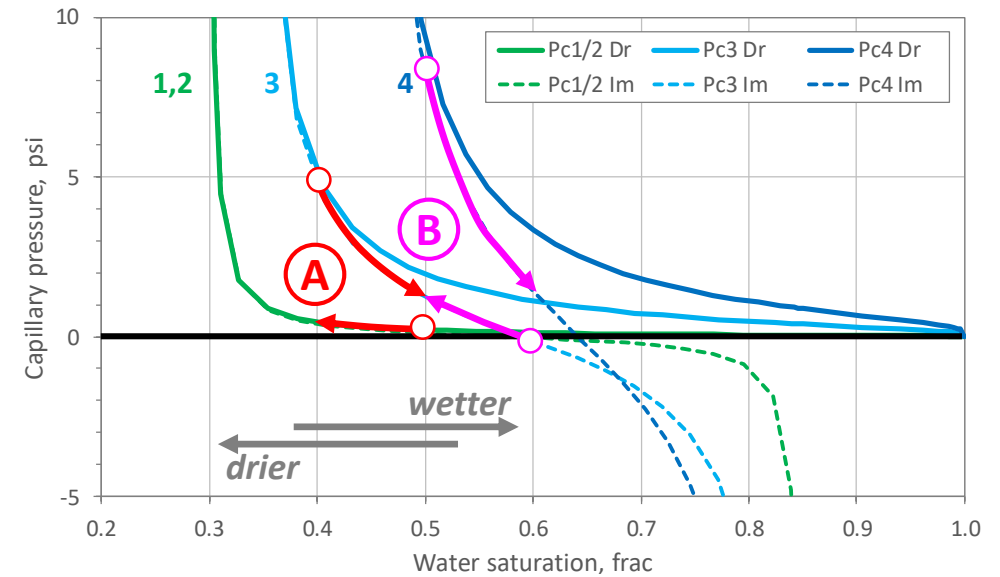
Understanding 1 – capillary imbibition ‘dry towel’ effects

(A) Potential gain ~ 3 psi from Sw exchange by ca. 0.1 from unit 2 to unit 3

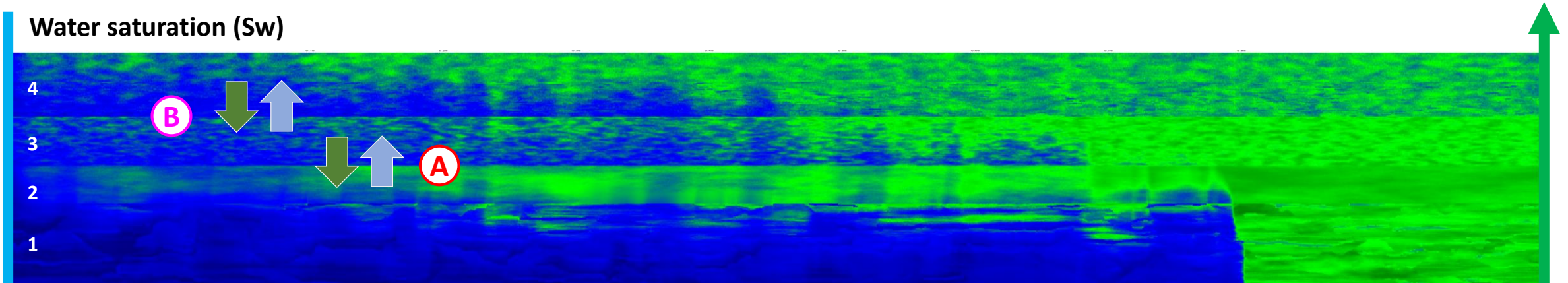
(B) Potential gain ~ 6 psi from Sw exchange by ca. 0.1 from unit 3 to unit 4

Water drawn up displaces oil down

Additional recovery from nominally ‘non-net’ material

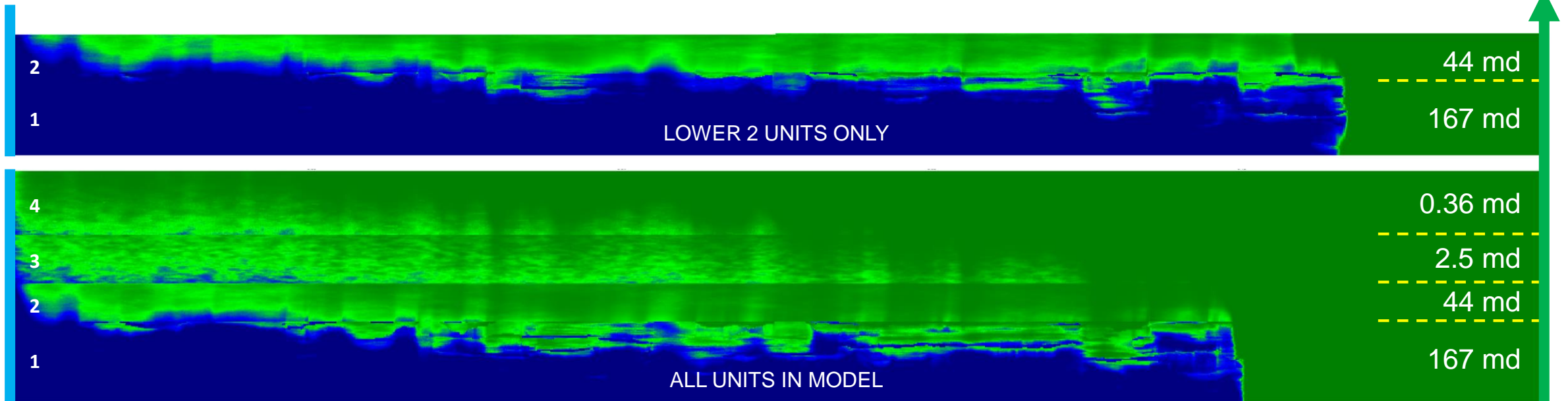
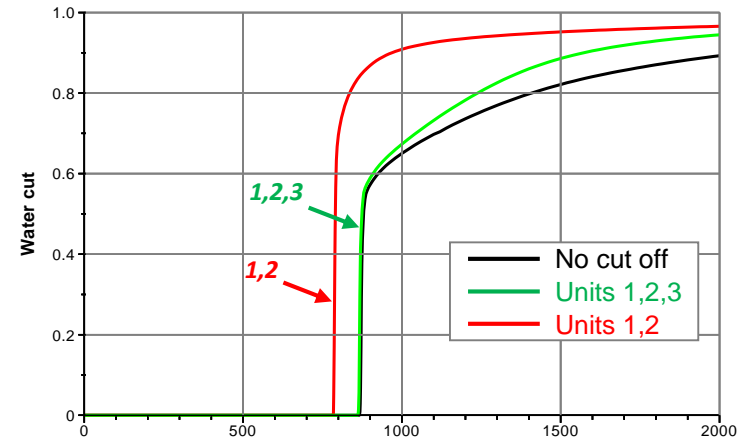


Water saturation (Sw)



Understanding 2 – flow-based determination of net

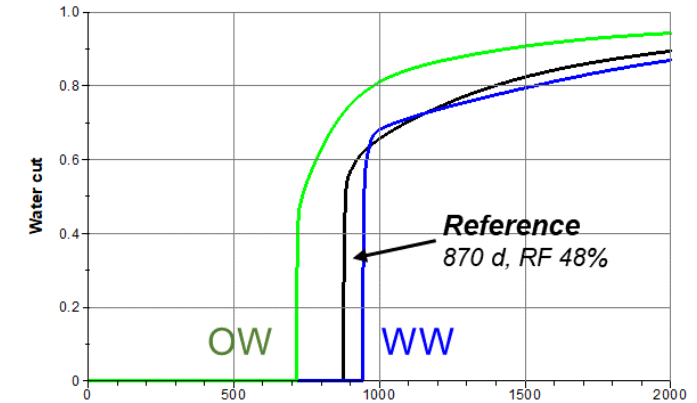
Water breakthrough time in Units 1 & 2 is 10% early if poorer units cut-off



Understanding 3: the impact of wettability

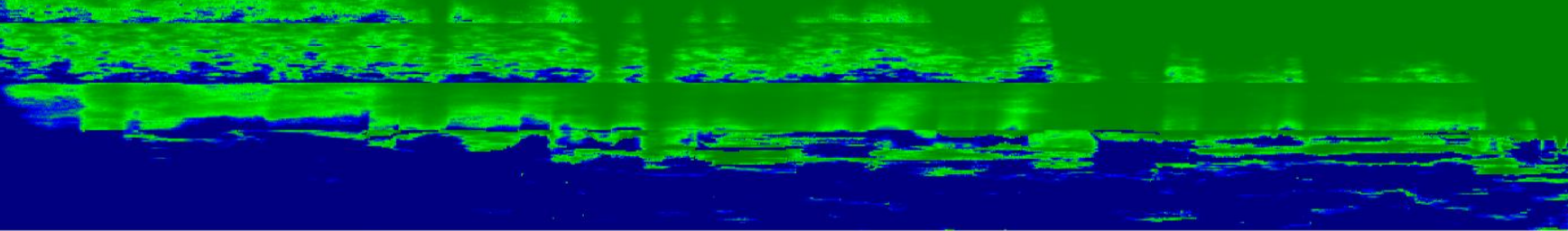
WW: WBT later by ~ 10%,
RF higher by ~ 3%
Stronger spontaneous imbibition
into upper units

OW: WBT earlier by ~ 20%,
RF lower by ~ 10%
Bypass of lower perm material
within lower unit



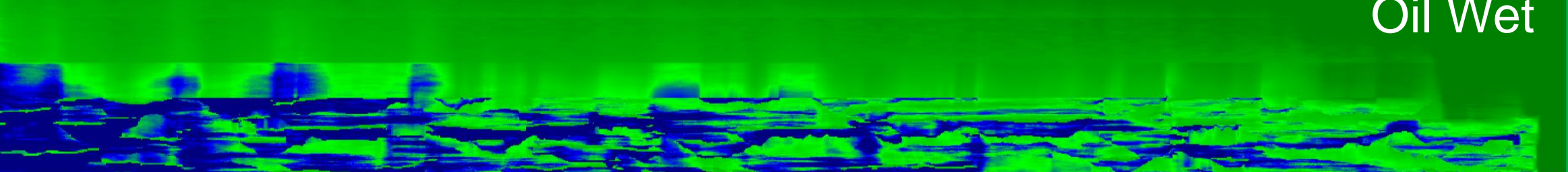
Krw @ 700d

Water wetting (Iw 0.8)



Water Wet

Oil wetting (Iw 0.2)



Oil Wet



Understanding 4 - Locating Remaining Oil

Saturation behind the flood front

Explore sim grid cell X=5 flowing ~90% water-cut

Residual oil saturation

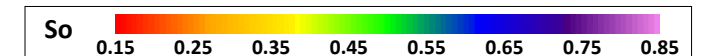
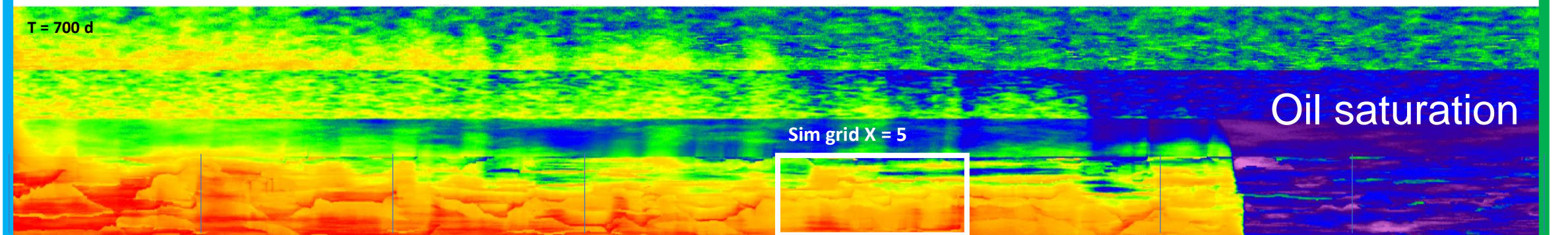
Same result in fine and sim grid models

...but fine model illustrates where the higher S_{or} is located

Model	Swi	W/cut	Krw	Kro	Soil
Ultra fine grid	30.7%	87%	0.1305	0.0188	34%
Sim grid X=5	30.6%	93%	0.0992	0.0076	34%

Oil saturation (S_o)

T = 700 d



Upscaling to normal life

Ultra Fine 0.25 x 0.02 m
320,000 cells

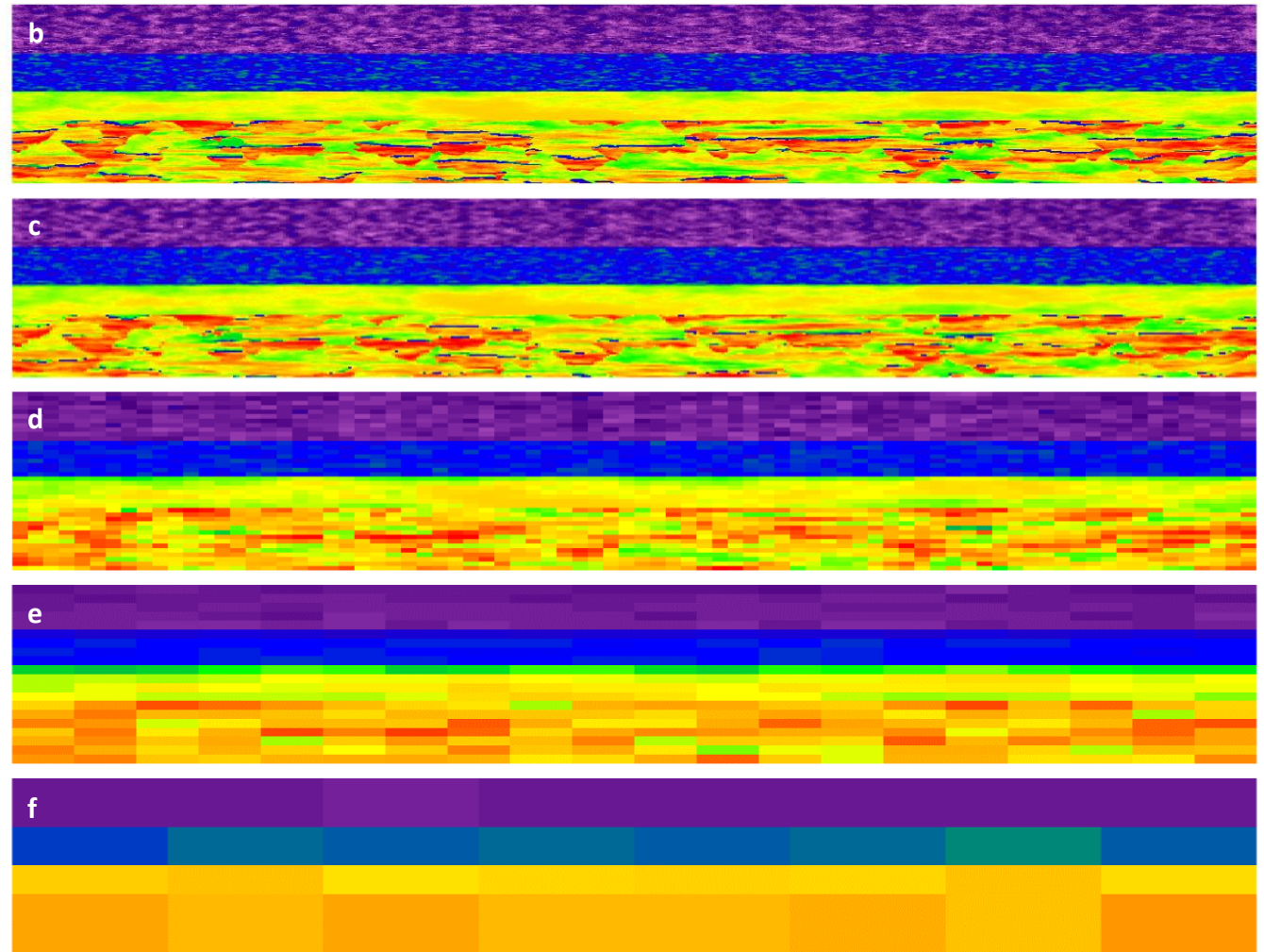
Fine 1 x 0.04 m
40,000 cells

'Logging scale' 5 x 0.1 m
3,200 cells

'High res' simulation 20 x 0.2 m
400 cells

'Normal simulation' 50 x 1 m
32 cells

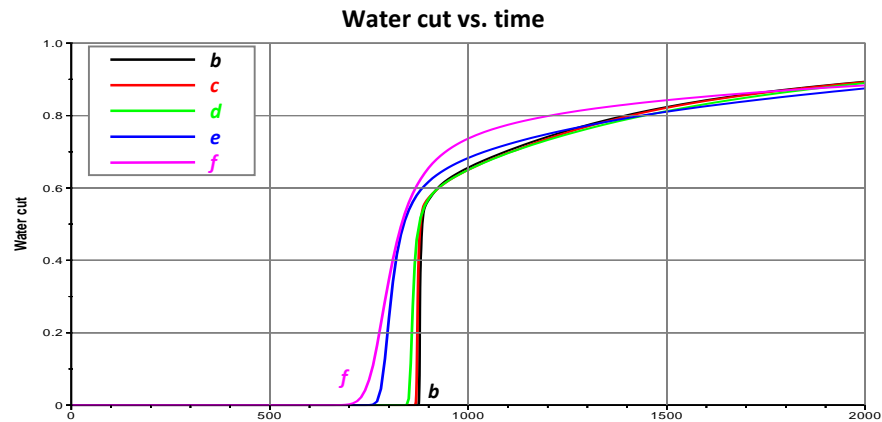
Permeability



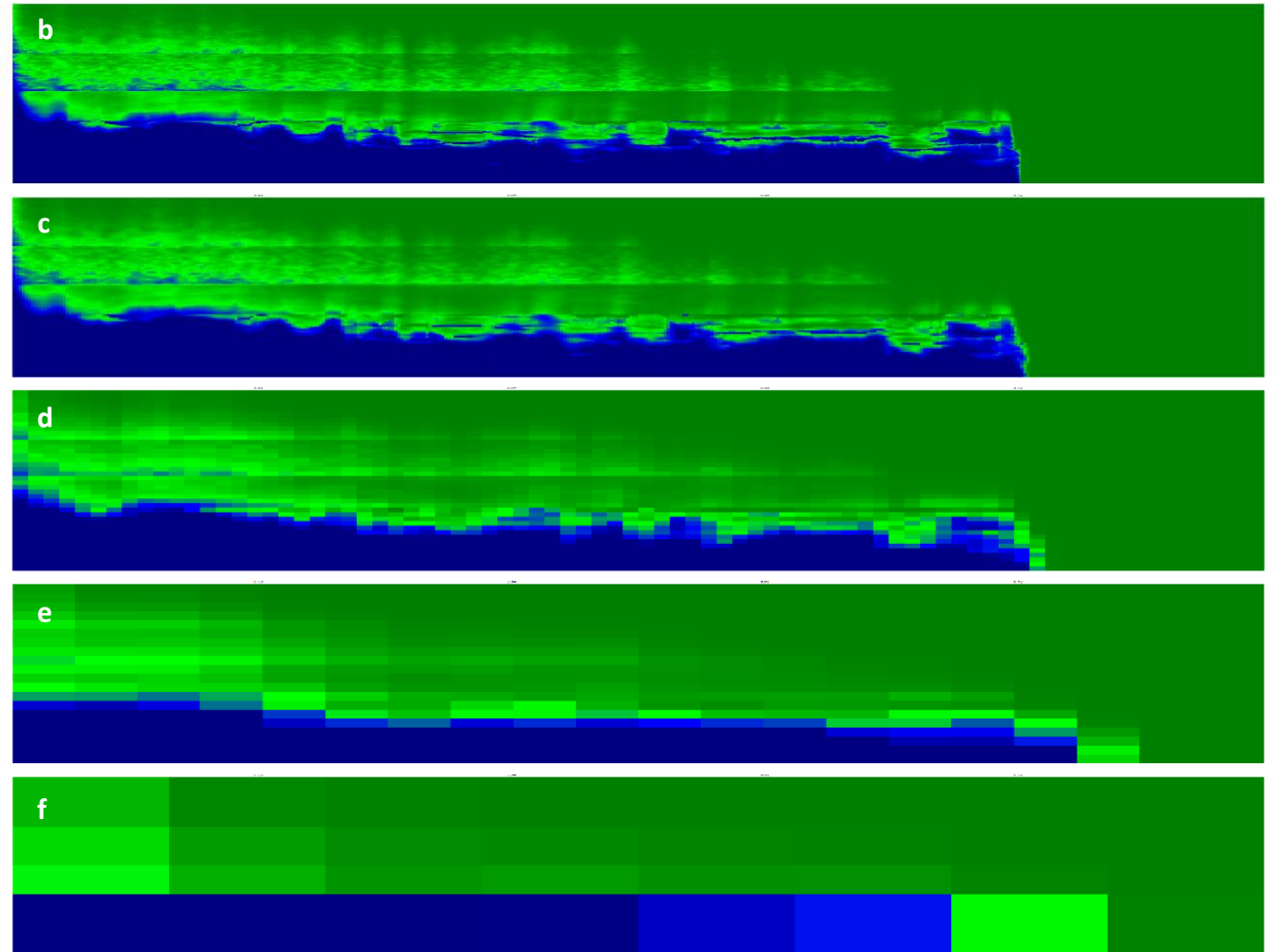
Upscaling to normal life

Ultimate recovery similar
(within 3%)

But breakthrough times
progressively error-prone
(up to 20%)



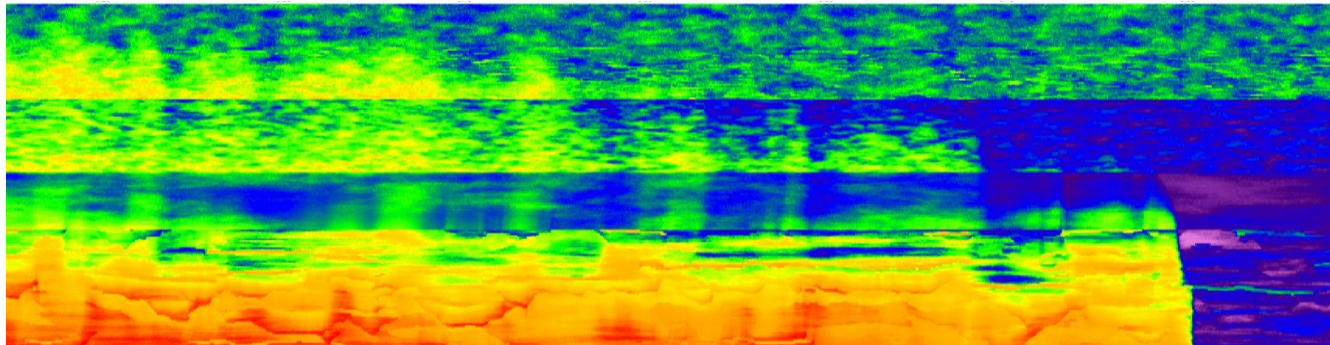
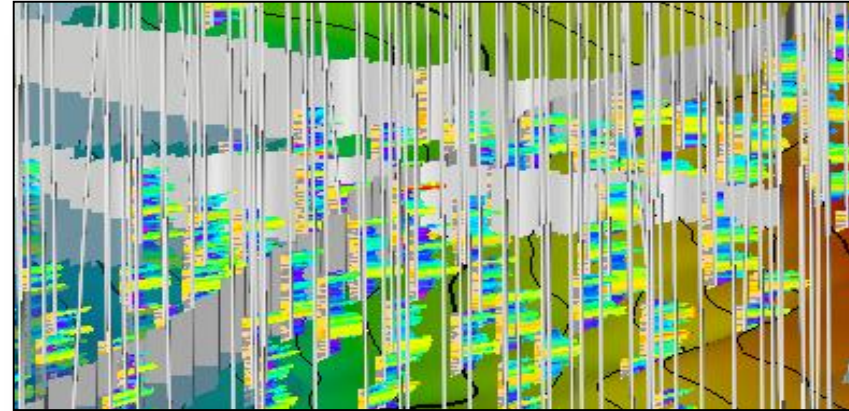
Krw @ 700d



The role of 'Ultimate Truth' models

Truth models repeatedly show that removing detail is a *systematic bias*

Big, 'complex' full-field models tend to over-optimism



We understand more through deconstruction

... and can then make appropriate workflow adjustments at larger scales



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