WATER SATURATION PREDICTION IN 3D MODELS: PARADIGM CHANGE FROM FREE WATER LEVELS TO INTERFACIAL NORMALIZED FREE WATER LEVELS

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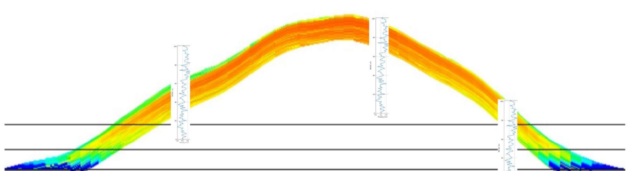
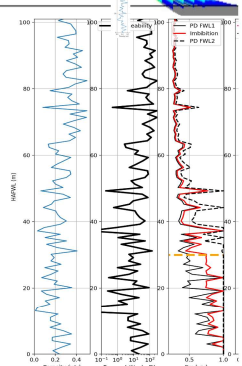
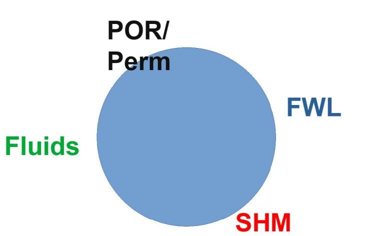
From Sw to SHM via Pc_IFT1





Inputs for Sw prediction



$$Pc = 2\,\sigma\,\cos(\theta_{fl})/r\_p$$

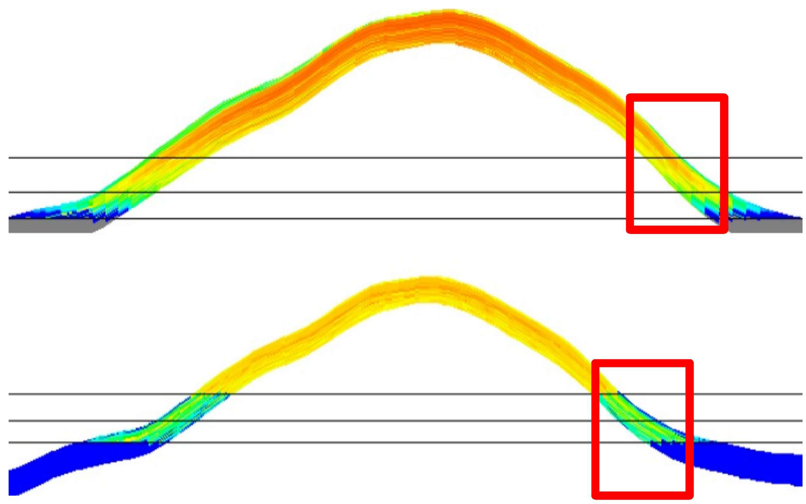
$$Pc\_IFT1 = Pc/\sigma\,\cos(\theta_{fl}) = 2/r\_p$$

$$Sw = Swi + (1 - Swi)\left({PCe\_IFT1}/{PC\_IFT1}\right)^{1/Npc}$$

WHY?

We need to get the Sw away from the wells!

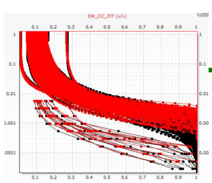
From Sw to SHM via Pc_IFT1



Building flPc_IFT1 models has tremendous advantages, prevents unnecessary errors!

SHM build via Pc_IFT1 (core)

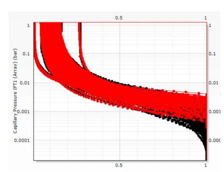
PC_LAB



$$\times \frac{1}{ift_{lab} \times \cos(\theta_{lab})}$$

$$\times \frac{ift_{res} \times \cos(\theta_{res})}{ift_{lab} \times \cos(\theta_{lab})}$$

PC_IFT1



=PC @ IFT=1

$$\times ift_{res} \times \cos(\theta_{res})$$

PC_RES

$$\times \frac{1}{g \times (\rho_{water} - \rho_{hydr})}$$

$HAFWL$

Advantage: IFT normalization makes CF/PP and MICP compatible!

https://onepetro.org/SPEADIP/proceedings-abstract/18ADIP/2-18ADIP/213041

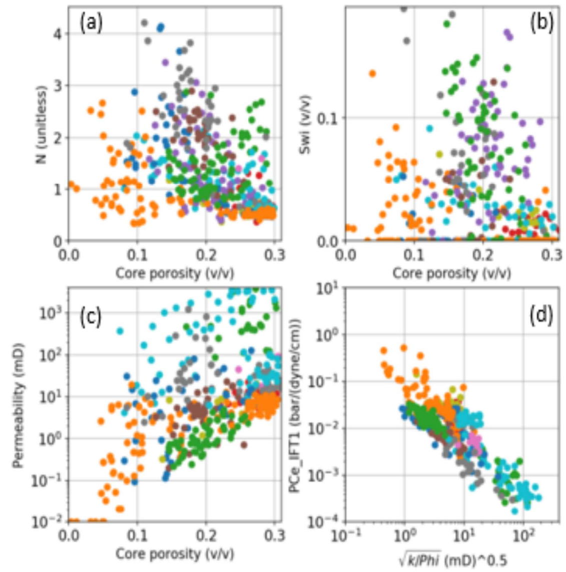
SHM build via Pc_IFT1 (core)

$$Sw = Swi + (1 - Swi)\left(\frac{PCe\_IFT1}{PC\_IFT1}\right)^{1/Npc}$$

Reality of building a log based SHM?

Long list of problems … INCLUDING an additional parameter: FWL!

Reality of building a core SHM!



https://onepetro.org/SPEADIP/proceedings-abstract/18ADIP/2-18ADIP/213041
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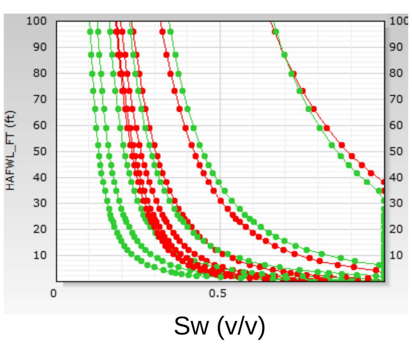
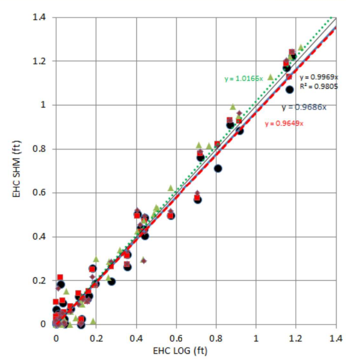
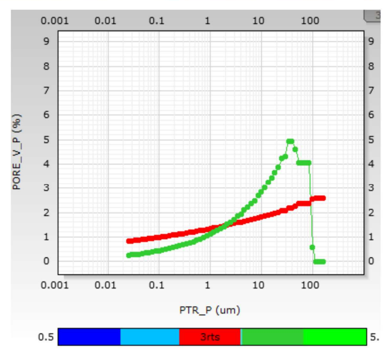
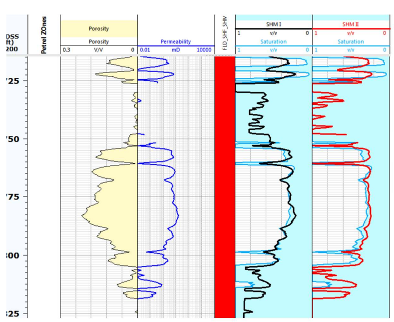
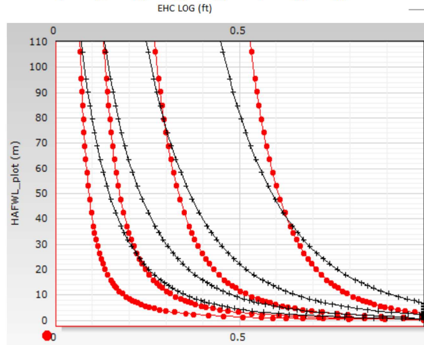
SHM build in the log domain

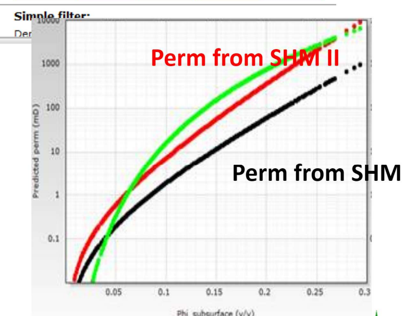




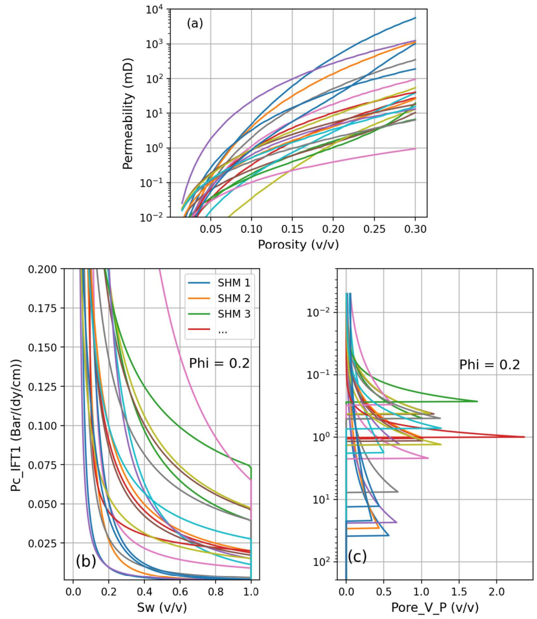


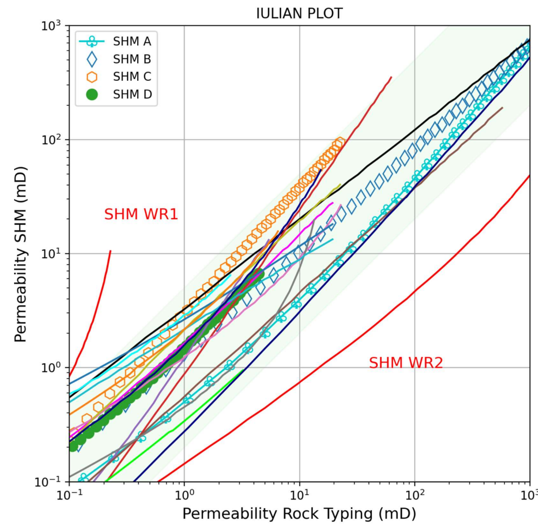






Iulian plot: not all SHM represent reality





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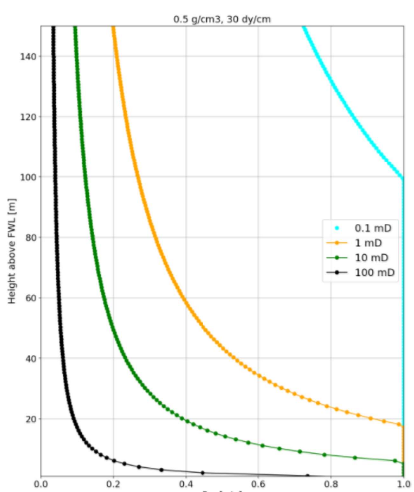
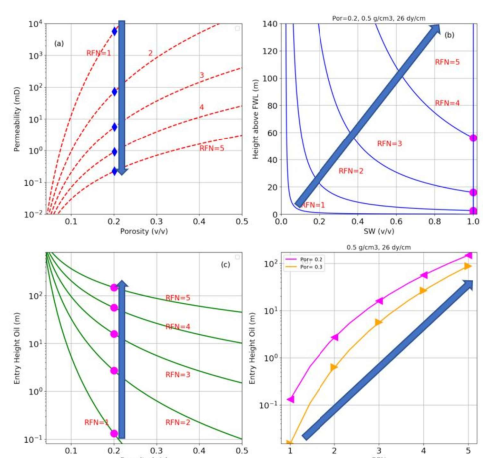
Contacts vs FWLs





Not really the same!

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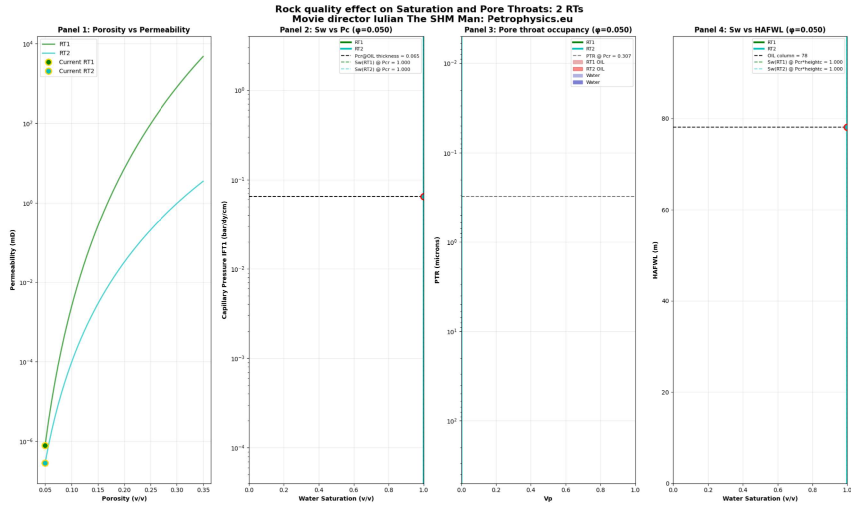
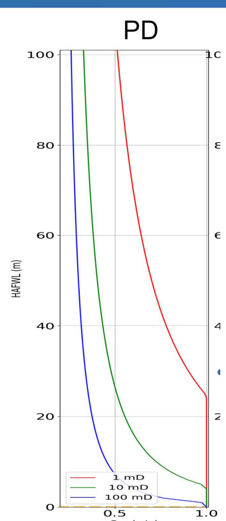
Pore filling and rock quality (via Pc_IFT1)

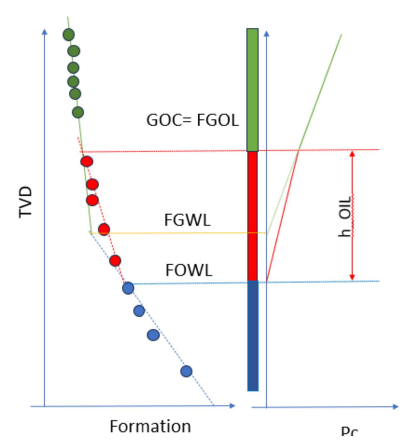


Permeability is the dominant force that governs the entry height!

Introduction: FWL vs contacts



FWL

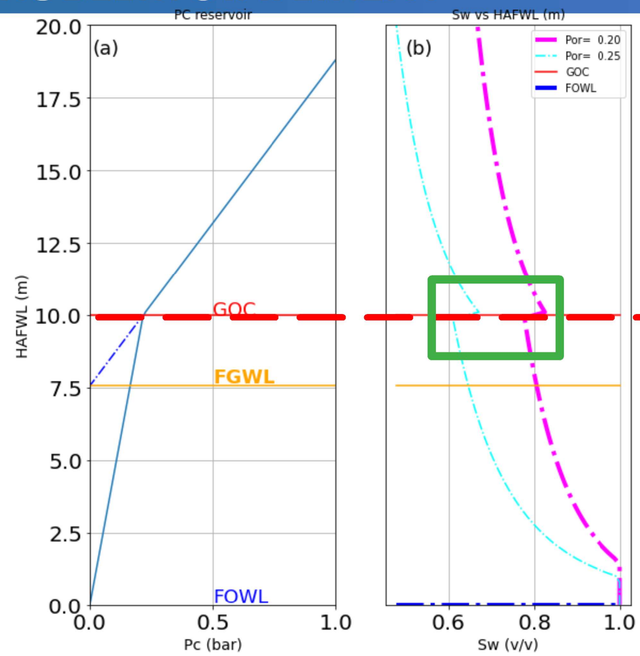


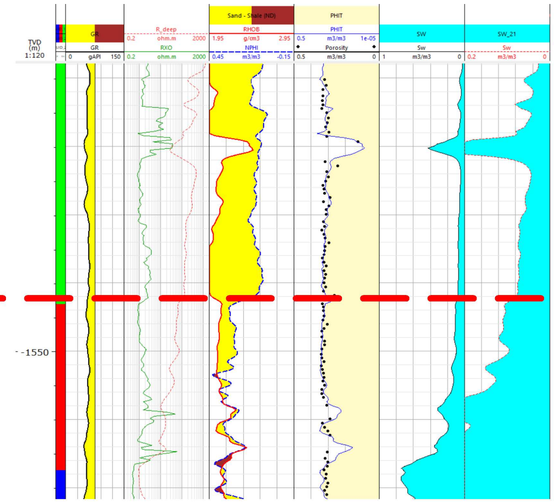
FGWL=FOWL + h_OIL (1-(grado/ gradg))

- A fundamental difference between primary drainage and imbibition is the rock quality influence-on them. PD -clear, IMB- adds ambiguity

https://doi.org/10.30632/SPWLA-2026-0082

PROBLEM STATEMENT

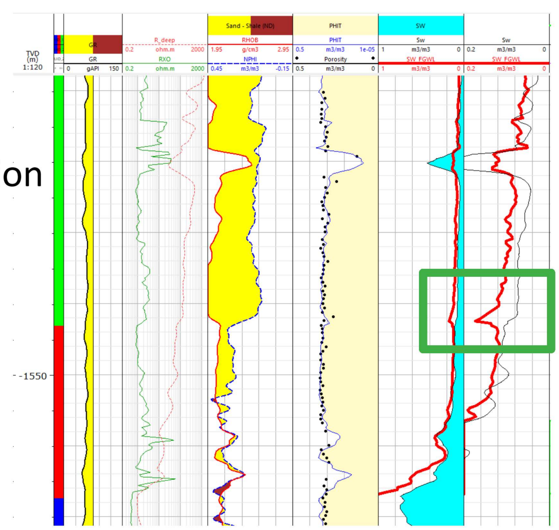




- Cannot be validated from logs!!!

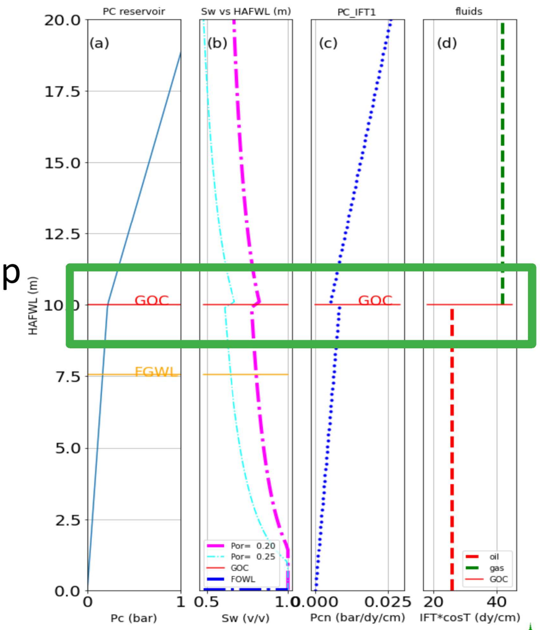
PROBLEM STATEMENT

- The effect is visible in the log domain, a divergence between log and SHM prediction impossible to miss!

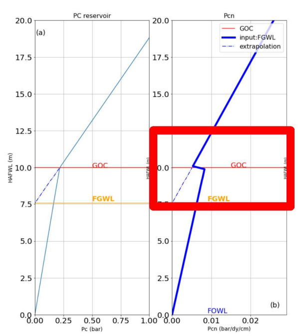


Where might the peculiarity come from?

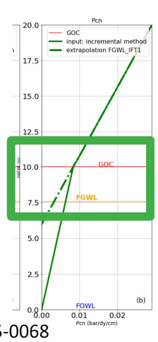
- At the GOC the interfacial tension has a step change
- Leads to a sudden decrease in Pcn @ GOC



VALIDATE NORMALIZED PRESSURE (IFT1)



- How can we validate the Pcn behavior?



- An alternative is to build the Pcn step by step:

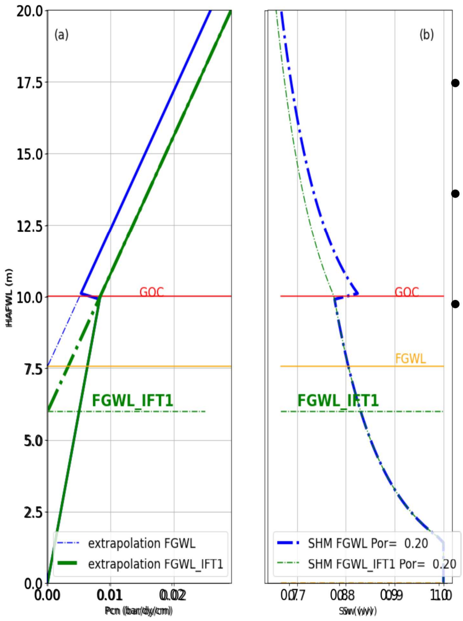
$$Pcn = Pcn\_oil + Pcn\_g \text{ with :}$$

$$Pcn\_oil = grado/(\sigma_{oil} \cos(\theta_o))*(hafwl-FOWL)$$

$$Pcn\_g = gradg/(\sigma_g \cos(\theta_g))*(hafwl-GOC)$$

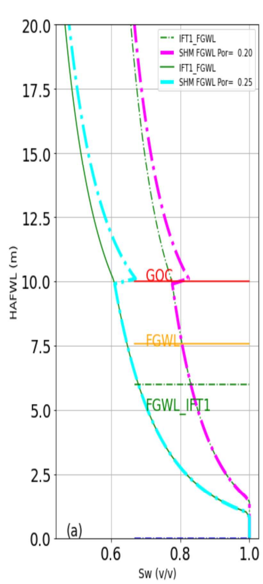
$$***grad\_hc = (\rho_{water}-\rho_{hc})g$$

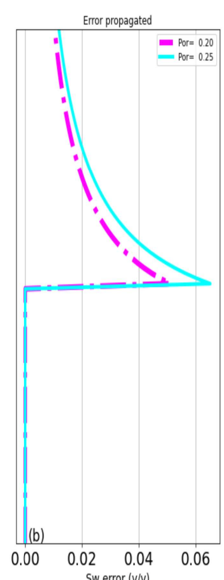
FGWL vs IFT1 normalized FGWL → FGWL_IFT1



- No reason to accept Pc_IFT1 should have a minimum @GOC
- The error comes from normalizing oil rim Pc indirectly assuming it behaves like gas
- Sw prediction can be resolved by introducing FGWL_IFT1 resulting from the proper calculation of gas gradient.

FGWL_IFT1, FGWL … why should I care?



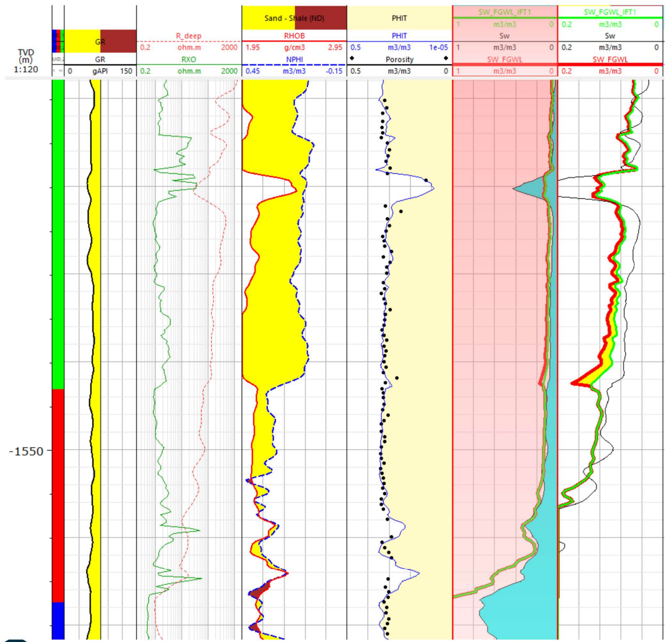


- What kind of errors can be made by using FGWL?
- Remarkable about the IFT1 FGWL is that is deeper, obtained by extrapolating the gas gradient at the top of the oil rim

FGWL = FOWL + h_OIL (1 - (grado/ gradg))

FGWL_IFT1 = FOWL + h_OIL(1 – (grado/ gradg)* $\sigma g \cos(\theta_g) / \sigma_o \cos(\theta_o)$)

SW DIFFERENCE BETWEEN THE 2 FGWL USED



- SHM using FGWL
- SHM using FGWL_IFT1

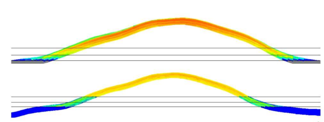
The correction results in HC saturation increase

Conclusions

- Conventional FGWLs are not the best choice for an oil rim Sw modelling.
- A Sw increase at the GOC is an artifact resulting from an inconsistency between using FWLs and PC_IFT1 input required by the SHM.
- Instead of FGWL **a FGWL_IFT1** property must be used
- The **FGWL_IFT1** is deeper than FGWL and it is expected to increase gas volumes.
- This correction brings consistency between the IFT1 SHM and the FGWL.

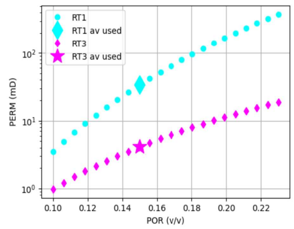
FGWL = FOWL + h_OIL (1 - (grado/ gradg))

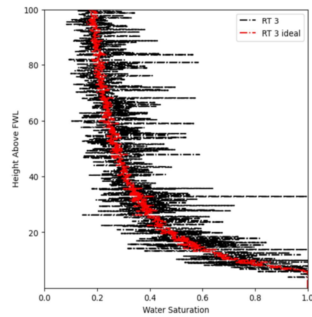
FGWL_IFT1 = FOWL + h_OIL(1 – (grado/ gradg)* $\sigma g \cos(\theta_g) / \sigma_o \cos(\theta_o)$)

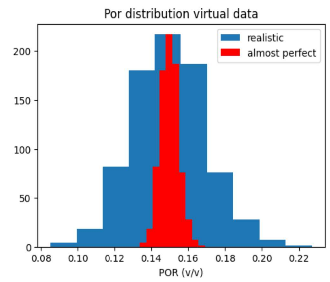


One last warning: extracting FWL by using a SHM

🔍 Determining FWL: example using synthetic data
Testing the workflow , in a unique position!







Which RT has the lower error?