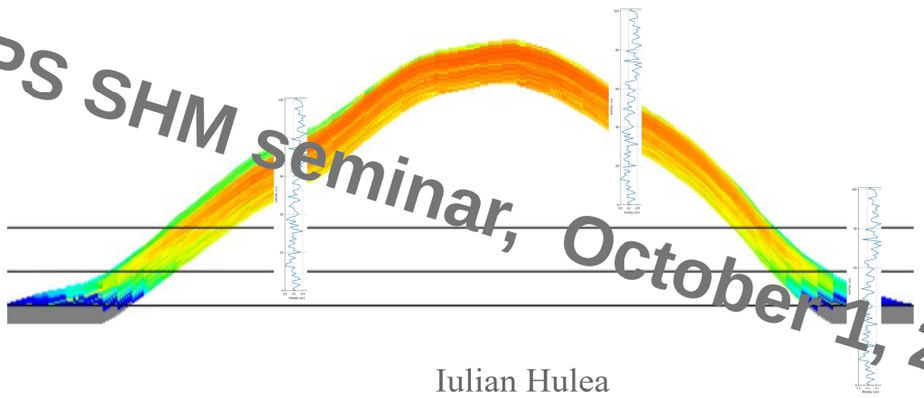
QUICK SHM INTRO



LPS SHM seminar, October 1, 2026

Iulian Hulea

Global Petrophysics Advisors BV

Petrophysics.eu

"the SHM man" : SHM is really easy, really easy to get wrong!

Definition: what are we talking about

A saturation height model (SHM) is a mathematical equation used in petroleum engineering to calculate fluid saturation (like water or oil) at any point in a reservoir based on its height above the free water level, rock and fluid properties.

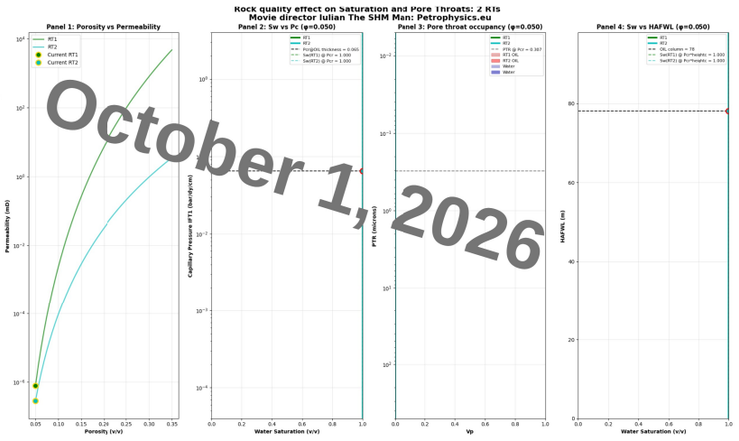
LPS SHM seminar, October 1, 2026

Core Concepts and key inputs:

Free Water Level (FWL), fluids, rock properties
Methods:
- Capillary Pressure
- Logs

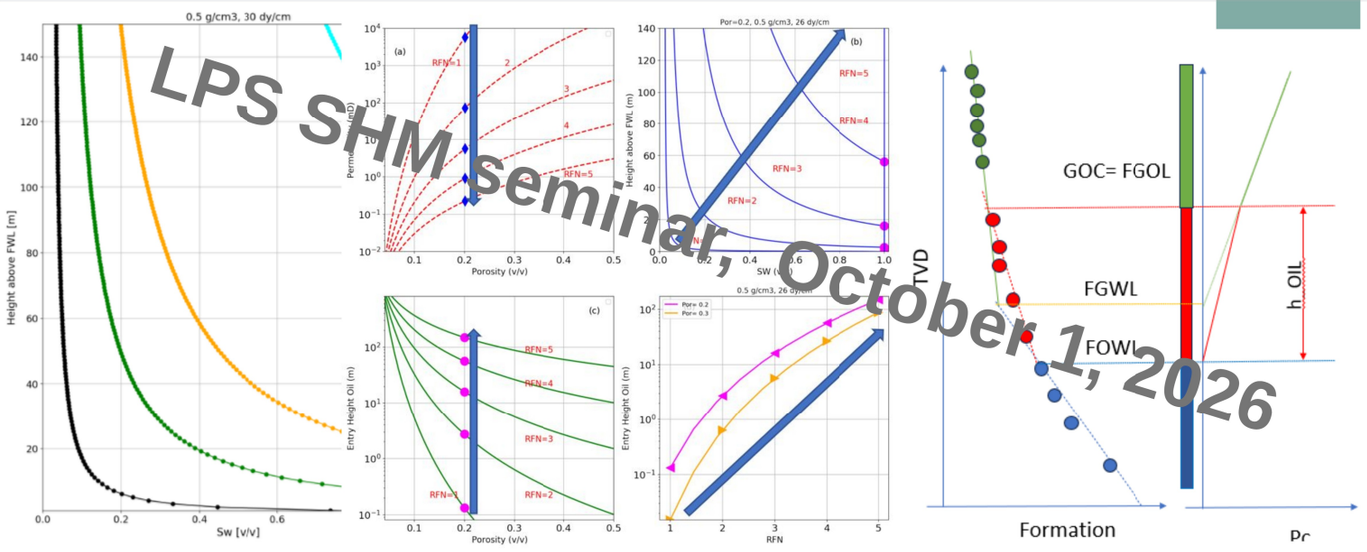
Functions/ mathematical expressions

Why do we use SHMs? How?



Core inputs: FWL (and NOT “contacts”)

LPS SHM seminar, October 1, 2026



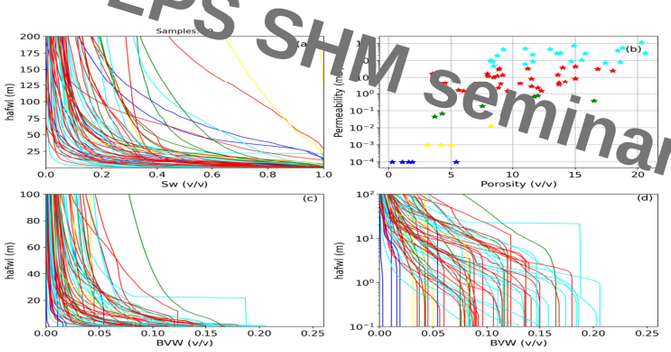
Hulea IN, SPWLA-2025-0068 (2025).

Hulea IN, SPE-193164 (2018).

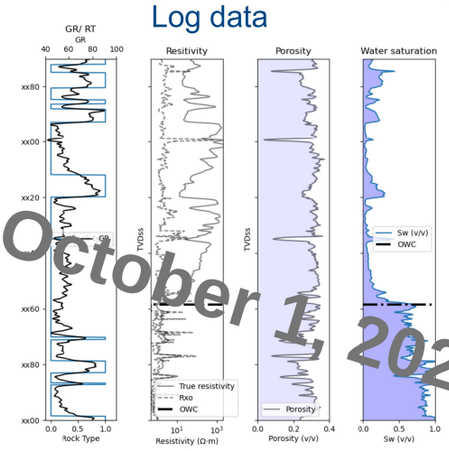
Methods: data used

LPS SHM seminar, October 1, 2026

Capillary pressures



Log data



Each data type comes with its own limitations as far as SHM is concerned.
Fluids, stress, Pc=0 point can be a challenge

Methods: Pc_IFT1, Pc, height...



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

$$Pc_IFT1 = Pc/\sigma\cos(\theta_{fl}) = 2/r_p$$

$$Sw = Swi + (1 - Swi)\left(PCe_IFT1 / PC_IFT1\right)^{1/Npc}$$

There's more: what inputs (when perm, what kind of perm?), corrections (like stress) ?

Hulea et al. Petrophysics 59, 397 (2018). Hulea et al. https://doi.org/10.30632/PJV59N3-2018a7

LPS SHM seminar, October 1, 2026

Methods: Functions

Sw=f(Pc) Functions:

Lambda

$$S_w = aPC^{-\lambda} + b$$

Brooks-Corey

$$S_w = S_{wi} + (1 - S_{wi})(PC_e/PC)^{\frac{1}{n}}$$

Thomeer

$$S_w = S_{wi} + (1 - S_{wi})\left(1 - e^{(G/\ln(PC_e/PC))}\right)$$

J, etc

There's more: what inputs, corrections, stress ?

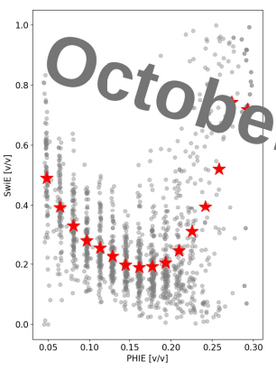
LPS SHM seminar, October 1, 2026

London Petrophysical Society - "Saturation Height Modelling Investigated" - Thursday 1st October 2026

Start Time	End Time	Name	Company	Talk Title
09:00	09:25	Doors Open and Registration		
09:25	09:35	Martin Leonard	LPS	LPS Seminars - Introduction
09:35	10:10	Iulian Hulea	Global Petrophysics Advisors BV	Quick Introduction to Saturation Height Modelling / Unifying Primary Drainage and Imbibition Saturation Height Modeling: Closing a Gap in Water Saturation Prediction
10:10	10:40	Paul Spooner	Geoactive	Evaluating the uncertainty in a Saturation Height model
10:40	11:10	Bob Harrison	Sustainable Ideas Ltd	Influence of Selected Saturation Model on Volumetric Hydrocarbon-in-place Estimate
11:10	11:30	Break		
11:30	12:00	Steve Cuddy	Independent	Saturation Height Modelling using a Bulk Volume of Water Function
12:0	12:30	Chris Skelt	Independent	Relations between saturation, height, porosity and permeability
12:30	13:00	[illegible]	Interactive Petrophysical Solutions	Saturation Permeability Revisited – 40 Years On
13:00	14:00	Lunch		
14:00	14:30	Richard Harris	Sasol	J-Functions and More: A Guided Tour of Leverett's Elegantly Written 1940 Paper, with an Example Application of J-Functions to a Real Reservoir
14:30	15:00	Colin McPhee	Independent	Mercury Injection Capillary Pressure Tests: Size (and Shape) Matters!
15:00	15:30	Mike Millar	Independent	Saturation-Height Functions from Log Data
15:30	15:50	Break		
15:50	16:20	Olivier Marché	SLB	Integrating Capillary Pressure and Relative Permeability for Consistent Reservoir Saturation - From Petrophysical Interpretation and Core Measurements to a Volumetrically Reconciled Static and Dynamic Model
16:20	16:50	Adam Moss	Islay Subsurface & Engineering	Twin Samples as QC Tool in Capillary Pressure Measurements and Modelling: From MCIP to Centrifuge on the Road to an Integrated Saturation Height Model
16:50	17:20	Craig Lindsay	Core Specialist Services	Saturation Modelling – Keep it Simple
17:20	17:25	Philip Gibbons	LPS	LPS President - Closing Remarks
17:25		Networking Reception in the Library		

How do we check our SHMs?

1 BENCHMARKS/Analogues
2 ENTRY WEIGHT CHECK
3 PORE THROAT DATA/ANALOGUE COMPARISON
4. Iulian plot
5. Effective Hydrocarbon column calculation
6. Sw log-model distribution
7. SWI vs porosity/permeability at a given Pc
….
…

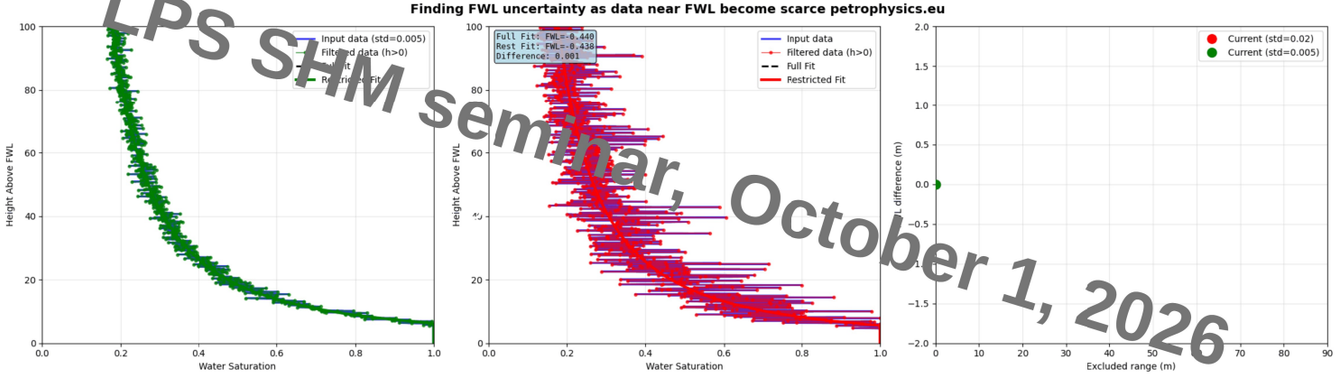




LPS SHM seminar, October 1, 2026

Hulea et al., Petrophysics 57, SPWLA-2016-v57n3a1

SHMs (over)use: FWL extraction

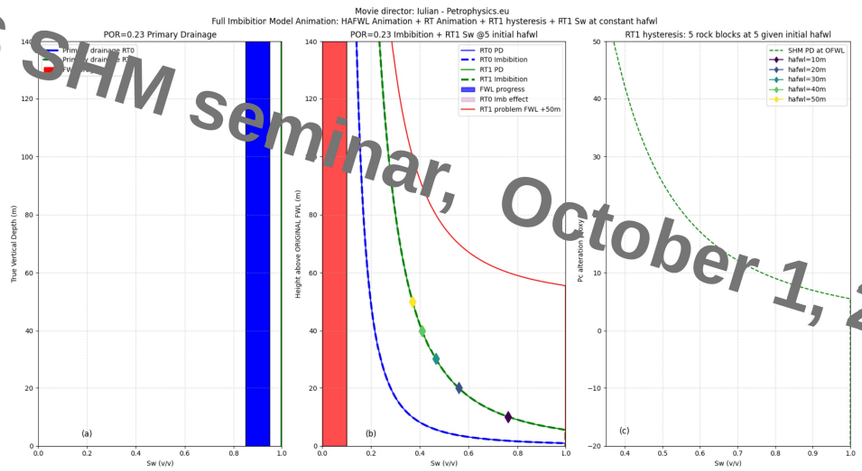


LPS SHM seminar, October 1, 2026

Uncertainty: Extracted FWL is a lot more qualitative than you would like it to be!

And then … there's imbibition!

LPS SHM seminar, October 1, 2026



And then ...the bigger problems start!

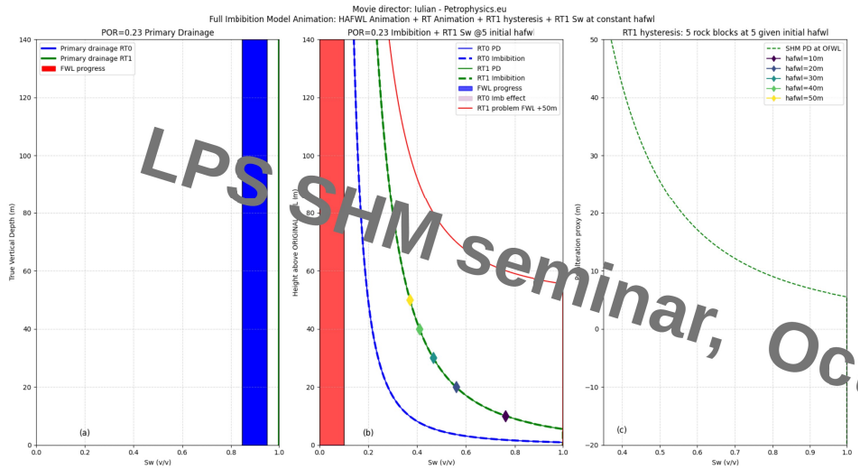
SPWLA-2026-0082

UNIFYING PRIMARY DRAINAGE AND IMBIBITION SATURATION HEIGHT MODELING: CLOSING A GAP IN WATER SATURATION PREDICTION

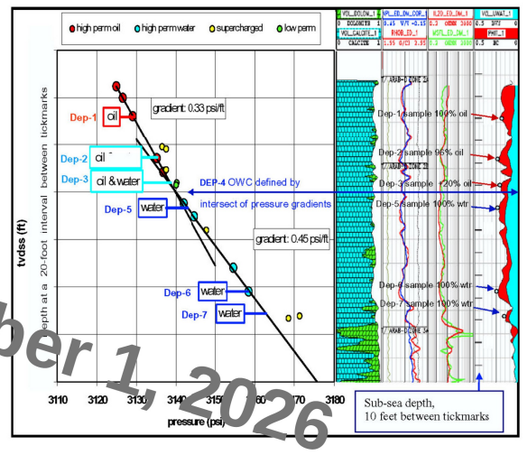
Iulian N. Hulea

Global Petrophysics Advisors B.V., The Netherlands

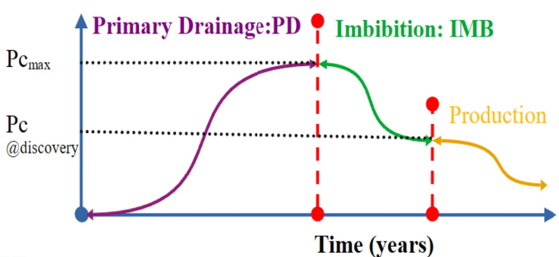
Introduction



LPS SHM seminar, October 1, 2026

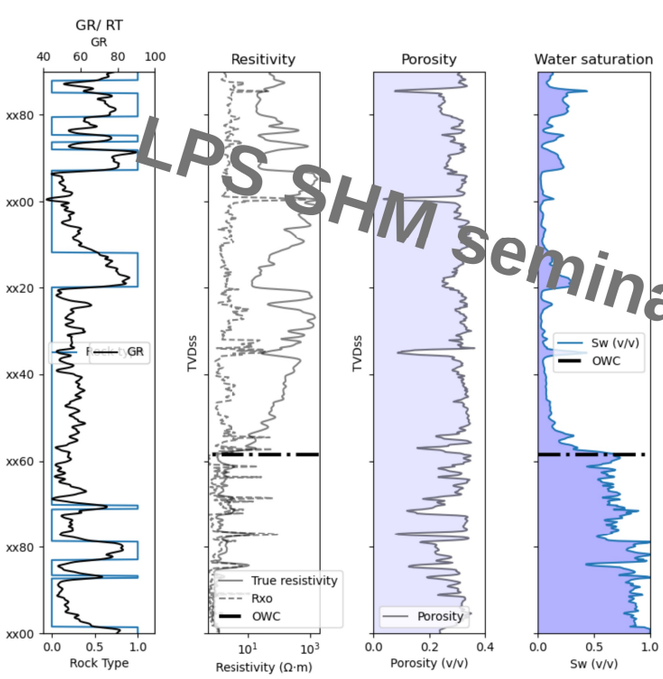


Capillary pressure



- In SHM Primary Drainage is usually assumed
- How often is that verified?

Does it matter if we are under imbibition?



LPS SHM seminar, October 1, 2026

Herlinger et al, SPE 228424 (2025).

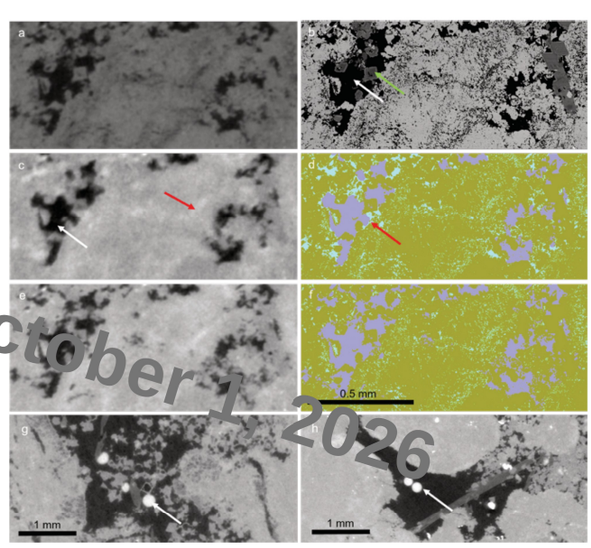


Fig. 13—Template illustrating the (a) dry sample X-ray μCT, (b) BSE image, (c and e) μCTs following the first (0.25 psi) and second (1.56 psi) drainage steps, and a segmented composition using μCT and BSE images, which reveals porosity that cannot be resolved by the resolution used in the X-ray imaging and therefore was quantified as microporosity. The BSE image (b) depicts the intershrub pores (white arrow) partially filled with dolomites (green arrow) and abundant microporosity. The μCTs (c and d) exhibit the oil with lower attenuation (white arrow) and the macro- and microporous brine-filled regions with higher attenuation (red arrow). The segmented coupled X-ray μCT/BSE images (d and f) illustrate the oil (purple) occupying the larger and brine (cyan) the smaller pores, wherein the advancement of the oil through the center of the pore (red arrow) can be observed, exhibiting a morphology typical of water-wet conditions after the first drainage step (d) and culminating in the total occupation of the pore. Finally, (g) and (h) exhibit examples of water droplets resulted from the snap-off process.

Xian, H. et al.,10.2118/188594-MS (2017); Masalmeh. et al., SCA2006-16 (2006); Adams SPE-84298-MS (2003)

Methodology employed

- PD: a Brooks-Corey formulation

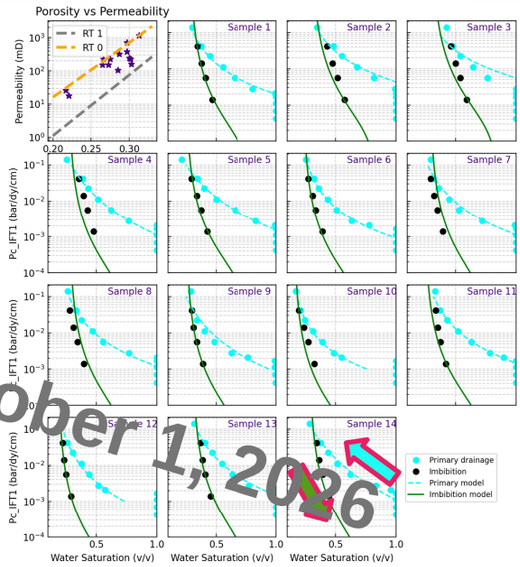
$$S_w = S_{wi} + (1 - S_{wi}) \left(\frac{P_{ce_{\mathrm{IFT1}}}}{P_{c_{\mathrm{IFT1}}}} \right)^{1/N}$$

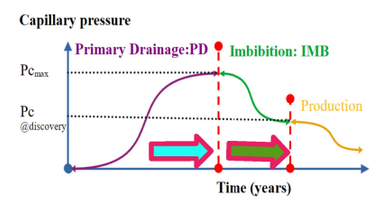
$$P_{ce_{\mathrm{IFT1}}} = 0.12 \left(\sqrt{\frac{k}{\phi}} \right)^{-1.39}$$

ALSO for imbibition

$$S_w = S_{win} + (1 - S_{win}) \left(\frac{P_{0_{\mathrm{IFT1}}}}{P_{c_{\mathrm{IFT1}}} + p_{x_{\mathrm{IFT1}}}} \right)^{1/N_{in}}$$

$$p_{x_{\mathrm{IFT1}}} = a \, P_{0_{\mathrm{IFT1}}}^{b}$$





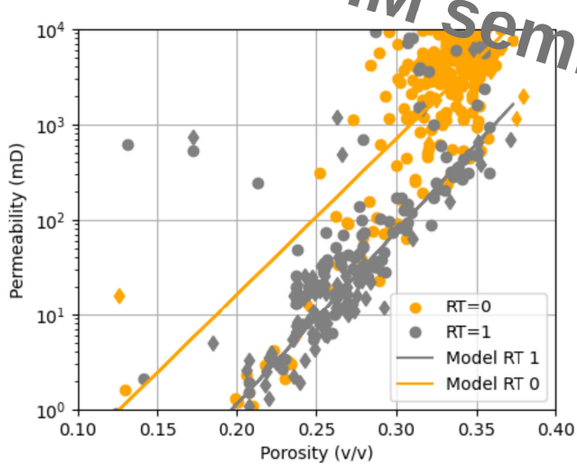
Hulea et al.,AAPG Bulletin, 96,, p. 1627-1642 (2012).
Hulea IN, SPE-193164 (2018).

LPS SHM seminar, October 1, 2026

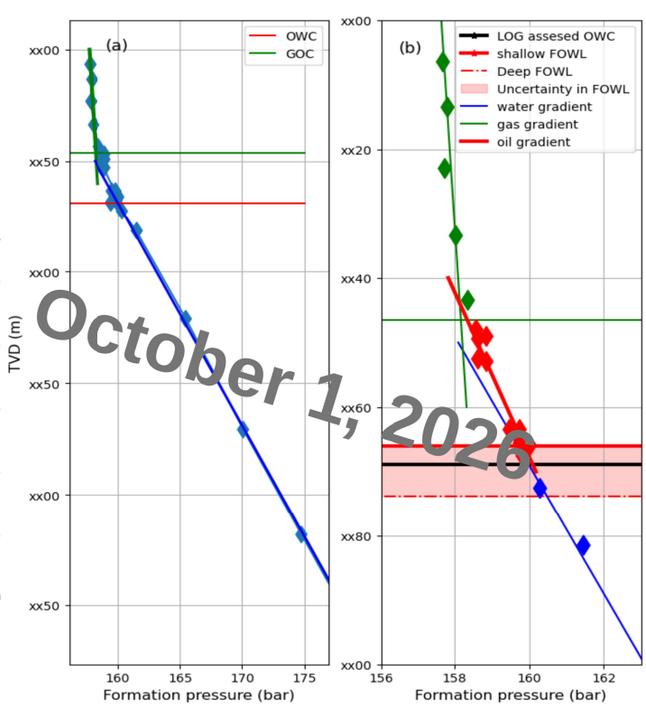
Peculiarities of this case:

2 RTs

Oil rim





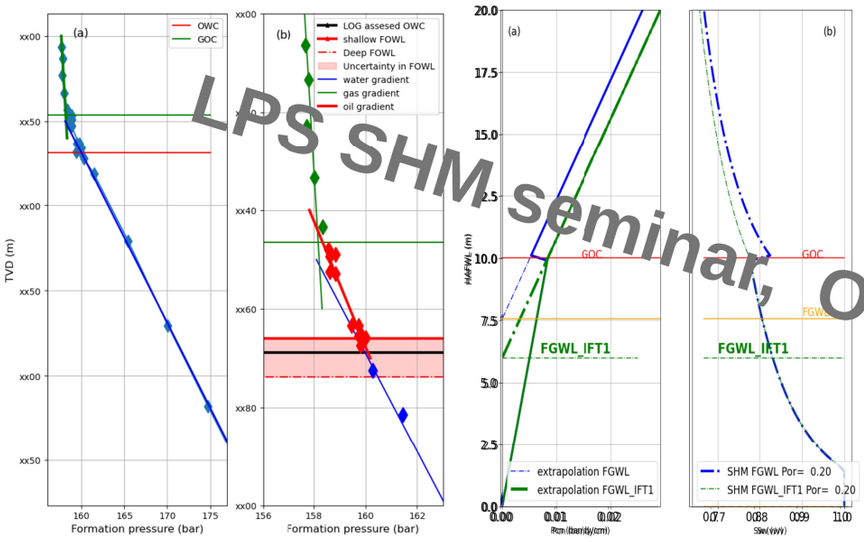


Hulea IN, SPWLA-2025-0068 (2025).

LPS SHM seminar, October 1, 2026

Peculiarities of this case: GOC issues

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



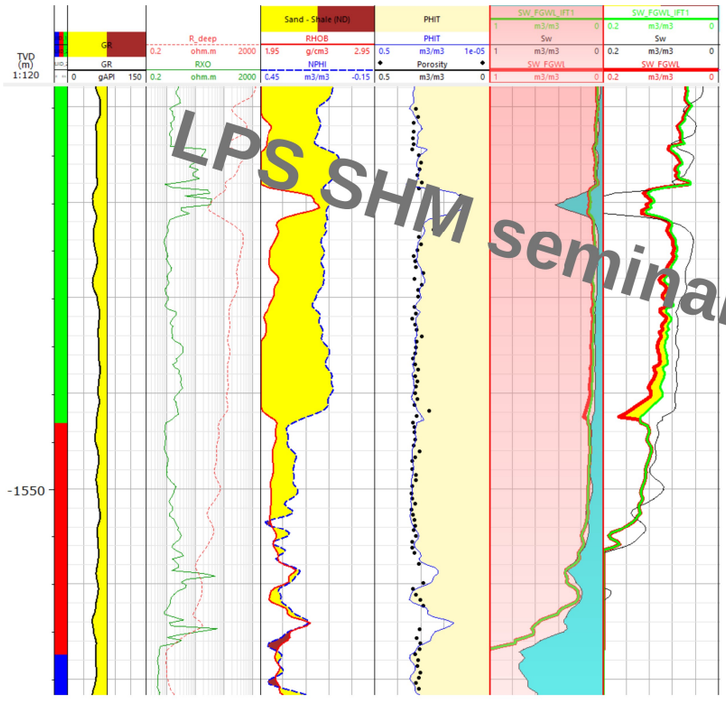
LPS SHM seminar, October 1, 2026

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

Hulea IN, SPWLA-2025-0068 (2025).

Peculiarities of this case: GOC issues



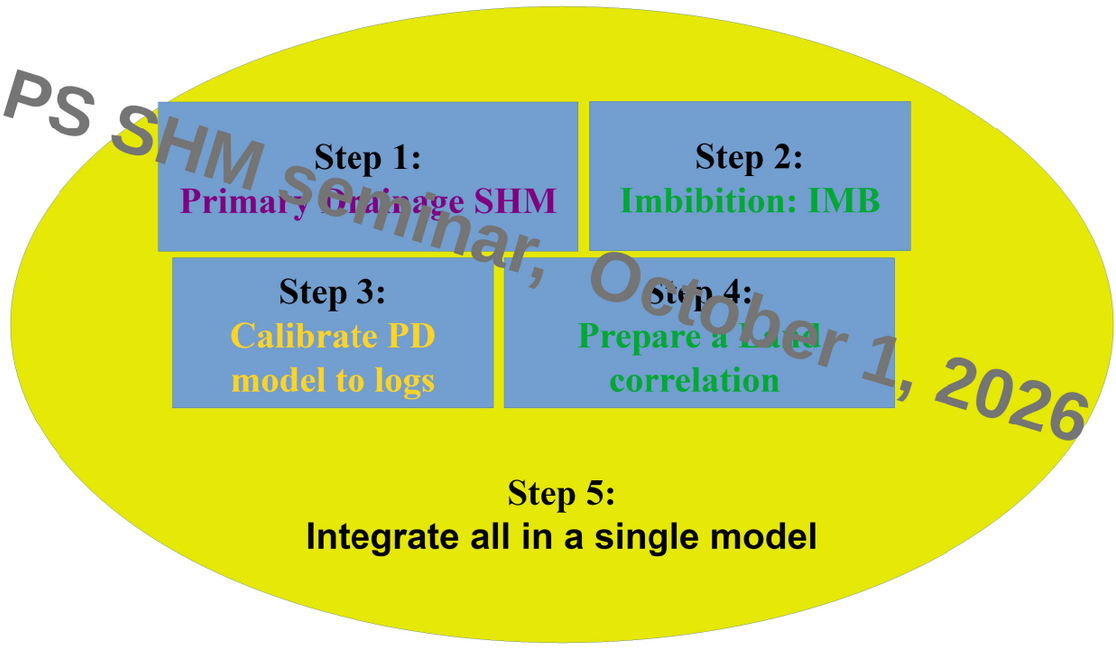
LPS SHM seminar, October 1, 2026

- SHM using FGWL
- SHM using FGWL_IFT1

The correction results in HC saturation increase

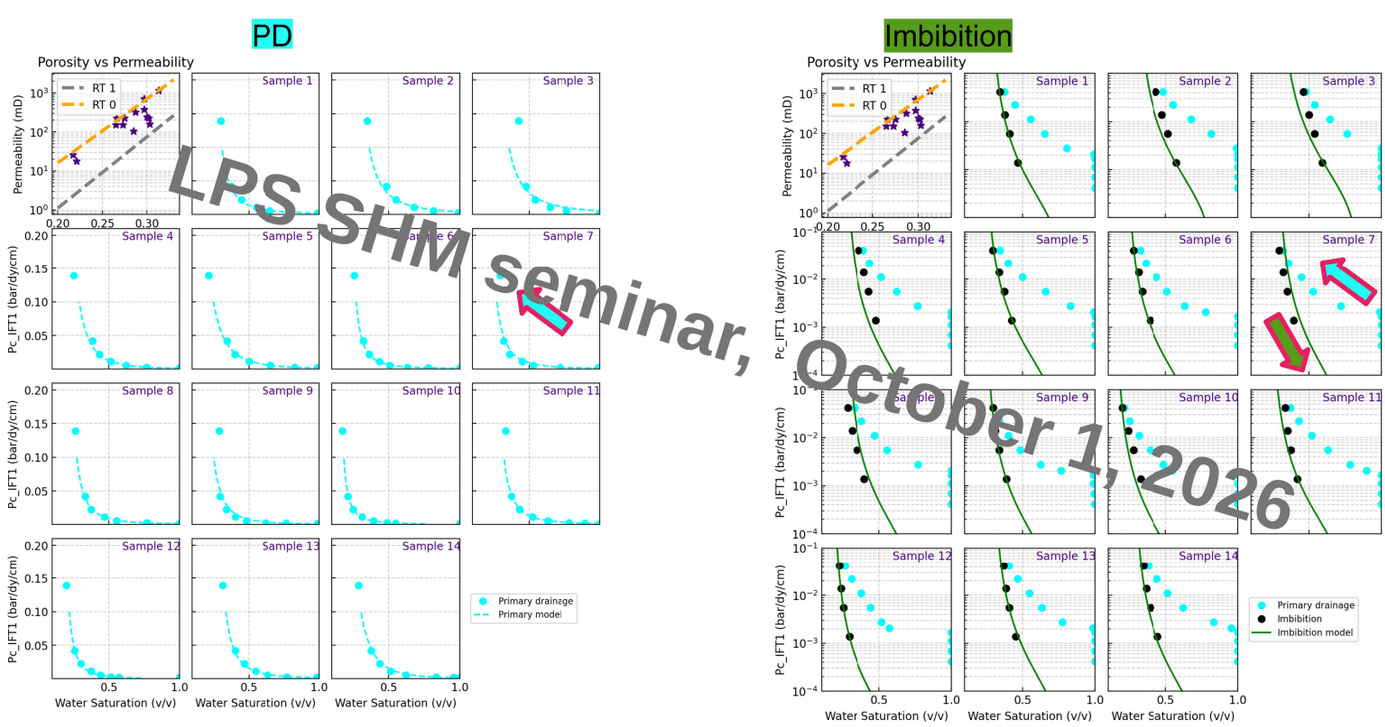
Hulea IN, SPWLA-2025-0068 (2025).

Seamless imbibition modelling



LPS SHM seminar, October 1, 2026

Steps I and II-- SCAL based

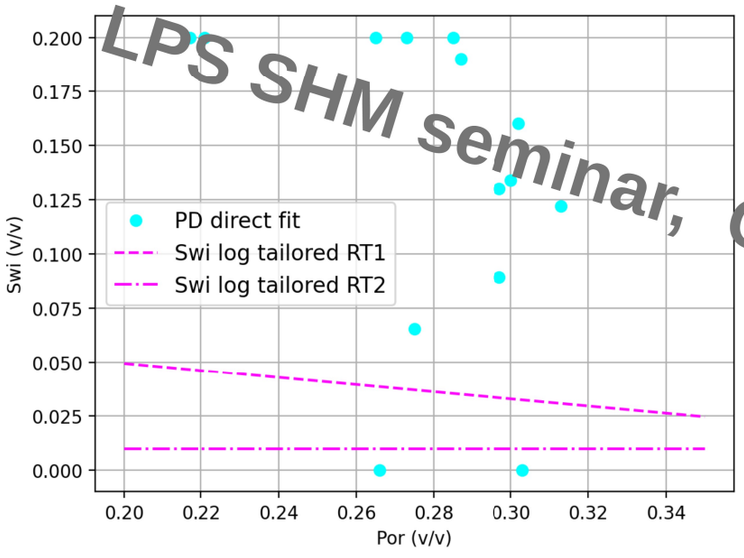


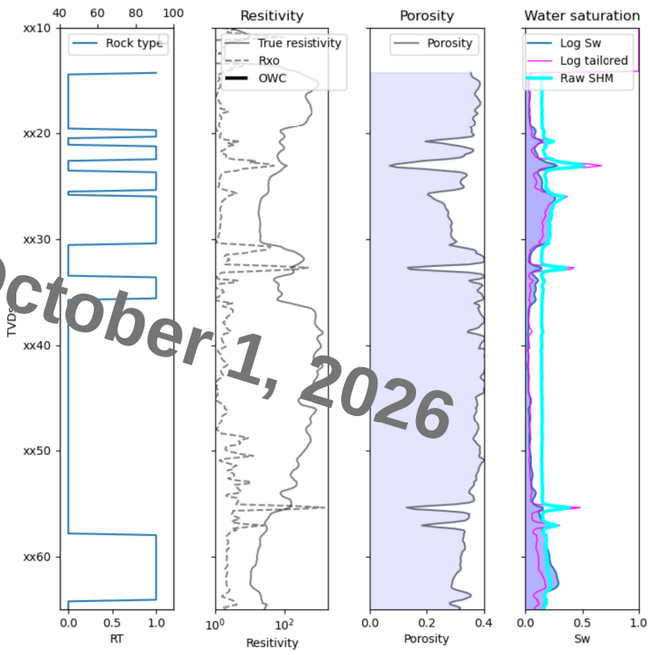
LPS SHM seminar, October 1, 2026

Core based models: Primary and imbibition

Step III

- Altering Primary drainage Swi to match the logs

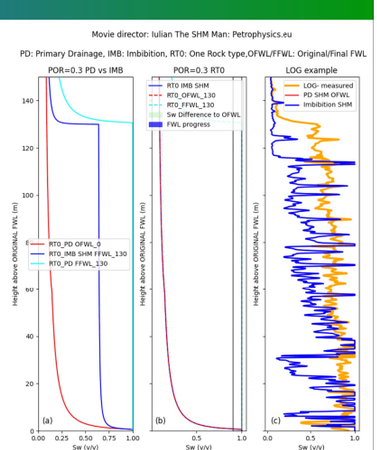


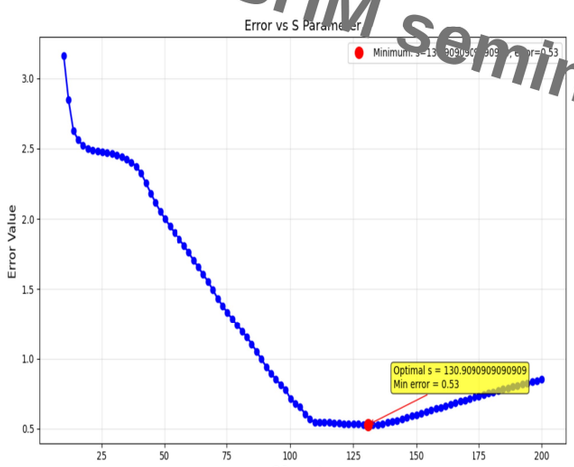


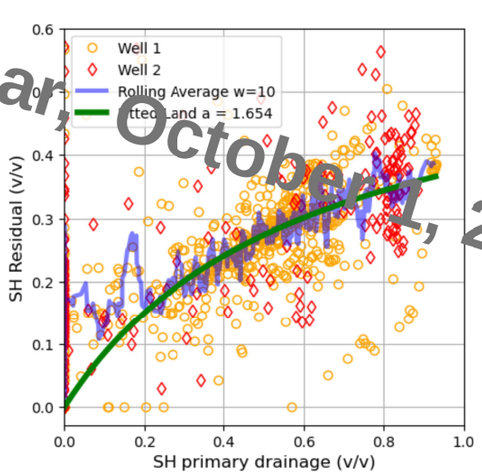
LPS SHM seminar, October 1, 2026

Step IV

- IV #1: asses oFWL position
- IV #2: derive a Land- type correlation







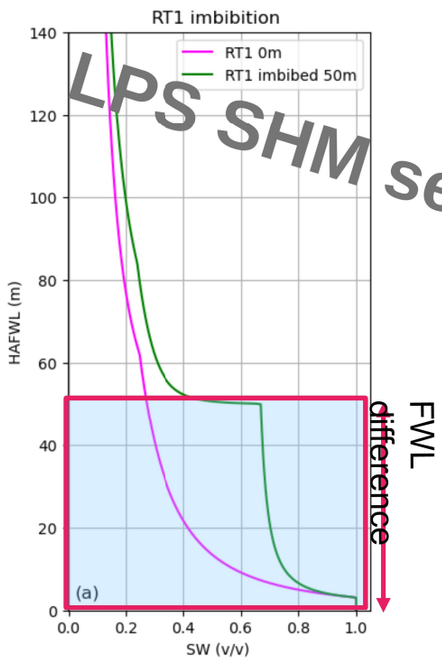
LPS SHM seminar, October 1, 2026

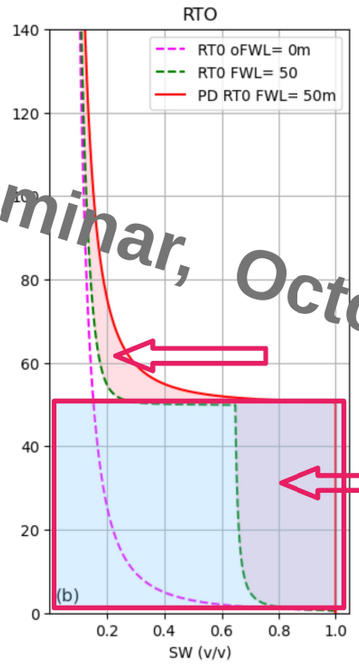
Landt et al, *10.2118/1942-PA (1968).*

Shr= Shi/(a*Shi + 1)

Step V

- Integrate the Primary drainage and imbibition with Land correlation





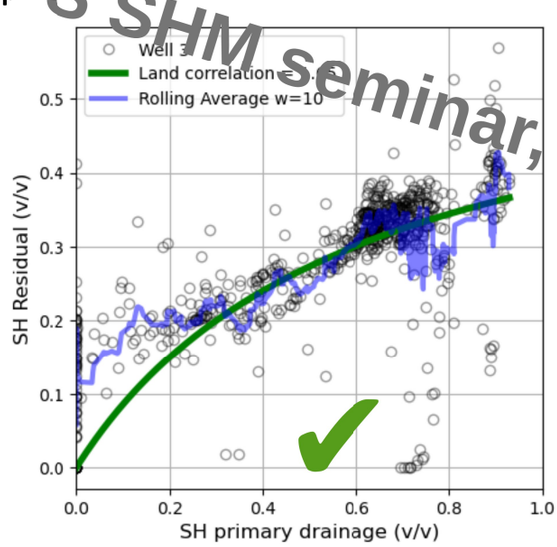
LPS SHM seminar, October 1, 2026

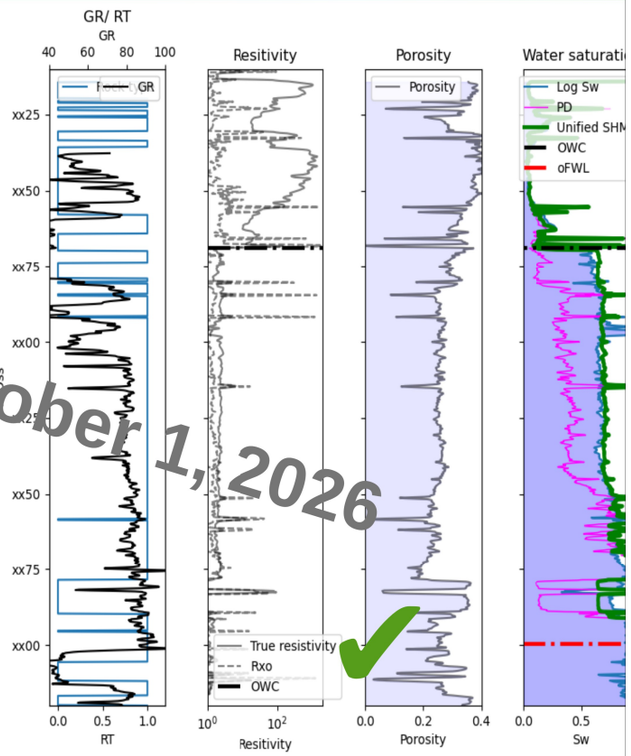
Something crucial we see?

Significant differences are not only under FWL

Model validation: 3 checks

- #1 Compare to data used in building
- #2 Compare to data the model has not seen

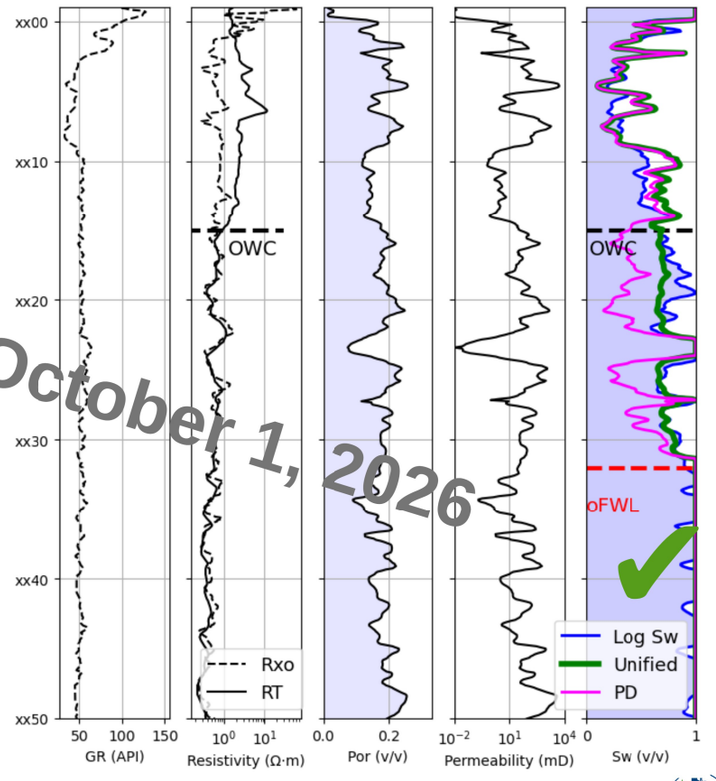




LPS SHM seminar, October 1, 2026

Model validation: bonus #3

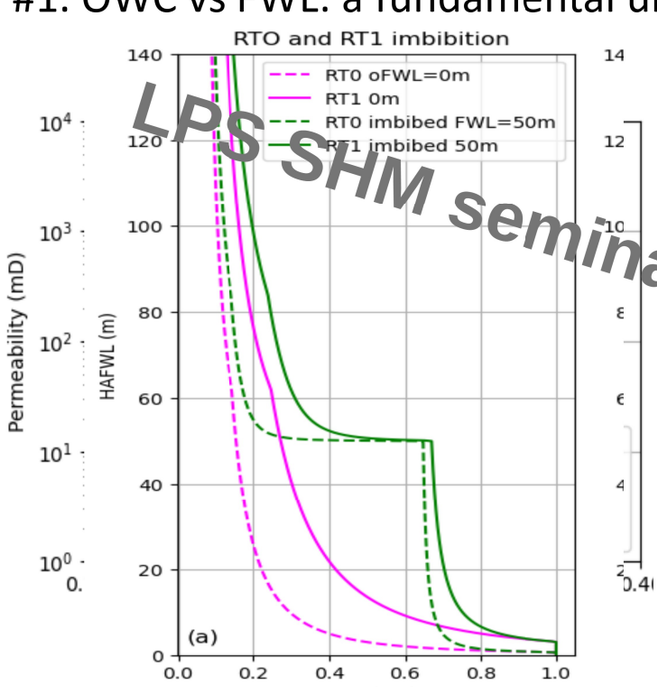
- Additional adjustments of the model above:
  - #1 : 1 RT only
  - #2 : Swi is tailored to the new logs

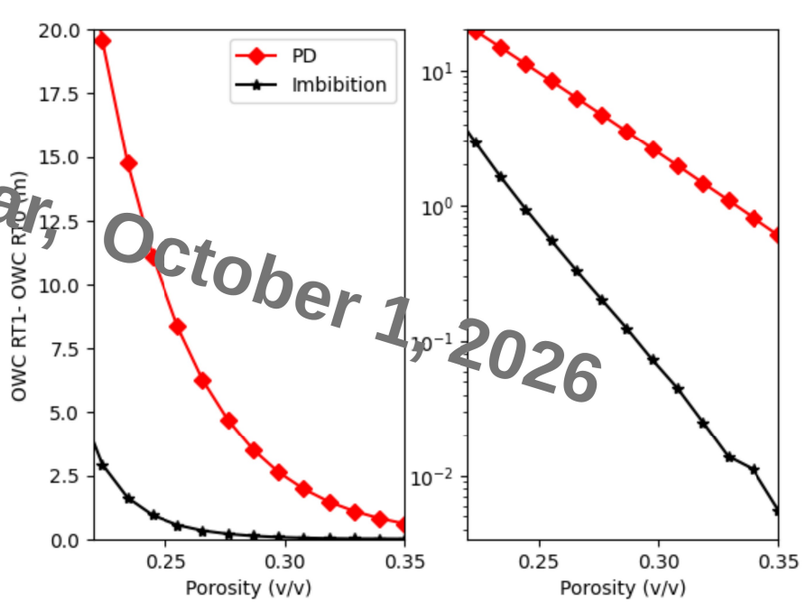


LPS SHM seminar, October 1, 2026

Discussion and implications: OWC vs FWL

#1. OWC vs FWL: a fundamental understanding change!





LPS SHM seminar, October 1, 2026

Discussion and implications: #2. Wetability

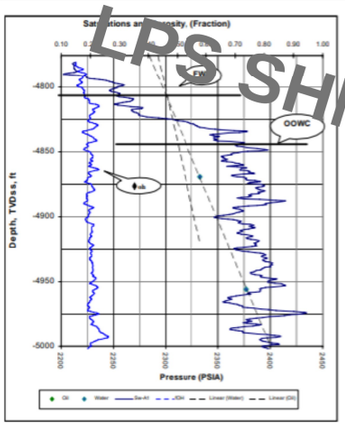


Fig.15-Example of pressure behavior in oil-wet Nubian Sandstone rocks from well L7.

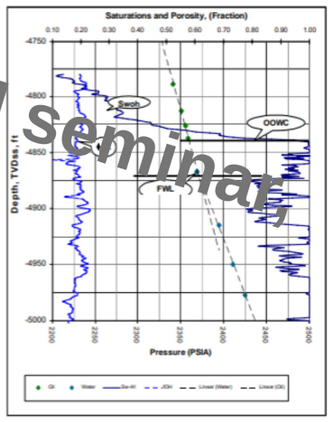


Fig.16-Example of pressure behavior in water-wet Nubian Sandstone rocks from well A1.

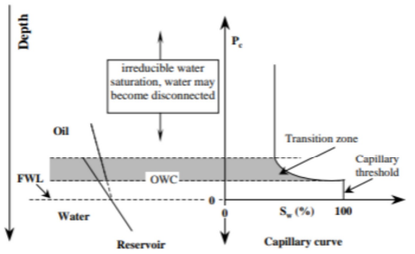


Fig.13-Fluid pressure, capillary pressure, and saturation distribution a water-wet reservoir

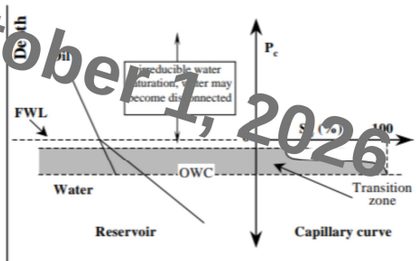


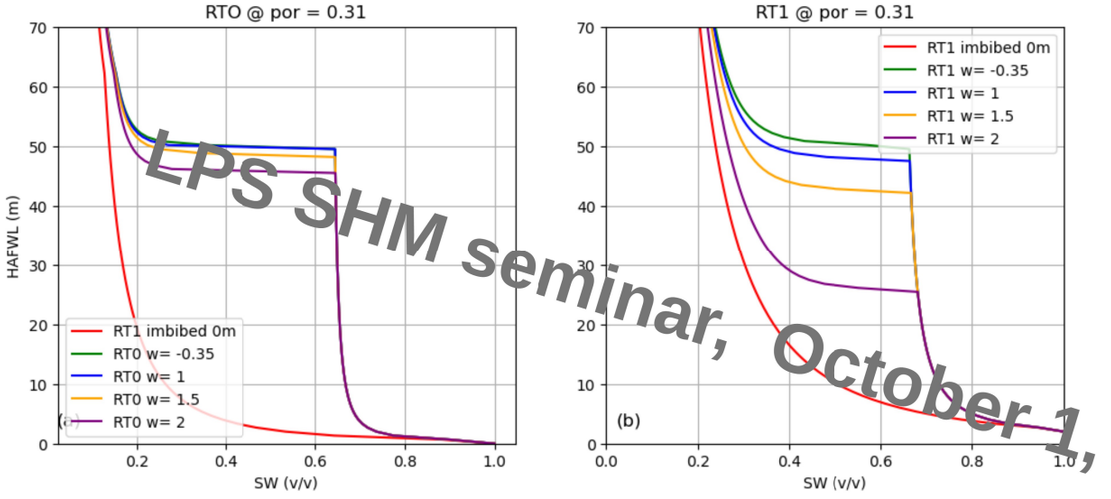
Fig.14-Fluid pressure, capillary pressure, and saturation distribution an oil-wet reservoir

#1. OWC vs FWL: wetability or imbibition?

#2. OWC vs FWL: wetability or imbibition?

LPS SHM seminar, October 1, 2026

Discussion and implications: #2. Wetability mapping



LPS SHM seminar, October 1, 2026

$$S_w = S_{win} + (1 - S_{win}) \left(\frac{P_{0_{\mathrm{IFT1}}}}{P_{c_{\mathrm{IFT1}}} + p_{x_{\mathrm{IFT1}}}} \right)^{1/N_{in}}$$

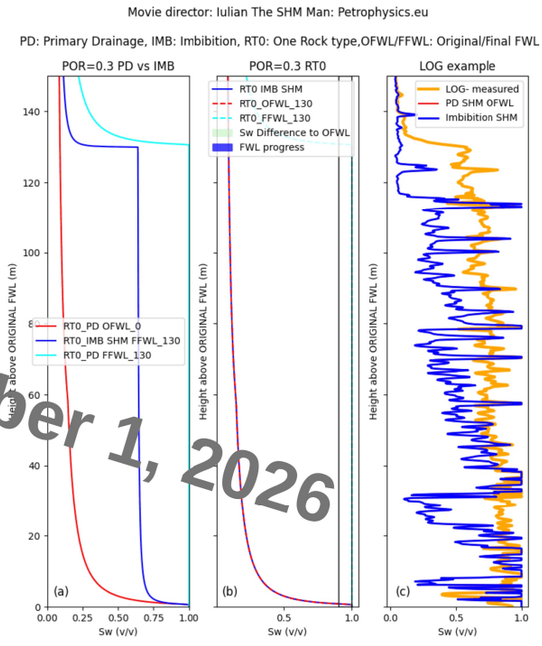
$$\log_{10}(p_{x_{\mathrm{IFT1}}}) = b \log_{10}(P_{0_{\mathrm{IFT1}}}) + w$$

$$p_{x_{\mathrm{IFT1}}} = a\, P_{0_{\mathrm{IFT1}}}^{b}$$

Conclusions

- Unified SHM has been shown to reproduce both PD and Imb data
- Relationship between OWC and FWL is distorted once imbibition starts
- This solution has the capability of wetability mapping
- Let's stop pretending IMB is optional physics.

Imbibition is normal. Pretending it's exotic is the exotic part.



LPS SHM seminar, October 1, 2026

Acknowledgments

The author expresses his gratitude to NL LOG and Vermillion Energy BV (Hans de Koningh) for providing the logs shown in Figure 12.

Additional information used in this study was obtained from the publicly accessible repository at https://factpages.sodir.no/.

The author also thanks Olaf van der Veen and Steve Adams for their constructive comments that improved the manuscript. .

LPS SHM seminar, October 1, 2026