Enhancing Reservoir Decision Quality through Rock Typing and SCAL Modeling

Muhammad Nur Ali Akbar, Prores

Ardian Pradhana Putra , Vår Energi

FORCE
Decision Quality Seminar: Better Decision-Making in the Age of AI: Opportunities and Challenges in Subsurface

Stavanger, 11 June 2025

Prores

Presentation Outline

INTRODUCTION

- The value of SCAL

METHODS

- PGS Rock Typing
- Corey SCAL Model

CASE STUDY

- Case study overview
- Study workflow

DISCUSSION

- Reservoir Modeling
- Uncertainty Analysis & Mitigation

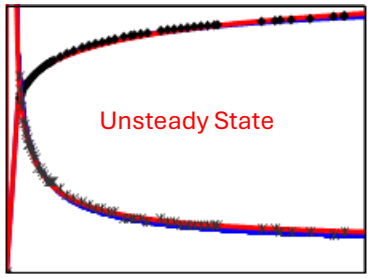
CONCLUSION

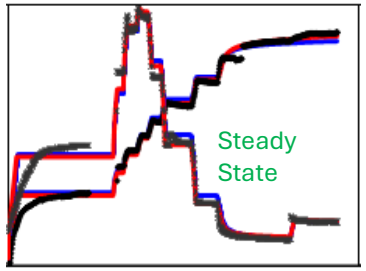
Prores

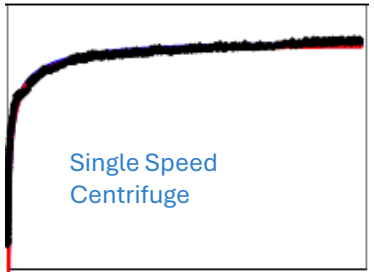
SCAL – Why is it Important?

SCAL : Special Core Analysis

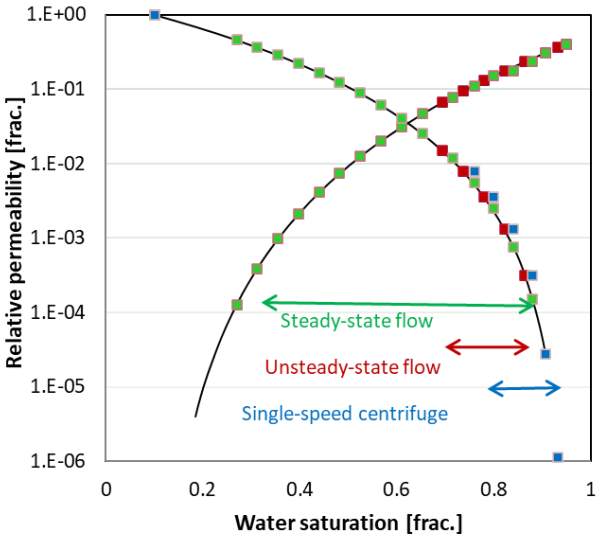
Spending a lot

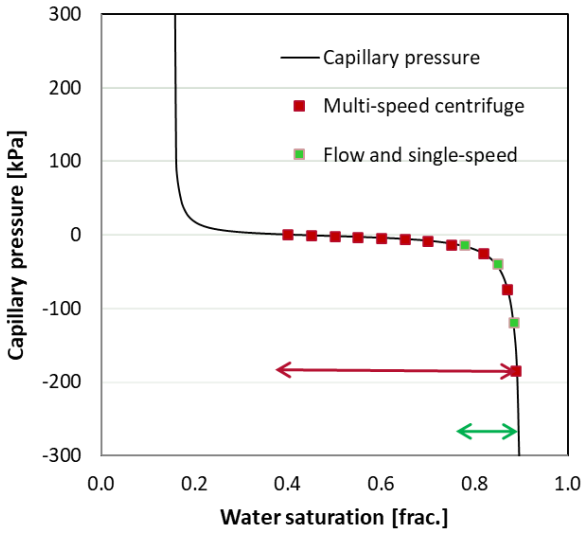


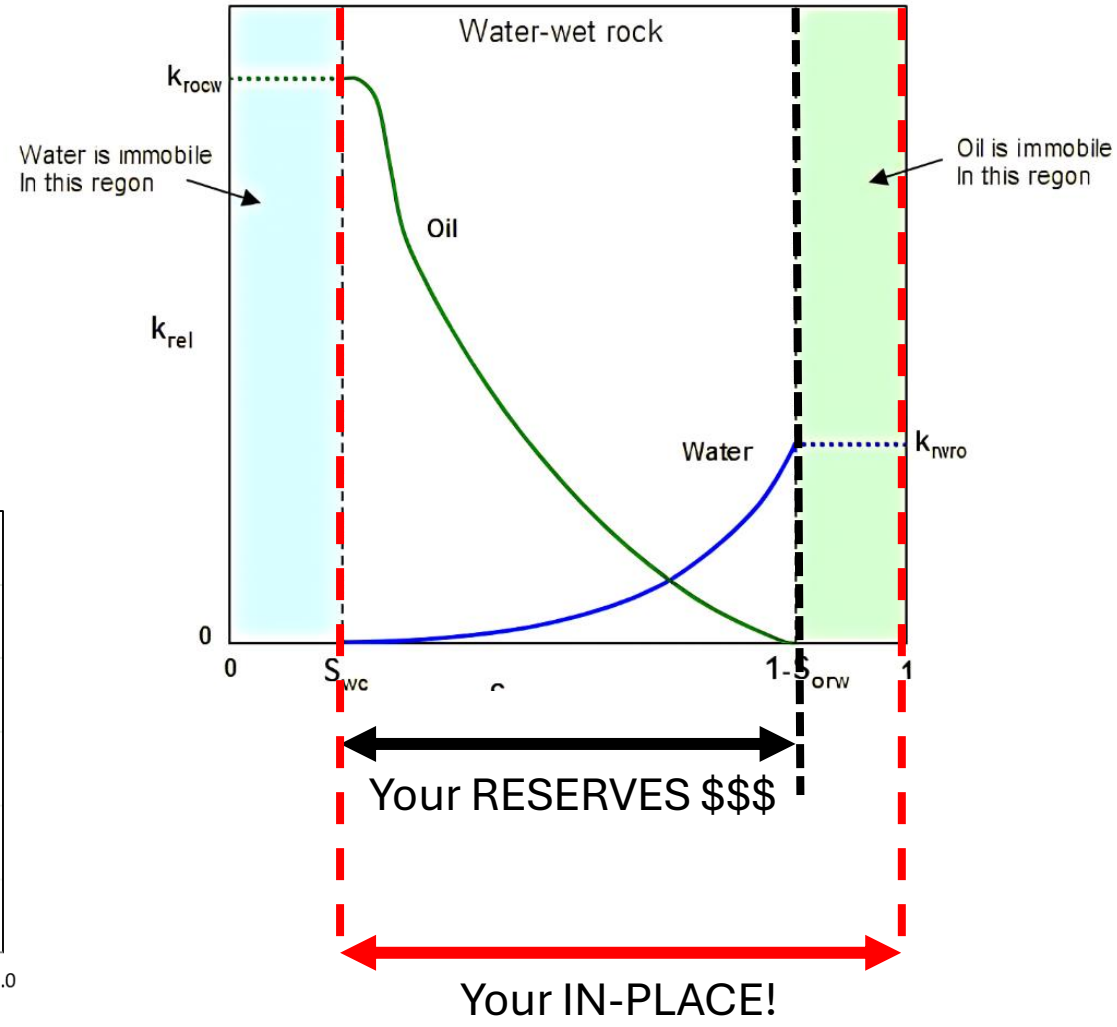




In general, the accuracy of relative permeabilities are defined by the experimental approach:





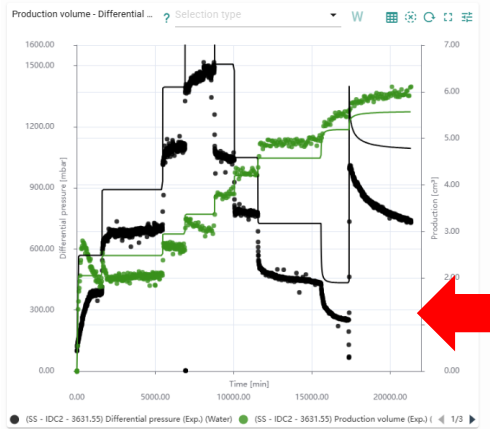


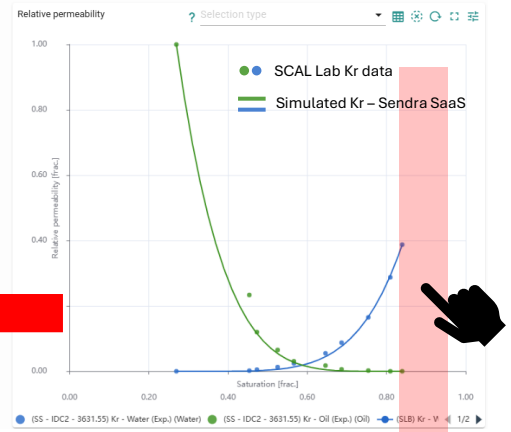
Prores

Coreflood simulation is needed!

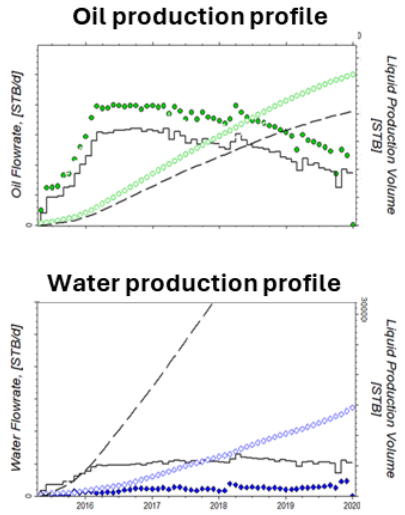
- Quality control your SCAL experiment(s)
  - Uncover invalid experiments
  - Improve interpretation of k_r and P_c
- Standardize how you analyze your SCAL experiment(s)
- Find reliable relative permeability and capillary pressure information for a core/well/field
  - Make recommendations for the flow properties for field applications
- Reduce uncertainty in experiment and output
  - Assess accuracy in k_r/P_c
  - Find trends in output data
- Planning for experimental design
  - Map uncertainties
  - Perform sensitivity of experimental setup

Just simple fitting from SCAL Lab. measurement!



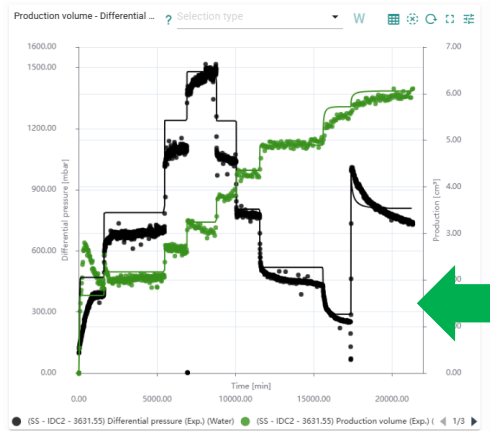


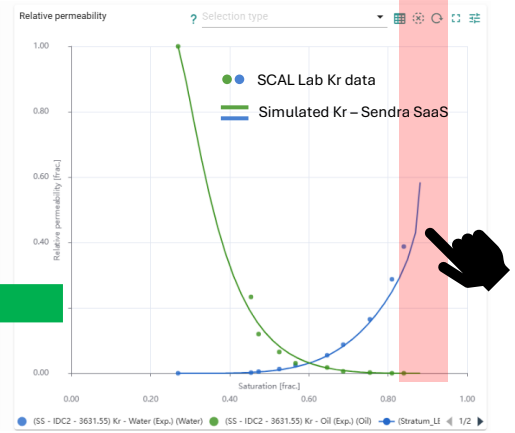
Full-Field History Matching



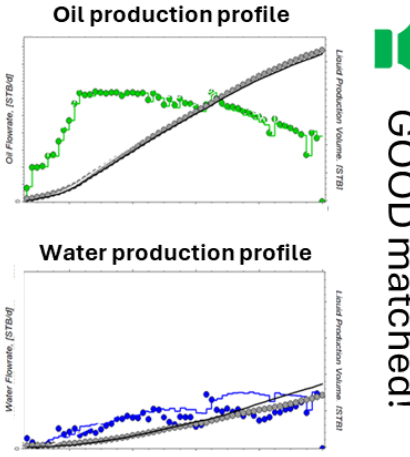
NOT matched!

After SCAL QC/QA Core-Flood Simulation





Full-Field History Matching

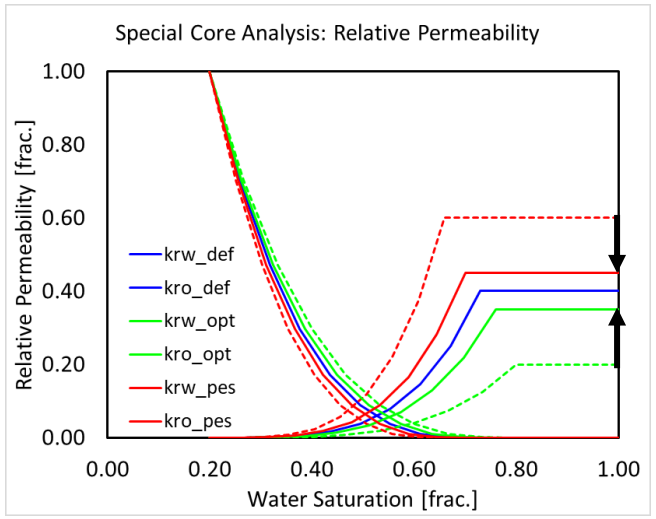


GOOD matched!

Prores

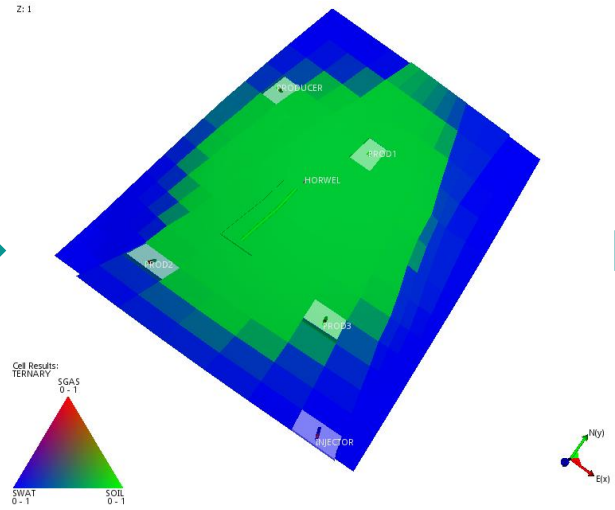
Background & Objectives

- Assess the uncertainty range of Special Core Analysis (SCAL) data and its effect on oil production forecasting.
- Investigate the significance of rock typing and SCAL modeling in enhancing the understanding of static and dynamic saturation distributions, thereby reducing uncertainty in production forecasts.
- Predict absolute and relative permeabilities across different rock types and saturation numbers (SATNUM).

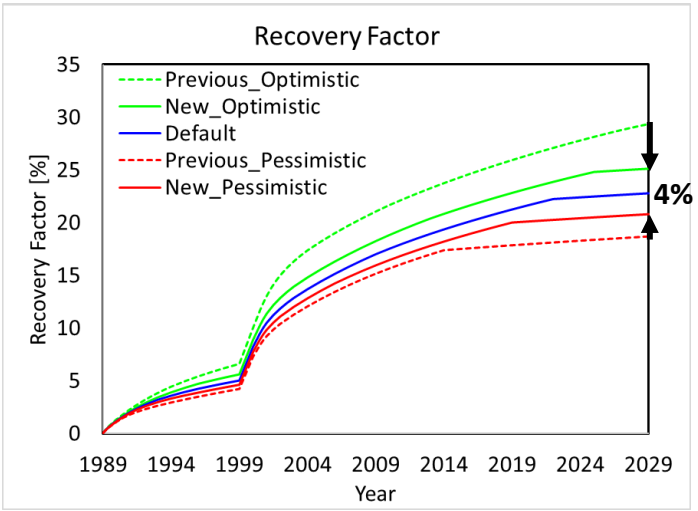


Initial Range of Relative Permeability

Updated with SCAL model and data-driven range:
Sorw Uncertainty: 0.24 – 0.30
krw@Sorw Uncertainty: 0.35 – 0.45



Reservoir Model



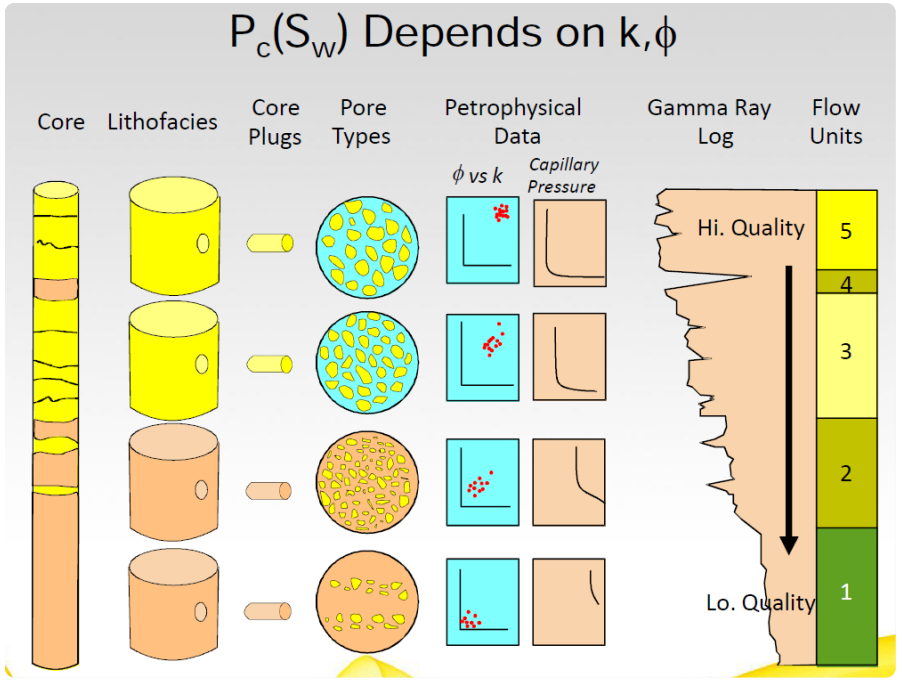
Initial RF Uncertainty: 18.7% - 29.7%

Minimize RF Uncertainty: 20.8 – 25.1 %

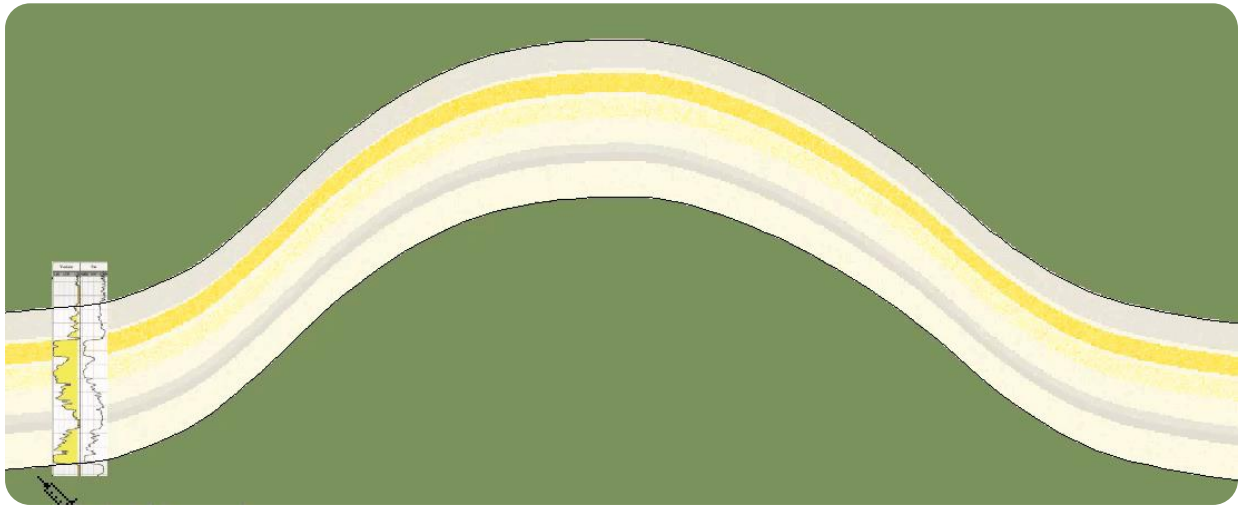
Prores

Rock Typing for Saturation Modeling

"Reservoir rock typing is a process of analyzing and integrating geological and petrophysical data to characterize a reservoir and dividing it into groups, each of which has certain relations among rock properties and the same dynamic rock properties needed for estimating the initial hydrocarbon in place and forecasting the reservoir performance"



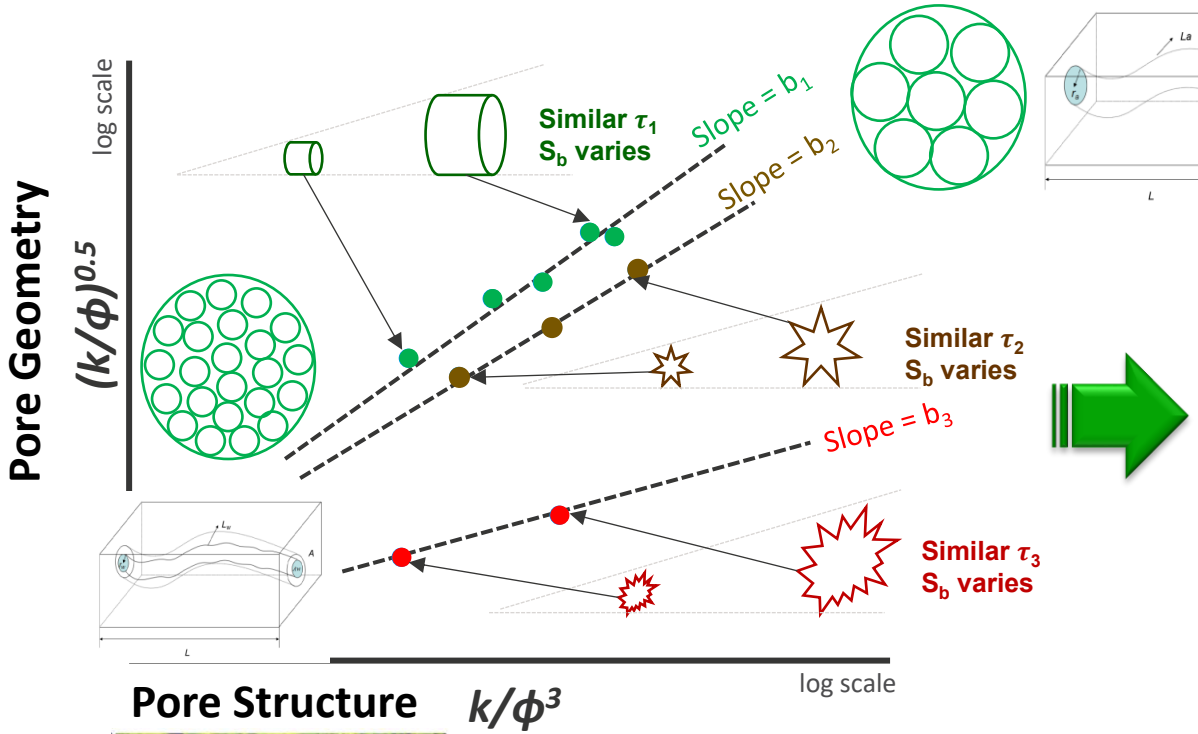
Modified after Ebanks, W.J., Jr.; Scheiling, M.H.; Atkinson, C.D. *Flow Units for Reservoir Characterization*; Morton-Thompson, D., Ed.; Development Geology Reference Manual; AAPG: Tulsa, OK, USA, 1992.

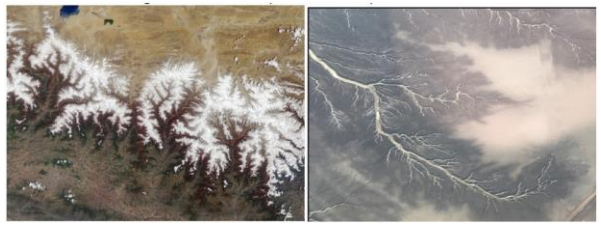


Fluid saturation distribution based on capillary pressure is strongly dependent on rock properties. Rock typing is the key for better saturation modeling.

Prores

Newly Developed PGS Rock Typing

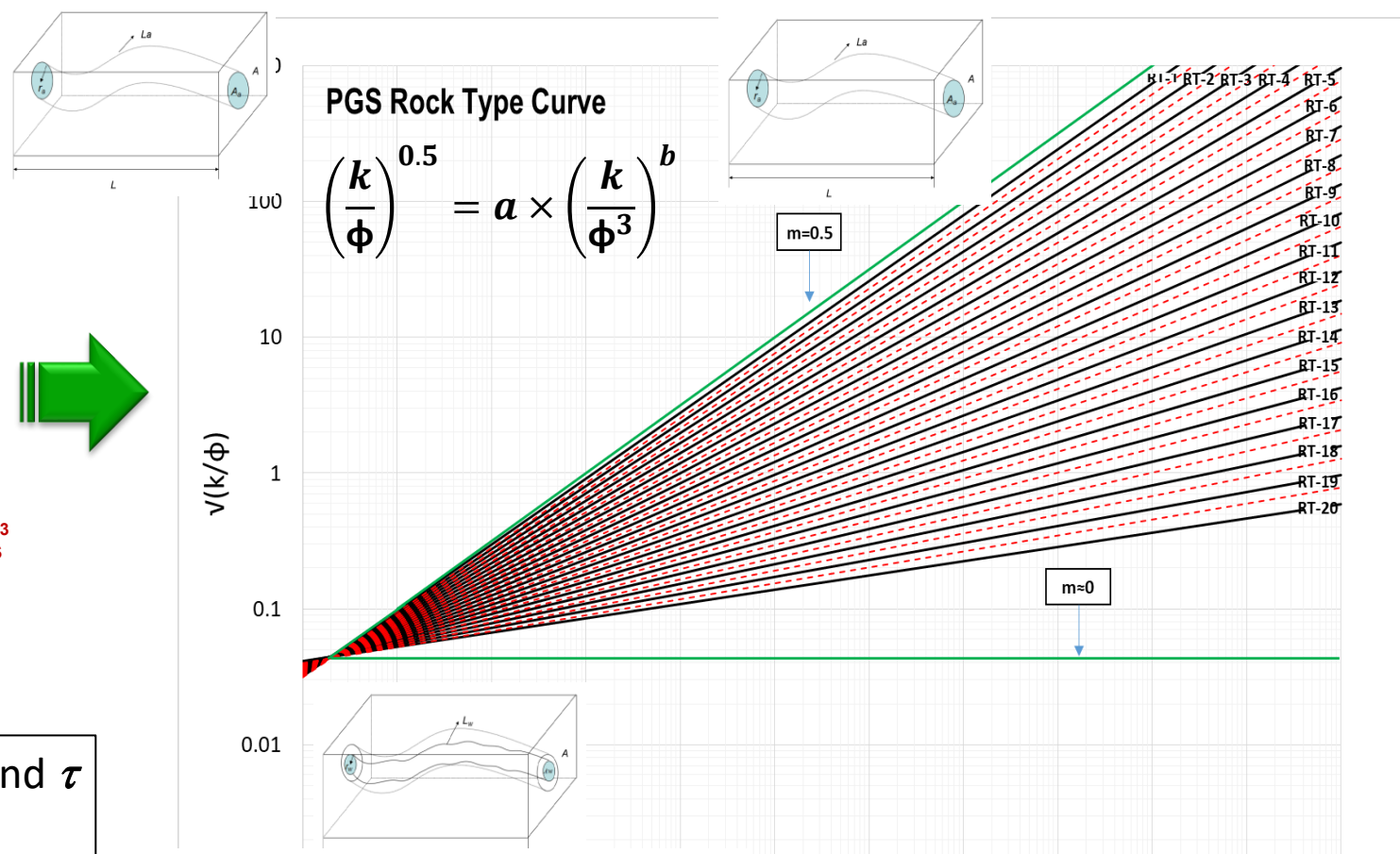




Each RT line has same F_s and τ but different S_b from one sample to the others.

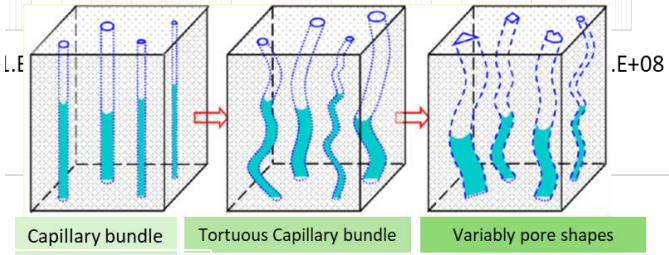
$b_1 > b_2 > b_3$

More complex pore systems produces lower slope.



b representing complexity of pore structure. *b* = 0.5 is maximum (capillaric pipes, τ≈1);

Natural porous media (*b* < 0.5, τ>1).

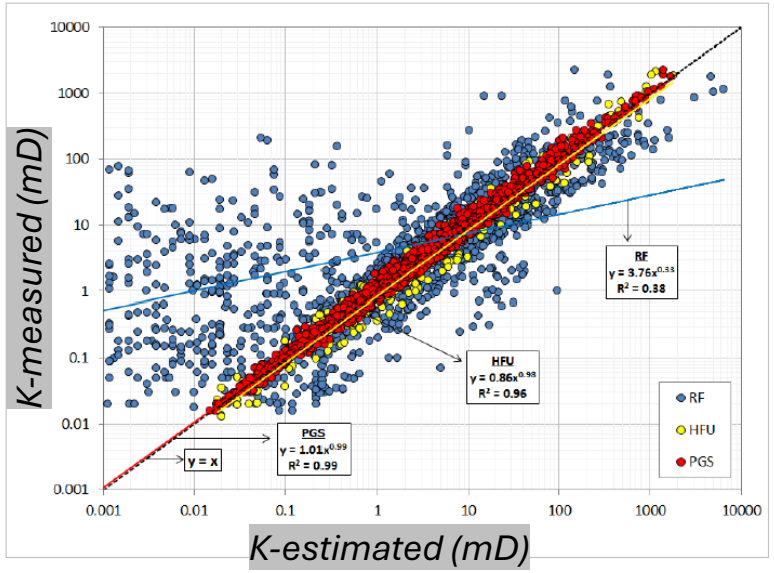


k : *Permeability,* ***ϕ*** : *Porosity,* ***τ*** : *Tortuosity,*
F_s : *Shape factor,* S_b : *Internal specific surface area*

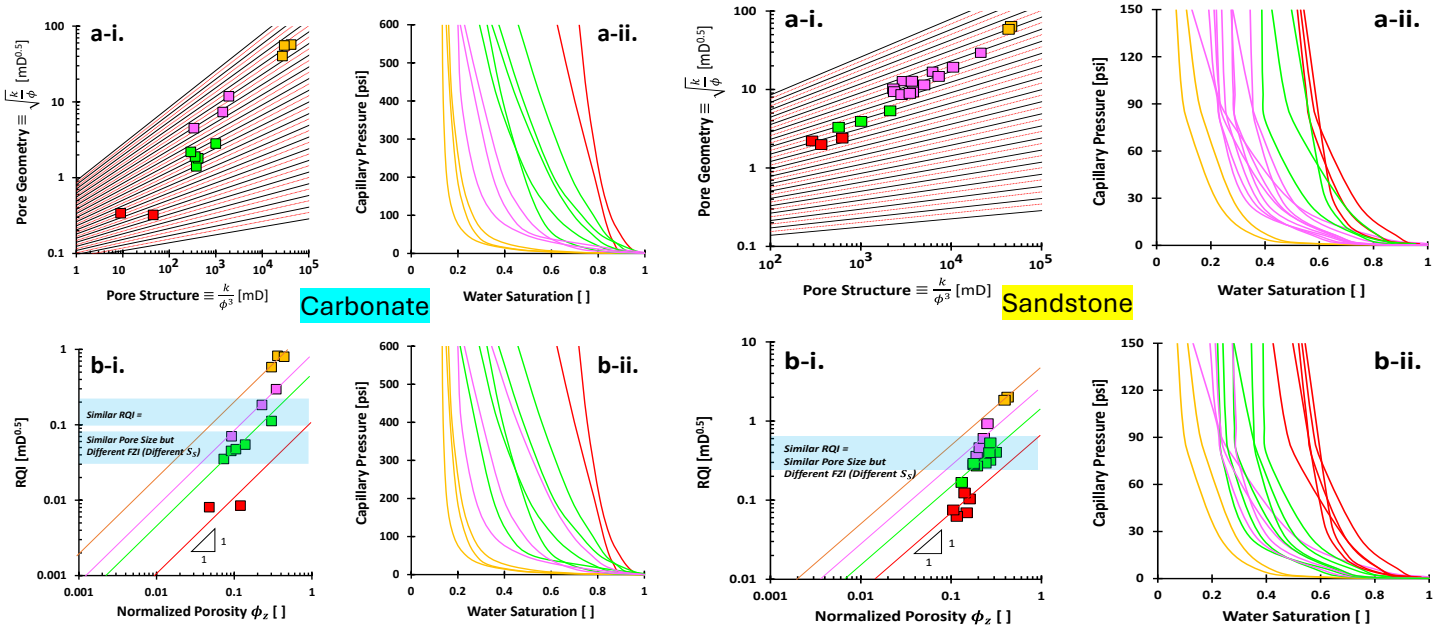
Prores

Rock Typing Comparison

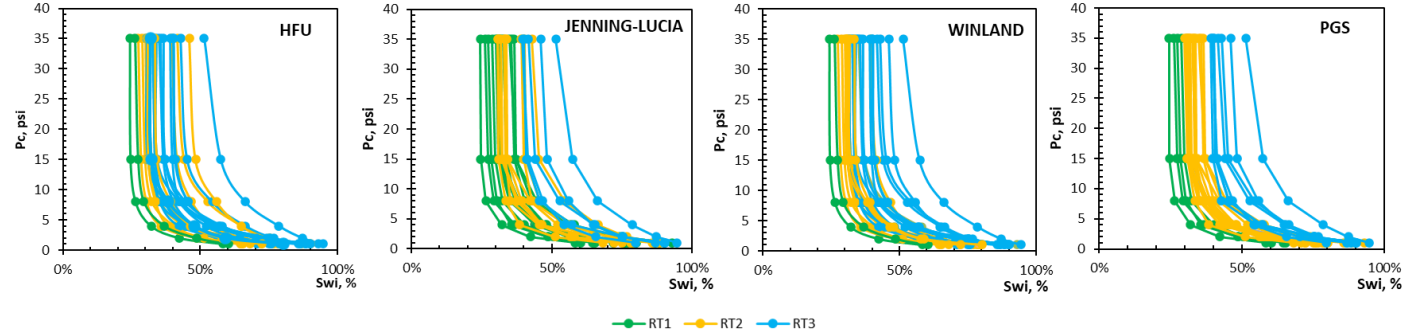
- PGS has better consistency in terms of grouping capillary pressure for saturation height models than other rock typing methods.
- PGS shows better permeability Prediction in both sandstone and carbonate rocks than HFU.
- Effective to identify active micro-fractures (dual porosity and permeability effects) and any diagenetic process.
- Tested in various case studies in petrophysics, 3D static and dynamic modelling.



Hakiki and Akbar., 2024 ***(On the pore geometry and structure rock typing) - ACS Omega***



Capillary Pressure Curves Comparison in Different Rock Typing Methods – Carbonate Samples



Prores

SCAL Modeling Overview

- SCAL Model method is introduced by Ebeltoft et al. (2014) by using LET method, and further developed by Akbar et al., (2024) by using Corey model with the integration to PGS rock typing.
- SCAL Modeling was built based on a large dataset and consistent with the wettability physics.
- The primary goal is to generate a range of uncertainty in relative permeability that aligns with the wettability concept for each specific saturation region.
- SCAL modeling predicts relative permeability curves in each rock type by leveraging analogous data.
- This study introduces a novel solution by integrating Corey SCAL modeling with rock typing.

SCAL, LET Parameters

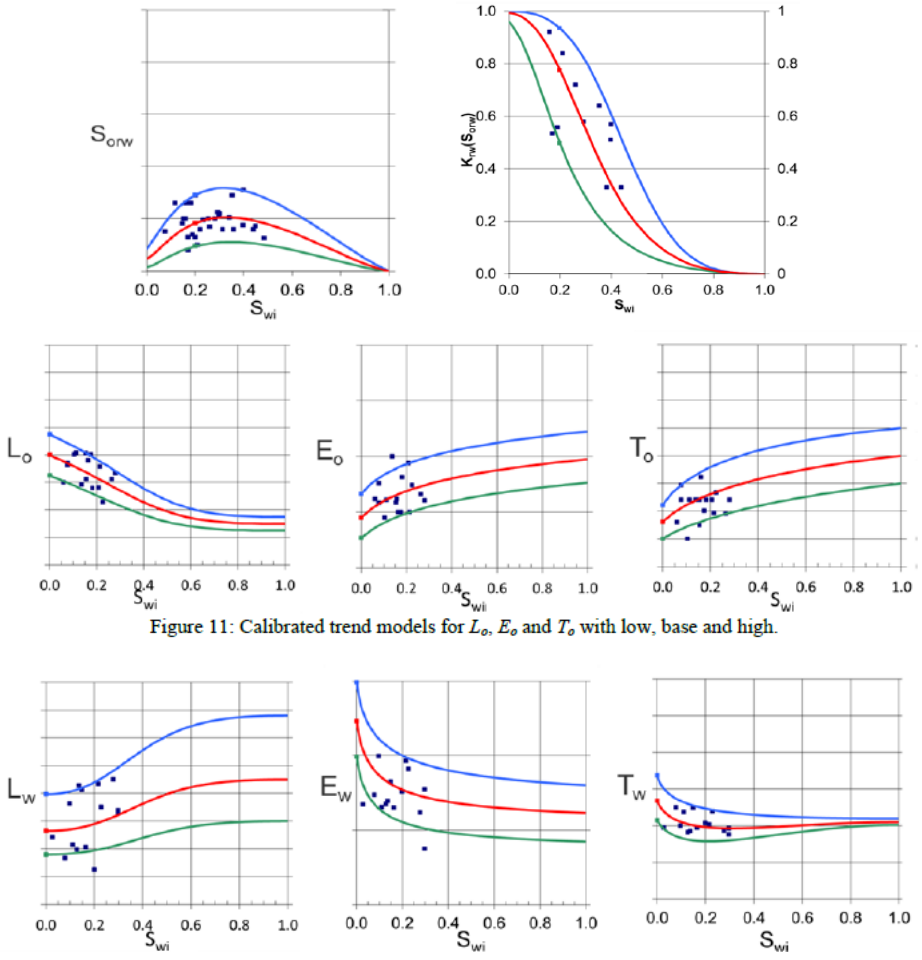
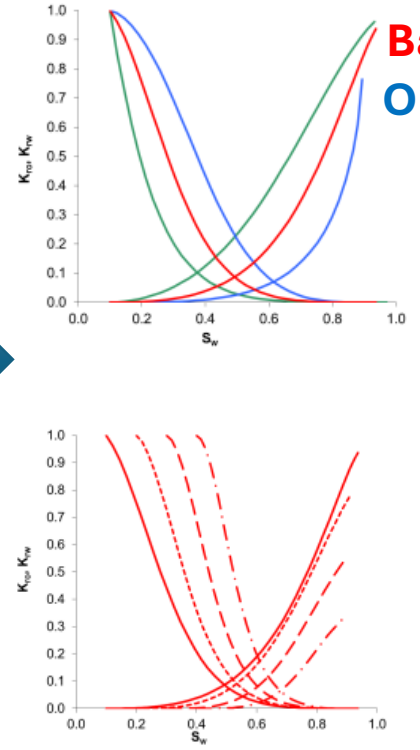


Figure 11: Calibrated trend models for L_o, E_o and T_o with low, base and high.

Results

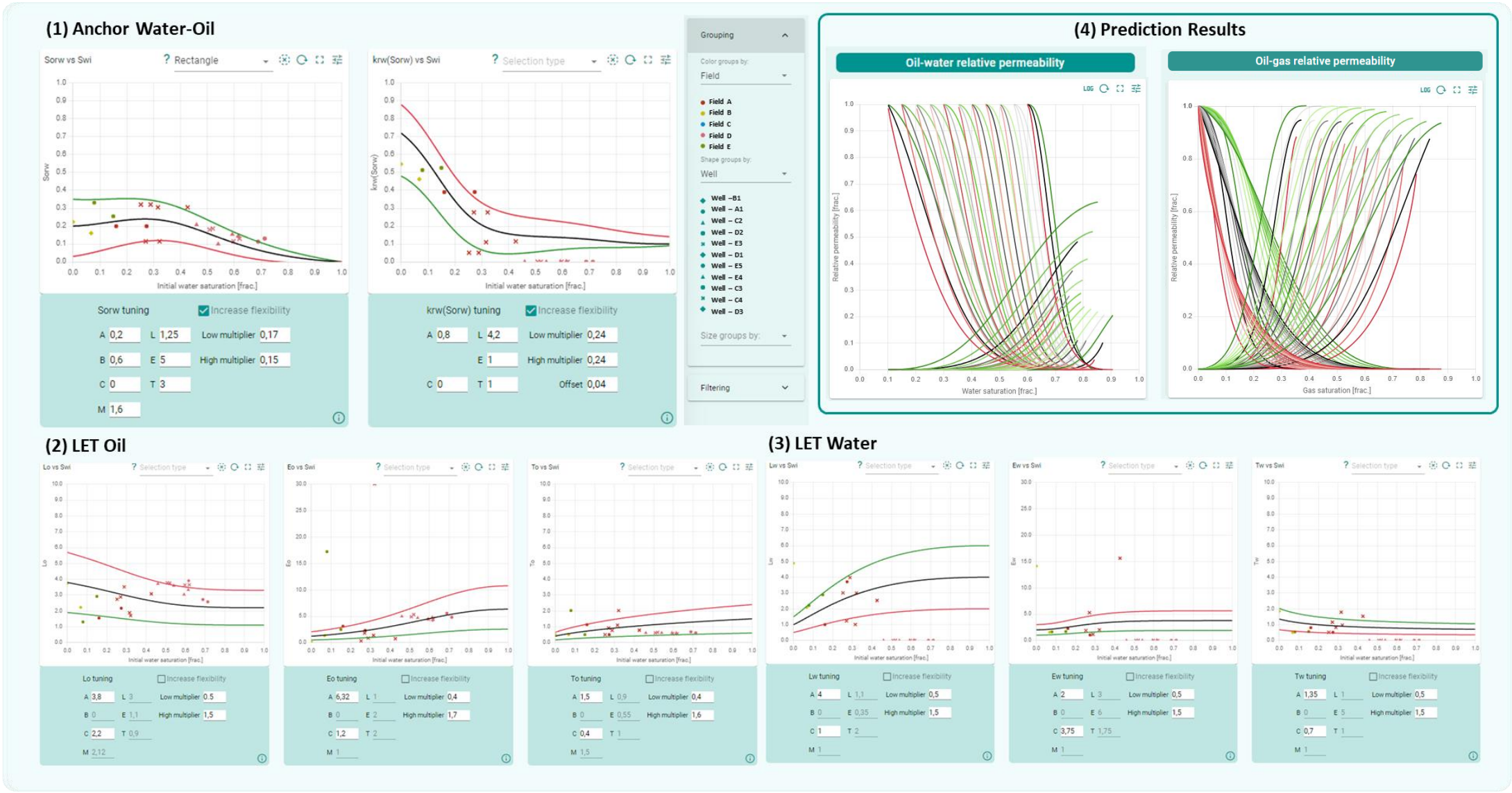
Pes.
Base
Opt.



Ebeltoft, E. et al., *Parameter Based SCAL - Analysing Relative Permeability For Full Field Application*, SCA2014-080, in *International Symposium of the Society of Core Analysts*. 2014. Avignon, France.

Prores

SCAL Trend Modelling Exp. With Analogue



Prores

Case Study Overviews

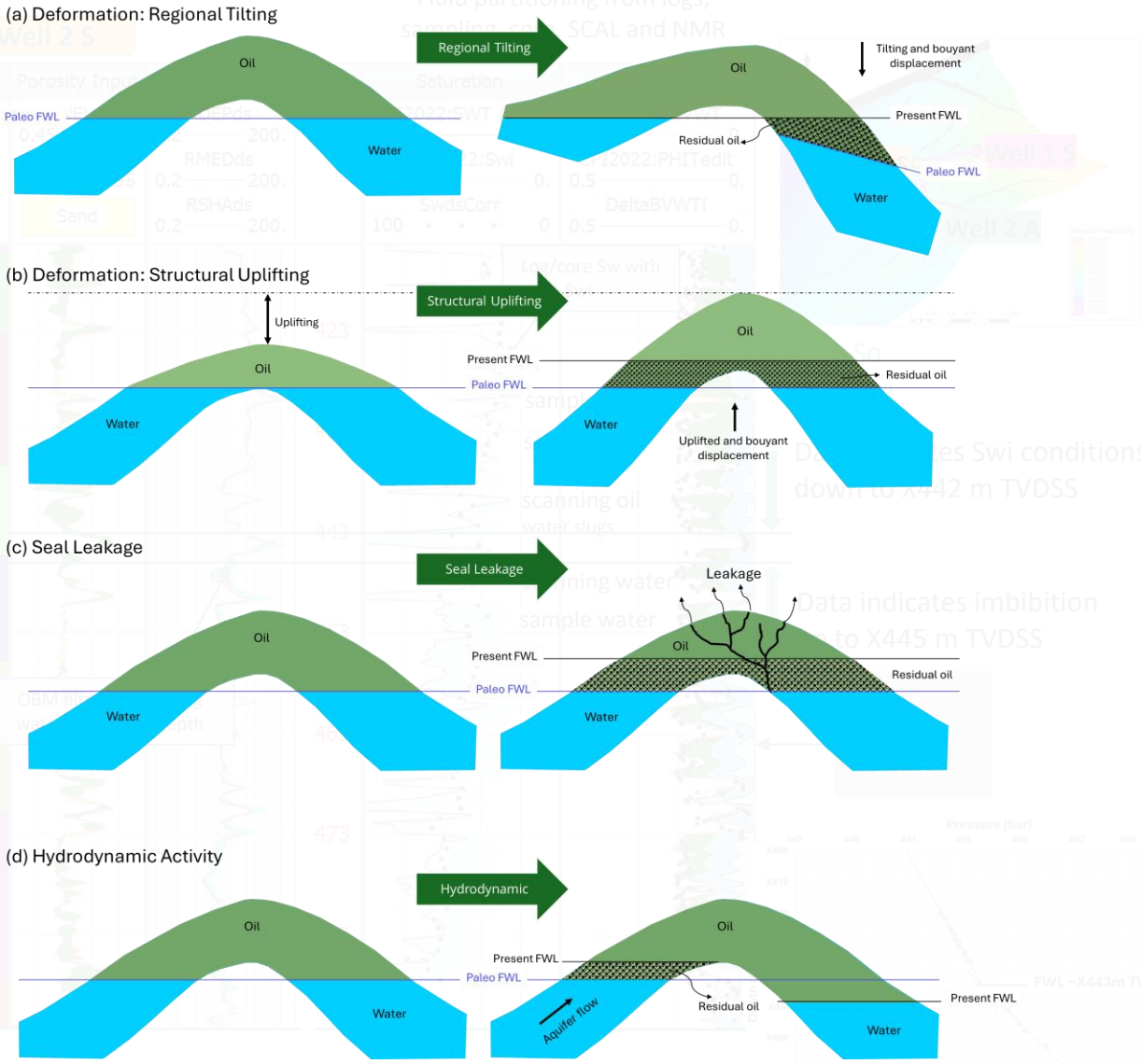
Observation:
Residual oil has been identified below the present-day Free Water Level (FWL).

Challenges:

- How to model it?
- does this affect the uncertainty in Hydrocarbon (HC) in-place volumes and reserves estimation?

Proposed Solution:

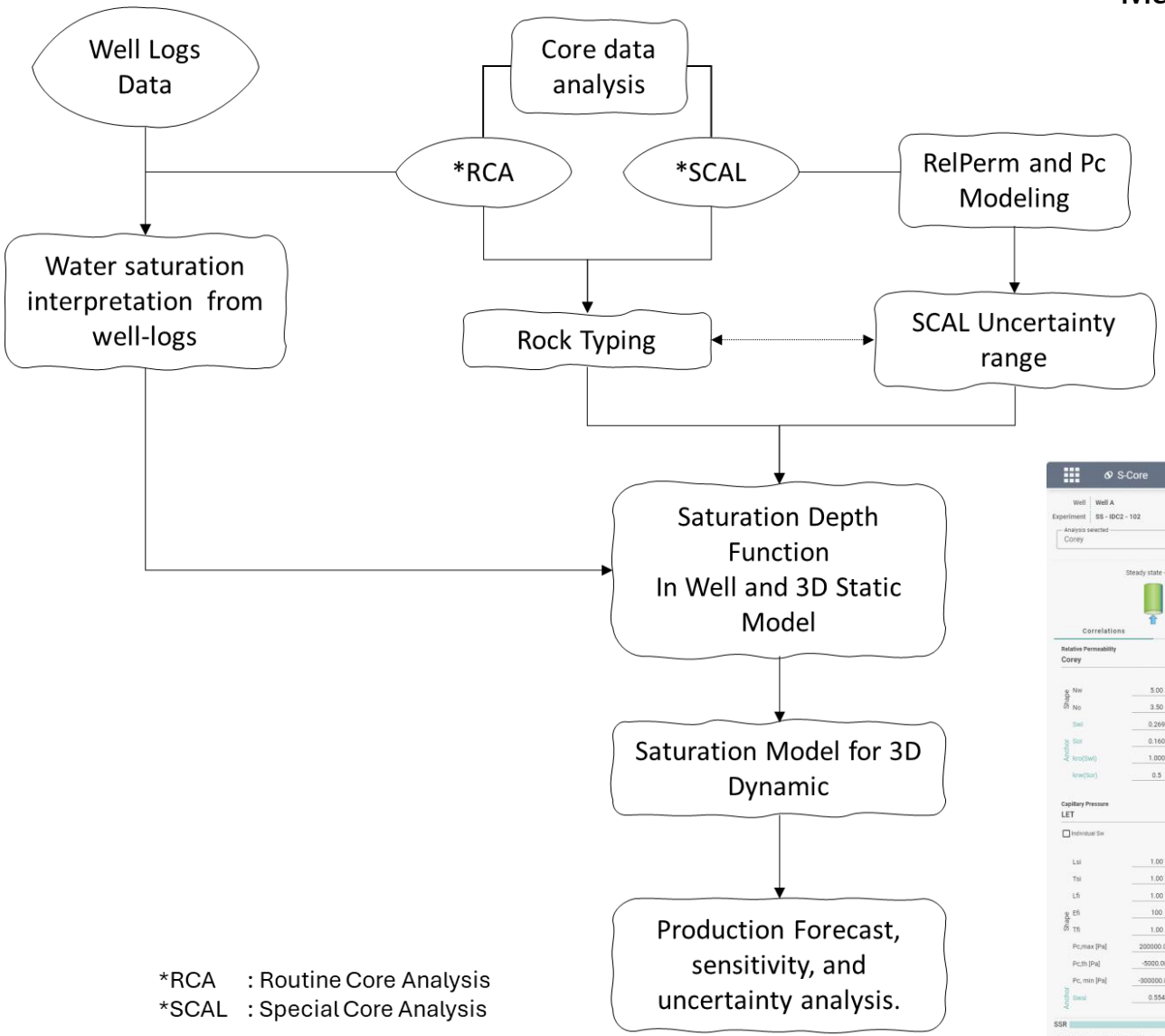
- Integrate SCAL (Special Core Analysis) studies and rock typing to enhance the reservoir saturation model.
- Implement a streamline-based workflow to establish a robust core-to-field solution.



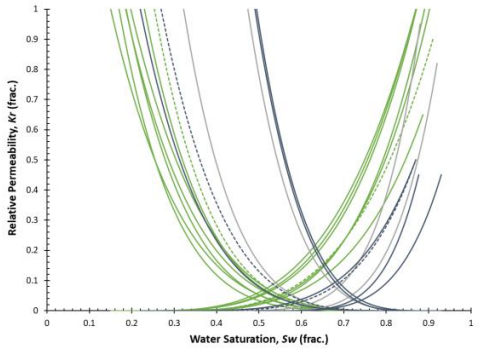
Prores

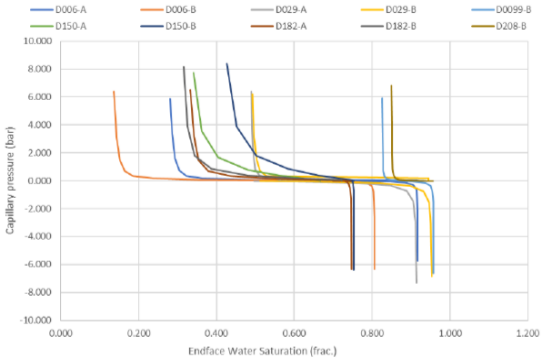
Case Study Workflow

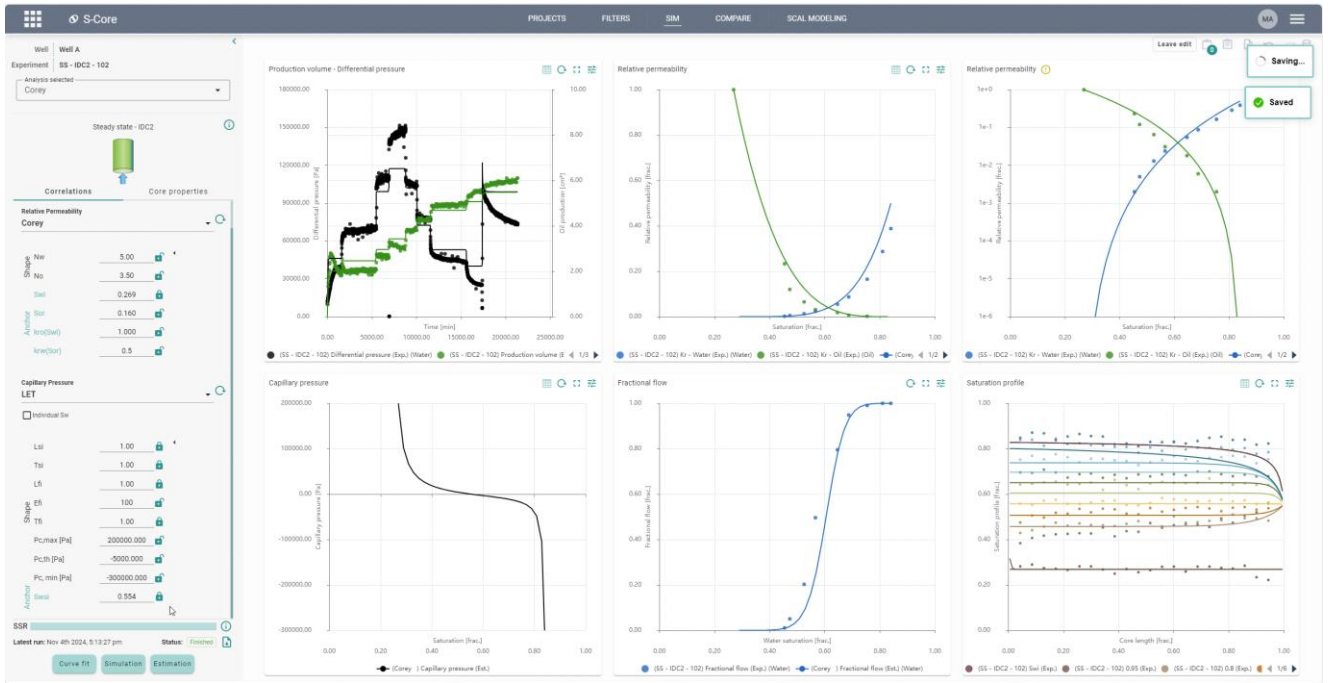
Maximizing SCAL and RCA data to enhance reserves uncertainty evaluation through SCAL Model and Rock Typing



*RCA : Routine Core Analysis
*SCAL : Special Core Analysis



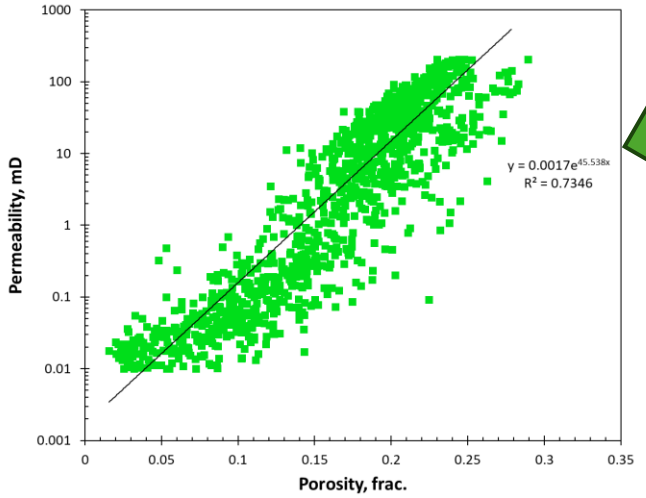




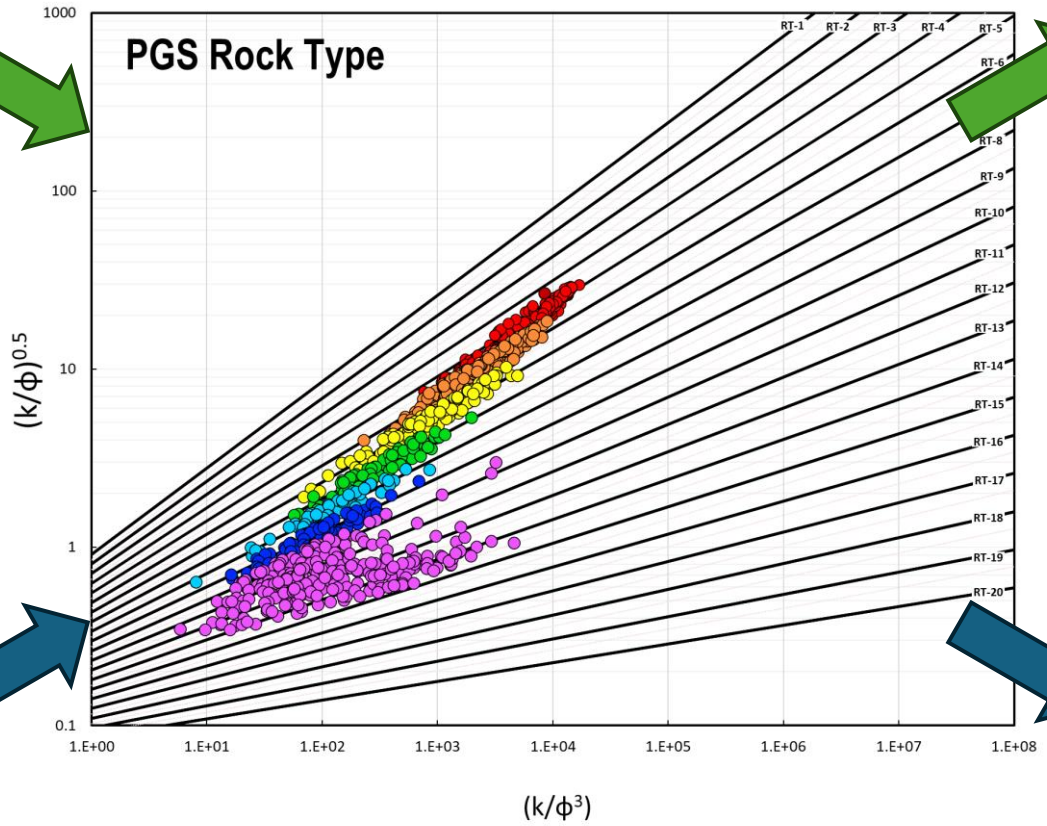
Prores

Rock Typing Results

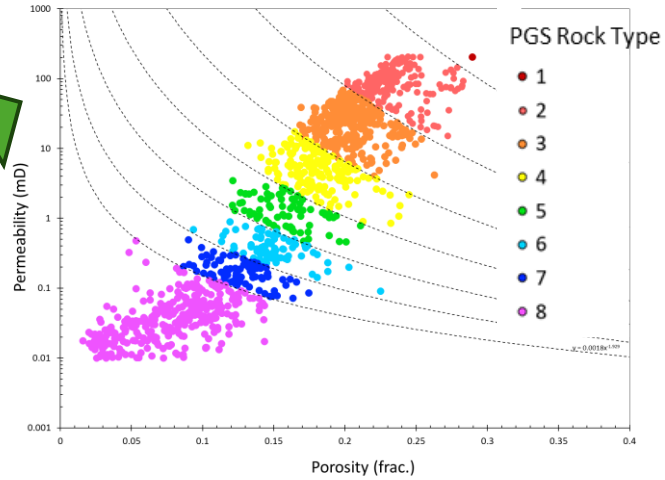
(a_0) Porosity vs. Permeability



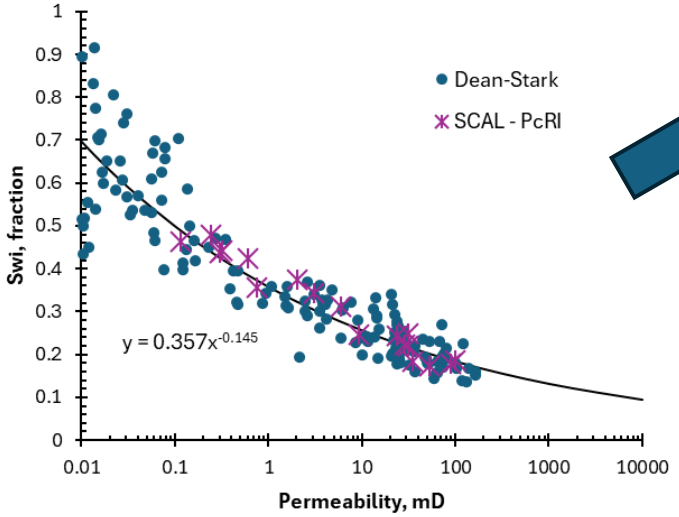
PGS Rock Typing Plot



(a_1) Por. vs. Perm. – After RT

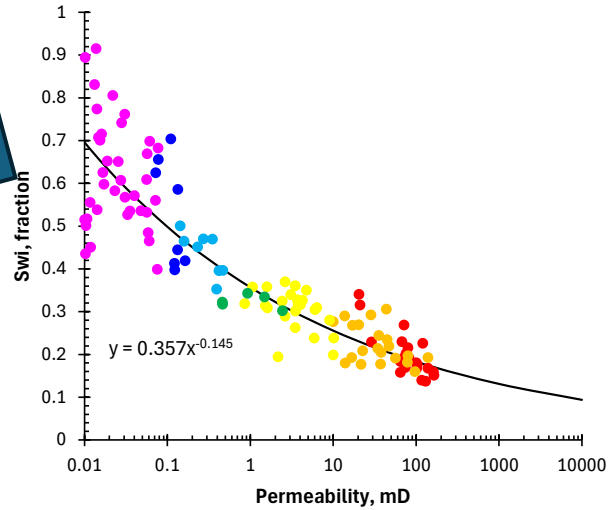


(b_0) Swi vs. Permeability



8 (eight) Rock Groups are established

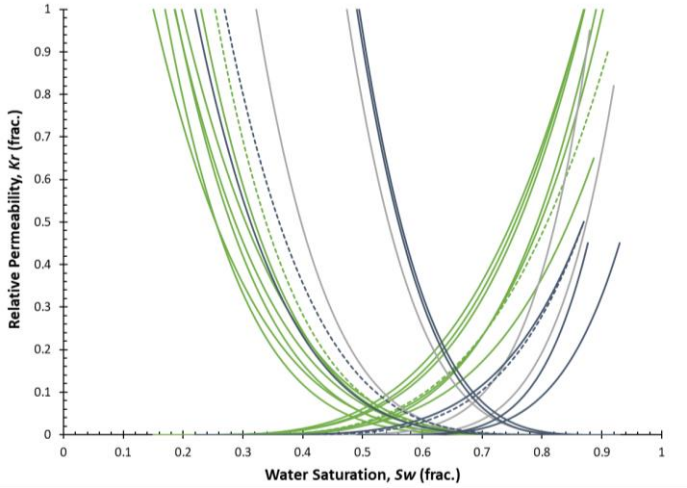
(b_1) Swi vs. Perm. – After RT



Prores

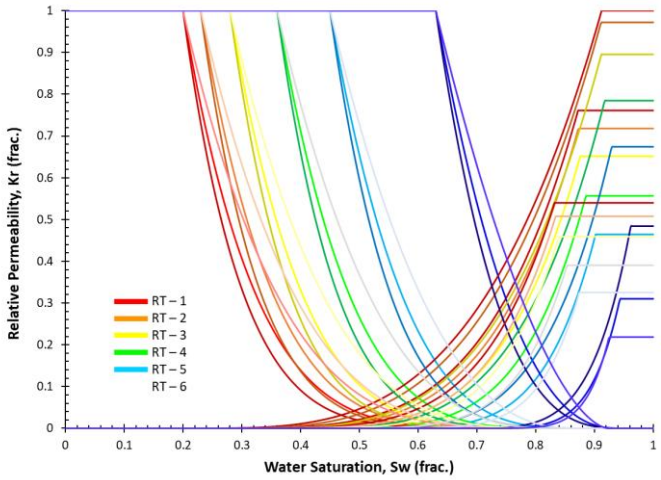
SCAL Modeling Results

- Kr Data from experiments



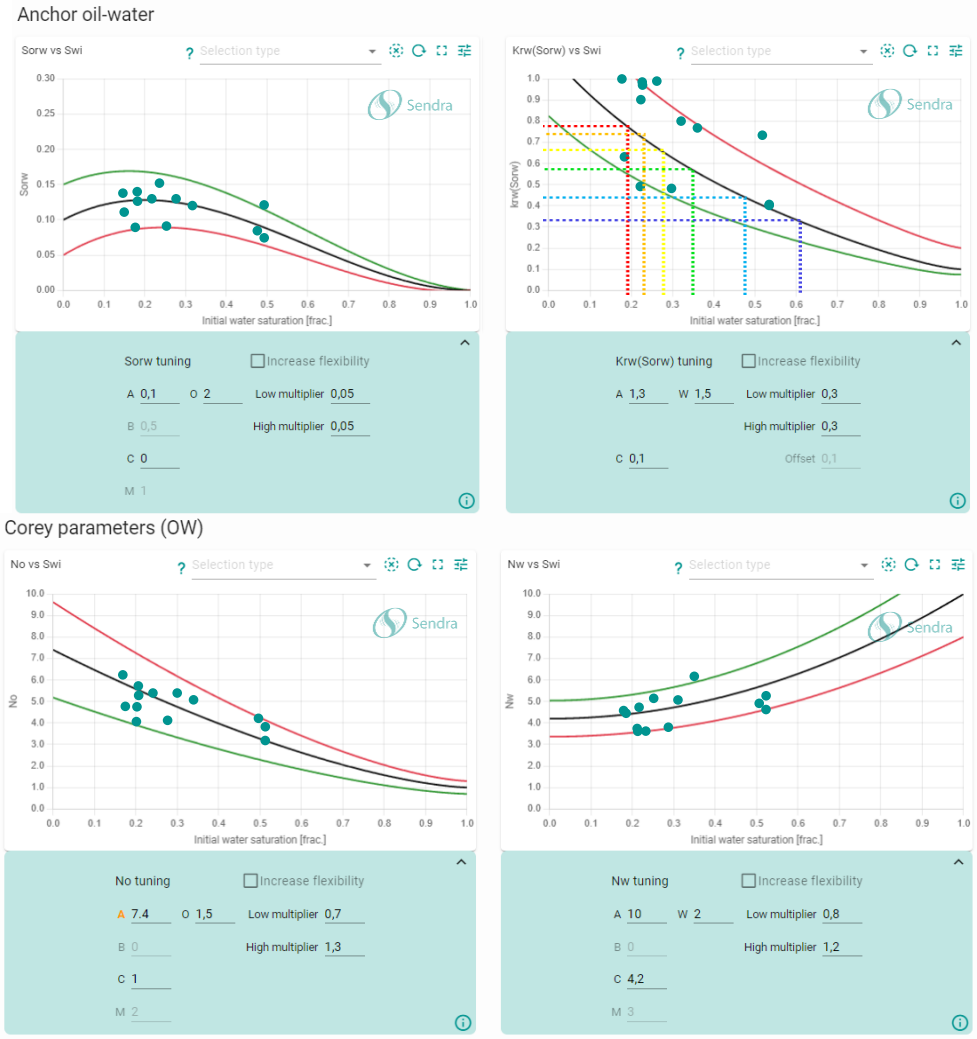
Corey Parameters
Swi, Sorw, Kr-end, no, nw

- Kr after SCAL modeling and PGS Rock Typing



Establish new Kr
from SCAL model
In each rock type

- Parameterized Corey Kr are then plotted on the SCAL modeling curve, plotted against Swi in each parameter.

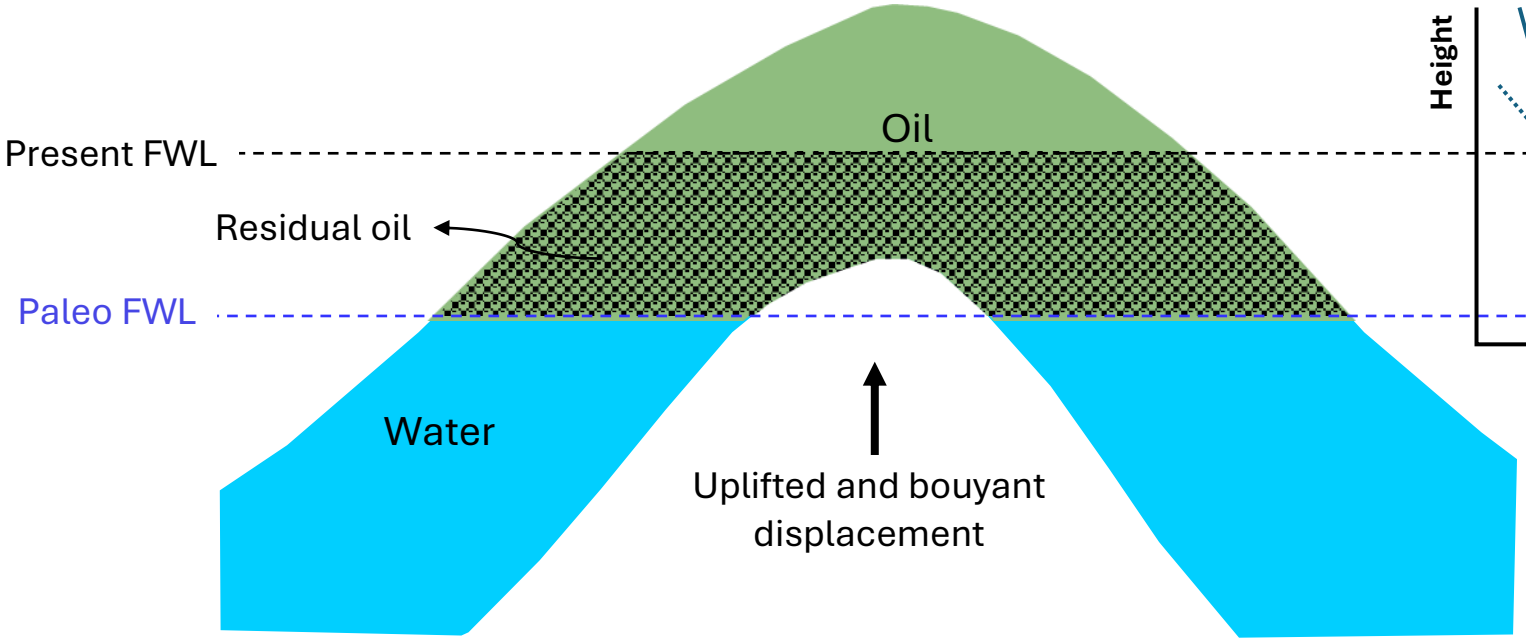


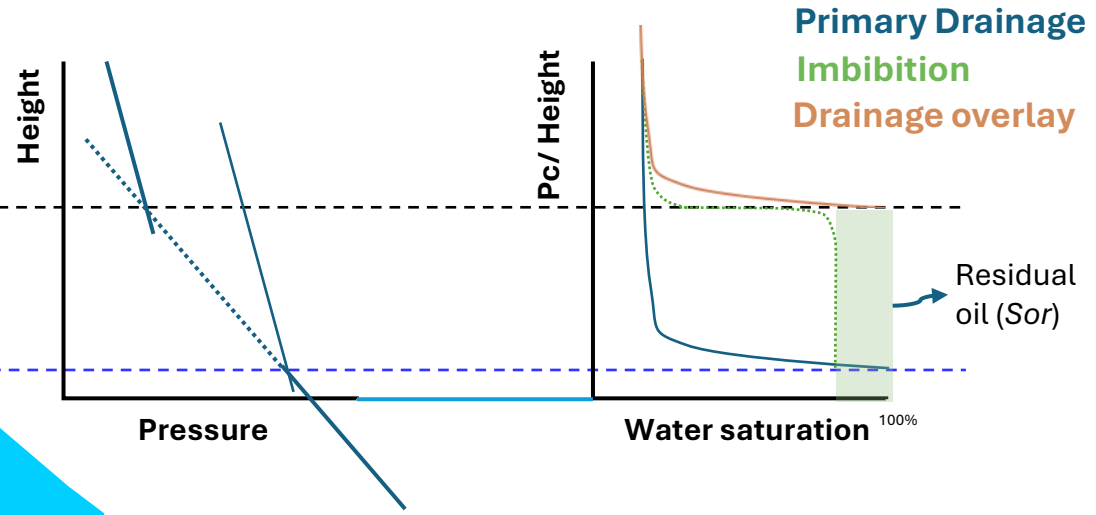
Akbar, M.N.A., Putra, A., and Reppert, M.G., 2024, A Versatile Workflow of Pore Geometry-Structure Rock Typing and Corey Parameter-Based Relative Permeability Trend Modeling, Paper SCA2024-1026 presented at the Society of Core Analysts, Fredericton, NB, Canada, 25–30 August.

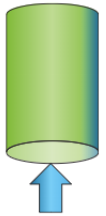
Prores

Paleo-Oil Conceptual Models

Overestimation with drainage Pc in the transition zone with present-FWL







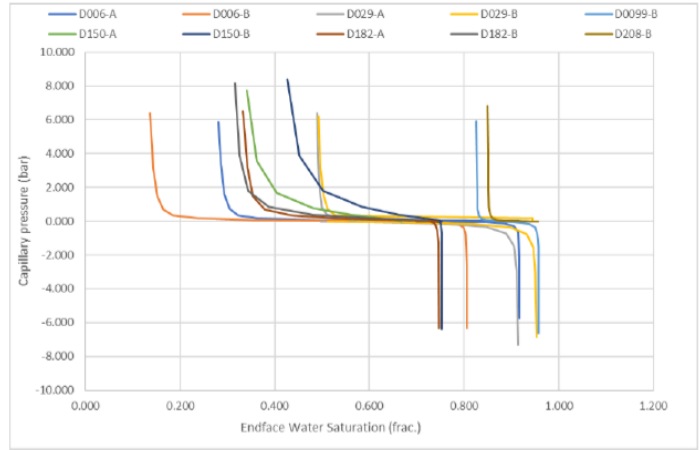


Figure 1.2 Capillary pressure curves – clean state

Akbar, Muhammad Nur Ali, Reppert, Matthew Guy, and Ardian Pradhana Putra. "Modeling Oil Saturation Below a Present-Day Free Water Level and its Impact on Reserves Uncertainty: An Integrated Approach Using Logs, PGS Rock Typing, SCAL Modeling and Saturation Depth Function." Paper presented at the SPWLA 66th Annual Logging Symposium, Dubai, UAE, May 2025

Prores

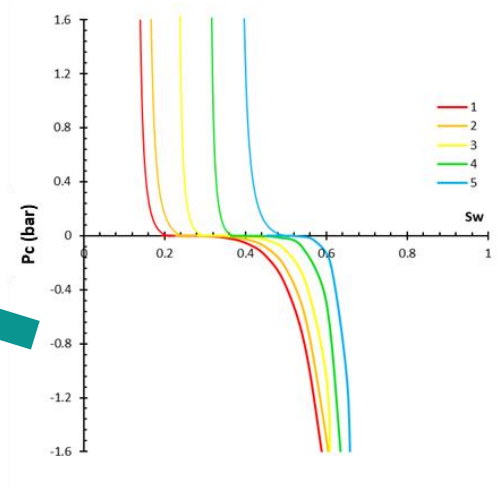
Water Saturation Model Workflow

Each rock type has its own water saturation functions

Define the
PGS Rock Type

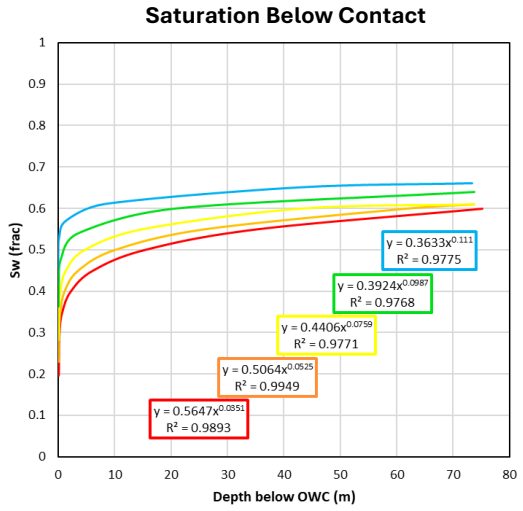
Calculated
Depth Below Contact

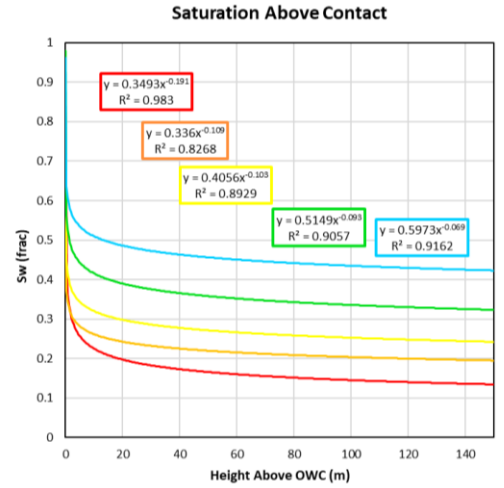
Saturation
Depth Function (SDF)
In each RT



Calculated
Height Above Contact

Saturation
Height Function (SHF)
In each RT

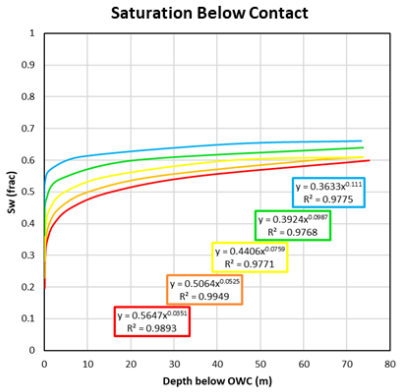




Merge The Saturation
And limit the depth Uncertainty

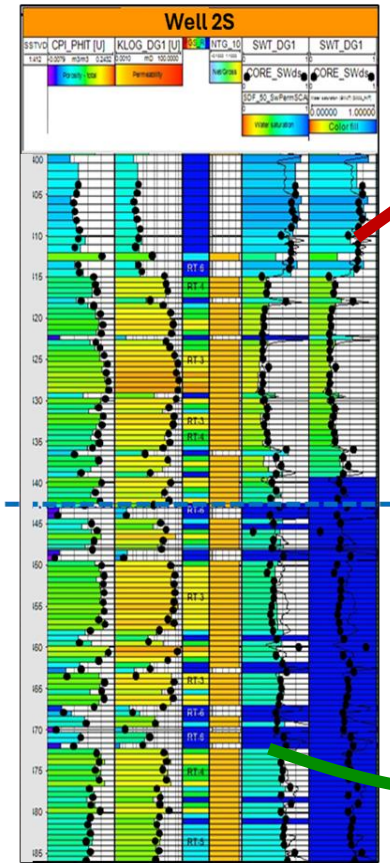
Calculate the
IOIP Volume + Uncertainty

Comparison of Different Sw Model



Saturation 'Depth' Function (SDF)

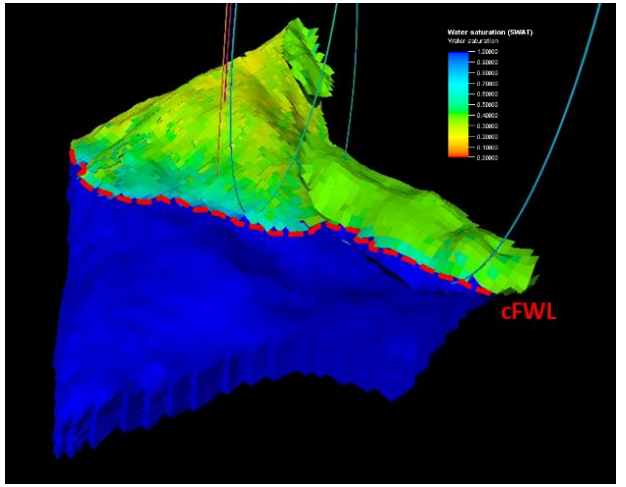
Saturation below present FWL is calculated based on *Pc*-Imbibition curves by converting *Pc* to depth function in each rock type.



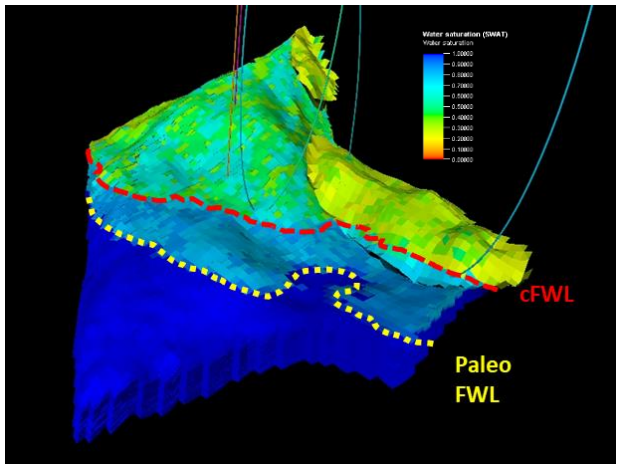
Drainage Only model (No Paleo Oil Zone)

Drainage + Imbibition Model (with Paleo Oil Zone)

Previous Sw Model based on Drainage Pc (No Paleo Oil Zone)

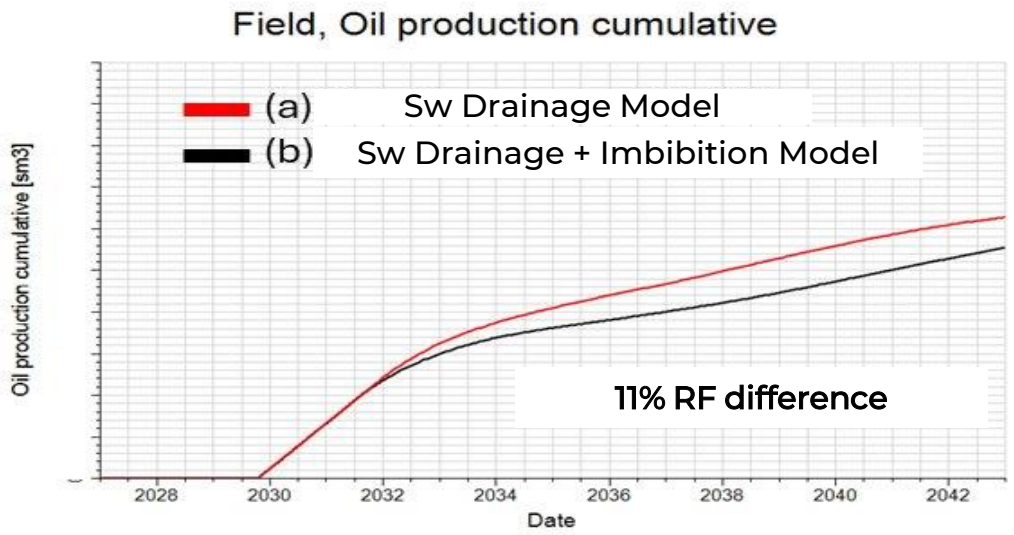


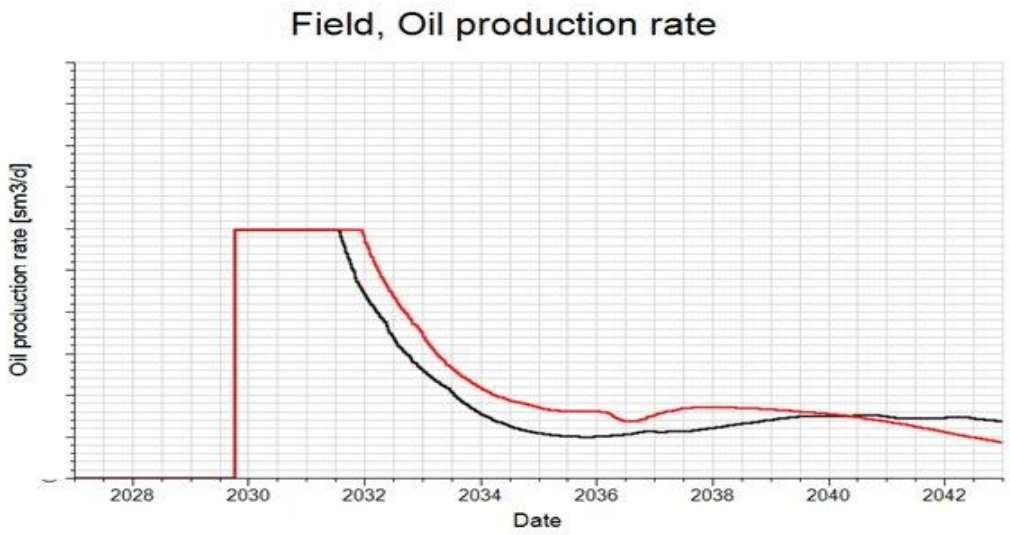
New Sw model based on Drainage + Imbibition (Paleo Oil Zone) by Integrating RT, SHF, and SDF

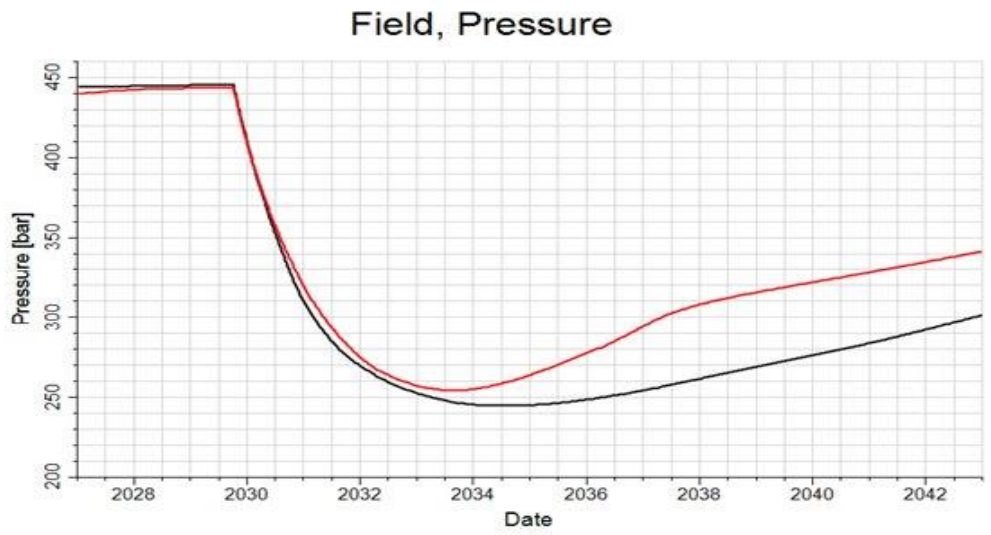


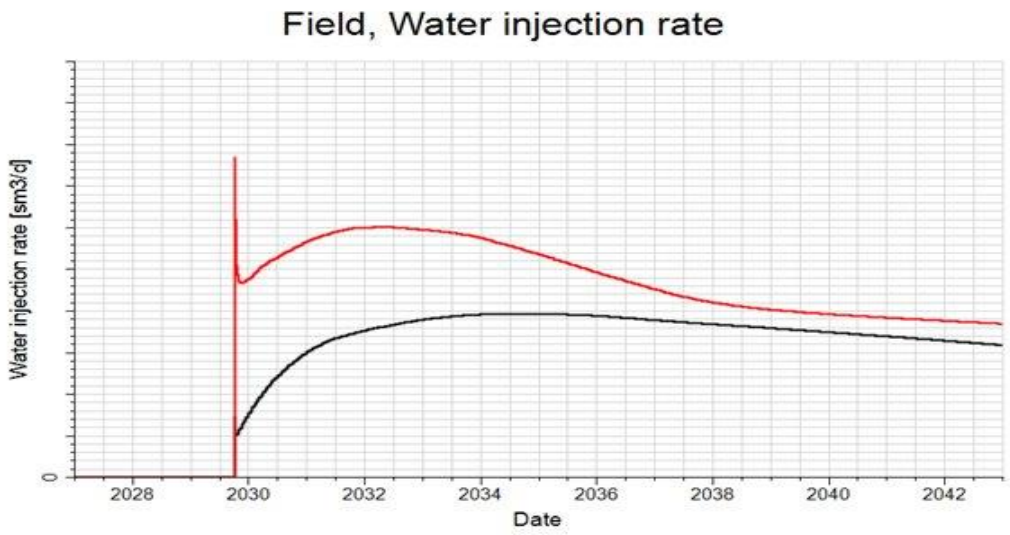
vår energi

Difference in Recovery Factor





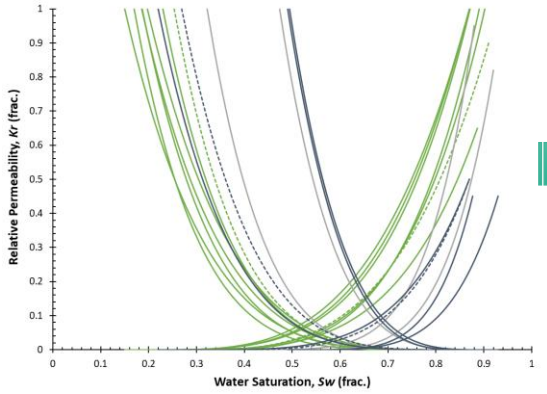




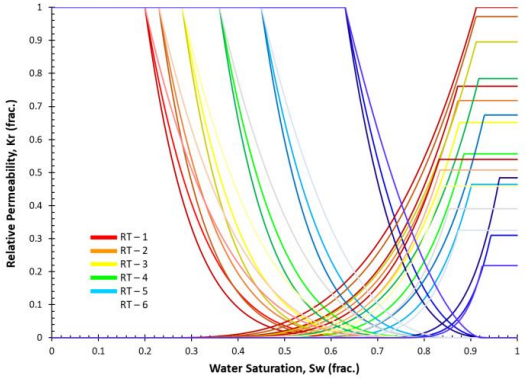
vår energi

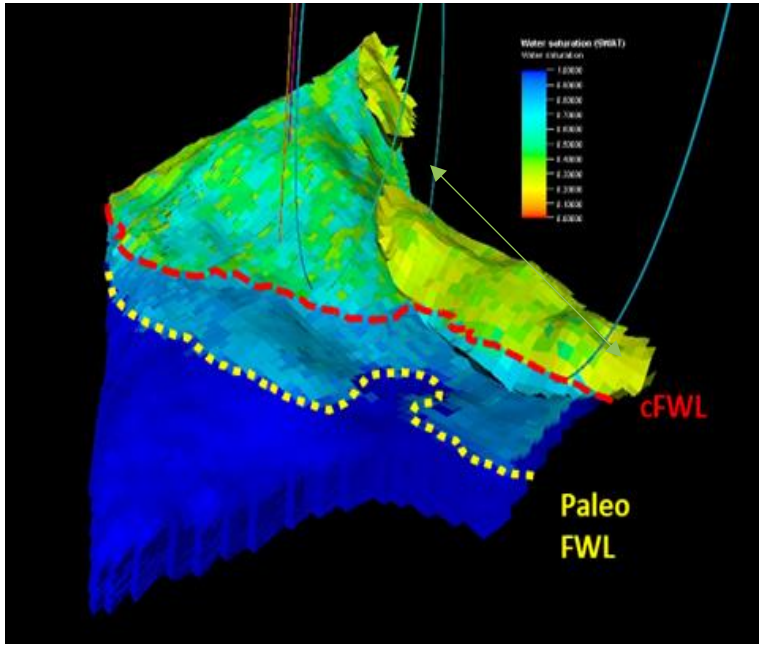
Reducing Uncertainty with Rock Typing

- Kr Data **from experiments**

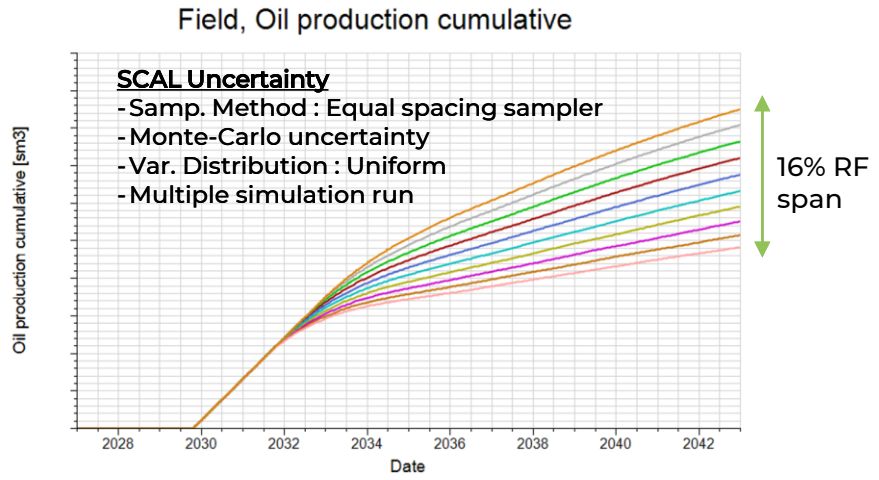


- Kr after **SCAL modeling and PGS Rock Typing**

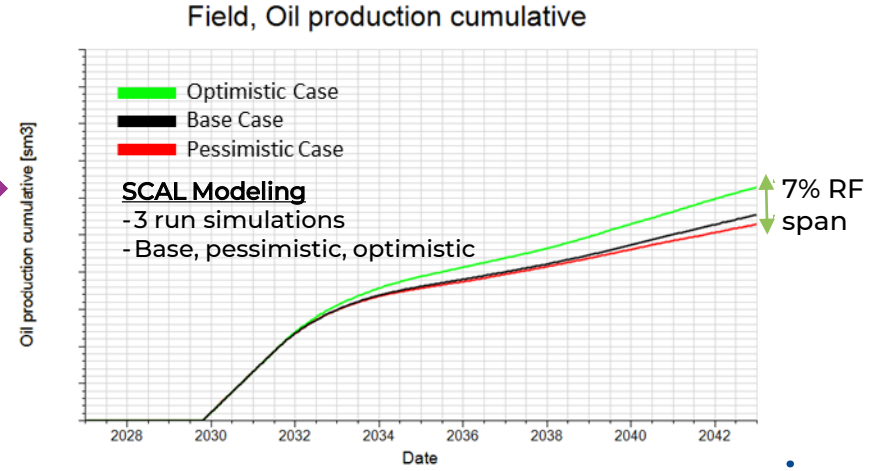




Uncertainty Analysis with Direct Kr Input



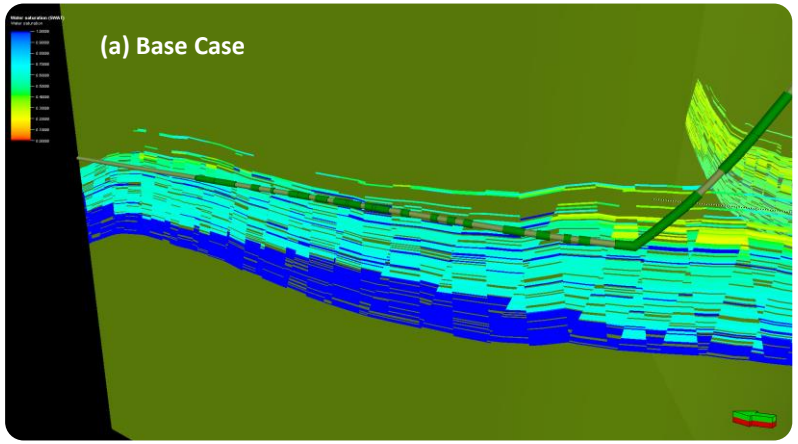
Uncertainty Analysis with SCAL Modeling & Rock Typing

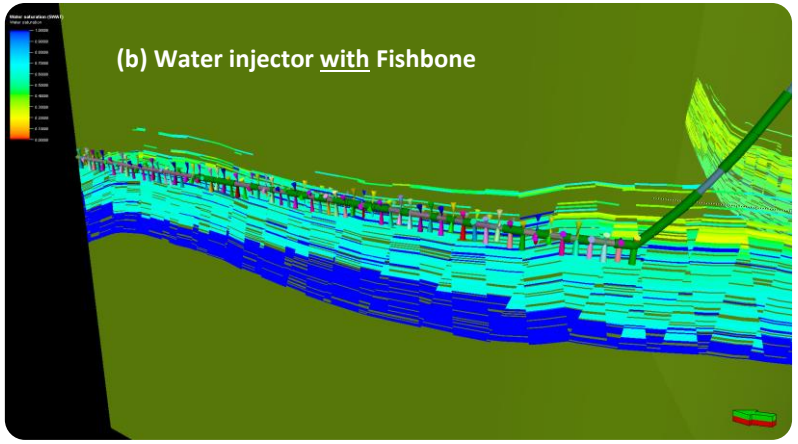


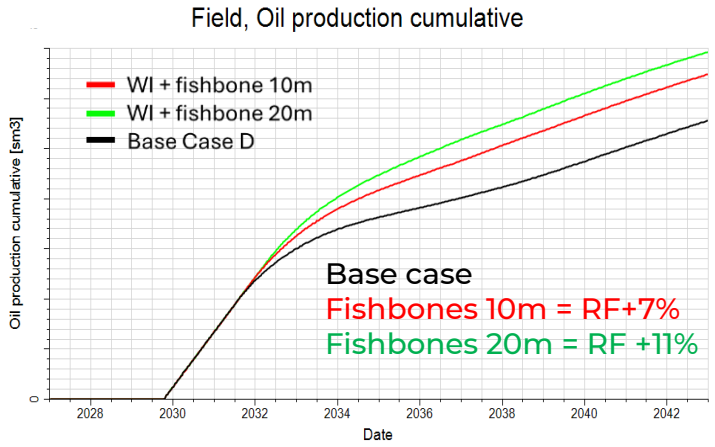
var energi

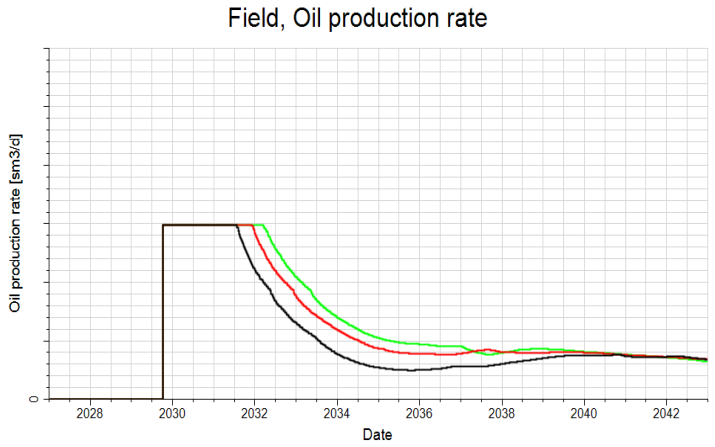
Unlocking Opportunity to Enhance Decision Quality

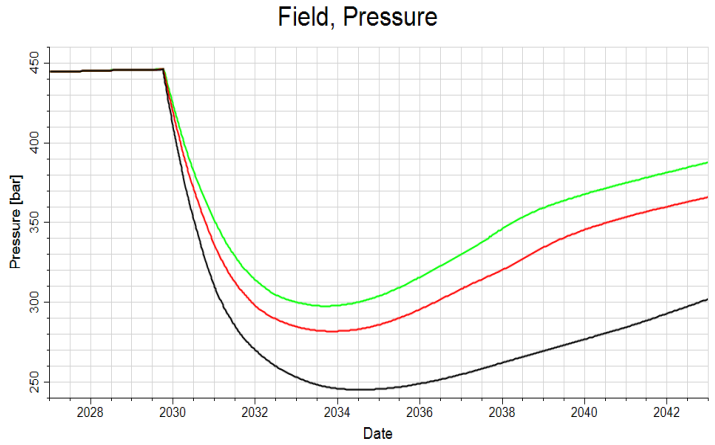
Sensitivity Study using Production Technology to Improve Injectivity

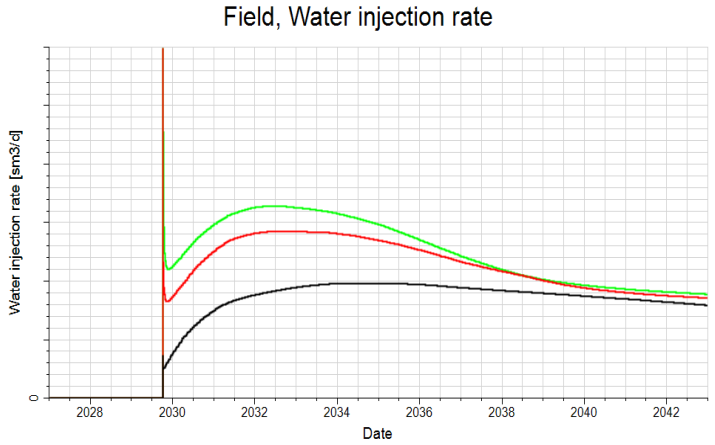












RF of New Sw Model with Paleo Oil Zone is improved by 7-11% with Fishbones

vår energi

Conclusion

- A robust SCAL database, integrated with well logs and other data, is essential for consistent and reliable reservoir simulation to support confident decision-making
- Implementing workflows like PGS rock typing with Corey-based SCAL modeling helps in resolving complex challenges, including paleo oil zone characterization
- SCAL modeling is important in quantifying subsurface uncertainty and uncovering opportunities to optimize field development strategies