Rock Typing

Quantified the Reservoir Heterogeneity from Core to Fieldwide Approach

FESM

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Objectives

→ Rock Typing Refreshment

→ Demonstrate the workflow from core analysis to field-scale permeability prediction in clastic reservoirs

→ Integrate core and log data for enhance reservoir properties prediction

Outline

→Rock Type Overview

→Predictive Rock Type from core data

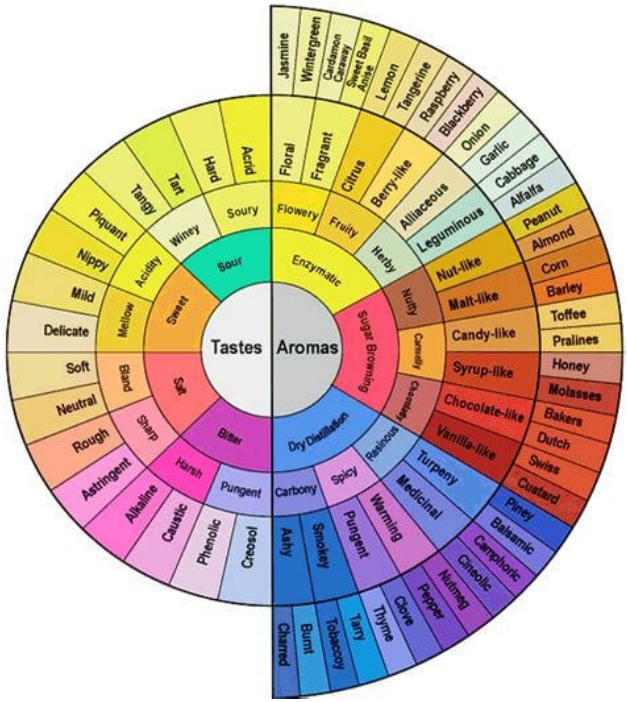
→Permeability calculation at un-cored wells

Icebreaker: What's Your Coffee Type?

What's your go-to coffee order?

How is it made?

What does it taste like?



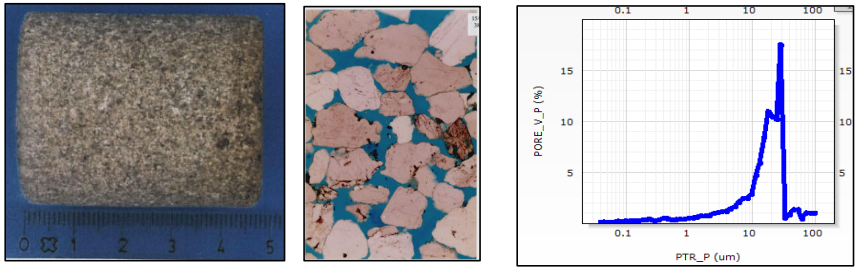
Different coffee brewing methods result in different flavors and textures, different rock types are formed through various geological processes, leading to unique reservoir properties

What is your rock…?

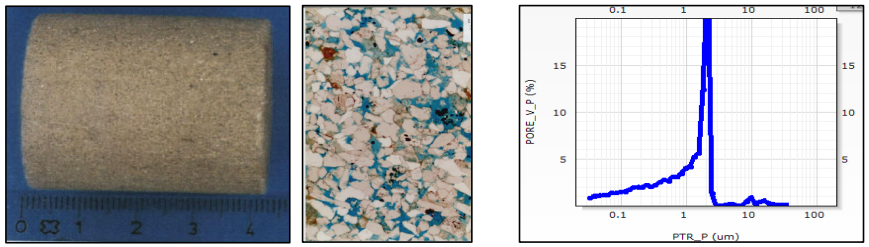
https://www.sciencefacts.net/sedimentary-rocks.html

- → Defined by facies
- → Texture
  - → Grain Size
  - → Sorting
  - → Rounding
- → Mineralogy Composition

Deposition Environment….?



Grey, coarse-grained sandstone, dominated by quartz.
Φ = 0.24 frac; K = 500 mD; Swirr = 0.1 frac.;PTR = 25.5 microns



Light grey, fine-grained sandstone. Muscovite & small amounts of pyrite and biotite.
Φ = 0.18 frac; K = 50 mD; Swirr = 0.2 frac.; PTR= 2.1 microns

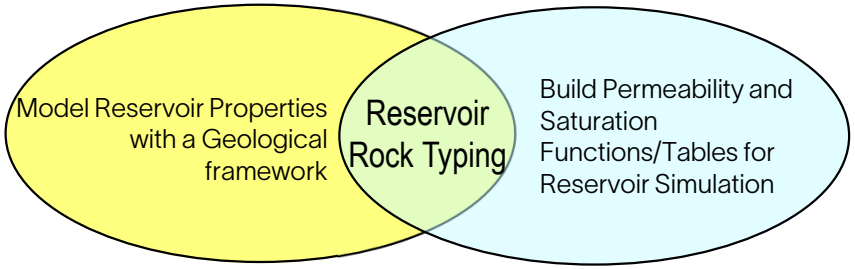
Elastic properties: Poisson ratio, Young modulus, Lambda, Mu…etc..?

What is Rock Typing?

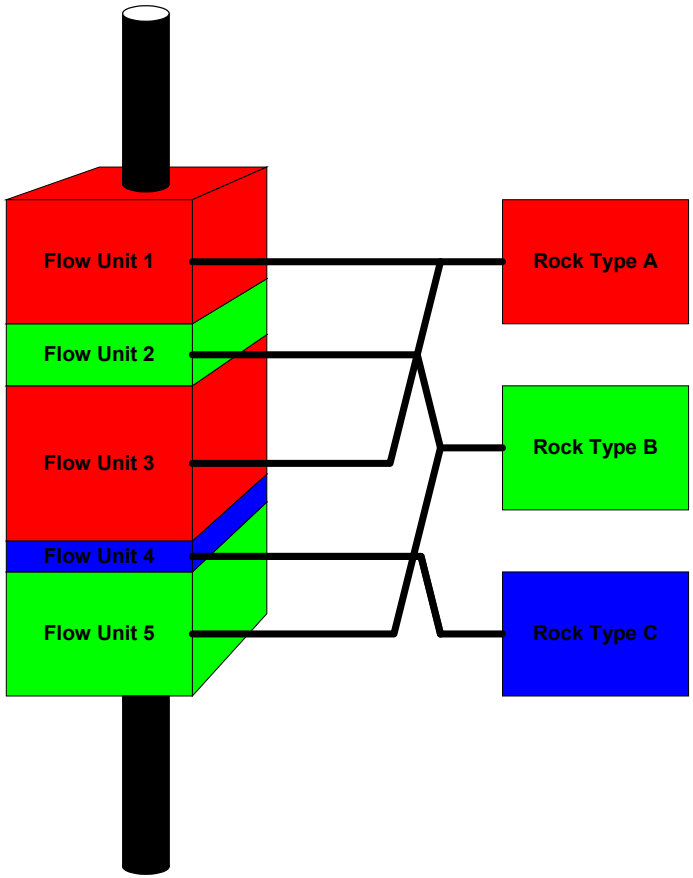
- G.E. Archie, *Introduction to Petrophysics of Reservoir Rocks*, 1950
  - Unique correlation between petrophysical properties of rock units.
  - Rock units share similar geological conditions and diagenetic processes.

- Gunter, Finneran, Hartmann, and Miller, 1997
  - Rock types are defined by similar deposition and diagenetic processes.
  - Unique porosity-permeability, capillary pressure, and water saturation relationships

- Reservoir Rock Types need to address two aspects of the reservoir models (3D)

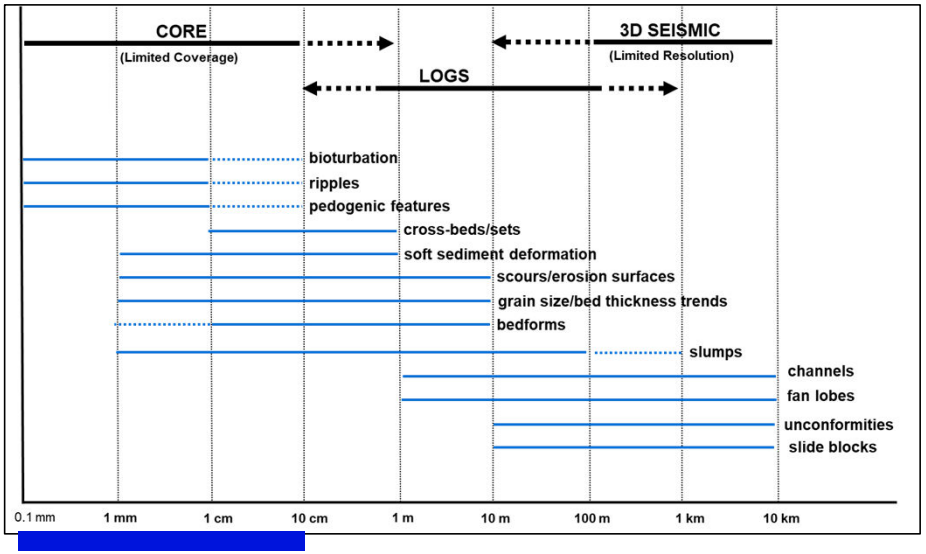


Rock Types - Flow Units

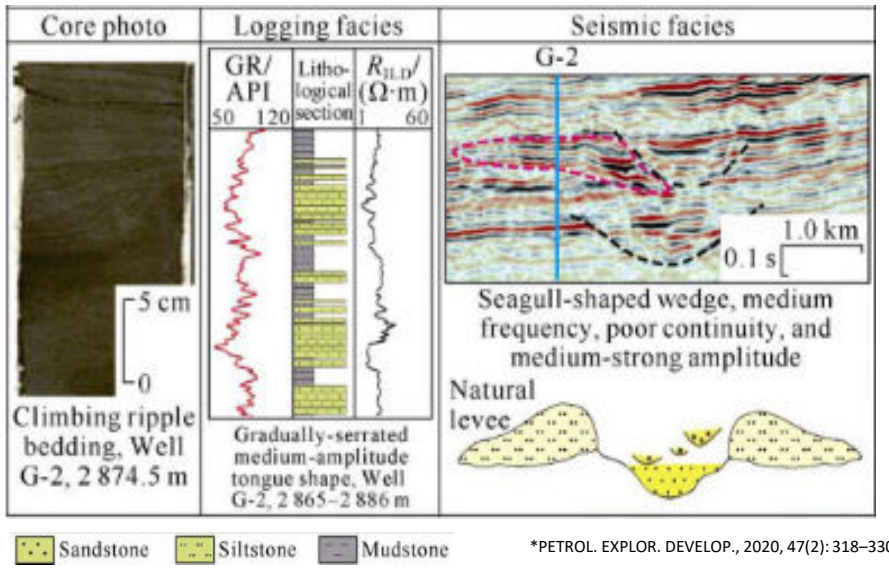


- W.J.Ebanks,Jr
  - Flow unit-Reservoir rock with consistent properties affecting fluid flow, distinct from other volumes.
  - Discrete zone, continuous laterally and vertically, with a single rock type.
- Flow unit: A discrete, continuous reservoir zone composed of a single rock type

Various Data Scale



- Winland R35
- Pittman R10-R70
- Aguilera R35
- Flow Zone Indicator (FZI)
- Reservoir Quality Indicator (RQI)
- K-PHI Ratio
- Etc...



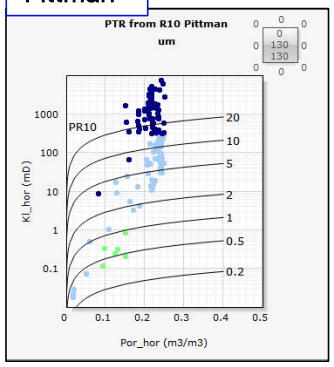
*PETROL. EXPLOR. DEVELOP., 2020, 47(2): 318–330

Rock typing is Anybody can do rock typing and will opine even if they can't!

- Core description driven (Geological Rock types)
- MICP/Poro-Perm driven (Petrophysical Rock types)
- Electrofacies driven (Deterministic/Statistical)

Core Based Rock Typing – Predictive Methods

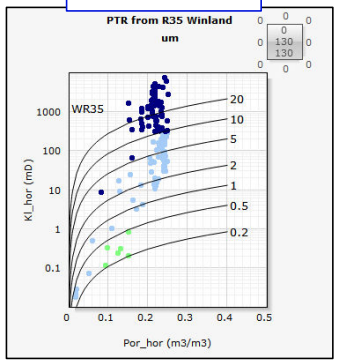
Pittman



Equations	Correlation Coefficient
Log r_{10} = 0.459 + 0.500 Log K - 0.385 Log Ø*	0.901
Log r_{15} = 0.333 + 0.509 Log K - 0.344 Log Ø*	0.919
Log r_{20} = 0.218 + 0.519 Log K - 0.303 Log Ø*	0.926
Log r_{25} = 0.204 + 0.531 Log K - 0.350 Log Ø*	0.926
Log r_{30} = 0.215 + 0.547 Log K - 0.420 Log Ø*	0.923
Log r_{35} = 0.255 + 0.565 Log K - 0.523 Log Ø*	0.918
Log r_{40} = 0.360 + 0.582 Log K - 0.680 Log Ø	0.918
Log r_{45} = 0.609 + 0.608 Log K - 0.974 Log Ø	0.913
Log r_{50} = 0.778 + 0.626 Log K - 1.205 Log Ø	0.908
Log r_{55} = 0.948 + 0.632 Log K -1.426 Log Ø	0.900
Log r_{60} = 1.096 + 0.648 Log K - 1.666 Log Ø	0.893
Log r_{65} = 1.372 + 0.643 Log K - 1.979 Log Ø	0.876
Log r_{70} = 1.664 + 0.627 Log K - 2.314 Log Ø	0.862
Log r_{75} = 1.880 + 0.609 Log K - 2.626 Log Ø	0.820

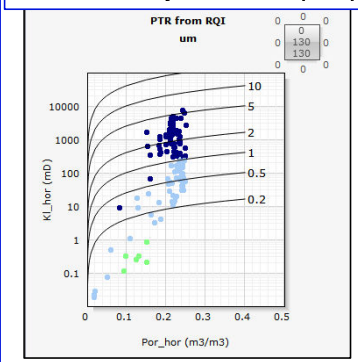
*Ø is statistically insignificant. A regression excluding Ø yields essentially the same result. k = permeability (md) and Ø = porosity (%).

Winland R35



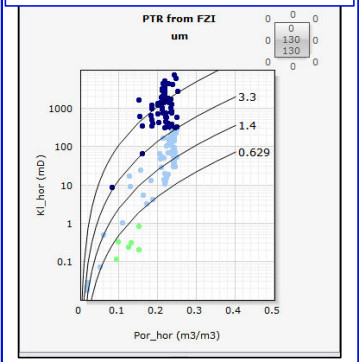
Winland R35=
$10^{0.732+(0.588*log_{10}k)-(0.864*log_{10}(\phi*100))}$

Rock Quality Indicator (RQI)



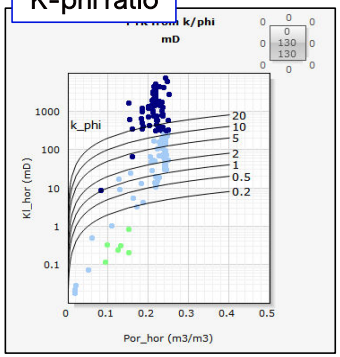
$$RQI = 0.0314 * (\frac{k}{\phi})^{0.5}$$

Flow Zone Indicator (FZI)



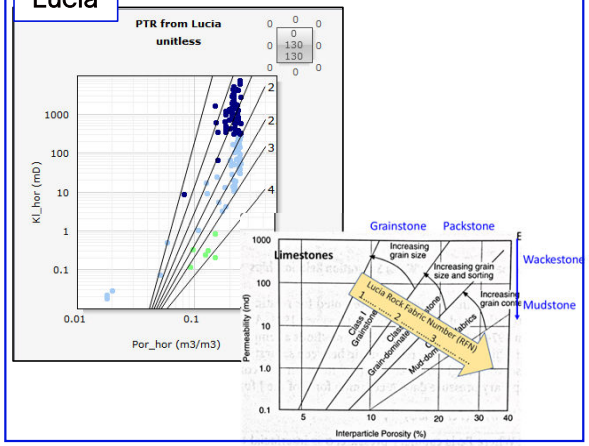
$$FZI = \frac{RQI}{PhiZ}, PhiZ = \frac{\phi}{1-\phi}$$

K-phi ratio

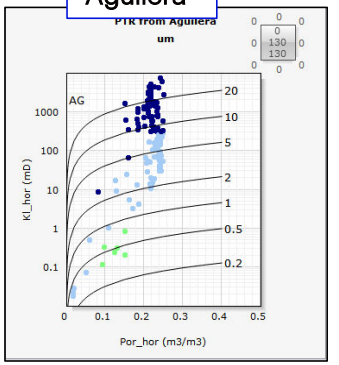


$$\frac{k}{\phi} ratio = \frac{k}{\phi * 100}$$

Lucia



Aguilera

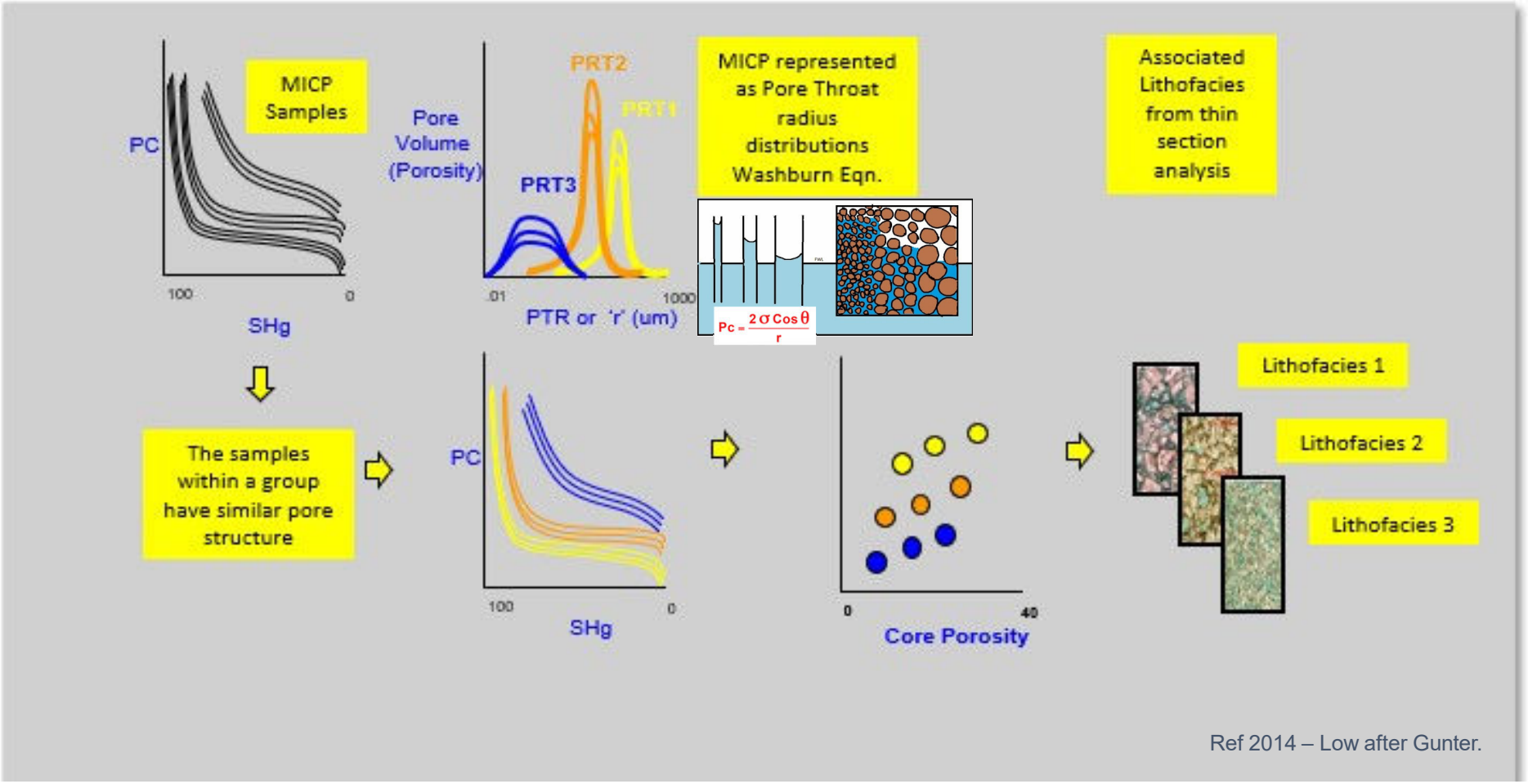


$$r_{p35} = 2.665(\frac{k}{100 * \phi})^{0.45}$$

r: grain size, microns
Φ : porosity, fract

k : permeability, md
Phiz : pore volume to grain volume ratio, frac

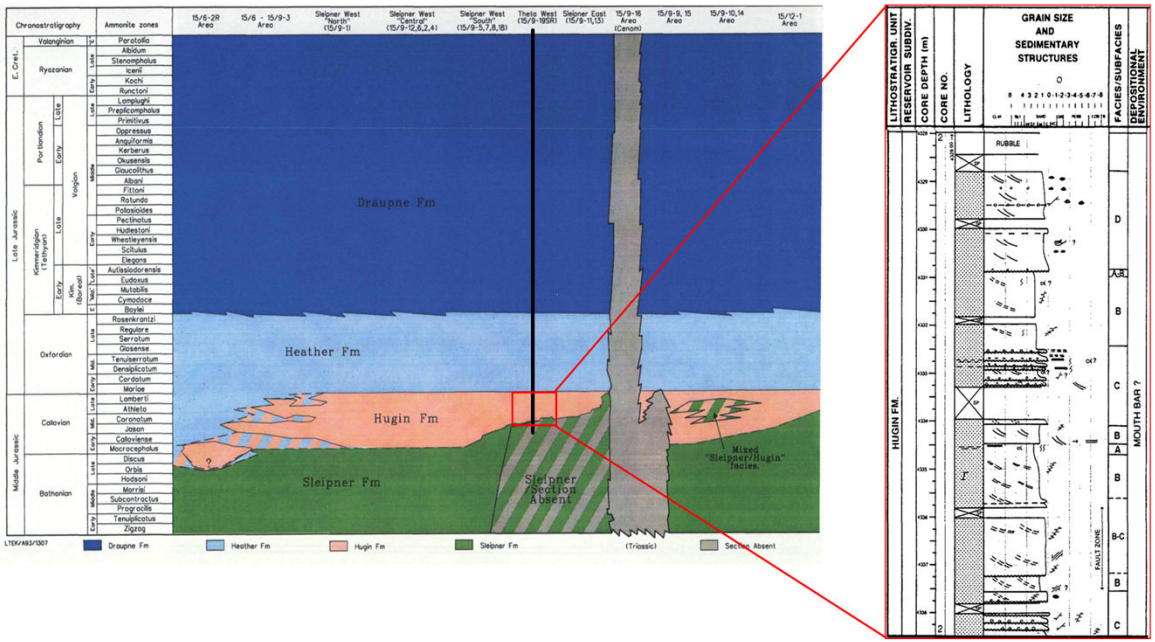
Mercury Injection Capillary Pressure – Pore Throat Size and PRT

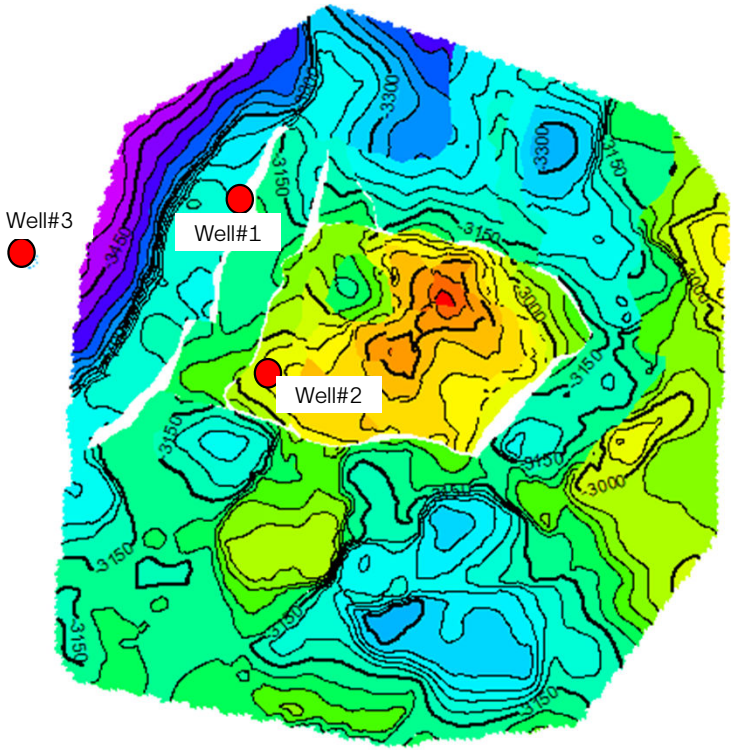


Ref 2014 – Low after Gunter.

- MICP data for distinguishing rock types by pore throat
- Compare MICP PTR with RCA-derived PTRi for classification

Dataset Information: Public Dataset – Volve, Norway

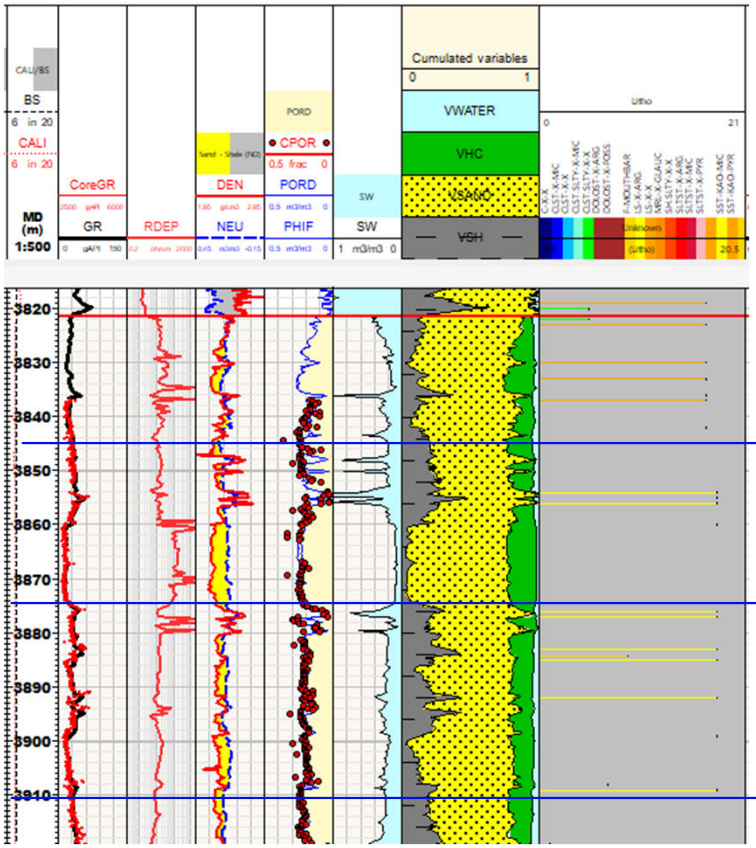




The Hugin Formation in the area consists of shallow marine shoreface, coastal plain/lagoonal, channel, and possibly mouth bar deposits. It is composed of fine- to coarse-grained, well- to poorly-sorted subarkosic arenite sandstones, with quartz content of up to 94% by weight. The formation exhibits good to excellent reservoir properties

- Petrophysics logs (Vsh, Porosity, Sw)
- Core data (RCA, MICP, Petrographic, Lithofacies)

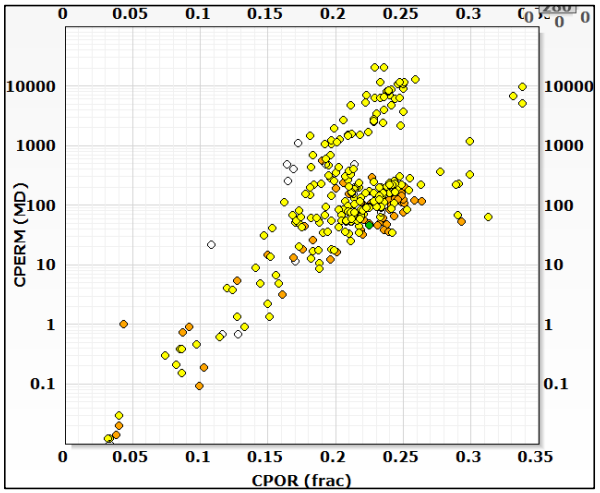
Lithofacies



Light grey, fine-grained sandstone with mica, minor pyrite, biotite (?), clay-rich spots, and possible organic matter. Rusty end surfaces. Well consolidated

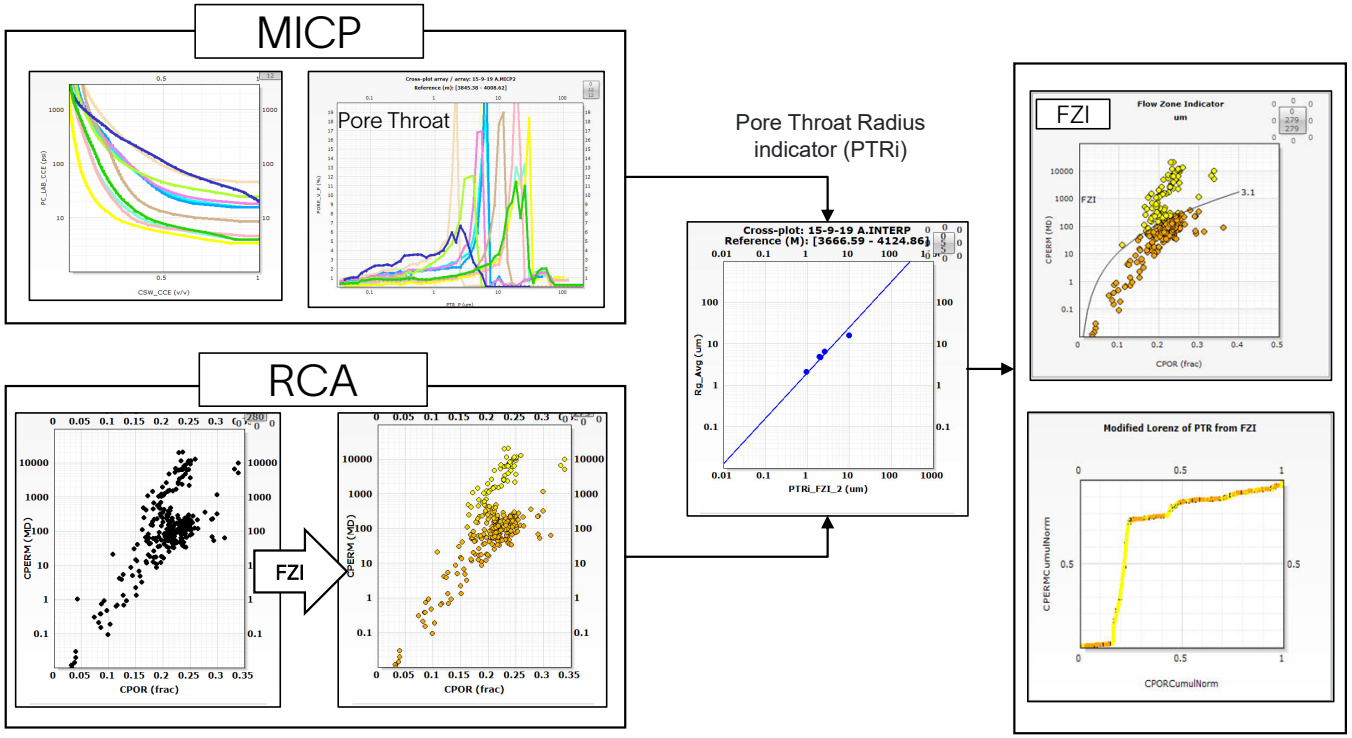
Grey, coarse-grained quartz sandstone with large crystals. Uneven sidewalls. Well consolidated but slightly less than the above sample.

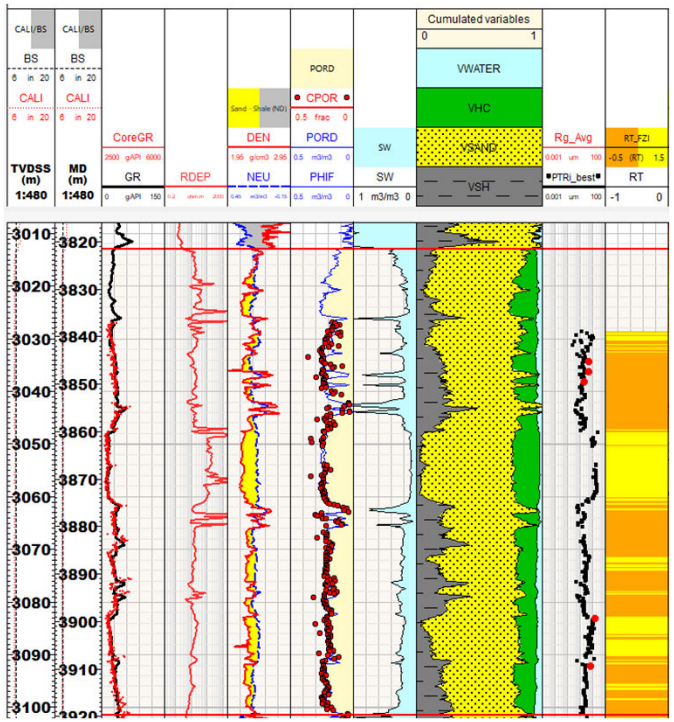
Light grey, fine-grained sandstone with mica, biotite (?), and possible clay spots. Rusty surfaces. Well consolidated



- The samples are predominantly kaolinitic sandstone with some siltstone and claystone.
- Grain size variation in kaolinitic sandstone results in an overlapping trend in the porosity-permeability plot

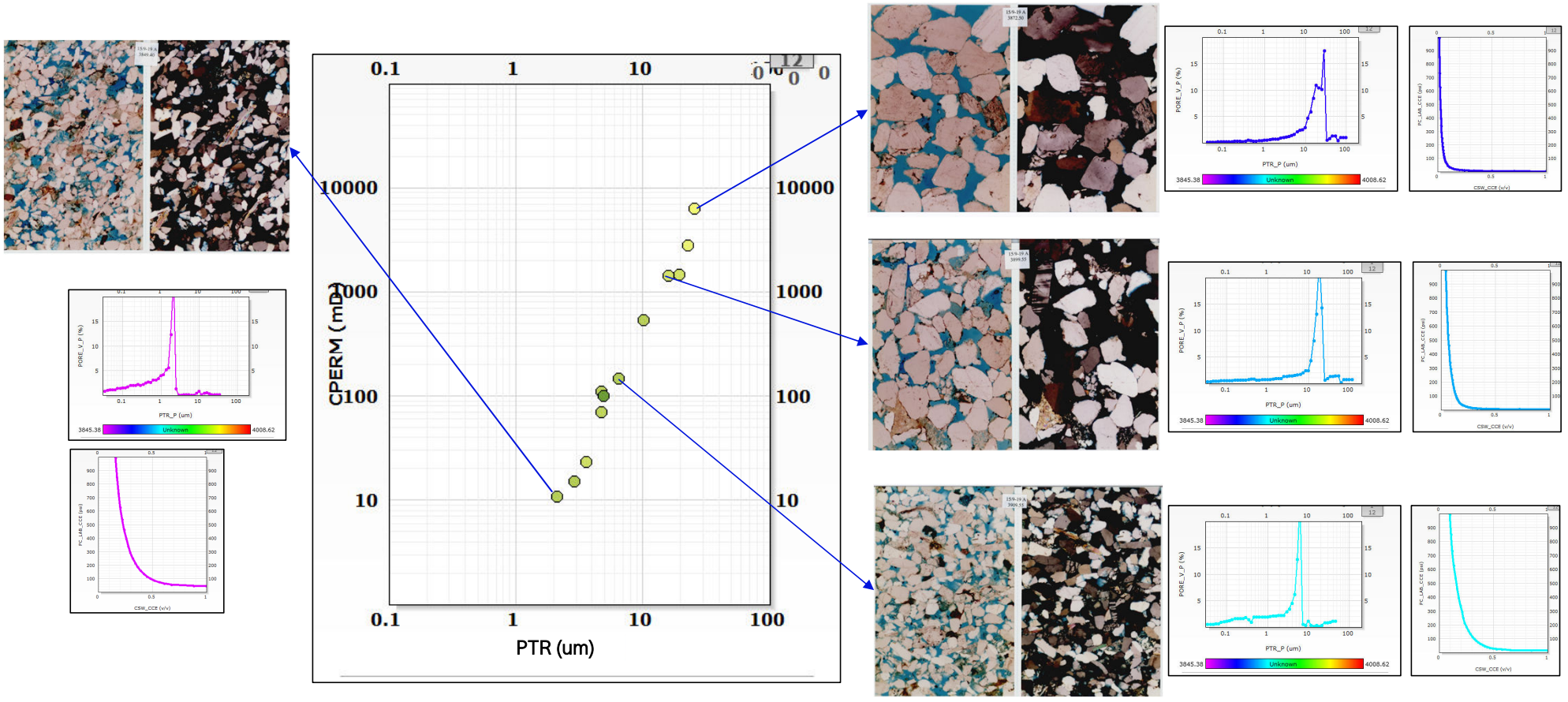
Pore Throat Radius Indicator





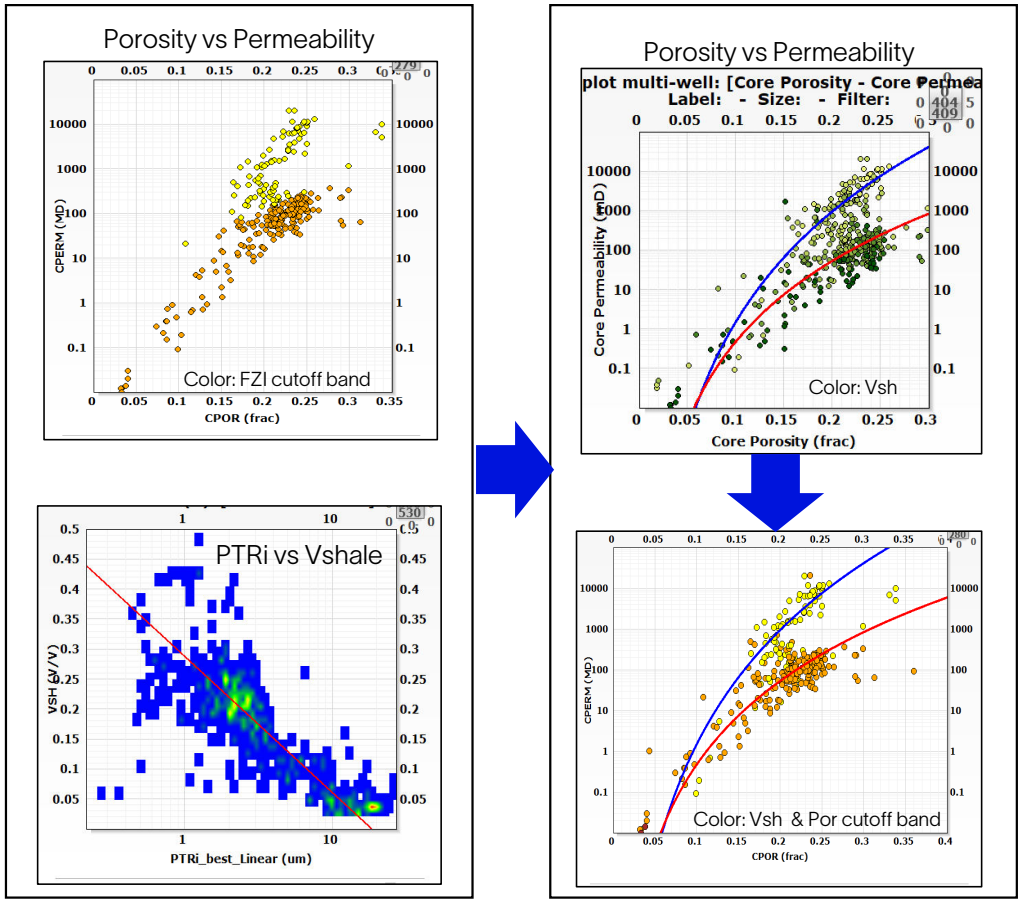
- MICP pore throat size distribution vs. RCA PTRi
- Good correlation between PTR and FZI-derived PTRi for rock type identification

Pore Throat Radius – Grain Size - Permeability



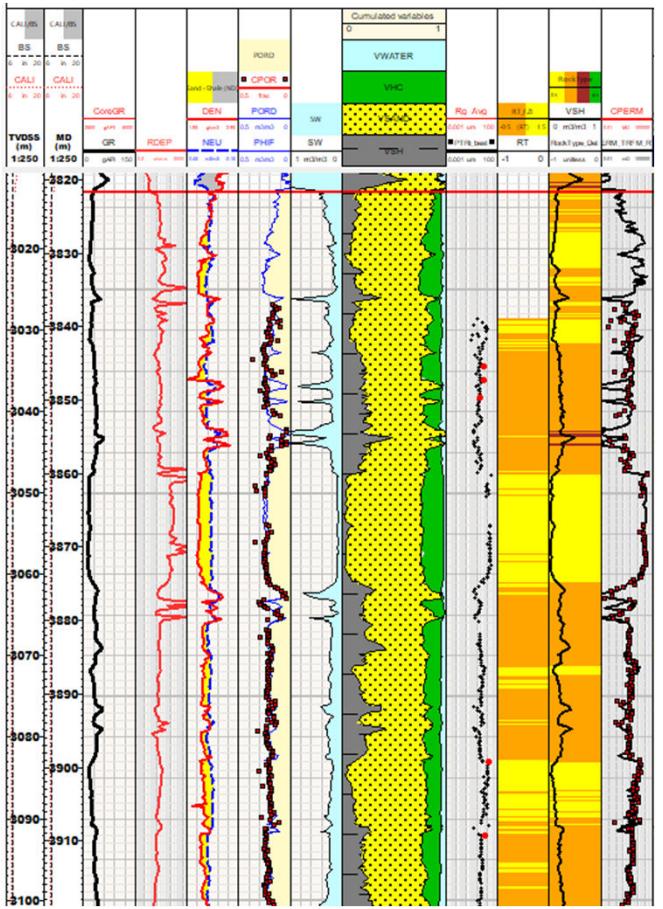
- Larger pore throat radius leads to higher permeability
- Grain size variation correlates with permeability

Permeability Prediction – Cored Wells



- RT1: Vsh<12% & Por>15%
- RT2: 12%<Vsh<20% & 10%Por<15%
- RT3: Vsh>20% & Por<10%

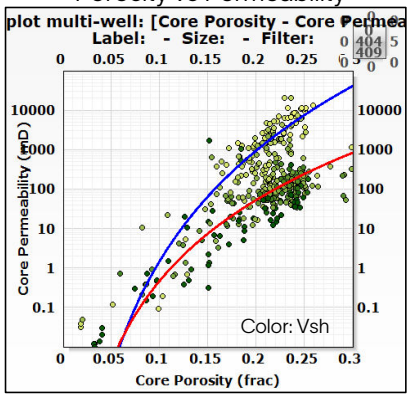
Well#1

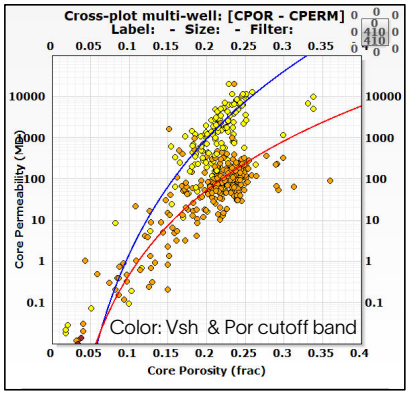


- Predict rock types using FZI, PTRi, and Vshale
- Define porosity-permeability relationships for each rock type

Permeability Prediction – Cored Wells

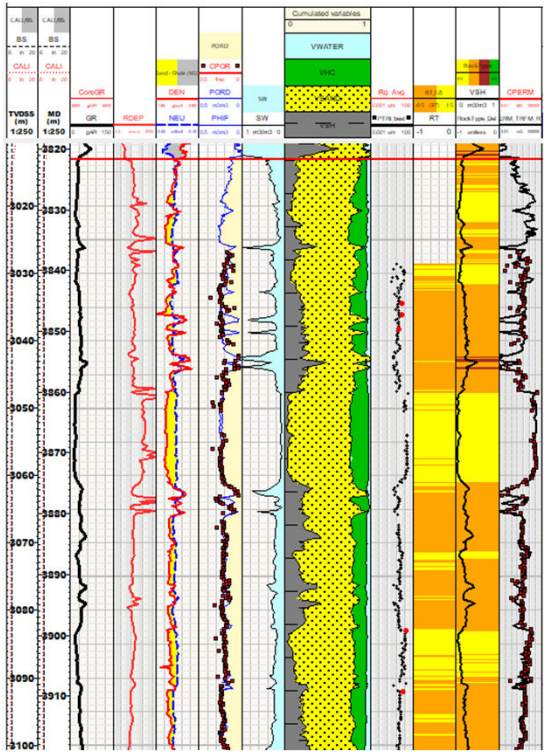
Porosity vs Permeability



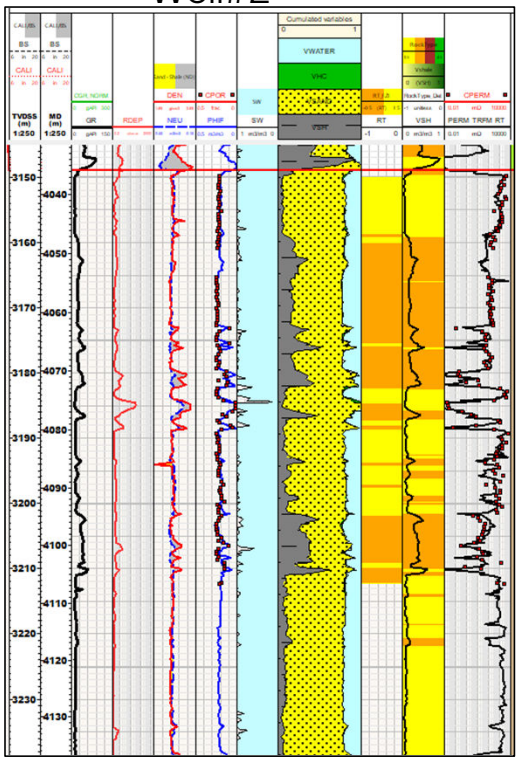


Equations:
RT1: y=3000000000*pow(x,9.3)
RT2: y=3000000*pow(x,6.8)

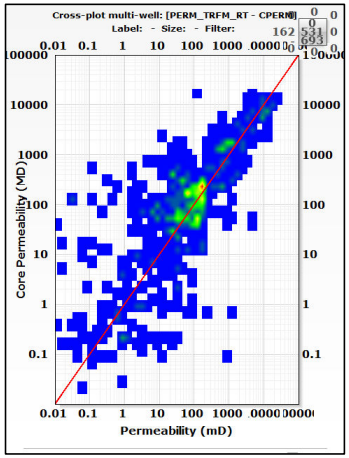
Well#1



Well#2

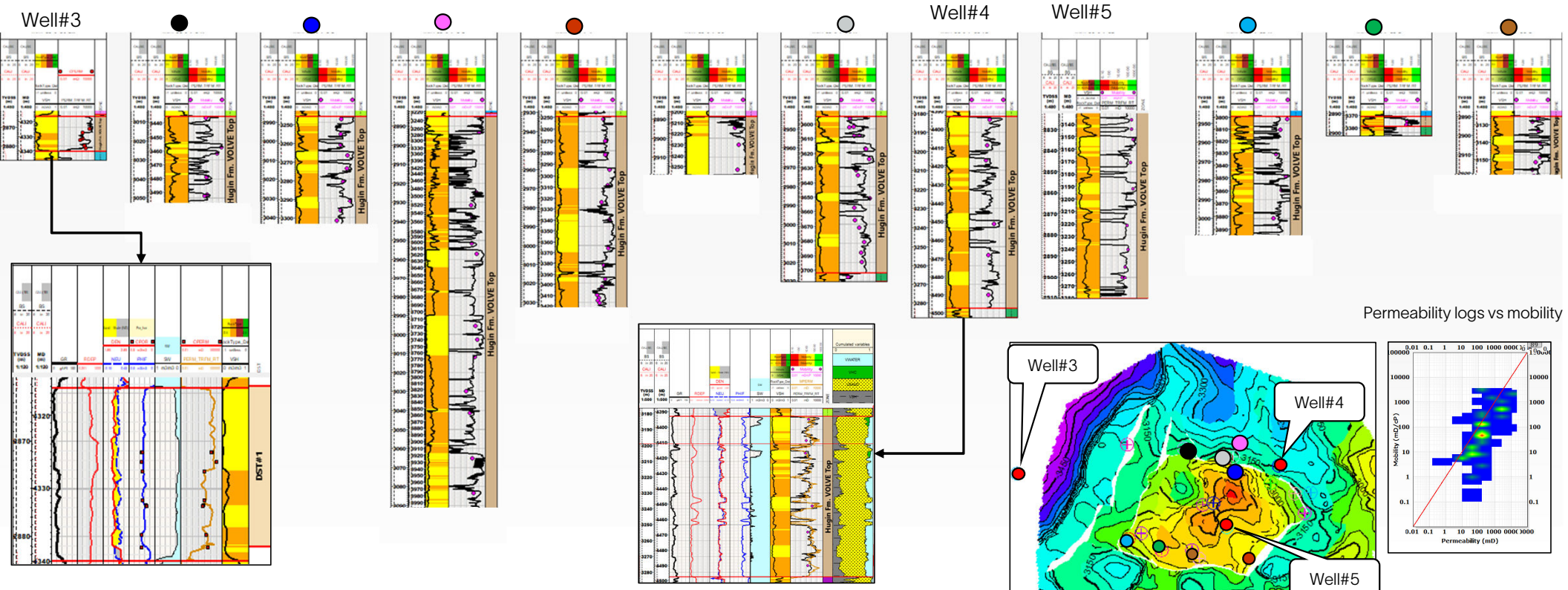


Permeability logs vs core



- Porosity-permeability relationships used to predict permeability
- Good correlation between predicted and core permeability

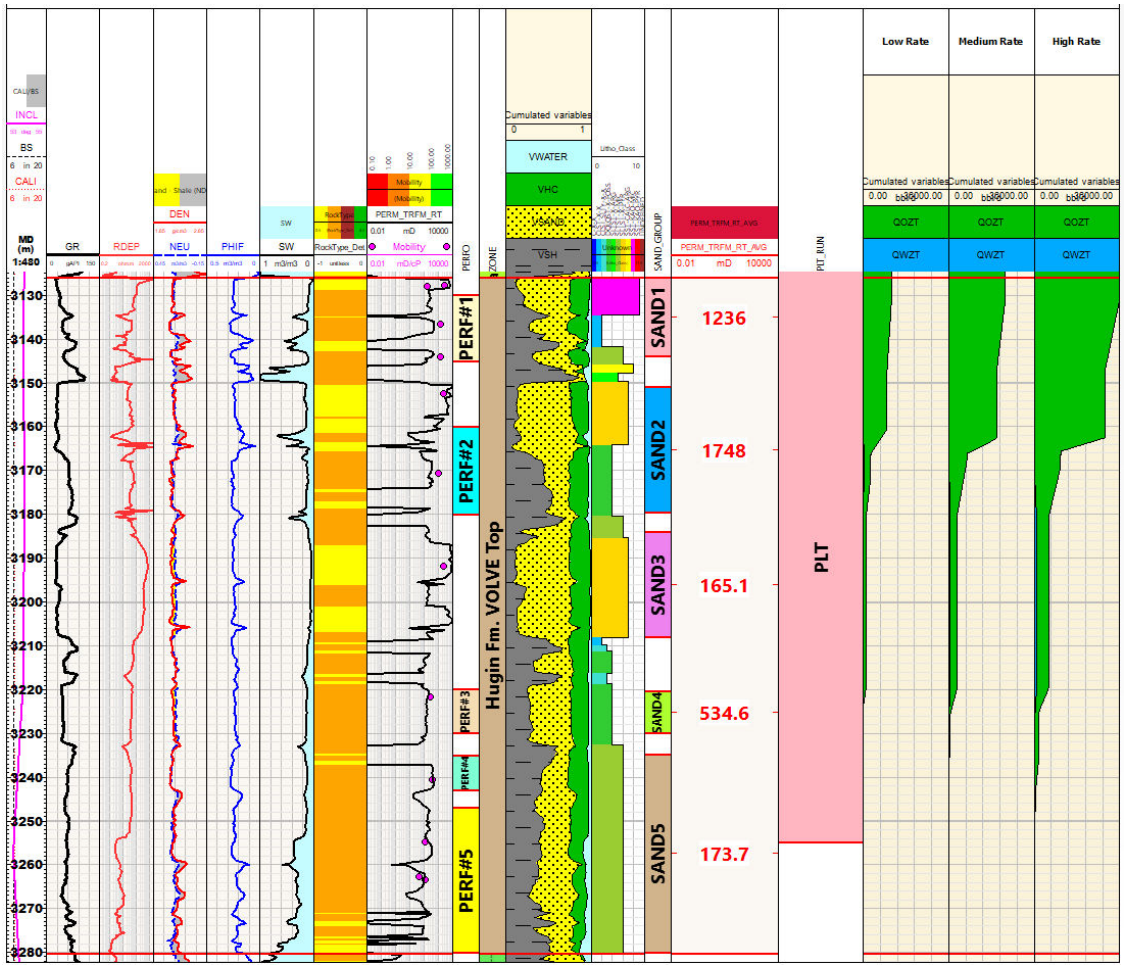
Fieldwide Permeability Prediction



Permeability logs vs mobility

- Rock typing and permeability evaluation using blind test well (another cored well)
- Expanded permeability predictions to uncored wells based on rock type
- Validated predictions with cored well data and NMR permeability measurements

Flow Profiles and Permeability Distribution: Well#5



- Approximately 83% of the oil is produced from the upper two completions, with the remaining coming from the lower three
- This flow profile remained consistent across all three flow rates and aligned with expectations based on permeability measurements from the open-hole logs

Conclusion

- The integrated data input, lab data to insitu measurement (logging data) will give better understanding for reservoir characterization, especially rock quality at this case
- By knowing the rock typing that we know the classification of the rock properties/quality
- The rock classification of rock properties which lead further to optimize the permeability prediction with consider the measured geological heterogeneity (grain size as an example, shale fraction)

Q&A