

# Permian Wolfcamp Interesting Log Interpretation Problem\*

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## Abstract

In the log analysis of a Permian Wolfcamp well the Wolfcamp was subdivided into two zone labeled Wolfcamp 1 and Wolfcamp 2. Using GEOCHEM [ECS] data the total porosity [PHI<sub>total</sub>] was calculated from the bulk density log using variable matrix analysis. Effective porosity [PHI<sub>e</sub>] was then determined [PHI<sub>e</sub> = PHI<sub>total</sub> – CBW].

The OOIP<sub>stb</sub> for both the Wolfcamp 1 and Wolfcamp 2 are listed below:

Wolfcamp 1  
OOIP<sub>stb</sub> 12.7mmbo

Wolfcamp 2  
OOIP<sub>stb</sub> 5.1mmbo

The logging suite for this well also included a CMR Log therefore OOIP<sub>stb</sub> could be calculated at different T<sub>2</sub> Relaxation Times. The results are listed below:

Wolfcamp 1 [T<sub>2</sub> 3ms Pore Size 76.5nm]  
OOIP<sub>stb</sub> 8.8mmbo

Wolfcamp 1 [T<sub>2</sub> 10ms Pore Size 250nm]  
OOIP<sub>stb</sub> 5.3mmbo

Wolfcamp 2 [T<sub>2</sub> 3ms Pore Size 76.5nm]  
OOIP<sub>stb</sub> 5.5mmbo

Wolfcamp 2 [T2 10ms Pore Size 250nm]  
OOIPstb 2.0mmbo

Note, in the above OOIPstb values Wolfcamp 1 has much greater OOIPstb values than Wolfcamp 2. An examination of the lithologies indicate that Wolfcamp 2 is more clay rich, and has a higher minimum closure stress [SHmin] and lower Brittleness Coefficient compared to Wolfcamp 1. Therefore the better reservoir with more hydrocarbons is Wolfcamp 1.

However, because the well was logged with a High Resolution Array Laterolog [HRLA] the author examined the log for invasion profiles [HRLA5>HRLA2>Rxo], which indicate zones of moveable hydrocarbons due to invasion. The better invasion profiles were located in Wolfcamp 2, not Wolfcamp 1 as I would have expected.

Next OOIPstb was calculated based on the degree of invasion (Tixier, 1956 and Asquith, 2015).

$$Y = (R_{mf}/R_{xo})^{0.5} - (R_w/R_t)^{0.5}$$

$$OOIPstb = (7758 * Y * h * A) / BOI$$

The results are listed below:

Wolfcamp 1 [Y Method : Tixier, 1956]  
OOIPstb 1.5mmbo

Wolfcamp 2 [Y Method : Tixier, 1956]  
OOIPstb 3.8mmbo

Unlike the other OOIPstb values the OOIPstb determined from the Y Method are just the reverse, indicating the Wolfcamp 2 is the better reservoir [i.e. greater invasion]. The author has used the Y Method for years in many reservoirs including the Wolfcamp, and found it to be reliable [Asquith, 2015: WTGS Fall Symposium]. So the question is what is causing the Y Method to indicate that the better reservoir is Wolfcamp 2, when the other calculated OOIPstb values and Geomechanical properties indicated Wolfcamp 1 has the better reservoir potential?

### Selected References

Asquith, G.B., 2015, VOOIP Utilizing GEOCHEM [ECS] Data, Triple Combo Data Only, and Pyrolysis S1 Data, Permian Wolfcamp "A" and "B" Shales, Midland Basin, Texas: [Search and Discovery Article #110207 \(2015\)](#). Website accessed September 2016.

Asquith, G.B., 2014, OOIP Utilizing GEOCHEM [ECS] Data, Triple Combo Data Only, and Pyrolysis S1 Data, Permian Wolfcamp “A” and “B” Shales”: [Search and Discovery Article #41406 \(2014\)](#). Website September 2016.

Brown, A.A., 2015, Are Gas Shales Suitable Analogs for Oil Shale Exploration?: [Search and Discovery Article #41624 \(2015\)](#). Website accessed September 2016.

Millican, M.L., L.L. Raymer, and R.P. Alger, 1964, Wellsite Recording of Moveable Oil Plot: Society of Professional Well Log Analysts, 5th Annual Logging Symposium, Transactions, Paper F, p. F1-F11.

Rafatian, N., and J. Capsan, 2015, Petrophysical Characterization of the Pore Space in Permian Wolfcamp Rocks: Petrophysics, v. 56/1, p. 45-55.

Tixier, M.P., 1956, Fundamentals of Electric Logging: Petroleum Engineering Conference, University of Kansas, 171 p.

**PERMIAN WOLFCAMP  
INTERESTING  
LOG INTERPRETATION  
PROBLEM**

**G.B. Asquith, TEXAS TECH UNIVERSITY**

# KEY FACTORS for ECONOMIC SHALE

[from: Rick Lewis (2013)]

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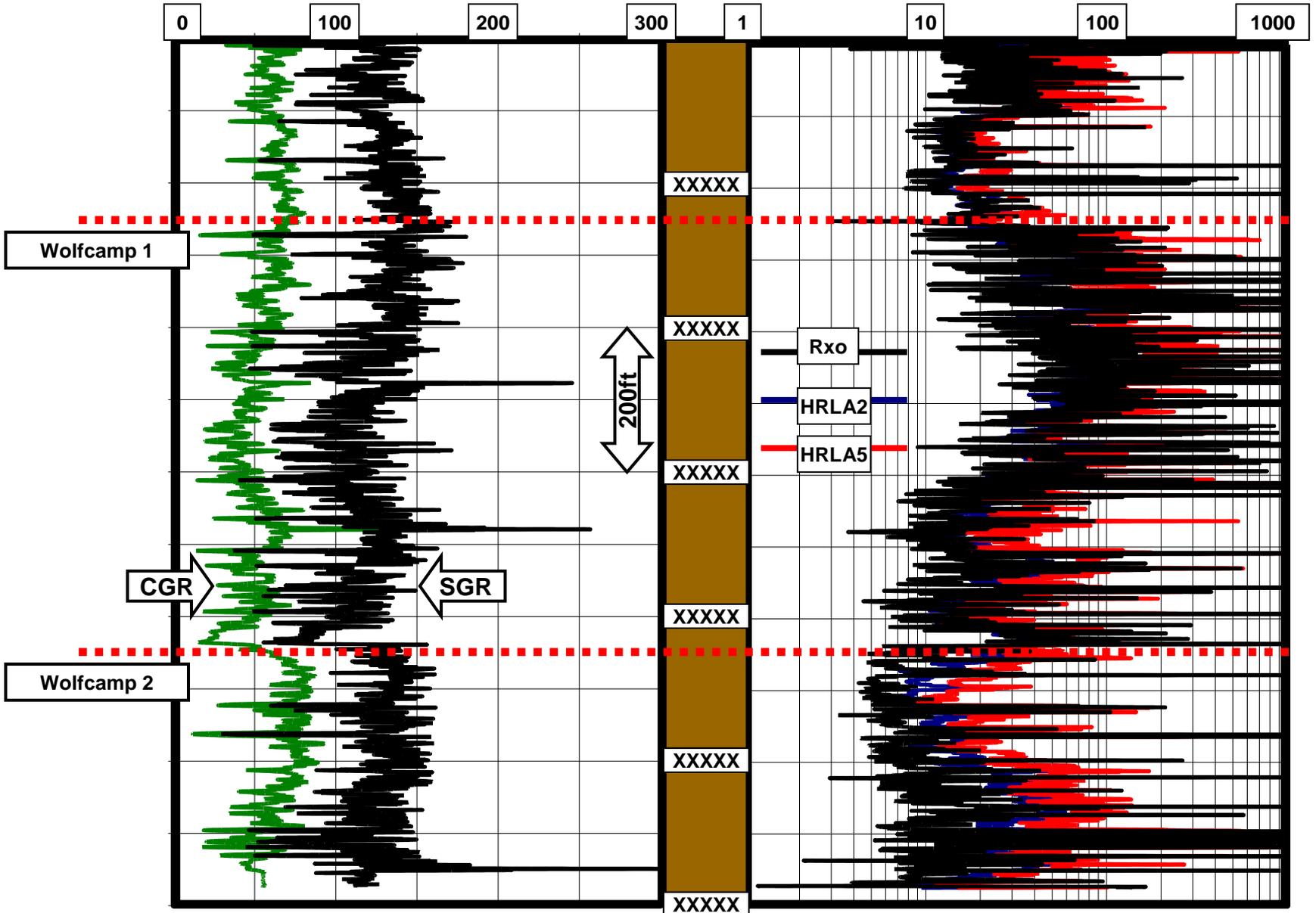
## RESERVOIR QUALITY

- **Hydrocarbons in Place**
- **Matrix Permeability**
- Pore Pressure

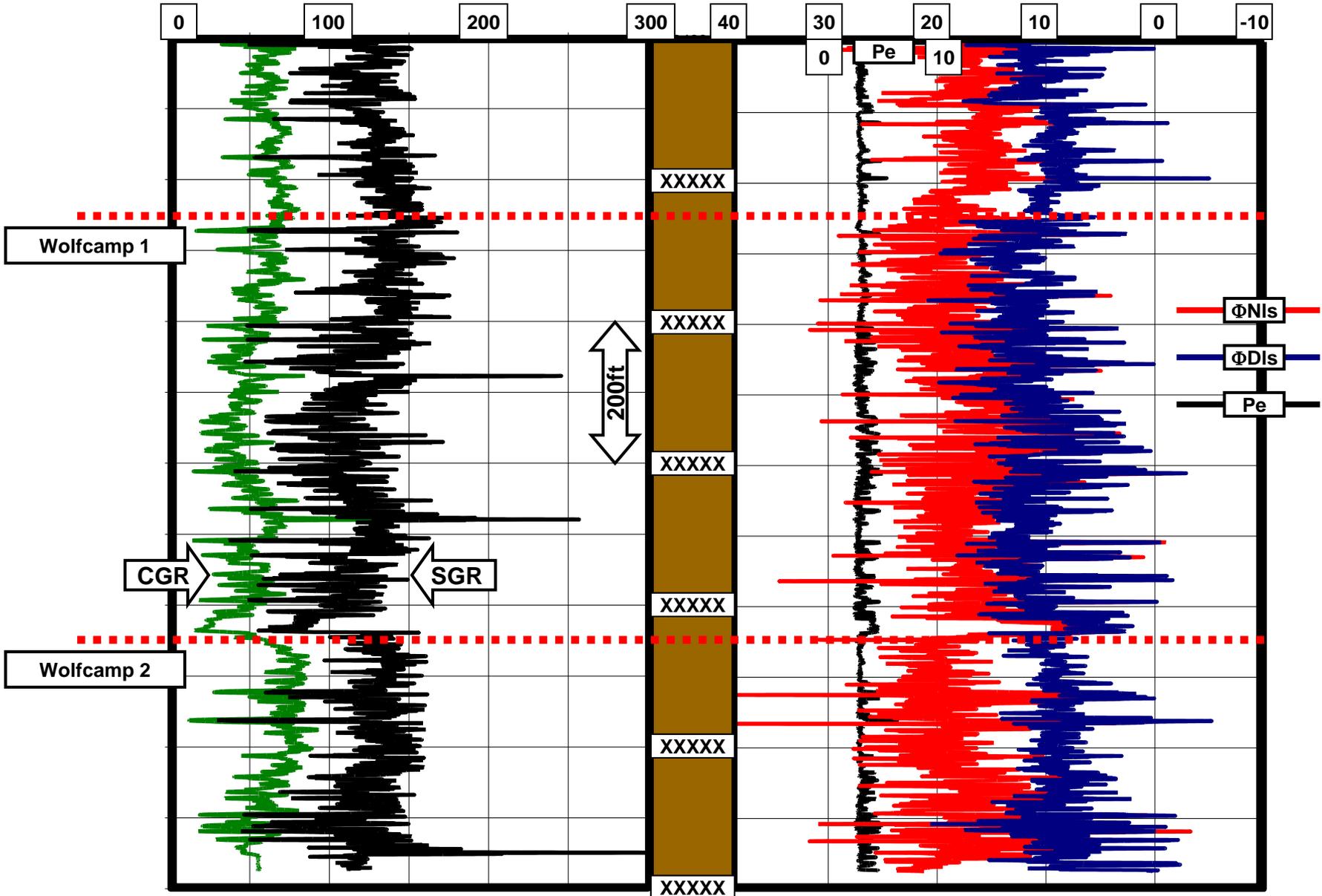
## COMPLETION QUALITY

- **Hydraulic Fracture Surface Area**
- Hydraulic Fracture Conductivity
- Hydraulic Fracture Containment

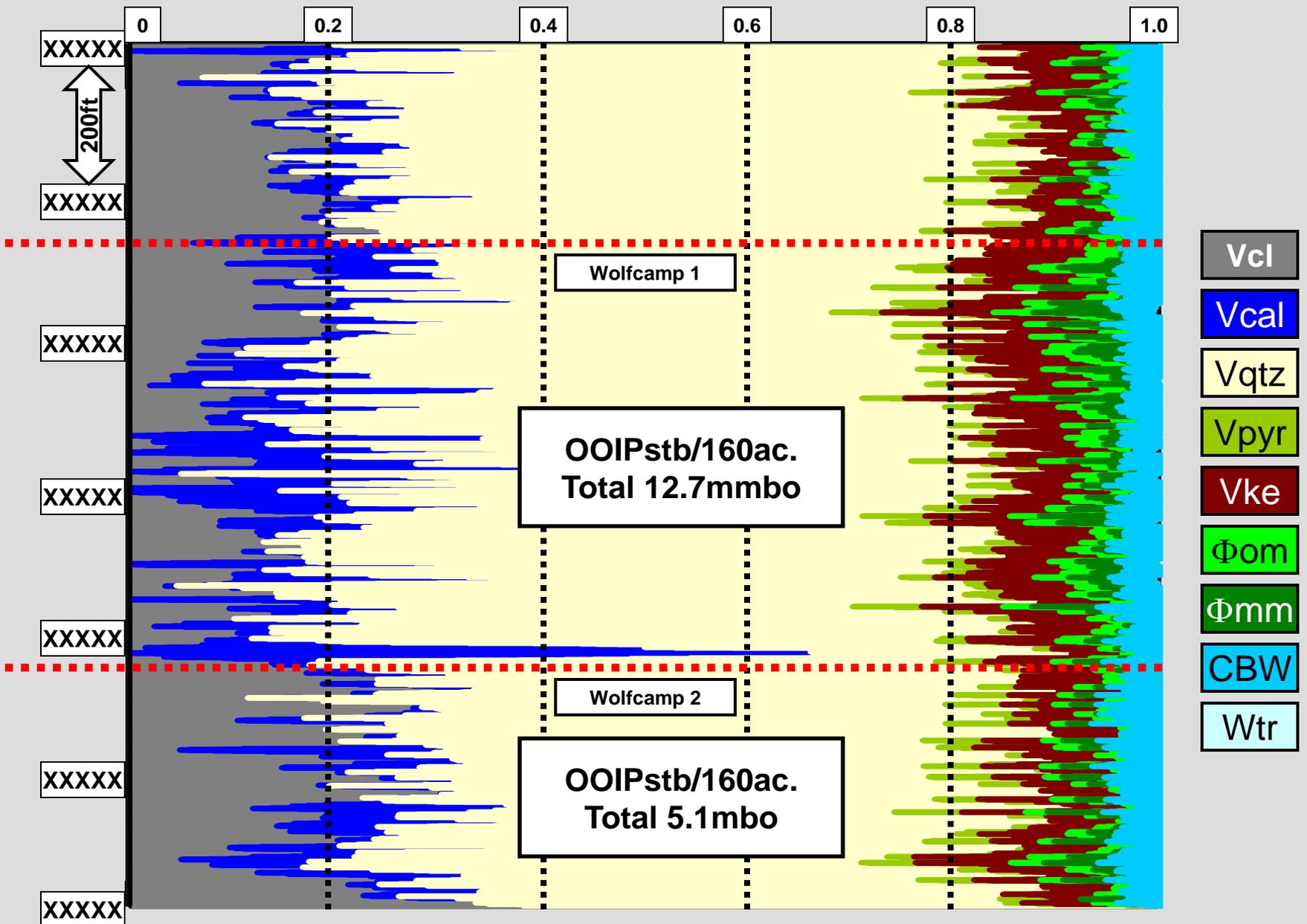
# Gamma Ray [SGR & CGR] and Resistivity [HRLA] Permian Wolfcamp



# Gamma Ray [SGR & CGR] and Neutron-Lithodensity Permian Wolfcamp



# Lithology [ECS] & Saturations Permian Wolfcamp

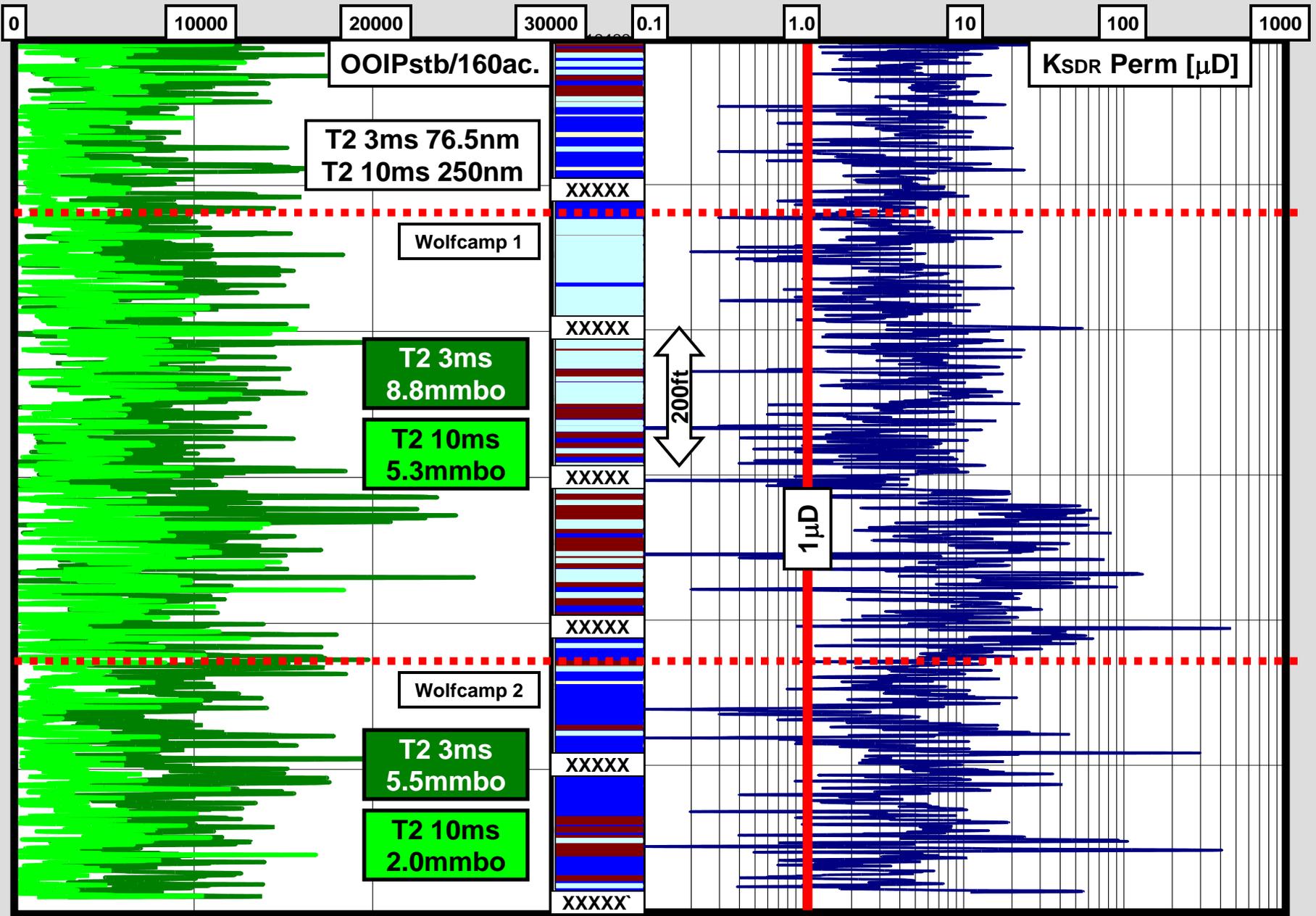


## **Permeability Cut Off Unconventional OIL Reservoirs**

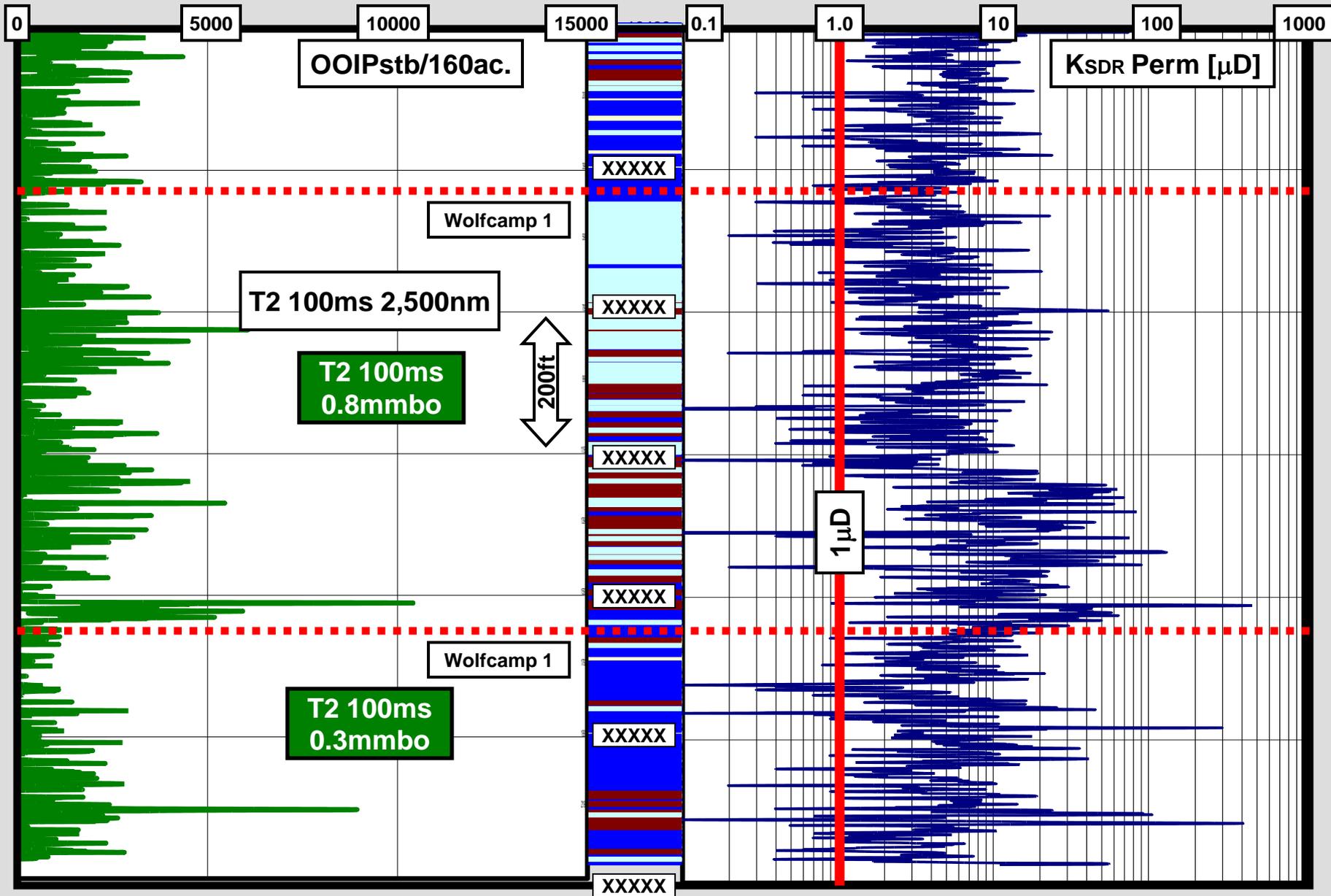
**Higher absolute permeability than in gas shales (~1 microDarcy minimum and preferably much higher).**

**NanoDarcy-scale mudstone permeabilities are too low for economic oil production rates. (Brown, 2015: SW AAPG).**

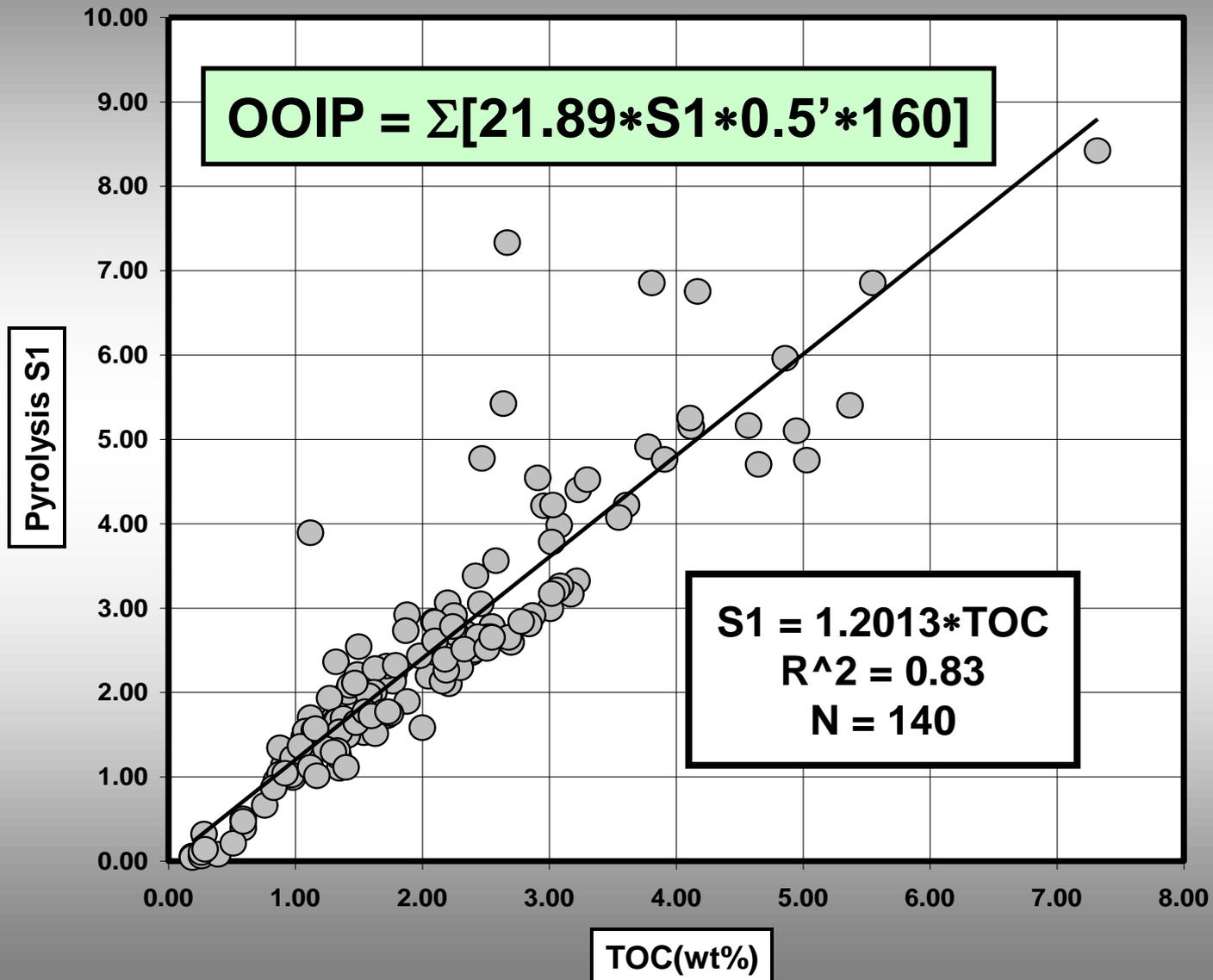
# OOIPstb [T2 3ms T210ms & KSDR Permeability] Permian Wolfcamp



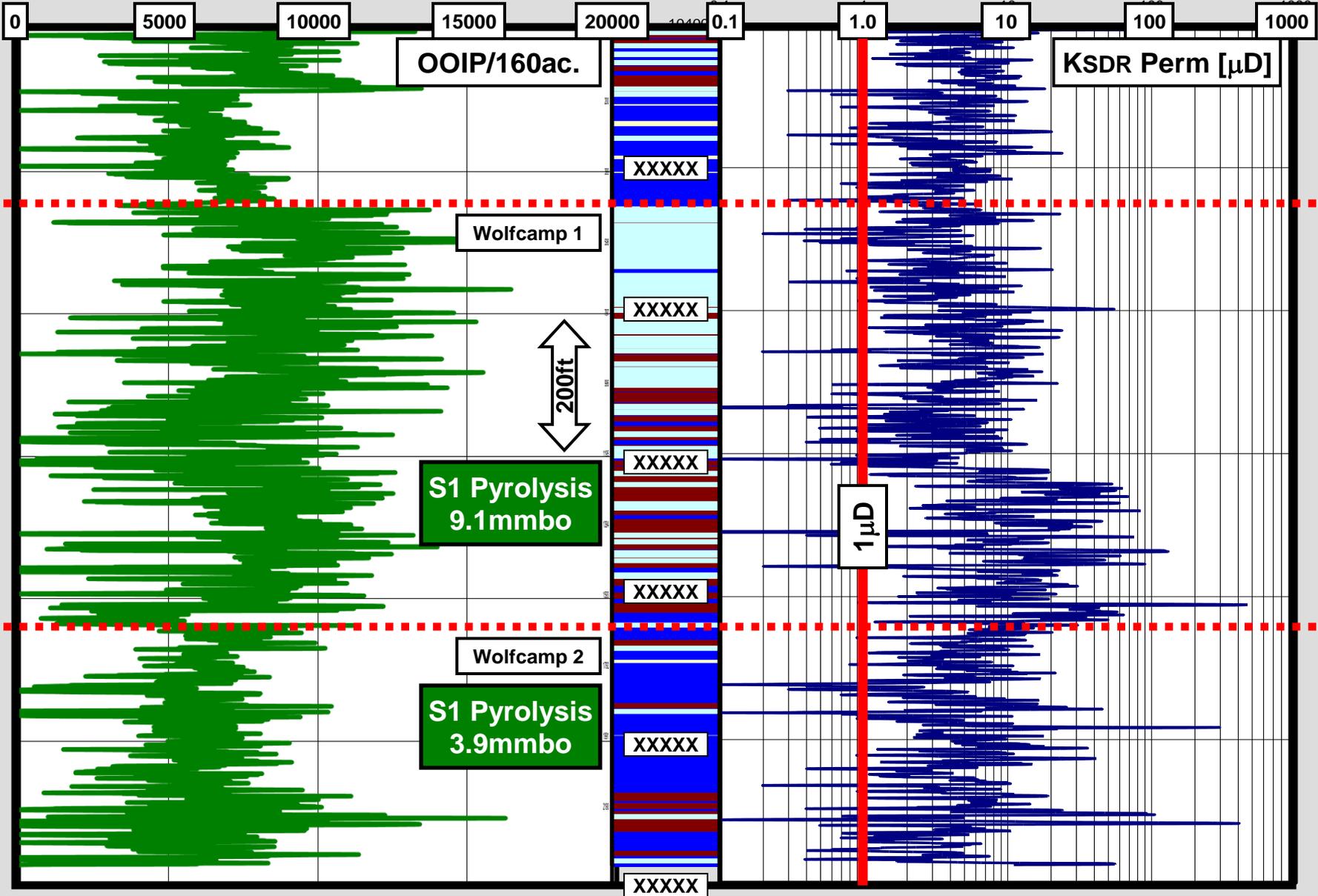
# OOIPstb [T2 100ms] & KSDR Permeability [ $\mu$ D] Permian Wolfcamp



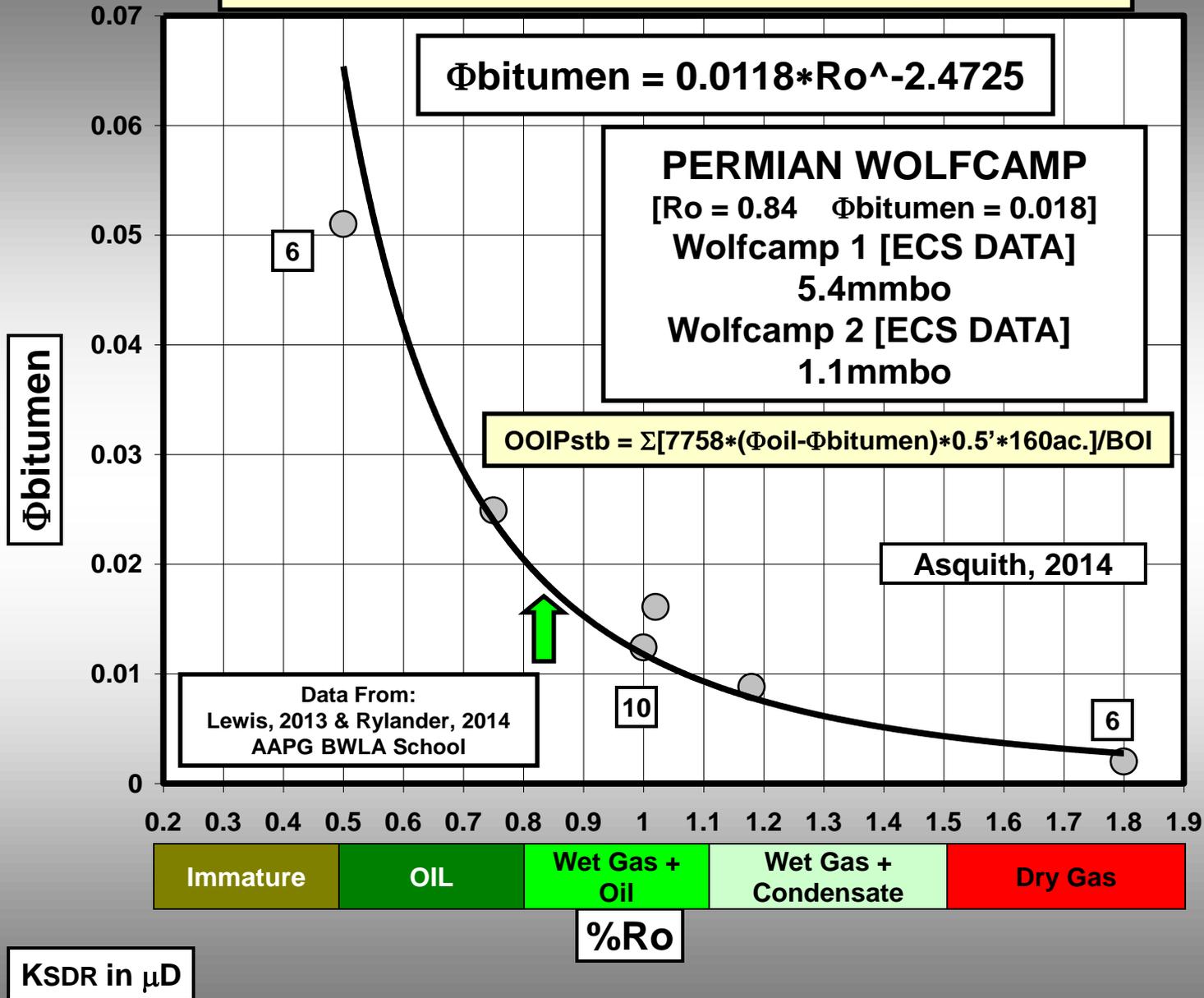
**TOClab versus Pyrolysis S1 [mgHC/g] Permian Wolfcamp Midland Basin**



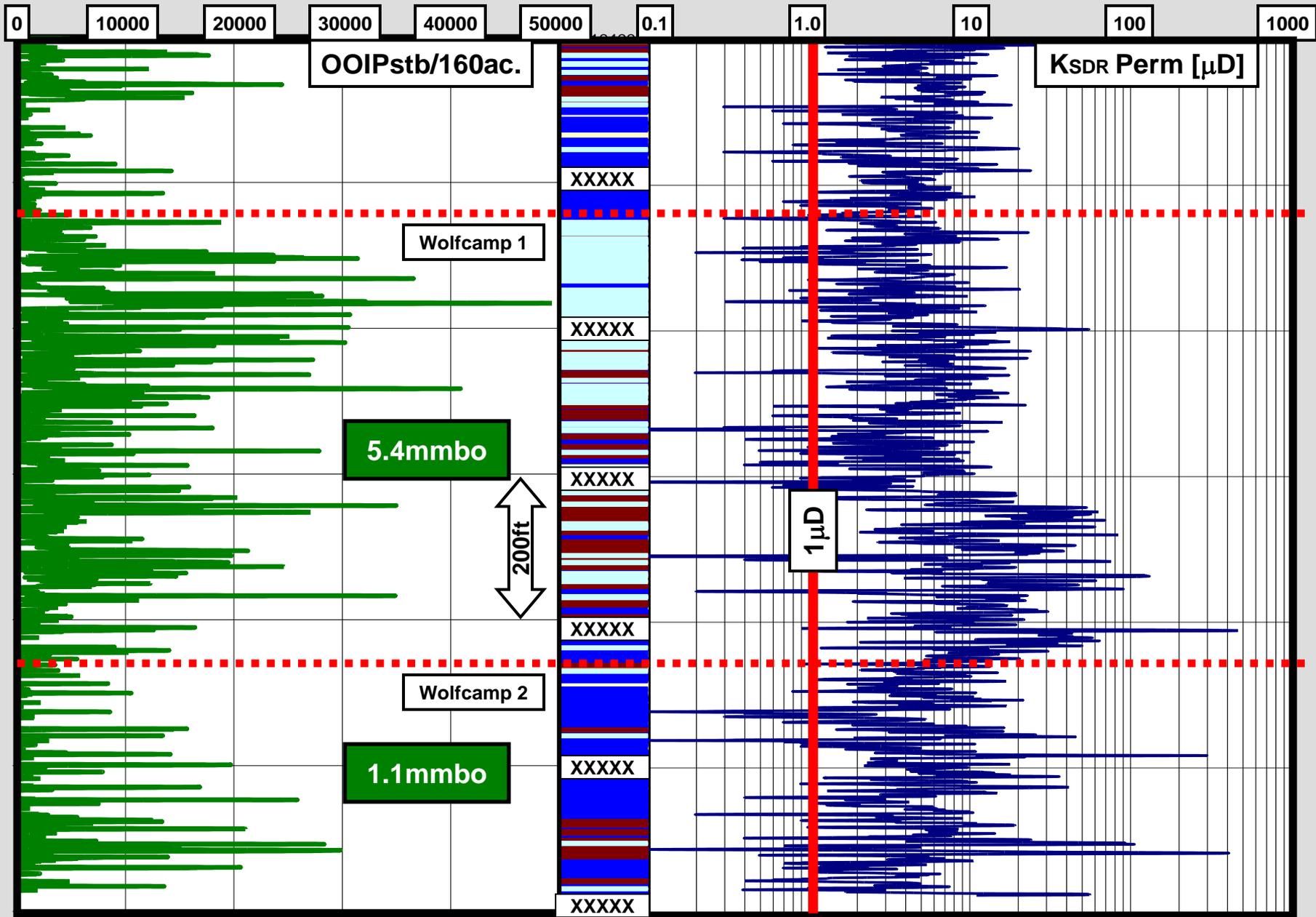
# OOIP [Pyrolysis S1] & K<sub>SDR</sub> Permeability [ $\mu$ D] Permian Wolfcamp



# Ro versus Non-Producible Bitumen [ $\Phi$ bitumen]



# OOIPstb [Bitumen Corrected] & KSDR Permeability Permian Wolfcamp



Walls & others 2012	Lewis, 2010
Pe<3 & RHOb<2.5	Pe<4 & RHOb<2.53

1      10      100      1000      10000

KSDR/PHI3ms

XXXXX

Wolfcamp 1

XXXXX

Avg. KSDR/PHI  
357

XXXXX

200ft

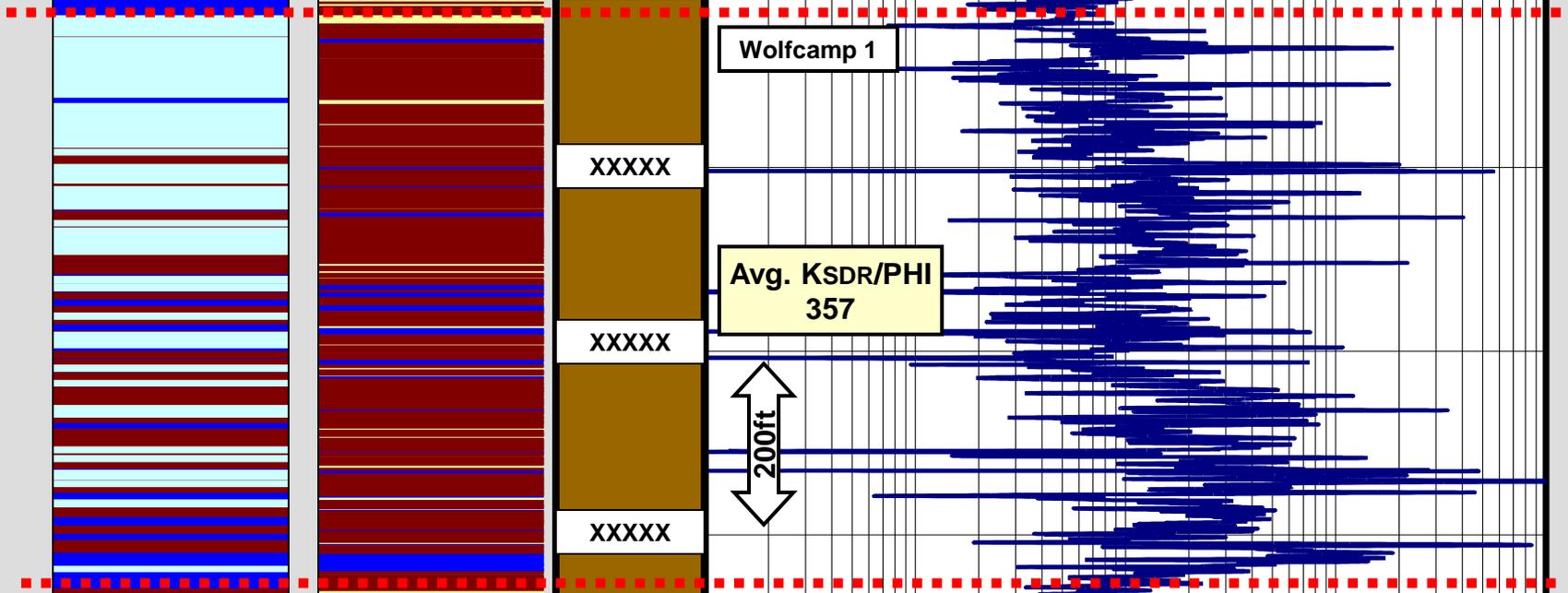
XXXXX

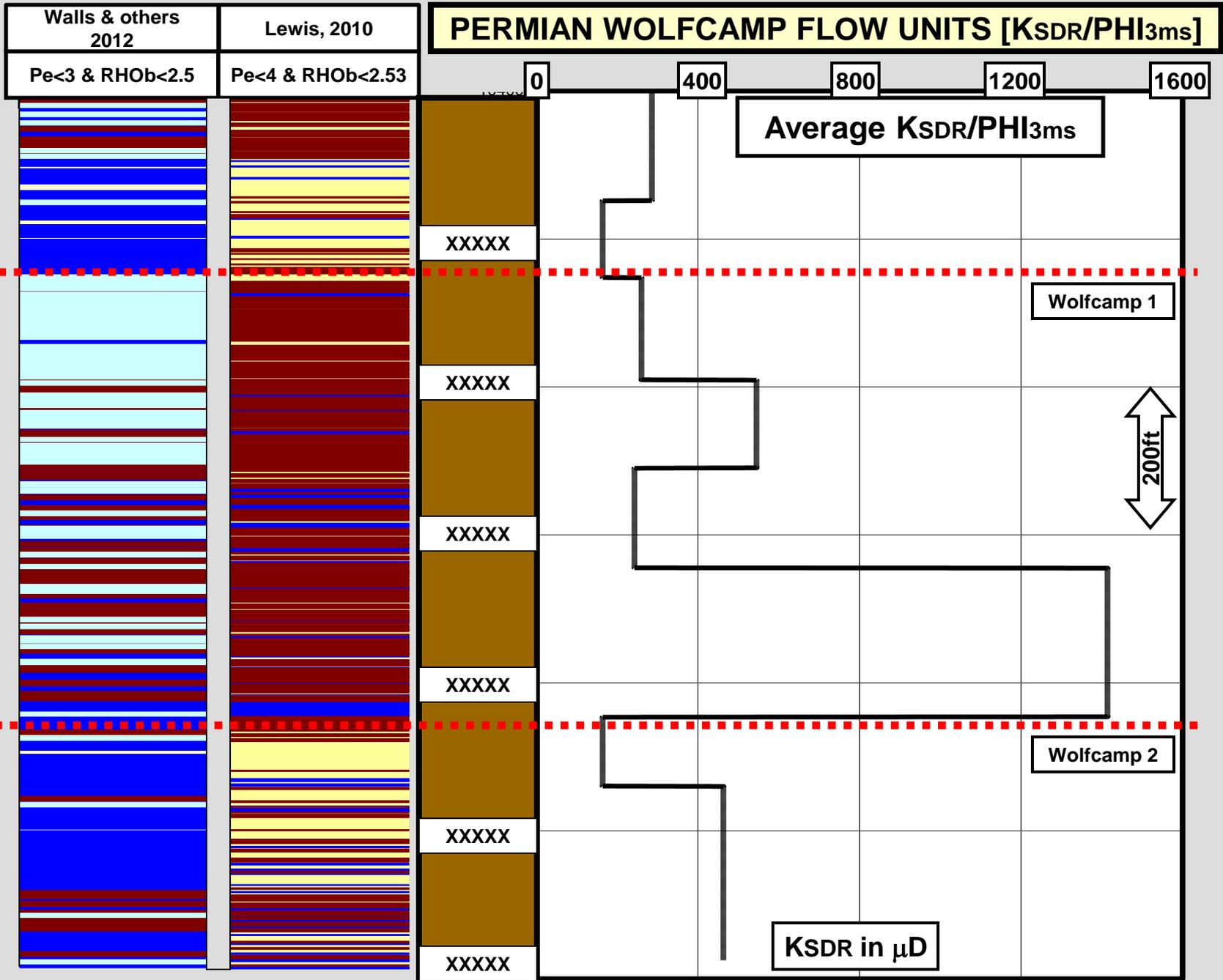
Wolfcamp 2

XXXXX

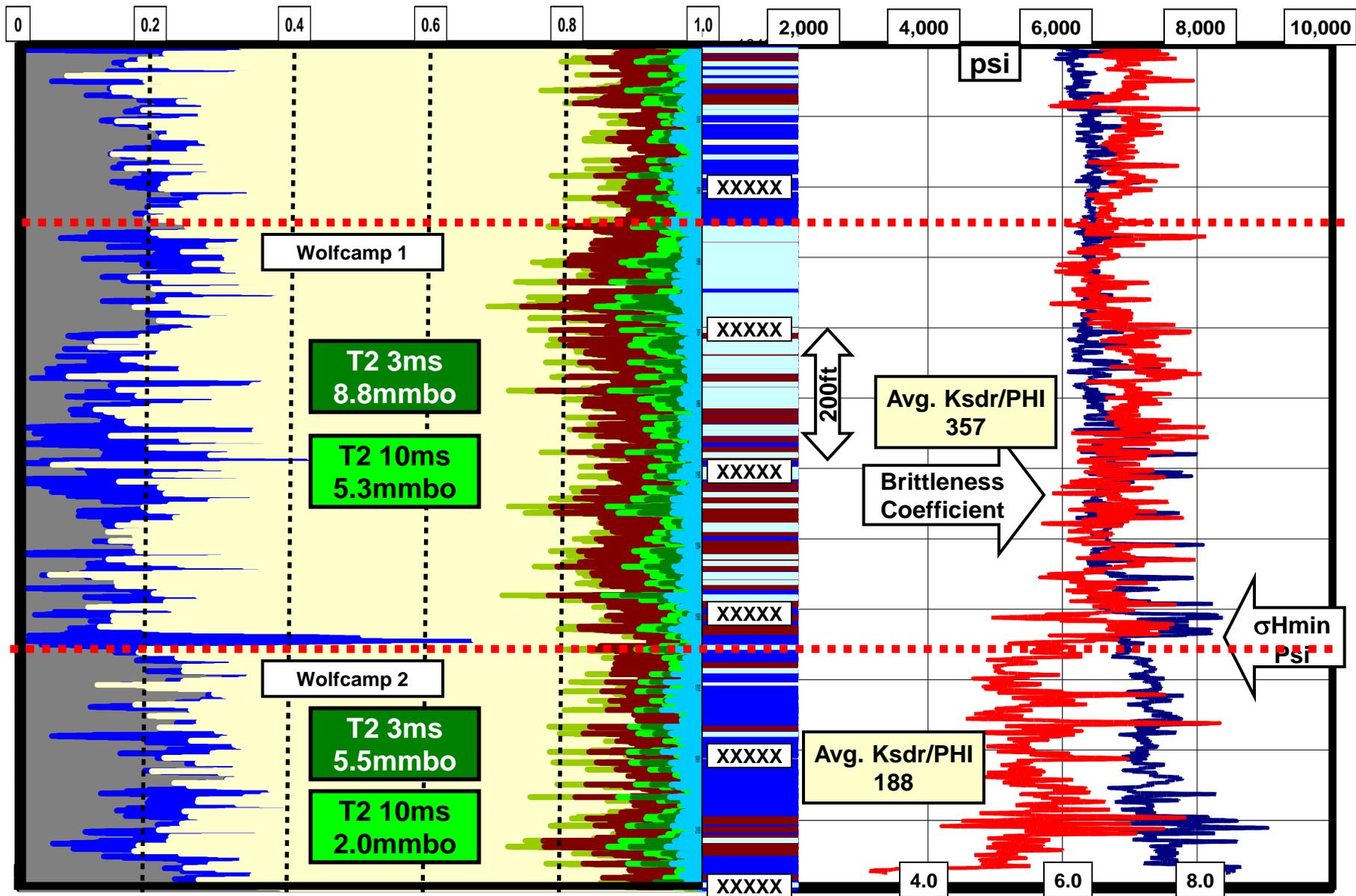
Avg. KSDR/PHI  
188

KSDR in  $\mu$ D





# Lithology [ECS] & Geomechanics Permian Wolfcamp



# CONCLUSION

**LATERAL LANDING POINT**

**WOLFCAMP 1**

**HIGHER OOIP<sub>stb</sub>**

**BETTER GEOMECHANICS**

**HIGHER  $K_{sDR}$  PERM**

**TO BE SURE  
LET'S TRY ONE MORE  
METHOD of DETERMINING  
OOIPstb  
USING  
RESISTIVITY INVASION  
PROFILES**

# **VERY IMPORTANT QUOTE**

**Concerning  
Moveable Hydrocarbons**

**“effective log interpretation requires more than evaluating oil saturation, it requires identification of moveable oil.”**

***FROM:* Millican, M.L., L.L. Raymer, and R.P. Alger, 1964, Wellsite Recording of Moveable Oil Plot: Soc. of Professional Well Log Analysts, 5<sup>th</sup> Annual Logging Symposium, paper F.**

# MAXIMUM PRODUCIBLE OIL INDEX (Y)

(Tixier, M.P., 1956, Fundamentals of Electric Logging:  
Petroleum Engineering Conference, University of Kansas, 171p.)

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$$Y = [(R_{mf}/R_{xo})^{0.5} - (R_w/R_t)^{0.5}]$$

Y = Maximum Produccible Oil Index at Reservoir Conditions  
(i.e. the amount of oil per unit volume which is displaced by mud filtrate)

$$\text{Mobile OOIP}_{\text{stb}} = \{7758 * \Phi * [(1 - S_w) - \text{RHS}] * h * A\} / \text{BOI}$$

$$\text{Mobile OOIP}_{\text{stb}} = (7758 * Y * h * A) / \text{BOI}$$

Where:

OOIP<sub>stb</sub> = original oil in place in stock tank barrels (stb)

7758 = barrels of oil in an acre-foot

Φ = porosity

S<sub>w</sub> = water saturation [Soil = 1 - S<sub>w</sub>]

RHS = residual hydrocarbon saturation

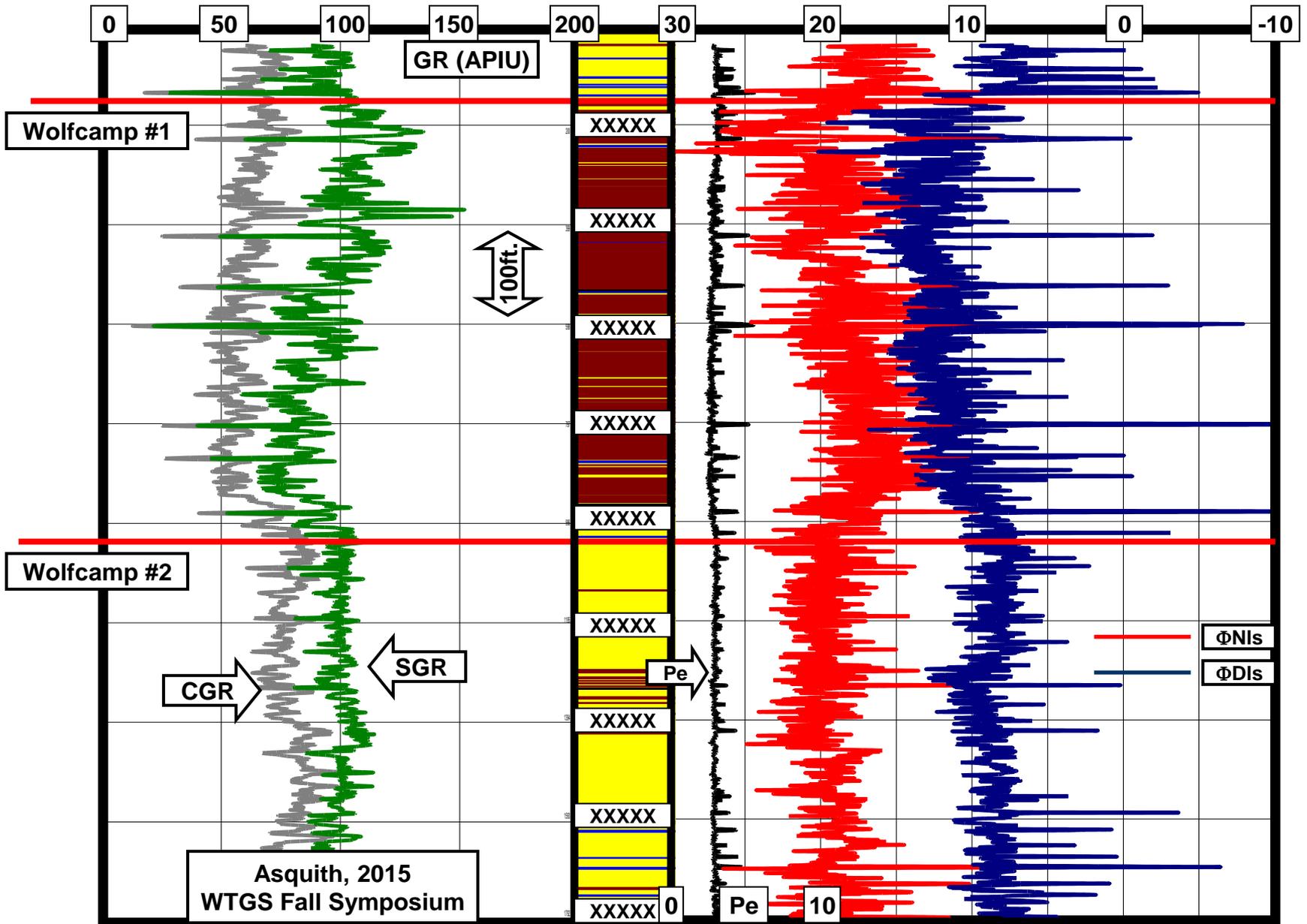
A = area

h = thickness

BOI = shrinkage factor (reservoir barrels to surface barrels of oil)

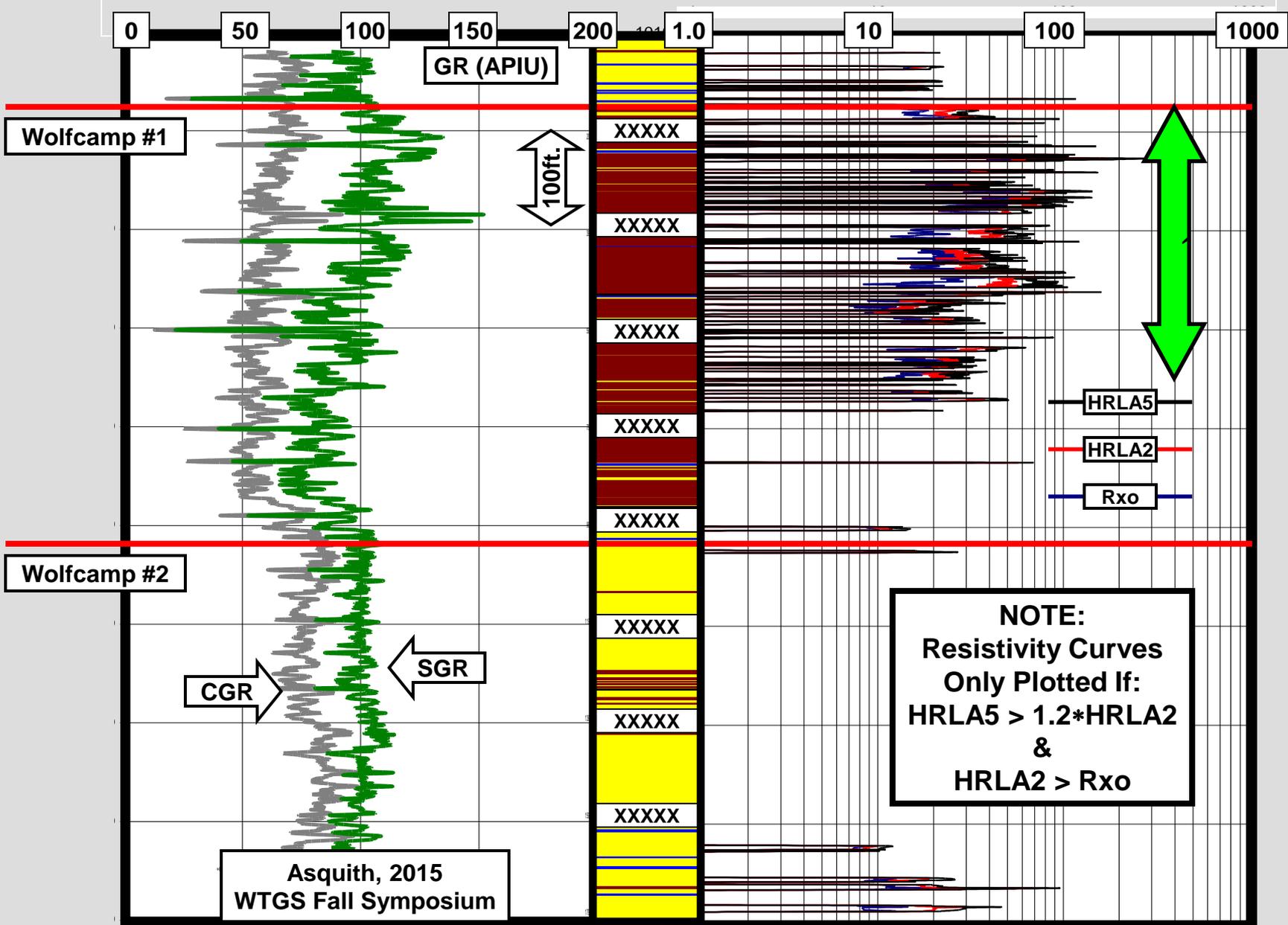


# Gamma Ray [SGR & CGR] Neutron-Lithodensity Log Permain Wolfcamp



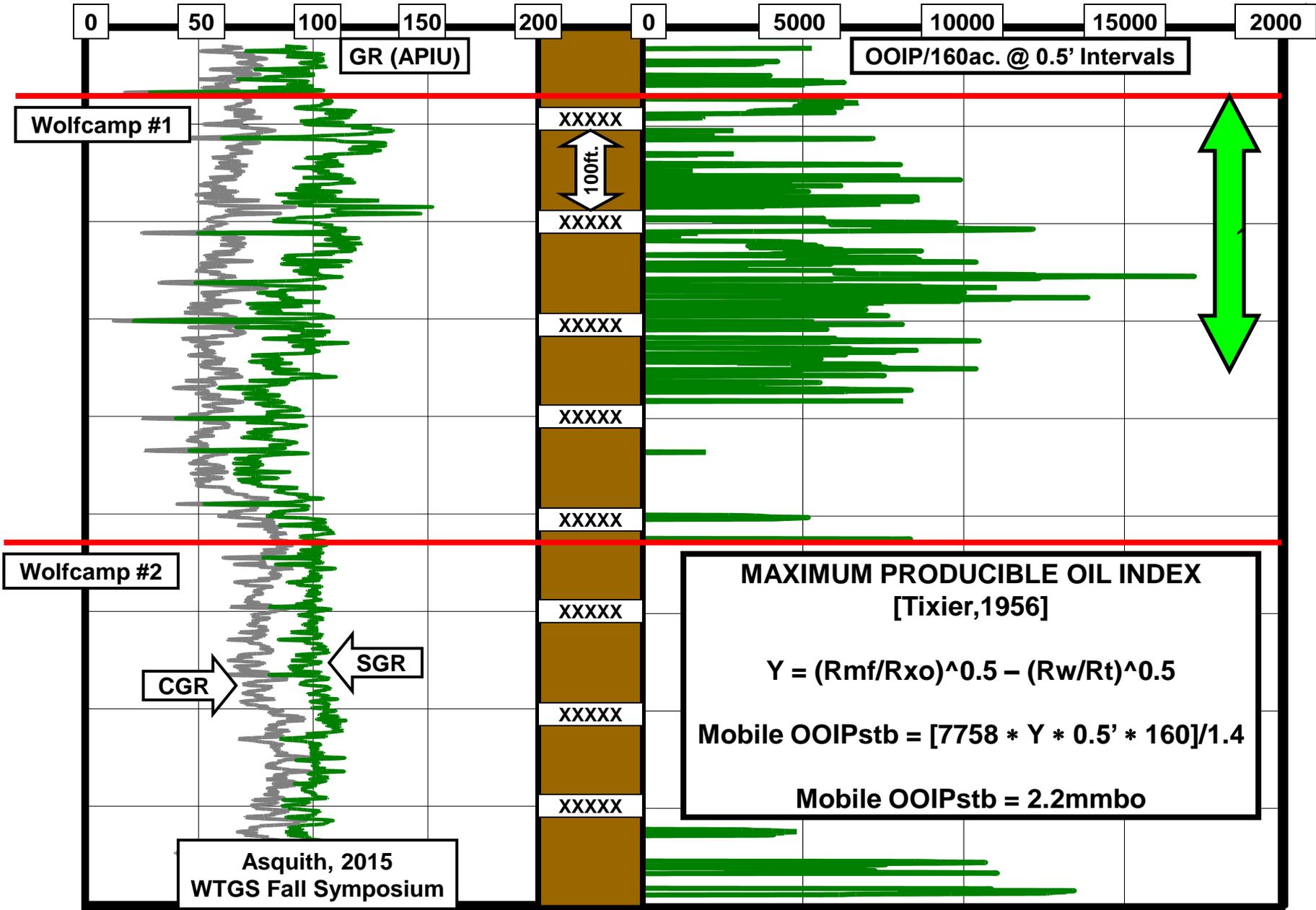


# Gamma Ray [SGR & CGR] and Resistivity [HRLA] Permian Wolfcamp



Asquith, 2015  
WTGS Fall Symposium

# Mobile OOIP/160ac. from [MPOI] Permian Wolfcamp



# **Petrophysical Characterization of the Pore Space in Permian Wolfcamp Rocks**

**[Rafatian and Capsan, 2015]**

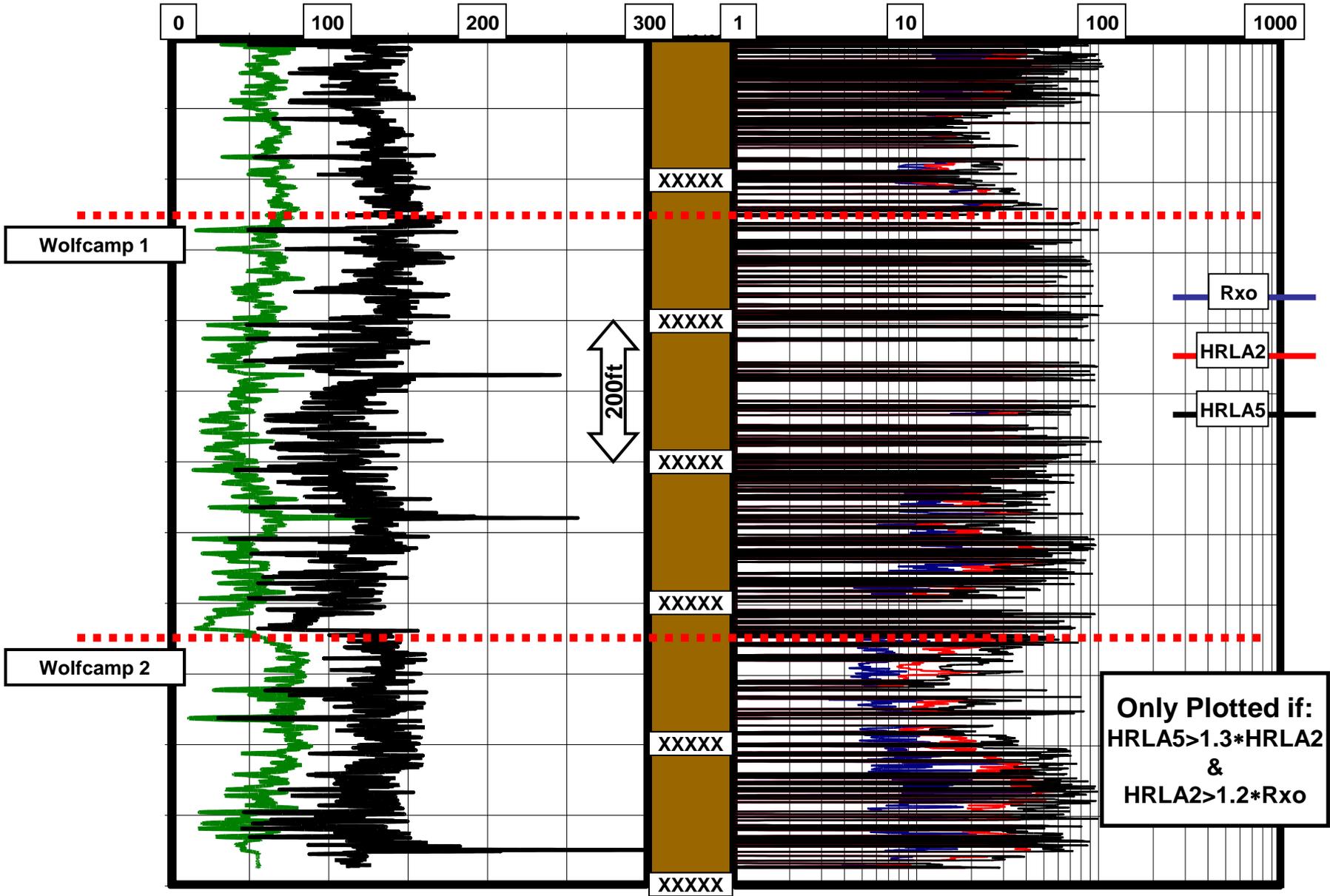
**PETROPHYSICS VOL. 56, No. 1, p. 45-55.**

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**“the largest pore spaces and, by proxy, the largest continuous connected pore throats, have the largest impact on fluid flow”**

**and therefore the largest impact on the degree of invasion.  
[Asquith, 2015 WTGS FALL SYMPOSIUM]**

# Gamma Ray [SGR & CGR] and Resistivity Invasion Profiles Permian Wolfcamp



# MAXIMUM PRODUCIBLE OIL INDEX (Y)

(Tixier, 1956)

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$$Y = [(R_{mf}/R_{xo})^{0.5} - (R_w/HRLT)^{0.5}]$$

Y = Maximum Produccible Oil Index at Reservoir Conditions  
(i.e. the amount of oil per unit volume which is displaced by mud filtrate)

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Permian Wolfcamp  $R_{mf} = 0.021$   $R_w = 0.05$   
Area = 160ac. (assumed) BOI = 1.4 (assumed)

$$\text{Mobile OOIP}_{stb} = \Sigma[(7758 * Y * 0.5' * 160)/1.4]$$

**5.3MMBO [Mobile OOIP<sub>stb</sub>]**



# QUESTION?

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**Why does the Wolfcamp 2 have such good invasion profiles indicating permeable reservoir with high OOIPstb values, and yet all other methods indicate lower OOIPstb values compared to Wolfcamp 1?**

**In addition, why do the Brittleness Coefficient and SHmin indicate poorer GEOMECHANICAL values in Wolfcamp 2, compared to Wolfcamp 1, when the invasion profiles indicate Wolfcamp 2 is the better reservoir?.**