OOIP Utilizing GEOCHEM [ECS] Data, Triple Combo Data Only, and Pyrolysis S1 Data, Permian Wolfcamp "A" and "B" Shales*

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Abstract

As a result of a very complete data set including Pyrolysis S1 data over an interval of 8035 ft to 8497 ft at 5 ft intervals on a Wolfcamp well in the Midland Basin of Texas enabled the author an opportunity to compare different methods of calculating Oil in Place. The first OOIP stb calculation was done using only resistivity (AIT90), bulk density (*b), and neutron porosity (*nls) data with TOC determined by the Schmoker Equation. The volume of clay (Vcl), volume of quartz (Vqtz), and total porosity (*total) were determined by the Simultaneous Equation Method developed by Rick Lewis with Schlumberger. Effective porosity (*e) was calculated as *e = *total – (Vcl×*clay). Using a permeability cut-off of ka > 100 nD {ka = [(0.0108×*oil) – 0.000256]×10^6} the OOIP stb/160 acres over the interval from 8035 ft to 8494 ft was 4.8 mmbo.

The next OOIP stb calculation was done using AIT90, *b, and *nls data along with GEOCHEM [ECS] data. TOC was determined by the Schmoker Equation. The *total was determined with a variable matrix analysis using Vqtz, Vcalcite, Vkerogen, Vcl, and Vpyrite. Effective porosity (*e) was calculated as *e = *total – (Vcl×*clay). Using a permeability cut-off of ka > 100 nD {ka = [(0.0108×*oil) – 0.000256]×10^6} the OOIP stb/160 acres over the interval from 8035 ft to 8494 ft was 6.1 mmbo.

The third method to determine Oil in Place was based on the method outlined by Downey and others (2011) using Pyrolysis S1 data. The equation used is listed below:

Oil in Place/160 acres = *[1241.34×*b*S1×*oil*5'] 8035 ft to 8497 ft

Using the above equation the calculated Oil in Place/160 acres was 5.2 mmbo. The 5.2 mmbo value compares favorably with the OOIP stb calculated by the other two methods [4.8 mmbo and 6.1 mmbo].

The general agreement of OOIP stb from GEOCHEM [ECS] and Triple Combo data with Oil in Place from Pyrolysis S1 data suggest that the use of a permeability cut-off of ka > 100 nD may have validity in establishing a net pay cut-off for the Wolfcamp. In addition, the OOIP stb values calculated with only the Triple Combo data [AIT90, *b, and *nls] gave reasonable values [4.8 mmbo] versus [6.1 mmbo] using GEOCHEM [ECS] data is important, because a great many wells have only Triple Combo data.

Selected Reference

Downey, A.C., E.M. Powers, and L. Hasbargen, 2011, Lyell rides again in upstate New York; a pedagogical virtual expedition to explore the past based on modern fluvial processes and deposits: GSA, v. 43/5, p. 476.

OOIP UTILIZING
GEOCHEM [ECS] DATA
TRIPLE COMBO DATA ONLY
PYROLYSIS S1 DATA
PERMIAN
WOLFCAMP “A” & “B” SHALES
MIDLAND BASIN, TEXAS

G.B. Asquith, TEXAS TECH UNIVERSITY

KEY FACTORS for ECONOMIC SHALE

[from: Rick Lewis (2013) w/ SCHLUMBERGER]

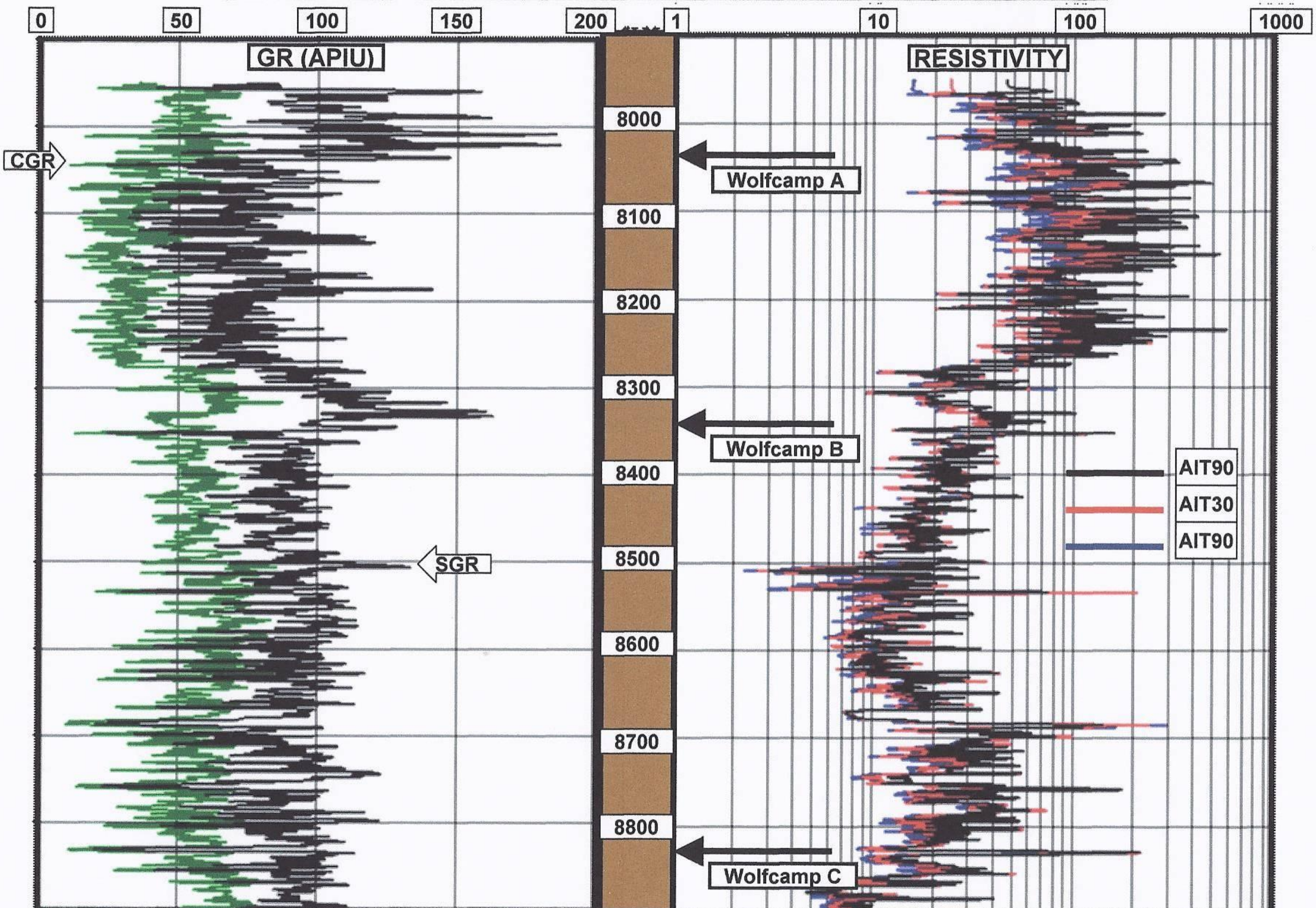
RESERVOIR QUALITY

- Hydrocarbons in Place
- Matrix Permeability
- Pore Pressure

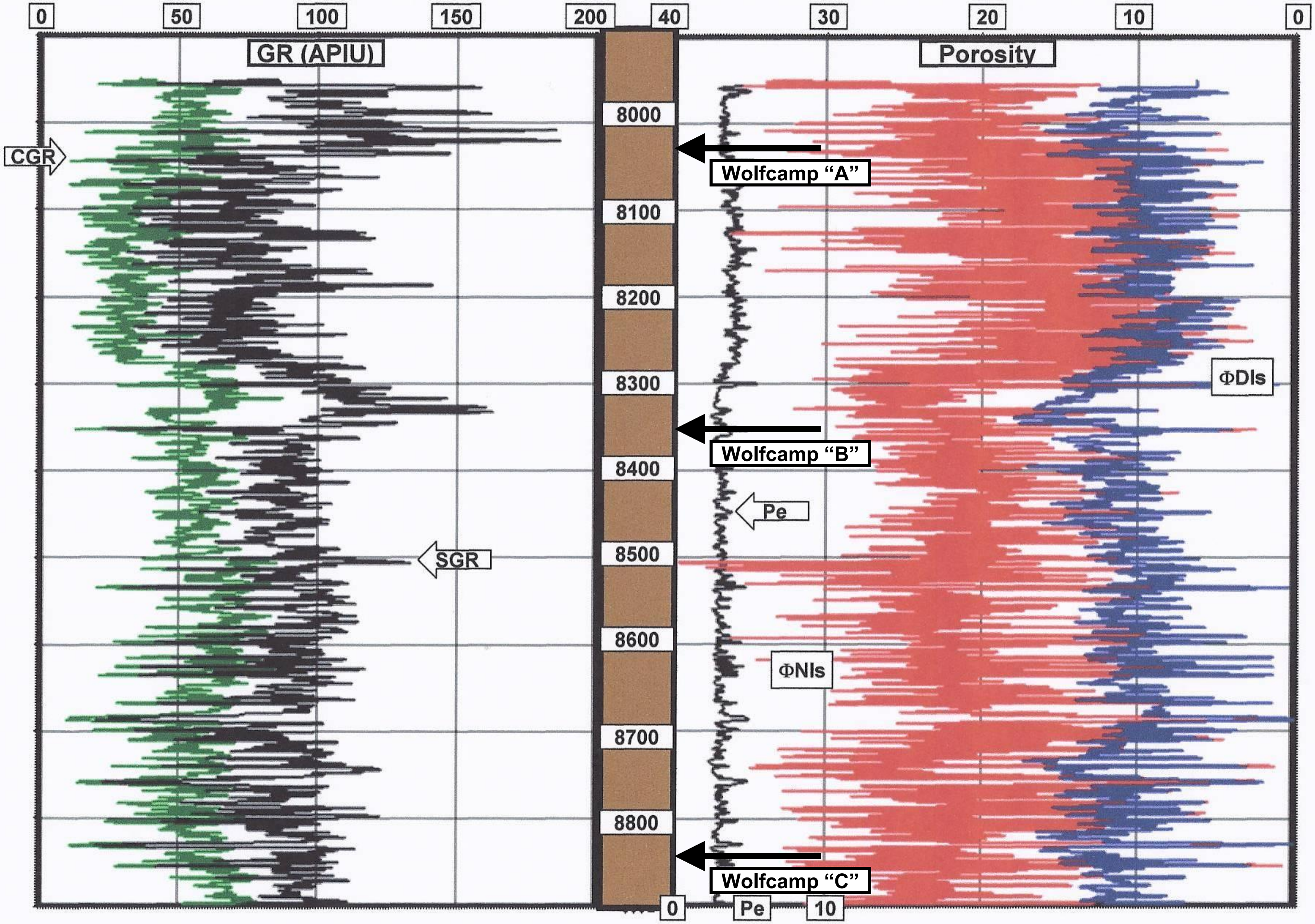
COMPLETION QUALITY

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

PERMIAN WOLFCAMP: Midland Basin Texas



PERMIAN WOLFCAMP: Midland Basin Texas

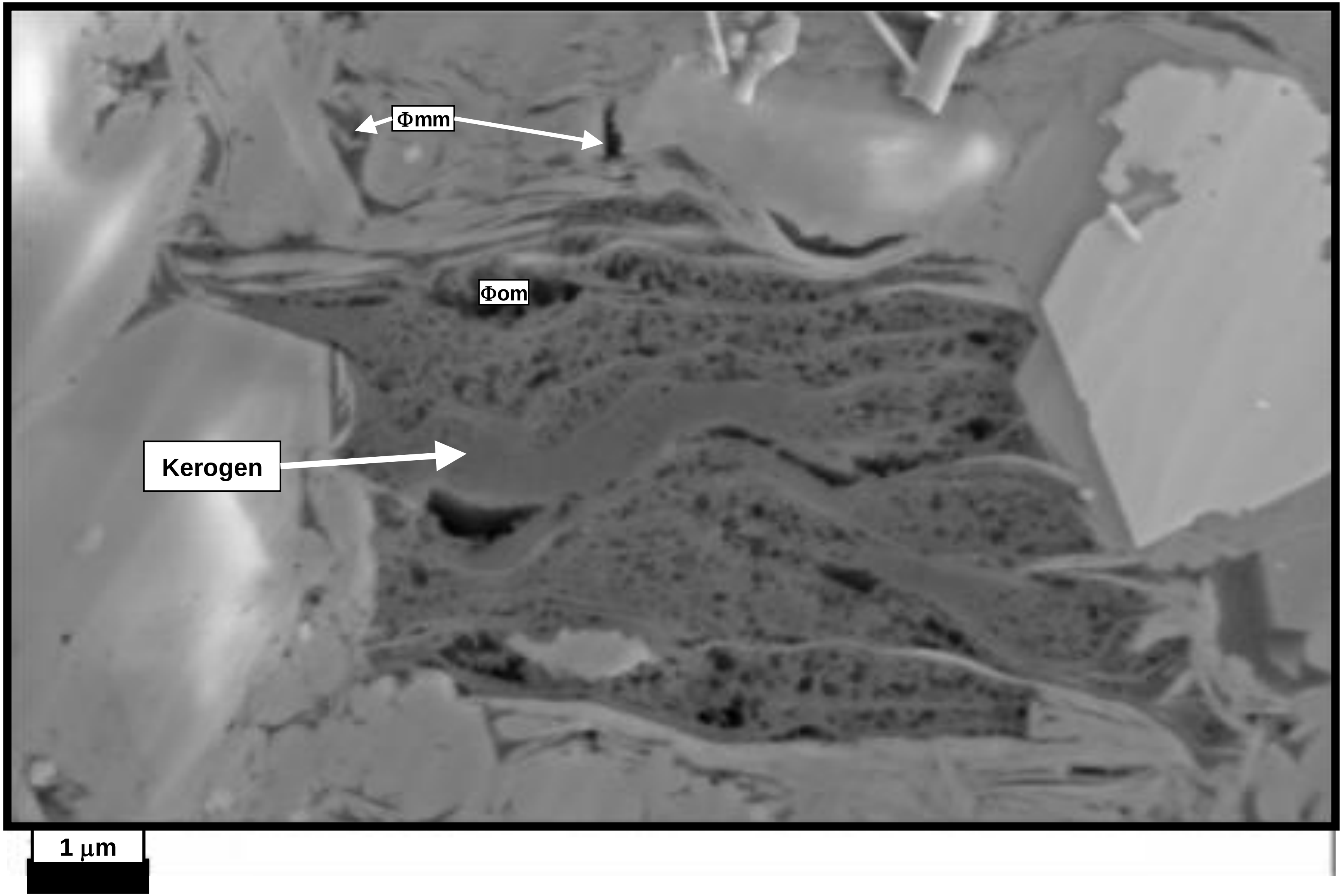


TOClab & TOCschmoker

- TOClab(wt%):
- 0.43 to 8.7   avg. = 3.3wt% N = 94

- TOCschmoker(wt%):
- 1.46 to 6.8   avg. = 3.8wt% N = 94

ORGANOPOROSITY [Φom] & MINERAL MATRIX POROSITY [Φmm]
[Courtesy of Rick Lewis w/ SCHLUMBERGER]



POROSITIES
in
ORGANIC-RICH SHALES

Φtotal and Vcl **from Simultaneous Equations or ECS and Variable Matrix Analysis**

Φe = Φtotal – CBW   CBW = Vcl∗Φclay

Φe = Φom + Φmm

Φom = *Vke*∗OM OM = Φ in Kerogen

Φmm = *Φ*e – Φom

Φclay = 0.10 [Illite]

OM = 0.30

Ke = 1.1g/cc to 1.5g/cc during HC generation

OOIPstb DUAL POROSITY PROCEDURE

OOIPstb ORGANOPOROSITY [Φom]:

$\Phi oil = \Phi om * (1-Sw)$ $Sw = 0.0$

$OOIPstb = \Sigma[(7758 * \Phi oil * h * A)/BOI]$

h = 0.5ft. A = 160ac. BOI = 1.4

OOIPstb MINERAL MATRIX POROSITY [Φmm]:

$\Phi oil = \Phi mm * (1-Sw)$

$Sw = (Ro/Rt)^{0.5}$ $Ro = 1/\Phi^{0.5}$

$OOIPstb = \Sigma[(7758 * \Phi oil * h * A)/BOI]$

h = 0.5ft. A = 160ac. BOI = 1.4

NET PAY CUT-OFF: k > 100nD

$k = [(0.0108 * \Phi oil) – 0.000256] * 10^6$

OOIPstb
TRIPLE COMBO DATA ONLY
AIT90, ρb, and ΦNls

MINERAL VOLUMES and TOTAL POROSITY

- $Vcl + Vqtz + Vke + \Phi total = 1.0 \quad Vke = (TOC*Kvr*\rho b)/\rho kerogen$
- $Vcl*\rho cl + Vqtz*\rho qtz + Vke*\rho ke + \Phi total*\rho f = \rho b$
- $Vcl*\Phi ncl + Vqtz*\Phi nqtz + Vke*\Phi nke + \Phi total*\Phi nf = \Phi n$

$$TOCwt\% = (156.956/\rho b) – 58.271$$

← Schmoker Equation

Vcl = volume of clay

ρcl = density of clay Φncl = neutron porosity of clay

Vqtz = volume of quartz

ρqtz = density of quartz Φnqtz = neutron porosity of quartz

Vke = volume of kerogen

ρke = density of kerogen Φnke = neutron porosity of kerogen

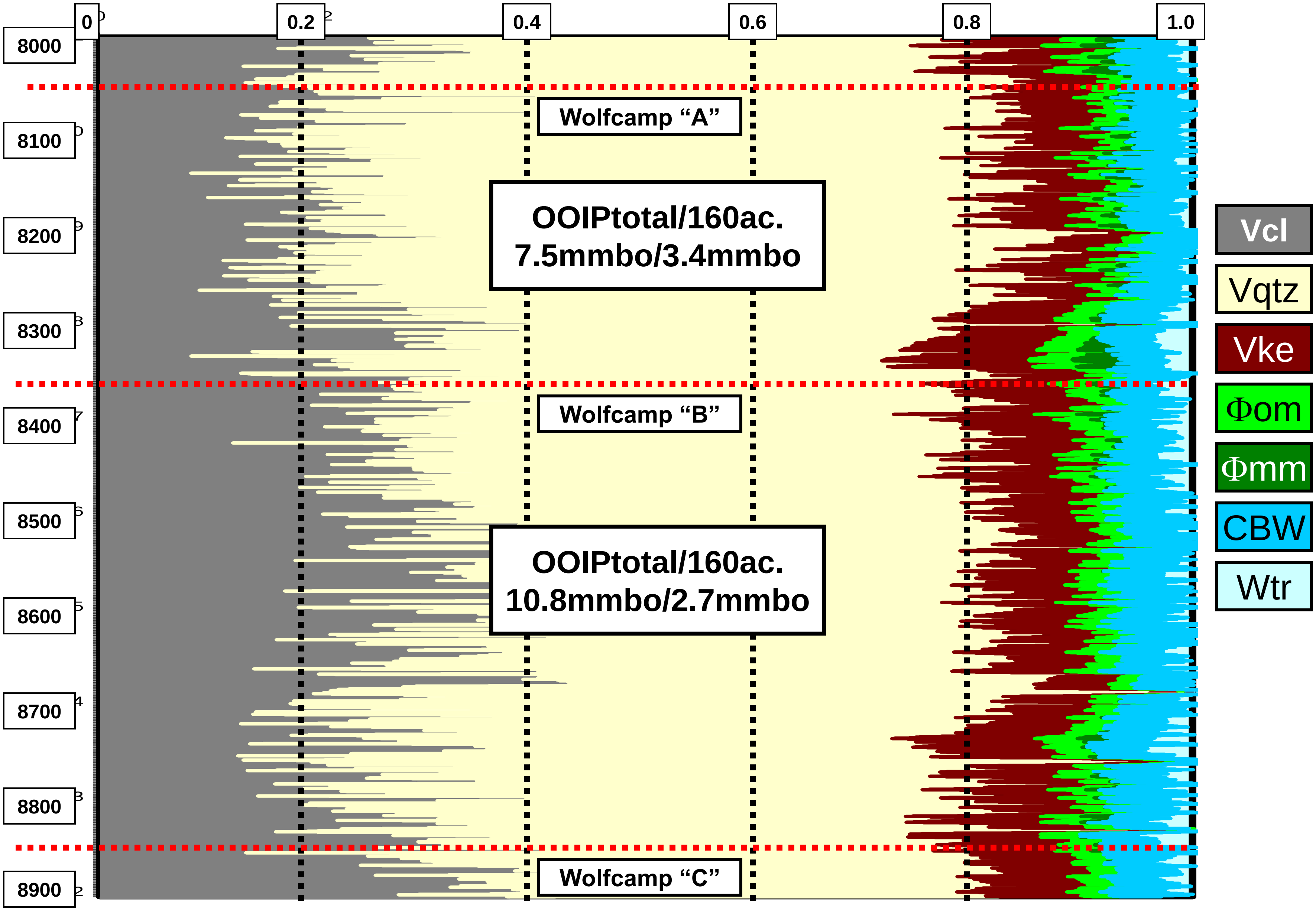
Φtotal = total porosity

$\rho f = Sw*\rho water + (1-Sw)*\rho oil$

$\Phi nf = Sw*\Phi nwater + (1-Sw)*\Phi noil$

Modified After: Lewis, 2009

Lithology [simultaneous eq.] & Fluid Saturations: Permian Wolfcamp Shale: Texas



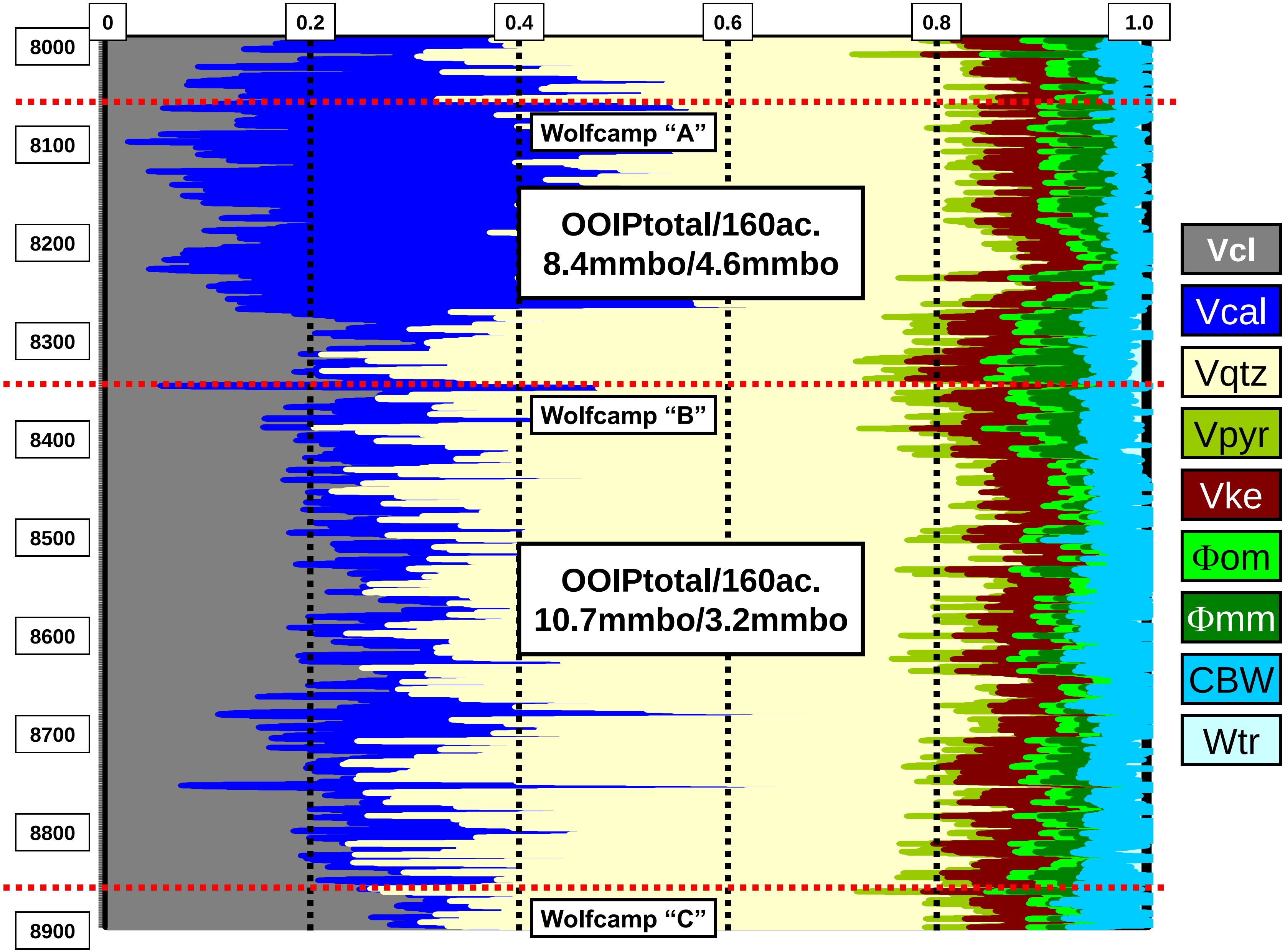
OOIPstb
TRIPLE COMBO DATA
+
GEOCHEM DATA [ECS]

VARIABLE MATRIX [GEOCHEM DATA]

- $\rho ma = (Vcl * \rho cl)+(Vcal * 2.71)+(Vqtz * 2.65)+(Vpyr * 5)+(Vke * \rho ke)$
- $\rho ke = 1.5$ g/cc $Vke = (TOC * Kvr * \rho b)/\rho kerogen$
- ρcl
  - Kaolinite = 2.61g/cc
  - Chorite = 2.92g/cc
  - Illite = 2.71g/cc
  - Illite/Smectite = 2.45g/cc
  - Smectite = 2.26g/cc

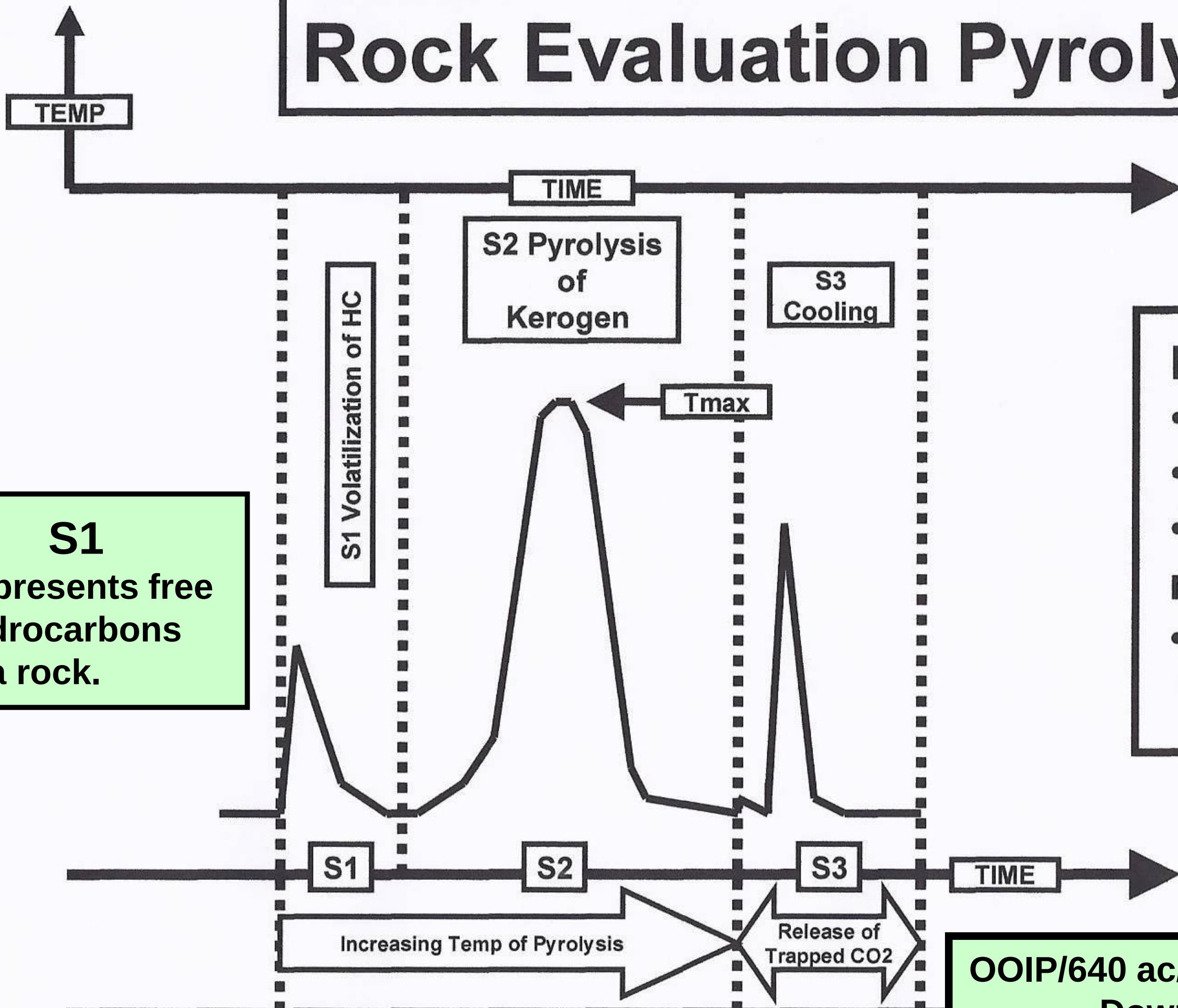
- $\Phi total = (\rho ma - \rho b)/(\rho ma - \rho f)$
- $\rho f = (Sw * 1.1) + [(1-Sw) * \rho hc]$ $\rho gas = 0.1$g/cc $\rho oil = 0.85$g/cc

Lithology [ECS Log] & Fluid Saturations: Permian Wolfcamp Shale: Texas



OIL in PLACE
PYROLYSIS S1 DATA

Rock Evaluation Pyrolysis

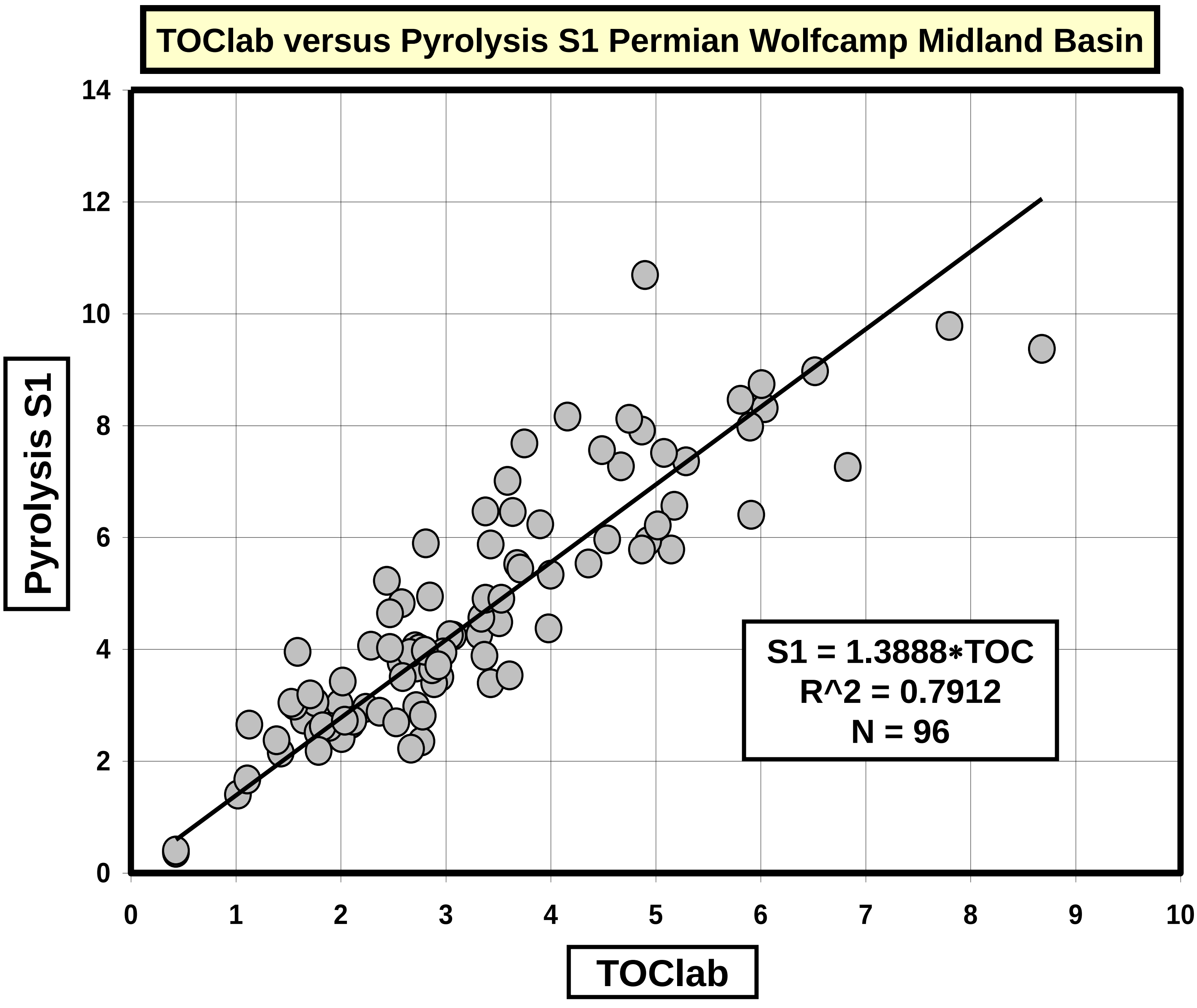


S1
Represents free hydrocarbons in a rock.

Determines:
- **TOC content**
- **Kerogen type**
- **Kerogen maturity**
- **Amount of free hydrocarbons**

OOIP/640 ac/ft = 4965.36*ρb*S1*(1/ρoil)
Downey & others (2011)

Hydrocarbon Index(HI) = S2*(100/TOC)


TOClab versus Pyrolysis S1 Permian Wolfcamp Midland Basin
Pyrolysis S1
TOClab
S1 = 1.3888*TOC
R^2 = 0.7912
N = 96
0
2
4
6
8
10
12
14
0
1
2
3
4
5
6
7
8
9
10

OOIP from Pyrolysis [S1] Data

- **OOIP/640 ac./ft = 4965.36∗ρb∗S1∗(1/ρoil)**

  [Downey & others, 2011]

- **OOIP/160ac. = Σ[1241.34∗ρb∗S1∗(1/ρoil)∗0.5’]**

  TOC = (156.956/ρb) - 58.271 [Schmoker Equation]

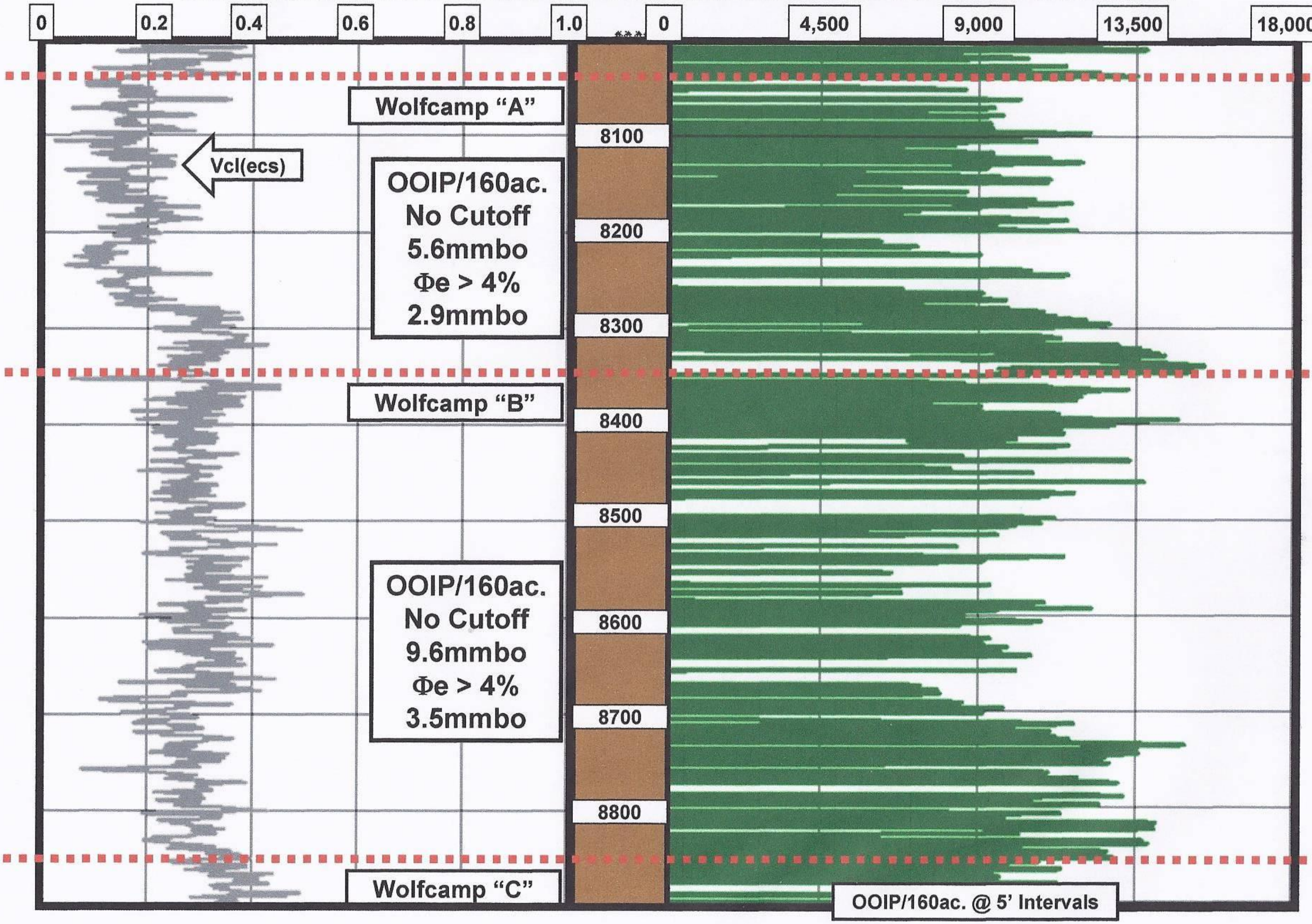
  ρb = bulk density from well log

  S1 = 1.3888∗TOClog

  ρoil = oil density [default value: 0.85g/cc]

  0.5 ft. = log data interval

Vcl(ecs) vs. OOIP/160ac. @ 0.5ft Inlervals Pyrolysis [S1] Data
Permian Wolfcamp A & B Midland Basin Texas



Summary: Volumetric OOIPstb[mmbo] & Pyrolysis S1 OOIP[mmbo]
Permian Wolfcamp “A” and “B” Midland Basin Texas

DATA	Triple-Combo	Triple Combo/ECS	Pyrolysis S1
Wolfcamp A ka>100nD no ka or Φe cutoff	 3.4 7.5	 4.6 8.4	 2.9 [Φe>4%] 5.6
Wolfcamp B ka>100nD no ka or Φe cutoff	 2.7 10.8	 3.2 10.7	 3.5 [Φe>4%] 9.6
TOTALS ka>100nD no ka or Φe cutoff	 6.1 18.3	 7.8 19.1	 6.4 [Φe>4%] 15.2

CONCLUSIONS

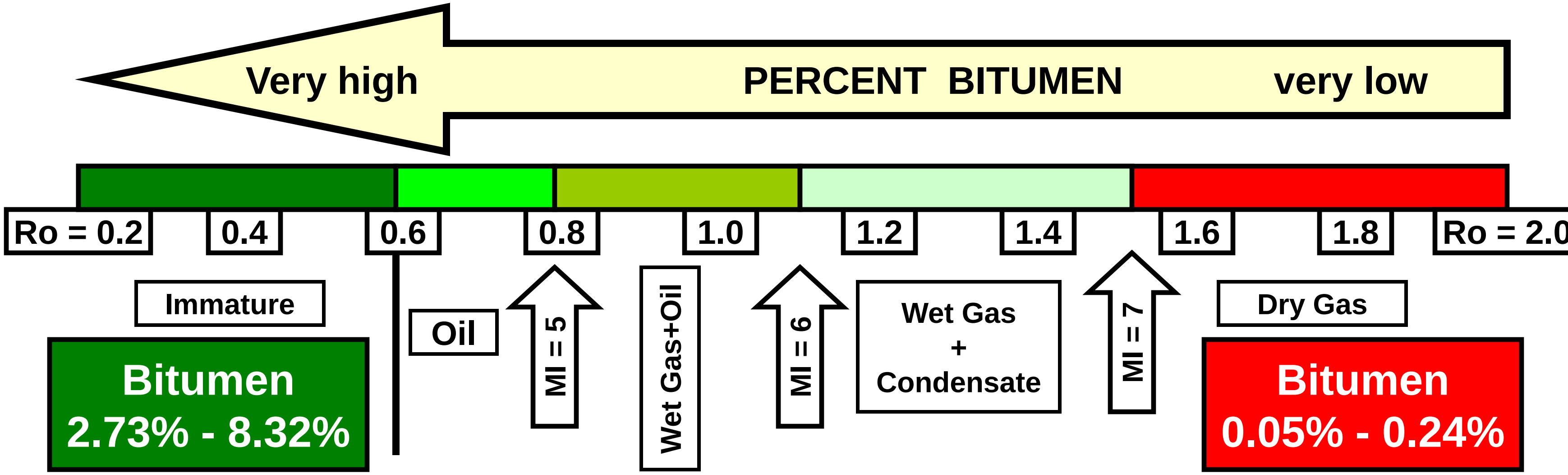
- Using a permeability cut-off [ka>100nD] OOIPstb calculated using GEOCHEM data compared well with OOIPstb calculated using only Triple Combo data in both Wolfcamp “A” and Wolfcamp “B”.

- However, in the Wolfcamp “A” and “B” OOIP from Pyrolysis S1 data is slightly lower.

CONCLUSIONS

- OOIP calculated from Pyrolysis S1 Data has the following advantages:
- NO Rw Needed
- NO Porosity Needed [no a, m, & n]
- NO BITUMEN in the Calculation

WHY KNOWLEDGE of MATURITY is IMPORTANT

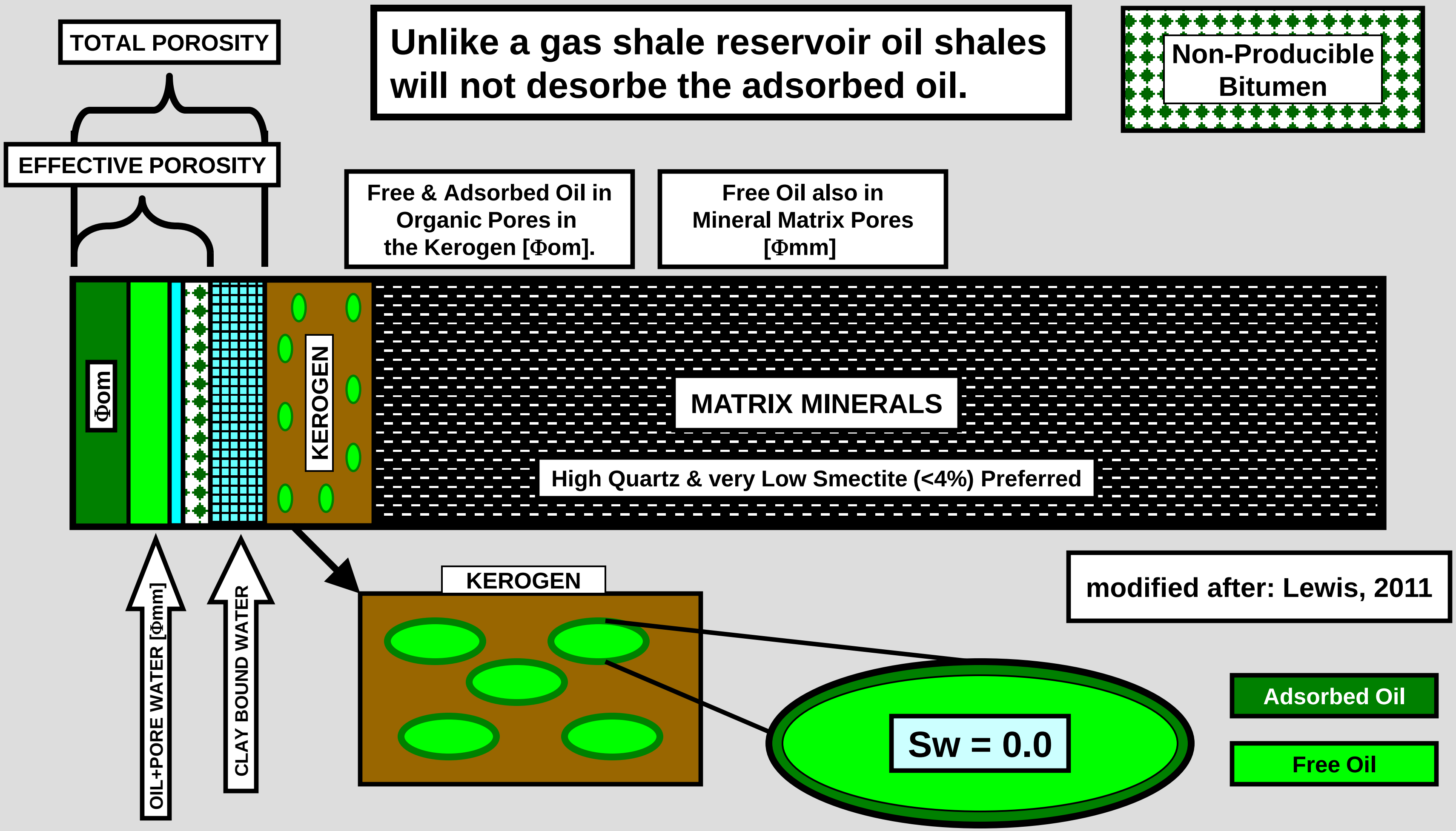


NOTE: As maturity increases the non-producible bitumen is converted to producible oil and gas.

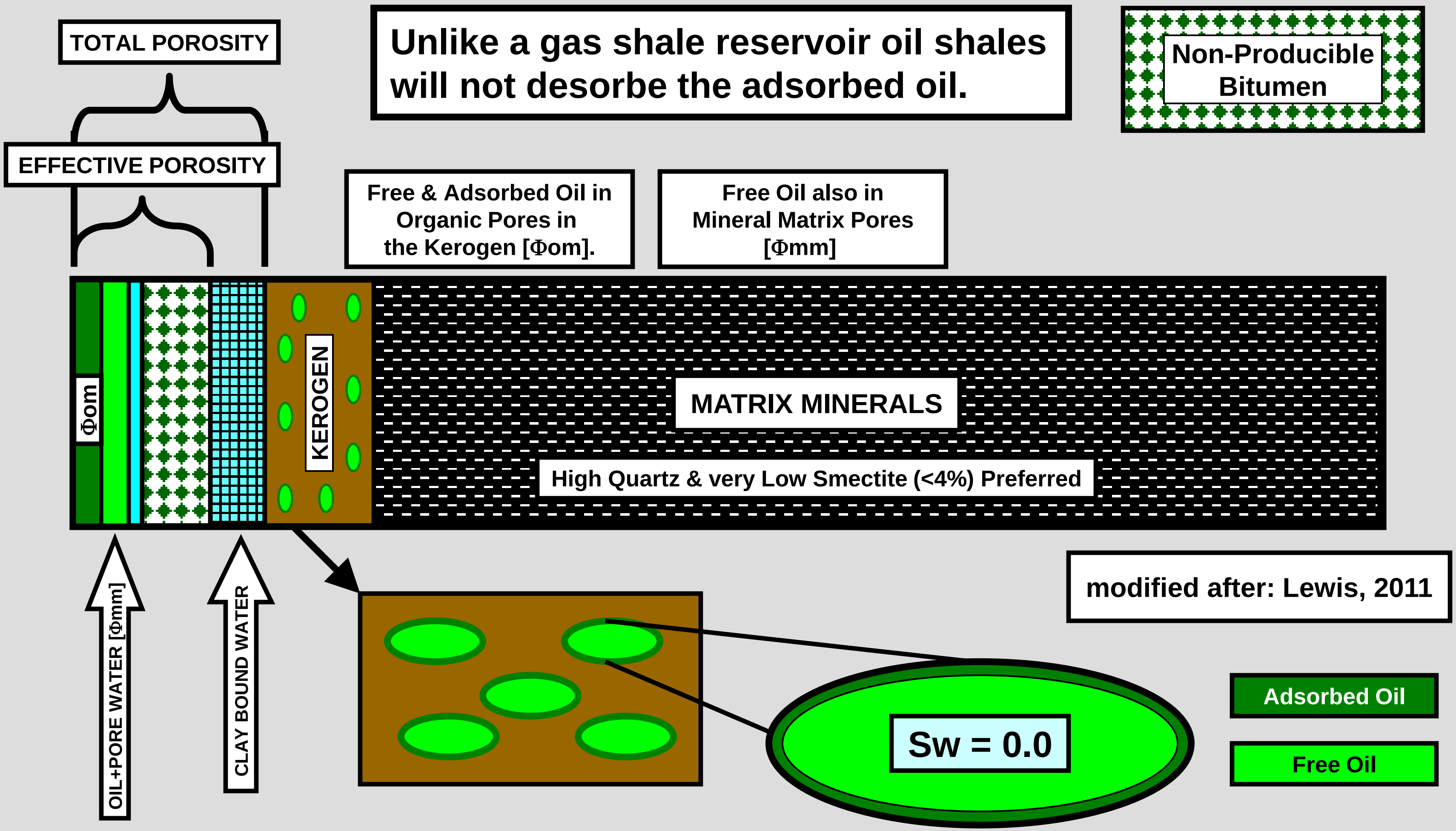
% Bitumen from: Lewis (2013)

Wolfcamp Midland Basin Well: Ro(avg.) = 0.84   N = 96

SHALE POROSITY [High Maturity]



SHALE POROSITY [Low Maturity]



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Permian Wolfcamp “A” and “B” Midland Basin Texas

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NOTE: The similar values for volumetric OOIPstb and OOIP from Pyrolsis S1 Data indicates a minor amount of BITUMEN.

Oxygen Index vs. Hydrogen Index Permian Wolfcamp Shale Midland Basin