

Resource Potential of the Woodford Shale in New Mexico*

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Abstract

Shale resource plays are either shale-gas or shale-oil. Better evaluation procedures considering more number of parameters are needed to estimated resource potential. Successful shale-gas and shale-oil plays in the United States are variable in geological age, depositional sequence, organic richness, thermal maturity, kerogen type, and mineralogy among a few key parameters.

The Upper Devonian Woodford Shale ranges from a thickness of 0 ft to 300 ft and is found at depths of 7,000 ft to 18,000 ft in the Delaware Basin. The Woodford is thermally mature over its entire extent in New Mexico: In the deeper parts of the Delaware Basin, it is in the thermogenic gas and condensate window; on the Northwest Shelf and where present on the Central Basin Platform, it is in the oil window (Broadhead 2010). Southeastern New Mexico is subdivided into Regions I, II and III based on the intensity of the fracture networks, thermal maturity and Total Organic Carbon (TOC) (Comer 2005). Each of the regions (Regions I, II and III) were ranked for the prospects of shale Bas using Miller's (2010) ranking scorecard and assigned a score of 68, 66 and 48 respectively. The results showed that Region I and II have better chances of finding shale Bas. Finally an assessment was made to quantify the volumes of oil and Bas in-place using Comer's (2005) Hydrogen mass balance method. The estimated volumes were 36 billion barrels of original oil in-place and 44.5 trillion cubic feet of original Bas in-place in comparison to 119 billion barrels of original oil in-place and 230 trillion cubic feet of Bas in-place in the Woodford for the entire Permian Basin (Texas and New Mexico). The assessment confirms that Woodford shale is a major unconventional source of both oil & Bas in New Mexico.

The work described in this paper was performed in conjunction with a contract from the U.S, Bureau of Land Management, Pecos District to help estimate oil and gas development in southeastern New Mexico for the next 20 years.

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Resource Potential of the Woodford shale in New Mexico

**AAPG South West Section Meeting
2011**

**Presented By
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Graduate Student
Petroleum Engineering**



Author's Profile

- Bachelor's in Applied Petroleum Engineering from University of Petroleum & Energy Studies (UPES), India (2003-2007)
- Software Engineer (Oil & Gas) – Infosys Technologies Limited, India (2007-2009)
- Master's in Petroleum Engineering from New Mexico Institute of Mining and Technology (2009-2011)
- Author of four International Publications
- “Outstanding Graduate Student Award 2010-2011” SPE NMT Student Chapter

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Ron Broadhead, NM Bureau of Geology – Source Rock Characteristics

Dr. Randy Miller , Core Labs - Shale Gas Ranking Score Card

Dr. John Comer, Hydrogen Mass Balance for Resource Estimation

Advisors:

Dr. Robert Balch, Dr. Tom Engler and Ms. Martha Cather for reviewing my work and guiding me throughout the process

Bureau of Land Management (BLM), Pecos District, for the Project contract

Outline of the Talk

- Objective
- Study Area
- Depositional Environment
- Characteristics of Source Rock
- Ranking of the Woodford Shale
- Estimated Resource Potential
- Conclusions & Recommendations
- References

Agenda

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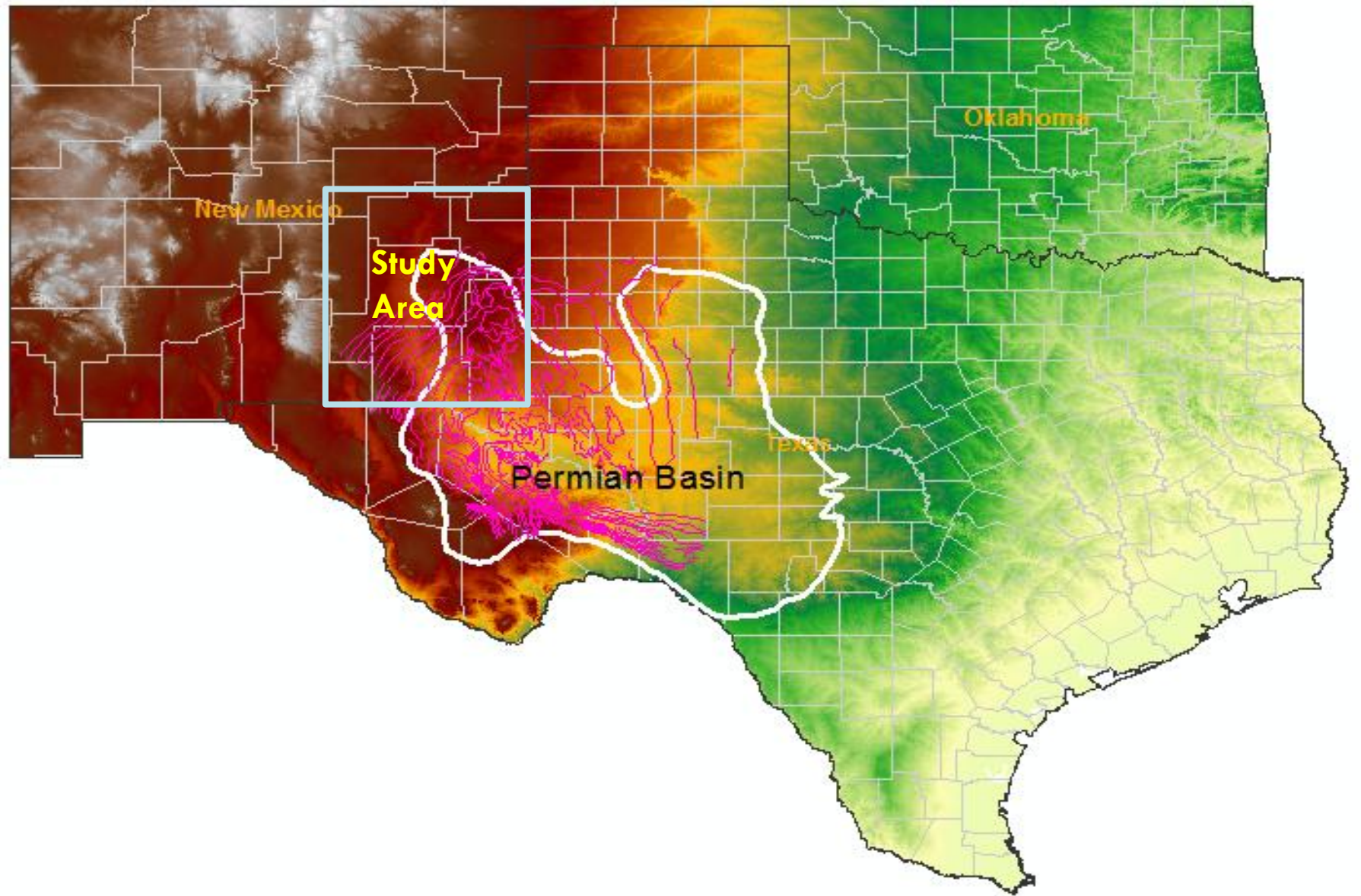
Main Objective of Today's Talk

**“ Estimating the Resource Potential of
the Woodford Shale”**

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Study Area



Source: Modified from USGS data

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Stratigraphic Unit

System	Series	Stage	Lithostratigraphic Unit
Devonian	Upper	Famennian	Woodford Shale
	Middle	Frasnian	Pre-Woodford Shale
		Givetian	
		Eifelian	
	Lower	Emsian	
		Pragian	
		Lochkovian	

Thirtyone fm

Reference : Broadhead 2010

Note:

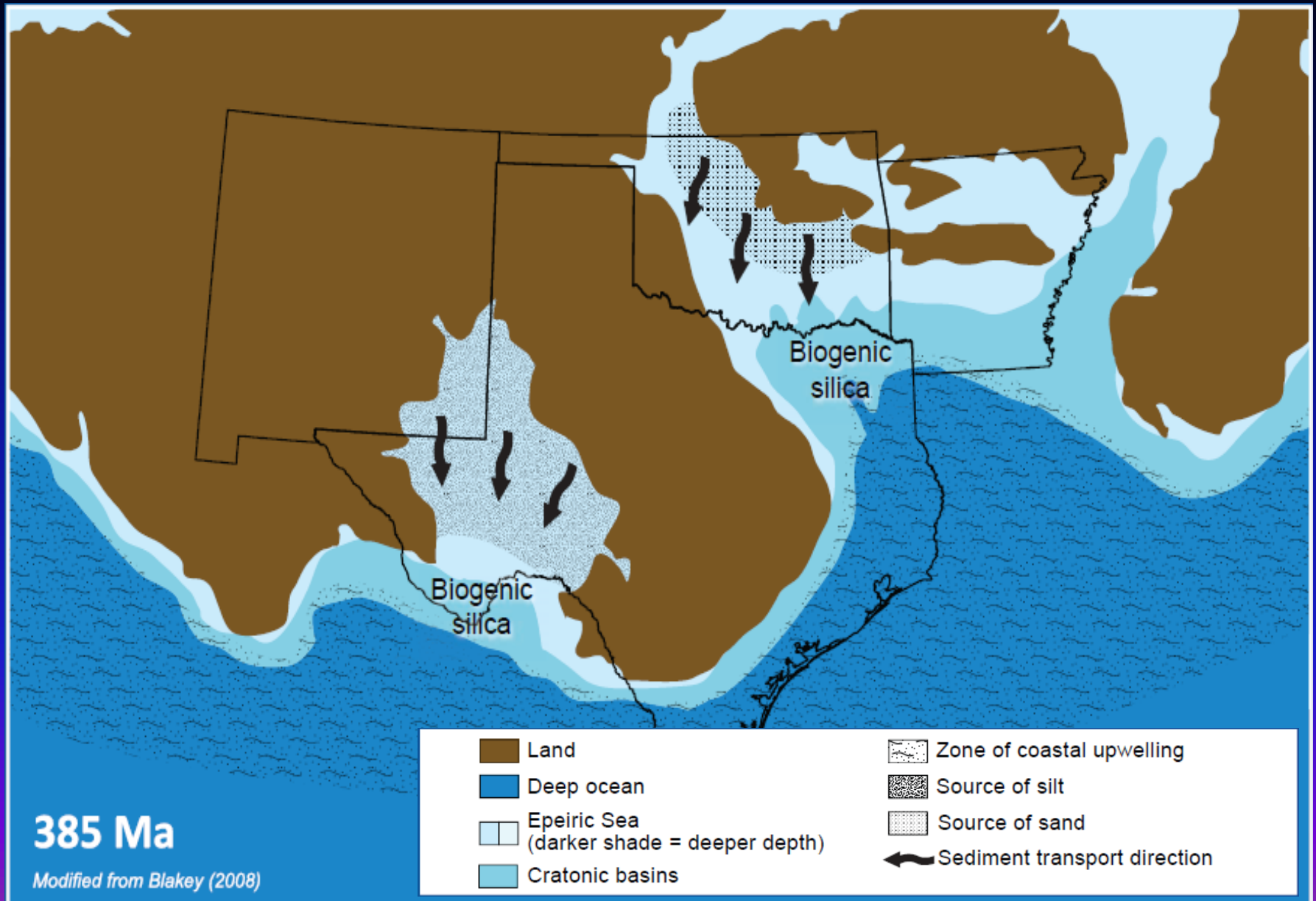
Famennian Stage – 359 Ma to 374 Ma

Frasnian Stage – 374 Ma to 385 Ma

Overlies Wristen(Silurian) and Thirtyone (Lower Devonian)

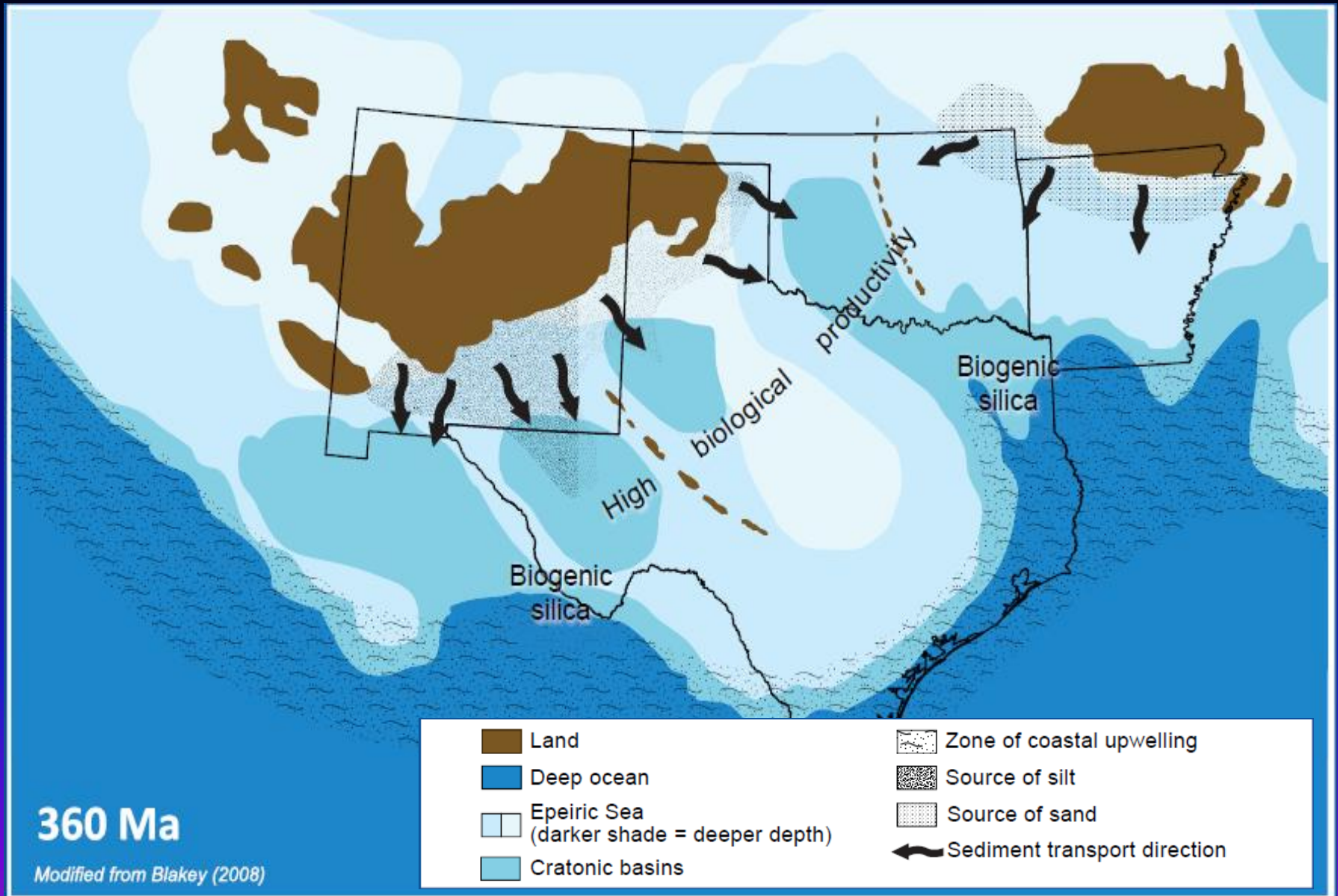
Carbonates

Paleogeography



Reference : Comer 2008

Paleogeography



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Source Rock data used

Data Source

1. 19 cored wells from Broadhead (2005)
2. 4 cored wells from Comer (2008)
3. 4 Outcrops samples from Comer (2008)

Evaluated Parameters

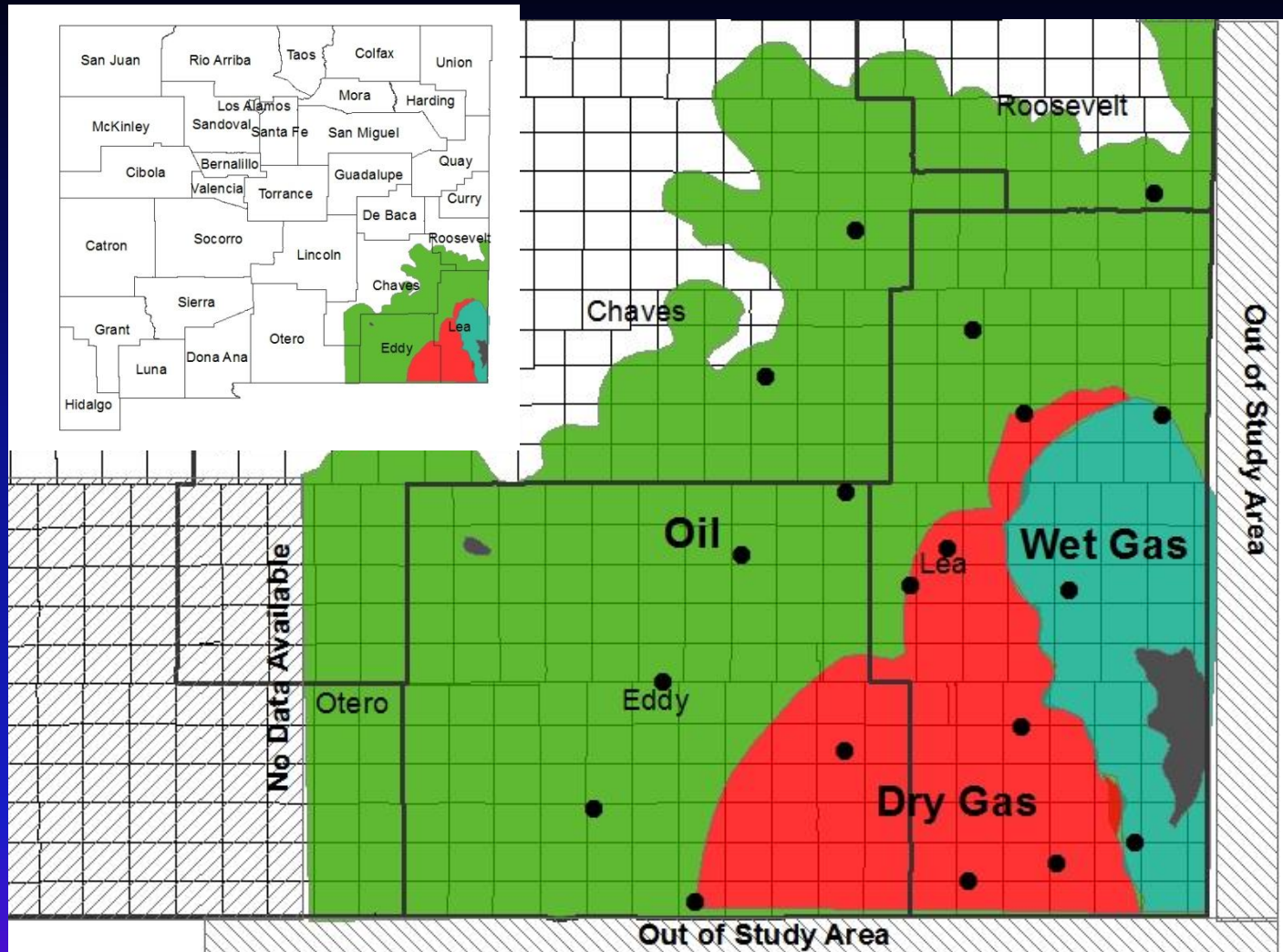
1. Total Organic Carbon (TOC)
2. Thermal Maturity (TMax)
3. Vitrinite Reflectance (Ro)
4. Organic Fraction of Carbon (C_{org}) & Hydrogen (H_{org})
5. Density of the rock
6. Fraction of Immature rock
7. % of Clay & Quartz content

Characteristics of Source Rock

(Broadhead 2010)

1. Black organic-rich shales - Hydrocarbon source facies
2. Present day TOC range 1.7 to 4.9 wt.%
3. Original, pre-maturation TOC range 1.8 to 6.8 wt%
4. Kerogen fraction is dominated by amorphous and herbaceous type shales
5. Woody & inertinitic types are prevalent to the north, closer to the pinch out.
6. Thermal Maturity is greatest in southwestern Lea and Southeastern Eddy Counties – Thermogenic gas & Condensate Window
7. Thermal Maturity is lower to the north and west – Oil Window

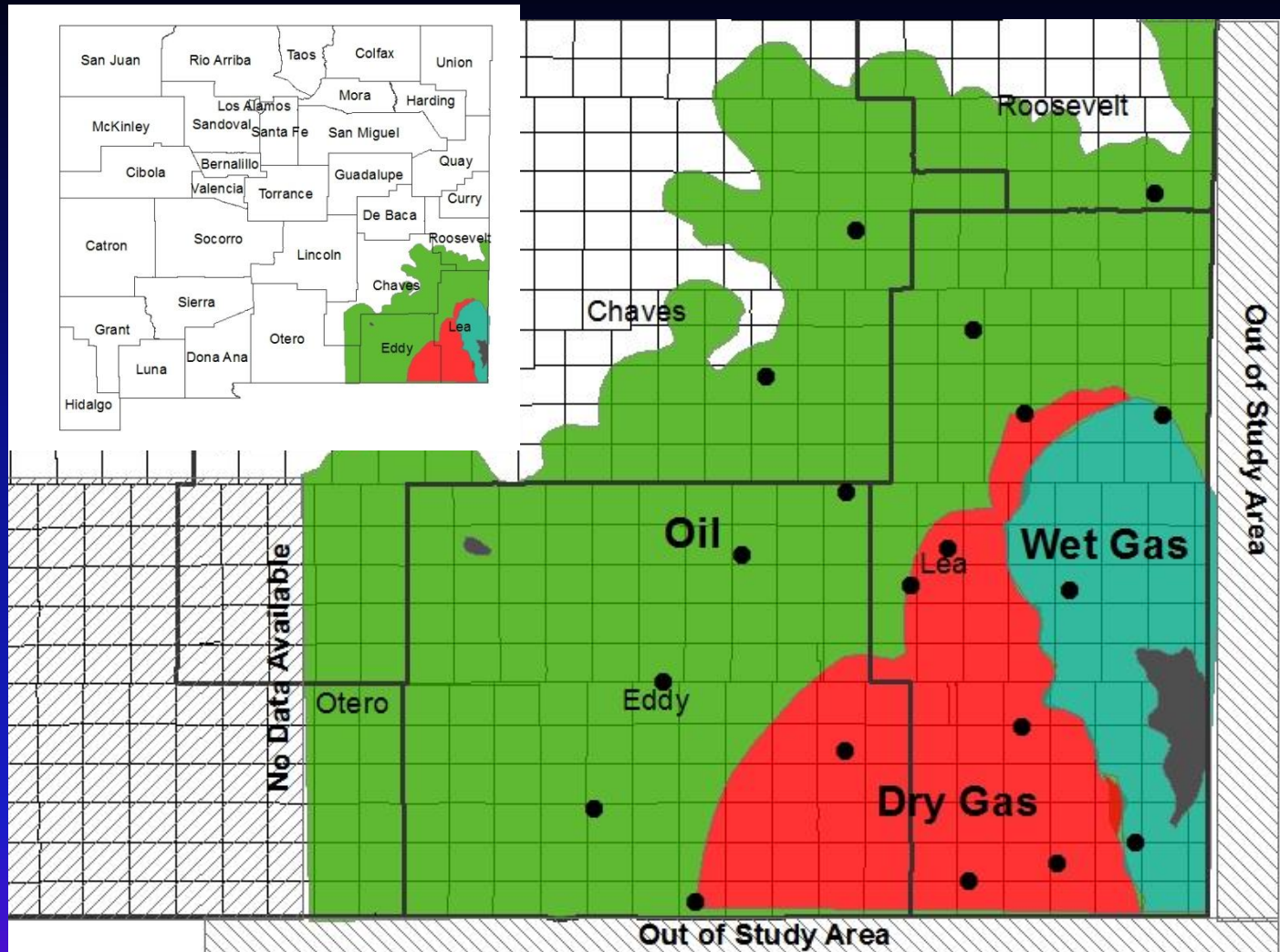
Classification into Regions



Region I (thermal maturity (early oil to oil generation window), high TOC and high fracture intensity); - Blue

Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005

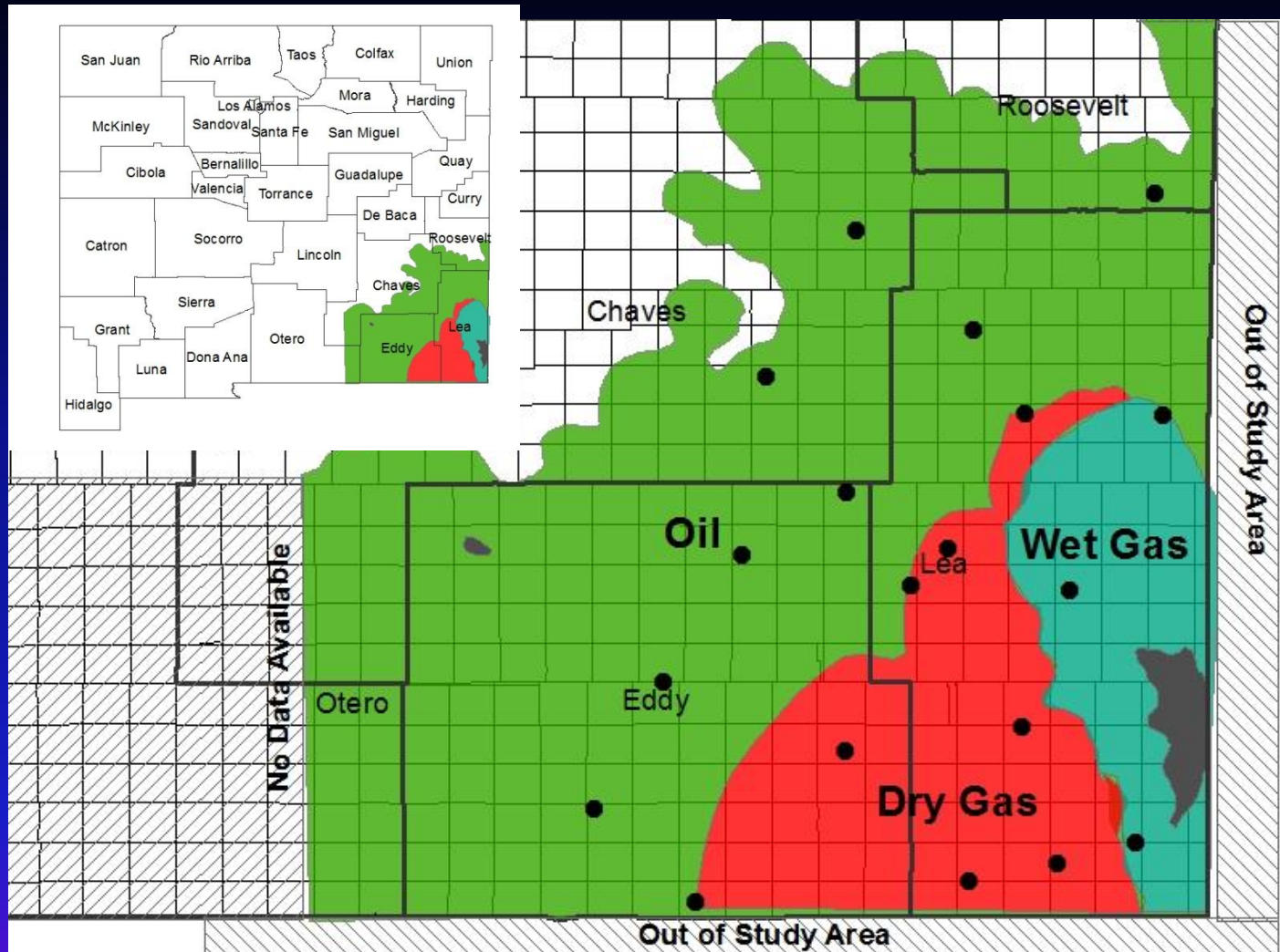
Classification into Regions



Region II (thermal maturity (dry gas generation), moderate TOC and sparsely fractured); - Red and

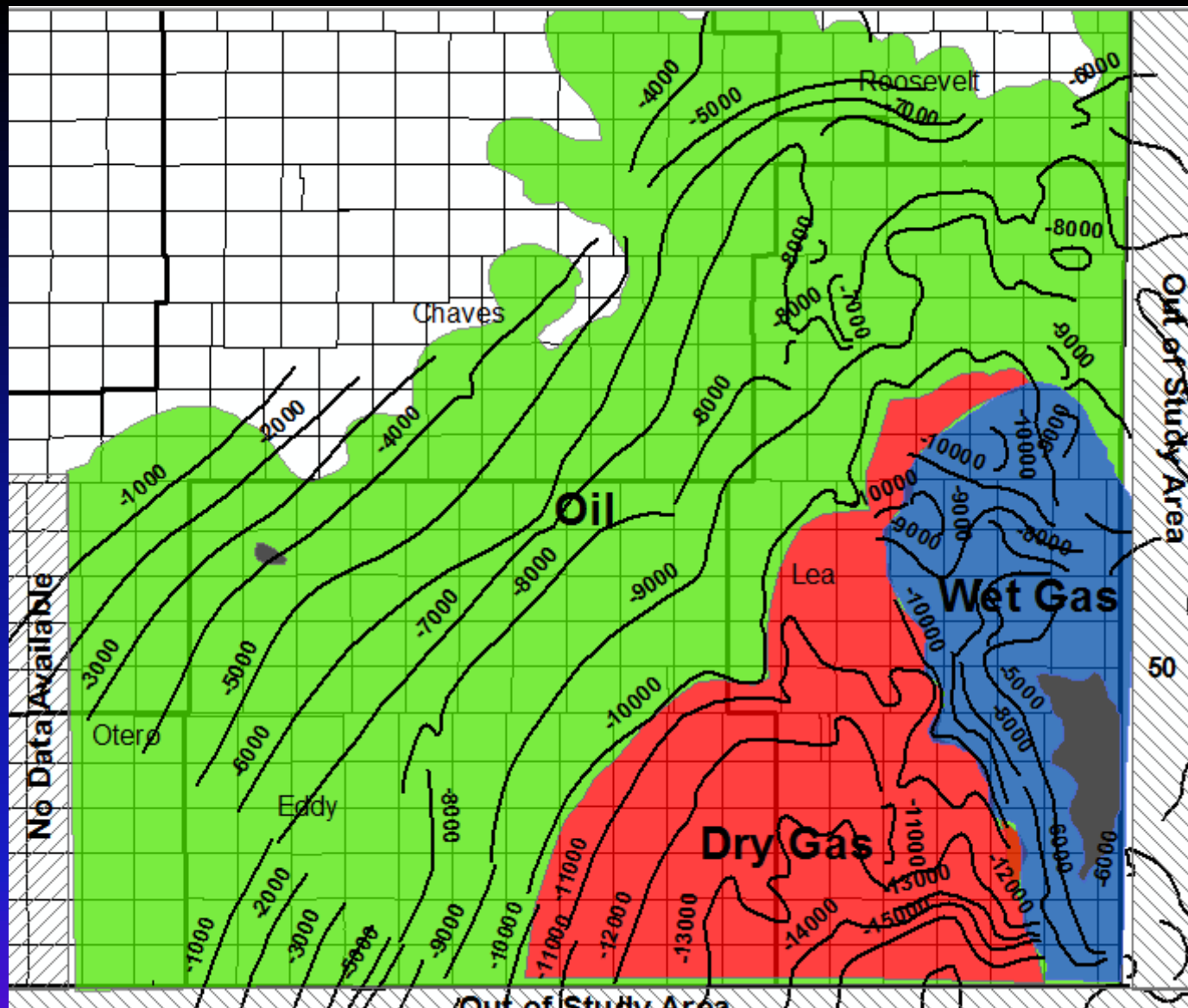
Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005

Classification into Regions



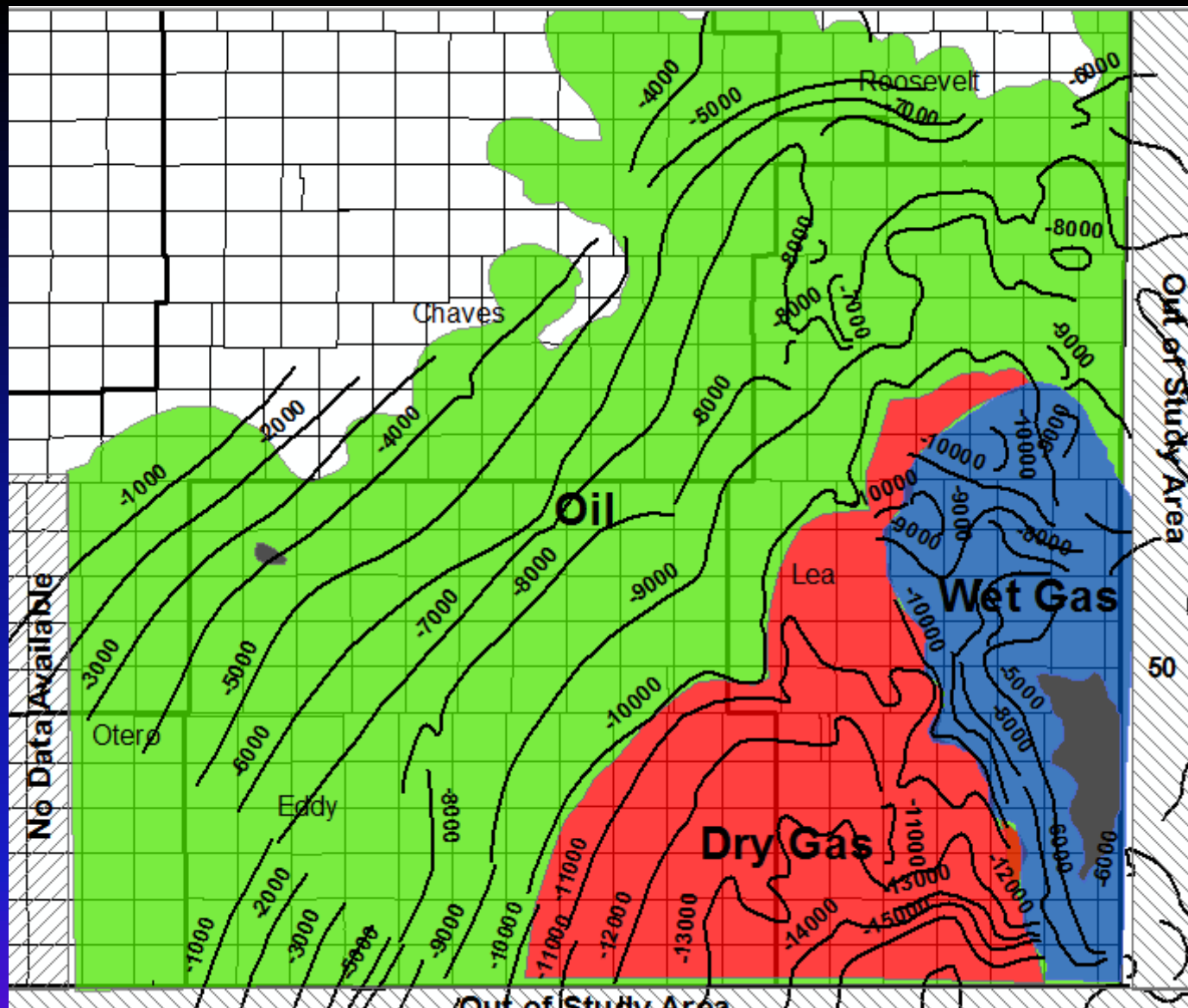
Region III (thermal maturity (oil window), reasonable TOC and local fractures) - Green

Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005



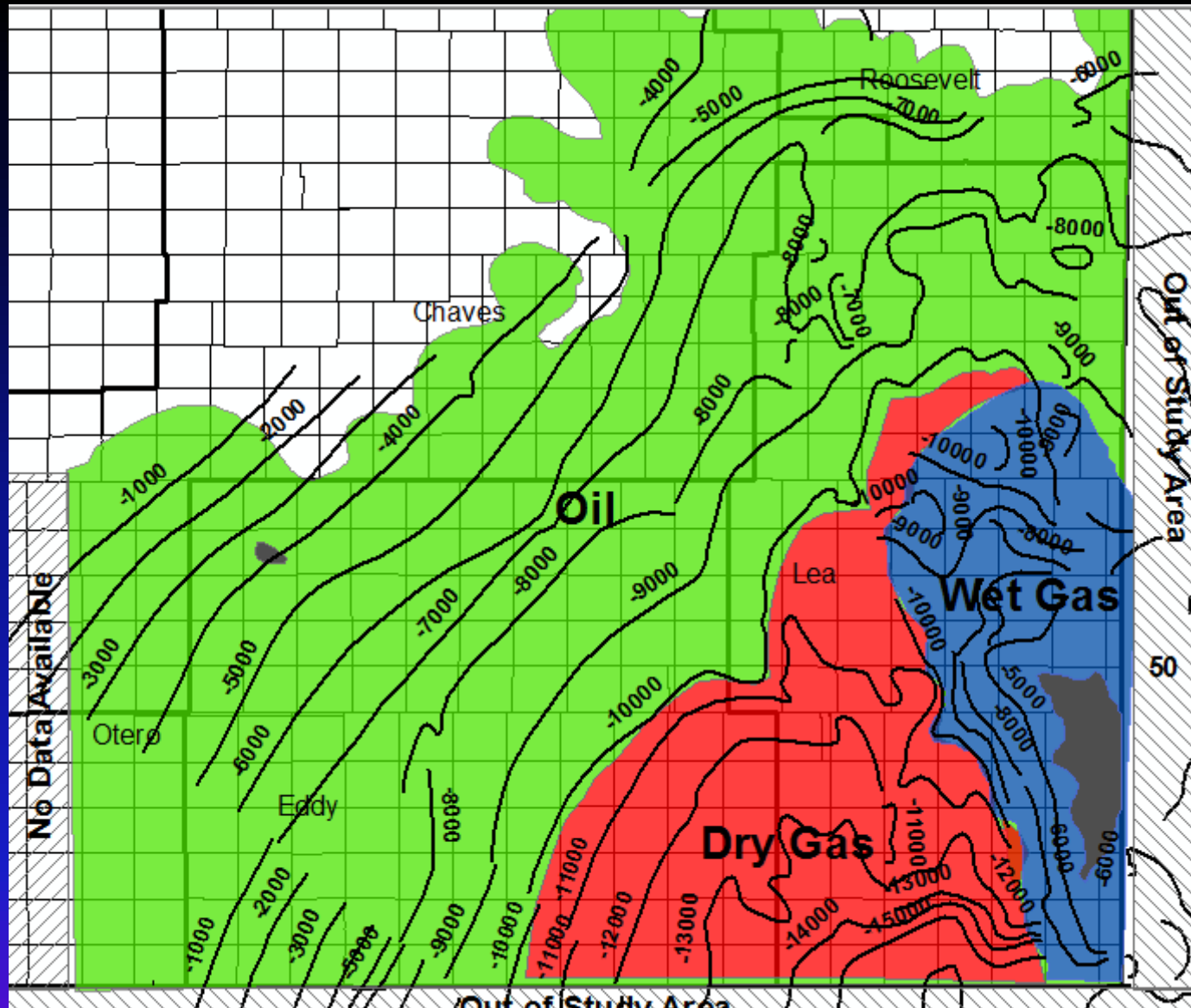
0-300ft thick in southeastern New Mexico.

Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005



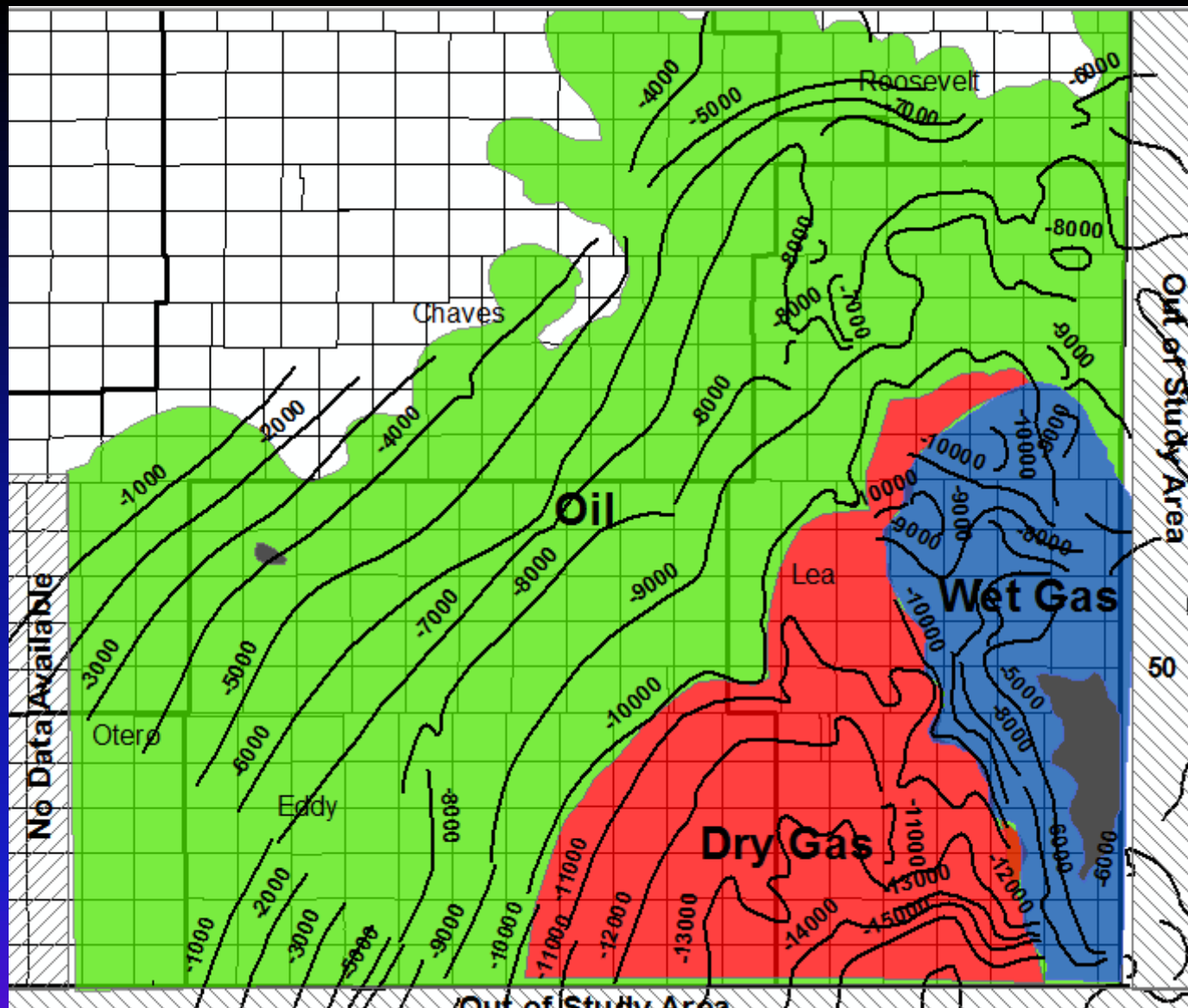
Max. thickness in the South Central Lea County (Depths of 18,000ft)

Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005



Pinches out to the North and northwest in Roosevelt and Chaves counties (Depth less than 7000ft)

Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005



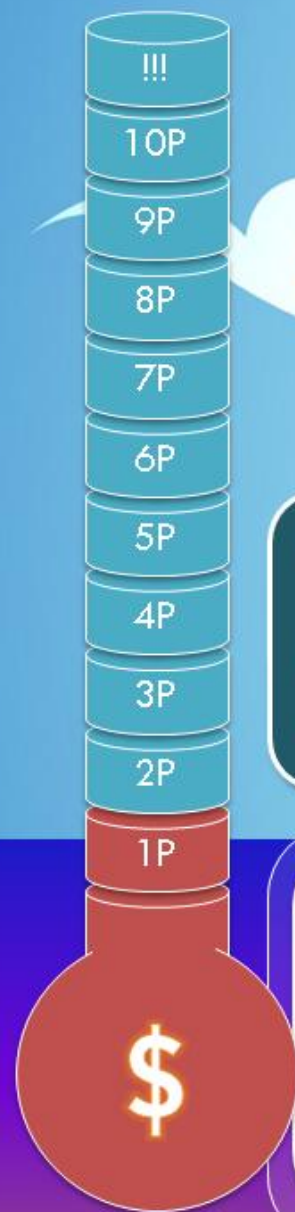
Absent from the highest parts of the central basin platform in southeastern Lea County.

Note: Regions Divided Based on Work from Broadhead 2010 and Comer 2005

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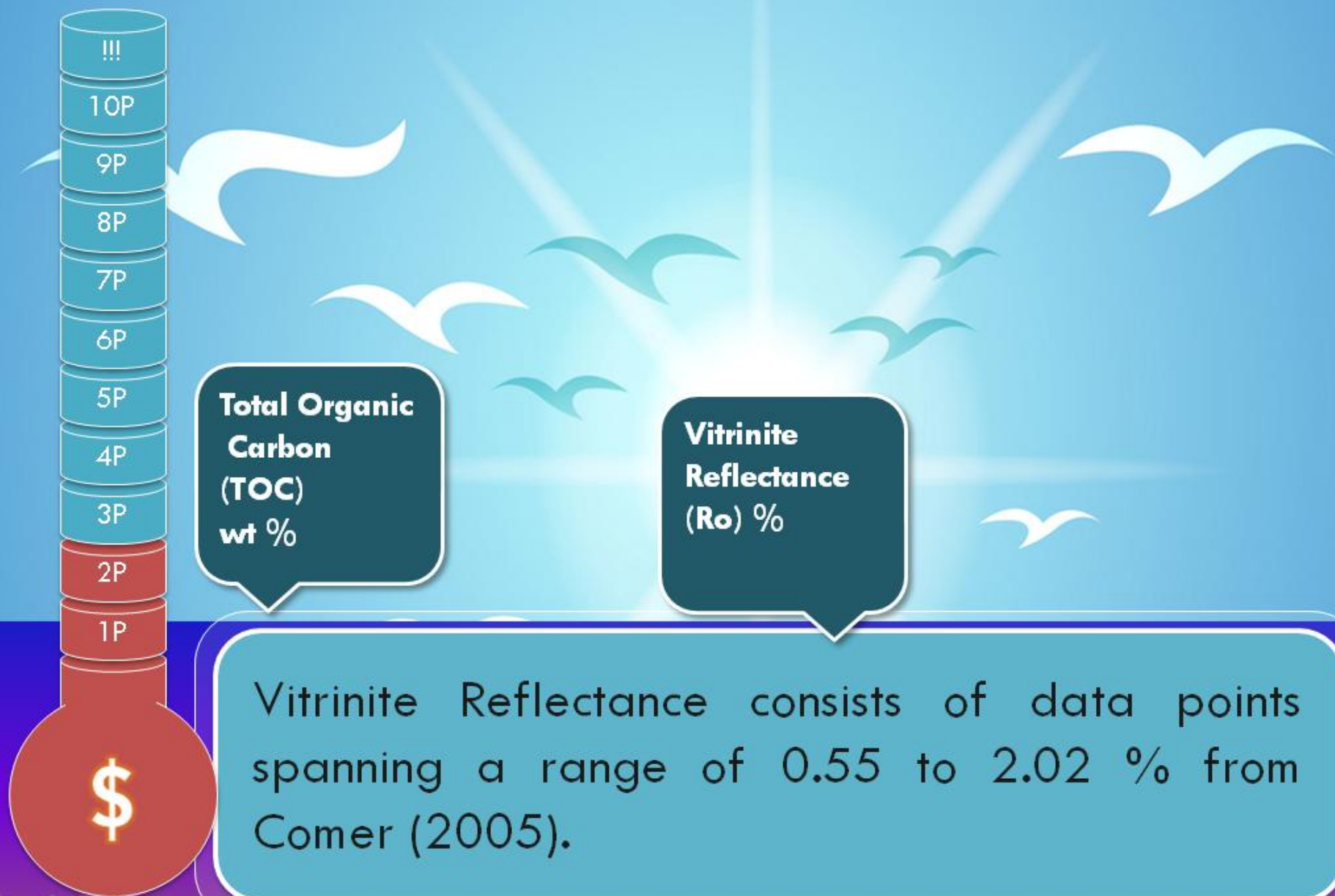
Ranking the Potential of Woodford Shale in New Mexico



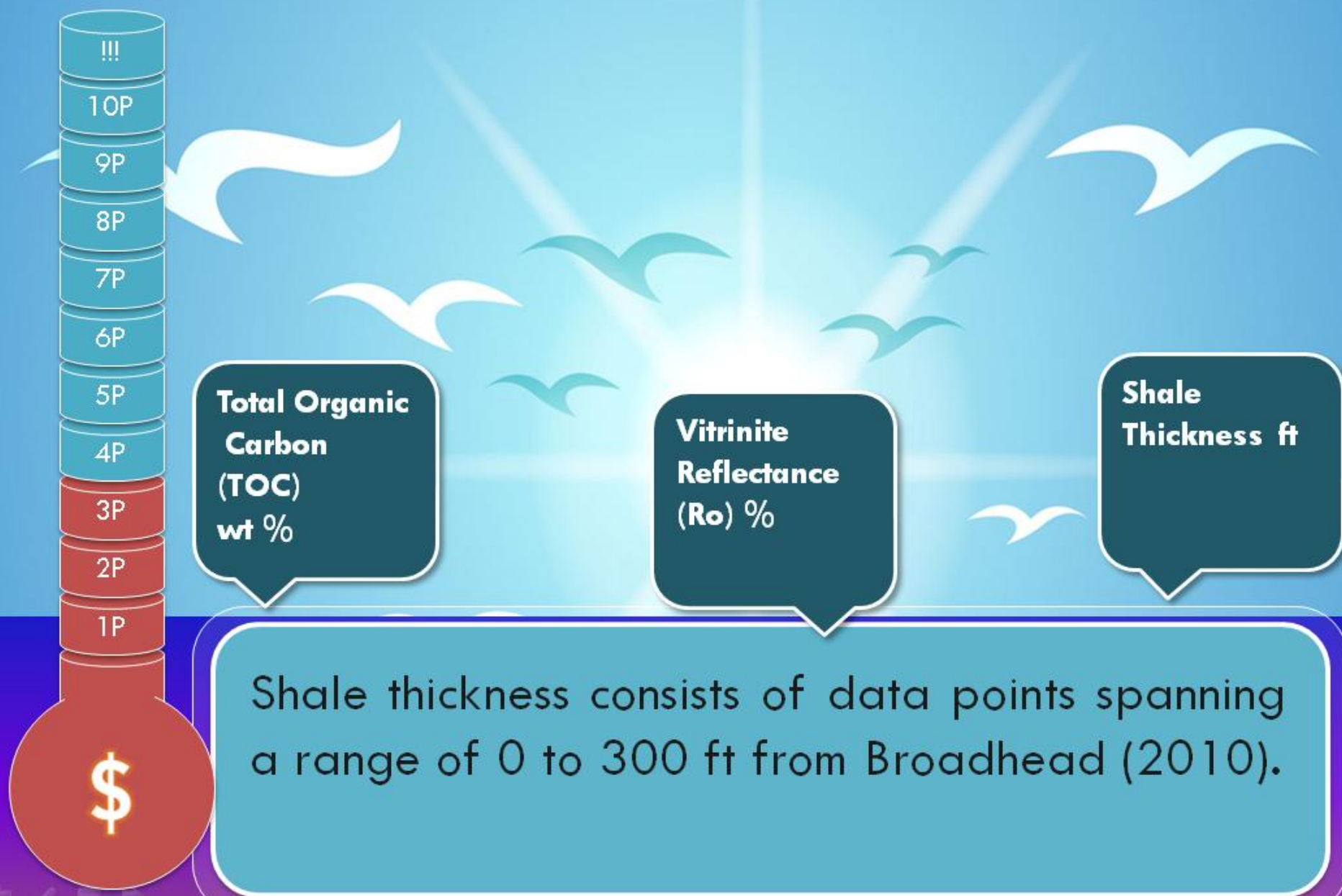
**Total Organic
Carbon
(TOC)
wt %**

Total organic carbon consists of data points spanning a range of 1.7 wt % to 4.93 wt % from Broadhead (2010).

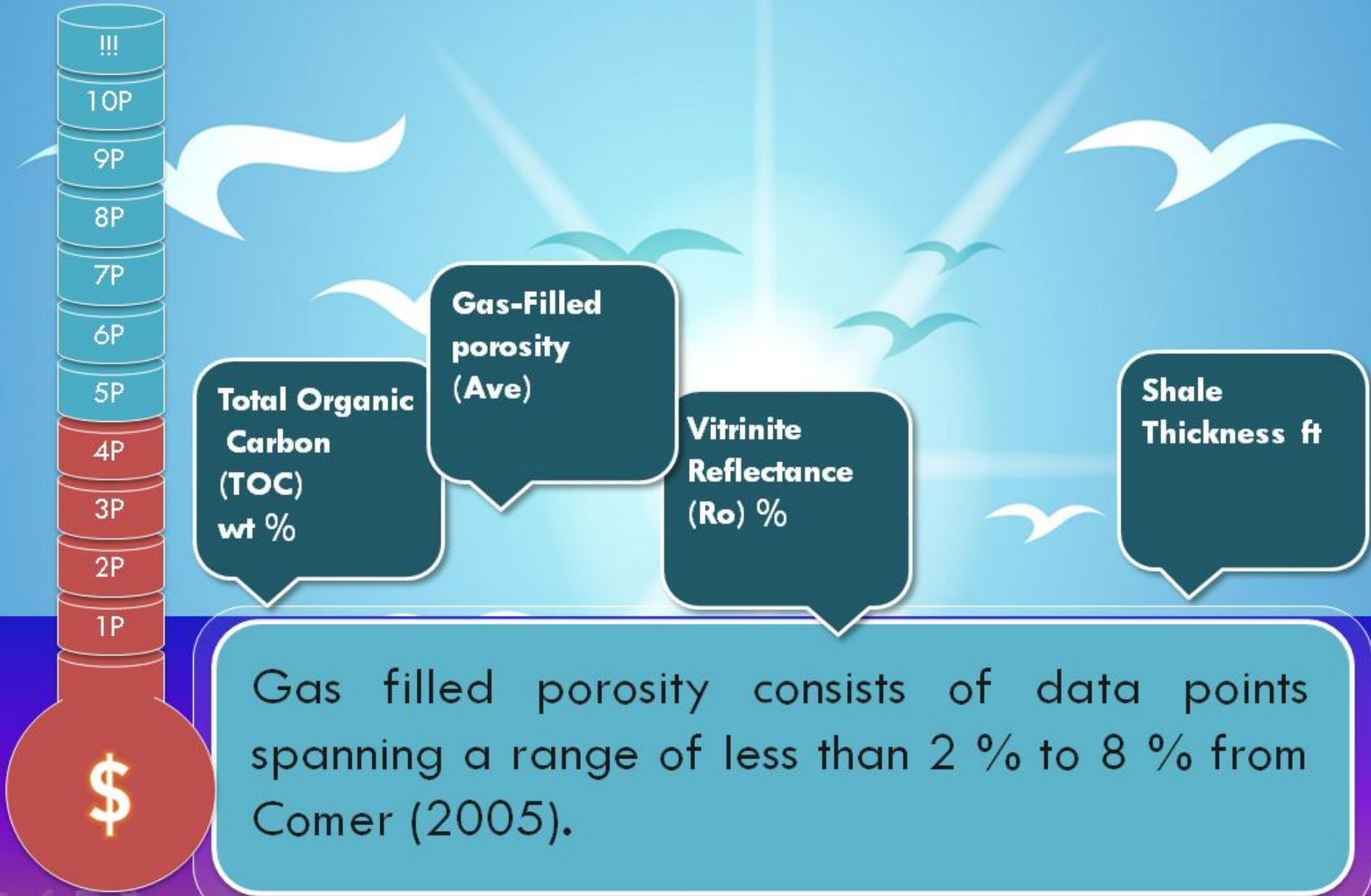
Ranking the Potential of Woodford Shale in New Mexico



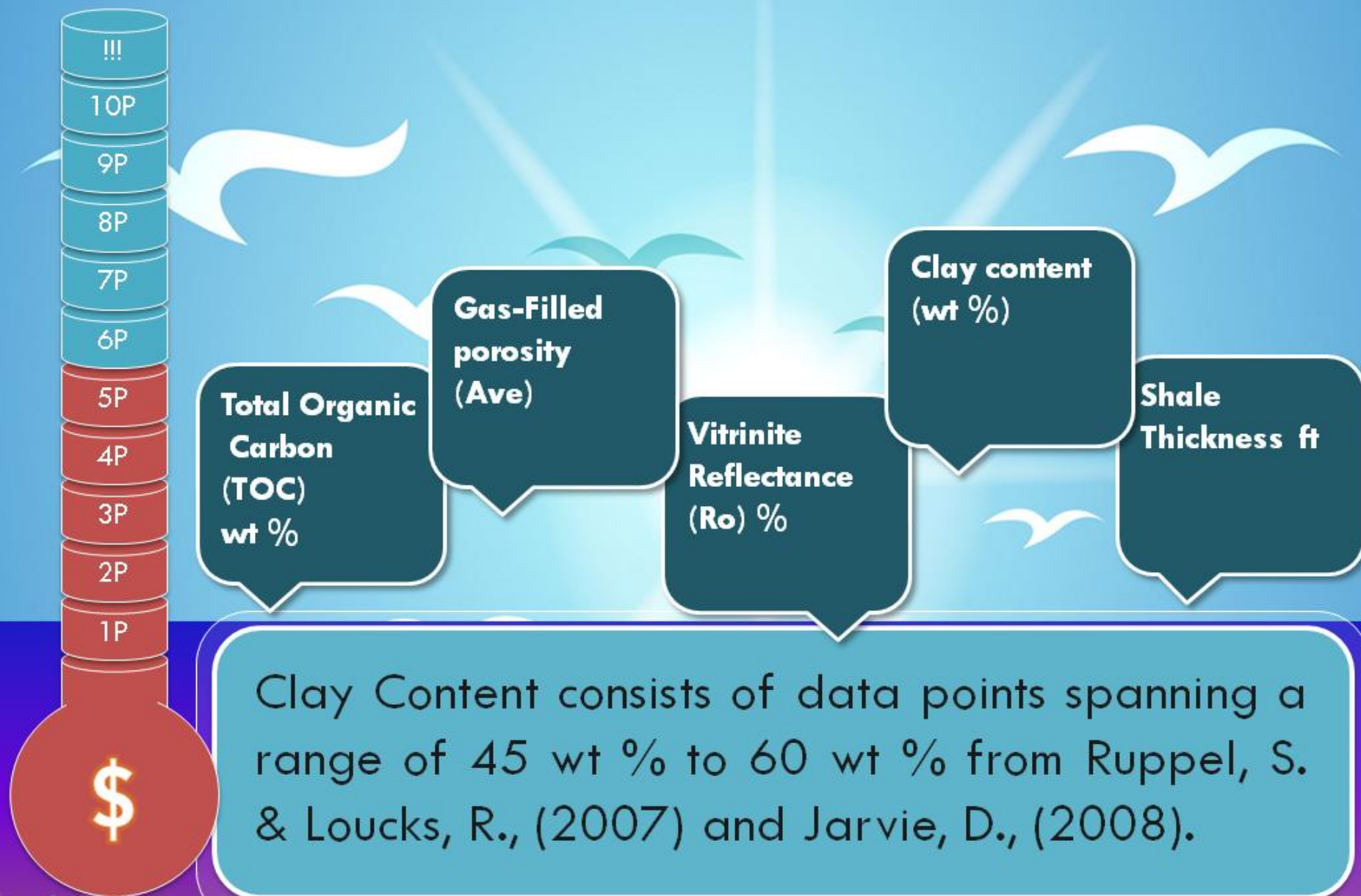
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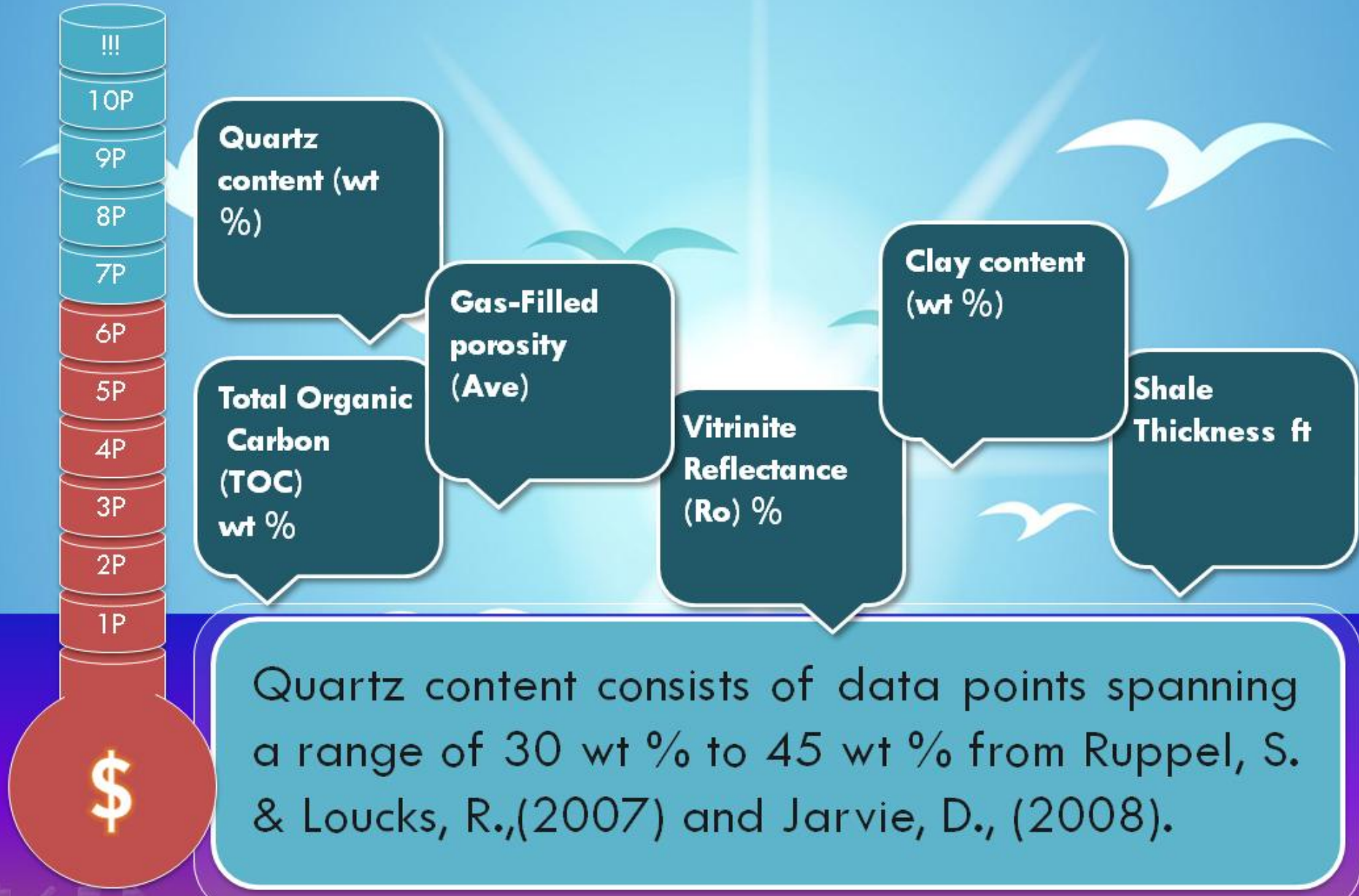
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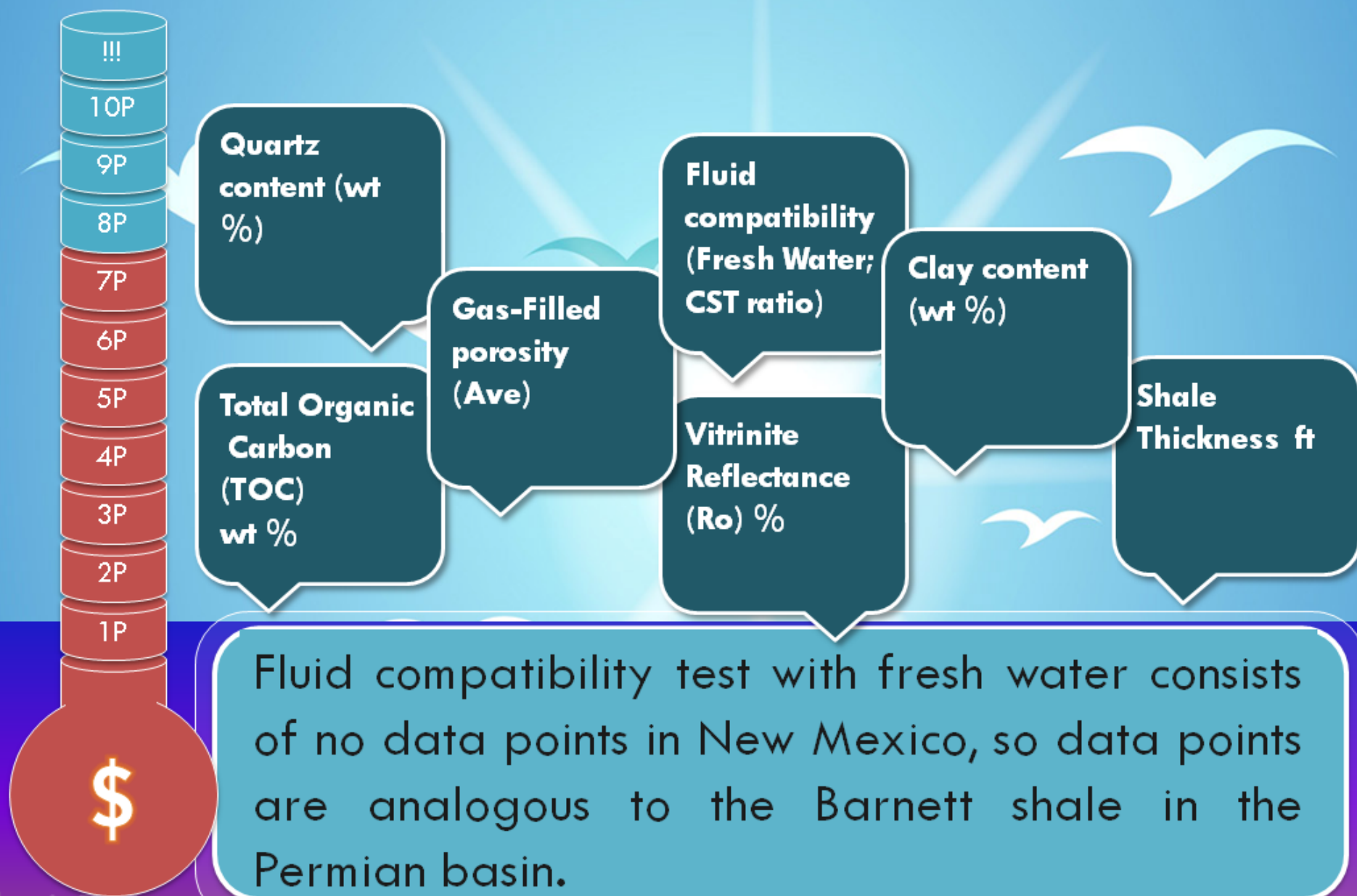
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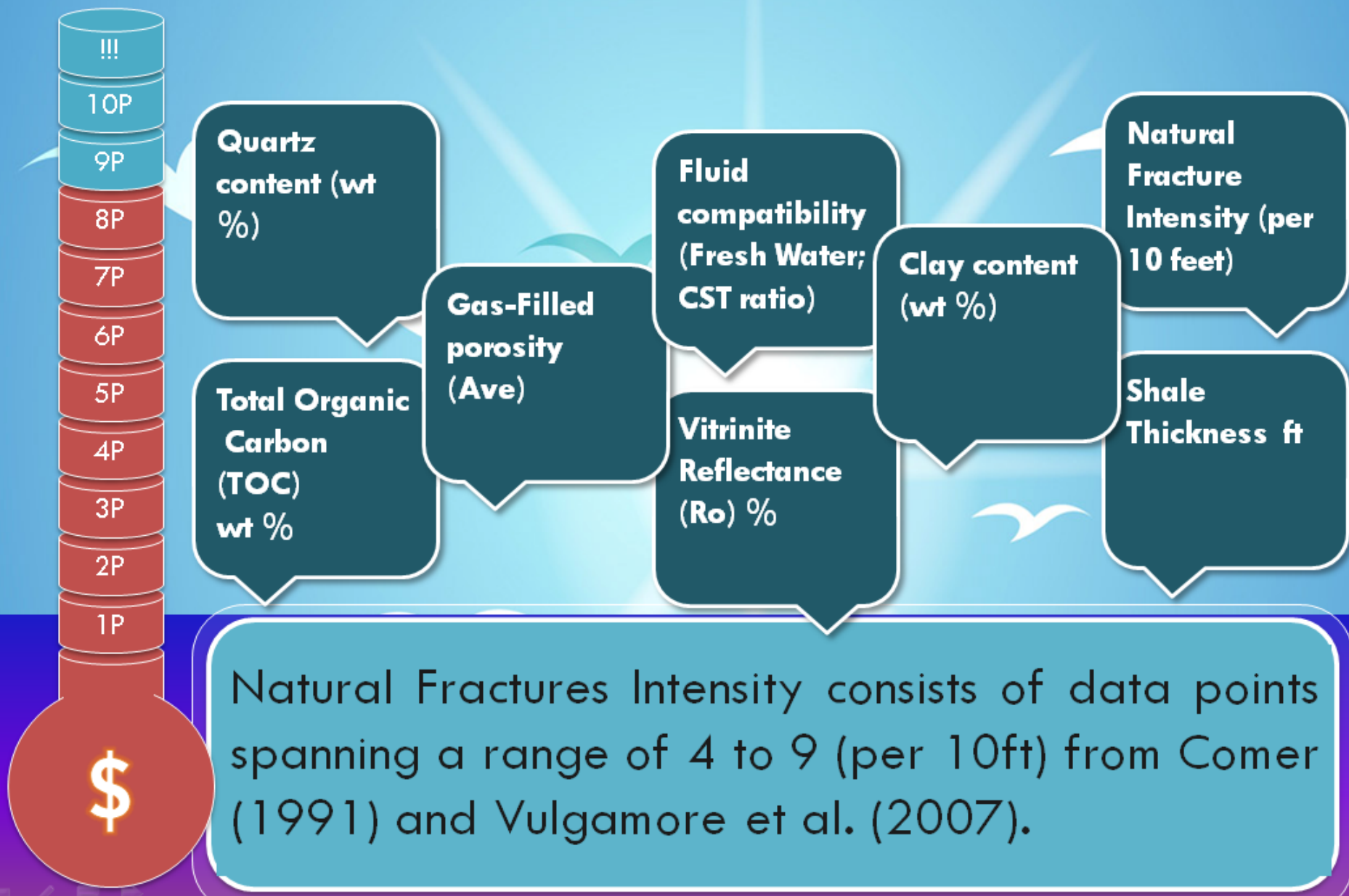
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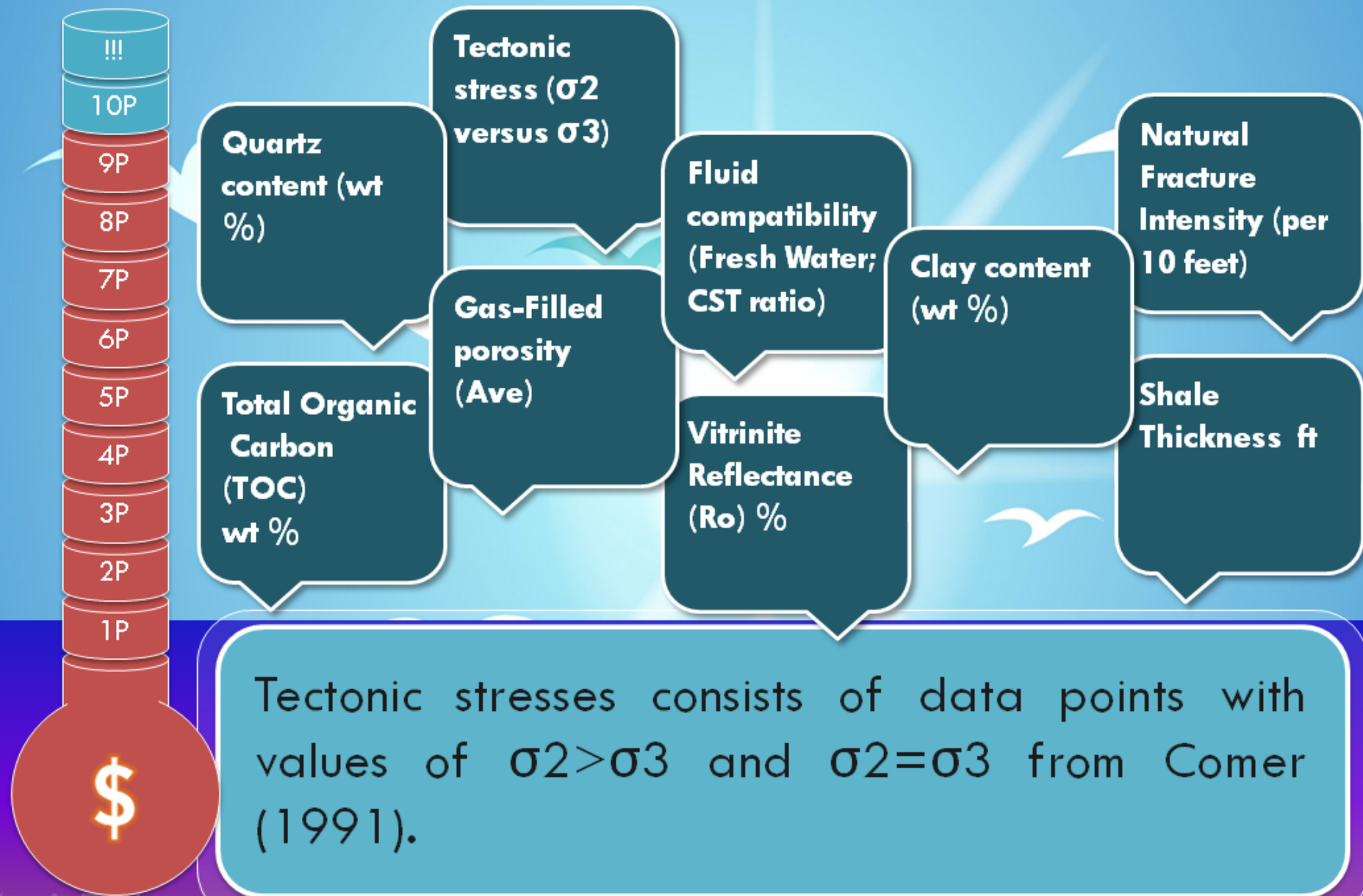
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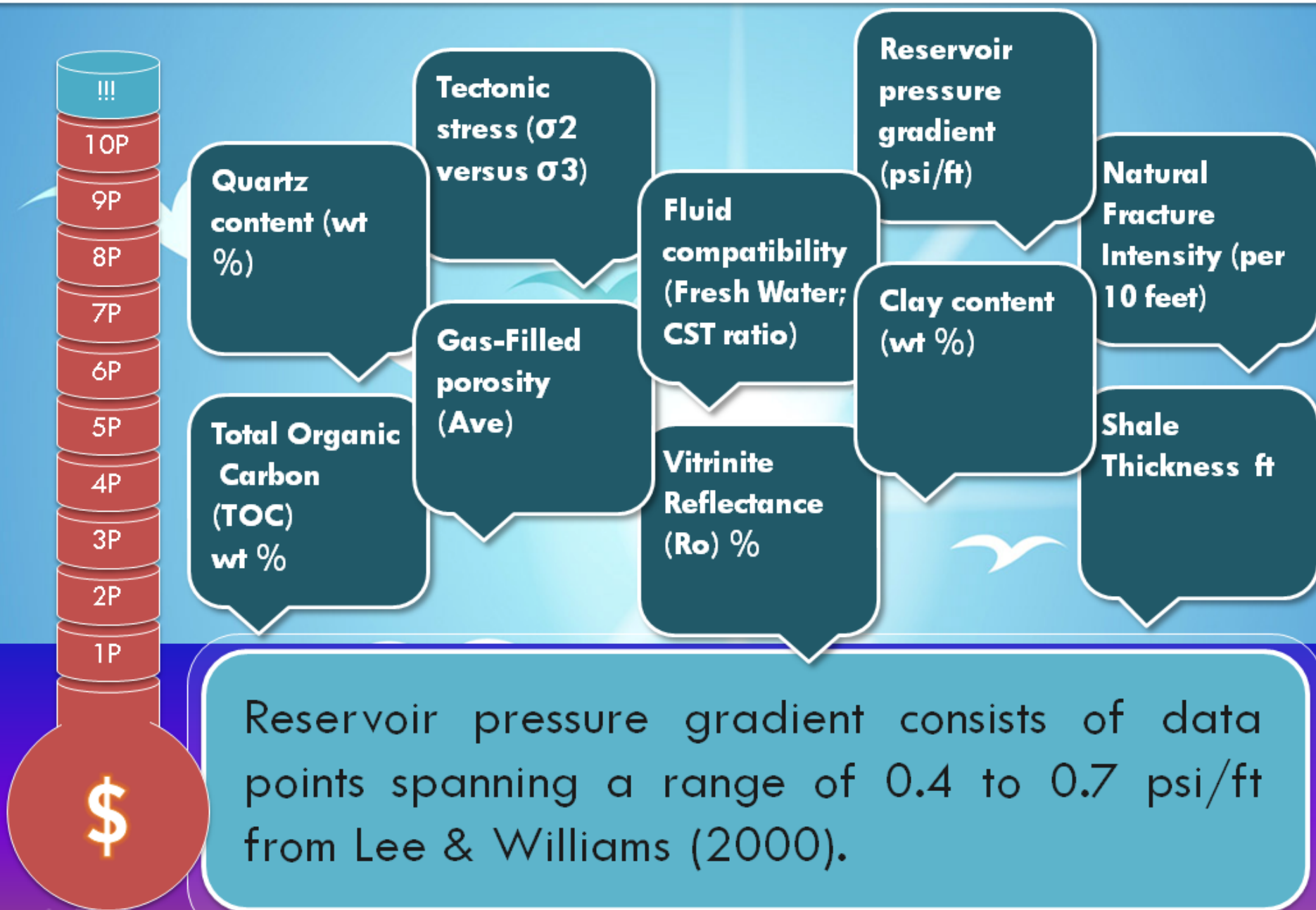
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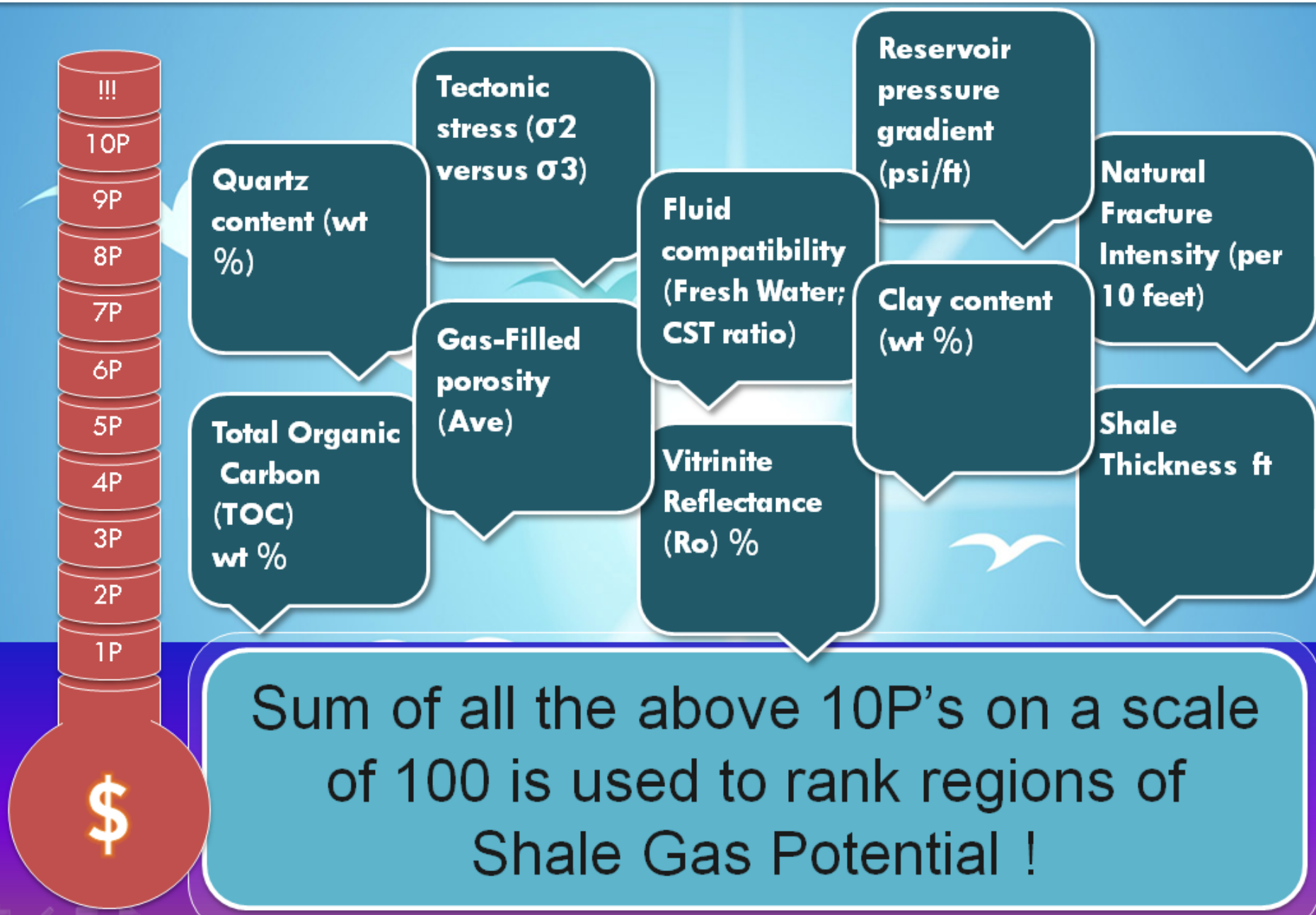
Ranking the Potential of Woodford Shale in New Mexico



Ranking the Potential of Woodford Shale in New Mexico



Ranking the Potential of Woodford Shale in New Mexico



Summary of Ranking

Parameters	Ranking on the Shale Scale		
	Region I	Region II	Region III
Total Organic Carbon (TOC) – wt %	8	6	4
Vitrinite Reflectance (Ro) - %	6	8	4
Shale Thickness - ft	8	6	4
Gas-Filled porosity (Ave)	6	8	4
Clay content (wt %)	4	4	4
Quartz content (wt %)	6	6	6
Fluid compatibility (Fresh Water; CST ratio)	4	4	4
Natural Fracture Intensity (per 10 feet)	8	6	6
Tectonic stress (σ_2 versus σ_3)	10	10	6
Reservoir pressure gradient (psi/ft)	8	8	6
Total Score	68	66	48

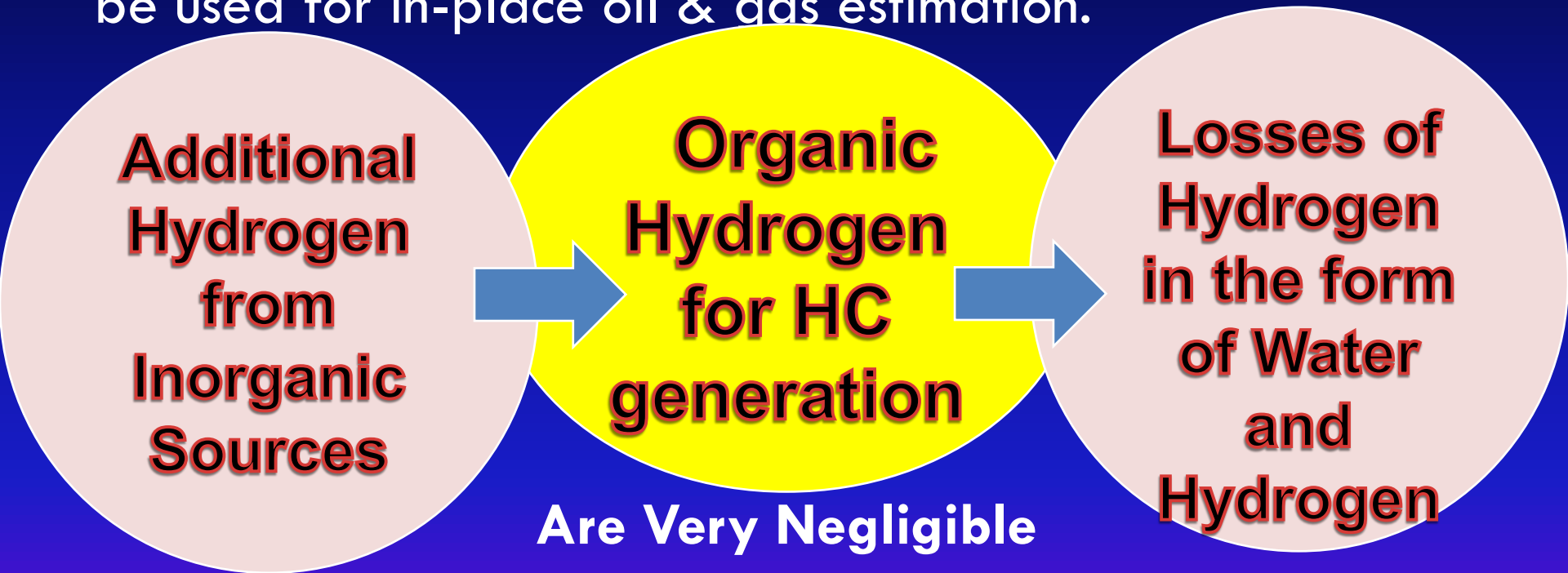
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Estimated Resource Potential

Assumptions based on Observations:(Comer 2005)

1. Oil & Gas in the Woodford Shale are indigenous.
2. Because it is indigenous conventional source rock data can be used for in-place oil & gas estimation.



So, hydrogen available for HC generation is equivalent to the amount of organic hydrogen present at the onset of the main stage of oil generation

Estimation of Resource Potential (Cont.)

Methodology:

With all of Comer's assumptions and observations, the volume of evolved HCs is estimated using

Mass balance of organic hydrogen (H_{org})

The units being used are Metric Tons (MT), kilometers (km), weight fraction (wt fraction), barrels (bbl), and cubic feet (ft^3).

Estimation Procedure

1. Reservoir Mass Determination:

$$\text{Reservoir Mass (MT)} = \text{Thickness (km)} \times \text{Area (km}^2\text{)} \times \text{Density (MT/km}^3\text{)}$$

Woodford Shale of New Mexico	Thickness (km)	Area (km ²)	Volume (km ³)	Density (MT/km ³ x 10 ⁹)	Mass (MT x 10 ⁹)
Region I	0.030	3331.12	99.93	2.4	239.84
Region II	0.043	5806.55	252.20	2.4	605.28
Region III	0.015	22200.21	341.04	2.4	818.49

2. Core Samples Data used

(Oklahoma Woodford analogous to New Mexico Woodford Shale)						
Woodford Shale of New Mexico	Present Corg (%)	Immature Corg (%)	Present Horg (%)	Immature Horg (%)	Present Ro (%)	Immature Ro (%)
Region I	82.00	82.20	7.72	7.74	0.55	0.39
Region II	90.50	82.20	4.38	7.74	2.02	0.39
Region III	85.60	82.20	6.08	7.74	1.09	0.39

Estimation Procedure (Cont.)

3. Converting the organic fraction from core sample to Whole rock: $(C_{org}/H_{org})_{kerogen} = (C_{org}/H_{org})_{whole\ rock}$

Woodford Shale of New Mexico	Present C _{org} (%)	Immature C _{org} (%)	Present H _{org} (%)	Immature H _{org} (%)
Region I	7.80	8.00	0.73	0.75
Region II	4.20	5.80	0.20	0.55
Region III	3.60	4.00	0.26	0.38

4. Calculating the Total hydrocarbon mass H_{org} (MT) using wt fraction of the whole rock:

Total Organic Hydrogen H_{org} (MT) = Immature H_{org} – Residual H_{org}

Immature H_{org} Mass (MT) = Reservoir Mass (MT) x Immature H_{org} (wt fraction)

Residual H_{org} Mass (MT) = Reservoir Mass (MT) x Present H_{org} (wt fraction)

Estimation Procedure (Cont.)

5. C_{org} Mass Determination:

$$C_{org} \text{ Mass (MT)} = \text{Reservoir Mass (MT)} \times \text{Immature } C_{org} \text{ (wt fraction)}$$

6. Total Natural Gas Co-Generated (Gas MT):

$$\text{(Oil Window) Gas (MT)} = \text{Gas (MT/MT } C_{org}) \times C_{org} \text{ (MT)}$$

For thermal maturities the saturated light hydrocarbons content is in the range of 1×10^{-4} MT/MT C_{org} to 1×10^{-2} MT/MT C_{org} (Schaefer and Leythaeuser, 1983; Comer 2005).

7. Total mass of organic hydrogen that exits as natural gas (H_{gas})

$$H_{gas} \text{ (MT)} = \text{Gas (MT)} \times H_{org} \text{ (wt fraction)}$$

8. Total mass of hydrogen contained in Crude Oil (H_{oil})

$$H_{oil} = (\text{Total Hydrocarbon } H_{org} - \text{Oil Expelled}) \times 2 \times 10^{-2}$$

Woodford Shale of New Mexico	C_{org} MT x 10^9	Gas MT x 10^9	H_{gas} MT x 10^9	H_{oil} MT x 10^9
Region I	19.71	0.0020	0.00049	0.047
Region II	35.11	4.45	1.48295	0.635
Region III	32.74	0.33	0.00085	0.981

Estimation Procedure (Cont.)

Volumes of Oil & Gas Generated and Expelled

Oil Volume (bbl) = Hydrocarbon H_{org} (MT)/ 2.0×10^{-2} (MT/bbl)

Gas Volume (ft³) = Oil Volume (bbl) x 3000 (ft³/bbl)

	Generated		Expelled		Original In-Place	
Woodford Shale of New Mexico	Oil MMbbl	Gas Bft ³	Oil MMbbl	Gas Bft ³	Oil MMbbl	Gas Bft ³
Region I	2398	98	719	78	1678	19
Region II	105924	222441	31777	177953	0	44488
Region III	49109	2	14732	2	34376	0.51

Note: Original Oil In-place for Region II is assumed to be zero because the thermal maturity indicates Gas Window (Comer 2005)

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Conclusions

	Original In-Place (Woodford Shale - Study Area)		Original In-Place (Woodford Shale - Total Permian basin)	
	Oil Billion bbl	Gas Trillion ft ³	Oil Billion bbl	Gas Trillion ft ³
Region I	1.68	0.019	35	.11
Region II	0	44.49	0	220
Region III	34.38	0.00051	84	9.0
Total	36	45	119	229

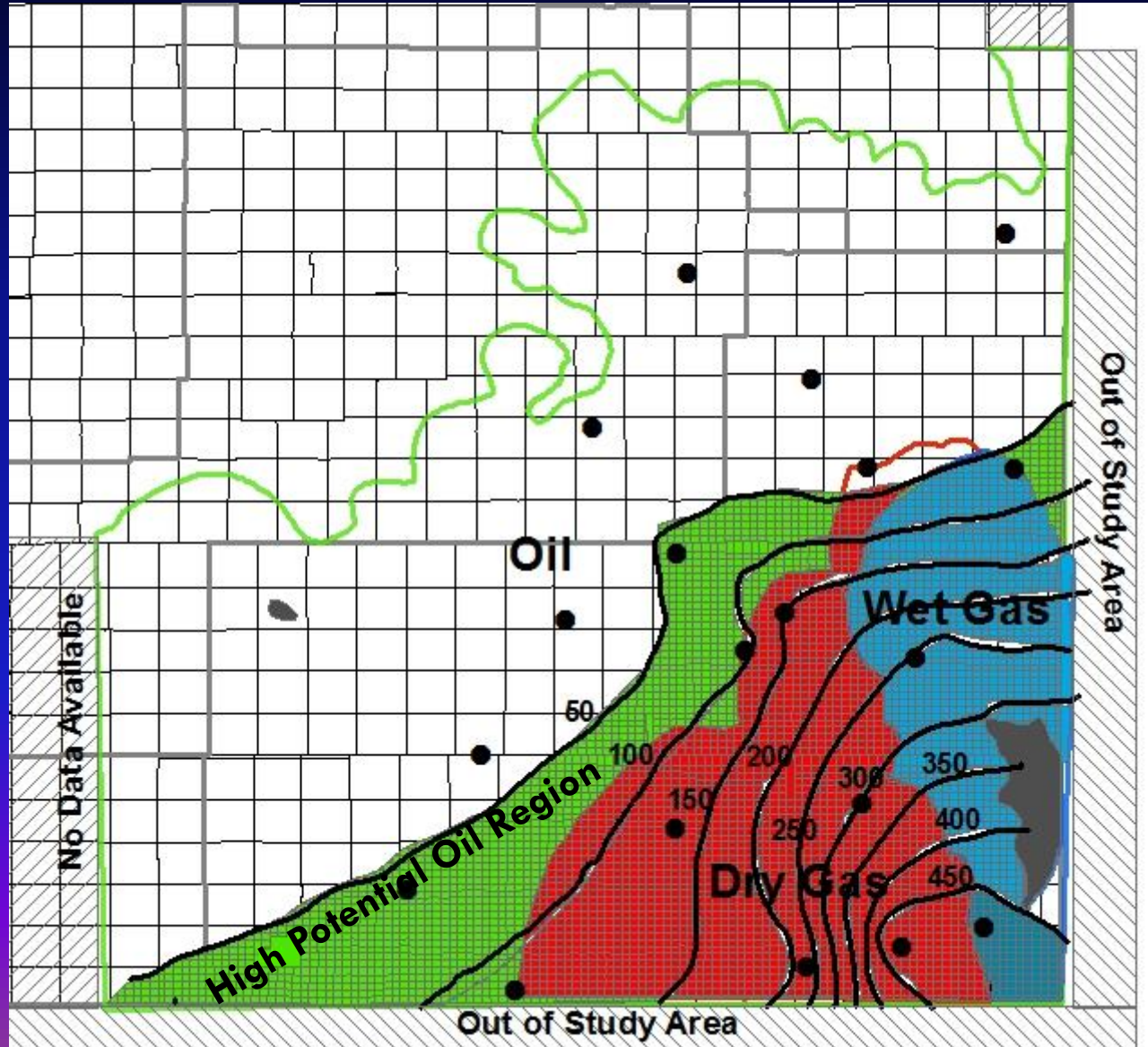
The Woodford shale in New Mexico is found at great depths which contribute to its lack of production.

However, 30% of the total Permian Basin Resource is in New Mexico.

This assessment strongly indicates that the Woodford Shale has high potential future potential as an unconventional oil & gas resource in New Mexico.

Recommended Resource Development

The difference between TOCo (Original) and TOCpd (Present Day) multiplied by thickness of the Woodford will be an indication of the relative volumes of hydrocarbons generated. (Broadhead 2010).

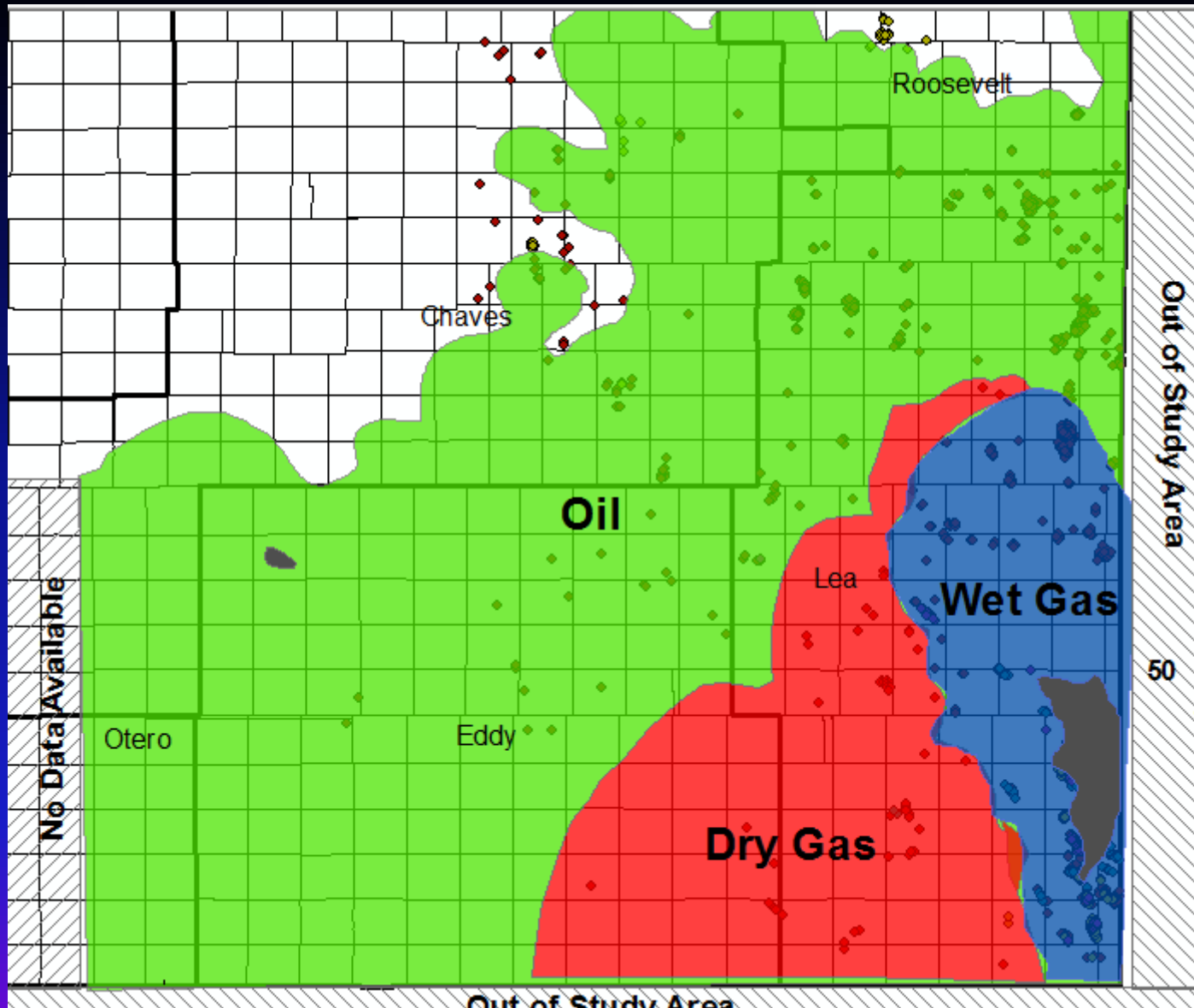


Recommended Resource Development (Cont.)

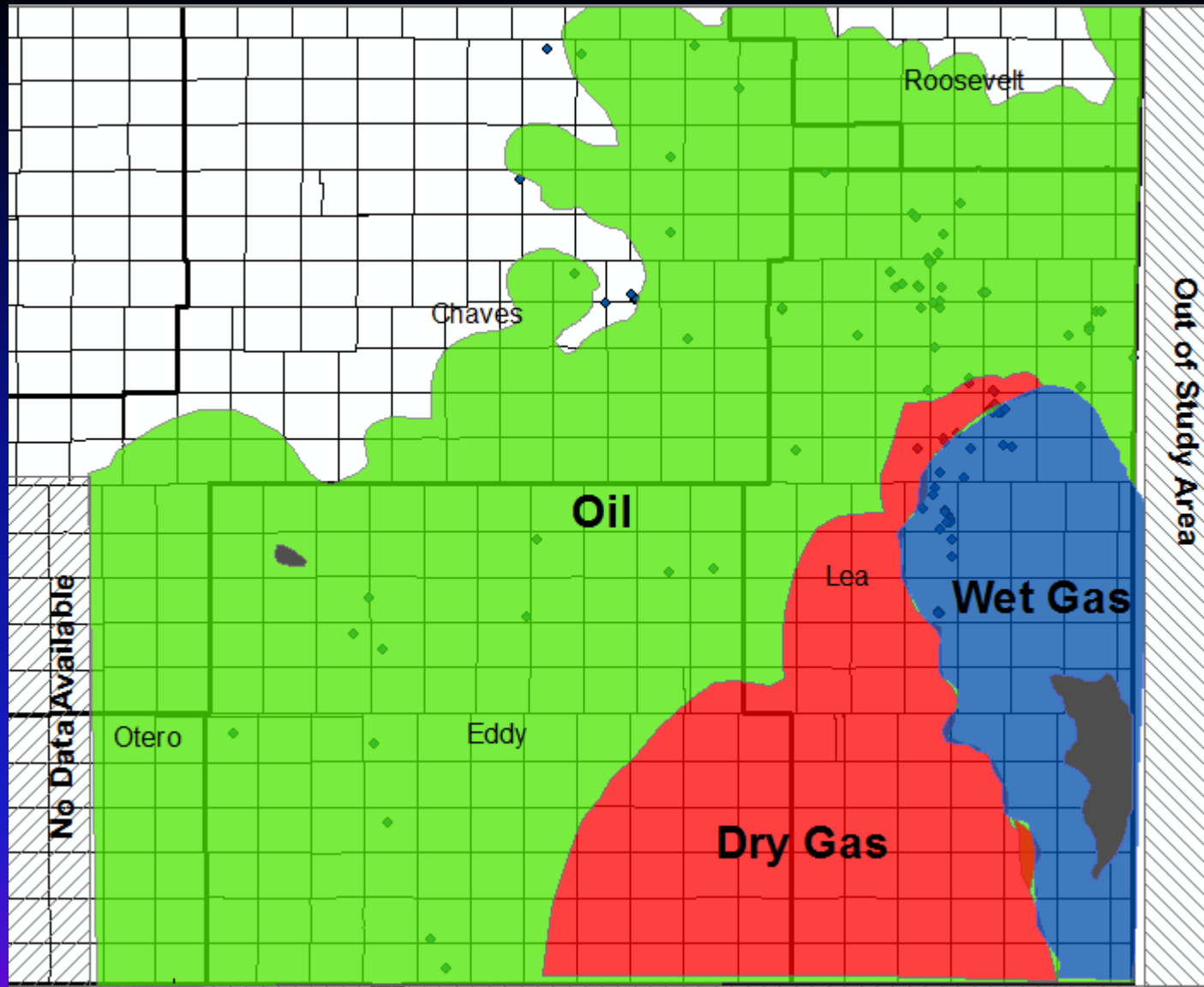
4 Horizontal Wells per section

Each well has

- ❖ 1 MMbbls(approx) of Oil as available resource in the Green Region (High Potential Oil Region).
- ❖ 4.65 BCF of Gas in the Red Region &
- ❖ 0.94 MMbbls of Wet Gas for the Blue Region
- ❖ Economics & Completion Technologies will be the game changers.



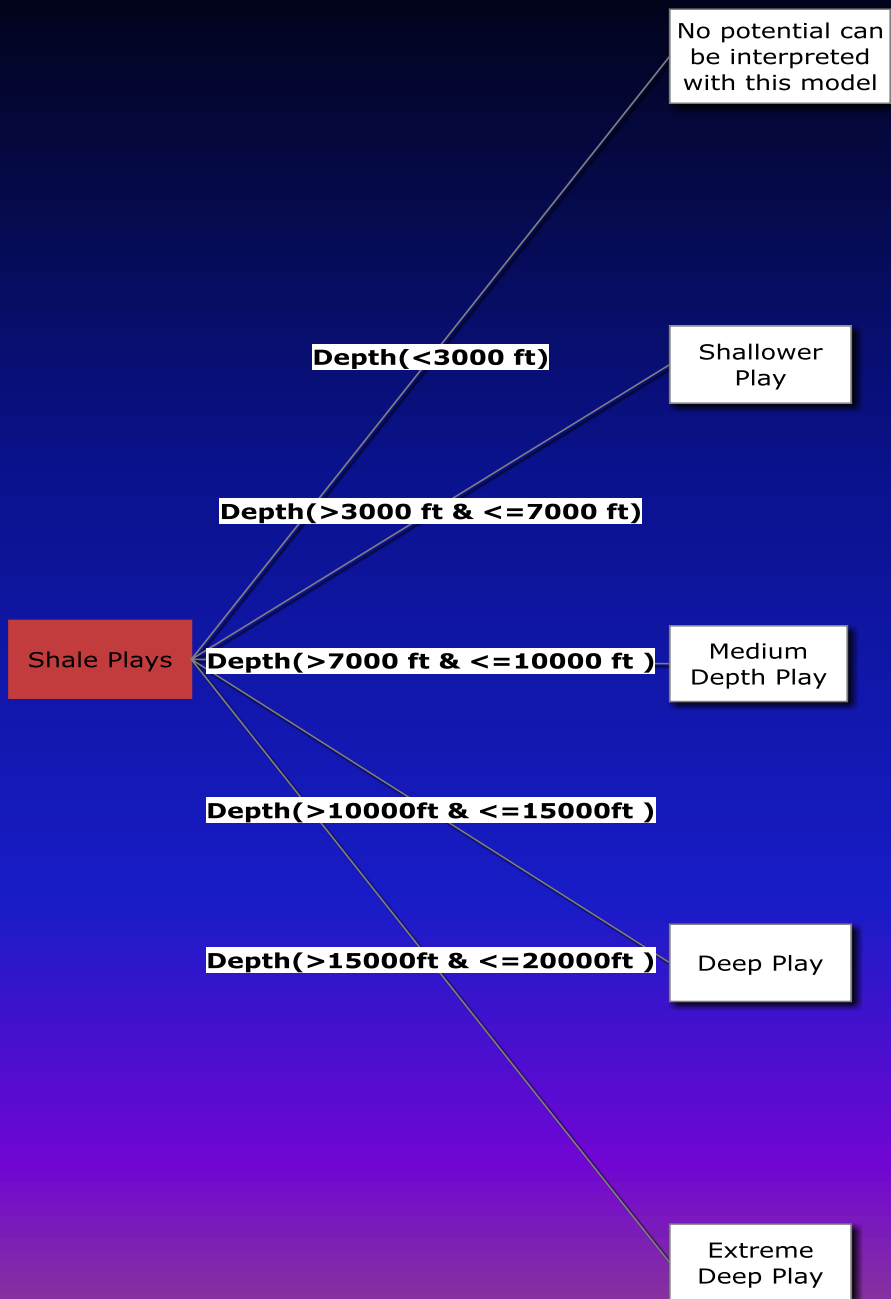
**Existing 1100 Wells (Approx) have an Up-hole Potential
(Wristen, Fusselman, Simpson & Ellenburger)**



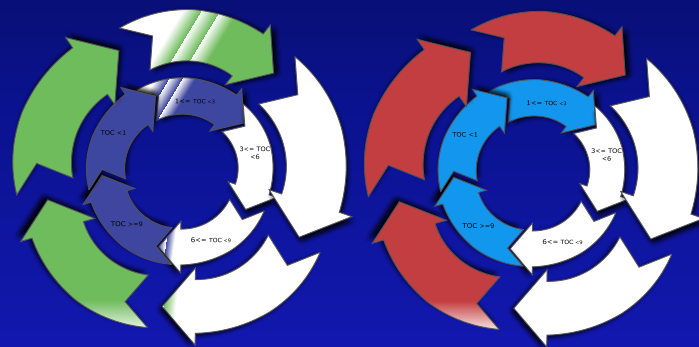
Existing 108 Mississippian Wells Have a Down-Hole Potential

Work in Progress

SPIN – Shale Potential Interpretation Network



TOC, HI, Thickness & Thermal Maturity



Porosity



Hydrocarbon Potential Maps

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References

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Thank You!

Any Questions



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