Texas CCUS Project Development

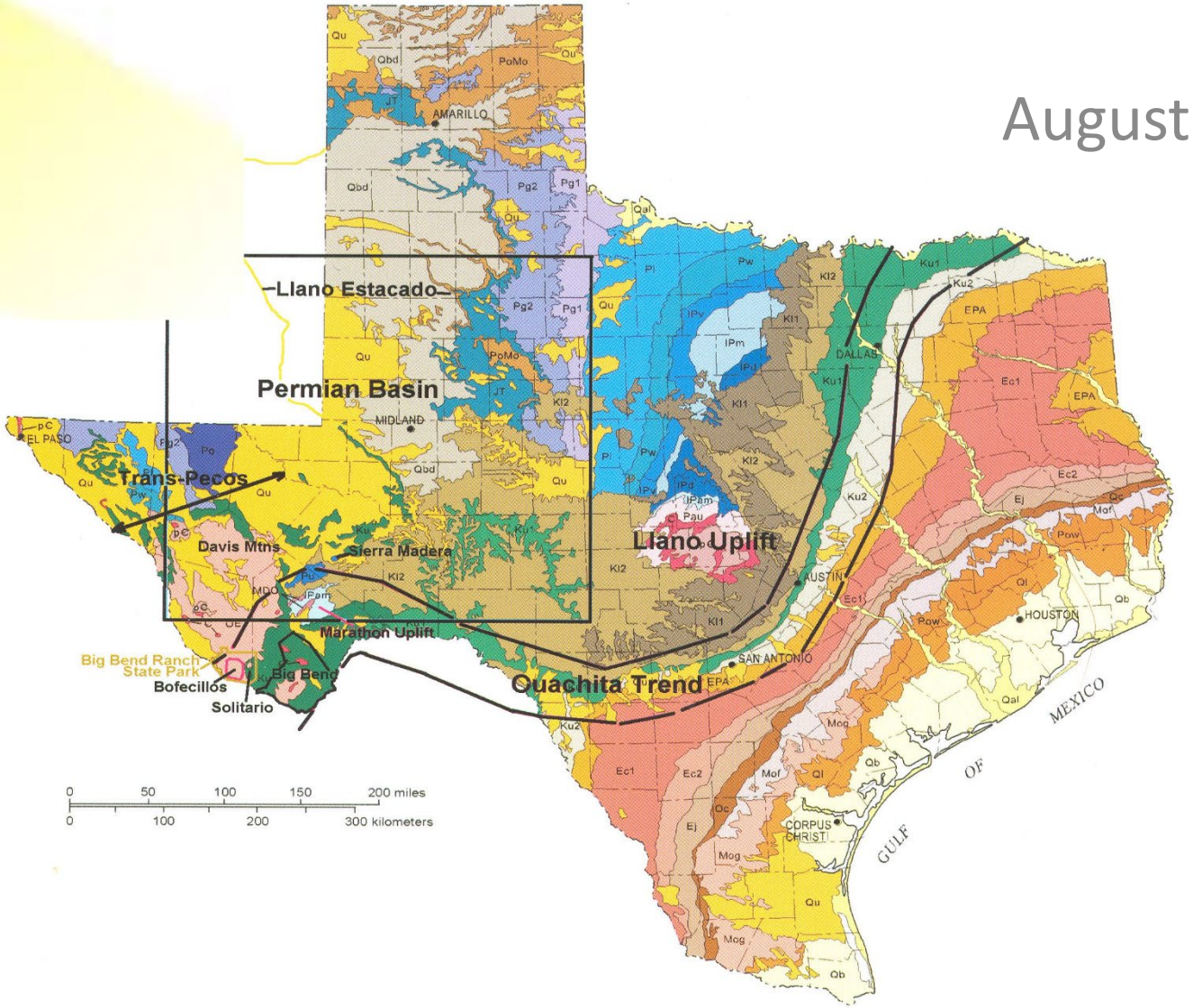
Lessons Learned and Still More to Come

Christine Ehlig-Economides

Steve Melzer

The Permian Basin: A Bright Spot for CCUS

August 27, 2020



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Subjects for Today

I. Overview
II. Focus on the San Andres Formation
III. Residual Oil Zones (ROZs)
IV. Needs for New Expertise

Legal Framework - Process CO_2

- Usually defined in product form with specifications such as >95% purity and above 1500 psi
- Historically treated as a valued commodity on the surface **and in the ground** for CO_2 EOR
  - 50 years of experience at processing plants, pipelines and in the reservoir
  - Subject to mineral law
- Interest today in Carbon Capture Utilization and Storage (CCUS)
  - Leverage experience
  - Use process CO_2

Legal Framework - CC**U**S and CC**G**S

- April 2009 - US EPA declared CO_2 a pollutant
  - CO_2 is frequently vented from industrial processes and in transportation
  - Former natural compound is now considered a contaminant
  - Climate change initiatives set objectives to reduce atmospheric CO_2
- CO_2 used for EOR (CC**U**S) classed as process CO_2
- CO_2 injected for permanent geologic storage (CC**G**S)
  - Carbon Capture and **G**eologic Storage
  - Classed as waste

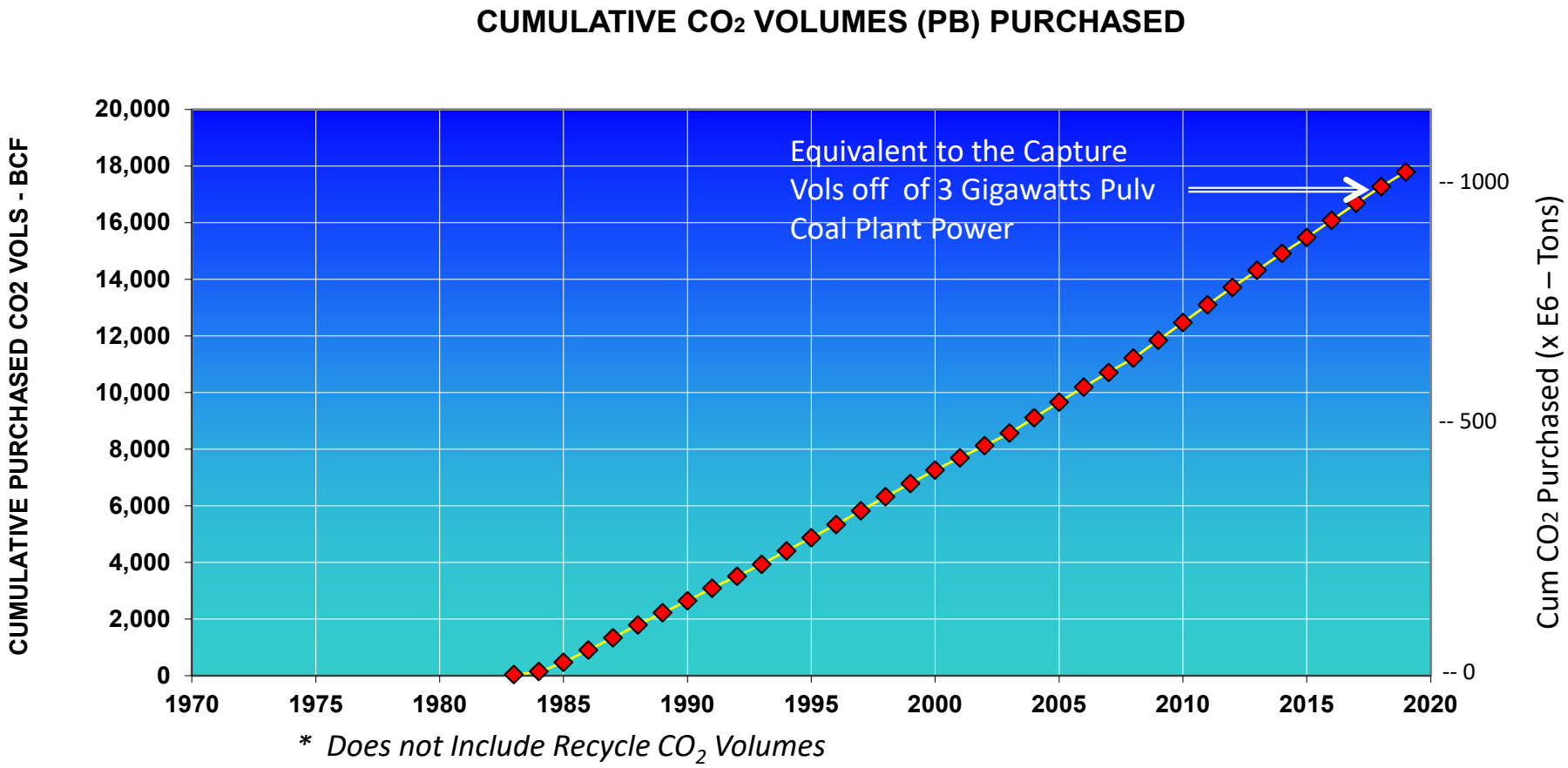
Regulatory Oversight on CO_2 Injection

- UIC Class II wells governed by states rules
  - 50 years of experience
  - Large injection volumes for reservoir pressure maintenance and EOR
- UIC Class VI governed by EPA Rules (Some states have sought and are obtaining primacy)
  - ~10 years experience to-date
  - Small injection volumes can raise reservoir pressure
  - Better reporting of injection volumes

Underground Injection Control - UIC

PB (New*) CO_2 Injection History

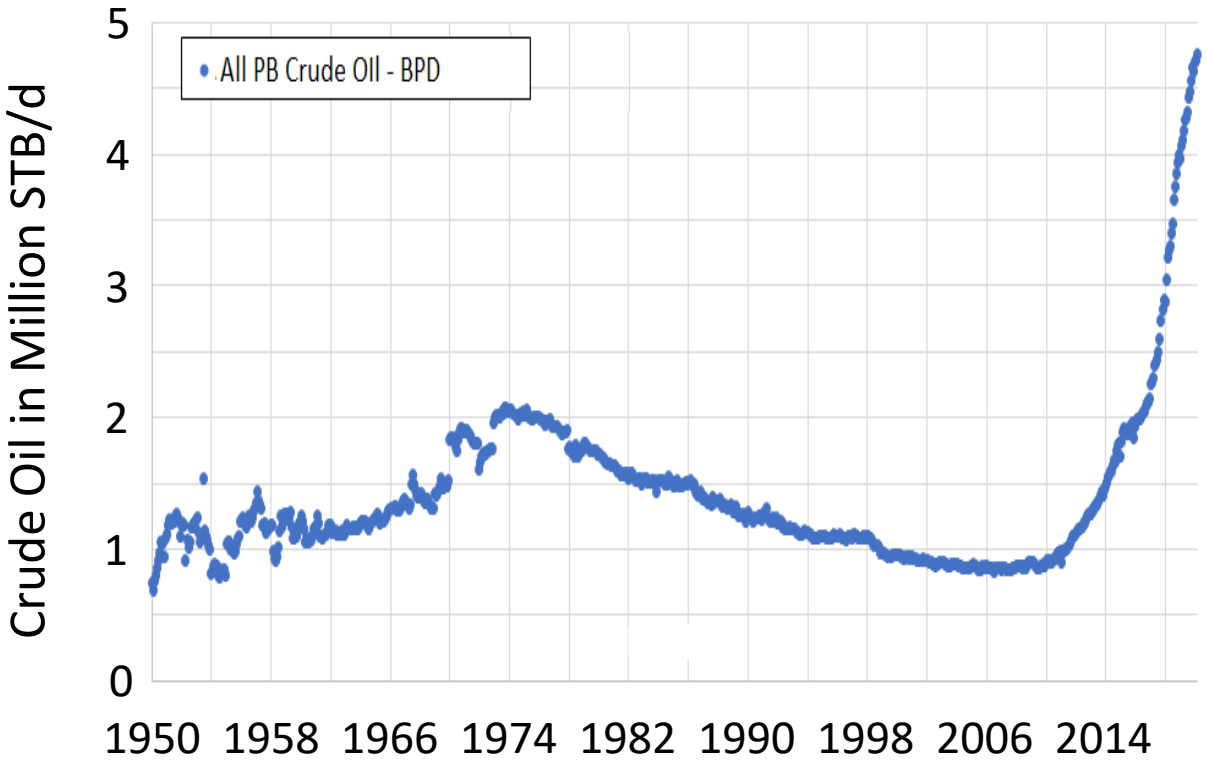
Since 1982

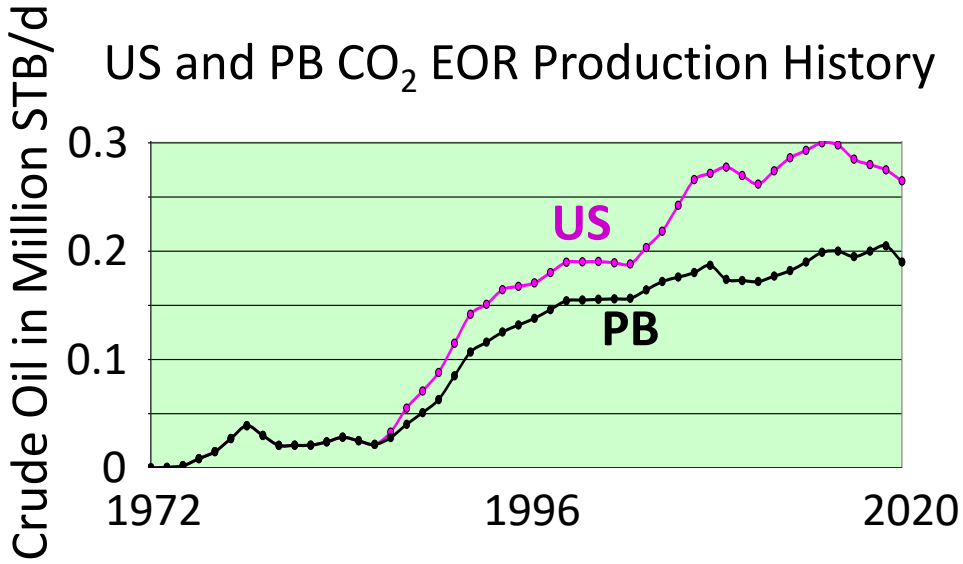


* *Does not Include Recycle CO_2 Volumes*

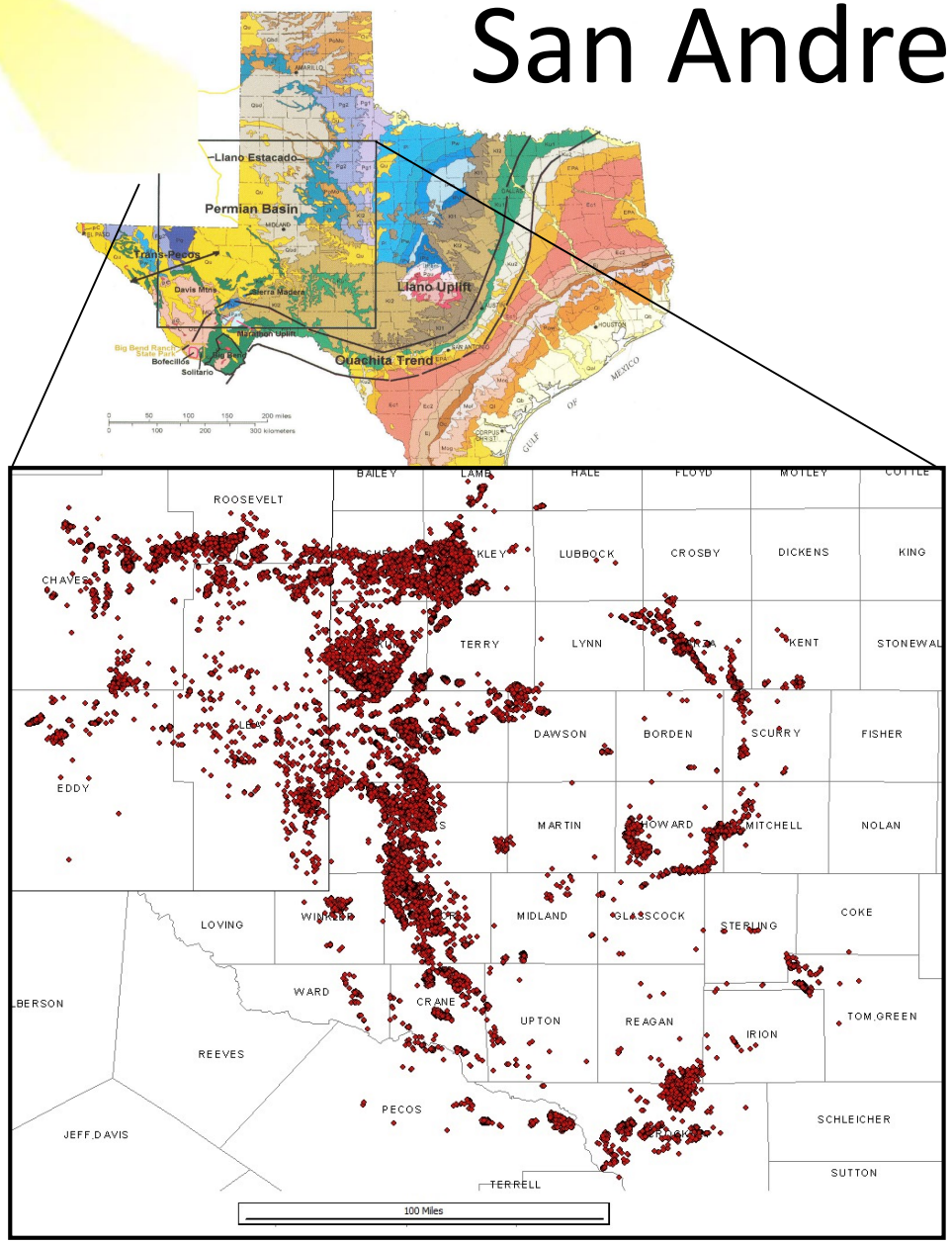
Produced 1.6 billion crude oil bbls

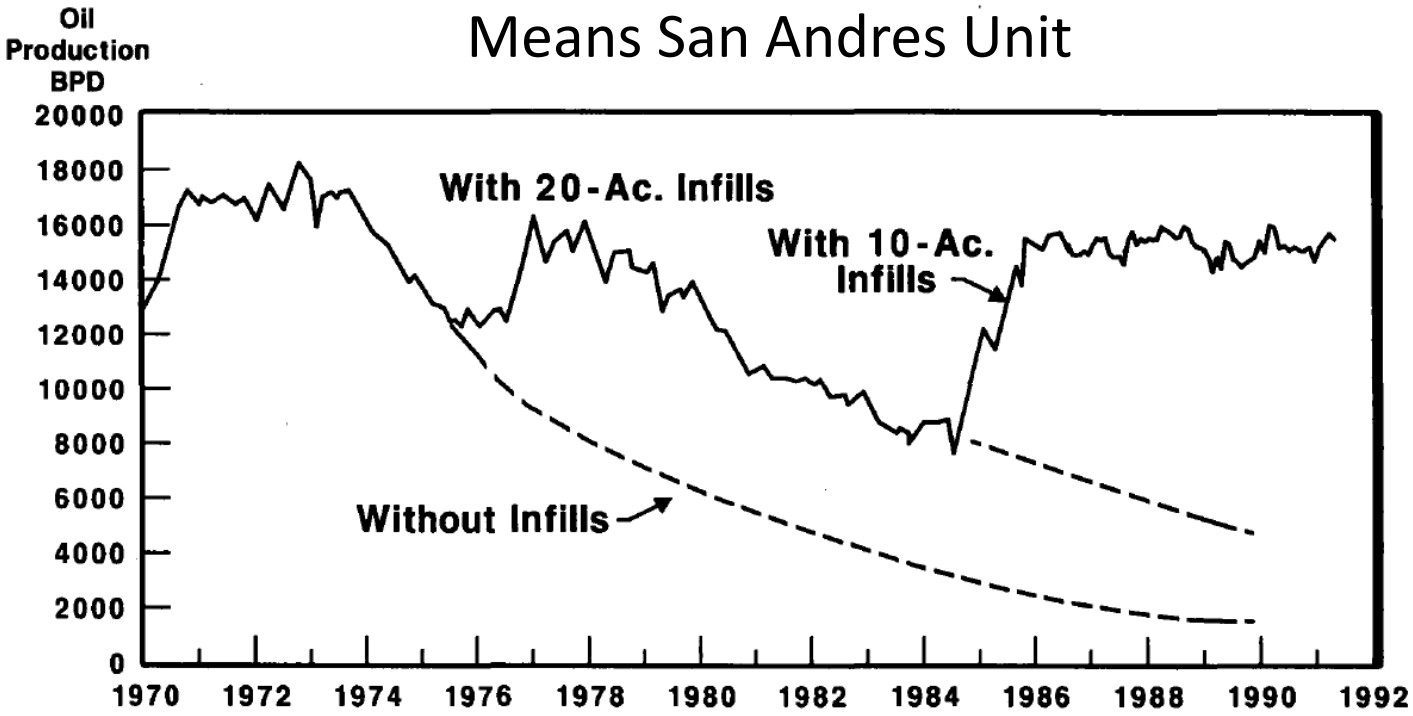
Historical Crude Oil Production from the Permian Basin





San Andres Formation Producing Wells





Means San Andres Unit

Source: Thakur

Currently 80 active CO_2 EOR projects

The 'New' Goal: Reducing Greenhouse Gas (GhG) Emissions

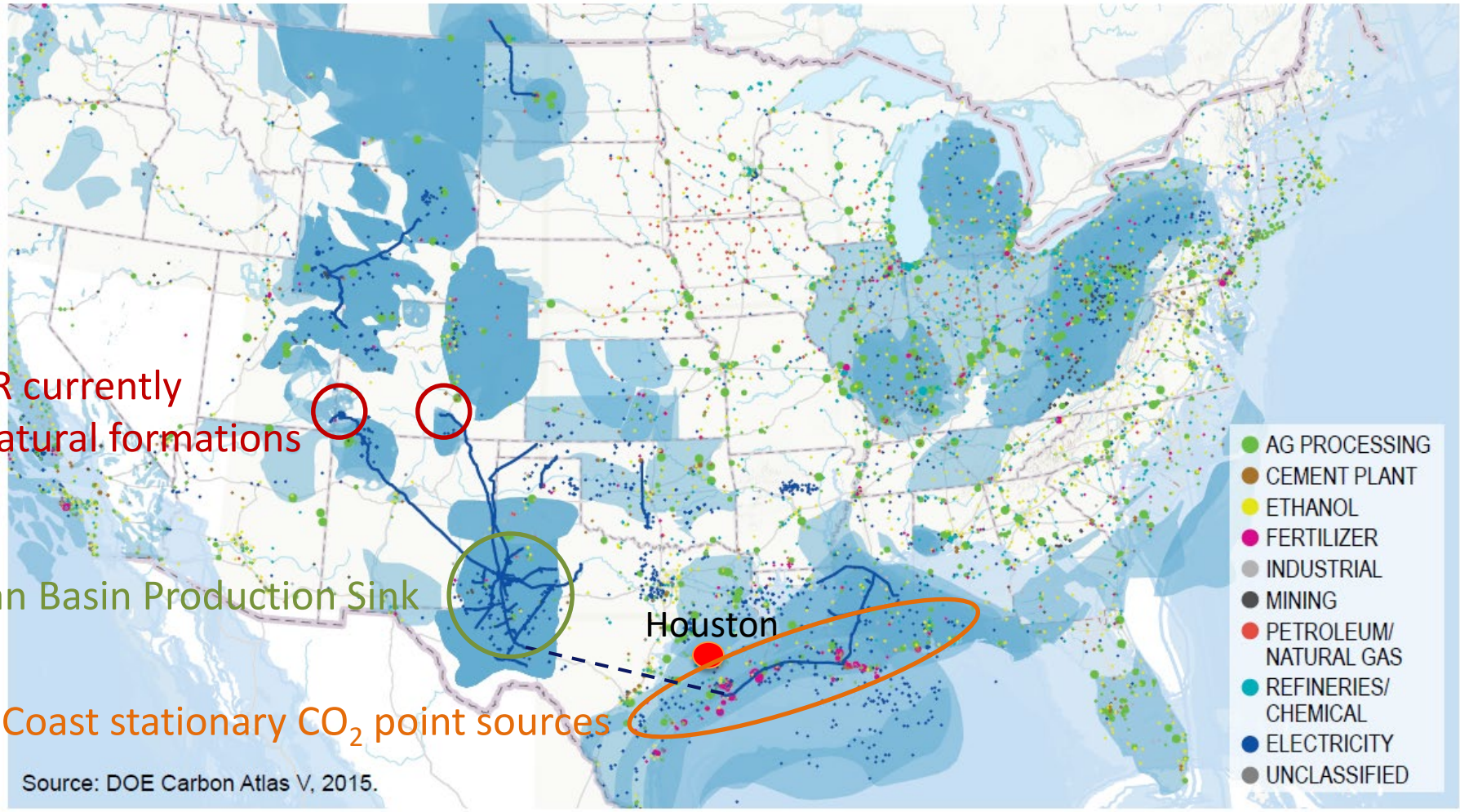
The Extreme Positions

- One Side: Stop all fossil fuel combustion
- Other Side: Global warming is a hoax

Somewhere in the Middle

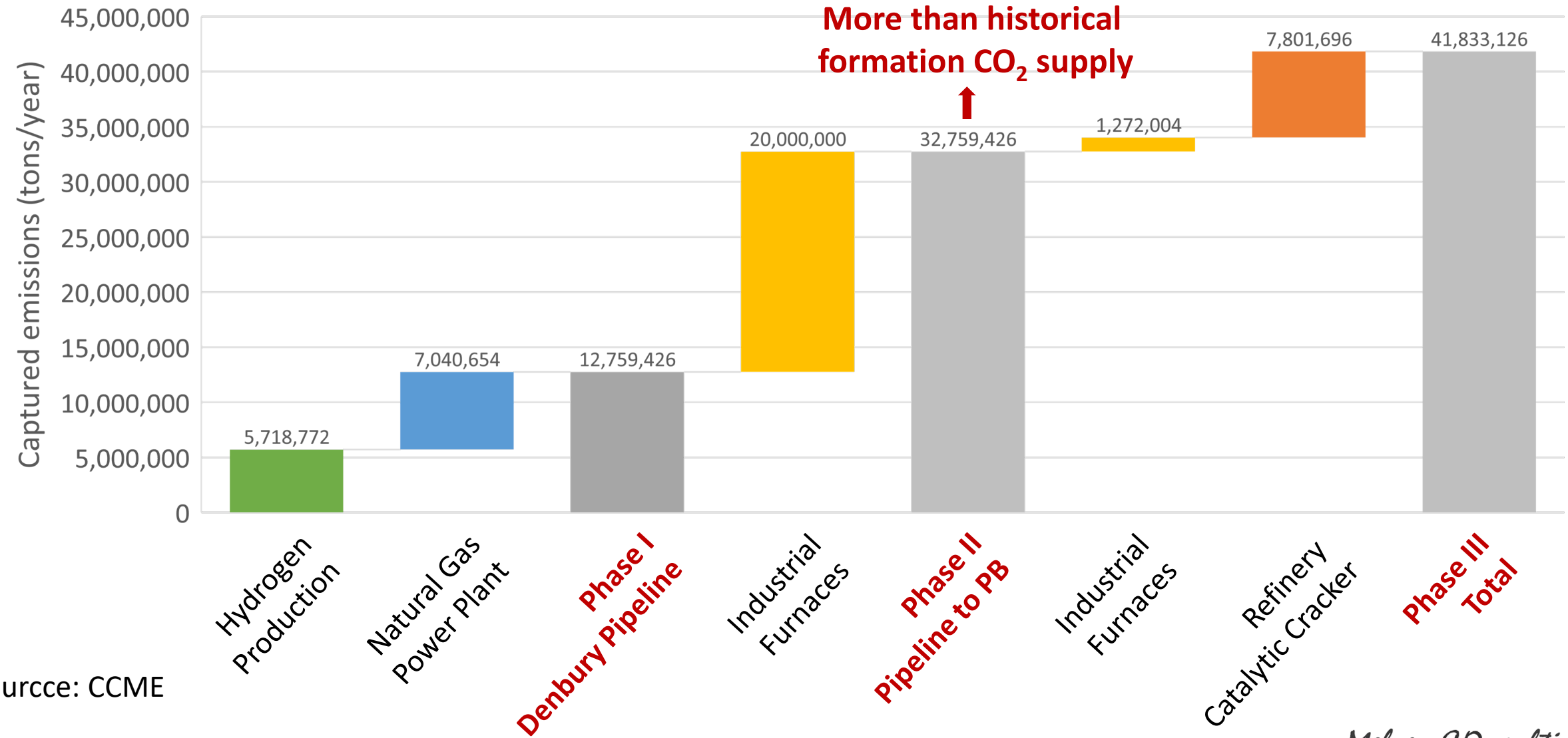
- Sources of energy are huge and vital: consider the economy and find ways to reduce GHG emissions

CO_2 Sources, Sinks, and Pipelines



Sourcce: CCME

Potential Gulf Coast CO_2 Supply



Sourcce: CCME

The ROZ ‘Journey’

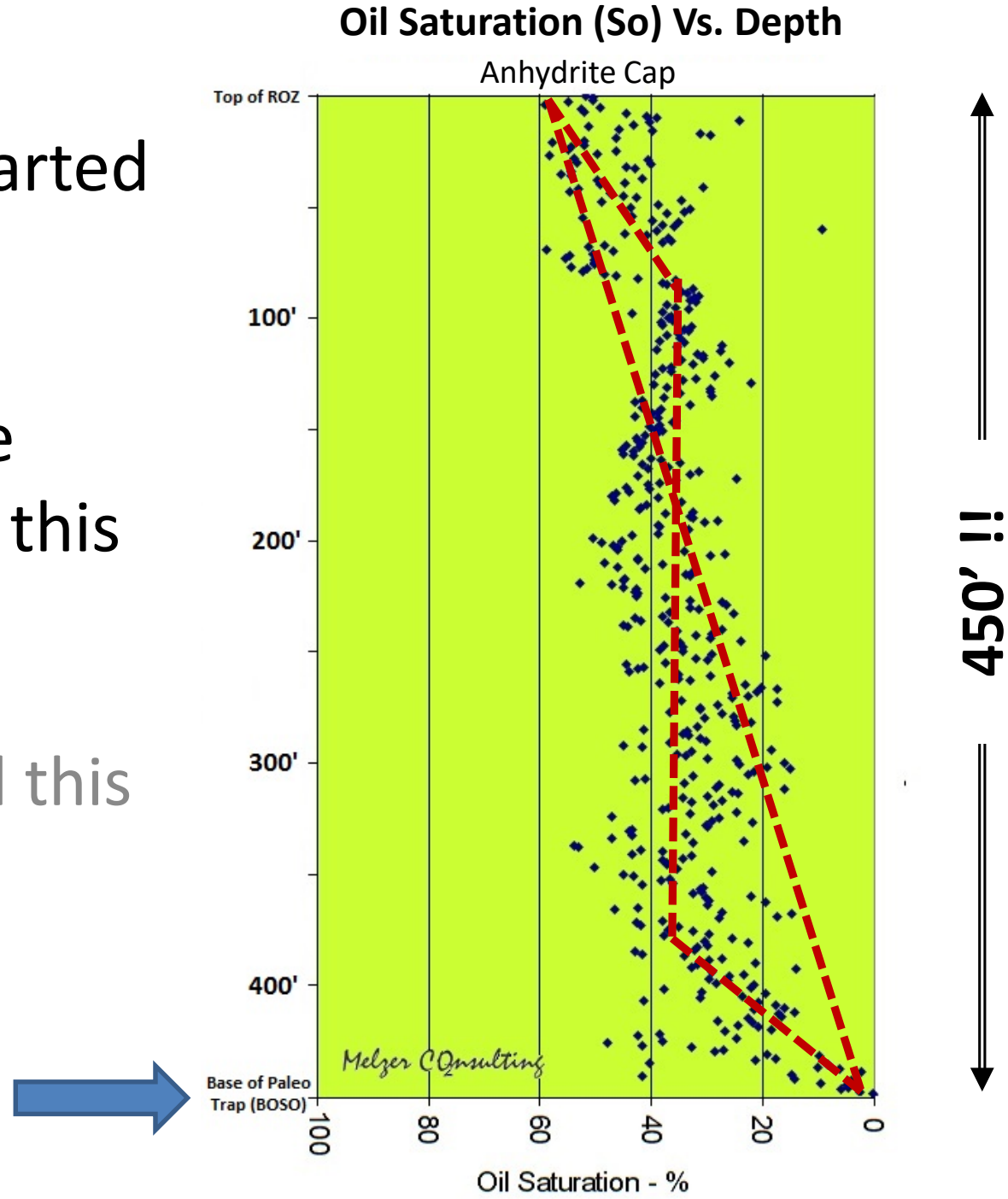
Let’s Take a Field Trip

One of the Field Trips?

The ROZ Journey Started Here…

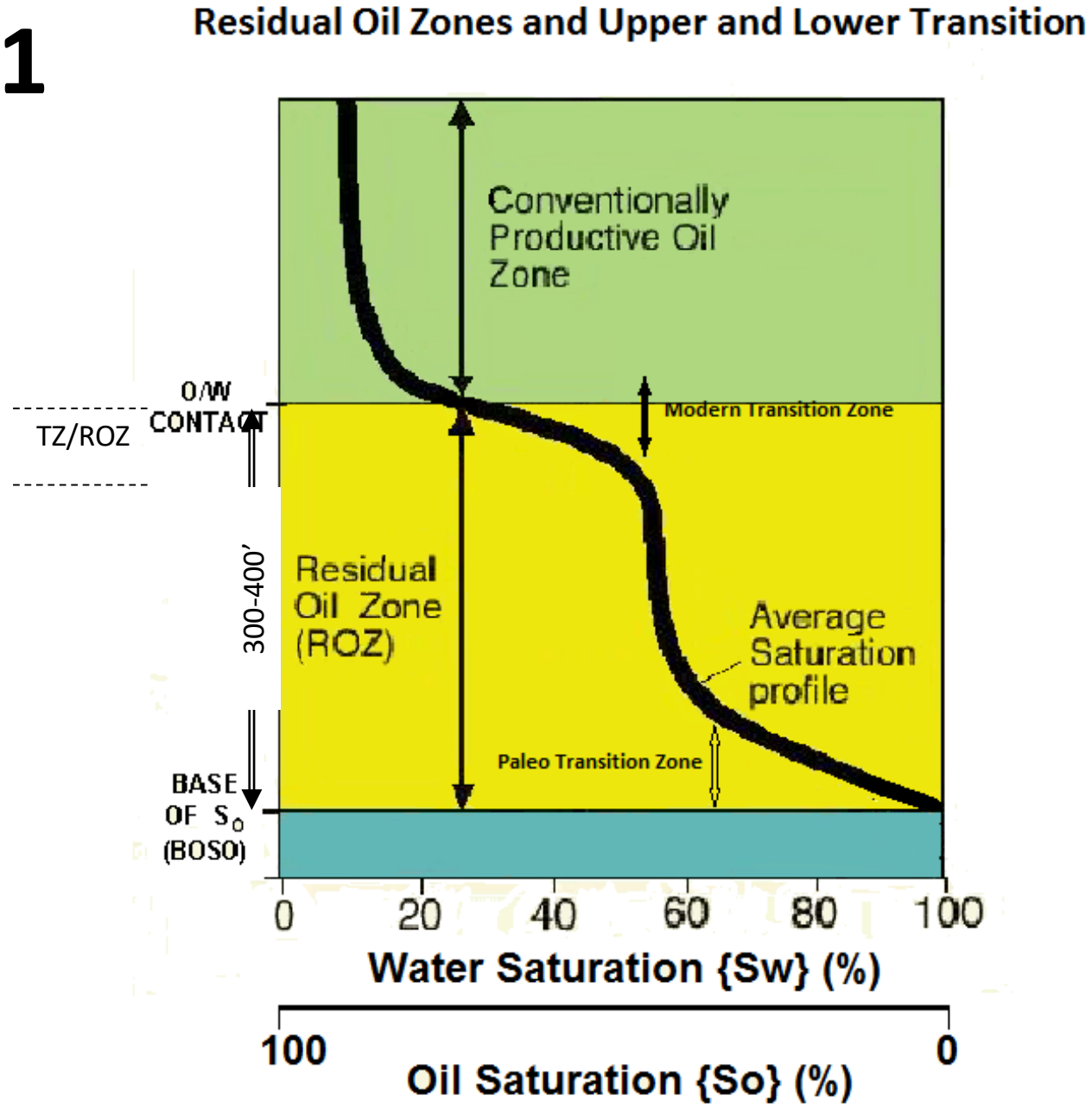
Please Note the Thickness Scale on this graphic….

What would you call this zone?



ROZ Discovery #1

- Before 2000, the Bottom of an Oil Reservoir had to be a Transition Zone
- We Needed a More General Concept: ‘Residual Oil Zones’



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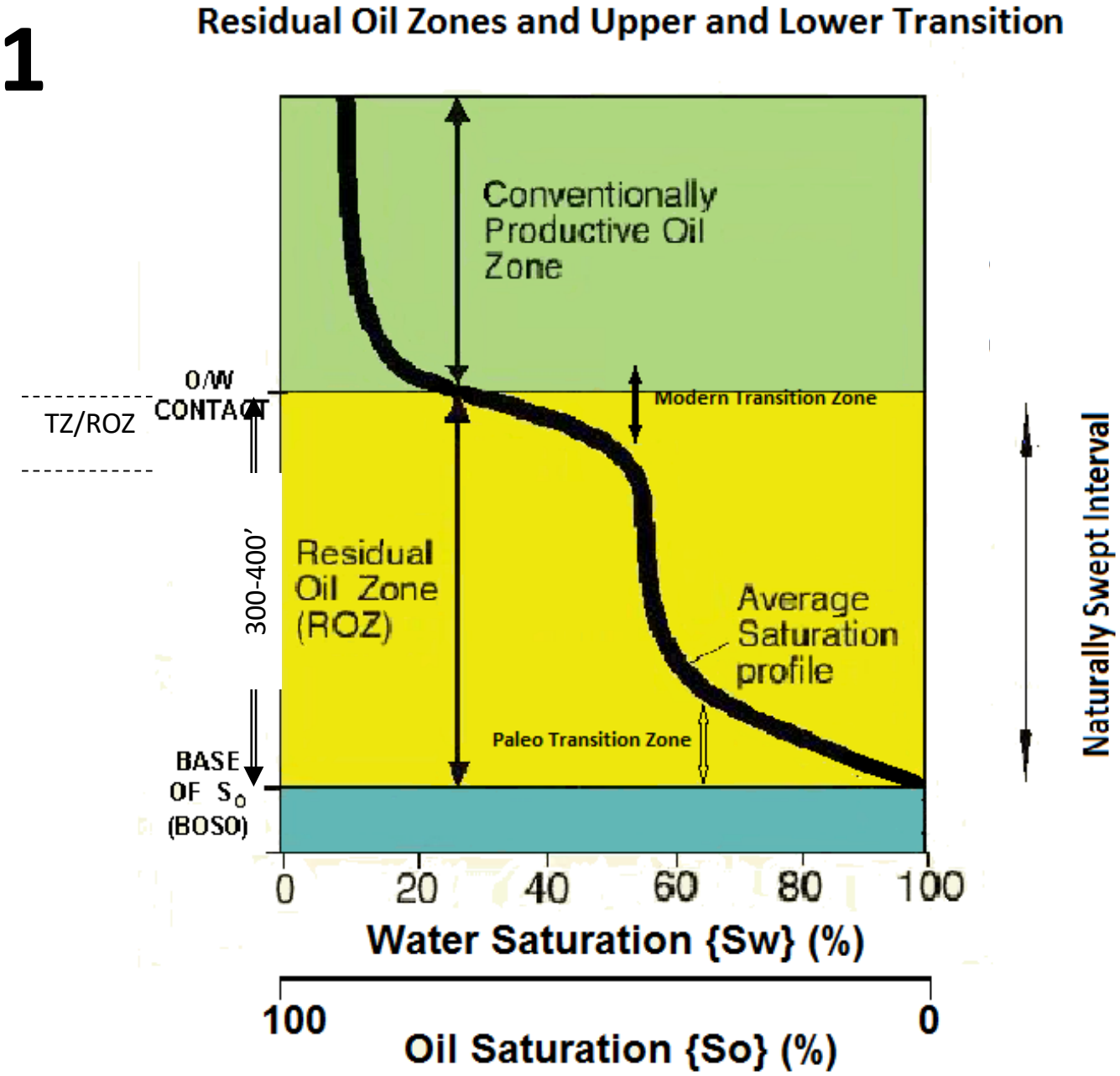
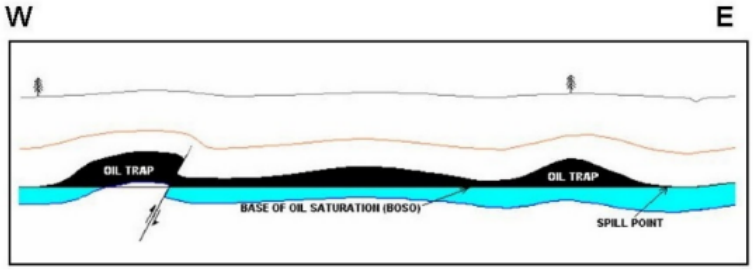


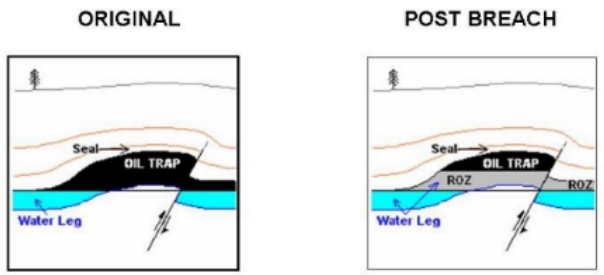
A Graphical Look at ROZs

Original Oil Accumulation Under Static Hydrological Conditions (a Hypothetic Example)



RESIDUAL OIL ZONES: TYPE 2

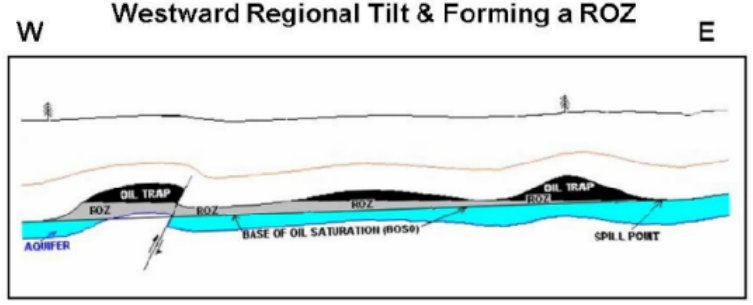
Original Accumulation with a Breached then Repaired Seal & Forming a ROZ



Breached Seal

RESIDUAL OIL ZONE: TYPE 1

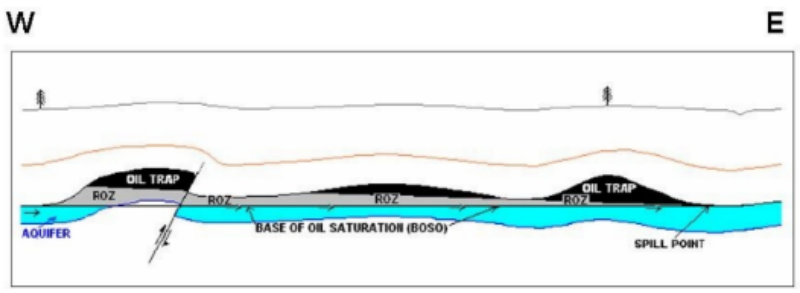
Original Accumulation Subject to a Westward Regional Tilt & Forming a ROZ



Basinwide Tilt

RESIDUAL OIL ZONES: TYPE 3

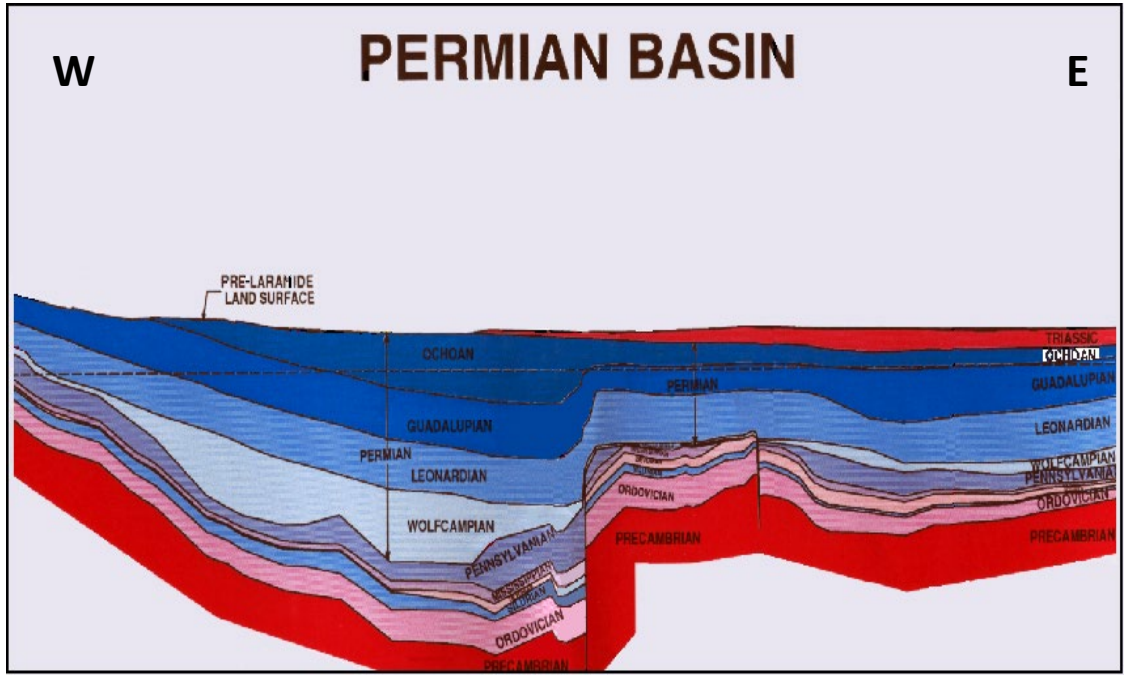
Change in Hydrodynamic Conditions, Sweep of the Lower Oil Column, Oil/water Contact Tilt, and Development Of The Residual Oil Zone



Laterally Swept

ROZ Type 3: The San Andres of the Permian Basin

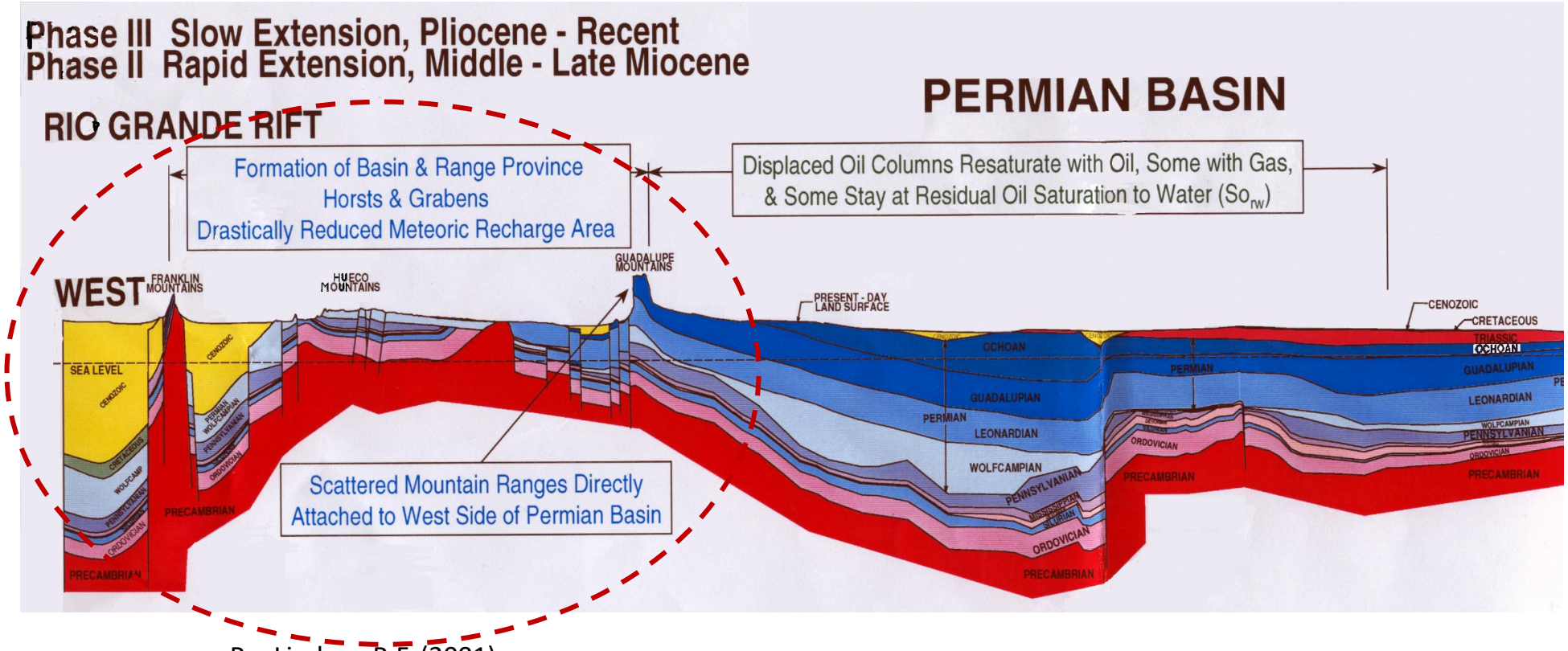
Pre-Laramide



Re: Lindsay, R.F. (2001)

ROZ Type 3: The San Andres of the Permian Basin

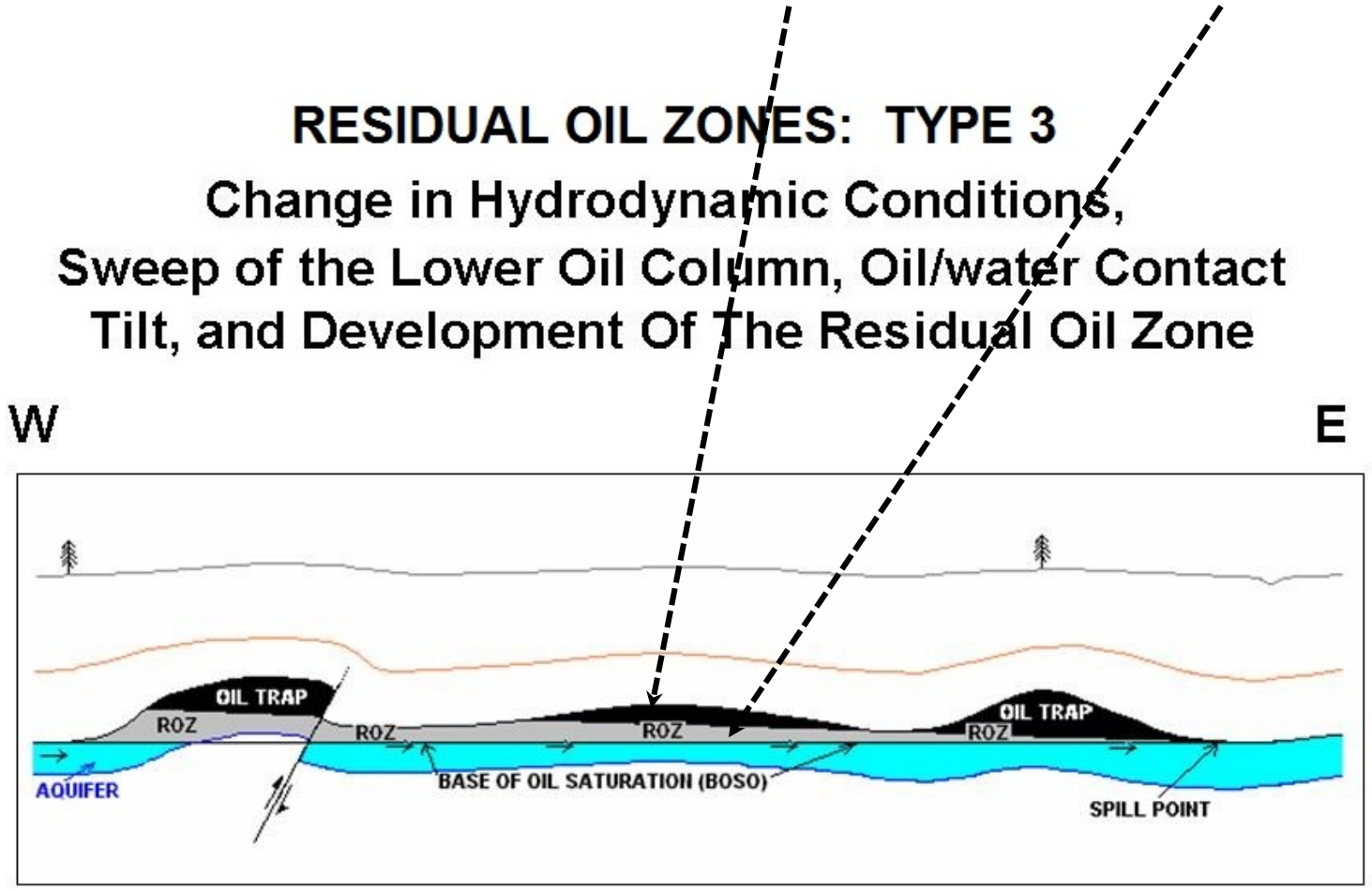
Today



Re: Lindsay, R.F. (2001)

The Net Effect Was to Sweep What was a Massively Large Oil Trap in the San Andres. The Isolated Exceptions were Closures Atop the ROZ (Like the Wasson and Seminole Fields).

In These Cases we Call the ROZ below the Main Pay Zone a "Brownfield" ROZ*



* To Exploit the oil, Wells can be Deepened

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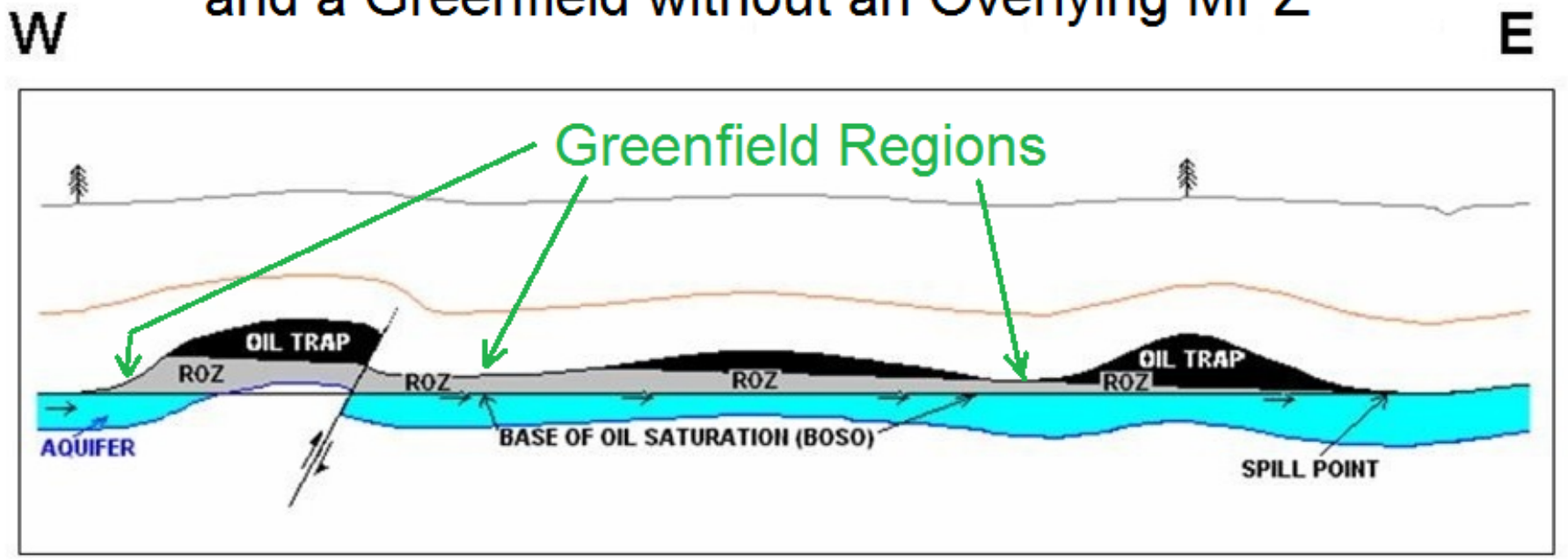
If All the Mobile Oil is Swept Out, We Call it a "Greenfield" ROZ Since New Wells need to be Drilled to Try and Exploit the ROZ

Type 3 Residual Oil Zones
Lateral Sweep with ROZs formed beneath a Field and a Greenfield without an Overlying MPZ



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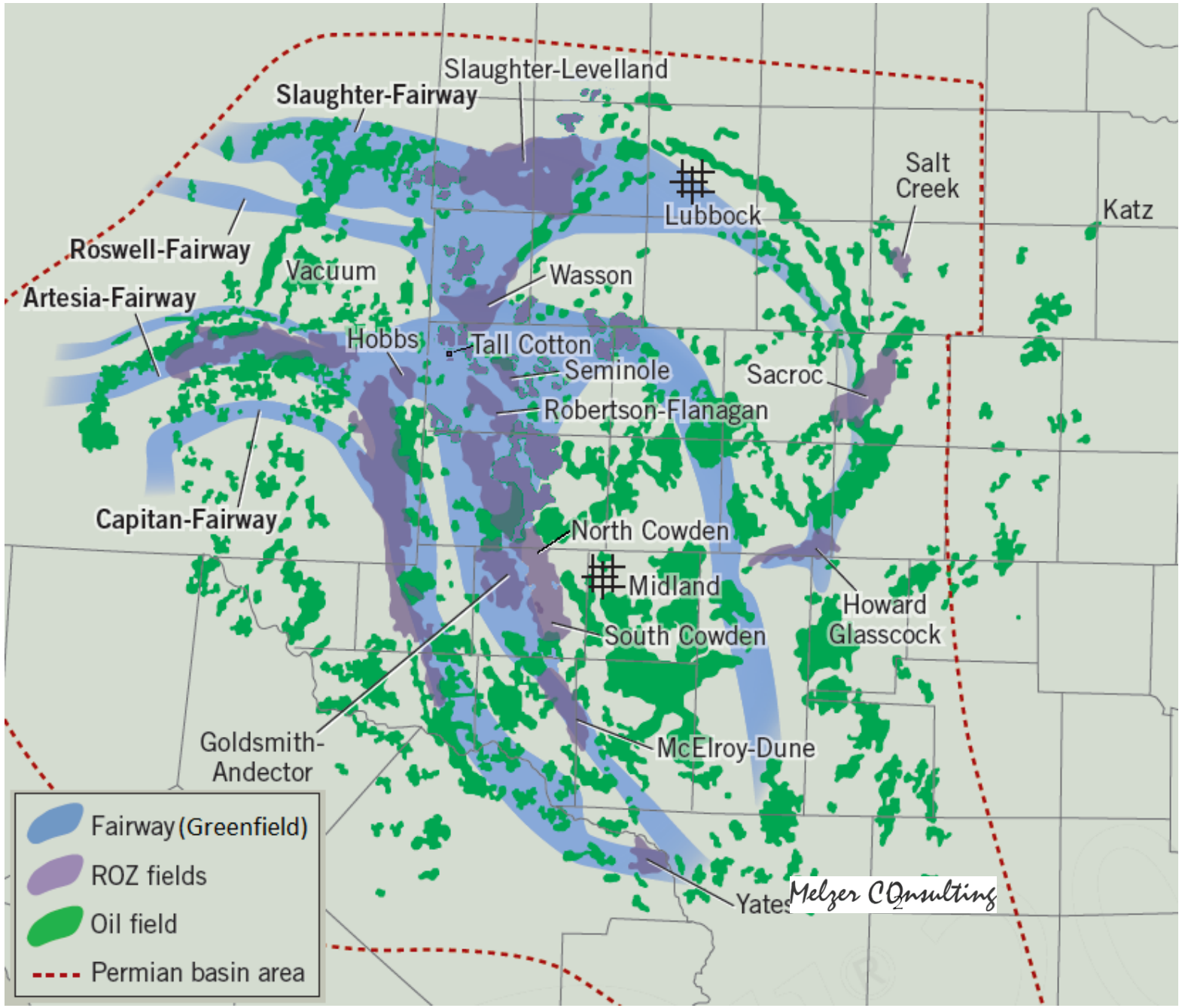
Thanks to RPSEA Financial Support, we were able to Map the Greenfields (aka Fairways of Sweep)



Ref: RPSEA II Report Trentham, R. et al (2016), "Identifying and Developing Technology for Enabling Small Producers to Pursue the Residual Oil Zone (ROZ) Fairways in the Permian Basin San Andres Formation," Research Partnership to Secure Energy for America and U.S. Dept of Energy Final Report, http://residualoilzones.com/rpsea-ii/

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More New Concepts ('Discoveries')

Why on Earth Would Mother Nature's Water Floods Leave 30-45% in Residual Oil Saturation Values?

To Explain Why, We Need to Understand Biogeochemistry

Do you Know How Microbes Live and Work?

The Simple Explanation is that they "Broker" electron exchanges between molecules (think Wall Street Brokering)

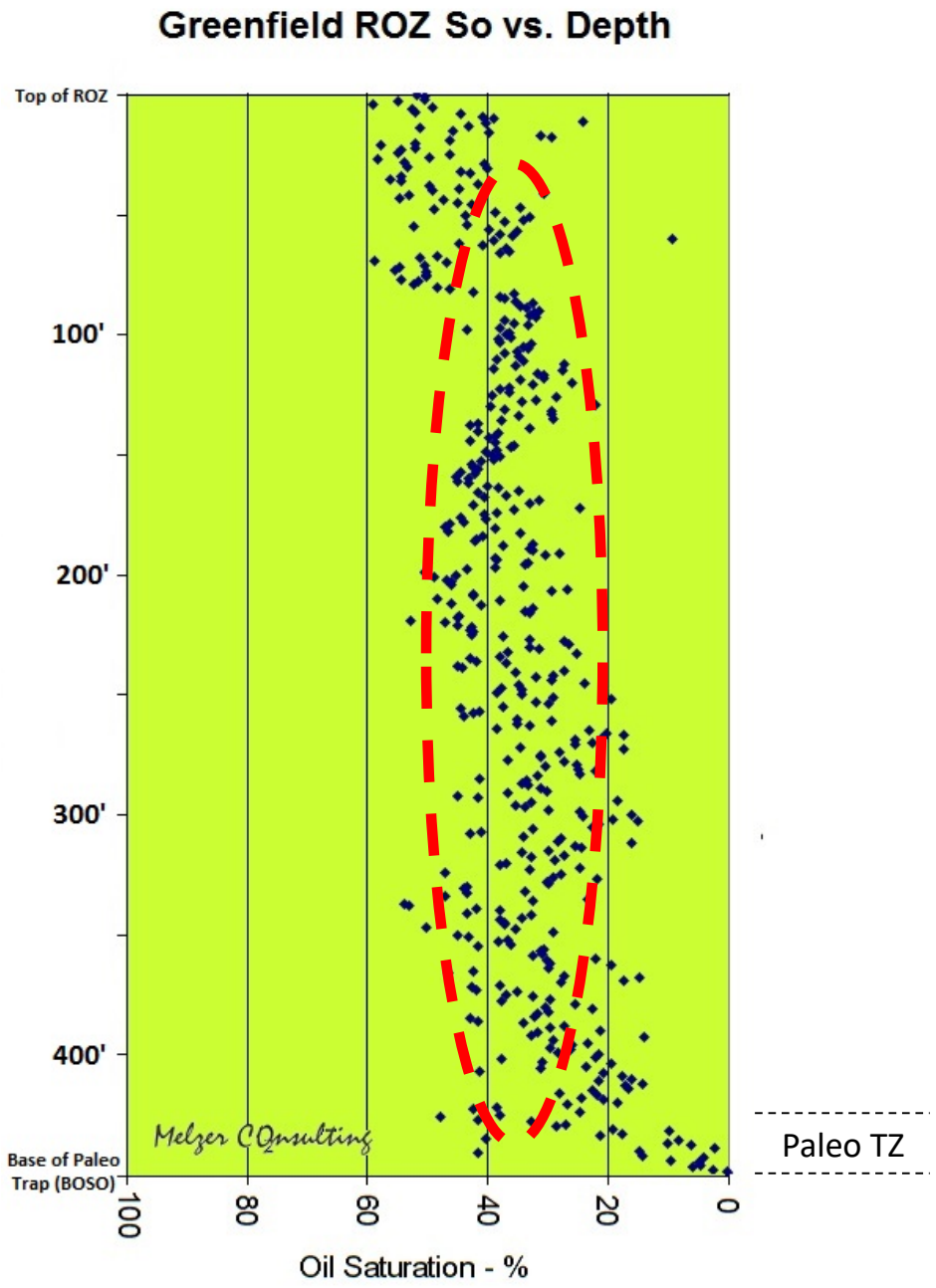
When uninhibited, they Change the Rocks and the Oils

Hmmm?

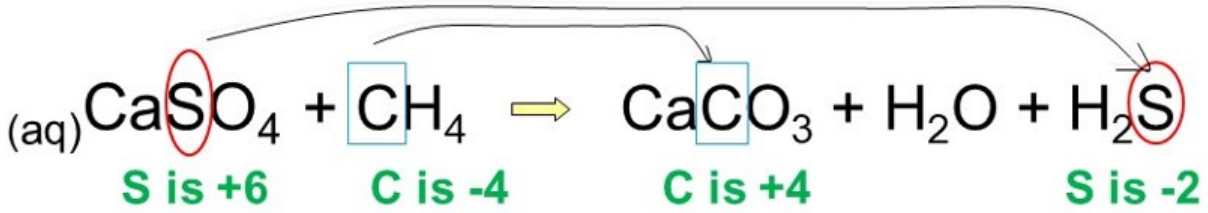
Back to how this Happens

From the Gaines County Tall Cotton Area…

The Greenfield CO_2 EOR Project



Key Biogenic (Redox) Reaction



We are showing Methane here as the source of carbon but…..it may be other hydrocarbons molecules also

- **Microbes remove 8 Electrons from the Carbon and transfer them to the Sulfur**
- **H_2S is Created and Can Inhibit Future Activity (But…A Flowfield Can Disperse)**
- **Dolomitization Typically Follows as Well**

$$CaCO_3 + Mg \Rightarrow MgCa(CO_3)_2$$

Re: Vance, David (2012), RPSEA II Project Chapter 4

Souring the Oil and Gas

New Dolomite Surfaces Attract Oil over Water, Re: Oil Wettability

Mature Sweep Can Keep the Inhibiting H_2S Dispersed: Let's Think about Single & Multiple Pore Volume Sweep in the ROZ

- Type 1 ROZ: Basin Tilting Single PV Sweep
- Type 2 ROZ: Breached Seal Probably Single PV Sweep..but multiple stages of pressure buildup and breach can occur
- Type 3 ROZ: Lateral Sweep Vertical Profile Variable but, Generally, Multiple Pore Vols

ROZ Related Changes to the Reservoir

- Late Stage Rock Diagenesis (aka 'Late-Stage' Dolomitization)
- Extracts Components from the Oil During the Sweep
- Souring of Oil, Gas and Water
- Wettability Alteration

With all the Smart Folks in our Industry, Why Haven't We Noticed this Natural Water Sweep and Biogeochemistry Thing Before?

1) The By-product H_2S can Accumulate Absent a Hydrodynamic Gradient to Carry it Away and Concentrations of >200 ppm Inhibit the Microbes from Doing their Work – we refer to this as Microbial Self Limitation*
2) We Didn't Recognize the Gradients (ROZ Sweep) until recently and they are not Present in the Main Pay Zones so the Effects on Rocks and Oil Noted Above are Minimal

* Vance, David (2014), "Microbial Self Limitation (MSL), Residual Oil Zones (ROZs) and Carbon Capture Utilization & Sequestration (CCUS)," WTGS Bulletin Vol. 53 No. 6- (July/August 2014)

When Recognizing These Processes at Work in Type 3 ROZs with their Mature Sweep,

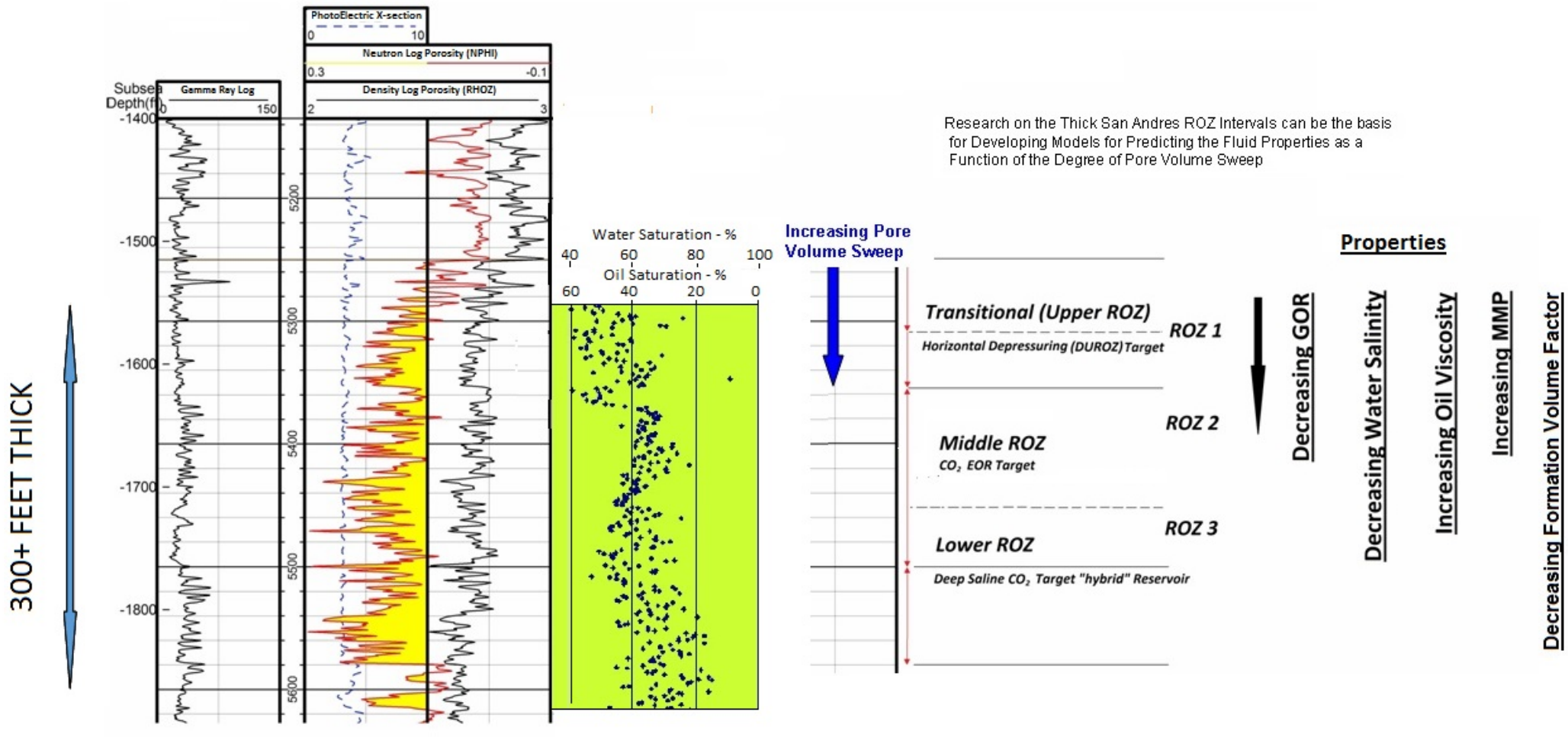
It gets One to Thinking….

- We can Postulate that More-Limited Biogeochemistry Effects Could also be present during the Entrapment Stage when Oil is Replacing Water to form the Original Oil Entrapment
- Does this explain the Mixed-wet characteristics now recognized in Many Main Pay Intervals?

….And one thing we believe is now clear – Biogeochemistry is often important for understanding many characteristics of our oil reservoirs – from dolomitization to Gas/Oil Ratios GORs) to souring of gas/oil and to wettability

What are the Changes to Multiple Pore Volumes of Sweep?

Example of a Laterally Swept Greenfield* Paleo Oil Trap Illustrating Vertical Variable Properties



*** "Greenfield" is a Term to Desribe a Trap Fully Swept to the Top of the Paleo Reservoir Leaving behind no Mobile Oil vs. a "Brownfield" ROZ that had Structural Closure at it Top that was Isolated from the Deeper Water Sweep**

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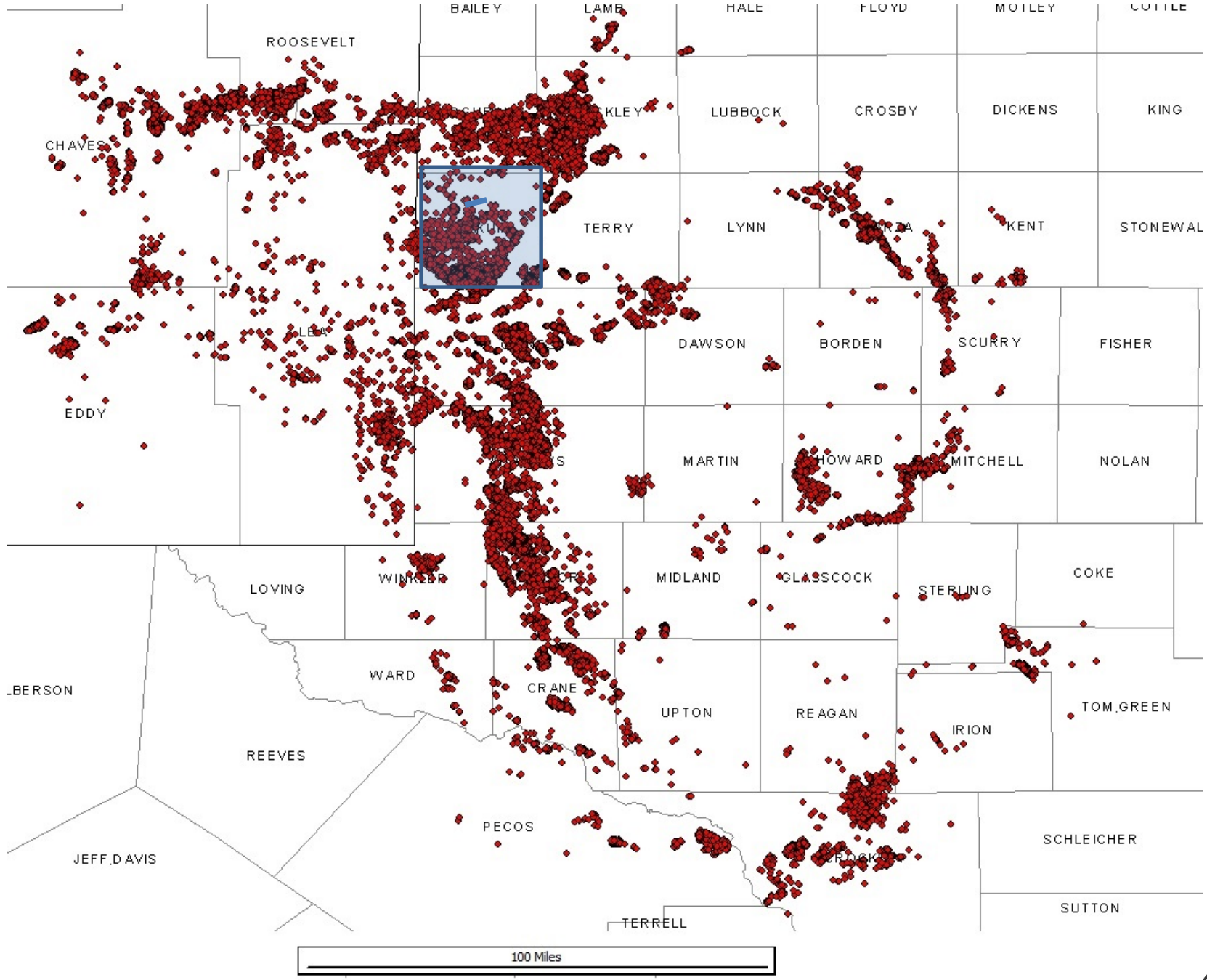
So What is Below the Paleo Oil/Water Contact?

- If it Had Excellent Depositional Porosity, the Zone Below the Paleo OWC is Still Laterally Swept
- It Can Be Very Thick
- We Like to Call it the Pervasively Dolomitized Interval or PDI

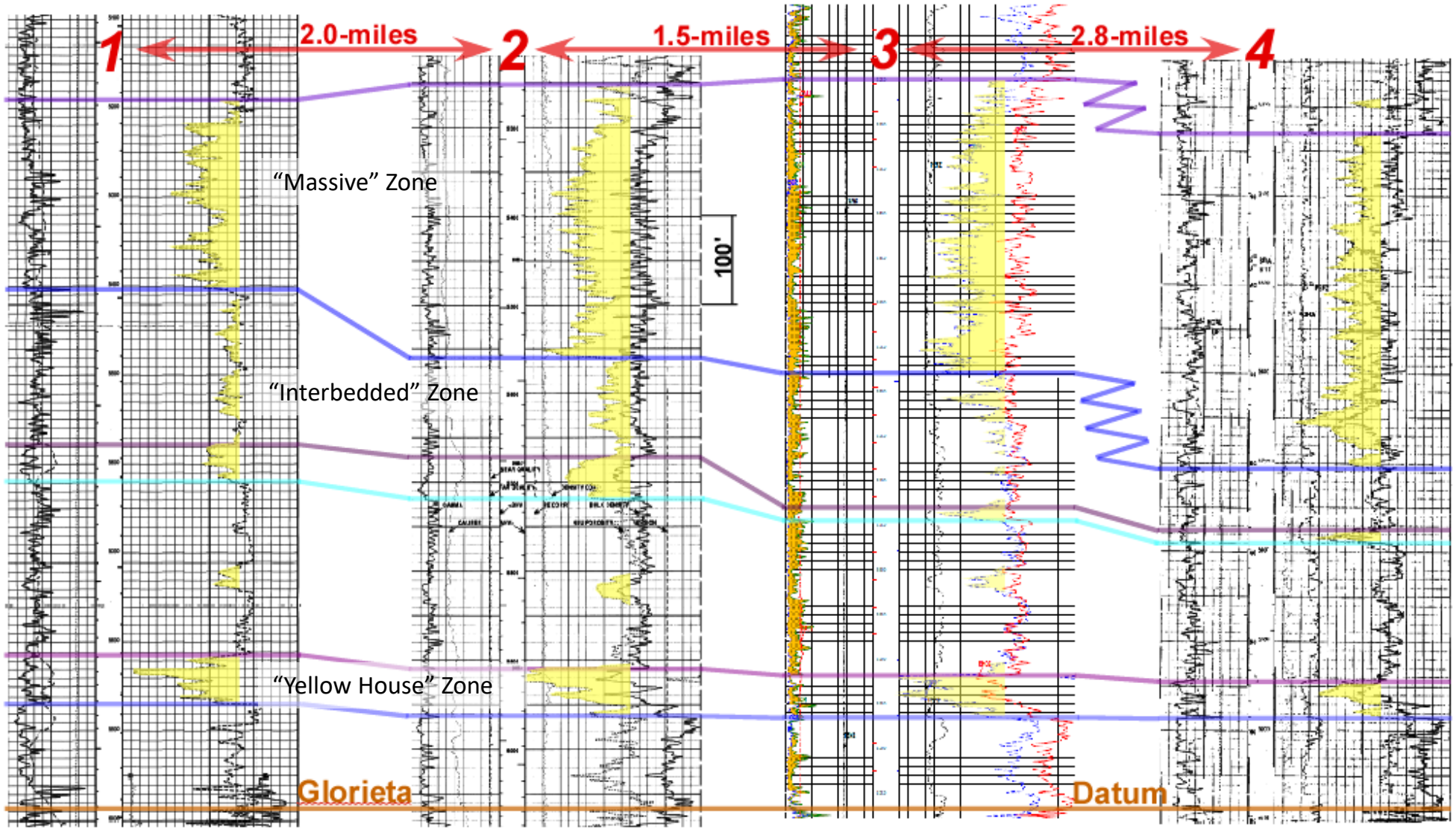
Let's Look at a Couple of Examples

No Central Yoakum County Cross Section

San Andres Stratigraphic Cross Section on the North Shelf



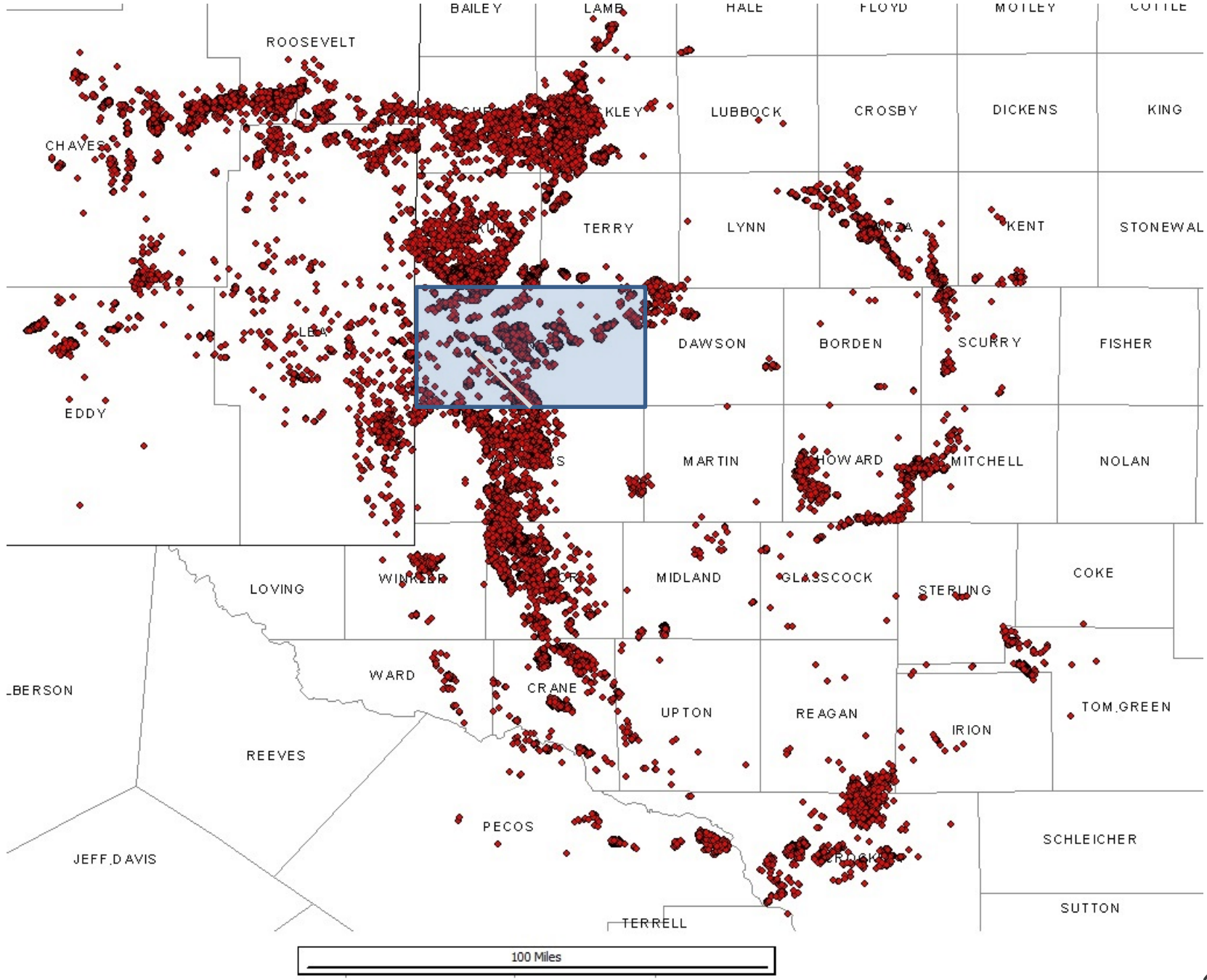
An Example Permian Basin North Shelf (Yoakum County) Porosity Well Log Stratigraphic* 6+ mile Cross Section Illustrating Thick and Laterally Continuous San Andres Porosity Intervals

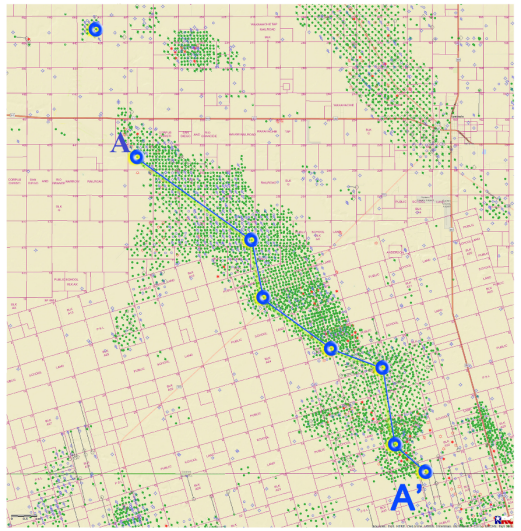


* X-Section Tied to the Base of the San Andres Formation (aka Top of the Glorieta Formation)

North Riley to Andrews County Cross Section

San Andres Structural Cross Section on the Central Basin Platform



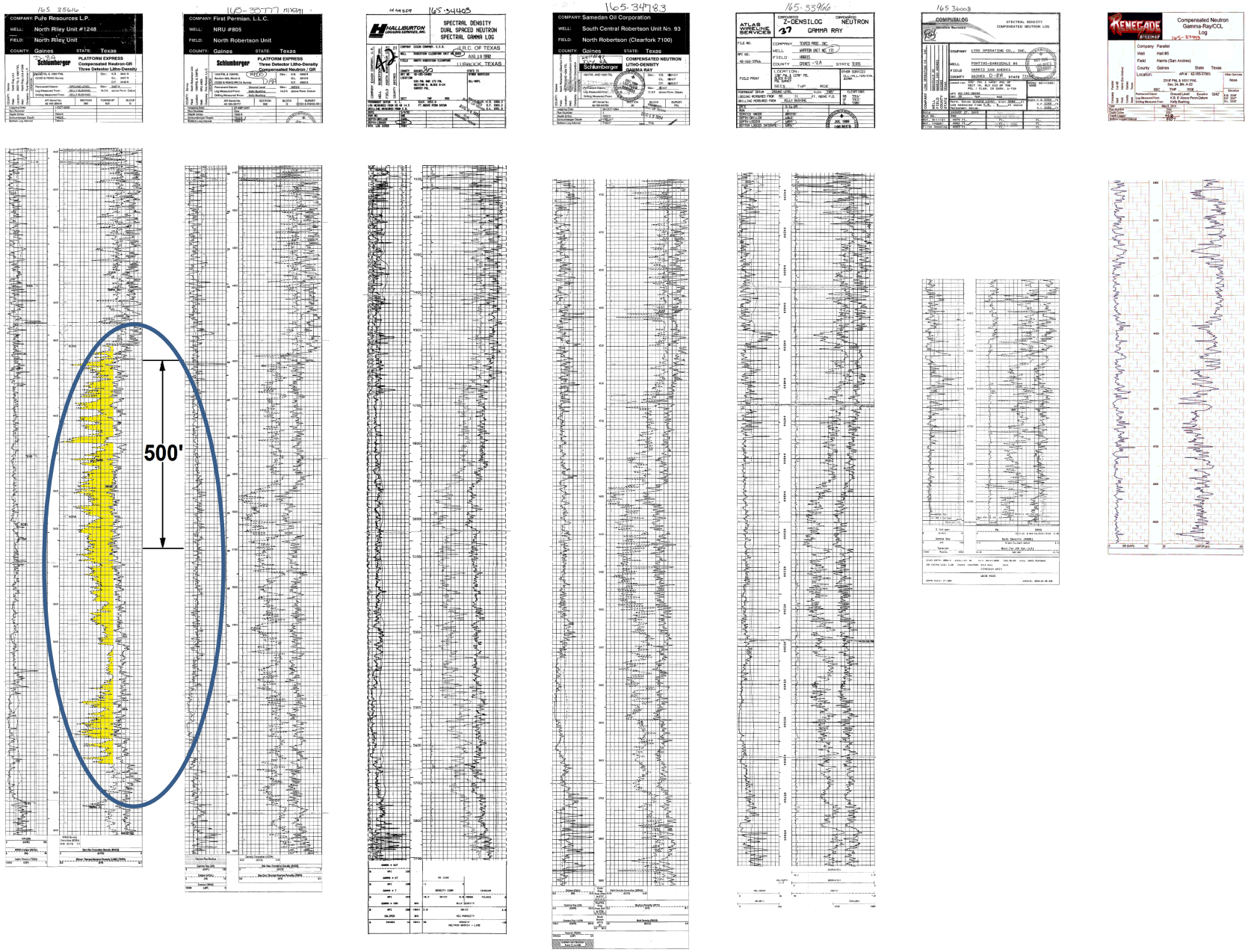


Another Example (15-Mile long X-section) of a Huge Porosity Section in the San Andres Formation

Pure Resources	First Permian	Exxon	Samedan Oil	Texaco	LYNX Operating	Parallel
N Riley Unit #1248	NRU #805	Robertson CF Unit #6603	S Central Robertson Unit #93	Wharton Unit #171	Pontius-Barksdale #8	Hall #5

A

A'



Summary of These New Concepts & Observations

Part 1

(Maybe Some of You Will Continue this Legacy of Discoveries?)

- Residual Oil Zones are Common; they can be Caused not only by Humans ***but also by Nature***
- Not all Residual Oil is Dead Oil
- If the Pore Volume Sweep is Minor, the ROZ Oil can be "Live Oil" (possess Considerable Solution Gas)
- ROZs are often Below Main Pay Zones and also without overlying MPZs (Greenfields)
- The San Andres in the Permian Basin is a Wonderful Example of Enormous Pore Space that can Accommodate Huge Volumes of CO_2 in both CCUS and CCS

Summary of These New Concepts & Observations

Part 2

- Over 700 New Laterals are Exploiting the Upper (lightly swept) San Andres ROZ Oil (we refer to this process as DUROZ)
- Those Wells Need a Light Stimulation
- DUROZ Wells are Spread out over 7 Counties in the ROZ Fairways and are Making 50,000 BOPD now and have Accumulated Almost 60 Million BO to Date
- There is Some Excellent Evidence that Other Formations also have ROZs and are Being Exploited in the PB and Mid-Continent via Horizontal Wells *(think Dewatering)*

Before we stop, Let's Take a Quick Environmental Sidebar

How Do the New ROZ Understandings Relate to CCUS?

- Storing Large Quantities of CO_2 During CO_2 EOR is Now Widely Known and Better Understood
- Commerciality of CO_2 EOR with Concurrent Storage is On-going but Commercially Challenged on its Own Due to Long Payout Times and Competition for Funding from Higher Rates of Return Projects like the Shale Horizontals

…..But, Things are Changing….

- Tax Credits in the U.S. are now Available (45Q)
- Huge Reservoir Targets for CO_2 Storage in ROZs are Now Recognized
- The Depressured ROZs Provide Enormous Pressure Sinks and Reservoir Targets for CO_2 Injection
- One Operator is already Receiving Recognition for Storing CO_2 During EOR – Not Yet in the ROZ but Likely Will Soon

I Hope you are Feeling the Excitement over CCUS and the "New Day" in Oil and Gas?

Steve Melzer

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Midland, Texas

For More Information See: www.CO2Conference.net

www.ResidualOilZones.com

Key References

1 "The San Andres Play: Observations and Challenges in Horizontal Wells on the Central Basin Platform, Permian Basin," Alimahomed, F., Melzer, L.S. et al, SPE-189865-MS, Presented at the SPE Hydraulic Fracturing Technology Conf, The Woodlands, TX, USA, 23-25 January 2018

2 ROZ Science, Activity Updates on Horizontal Depressuring the San Andres Formation and ROZ EOR, a Seminar at the 2017 CO_2 and ROZ Conference, Dec 2017, Melzer L.S. (editor and contributor), Midland Tx, www.CO2Conference.net

3 (RPSEA II) Identifying and Developing Technology for Enabling Small Producers to Pursue the Residual Oil Zone (ROZ) Fairways in the Permian Basin San Andres Formation, Coauthor with Trentham, R.C. & Vance. D. (2016) Research Partnership to Secure Energy for America and U.S. Dept of Energy Final Report, www.netl.doe.gov/file%20library/research/oil-gas/10123-17-final-report.pdf

4 (RPSEA I) Commercial Exploitation and the Origin of Residual Oil Zones: Developing a Case History in the Permian Basin of New Mexico and West Texas, Jun 2012, Coauthor with Trentham, R.C. & Vance. D. (2016) Research Partnership to Secure Energy for America and U.S. Dept of Energy Final Report, http://www.rpsea.org/0812319/

5 "Origins, Processes and Exploitation of Residual Oil Zones," (Director and Contributor), Seminar conducted at the 2015 CO_2 Conference, Dec 9, 2015 (www.CO2Copnference.net)

6 "The Origin and Resource Potential of Residual Oil Zones," SPE paper 102964, w/ G.J. Koperna and V.A. Kuuskraa, presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Tx Sept 24-27, 2006.

7 Where it all Began - Stranded Oil In The Residual Oil Zone, Report sponsored by the United States Department of Energy, 2006 download report at http://residualoilzones.com/wp-content/uploads/2018/02/Melzer2006.pdf