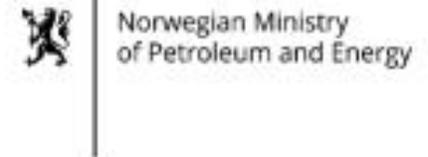


New Insights on Transmissive Fractures from the Horizontal Well Revolution *(and Born of the ROZ Studies)*

A Presentation to the
4th Biennial CO₂ for EOR as CCUS Conference 2019



Rice University - BRC Auditorium
September 25th, 2019

New Insights on Transmissive Fractures from the Horizontal Well Revolution

Are You Feeling **the Excitement** about the O/G Industry?

Background for the Talk: Occasional Frustrations: Low Oil Cuts, Sour Oil and Gas, and Injectant Containment Issues ([the Nat'l Fracture Connection](#))

1. Where Does the New Science Come From?
2. Types of Transmissive Fractures
3. What are the Diagnostic Measurements?
4. From the Field: New Realizations/Case Histories
5. Closing

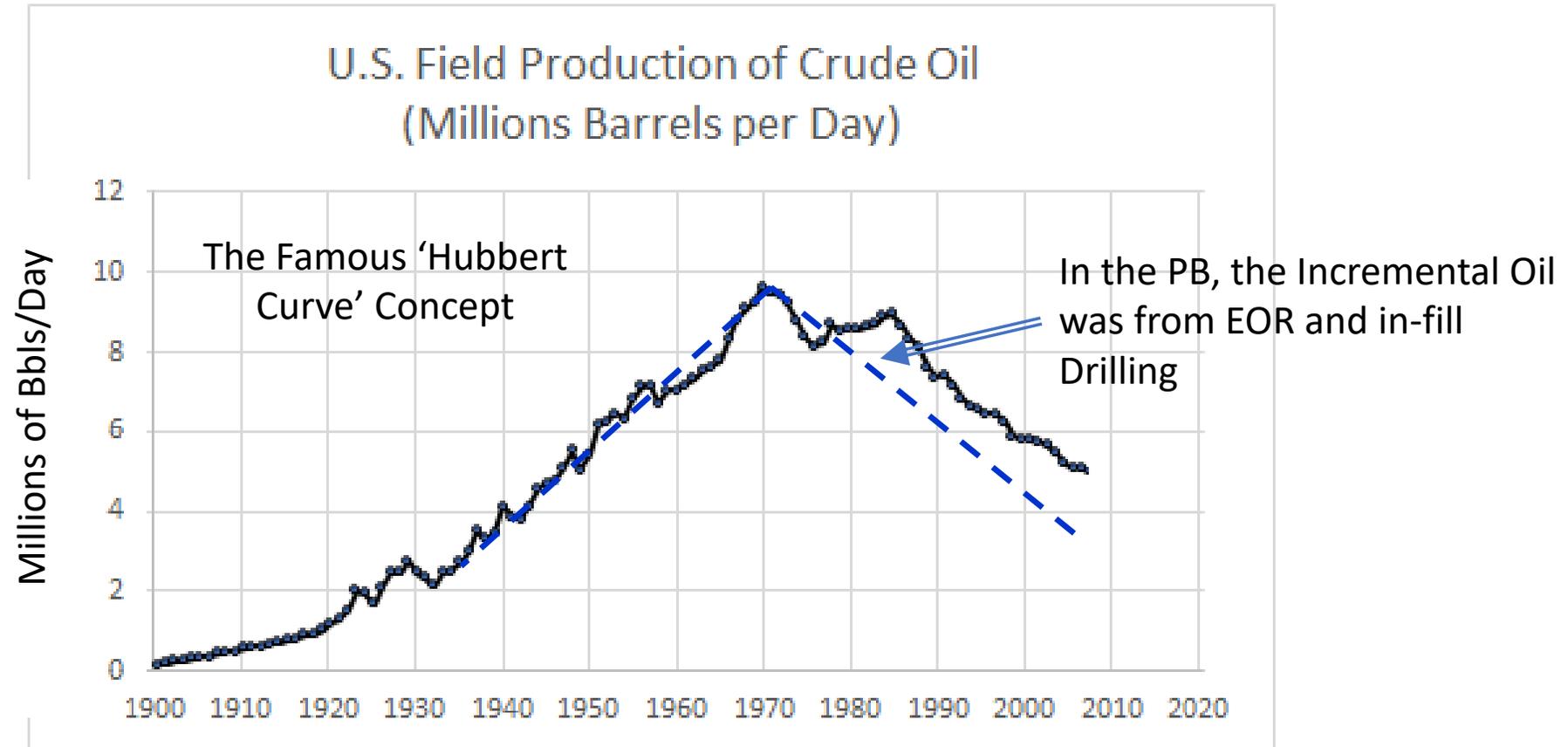
We'll Look First at the Obvious

What is all the Buzz About in the O&G Business*?

* From a "Student" in the Field

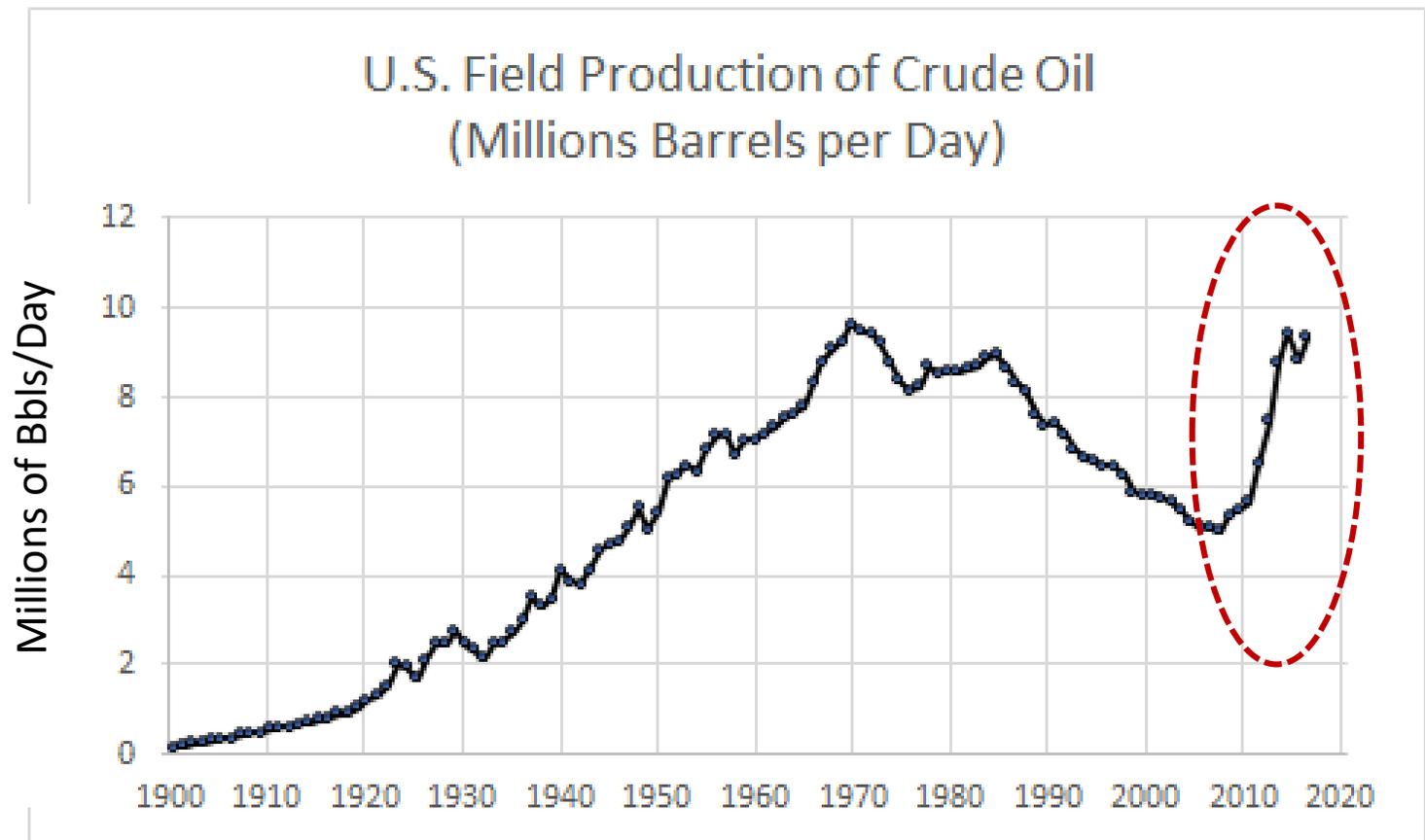
For Maturing Basins...

Things Looked A Bit Dim for the Future Ten Years Ago



From: Energy Information Agency U.S. Field Production of Crude Oil
<https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus1&f=a>

But, Now There is a **New Excitement** out There?



From: Energy Information Agency U.S. Field Production of Crude Oil
<https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfps1&f=a>

Why We are *Feeling the Excitement*

- Producing Unconventional Reservoirs
- Producing Unconventional Oil (More on this Later)
- Horizontal Drilling Technologies and the Explosion of Innovative Tools for Horizontal Completions
- Better Drilling Rigs and Bits for Faster Drilling
- And...There is a Lot More **Excitement** Beyond the Above

Reservoirs: *Feeling the Excitement*

“One Horizontal Well in a Section (mi²) is Worth More than 16 Verticals”

This Quote comes from a flood guy and a former disciple for vertical wells

To explain, lateral continuity of a reservoir has always been a big question. With a mile-long lateral, we can now witness the changes in both the oil and rock in a continuous fashion with the new, modern mud logs and Measurement While Drilling (MWD) tools.

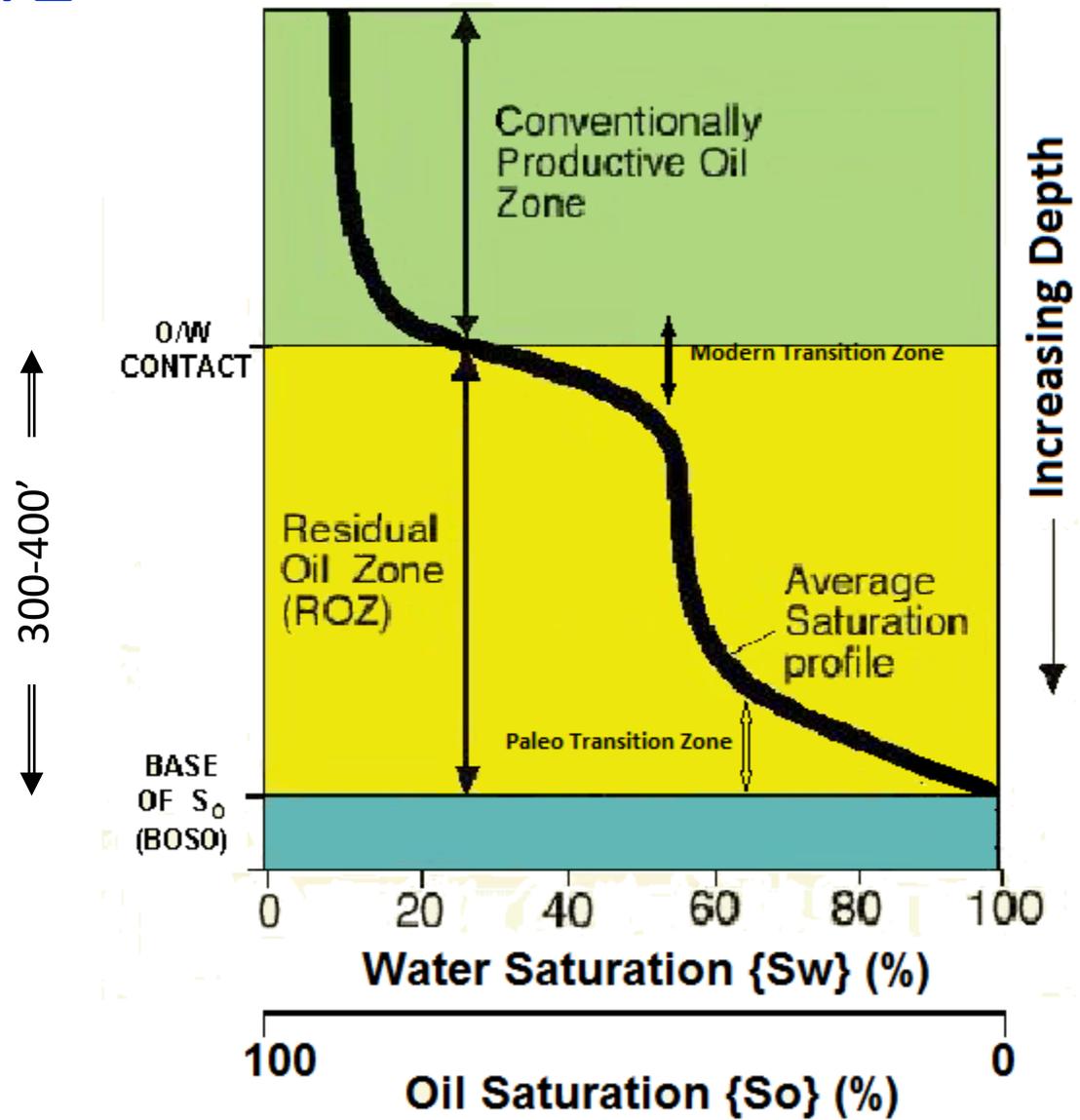
Let's Quickly Look at the New Reservoir Developments

(Serendipity Strikes Here – in the Form of
Residual Oil Zone {ROZ} Studies)

New Discovery (Realization) #1

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

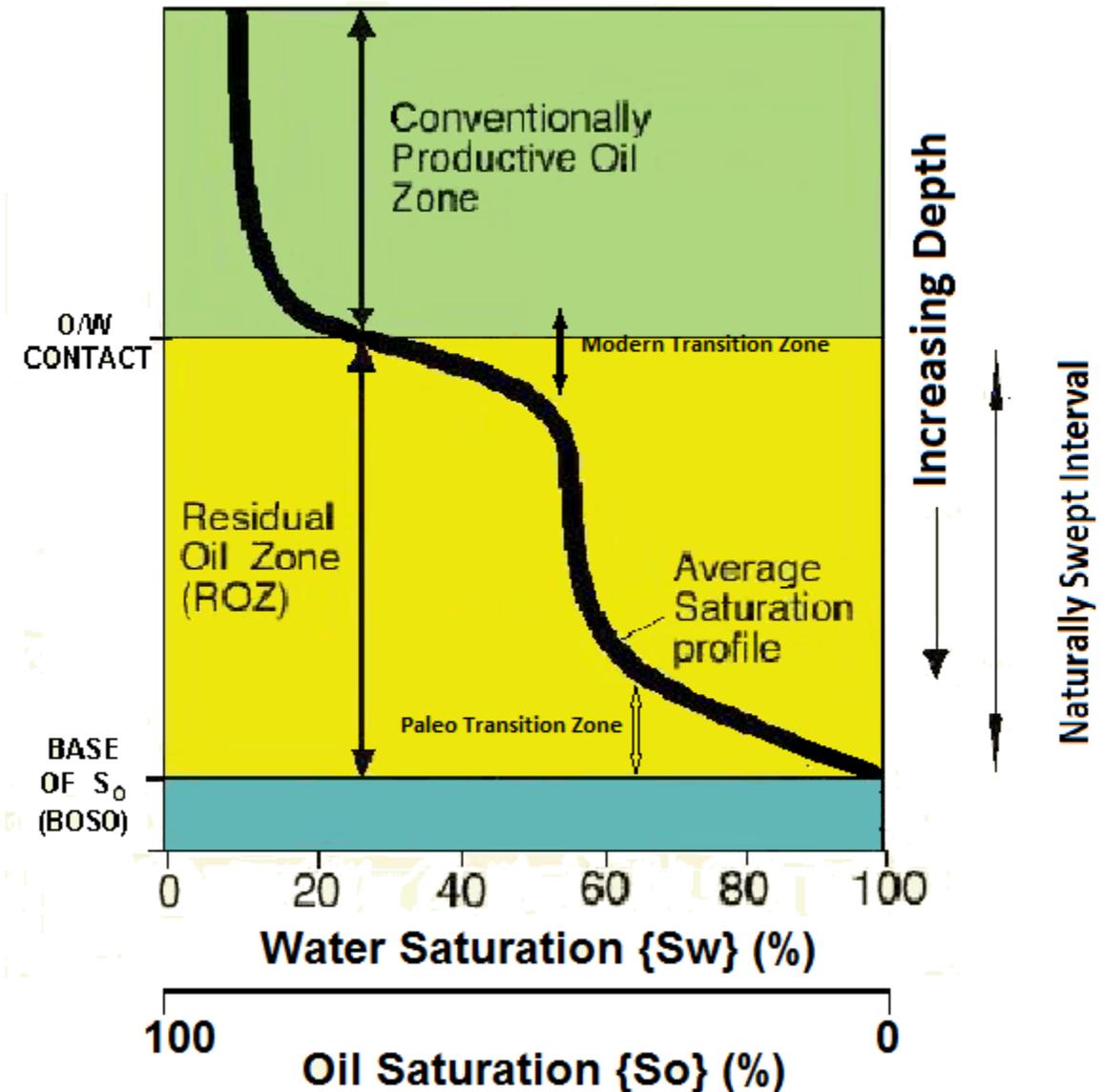
Residual Oil Zones and Upper and Lower Transition



New Discovery (Realization) #1

- Before the Year 2000, the Bottom of an Oil Reservoir had to be a Transition Zone
- We Thought we Needed a More General Concept: 'Residual Oil Zones'
- So What Causes a Residual Oil Zone?

Residual Oil Zones and Upper and Lower Transition



Types of ROZs

All Three of the Concepts below can be Thought of as Moving Oil and Water around in Conventional Oil Entrapment (Trap) and Occuring in a Later Stage Tectonic Event after the Initial Oil Entrapment*

*1st Stage Tectonics: Basin Subsidence, Oil Generation & Migration to a Trap **Followed by:***

- A Basinwide Tilt (Type 1),
- A Breached (and often Reformed) Seal (Type 2), or
- An Asymmetric Basin Uplift and Lateral Flushing (Type 3)

* so oil is present when these things are happening

How Common are ROZs?

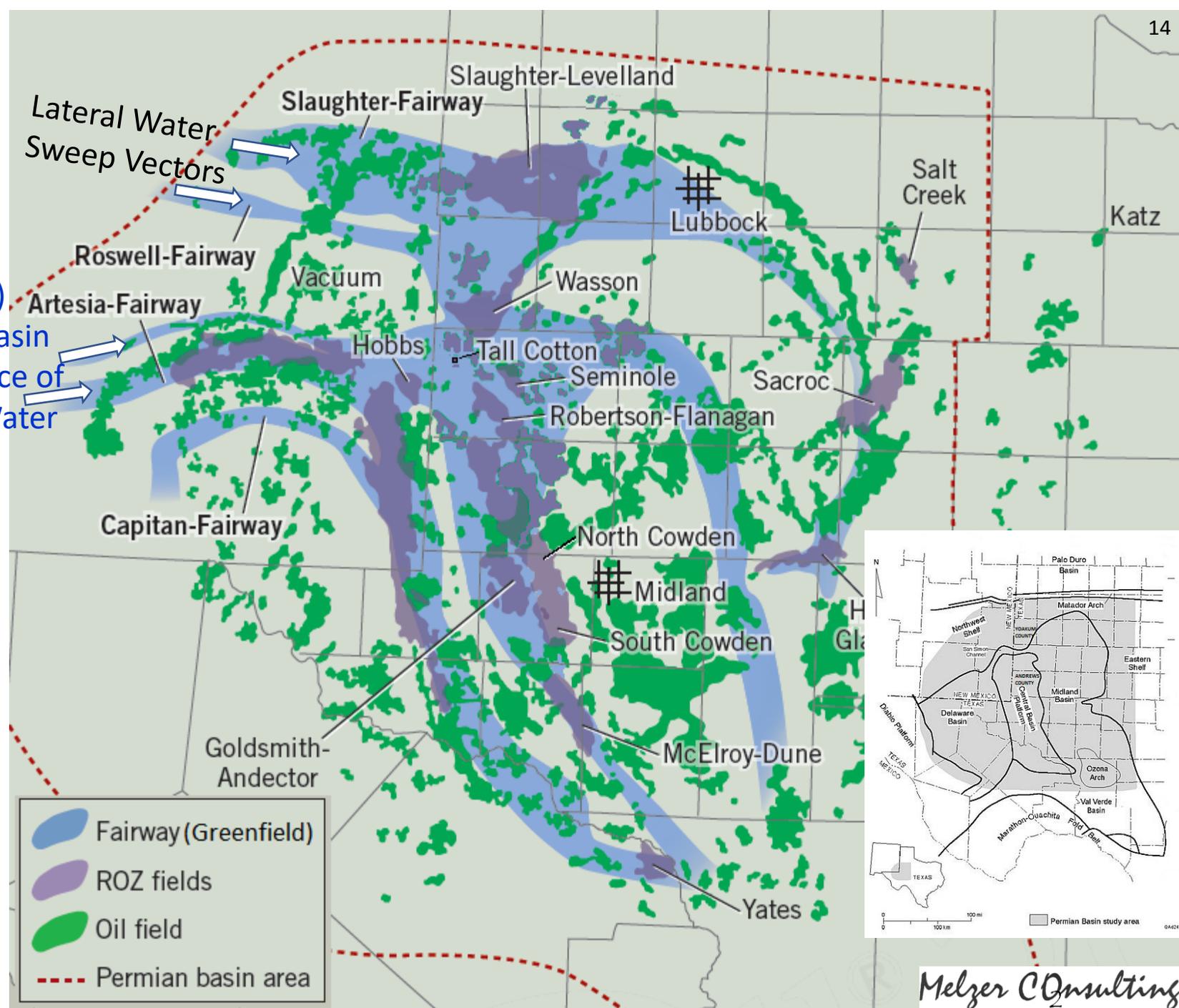
We Are Still Looking for the Oil Basin Without Post-Oil-Emplacement Tectonics and ROZs

- It is Not the Permian Basin
- It is Not the Gulf Coast
- It is Not the Williston
- Nor the Bighorn
- Not the North Sea
- Nor the Cooper-Eromanga
- Not the Baltic
- Nor the Arabian
- And so on.....and on

Thanks to RPSEA, we were able to Map the 'Greenfields' in the Permian Basin (aka Fairways of Sweep)

Ref: RPSEA II Report www.netl.doe.gov/file%20library/research/oil-gas/10123-17-final-report.pdf

Western (Uplifted) Side of Basin and Source of Sweep Water



So What's the Big Deal about the Science: How Do You Exploit the Residual Oil?

- EOR Mobilizes the Immobile Oil Just Like it Does after Man's Waterflood

New Realization #2

CO₂ EOR

*And, **Hold on**, more breaking (**exciting**) news just coming in....*

- If the Oil Retains Enough Gas, Depressuring the Reservoir can Commercially Mobilize Some of the Oil

New Realization #3

**Depressuring
the Upper
ROZ (DUROZ)**

We Need to Move on – As **Exciting** as it is*, we Need to Save the Progress Made on Producing the ROZ Oil to another Time

* ROZs are Now Making 50,000 bopd

New Realization (Discovery) #4

Why in Earth Would Mother Nature's Water Floods Leave Behind 30-45% Residual Oil Saturations?

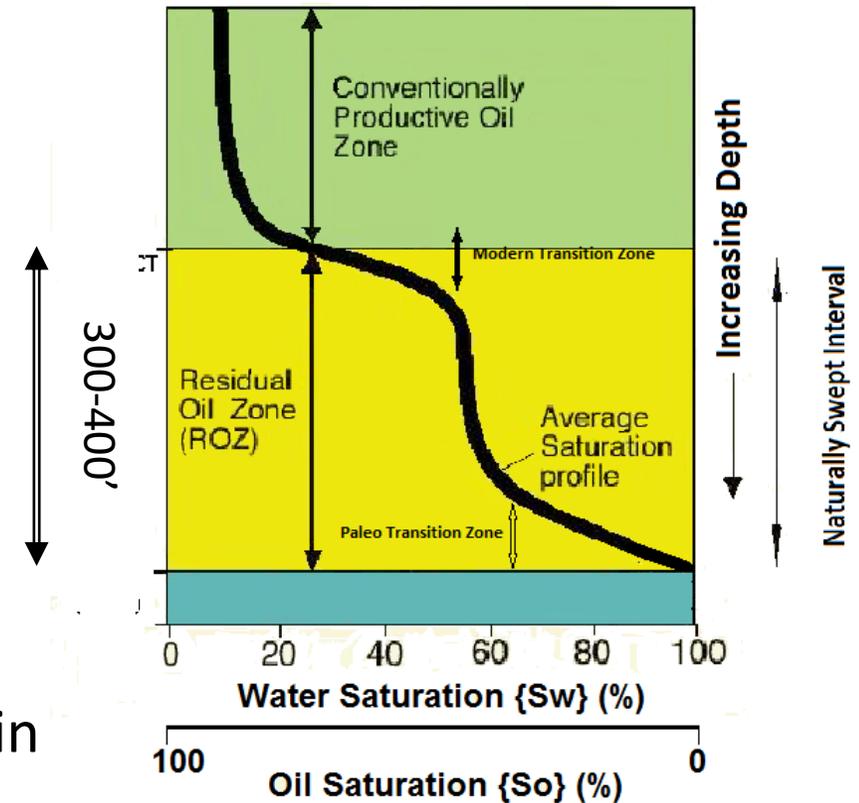
To Explain Why, We Need to Understand Biogeochemistry

Anaerobic Microbes are Intrinsic and Ubiquitous in the Subsurface and you Need Understand How Microbes Live and Work?

The Simple Explanation is that they "Broker" electron exchanges between Molecules

Another Data Set (a 'Greenfield' {without an Overlying Main Pay Zone}) and then a Common Example Will Help Explain

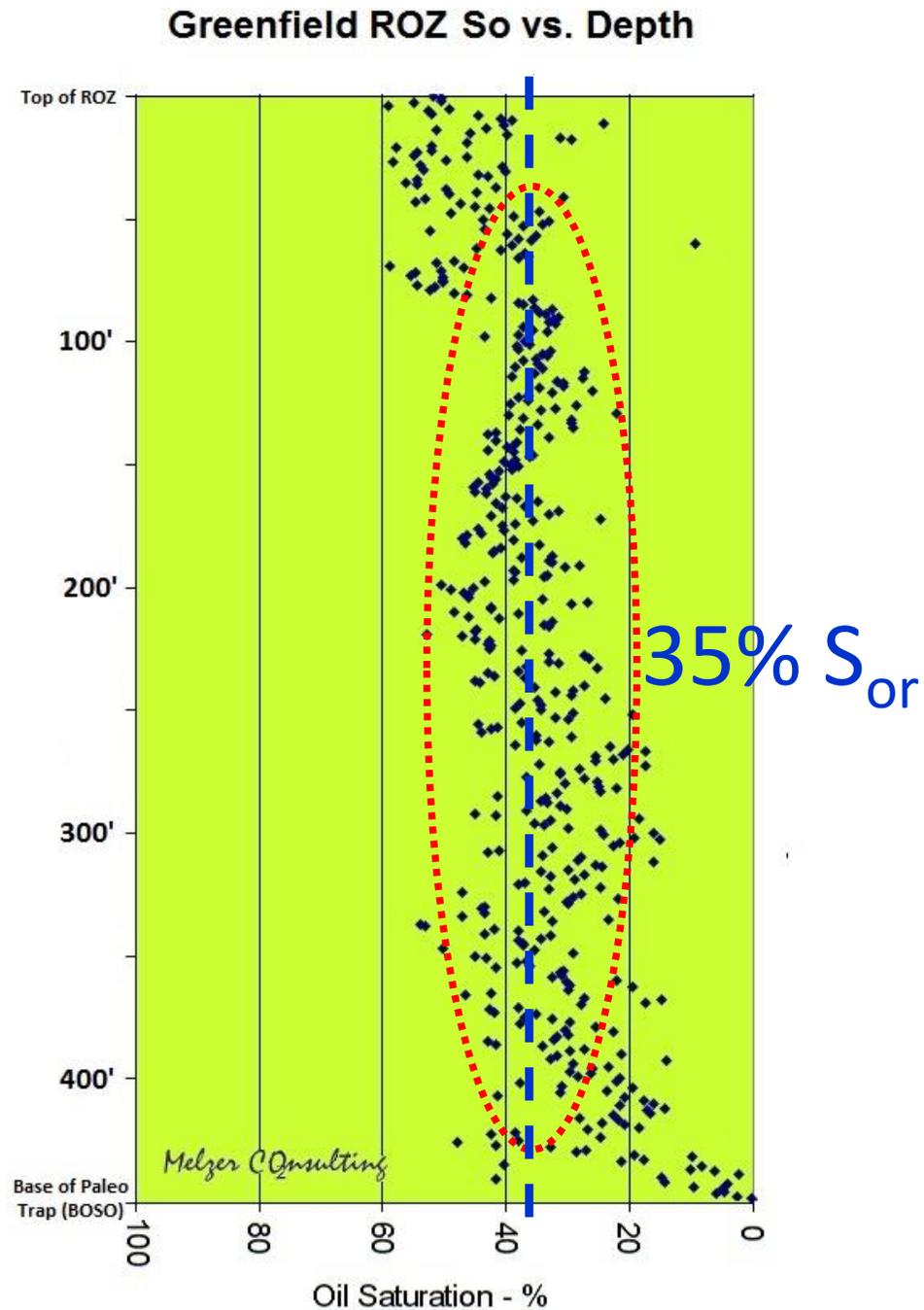
Residual Oil Zones and Upper and Lower Transition



How Does this
Happen?

Data From Near
the Tall Cotton
Greenfield ROZ
CO₂ EOR Project

A 'Greenfield'
CO₂ EOR Project



Chance Strikes Again....

Related Changes to the Reservoir

- Late Stage Rock Diagenesis
- Solubilizes Components from the Oil During the Sweep
- Souring of Oil
- Wettability Alteration

Key Biogenic Reaction

Note: We are Using Methane here as the Source of Carbon



- **Microbes remove 8 Electrons from the Carbon and transfer them to the Sulfur**
- **the Source Sulfate is Reduced and is Released as H₂S to Sour the Oil and Gas**
- **Dolomitization Typically Follows as Well**



Souring the Oil and Gas

New Solid Surfaces Are Formed

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

Thus, the Serendipitous ROZ Story Unfolds
from Explaining Thick Transition Zones to:

Souring O/G*, Wettability** Insights and...

Finally, We Get to Natural Fractures***

* Realization #5

** Realization #6

*** Realization #7

Remember Us Saying one Horizontal is Worth More than 16 Vertical Wells in a Square Mile?

- The Horizontal Revolution is Letting Us See How Common Vertical Natural (Transmissive) Fractures Might Be
- With Modern Wireline and Mud Logs We are Getting Better at Finding Those Fractures
- If We can Find them, We might Avoid Stimulating into Them

The Vertical Transmissive Fracture Science (1)

- Uranium (and Thorium) were formed during the Creation of the Earth
- Both are Radioactive with Long Half-Lives so are Present Today
- Uranium is Soluble in Water so Can be Transported from its Crustal Basement Residence
- Thorium is Essentially Insoluble in Water
- Vertical Transmissive Fractures Can Offer a Path for the Uranium to Reach Shallower Depths
- Uranium Affixes to Organics (Carbonaceous Materials) so can Come out of the Water
- Residual Oil (and Organic-Rich Sediments) Can Host Uranium

The Vertical Transmissive Fracture Science (2)

- When Uranium Radioactively Decays, it Gives off an Alpha Particle (2 Protons) and forms a Helium atom
- Mass Spectrometry can Detect off-gassing Helium from Fluid (Muds)
- The 'Daughter' atom after the Alpha Emission, is instable and Gives off Gamma Emissions of a Specific Energy Spectrum
- The Energy Spectrum of the Gamma Ray from Uranium can be Detected and Differentiated from Thorium or Potassium Gamma Emissions
- The Presence of Either or Both Helium or Uranium Gamma Energy is an Indicator of a Host Site for Uranium
- The Site can be the Water Coming from the Basement Connected Fracture and/or the Carbonaceous Material Lining the Fracture

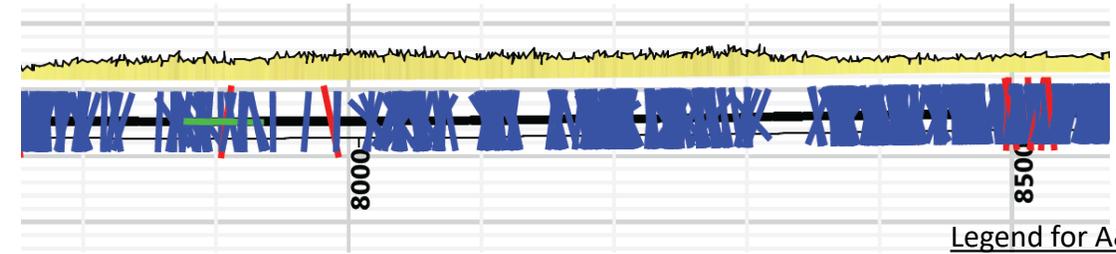
For This Purpose, we are Using a New Fracture Categorization Framework for Near Vertical 'Transmissive Faults' (VTFs)

A. Localized Natural Fractures

For the sake of simplicity, let's call them drilling induced

B. Flexural Faults/Fractures Over Deep Seated Structures

C. Crustal Basement Based, Recurrent Faults/Lineaments



Legend for A&B

Bed Boundary: green

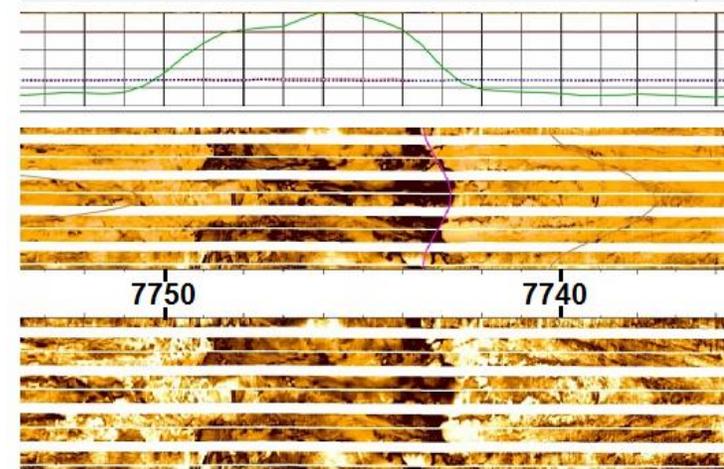
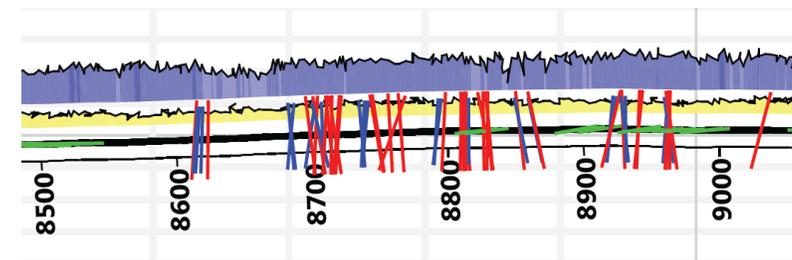
Partially Conductive

Fractures: blue

Conductive Continuous

Fractures: red

Gamma Ray: 0-150 GAPY



Images Compliments of Schlumberger Oilfield Services

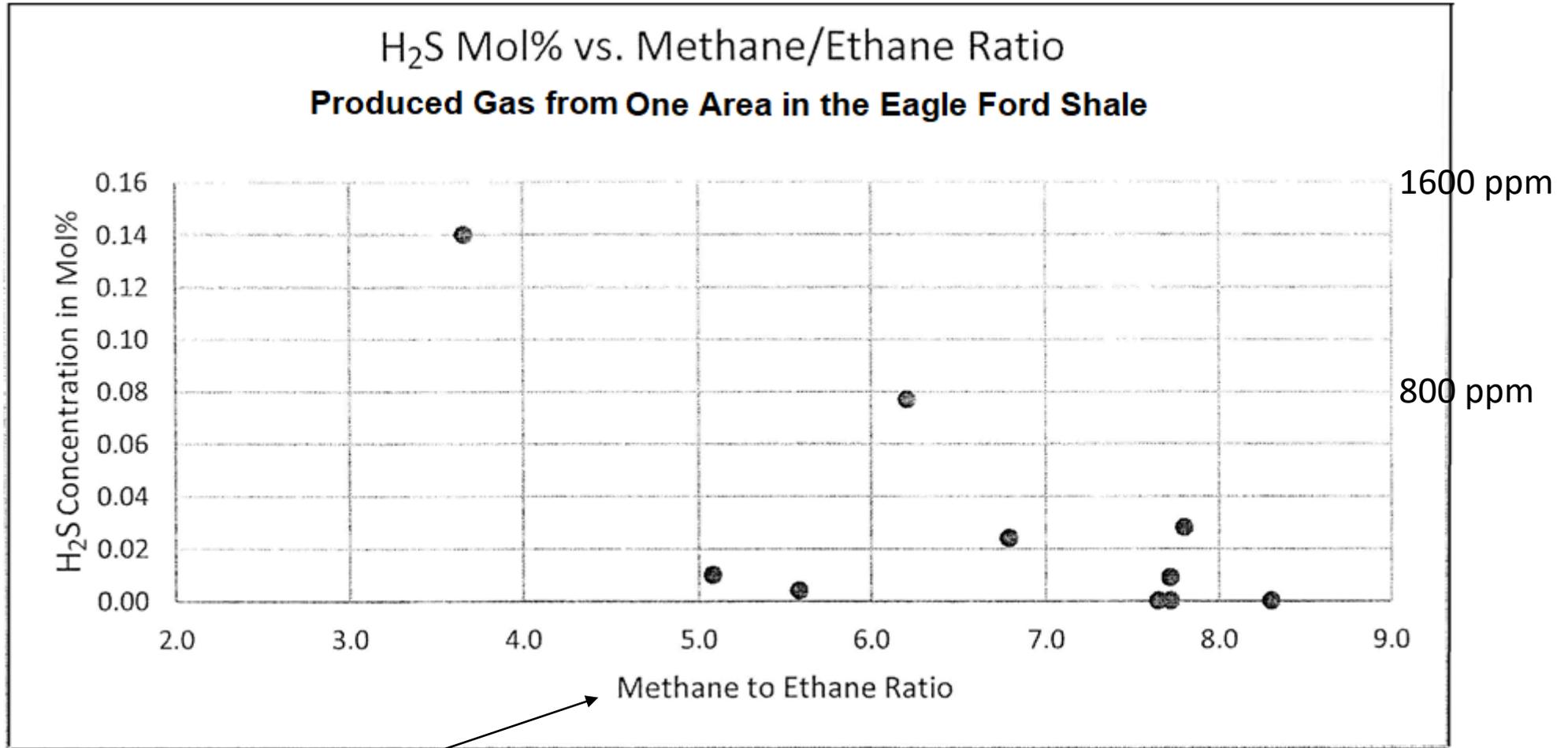
2

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If the Faults/Fractures are Transmissive

- Wouldn't They Disseminate the Microbial By-product H_2S and Allow the Uninhibited Microbes to Sour the Oil and Gas?
- Wouldn't They Create a Long-term Pathway Leading to Significant Water Production?
- Might they also Affect the Viscosity of the Oil?
- We Now Have Evidence of all the Above

Sour Oil in the (Sweet Oil) Shales



Remember the CH₄ Carbon Contributor?

Wrapping Things up (1)

Summary of New Realizations

1. Residual Oil Zones are Quite Common in the Oil Basins Around the World and Can Often Hold Significant Oil Resources
2. When Oil Properties are Right, ROZs Can Be Commercially Exploited by EOR – Being Demonstrated in the PB Today
3. When Oil Properties are Right, ROZs Can Be Commercially Exploited by Reservoir Depressuring - Being Recognized & Demonstrated in the PB Today
4. Natural, Intrinsic Anaerobic Microbes are present in the Subsurface and Can do Lots of Work on Rocks and Oils if Uninhibited

Wrapping Things up (2)

Summary of New Realizations

5. The Microbes can Sour the Oil and Gas
6. The Microbes can Alter Wettability Biasing the Reservoir to be More Oil-Wet
7. Vertical Transmissive Fractures (VTFs) are More Common than Most People Thought in the Days of Vertical Wells
8. VTFs can Create Sour Oil and Gas when They Create a Flow-field – they can Also Create Low Oil-cut Wells
9. Uranium is a Key Indicator of Basement Connected Faulting

Takeways from this Talk?

I Hope you can Feel **the Excitement** over the “New Day” in Oil and Gas?

The Horizontal Well Revolution is a Huge Deal but Really Just a Part of **the New Excitement**

Steve Melzer

Melzer CO₂ Consulting

Midland, Texas

Thanks out to the “ROZ Team”
“Dr. Bob” (Robert Trentham) &
David Vance our ‘Bug Man’

For More Information See: www.CO2Conference.net

www.ResidualOilZones.com

Melzer CO₂ Consulting

Key References

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- 2 ROZ Science, Activity Updates on Horizontal Depressuring the San Andres Formation and ROZ EOR, a Seminar at the 2017 CO₂ and ROZ Conference, Dec 2017, Melzer L.S. (editor and contributor), Midland Tx, www.CO2Conference.net
- 3 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)
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- 6 “Origins, Processes and Exploitation of Residual Oil Zones,” (Director and Contributor), Seminar conducted at the 2015 CO₂ Conference, Dec 9, 2015 (www.CO2Cpnference.net)
- 7 “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.
- 8 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>



The Upcoming CCUS, CO₂ Conference

Dec 9-13, 2019 Midland, Texas

- Monday – EOR Carbon Management Workshop
- Tuesday – Field Trip to Kinder Morgan’s SACROC Project (the Oldest {and best?}) CO₂ Flood in the World)
- Wednesday – Full-Day Short Course on the Science, Attributes, and Case Histories of Vertical Transmissive Fractures
- Thursday AM & PM and Friday AM Sessions – Cyclic Injection (IOR) Projects, New Surface Plant Designs and U.S. and International CO₂ EOR Case Histories

To see Agenda Details or Register go to www.CO2Conference.net

Thank you

Time for Questions?

Supplemental Slides

(Not Presented)

Wrapping Things up (3)

Does Any of this Relate to CCUS?

- CO₂ EOR's Storing of Large Quantities of CO₂ Now Widely Known and Better Understood (and is actually occurring)
- ROZs can Offer Large Sinks for CCUS
- Now that we Understand Uranium can play a Role in the Detection of Natural, Transmissive Fractures, More Work Needs to be Done in Some Sites to Assure Long Term Containment – especially in CCS

Conceptual View of Deep Seated (Crustal Basement) Faulting, Extending Upwards into the San Andres, Terminating at the Permian Guadalupian and Ochoan Evaporites Which Act as a Series of Optimal Vertical Seals

