

CO₂ EOR, CCUS and the Horizontal Revolution in the Permian Basin

A Presentation to the

2018 CCUS STUDENT WEEK



Colorado School of Mines
October 18, 2018

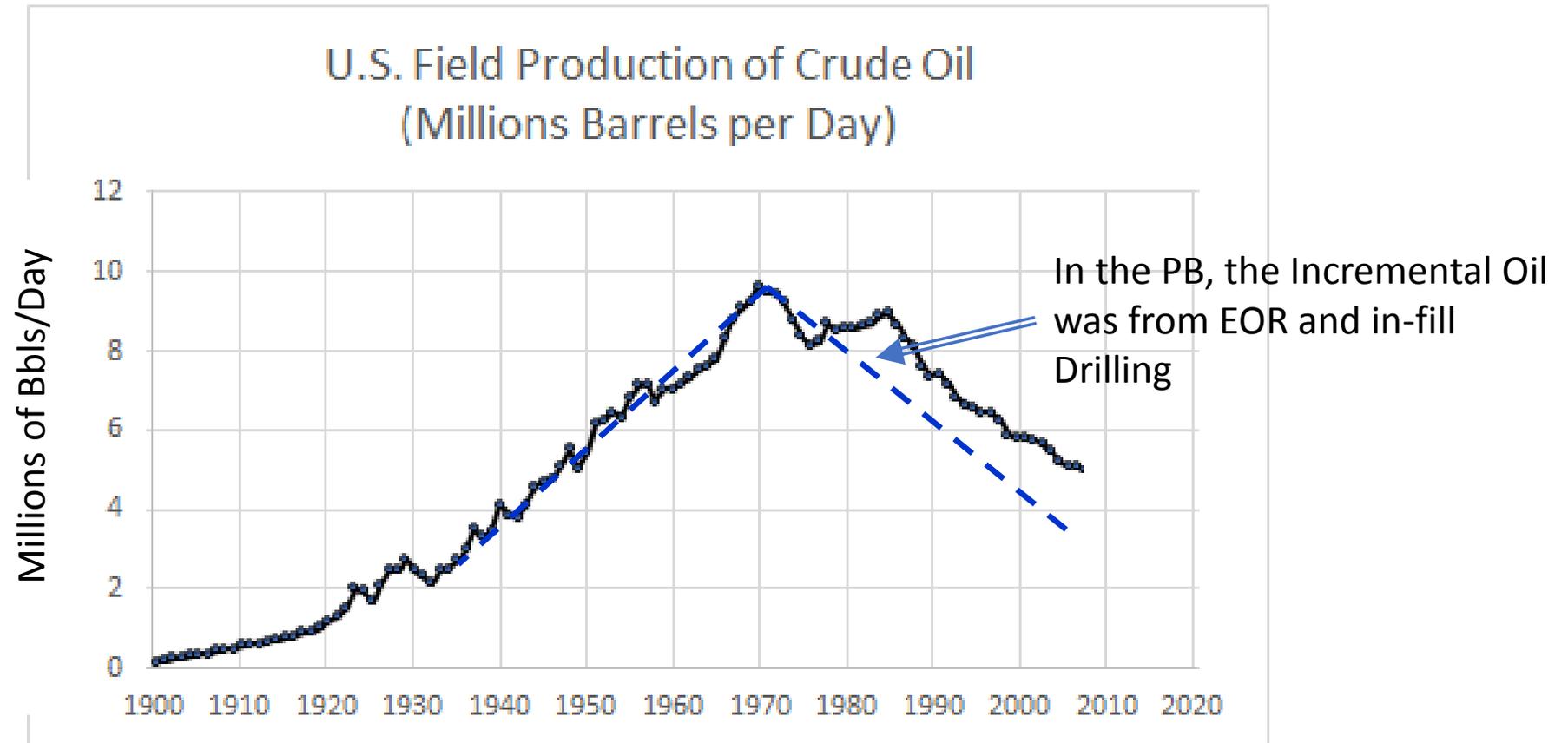
CO₂ EOR, CCUS and the Horizontal Revolution in the Permian Basin

1. Why all the New Excitement?
2. It's All About Horizontal Shale Revolution..... But Wait.... "Not So Much"
3. Overview of PB Progress
4. From the Field: Some Fascinating New Realizations/Case Histories
5. Setting the Stage for CCUS
6. Closing

What is all the Buzz About in the PB?

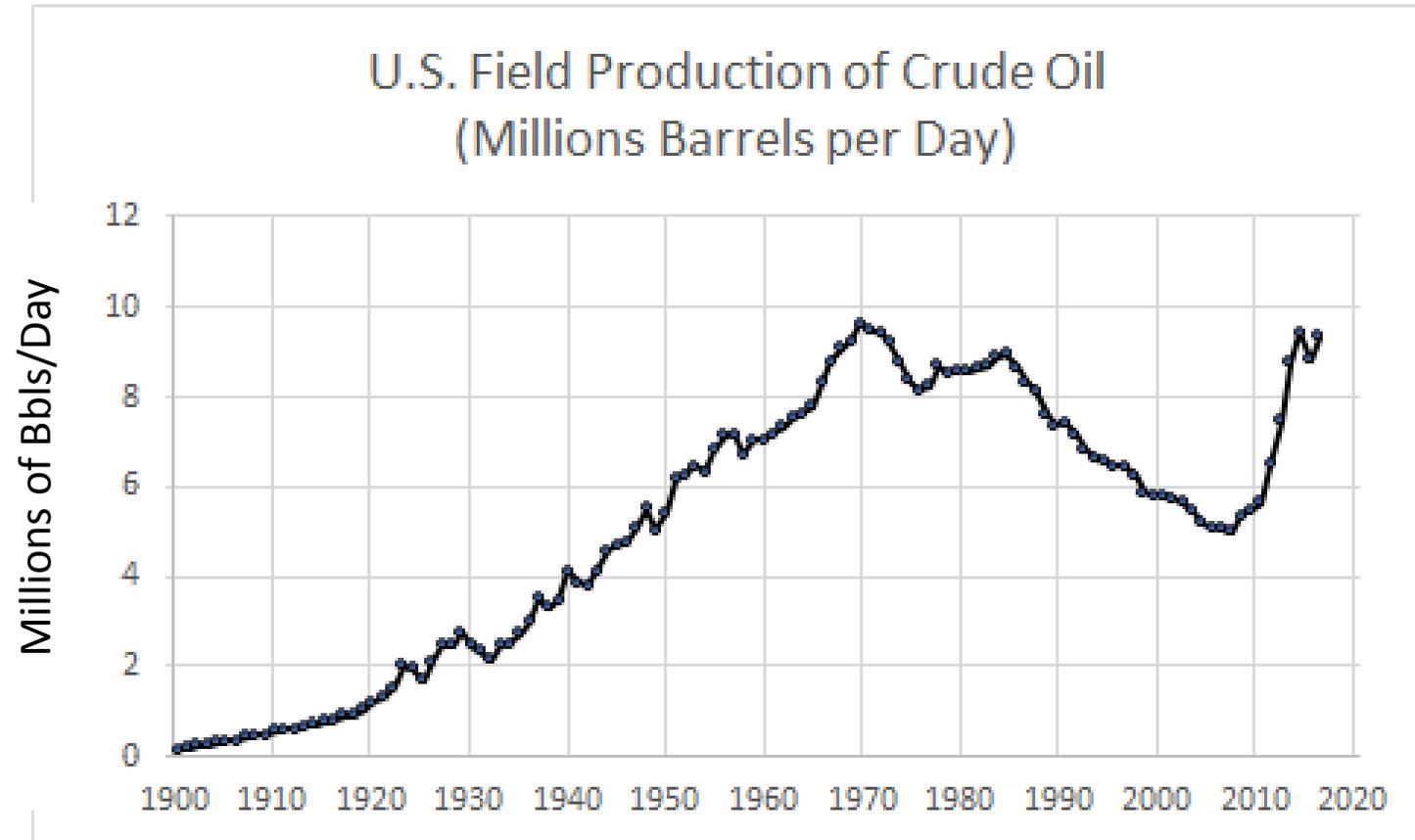
For Maturing Basins...

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=mcrfpus1&f=a>

Why We are Feeling the Excitement

- Producing Unconventional Reservoirs
- Producing Unconventional Oil (More on this Later)
- The Explosion of Innovative Tools for Horizontal Completions
- Better Drilling Rigs and Bits for Faster Drilling

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 Look at the New Developments

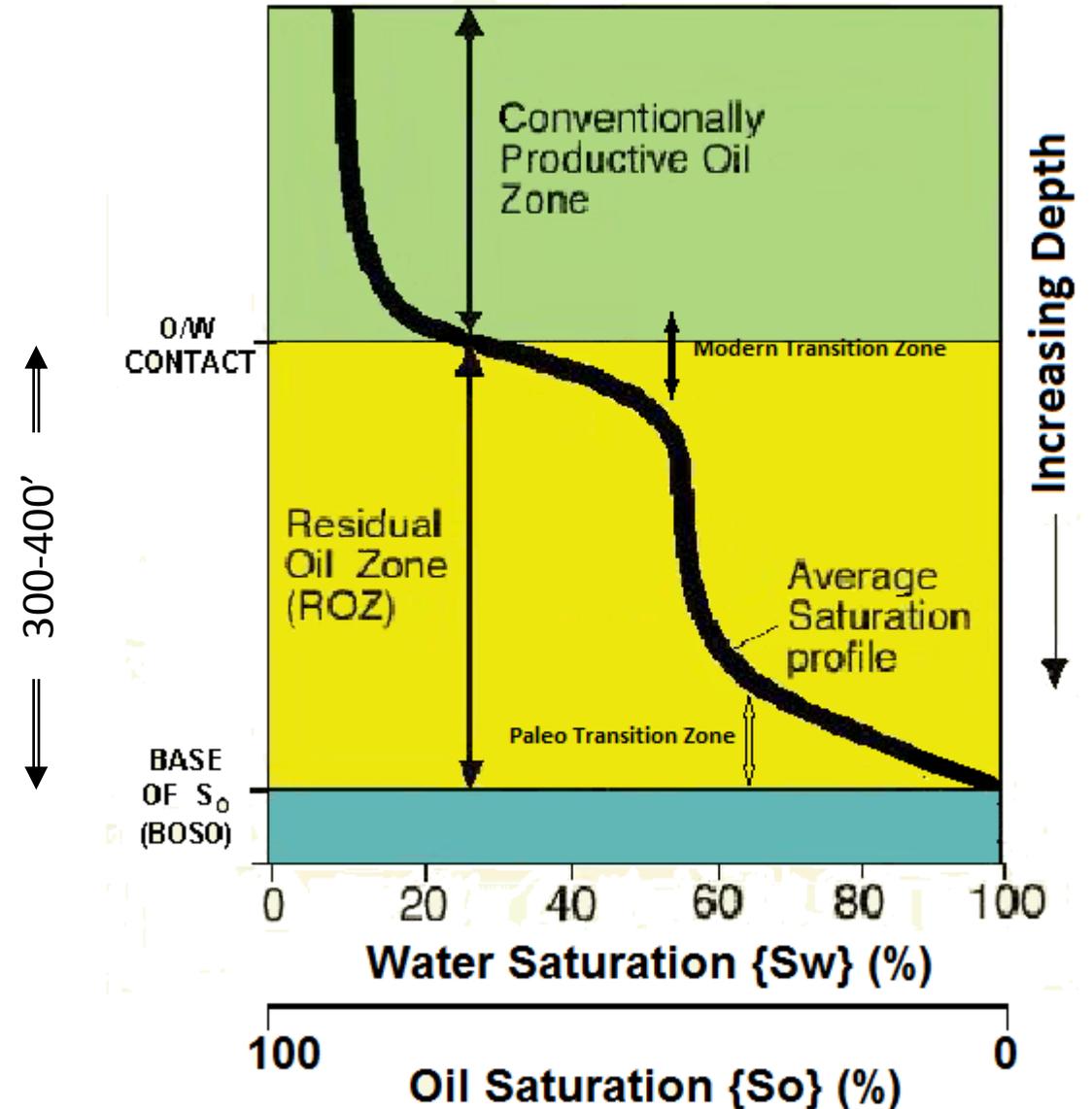
(but We'll Leave the Shale Excitement i.e.,
Unconventional Reservoirs) to Others and
Concentrate on Conventional Reservoirs
with Unconventional* Oil)

* Also Known as Residual Oil

New Discovery (Realization) #1

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

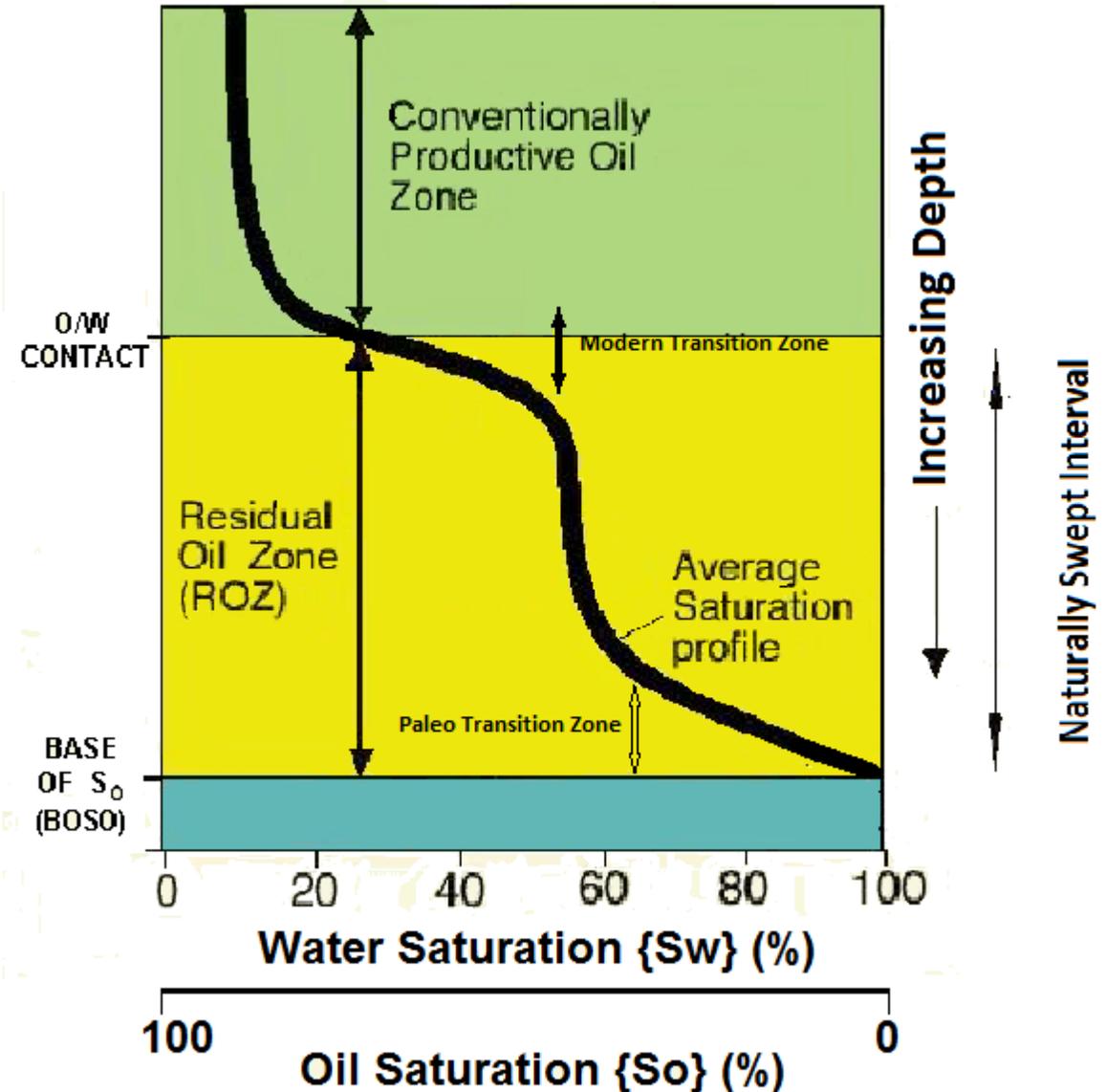
Residual Oil Zones and Upper and Lower Transition



New Discovery (Realization) #1

- Before 2000, the Bottom of a Reservoir had to be a Transition Zone
- 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

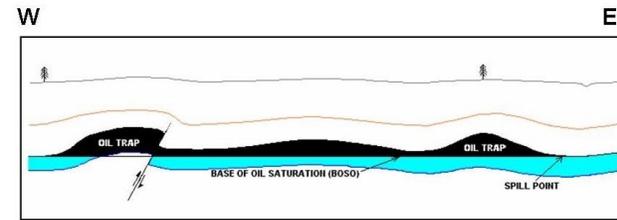
All Three of the Concepts below can be Thought of as Moving Oil and Water around in Conventional Oil Entrapment (Trap) in a Later Stage Tectonic Event after the Initial Oil Entrapment

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)

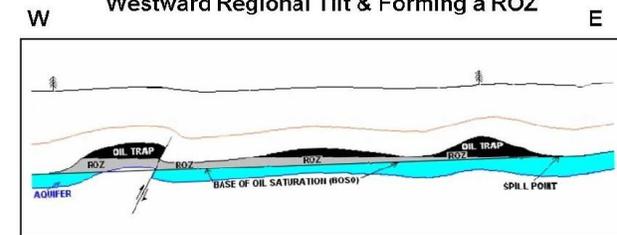
A Graphical Look at ROZ Creation Mechanics

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



RESIDUAL OIL ZONE: TYPE 1

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

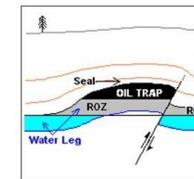
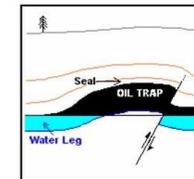


RESIDUAL OIL ZONES: TYPE 2

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

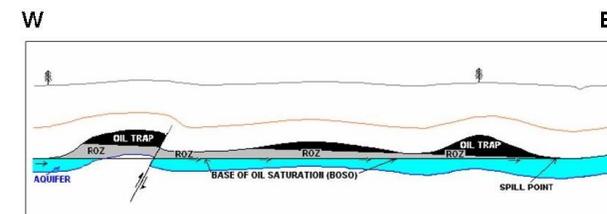
ORIGINAL

POST BREACH



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



Uplift in the West

Type 1:
Basinwide Tilt

Type 2:
Breached Seal

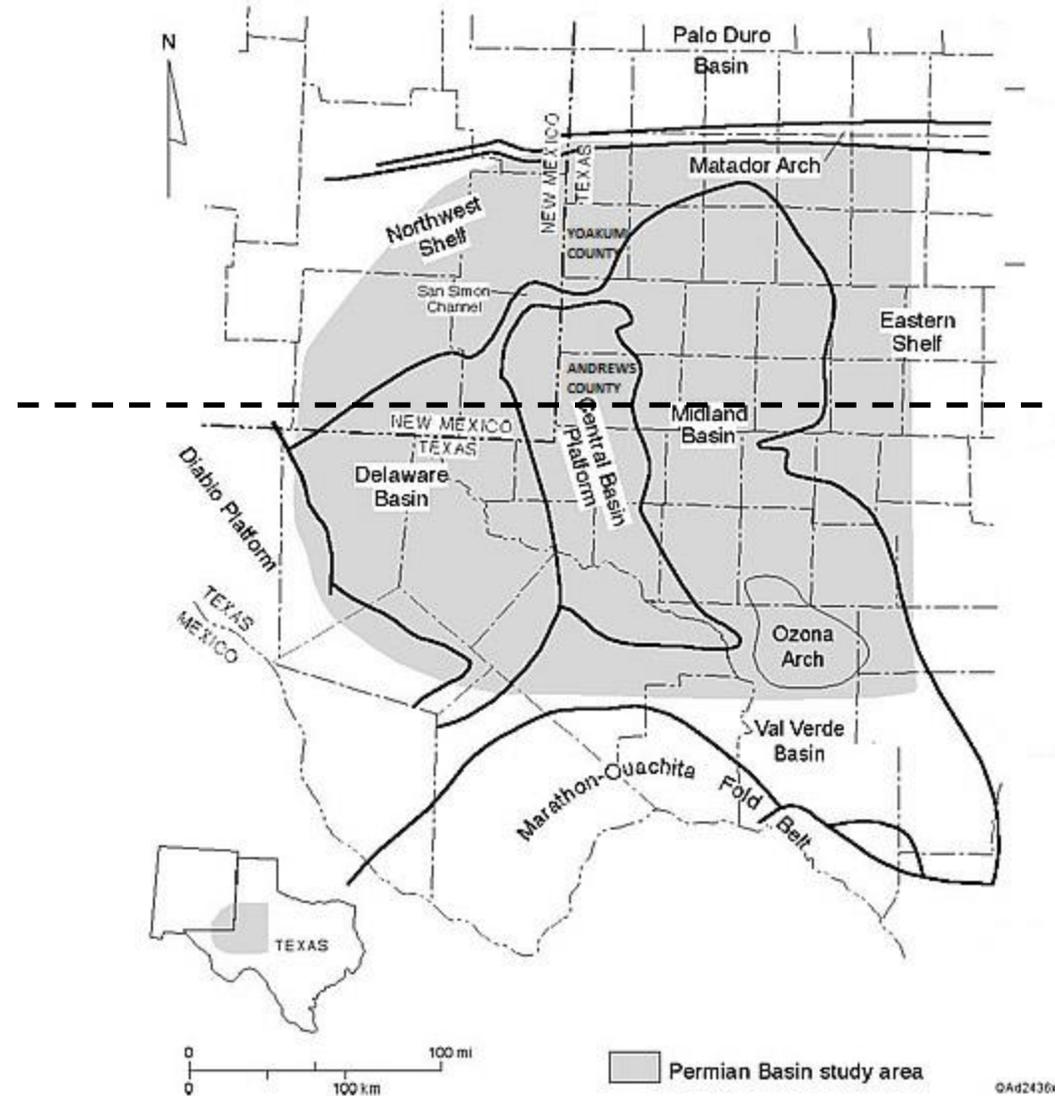
Type 3: Laterally Swept

How Common are ROZs?

We Are Still Looking for the Oil Basin Without ROZs

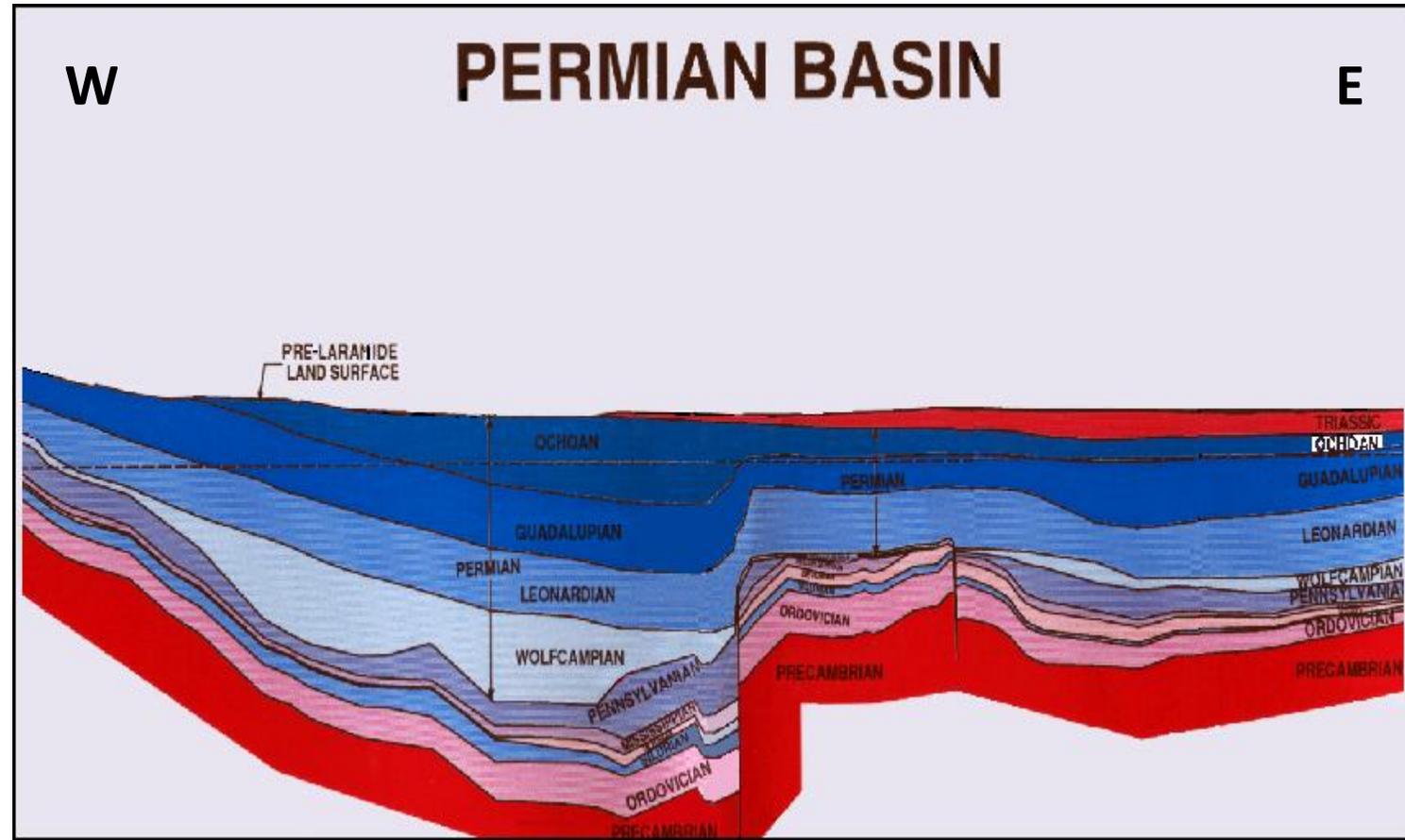
- It is Not the Permian Basin
- It is Not the Gulf Coast
- It is Not the Williston
- Nor the Bighorn
- Not the North Sea
- Nor the Cooper-Eromanga
- Not the Baltic
- Nor the Arabian
- And so on.....and on

The Permian Basin San Andres Formation Case History



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

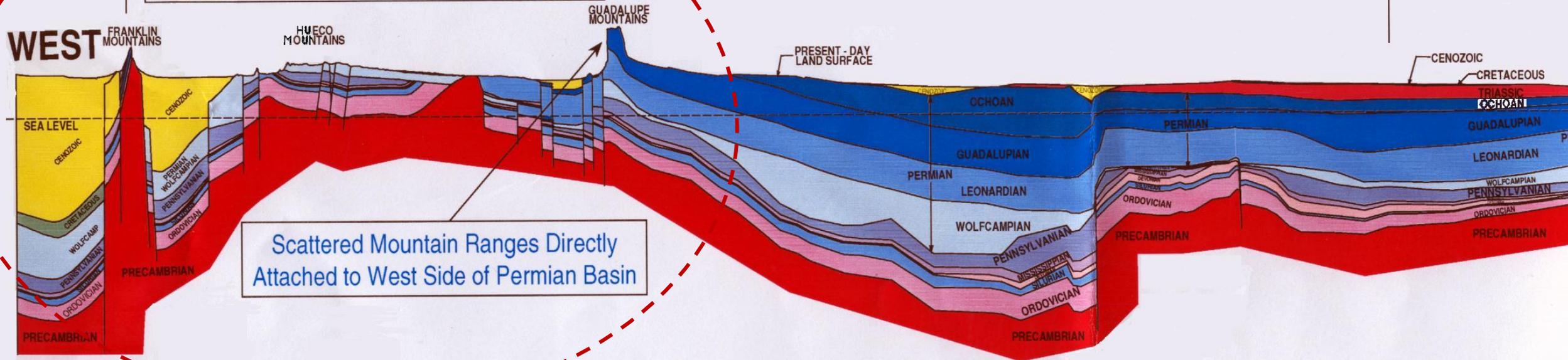
Phase III Slow Extension, Pliocene - Recent
Phase II Rapid Extension, Middle - Late Miocene

PERMIAN BASIN

RIO GRANDE RIFT

Formation of Basin & Range Province
Horsts & Grabens
Drastically Reduced Meteoric Recharge Area

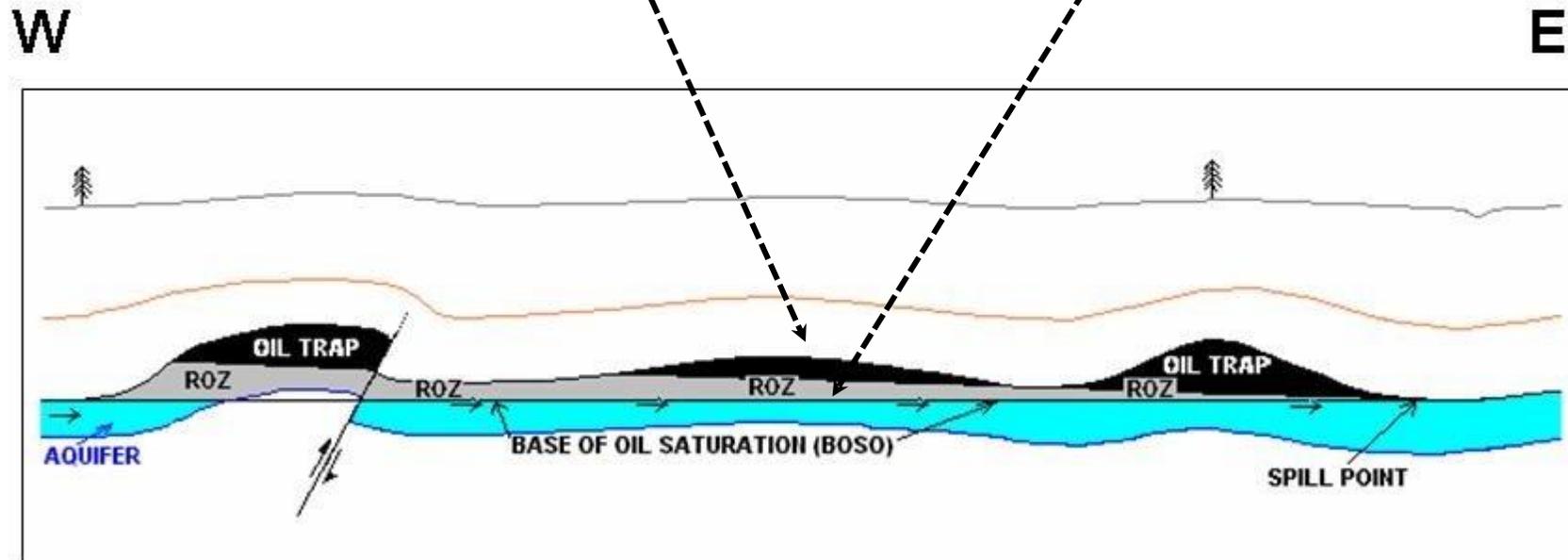
Displaced Oil Columns Resaturate with Oil, Some with Gas,
& Some Stay at Residual Oil Saturation to Water (S_{orw})



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 to the Sweep 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*

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



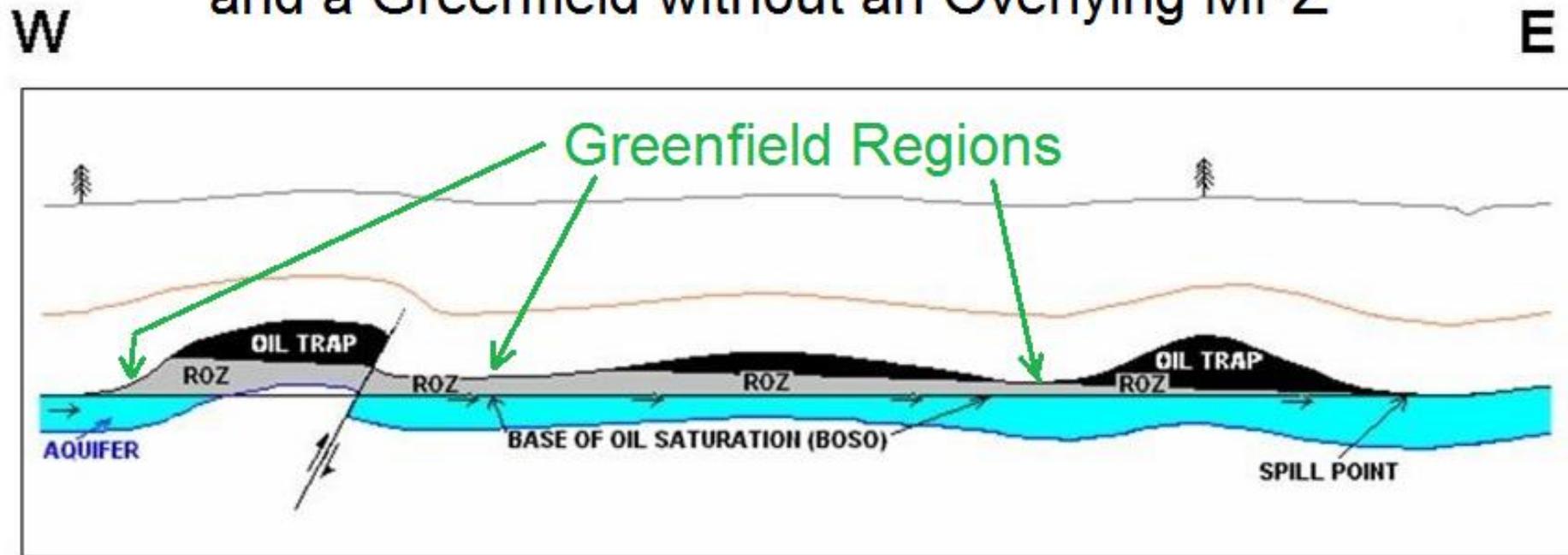
* To Exploit the oil, Wells can be Deepened

Melzer Consulting

If All the Mobile Oil is Swept Out,
We Call it a “**Greenfield**” ROZ Since New Wells Need to be Drilled

Type 3 Residual Oil Zones

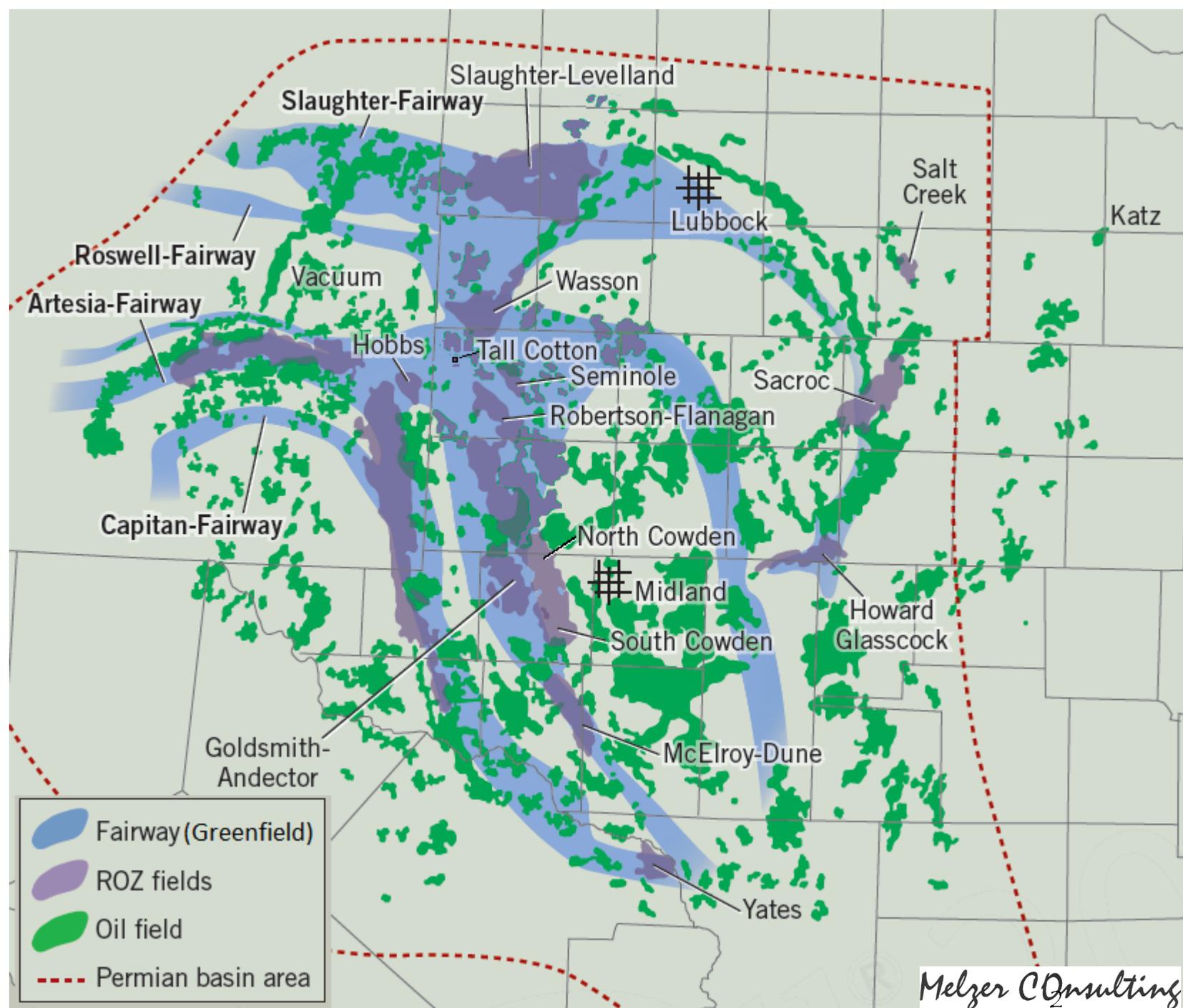
Lateral Sweep with ROZs formed beneath a Field
and a Greenfield without an Overlying MPZ



Direction of Sweep →

Melzer Consulting

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



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

So How Do You Exploit the Residual Oil?

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

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

So How Do You Exploit the Residual Oil?

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

CO₂ EOR

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

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

**Depressuring
the Upper
ROZ (DUROZ)**

New Technology (Realization) #2

- Brownfield ROZs are Being Exploited via CO₂ EOR
 - There are 17 CO₂ EOR Projects Deepened into the ROZ at last count
 - All are Within the Permian Basin
 - All but one are San Andres Formation Carbonates
- A Greenfield ROZ CO₂ EOR Project has been Implemented
- We Estimate that over 20,000 bopd are Coming from the ROZ EOR Projects and ROZ Production is Growing Rapidly now

Now Let's Talk about Depressuring the Upper ROZ (DUROZ)

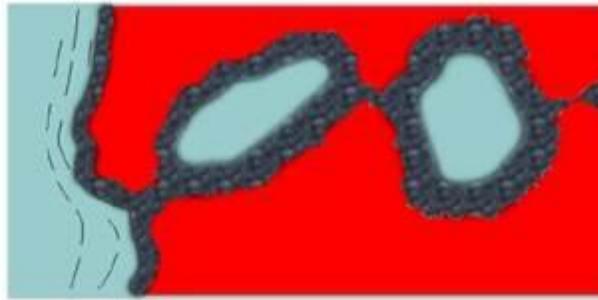
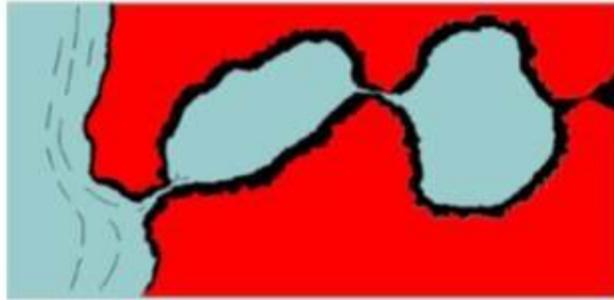
New Concept ('Discovery') #3

- One Needs to Recognize that not all Residual Oil is Dead Oil
- If the Pore Volume Sweep is Minor, the ROZ Oil can have Considerable Solution Gas
- Over 200 Laterals are Currently Exploiting the Upper (lightly swept) San Andres ROZ Oil (DUROZ) – Started in 2012
- Those Wells Need only a Light Stimulation
- DUROZ Wells are Spread out over 6 Counties in the ROZ Fairways and are Making Over 40,000 bopd now and have Accumulated Almost 30 Million BO to Date
- There is Some Good Evidence that Other Formations also have ROZs and are Already Being Exploited via Horizontal Wells

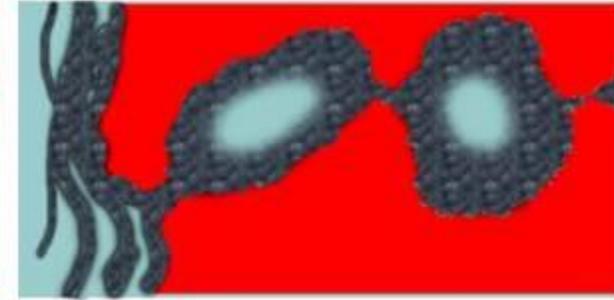
The DUROZ Production Process

How Does ROZ Depressuring Work?

The ROZs have Oil Affixed to the Rock Surfaces and, if that Oil Has Gas in it, Depressuring Releases Some of the Oil and Entrained Gas



Bubbles swell.



Oil Seeps out of the pores. ...

...and into the flowstream to flow to the well. Lots of water is produced to accomplish the depressuring

New Concept (Discovery) #4

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

To Explain Why, We Need to Understand Biogeochemistry

Do you Know How Microbes Live and Work?

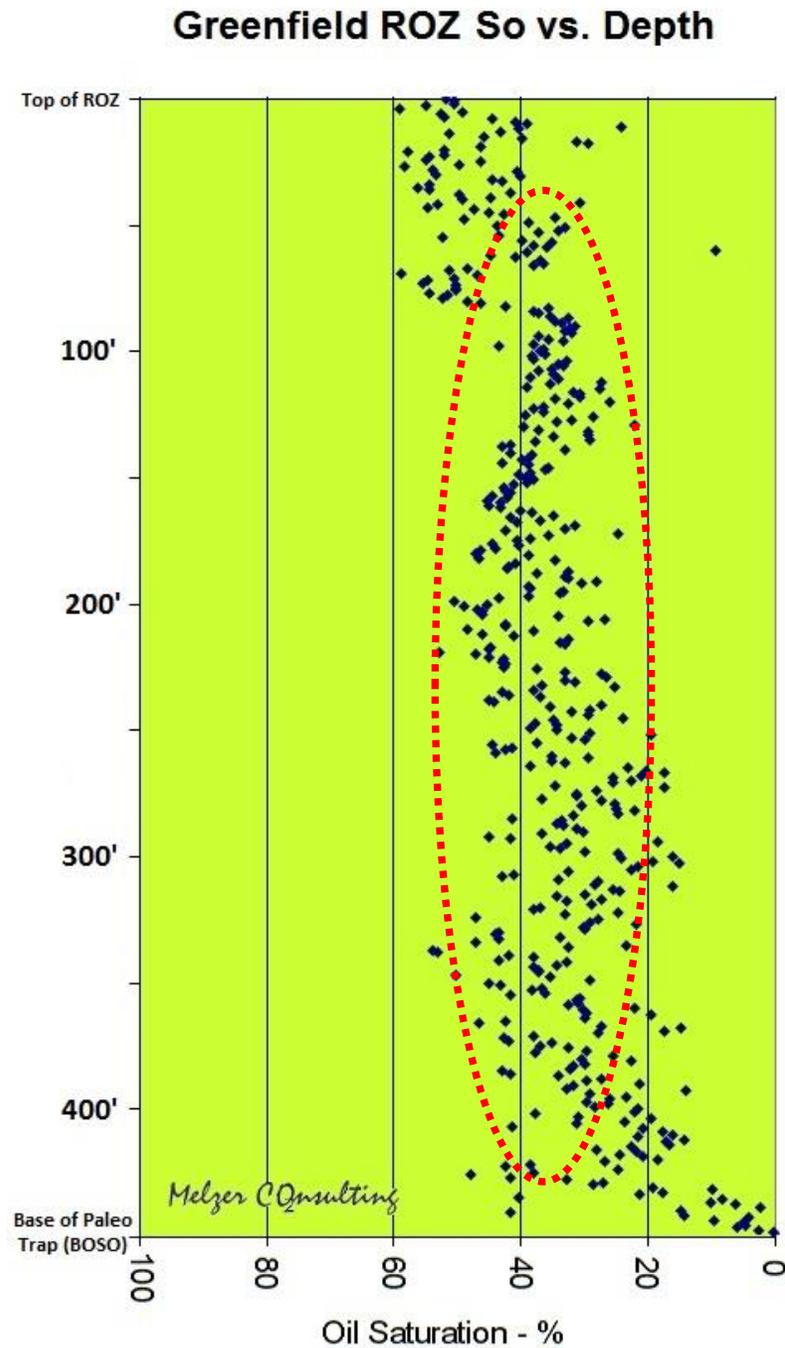
The Simple Explanation is that they "Broker" electron exchanges between Molecules

An Observation and then a Common Example Will Help Explain

Hmmm?
How Does this
Happen?

Data From
Near Tall
Cotton

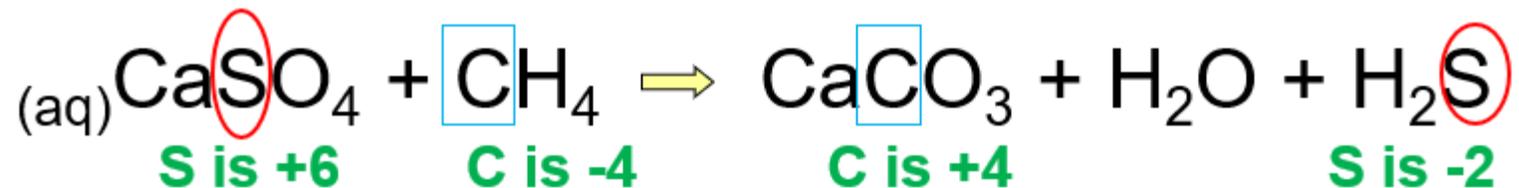
The
Greenfield
CO₂ EOR
Project



Type 3 ROZ - 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



- **Microbes remove 8 Electrons from the Carbon and transfer them to the Sulfur**
- **H₂S is Often Oxidized Back to Elemental Sulfur S⁰**
- **Dolomitization Typically Follows as Well**
$$\text{CaCO}_3 + \text{Mg} \longrightarrow \text{MgCa}(\text{CO}_3)_2$$

Souring the Oil and Gas

When Collecting In a Static Place (like an Attic) - Free Sulfur Deposits

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

Wrapping Things up

How Does All of this Relate to CCUS?

- Storing Large Quantities of CO₂ During CO₂ EOR is Now Widely Known and Better Understood
- Commerciality of CO₂ EOR with Concurrent Storage is On-going but Commercially Challenged on its Own Due to Long Payout Times and Competition for Funding from Higher Rate of Return Projects like the Shale Horizontals

.....But, Things are Changing.....

- Tax Credits for CCUS in the U.S. are now Available (45Q)
- Huge Reservoir Targets for CO₂ Storage in ROZs are Now Recognized
- The Depressured ROZs Provide Huge Pressure Sinks and Reservoir Targets for CO₂ Injection

Takeways from this Talk?

I hope you are Feeling the
Excitement over the “New Day” in
Oil and Gas?

Steve Melzer

Melzer CO₂ Consulting

Midland, Texas

For More Information See: www.CO2Conference.net

www.ResidualOilZones.com

Melzer CO₂ Consulting

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 CO₂ 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 CO₂ Conference, Dec 9, 2015 (www.CO2Cpnference.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>

The Upcoming CCUS, CO₂ EOR & ROZ Conference

Dec 3-6, 2018 Midland, Texas

- Monday – EOR Carbon Management Workshop
- Tuesday – A Close Look at the New 45Q (CO₂ Storage Tax Credit) Legislation
- Wednesday AM – Field Trip to Kinder Morgan’s Tall Cotton Greenfield ROZ CO₂ EOR Project (a ‘One-of-a-Kind’ Project for the World)
- Wednesday PM Session – Status of Horizontal Well Depressuring of the Upper ROZ and Well Completion Advances
- Thursday Sessions – A Day full of U.S. and International CO₂ EOR Case Histories

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

Thank you

Time for Questions?