

The CO<sub>2</sub> Study Group Presents:

**Projects 08123-19 & 10123-17  
Permian Basin CO<sub>2</sub> Projects  
– The Future from the Past**

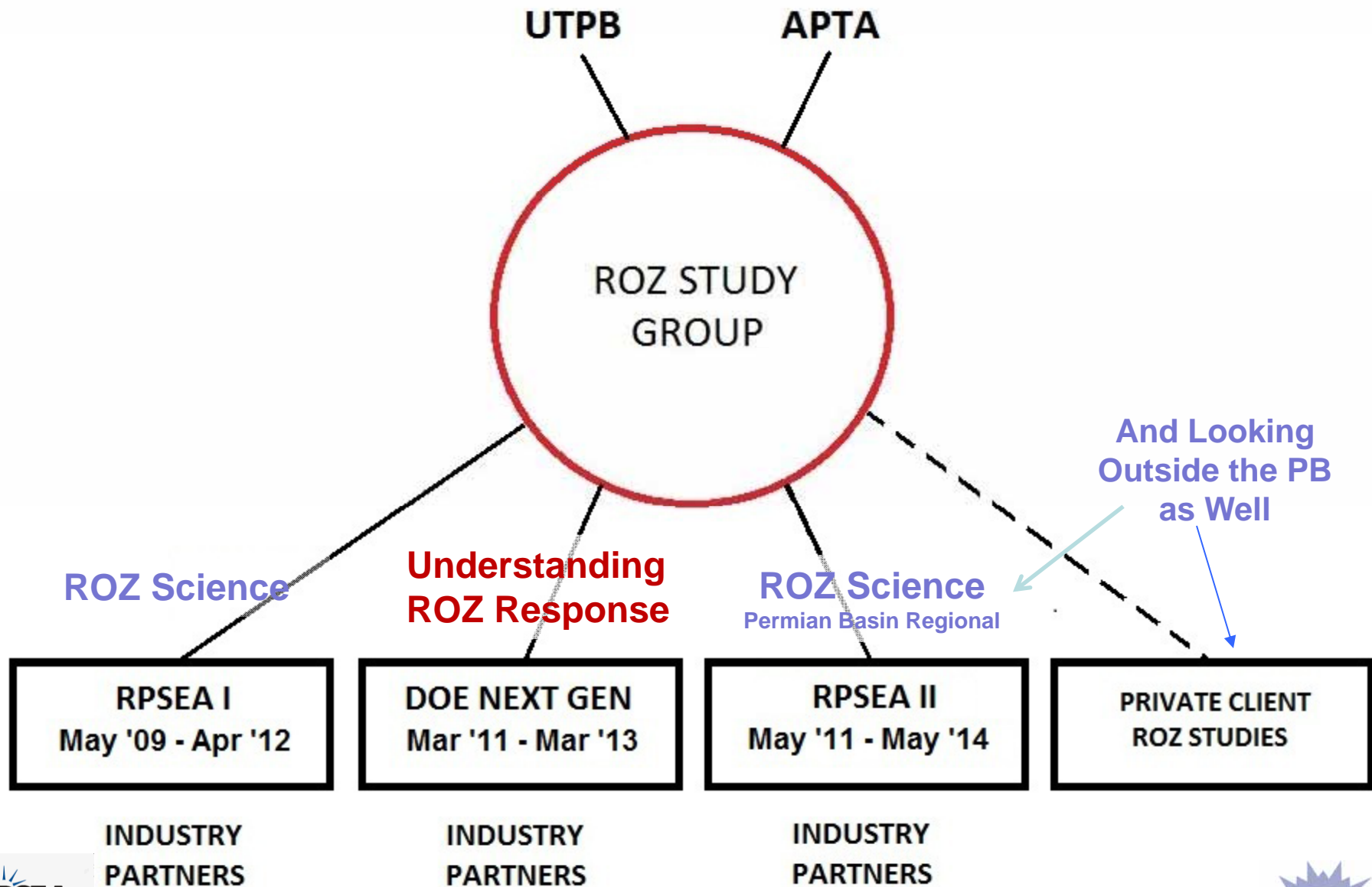
Bob Trentham, CEED, UTPB

*RPSEA Onshore Production  
Conference: Technological Keys to  
Unlocking Additional Reserves*

*Lawrence, KS*

*November 8, 2011*





## UTPB – APTA Projects

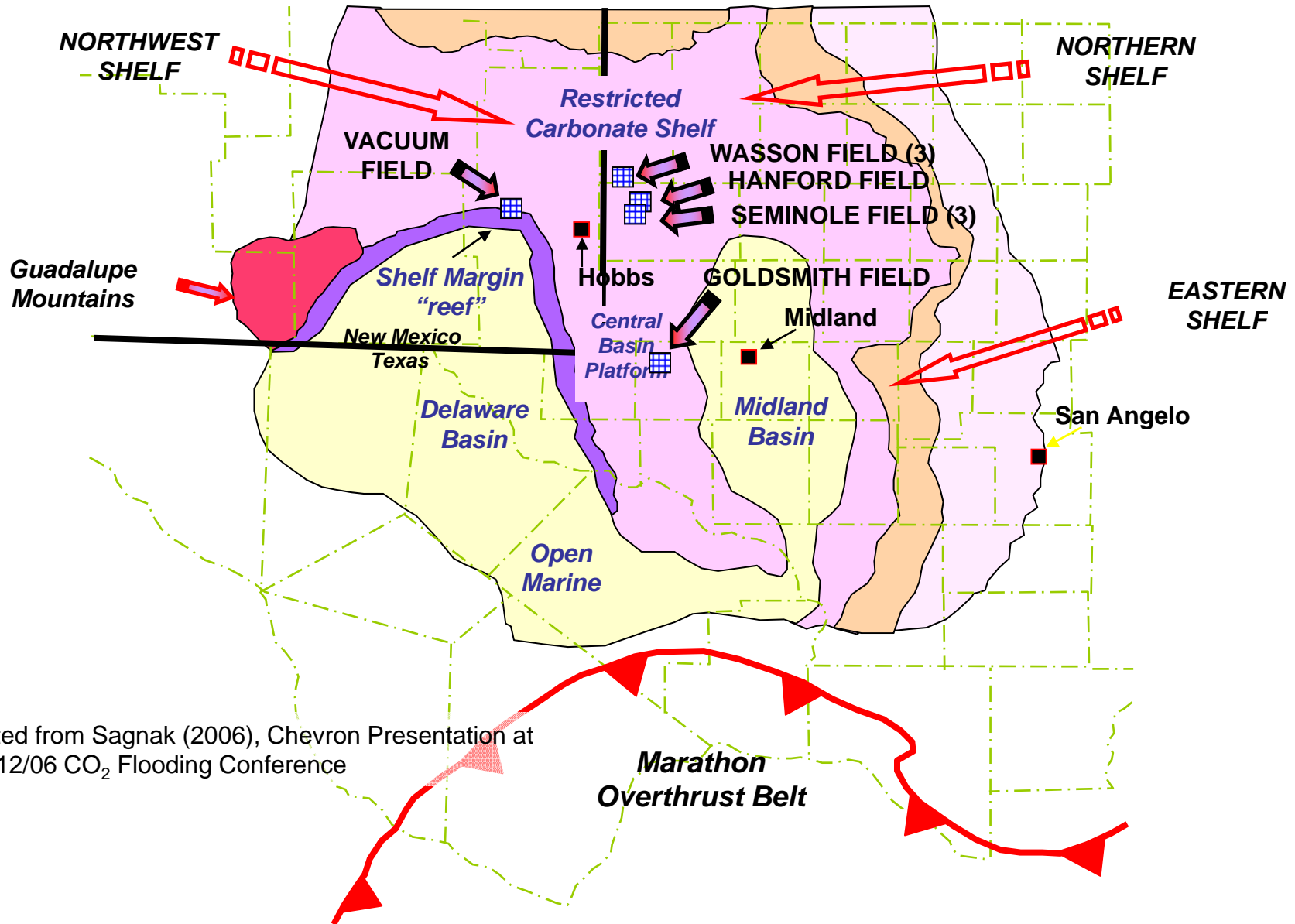
- DOE\_Research Partnership to Secure Energy (RPSEA): Improved Oil Recovery for Small Producers, **“Commercial Exploitation and the Origin of Residual Oil Zones: Developing a Case History in the Permian Basin of New Mexico and West Texas”**. Co-PI’s: Robert C. Trentham, Steve Melzer, **2 1/2 years, \$ 631,001, Plus \$110,000 from industry partners**, End date March 9, 2012
- DOE: Recovery Act: Regional Sequestration Technology Training, **“Carbon Capture and Storage in the Permian Basin, A Regional Technology Transfer and Training Program.”** Co PI’s: PTTC, AAPG, APTA, **Total Funding Requested: \$ 994,998, UTPB/CEED as Subcontractor: \$84,270, July 22, 2009.**
- DOE Recovery Act: **“A Modular Curriculum for Training University Students in Industry Standard CO2 Sequestration and Enhanced Oil Recovery Methodologies”**, Co-PI’s: Dr Emily Stoudt, Dr Robert Trentham, **DOE \$ 296,000, Start Date Aug 11, 2009.**
- National Energy Technology Lab (NETL): **“Using Next Generation CO2 EOR Technologies to Optimize the Residual Oil Zone CO2 Flood at Goldsmith Landreth Unit, Ector County, Texas”**, PI: Robert Trentham, Start 2/23/2011-9/30/2013. NETL \$1,198,547.00 Industry Match \$654,563.00
- RPSEA: **“Identifying and Developing Technologies for Enabling Small Producers to Pursue the Residual Oil Zones (ROZ) Fairways in the Permian Basin, San Andres”** Co-PI’s Robert C. Trentham, Steve Melzer, Start 5/01/2011, end 11/01/2013, \$1,243, 369.98, RPSEA Share, \$859,269.98 Industry Match: \$374,100.00

# **The World of Residual Oil Zones**

Focus Today: San Andres ROZs  
in the Permian Basin

# MIDDLE SAN ANDRES PALEOGEOGRAPHY

with Location of Industry Documented ROZ Zones/Fields\*



\* Adapted from Sagnak (2006), Chevron Presentation at the 12/06 CO<sub>2</sub> Flooding Conference

# The List of On-going ROZ Projects

Type and operator	Field	State	County	Top MPZ Depth, ft	Pay zone
<b>Active CO<sub>2</sub> miscible</b>					
Chevron	Vacuum San Andres Grayburg Unit	NM	Lea Co.	4,550	San Andres/Grayburg
Fasken	Hanford	Tex.	Gaines	5,500	San Andres
Hess	Seminole Unit-ROZ Phase 1	Tex.	Gaines	5,500	San Andres
Hess	Seminole Unit-ROZ Phase 2	Tex.	Gaines	5,500	San Andres
Hess	Seminole Unit-ROZ Stage 1 Full Field Dev	Tex.	Gaines	5,500	San Andres
Legado	Goldsmith-Landreth Unit	Tex.	Ector	4,200	San Andres
Occidental	Wasson Bennett Ranch Unit	Tex.	Yoakum	5,250	San Andres
Occidental	Wasson Denver Unit	Tex.	Yoakum	5,200	San Andres
Occidental	Wasson ODC	Tex.	& Gaines	5,200	San Andres

Announced Additions:

Rumored Additions:

Exxon at Means (2011)

Conoco at East Vacuum (2011)

Chevron at Central Vacuum (2012)

XTO at CA Goldsmith (2013?)

Tabula Rasa at E. Seminole and Lindoss (2013)

# Where we are today

- ROZ's appear to be common in Leonardian and Guadalupian carbonates on the Central Basin Platform and Northwest Shelf.
- Exploitation of thick ROZ's associated with many of the major San Andres fields has begun with CO2 projects underway at Wasson, Seminole, Vacuum, Means, Goldsmith, and Hanford Fields, with others planned.
- Production from ROZ's and anecdotal evidence from exploration wells, coupled with the theory/model of the development of Residual Oil Zones (ROZ's), has led to the belief that there are potentially billions of barrels of additional producible tertiary reserves in the Permian Basin and elsewhere.

# *Calibrating the Oil Recovery Models and Estimating Technically*

## *Recoverable ROZ Oil – MPZ and TZ/ROZ Oil in Place*

56 fields in five major Permian Basin oil plays that have potential for significant TZ/ROZ resources were identified by ARI.

**TZ/ROZ OOIP in these 56 fields is estimated to be 30.7 Billion Barrels.**

Field/Unit	MPZ OOIP (BB)	TZ/ROZ OOIP (BB)	No. of Fields	No. of MPZ Fields with CO <sub>2</sub> -EOR Projects	No. of Fields with TZ/ROZ CO <sub>2</sub> -EOR Projects
1. Northern Shelf Permian Basin (San Andres)	13.0	13.2	13	5	1
2. North Central Basin Platform (San Andres/Grayburg)	2.9	2.6	6	2	1
3. South Central Basin Platform (San Andres/Grayburg)	9.9	7.9	16	5	0
4. Horseshoe Atoll (Canyon)	5.4	2.9	10	4	2
5. East New Mexico (San Andres)	2.3	4.1	11	2	0
<b>Total</b>	<b>33.5</b>	<b>30.7</b>	<b>56</b>	<b>18</b>	<b>4</b>

# ***Technically Recoverable Resources from the MPZ and ROZ***

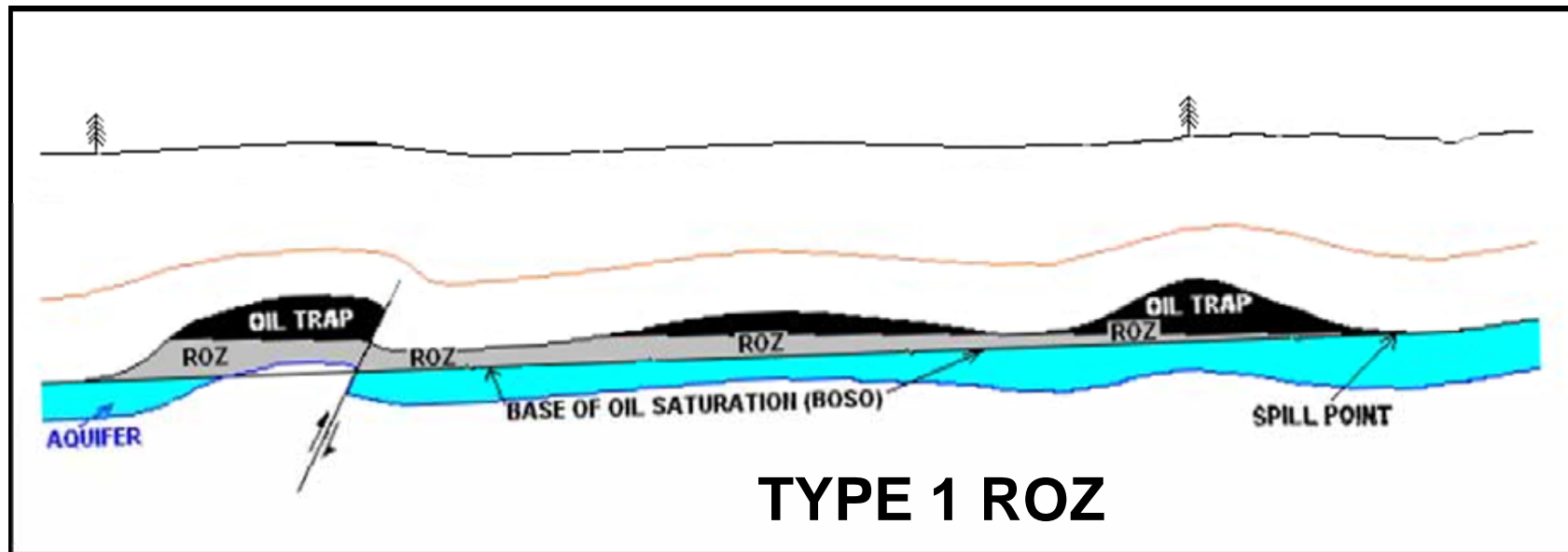
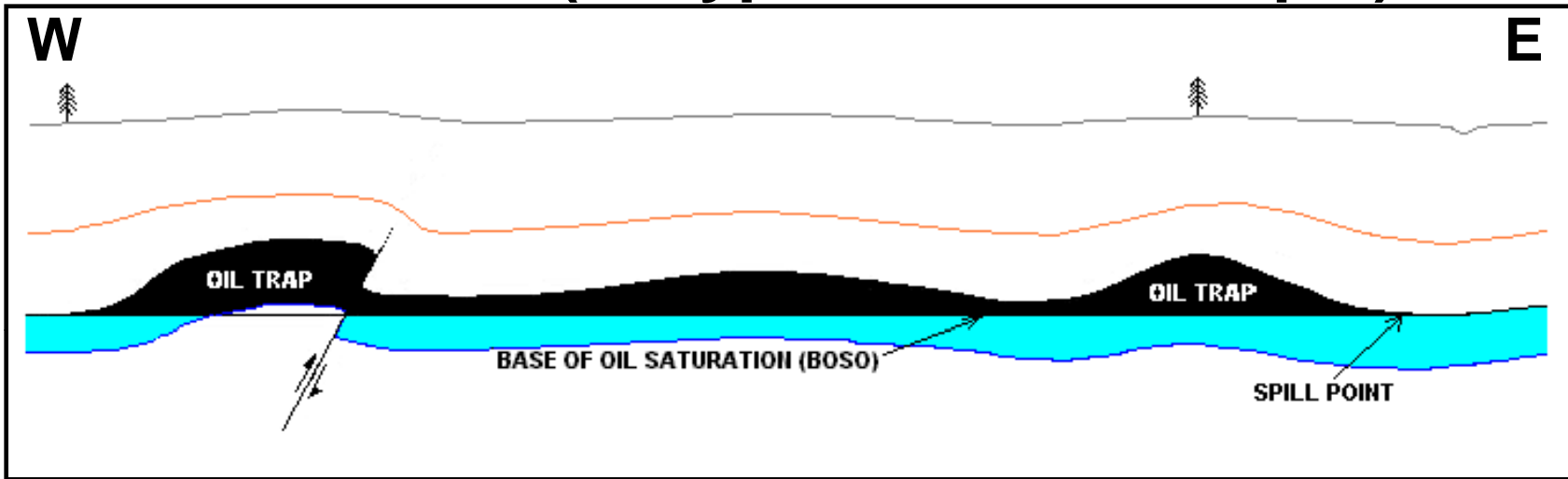
Based on reservoir modeling of applying CO<sub>2</sub>-EOR to the TZ/ROZ resources, ARI estimates that

**11.9 Billion BO is technically recoverable from the 30.7 Billion BO of TZ/ROZ oil in-place** in these five Permian Basin oil plays

Field/Unit	Total CO <sub>2</sub> -EOR (BB)	MPZ CO <sub>2</sub> -EOR (BB)	TZ/ROZ CO <sub>2</sub> -EOR (BB)
1. Northern Shelf Permian Basin (San Andres)	8.3	2.8	5.5
2. North Central Basin Platform (San Andres/Grayburg)	1.5	0.6	0.9
3. South Central Basin Platform (San Andres/Grayburg)	4.6	1.7	2.9
4. Horseshoe Atoll (Canyon)	2.7	1.4	1.3
5. East New Mexico (San Andres)	1.7	0.4	1.3
<b>Total</b>	18.8	6.9	<b>11.9</b>

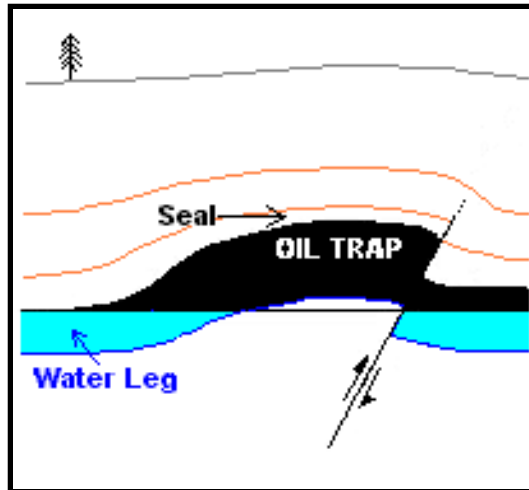
# **The Science of Residual Oil Zones**

# Original Oil Accumulation Under Static Aquifer Conditions (A Hypothetical Example)

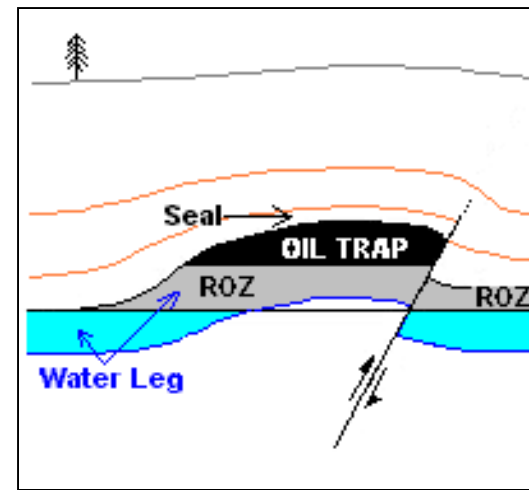


# Original Accumulation with a Breached then Repaired Seal & Forming a ROZ

ORIGINAL

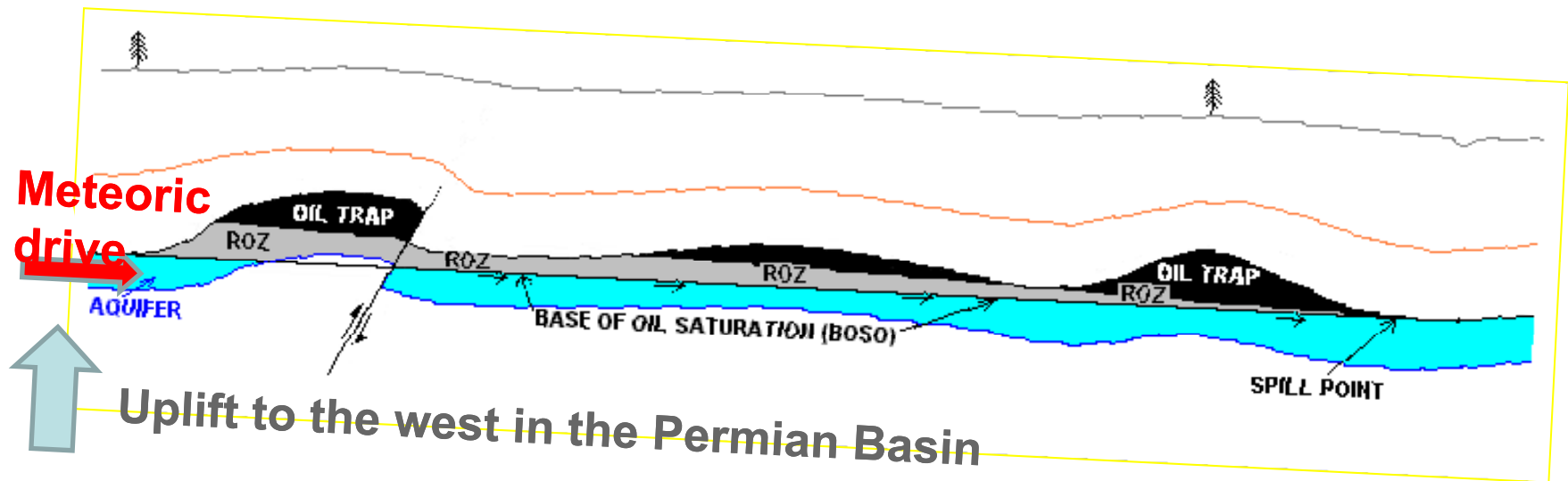


POST BREACH

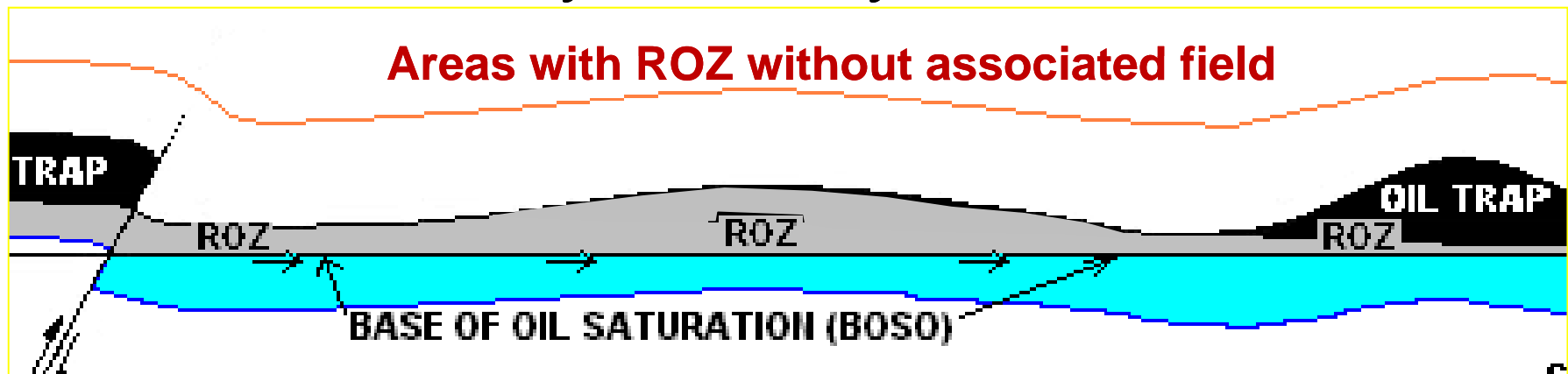


**TYPE 2 ROZ**

TYPE 3. Change in Hydrodynamic Conditions, Sweep of the lower part of the Oil Column and Development of a Residual Oil Zone.

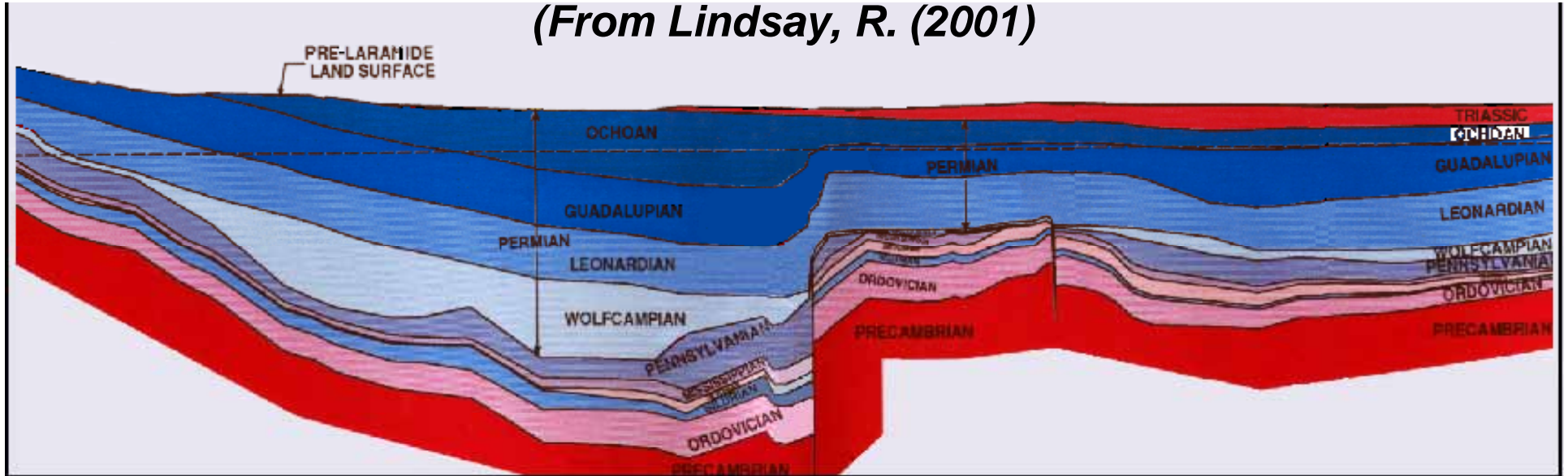


## Dynamic System



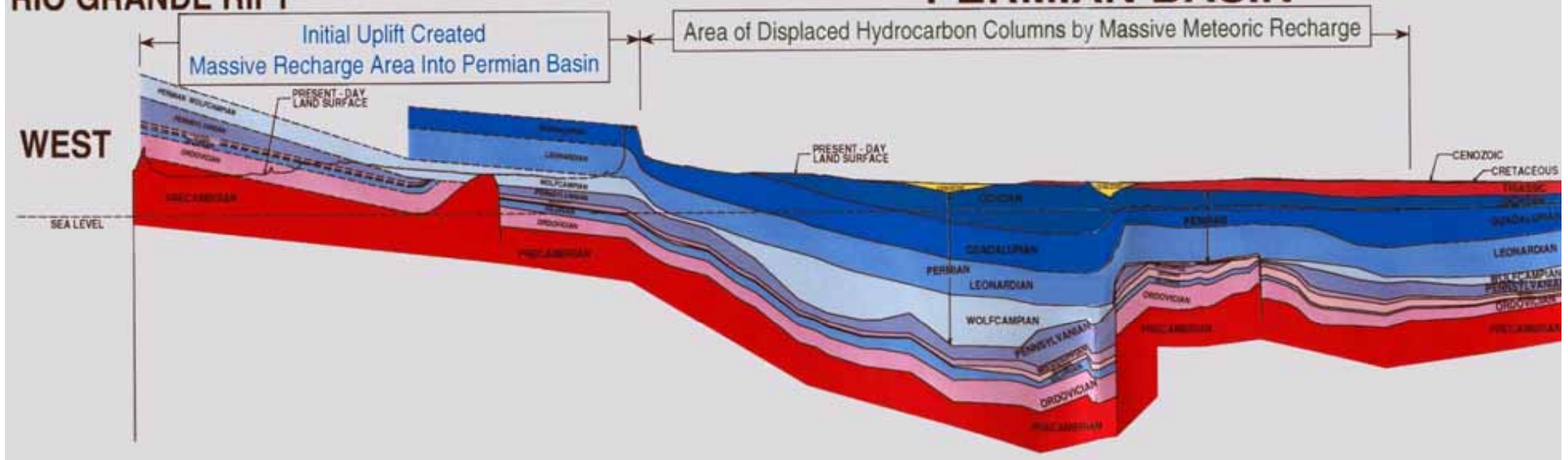
# Post-Subsidence Phase of Permian Basin Development

(From Lindsay, R. (2001))



## Phase I Initial Uplift, Late Oligocene - Early Miocene

### RIO GRANDE RIFT



# Extensional Phases and Reduction of Hydrodynamic Gradients in the Permian Basin (From Lindsay, R. (2001))

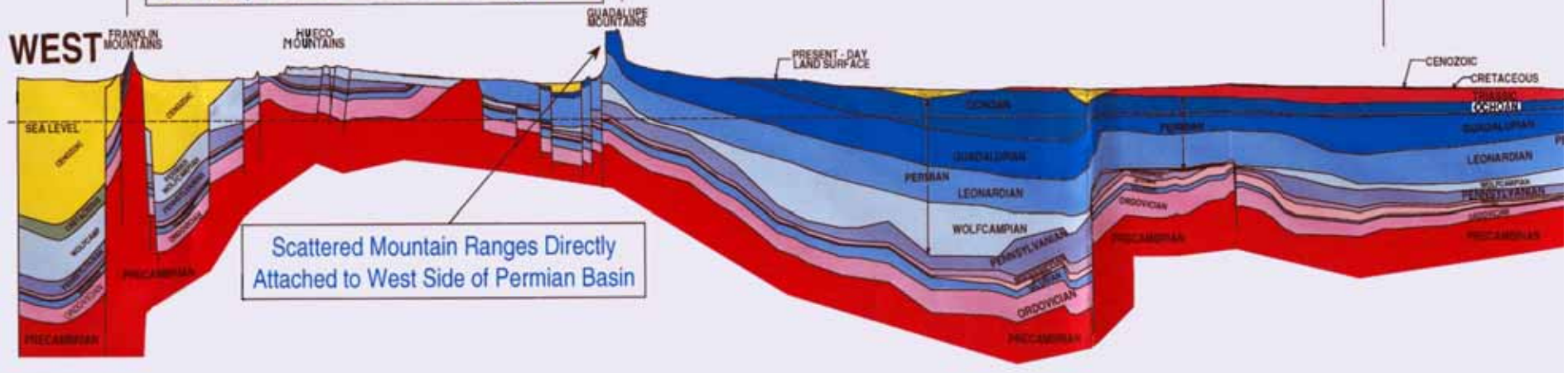
Phase III Slow Extension, Pliocene - Recent  
 Phase II Rapid Extension, Middle - Late Miocene

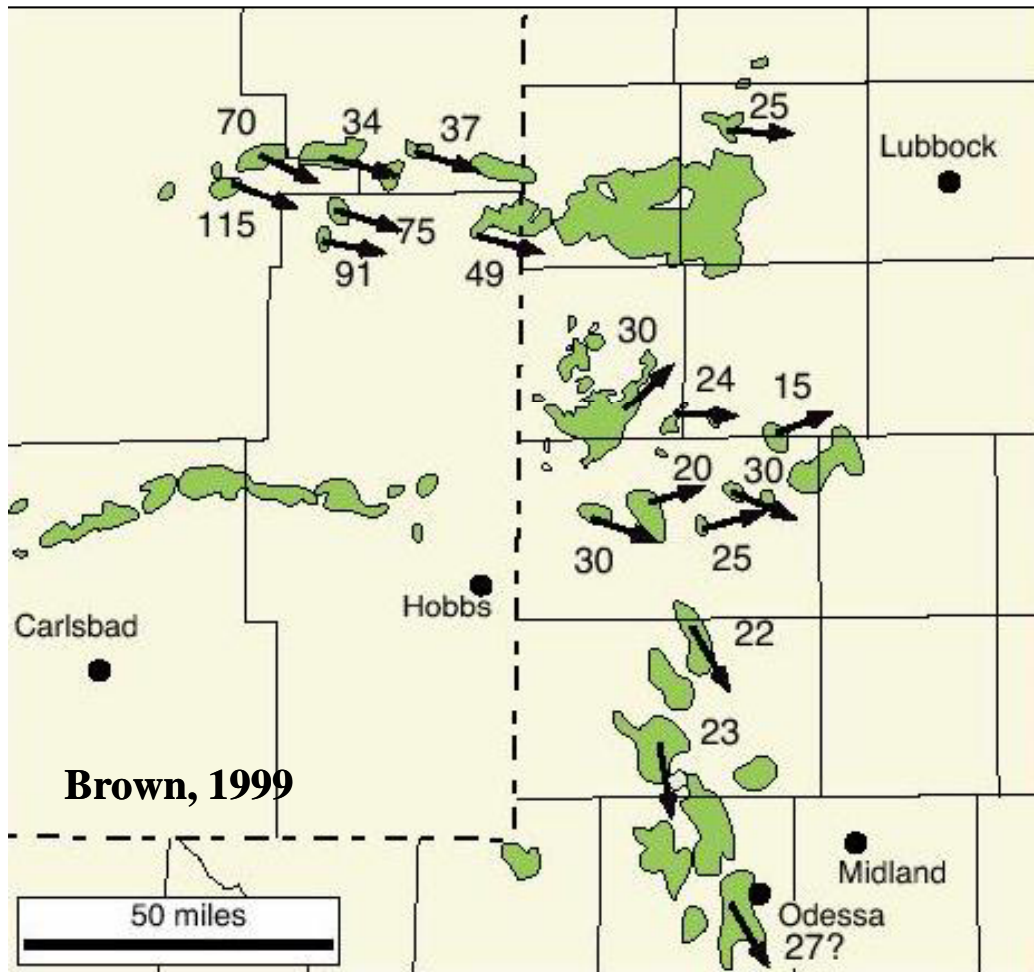
## PERMIAN BASIN

### 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 ( $S_{orw}$ )

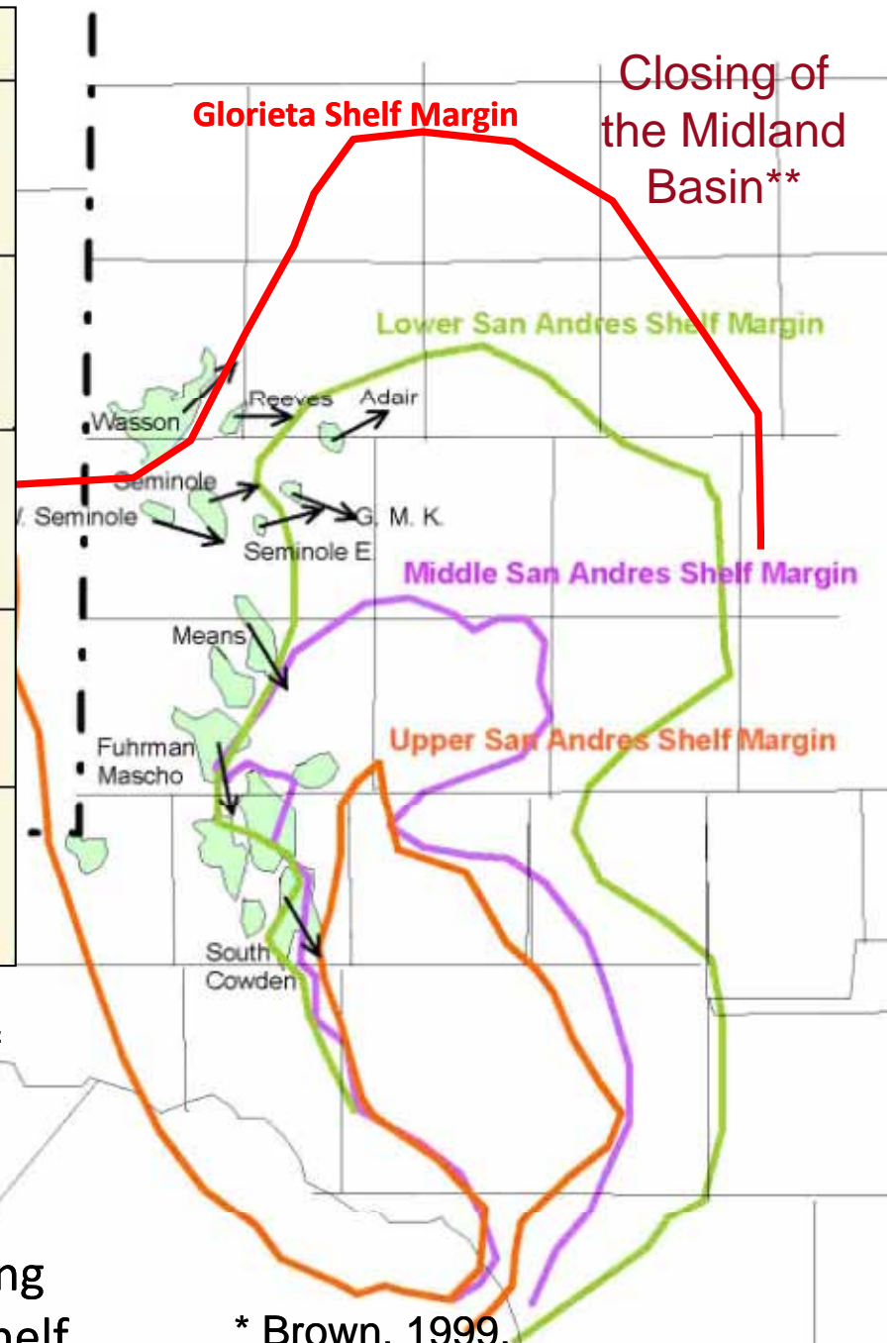




Distribution of Tilted Oil-Water Contacts in the Northern Shelf and Central Basin Platform Areas of the Permian Basin\*

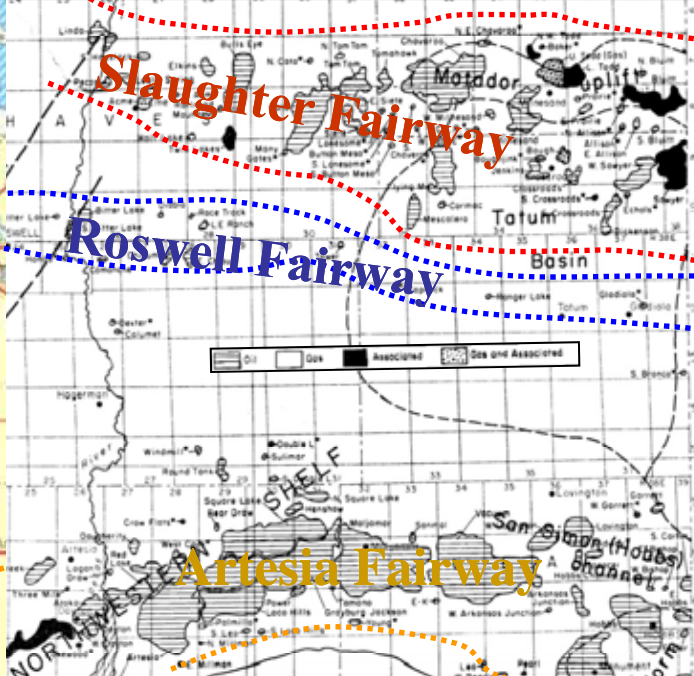
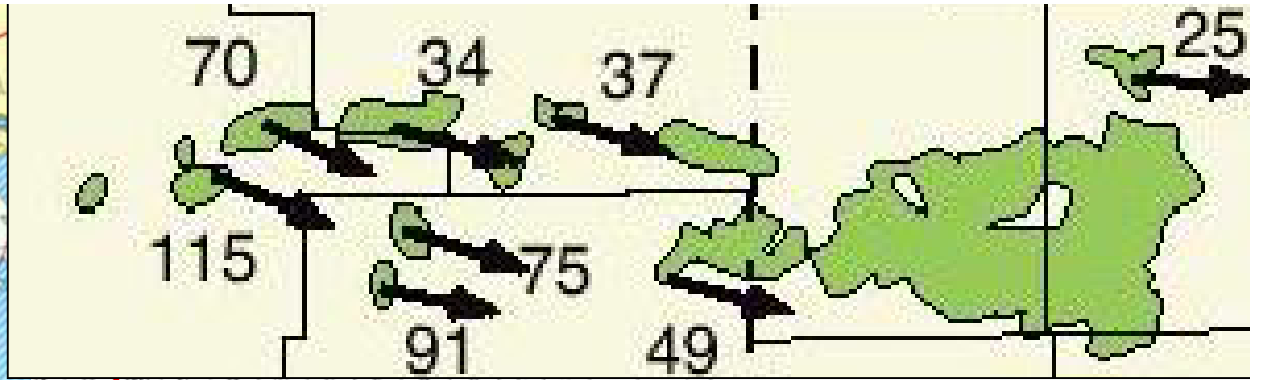
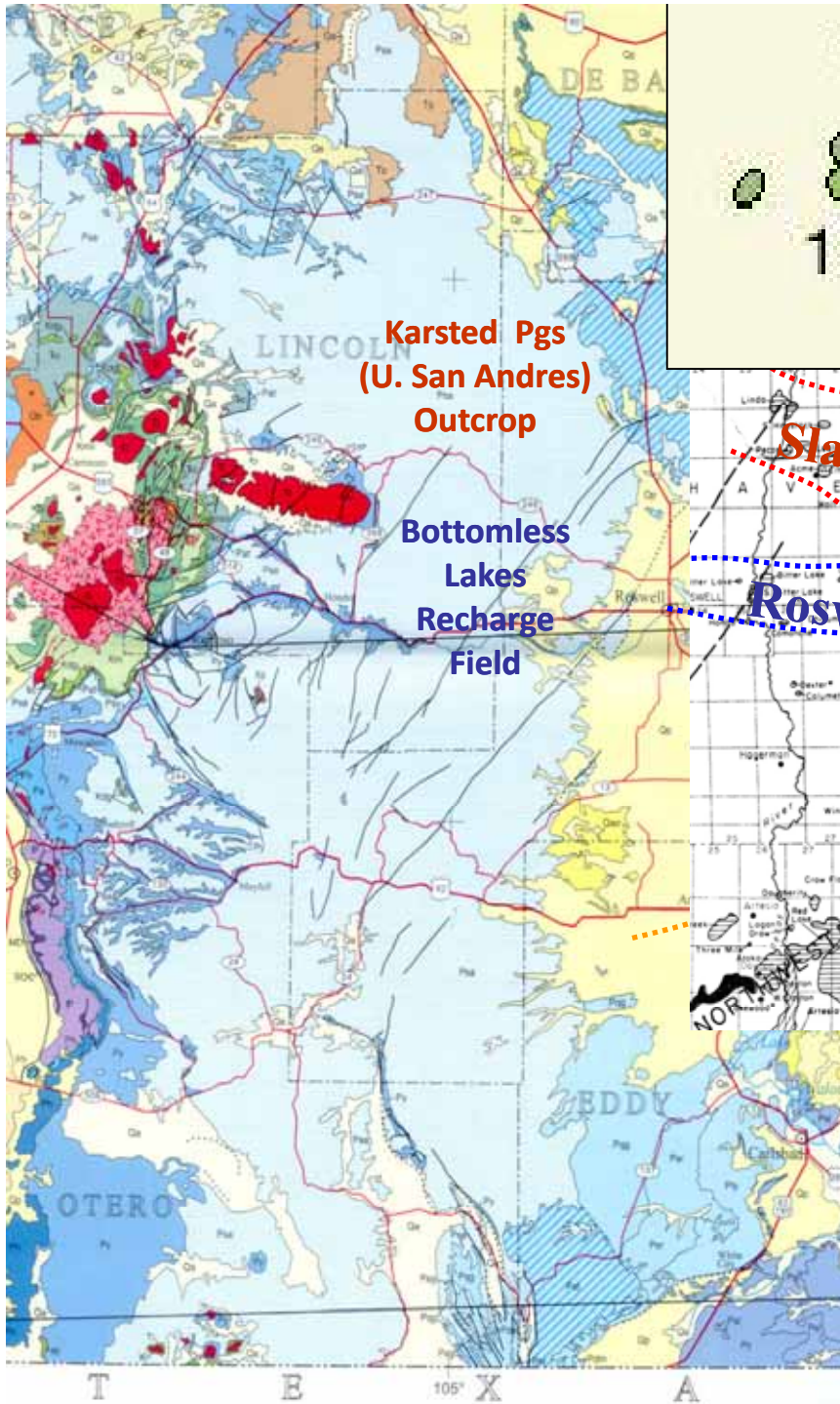
The direction of OWC tilt may be influenced by the age of the producing interval and its relationship to the shelf margin

*Melzer Consulting*



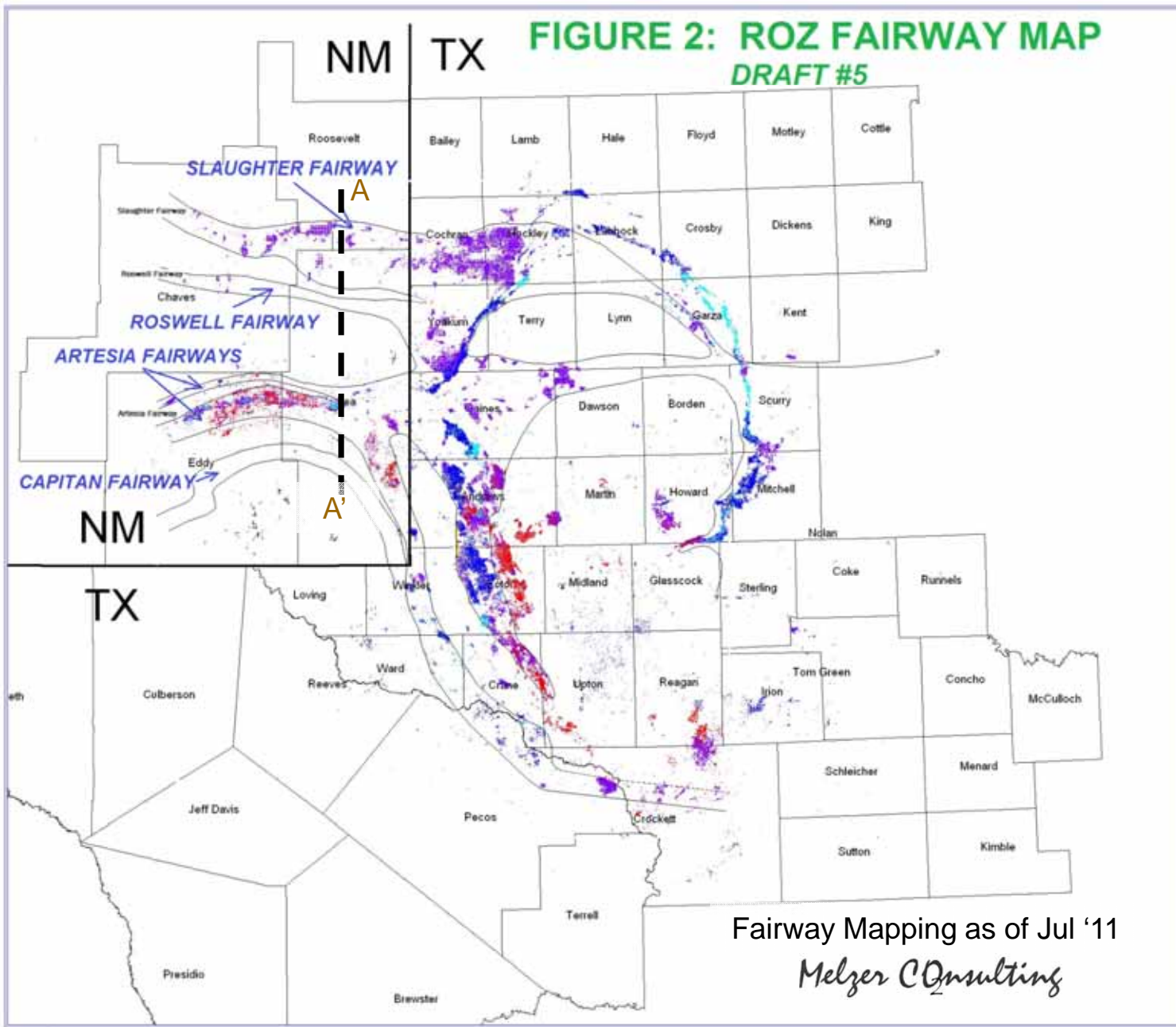
\* Brown, 1999,

\*\* Ward et al, 1986



Relationship of San Andres outcrops and San Andres Fairways in New Mexico.

# FIGURE 2: ROZ FAIRWAY MAP DRAFT #5



Melzer Consulting  
Shawn Coz?



Fairway Mapping as of Jul '11  
Melzer Consulting

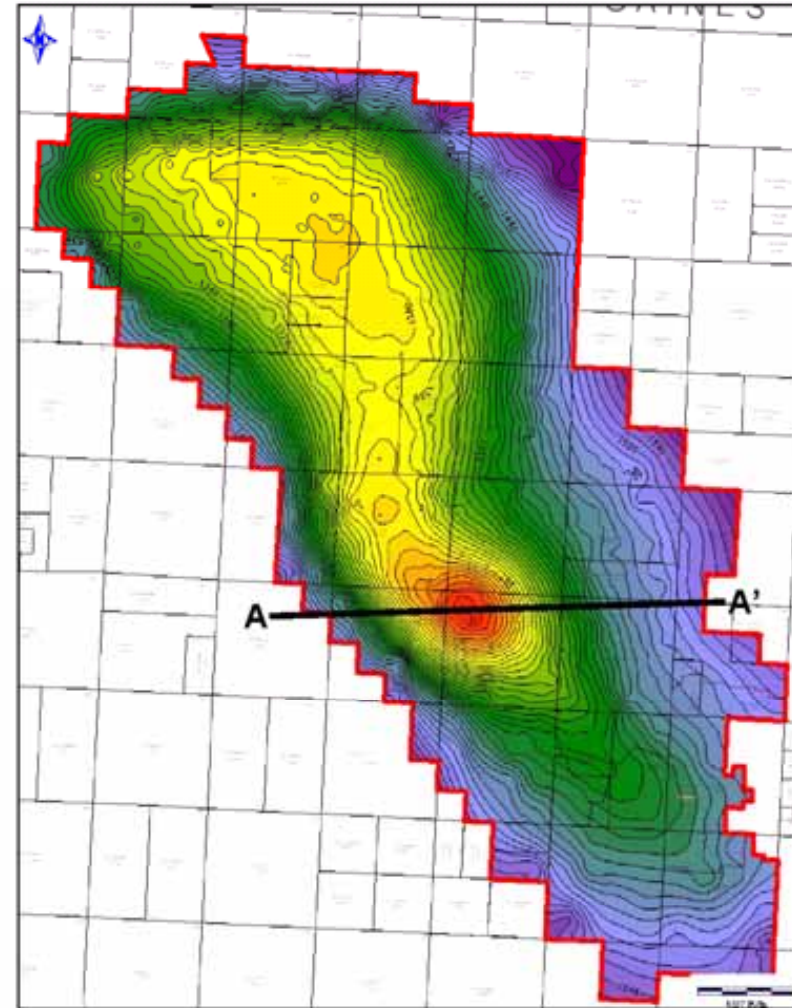
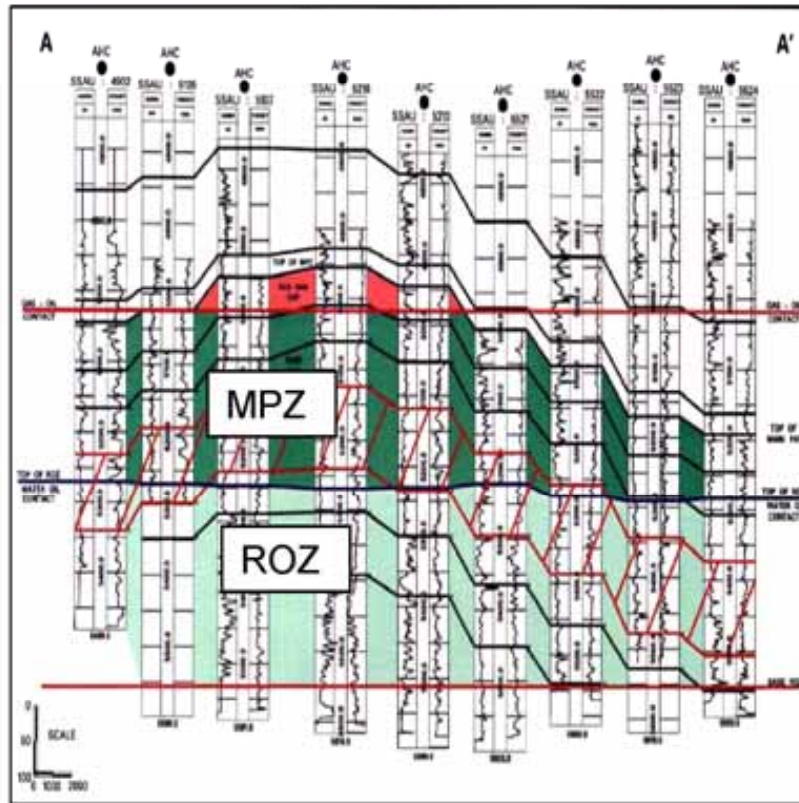
# The Gold Standard

## Seminole San Andres Unit

### SSAU Structure Map & Cross Section



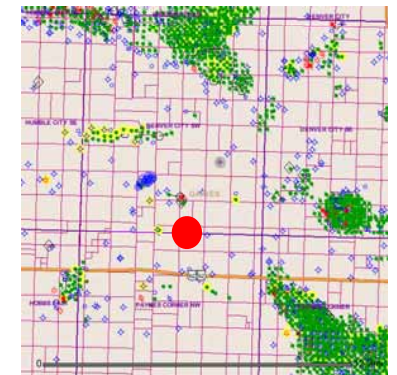
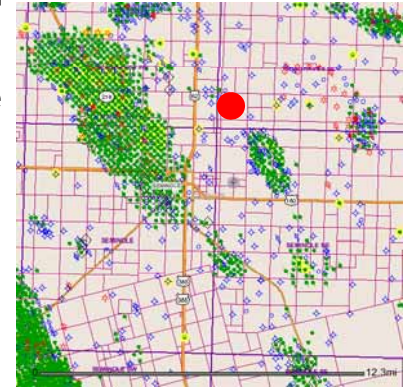
	<u>Net Thickness</u>	<u>Average Permeability</u>	<u>Initial Oil Saturation</u>
Main Pay Zone (MPZ):	126'	9 md	84%
Residual Oil Zone (ROZ):	213'	12 md	32%



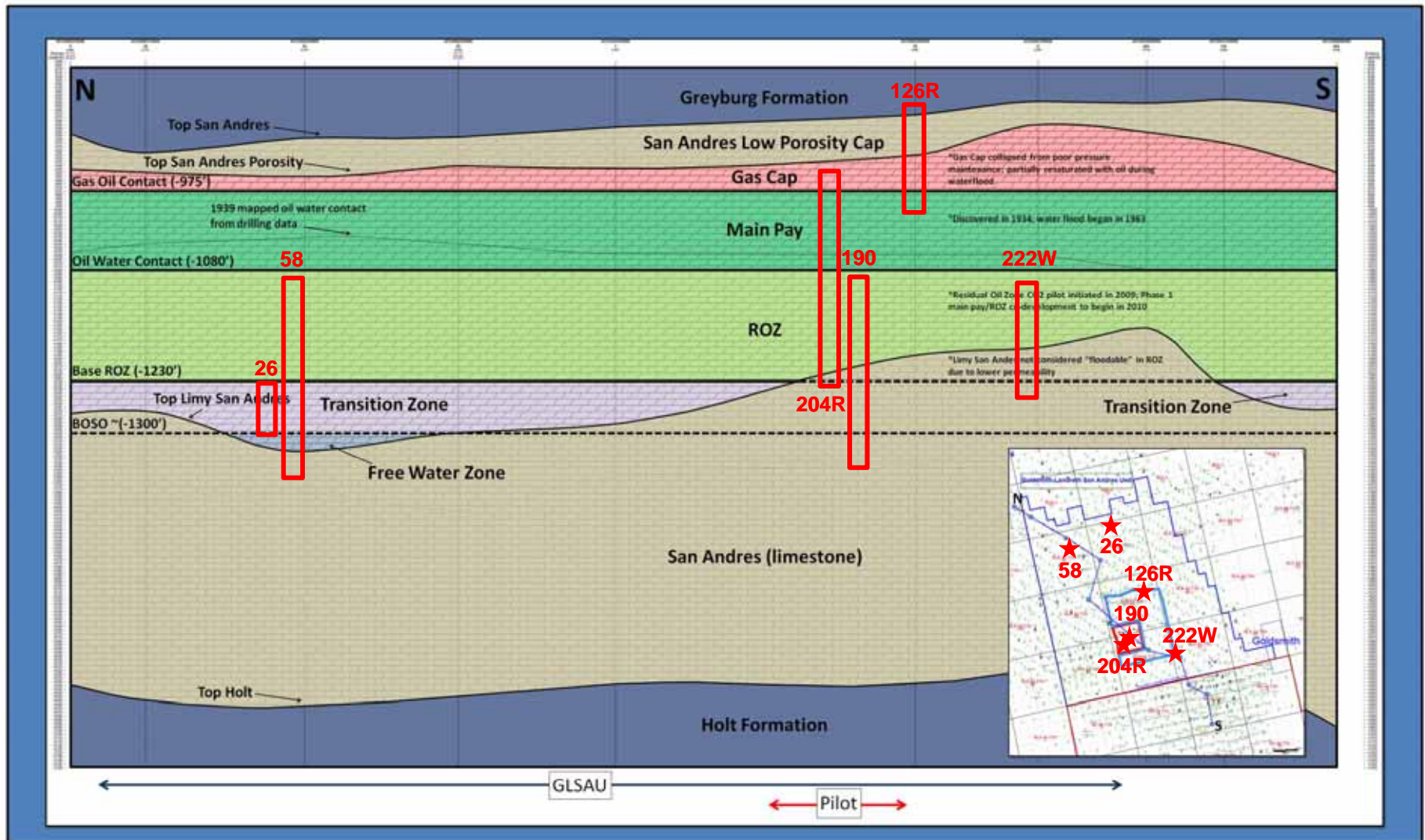


# Gaines, Future Targets or goat pasture?

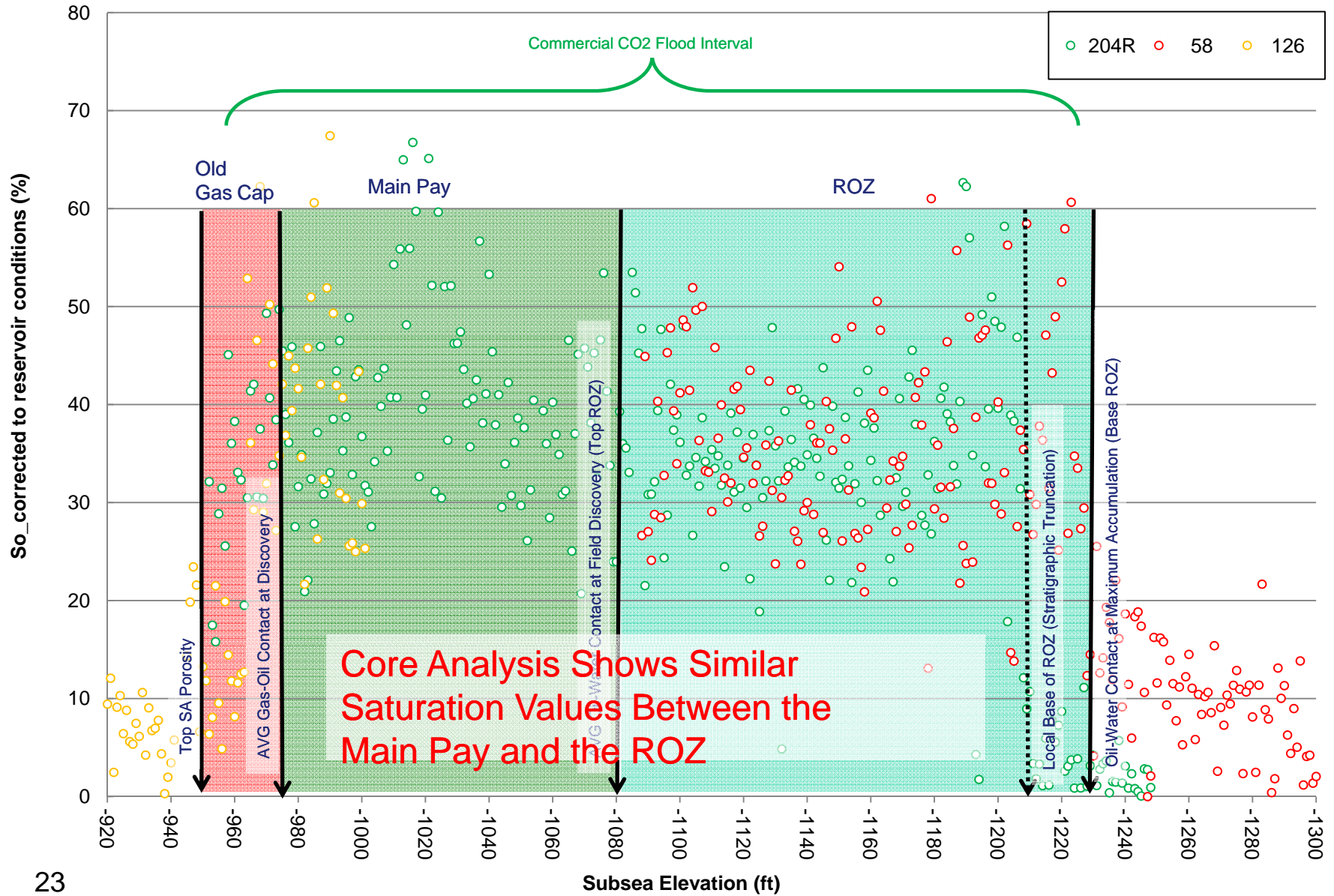
- A Clearfork test, the **IP #1 Campbell Heirs “158”** set pipe on “WET” San Andres test just south of Seminole.
- All wireline logs, drill time, gas curves and samples shows said “slam dunk” oil production. Atlas log analyst said it should be a producer. 100% water test with barely a sniff of live oil. ROZ?
- **Anschutz #1 Patrick Keating “447”**, drilled for San Andres west of Seminole, had good shows but made only water for a few months before P & A (**3600 BW, 3 BO**). Water analyses show progressive drop in TDS over the two months of production.
- The 2 CORED intervals, from 5464 – 5602, had oil saturations ranging from 15 to 35%, 3 - 12% porosity, & 50-100% fluorescence.



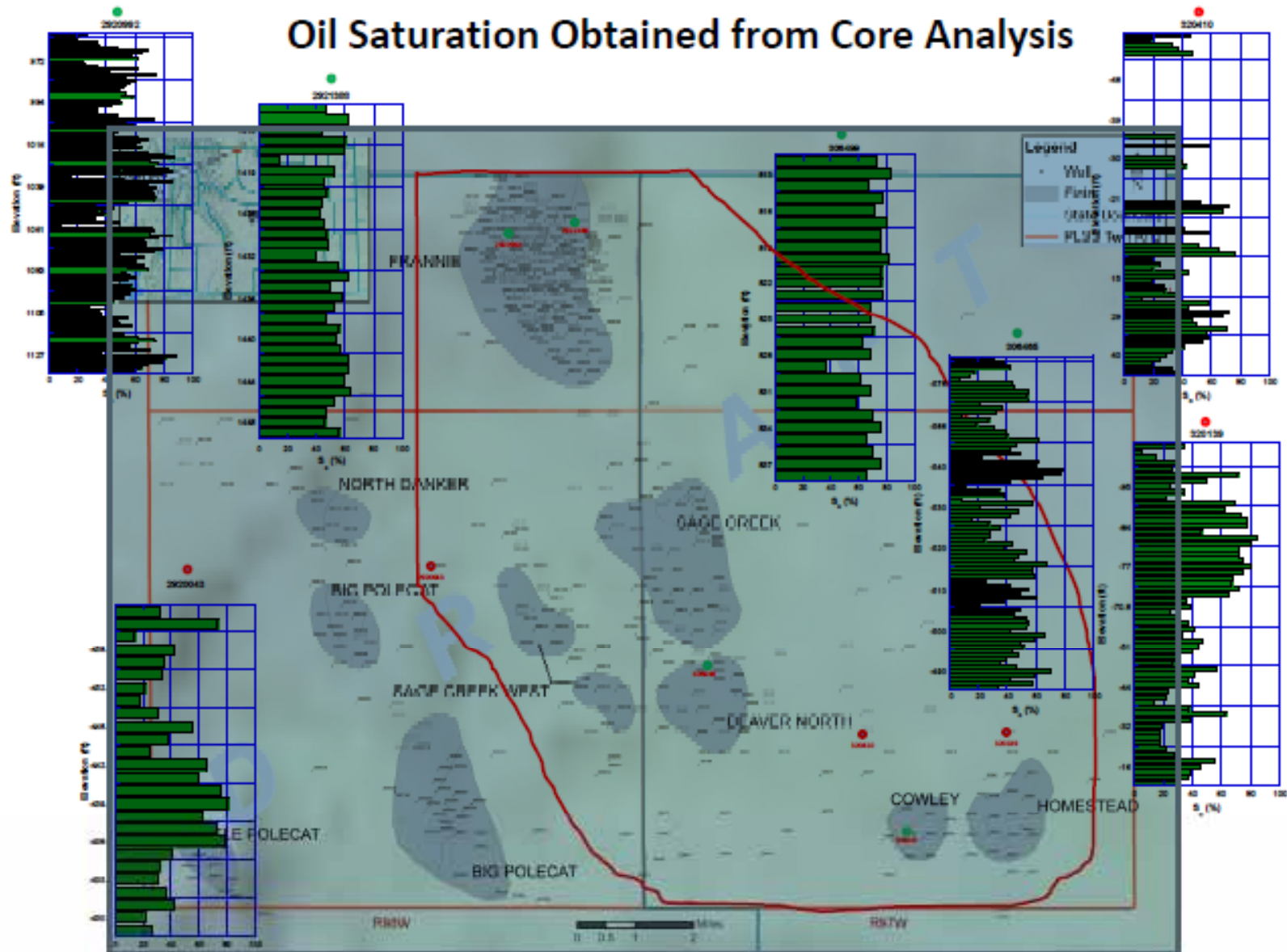
# GLSAU Geologic Model



# Core Saturation



# Wyoming – Big Horn Basin Ten Sleep Formation

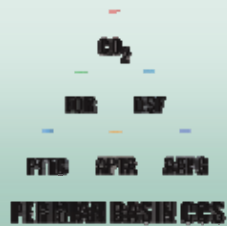


# One of the “Other“ basins we are looking at for ROZ potential

## ARI estimated TZ/ROZ OIP in 13 Bighorn Basin Tensleep Productive reservoirs: **4.4 BBbls**

- These 13 Tensleep reservoirs with cumulative production: **from 345.4 to 6.2 MMBbls**  
13 Bighorn Basin Tensleep Reservoirs

	MPZ OOIP (BBbls)	MPZ Remaining OIP (BBbls)	TZ/ROZ OIP (BBbls)	Total Reserve for CO <sub>2</sub> -EOR (BBbls)
1. CO <sub>2</sub> -miscible fields: 8	4.5	3.1	4.4	7.5
2. CO <sub>2</sub> -immiscible fields: 5				
CO <sub>2</sub> -EOR recovery: 11%		0.34	0.48	0.82
CO <sub>2</sub> -EOR recovery: 30%		0.93	1.32	2.25



## Professional CO<sub>2</sub> CCUS-EOR Training

# OVERVIEW OF THE ELEMENTS OF CCS (& CO<sub>2</sub> EOR + CCS)

Presented by the Applied Petroleum Technology Academy  
([www.aptapb.org](http://www.aptapb.org))

and Petroleum Technology Transfer Council  
(<http://www.pttc.org/>)

and the American Association of Petroleum Geologists  
(<http://www.aapg.org/>)

**Texas Railroad Commission Building  
1701 N. Congress  
Austin, TX**

*June 15, 2011*



# Overview of the Elements of CCS

Topics to be Covered Today

AM \*

1. EOR and CCS Industry Overview.....Trentham
2. Existing CO<sub>2</sub> Markets.....Trentham
3. CO<sub>2</sub> EOR and the Baseline for CCS.....Trentham
4. Synergies of Carbon Management and EOR.....Trentham/Rychel
5. Properties of CO<sub>2</sub>.....Trentham
6. CO<sub>2</sub> Sources & Capture Technologies.....Rychel
7. Ongoing Research.....Rychel
8. Transportation and Metering.....Trentham
9. Injection Projects.....Trentham/Rychel
10. Reservoir Considerations.....Trentham
11. CO<sub>2</sub> Operations.....Trentham
  - A. Downhole Equipment, Considerations
  - B. Surface Facilities and Process Flow
12. Monitoring, Verification, and Accounting (Surveillance).....Rychel
13. Regulatory Frameworks and The 'Bidness' of CO<sub>2</sub> .....Trentham

PM \*

*\* If all goes well*

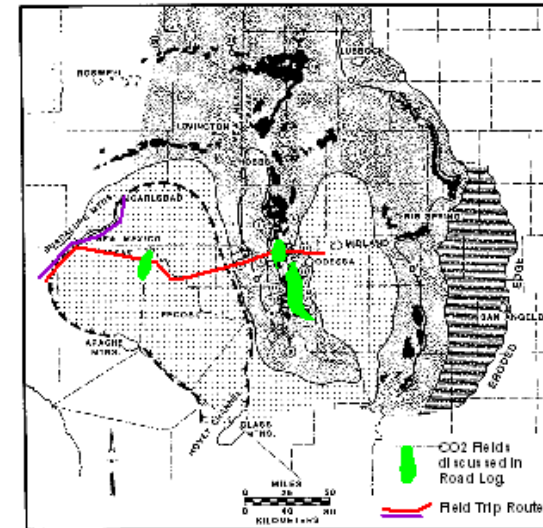
2010  
Carbon Capture and Storage Field Trip  
Odessa – Kermit – Orla – Salt Flat - Carlsbad  
By Bob Trentham

Modified from road logs by Bob Lindsay, Bob Ward and Bob Trentham & Peter Scholle.

# Student CCS Modules Project

Road Logs,  
Plant and Field  
descriptions  
Core from CO2 fields

<u>Interval Mileage</u>	<u>Cumulative Mileage</u>	<u>Description</u>
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PERMIAN  
LOWER GUADALUPIAN SERIES  
SAN ANDRES FORMATION

Welcome to the Carbon Capture and Storage Field Trip to the Guadalupe Mountains. Today, we will leave the Center for Energy and Economic Diversification located at the intersection of SH 191 and FM 1788 in western Midland County between Midland and Odessa and head west on SH 191 through Odessa. We will then be driving west on SH 302 thru Notrees, Kermit and Mentone. Turn north on US 285 to Orla and west on FM 652 to US 62 /180, west/south on US 62/180 to Pine Spring and the Salt Flat Graben. Then backtrack to Carlsbad.

On this trip we will be reviewing the Permian Guadalupian basin and shelf deposits in the Delaware and Guadalupe Mountains and the utilization of CO2 in Enhanced Oil Recovery project in the Permian Basin. CO2 has been utilized in Enhanced Oil Recovery projects in the basin for the past 40 years. Today, 4 billion cubic feet of CO2 is "handled" daily in over 60 producing oil fields. Over