

# Residual Oil Zones (ROZ's) and the long term future of the Permian Basin (and Elsewhere)

PBPA

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# First basinwide study of Residual Oil Zones (ROZ's) in the upper Permian carbonates in the basin.

- It is supported by the Research Partnership to Secure Energy for America (RPSEA) and industry partners.
- Co-PI Steve Melzer
- Arcadis - David Vance, Steve Tischer
- Phil Eager, Edith Stanton, Saswati Chakraborty
- Industry Partners Chevron & Legado
- George Koperina & Advanced Resources

International



# 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

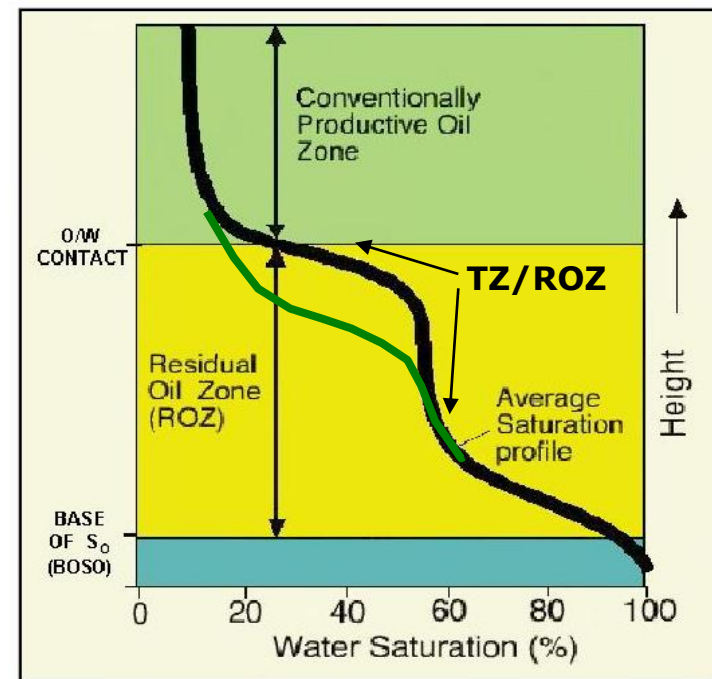
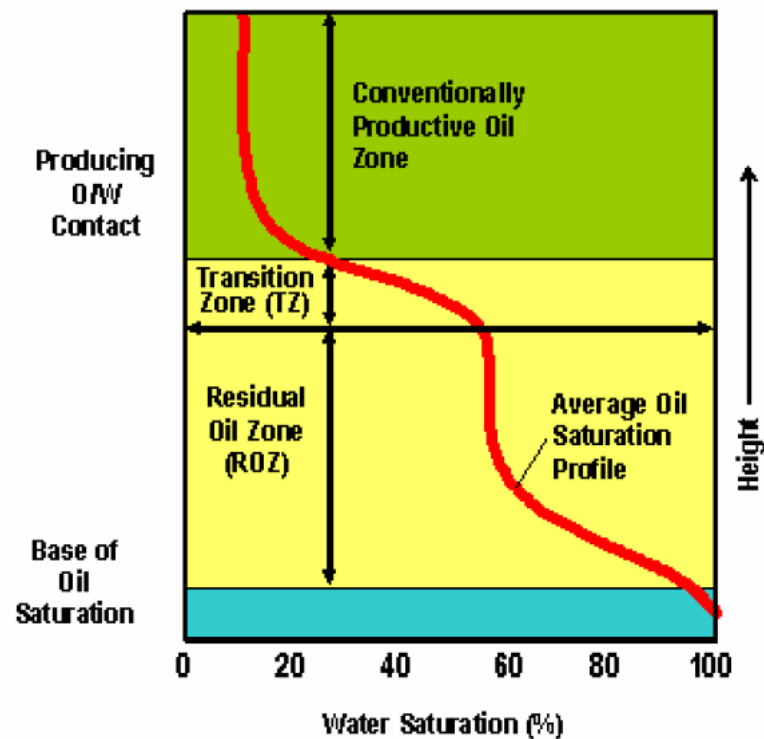
Based on reservoir modeling of applying CO<sub>2</sub>-EOR to the TZ/ROZ resources, ARI estimates that

**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. Almost double the estimated Main Pay CO<sub>2</sub> EOR total.

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>	<b>18.8</b>	<b>6.9</b>	<b>11.9</b>

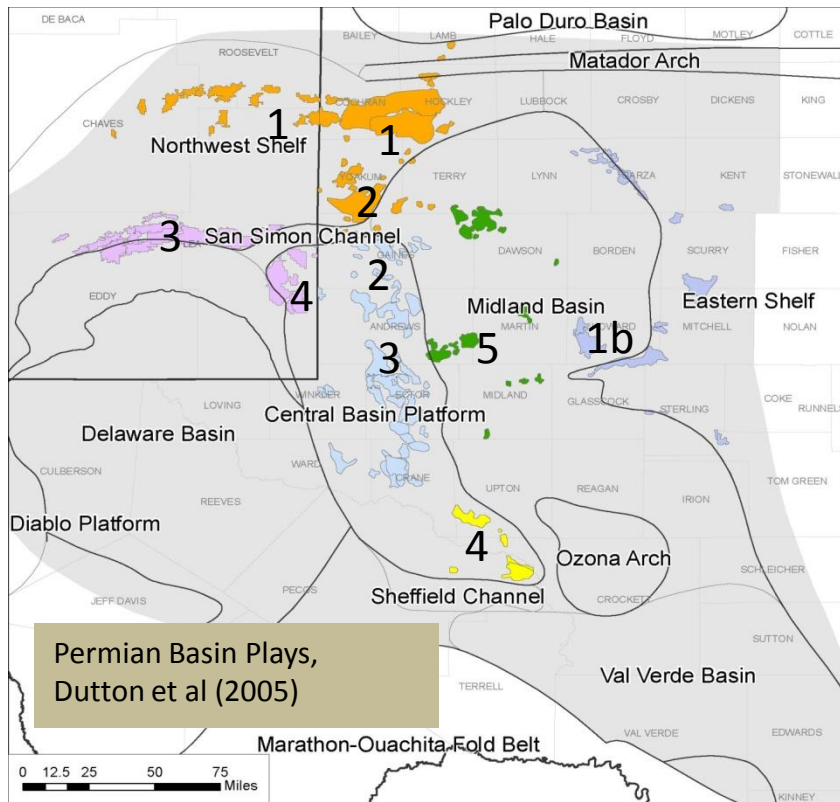
# Some Terminology

- **Oil/Water Contact.** Typically identified as the depth beneath which early wells will produce water on completion.
- **Transition Zone.** That interval which is capable of producing some oil with significant water during Primary or Secondary Recovery (Waterflood).
- **Residual Oil Zone.** That zone which is capable of producing oil only during Tertiary Recovery (CO<sub>2</sub> or Surfactant).
- **Base of Oil Saturation.** Depth below which there is very little to no oil saturation in the formation.



# Where we They?

- ROZ's appear to be common in Leonardian and Guadalupian carbonates.
- Exploitation of thick ROZ's with CO2 has begun in a number of the major San Andres fields.

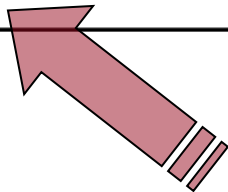


	Formation	Area	Field
Guadalupian	Queen		
	Grayburg	C. B. P. N. W. S.	N. & S. Cowden Maljamar
	U. San Andres	C. B. P. N. W. S.	Means Hanford N.M.F.U.? Eunice Mon.?
	M. San Andres	C. B. P. N. W. S	Seminole Vacuum Wasson Robertson?
Leonardian	L. San Andres	N. W. S. C. B. P.	Goldsmith Yates? McCamey?
	Glorieta	C. B. P.	W. A. Estes
	U. Clearfork	C. B. P.	R N. W. Eobertson?
	Tubb Sand		
	L. Clearfork	C. B. P	Sand Hills? N. W. E
	ABO	N. W. S.	Empire?

# ROZ BACKGROUND

## The 3 types of Residual Oil Zones

ROZ TYPE	Oil-Water Contact	Base of Oil Saturation	Other Characteristics
Regional Tilt (1)	Horizontal	Tilted	Wedge with thin side Downdip
Breached Seal and Reaccumulation (2)	Horizontal	Horizontal	Stratified Tar Mats, Anomolously Low GOR
Hydrodynamic Tilt (3)	Tilted	Horizontal	Wedge with thin side in Direction of Flow (to Spill Point)



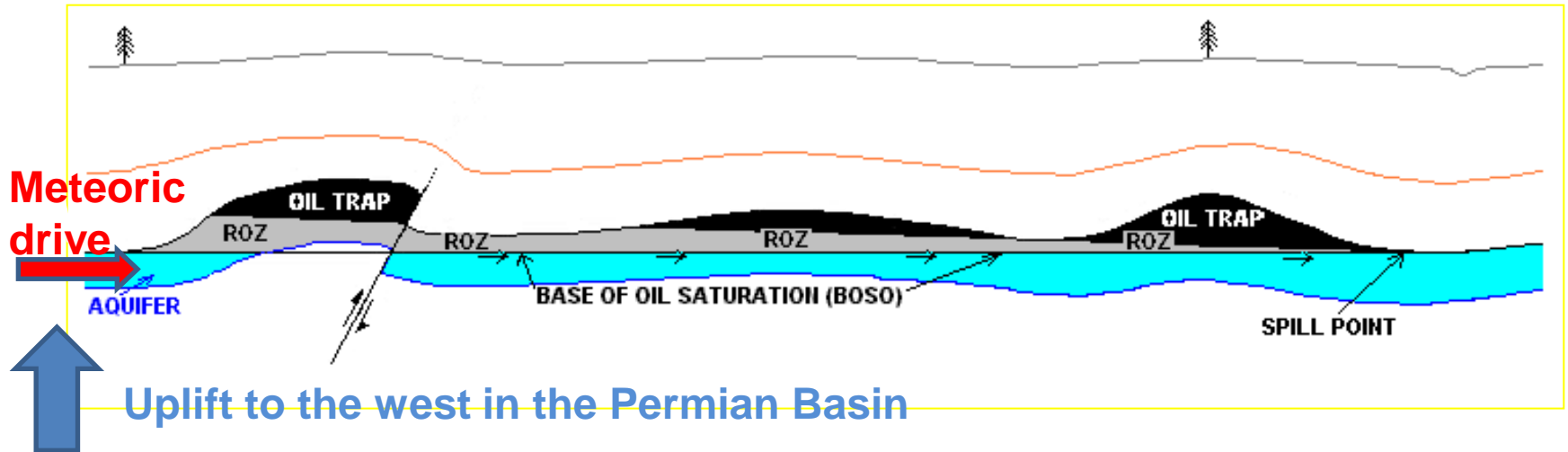
The Evidence suggests Type 3 are common in the Permian Basin “Mother Natures Waterfloods” are a result of post oil emplacement tectonics and Hydrodynamic Tilt



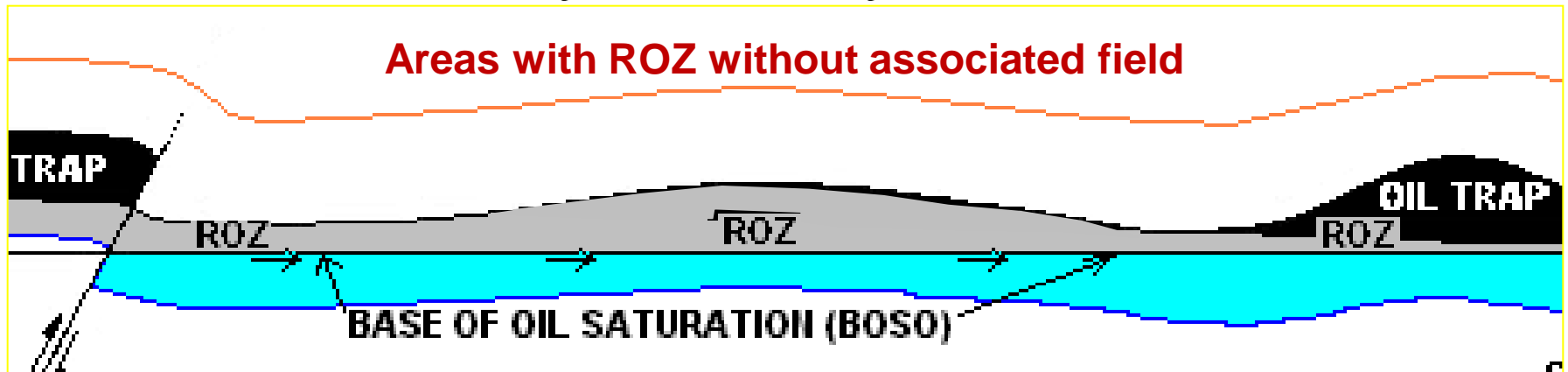
TYPE 3. Change in Hydrodynamic Conditions, Sweep of the lower part of the Oil Column and Development of a Residual Oil Zone.

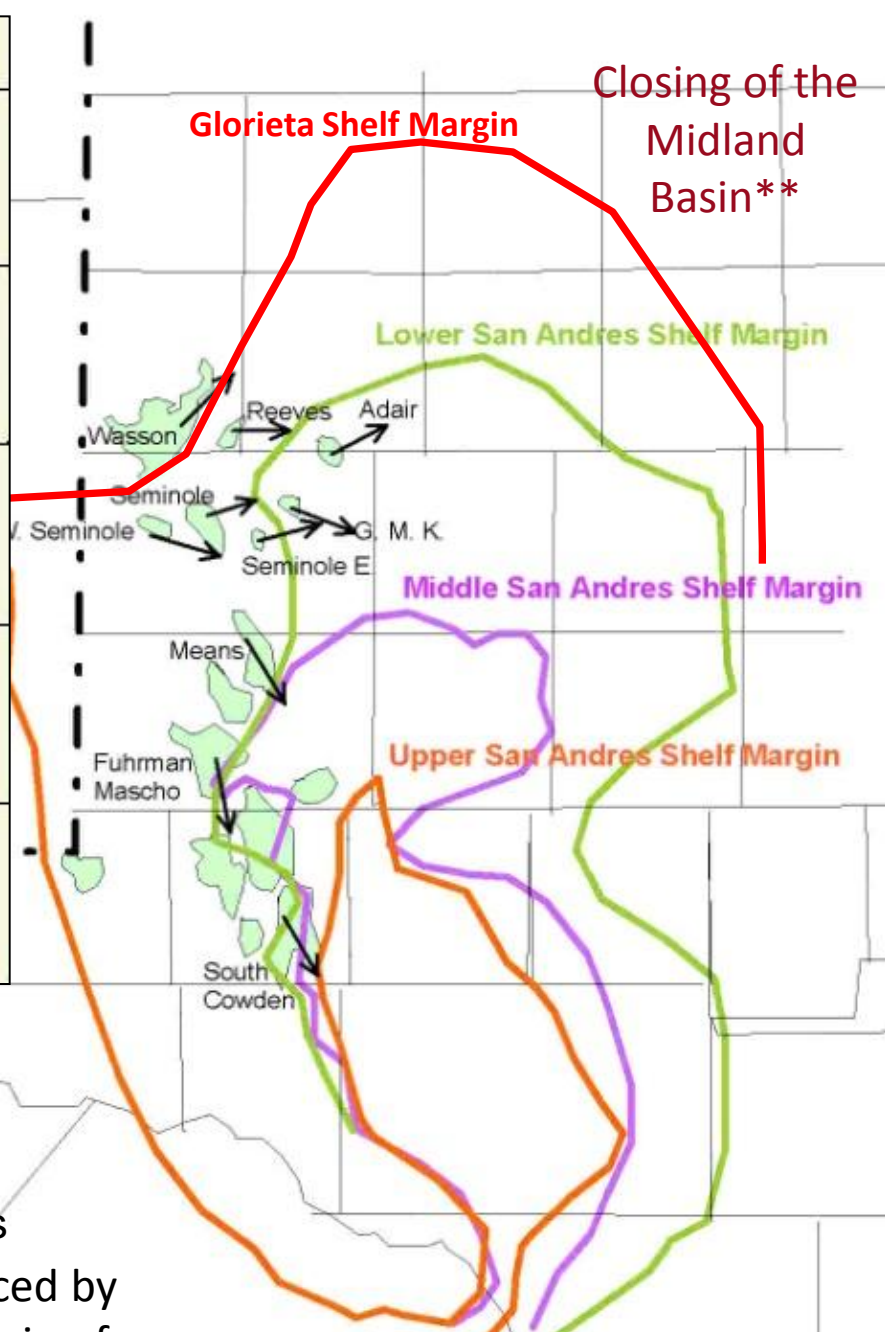
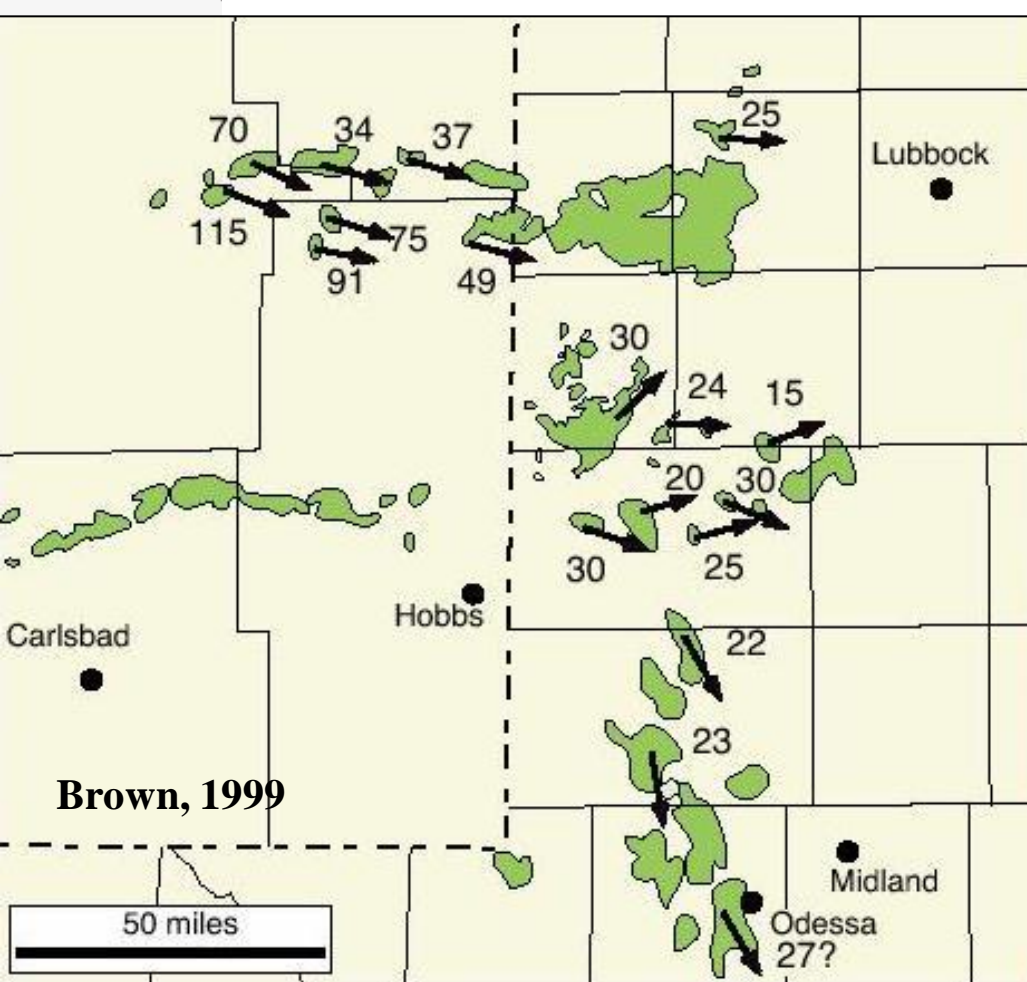
Oil/Water Contact is Tilted

Base of the ROZ locally almost flat, regionally tilted.



## Dynamic System





**Alton Brown** documented the effects of hydrodynamics on Cenozoic oil migration in the Wasson area and elsewhere on the Northwest Shelf. He proposed hydrodynamics as a more reasonable mechanism for Wasson OWC tilt than capillary effects

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



*Melzer Consulting*

\* Brown, 1999,  
\*\* Ward et al, 1986

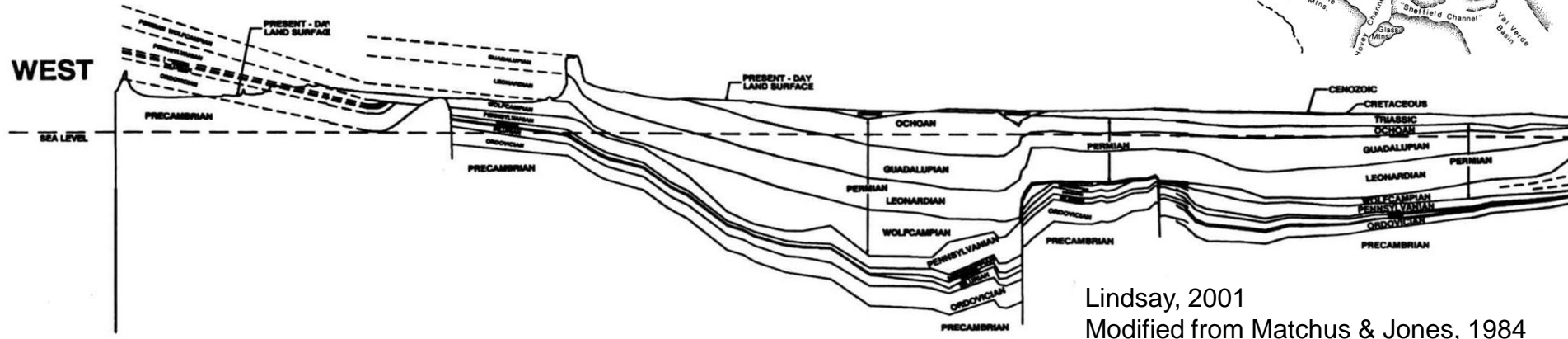


**Bob Lindsay**, documented meteoric sweep and the development of Residual Oil Columns in a number of fields on the Central Basin Platform & envisioned massive recharge of meteoric waters into the subsurface during the Mid to Late Tertiary as a result of the uplift in the Rio Grande Rift area. The oil being swept out of the structures.

**PERMIAN BASIN**



**RIO GRANDE RIFT**



Lindsay, 2001  
Modified from Matchus & Jones, 1984

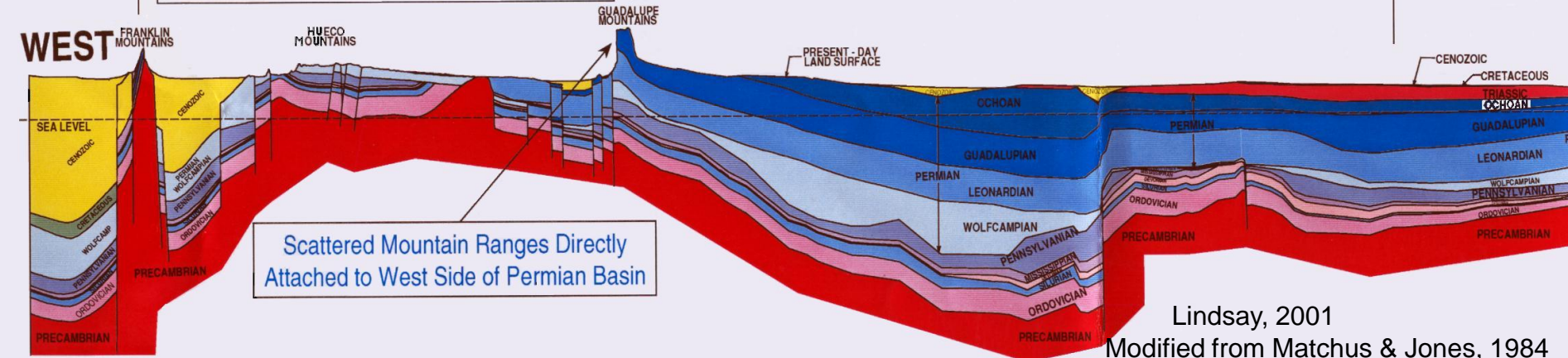
Phase III Slow Extension, Pliocene - Recent  
Phase II Rapid Extension, Middle - Late Miocene

**PERMIAN BASIN**

**RIO GRANDE RIFT**

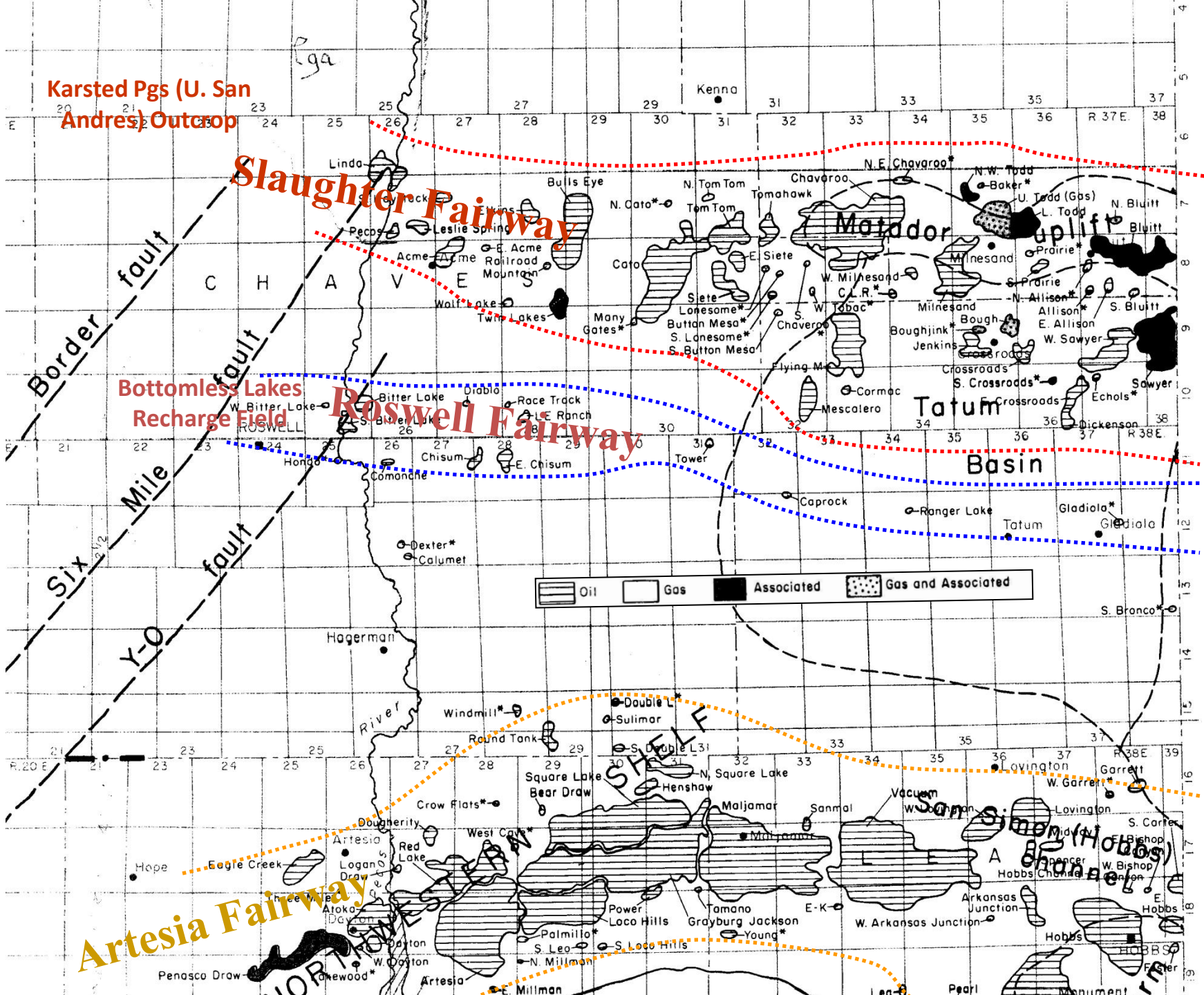
Formation of Basin & Range Province  
Horsts & Grabens  
Drastically Reduced Meteoric Recharge Area

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



Scattered Mountain Ranges Directly Attached to West Side of Permian Basin

Lindsay, 2001  
Modified from Matchus & Jones, 1984







Karsted Pgs (U. San Andres) Outcrop

Slaughter Fairway

Bottomless Lakes Recharge Field

Roswell Fairway

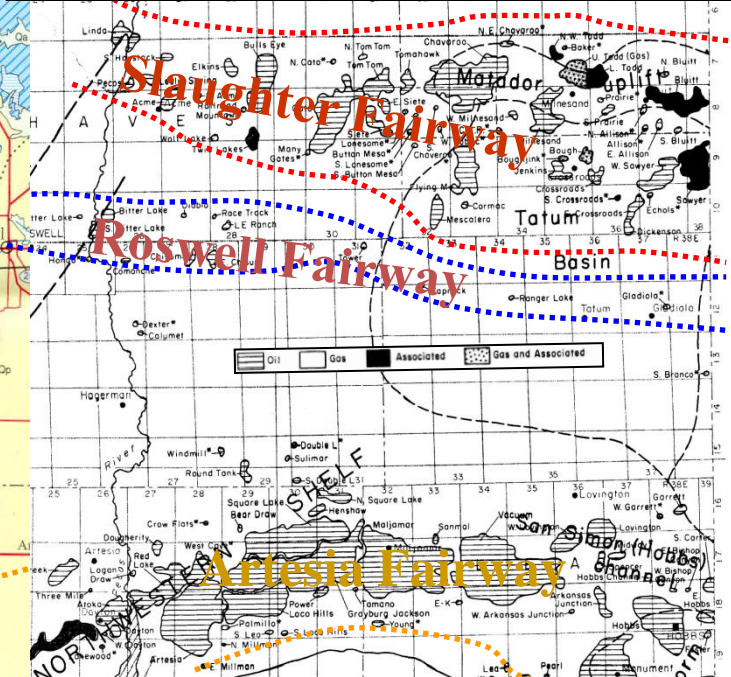
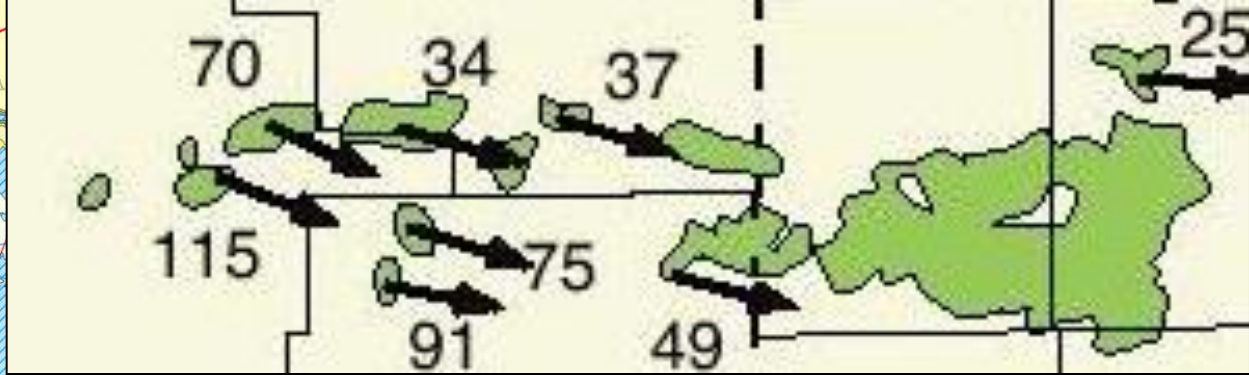
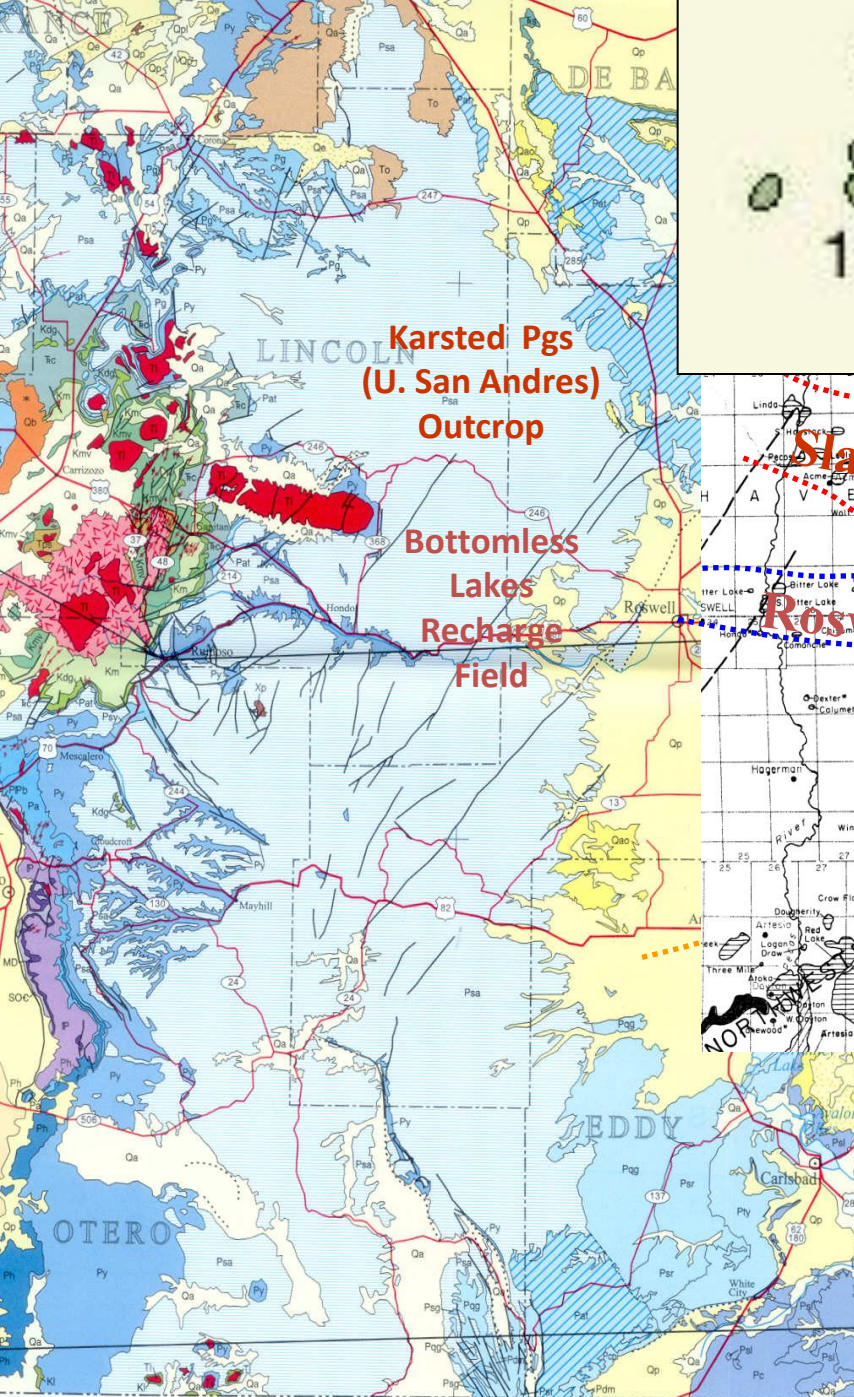
Border fault  
Six Mile fault  
Y-O fault

			
Oil	Gas	Associated	Gas and Associated

Artesia Fairway

SHELL

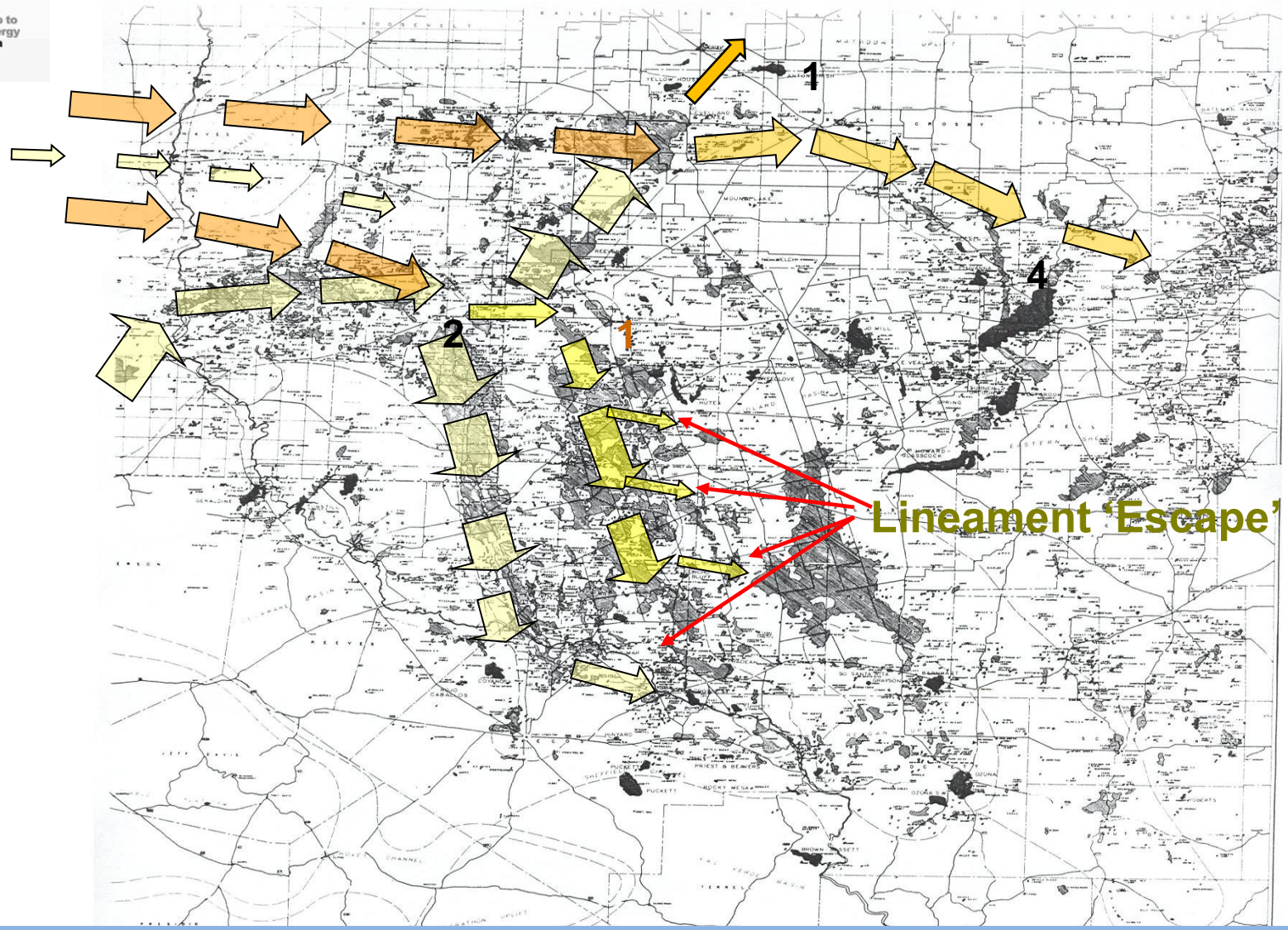
SAN ANTONIO (HOBBS) CHANNEL



San Andres outcrop (light Blue) is the present day extent of the recharge area for the meteoric water that sustains the tilted oil water contacts in San Andres reservoirs.

# PERMIAN BASIN FIELD MAP

WITH THEORIZED (U. PERMIAN) HYDRODYNAMIC FAIRWAYS



There are a number of probable pathways that will eventually be documented

# Published Seminole Field Water Saturation Profile.

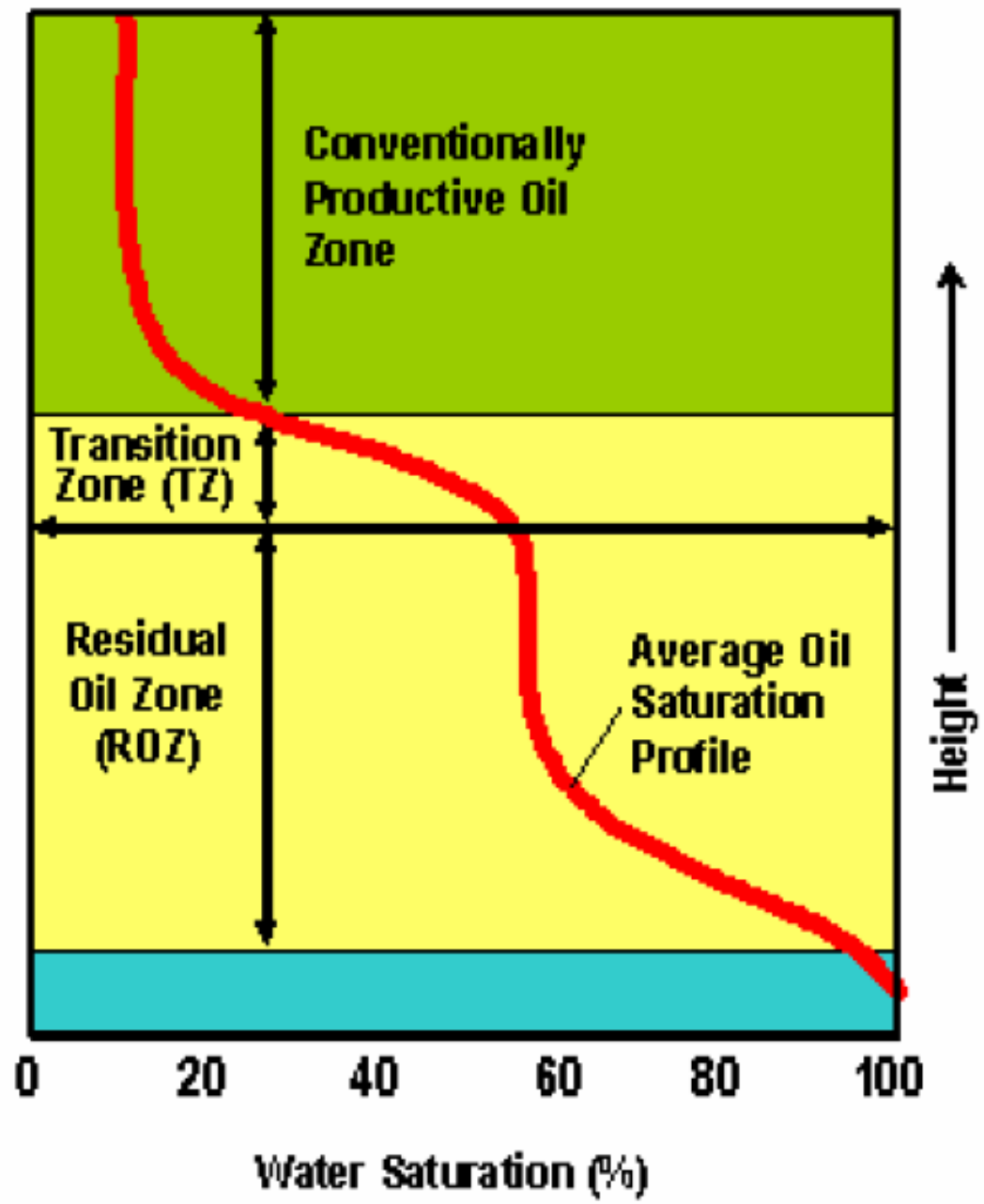


<b>Reservoir Description</b>	Limestone and dolomite deposited in a shallow carbonate ramp environment
<b>Fluid Type</b>	Saturated black oil
<b>Drive Mechanism</b>	Gas in solution and gas cap during primary. External energy from water and CO2 injection during secondary and tertiary recovery.
<b>Develop. History</b>	1936 Discovery 1936 First Production 1969 Unitized/Waterflood 1983 MPZ CO2 Flood Begins 1996 ROZ Phase 1 Pilot 2004 ROZ Phase 2 Pilot 2007 ROZ Stage 1
<b>Cumulative Production</b>	675 MMBO, 40 MMBOE NGL, 702 BCF HC Gas
<b>Current Rate</b>	19.6 MBOPD, 200 MMCFD CO2+HC 25,500 MBOEPD (Oil+NGL+Gas)

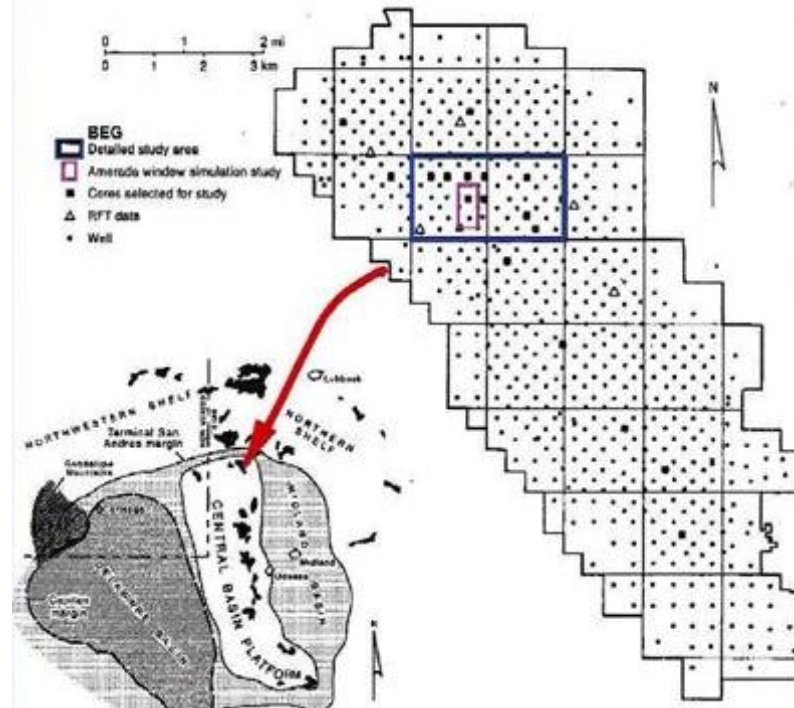
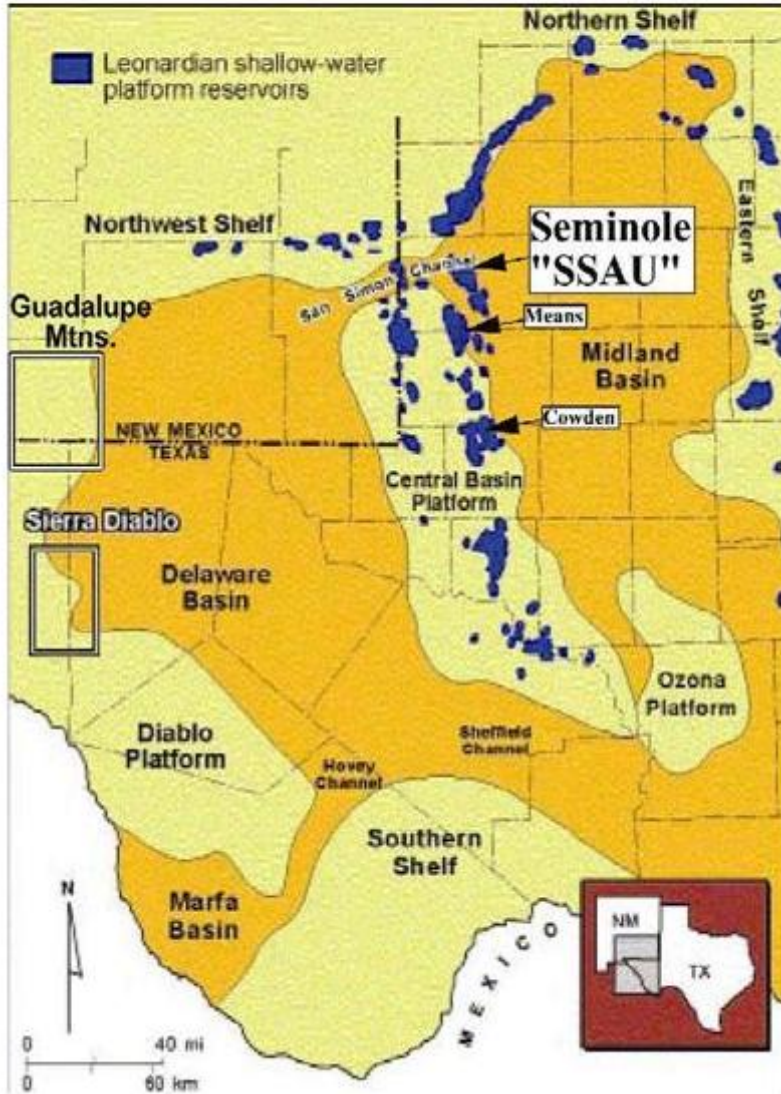


Producing  
O/W  
Contact

Base of  
Oil  
Saturation



# Seminole San Andres Unit SSAU Geologic Setting



<b>Develop. History</b>	1936 Discovery
	1936 First Production
	1969 Unitized/Waterflood
	1983 MPZ CO2 Flood Begins
	1996 ROZ Phase 1 Pilot
	2004 ROZ Phase 2 Pilot
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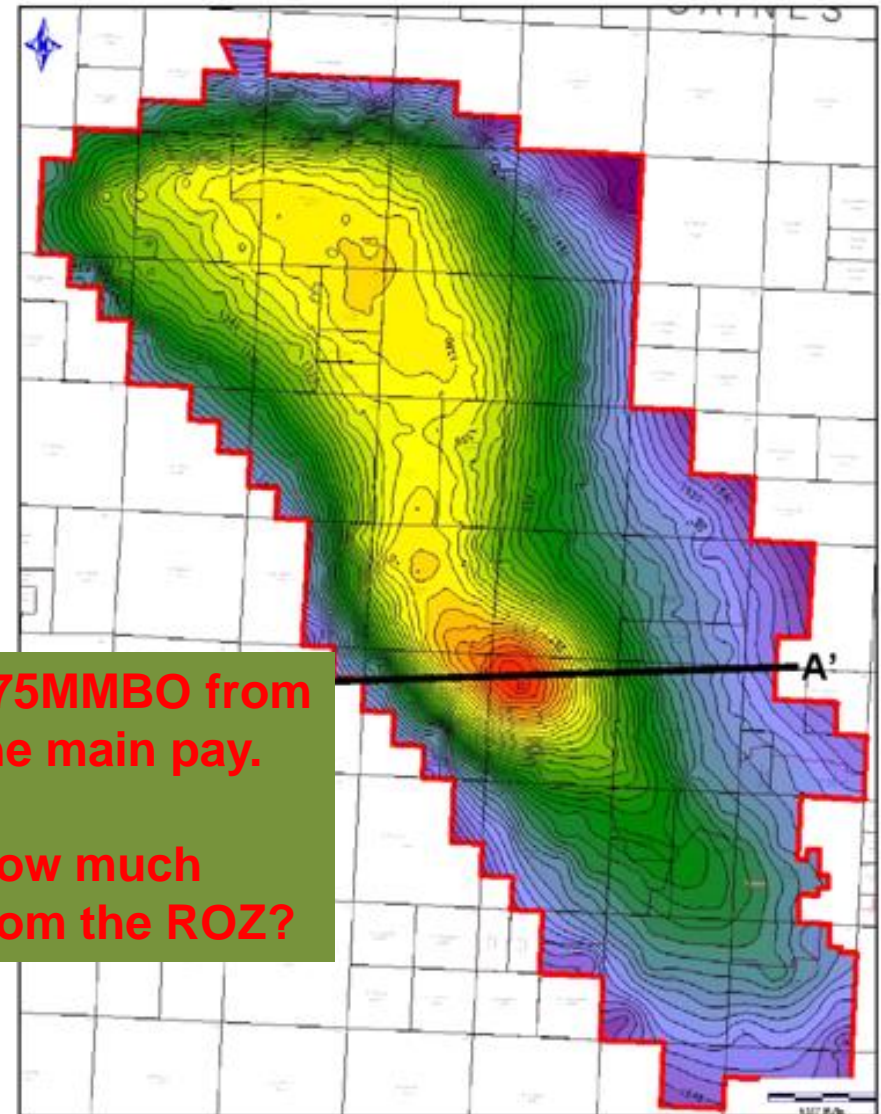
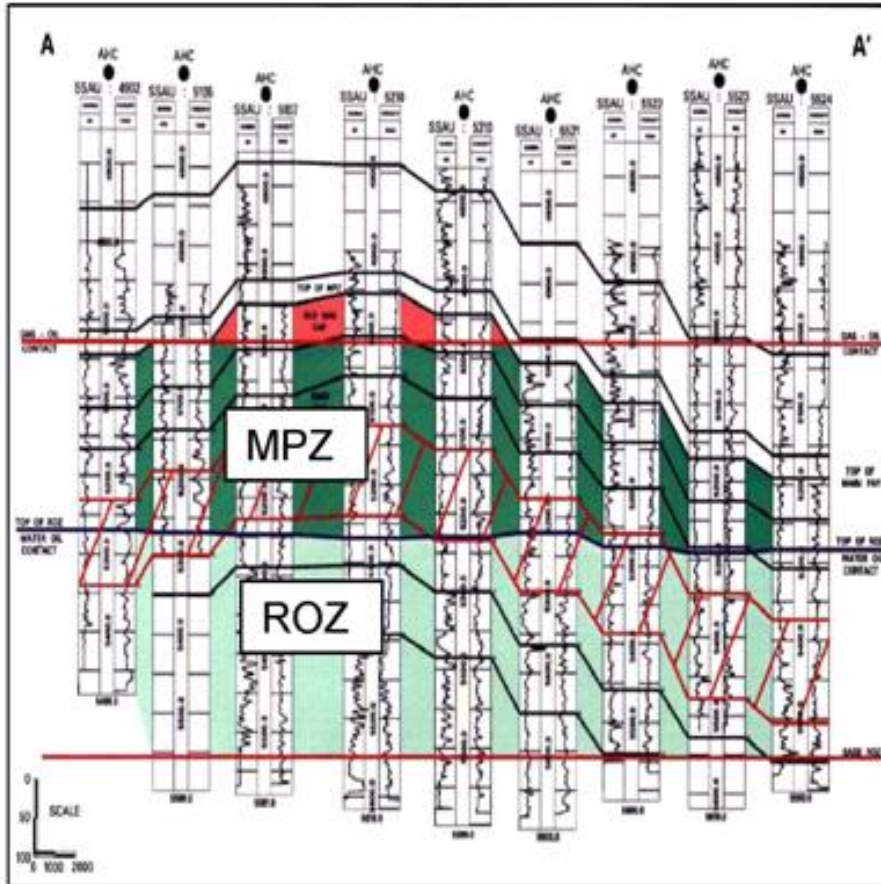
Producing  
ROZ's



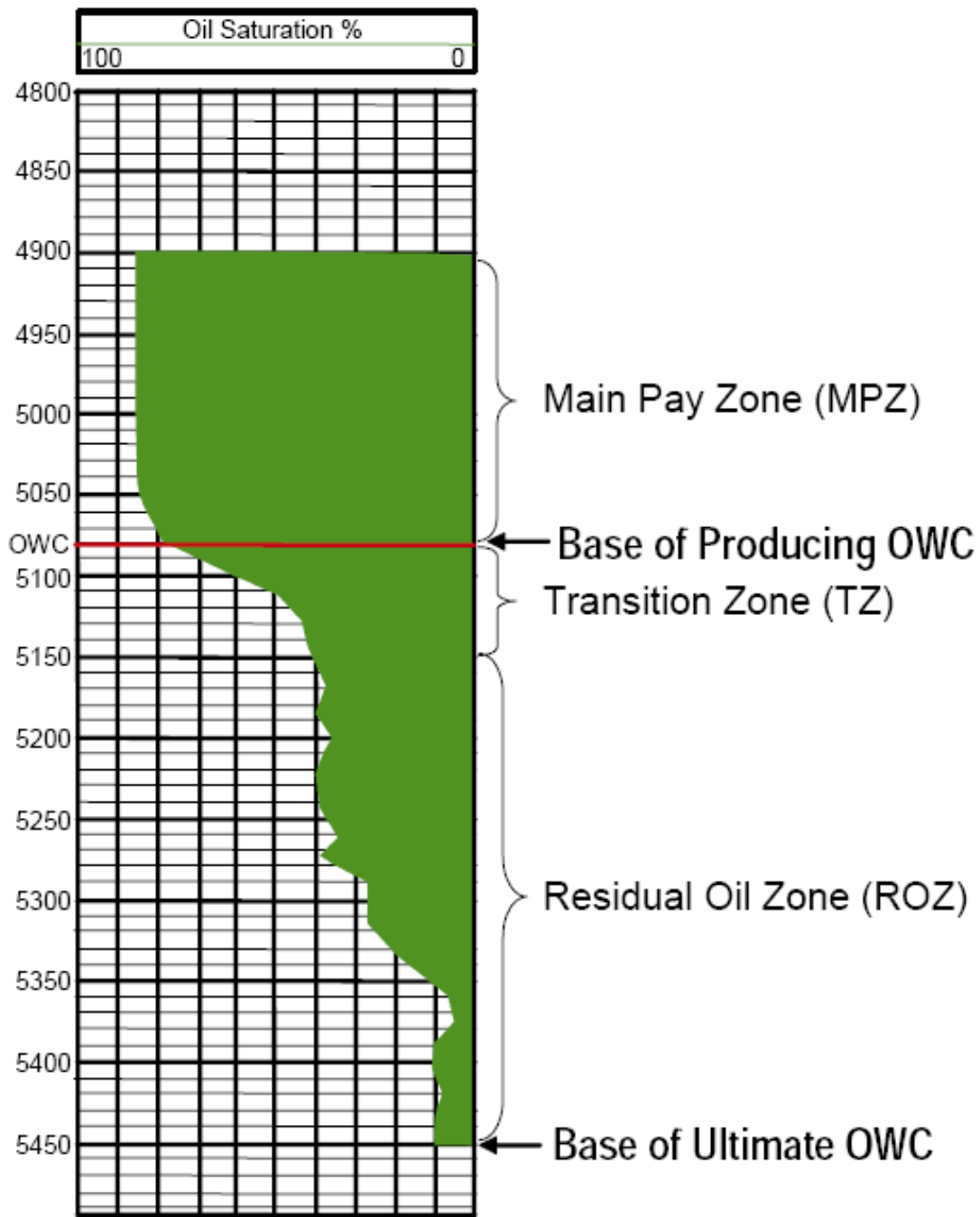
# Seminole San Andres Unit SSAU Structure Map & Cross Section



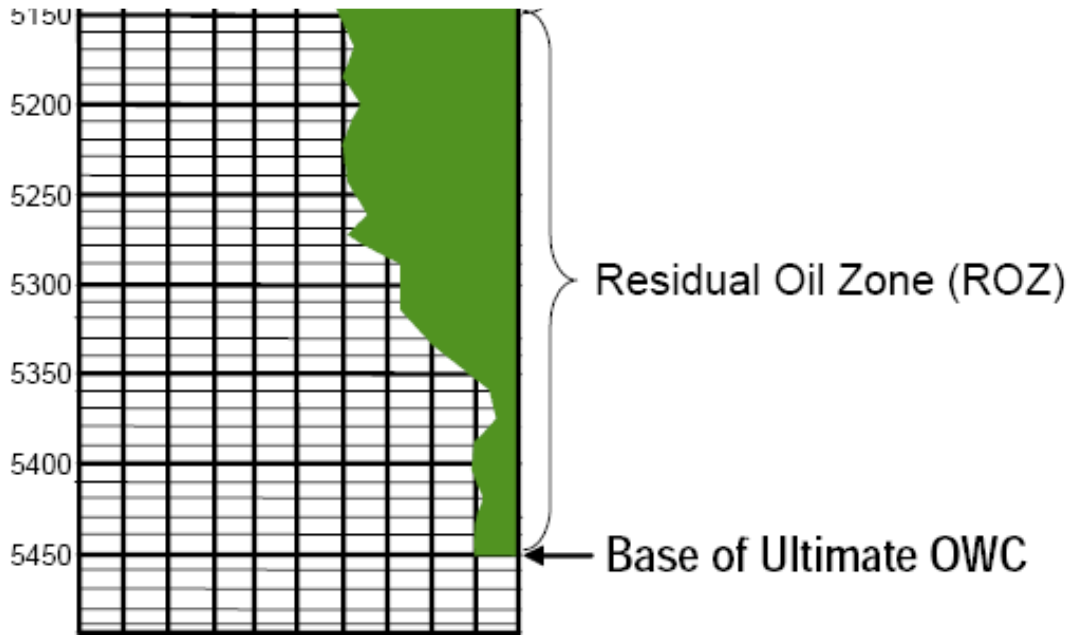
	<u>Net Thickness</u>	<u>Average Permeability</u>	<u>Initial Oil Saturation</u>
Main Pay Zone (MPZ):	126'	9 md	84%
Residual Oil Zone (ROZ):	213'	12 md	32%



**What happens  
 when the entire  
 oil column is  
 swept by Mother  
 Nature?**

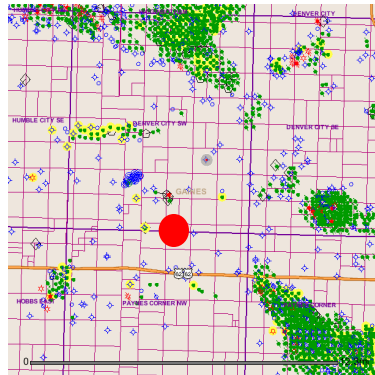
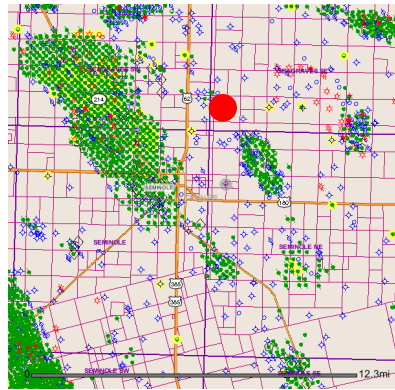


**Your left with a  
tertiary recovery  
target.**



# 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 sample 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.



# Anecdotal Evidence

- The anecdotal evidence from a growing number of exploration wells documents examples of what can be interpreted as ROZ's where the tests were unsuccessful as there was no associated primary production. From discussions with a number of explorationists and review and reinterpretation of research articles on Permian Basin fields, a set of common ROZ characteristics is developing:
  - The presence of sulfur crystals associated with gypsum in the swept carbonates,
  - Evaporites may be dissolved or altered in the lower part of the main pay.
  - Enhanced porosity and permeability developed as the result of meteoric dissolution of sulfates in the ROZ
  - Sample shows of oil and/or gas,
  - Sulfur water produced on DST's or attempted production tests not salt water,
  - Core with 20-40% oil saturation,
  - Log calculations that suggest producible hydrocarbons.
  - Porosities and Permeabilities can be higher in the ROZ than in the main pay zone as a result of the meteoric dissolution.
  - Pervasive "late" dolomitization may indicate meteoric sweep.

4 Miles

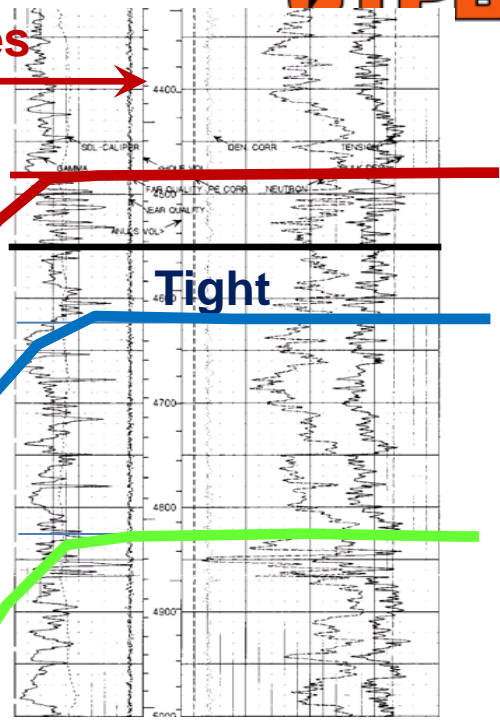
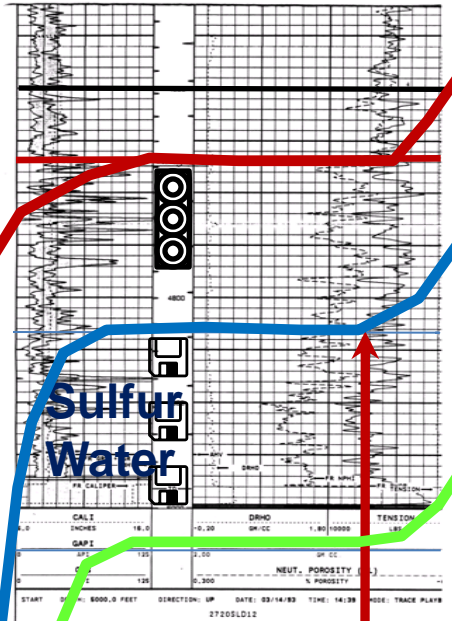
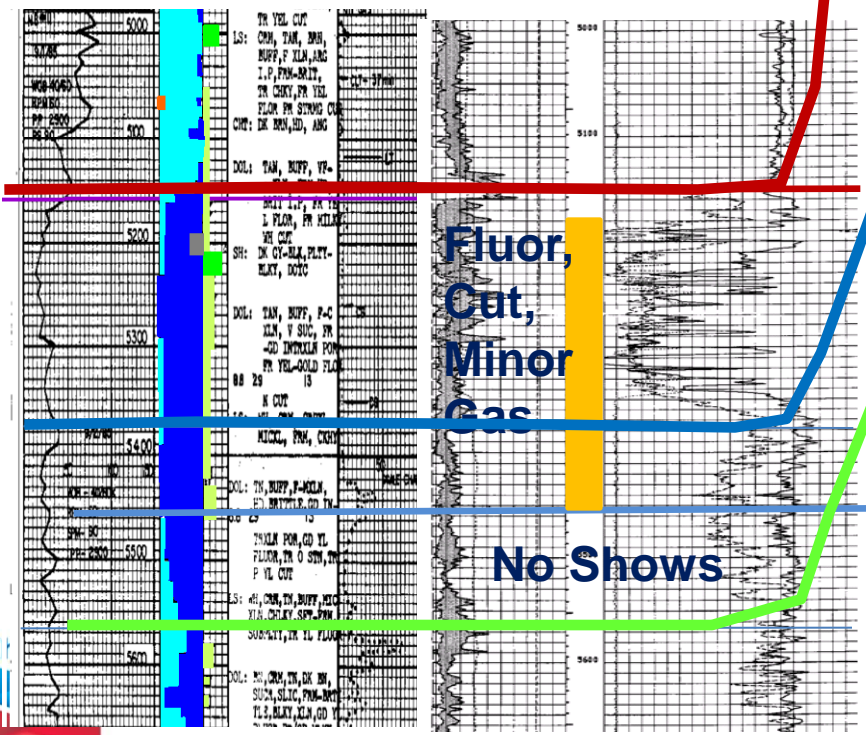
Production

3 Miles

**Large ROZ/CCS Targets.**

ROZ's maybe significantly larger than the existing field. In this case, there maybe CO2 flood potential up to 4 miles beyond the limit of the field, and 550' below the existing perfs.

Who owns the ROZ? CCS Target?



ROZ Maximum 550' !

Base ROZ ?

