Residual Oil Zones:
Oil Production and CO2 Sequestration Target

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UTPB/CEED

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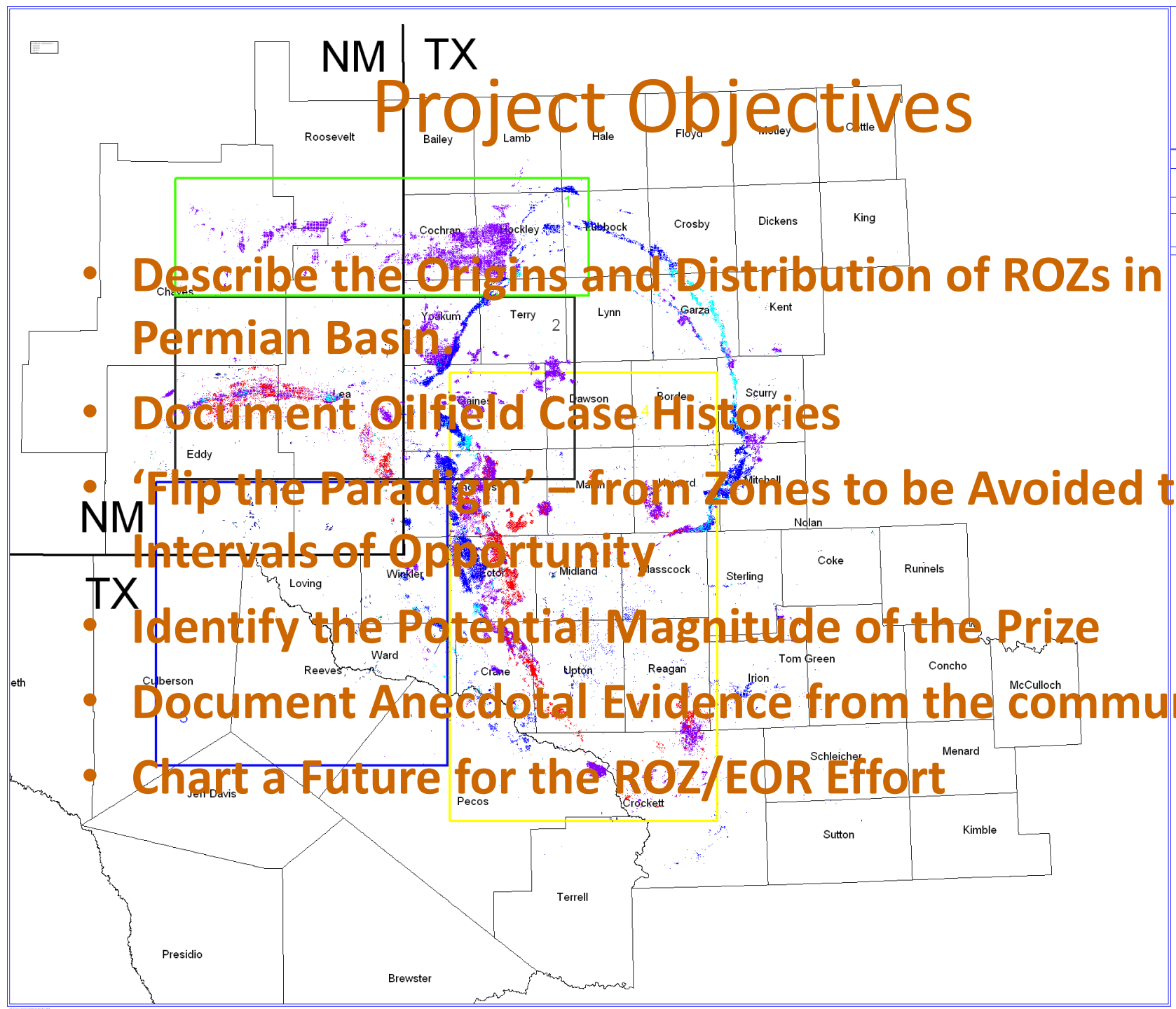
Sul Ross State University

Geology Club

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.
- ROZ's have historically been interpreted as being long Transition Zones. Although the upper portions of TZ's/ROZ's have long been assumed to contribute to production in some fields, until recently their potential as a CO2 recovery target has not been exploited.
- Development wells, scheduled to test deeper horizons, have often been drilled through zones with good shows in samples, porosity and oil saturation in core, and where the zones are calculated to be oil productive. These wells, however, have a poor record of successful completions.



Project Objectives

- Describe the Origins and Distribution of ROZs in the Permian Basin.
- Document Oilfield Case Histories
- ‘Flip the Paradigm’ – from Zones to be Avoided to Intervals of Opportunity
- Identify the Potential Magnitude of the Prize
- Document Anecdotal Evidence from the community
- Chart a Future for the ROZ/EOR Effort

Thanks go to….

- Steve Melzer
- Arcadis - David Vance, Steve Tischer
- Phil Eager, Edith Stanton, Saswati Chakraborty
- Chevron
- Legado
- George Koperna, Advanced Resources International
- Hoxie Smith
- All those who have battled with ROZ's in the past.

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 EstimatingTechnically Recoverable ROZ Oil – MPZ and TZ/ROZ Oil in Place

Advanced Resources International, Inc.

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 CO2-EOR Projects	No. of Fields with TZ/ROZ CO_2-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
Total	**33.5**	**30.7**	**56**	**18**	**4**

Technically Recoverable Resources from the MPZ and ROZ

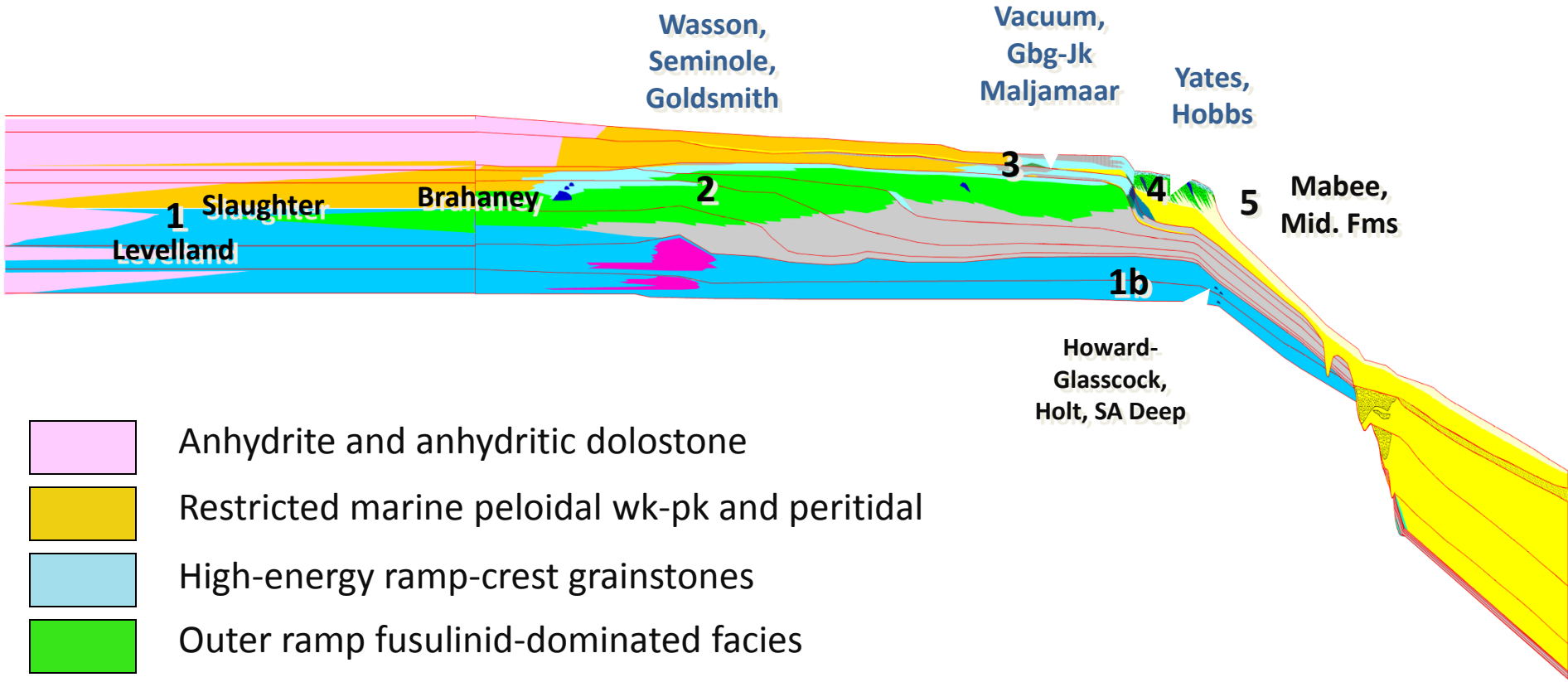
Advanced Resources International, Inc.

Based on reservoir modeling of applying CO_2-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_2-EOR (BB)	MPZ CO_2-EOR (BB)	TZ/ROZ CO_2-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
Total	18.8	6.9	11.9

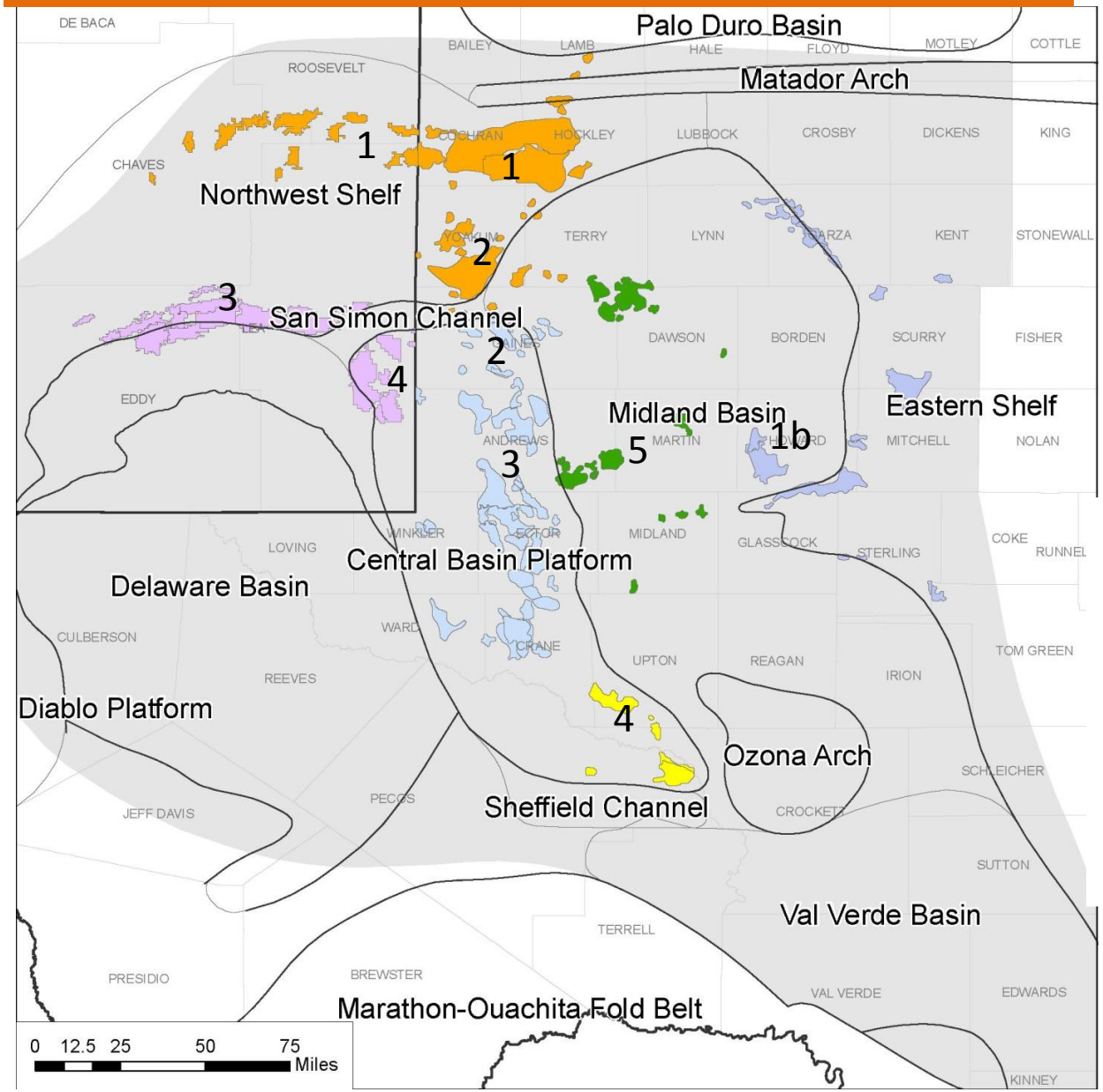
San Andres Reservoir Settings.
All fields are not alike.



- Anhydrite and anhydritic dolostone
- Restricted marine peloidal wk-pk and peritidal
- High-energy ramp-crest grainstones
- Outer ramp fusulinid-dominated facies
- Open marine limestones and dolostones, L7-8
- Deeper-water mudstones (Cutoff)

C. Kerans, Bureau of Economic Geology, PGGSP Annual Meeting,
2/27-8/06, Austin, TX

There are many large San Andres reservoirs with potential for ROZ EOR development



Classification of San Andres Reservoirs on basis of Stratigraphic Setting

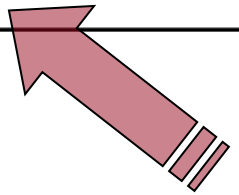
- nw_sanandres_carbonate_nm
- nw_sanandres_carbonate_tx
- upper_sanandres_central_nm
- upper_sanandres_artesia_nm
- e_sanandres_carbonate_tx
- sanandres_grayburg_tx
- sanandres_carbonate_tx
- sanandres_karst_tx

1. L7-8-G1-2 interc. dolo-evap
1b. L7-L8, G1? Open shelf and buildups
2. Cyclic G1-4
3. Stacked G8-9 and Gbg G10
4. Karst-modified, anhydrite-free G8-9
5. Oolitic Grayburg lowstand G10

Permian Basin Plays, Dutton et al (2005)

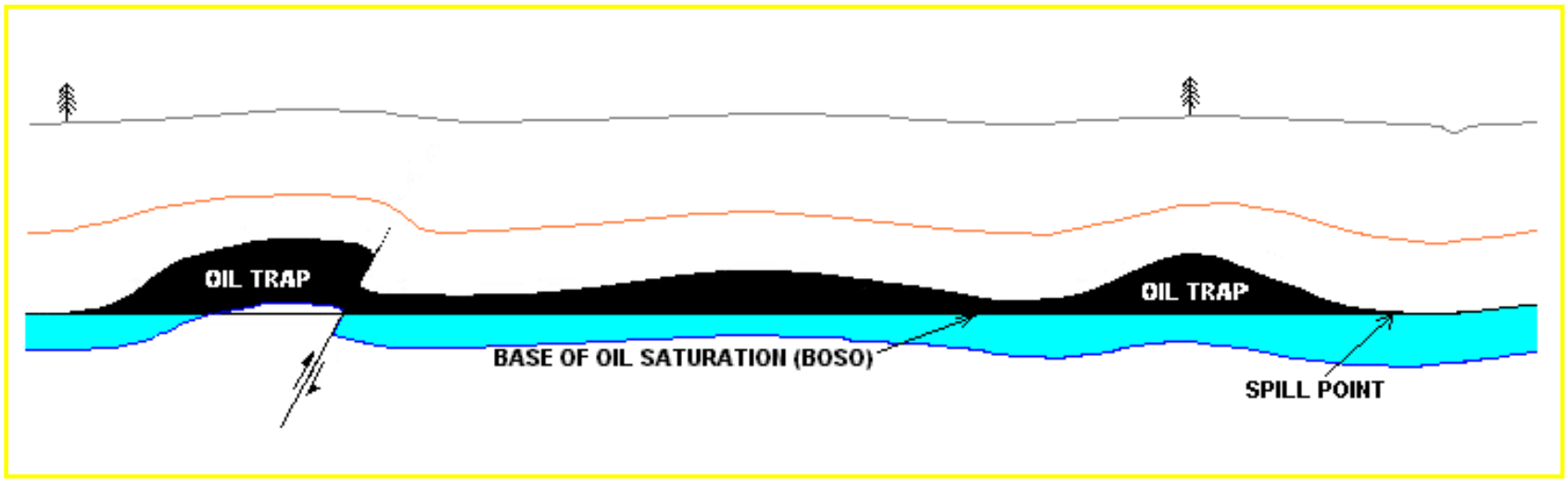
ROZ BACKGROUND
The 3 types of Residual Oil Zones

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)

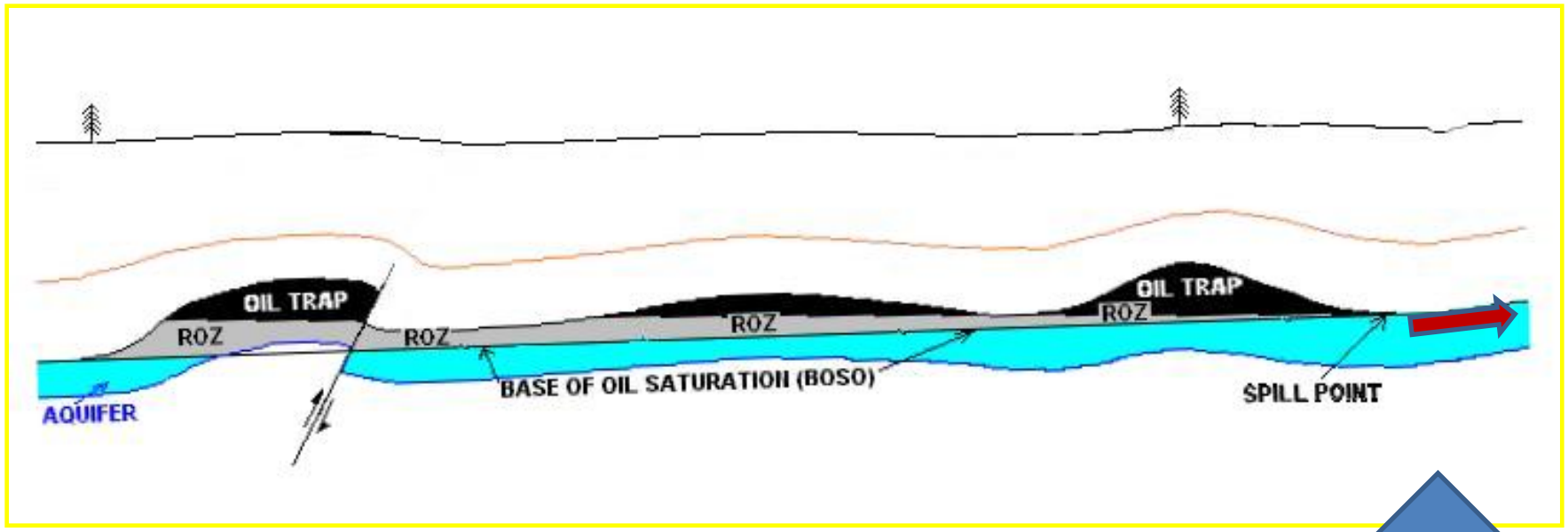


The Evidence suggests Type 3 are common in the Permian Basin

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

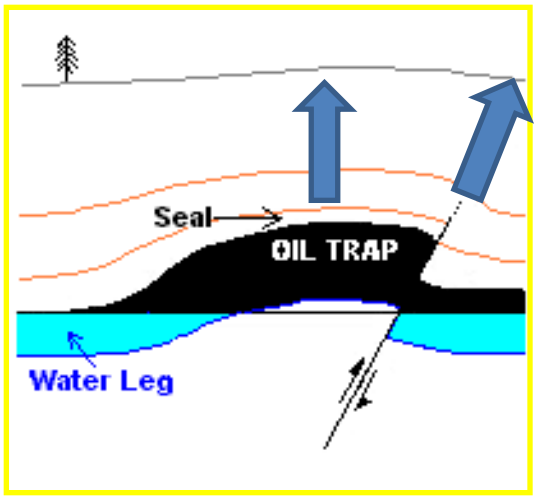


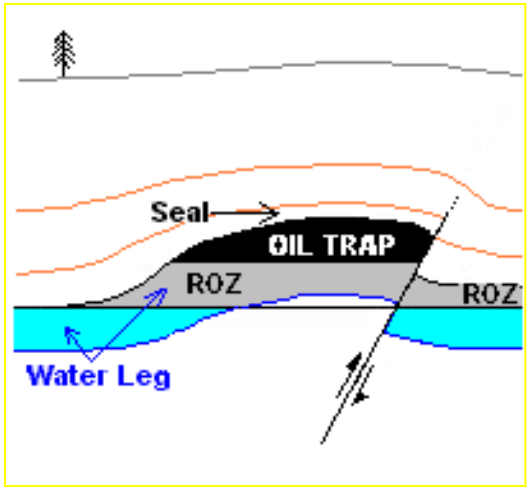
TYPE 1. Original Accumulation Subject to a Eastward Regional Tilt & Forming a ROZ.
The new O/W contact is horizontal
The base of the ROZ is tilted
Oil would have migrated out of the basin.



Static System

TYPE 2. Original Accumulation with a Breached, then Repaired, Seal, forming a ROZ/TZ.
A horizontal O/W contact on the main pay and the ROZ.
May also “de-gas” the reservoir.
Present in the Permian Basin.



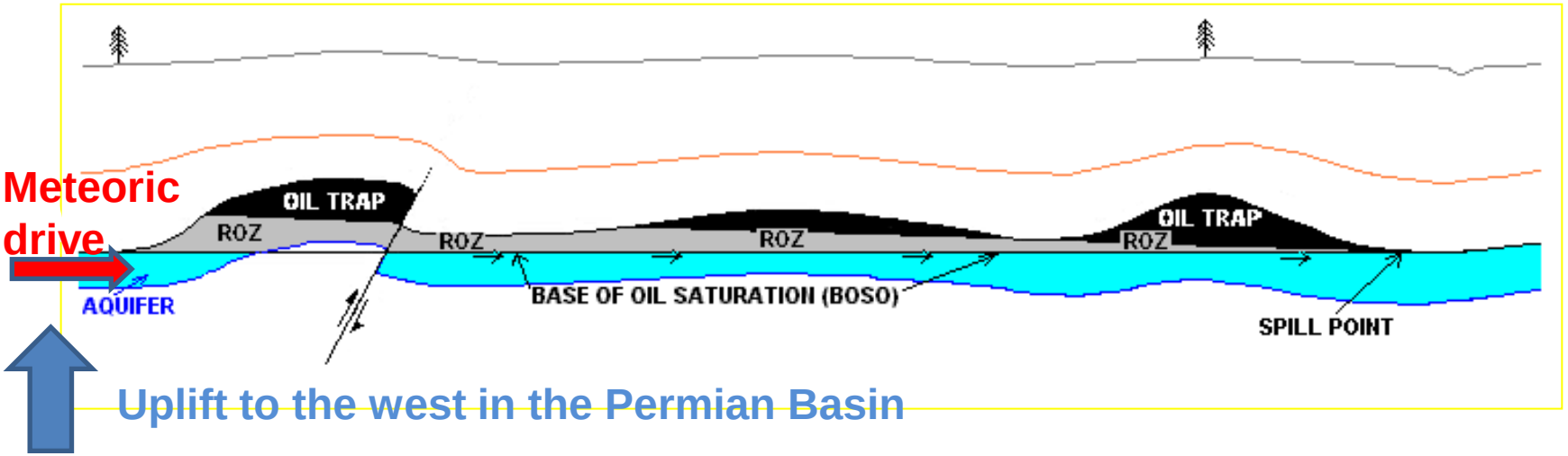


Static System

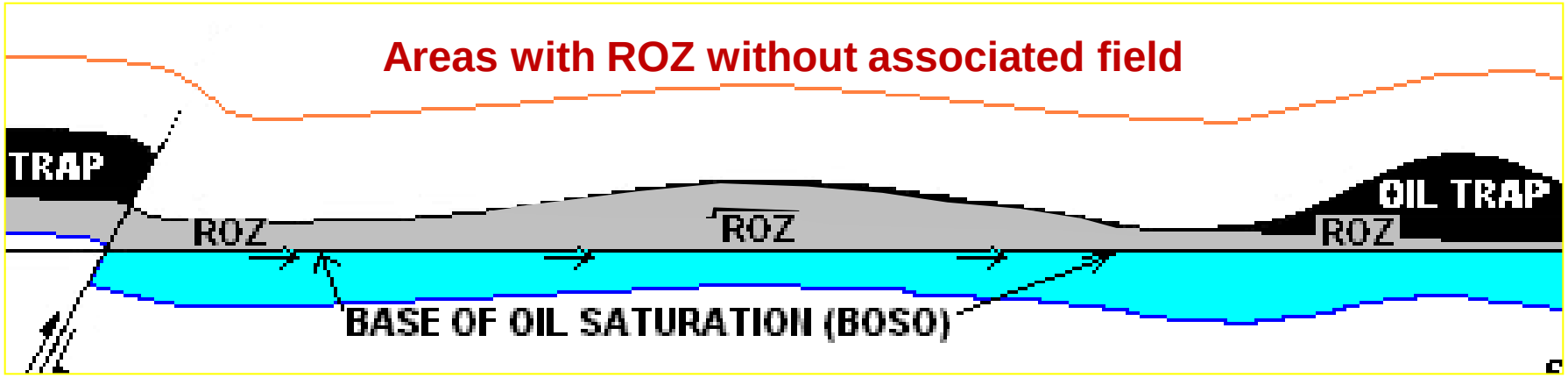
TYPE 3. Change in Hydrodynamic Conditions, Sweep of the lower part of the Oil Column and Development of a Residual Oil Zone.

Oil/Water Contact is Tilted

Base of the ROZ locally almost flat, regionally tilted.



Dynamic System



“Mother Natures Waterfloods” are a result of post oil emplacement tectonics and Hydrodynamic Tilt

ROZ TYPE	Oil-Water Contact	Base of Oil Saturation	Other Characteristics
Regional Tilt (1)	Horizontal	Tilted	Wedge with thin side Downdip
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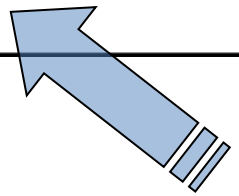


Let’s Look at the evidence

“Common Knowledge”

- Where there are tight rocks beneath the oil/water contact, there are longer Transition Zones.
- At the base of these fields, the TZs extend to the Base Of Saturation of Oil (BOSO).
- Some contribution to production can be expected from the uppermost Transition Zone.
- Residual Oil Zones are no different than Transition Zones. It’s just semantics.
- There are two periods of oil migration (post-Permian & Cretaceous/Tertiary) commonly proposed for Permian fields in the basin.
- There is a late (Cretaceous) tectonism that “adjusts structure” and created larger closures and reset oil/water contacts.
- Pathway of dolomitizing fluids is perpendicular to the shelf margin and
- Oil was flushed out of the crest of structures down dip into the basin and back.

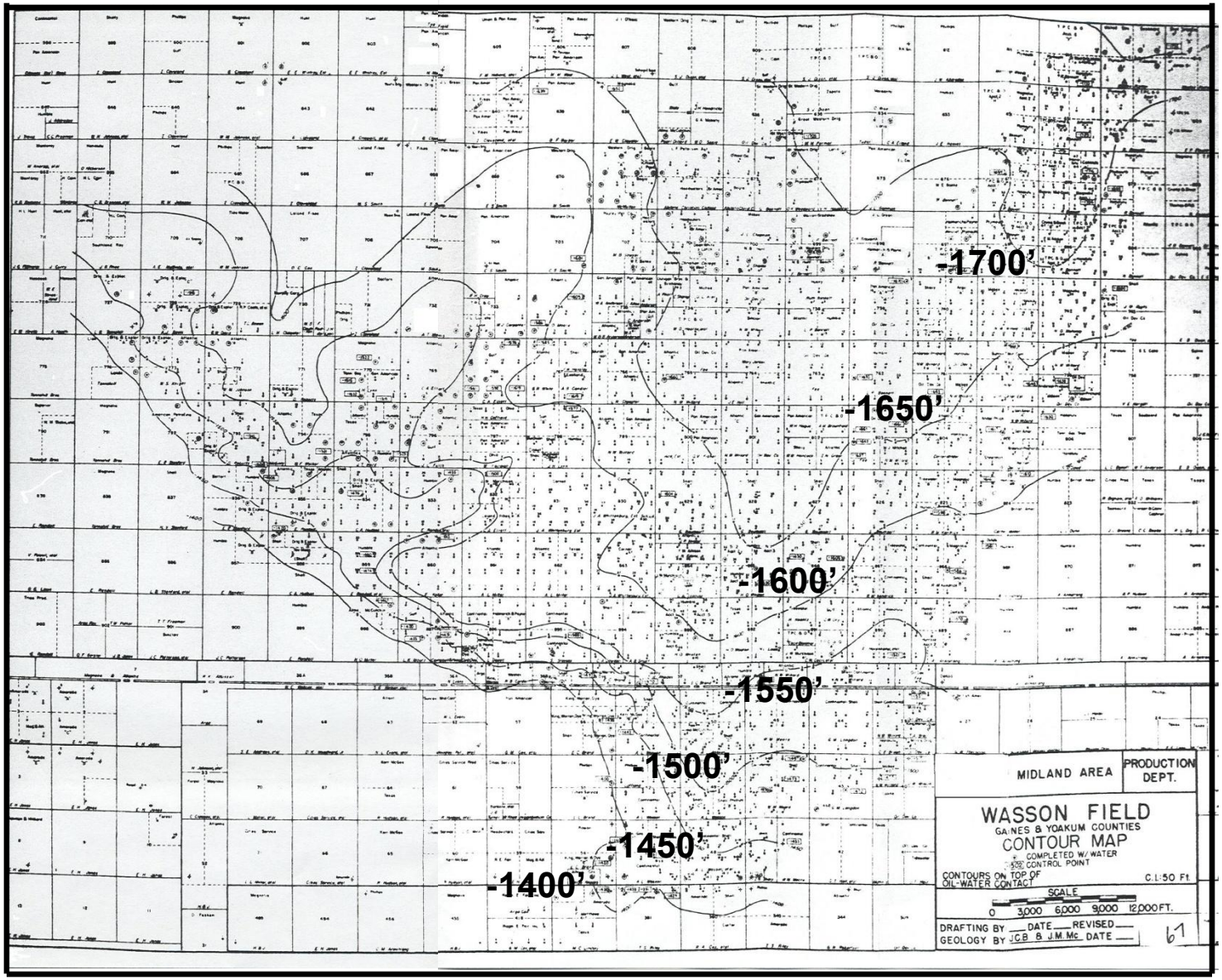
The new Residual Oil Zone Paradigms

- Large intervals and areas have been swept by “Mother Natures Waterflood” which occurred post/syn oil emplacement.
- ROZ’s have the same saturation characteristics as mature waterfloods in the swept intervals.
- ROZ’s often are interpreted/calculated as producible in Exploration Wells, and Primary and Secondary Production Environments:
  - Good Odor, Cut, Fluorescence, and Gas in samples
  - 20 -40 % oil saturations in core
  - Calculate as oil productive on logs
- ROZ’s produce high percentage of water on DST’s or completions, but not a “deal killer”.
- ROZ’s originally there intervals were there were significant thicknesses (50 to 300’) of producible hydrocarbons in producing fields AND outside the present limits of producing fields.
- This “faux-productive” appearance of ROZ’s is presently found both beneath producing fields and in areas where there is no, or a minimum, producible oil column.

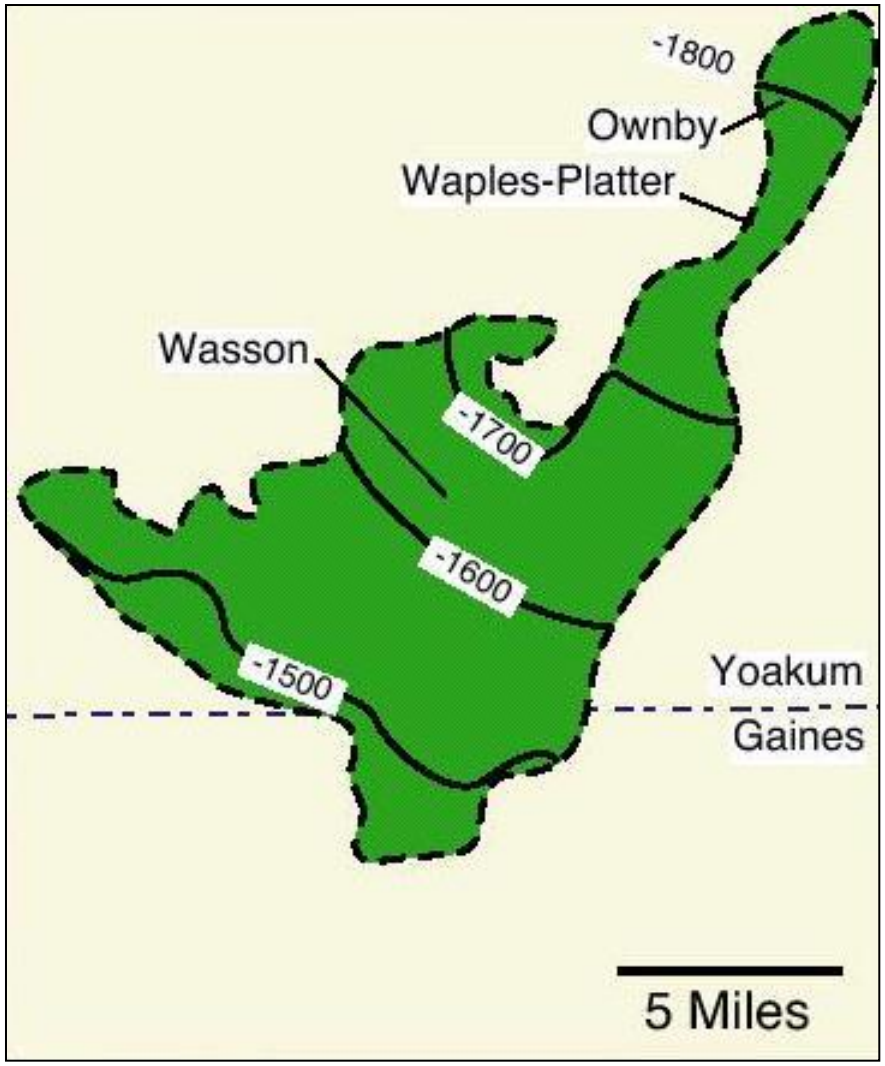
How did we get here?
Alton Brown and Bob Lindsay

- **Alton Brown** documented the effects of hydrodynamics on Cenozoic oil migration in the Wasson area and elsewhere on the Northwest Shelf.
- Using available data, Alton proposed hydrodynamics as a more reasonable mechanism for the Wasson OWC tilt than capillary effects. And that the hydrodynamic charge model also explains that the ROZ is a relict from previous hydrostatic trapping conditions.
- He documented the tilting of OWC in a number of field on the Northwest Shelf and Central Basin Platform.

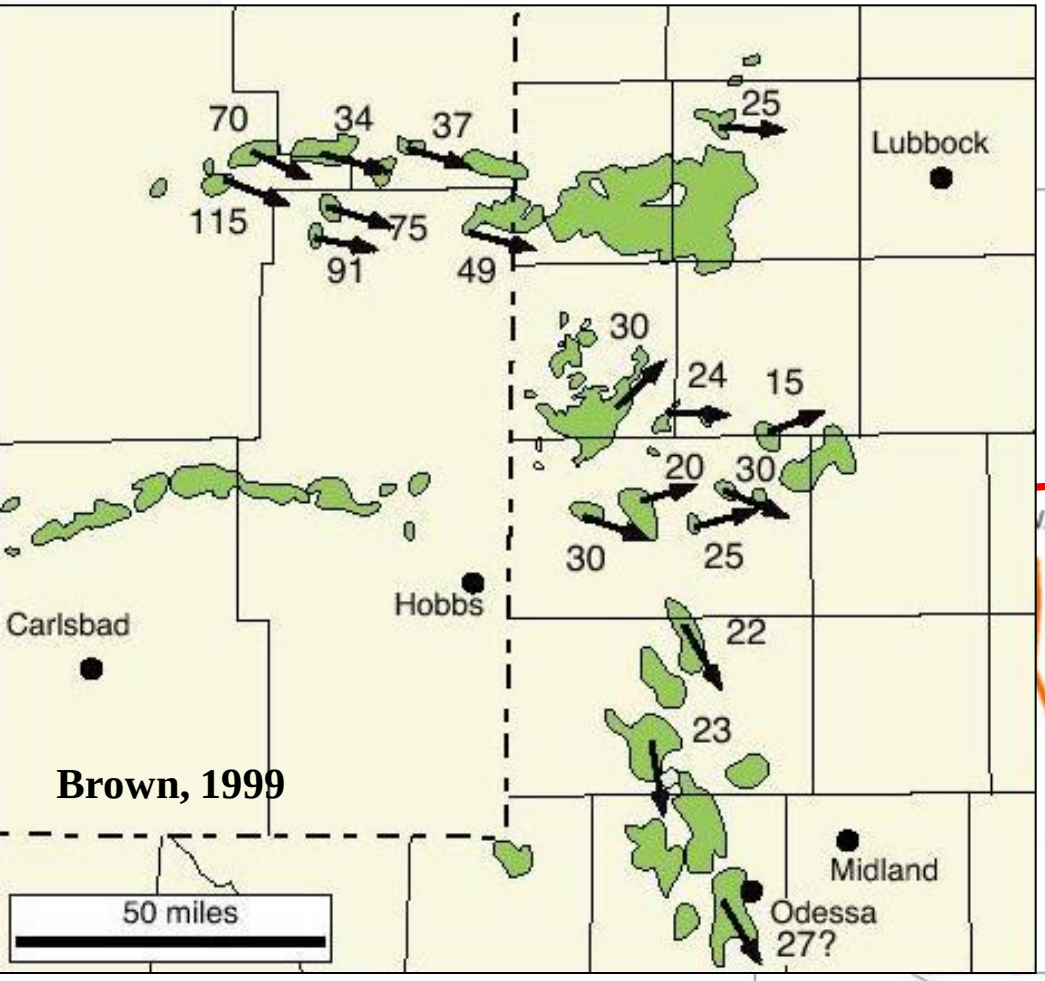
Wasson Field Oil-Water Contact Contour Map – Texas RR Commission Filing, October 1964

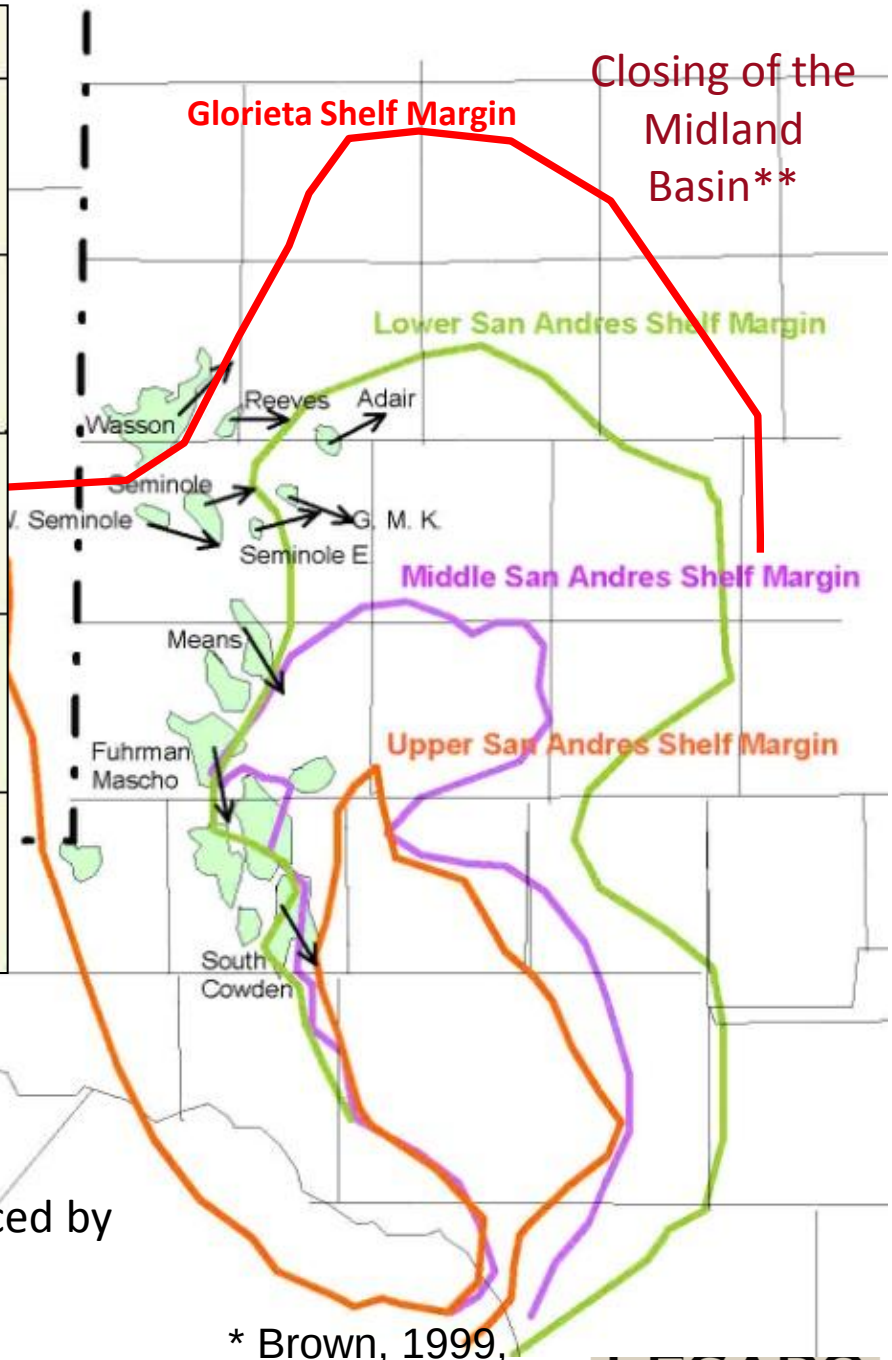


Wasson Field Area O/W Contact Structural Contours*



* From Ref 6





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 it's relationship to the shelf margin

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

Melzer COnsulting

Chevron

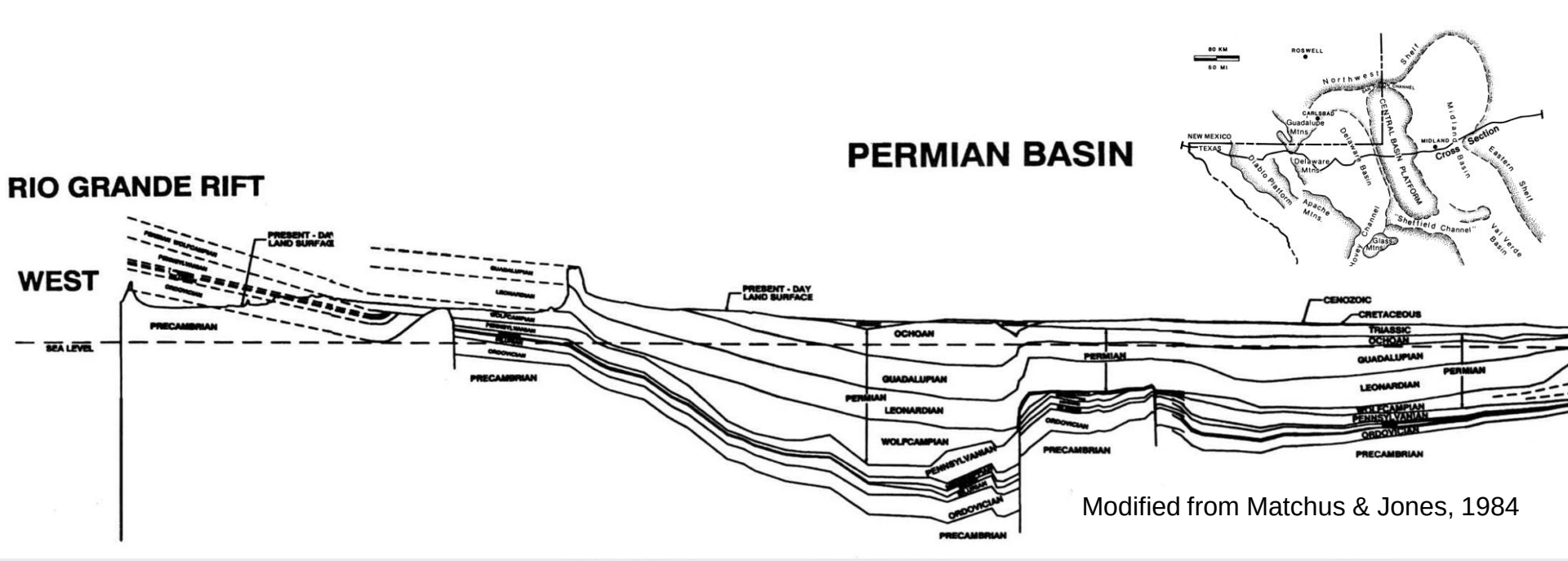
LEGADO resources

Tilted Oil Water Contacts

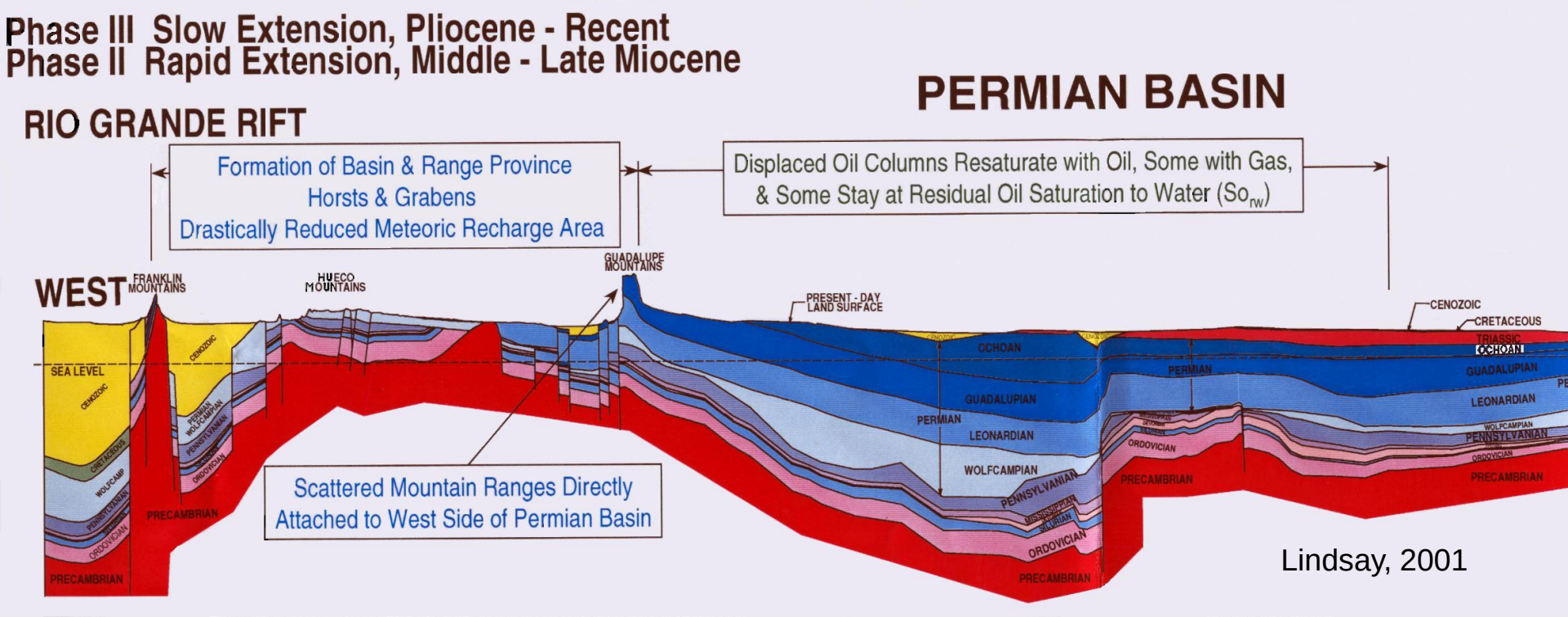
- New Axiom – " If you have a tilted oil/water contact in the San Andres, you have a ROZ.
- If you have an ROZ…….find a contract for CO_2.

How did we get here?
Alton Brown and Bob Lindsay

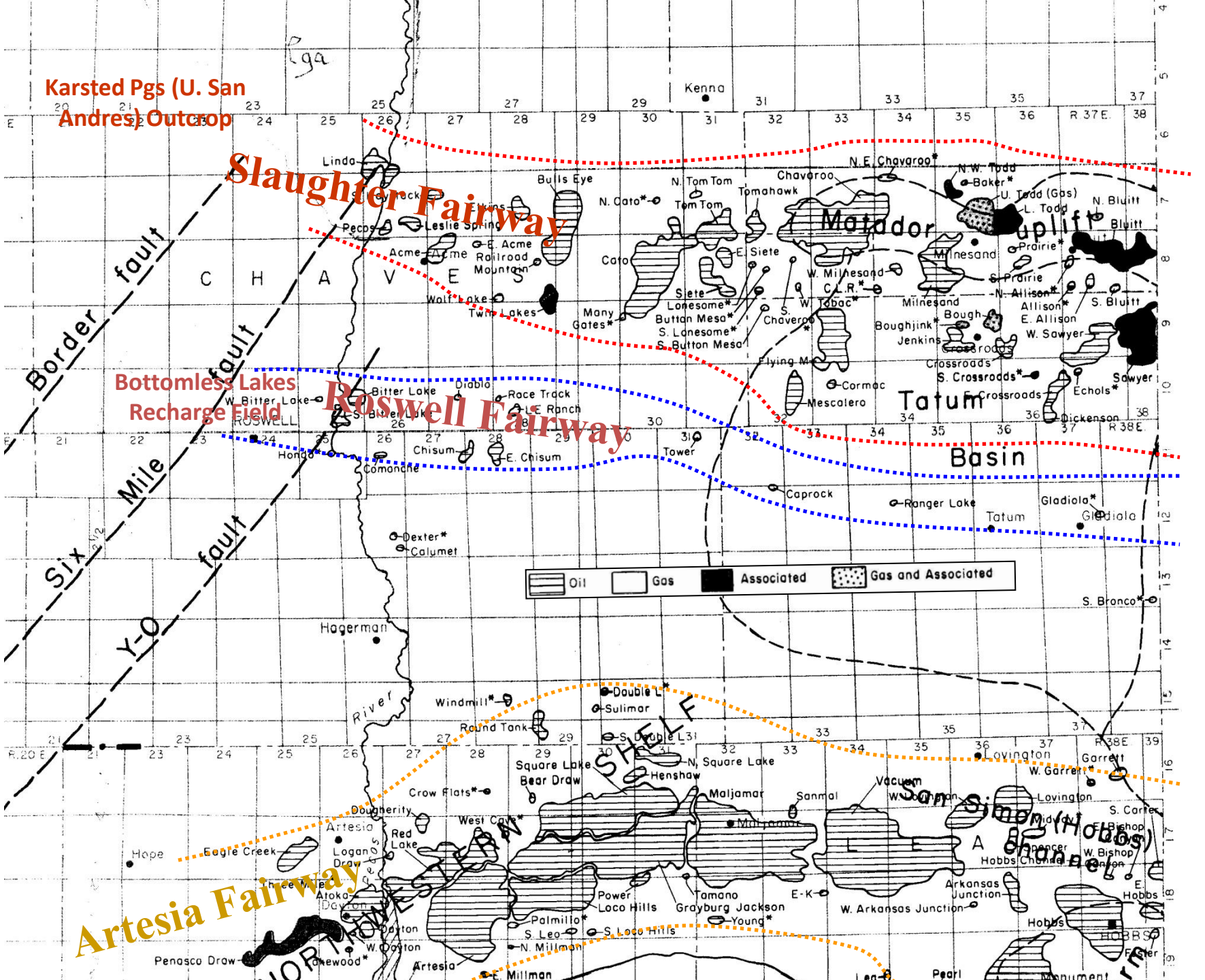
- **Bob Lindsay**, while at Chevron, looked at outcrop-core-production relationships, documented meteoric sweep and the development of Residual Oil Columns in a number of fields on the Central Basin Platform.
- He envisioned massive recharge of meteoric waters into the subsurface during the Mid to Late Tertiary as a result of the uplift in the Rio Grande Rift area. The oil was swept out of the crest of the structures and down dip into the flanks.
- The later extensional development of the Basin and Range structures reduced the “hydraulic head”. Some oil was left behind on the downdip flanks, and the meteoric waters introduced “bugs” which reduced the volume of oil.
- Following the reduction in head, and the enhancement of structure, new oil/water contacts were established in the fields with significant thicknesses of partially oil saturated reservoir now below the oil/water contact.

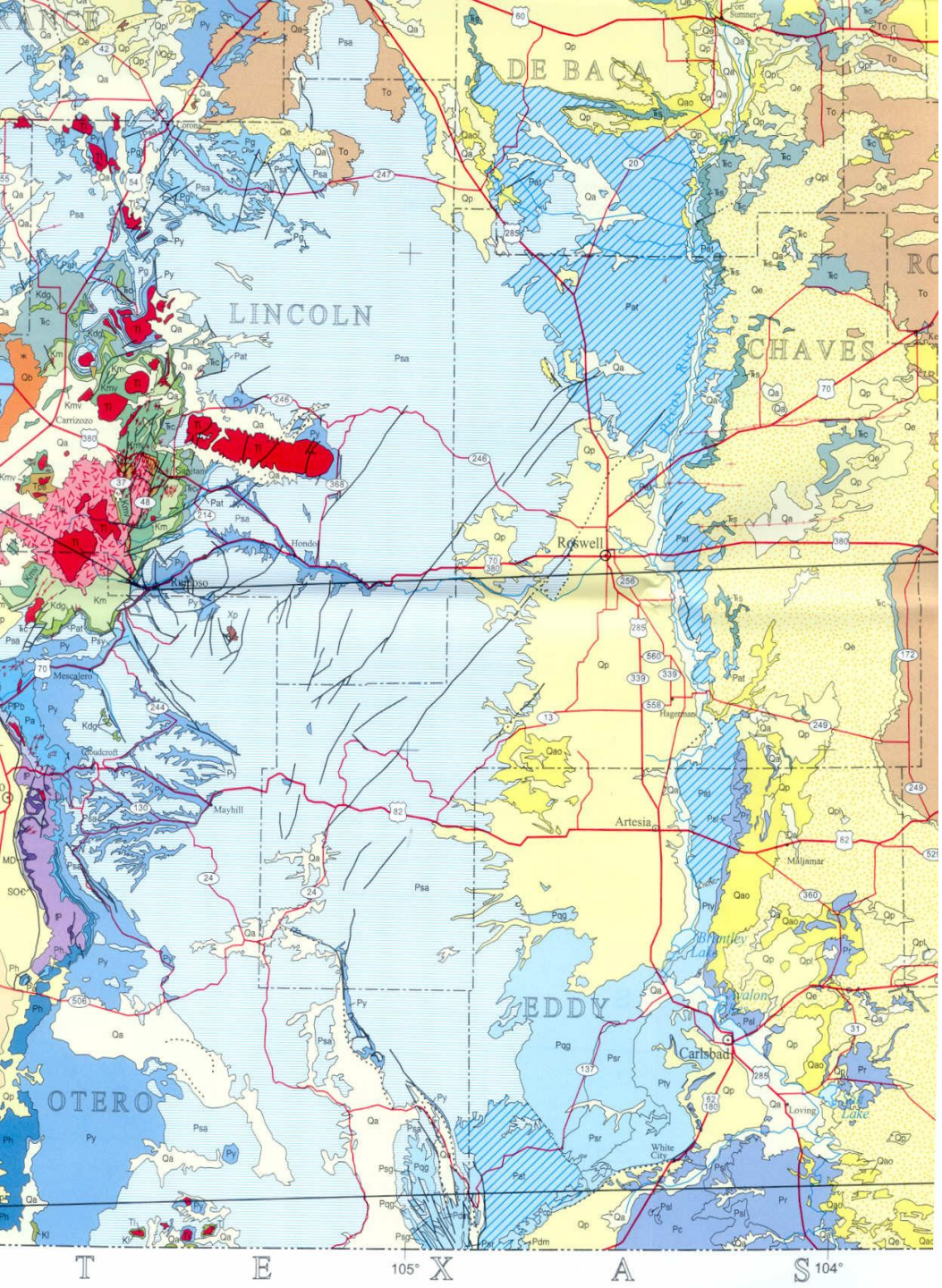


Modified from Matchus & Jones, 1984

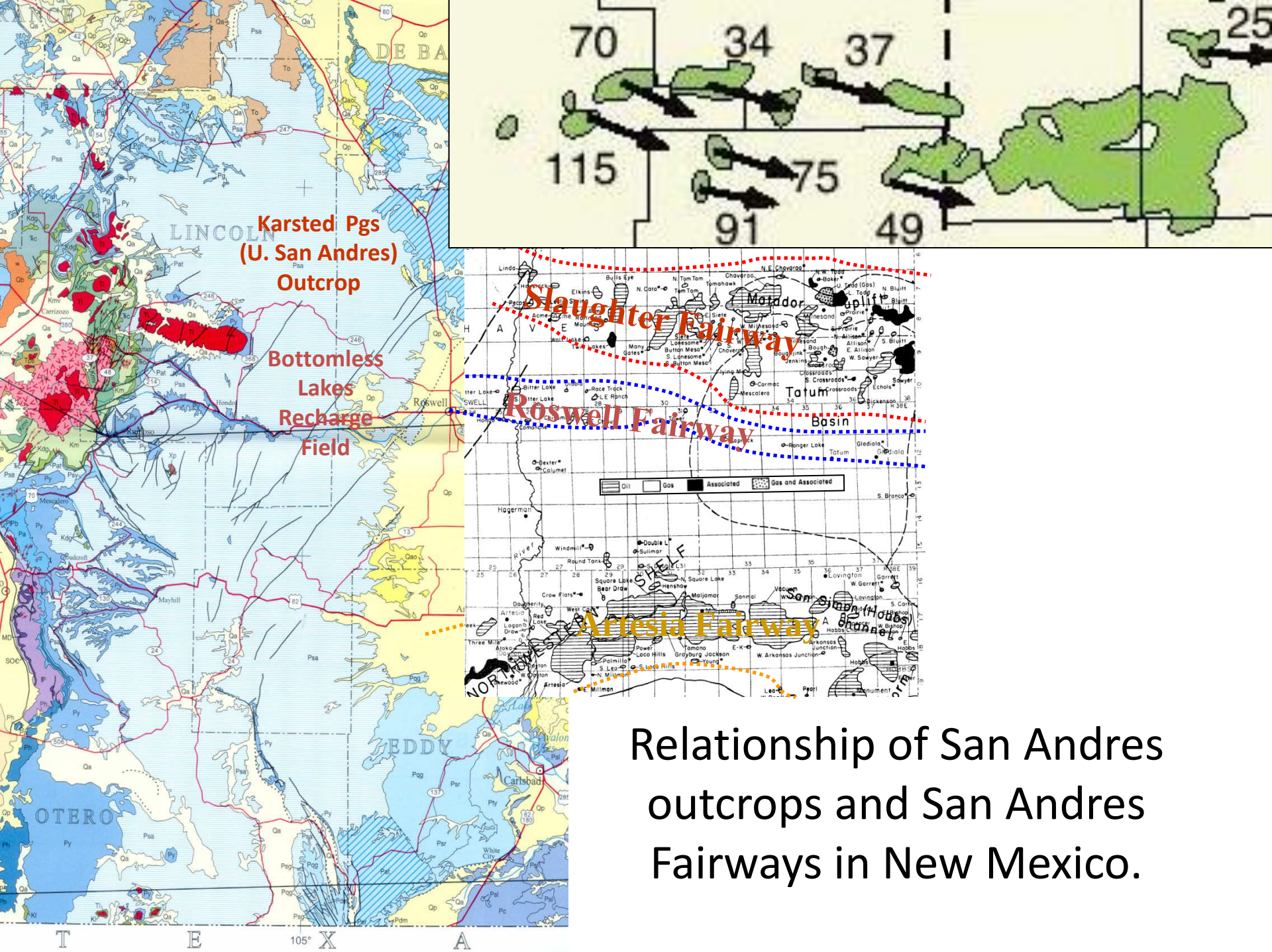


Lindsay, 2001


Karsted Pgs (U. San Andres) Outcrop
Slaughter Fairway
Bottomless Lakes Recharge Field
Roswell Fairway
Artesia Fairway
Border fault
Six Mile fault
Y-O fault
CHAVES
Kenna
Linda
Bulls Eye
Pecos
Leslie Spring
Acme
E. Acme
Railroad Mountain
Wolf Lake
Twin Lakes
N. Tom Tom
Tom Tom
N. Cato*
Tomahawk
Chaveroo
N.E. Chaveroo*
N.W. Todd
Baker*
U. Todd (Gas)
L. Todd
N. Bluitt
Bluitt
Prairie*
Milnesand
Cato
E. Siete
W. Milnesand
C.L.R.*
S. Prairie
N. Allison*
Allison*
S. Bluitt
E. Allison
W. Sawyer
Siete
Lonesome*
Button Mesa*
S. Lonesome*
S. Button Mesa
Many Gates*
S. W. Tobac*
S. Chaveroo*
Boughjink*
Jenkins
Bough
Crossroads
S. Crossroads*
E. Crossroads
Flying M
Cormac
Mescalero
Tatum
Sawyer
Echols*
Dickenson
Basin
Bitter Lake
W. Bitter Lake
S. Bitter Lake
Diablo
Race Track
L.E. Ranch
ROSWELL
Hondo
Chisum
E. Chisum
Comanche
Tower
Caprock
Ranger Lake
Gladiola*
Gladiola
Dexter*
Calumet
Oil
Gas
Associated
Gas and Associated
S. Bronco*
Hagerman
Windmill*
Double L*
Sulimar
S. Double L
Round Tank
River
SHELF
Square Lake
Bear Draw
N. Square Lake
Henshaw
Crow Flats*
Maljamar
Sanmal
Vacuum
W. Vacuum
Lovington
W. Garrett
Garrett
S. Carter
Dougherty
Artesia
Red Lake
West Cave*
Hope
Eagle Creek
Logan Draw
Three Wells
Atoka
Dayton
Penasco Draw
Lakewood*
Power
Loco Hills
Tamano
Grayburg Jackson
Young*
E-K
Palmillo*
S. Leo
S. Loco Hills
N. Millman
E. Millman
Arkansas Junction
W. Arkansas Junction
Hobbs
HOBBS
Pearl
Monument
Foster
San Simon (Hobbs) Channel
NORTHWESTERN



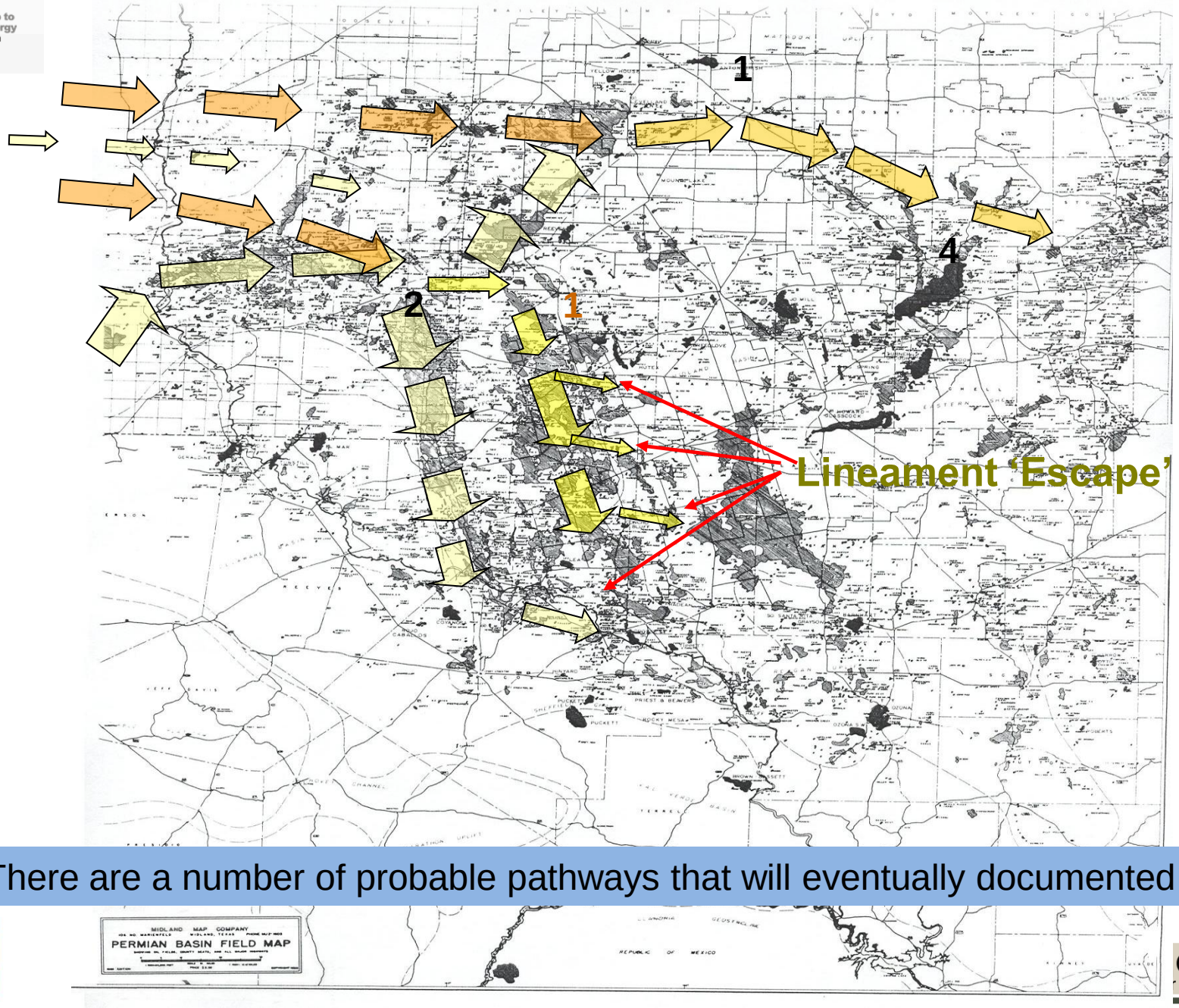
San Andres outcrop (light Blue) is the present day extent of the recharge area for the meteoric water that sustains the tilted oil water contacts in San Andres reservoirs.



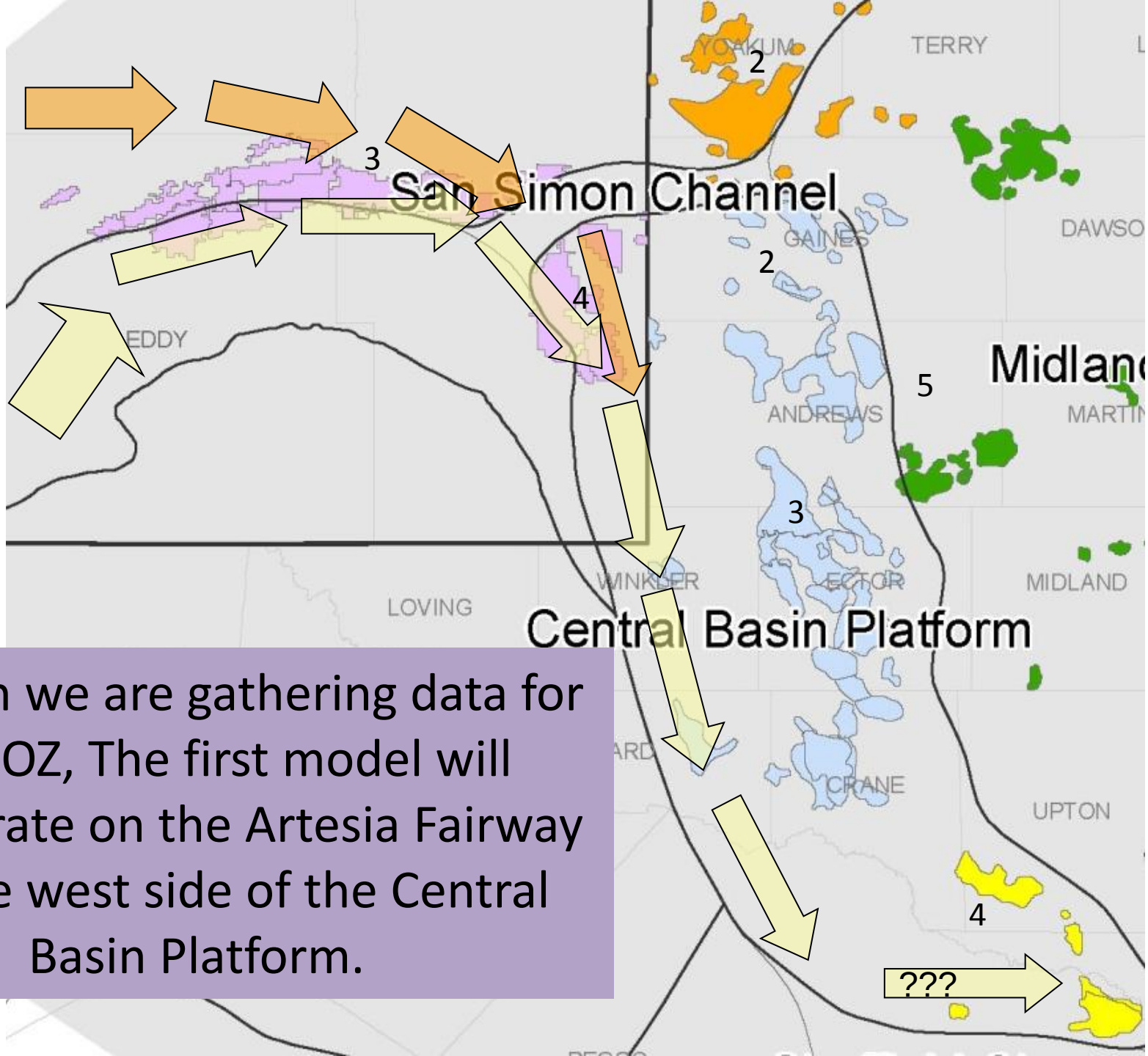
Relationship of San Andres outcrops and San Andres Fairways in New Mexico.

PERMIAN BASIN FIELD MAP

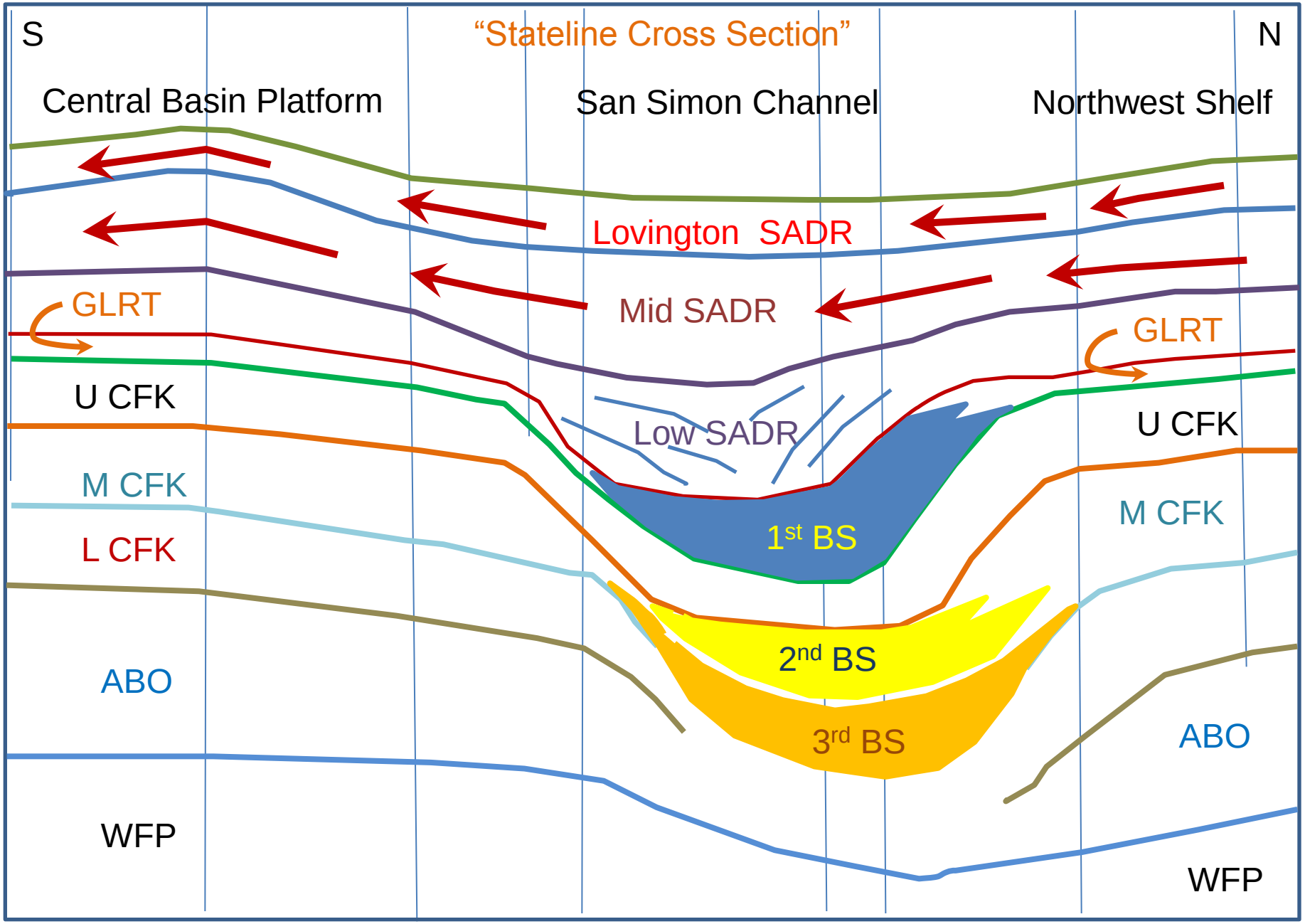
WITH THEORIZED (U. PERMIAN) HYDRODYNAMIC FAIRWAYS



There are a number of probable pathways that will eventually documented



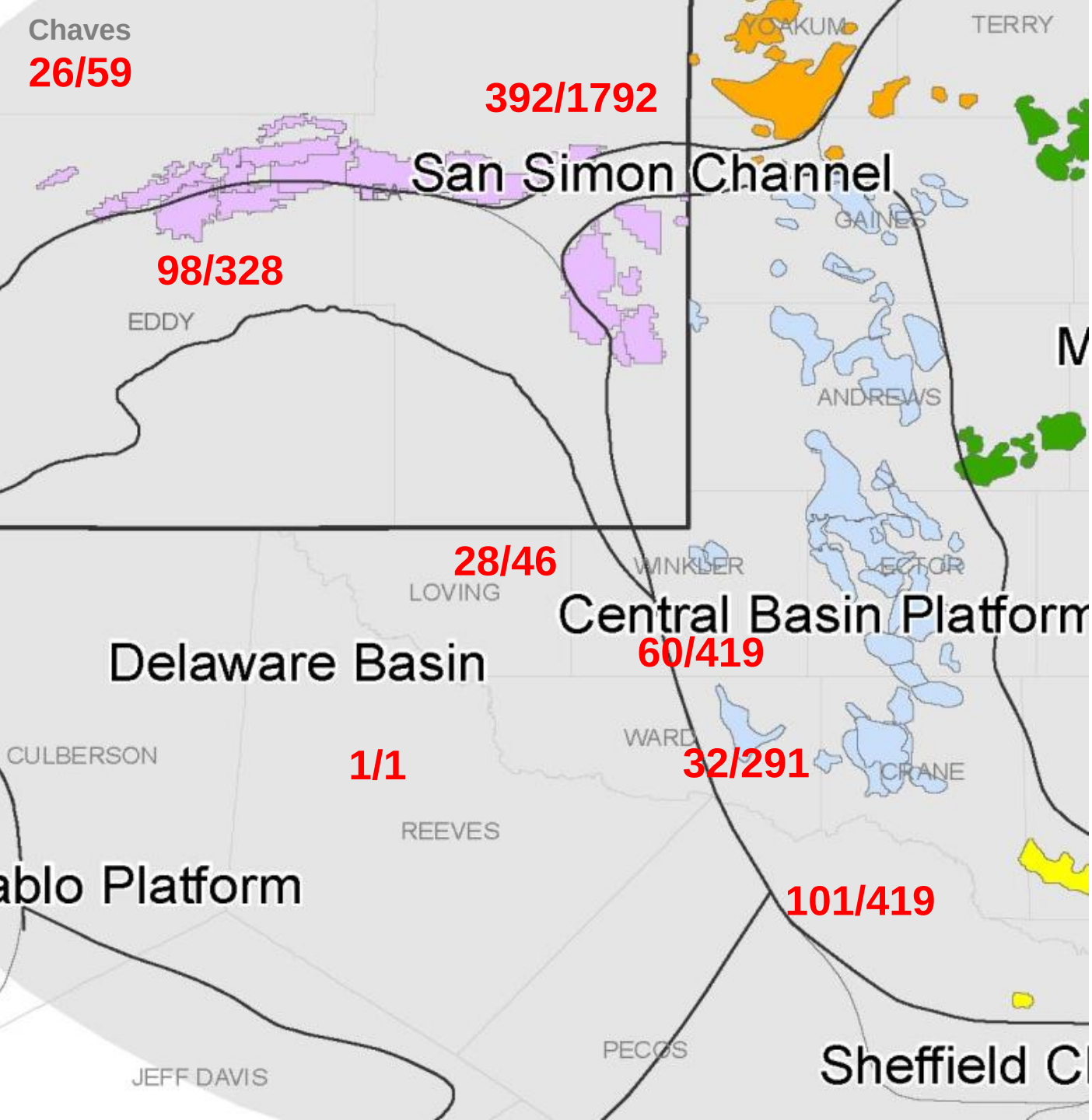
Although we are gathering data for any ROZ, The first model will concentrate on the Artesia Fairway and the west side of the Central Basin Platform.



Pathway from NW Shelf to CBP

Modeling of the system that created "Mother Natures Waterflood".

- Focus on/Identify/Define the Artesia - West Central Basin Platform Trend
- Gather
  - Well data – location, tops, correlations
  - Pressure Data - DST's, Well Test Data
  - Permeability and Porosity Data (Core)
  - Water Chemistry
- Arcadis will use ModFlow, a U. S. G. S. developed, finite ground water modeling program with regional capabilities.



DST and Water Chemistry Data collected from various sources, by county

Wells by County

346/1563

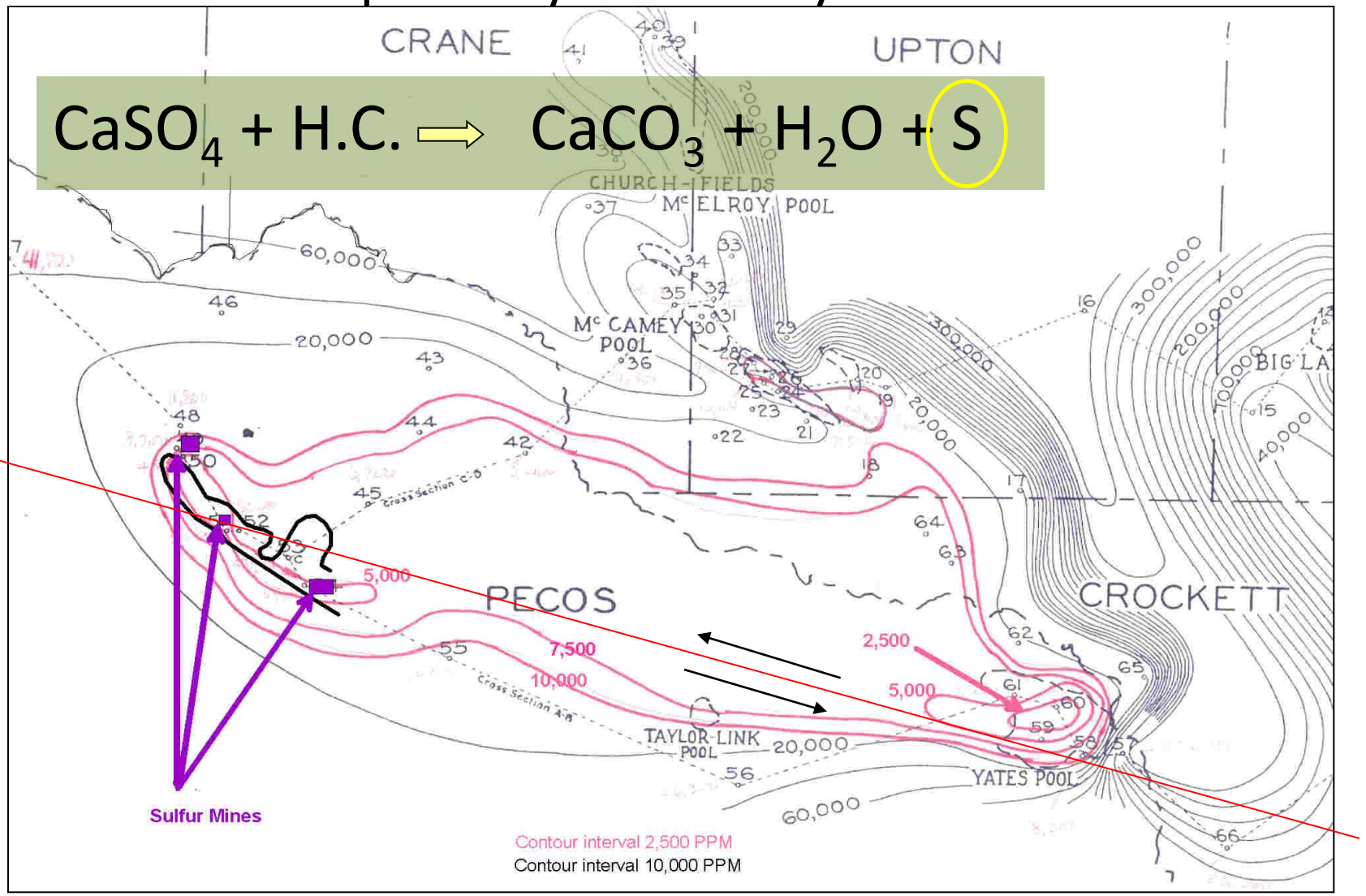
DST / Water Chem

Permian Basin Plays, Dutton et al (2005)

DISCHARGE PATH CONCEPTS (Hose Nozzle)

- We have a source of the water, we also need discharge points in order to have movement of the meteoric water.
- Direction of OWC tilt is evidence of both Movement and Direction.
- Do we have other pathway clues?

The ‘Heel of the Boot’ of the Central Basin Platform is also the location of Sulfur mines which document exit pathways for the system



San Andres Water Salinities and Sulfur Deposits

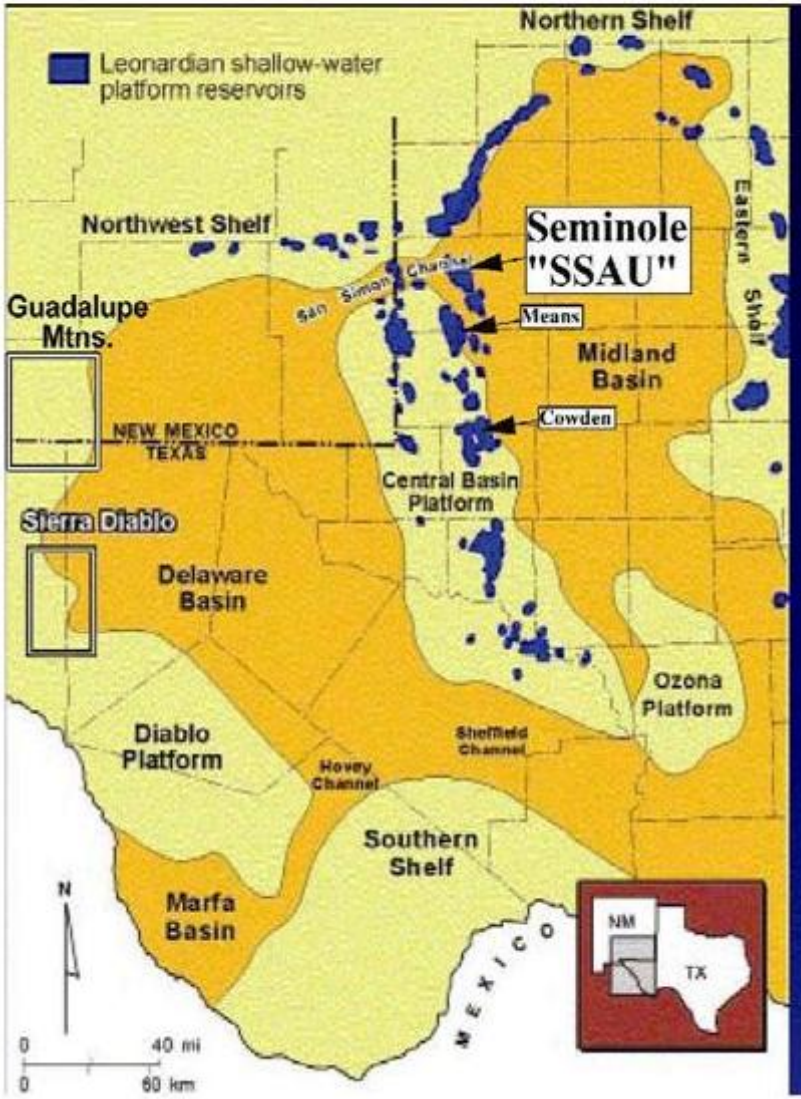
Sulfur

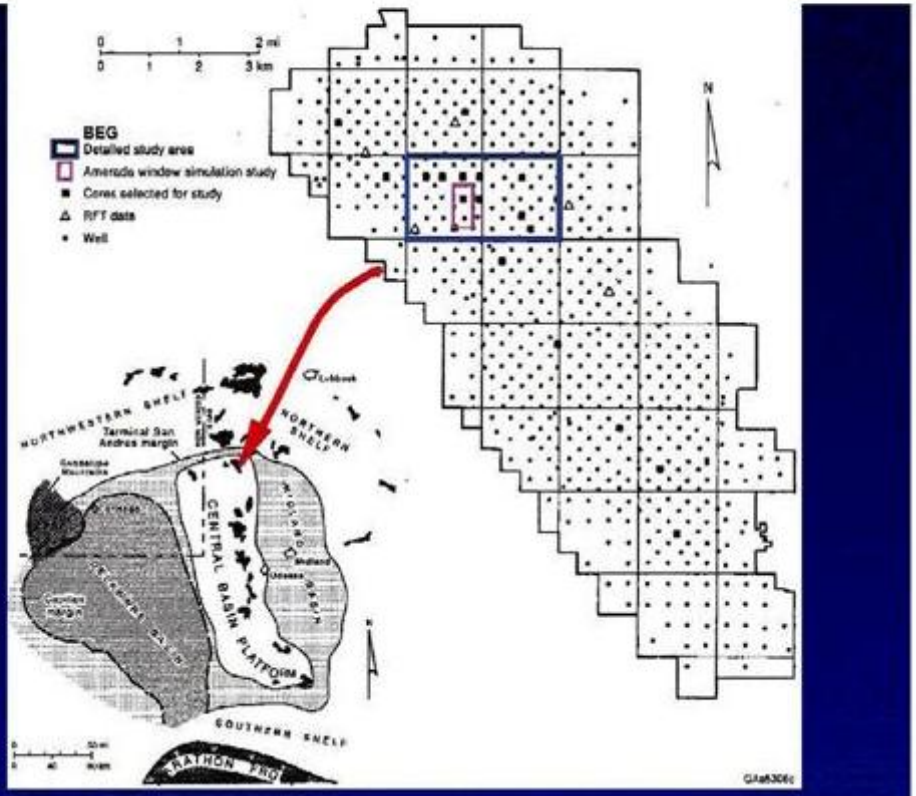
- The large sulfur deposits in northern Pecos County are believed to represent one exit point on the Central Basin Platform for the flushed oil and meteoric waters.
- Other potential Sulfur deposit exit points on the Eastern Shelf.
- These deposits are the result of the mutual occurrence of Water, Oil and a Source of Sulfur
  - Water – from the meteoric system
  - Flushed Oil (Replenishing the Food for the Anaerobes)
  - Sulfur – from dissolution of evaporites
    - As the Source of H_2S (and Sour Oil)
- The Sulfur Deposits (product-of-reaction, residue)
  - Are Proof of Oil 'Passing By'
  - Fairways of Oil Movement
  - As Proof of Oil 'Consumption'

Producing ROZ's

Seminole San Andres Unit

SSAU Geologic Setting





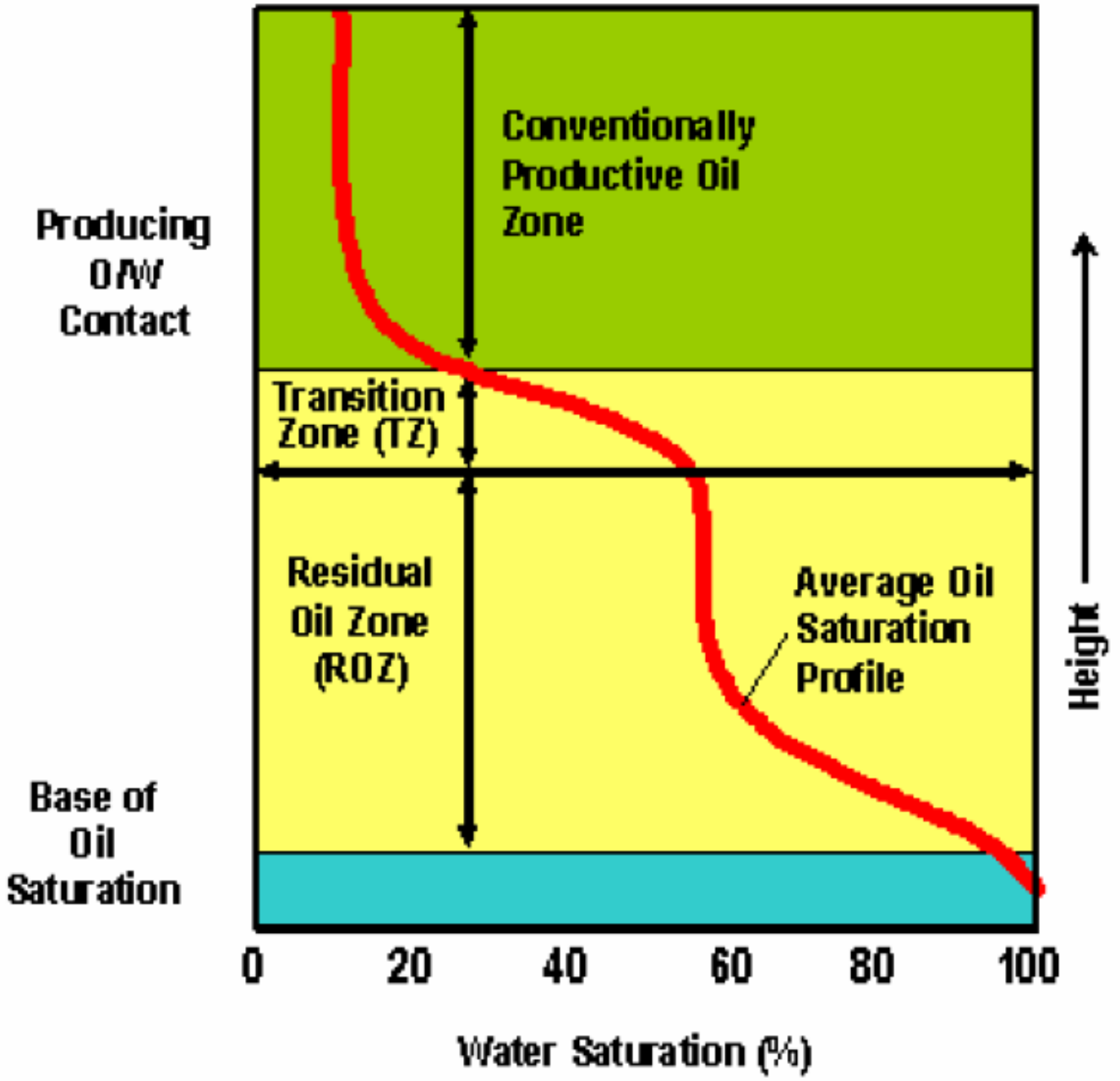
- In the lower San Andres (late Leonardian), Seminole was an aggradational buildup isolated from the Central Basin Platform (left).
- By late San Andres time (above) this low and the San Simon Channel were annealed by carbonate progradation.
- Later differential compaction re-accentuated these paleo-structures, forming present day producing structures.

Published Seminole Field Water Saturation Profile.

HESS

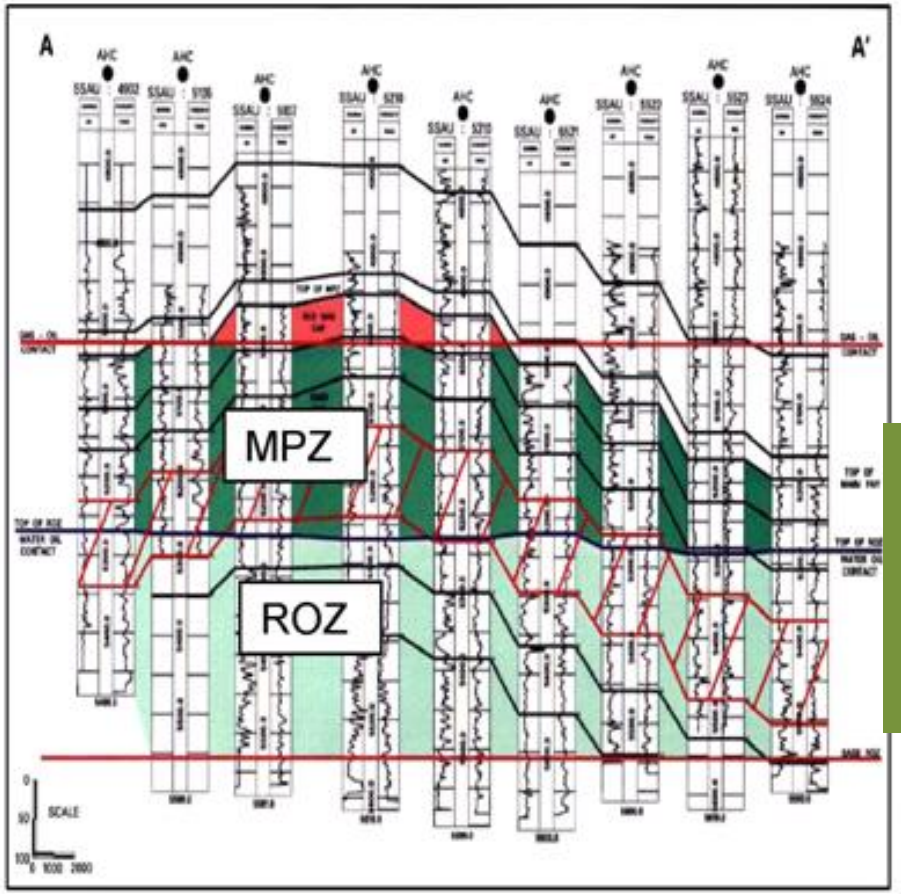
Reservoir Description	Limestone and dolomite deposited in a shallow carbonate ramp environment
Fluid Type	Saturated black oil
Drive Mechanism	Gas in solution and gas cap during primary. External energy from water and CO_2 injection during secondary and tertiary recovery.
Develop. History	1936 Discovery 1936 First Production 1969 Unitized/Waterflood 1983 MPZ CO_2 Flood Begins 1996 ROZ Phase 1 Pilot 2004 ROZ Phase 2 Pilot 2007 ROZ Stage 1
Cumulative Production	675 MMBO, 40 MMBOE NGL, 702 BCF HC Gas
Current Rate	19.6 MBOPD, 200 MMCFD CO_2+HC 25,500 MBOEPD (Oil+NGL+Gas)

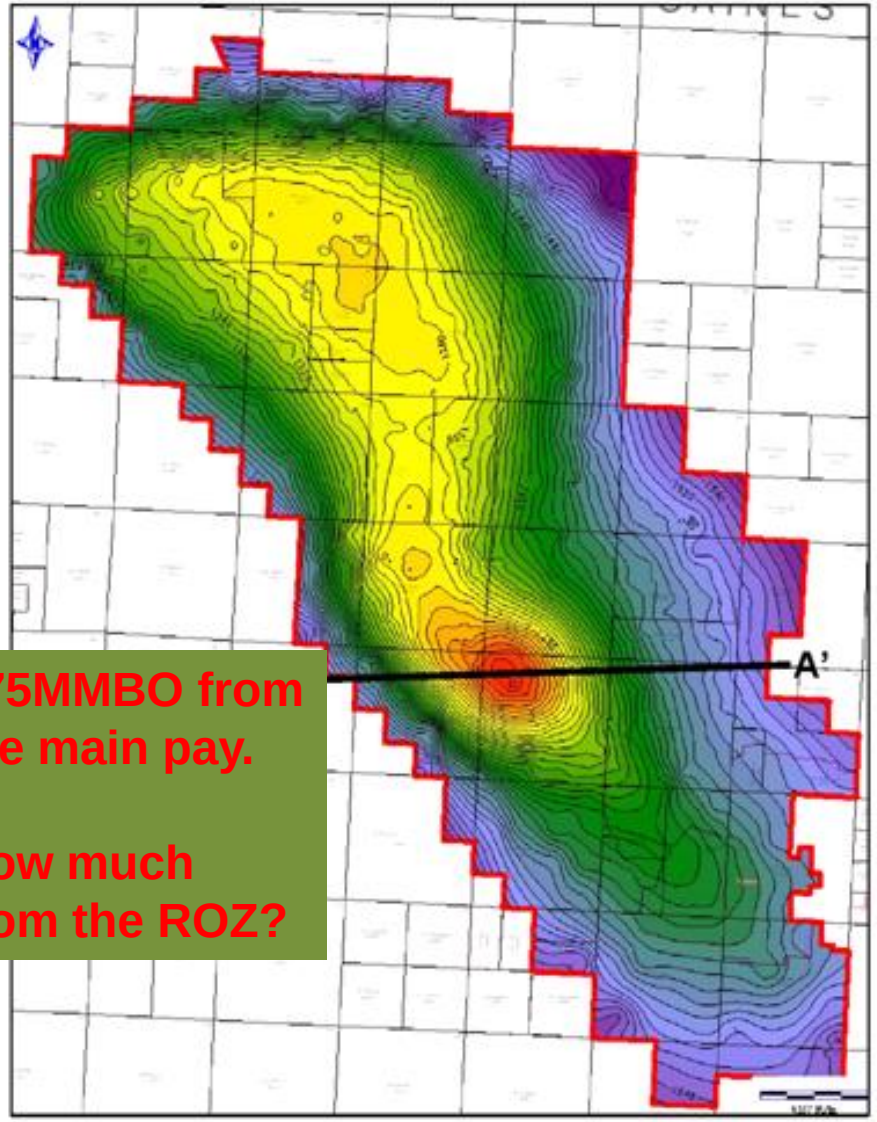
Chevron



SSAU Structure Map & Cross Section

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





675MMBO from the main pay.

How much from the ROZ?

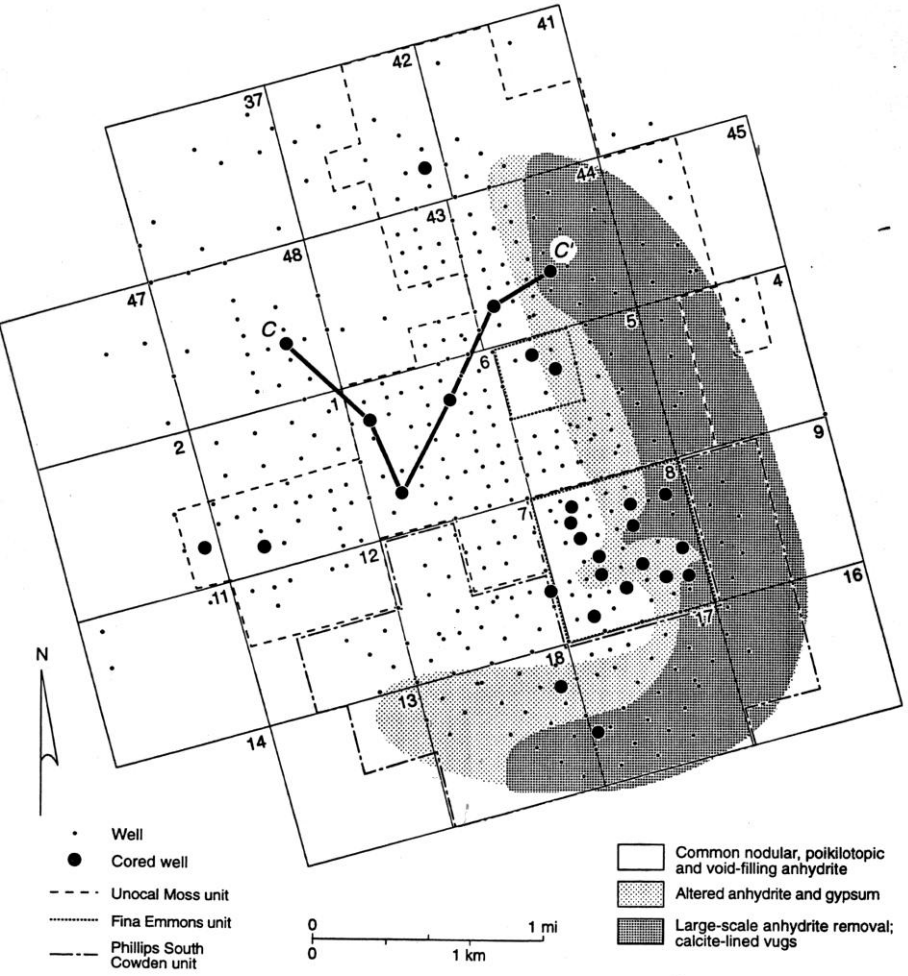
Evidence from other fields

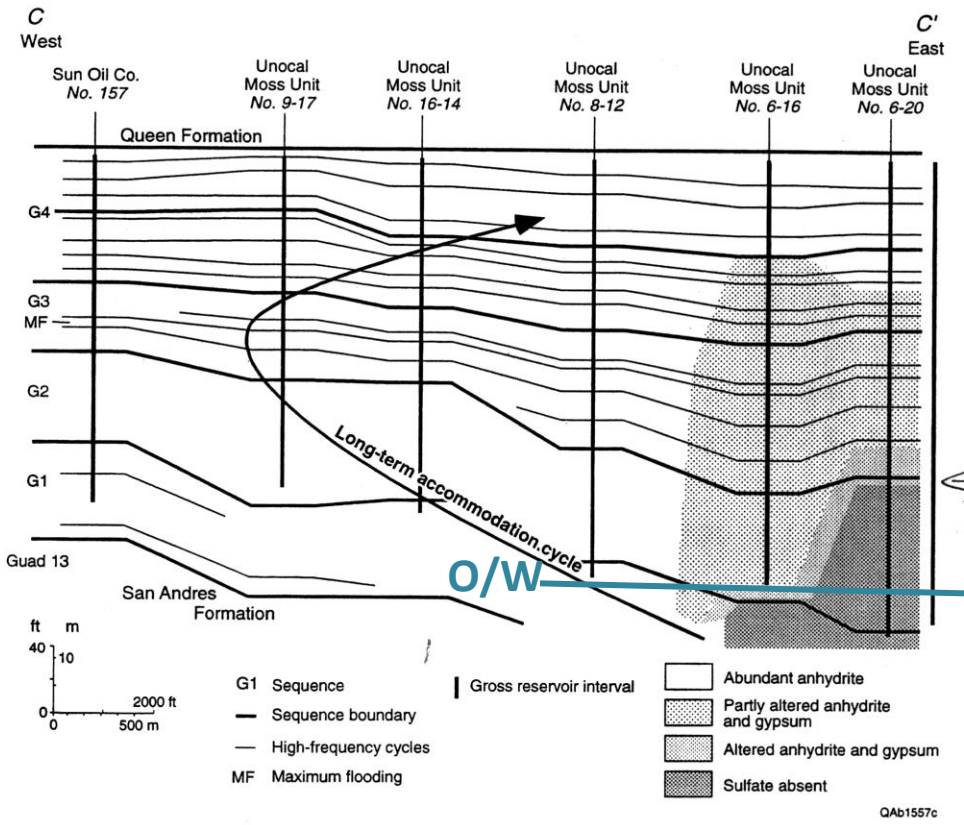
- There appear to be ROZ's in numerous other field around the basin in the San Andres, Grayburg, and Clearfork.
- The "classic" explanation of Transition Zones can be redefined using the ROZ model. A different scenario can be presented that is related to the Meteroic Sweeping of the reservoirs as opposed to variations in porosity and permeability.

South Cowden

- There appears to be an ROZ in **South Cowden** in the Grayburg, based on BEG work on South Cowden.
- There was “massive sulfate removal mostly below the oil/water contact, an interval of carbonate diagenesis and the zone of altered sulfate.”
- This removal zone is concentrated on the east and south side of the field and is associated with the mud rich, deeper water facies. For the most part, intervals of total sulfate removal are restricted to depths below the estimated field oil/water contact(-1850’).
- Using the ROZ model, a different scenario can be presented that is related to the Meteroic sweeping of the reservoirs from north to south and paralleled the shelf margin and not perpendicular to it.

A. D distribution of altered sulfate & complete removal.
B. Dip section showing distribution and removal.





sulfate removal resulted in highest permeability in zone of sulfate removal.

Patterns of vertical and lateral distribution demonstrate that the alteration and removal of sulfate in S. Cowden are related to structural position. Sulfate diagenesis crosscuts facies and stratigraphy in the field.

Melzer Consulting

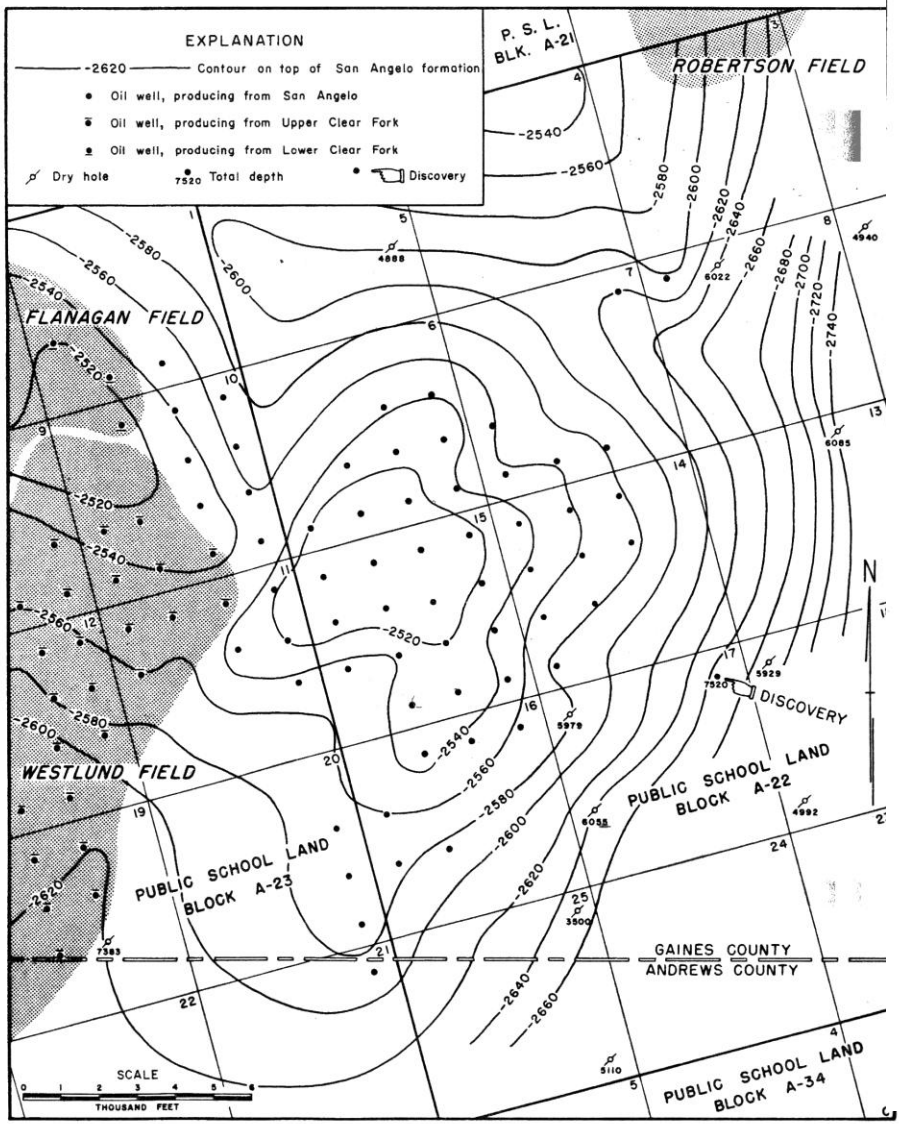
More Evidence

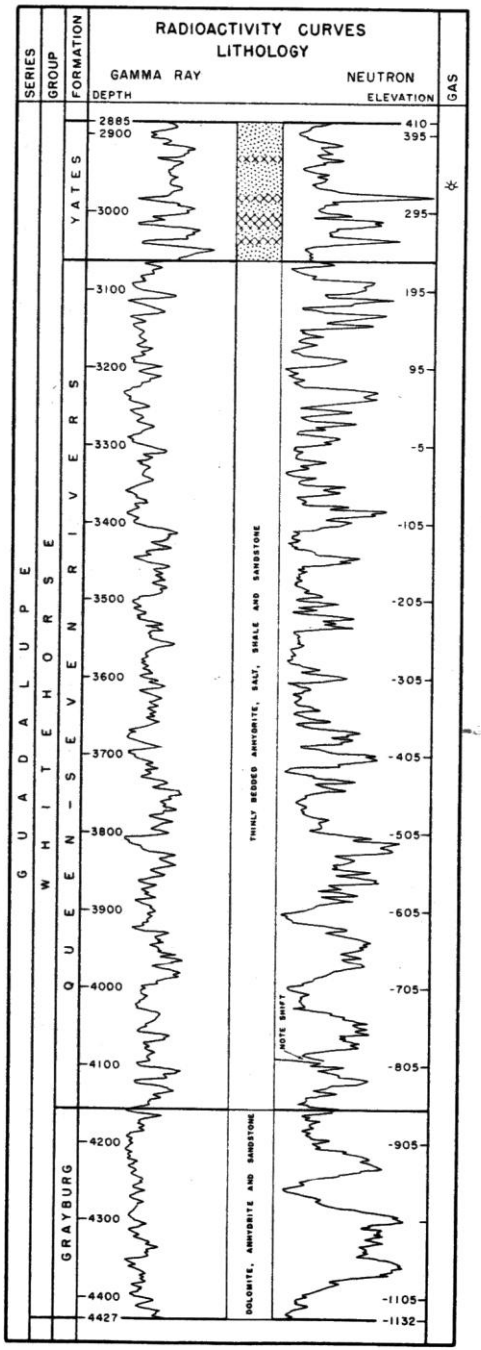
- Robertson Field (Right) - Main pay is the Upper Clearfork. There is a minor San Andres pay (25’ thick). It has been reported that there is a 250-300’ thick oil bearing, non-productive interval. ROZ?
- Dune Field - Extremely depleted d13C values typical of calcites produced as a byproduct of sulfate reduction and bacterial oxidation of crude oil in the presence of METEORIC FLUIDS.
- “Oil Shows” below the historic O/W have been reported at Penwell and Andector Fields.

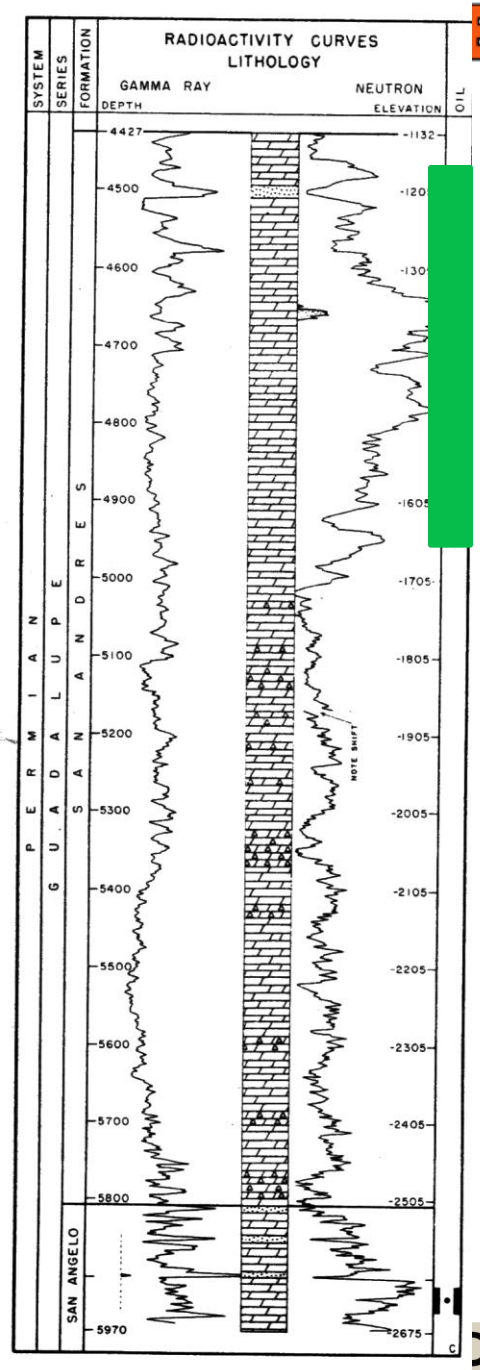
Harris – Robertson Field

Oil shows

in Harris Field – ROZ?







McCamey Field, Oil/Water contacts from core

- **Oil/Water contacts from core, McCamey Field**

Well	Fm @ O/W	Depth	Fm @ ROZ O/W	Depth	
Meridian 3622 "A" Lane	GRBG	+/-320,	SADR	SHR	+/-270,
Meridian 51R "A" Lane	SADR	+/-330,		SHR	+/-280
Meridian #19 Reese N244	SADR	+/-304		SHR	+/-264
BR N353 McCamey Unit	SADR	+/-326		SHR	+/-286
BR 549RW McCamey Unit	SADR	+/-340		SHR	+/-288
BR #1087 McCamey Unit	SADR	+/-340,		SHR	+/-240
Meridian 9R "A" Baker	GRBG	+/-385	SADR	SHR	+/-282
Gulf #16 B Shirk	GRBG	+/-280,	GRBG	SHR	+/-245

- Burlington said there are two periods of oil charging at McCamey.
- The thick SHR zone in the SADR is the result of "an early and late oil migration". Using the ROZ model, are we looking at swept oil column?
- Question: is the Grayburg O/W the same as the O/W for the San Andres? Historically, the operators used +/-330 as the O/W contact for the field. Based on SHR in core, +/- 280 is probably the original O/W contact.
- Therefore there was **+/-50'** of oil column swept at McCamey. 50' covering ~15 sq miles…**9600 acres X 50' X 20% porosity X Sw~20% X 7700 = 575,000,000 BO! 575,000,000 X .25 (residual to natures waterflood) = 150,000,000 BO in ROZ 150,000,000 X .66 = 100,000,000 BO potentially recoverable from ROZ.**
- **Unfortunately, SHR is a poor target for Tertiary Recovery.**

North Ward Estes, western margin Central Basin Platform

- Some Production in Glorieta
- In the lower San Andres, **H. S. A. #1449** core had good oil stain in fusulinid rich outer shelf facies, but is not productive. Lower SADR producers - **#73, #76, #77, #79 Richter** had 13% or better porosity rhombic dolomite, higher on structure.
- Minor production in upper San Andres updip on H. S. A. lease.
- The complete Grayburg oil column has been swept to Mother Natures Waterflood with no moveable oil for primary or secondary recovery. This area covers a six square miles. The interval has been cored and contained very dark oil saturation where, unfortunately, not a drop of oil was produced.
- What's going on?

W. A. Estes "Holt" Field (actually Glorieta)

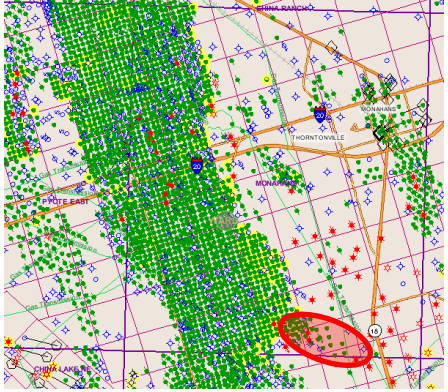
Discovered in 1991, produced over 1MMBO from a small closure with "tight" tidal flat and shallow subtidal carbonates.

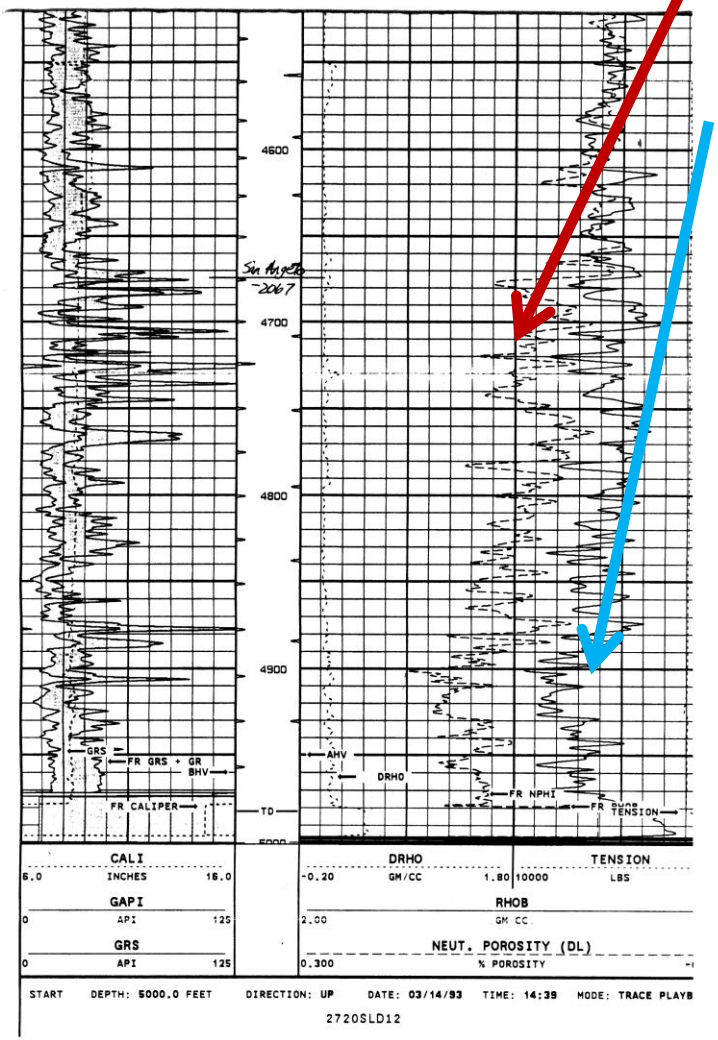
Why did it take so long to discover it?

It's a cap for a thick porous dolomite considered to be the "pay" in the area. The interval had shows & calculated as productive, DST's a skim of oil and lots of sulfur water, tested a few times and left alone.

What is going on? It's postulated that the lower, porous portion was swept and only the tight, up-dip facies were left with >70% S_o.

Thick, porous ROZ with CO2 potential?



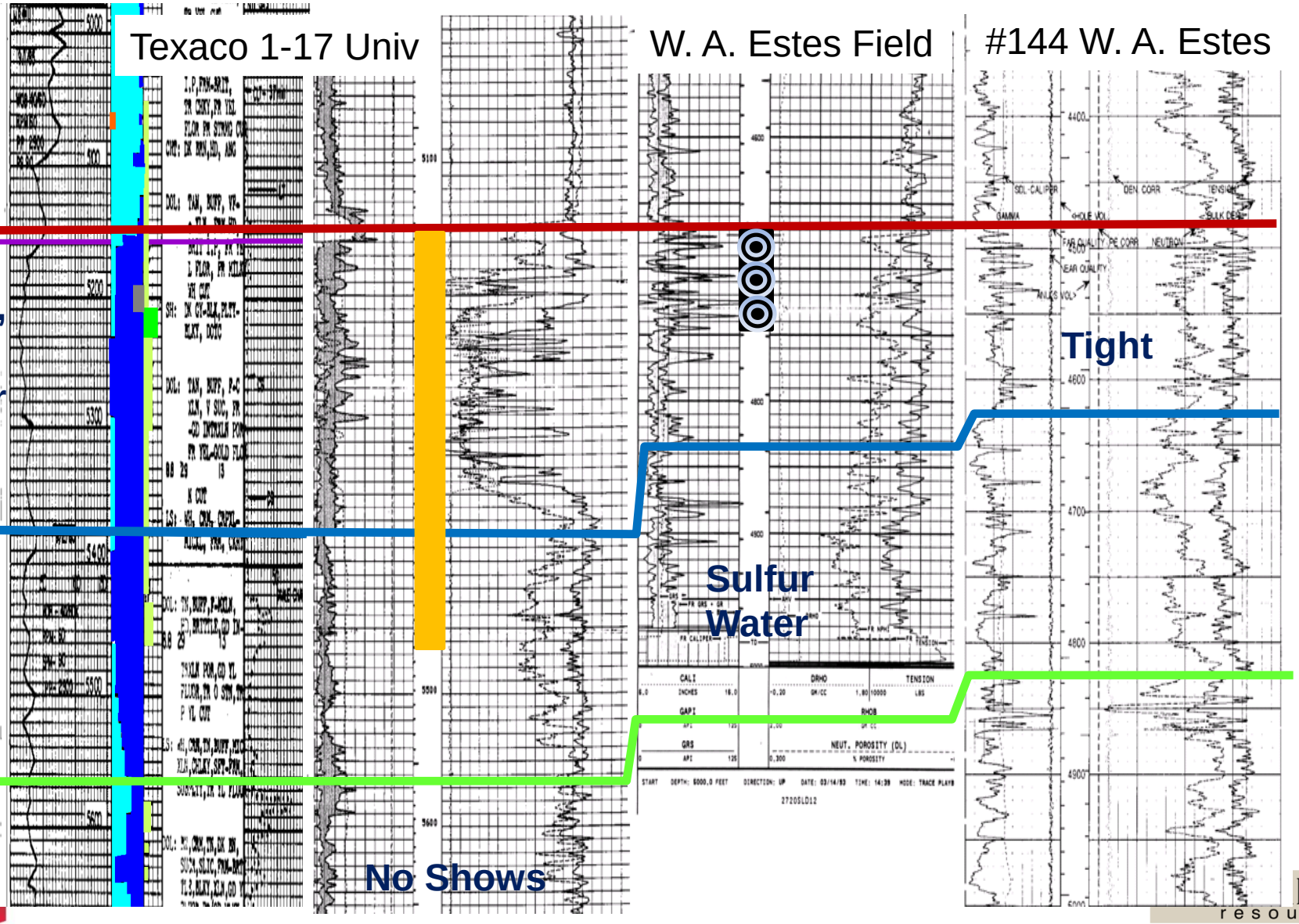


The pay is the upper Glorieta/San Angelo.

The more porous lower section calculates as productive on logs and is oil stained BUT 100% sulfur water productive.

Outer Shelf to Tidal Flat

The updip section thinned by pre San Andres tilt and Erosion



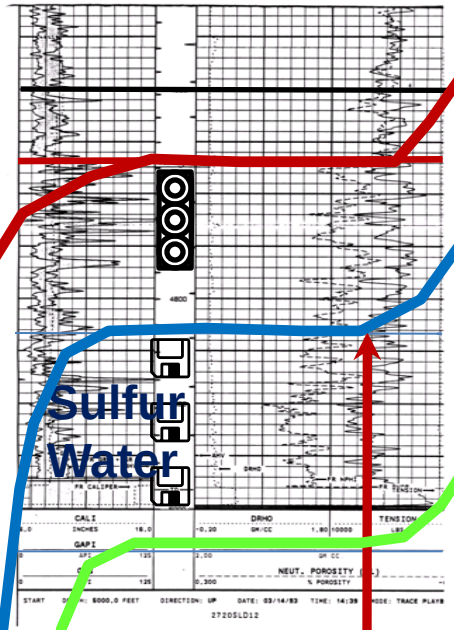
Research Partnership to Secure Energy for America

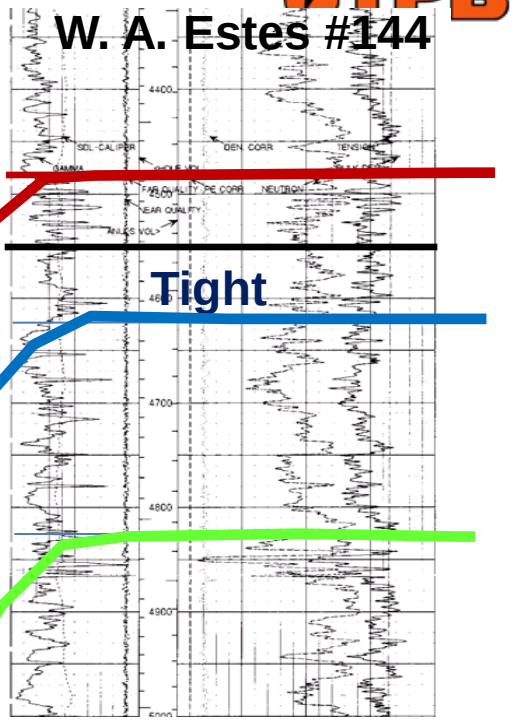
ITPB

Texaco #1-17 Univ

W. A. Estes Field

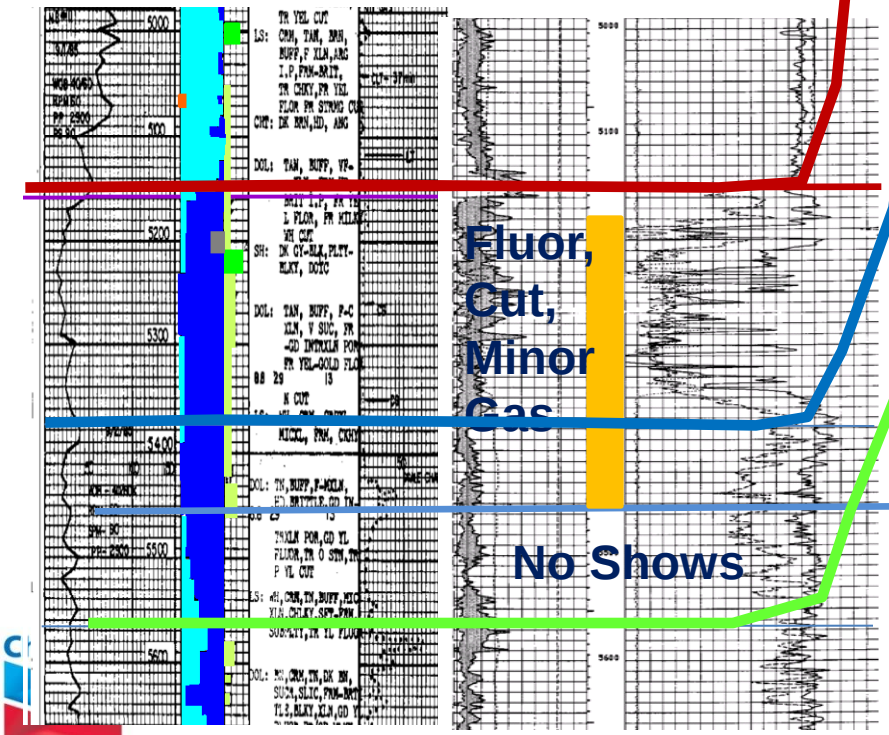
W. A. Estes #144





Tight

Sulfur Water

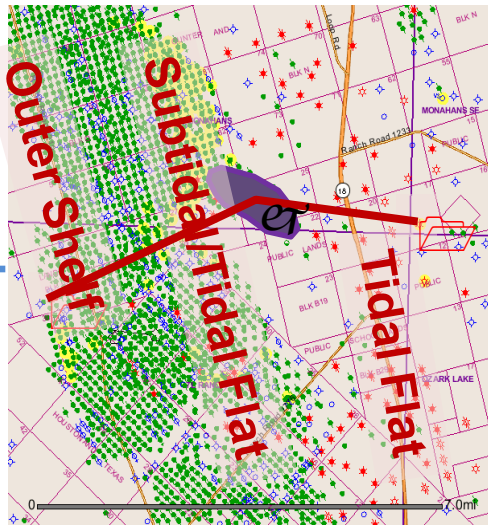


Fluor, Cut, Minor Gas

No Shows

ROZ Maximum 550' !

Base ROZ ?



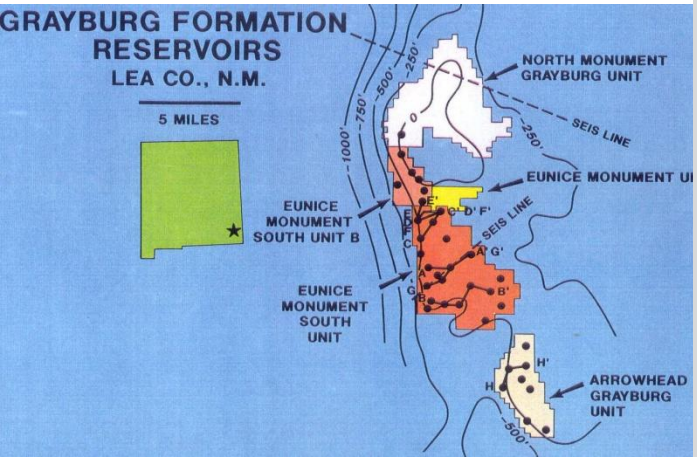
Eunice Monument/South Monument

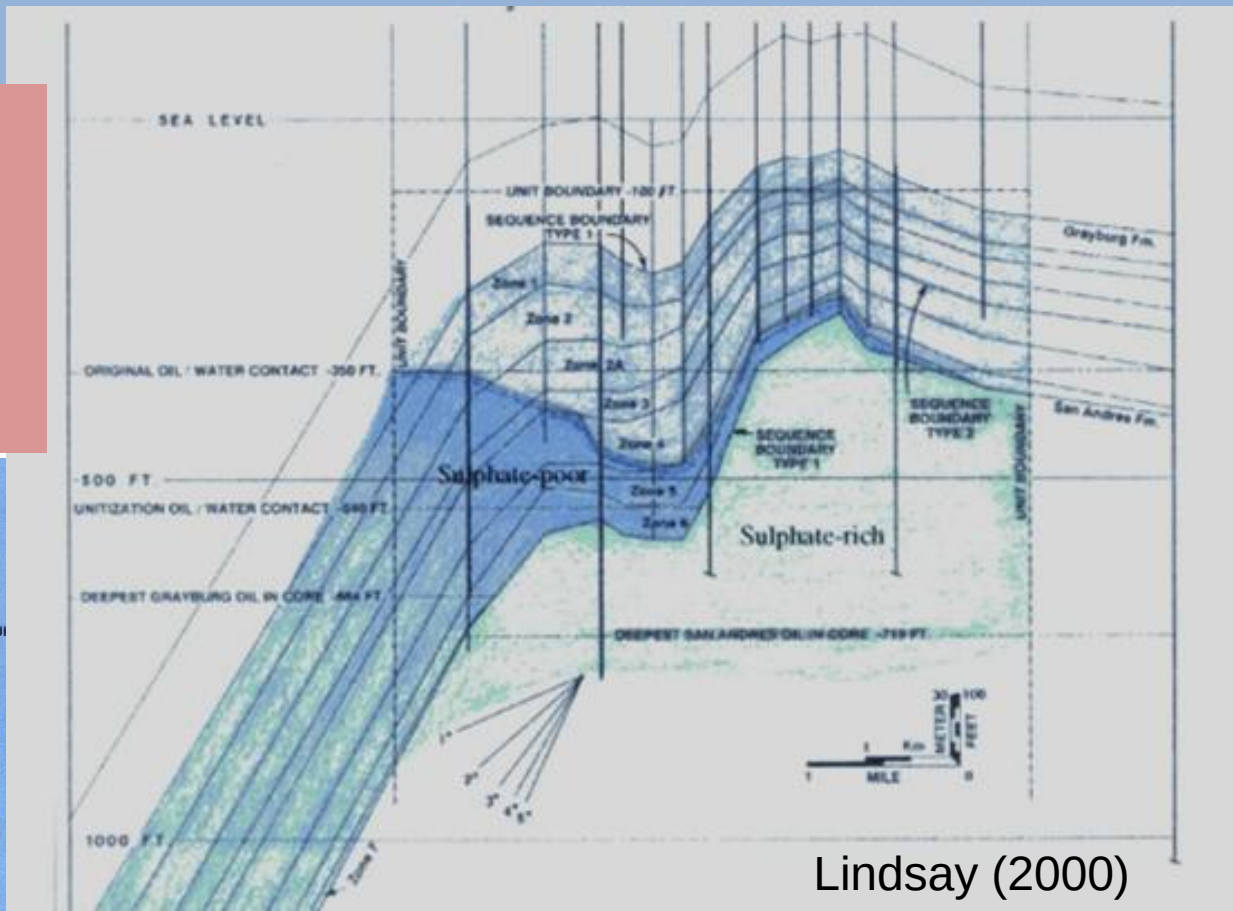
- Grayburg productive with NaCl rich connate water
- San Andres mostly wet with sulfate rich connate water
- Two different sources for the connate waters
- Thickness of San Andres swept reservoir?
- **Eunice Monument South Unit** Productive from the Grayburg with minor production from the underlying San Andres Formation–
- Discovery Oil/Water contact -350’
- Unitization Oil/Water contact -540’
- Deepest Grayburg Oil in core -664’
- Deepest San Andres Oil in core -719’
- >300’ thick SADR w/oil saturation below O/W in Eunice Monument

North Monument Grayburg, Eunice Monument, Eunice Monument South "B", Eunice Monument South, and Arrowhead Grayburg Unit .

- area combined total of 57 square miles.
- Lindsay suggests the sulfate poor edge water is recharged from the Guadalupe Mountains thru the Goat Seep Reef. The Sulfate-rich bottom water drive in the San Andres is recharged from the Sacramento Mountain thru the evaporite rich San Andres. **Eunice Monument South Unit.** The edge water was pulled into the oil leg since production was established in 1929 (from Lindsey, Chevron in-house pubs).
- Structural closures formed by re-activation of existing deep seated faults which folded and fractured the Permian. The structural event increased closure on the reservoir and trapped a larger oil column.

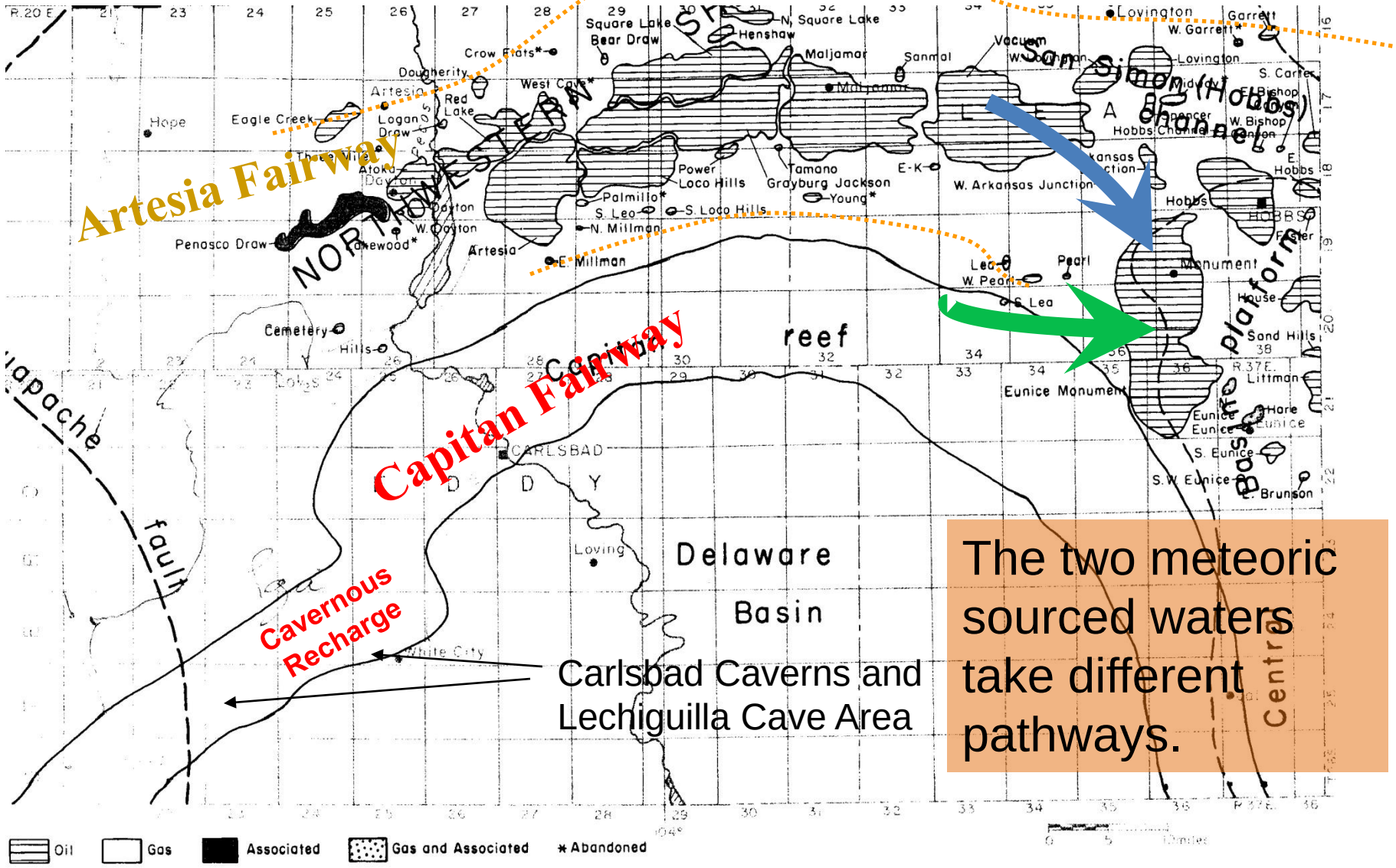
- Eunice Monument
- -150 G/O, -400' O/W (150' below top SADR).
- Na 2000ppm, Cl 2950ppm, TDS 7800PPM (similar to Capitan Reef in Winkler Co.)





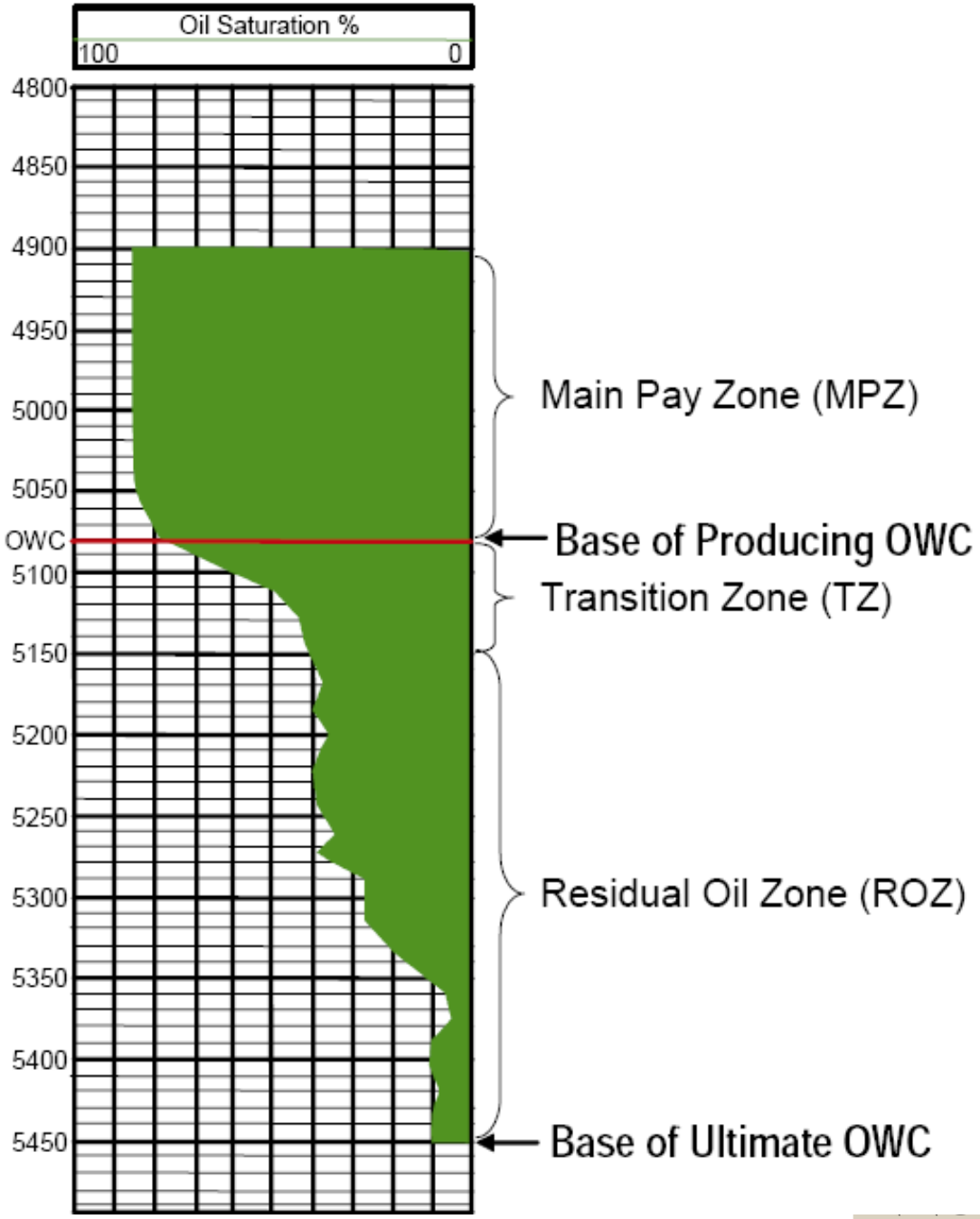
Lindsay (2000)

SE NM Grayburg & Upper San Andres Dolomitization Trend

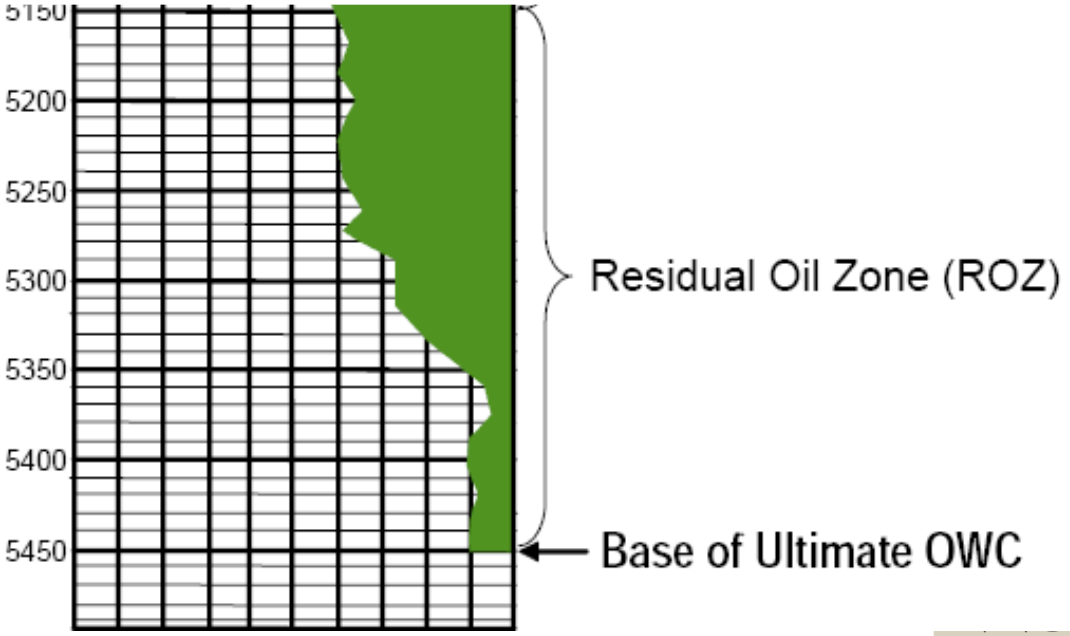


Ref: Future Petroleum Provinces in New Mexico – Discovering New Reserves, Philip R. Grant, Jr. and Roy W. Foster, NM Bur of Mining & Mineral Resources, 1989

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



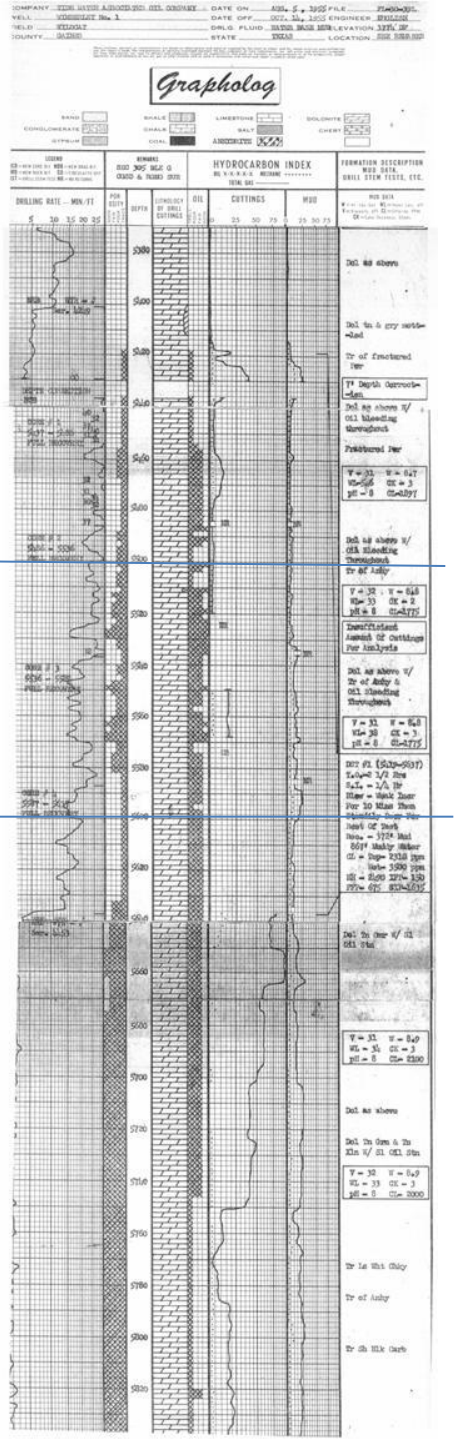
Your left with a tertiary recovery target.

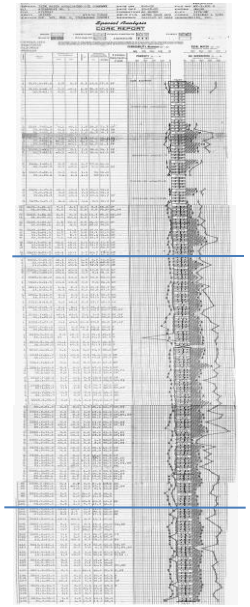


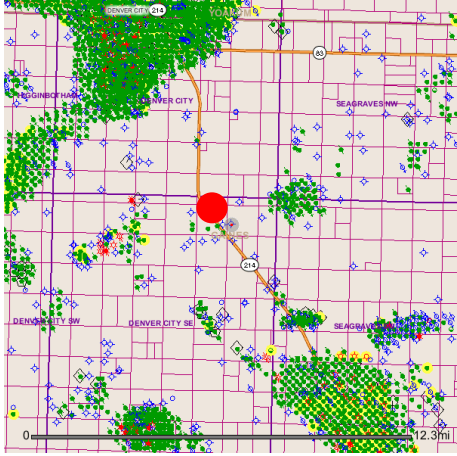
Anecdotal Evidence

- 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.

ROZ's have been tested for 50 years.



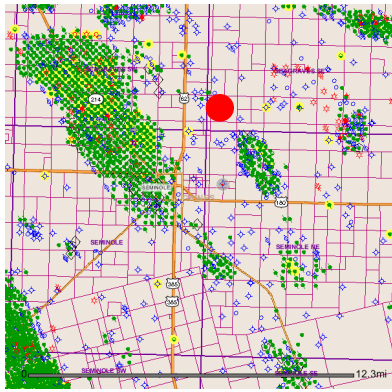




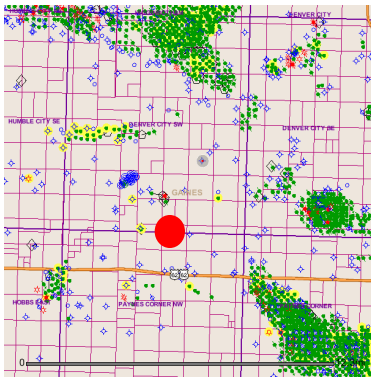
At **Bale East**, Gaines Co., **Tidewater #1 Wimberley**, sec 305, Blk G CC&RGNGRR.
Is on the east flank of a structure.
Drilled in **1955**. Cored interval, 5437-5637, had bleeding oil & gas throughout, has 20 to 30% oil saturation throughout the length.
DST'd 5419-5637, rec 372' mud, 867' MCSW.
Mudlog Sample cut, good bleeding oil to 5745'.

ROZ?
The total length of core and sample shows is 310', from 5437[in core] to 5745[in samples].
DST in the San Angelo (6680-6785) rec 150' muddy Water, 4830' black water (sulfur?).

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.

Oil Saturations

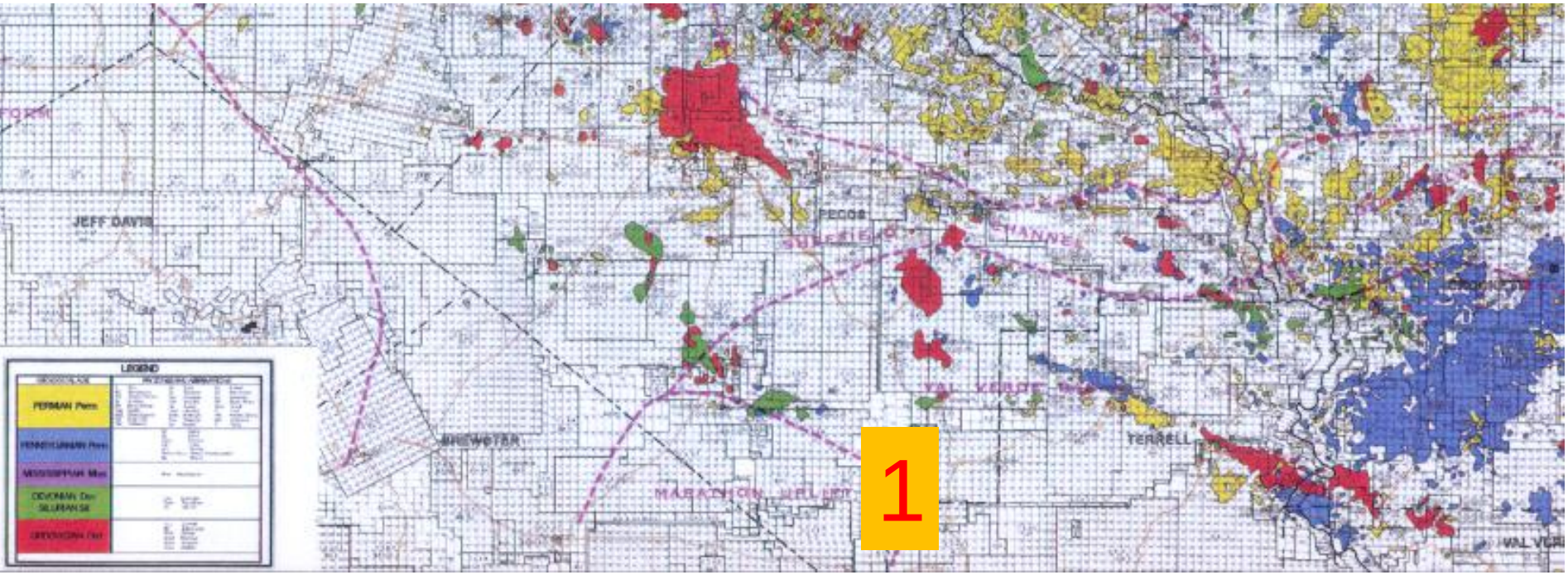
- *Higher Oil Saturations*
- •Laterally Driven, Pervasive Dolomitization by Mg Rich High Salinity Waters
- •Lateral Flushing of Oil Entrapments with High Salinity Water While Displacing Oil
- •Oil Wetting of New Dolomitic Rock Surfaces
- •Establishes a 30-40% Sor *(good EOR target)*

- *Lower Oil Saturations*
- •Initial or Progressive Lateral Flushing of MPZ or ROZ Oil Entrapments with Low Salinity Water
- •Reversing of Oil Wetting of Formerly Oil Wet Dolomitic Rock Surfaces and (Partially?) Replacing ('De-sorbing')* Oil in Wetting Phase
- •Establishes a 10-20% Sor*(poorer EOR target)*

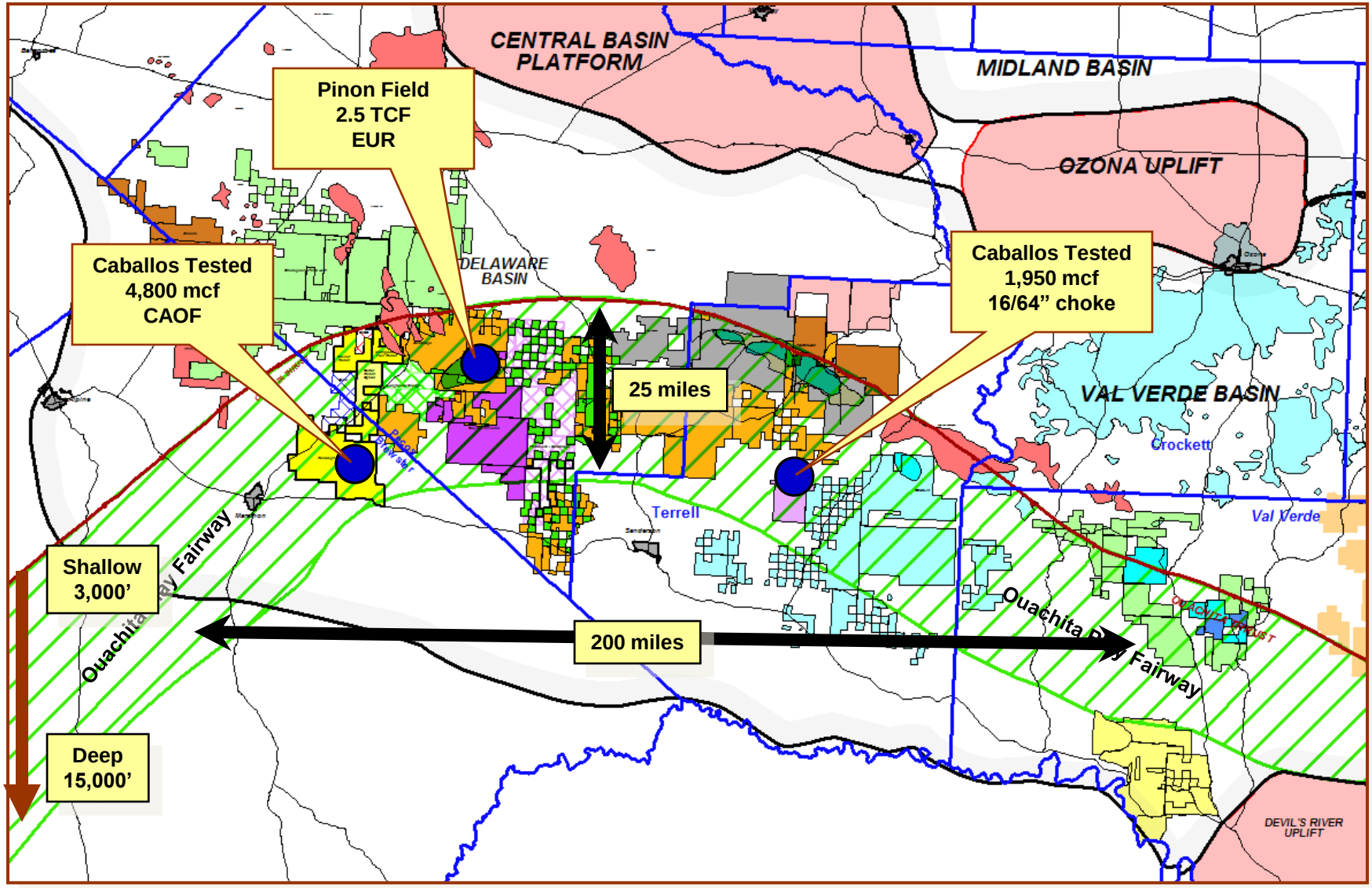
Other Areas of Discussion

- Dolomitization
  - Phases
  - Timing
  - Impact on Wettability
- Oil Migration
  - Pulses?
  - Timing
  - Impact on Wettability
- CO2 Sequestration in Residual Oil Zones
  - There are large potential volumes in ROZ's for storage of CO2

Marathon Overthrust
Sand Ridge



Fairway Dimensions



dB, LLC Petroleum Advisors

Stratigraphy & Cross Section

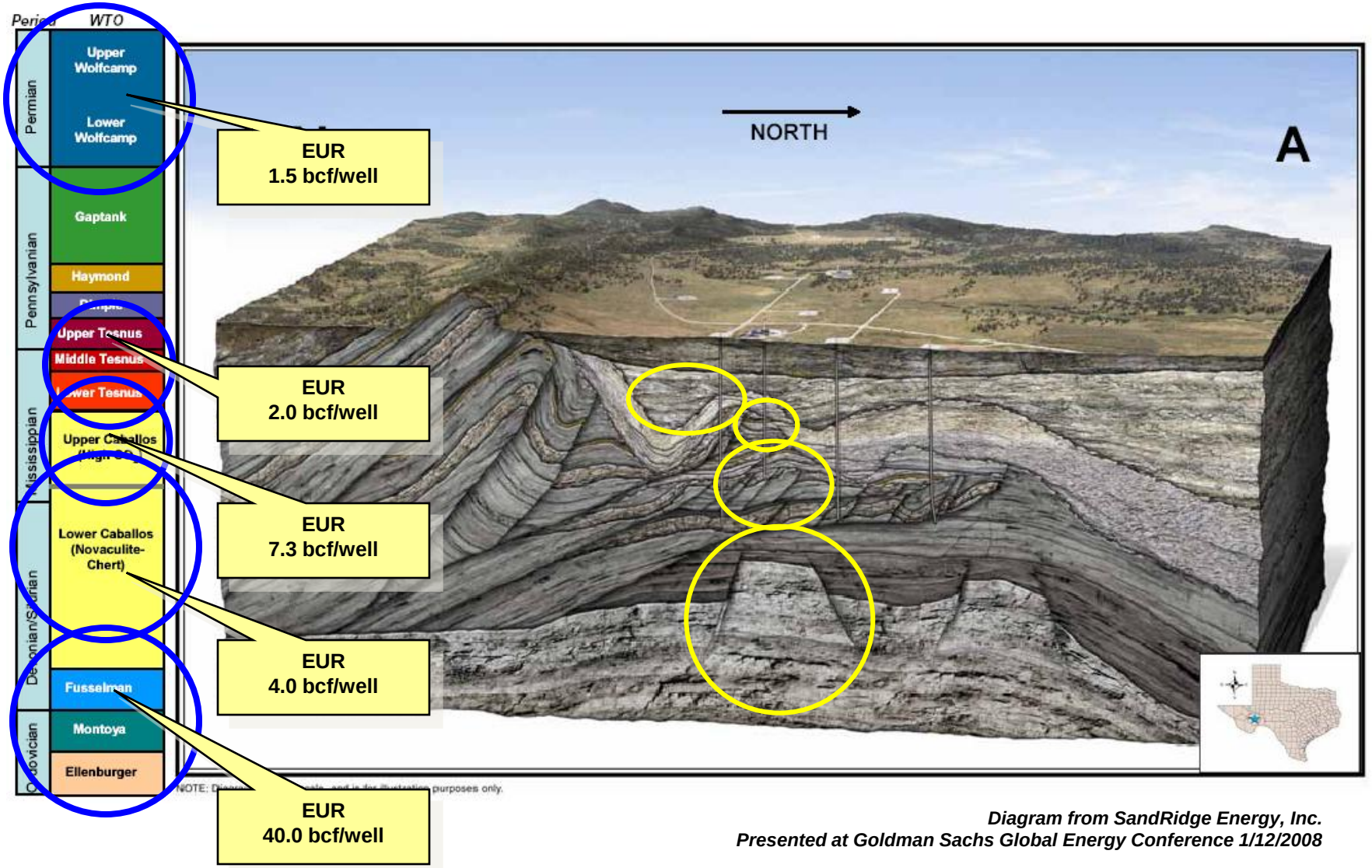
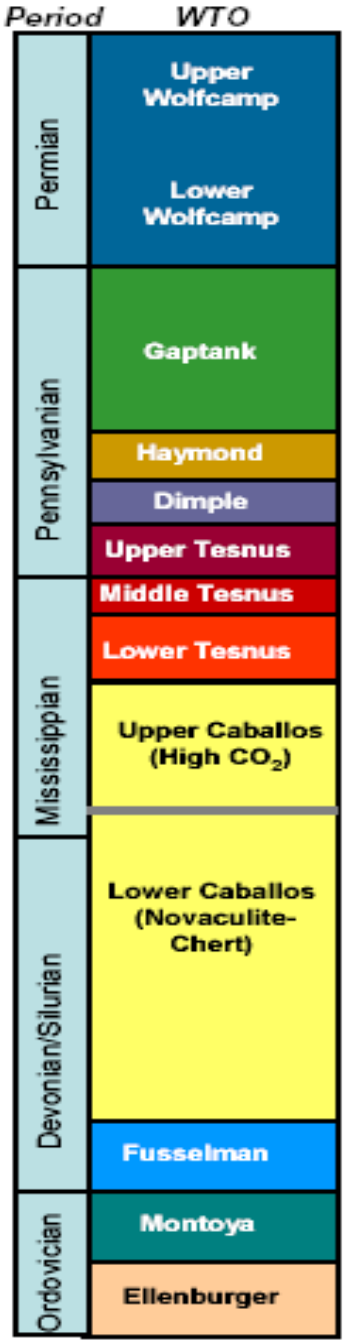
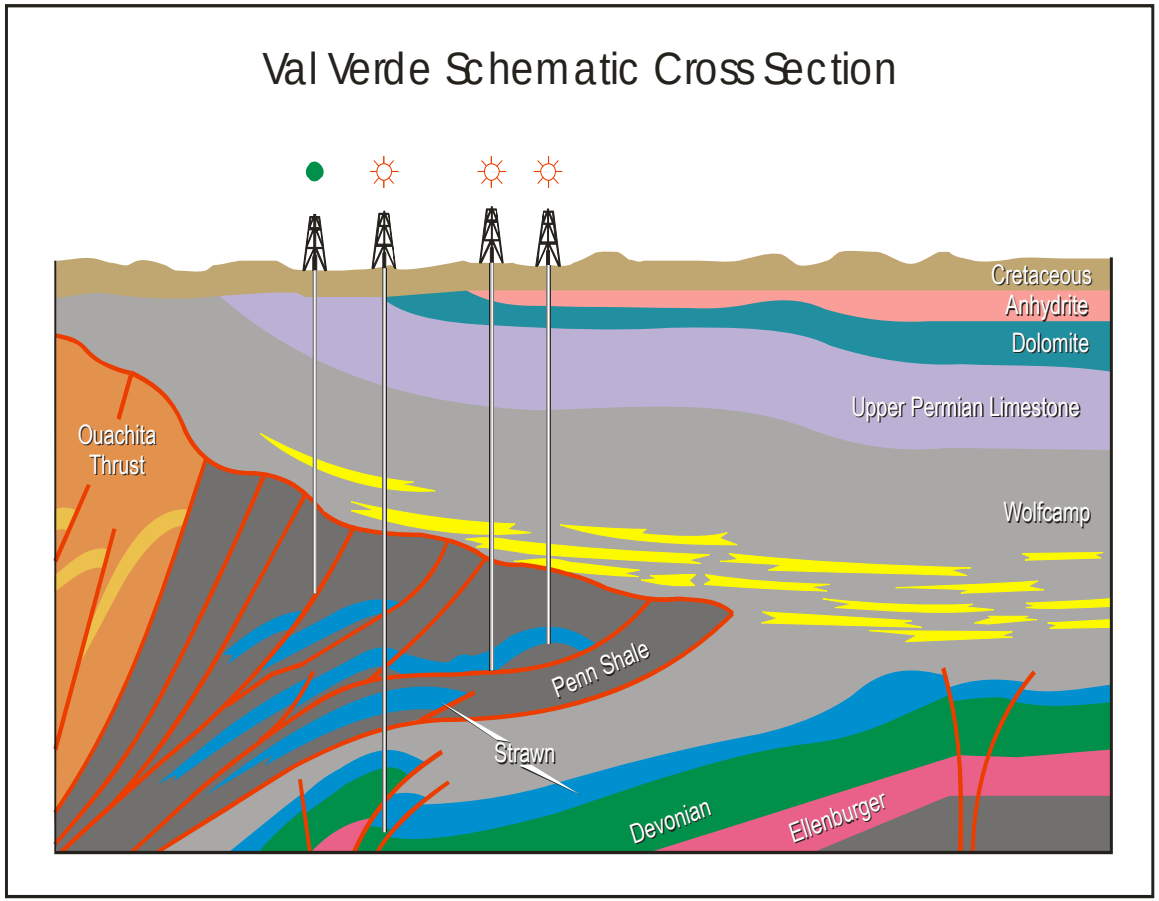


Diagram from SandRidge Energy, Inc.
Presented at Goldman Sachs Global Energy Conference 1/12/2008





Stacked Play Opportunities

- Wolfcamp Sands
- Tesnus Sands
- Caballos Novaculite
- Thrust Front Strawn
- Sub-thrust Paleozoic

Diagram Courtesy of Providence Technologies, Inc.

Pinon Field Completions

Formation	# of Wells	Gas	% of Fieldwide Methane Production	EUR/well
First Caballos	113	70% CO_2 Sour	38%	7.3 bcf
Second Caballos	77	2% CO_2 Sweet	40%	4.0 bcf
Tesnus	125	30% CO_2 Sweet	20%	2.0 bcf
Dimple	10	Sweet	1%	0.2 bcf
Wolfcamp	5	Sweet	1%	1.5 bcf

No CO_2 Reported in Ouachita Fields East of Pinon Field

CO2 Capture and EOR

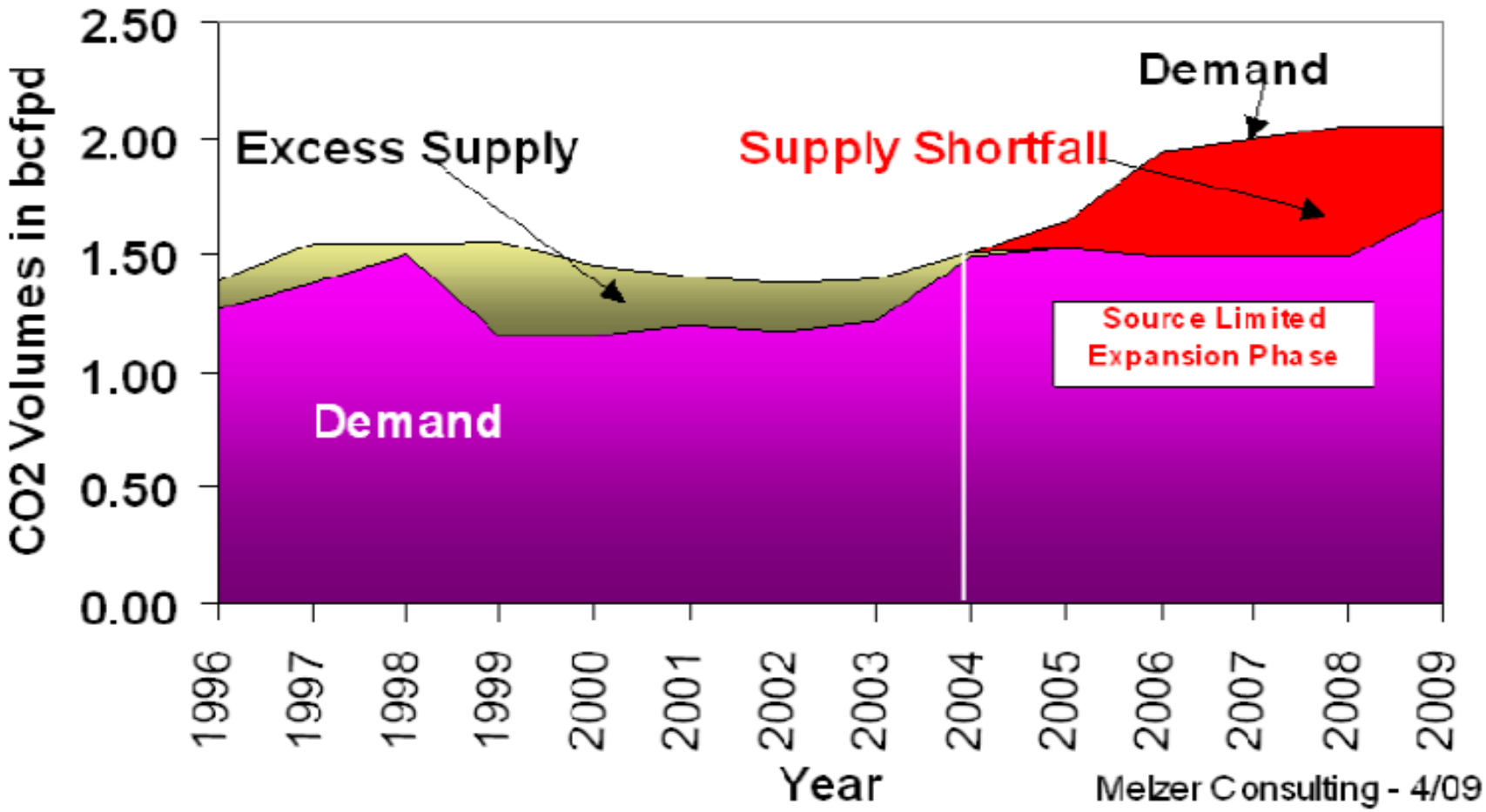
- Presently there are over 100 CO2 EOR projects currently producing >250,000 BOPD.
- Since 1985 >1.5 BBO have been produced using CO2 and another 1.5 BBO listed as Proven Reserves.
- Planned Federal CCS legislation could result in 69 to 109 GiggaWatts of coal and natural gas fired power generation, with the capture of 410 to 530 Million Tonnes of CO2 by 2030.
- If most of that CO2 is used in EOR projects, it could increase domestic oil production by 3.0 to 3.6 MMBO per day.

Impact of the Century Plant on Long Term Potential

- In 2008, SandRidge Energy, Inc. entered into an agreement with Occidental Petroleum Corporation (OXY) to build and operate the Century Plant, a CO2 extraction plant. located in Pecos County.
- Combined with existing SandRidge CO2 processing plants, they will allow treating of approximately 1.0 Bcf per day of high CO2 gas by year-end 2011.
- Currently, SandRidge has the capability to produce 70 MMcf per day of methane from high CO2 gas. SandRidge expects the new facility will enable it to produce 350 MMcf per day of methane from high CO2 gas and develop 1.7 Tcf of additional methane reserves from high CO2 gas.
- SandRidge will continue to drill, produce, and deliver high CO2 gas to the Century Plant.
- Oxy's total expected project costs of $1.1 billion, which will include pipelines from McCamey, Texas to Denver City, Texas
- Oxy will operate the Century Plant and treat the gas under a 30 year agreement. At the tailgates of the plants, SandRidge will retain 100 percent of the methane gas and Oxy will retain all CO2 for use in EOR projects in their Permian Basin Fields.

New supplies of CO2 are needed for basin-wide ROZ development to occur

Figure 3. CO_2 Supply and Demand in the Permian Basin



CO_2 Sequestration in ROZ's and the Brine Aquifer portions of Permian Basin oil fields.

- Each time CO_2 is cycled through a reservoir in a Main Pay CO_2 EOR or ROZ CO_2 flood, a percentage of the CO_2 is "left behind" in the reservoir.
- When the CO_2 releases the oil from the pore space/grain surfaces, a portion (20-50%) can remain "Sequestered" in the reservoir.
- As opposed to "classic" Carbon Capture and Storage, which is a costly process, storage of CO_2 left in the reservoir after EOR is revenue neutral or economically positive.

Retention of CO2

- We have "tons" of numbers, and the volumes of CO2 purchased for Permian Basin EOR are increasing as new supplies of CO2 come on line to meet the demand from existing and new EOR projects.
- One of the issues we are dealing with right now is "CO2 Retention." The way the industry has defined it in the past has been:

$$\frac{\text{(CO2 Injected* - CO2 Produced)}}{\text{(CO2 Injected*)}}$$

* Where CO2 Injected is Total Injected Volumes including recycle; we might call that ***'traditional'*** retention

- This leads to a problem because what sequestration folks are interested in are the stored volumes vs. what was delivered to the site (what we call "new" or "purchased" CO2. The better equation would be ***'Actual'*** Retention =

$$\frac{\text{(CO2 Injected* - CO2 Produced)}}{\text{(CO2 Purchased*)}}$$

- Now, over the life of a project, from any 10 CO2 molecules that are injected (purchased + recycled), we generally see 4-6 are "retained" in the reservoir. Another way to say that, over the total life of a project, that we inject about equal volumes of purchased and recycled CO2. Of course, early in a flood, we are not recycling so retention by either definition above is 100% since produced volumes are zero. But, late in the life of a very mature flood, we might be buying only 20% of the total injected volumes. The numerator is 10 – 8 or 2. The actual retention formula denominator is the purchase volume or 2 giving us 100% ***actual*** retention. Whereas, in the traditional retention formula, the retention would be 2 over the total injection volume of 10 = 20%. I think you'll agree that is misleading if what you are interested in are the losses.
- At the very end of a project we might only recycle CO2 and quit purchasing CO2. Although we know CO2 is still being stored, traditional retention would be close to 0% since the CO2 produced = CO2 injected. As mentioned, actual retention is still occurring as the produced volumes are declining but the definition breaks down since the denominator value is zero. As long as the losses at the surface are negligible, we essentially "retain" the purchased volume each day, whether a new or very mature flood!

- Over the next decade, we anticipate increasing the amount of CO2 required as new ROZ projects come on line along with traditional main pay zone EOR projects. Oxy's Century CO2 separation Phase I Plant, south of Ft Stockton, is to be completed late this year and is anticipated to add as much as 270 MMCG CO2, most of which will go to on-going EOR projects that have seen curtailed volumes for several years. The Phase II volumes will come on-line approximately 24 months from now and will go to new projects that Oxy has had on the shelf for the last few years.

Website

- A number of presentations have been/or will be made and can be found on our RPSEA supported website: **Residualoilzones.com**.
- We‘ve made presentations at:
- PBS-SEPM - Nov 2009
- 2009 Annual CO2 Flooding Conference - Dec 2009
- APTA CO2 Flooding School – Jan 2010
- Roswell Geological Society - Feb 2010
- ConocoPhillips - Feb 2010
- Society of Independent Professional Earth Scientists (SIPES) - Midland
- North Texas Geological Society
- And have been invited to discuss ROZ’s with Oxy.

Summary

- We've only just begun.
- ROZ's are real and a major tertiary recovery target for today and long into the future.
- Modeling using regional scale groundwater modeling package is underway.
- Documentation of areas/fields with large potential is underway.
- Phase 2 – testing models in the field, and developing a "Cook Book" for determining the ROZ EOR potential in a field.