Residual Oil Zones (ROZ's) and the Long Term Future of the Permian Basin (and Elsewhere).

Dr. Bob Trentham

University of Texas of the Permian Basin/Center for Energy and Economic Diversification (CEED)

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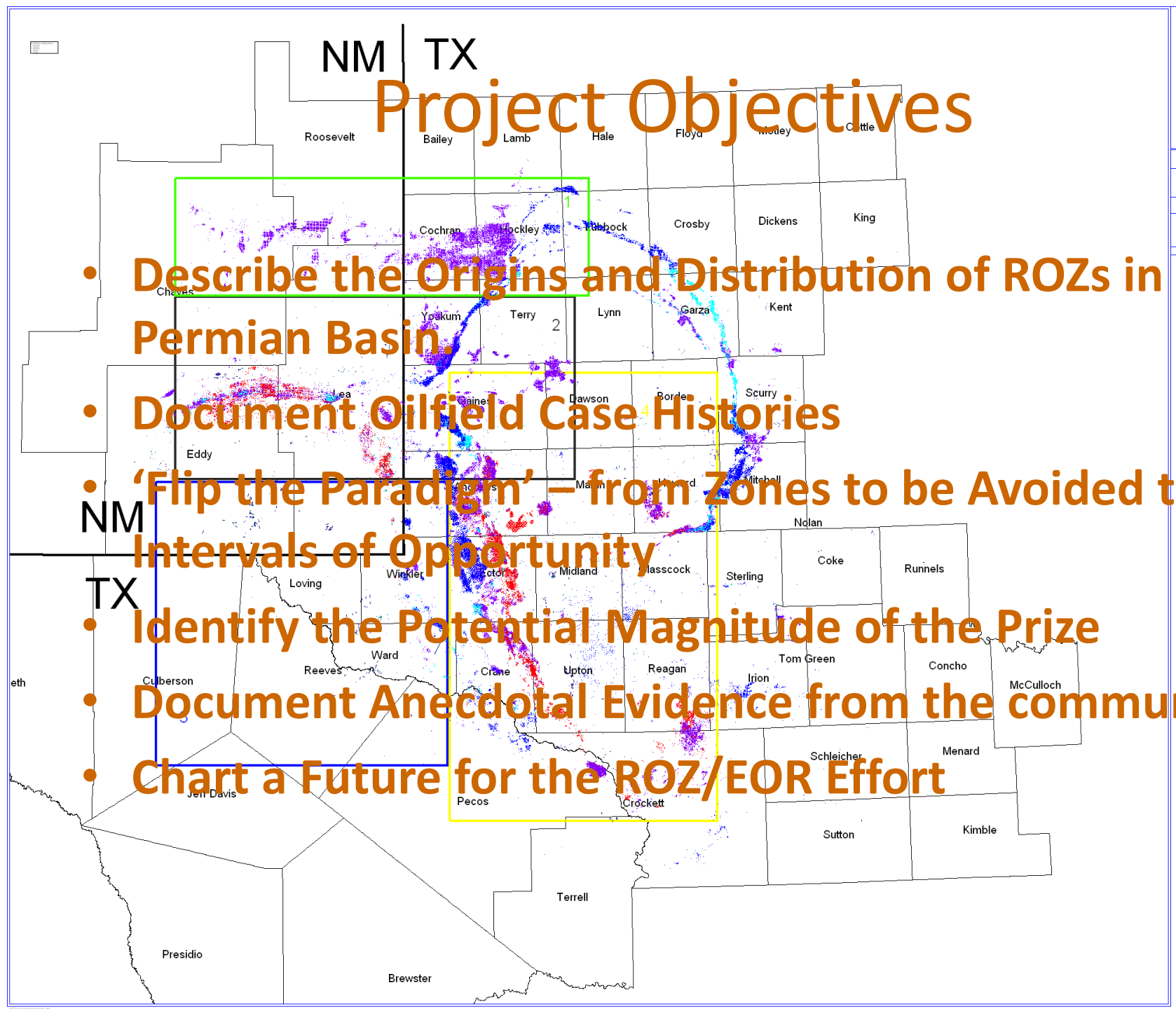
SPE Permian Basin Study Group of Gulf Coast Section



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.

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 Chevron & Legado Resources.
- 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.

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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

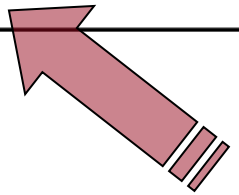
11.9 Billion BO is technically recoverable from the 30.7 Billion BO of TZ/ROZ oil in-place in these five Permian Basin oil plays

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

Review of History & Modeling

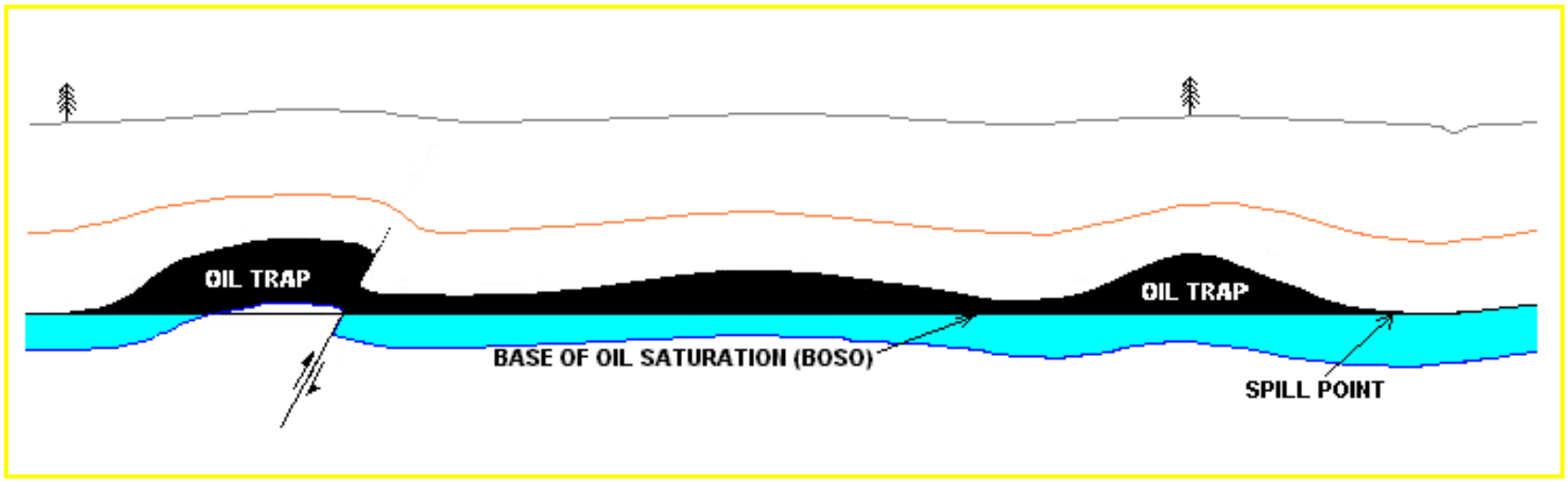
ROZ BACKGROUND
The 3 types of Residual Oil Zones

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)

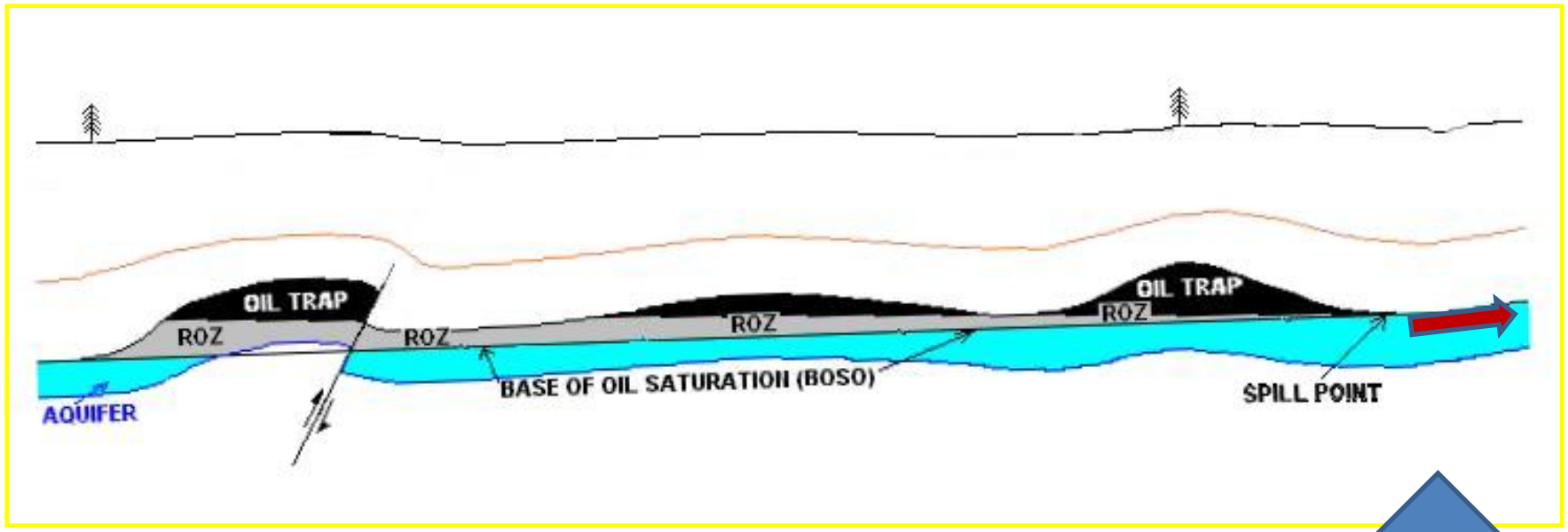


The Evidence suggests Type 3 are common in the Permian Basin

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

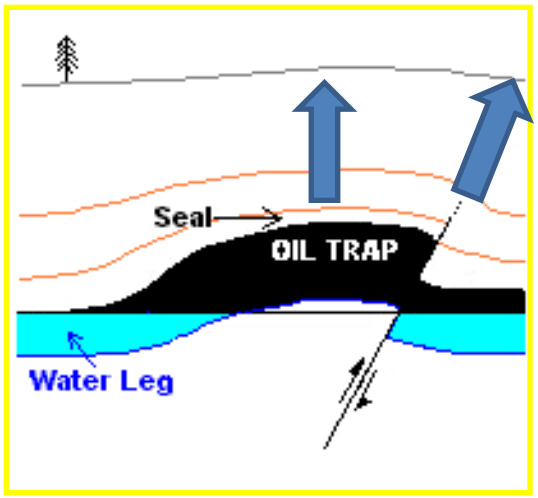


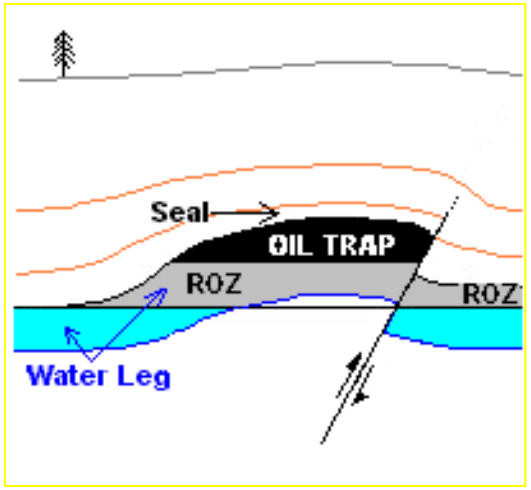
TYPE 1. Original Accumulation Subject to a Eastward Regional Tilt & Forming a ROZ.
The new O/W contact is horizontal
The base of the ROZ is tilted
Oil would have migrated out of the basin.



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.



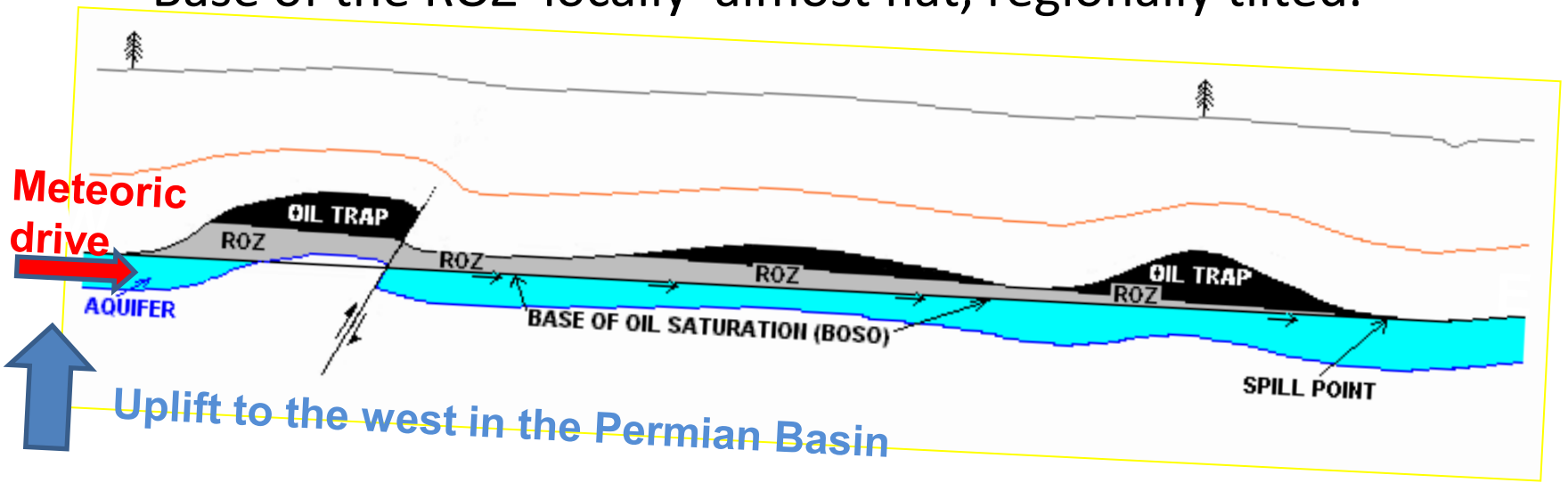


Static System

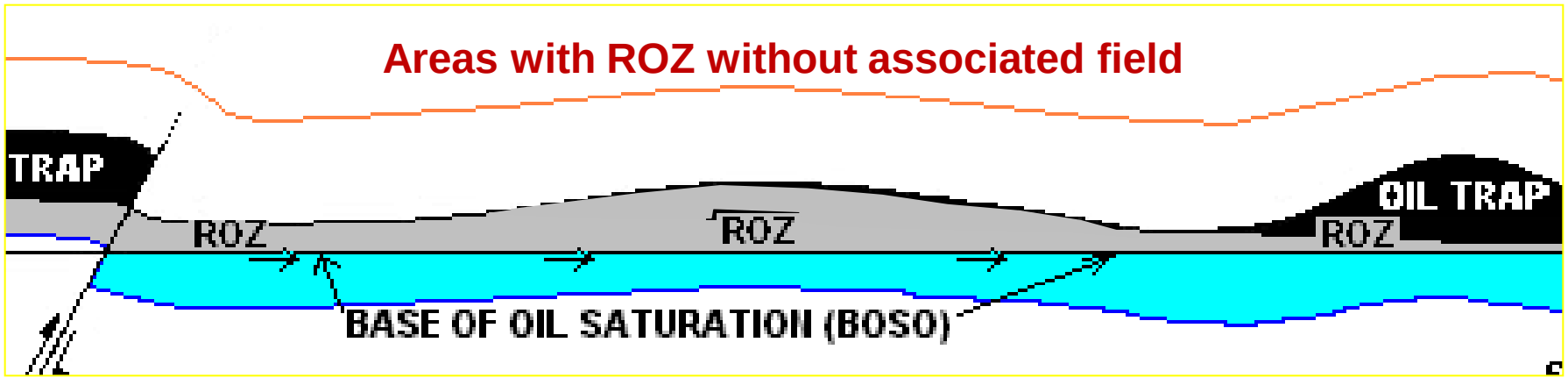
TYPE 3. Change in Hydrodynamic Conditions, Sweep of the lower part of the Oil Column and Development of a Residual Oil Zone.

Oil/Water Contact is Tilted

Base of the ROZ locally almost flat, regionally tilted.



Dynamic System



Attributes of the ROZ Types

ROZ TYPE	Oil-Water Contact	Base of Oil Saturation	Other Characteristics
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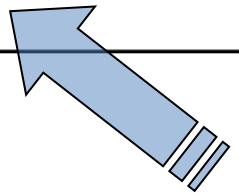
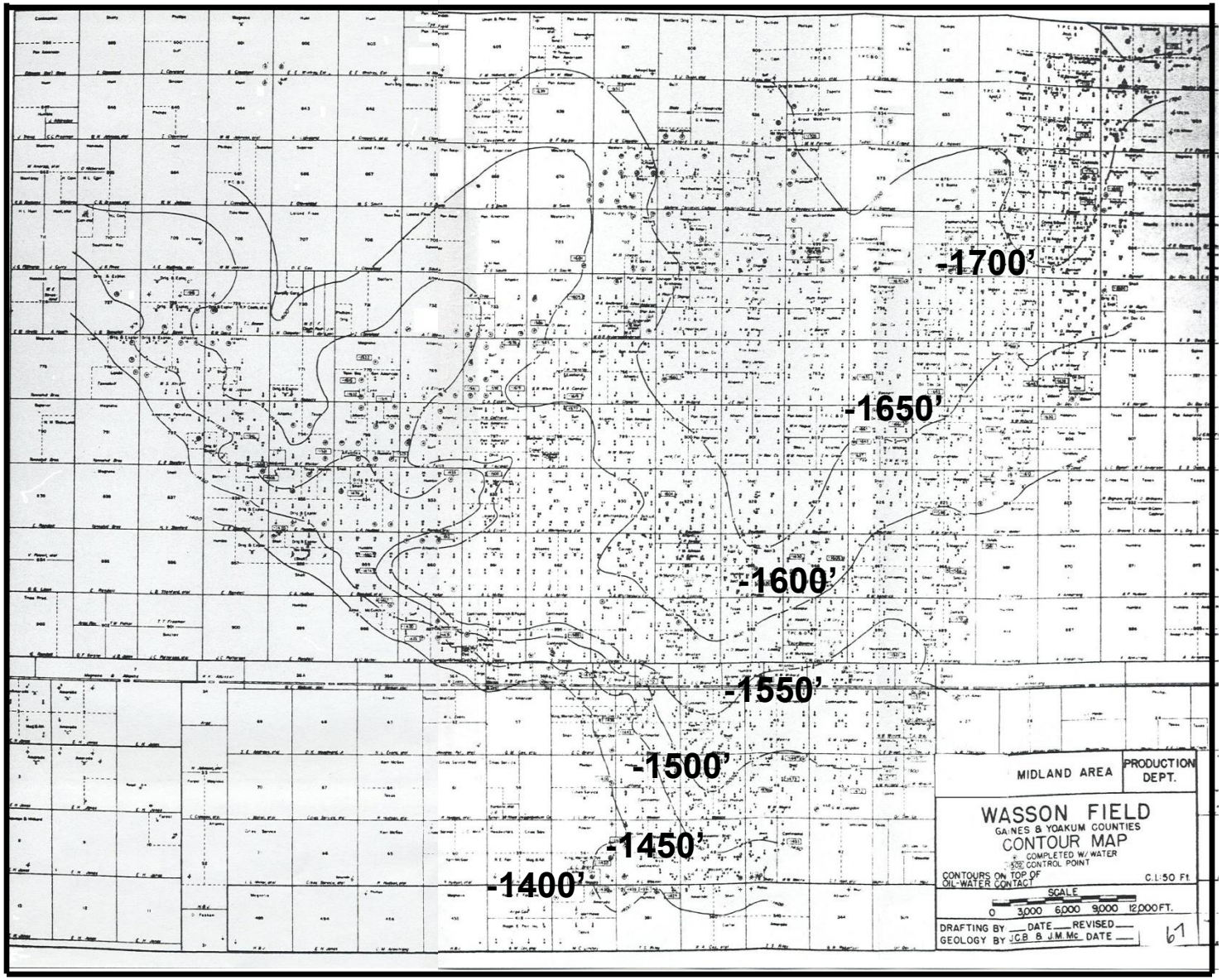


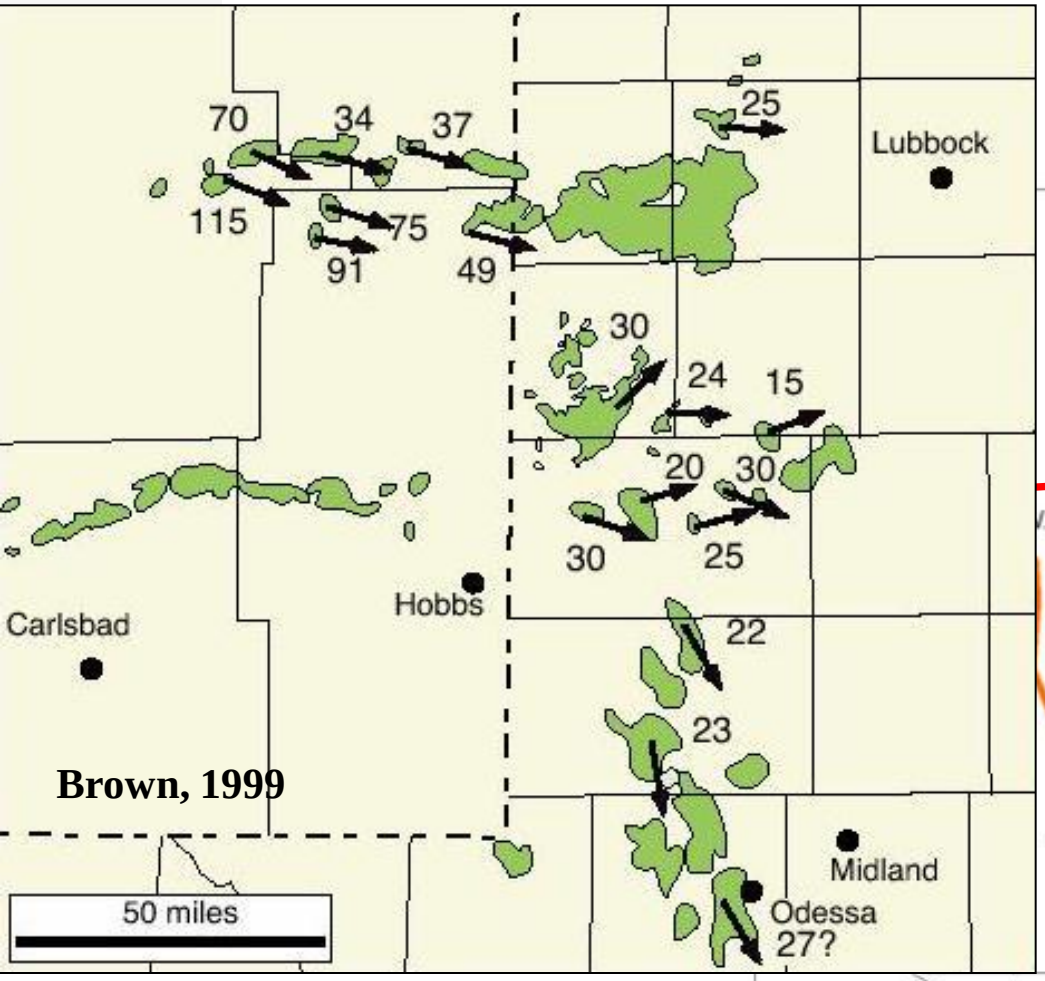
First, Let's Look evidence for OWC Tilt

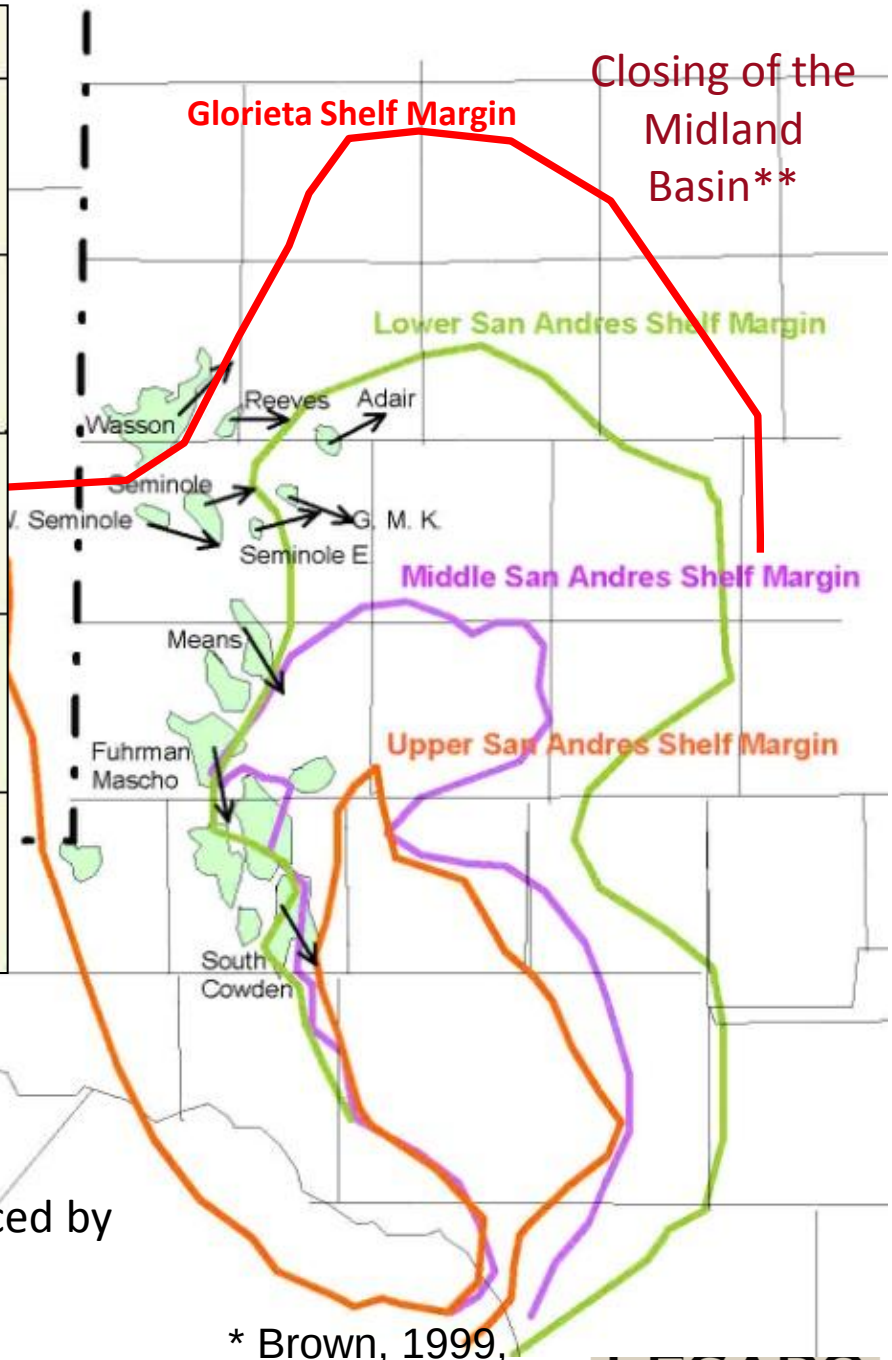
How did we get here?
Alton Brown and Bob Lindsay

- **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







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

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Chevron

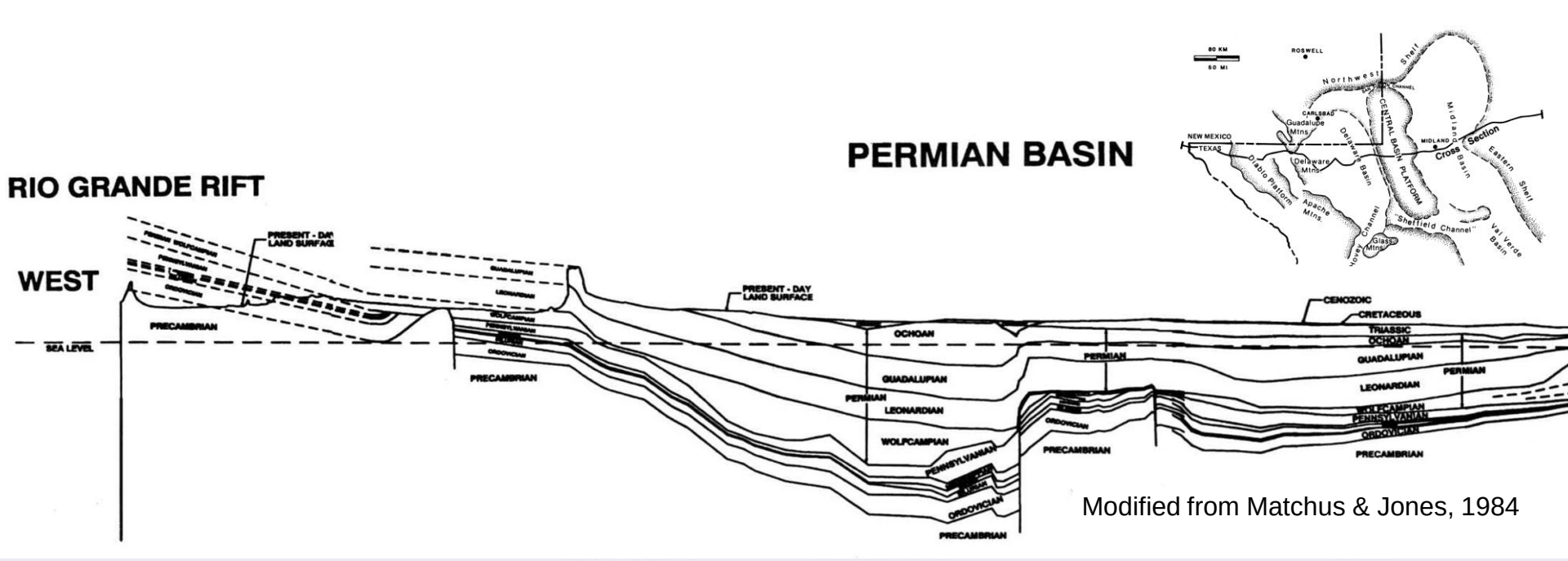
LEGADO resources

Tilted Oil Water Contacts

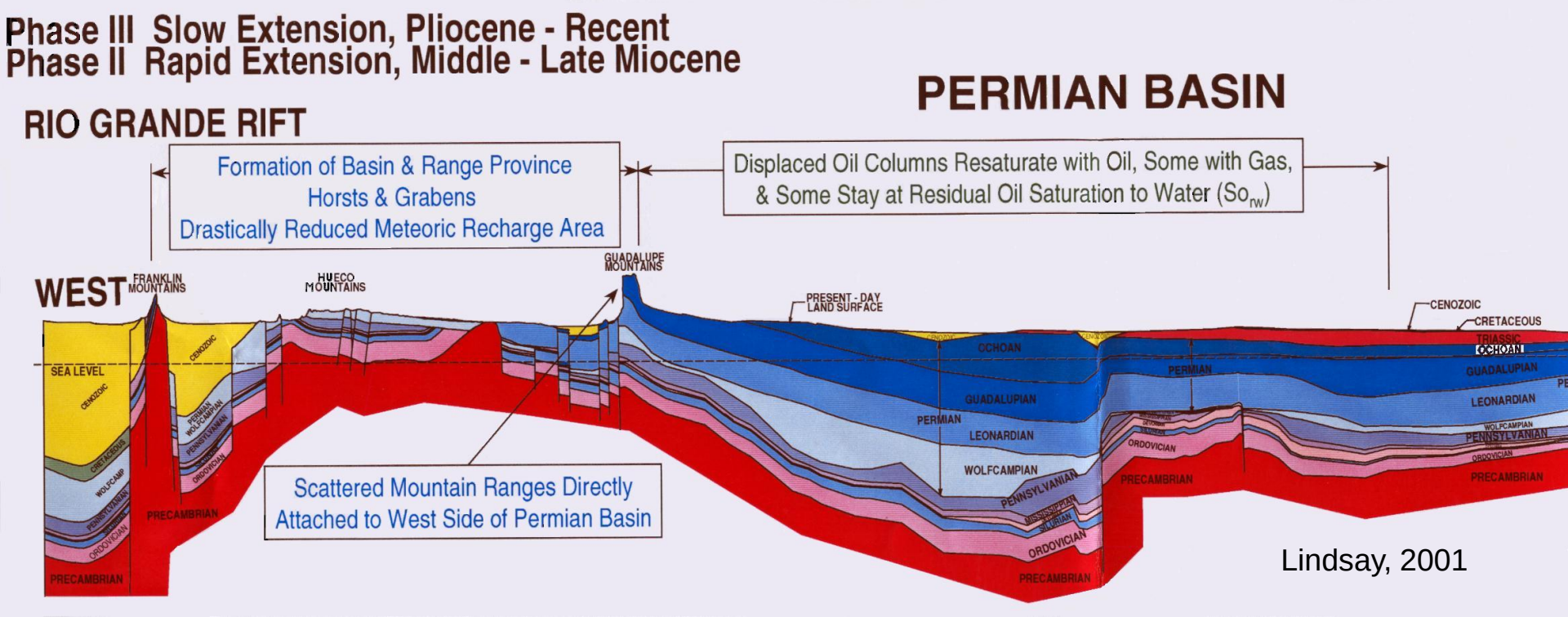
- New Axiom – " If you have a tilted oil/water contact in the San Andres, you have a ROZ.
- If you have an ROZ…….find a contract for CO_2.
- Be prepared for big hug from royalty owner.

How did we get here?
Alton Brown and Bob Lindsay

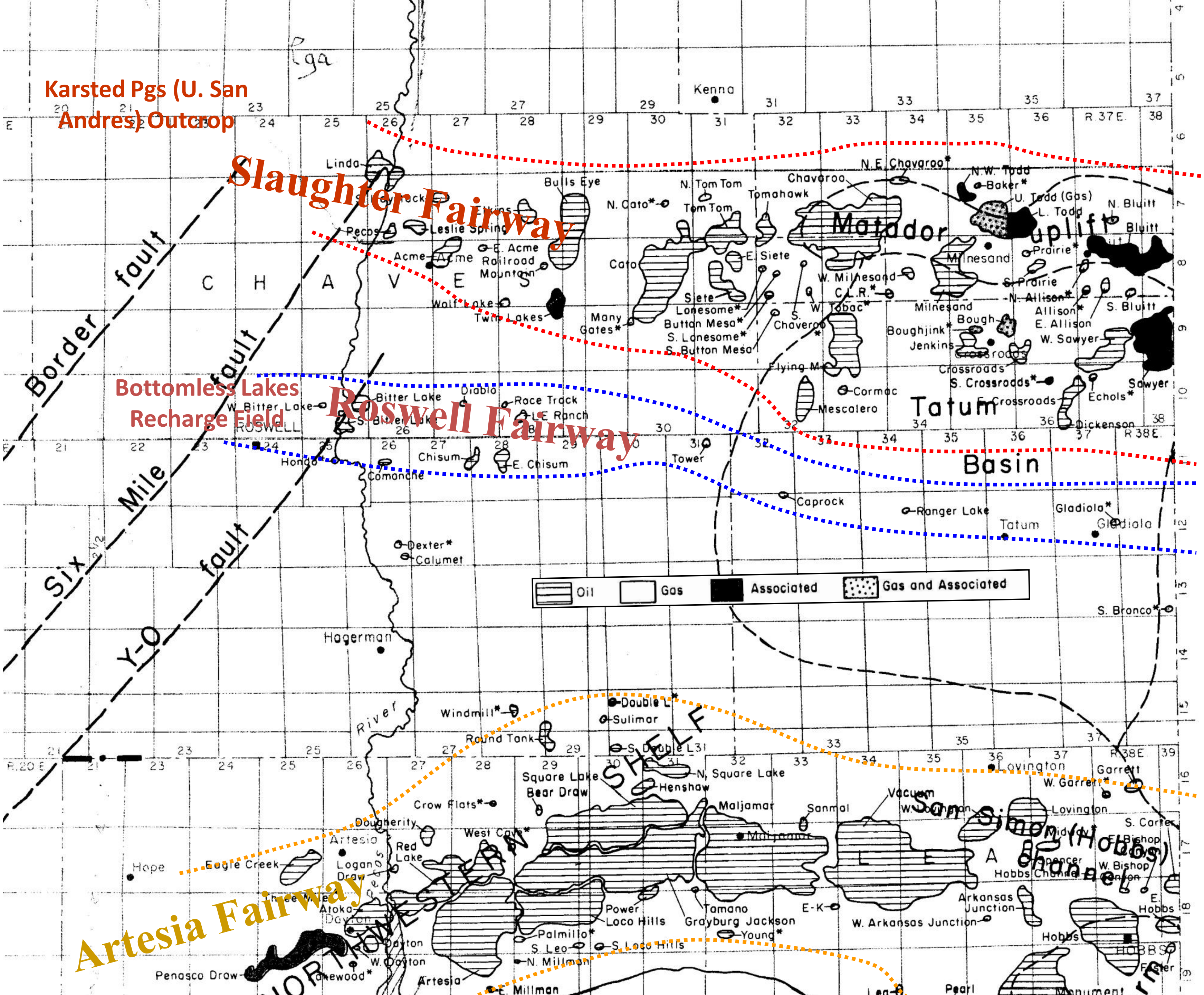
- **Bob Lindsay**, while at Chevron, looked at outcrop-core-production relationships, documented meteoric sweep and the development of Residual Oil Columns in a number of fields on the Central Basin Platform.
- He envisioned massive recharge of meteoric waters into the subsurface during the Mid to Late 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.



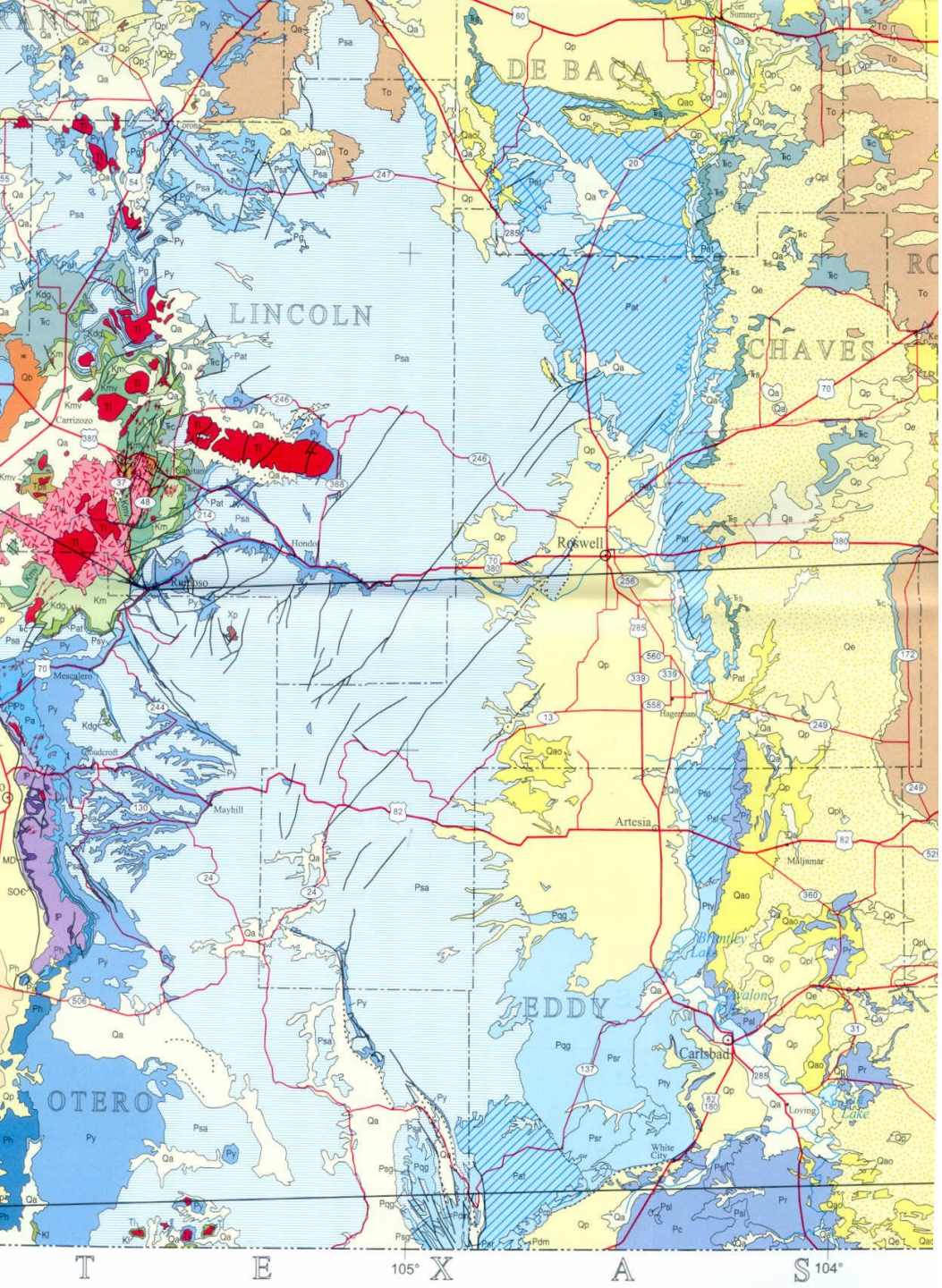
Modified from Matchus & Jones, 1984



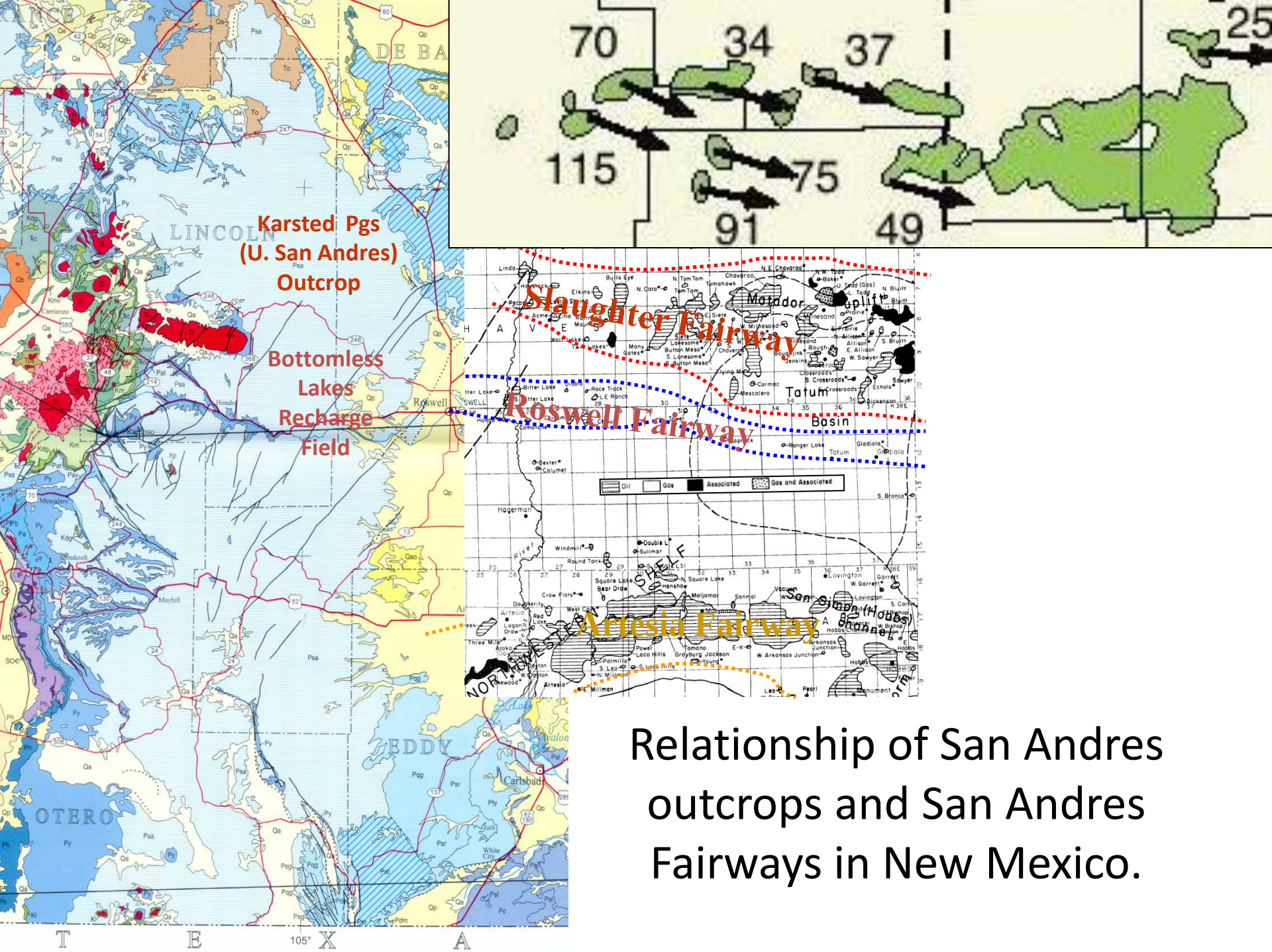
Lindsay, 2001



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



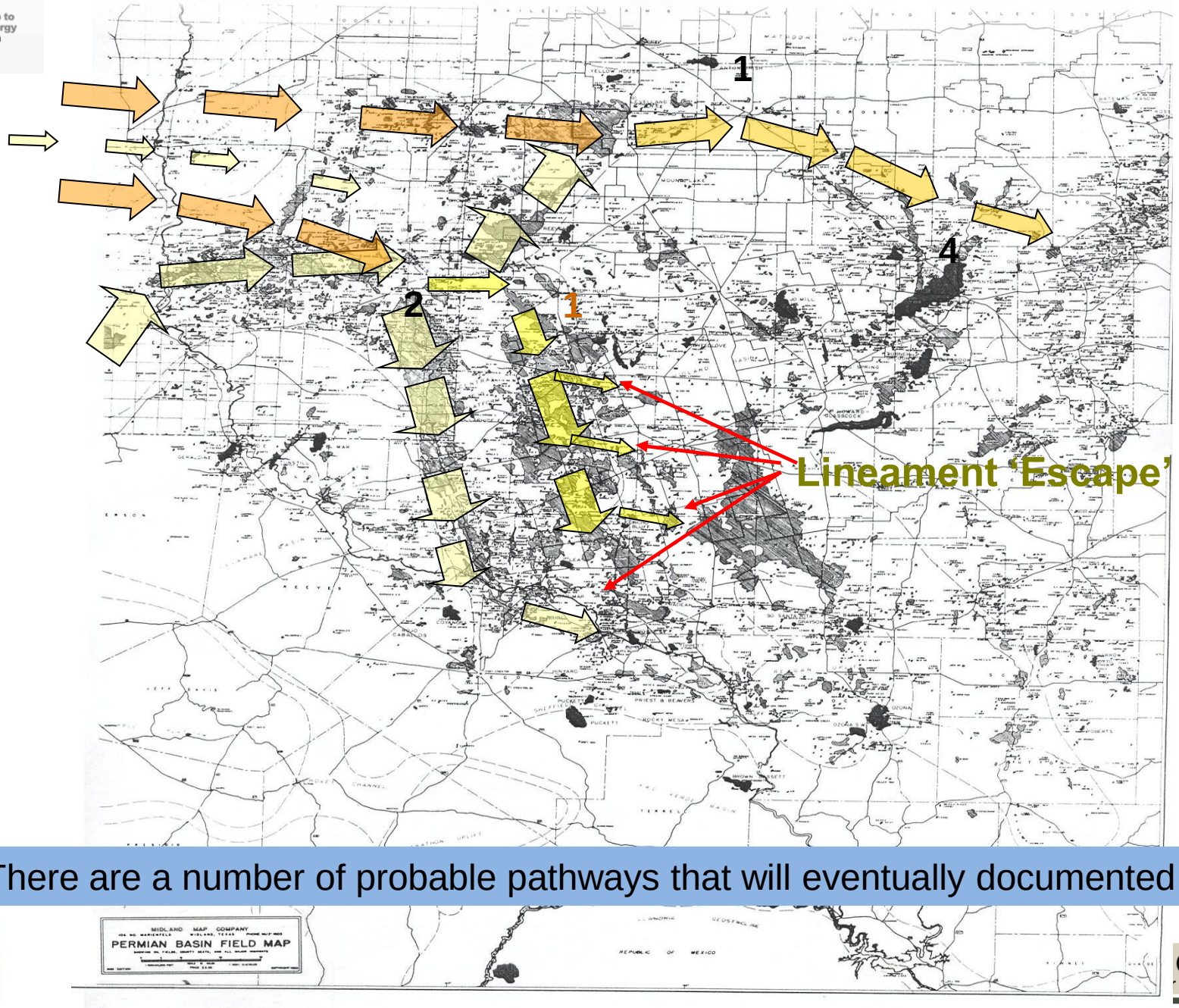
San Andres outcrop (light Blue) is the present day extent of the recharge area for the meteoric water that sustains the tilted oil water contacts in San Andres reservoirs.



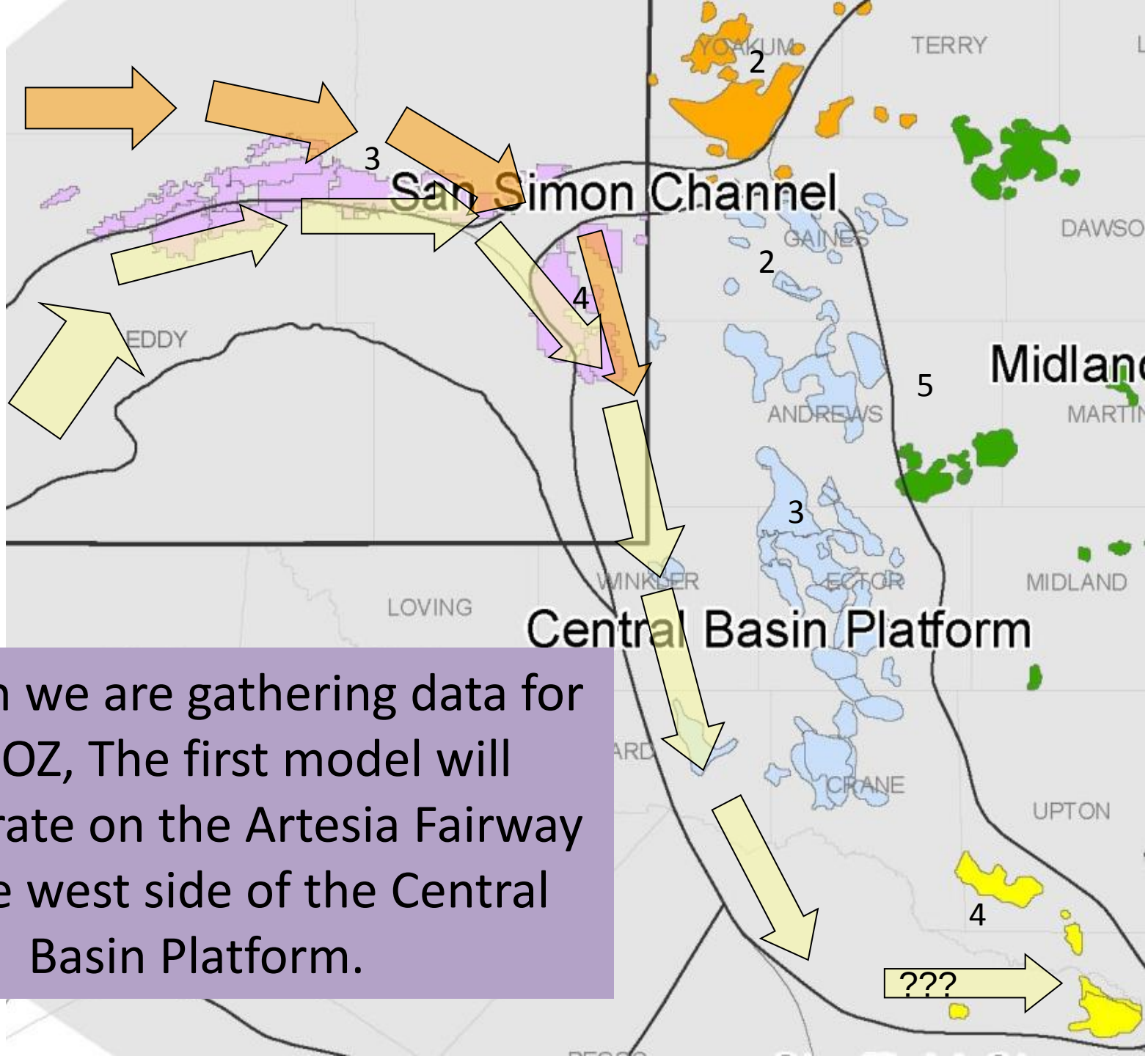
Relationship of San Andres outcrops and San Andres Fairways in New Mexico.

PERMIAN BASIN FIELD MAP

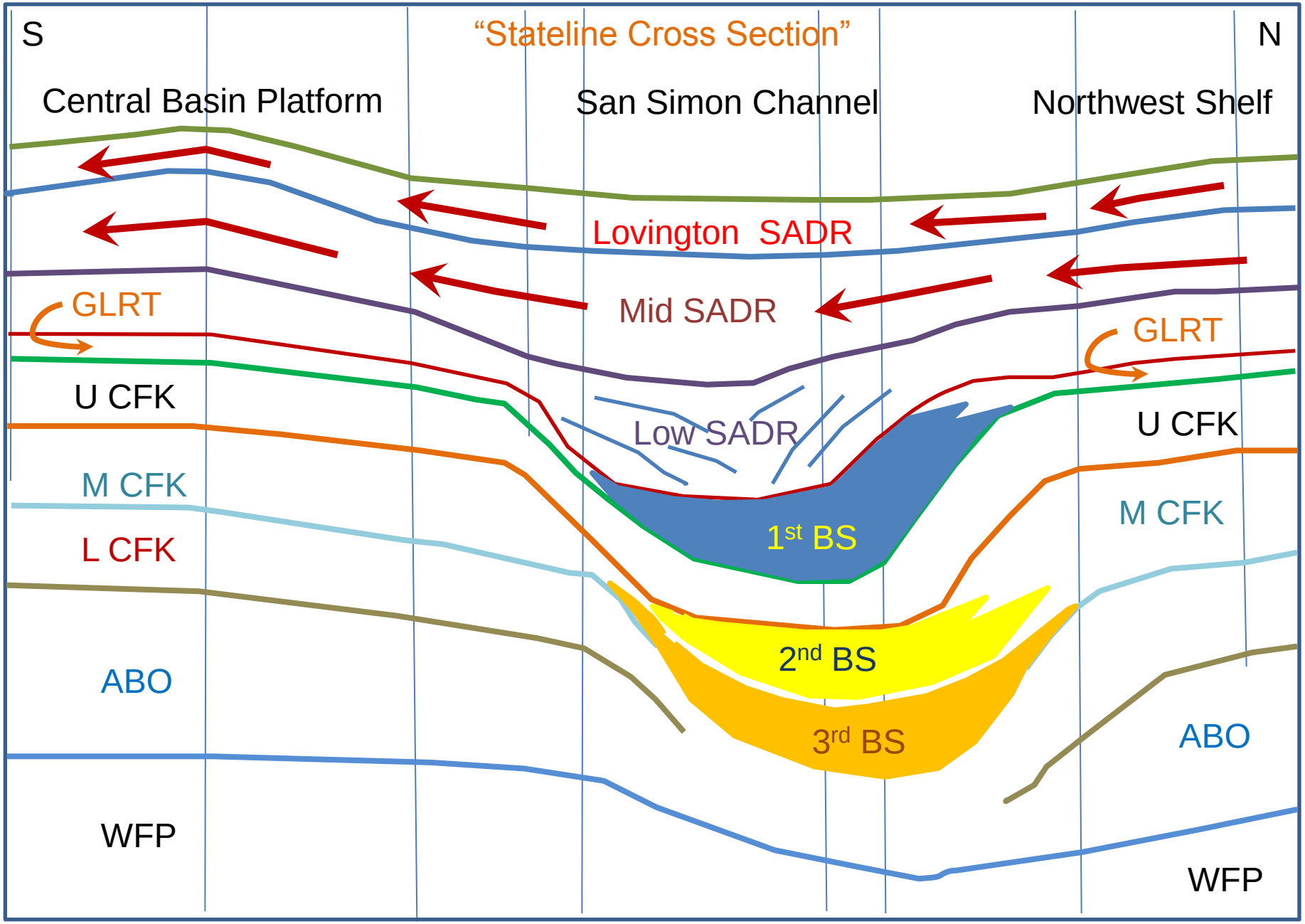
WITH THEORIZED (U. PERMIAN) HYDRODYNAMIC FAIRWAYS



There are a number of probable pathways that will eventually documented



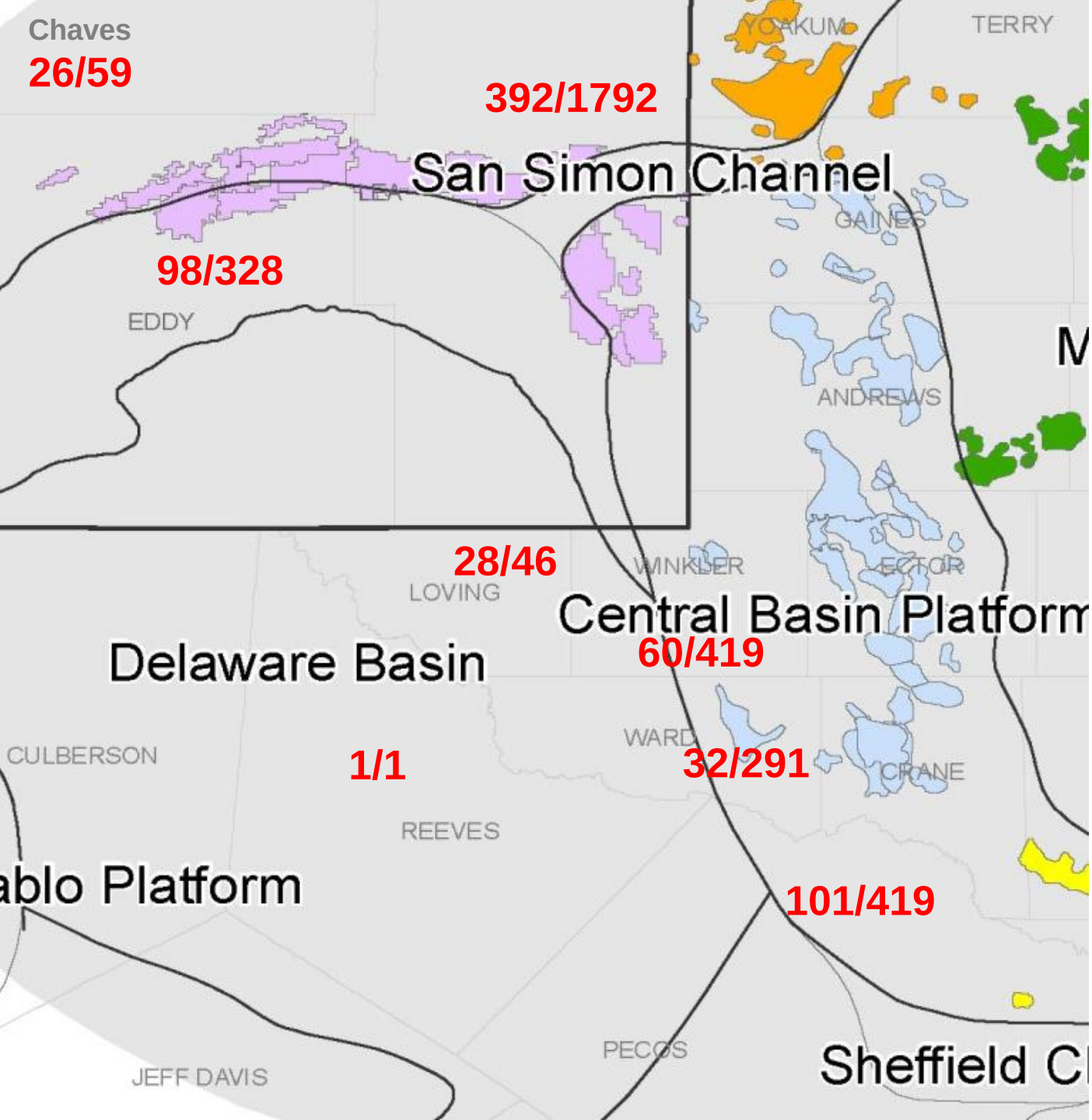
Although we are gathering data for any ROZ, The first model will concentrate on the Artesia Fairway and the west side of the Central Basin Platform.



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

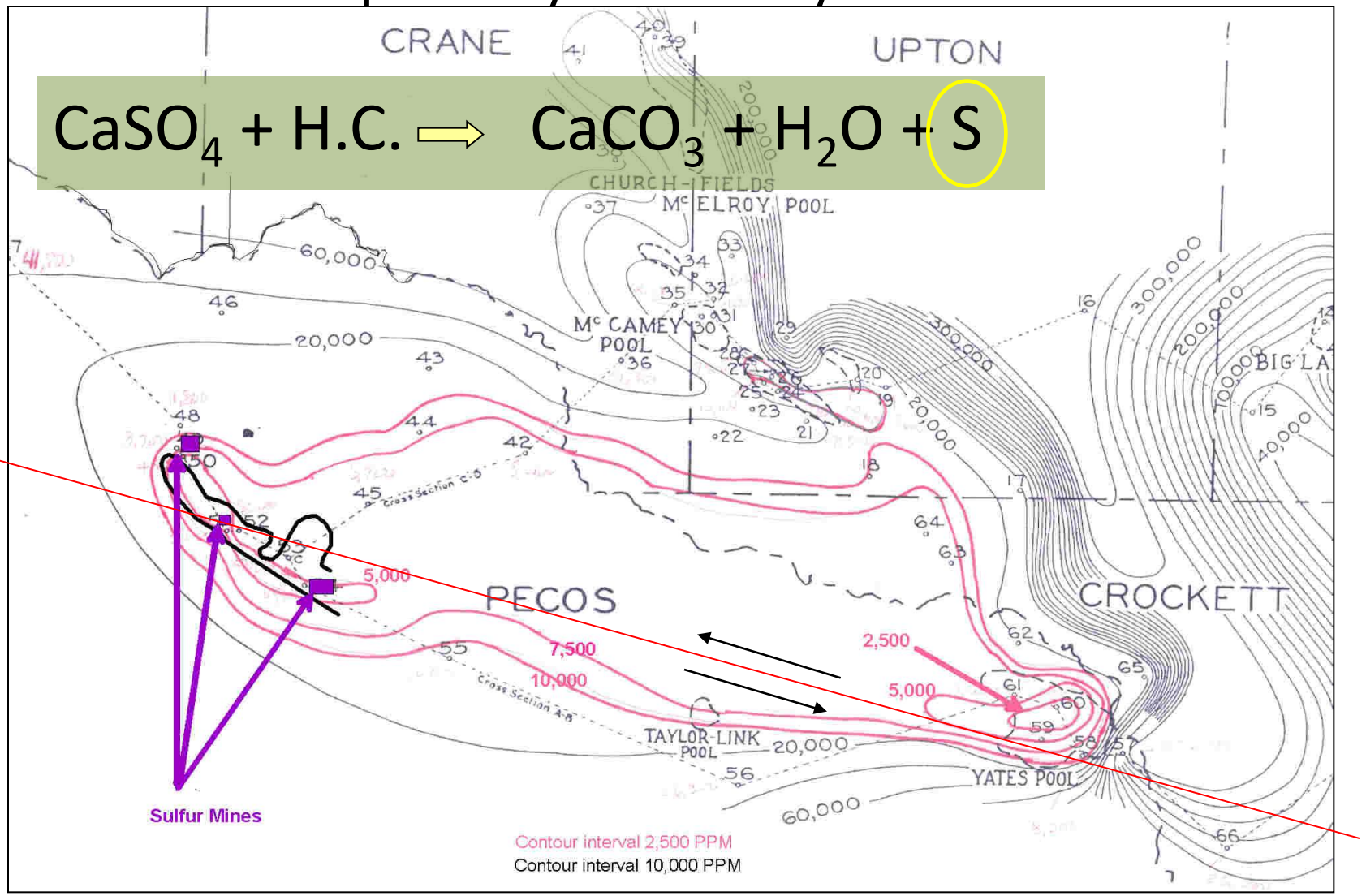
DST / Water Chem

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

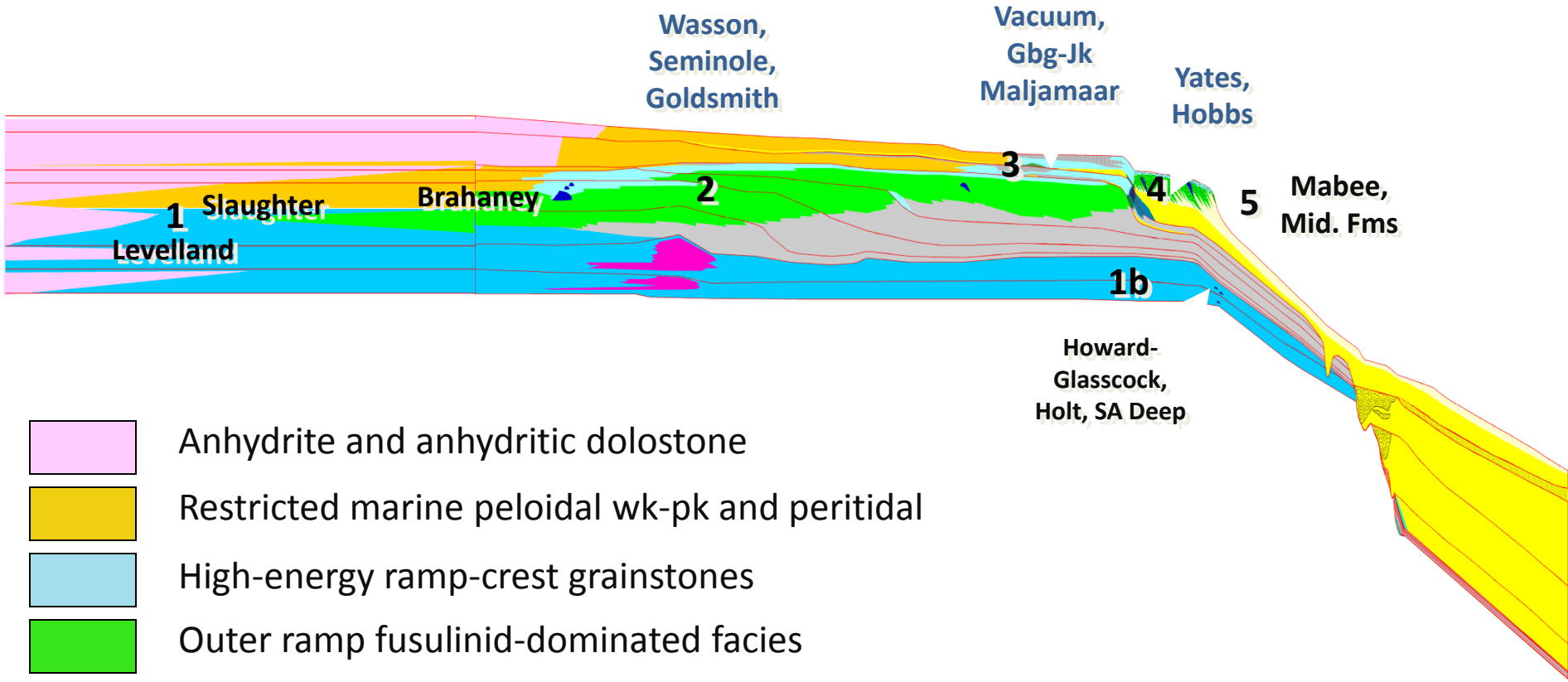


San Andres Water Salinities and Sulfur Deposits

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'

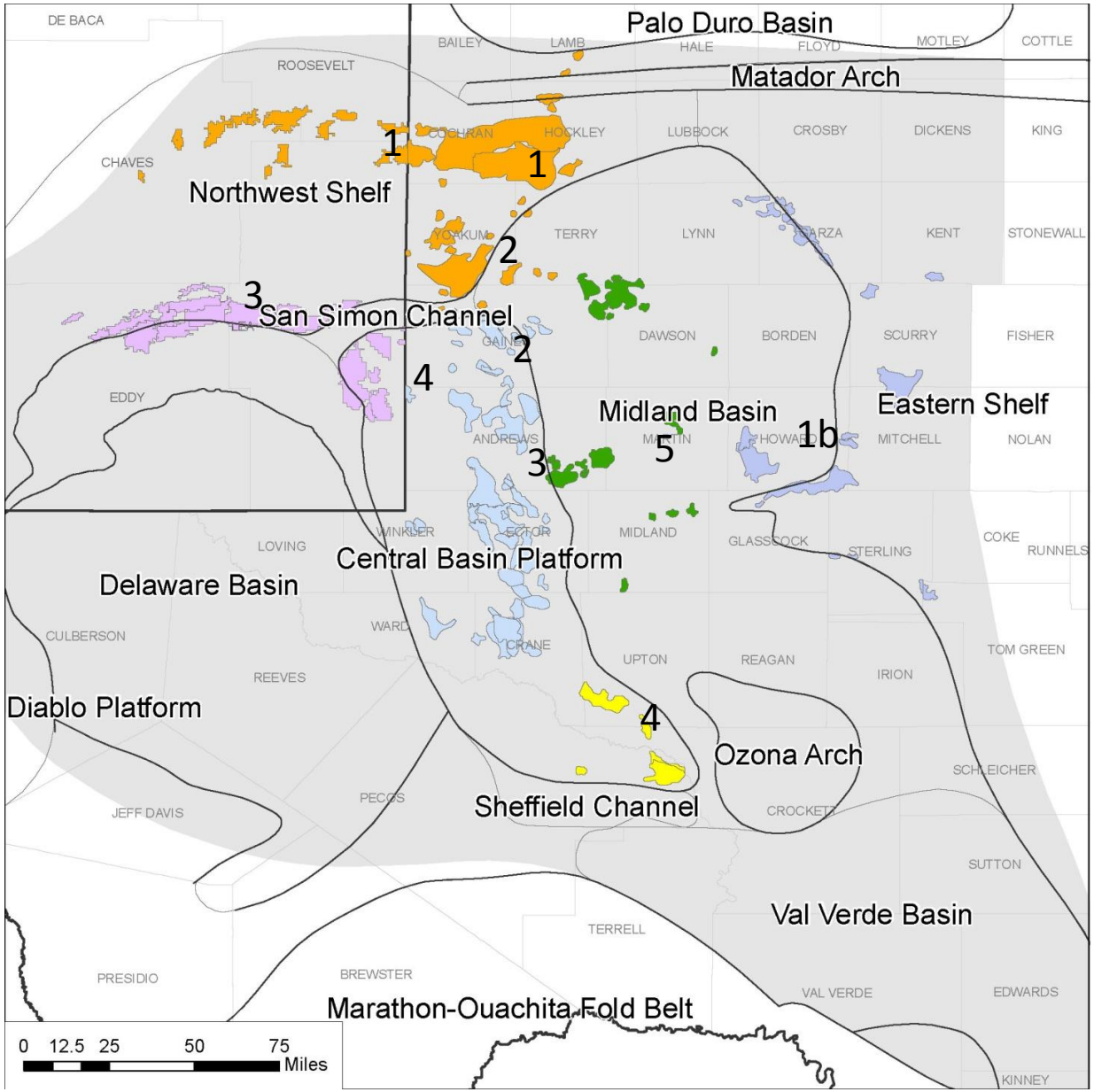
San Andres Reservoir Settings.
All fields are not alike.



- 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

Classification of San Andres Reservoirs on basis of Stratigraphic Setting



Legend

- 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)

“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 and production 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
- 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.

Anecdotal Evidence

- Info from a growing number of exploration wells documents what can be interpreted as ROZ's where the tests were unsuccessful as there was no associated primary production. Data from a number of explorationists and review and reinterpretation of research articles on Permian Basin fields, suggest a set of common ROZ characteristics:

  - 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
  - IP's similar to mature waterflood.

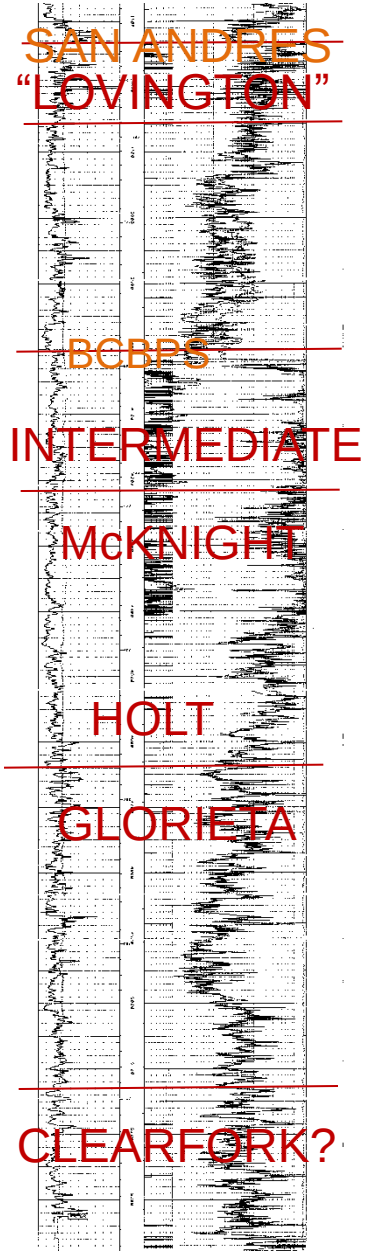
  - Evaporites may be dissolved or altered in the lower part of the main pay.
  - The presence of sulfur crystals associated with gypsum/anhydrite/calcite in the ROZ,
  - Solution enhanced fractures in lower portion of the ROZ
  - Enhanced porosity and permeability in the ROZ relative to in the main pay zone as the result of meteoric dissolution of sulfates.
  - Pervasive "late" dolomitization indicating meteoric sweep.
  - "Tight" high So intervals near the BOSO transition.
  - Sequence stratigraphic boundaries to top and bottom of ROZ.
  - Possible oil chemistry differences between main pay and ROZ.

Some other questions to consider:

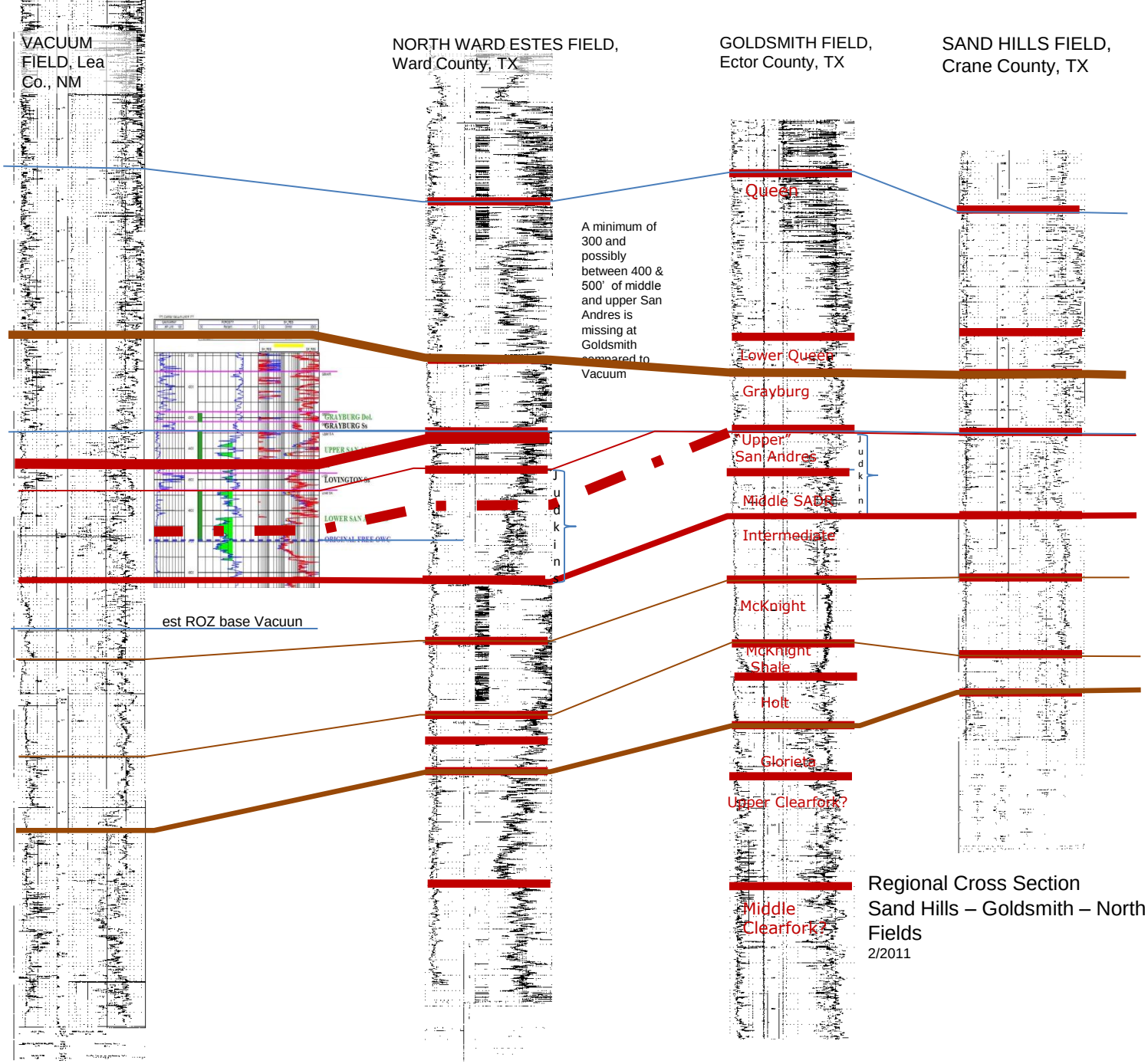
- The total thickness of the San Andres at major producing field ranges from 650-750’ [Yates and Goldsmith] to 1400 to 1600’[Seminole to Vacuum], yet,
- The ratio of ROZ to main pay thickness in those large field may remain close to 1:1.
- Where there is little to no main pay, the thickness of the ROZ can equal or exceed the thickness of the main pay AND the ROZ in some major fields.
- Why is there no major San Andres or Grayburg production south of the Texas/New Mexico border on the west side of the Central Basin Platform?
- Significant ROZ’s appear to be present in the Leonard (Glorieta and upper and lower Clearfork) which are below the San Andres (Guadalupian) path across the San Simon channel.

- Placing the San Andres in a regional context is important in understanding the development of the ROZ's.
- The San Andres can be divided into three intervals:
  - A lower San Andres composed of L7 & L8 (Holt) and G1 & G2 (McKnight),
  - a middle San Andres composed of G3-G4 (Intermediate), and
  - an upper San Andres composed of G8 (Judkins) and G9 (Lovington Sand - and Post- Lovington Carbonates).
- In addition, the southern end of the Central Basin Platform has had a different tectonic history then the northern end of the platform, the Northwest Shelf and the Guadalupe Mountains.

Nomenclature, based on Gulf Oil's Central Basin Platform "Formations"



G 9	Lovington Lime
G 8	Pre- Lovington
G 5 – 7	Brushy Canyon
G 3 – 4	Intermediate
G 1 – 2	McKnight
L 7 – 8	Holt
L 5 – 6	Glorieta



Regional Cross Section
Sand Hills – Goldsmith – North Ward Estes – Vacuum Fields
2/2011

WD3:Goldsmith:E-W X sec

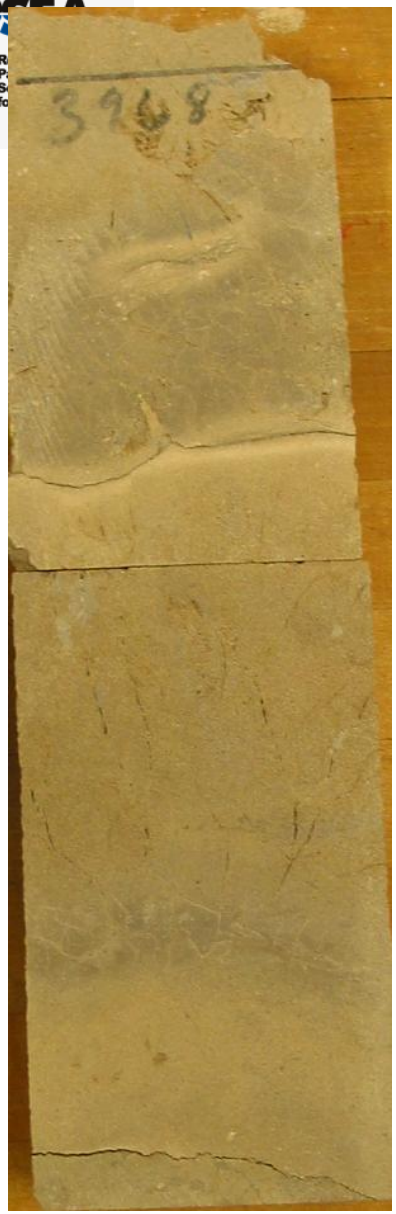
When does a "One Of a Kind" become a Trend?

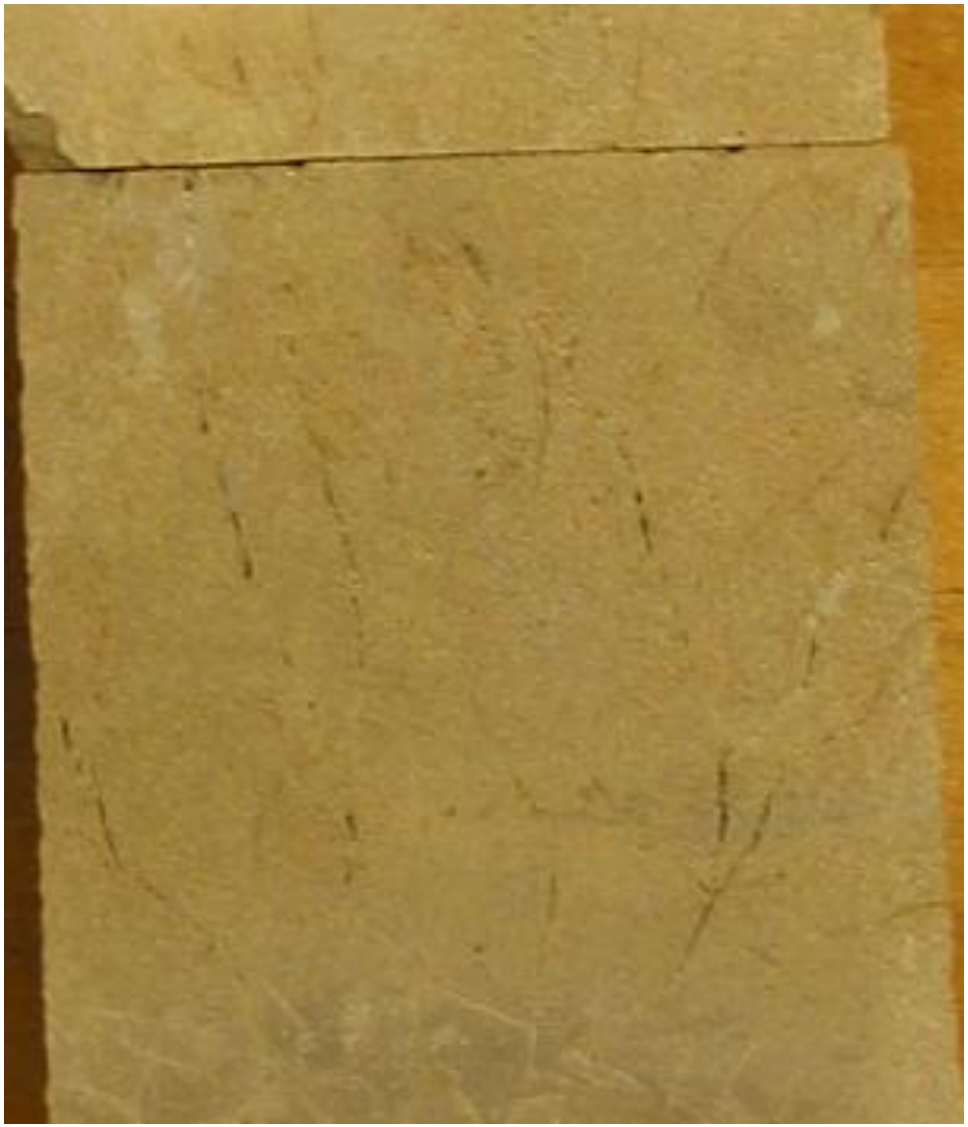
- There appears to be a number of attributes of the BOSO at or near the base of the ROZ:
  - Large vugs (removed Anhydrite Nodules) filled or partially filled with SULFUR
  - "Spotty" oil stain/SHR/Dead Oil in the tight portions of more porous intervals
  - Transition from dolomite above to limestone below
  - The presence of a baffle or barrier to vertical flow (Sequence or Cycle Set Boundary)
  - Solution enhanced fractures

Gypsum with Sulfur

Calcite with Sulfur

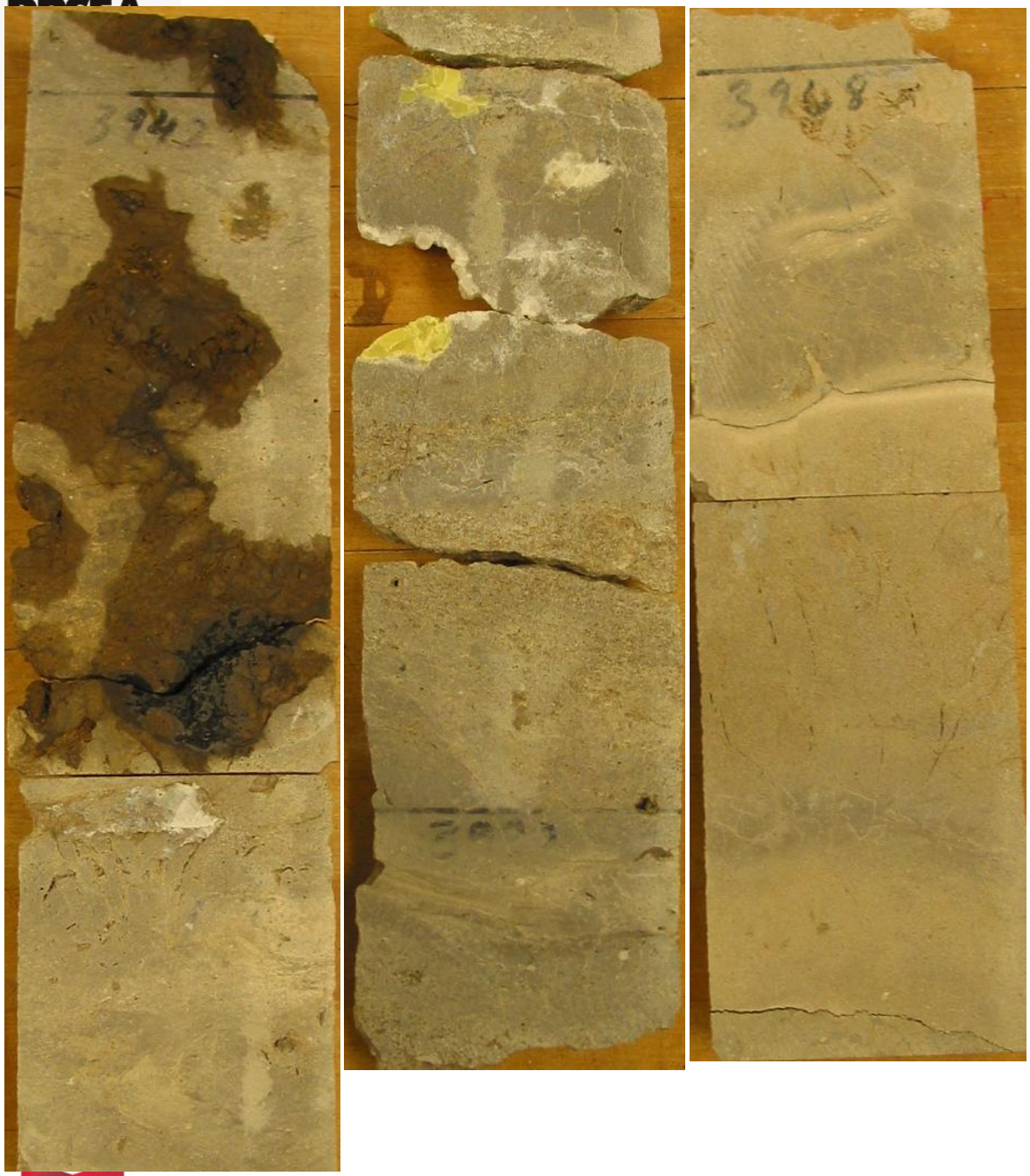
Calcite with Sulfur





Late solution enhanced fractures with no SHR on faces

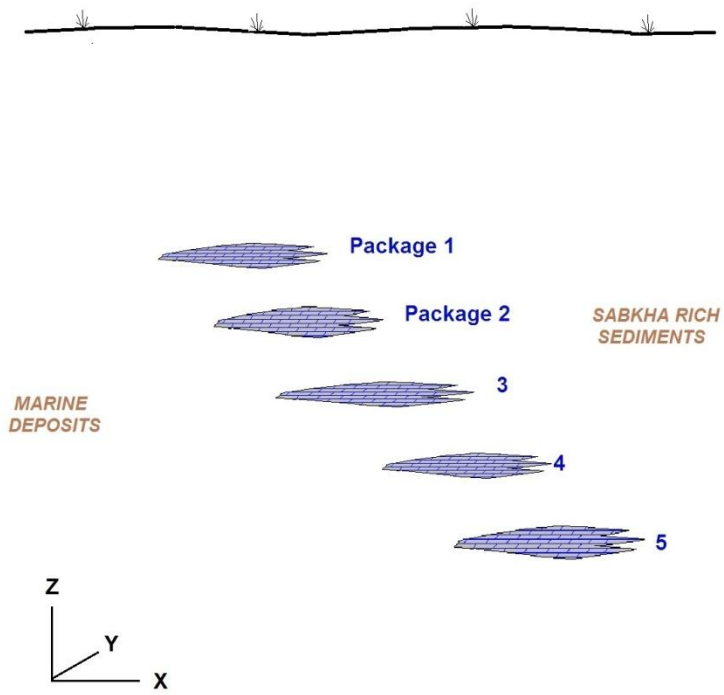
"Spotty" high oil saturation near BOSO



These late features can be found at or near the base of an ROZ regardless of the formation

- An un-named area in the Permian Basin where there has been production established in multiple zones above the residual oil zones (ROZs) for over 75 years and production below the zones for almost 50 years.
- The area encompasses ~140 sq miles (20 miles long by 7 miles wide) in which there were ~250 wells that penetrated the ROZs, most being drilled to develop deeper production.
- The major productive horizons above (100's of millions of BO) and below (10's of millions of BOE) the ROZs do not themselves have documented ROZs.

Figure 1: SCHEMATIC CROSSECTION OF ROZ (PDI) PACKAGES

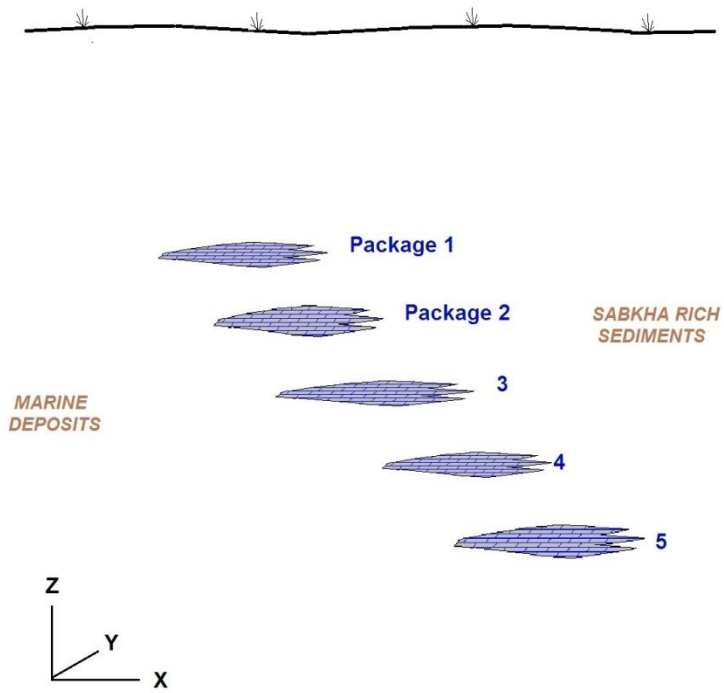


•The five ROZs are in a series of stacked carbonate ramps to shallow shelves with up dip stratigraphic traps where porosity and permeability are lost updip in evaporite rich sabkha deposits (see schematic cross section depiction in Fig. 1).

•There has been less than 3 MMBO produced from the five intervals with associated ROZs between the shallower and deeper major producing horizons.

•These ROZs are pervasively dolomited intervals (PDIs) of the type where the porous sections have been swept by Mother Nature's Waterflood (MNW) in the "Y" direction in the schematic cross section.

Figure 1: SCHEMATIC CROSSECTION OF ROZ (PDI) PACKAGES



•There is only minor associated primary production in isolated stratigraphic traps. This ROZ heavy vertical interval, without major main pays, has a gross thickness of 3000 to 3500' and reservoir quality rock approaching 2000' feet in some areas.

•The individual zones are separated by sections dominated by mud rich facies. Most of the section must have had oil entrapped prior to the MNW.

North Ward Estes, western margin Central Basin Platform

- Some Production in Glorieta
- In lower San Andres, **H. S. A. #1449** core had good oil stain I fusulinid rich outer shelf facies, but is not productive. Lower SADR producers - **#73, #76, #77, #79 Richter**. 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)

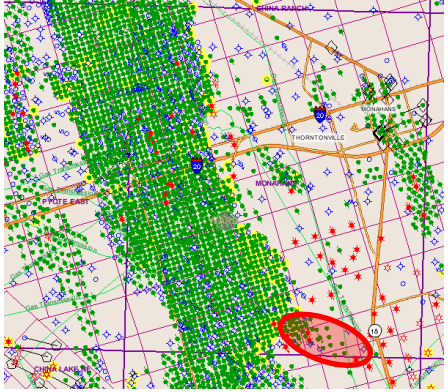
Discovered in 1991, produced over 1MMBO from a small closure with "tight" tidal flat and shallow subtidal carbonates.

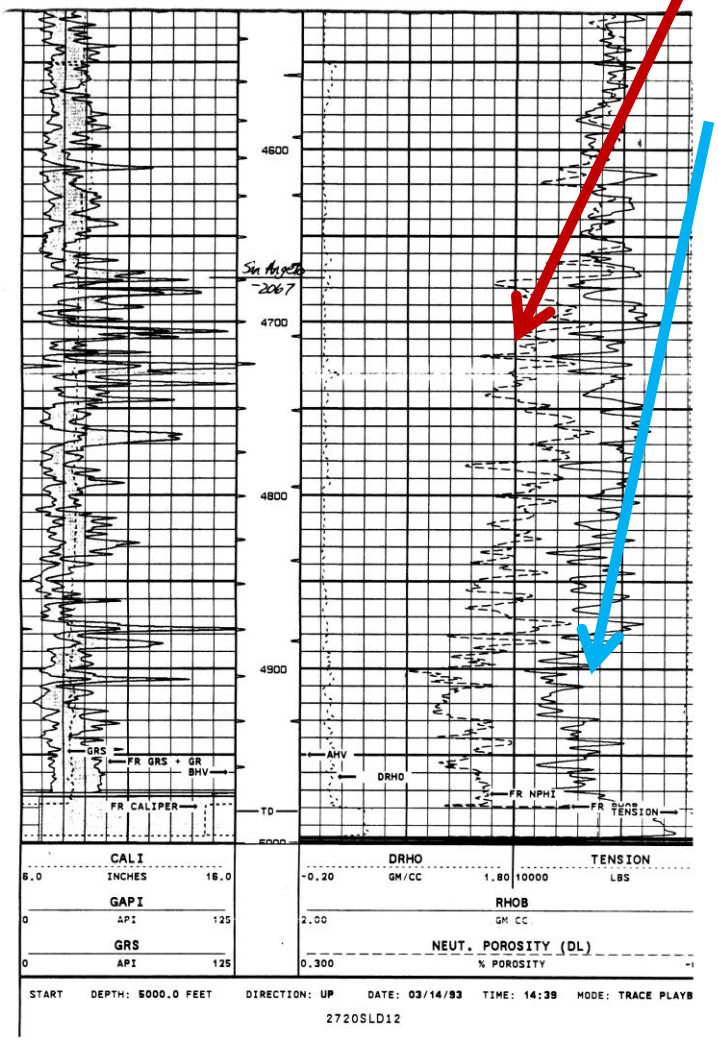
Why did it take so long to discover it?

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?



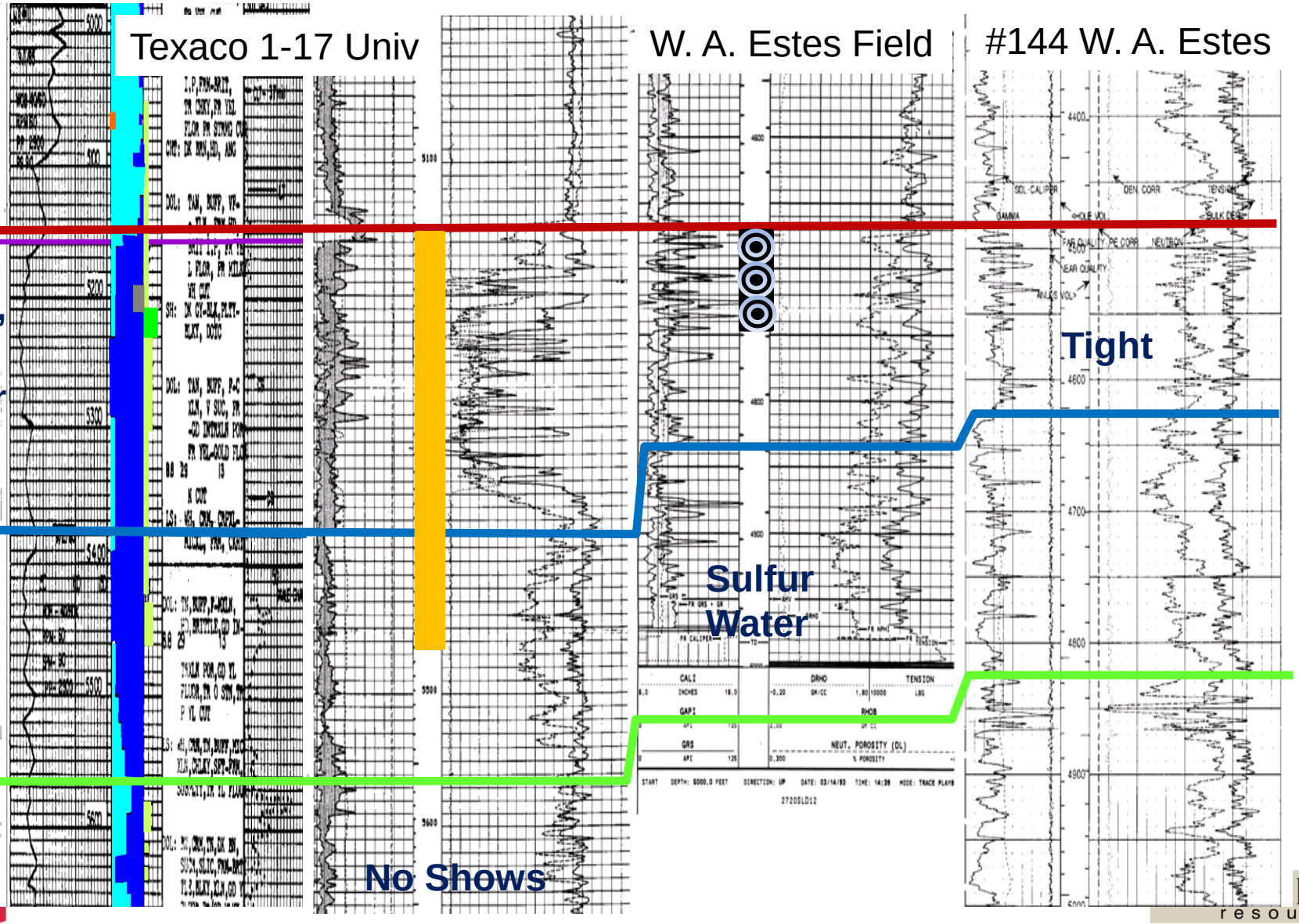


The pay is the upper Glorieta/San Angelo.

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



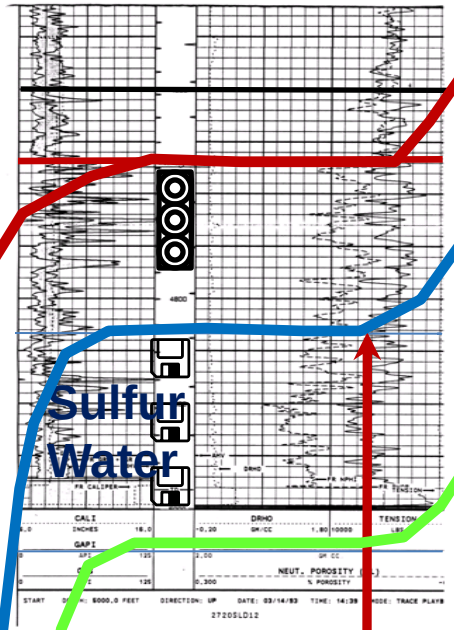
Research Partnership to Secure Energy for America

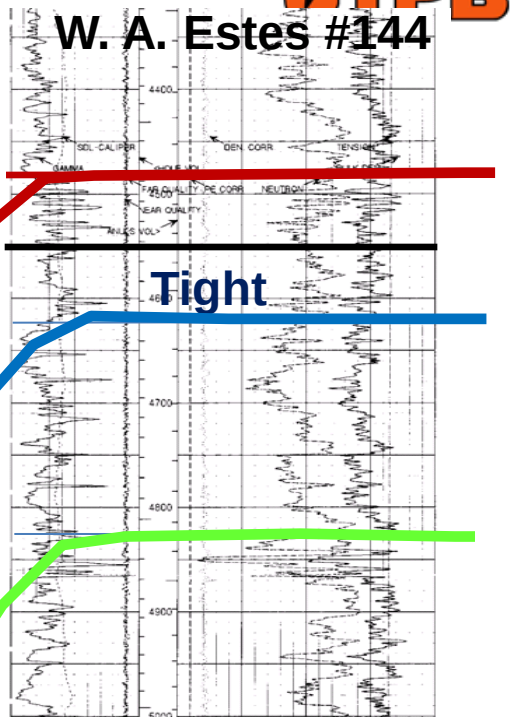
ITPB

Texaco #1-17 Univ

W. A. Estes Field

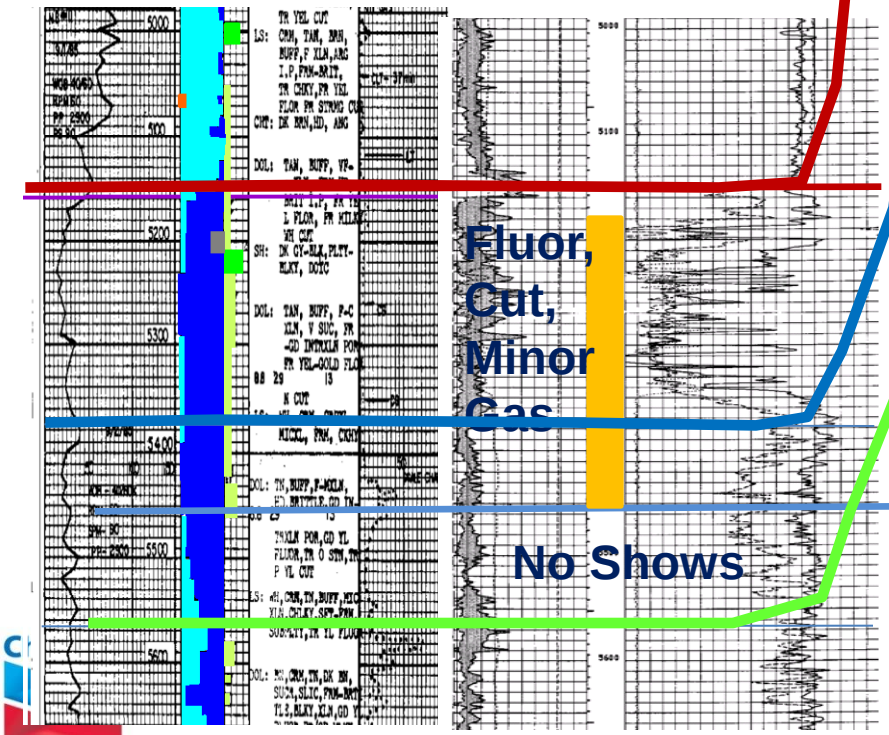
W. A. Estes #144





Tight

Sulfur Water

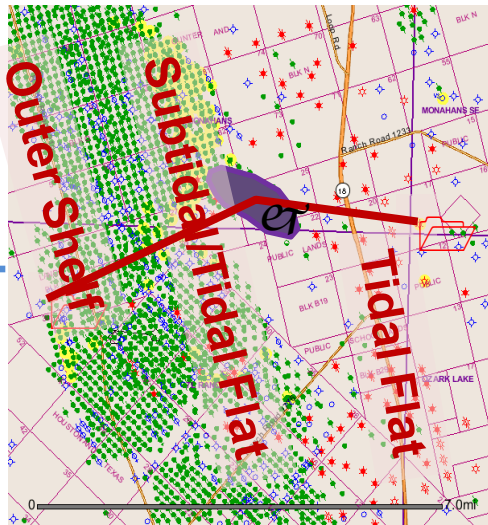


Fluor, Cut, Minor Gas

No Shows

ROZ Maximum 550' !

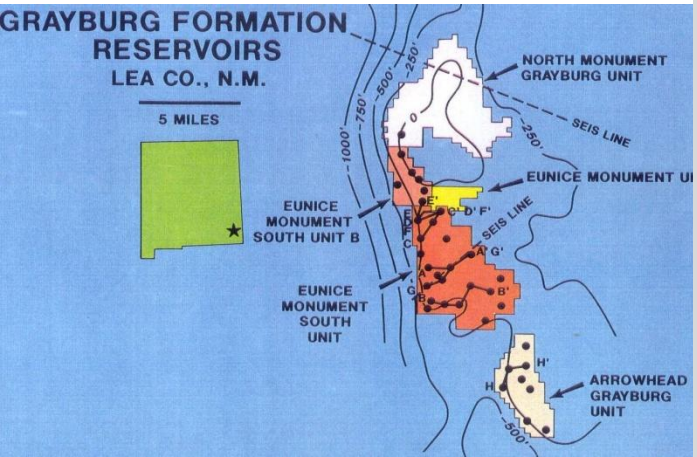
Base ROZ ?

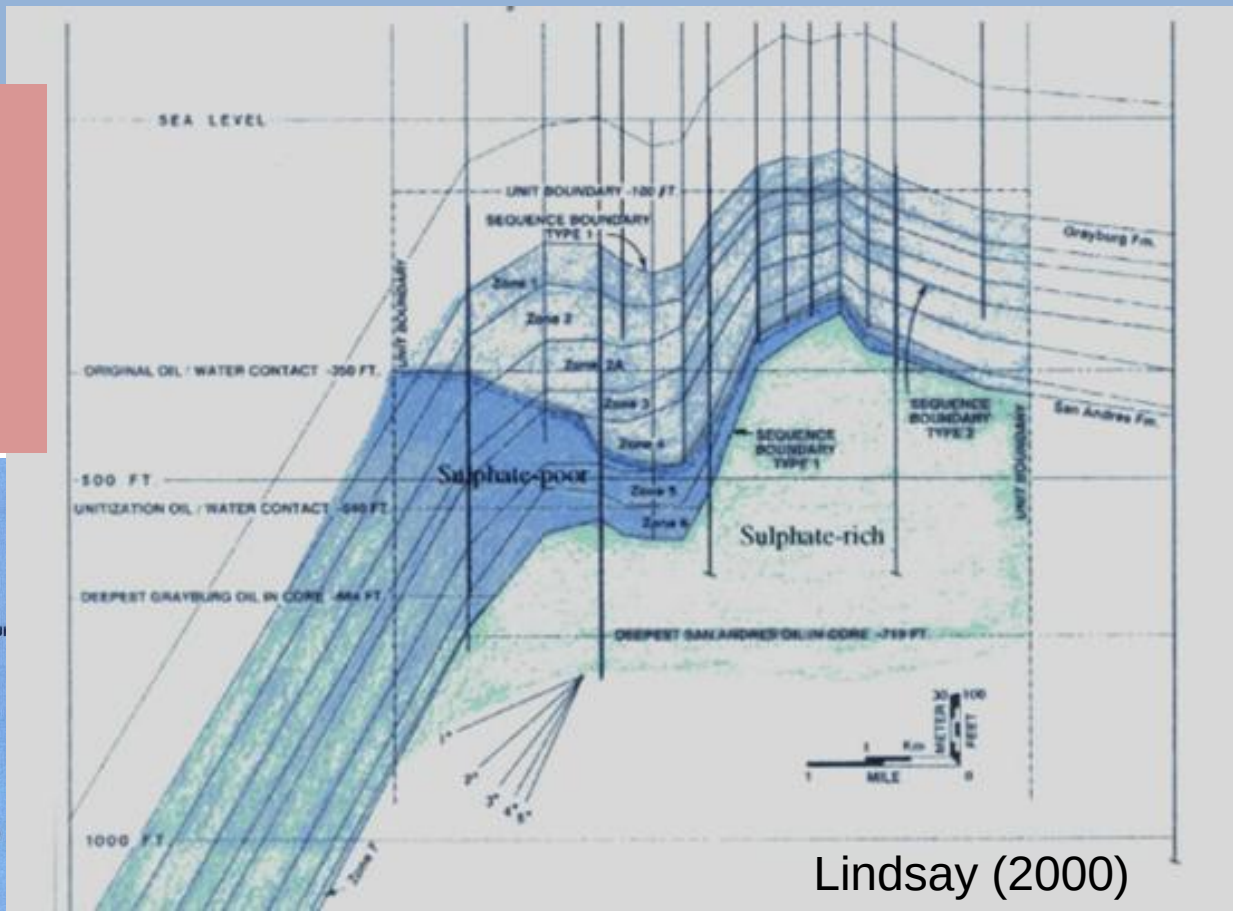


North Monument Grayburg, Eunice Monument, Eunice Monument South "B", Eunice Monument South, and Arrowhead Grayburg Unit .

- 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.

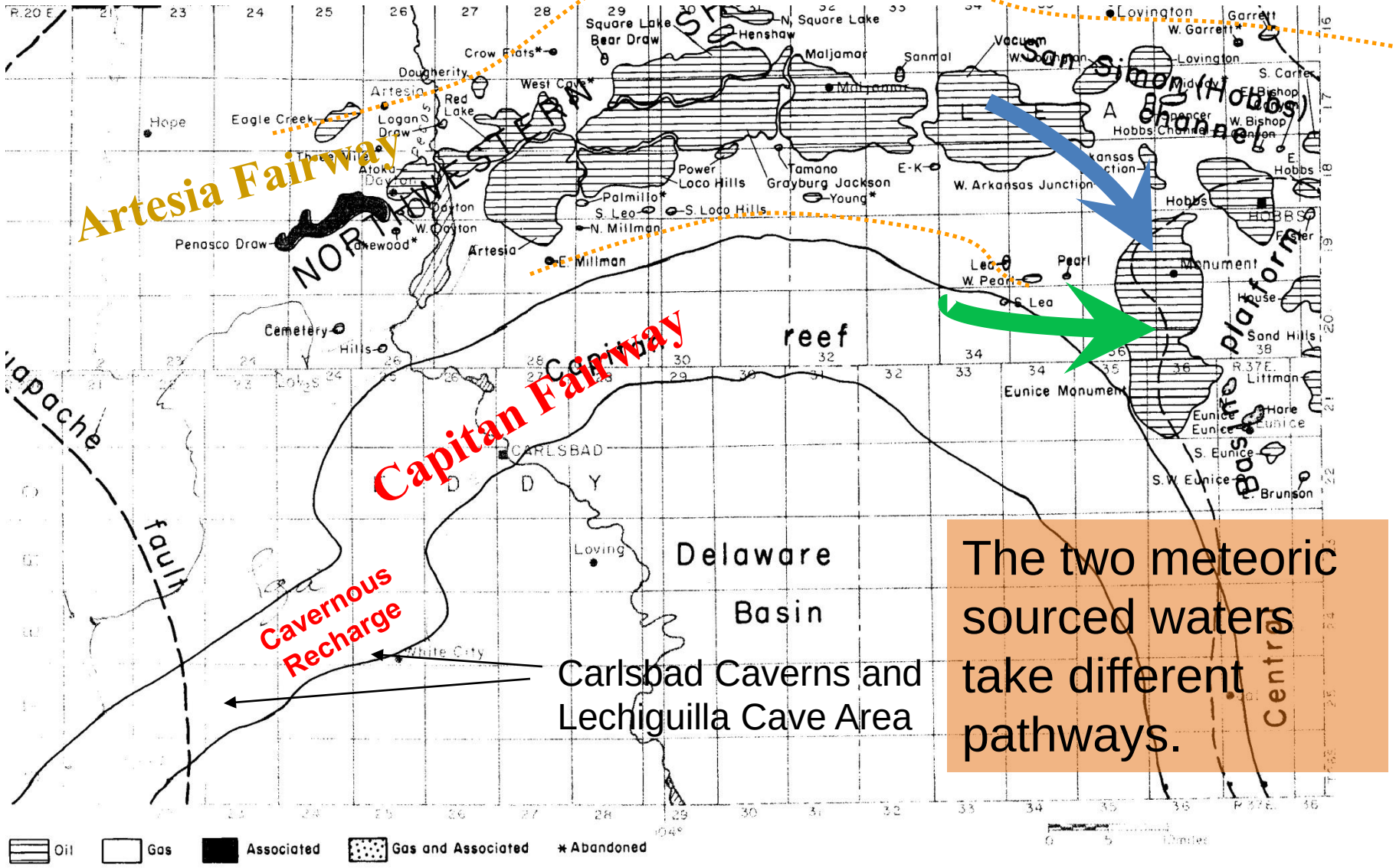
- Eunice Monument
- -150 G/O, -400' O/W (150' below top SADR).
- Na 2000ppm, Cl 2950ppm, TDS 7800PPM (similar to Capitan Reef in Winkler Co.)





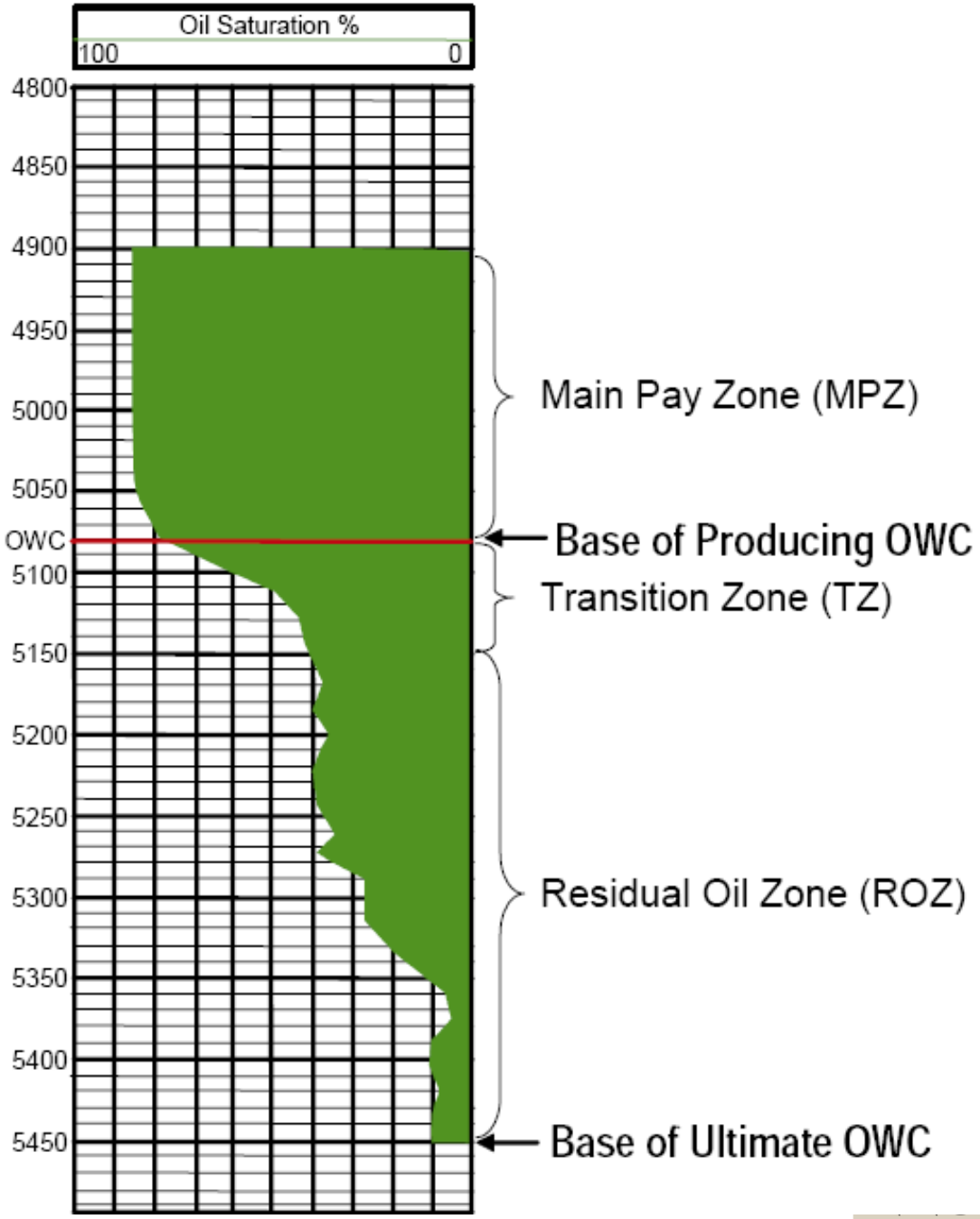
Lindsay (2000)

SE NM Grayburg & Upper San Andres Dolomitization Trend

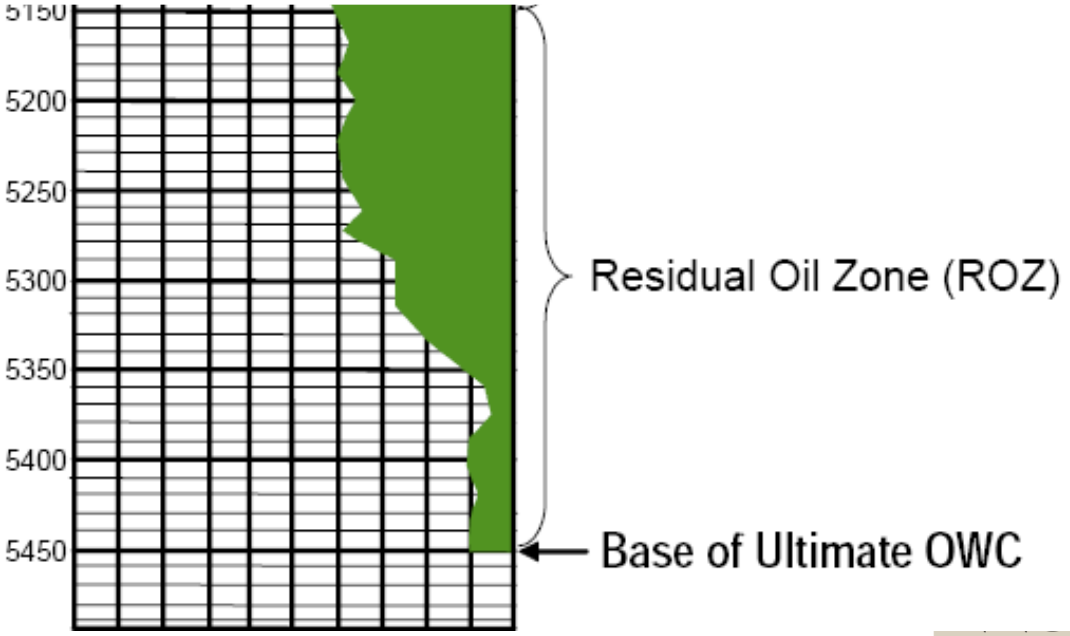


Ref: Future Petroleum Provinces in New Mexico – Discovering New Reserves, Philip R. Grant, Jr. and Roy W. Foster, NM Bur of Mining & Mineral Resources, 1989

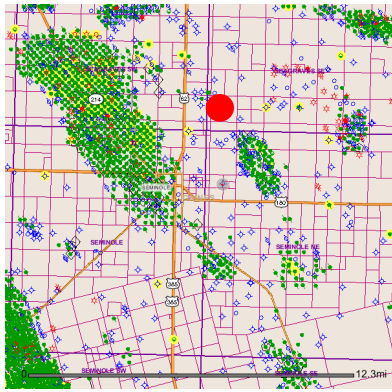
What happens when the entire oil column is swept by Mother Nature?



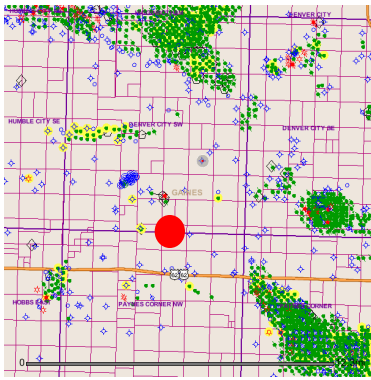
Your left with a tertiary recovery target.



Gaines, Future Targets or goat pasture?

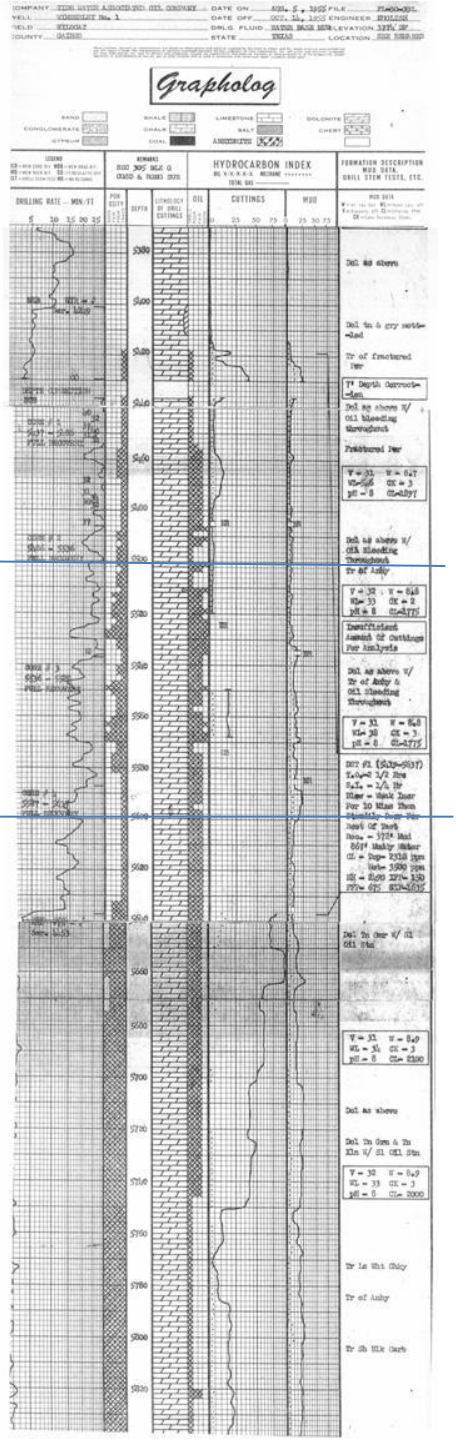


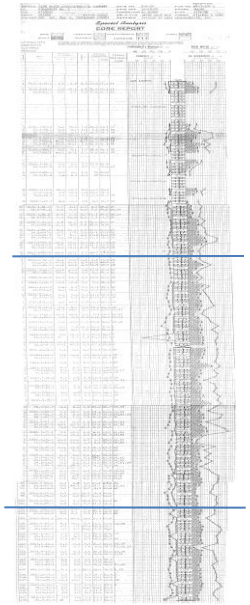
- A Clearfork test, the **IP #1 Campbell Heirs "158"** set pipe on "WET" San Andres test just south of Seminole.
- All wireline logs, drill time, gas curves and sample said "slam dunk" oil production. Atlas log analyst said it should be a producer.
- 100% water test with barely a sniff of live oil. ROZ?
- **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.

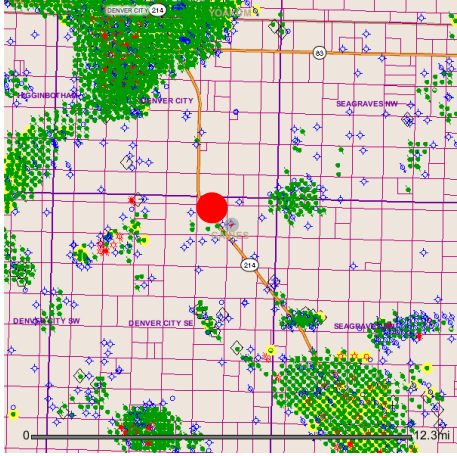


- The 2 CORED intervals, from 5464 – 5602, had oil saturations ranging from 15 to 35%, 3 - 12% porosity, & 50-100% fluorescence.

ROZ's have been tested for 50 years.





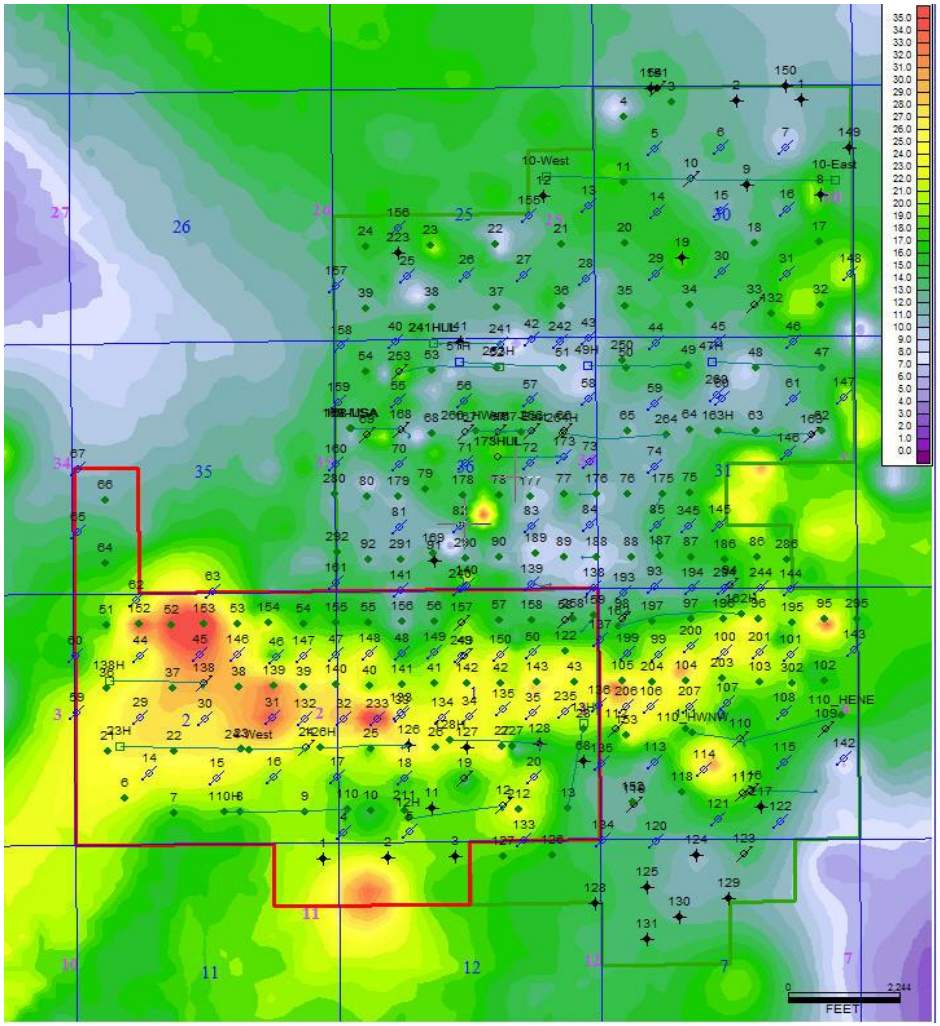


At **Bale East**, Gaines Co., **Tidewater #1 Wimberley**, sec 305, Blk G CC&RGNGRR.
Is on the east flank of a structure.
Drilled in **1955**. Cored interval, 5437-5637, had bleeding oil & gas throughout, has 20 to 30% oil saturation throughout the length.
DST'd 5419-5637, rec 372' mud, 867' MCSW.
Mudlog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

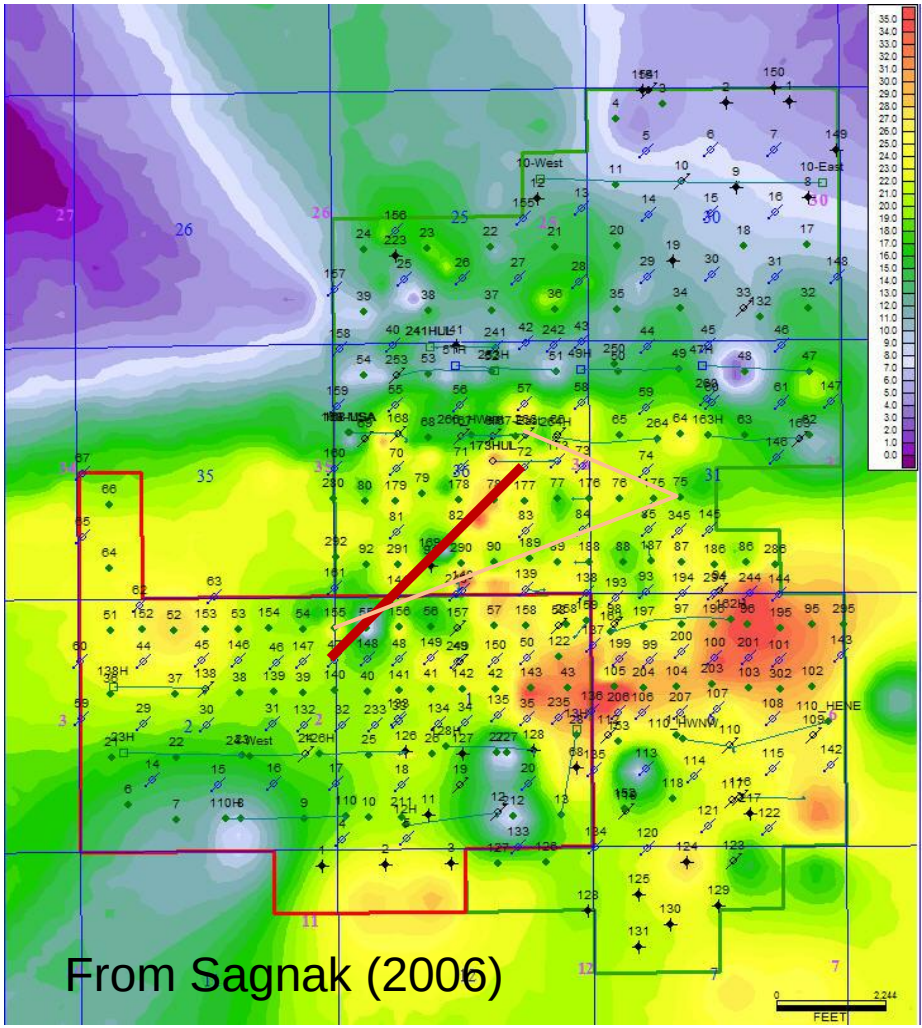
ROZ?
The total length of core and sample shows is 310', from 5437[in core] to 5745[in samples].
DST in the San Angelo (6680-6785) rec 150' muddy Water, 4830' black water (sulfur?).

Vacuum Field. The San Andres at Vacuum Field is composed of a full section of San Andres with deeper water lime/chert rich facies in the Lower San Andres {L7-L8 (Holt) and G1-G2 (McKnight)} and pervasively dolomitized G3-G4Pre Brushy Canyon Bypass Surface and G8-G12)e (HolVacuum Field

Upper San Andres PHIH

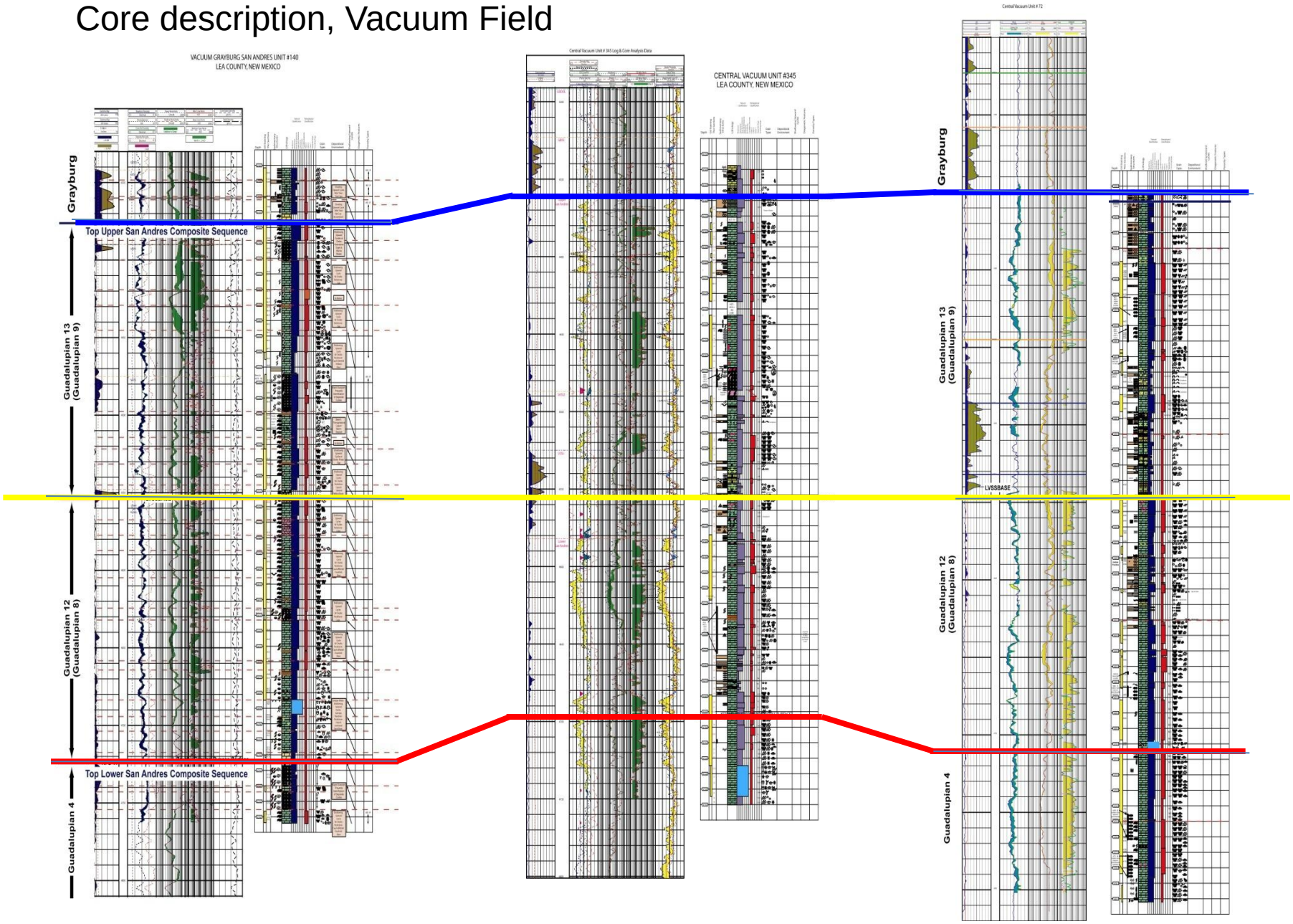


Lower San Andres PHIH



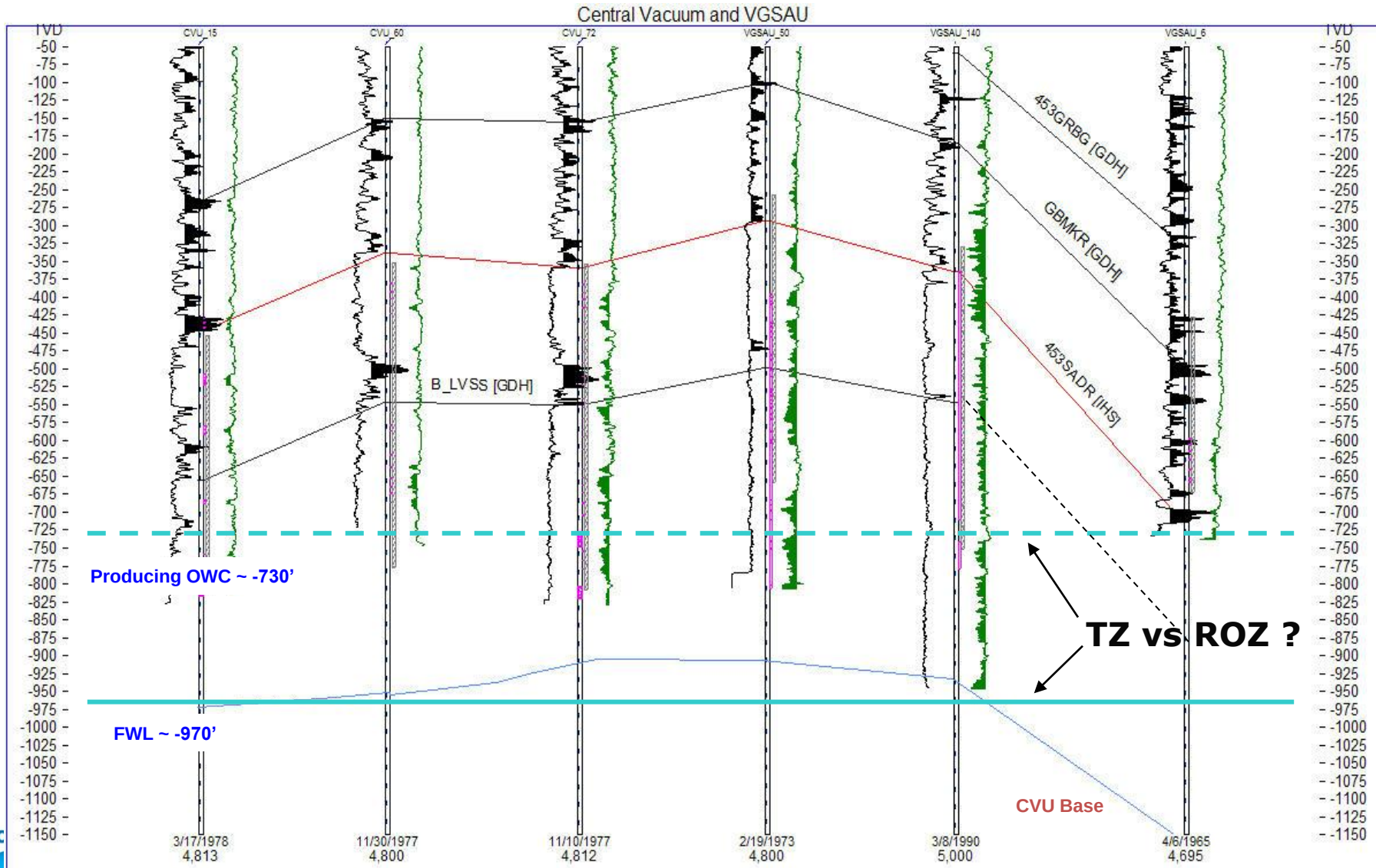
From Sagnak (2006)

Core description, Vacuum Field



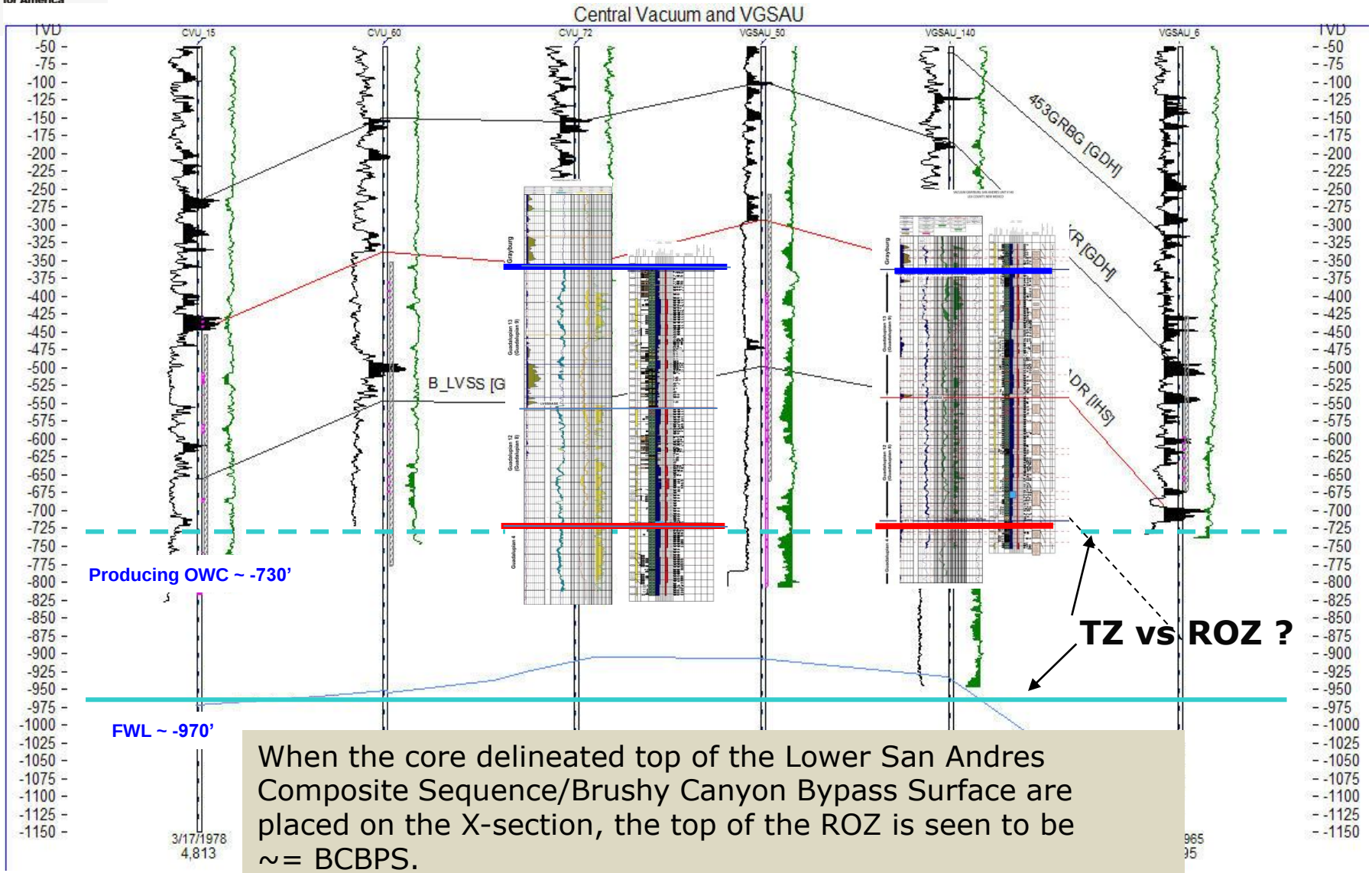
Modified from Stoudt & Raines (2000)

Vertical CO_2 Flood Expansion Opportunity



Sagnak (2006)

Vertical CO_2 Flood Expansion Opportunity



When the core delineated top of the Lower San Andres Composite Sequence/Brushy Canyon Bypass Surface are placed on the X-section, the top of the ROZ is seen to be ~= BCBPS.

Modified from Sagnak (2006) & Stoudt & Raines (2000)

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 Future Discussion/Work

- Dolomitization
  - Phases
  - Timing
  - Impact on Wettability
- Oil Migration
  - Pulses?
  - Tectonic Relationship
  - Impact on Wettability

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:
- Roswell Geological Society
- ConocoPhillips
- Society of Independent Professional Earth Scientists (SIPES) - Midland
- North Texas Geological Society
- PBS-SEPM

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.