

Residual Oil Zones (ROZ's) Moving From Science to Commercial Exploitation

AAPG GTW

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UTPB/CEED

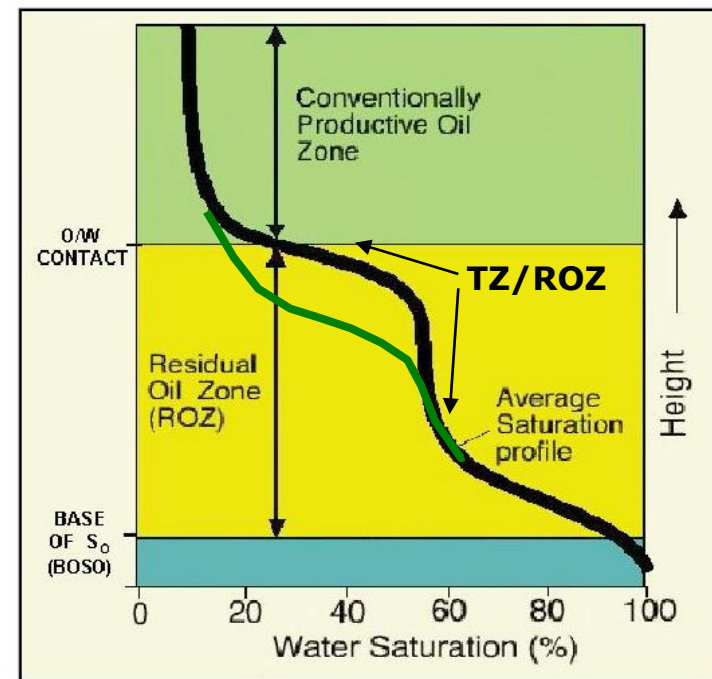
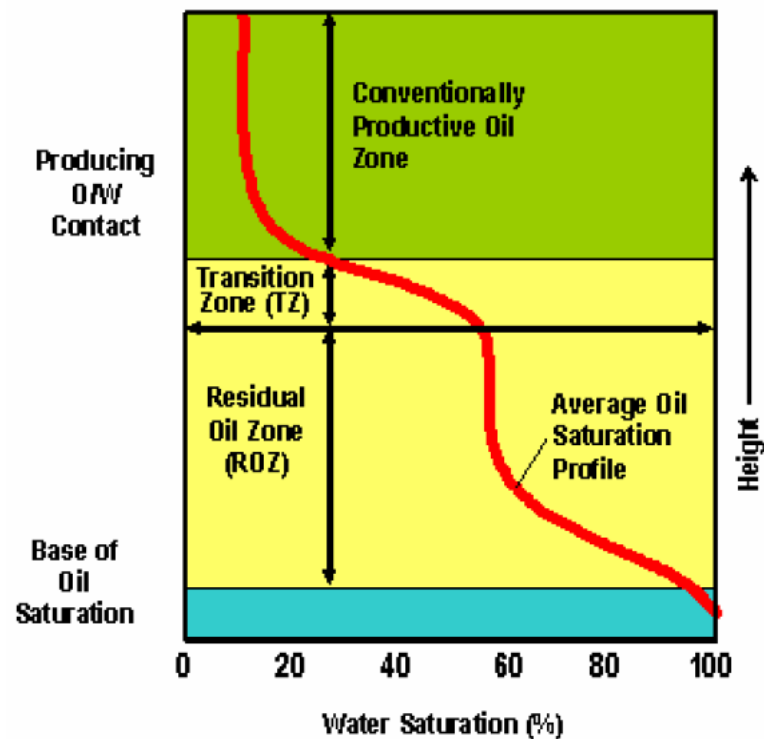
August 2010

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 Koperna & Advanced Resources International
- 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.

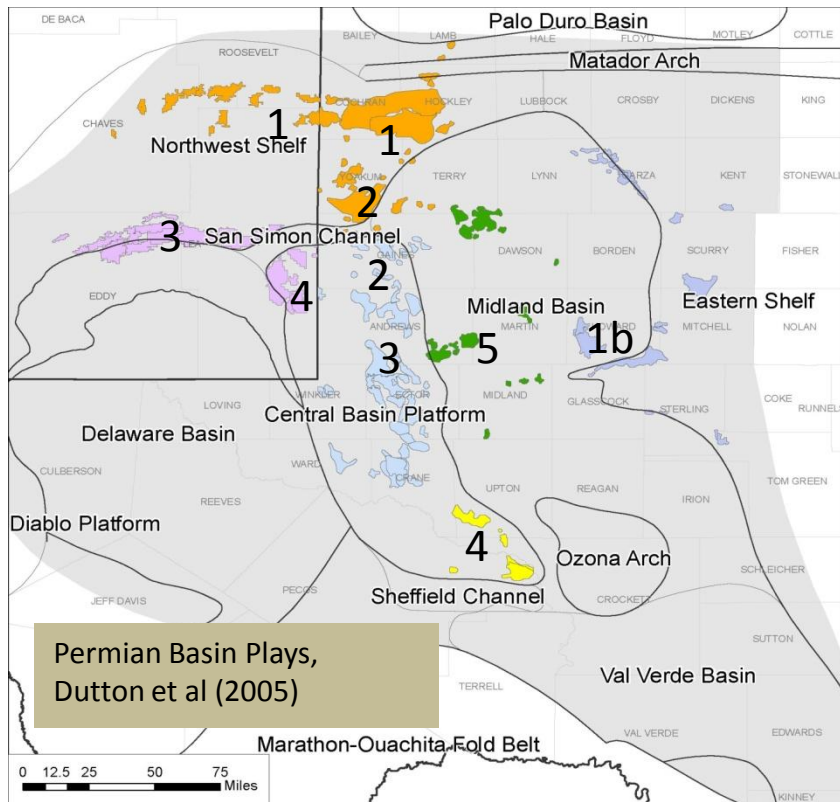
Some Terminology

- **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 (CO₂ or Surfactant).
- **Base of Oil Saturation.** Depth below which there is very little to no oil saturation in the formation.



Where we are today

- 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. | Robertson? |
| | Tubb Sand | | |
| | L. Clearfork | C. B. P. | Sand Hills? |
| | ABO | N. W. S. | Empire? |

Technically Recoverable Resources from the MPZ and ROZ

Based on reservoir modeling of applying CO₂-EOR to the TZ/ROZ resources, ARI estimates that

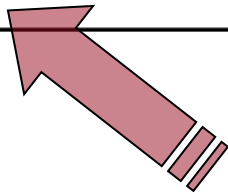
11.9 Billion BO is technically recoverable from the 30.7 Billion BO of TZ/ROZ oil in-place in these five Permian Basin oil plays

| 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 |

ROZ BACKGROUND

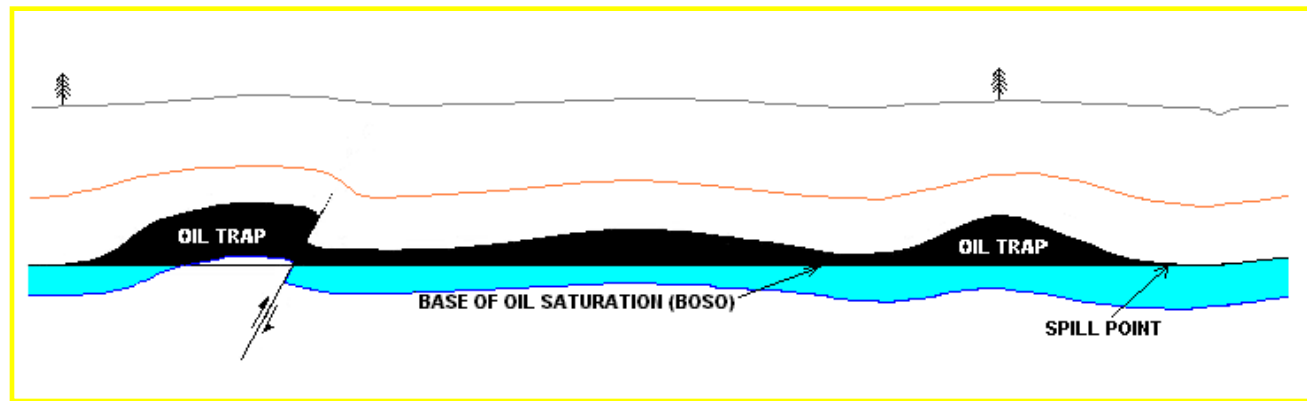
The 3 types of Residual Oil Zones

| 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) |

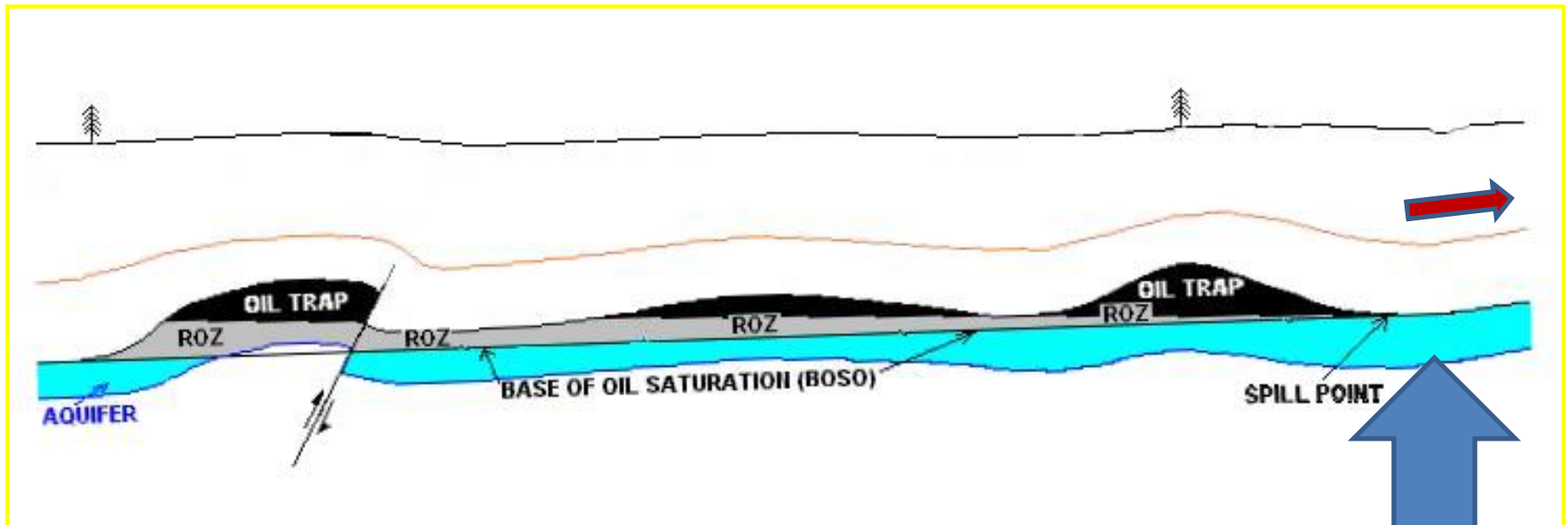


The Evidence suggests Type 3 are common in the Permian Basin “Mother Natures Waterfloods” are a result of post oil emplacement tectonics and Hydrodynamic Tilt

Original Oil Accumulation Under Static Aquifer Conditions (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.



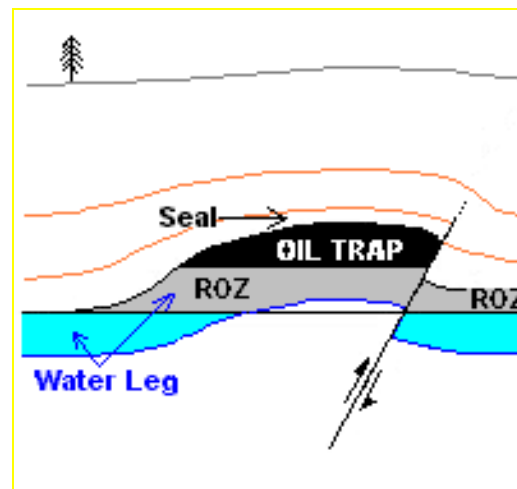
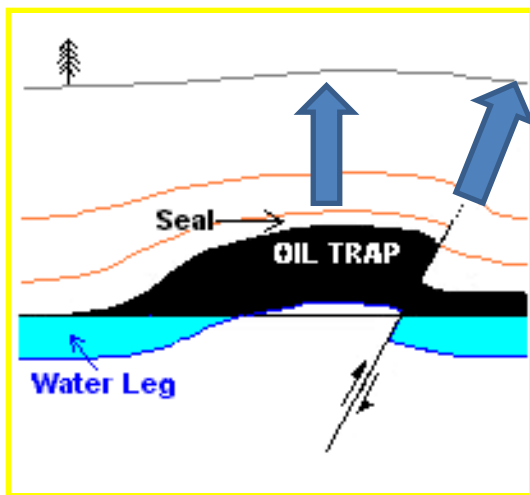
Static System

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.

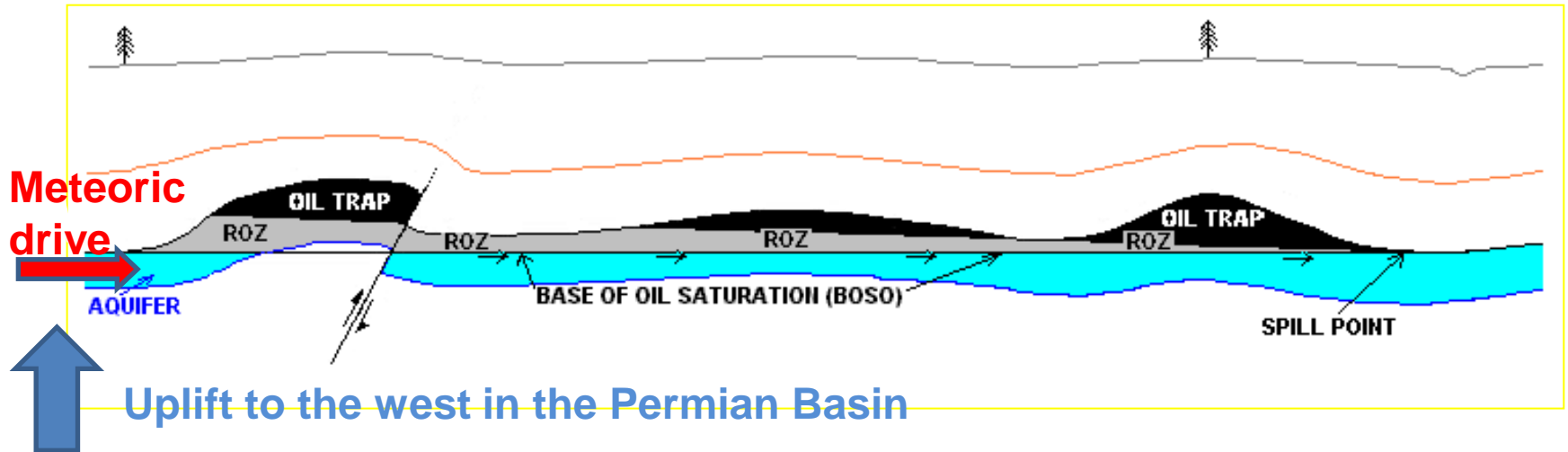


Static System

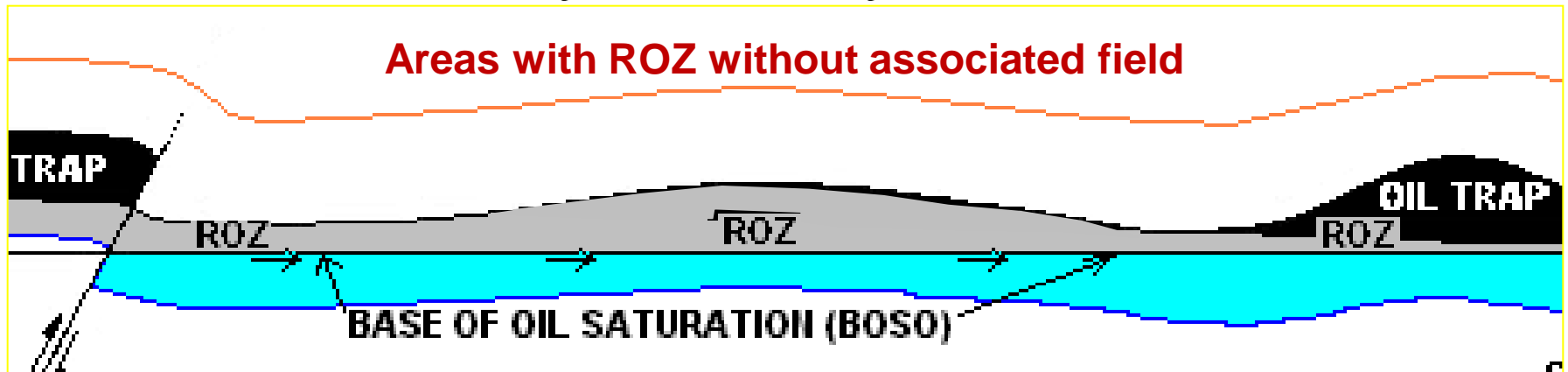
TYPE 3. Change in Hydrodynamic Conditions, Sweep of the lower part of the Oil Column and Development of a Residual Oil Zone.

Oil/Water Contact is Tilted

Base of the ROZ locally almost flat, regionally tilted.



Dynamic System

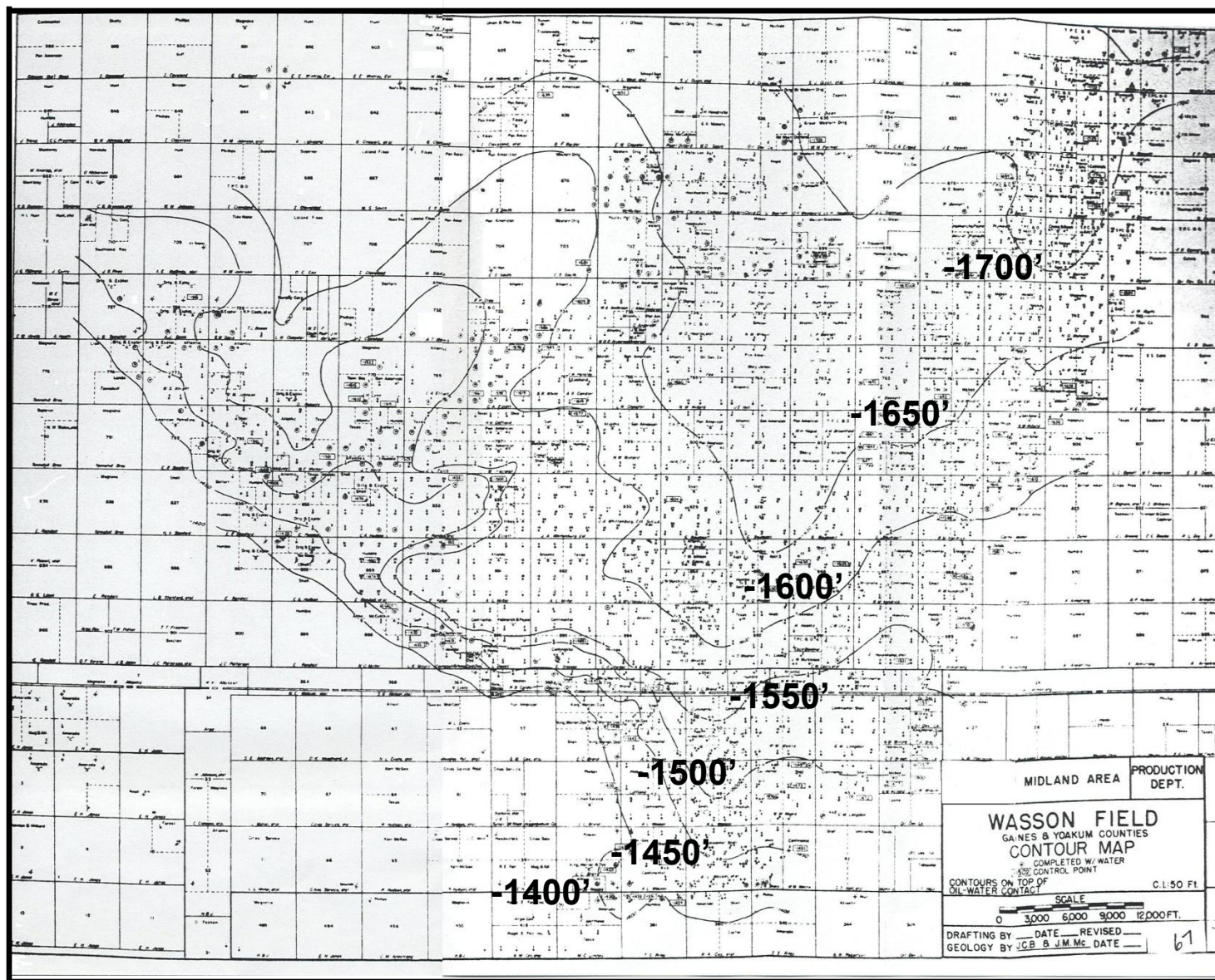


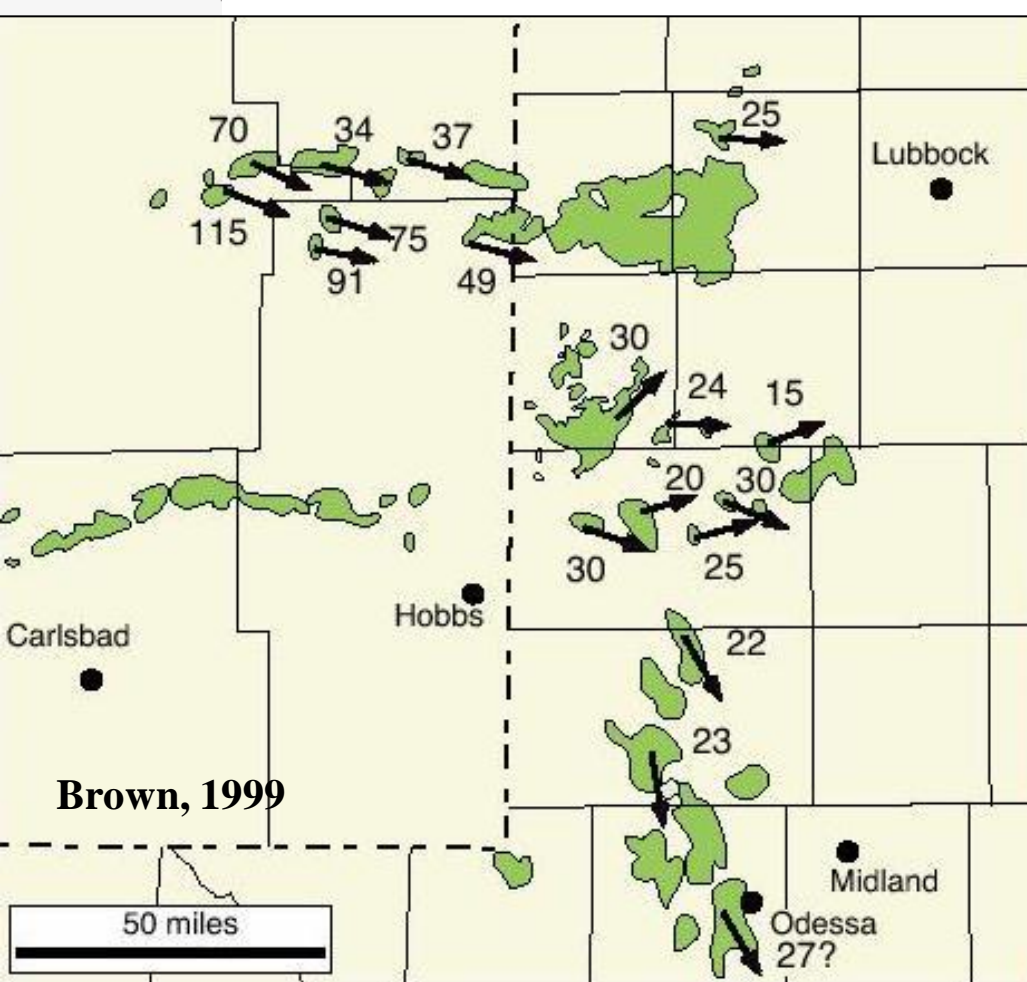
How did we get here?

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, he 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.
- **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.

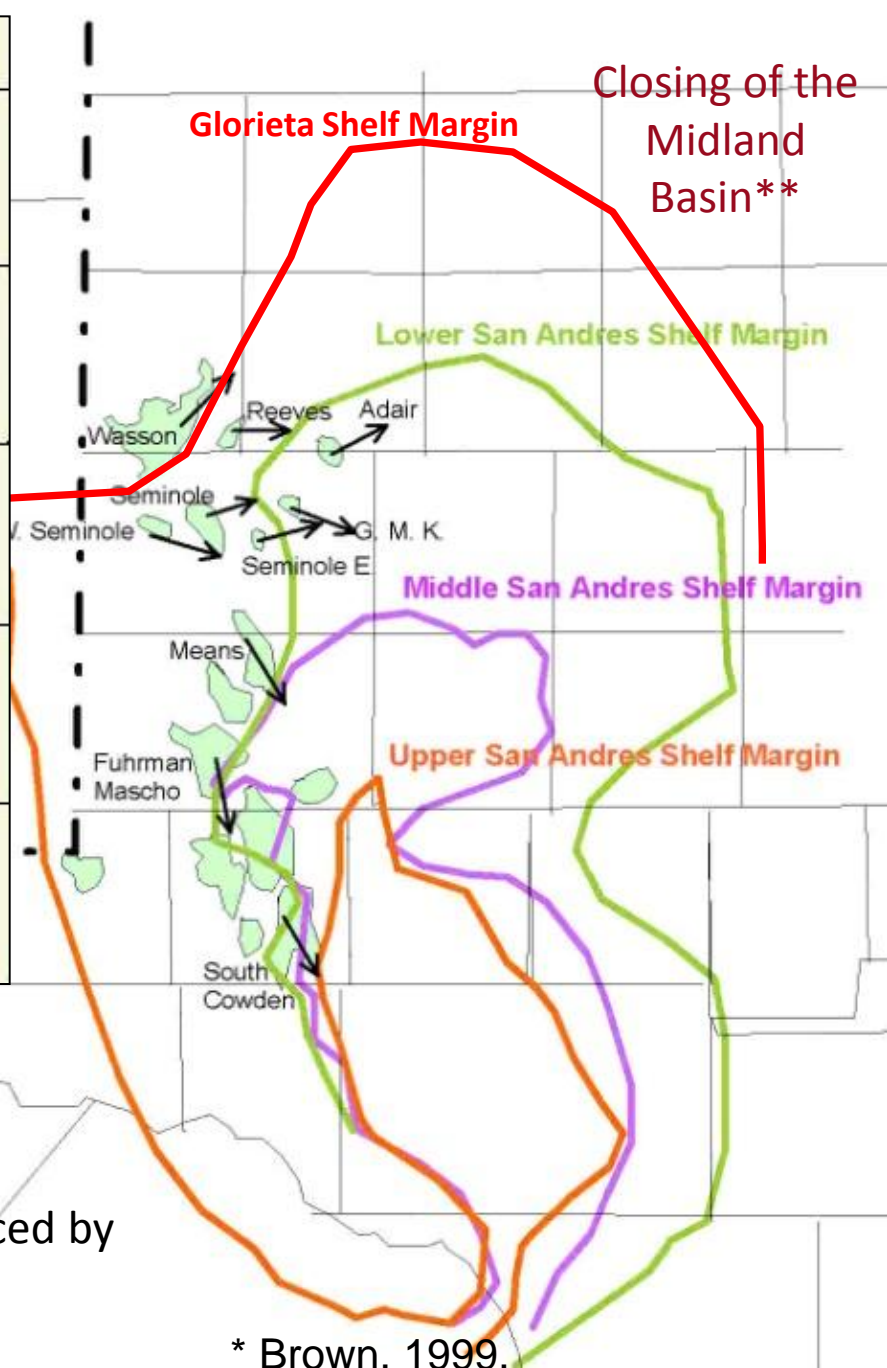
Wasson Field Oil-Water Contact Contour Map – Texas RR Commission Filing, October 1964





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

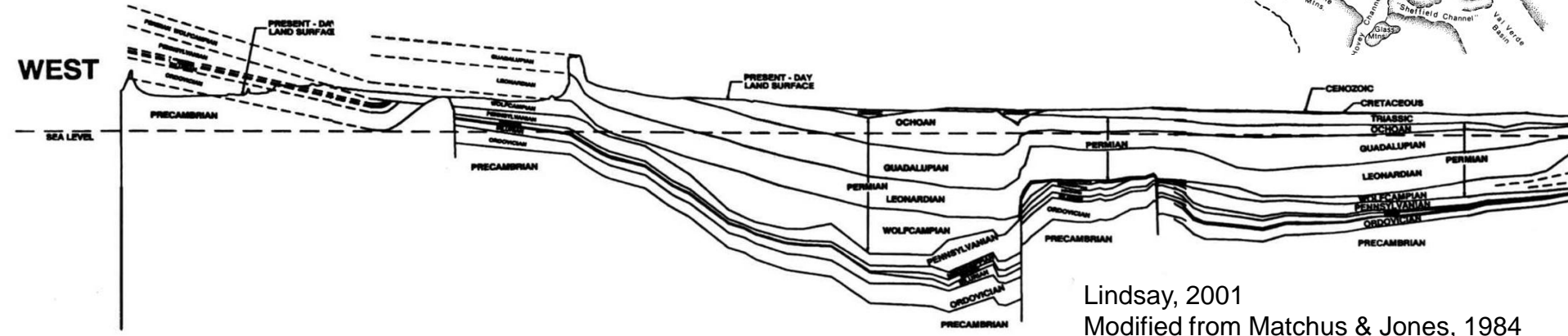
The direction of OWC tilt may be influenced by the age of the producing interval and its relationship to the shelf margin



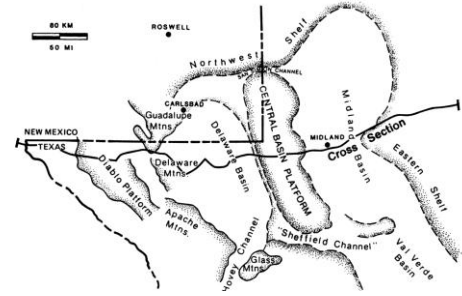
* Brown, 1999,
** Ward et al, 1986



RIO GRANDE RIFT



PERMIAN BASIN

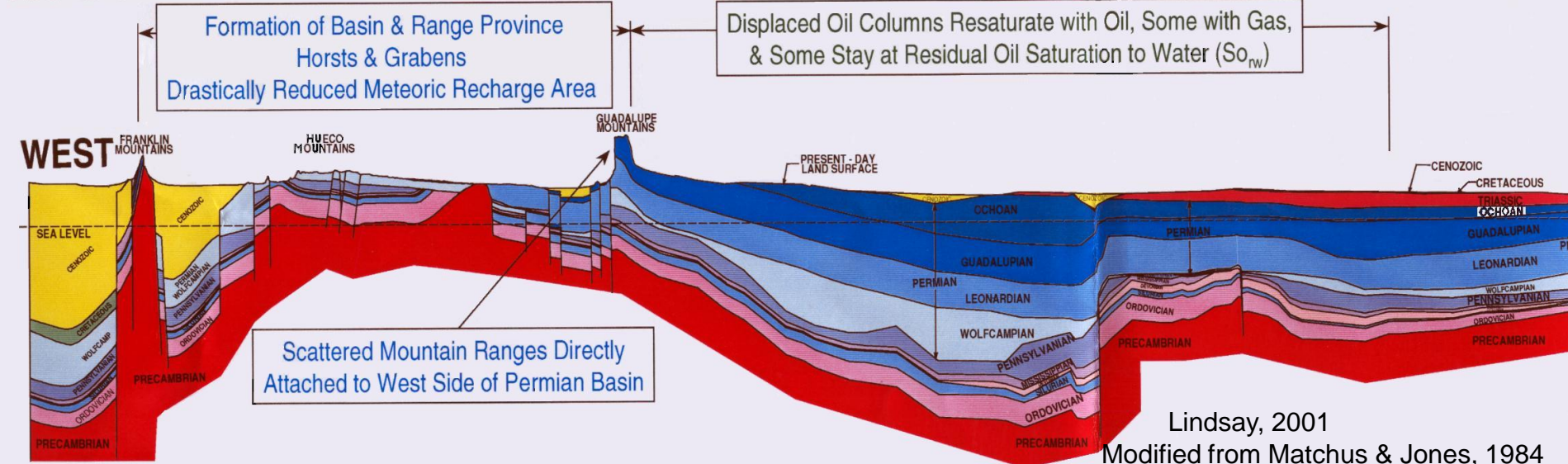


Lindsay, 2001
Modified from Matchus & Jones, 1984

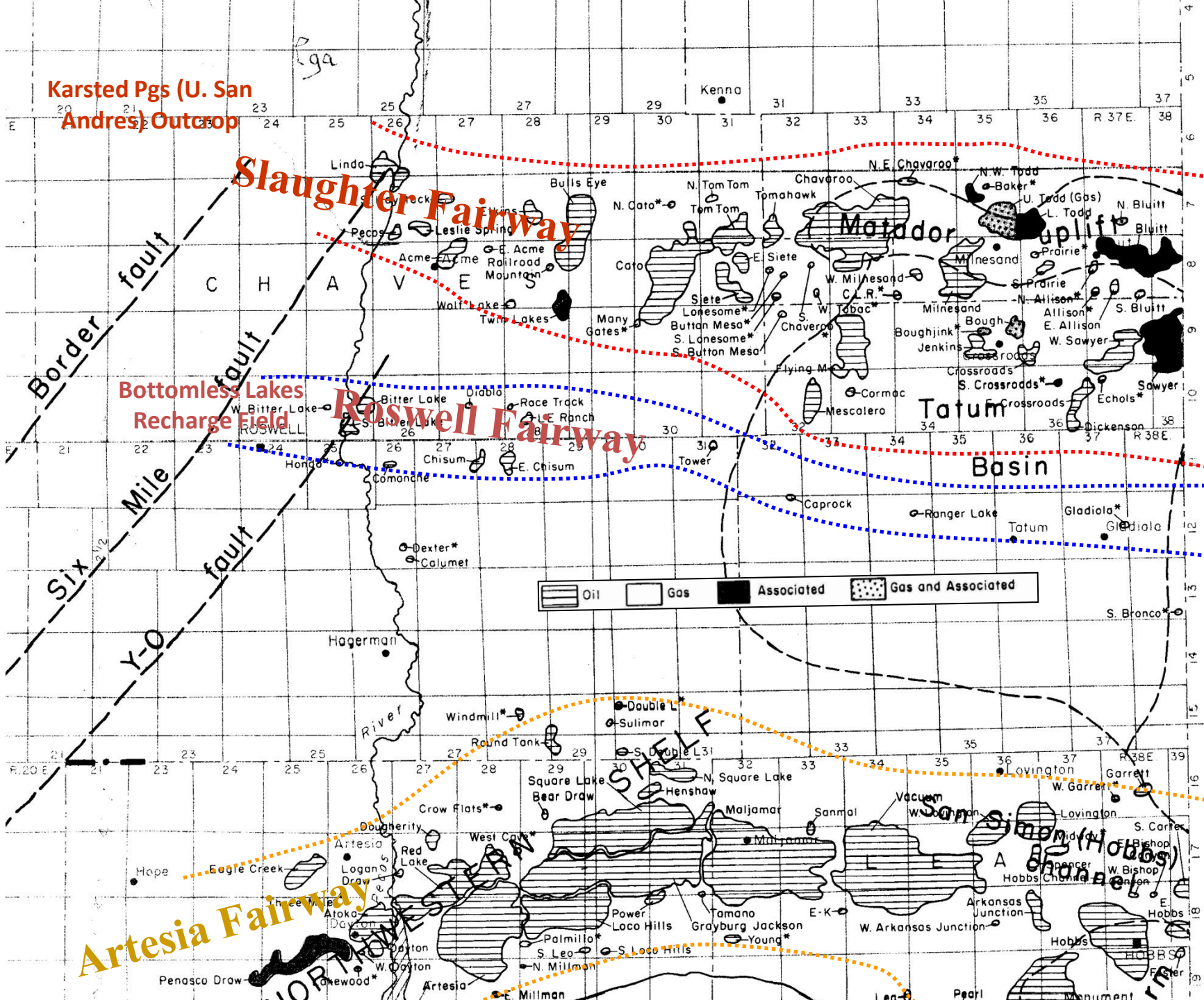
Phase III Slow Extension, Pliocene - Recent
Phase II Rapid Extension, Middle - Late Miocene

RIO GRANDE RIFT

PERMIAN BASIN



Lindsay, 2001
Modified from Matchus & Jones, 1984






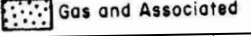
Karsted Pgs (U. San Andres) Outcrop

Slaughter Fairway

Bottomless Lakes Recharge Field

Roswell Fairway

Border fault
Six Mile fault
Y-O fault

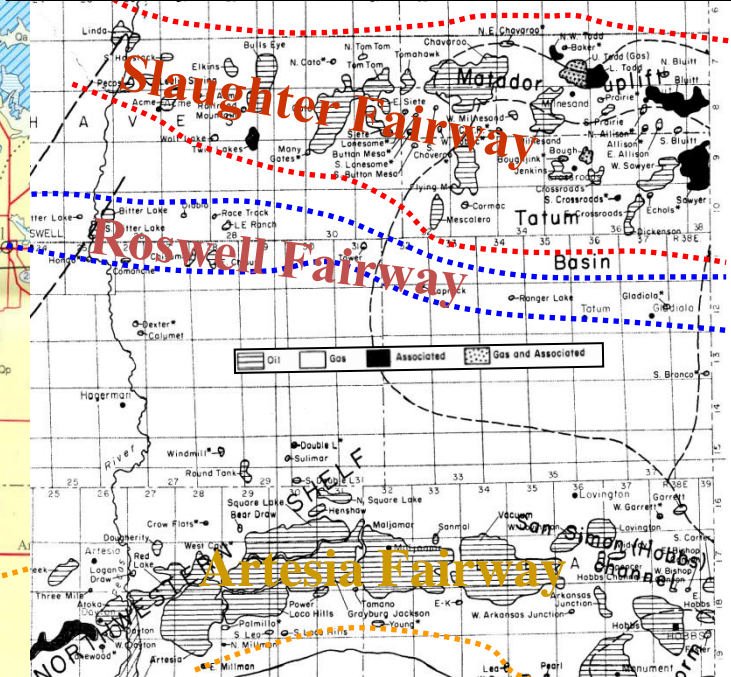
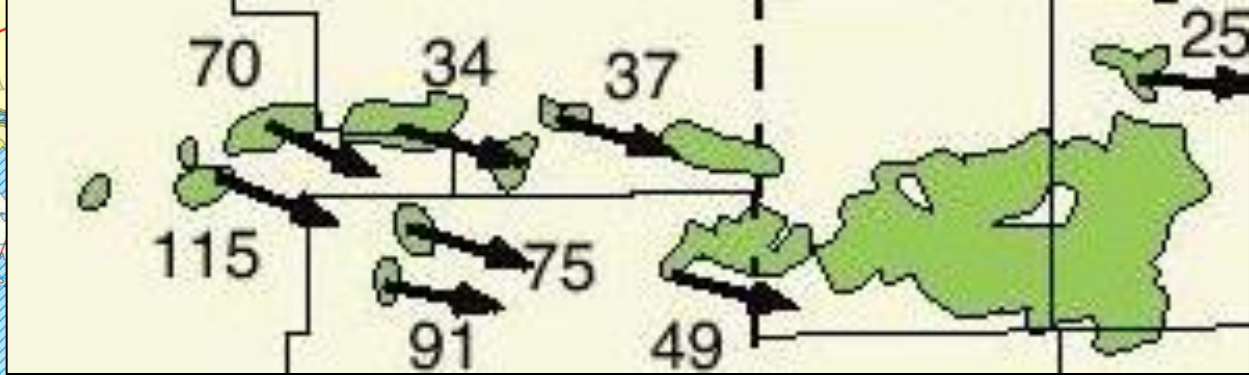
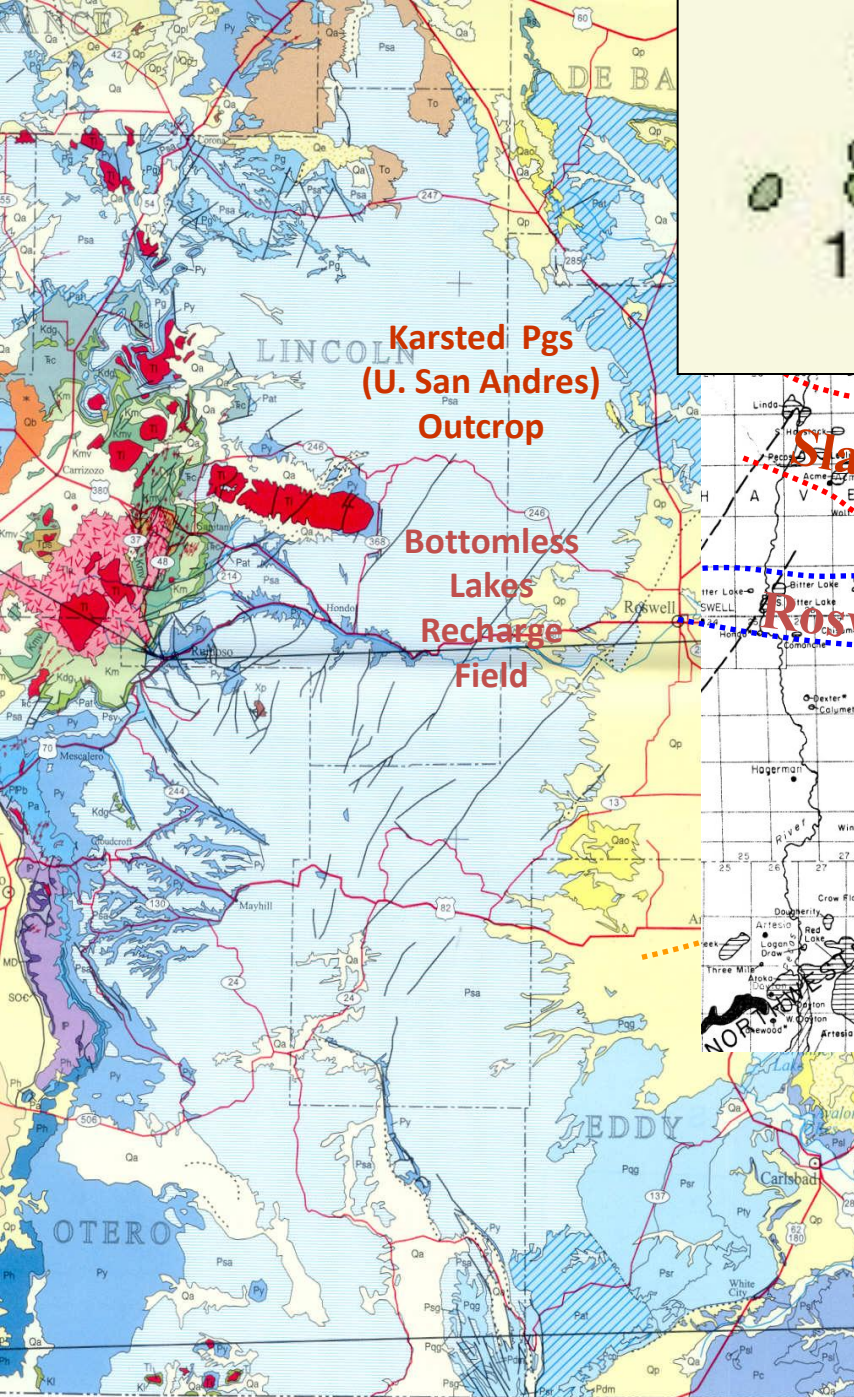
| | | | |
|---|--|---|---|
|  |  |  |  |
| Oil | Gas | Associated | Gas and Associated |

Artesia Fairway

SHELL

SAN ANTONIO (HOBBS) CHANNEL

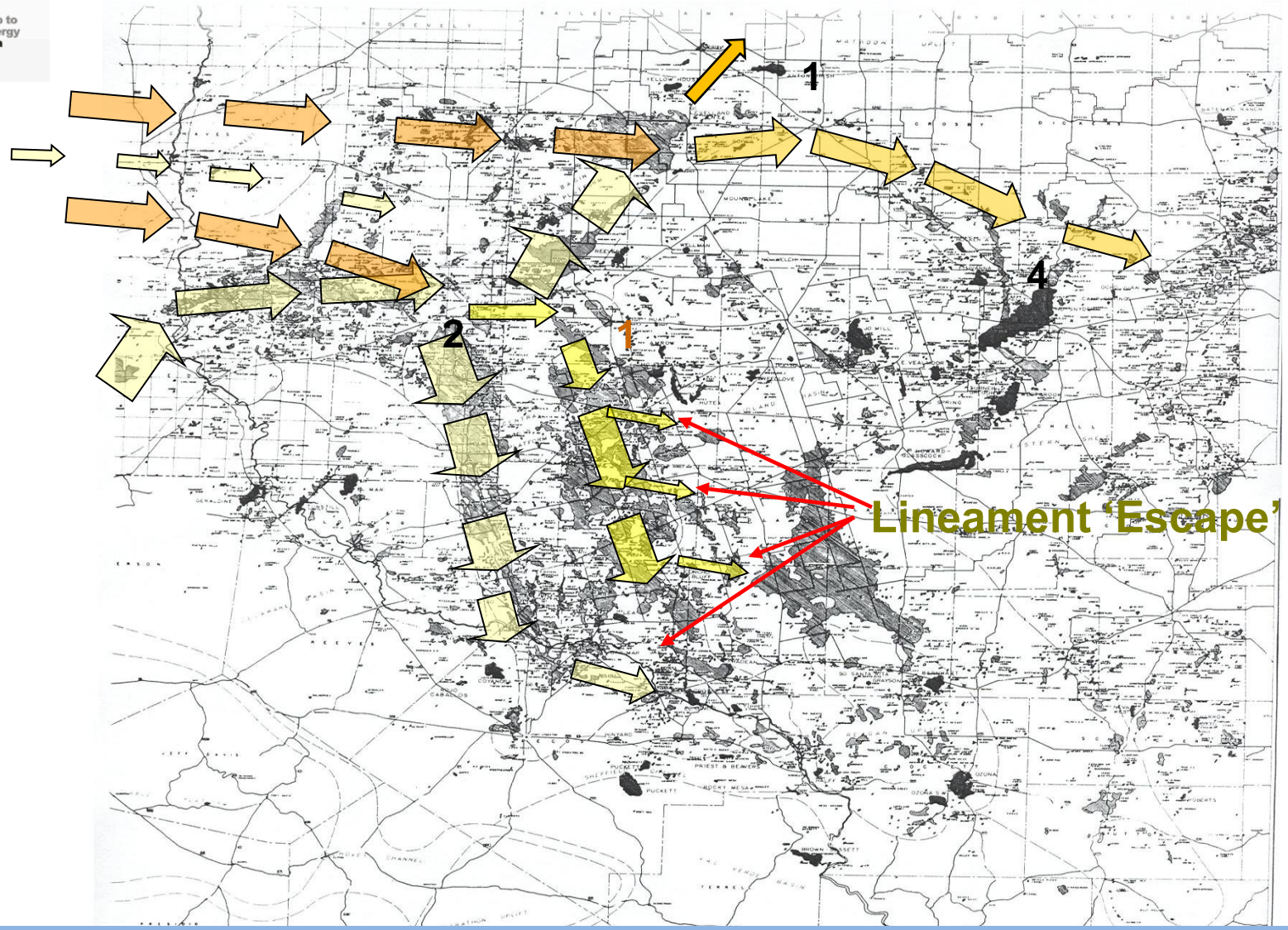
NORTH



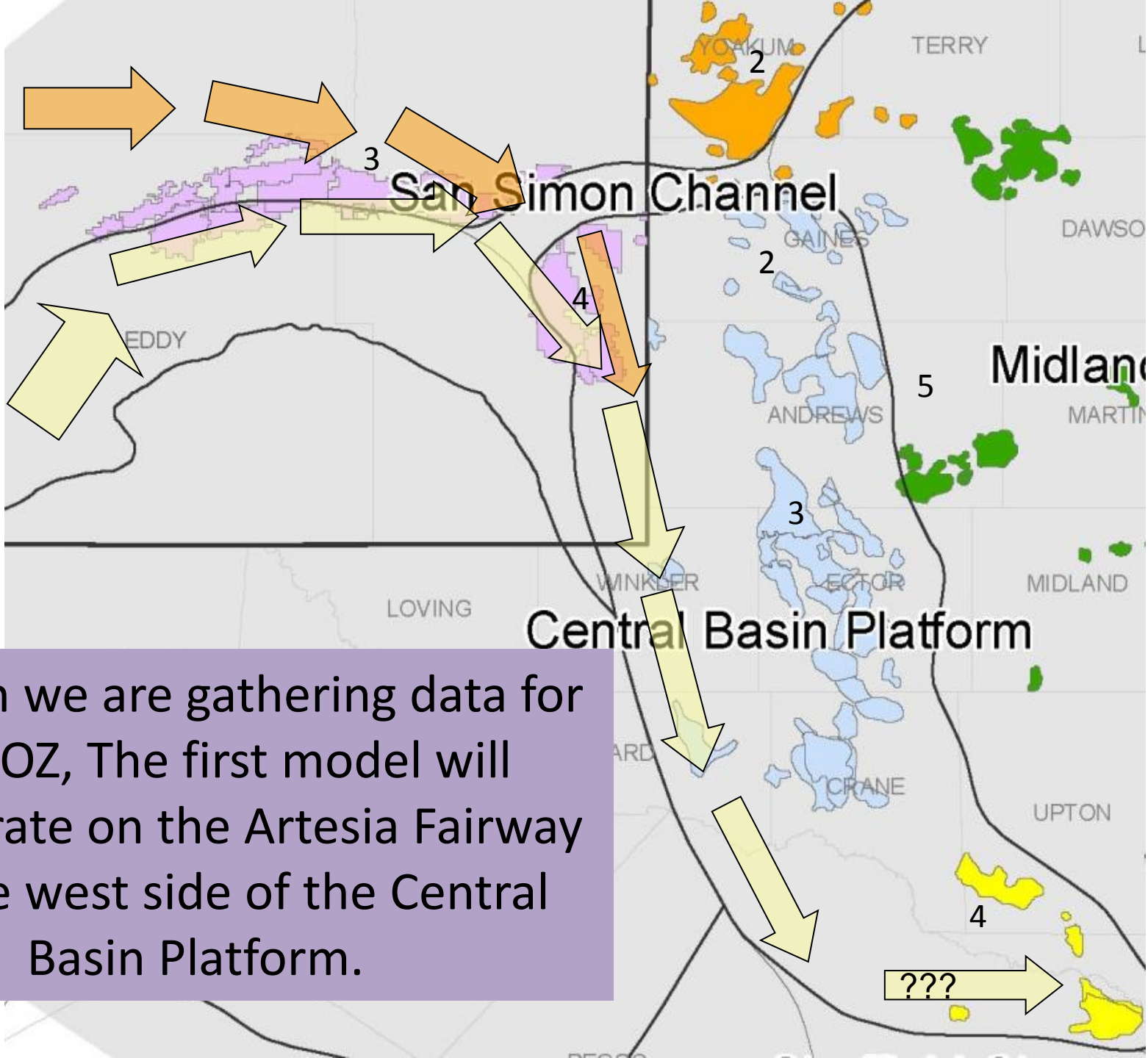
San Andres outcrop (light Blue) is the present day extent of the recharge area for the meteoric water that sustains the tilted oil water contacts in San Andres reservoirs.

PERMIAN BASIN FIELD MAP

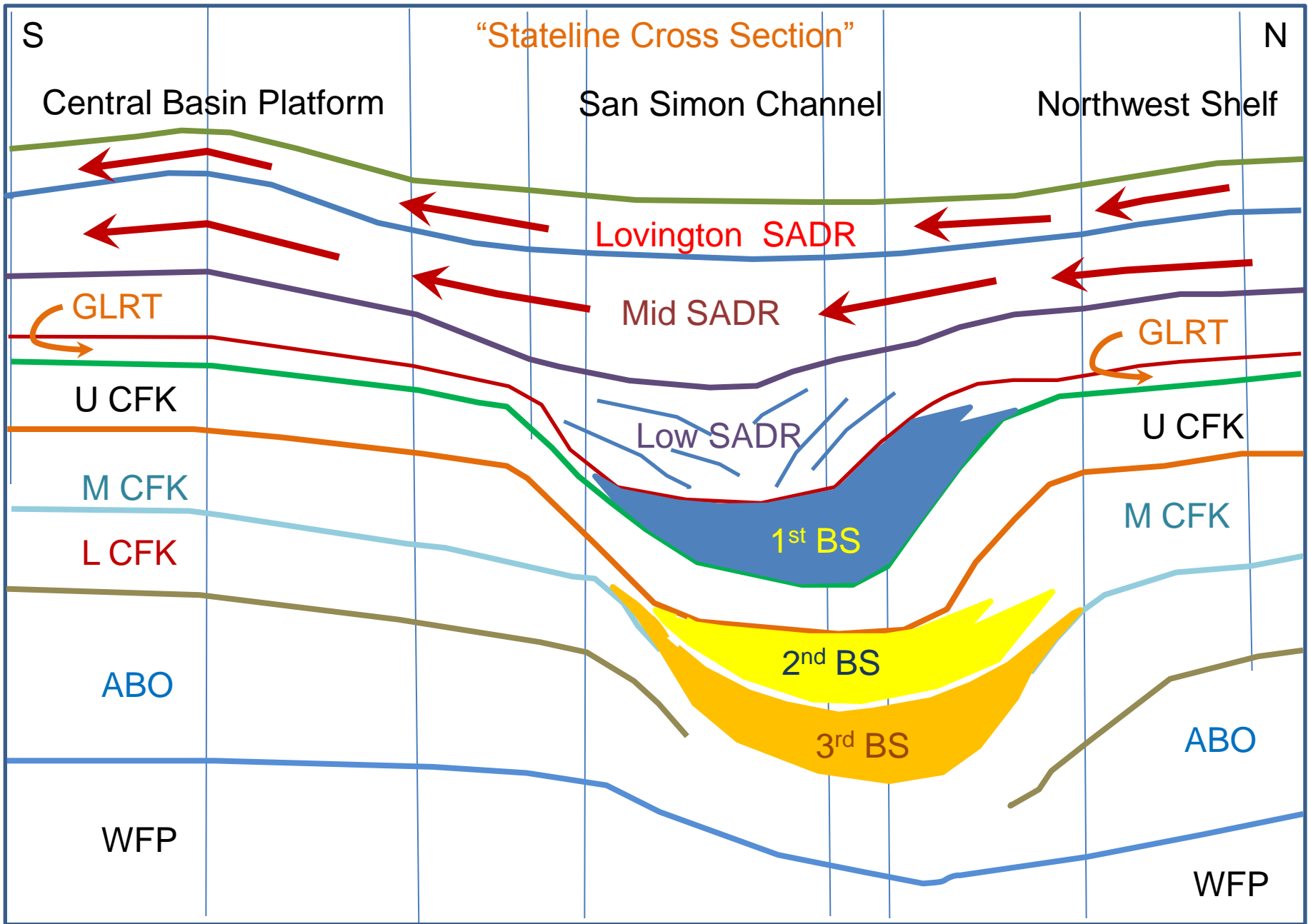
WITH THEORIZED (U. PERMIAN) HYDRODYNAMIC FAIRWAYS



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



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.



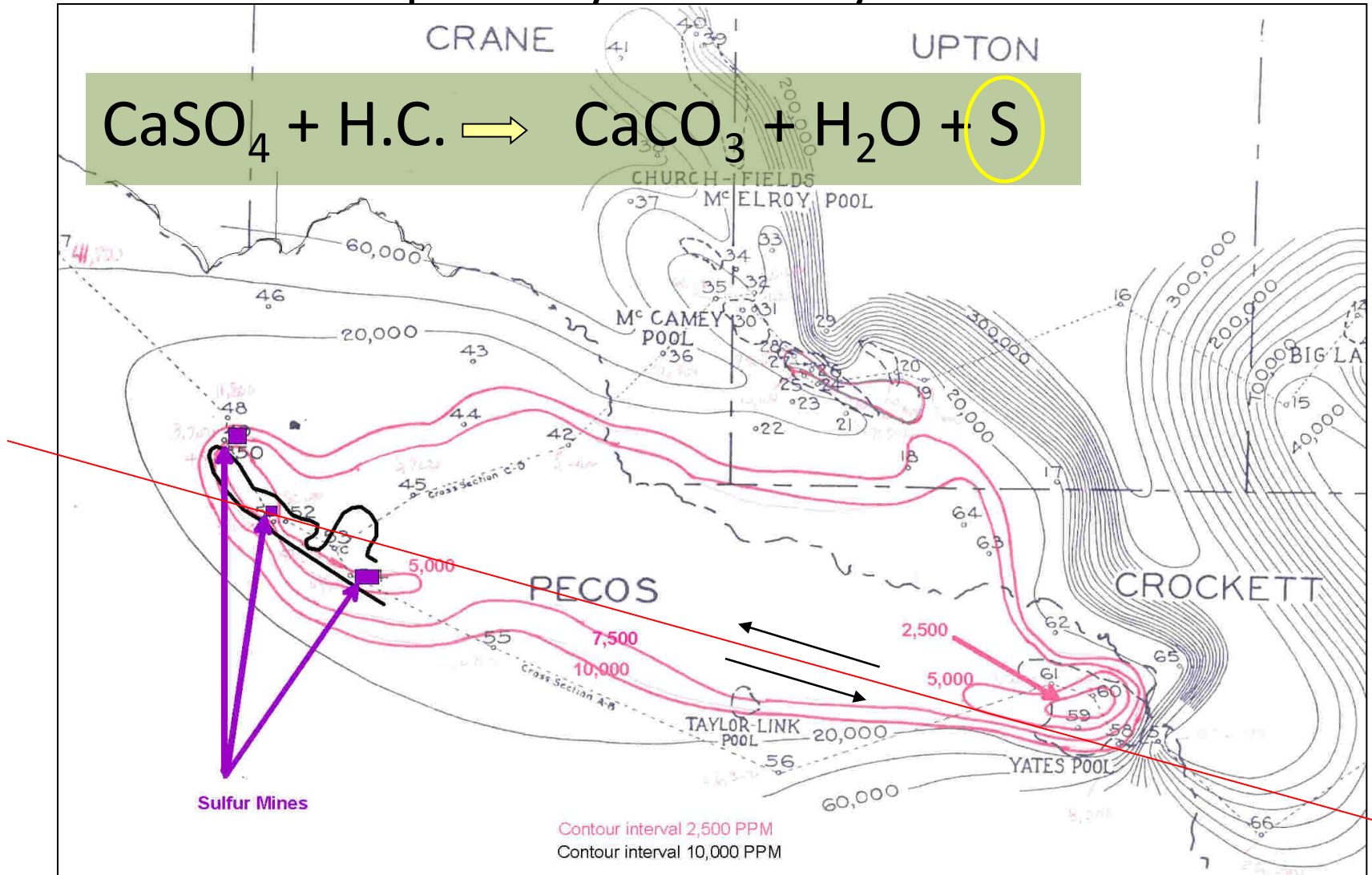
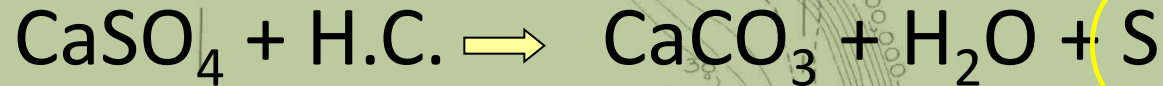
Pathway from NW Shelf to CBP

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.
- 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

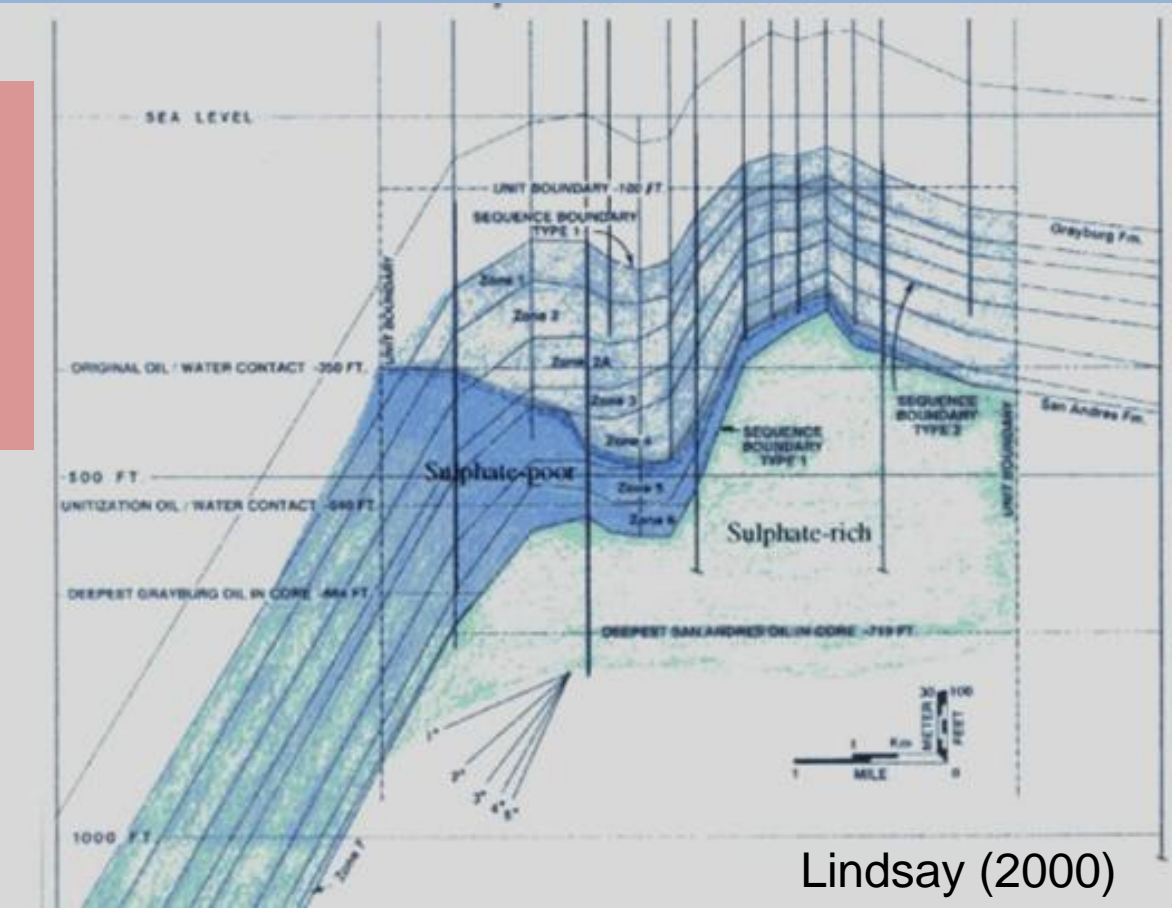
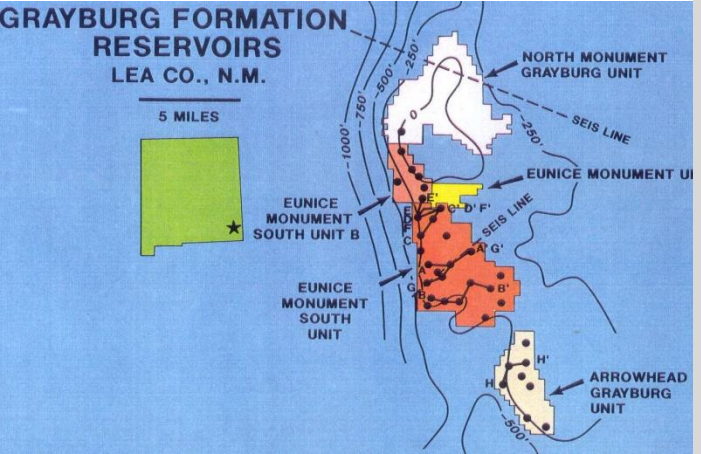


San Andres Water Salinities and Sulfur Deposits

North Monument Grayburg, Eunice Monument, Eunice Monument South “B”, Eunice Monument South, and Arrowhead Grayburg Unit .

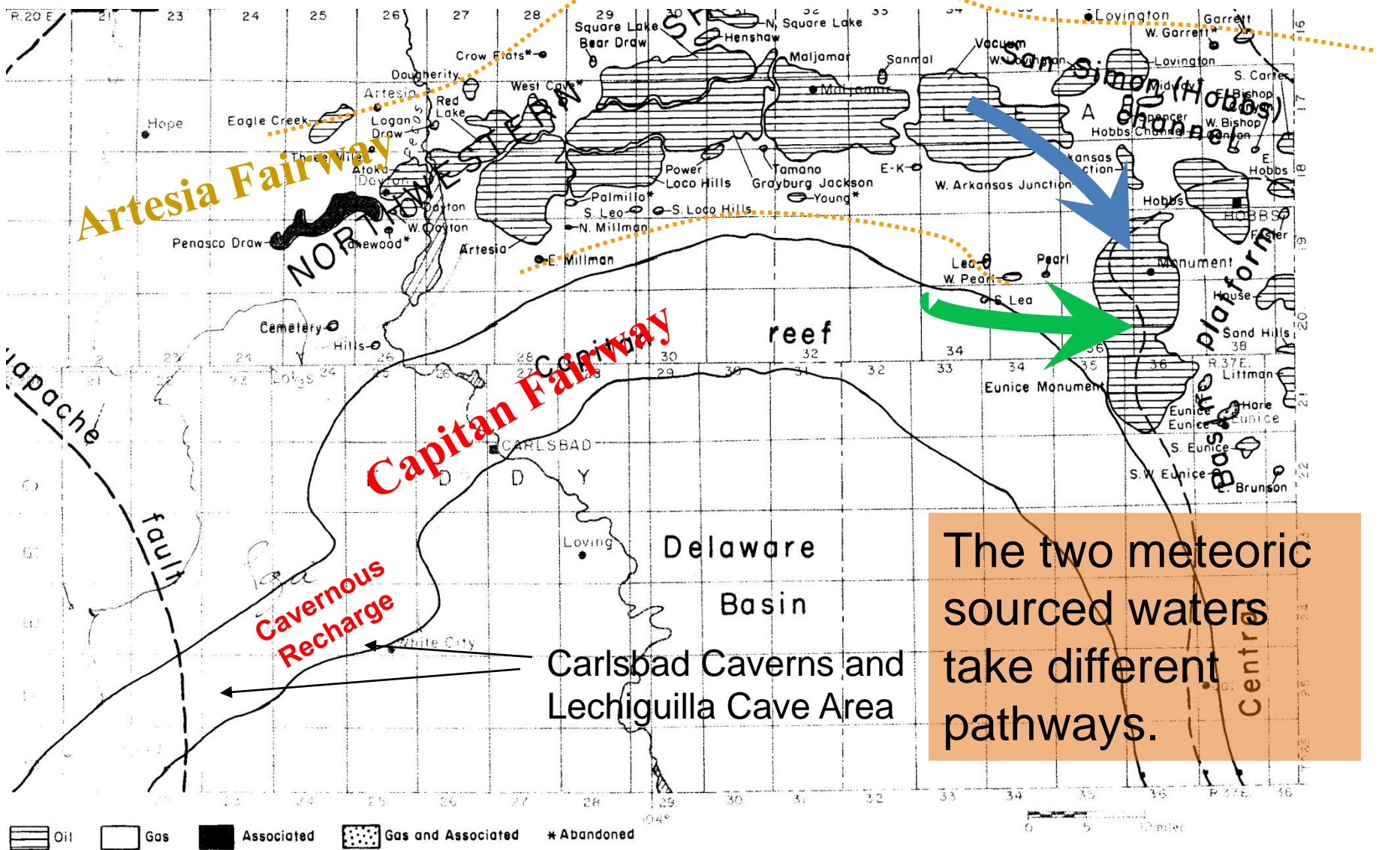
- area combined total of 57 square miles.
- Lindsay suggests the sulfate poor edge water is recharged from the Guadalupe Mountains thru the Goat Seep Reef. The Sulfate-rich bottom water drive in the San Andres is recharged from the Sacramento Mountain thru the evaporite rich San Andres.
- **Eunice Monument 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

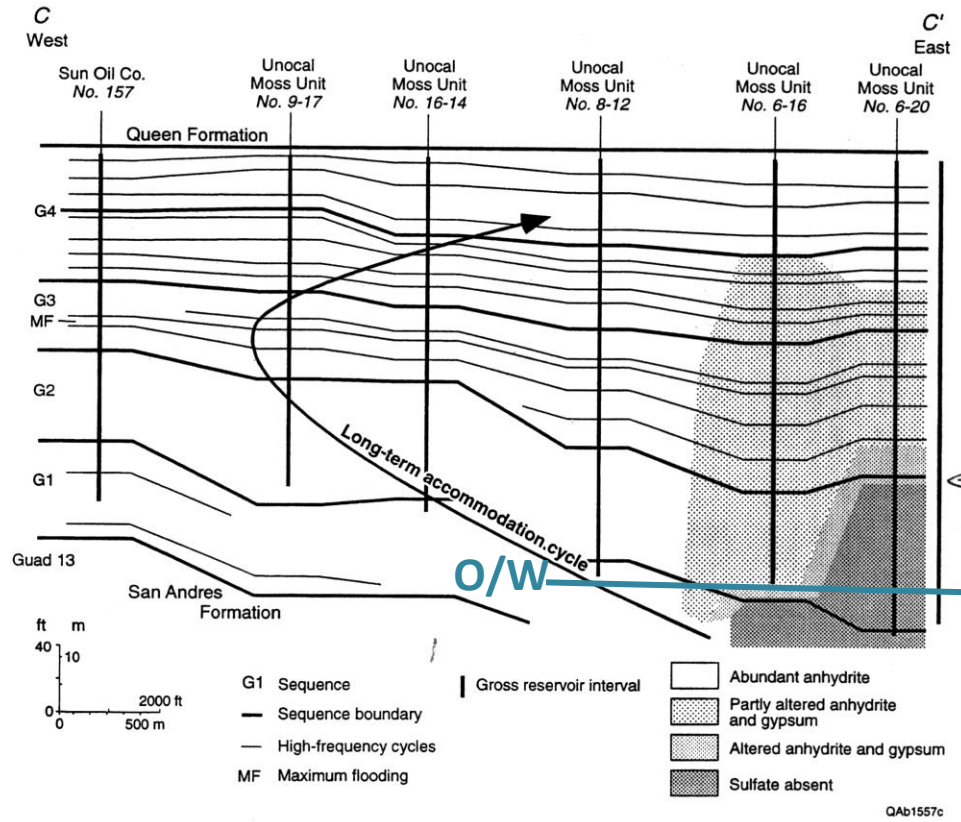
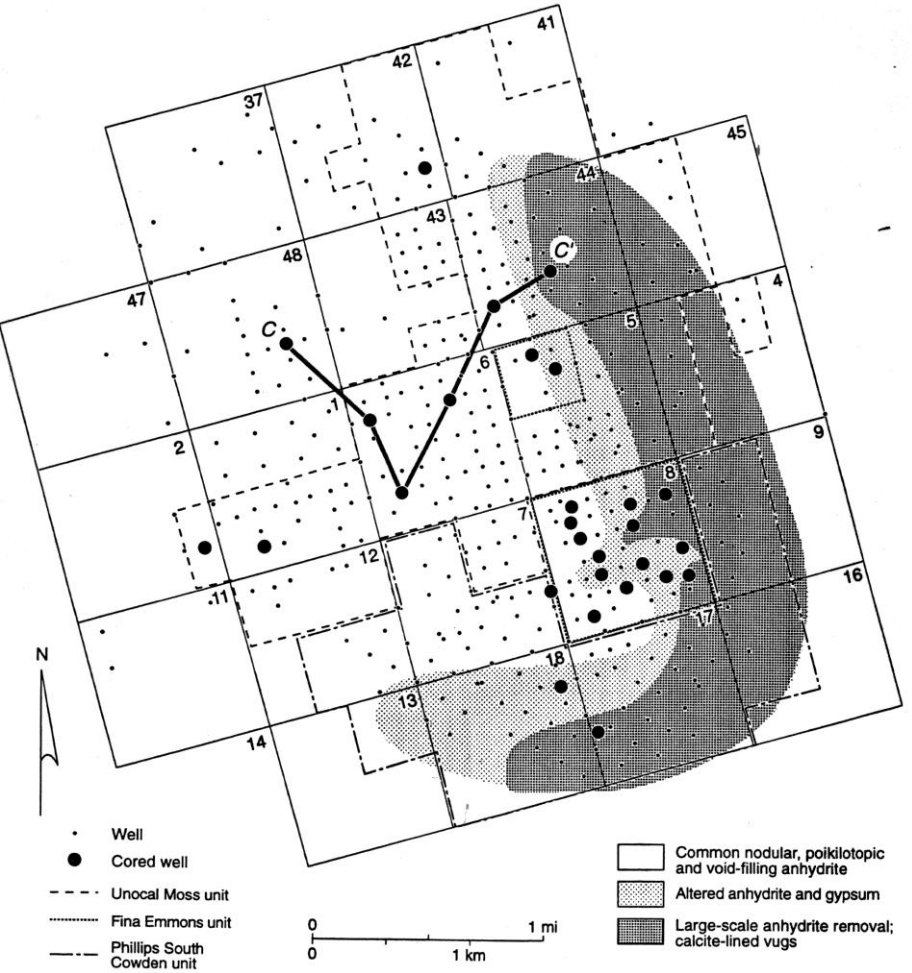


The two meteoric sourced waters take different pathways.

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

A. D distribution of altered sulfate & complete removal.

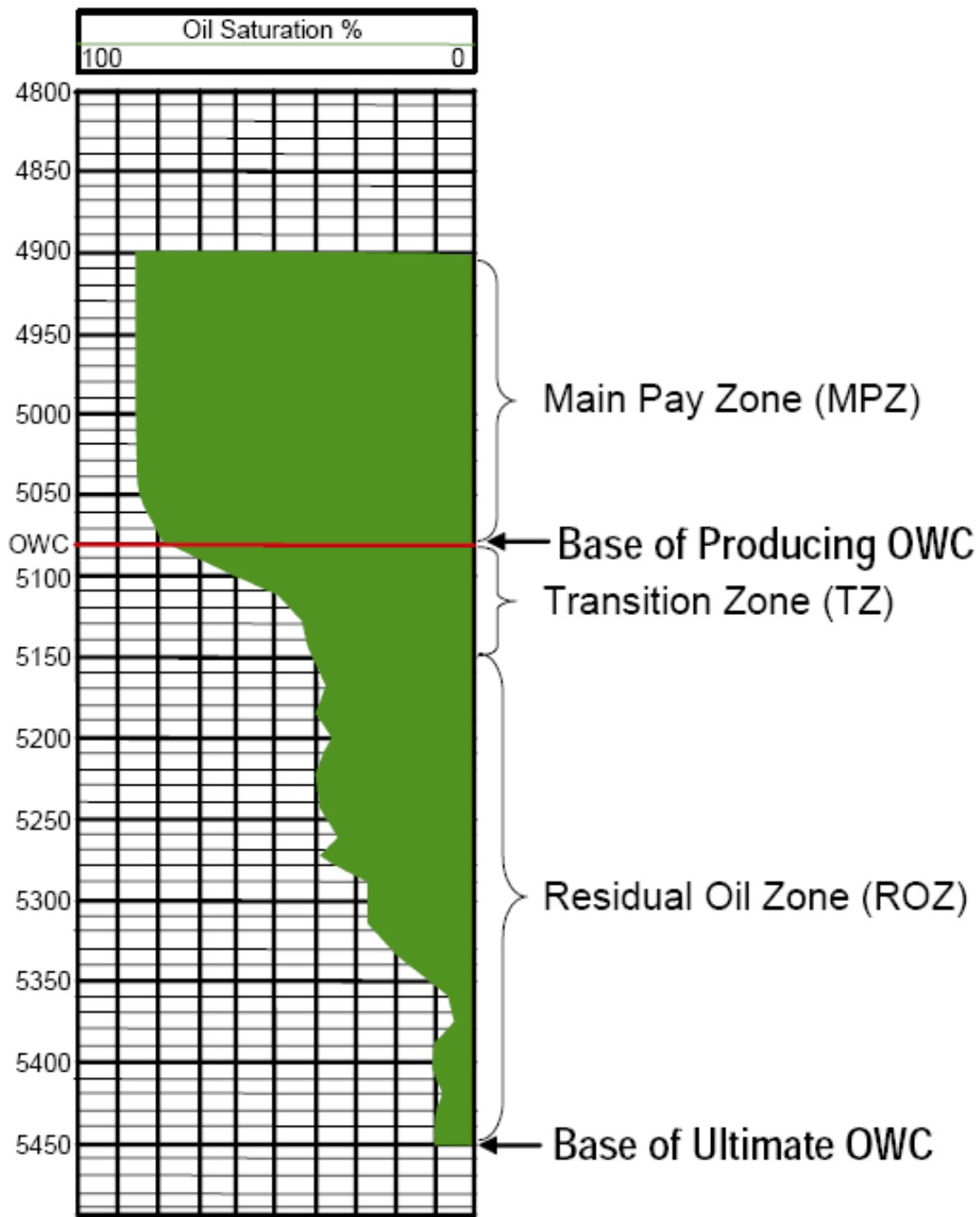
B. Dip section showing distribution and removal.



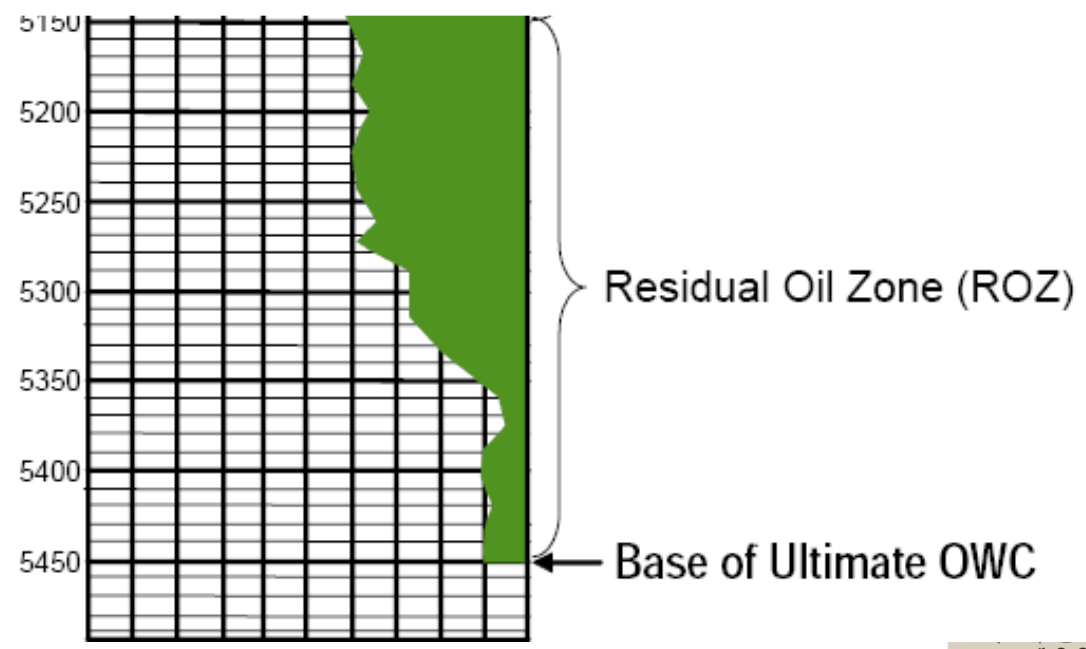
sulfate removal resulted in highest permeability in zone of sulfate removal.

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.

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

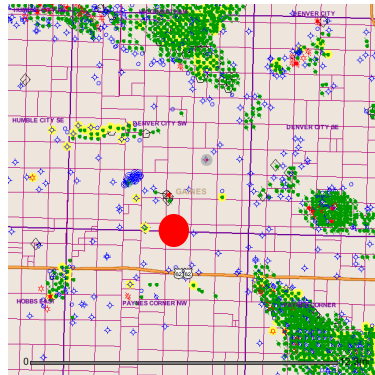
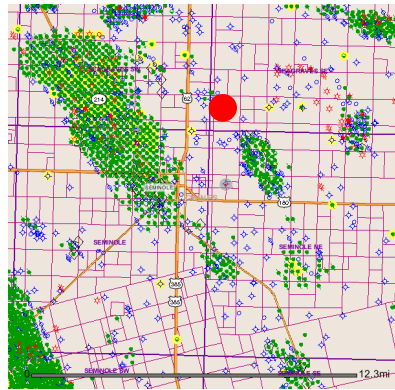


**Your left with a
tertiary recovery
target.**



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

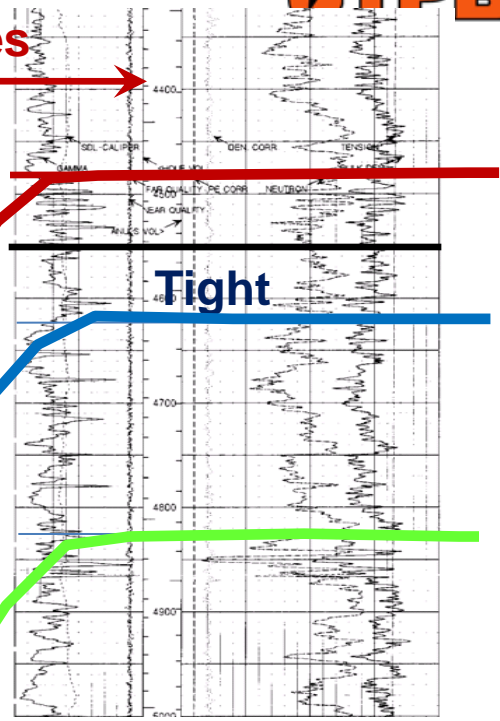
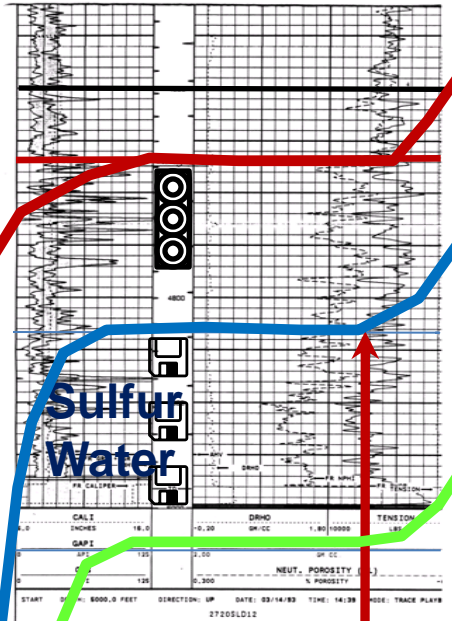
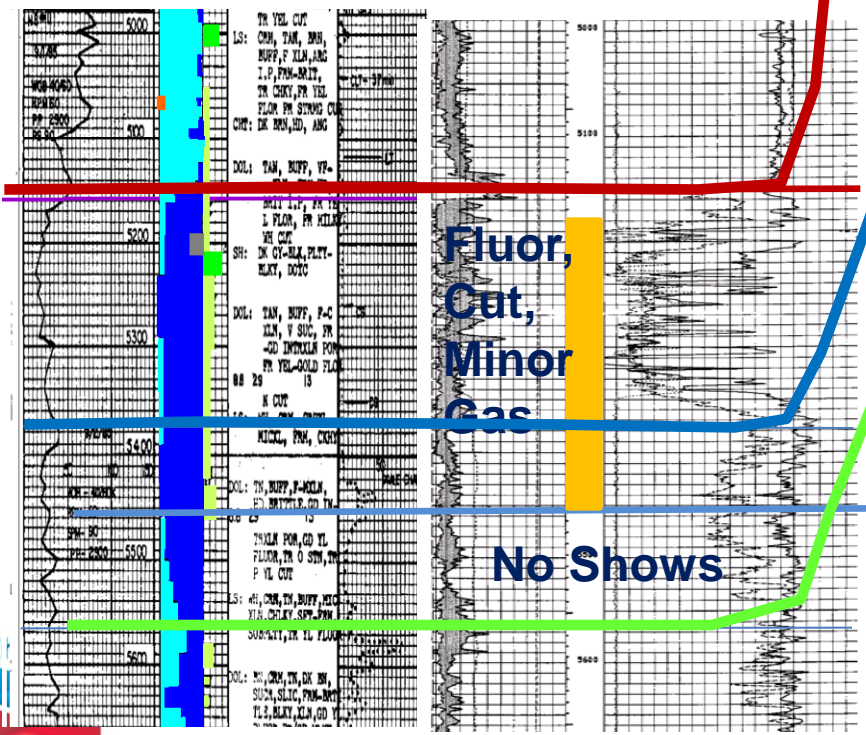
Production

3 Miles

Large ROZ/CCS Targets.

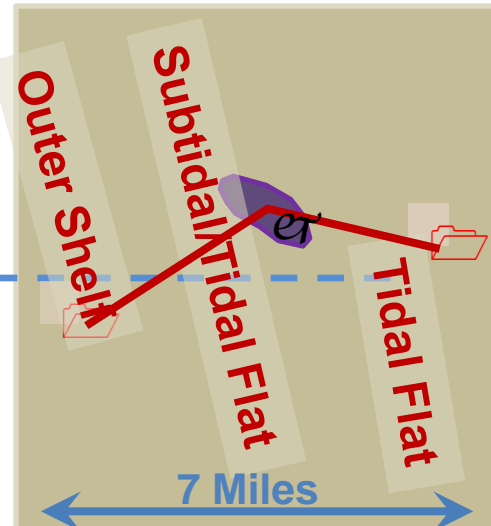
ROZ's maybe significantly larger than the existing field. In this case, there maybe CO2 flood potential up to 4 miles beyond the limit of the field, and 550' below the existing perfs.

Who owns the ROZ? CCS Target?

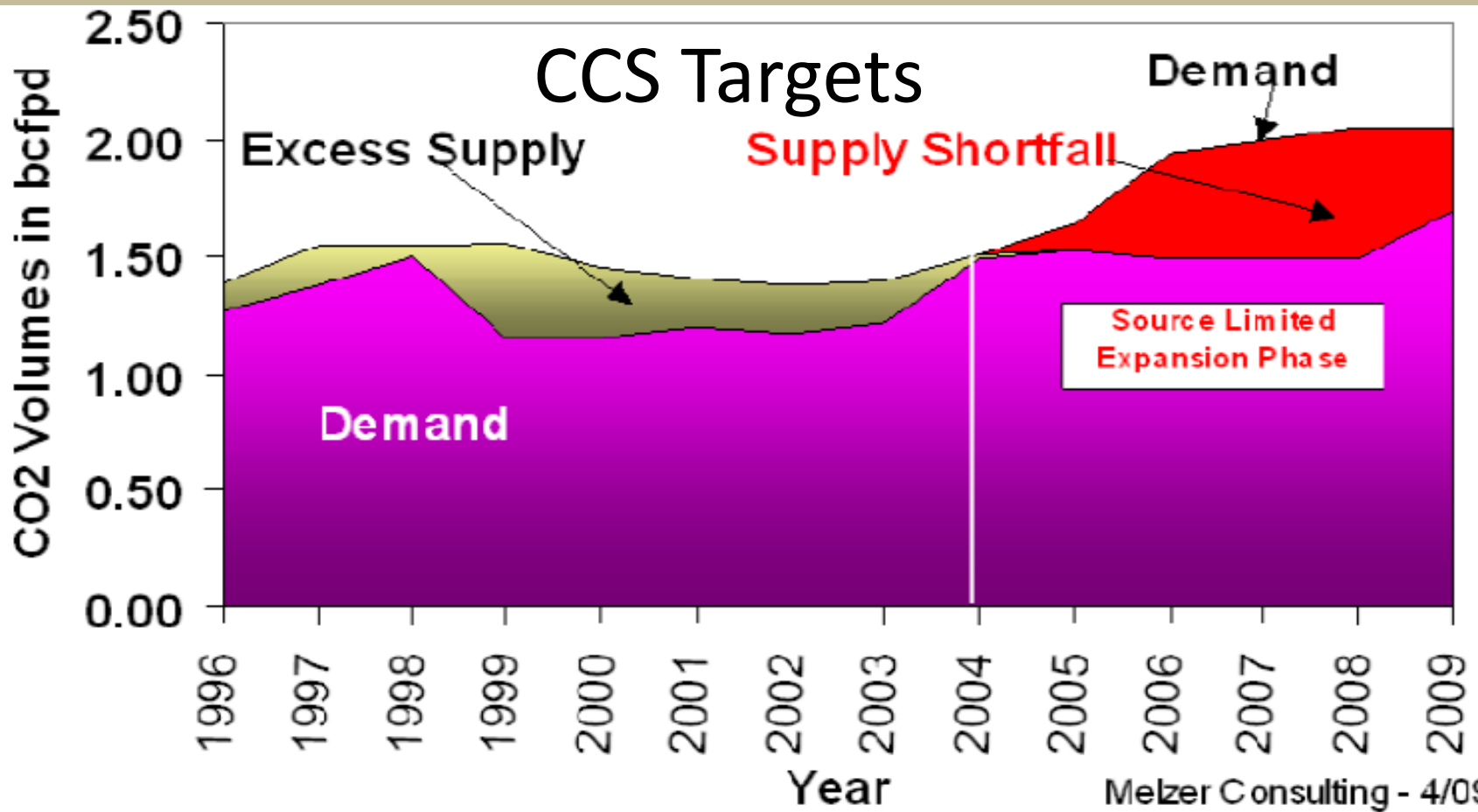


ROZ Maximum 550' !

Base ROZ ?



- Today, 1.8 to 2 BCF CO₂/day are imported into the Permian Basin for use in EOR projects. This volume is restricted by pipeline size. In 2011, ~300 MMCF of CO₂ volume will be added. All of it is going to Oxy projects waiting for CO₂.
- Summit Energy and Tenaska, Inc. are planning coal-fired CO₂ capture power plants in west Texas. Both will sell the captured CO₂ to EOR.



CO₂ Sequestration in ROZ's & the Brine Aquifer portions of Permian Basin fields.

- Each time CO₂ is cycled through a reservoir in a Main Pay CO₂ EOR or ROZ CO₂ flood, 20-40% of the CO₂ is “left behind” in the reservoir.
- When the CO₂ releases the oil from the pore space/grain surfaces, a portion is “Sequestered”.
- SACROC, a 40 year old CO₂ EOR project has “STORED” 3 TCF CO₂.
- As opposed to “classic” Carbon Capture and Storage, which is a costly process, storage of CO₂ 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:

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

* 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 =

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

- 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.

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.



Thanks go to....

- Hoxie Smith
- All those who have battled with ROZ's in the past.

- 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.

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 CO₂.

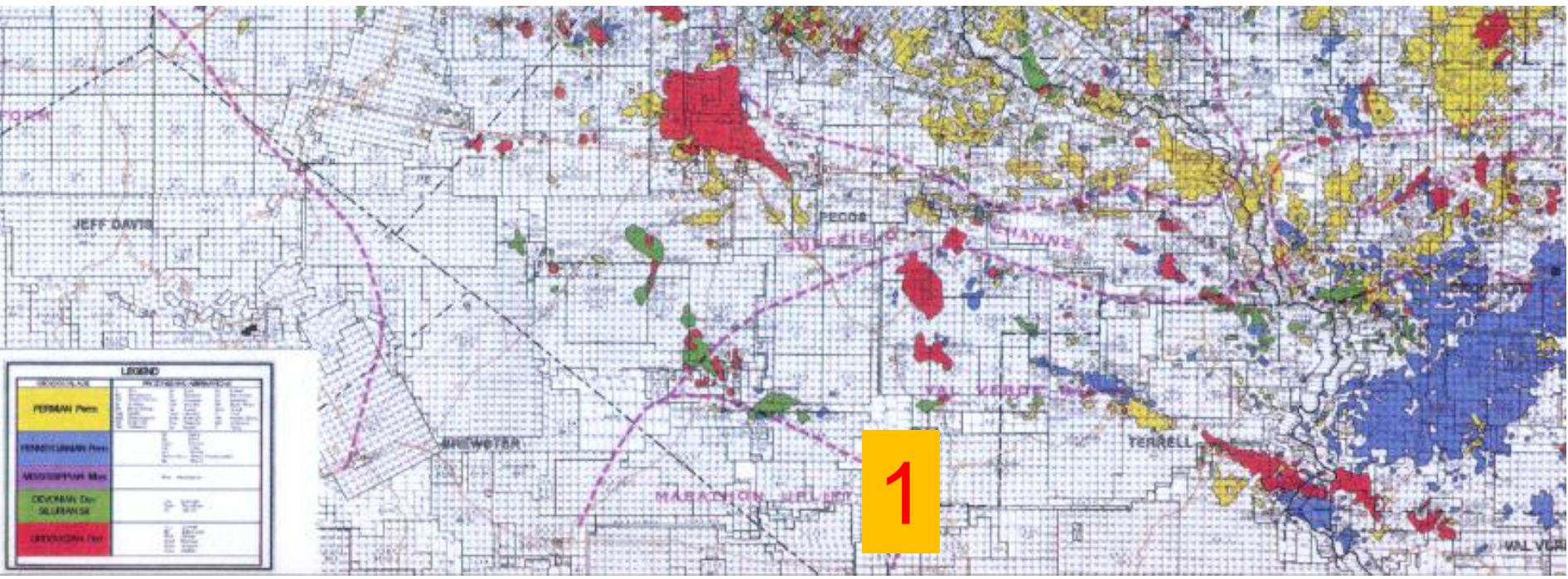
Oil Saturations

- *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*)

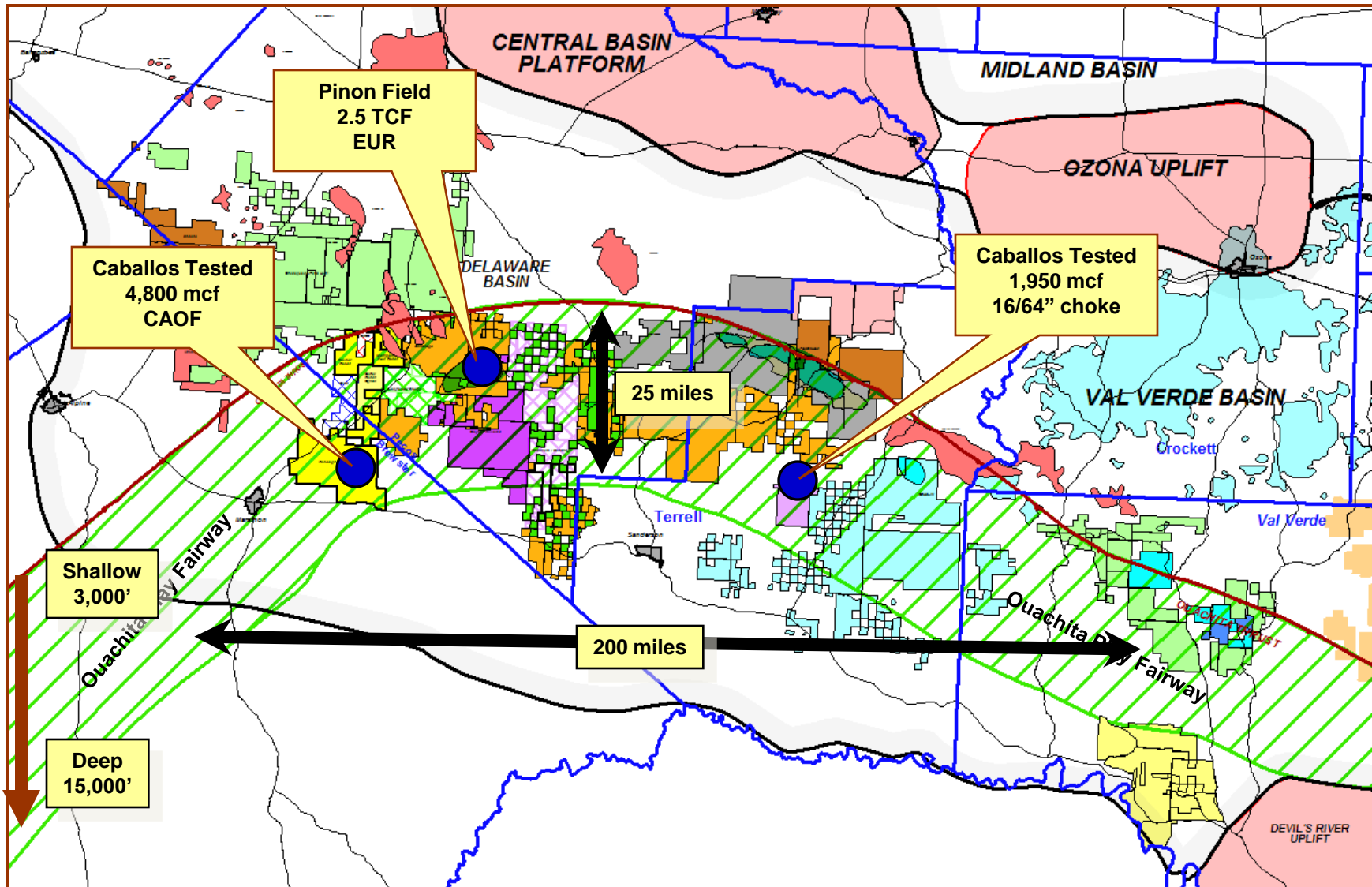
Other Areas of Discussion

- **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



Stratigraphy & Cross Section

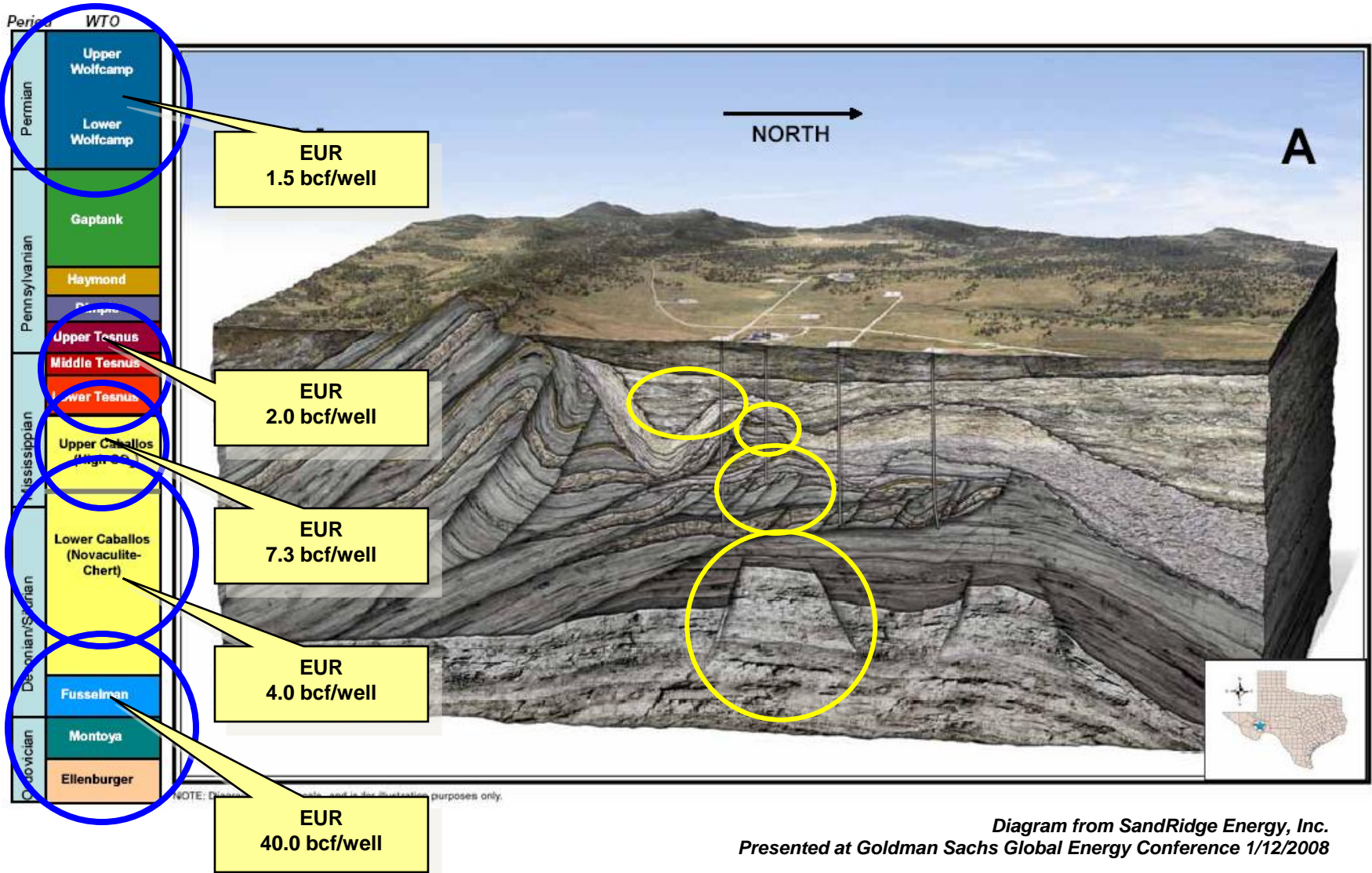
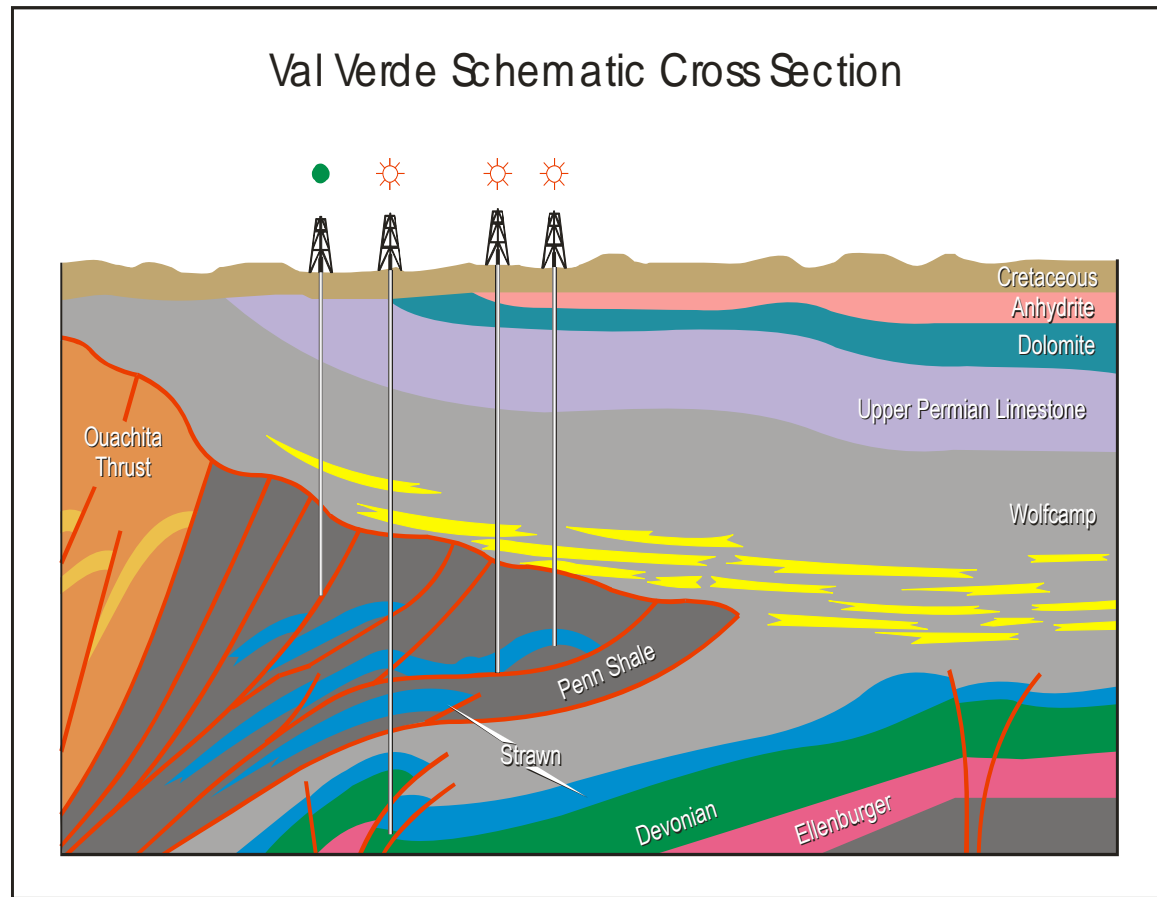


Diagram from SandRidge Energy, Inc.
Presented at Goldman Sachs Global Energy Conference 1/12/2008

| Period | WTO |
|-------------------|--|
| Permian | Upper Wolfcamp |
| | Lower Wolfcamp |
| Pennsylvanian | Gaptank |
| | Haymond |
| | Dimple |
| | Upper Tesnus |
| | Middle Tesnus |
| Mississippian | Lower Tesnus |
| | Upper Caballos (High CO ₂) |
| | Lower Caballos (Novaculite-Chert) |
| Devonian/Silurian | Fusselman |
| | Montoya |
| Ordovician | Ellenburger |



Stacked
Play
Opportunities

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

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 CO₂ Reported in Ouachita Fields East of Pinon Field

CO2 Capture and EOR

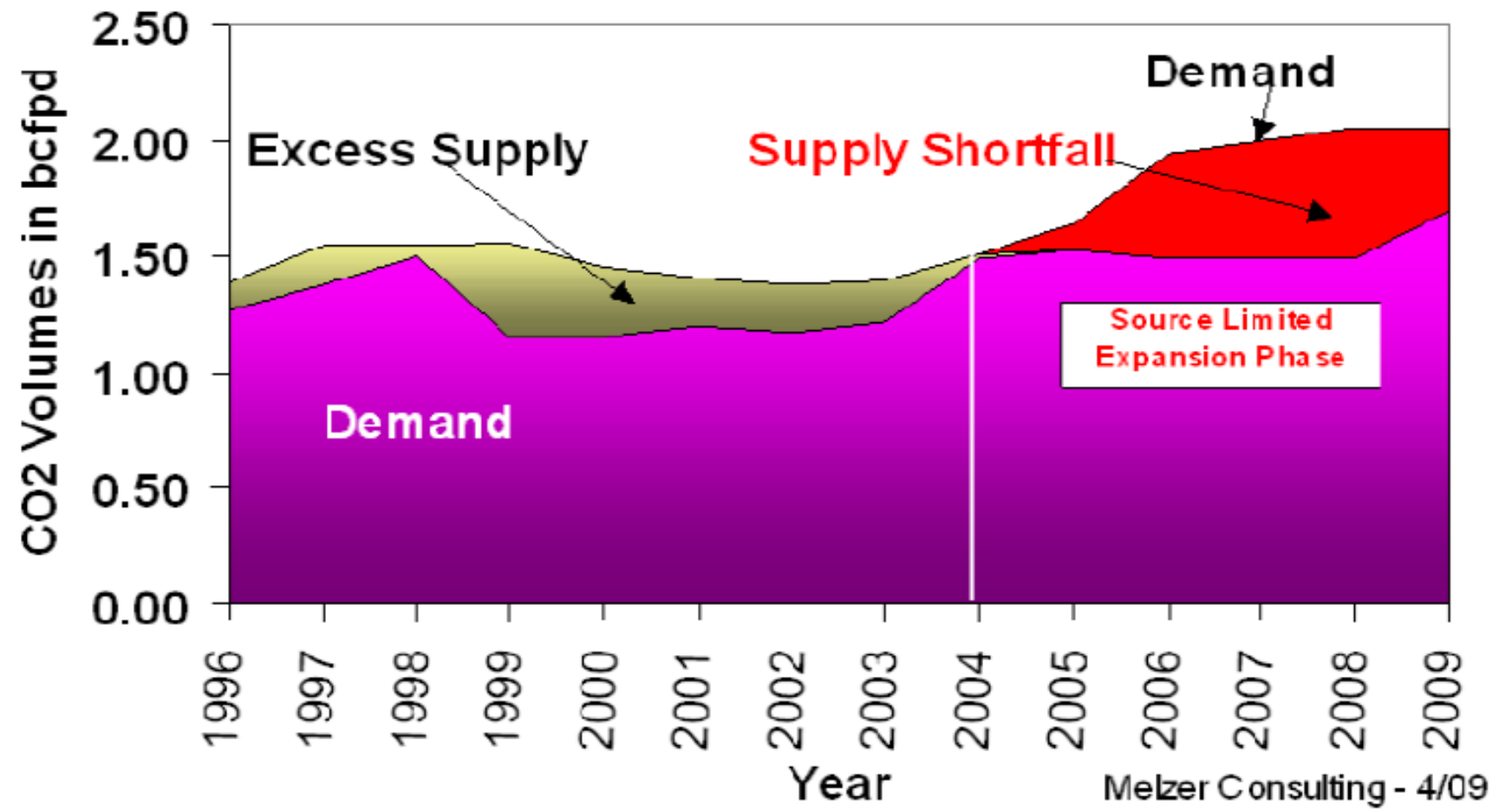
- Presently there are over 100 CO2 EOR projects currently producing >250,000 BOPD.
- Since 1985 >1.5 BBO have been produced using CO2 and another 1.5 BBO listed as Proven Reserves.
- Planned Federal CCS legislation could result in 69 to 109 GiggaWatts of coal and natural gas fired power generation, with 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. CO₂ Supply and Demand in the Permian Basin



Melzer Consulting - 4/09

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.

“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.

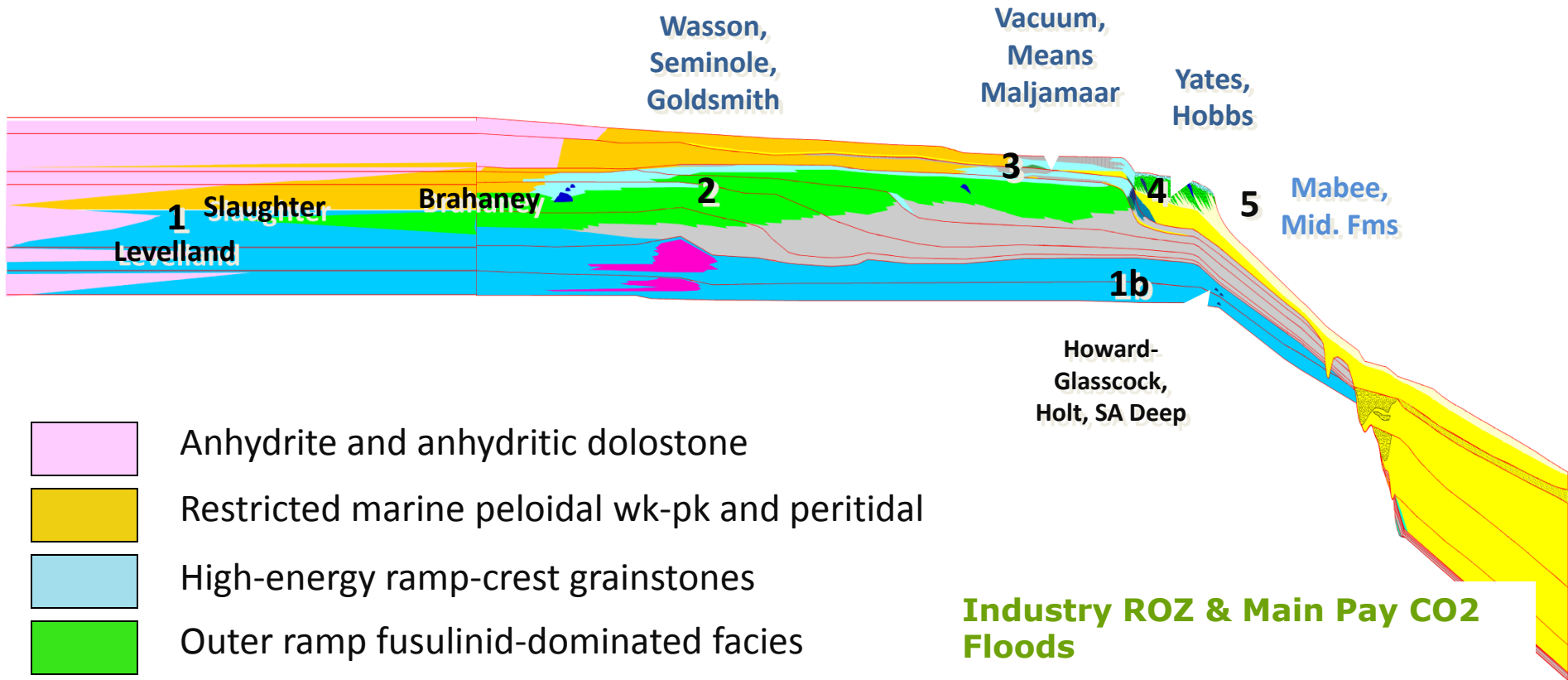
Evidence from other fields

- 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 Meteoric Sweeping of the reservoirs as opposed to variations in porosity and permeability.

- 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 Meteoric sweeping of the reservoirs from north to south and paralleled the shelf margin and not perpendicular to it.

San Andres Reservoir Settings.

All fields are not alike, but all settings have ROZ potential



- 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)

Industry ROZ & Main Pay CO2 Floods

- Seminole San Andres (HESS)
- Denver Unit -Wasson (OXY)
- Vacuum (Chevron)
- Goldsmith Field (Legado)
- Means (XOM)

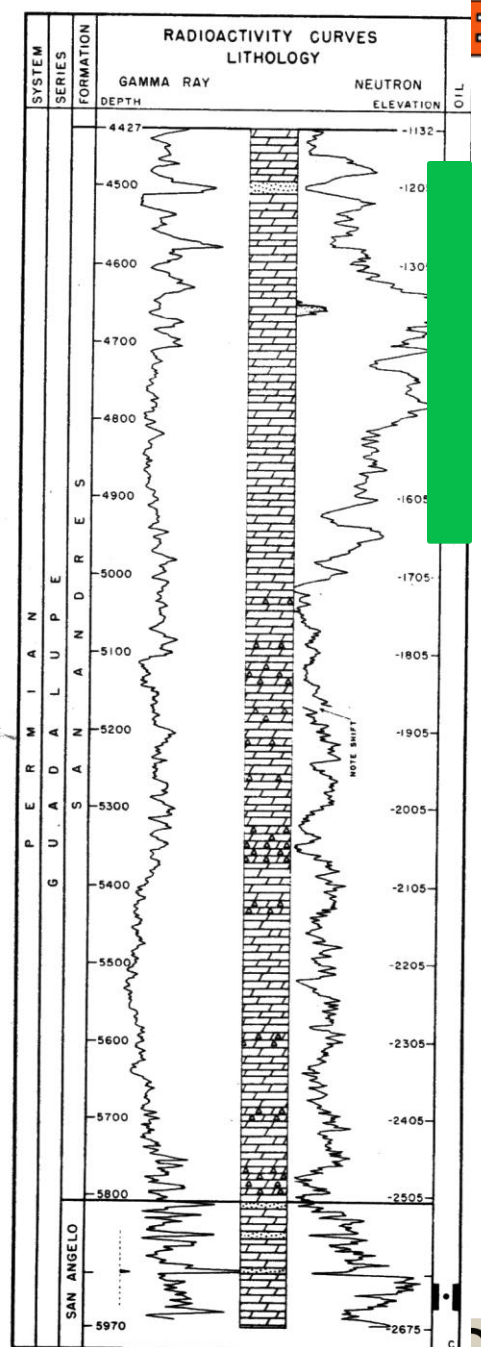
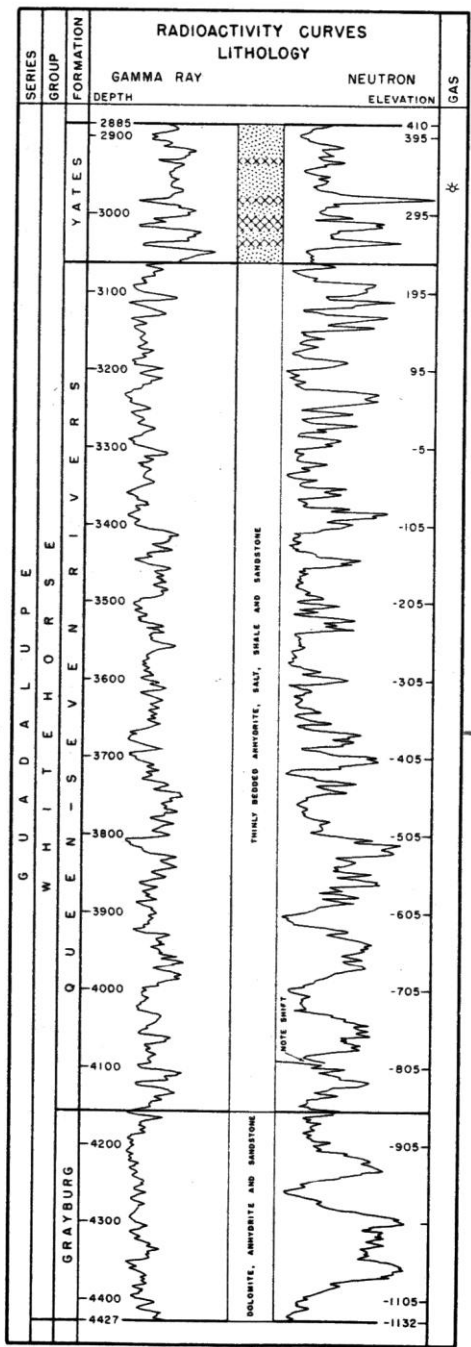
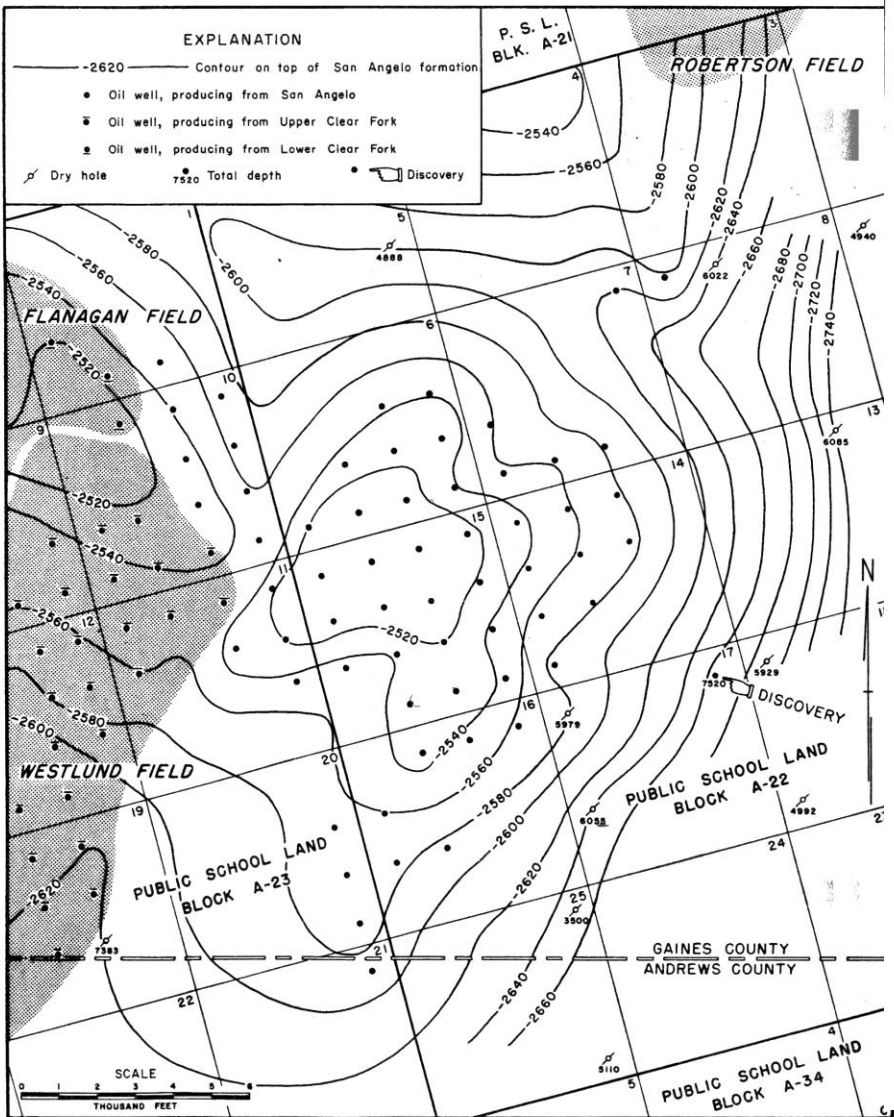
More Evidence

- 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 $d_{13}C$ 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 [REDACTED]

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 nature's 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.

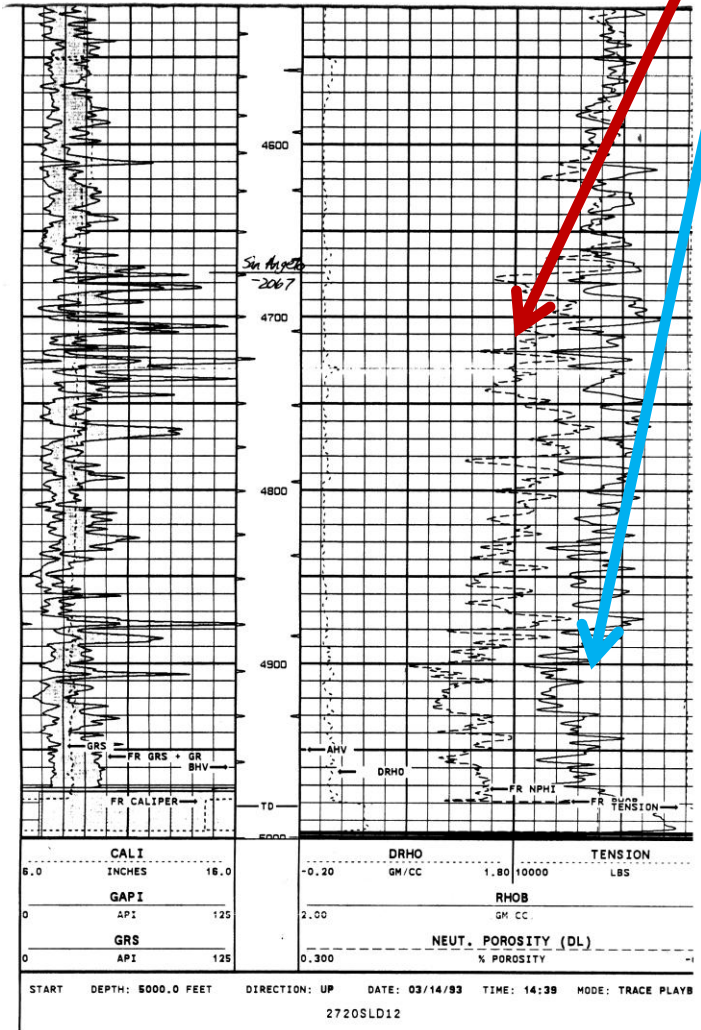
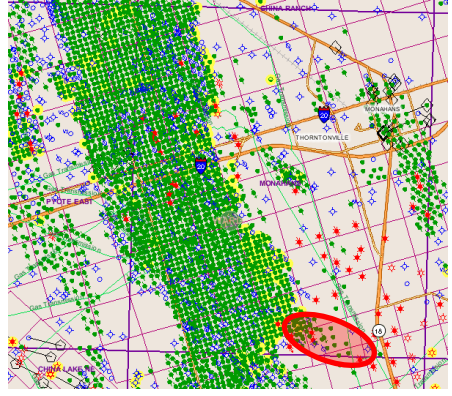
Why did it take so long to discover it?

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

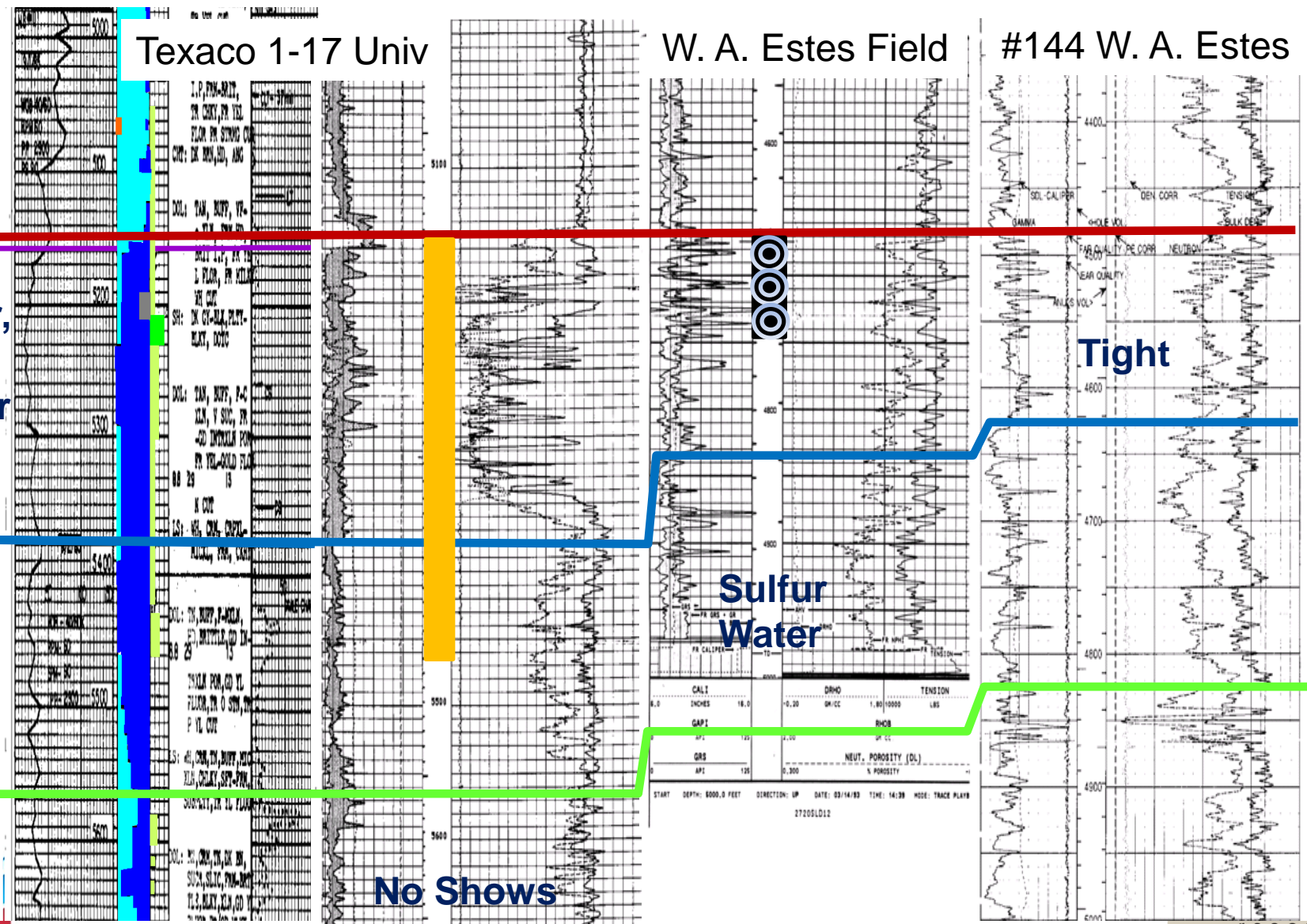
The updip section thinned by pre San Andres tilt and Erosion

Fluor, Cut, Minor Gas

Texaco 1-17 Univ

W. A. Estes Field

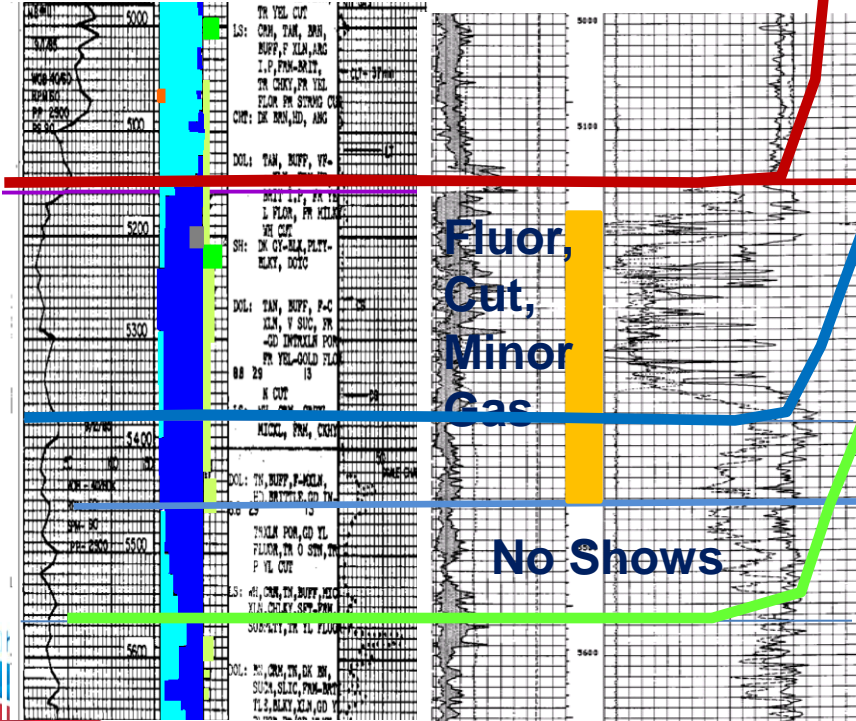
#144 W. A. Estes



Texaco #1-17 Univ

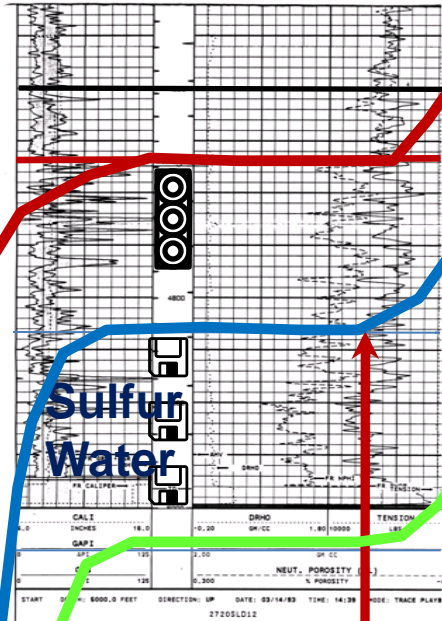
W. A. Estes Field

W. A. Estes #144



**Fluor,
 Cut,
 Minor
 Gas**

No Shows



**Sulfur
 Water**

Tight

**ROZ
 Maximum
 550' !**

Base ROZ ?

