

Residual Oil Zones

From Science to Commercial Exploitation

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UTPB/CEED

4th Annual Wyoming EORI CO2 Conference

Project Objectives

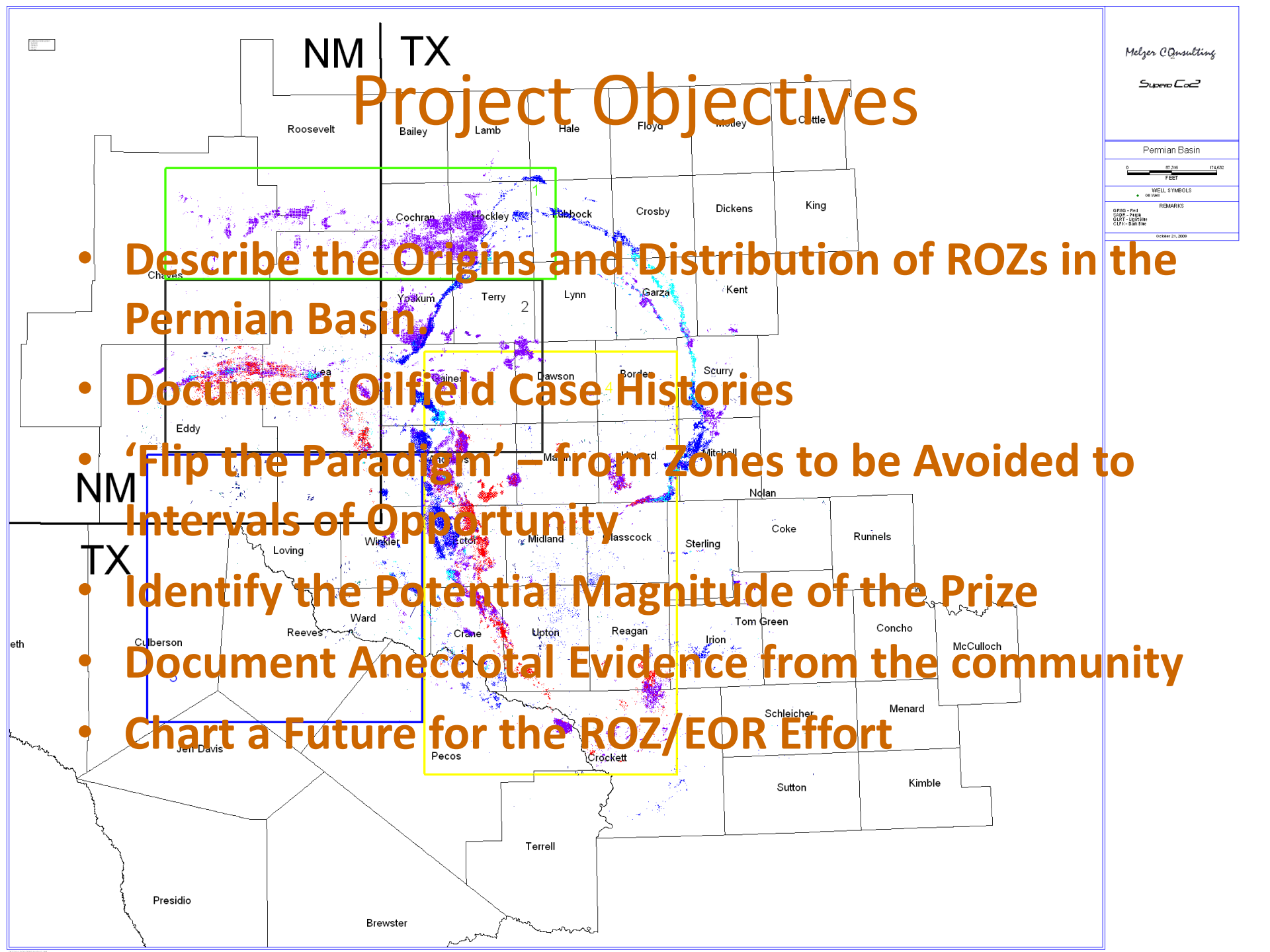
- Describe the Origins and Distribution of ROZs in the Permian Basin
- Document Oilfield Case Histories
- 'Flip the Paradigm' – from Zones to be Avoided to Intervals of Opportunity
- Identify the Potential Magnitude of the Prize
- Document Anecdotal Evidence from the community
- Chart a Future for the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

Permian Basin

WELL SYMBOLS
 * OR 100'

REMARKS
 CIPRO - Prod
 CIPRO - PAUSE
 CIPRO - STOPPED
 CIPRO - OAR 50'

October 21, 2009



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.
- 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.

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, others are 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.

	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 Goldsmith Robertson?
Leonardian	L. San Andres	N. W. S. C. B. P.	Wasson Yates? McCamey?
	Glorieta	C. B. P. N. W. S.	North Ward Estes
	U. Clearfork	C. B. P.	Robertson?
	Tubb Sand		
	L. Clearfork	C. B. P	Sand Hills?
	ABO	N. W. S.	Empire?

Calibrating the Oil Recovery Models and Estimating Technically

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

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

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

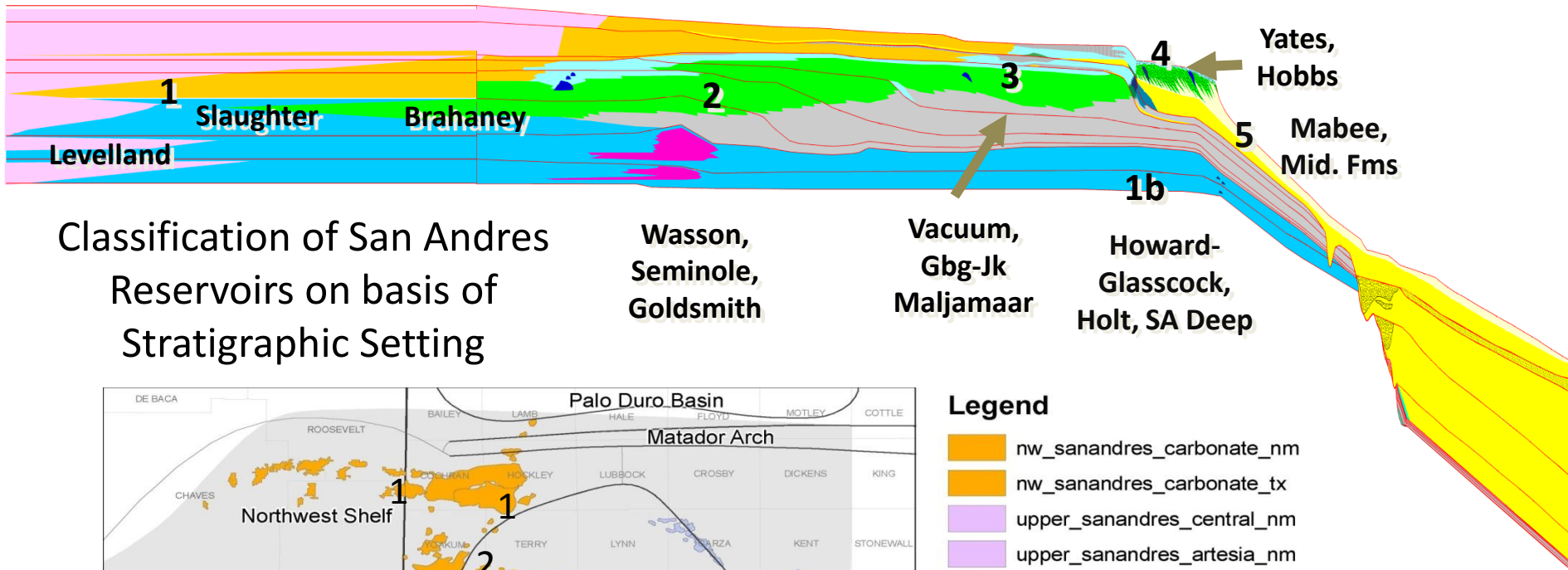
Field/Unit	MPZ OOIP (BB)	TZ/ROZ OOIP (BB)	No. of Fields	No. of MPZ Fields with CO ₂ - EOR Projects	No. of Fields with TZ/ROZ CO ₂ - EOR Projects
1. Northern Shelf Permian Basin (San Andres)	13.0	13.2	13	5	1
2. North Central Basin Platform (San Andres/Grayburg)	2.9	2.6	6	2	1
3. South Central Basin Platform (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

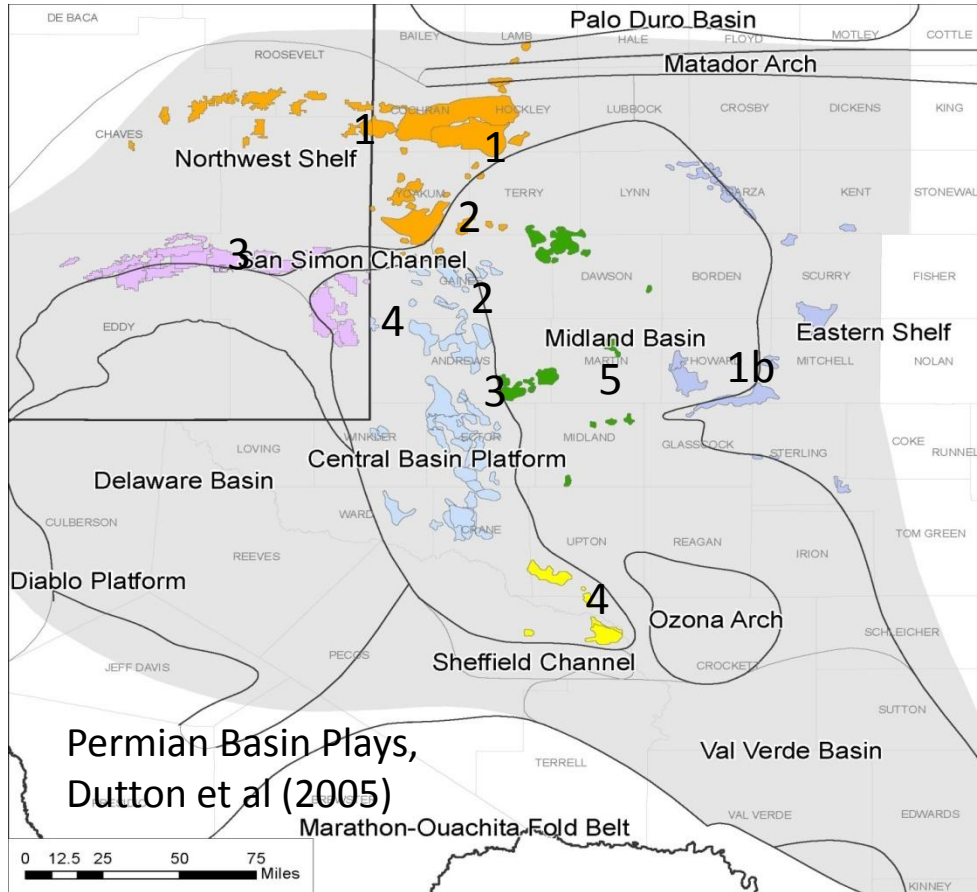
Based on reservoir modeling of applying CO₂-EOR to the TZ/ROZ resources, ARI estimates that

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



Classification of San Andres Reservoirs on basis of Stratigraphic Setting



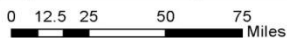
Legend

- 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)

Marathon-Ouachita Fold Belt



“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.

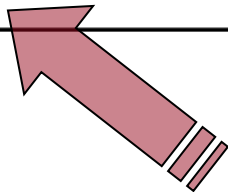
The new Residual Oil Zone Paradigms

- 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.

ROZ BACKGROUND

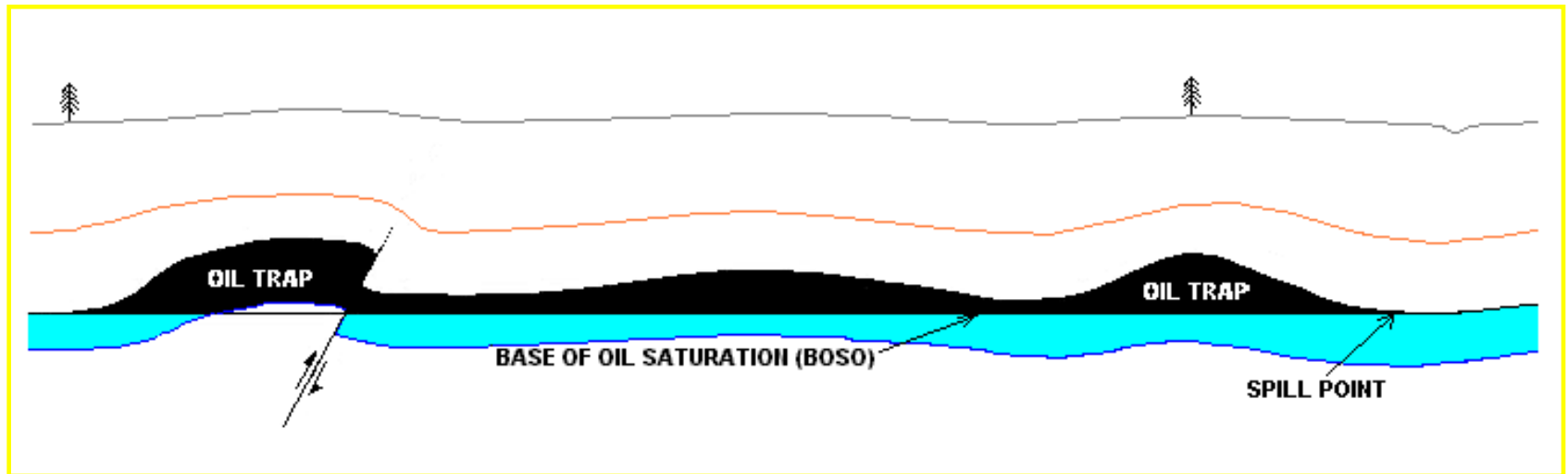
The 3 types of Residual Oil Zones

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)

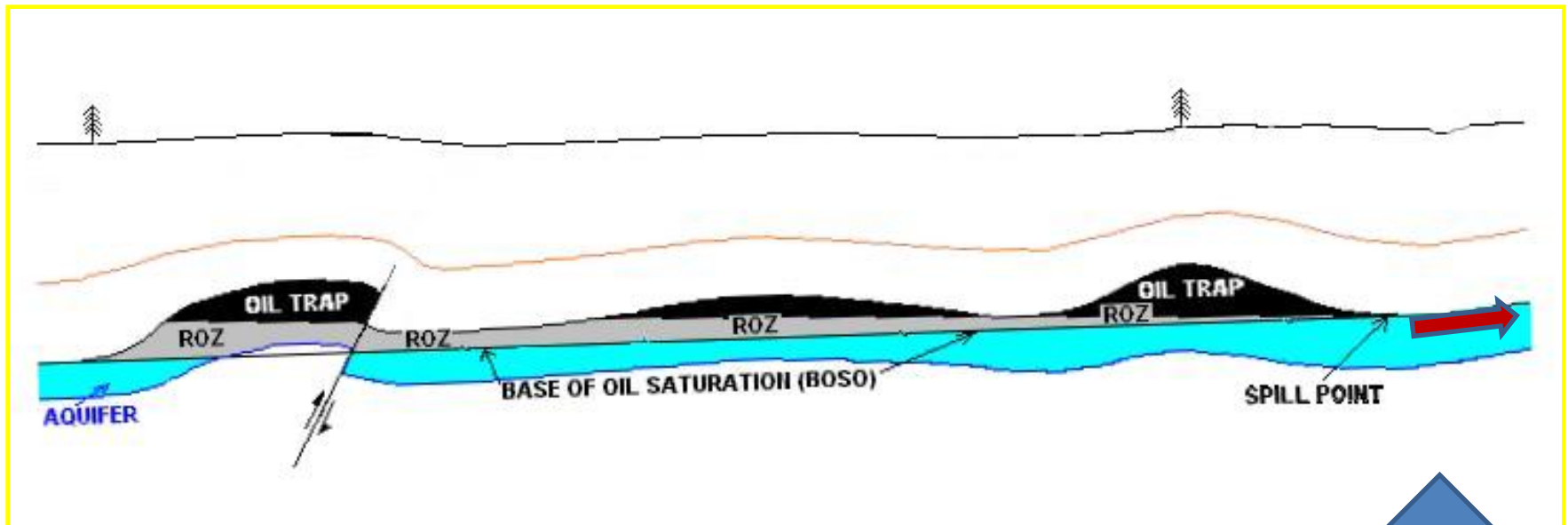


The Evidence suggests Type 3 are common in the Permian Basin

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.



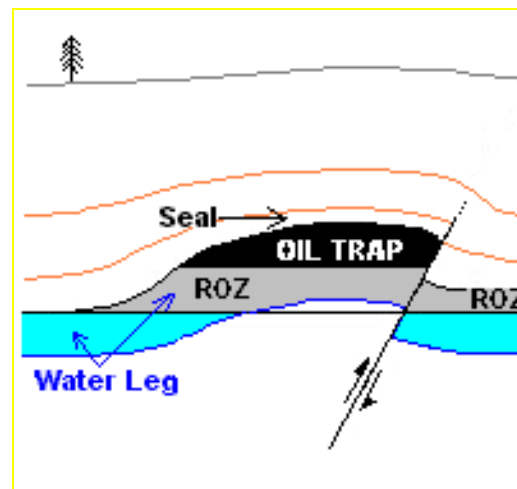
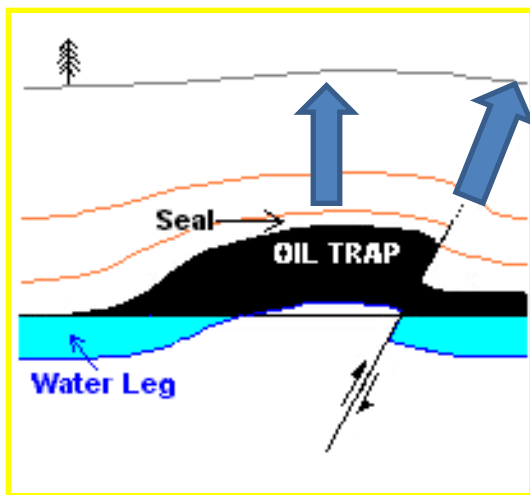
Static System

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.

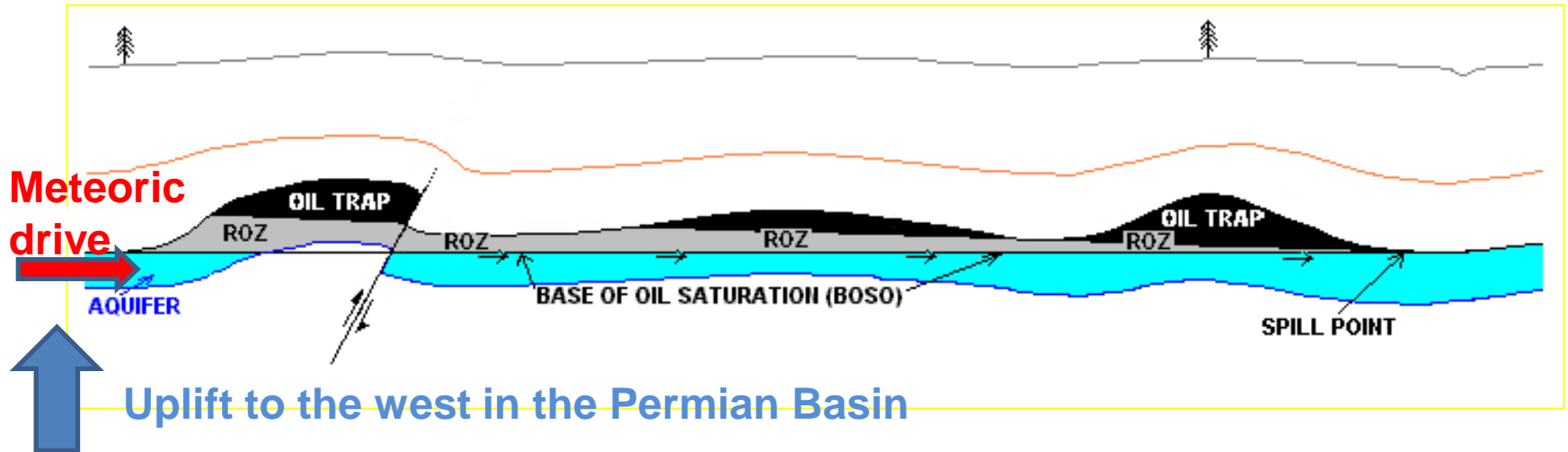


Static System

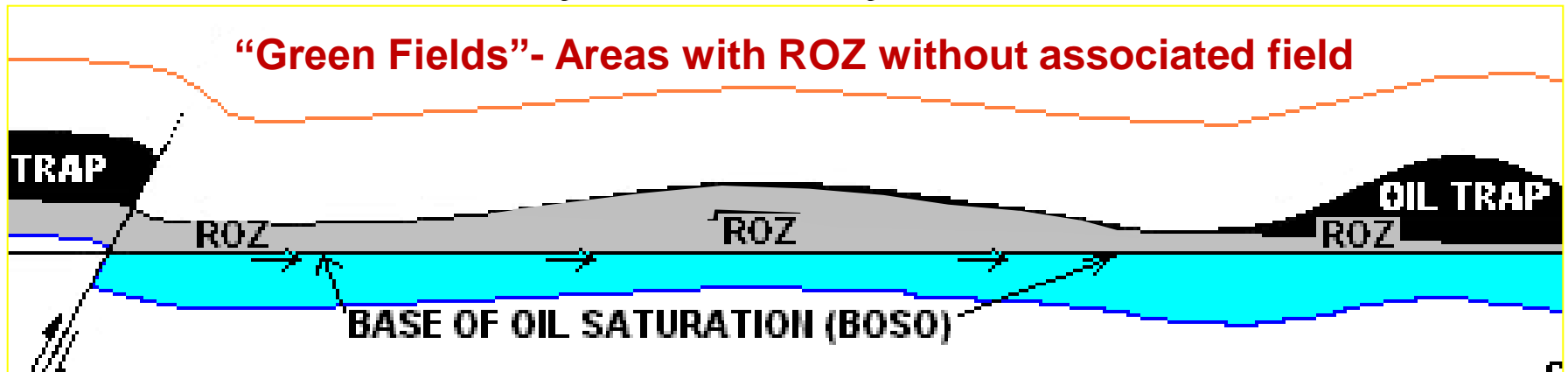
TYPE 3. Change in Hydrodynamic Conditions, Sweep of the lower part of the Oil Column and Development of a Residual Oil Zone.

Oil/Water Contact is Tilted

Base of the ROZ locally almost flat, regionally tilted.

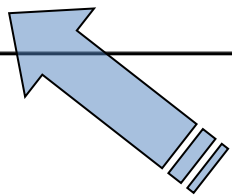


Dynamic System



Attributes of the ROZ Types

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



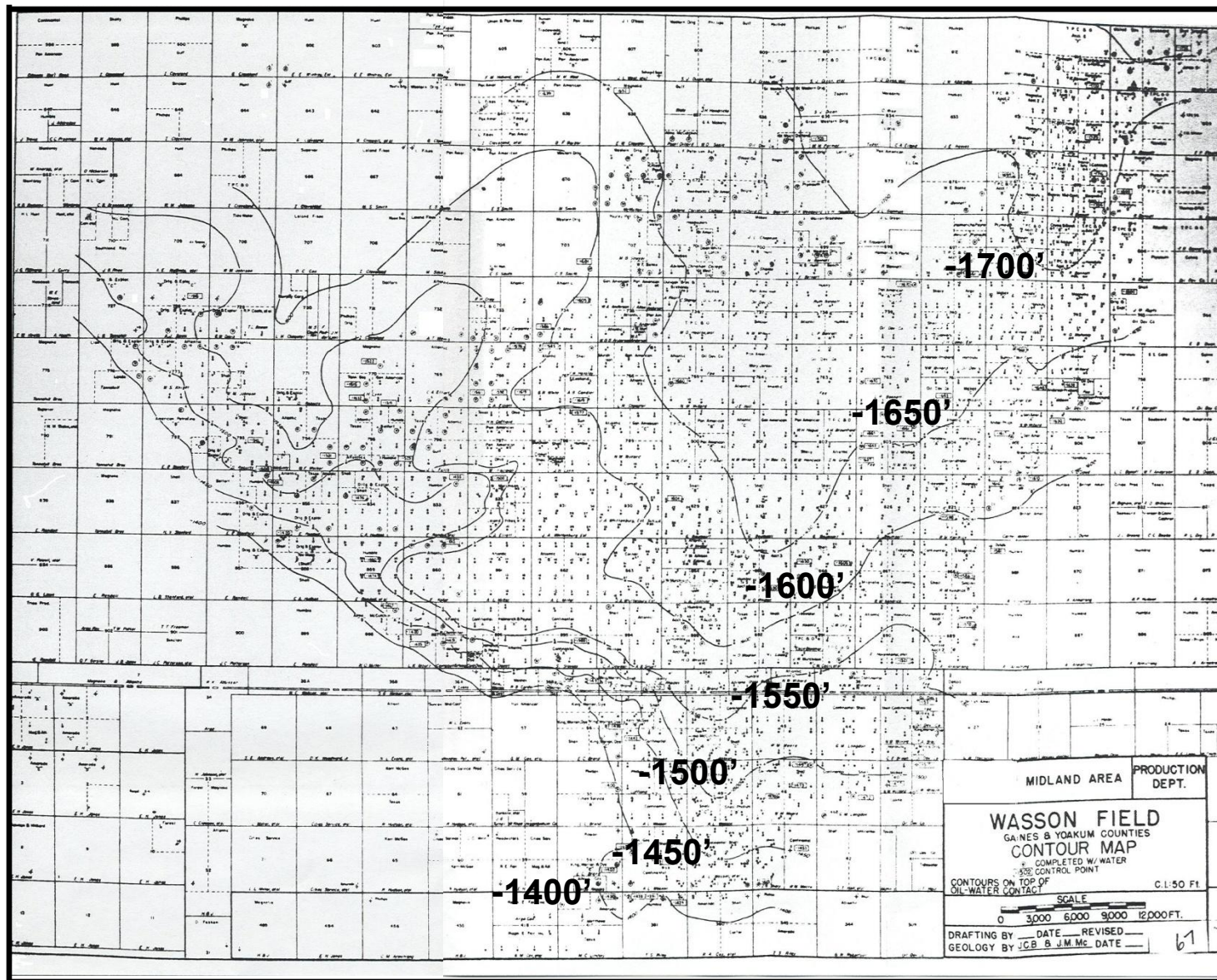
First, Let's Look evidence for OWC Tilt

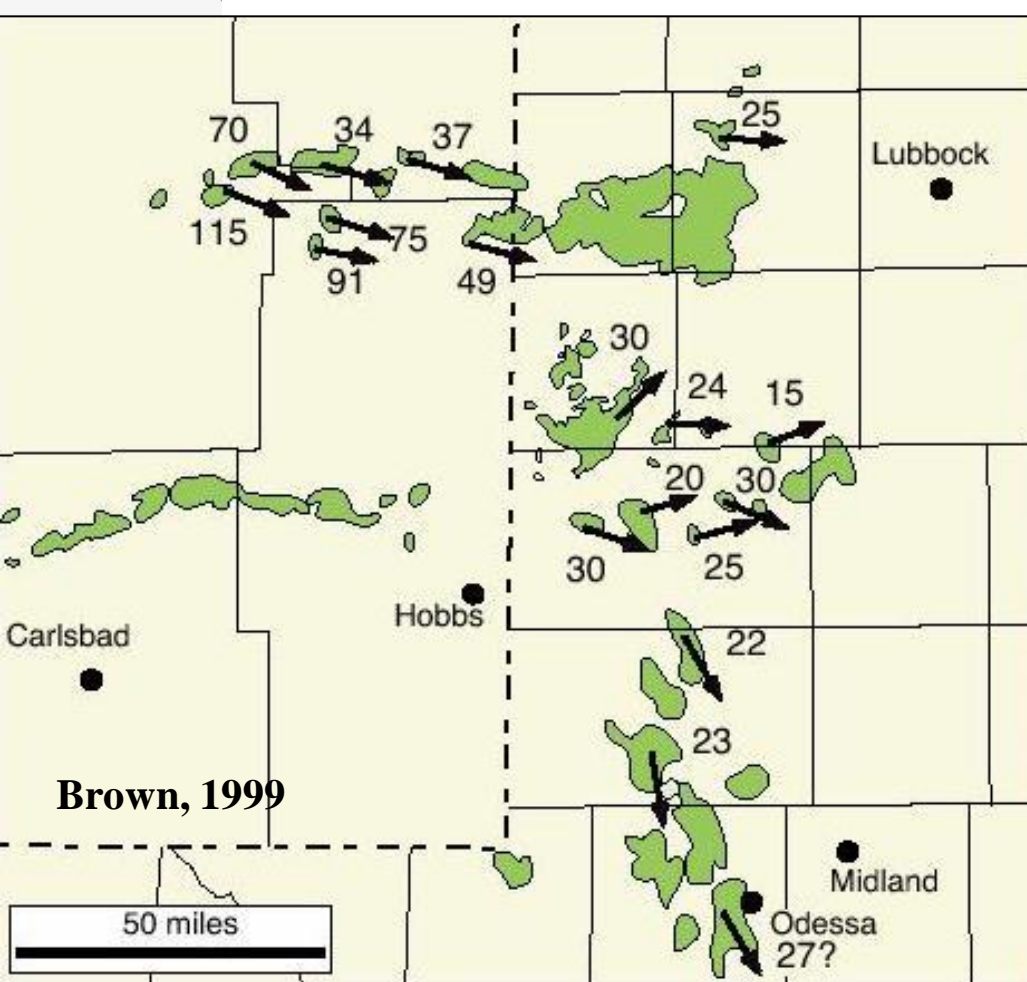
How did we get here?

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.

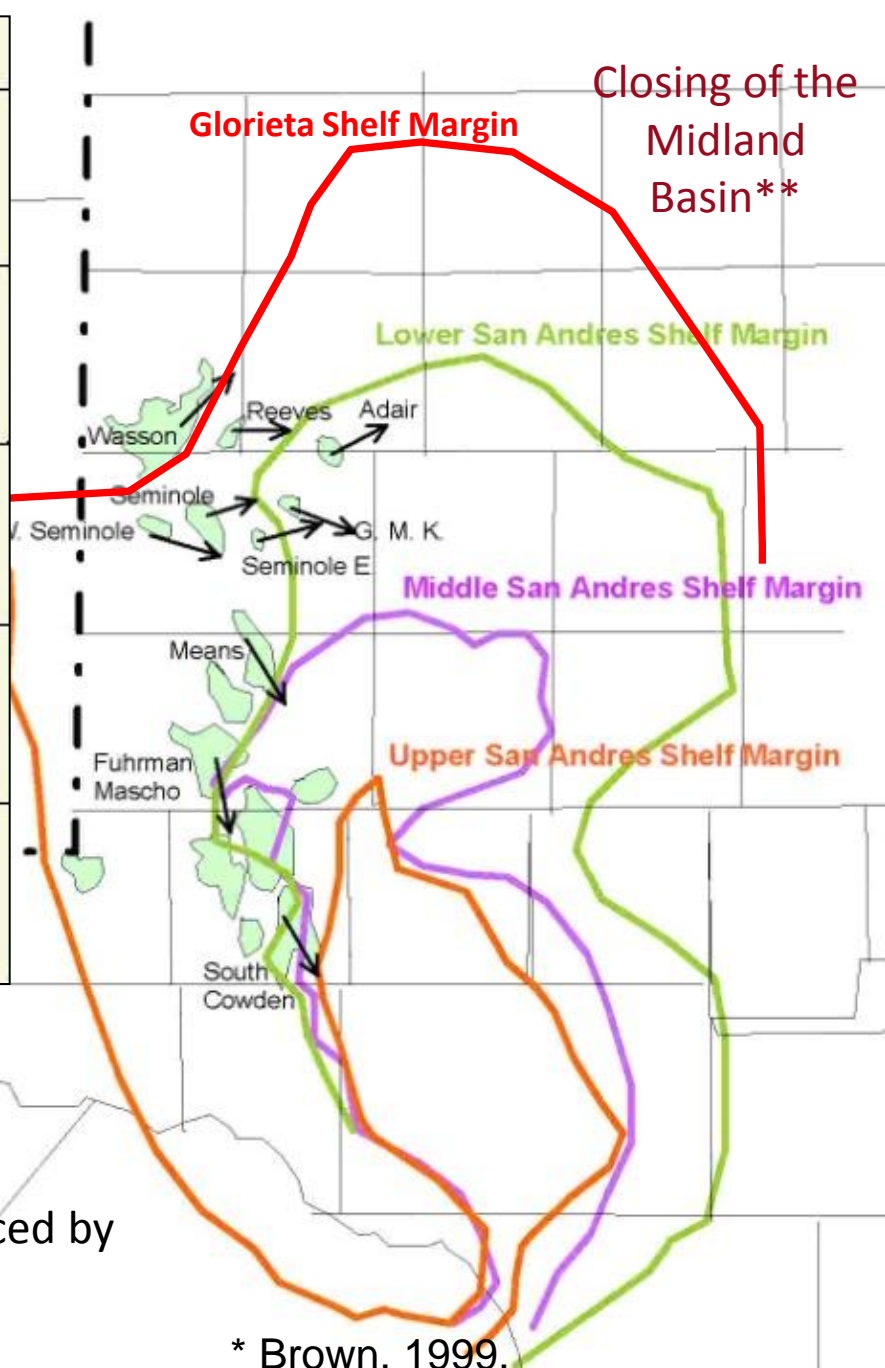
Wasson Field Oil-Water Contact Contour Map – Texas RR Commission Filing, October 1964





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 its relationship to the shelf margin



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



Tilted Oil Water Contacts

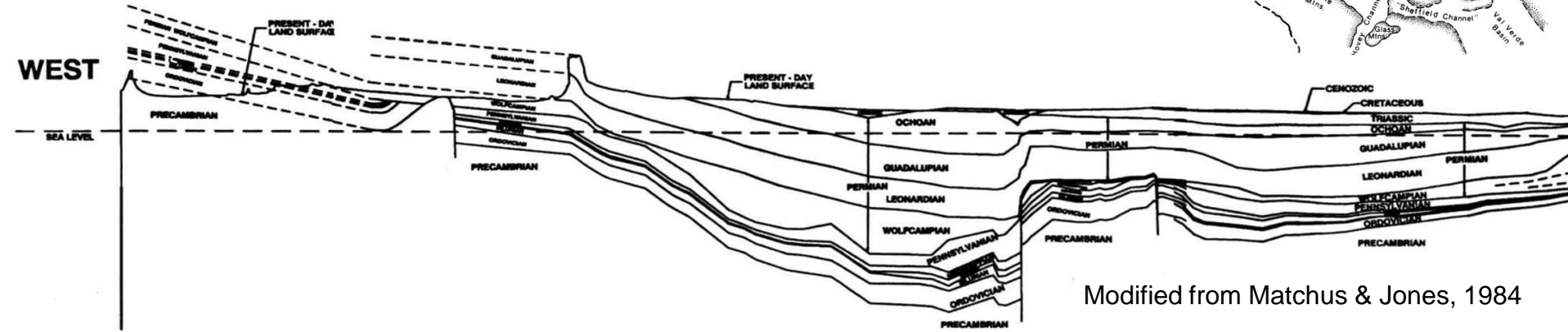
- New Axiom – “ If you have a tilted oil/water contact in the San Andres, you have a ROZ.
- If you have an ROZ.....find a contract for CO₂.

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.

RIO GRANDE RIFT

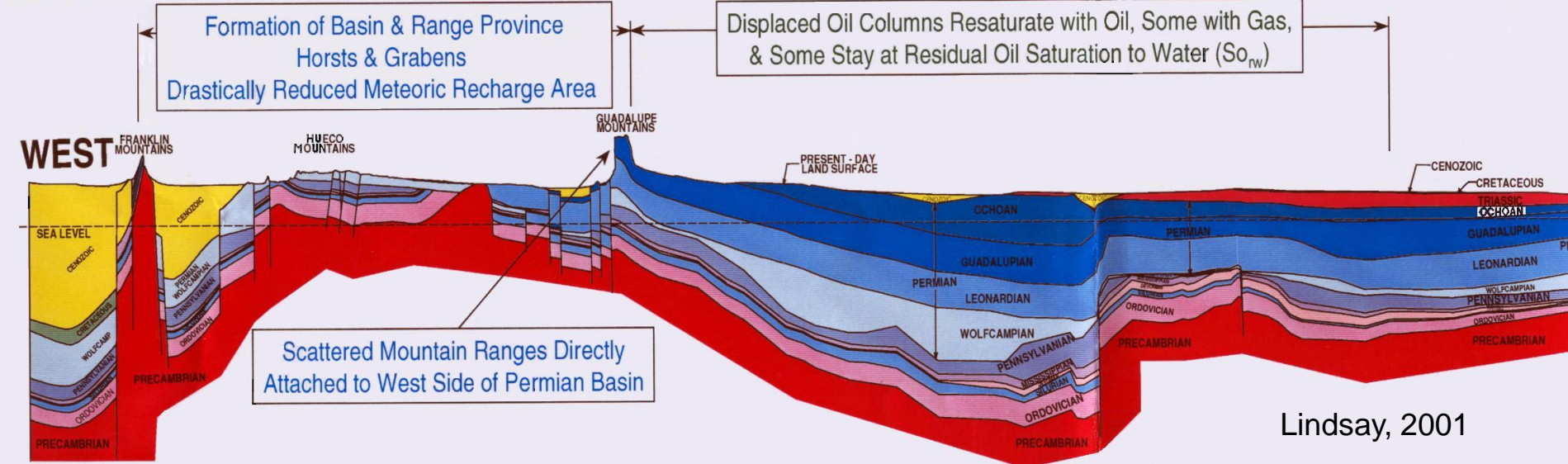


Modified from Matchus & Jones, 1984

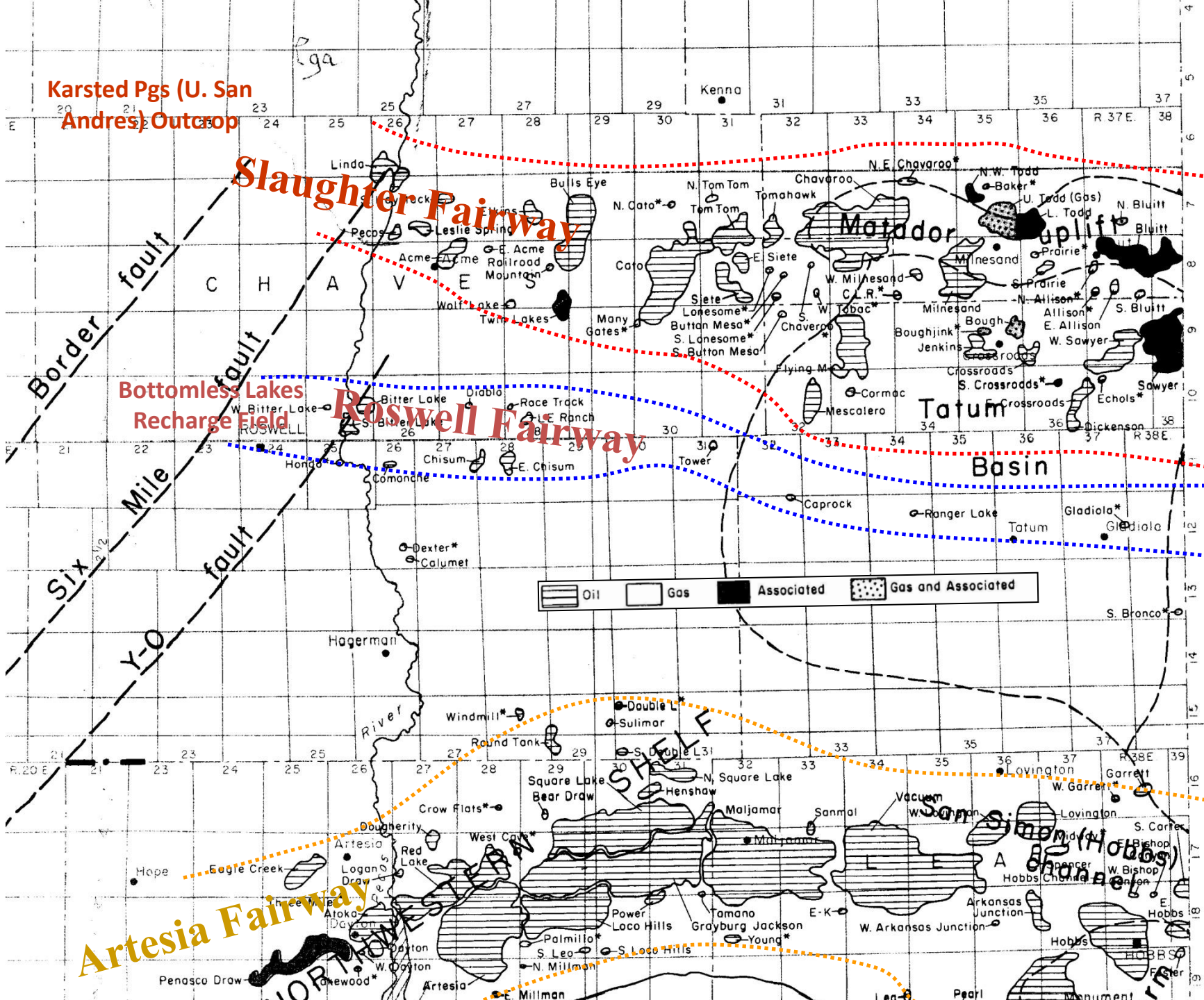
Phase III Slow Extension, Pliocene - Recent
 Phase II Rapid Extension, Middle - Late Miocene

RIO GRANDE RIFT

PERMIAN BASIN



Lindsay, 2001







Karsted Pgs (U. San Andres) Outcrop

Slaughter Fairway

Bottomless Lakes Recharge Field

Roswell Fairway

Artesia Fairway

	Oil		Gas		Associated		Gas and Associated
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SHELL

Tatum Basin

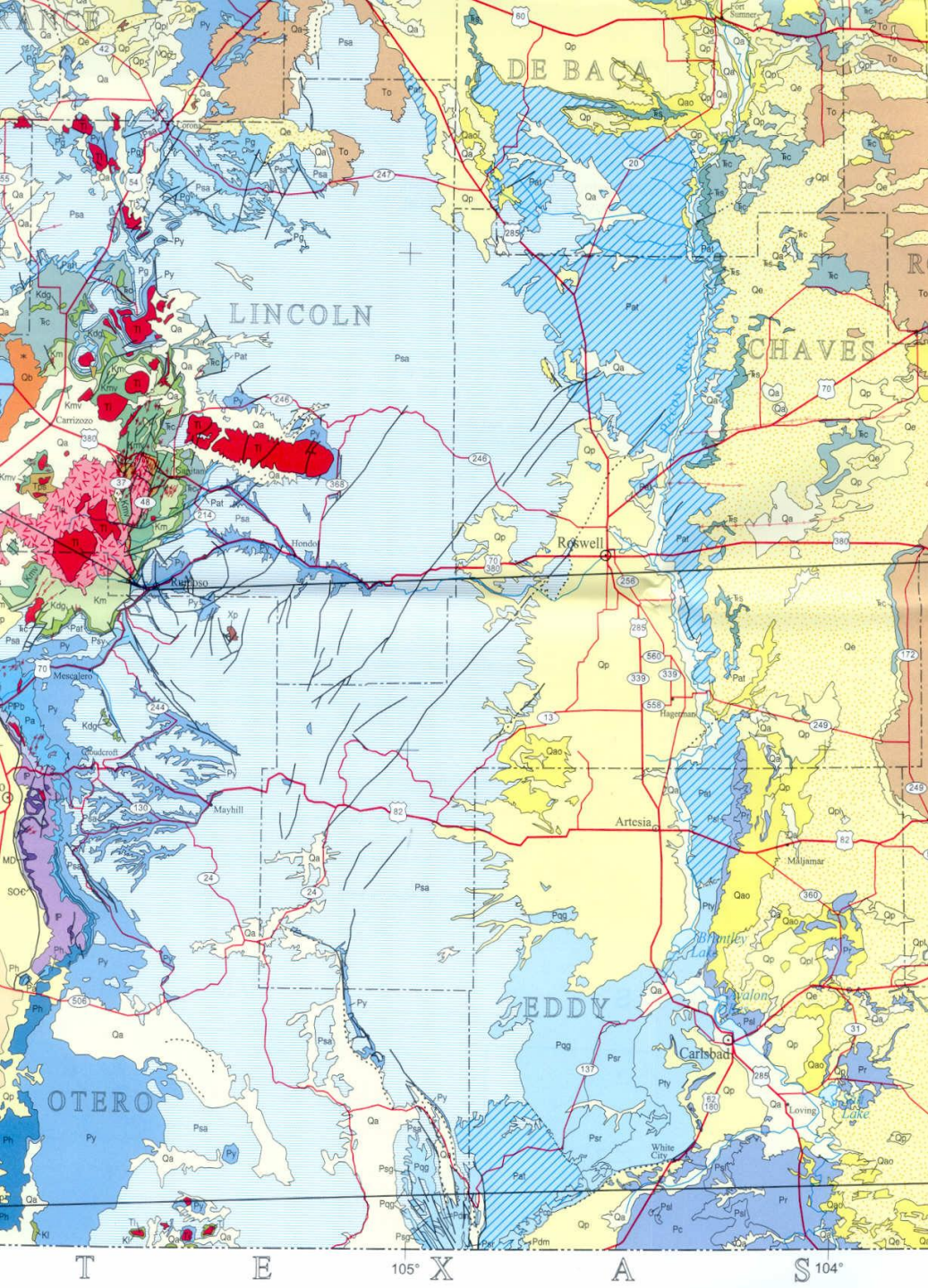
SAN ANTONIO (HOBBS) CHANNEL

C H A V E R O O

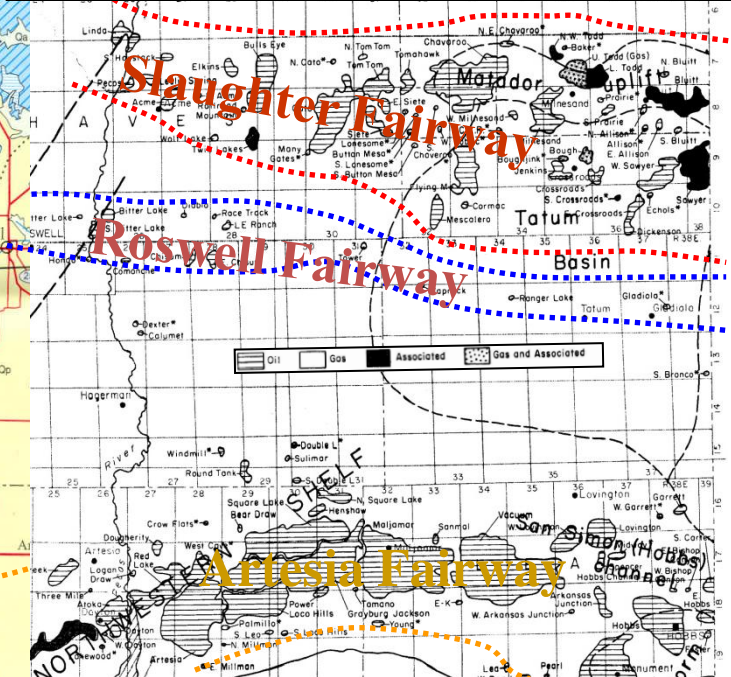
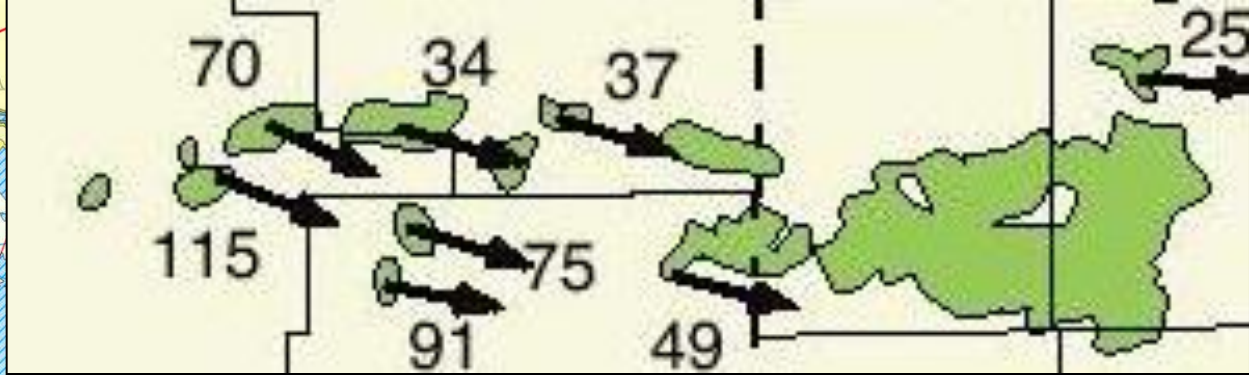
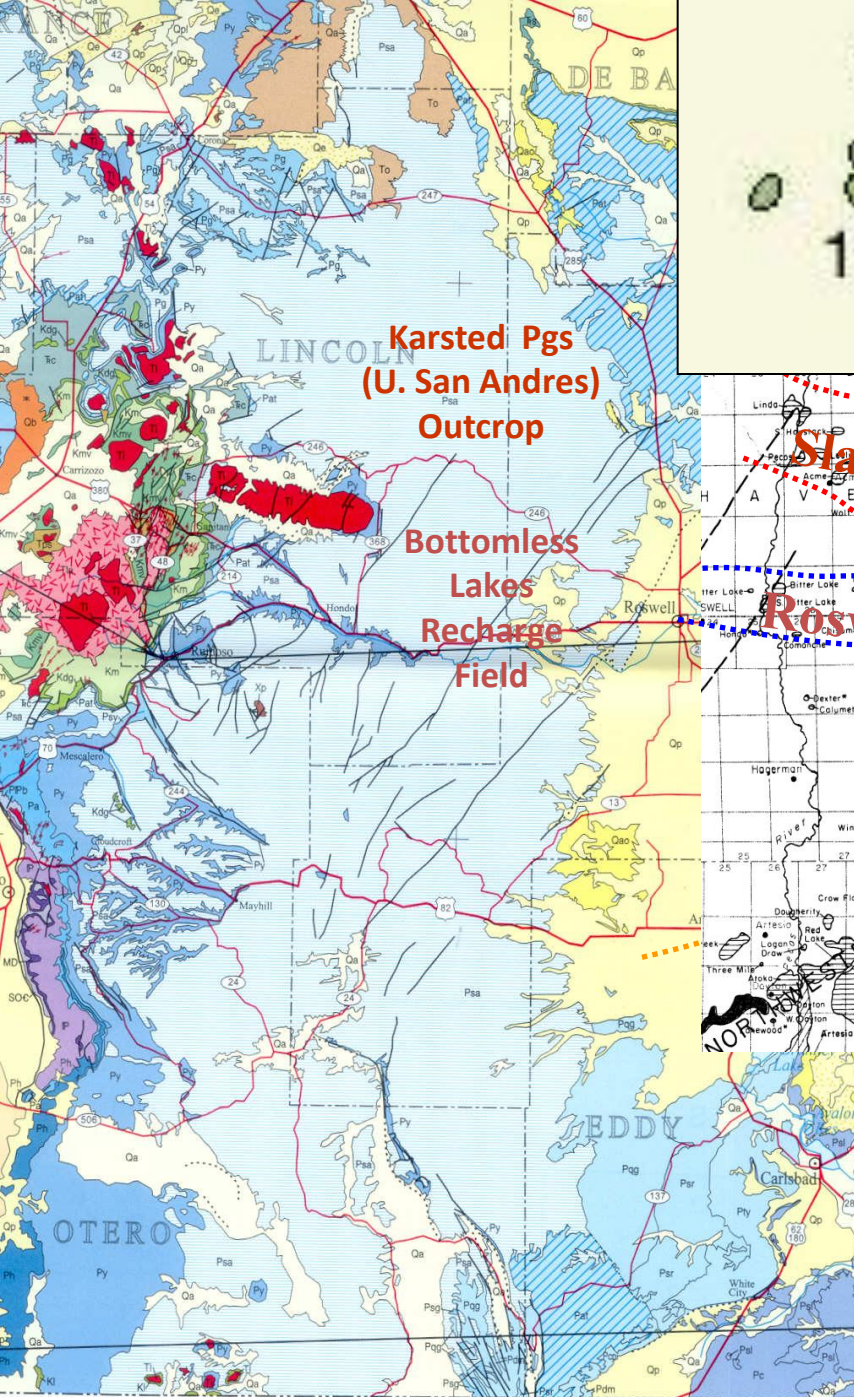
S H A N A N

NORTH

HOBBS



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.

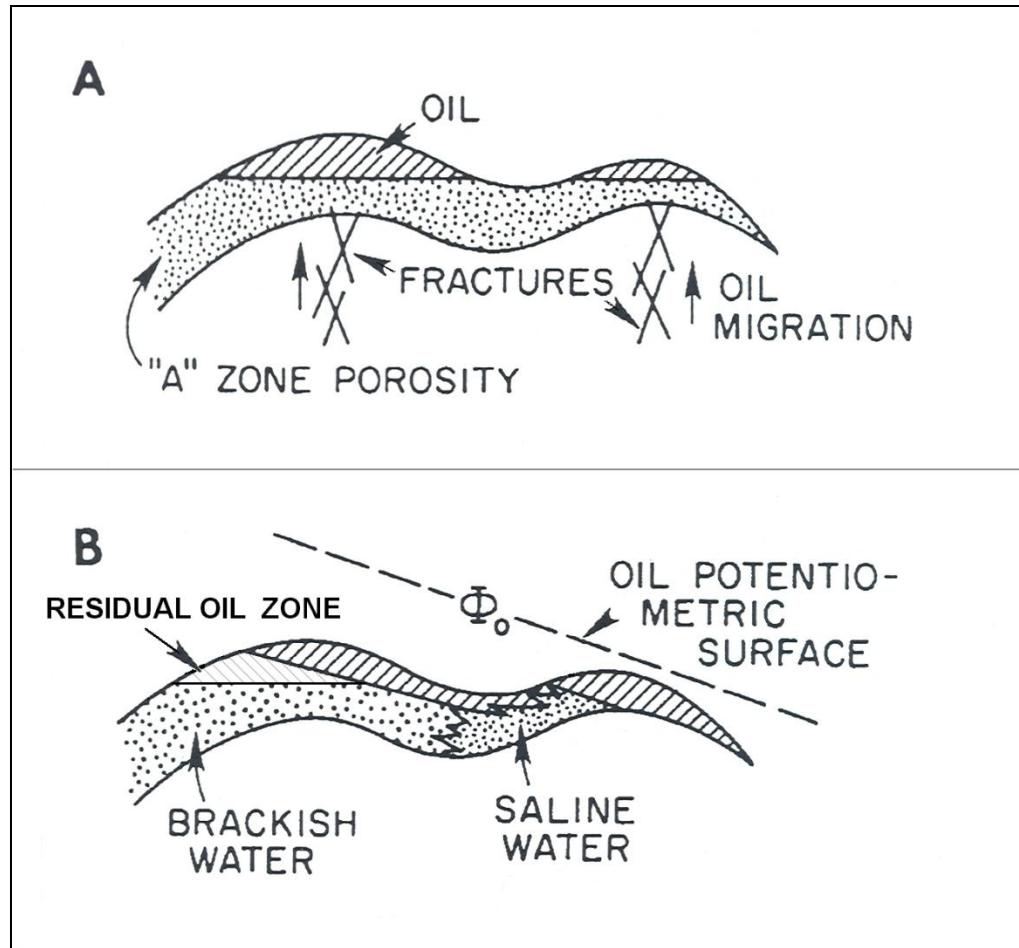


Relationship of San Andres outcrops and San Andres Fairways in New Mexico.

Why should someone working Wyoming, Montana, or North Dakota care about work on ROZ in the Permian Basin?

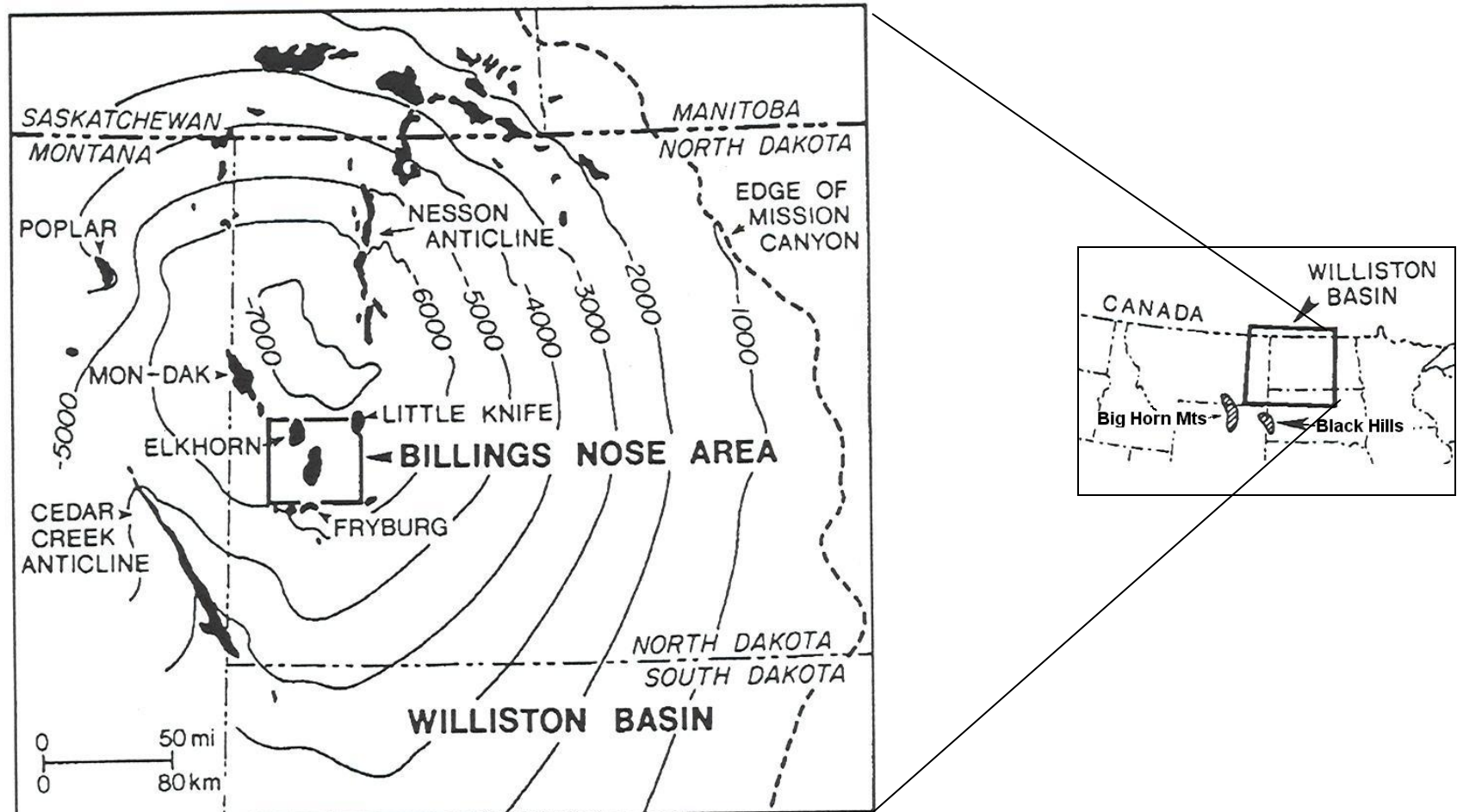
- ROZ's can be present whenever late tectonism meteoric derived water can enter reservoirs.
- Evidence for ROZ's exist in the Williston and Big Horn Basins.
- ARI has estimated 1 – 3 Billion barrels of recoverable reserves in ROZ's in these basins.

Sequence Of Oil Migration And Accumulation In The Billing Nose Fields, Williston Basin *



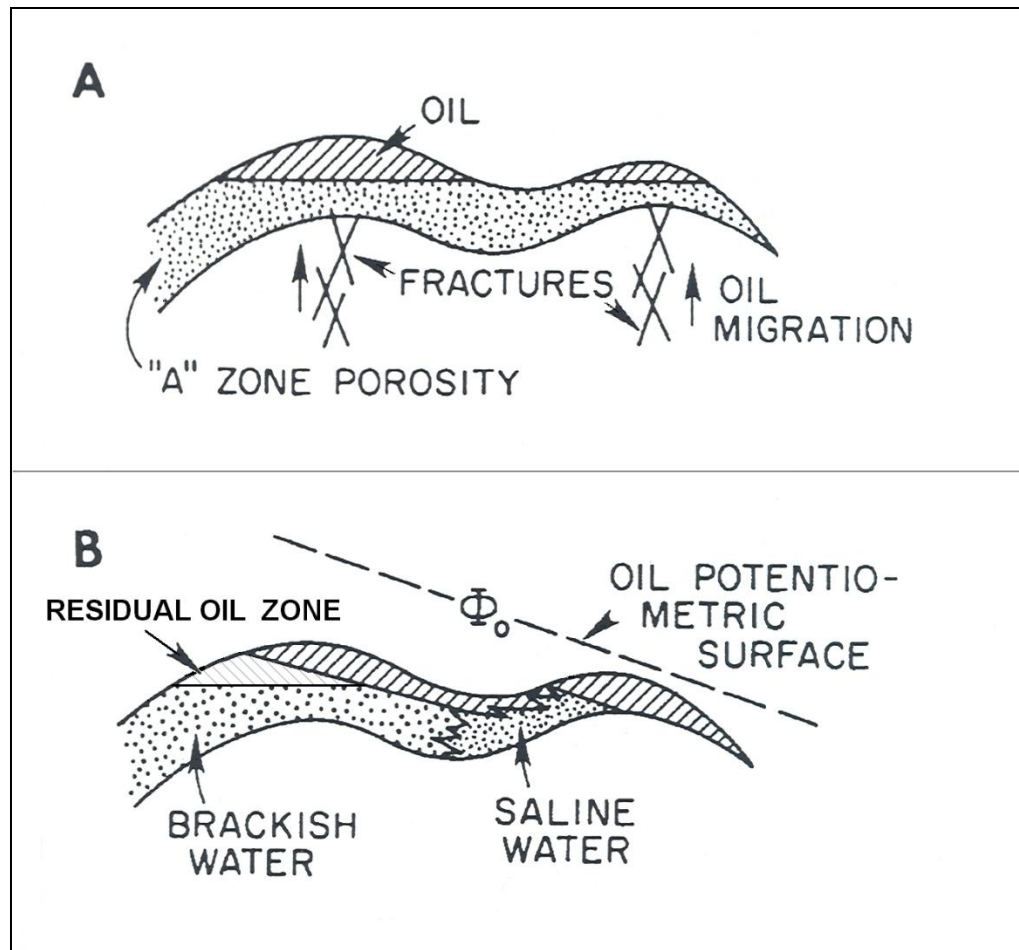
* Adapted from Ref 12

Regional Structure of the Mission Canyon Fm. and Location of Important Oil Fields and Greater Billings Nose Study Area, Williston Basin *



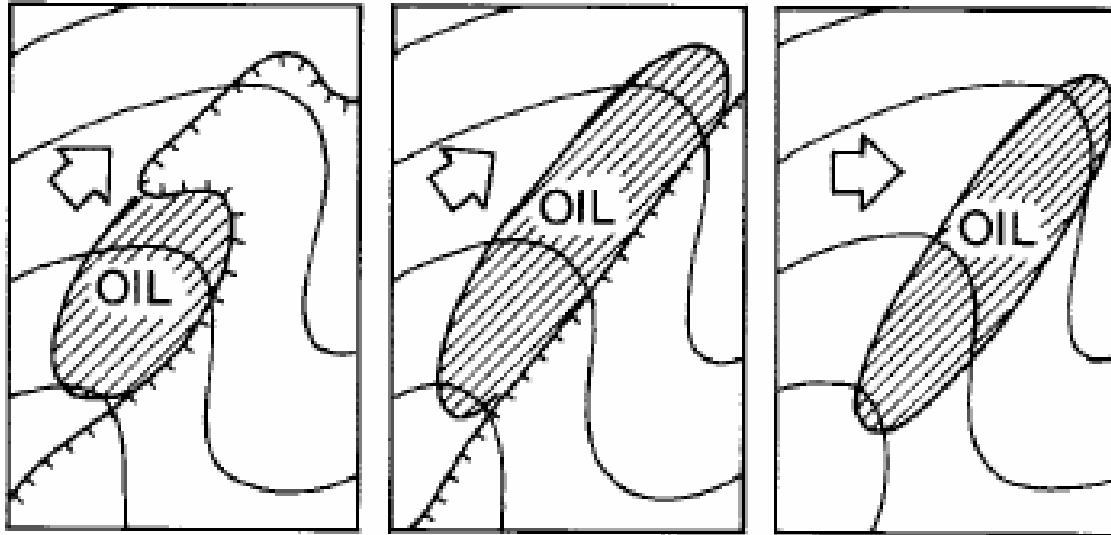
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Sequence Of Oil Migration And Accumulation In The Billing Nose Fields, Williston Basin *



* Adapted from Ref 12

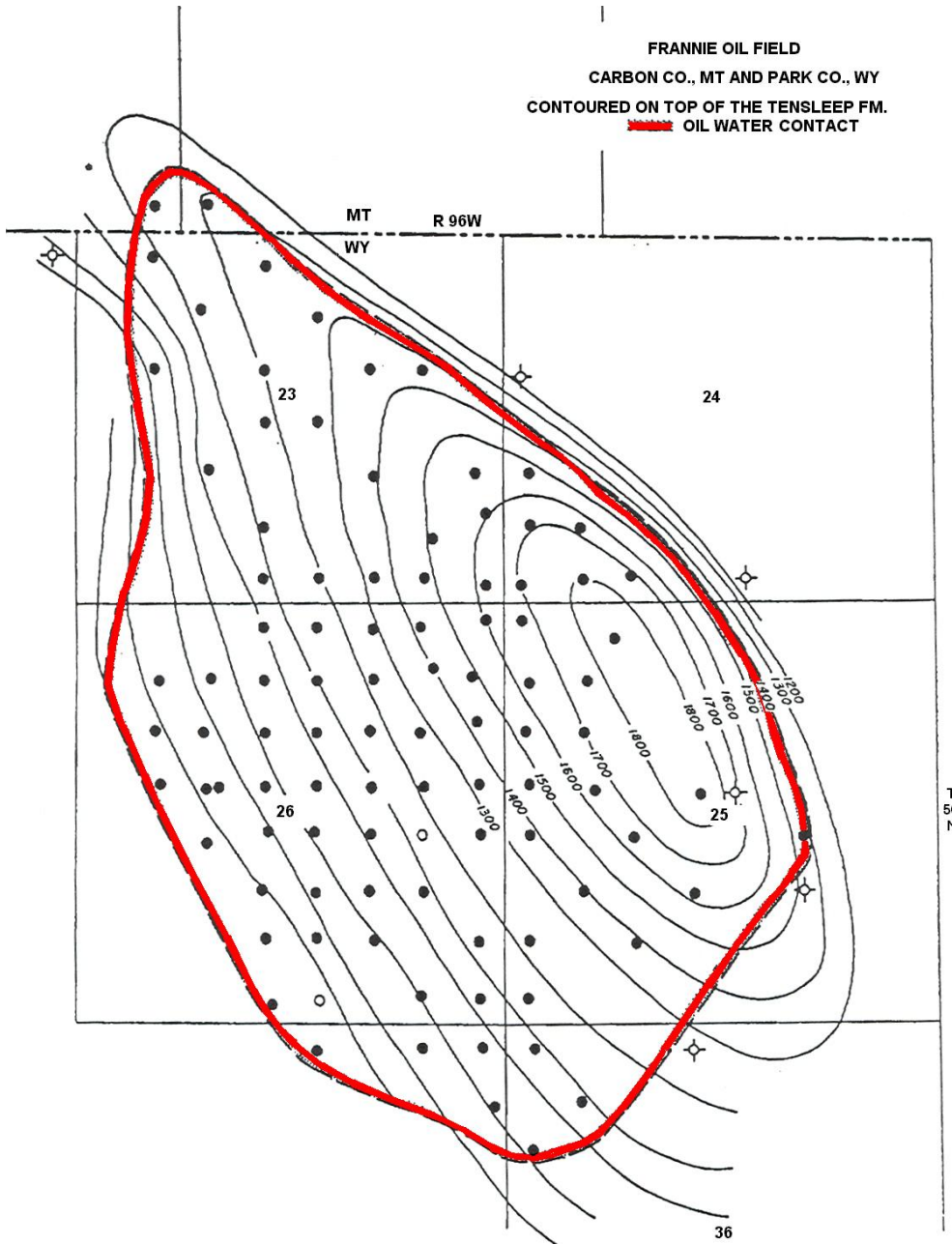
Figure 26: Examples of Hydrodynamic Traps *



-  **POROSITY PINCHOUT**
-  **STRUCTURAL FORM LINES**
-  **OIL ACCUMULATION**
-  **HYDRODYNAMIC FLOW DIRECTION**

* Adapted from Ref 12

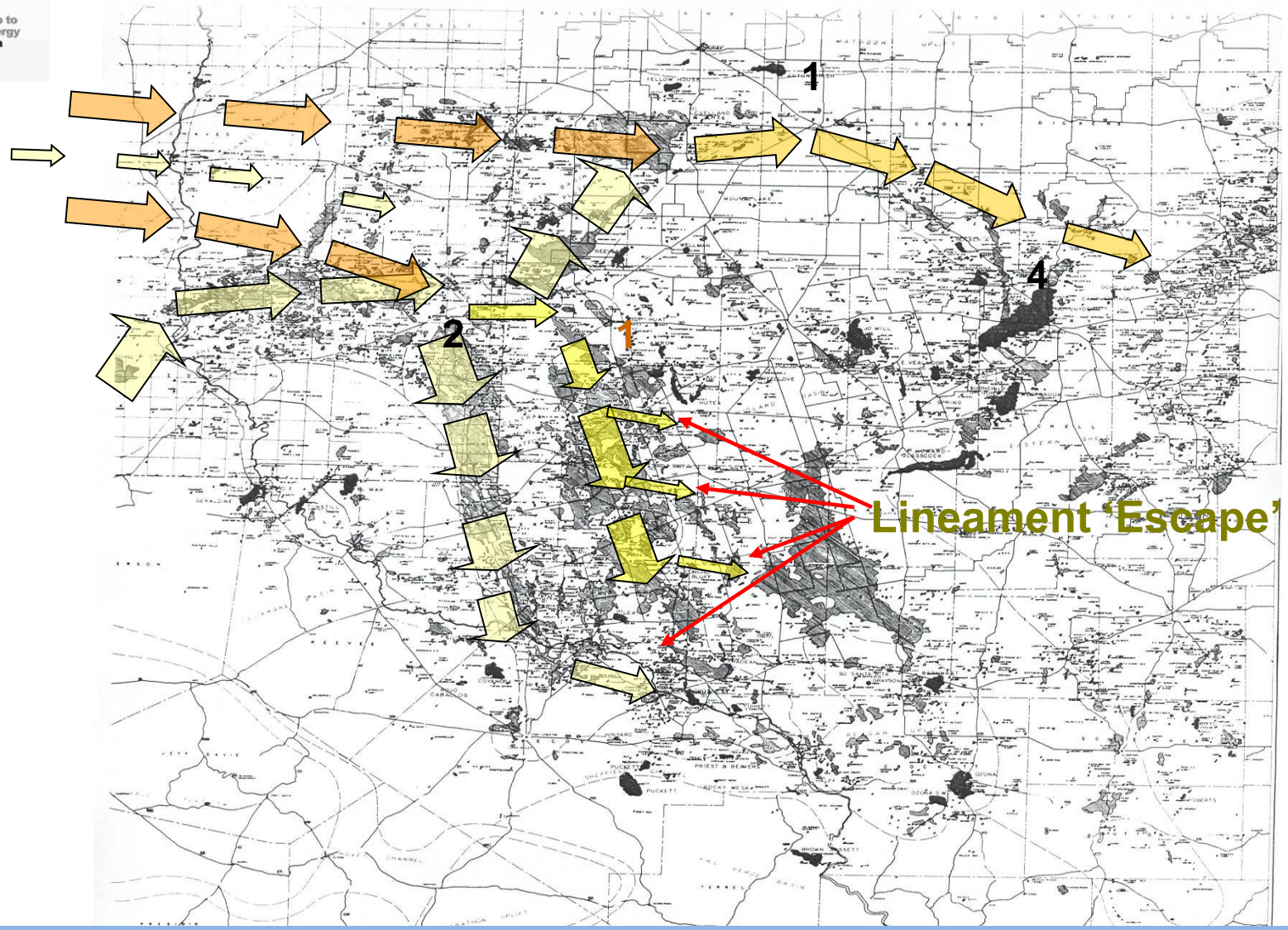
FRANNIE OIL FIELD
CARBON CO., MT AND PARK CO., WY
CONTOURED ON TOP OF THE TENSLEEP FM.
OIL WATER CONTACT



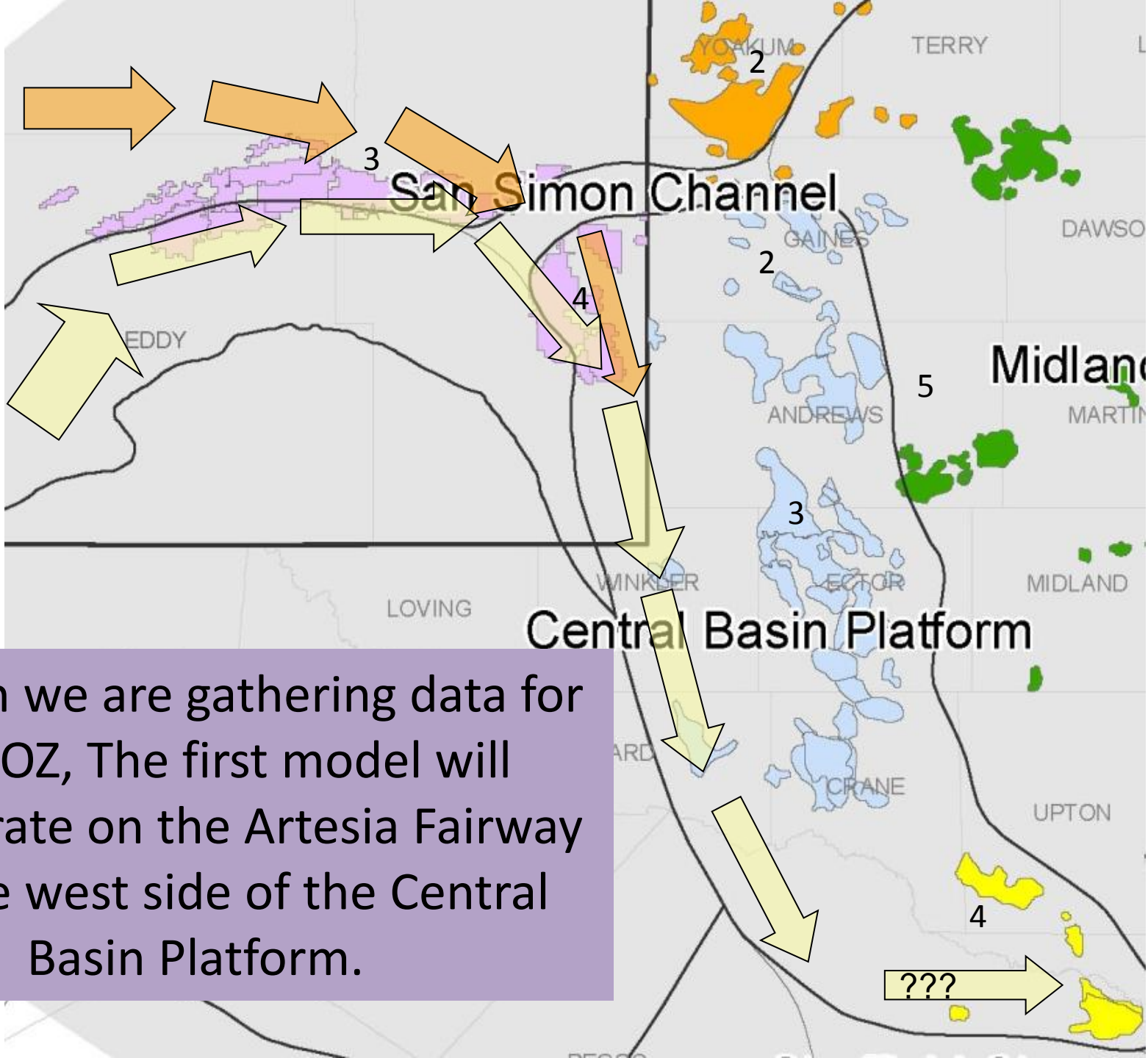
Frannie Oil Field, Big Horn Basin Illustrating the SW OWC Tilt of ~600 ft/mi

PERMIAN BASIN FIELD MAP

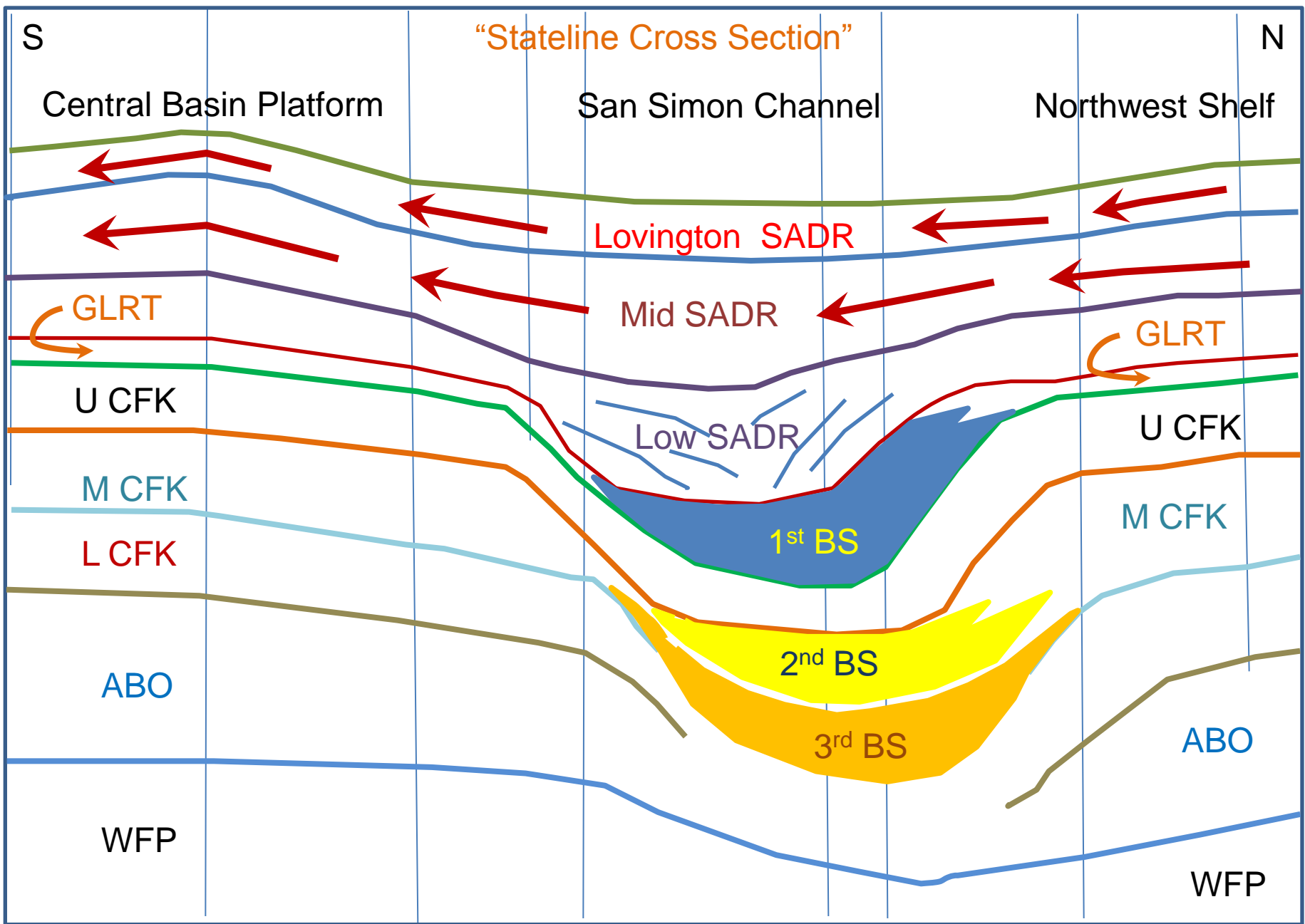
WITH THEORIZED (U. PERMIAN) HYDRODYNAMIC FAIRWAYS



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



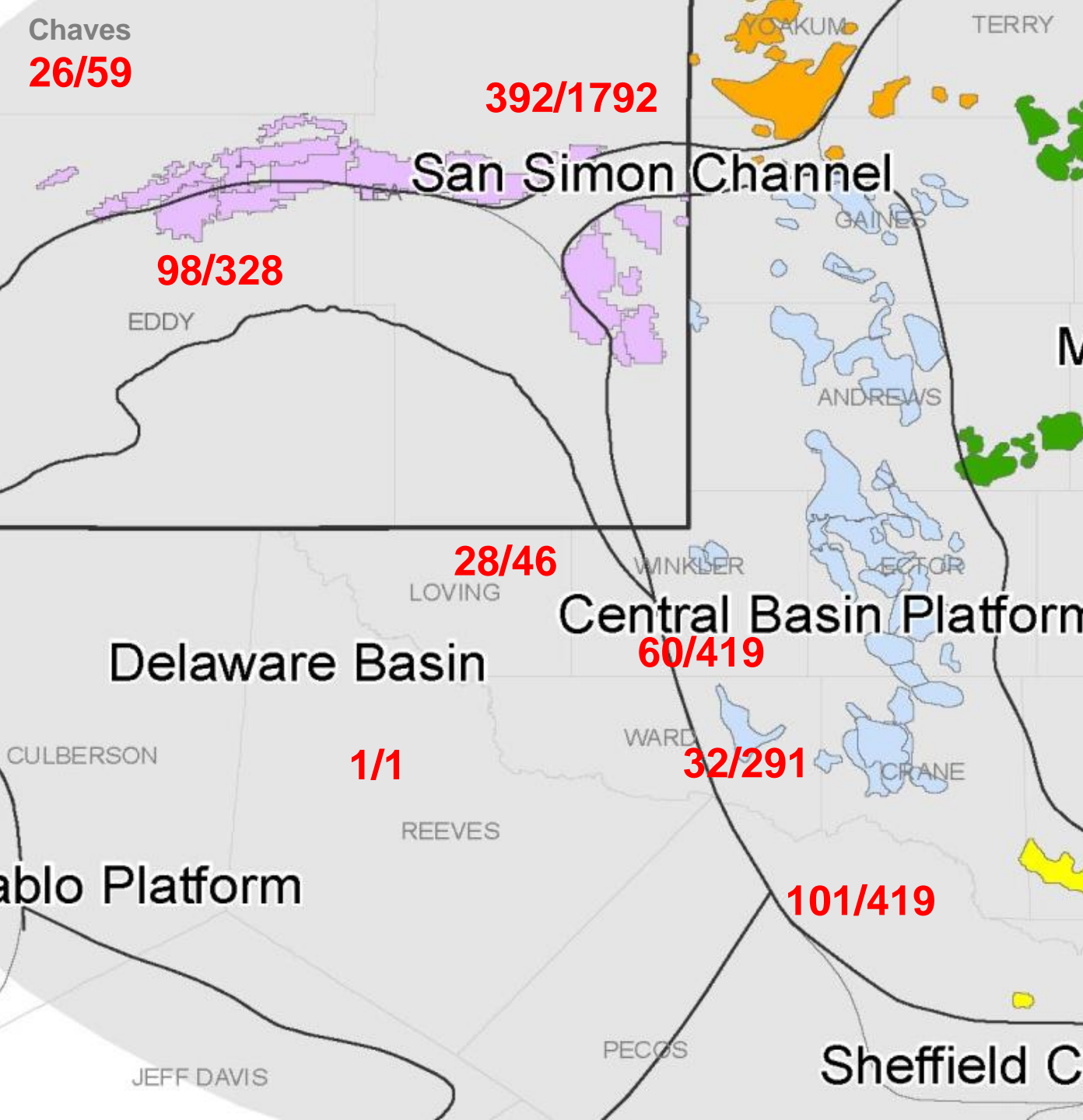
Although we are gathering data for any ROZ, The first model will concentrate on the Artesia Fairway and the west side of the Central Basin Platform.



Pathway from NW Shelf to CBP

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

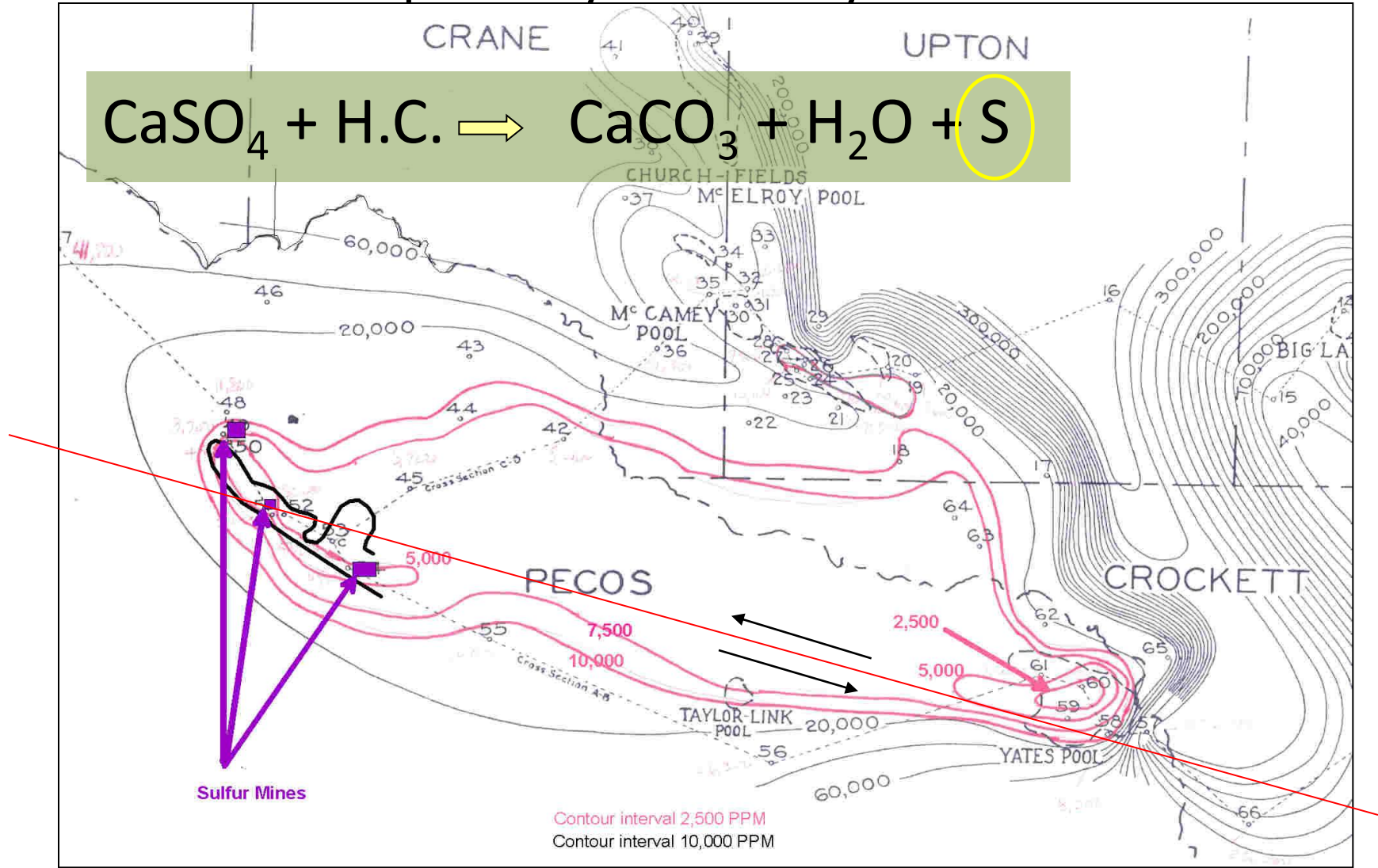
Permian Basin Plays, Dutton et al (2005)

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



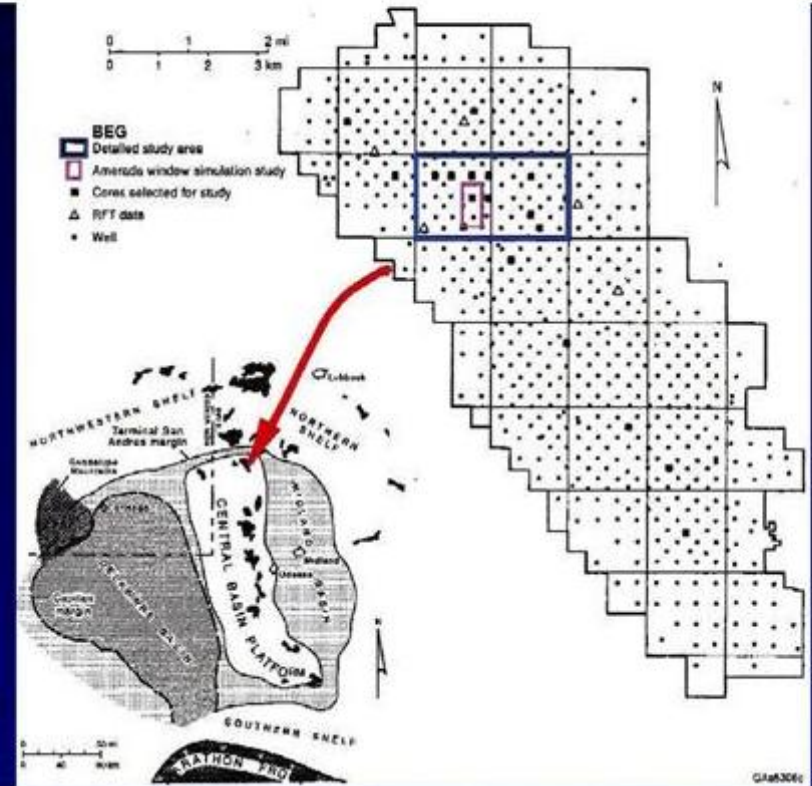
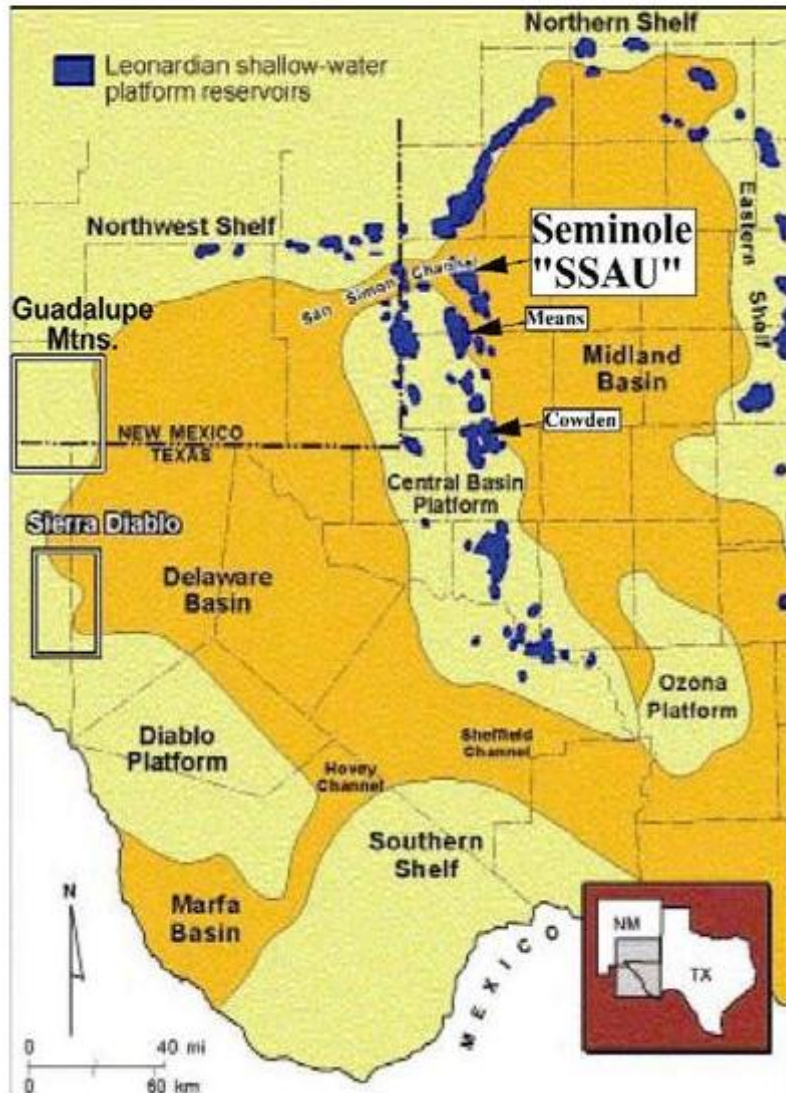
San Andres Water Salinities and Sulfur Deposits

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 H₂S (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.

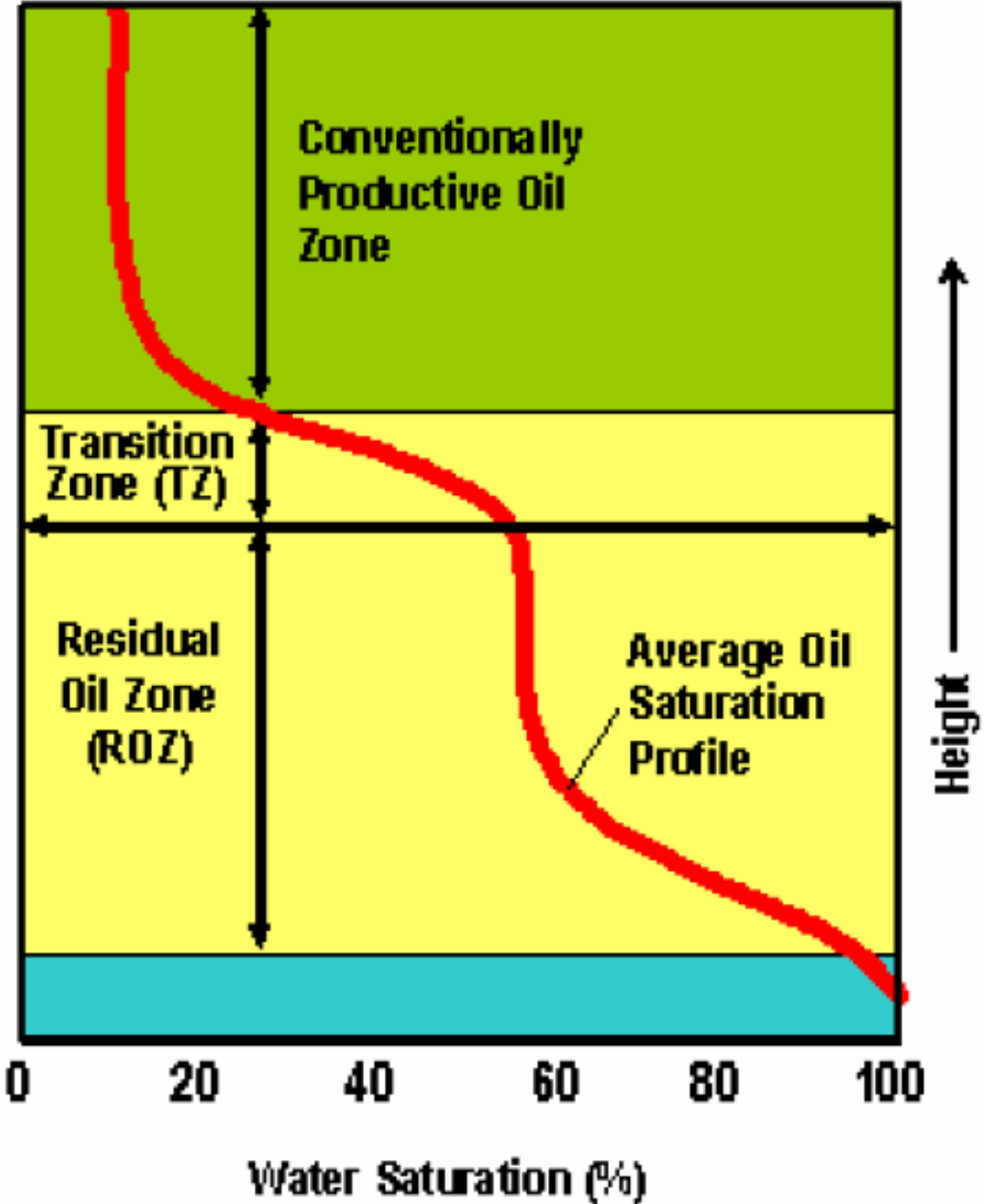


Reservoir Description	Limestone and dolomite deposited in a shallow carbonate ramp environment
Fluid Type	Saturated black oil
Drive Mechanism	Gas in solution and gas cap during primary. External energy from water and CO2 injection during secondary and tertiary recovery.
Develop. History	1936 Discovery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

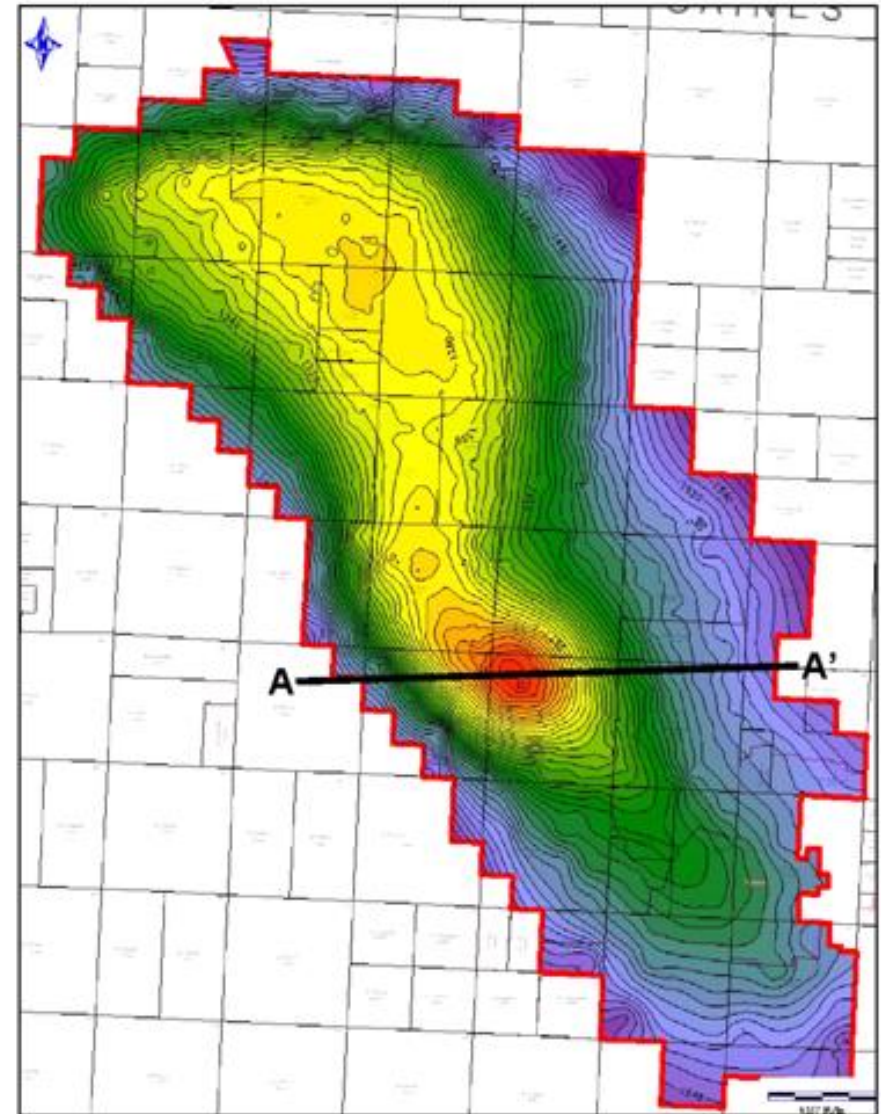
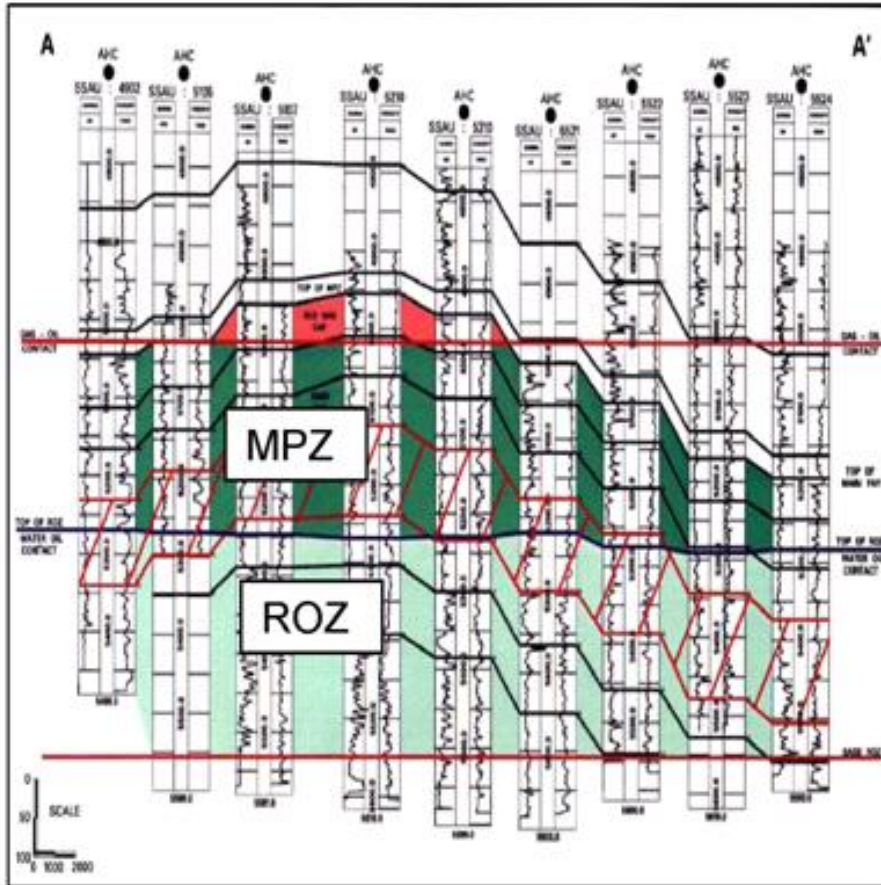


Producing
O/W
Contact

Base of
Oil
Saturation



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

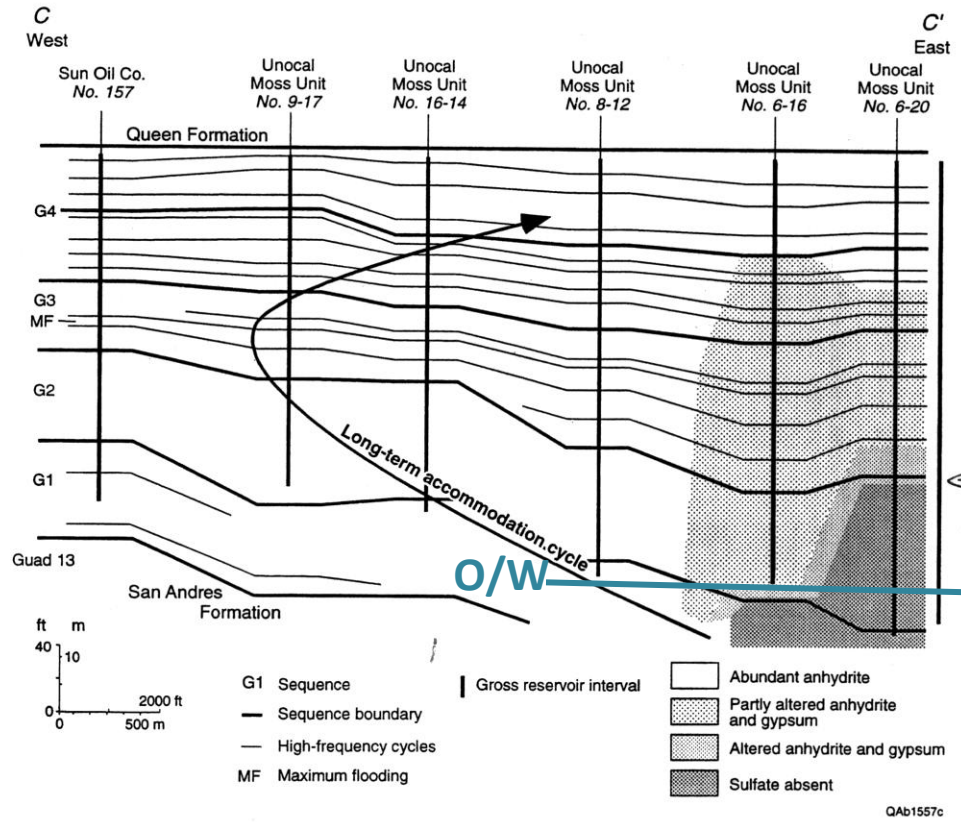
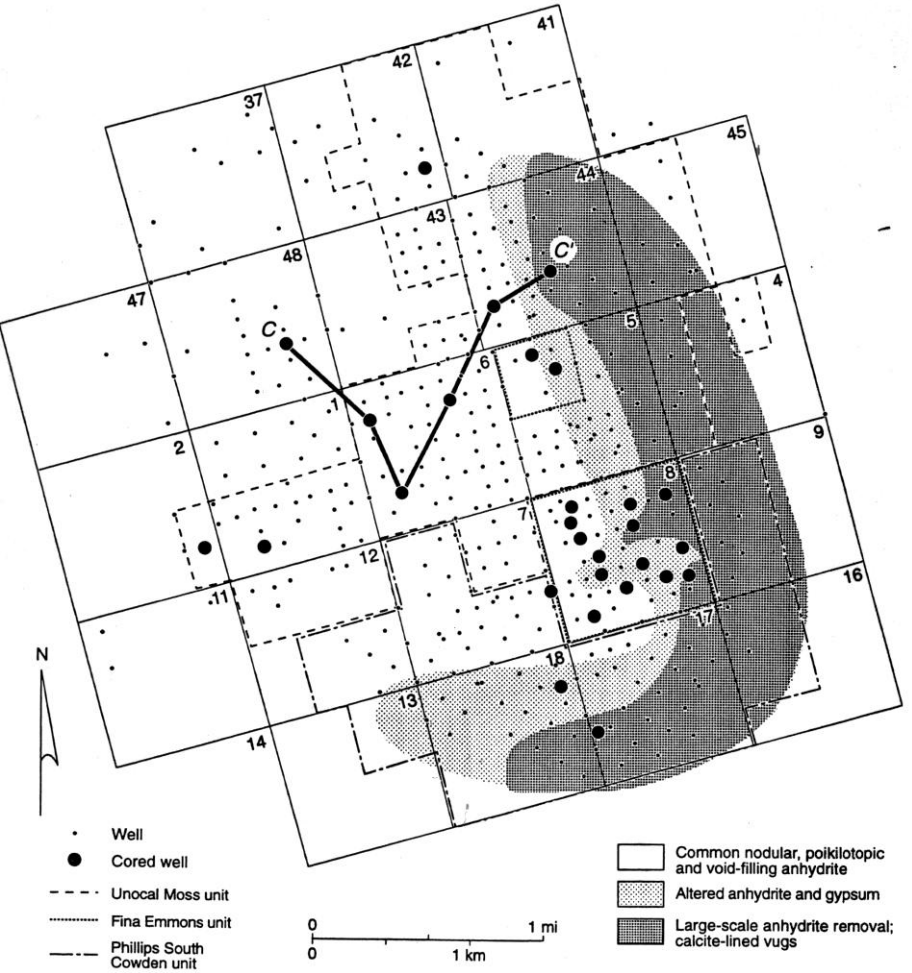


South Cowden

- 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 Meteoric 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.

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)

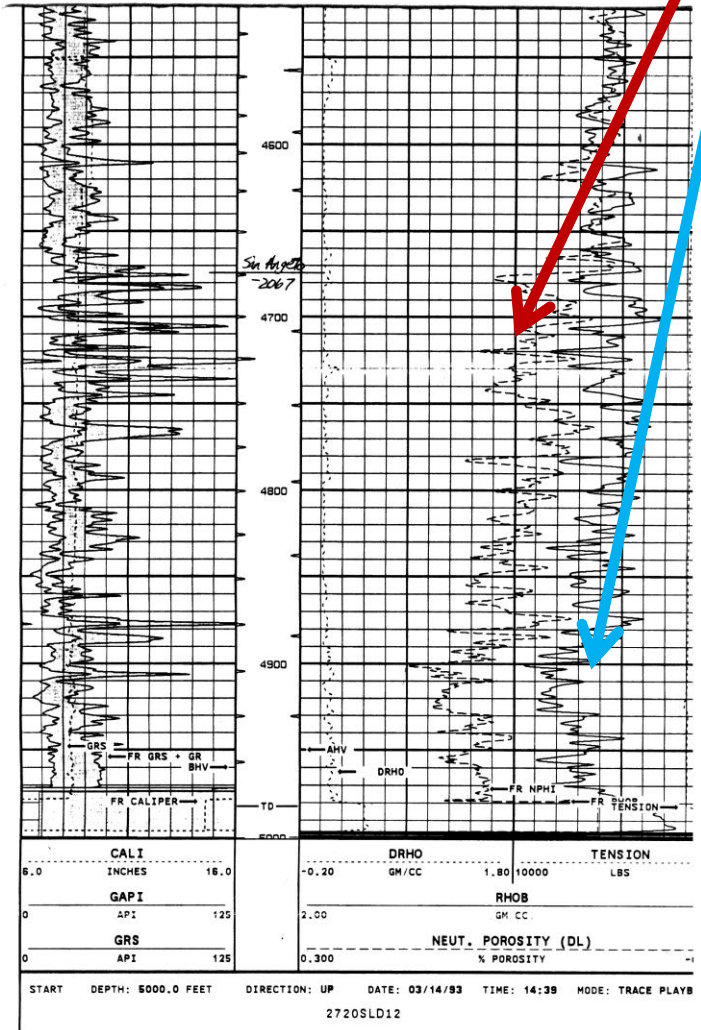
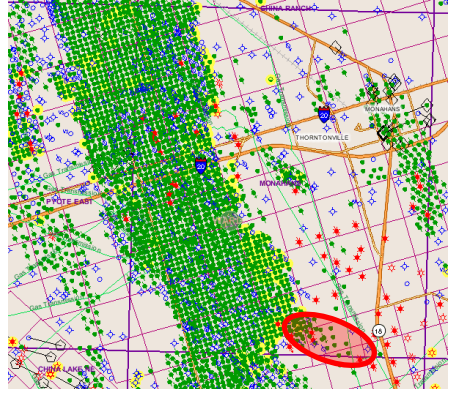
Discovered in 1991, produced over 1MMBO from a small closure with "tight" tidal flat and shallow subtidal carbonates.

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

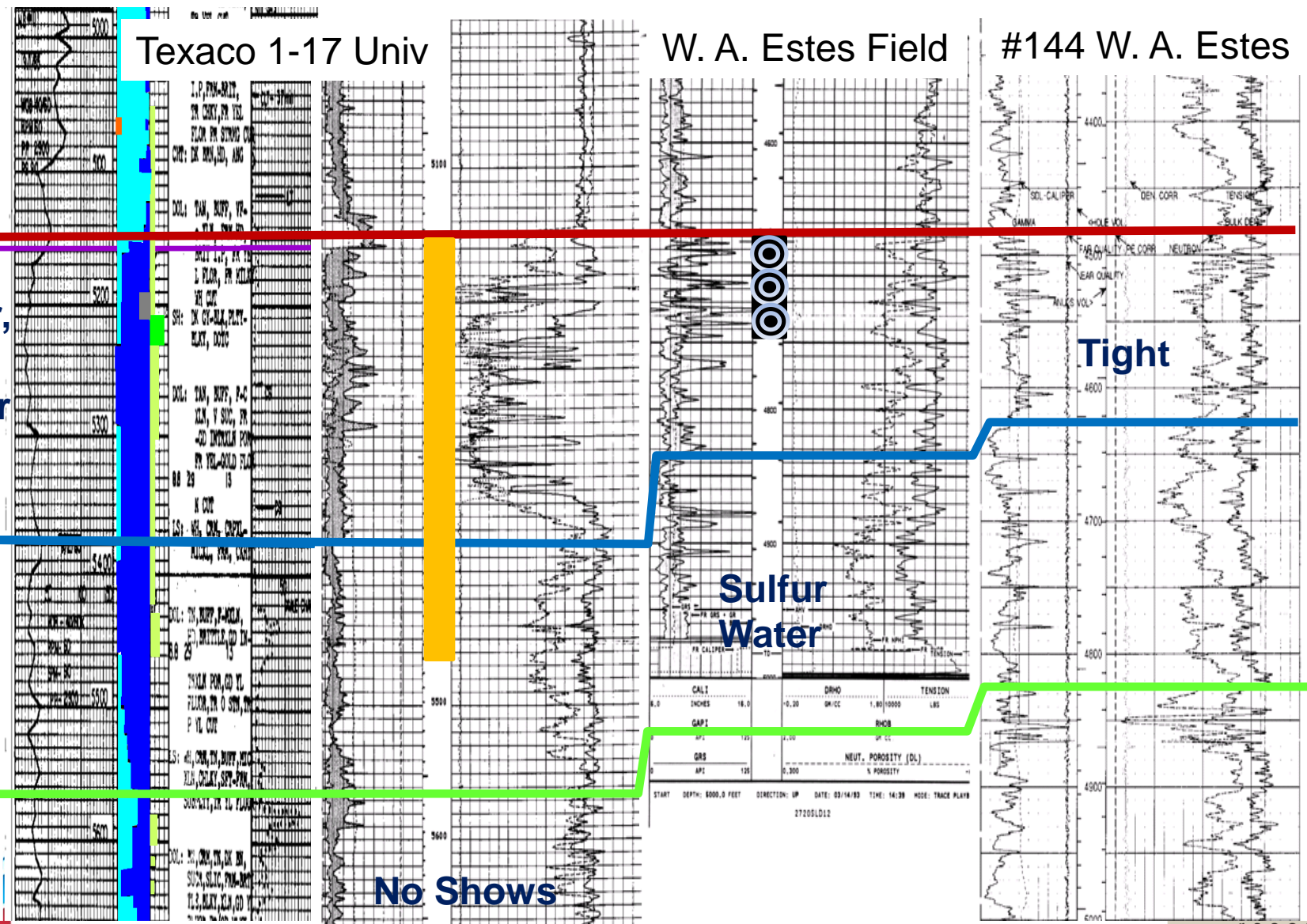
The updip section thinned by pre San Andres tilt and Erosion

Fluor,
Cut,
Minor
Gas

Texaco 1-17 Univ

W. A. Estes Field

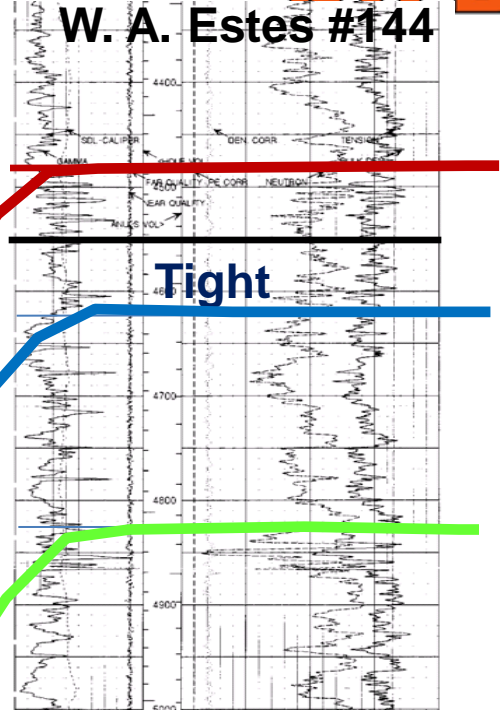
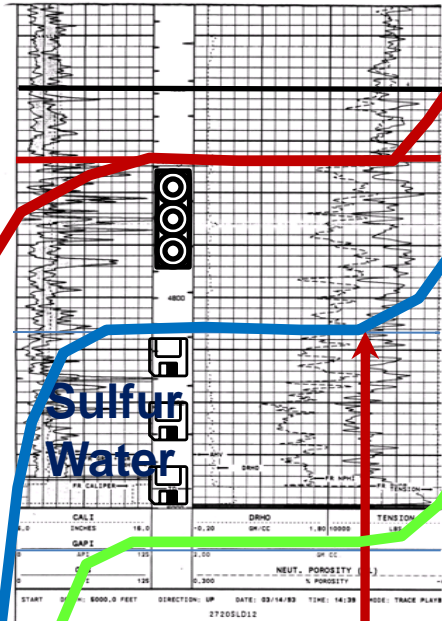
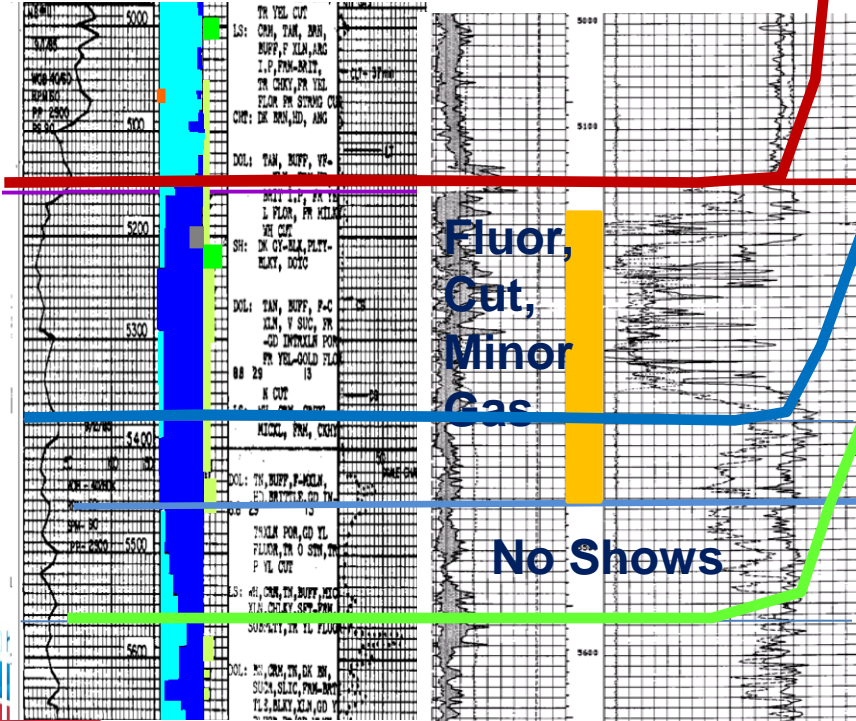
#144 W. A. Estes



Texaco #1-17 Univ

W. A. Estes Field

W. A. Estes #144

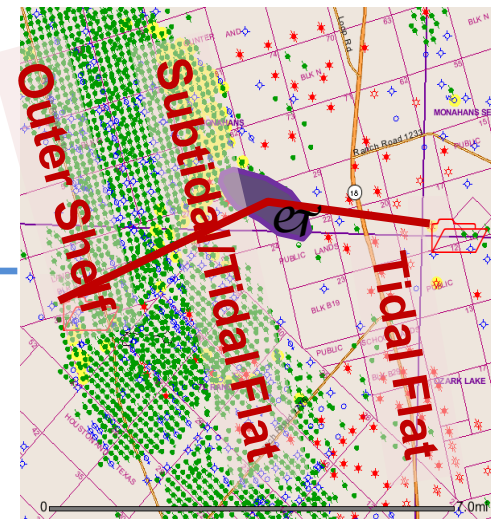


Fluor, Cut, Minor Gas

Sulfur Water

ROZ Maximum 550' !

Base ROZ ?



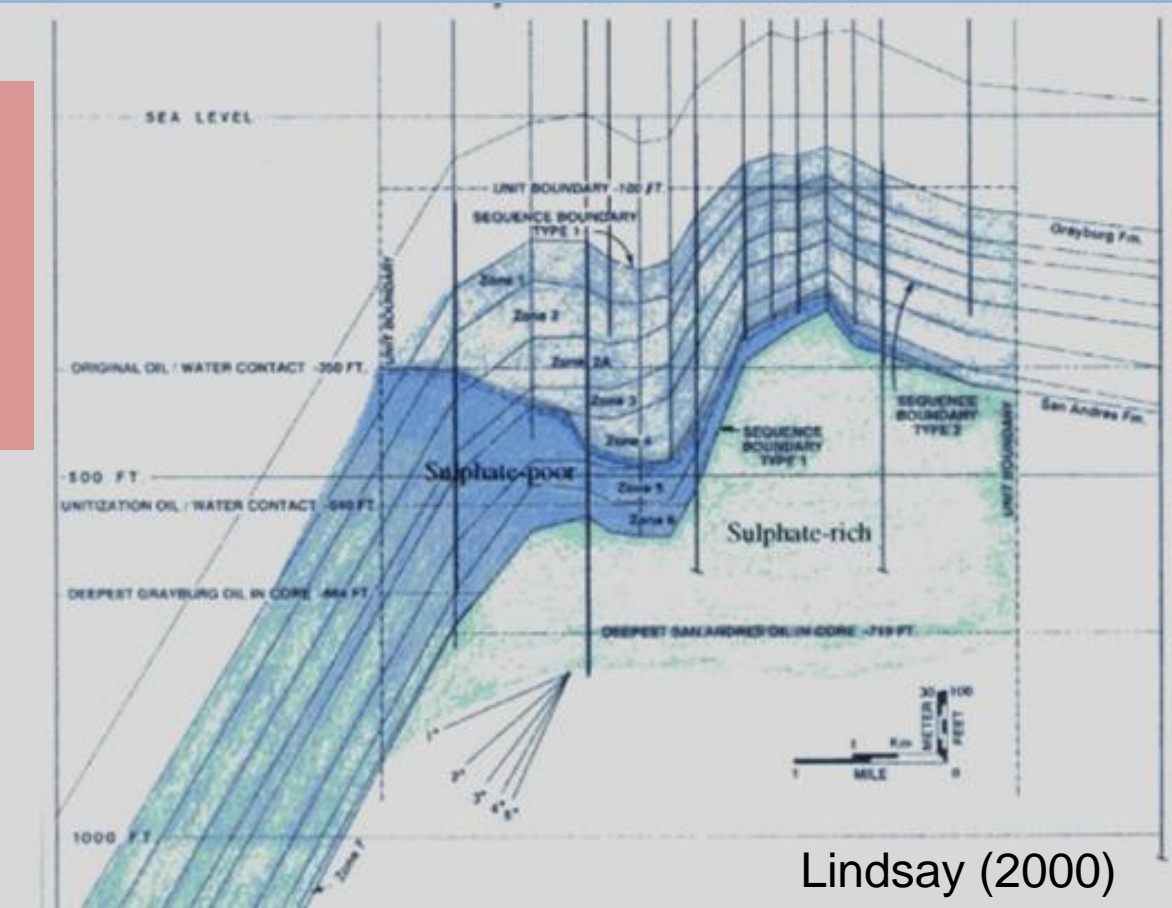
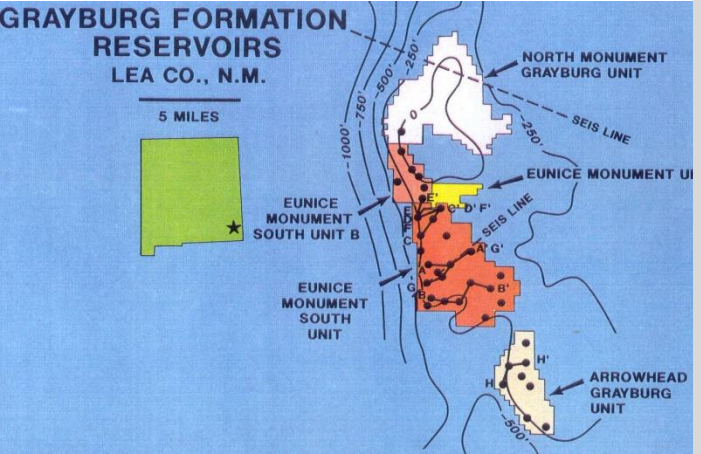
Eunice Monument/South Monument

- 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 .

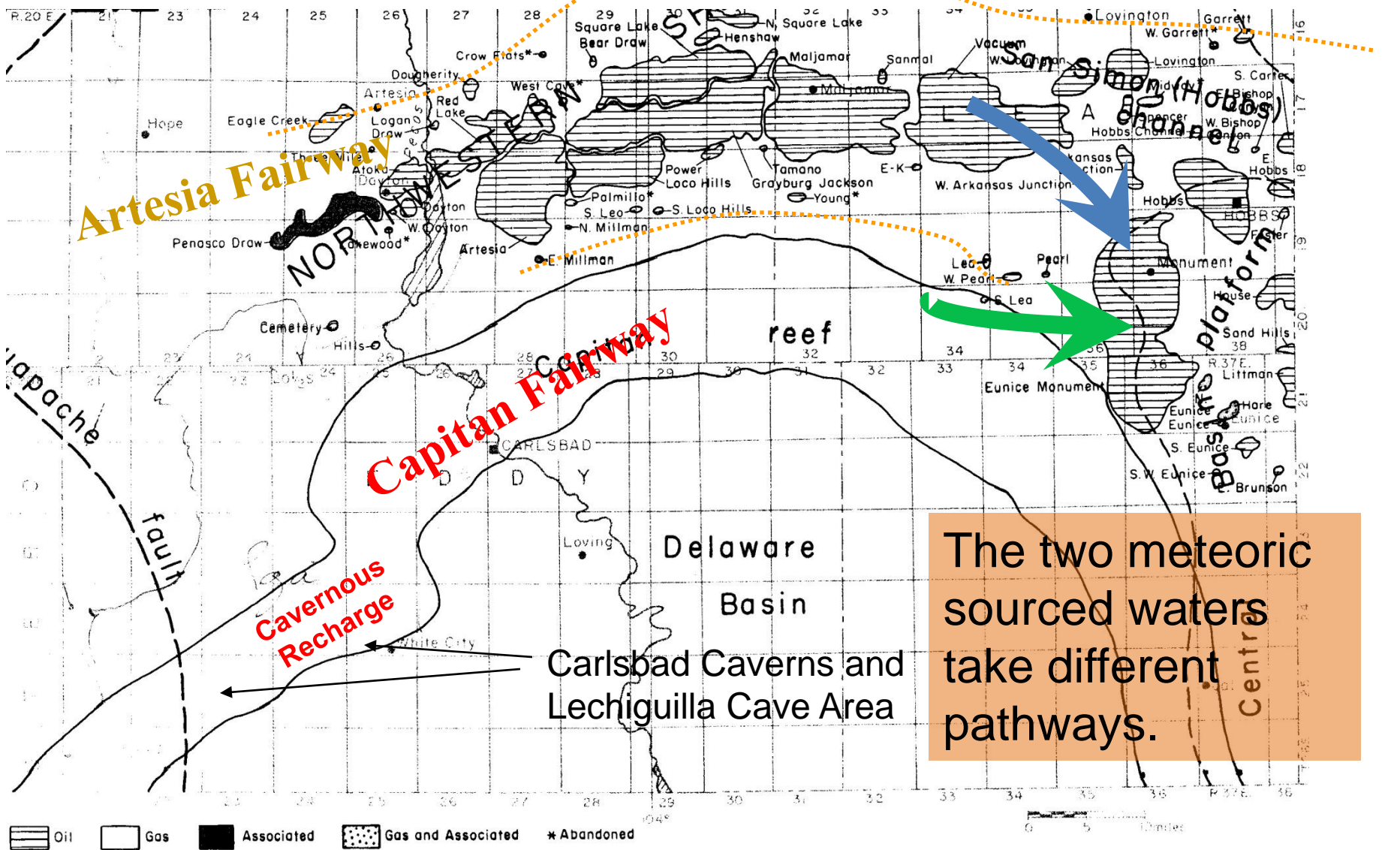
- area combined total of 57 square miles.
- Lindsay suggests the sulfate poor edge water is recharged from the Guadalupe Mountains thru the Goat Seep Reef. The Sulfate-rich bottom water drive in the San Andres is recharged from the Sacramento Mountain thru the evaporite rich San Andres.
- **Eunice Monument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

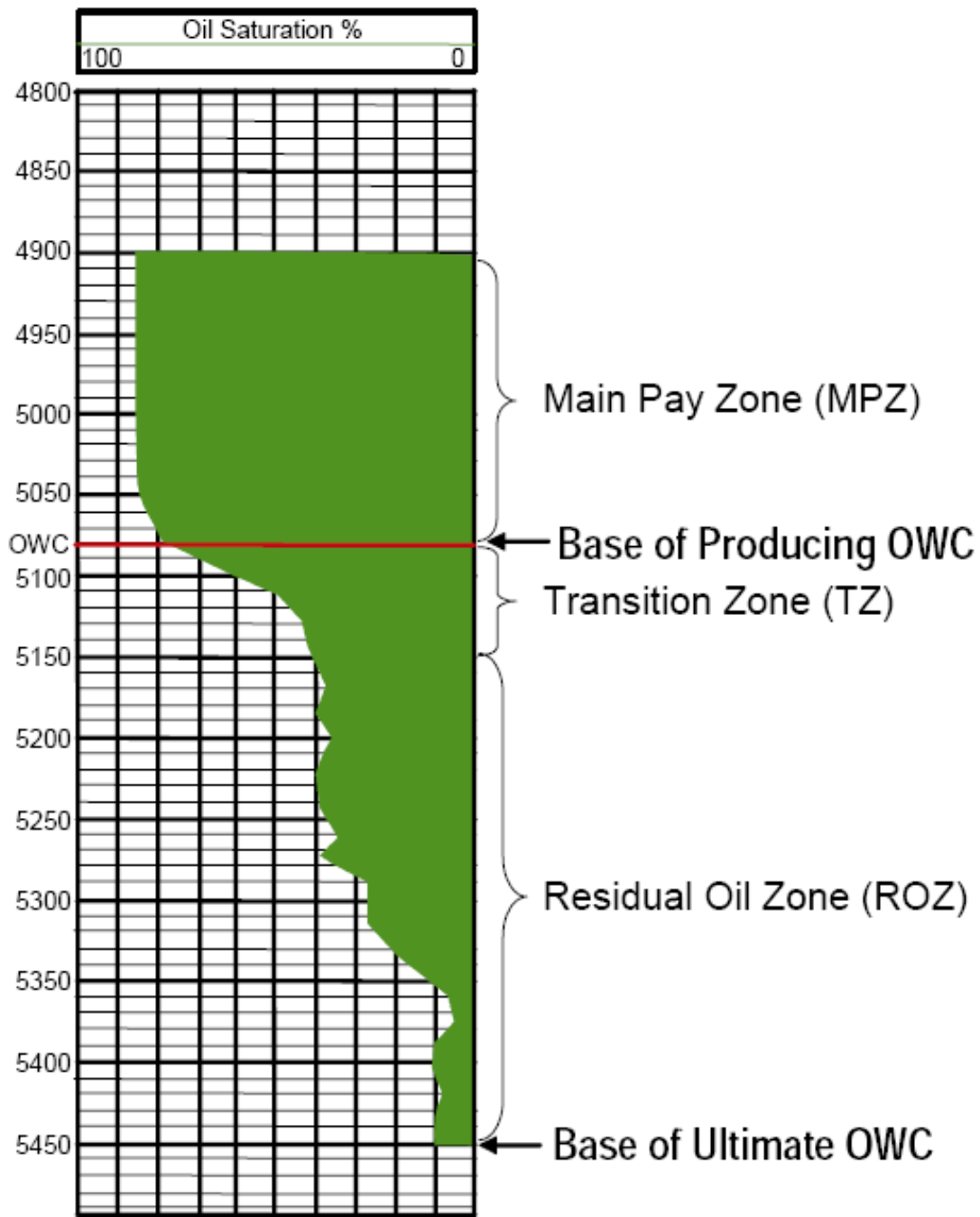
SE NM Grayburg & Upper San Andres Dolomitization Trend



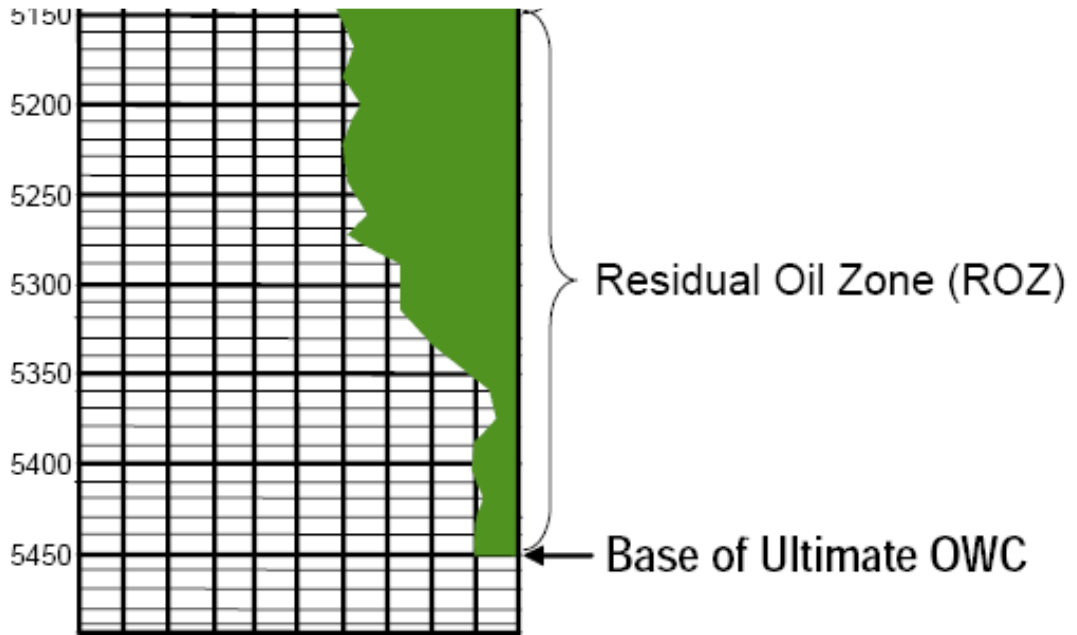
The two meteoric sourced waters take different pathways.

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

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

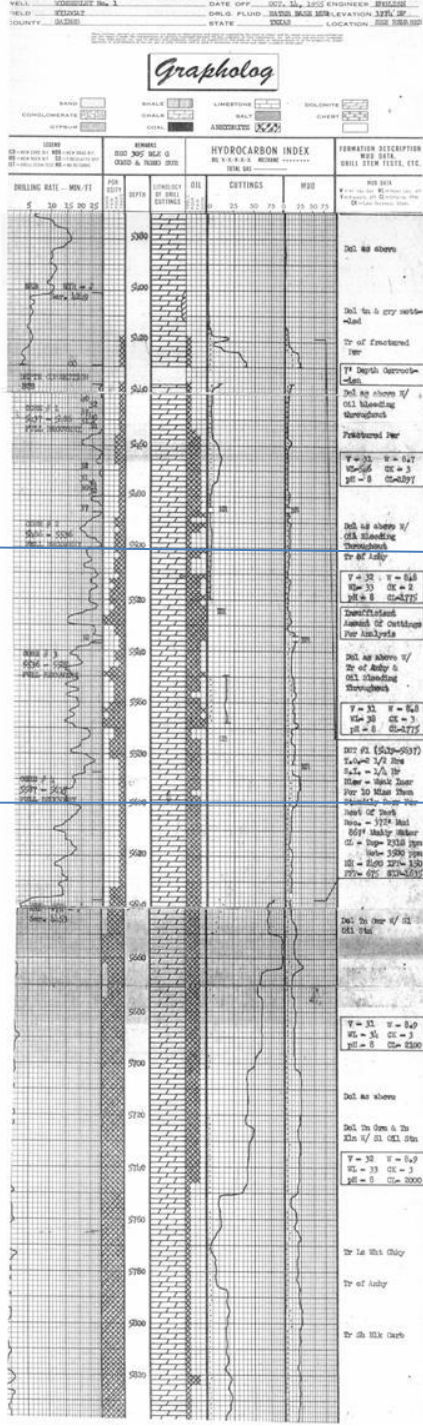


**Your left with a
tertiary recovery
target.**

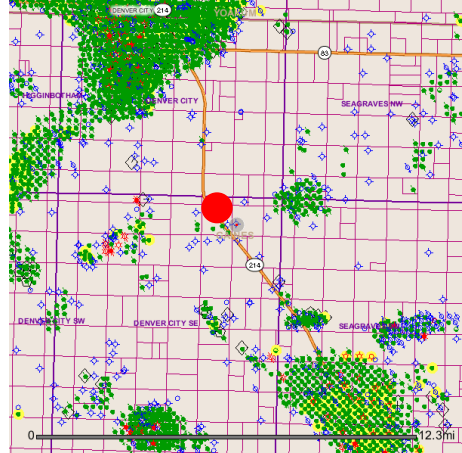


Anecdotal Evidence

- 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**, 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.

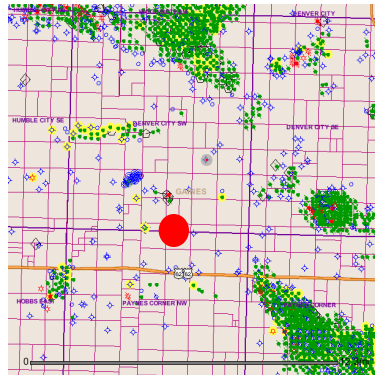
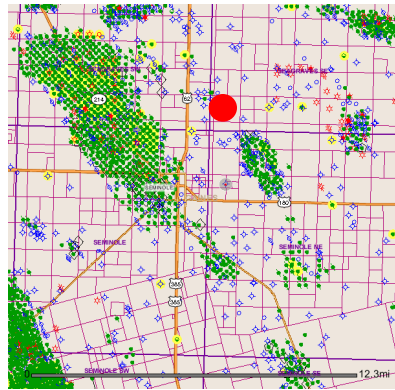
DST'd 5419-5637, rec 372' mud, 867' MCSW. Mudlog Sample cut, good bleeding oil to 5745'.

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

Other Areas of Discussion

- **Dolomitization**
 - Phases
 - Timing
 - Impact on Wettability
- **Oil Migration**
 - Pulses?
 - Timing
 - 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:
- 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.

“Common Knowledge” vs. ROZ Paradigm

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.
- Tight intervals, a function of stratigraphy, can be present beneath the Main Pay.
- The 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 present limits of producing fields.