First Ever

ROZ (Residual Oil Zone) SYMPOSIUM

Midland College Advanced Technology Center

October 22, 2009

Symposium Objectives

- Describe the Progress of Understanding the Origins and Distributions of ROZs in the PB
- Show Some Case Histories
- 'Flip the Paradigm' – from Zones to be Avoided to Intervals of Opportunity
- Potential Magnitude of the Prize
- Gather New Anecdotal Evidence by Learning from the Audience (Breakout Sessions)
- Begin to Chart a Future for the Effort

Welcome and Introductions

- Steve and Bob, Edith
- Chevron and Legado
- The Research Team:
  - Phil, Arcadis (Dave and Steve), Saswati, Jimmy, Bob K., Hoxie
- Valued Contributors
  - Bill, Blake, Lon
- And you!!!

BACKGROUND DISCUSSION

The Origins of Permian Basin Residual Oil Zones

- 'Piecing in' the Science
- Categories of Anecdotal Evidence
  - Sources of Water (caverns and karst)
  - Discharge Path Concepts
  - Oil Shows
  - Titled O/W Contacts
  - Dolomitization
  - Water Salinities
  - Sulfur Deposits
  - Corrosive Zones
- Some Example Case Histories
- What Makes this of Commercial Interest?
- Breakout Sessions and Anecdotal Data Gathering

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THE ROZ BACKGROUND

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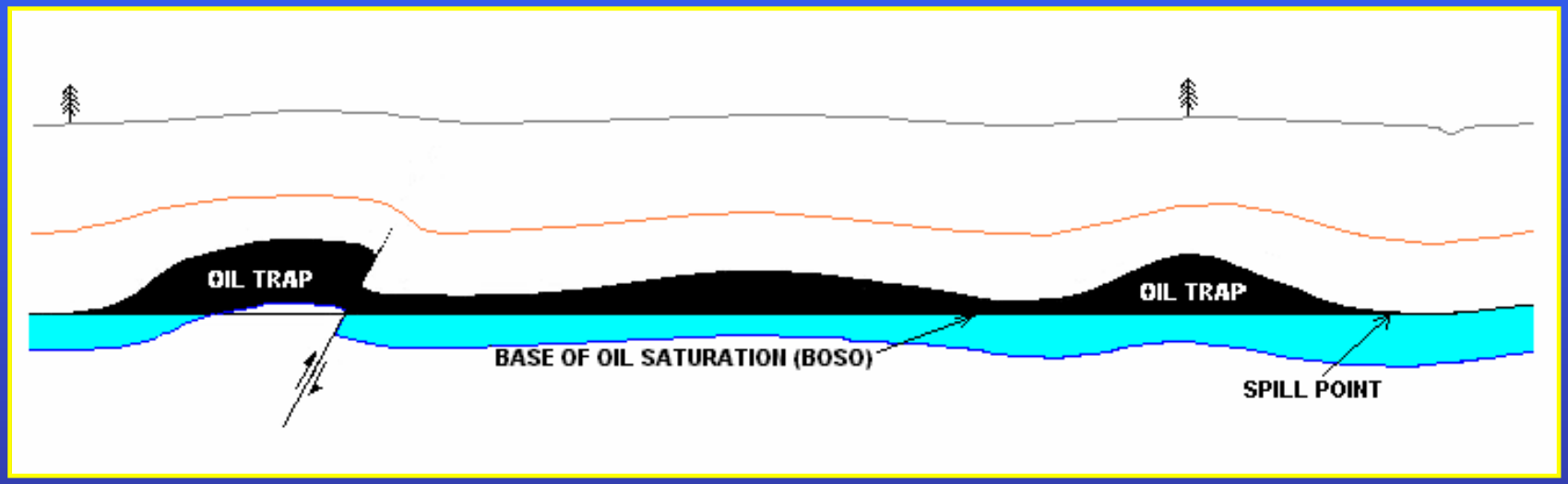
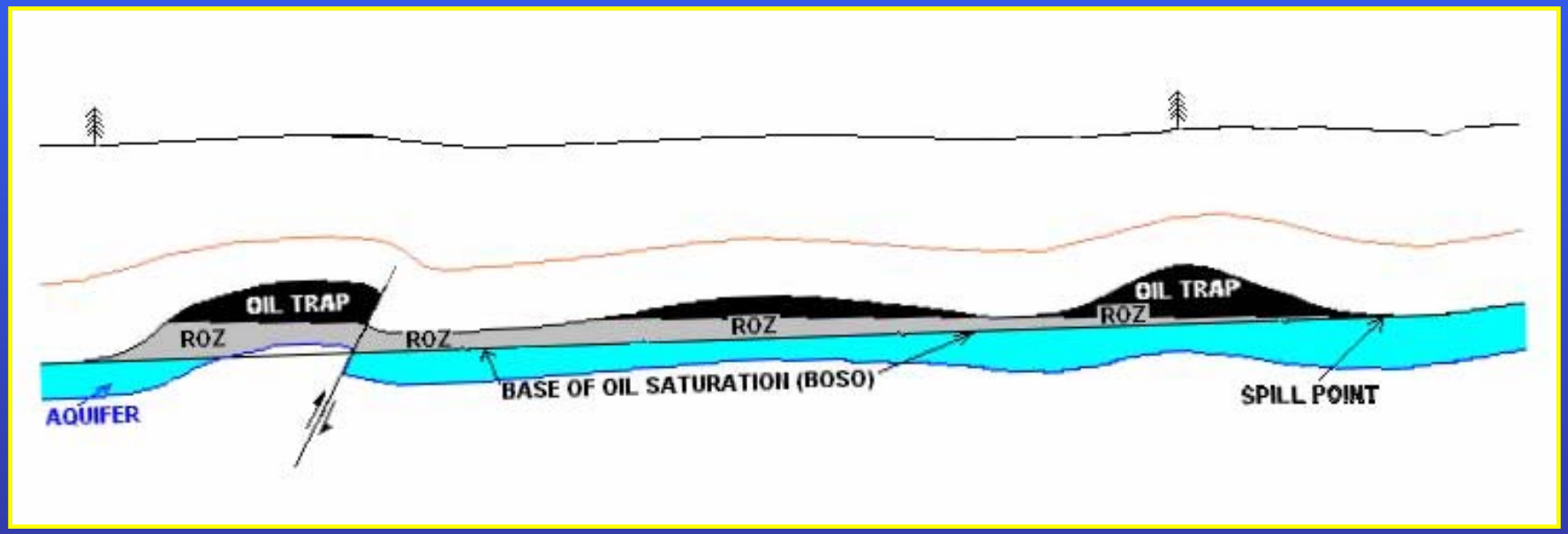
Original Oil Accumulation Under Static Aquifer Conditions (A Hypothetical Example)

W E



Original Accumulation Subject to a Westward Regional Tilt & Forming a ROZ

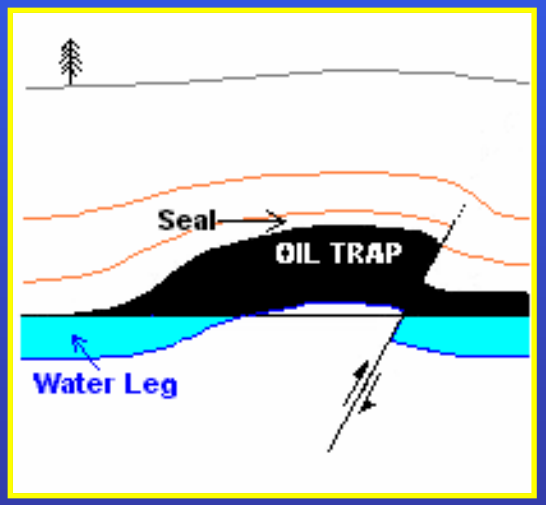
W E



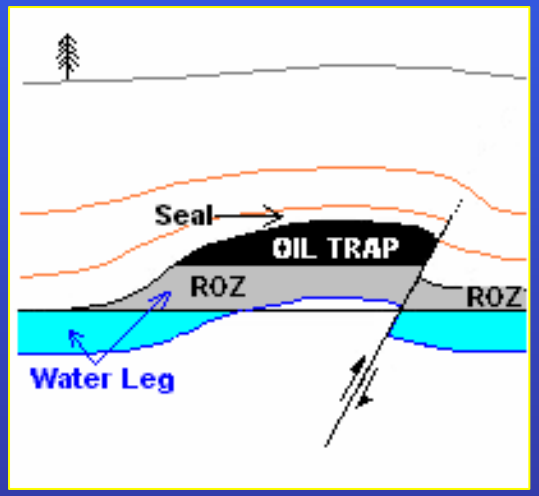
TYPE 1 ROZ

Original Accumulation with a Breached then Repaired Seal & Forming a ROZ

ORIGINAL



POST BREACH



TYPE 2 ROZ

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Change in Hydrodynamic Conditions, Sweep of the Lower Oil Column, Oil/water Contact Tilt, and Development Of The Residual Oil Zone

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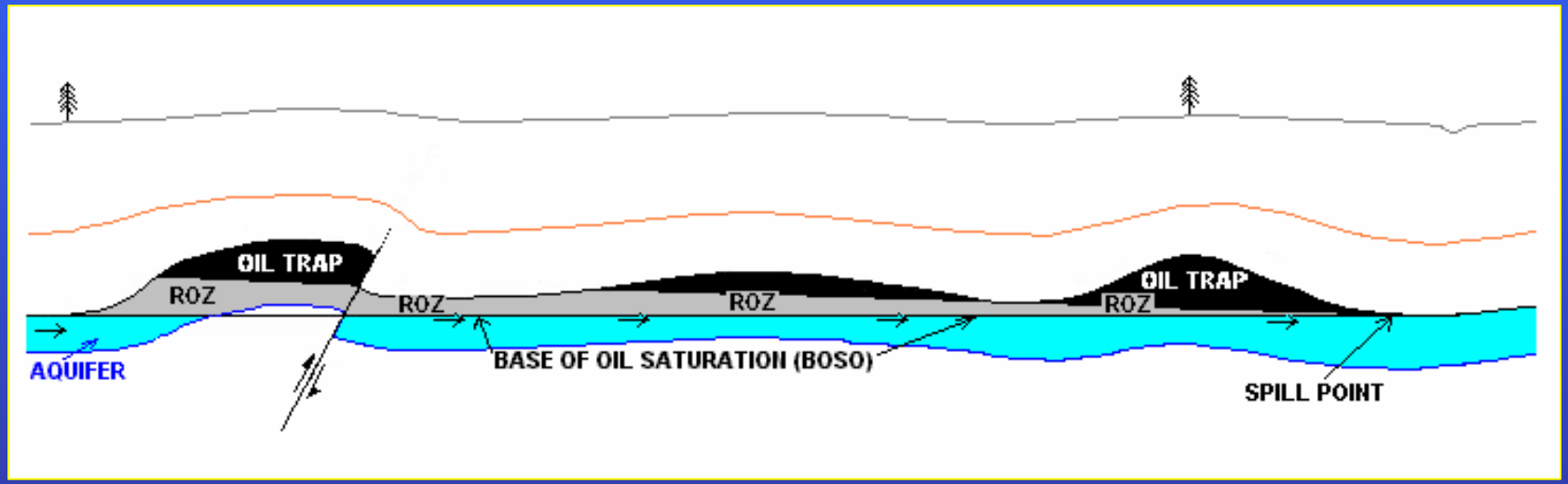

TYPE 3 ROZ

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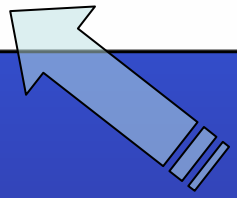
Attributes of the ROZ Types

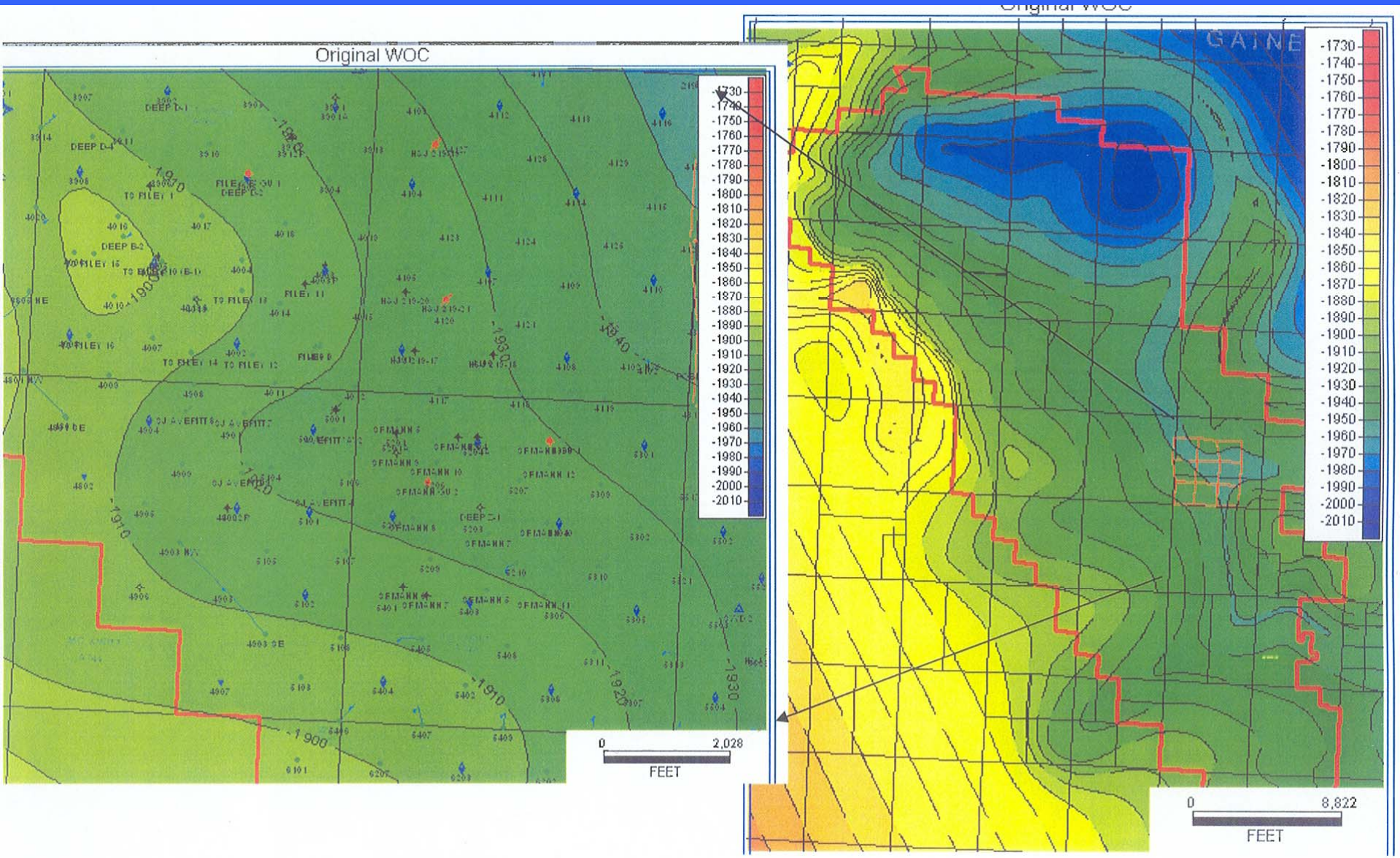
ROZ TYPE	Oil-Water Contact	Base of Oil Saturation	Other Characteristics
Regional Tilt (1)	Horizontal	Tilted	Wedge with thin side Downdip
Breached Seal and Reaccumulation (2)	Horizontal	Horizontal	Stratified Tar Mats, Anomolously Low GOR
Hydrodynamic Tilt (3)	Tilted	Horizontal	Wedge with thin side in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



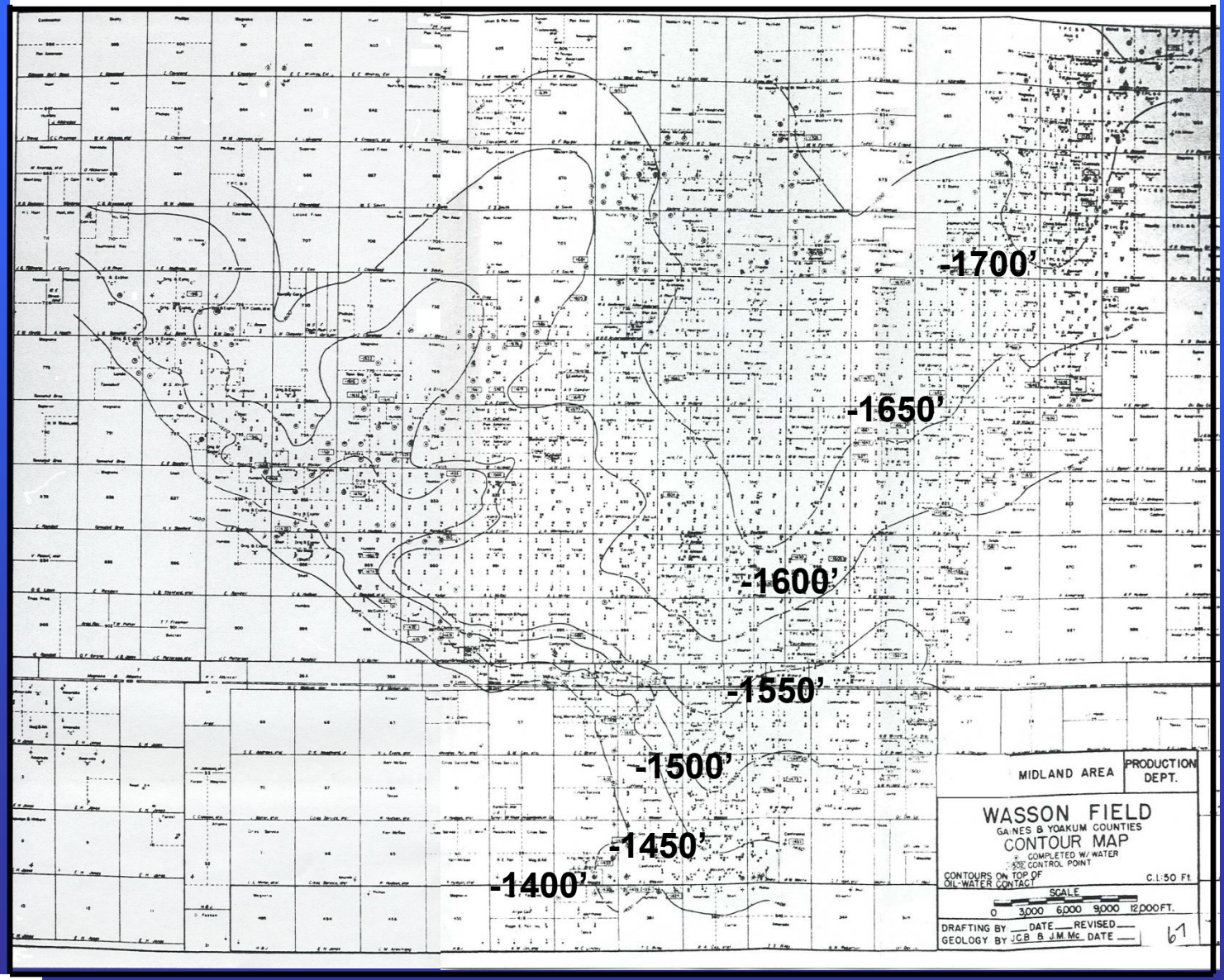
So Let's Examine the Evidence for Type 3 in the Permian Basin

First, Let's Look at OWC Tilt

Seminole (San Andres) Field
O/W Contact Structure Map – Adapted from Texas Railroad Commission Unitization Filings, 1969



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



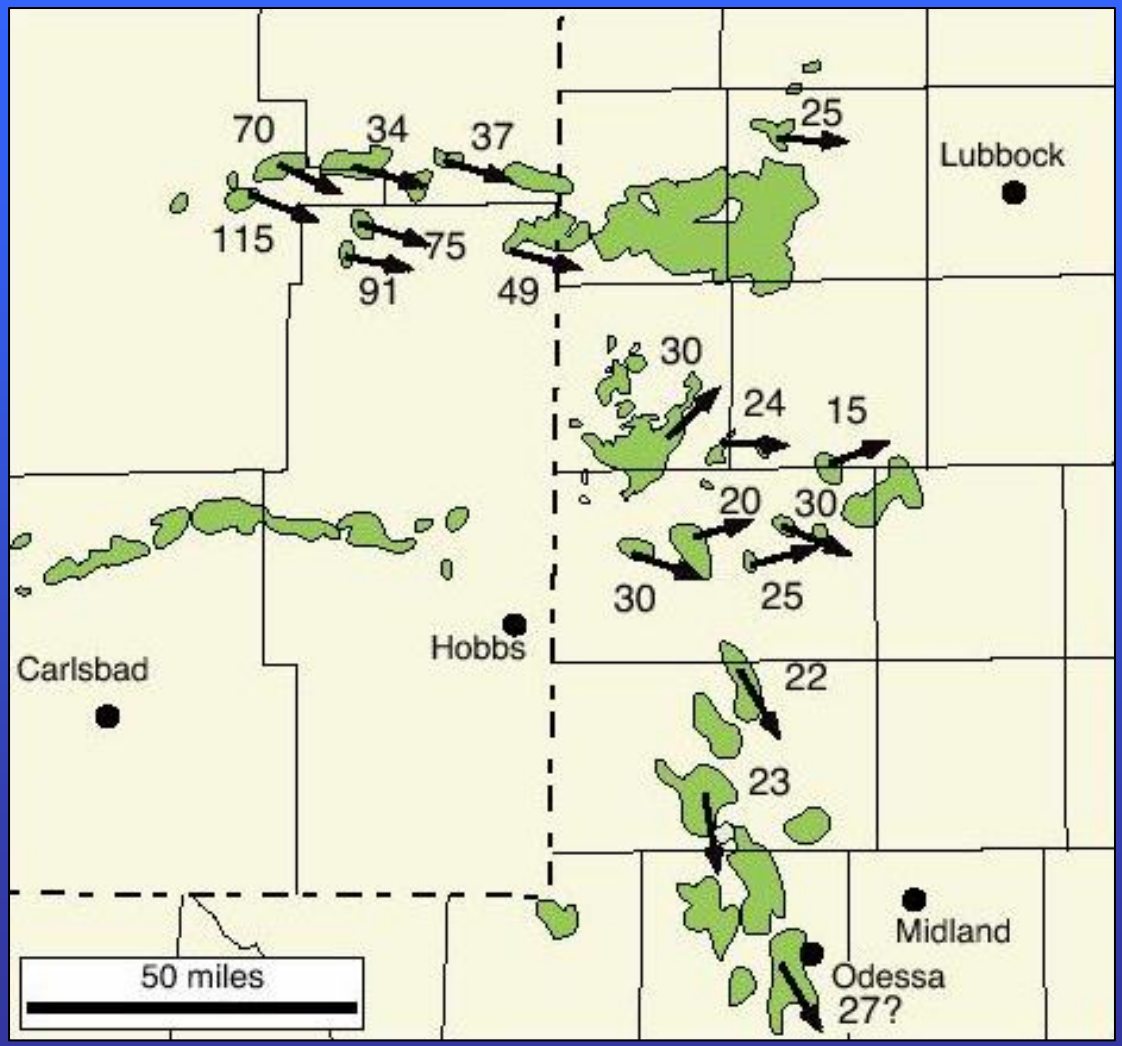
Wasson Field Area O/W Contact Structural Contours*

* From Ref 6

Wasson and Seminole are Huge Fields We Know a Lot About

- Are They Unique?
  - Tilted OWCs?
  - Very Thick ROZs?
  - In being Exploited in the ROZ?
- We Will Make a Case That They are Not

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



* from Ref 6

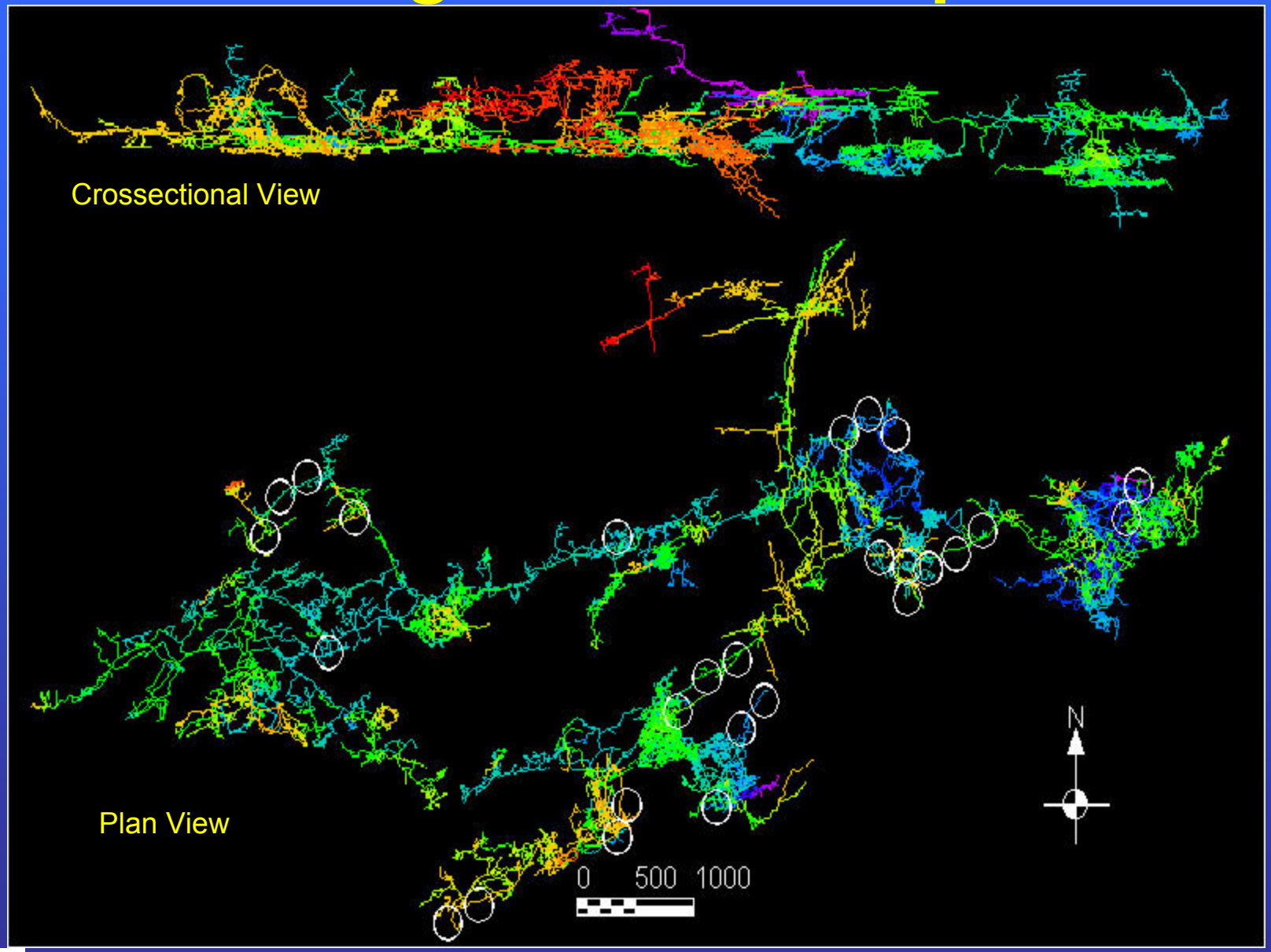
Other Anecdotal Evidence

- Mutual Occurrence of Water, Oil and a Source of Sulfur
  - Water
  - Flushed Oil (Replenishing the Food for the Anaerobes)
  - Sulfur (product-of-reaction, residue)
    - As the Source of H_2S (and Sour Oil)
    - As Proof of Oil 'Passing By' & Fairways of Oil Movement
    - As Proof of Oil 'Consumption'

THE FLUSHING MEDIUM

- Updip Origins
  - Surface Caverns
  - Karst
- Evidence of “Connection” to Petroleum Sources and Entrapments
  - Back to the Fairway Concept
    - ROZs
    - Sulfur?
- As Facilitator of Pervasive Dolomitization
- Discharge Concepts
  - Lineaments
  - Outcrops

Lechiguilla Cave Map



DISCHARGE PATH CONCEPTS

- If we have a source of the water, we have to have discharge points as well
- Direction of OWC tilt is evidence of Movement Direction (we'll come back to this)
- Do we have other pathway clues?

Biogenic Reactions

$$CaSO_4 + HC \rightarrow CaCO_3 + H_2O + S$$

Non-Biogenic Chemical Reactions

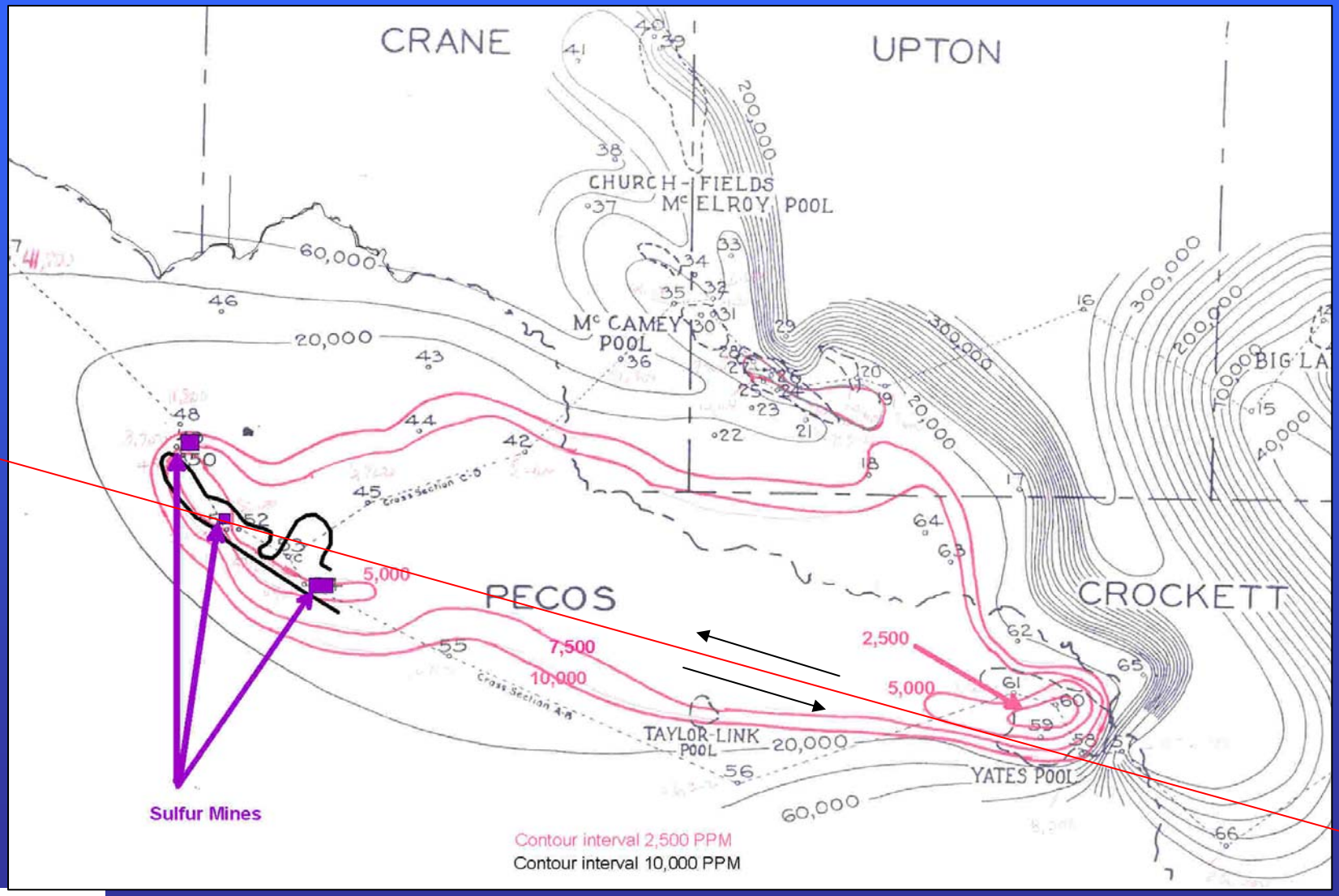
$$CaCO_3 + Mg \rightarrow MgCaCO_3$$

Picked up as Flush Water Moves through Mg Salts?

Sulfur in the ROZ?

Core on Display

The 'Heel of the Boot' of the Central Basin Platform

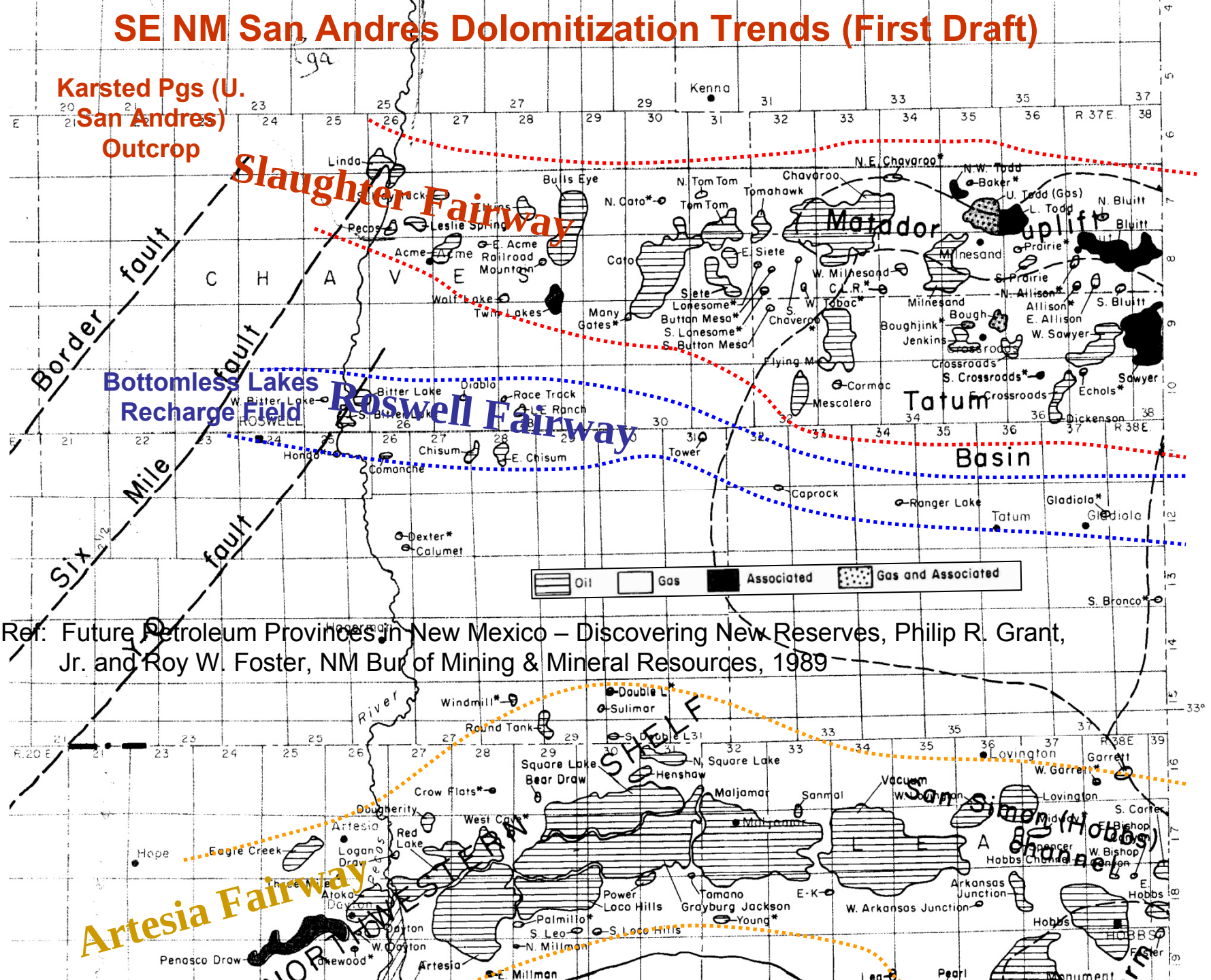


San Andres Water Salinities and Sulfur Deposits

What About Other Evidence?

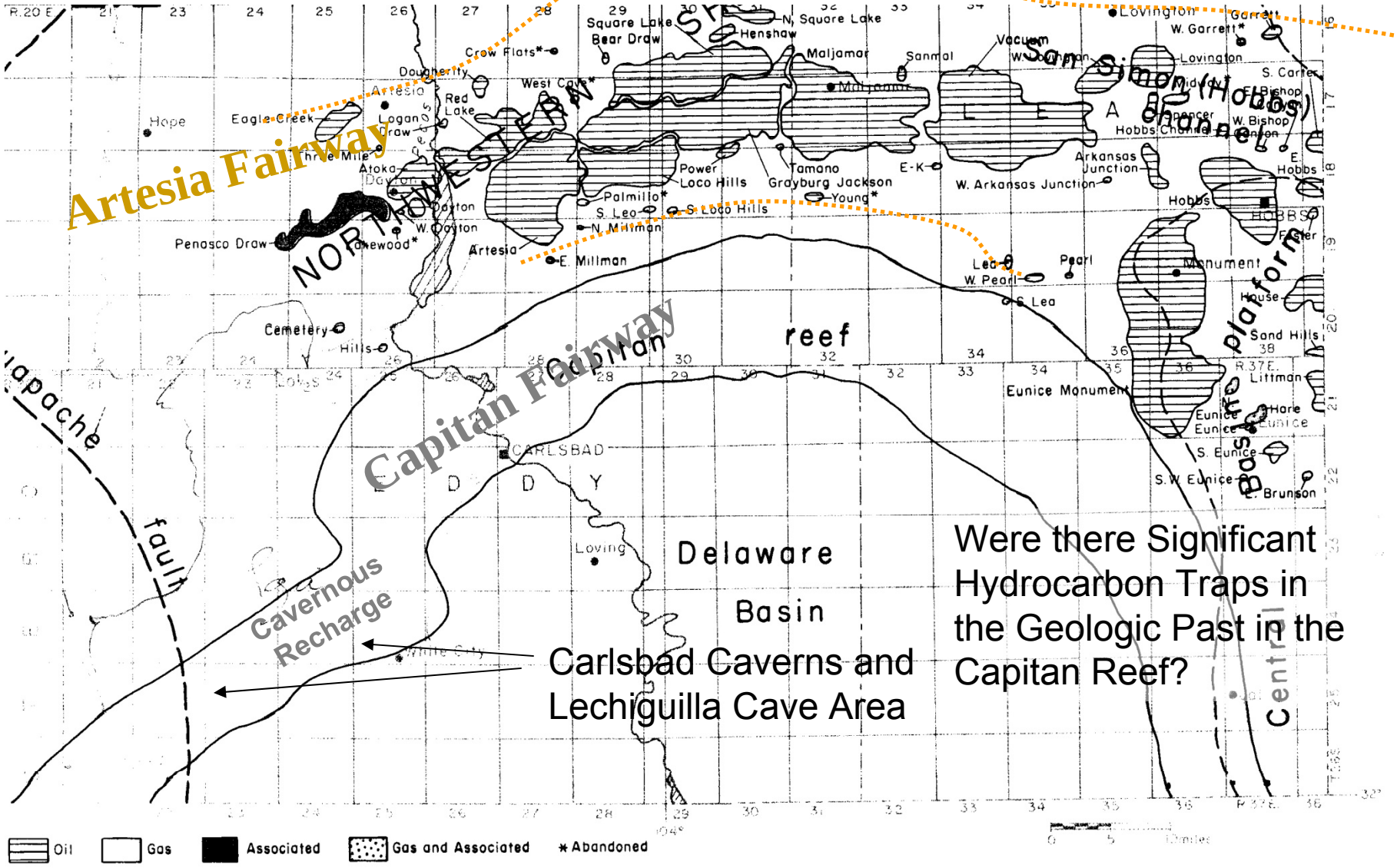
How about Using Trends of Producing San Andres Fields?

SE NM San Andres Dolomitization Trends (First Draft)



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

SE NM Grayburg & Upper San Andres Dolomitization Trend

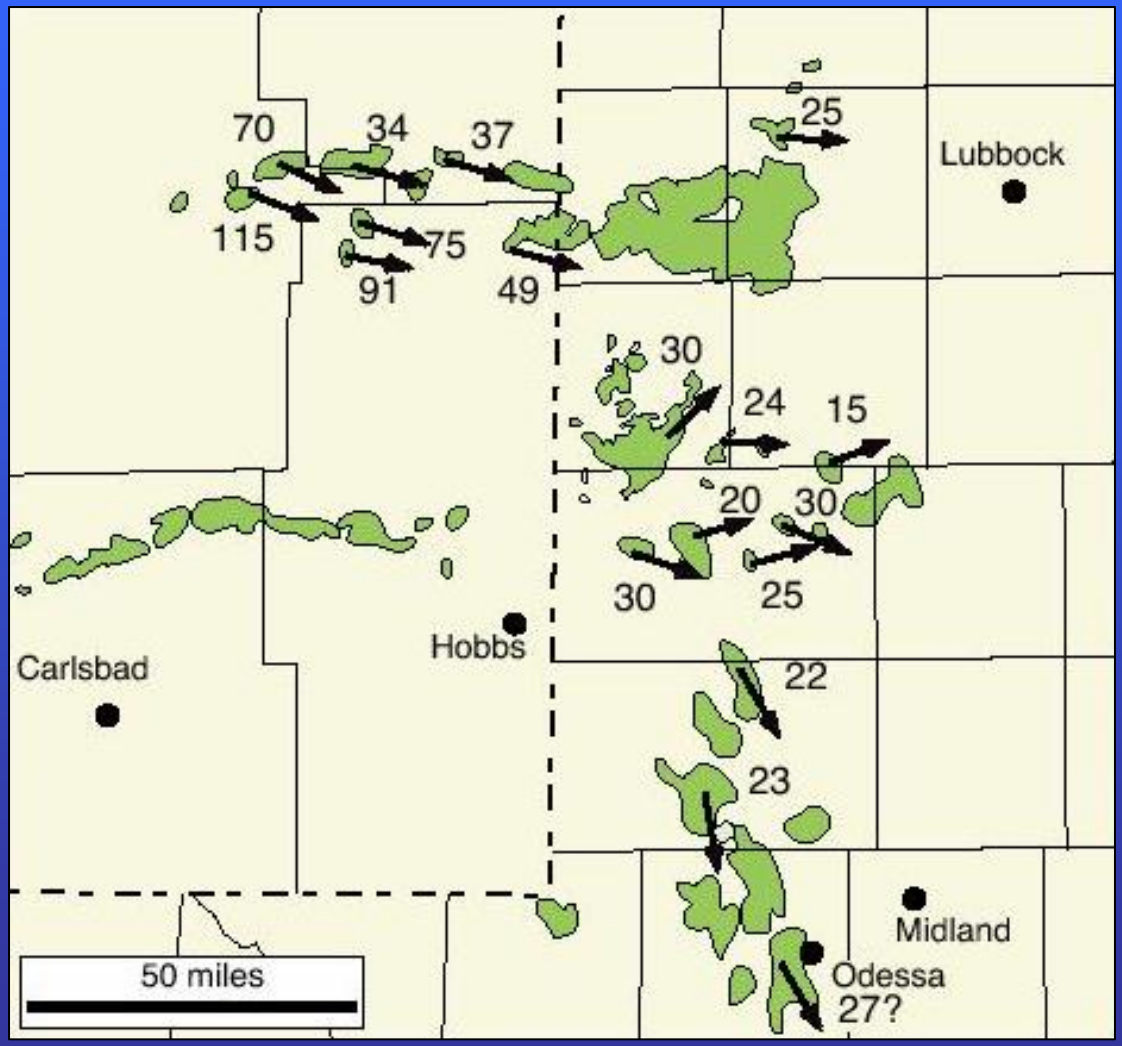


Ref: Future Petroleum Provinces in New Mexico – Discovering New Reserves, Philip R. Grant, Jr. and Roy W. Foster, NM Bur of Mining & Mineral Resources, 1989

Do These Fields have Tilted OWCs?

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

There are More Fields to Examine, More Work to be Done



*** from Ref 6**

OIL SHOWS

- Residual Oil in Cuttings
- Mud log Utility

Oil, Gas and Water Saturation for Continuous Phase and Residual Hydrocarbon Oil Shows*

	CONTINUOUS PHASE			RESIDUAL OIL		
	OIL	GAS	WATER	OIL	GAS	WATER
At Surface %	12	40	48	12	40	48
In Core Barrel %	30	0	70	30	0	70
In Reservoir %	70	0	30	30	0	70

* Schowalter, T.T, and Hess, P.D. (1982), Interpretation of Subsurface Hydrocarbon Shows, AAPG Bull Vol 66, No 9, Sep 82, pp 1302-1327

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TILTED OIL/WATER CONTACTS

- Previous Work
- Sponsor's Fields
- New Field Evidence

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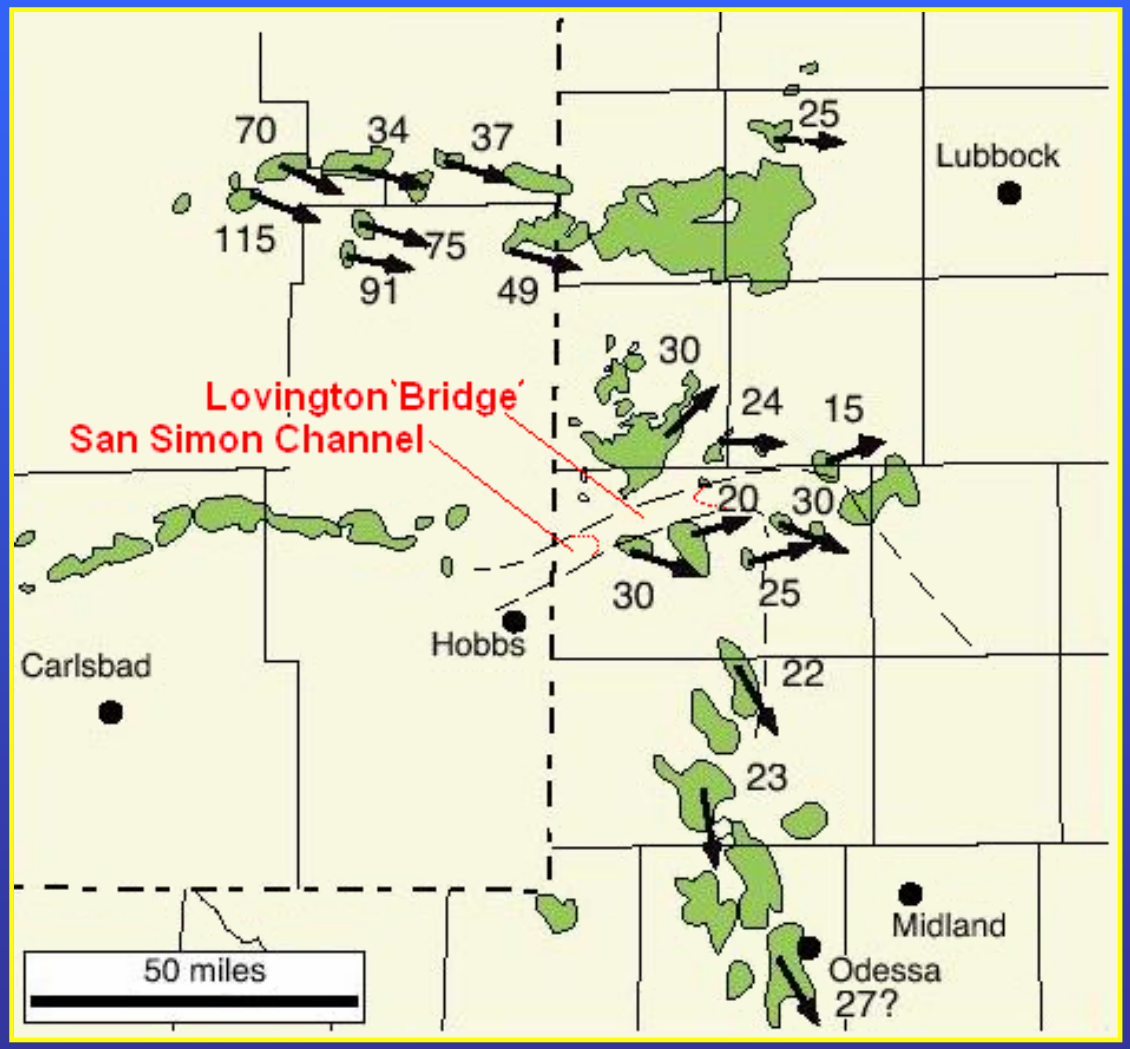
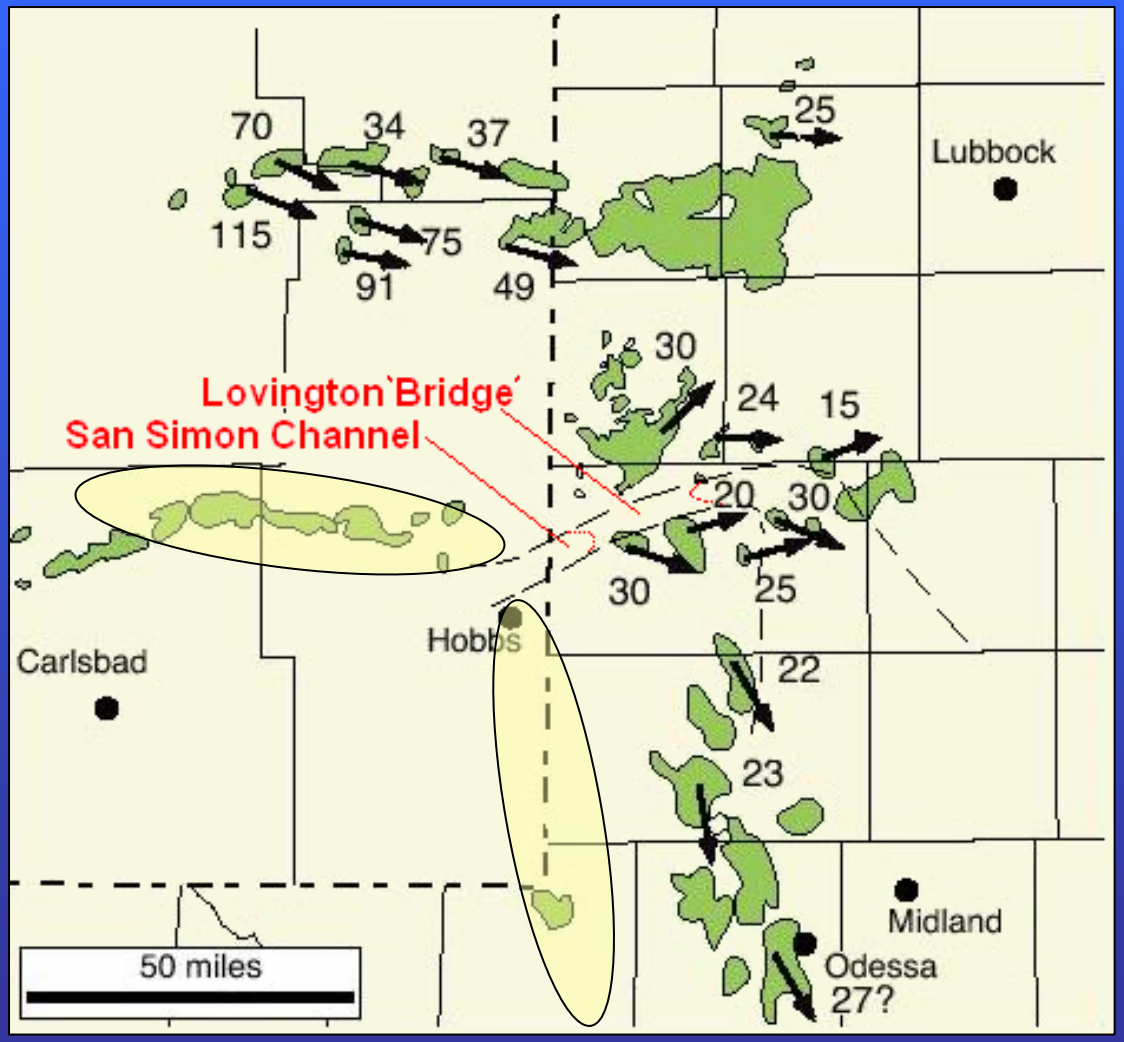
PREVIOUS WORK



PLANNED WORK



DOLOMITIZATION

- Magnesium Rich Waters
- Porosity Enhancements
- Pervasive Zonations
- Geological Timing (Staged Dolomitization?)
- …..and Thoughts on Wetting

Typical Log Character

- Spontaneous Potential Logs Illustrate Consistent Leftward Shift through the entire ROZ interval
- Porosity and Electric Logs Show Leftward (baseline type) Shift through the Interval
- Log Calculations Result in Sor values in the range of 10-50%
- Transition zones at top and bottom are common

DOLOMITIZATION & PERVASIVE ZONATION (1)

V_t = Total Volume = V_s (Vol solids) + V_f (Vol water)

and $V = m/\rho$ where m = mass and ρ = density

Assume porosity saturated with fresh water ($\rho_f = \rho_w = 1$ gm/cc)

For a unit mass of 1, $V_t = (1-\emptyset_i)/\rho_s + \emptyset_i/\rho_w$

Assume initially that is all limestone ($\rho_s = 2.71$ gm/cc) and then becomes completely replaced by dolomite ($\rho_s = 2.87$ gm/cc). Say that the $\emptyset_i$ for limestone rock was 8%)

$V_t = (1-.08)/2.71 + .08/1$

$V_t = 0.34 + 0.08 = 0.42$ = Total Volume of the unit mass

DOLOMITIZATION & PERVASIVE ZONATION (2)

Now, Conserving Volume with complete dolomite replacement of limestone solids – what is new Ø ($Ø_n$)?

$0.42 = (1-Ø_n)/\rho_s + Ø_n/\rho_w$

$\rho_s*(0.42) = 1-Ø_n + \rho_s*Ø_n/\rho_w$

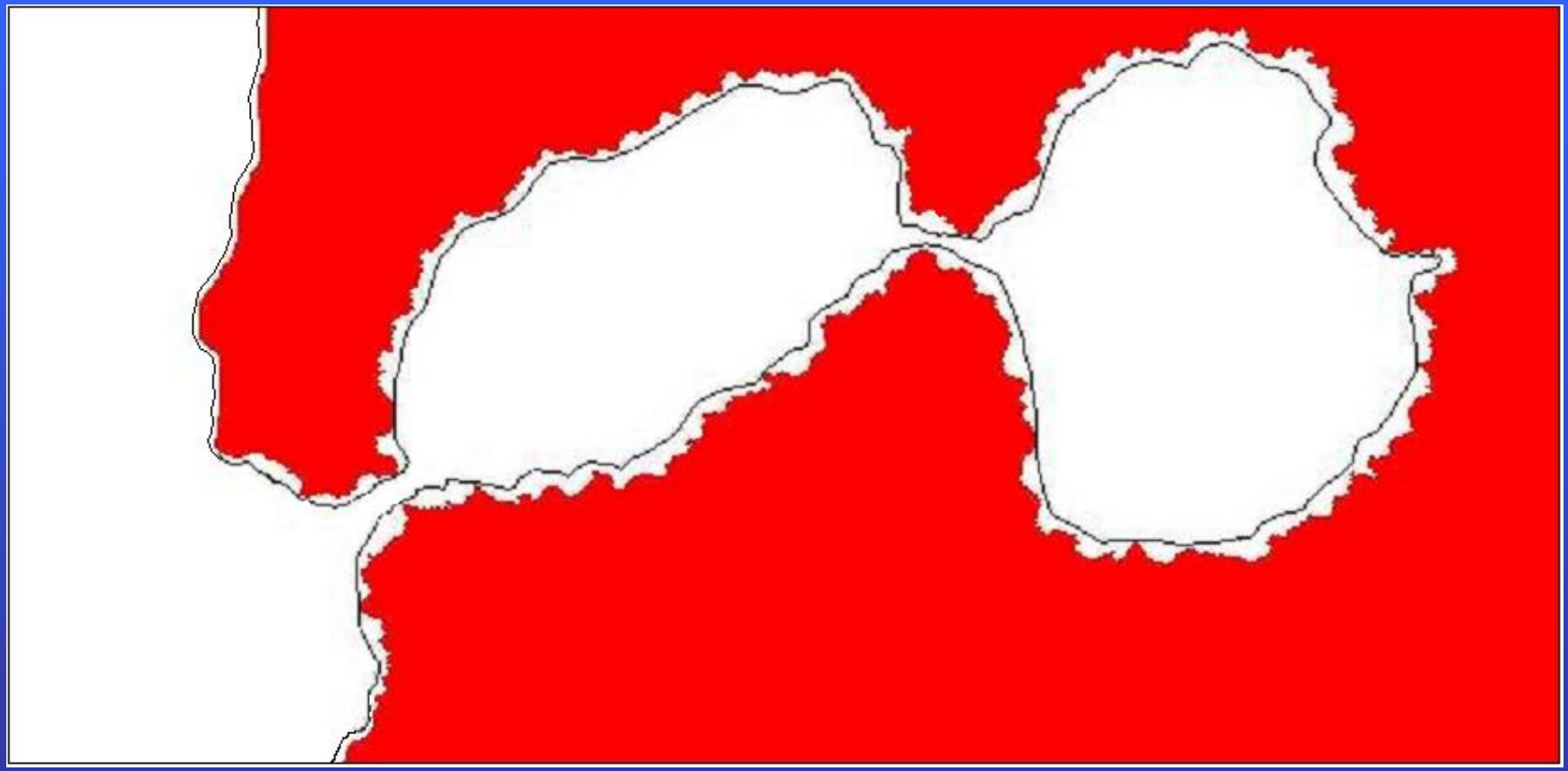
$\rho_s*(0.42) - 1 = (\rho_s/\rho_w - 1)*Ø_n$ or $Ø_n = \{\rho_s*(0.42) - 1\} / (\rho_s/\rho_w - 1)$

$Ø_n = (0.42*2.87-1) / (2.87/1 - 1)$

$Ø_n = 0.21/1.87 = 0.109$ – 10.9%

POROSITY ENHANCEMENT OF 10.9-8.0 = 2.9%

Pre-Entrapment



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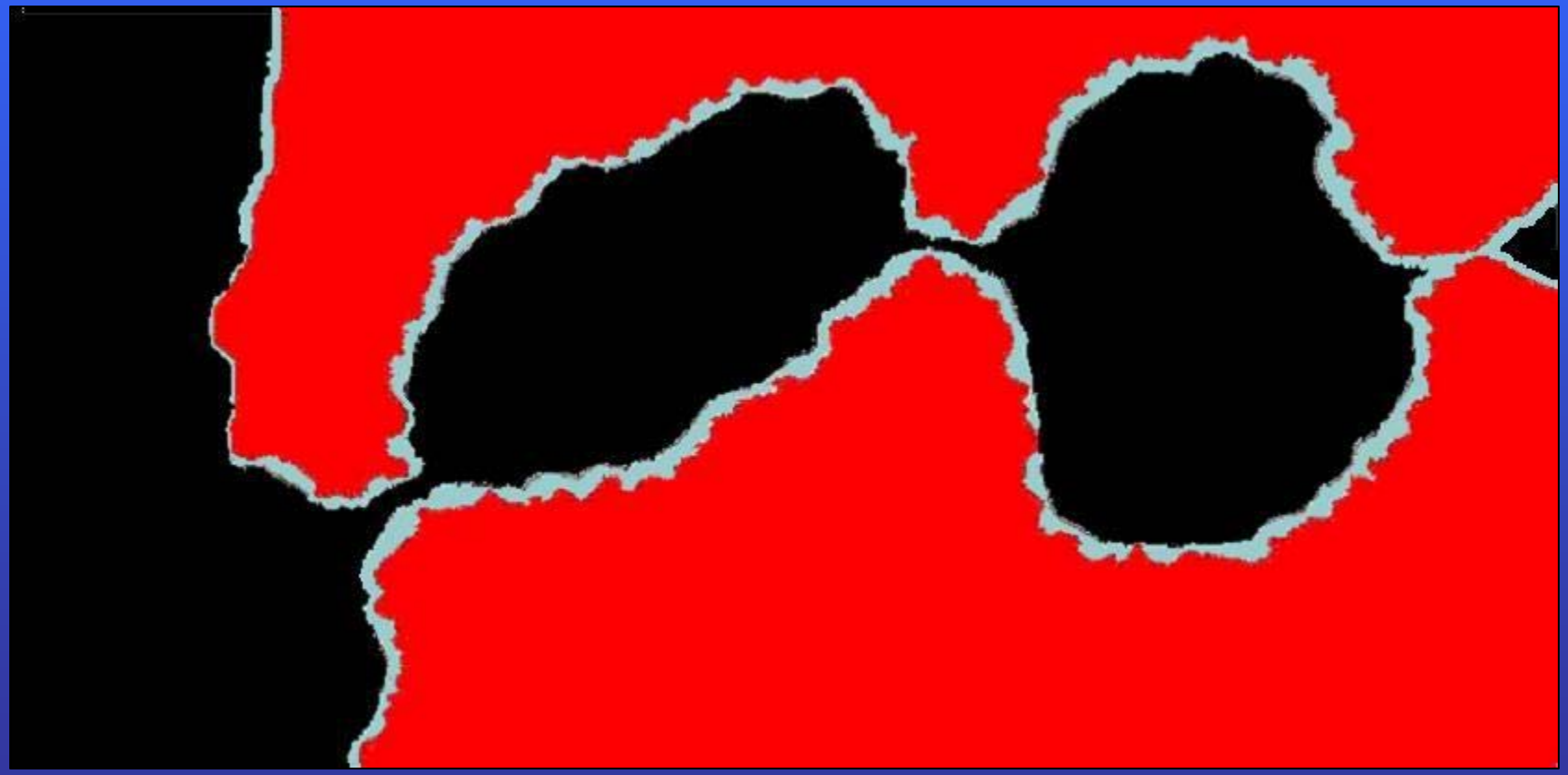
Post Oil Entrapment



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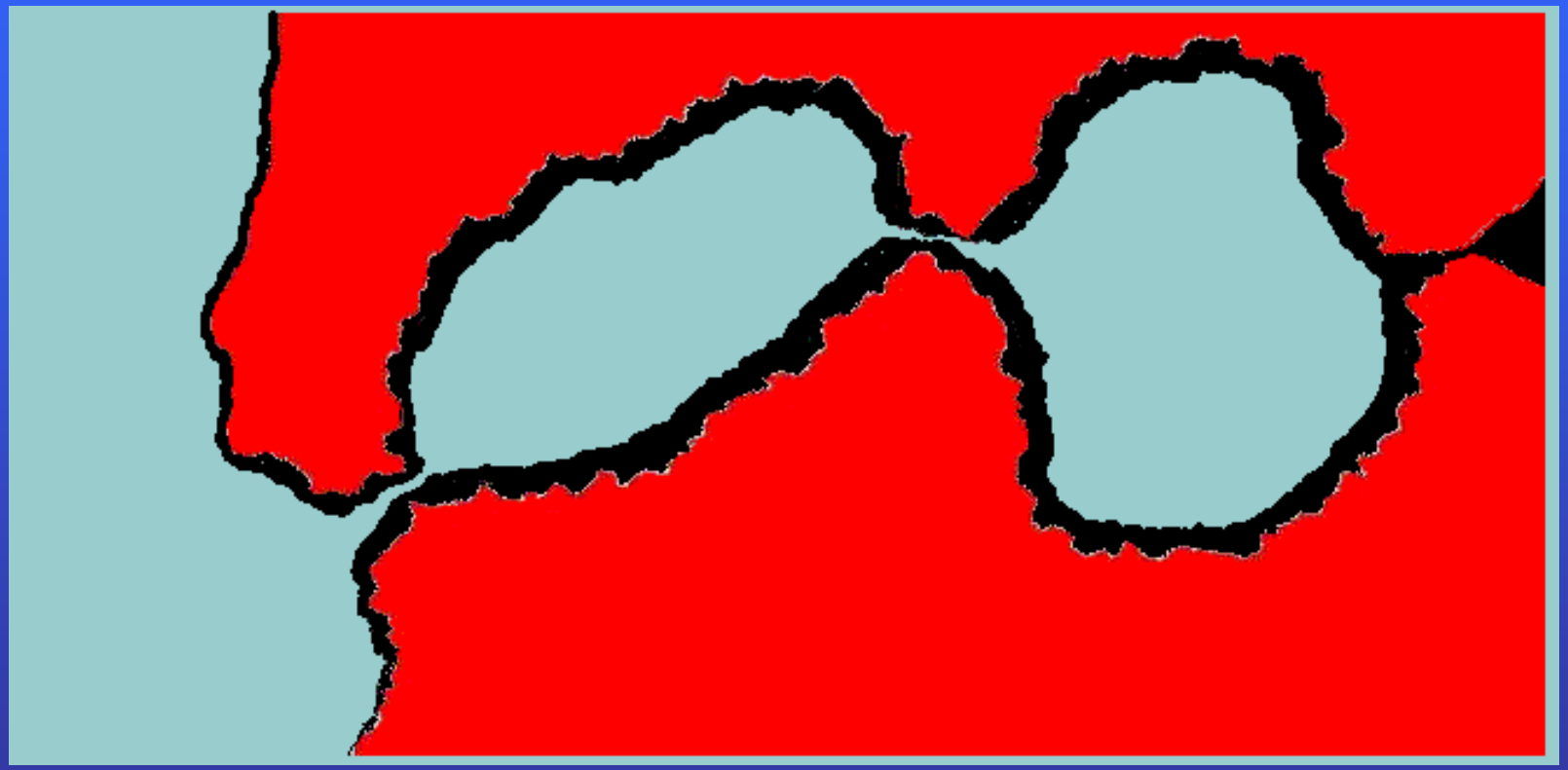
ROZ Development and Flushed Entrapment

Note: Wetting Change*



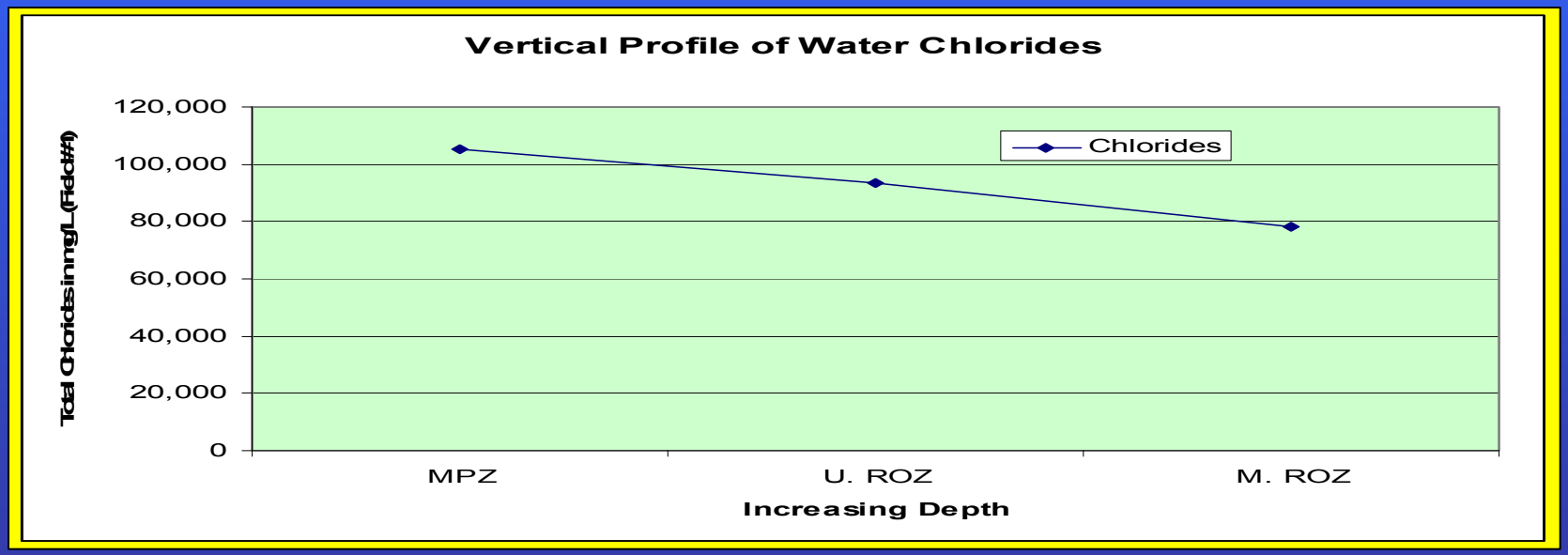
* Volumetric Changes in Rock and Pore Structure Due to Dolomitization Not Simulated Here

WATER SALINITIES

- Sulfur Water Occurrence
- Source to Discharge Mixing
- Evidence of Pathways

VERTICAL SALINITY PROFILE

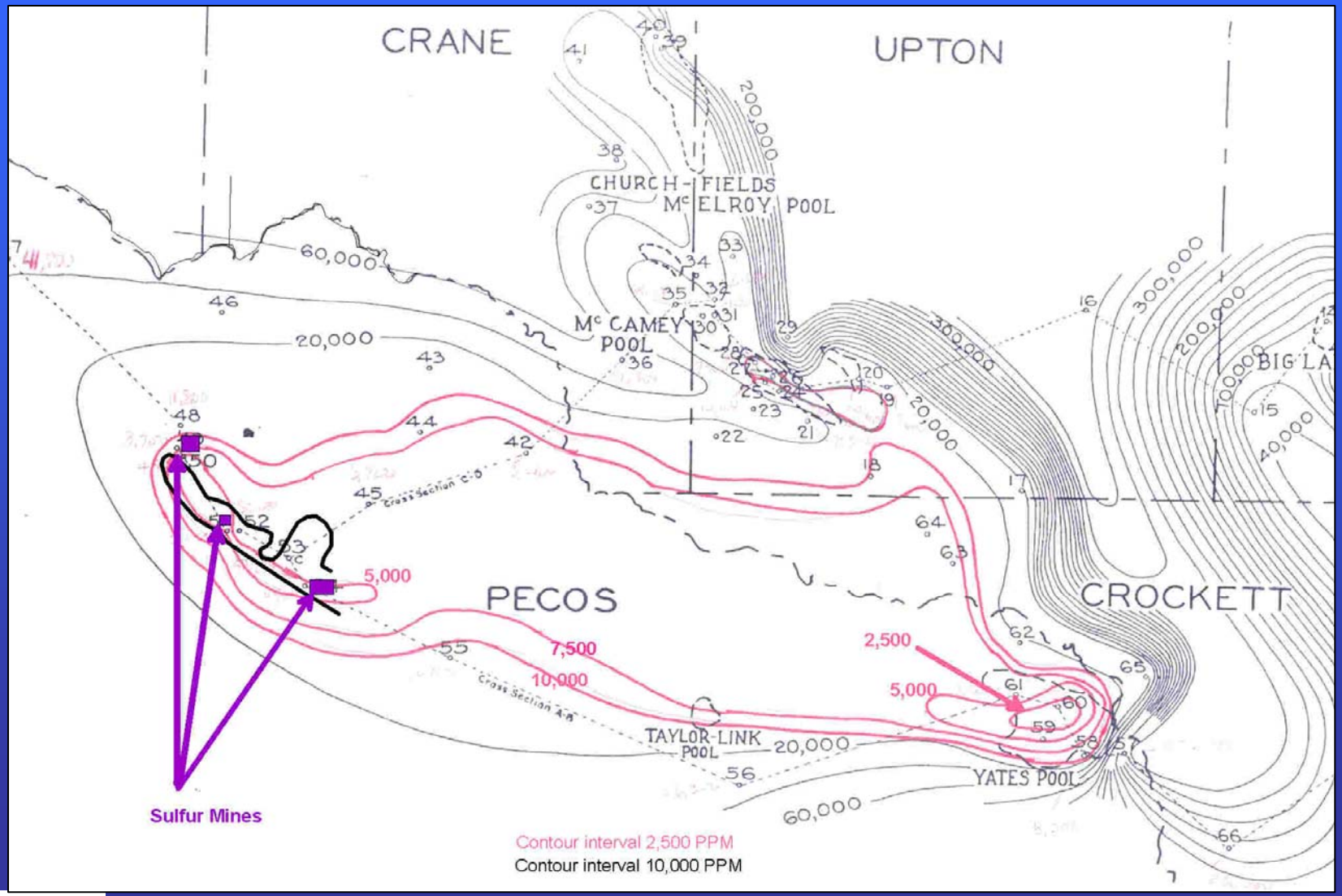
Profile of Water Salinity with Increasing Depth (Vacuum Data)



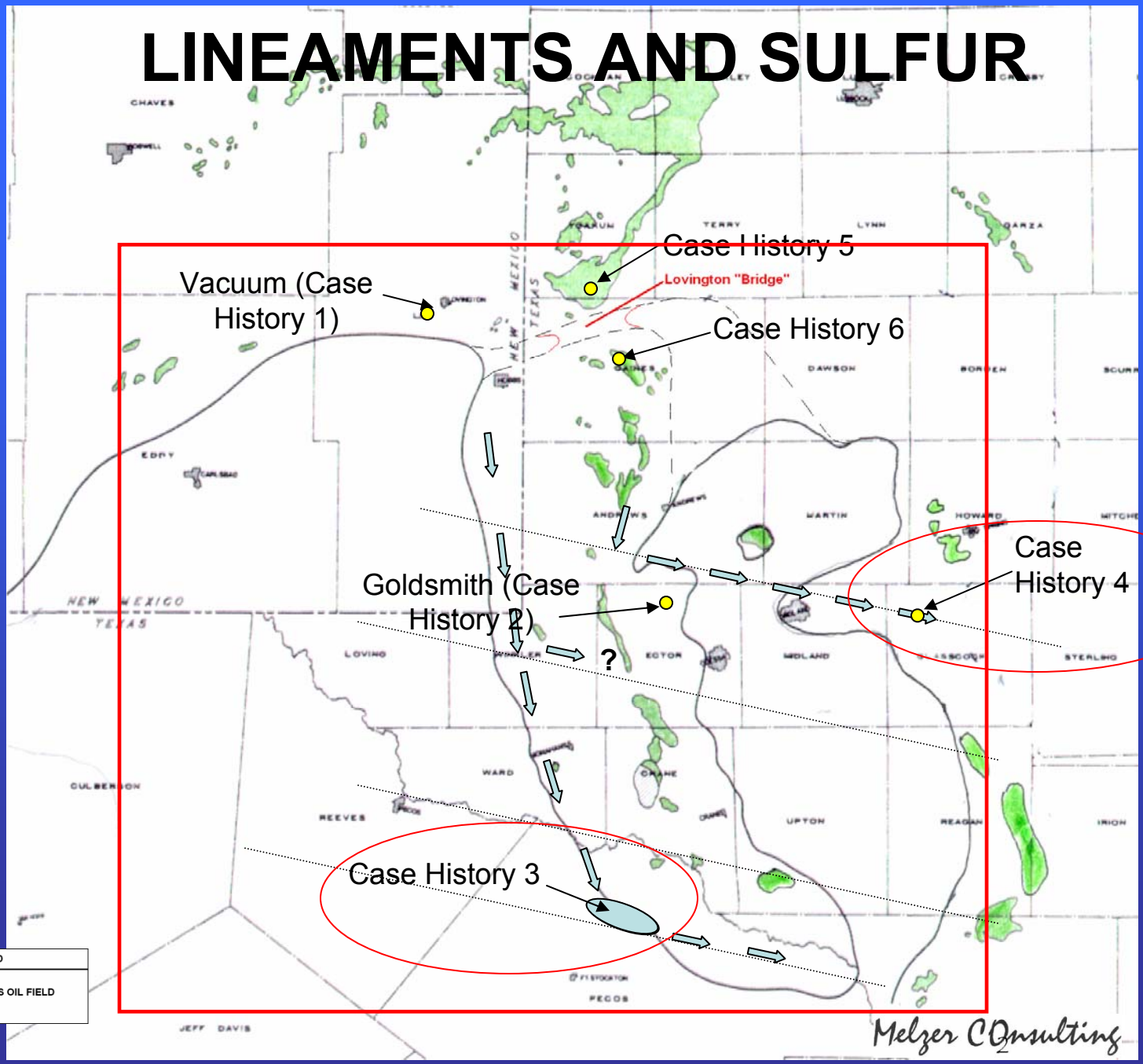
SULFUR ACCUMULATIONS

- Biological Processes
  - Aerobic
  - Anaerobic
- Associations
- Geographical Occurrence
- Quantitative Estimates of Petroleum ‘Consumption’

Value of Old Data
Water Salinities



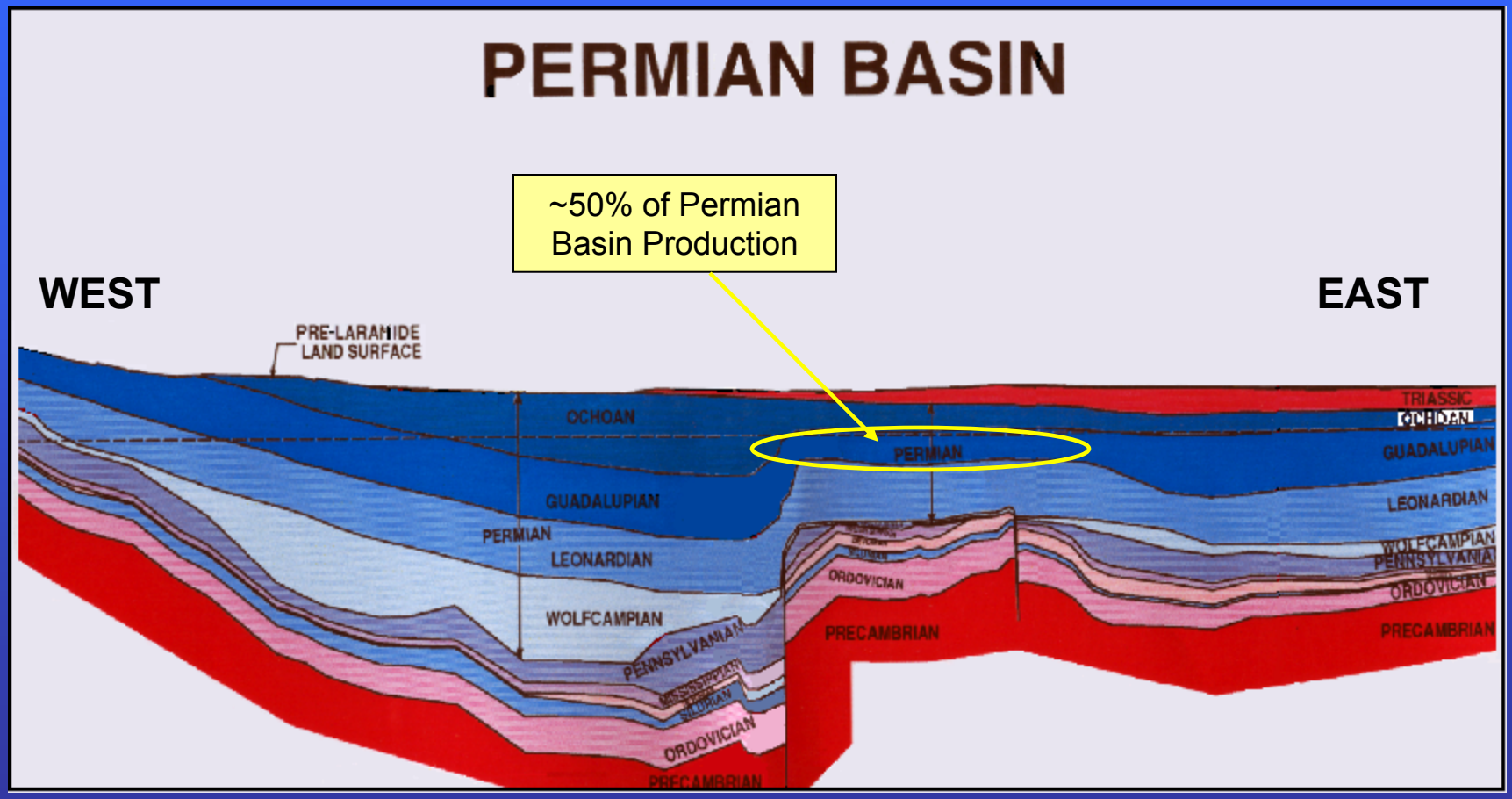
LINEAMENTS AND SULFUR



CORROSIVE ZONES

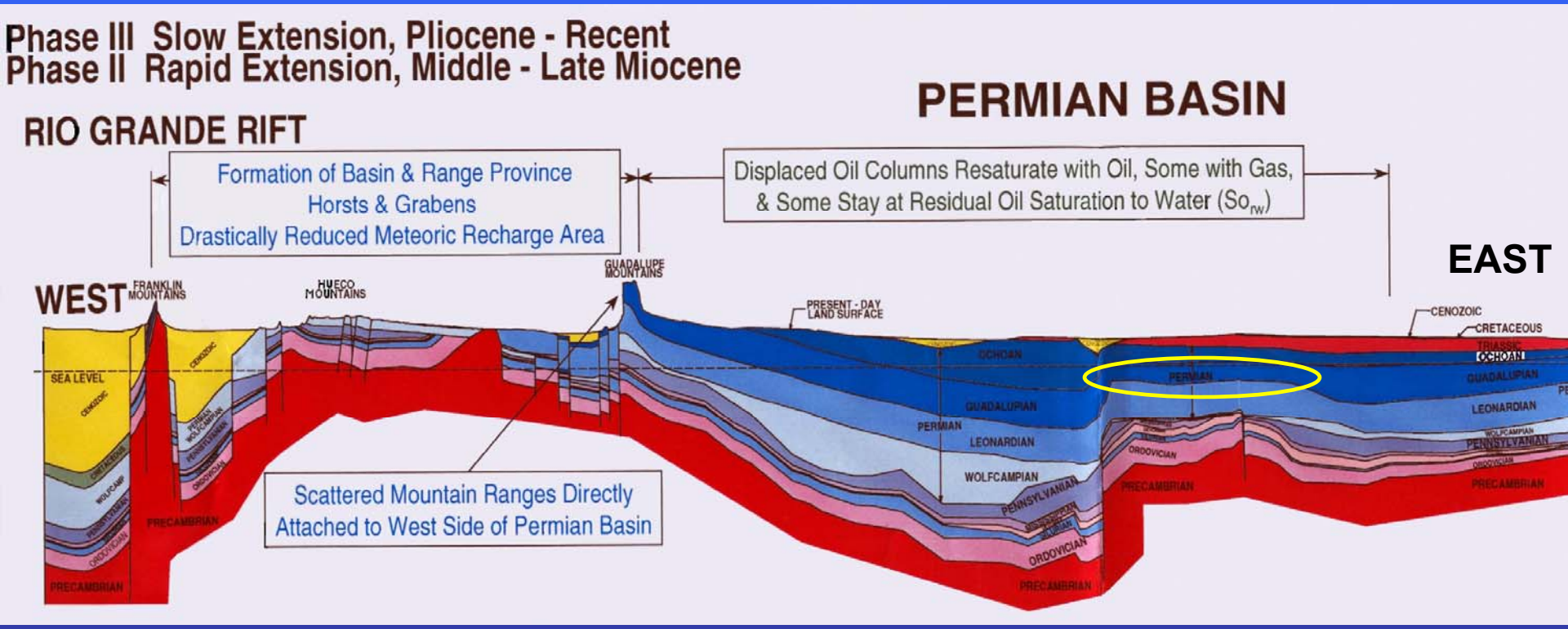
- ATTRIBUTES OF EXIT PATHS
- ACIDIC NATURE OF WATER
- WHAT WORK EXISTS ON THESE ZONES?
  - From Corrosion Engineers?
  - Geographically Speaking
    - Coleman Junction
    - Lower San Andres
    - Wichita Albany
- OTHER

Post-Subsidence Phase of Permian Basin Development*



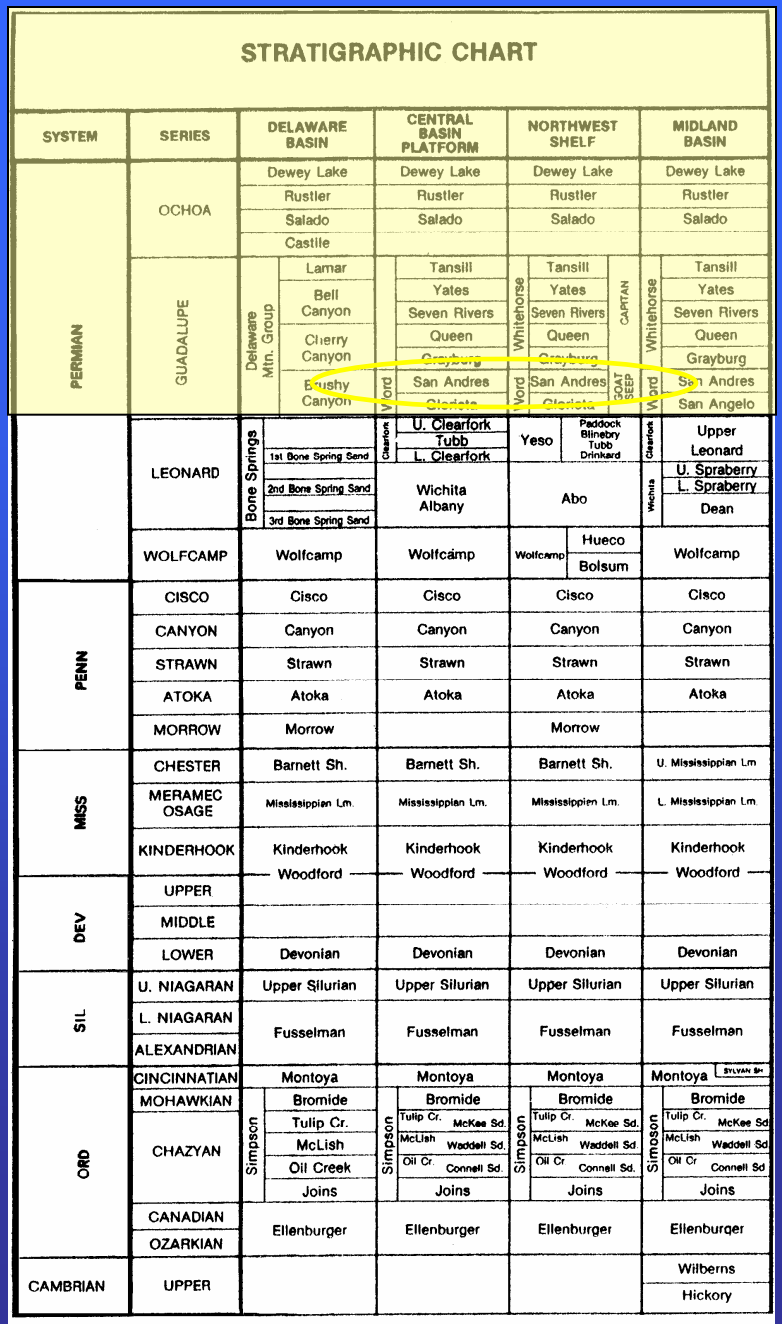
* Adapted from Lindsay, R.F. (2001), W. Tx Geological Society Fall Symposium, Oct 01, Midland Tx USA

Extensional Phases and Reduction of Hydrodynamic Gradients in the Permian Basin*



* Ref: Lindsay, R.F. (2001), W. Tx Geological Society Fall Symposium, Oct 01, Midland Tx USA

Permian Basin Stratigraphic Column



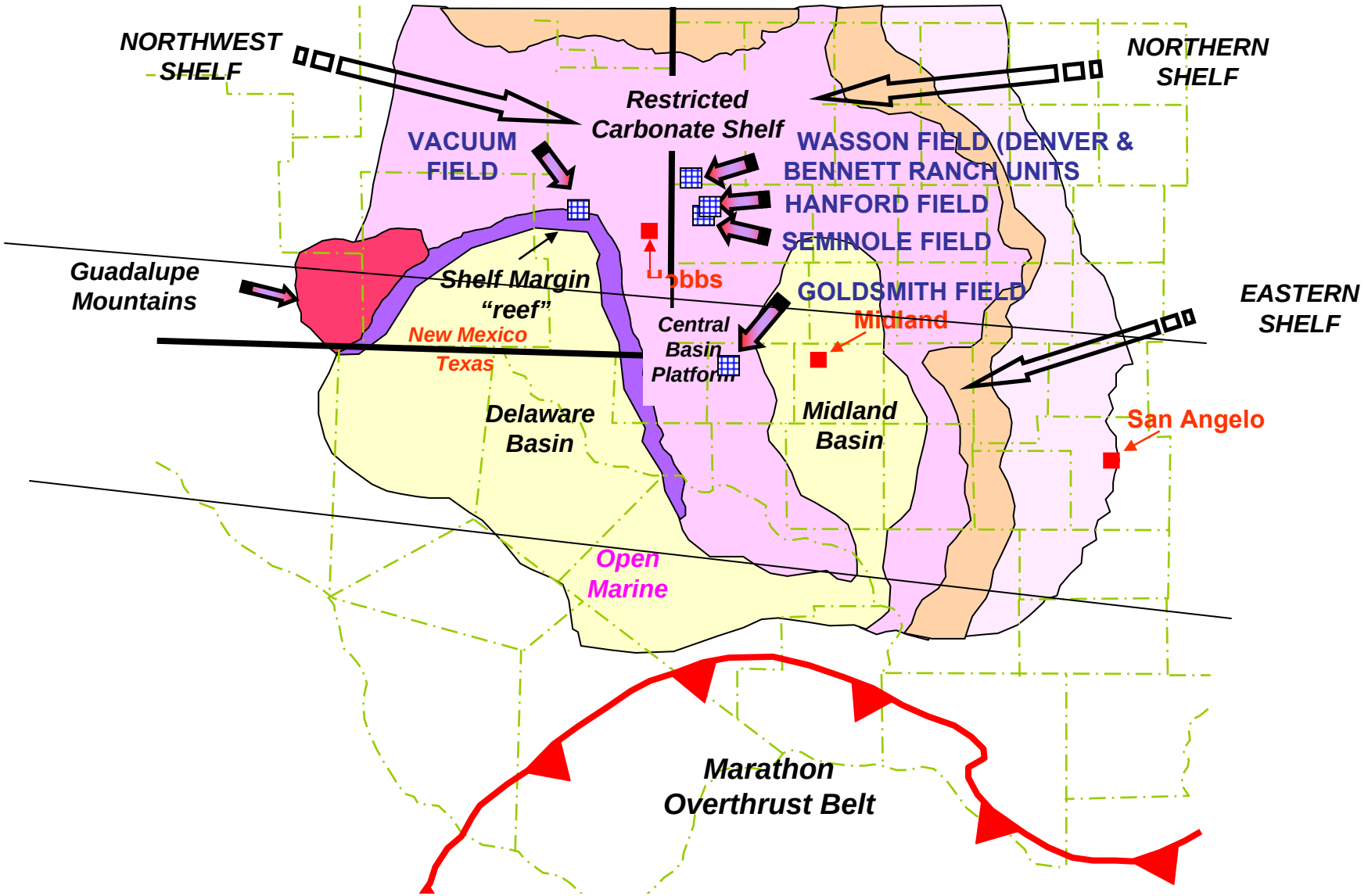
San Andres (Permian Guadalupian)

STRATIGRAPHIC CHART

SYSTEM	SERIES	DELAWARE BASIN		CENTRAL BASIN PLATFORM	NORTHWEST SHELF			MIDLAND BASIN	
PERMIAN	OCHOA	Dewey Lake		Dewey Lake	Dewey Lake			Dewey Lake	
		Rustler		Rustler	Rustler			Rustler	
		Salado		Salado	Salado			Salado	
		Castile							
	GUADALUPE	Delaware Mtn. Group	Lamar	Tansill	Tansill		CAPITAN	Whitehorse	Tansill
			Bell Canyon	Yates	Yates	Whitehorse			Yates
				Seven Rivers	Seven Rivers				Seven Rivers
			Cherry Canyon	Queen	Queen				Queen
				Grayburg	Grayburg				Grayburg
			Brushy Canyon	Word: San Andres	Word: San Andres		GOAT SEEP	Word	San Andres
				Word: Glorieta	Word: Glorieta				San Angelo

MIDDLE SAN ANDRES PALEOGEOGRAPHY

with Location of Active Industry ROZ Zones/CO_2 EOR Projects*



* Adapted from Sagnak (2006), Chevron Presentation at the 12/06 CO_2 Flooding Conference

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WHERE WE ARE TODAY

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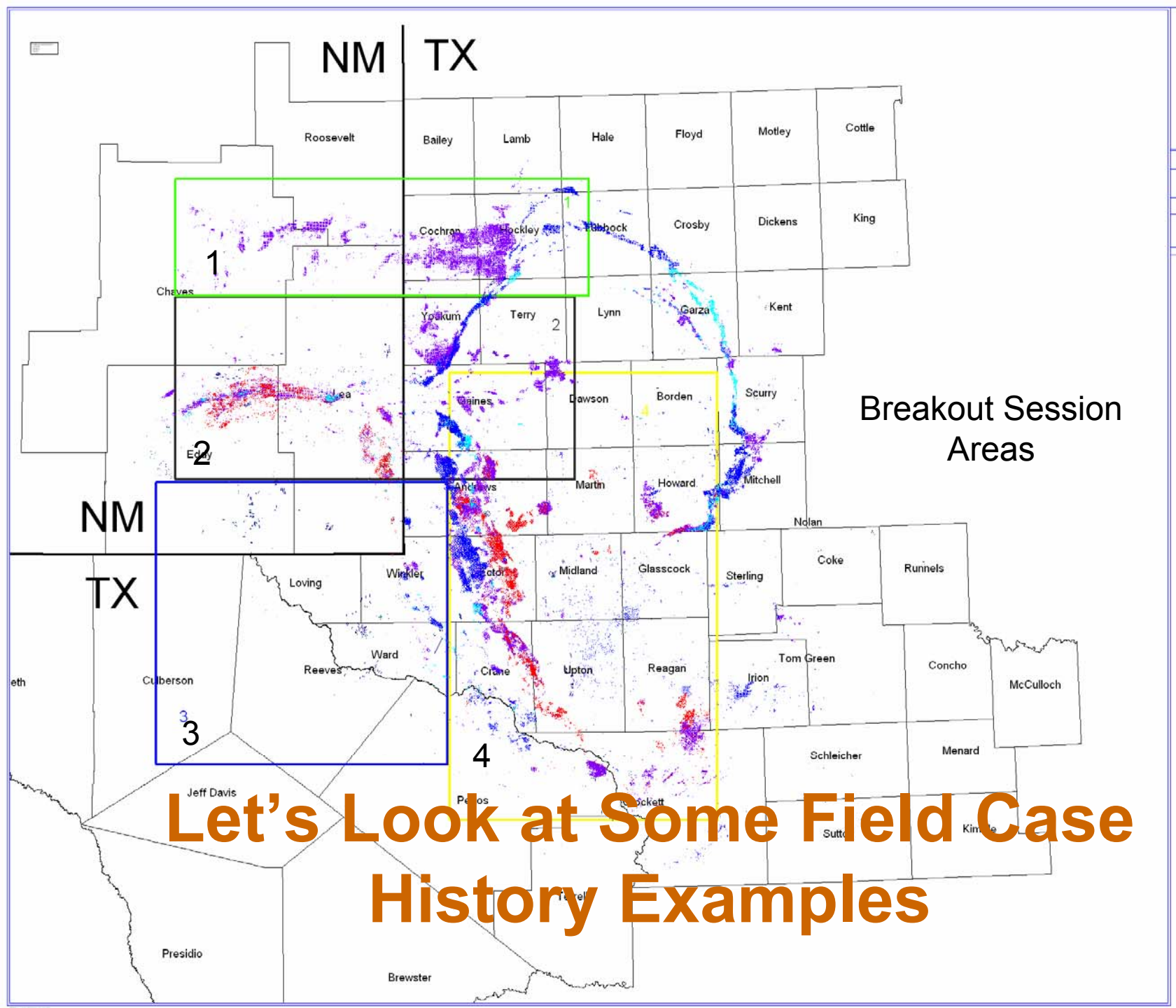
WHERE WE THINK WE ARE GOING

(BUT THIS IS RESEARCH, LET'S BE 'NIMBLE')

SUMMARY:
THE "ANECDOTAL" EVIDENCE

Oil Shows
Titled O/W Contacts
Water Salinities, Sulfur Water
Corrosive Zones
Sulfur Deposits
Dolomitization
Sources of Water (caverns and karst)
Discharge Paths, Lineaments

*In the breakout sessions, your observations related to these are **key***


NM
TX
Roosevelt
Bailey
Lamb
Hale
Floyd
Motley
Cottle
Cochran
Hockley
Lubbock
Crosby
Dickens
King
1
Chaves
Yoakum
Terry
2
Lynn
Garza
Kent
Lea
Gaines
Dawson
Borden
Scurry
Eddy
2
Andrews
Martin
Howard
Mitchell
Nolan
NM
TX
Loving
Winkler
Midland
Glasscock
Sterling
Coke
Runnels
Ward
Reeves
Crane
Upton
Reagan
Irion
Tom Green
Concho
McCulloch
Culberson
3
3
4
Schleicher
Menard
Jeff Davis
Pecos
Presidio
Brewster
Breakout Session Areas
Let's Look at Some Field Case History Examples
Permian Basin

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BACKUP SLIDES

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HESS' SEMINOLE FIELD EXPANSION ANNOUNCEMENT: 5-07

Seminole Sentinel

12 Pages, 1 Insert Sunday, May 20, 2007 Volume 98, Number 064

Hess to Expand

CORP. ANNOUNCES $300 MILLION PROJECT PLANS

By Dustin Wright *Sentinel* Managing Editor

The Hess Corp.'s green and yellow [illegible] have been a long time staple of Seminole and Gaines County.

They can be seen spotted throughout the county's landscape and in various locations within the Seminole city limits.

And to assure that the oil industry in Gaines County remains strong, Seminole's largest employer will begin work in July on the first stage of a project that is promising to extend the recovery of long-life oil reserves of the famed Seminole San Andres Unit (SSAU) for another 20-plus years.

[illegible] released by the Hess Corp. Seminole office Thursday, the [illegible] along with major partners British Petroleum (BP), Exxon Mobil, Occidental Petroleum (OXY), Marathon, Chevron and [illegible] have agreed to an approximate $300 million investment to expand production in the Residual Oil Zone (ROZ).

"We have operated a pilot program on this procedure since 1984 and a second program since 2004, and they have proved to be successful, so the partners have agreed to move ahead with a larger scale development in this zone," said Permian Operations for Hess Floyd Peterson, Manager of Permian Operations for Hess Corp.

According to Peterson, the ROZ lies directly underneath the SSAU's main pay zone and contains nearly one billion barrels of unconventional oil that must be mixed with carbon dioxide for [illegible].

The first stage of the development will include the deepening of 47 [illegible] wells into the ROZ, and the conversion of 29 wells that will be converted from production to carbon dioxide injection [illegible] for future production into the zone.

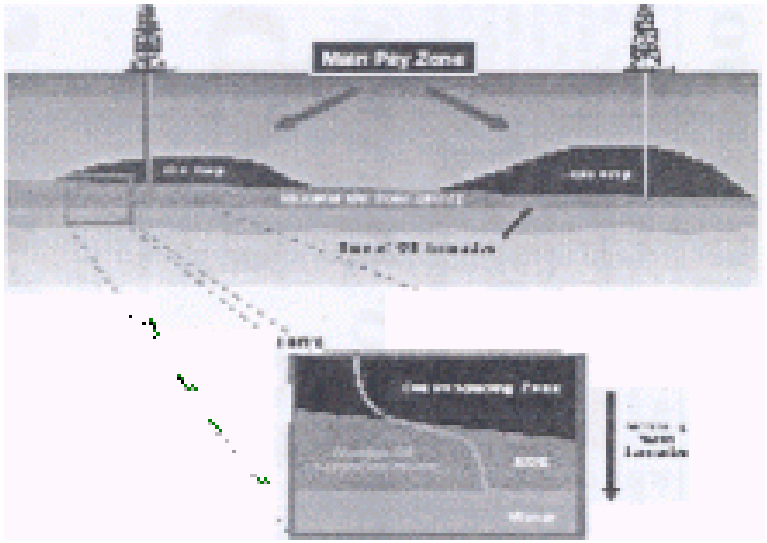
In addition to the field [illegible] the capacity of

See HESS Page 3

News

Hess: First Phase of Expansion

Geology of the Residual on Zone



this takes place, it does nothing but boost the local economy," said Shelby [illegible], Chief Executive Officer of the Seminole Chamber of Commerce.

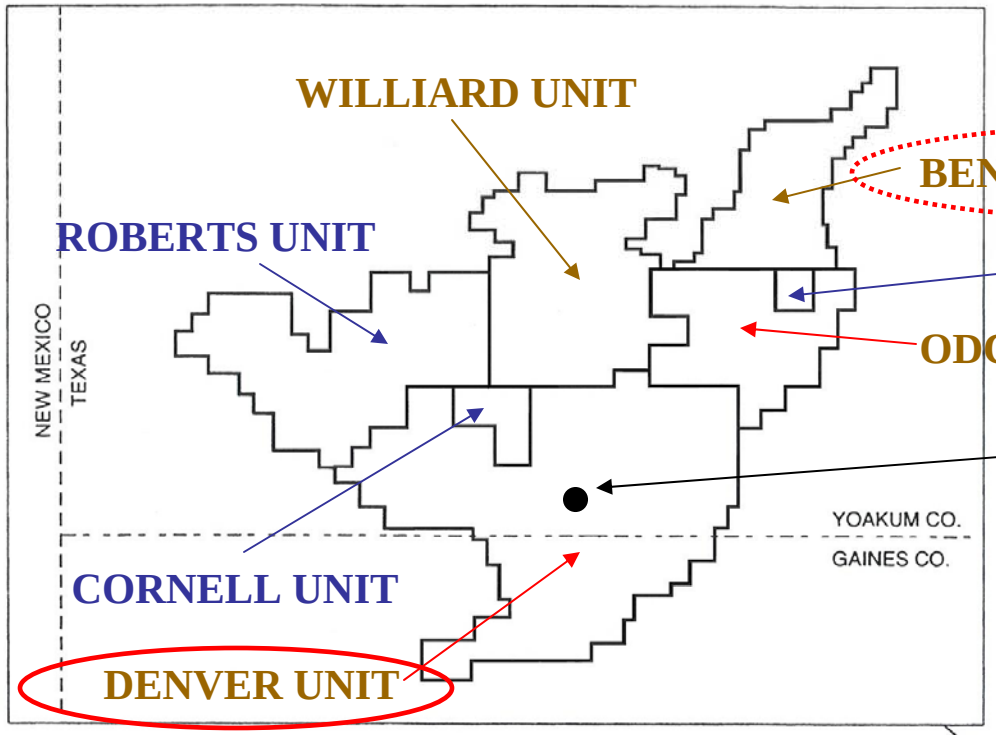
The Seminole Field, was first discovered in 1936 with production from the San Andres formation.

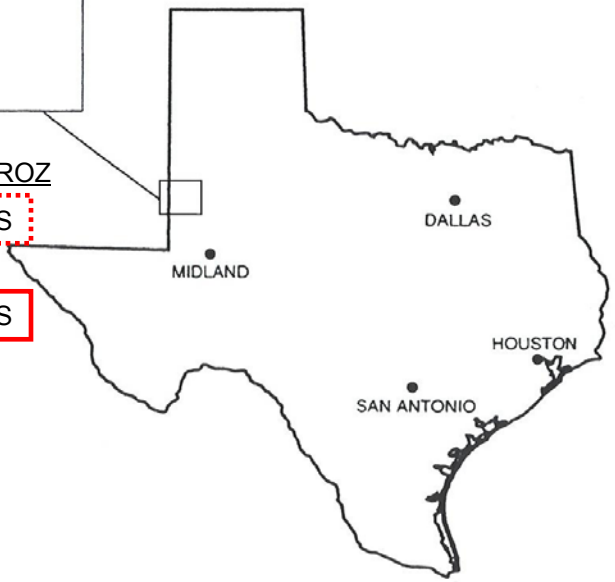
The original development targeted the conventional main pay zone, containing approximately one billion barrels of oil covering an area of almost 16,000 acres.

The SSAU was formed in 1969 to begin water flooding operations, and in 1980, the recommendation to inject carbon dioxide into the formation was approved by the working interest owners, which led to the construction of the Seminole Gas Processing Plant and the injection of carbon dioxide into the SSAU in 1983.

For numerous years, Gaines County has led the state in oil production, according figures posted monthly by the Texas Railroad Commission.

Wasson Field Area with San Andres Formation Producing Units and Attributes





UNIT	OPERATOR	ACRES*	NET PAY*	OOIP*	CO_2 MPZ	CO_2 ROZ
BENNETT RANCH	OXY PERMIAN	7,027	78	301	YES	YES
CORNELL UNIT	XTO ENERGY	1,920	122	141	YES	NO
DENVER UNIT	OXY PERMIAN	23,300	230	2,108	YES	YES
MAHONEY LEASE	XTO ENERGY	640	245	90	YES	NO
ODC UNIT	OXY PERMIAN	7,760	223		YES	NO
ROBERTS UNIT	APACHE	13,600	57		YES	NO
WILLIARD UNIT	OXY PERMIAN	13,100	180	6,220	YES	NO

* Source: Reference 5