2019 PBWIEC

New Insights on Transmissive Fractures and Water Production from the Horizontal Well Revolution

A Presentation to the 2019 Permian Basin Water in Energy Conference
February 20-22, 2019

Friday 2/22/19

Steve Melzer, Melzer Consulting

New Insights on Transmissive Fractures and Water Production from the Horizontal Well Revolution

Outline of Presentation

1) Some Perplexing Questions
2) The Two Classes of Unconventional Plays in the Permian Basin
3) A Quick Look at the Horizontal San Andres Play
4) Hor SA Play Analogs (optional portion)
5) A Transmissive Fracture Case History (San Andres)
6) Can Mass Spectrometry Mud Logging Add Valuable Contributions to Reservoir Understanding and Completion Engineering?
7) Crustal Connections and Sour Wells in the Shales

   Where to Go From Here?

Contributors/Reviewers

Thanks need to go out to:

- David Vance – Arcadis Midland
- Bob Trentham – UTPB
- Bruce Warren – Crown Geochemistry
- Craig Pearson – Tx Railroad Commission
- Russell Hall – RK Hall & Associates
- Farhan Alimohammed – Schlumberger Oil Field Services

Some Perplexing Questions

How can one horizontal well in a shale produce sweet oil and the adjacent lateral, landing at the same depth, produce sour oil?

Have you ever asked someone what is the best way to avoid drilling into a transmissive fracture or…. what is the best way to avoid high water cut producing laterals?

Or..Perhaps, is There a Way to Assess the Risk that my Disposal Well Could See Curtailed Injection or, Worse, to get Shut-in?

The Two Unconventional Plays

Liberated by the Horizontal Well Revolution

- The One You all Know About
  - Source-bed, Basinal Formations aka ‘Shales’
    - ✓ Unconventional Rocks and Conventional Oils
      - ➢ Examples: Wolfcamp, Bone Springs, Cline

- The Play Only Some of You are Following
  - Most Often Carbonate Shelf Formations
    - ✓ Oil Wet Rocks with Unconventional (Residual) Oils
      - ➢ Examples: ROZs in the San Andres, Yeso, Hunton

Let’s Learn Some Things from this One

Section 3:

A Quick Look at the Horizontal San Andres ROZ Play

Part 3A

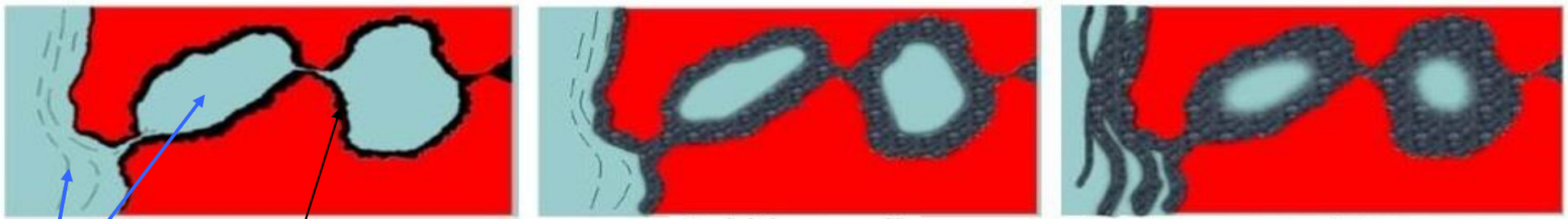
Play Concept

“Just Like the Shale Plays, it Takes a Gassy Oil”

Residual Oil Zone (ROZ) Depressuring

How Does ROZ Depressuring Work?

The ROZs have Oil Affixed to the Rock Surfaces and, if that Oil Has Gas in it, Depressuring Releases Some of the Oil and Entrained Gas



Bubbles swell

Oil Seeps out of the poors. . .

Mobile Water

Immobile Oil

. . .and into the flowstream to flow to the well. Lots of water is produced to accomplish the depressuring

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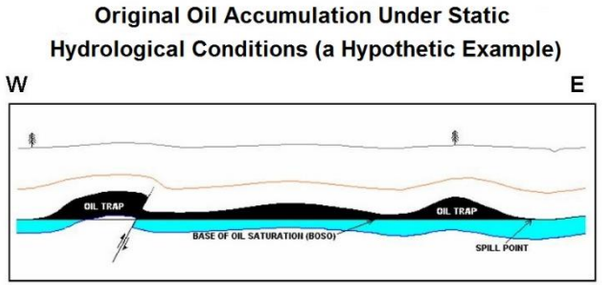
Types of ROZs

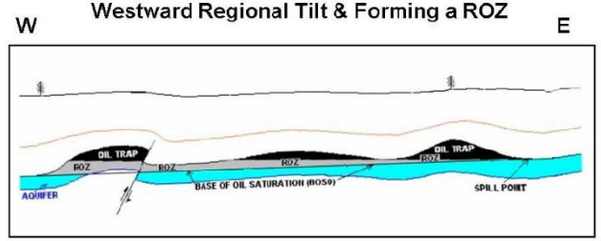
Original Entrapment Formed… then:

- Type 1: Basinwide Tilt
- Type 2: Breached Seal
- Type 3: Laterally Swept



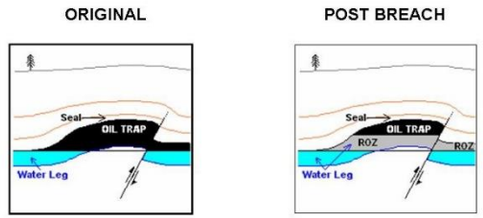
RESIDUAL OIL ZONE: TYPE 1

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



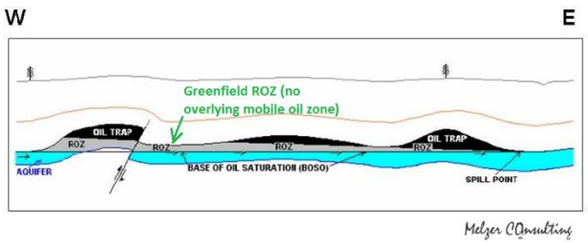
RESIDUAL OIL ZONES: TYPE 2

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



RESIDUAL OIL ZONES: TYPE 3

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



Examples:

Delaware Sands

San Andres Formation; NM Yeso & Abo Fms?

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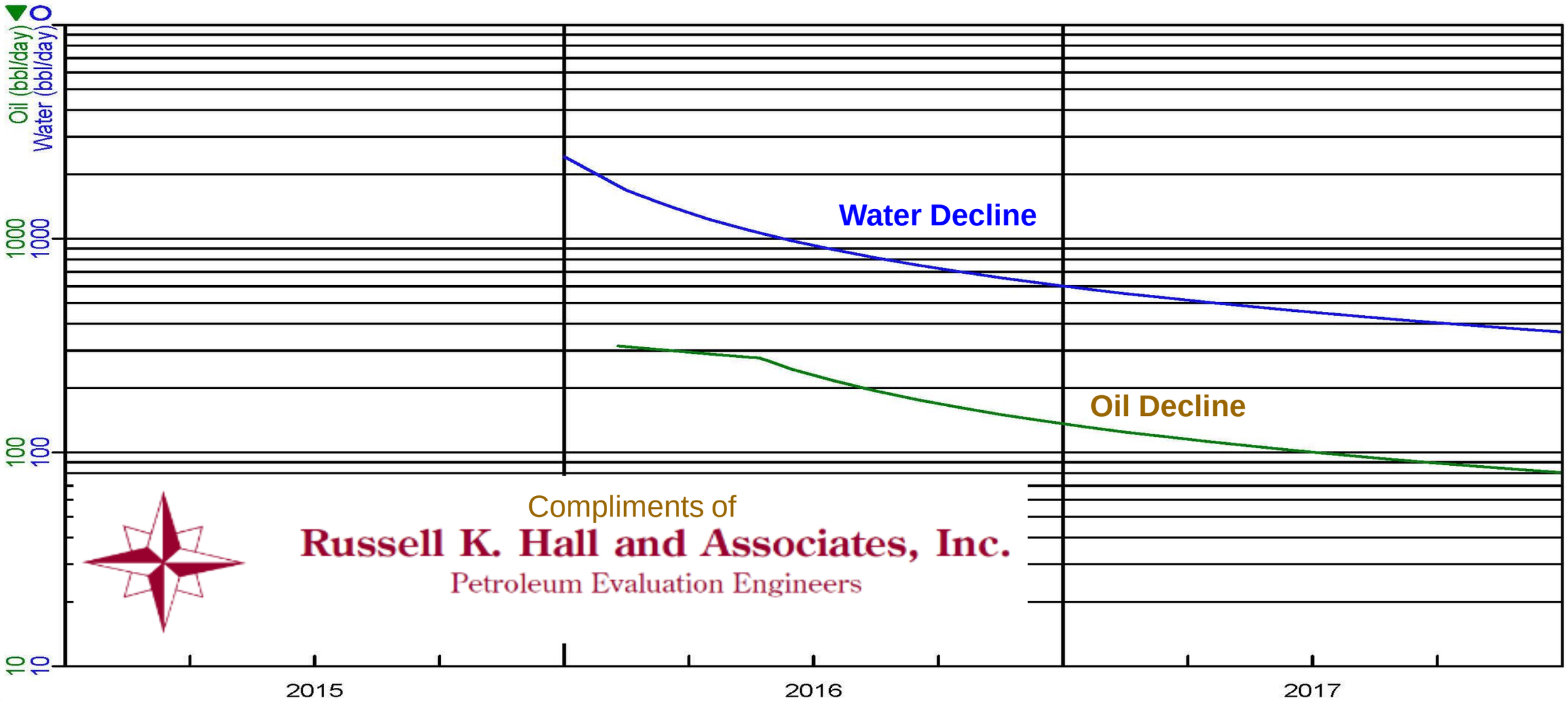
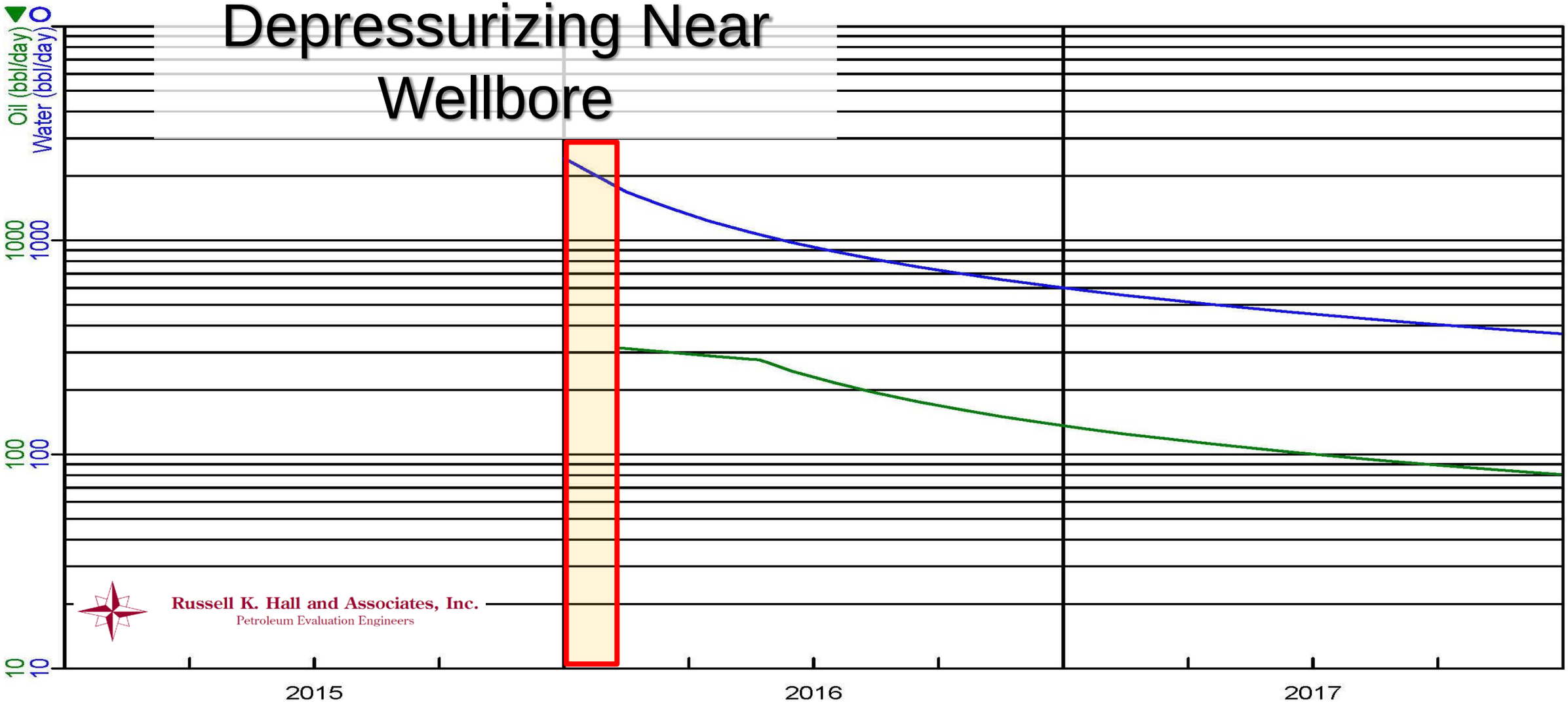
Typical Well Performance (1)



Typical Well Performance (2)

Depressurizing Near Wellbore



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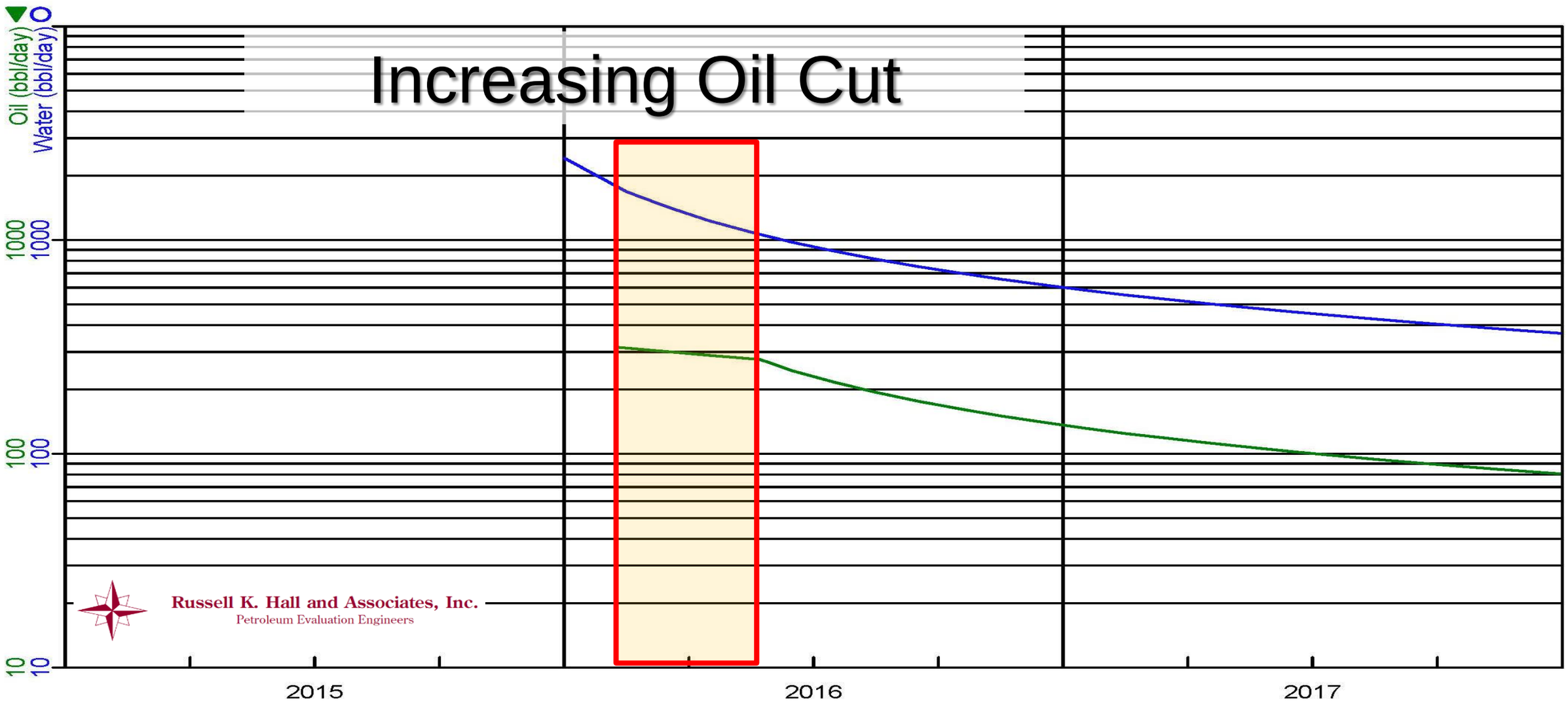
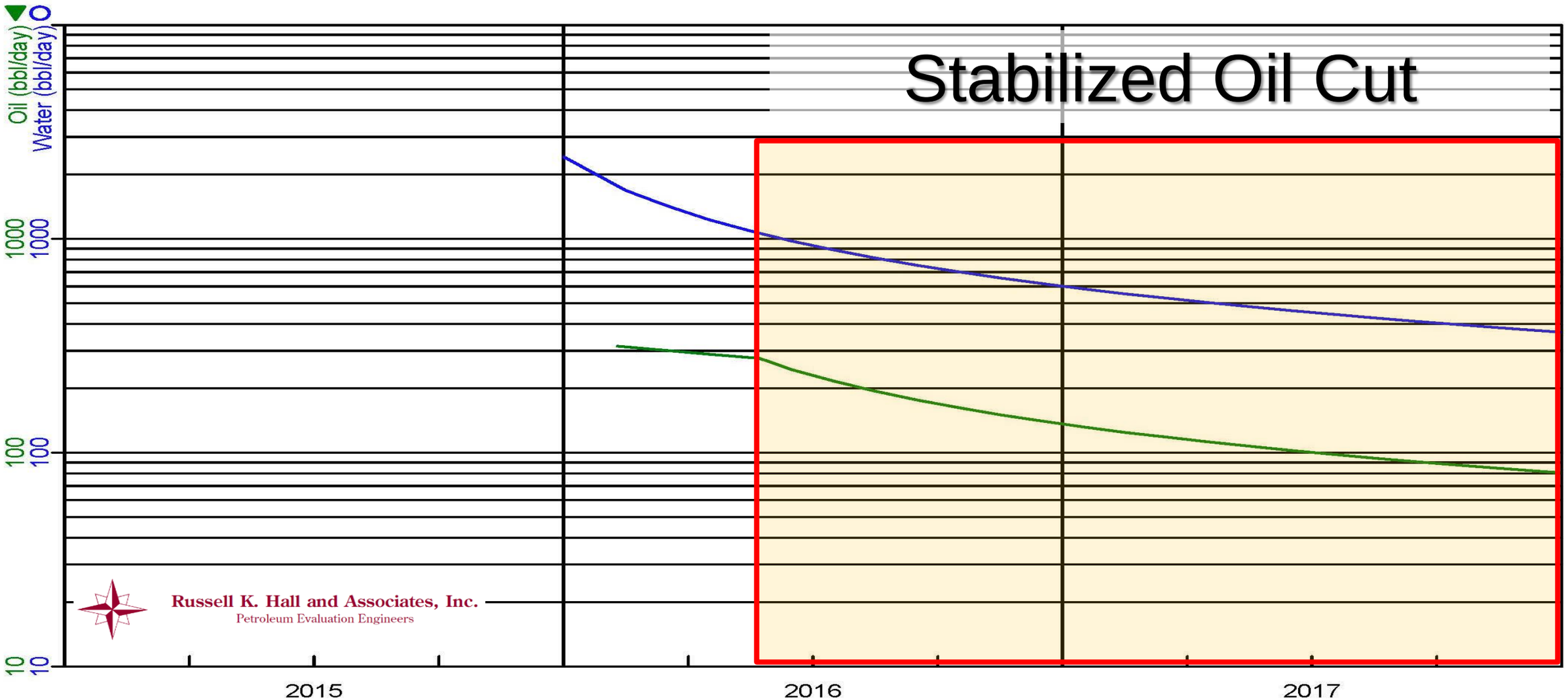
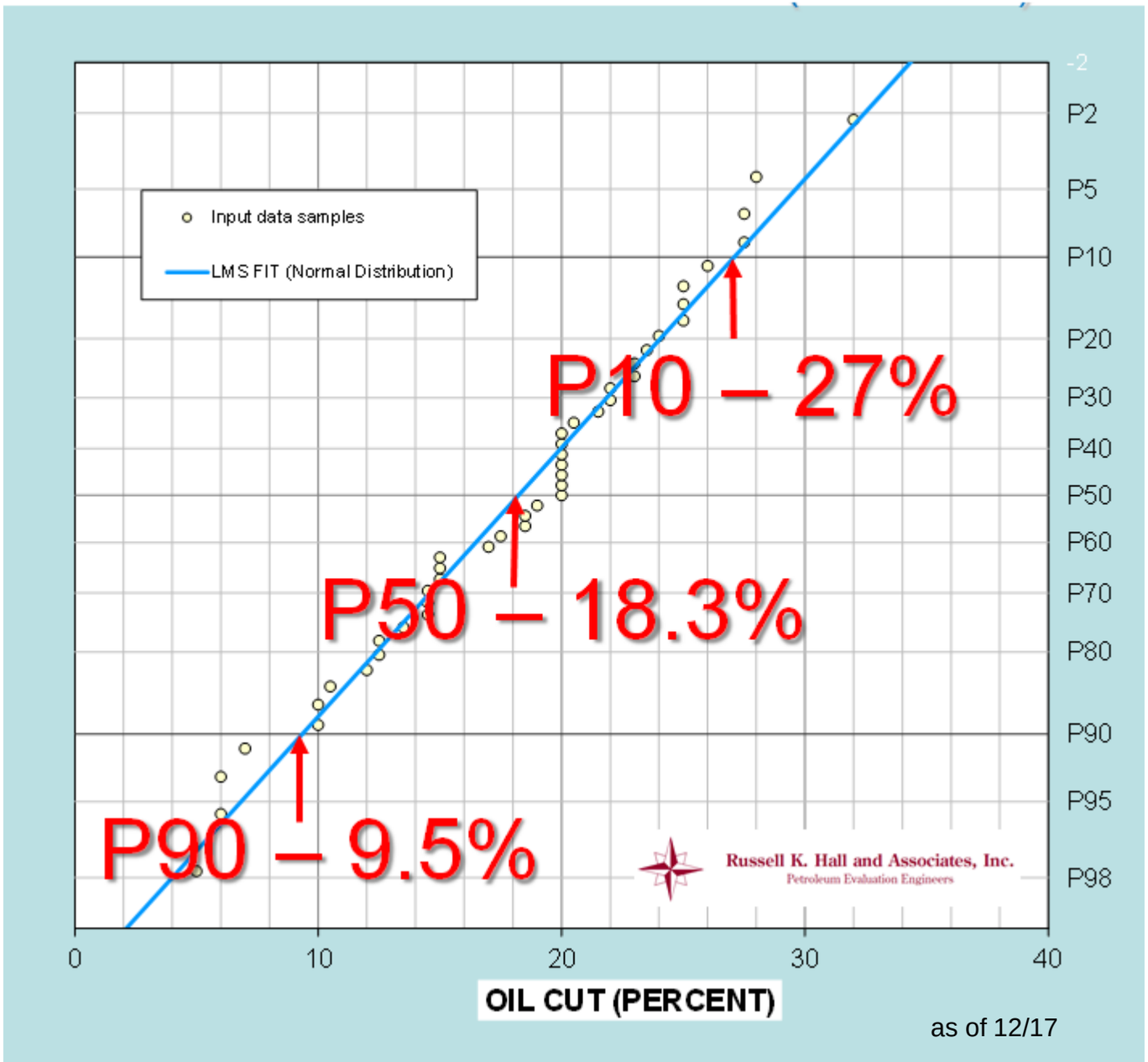
Typical Well Performance (3)



Typical Well Performance (4)



One Out of Five Barrels are Oil

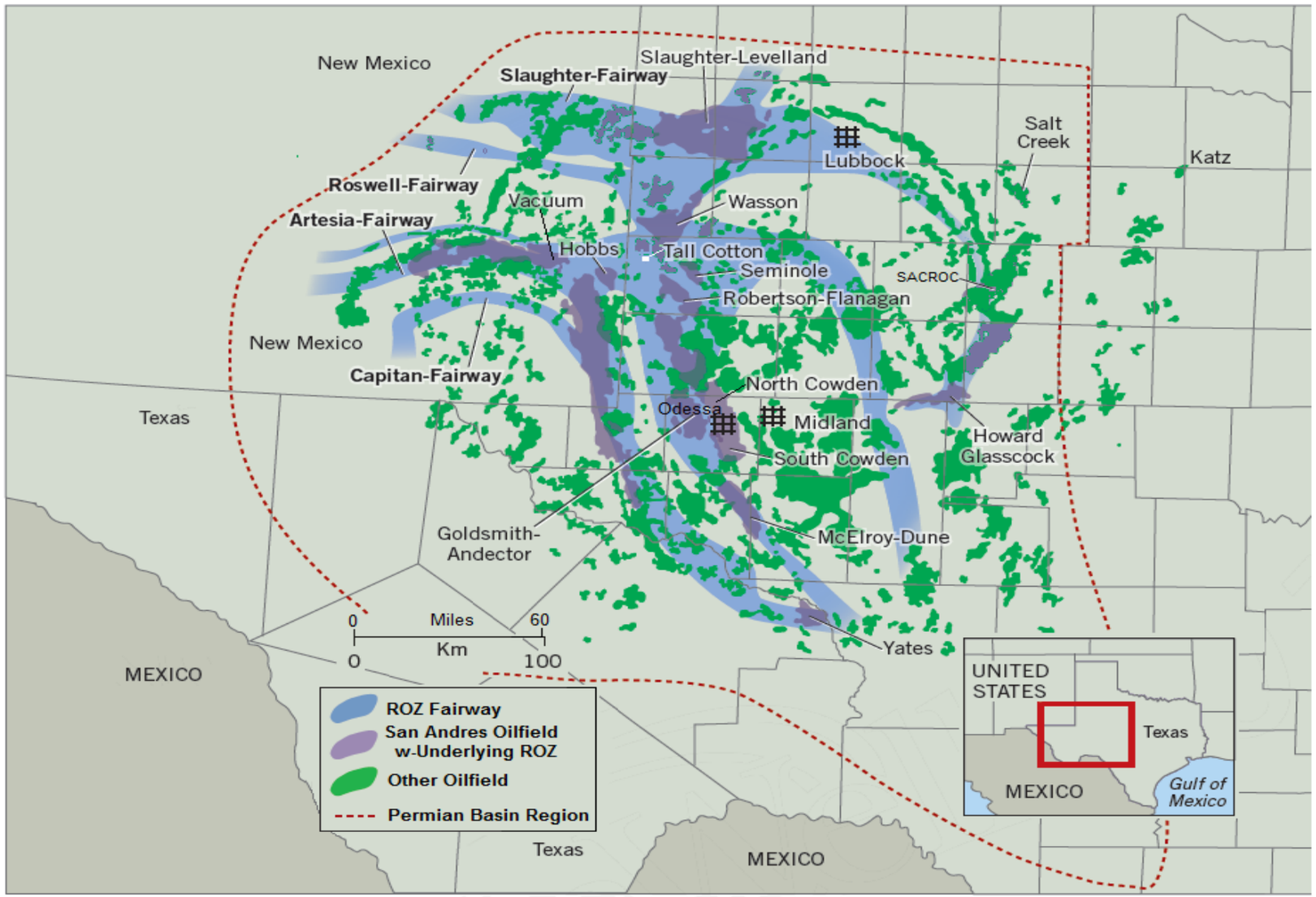


Part 3B

Geographical Data

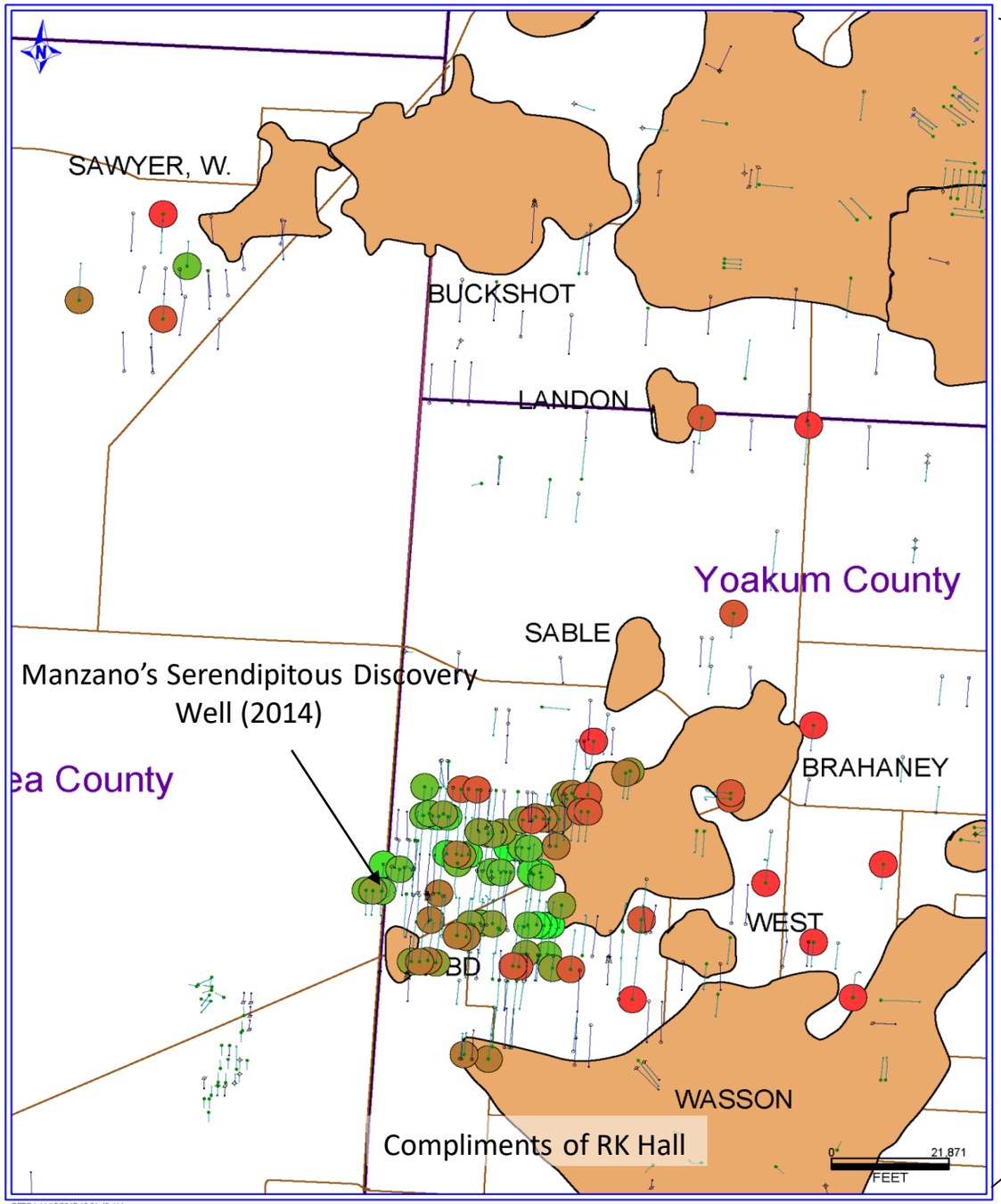
2018 Horizontal San Andres 6-County Study

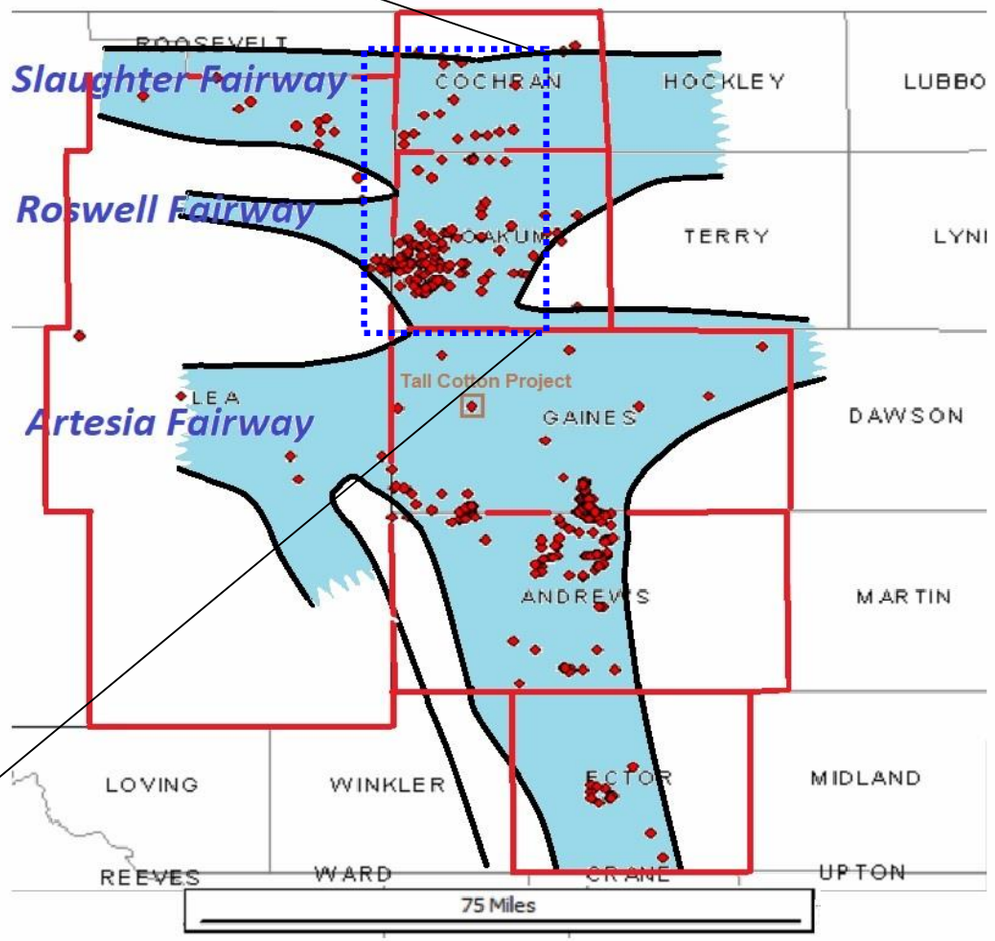
The Latest San Andres ROZ Fairway Map



Source: Melzer Consulting and Research Partnership to Secure Energy for America

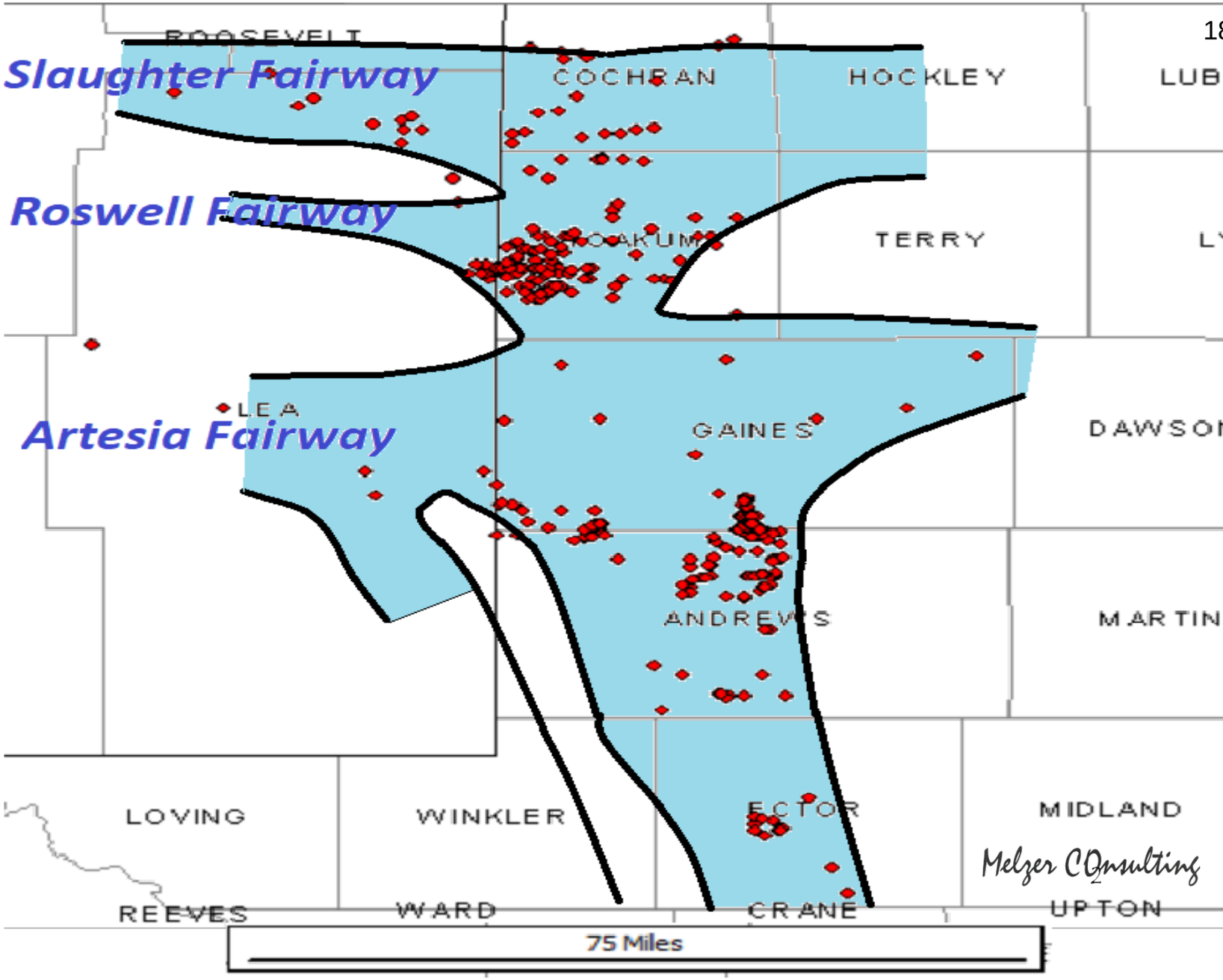
The 6-County SA ROZ Study Area





Happening in the Mapped ROZ Fairways

The San Andres Horizontal Wells and the Residual Oil Zone Fairways[1]



[1)] Identifying and Developing Technology for Enabling Small Producers to Pursue the Residual Oil Zone (ROZ) Fairways in the Permian Basin San Andres Formation, Melzer, L.S. , Trentham, R.C. & Vance. D. (2016) Research Partnership to Secure Energy for America and U.S. Dept of Energy Final Report, www.netl.doe.gov/file%20library/research/oil-gas/10123-17-final-report.pdf

Part 3C

Statistical Data

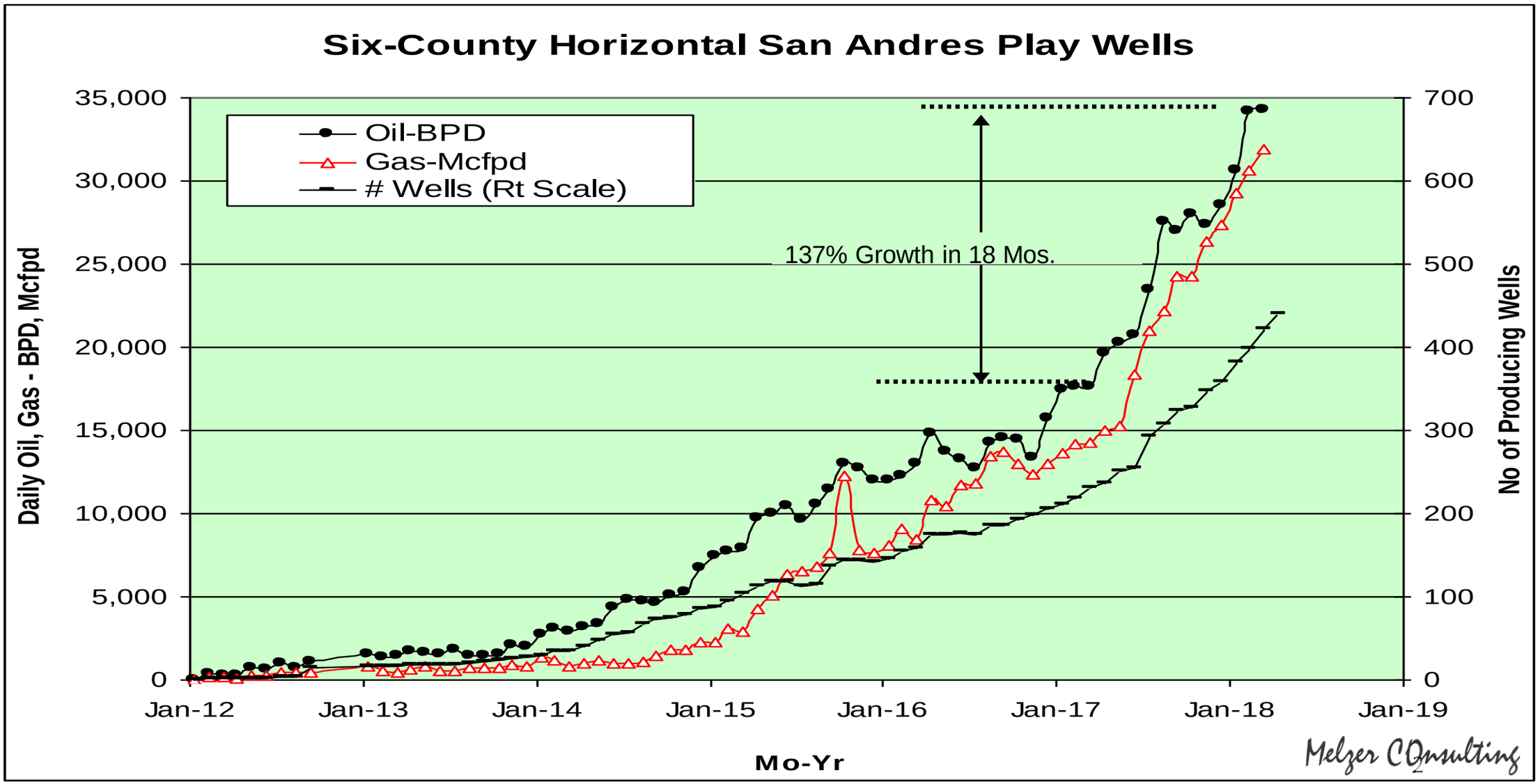
2018 Horizontal San Andres 6-County Study

6-Counties Statistics

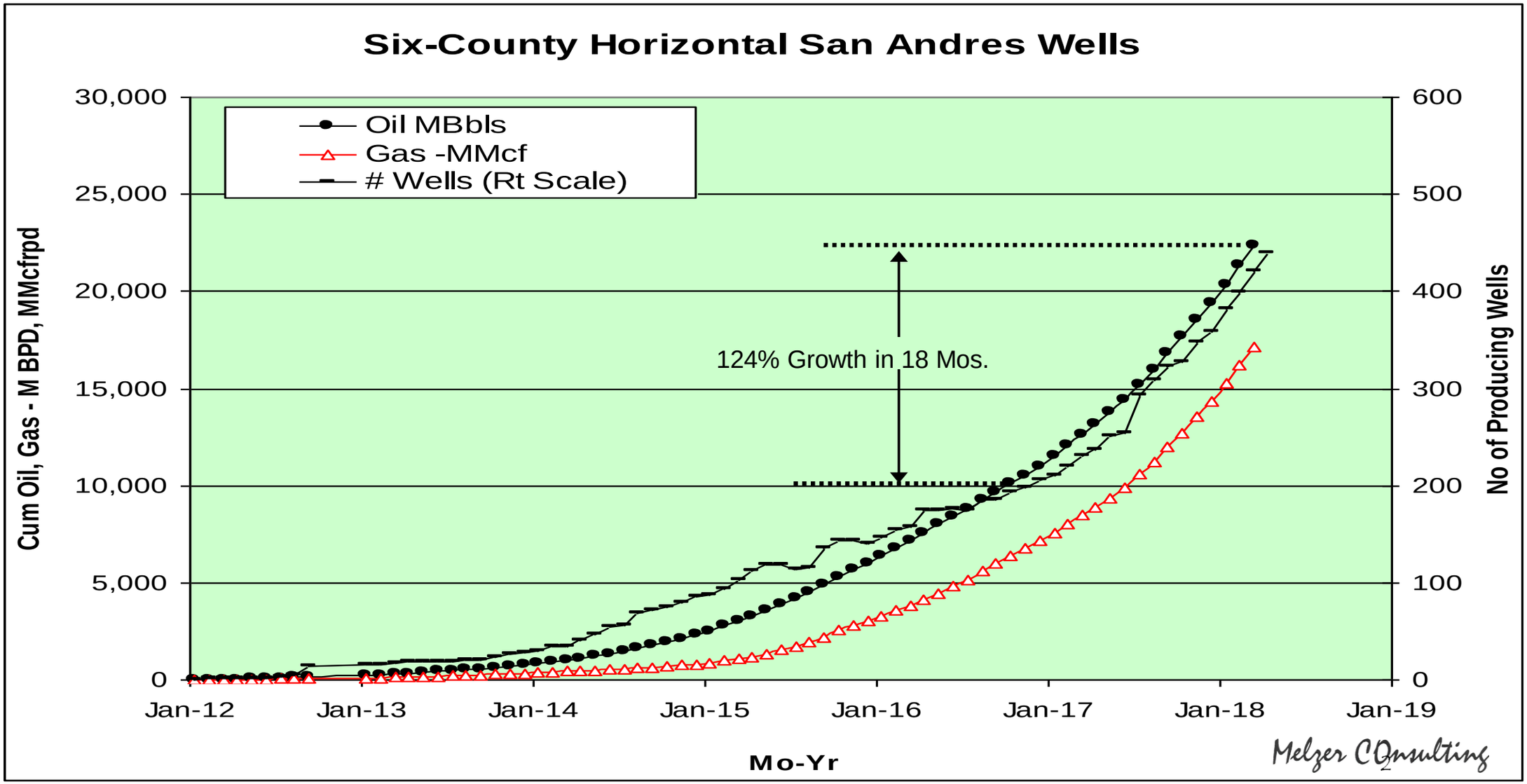
(as of 5/18)

	6-Counties	Yoakum	Andrews	Gaines	Cochran	Lea	Ector
# Wells	433	157	156	61	17	21	21
% of Total Wells		36.3%	36.0%	14.1%	3.9%	4.8%	4.8%
Current Daily Oil (Bo/D)	37,492	21,301	8,310	3,626	995	1,719	1,541
% of Daily Oil/D		56.8%	22.2%	9.7%	2.7%	4.6%	4.1%
Current Crude Oil/Well (Bo/D)		122	53	48	59	103	73
Cum Oil Jan '11 - May '18 (MBo)	26,866	11,799	10,551	1,772	472	830	1,441
Percent of Cum Oil		43.9%	39.3%	6.6%	1.8%	3.1%	5.4%
Current Daily Gas (Mcf/D)	37,262	26,116	4,274	1,905	1,371	1,500	2,096
Percent of Daily Gas		70.1%	11.5%	5.1%	3.7%	4.0%	5.6%
Cum Gas Jan '11 - May '18 (MMcf)	21,477	12,935	4,728	807	467	866	1,674
Percent of Cum Gas		60.2%	22.0%	3.8%	2.2%	4.0%	7.8%
GOR (CF/Bbl)		1,226	514	525	1,379	1,211	1,382

The Permian Basin's Horizontal San Andres Play: Daily Production Growth - 2012-2018



The Permian Basin's Horizontal San Andres Play: Cum Oil Production Growth - 2012-2018



Part 3D

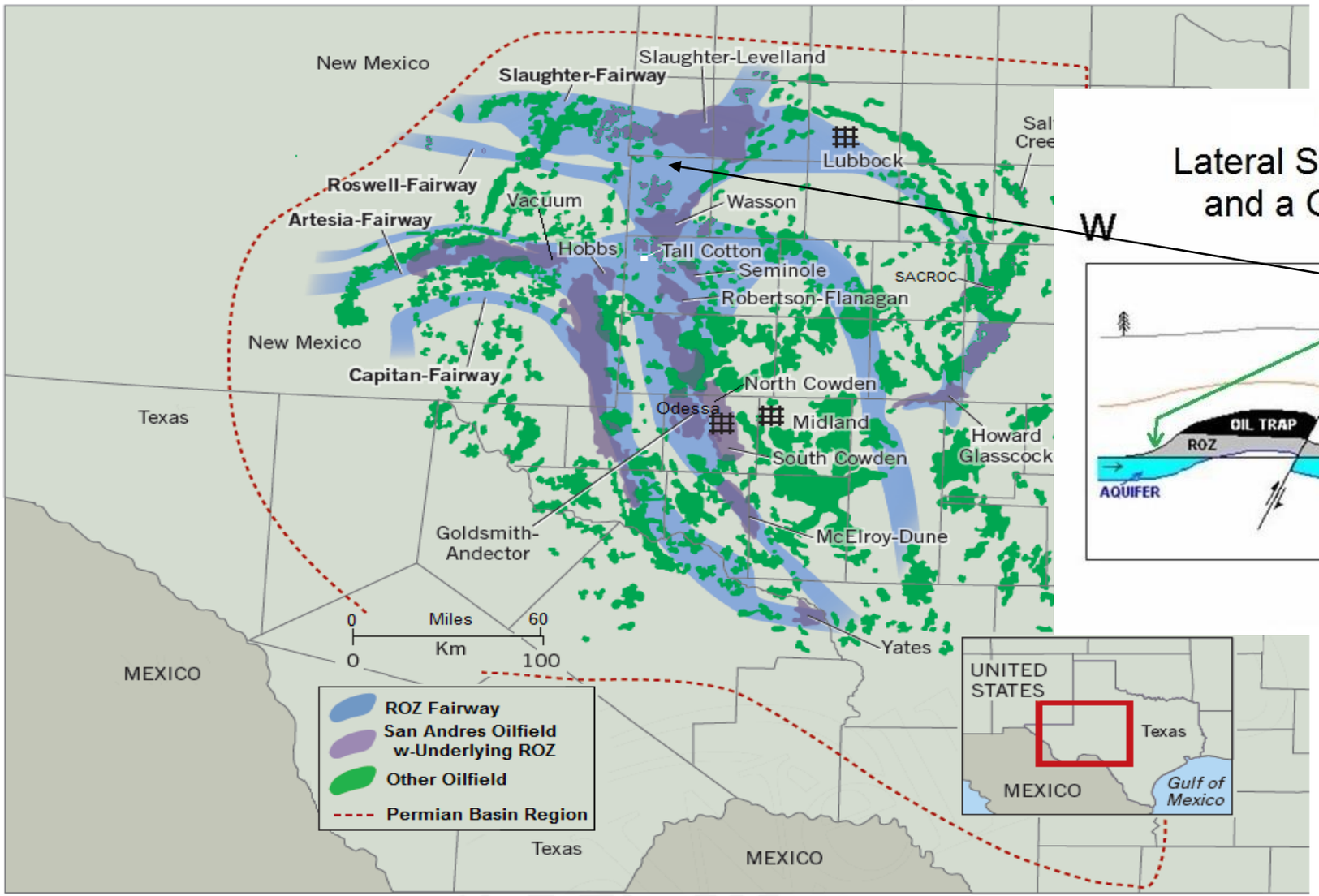
ROZ Science

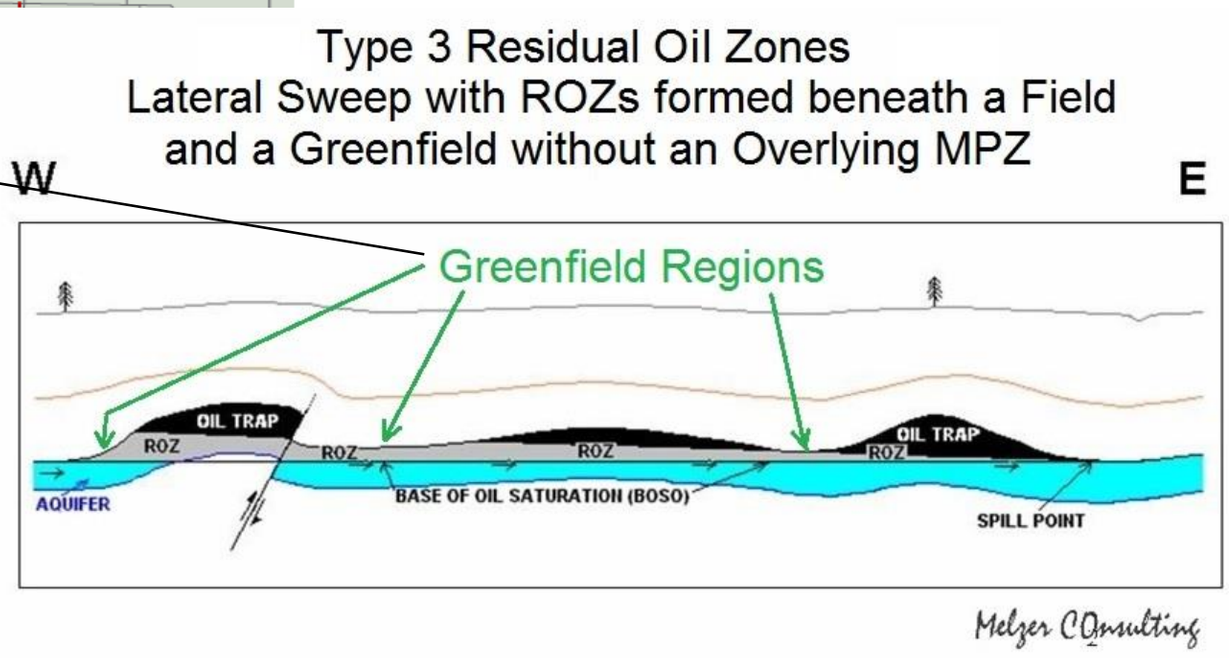
Key Findings from the ROZ Research

Key ROZ Findings (San Andres Formation)

- Type 3 ROZs align along Fairways
- There are both Brownfield and Greenfield ROZs
- The Sweep is Very Slow (cms/year)
- Sweep Maturity and its Effects
  - On Rocks – Later (Extra) Stage of Dolomitization
  - On Oils – Sweep Water Can Remove Light Ends (the Degree of Sweep is Important)
- Anaerobic Bacteria are Present in the Rock Fluids, Live in a “Picnic” Environment in the ROZ and Were Inhibited in the Main Pay Zones
- One Additional Large Impact was that the Microbial Effects Soured the Oil and Gas

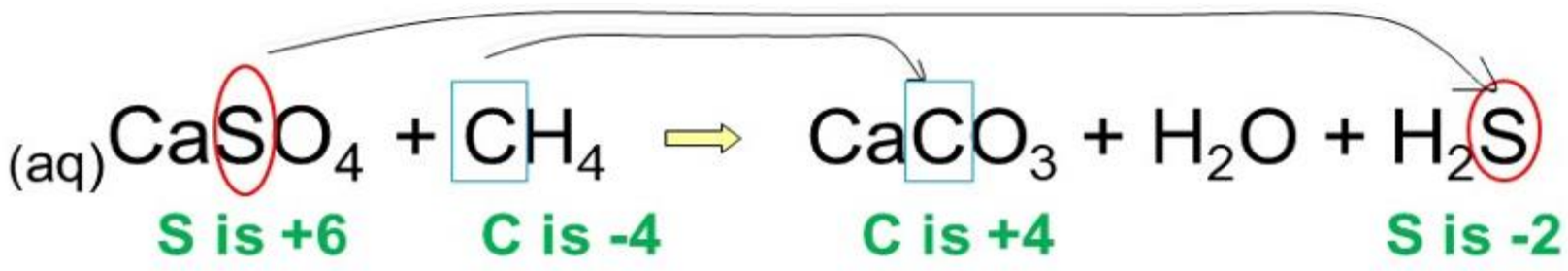
The San Andres ROZ Fairway Map (Note the Fairways Under & Adjacent to the Fields)





Source: Melzer Consulting and Research Partnership to Secure Energy for America

Key Biogenic (Redox) Reaction



We are showing Methane here as the source of carbon but…..it may be other hydrocarbons molecules also

- **Microbes remove 8 Electrons from the Carbon and transfer them to the Sulfur**
- **H_2S is Often Oxidized Back to Elemental Sulfur S^0**
- **Dolomitization Typically Follows as Well**

$$CaCO_3 + Mg \longrightarrow MgCa(CO_3)_2$$

Souring of the Oil and Gas

Free Sulfur Deposits When Collecting In a Static Place (like an Attic)

New Dolomite Surfaces Attract Oil over Water, Re: Oil Wettability

Re: Vance, David (2012), RPSEA II Project Chapter 4

Microbial Self Limitation (MSL)*

- The Previous Process that Generates Hydrogen Sulfide is also the One that Will Inhibit Further Microbial Activity When Concentrating over 100-200 mg/L
  - The Lack of a Flowfield Limits the Effects of the Process In the Static Environments (Isolated from the Sweep) of the Main Pay Zones – i.e., Microbes Go Inactive
  - This also Limits the Degree of Hydrocarbon Modification
  - The Hydrodynamic Environments in the ROZs Create a “Picnic” for the Microbes and Pervasive Dolomitization Occurs

Perpetual Free Lunch:
The Perfect Setting

* David Vance from the RPSEA II Research Report

Summary About The Role of Sulfur Biogeochemistry

- Sulfate Biogeochemical Processing Effects:
  - Porosity Enhancements Driven by Changes in The Rock Mineral Suites
  - Chemical Composition of the Petroleum
    - Some hydrocarbons are altered by sulfate reducing microbes – There is always a natural reaction in an audience that it could ultimately consume most of the oil – but, without very mature flushing volumes…..
    - **That process generates hydrogen sulfide that inhibits microbial activity at concentrations over 100 to 200 mg/L – That prevents significant hydrocarbon alteration/consumption**
  - Mobility of the Petroleum Hydrocarbons
    - Since the Light Ends in the Oil are preferentially Diffused into the Mobile Water, the Retained Oil can Possess Higher Viscosities than the Oil Isolated from the Sweep (e.g, Main Pay Zone Oil)

Section 4:

Other Depressuring/Dewatering Play Analogs
(Optional Section)

These are Two Plays Having Seen Horizontal Well Development in Oklahoma

Hunton Dewatering Play in Oklahoma

- A Lighter Oil than Our San Andres Oil
- A Likely Type 2 ROZ (Breached then Re-healed Seal)

Red Fork Dewatering Play in Oklahoma

- Also a Lighter Oil
- Also a Very Likely Type 2 ROZ

Neither of the Plays Below Have Seen Horizontal Well Development As Yet

Red River B & C ROZ Located Just off of the Crest of the Cedar Creek Anticline in the Williston Basin

- A Very Similar Oil to the San Andres Oil
- A Type 3 ROZ

Tensleep Formation in the Big Horn Basin

- A Heavy Oil
- A Type 3 ROZ
- Thoroughly Swept - Possessing ‘Fresh’ Formation Water

Less Studied, As Yet Undeveloped Analog Depressuring Plays

- PB Yeso in Eddy County (Type 3 ROZ)
- PB Abo in Eddy County (Type 3)
- PB Indian Basin (Type 3)
- Cooper Basin in Central Australia (Type 2)
- Deep Graben in the North Sea (Hybrid Type 3)
- Canyon/Strawn on the East Shelf PB (Hybrid Type 3)
- Baltic Region (Type 2)

Presented at the CO_2 ROZ Conferences

Oh – I almost Left out the Delaware Mountain Group…..But….

Section 5a:

A Transmissive Fracture Case History (San Andres)

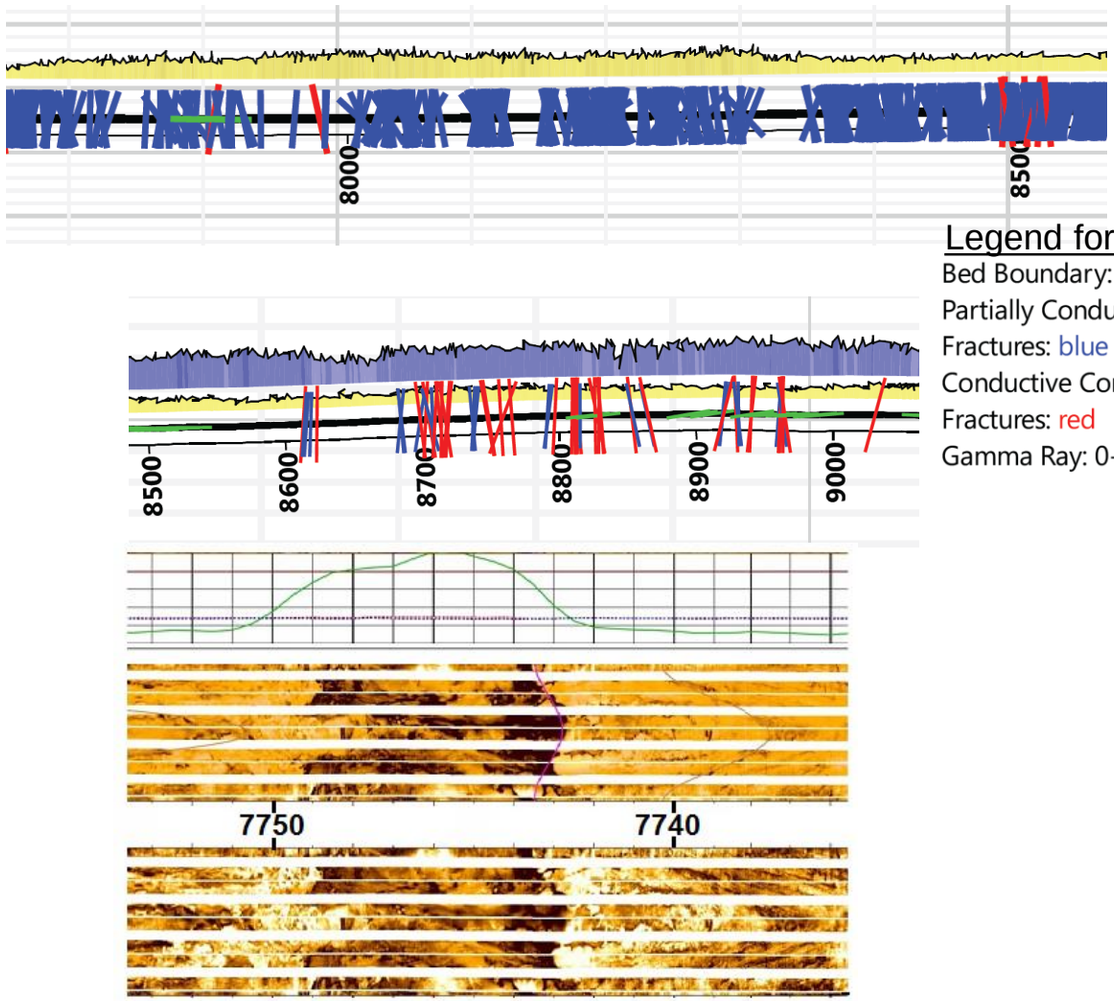
Crustal ‘Recurrent’ Faulting

An Important Categorization of ‘Faults’

A. Localized Natural Fractures

B. Flexural Faults/Fractures Over Deep Seated Structures

C. Recurrent Faults/Lineaments

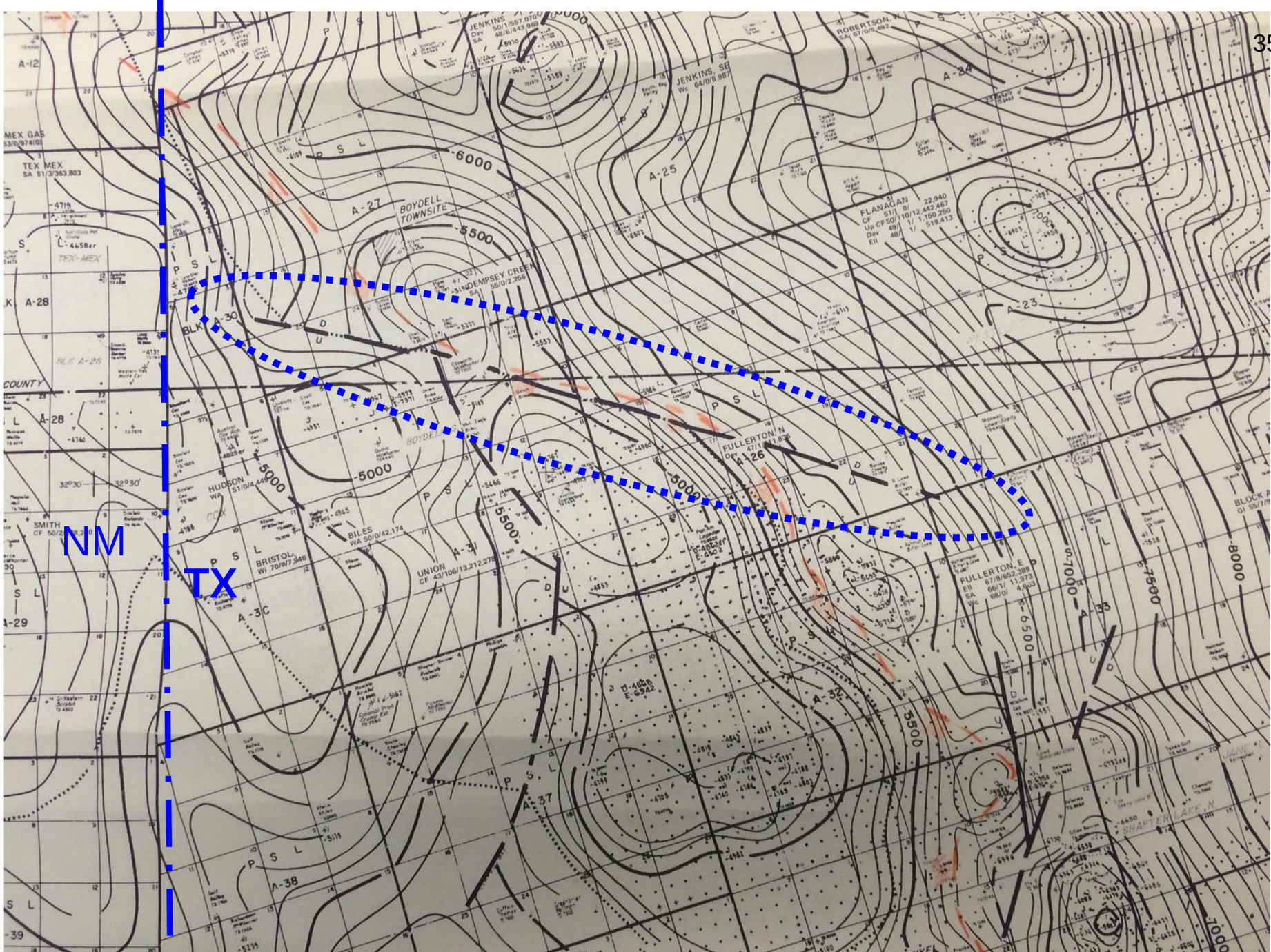


Legend for A&B
Bed Boundary: green
Partially Conductive Fractures: blue
Conductive Continuous Fractures: red
Gamma Ray: 0-150 GAPY

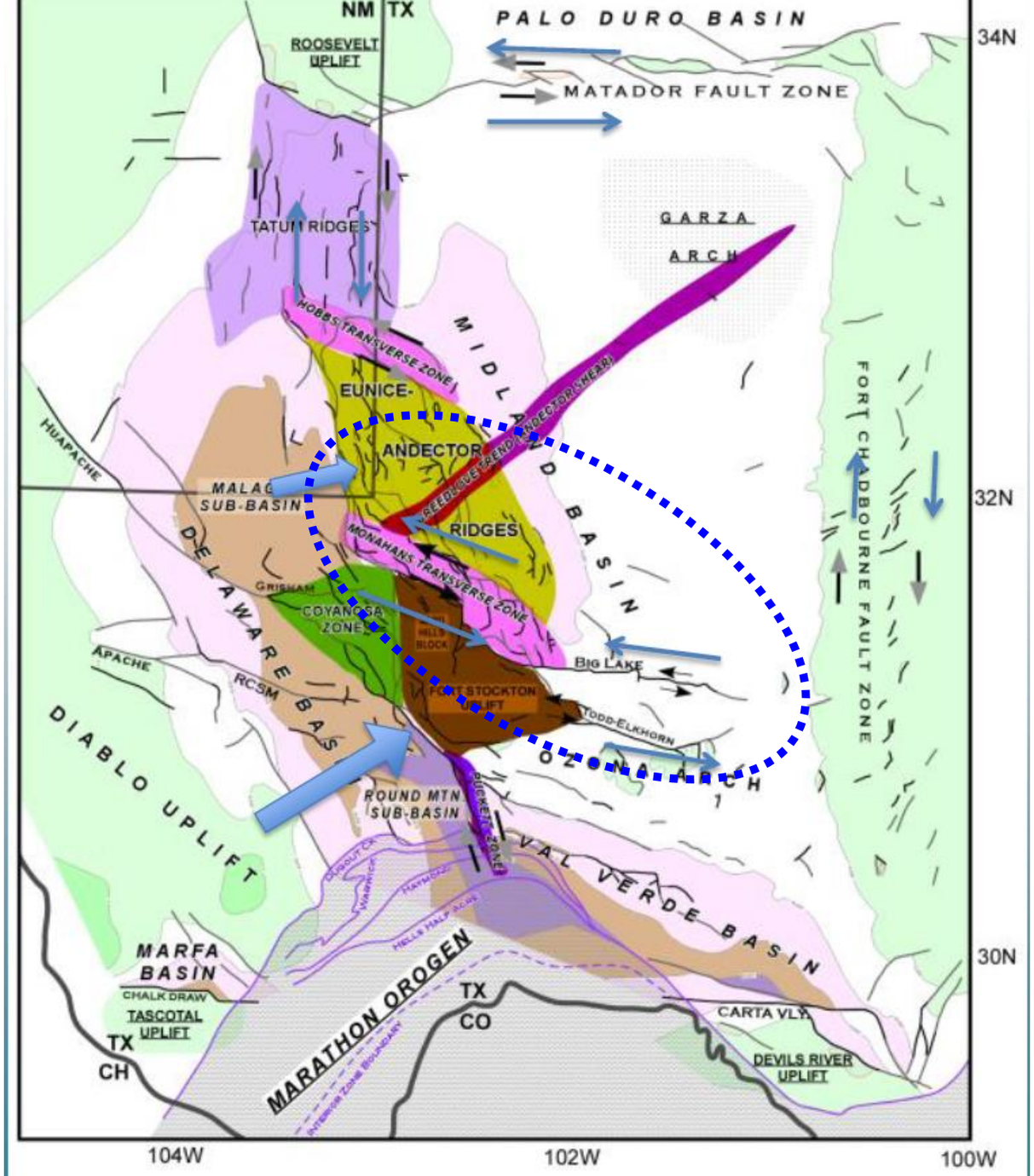
Images Compliments of Schlumberger Oilfield Services

Mapping of a Deep Fault Near the Case History Well

2- & 3-D Seismic Data also Show the Deep Structure but is Proprietary and Cannot be Shown



Permian Basement Left Lateral, Strike Slip Lineaments* with Episodic Reactivation



Ewing, Thomas E. (2013), Three Scales of Late Paleozoic Structures in the West Texas Basin - Description and Genesis, Search and Discovery Article #30273 (2013), http://www.searchanddiscovery.com/documents/2013/30273ewing/ndx_ewing.pdf

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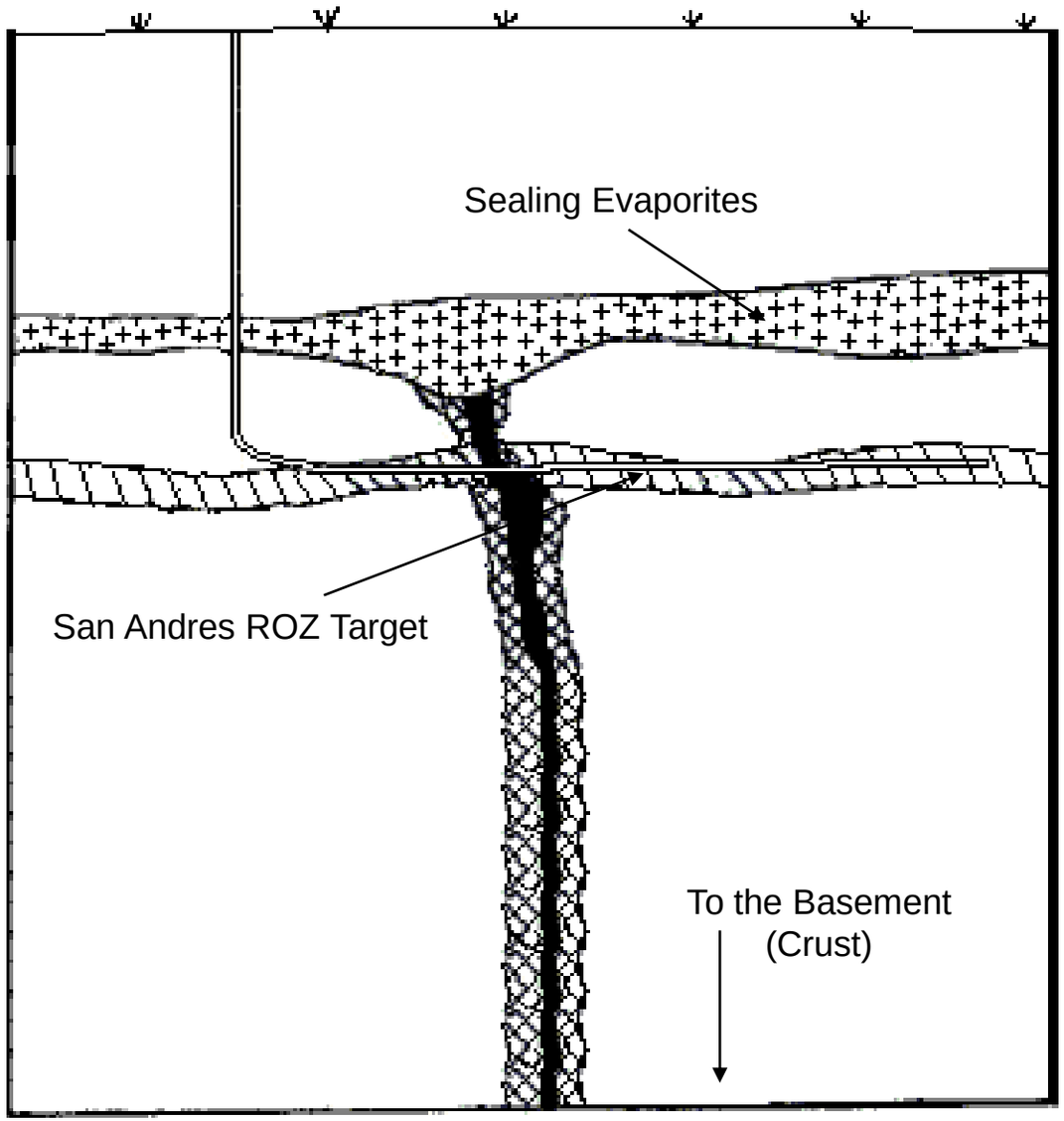
Conceptual View of Deep Seated (Crustal) Faulting, Extending Upwards into the San Andres, Terminating at the Permian Guadalupian and Ochoan Evaporites



With That Background in Mind;

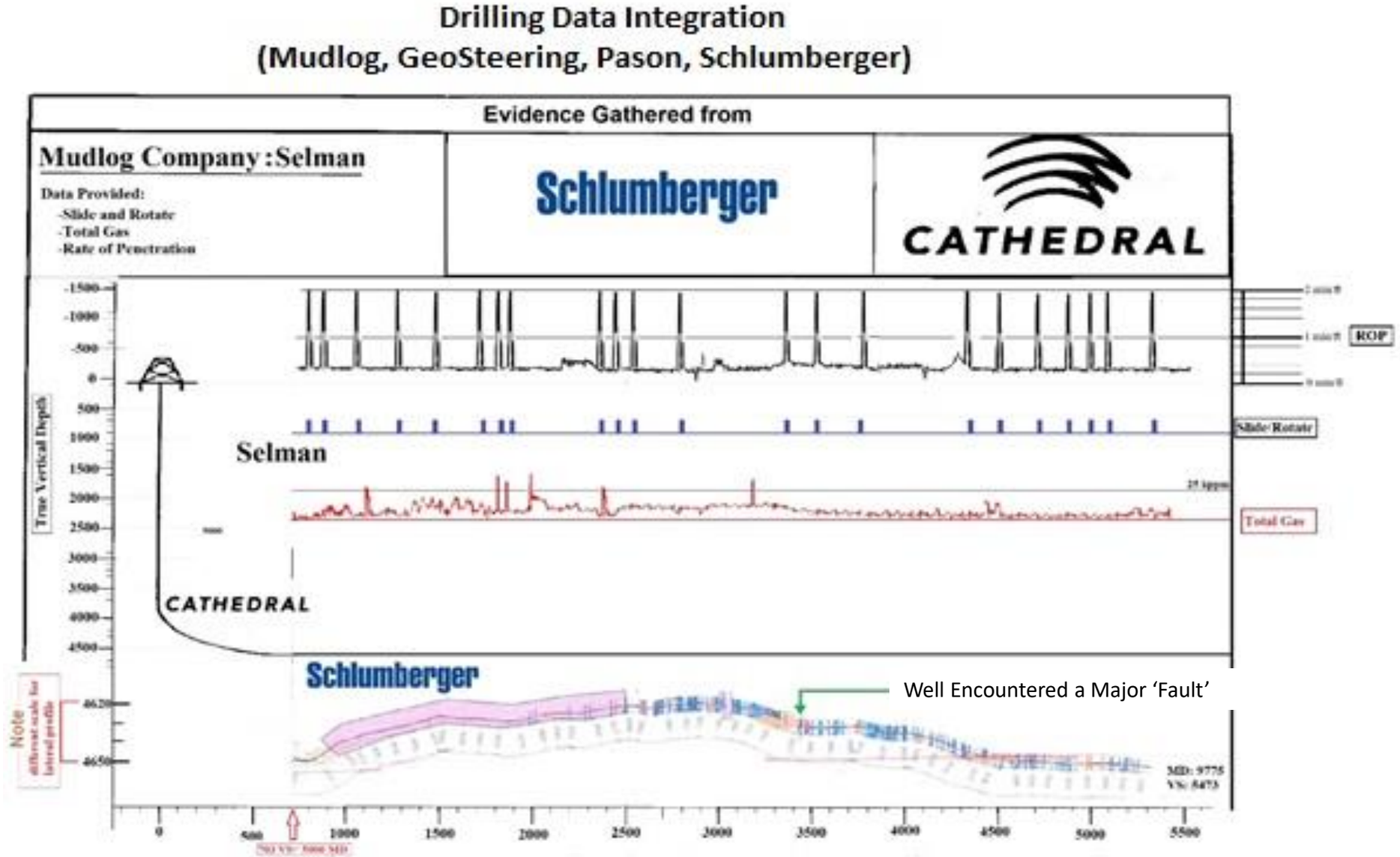
The Case History Well

Located in the Central Portion of the Central Basin Platform

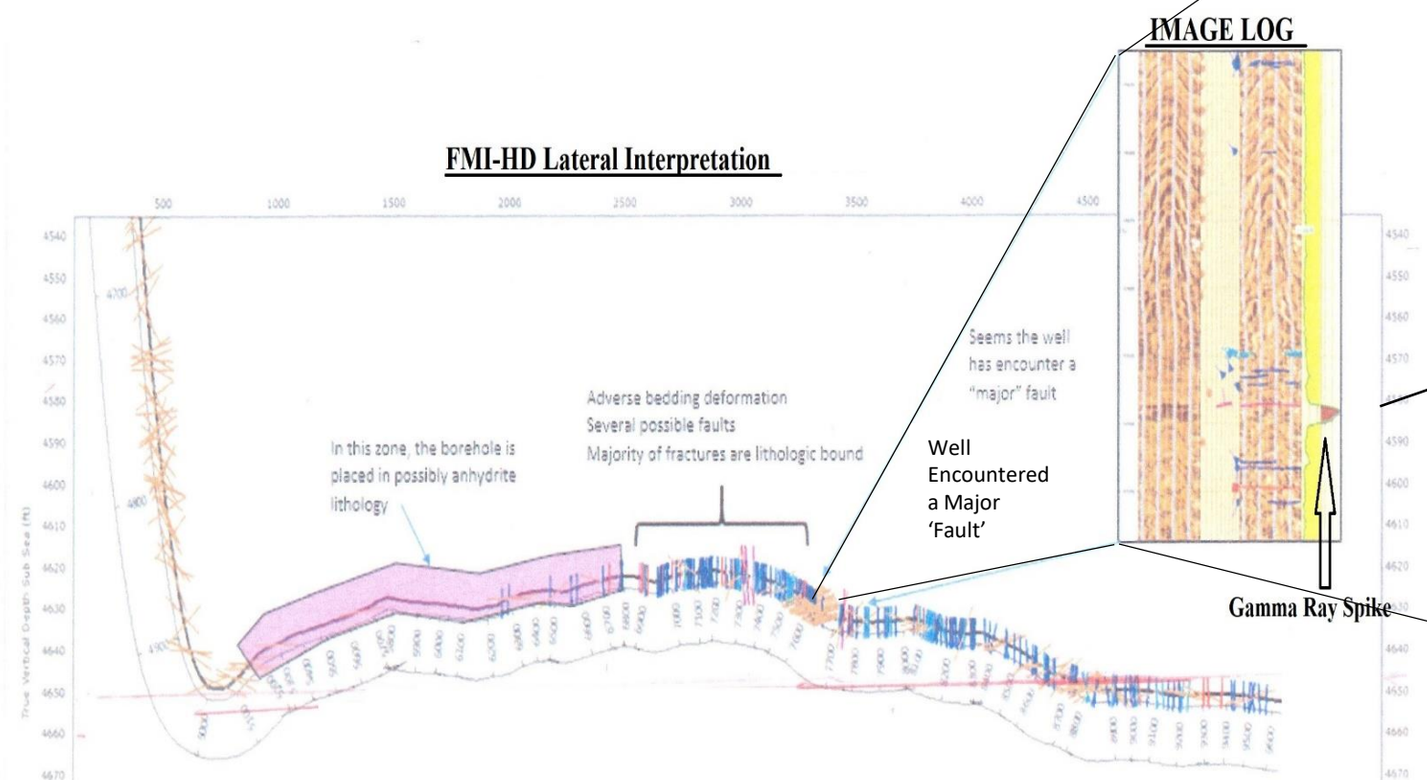
We are accumulating a lot of data during the drilling of a horizontal lateral
Most of it is for Geosteering but also can be used for reservoir insights

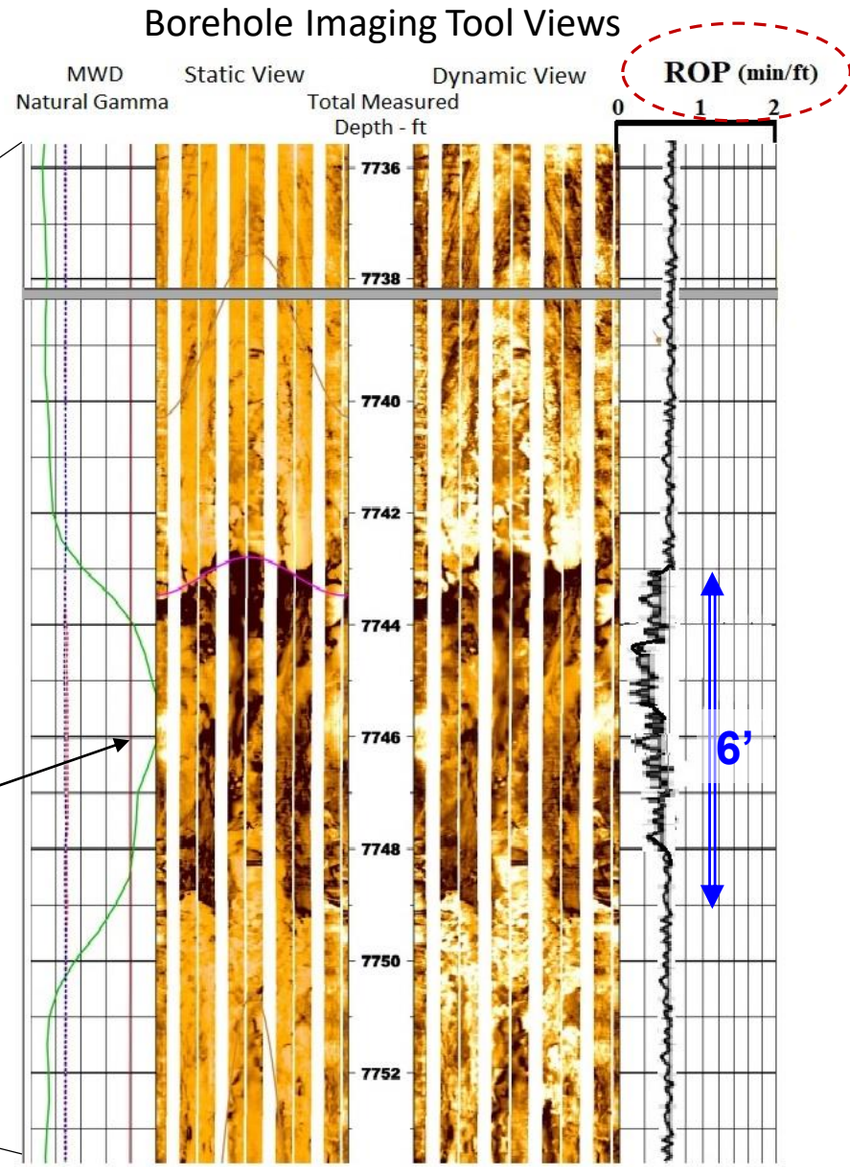
Data Integration Step 1

GeoData Integration



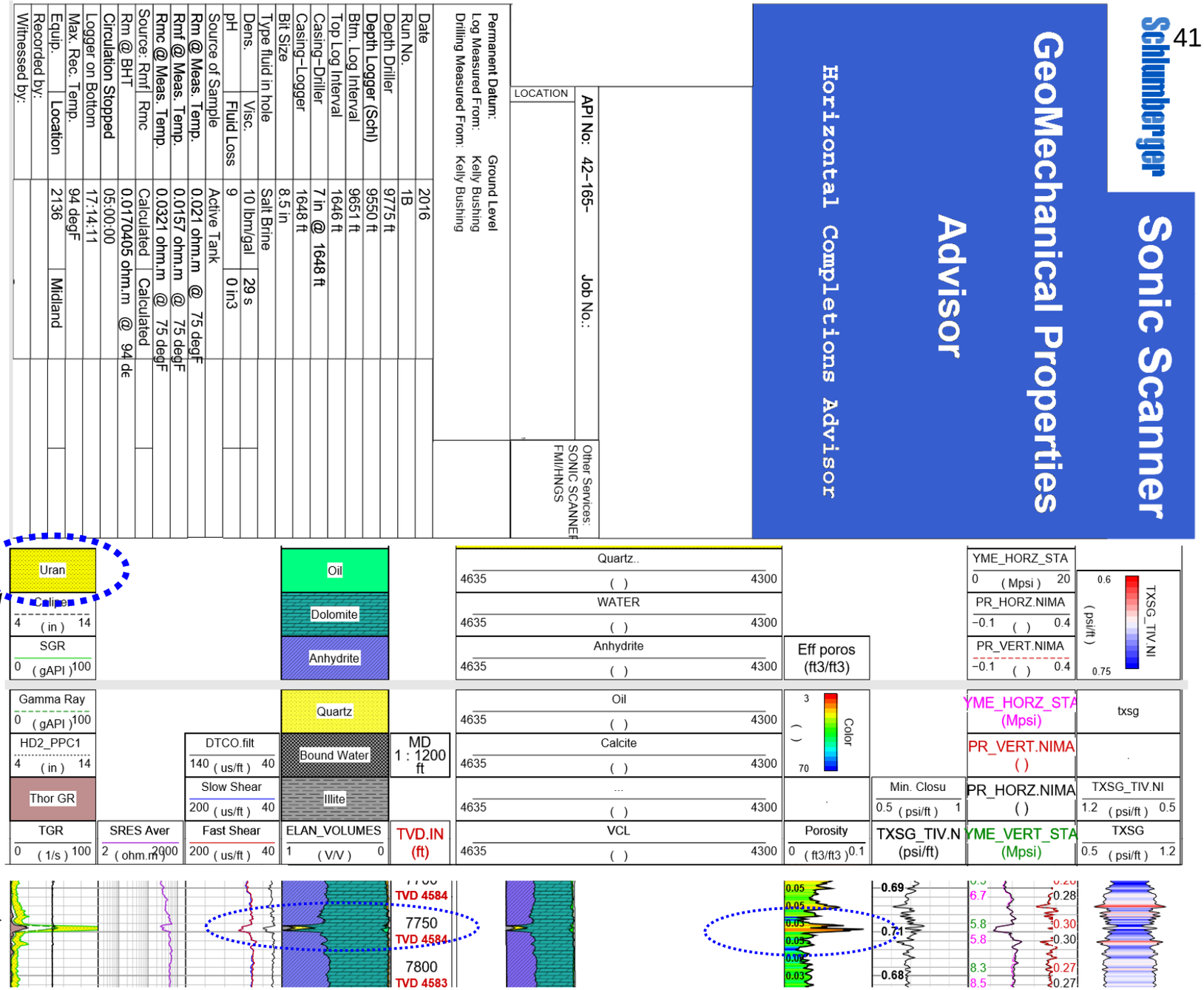
Further Data Integration (Step 1A) with A Detailed Thru Pipe Log Interpretation (Borehole Image Log)





Thru Pipe Gamma Spectrometry (Sonic Scanner) Log

Fracture & Uranium Anomaly



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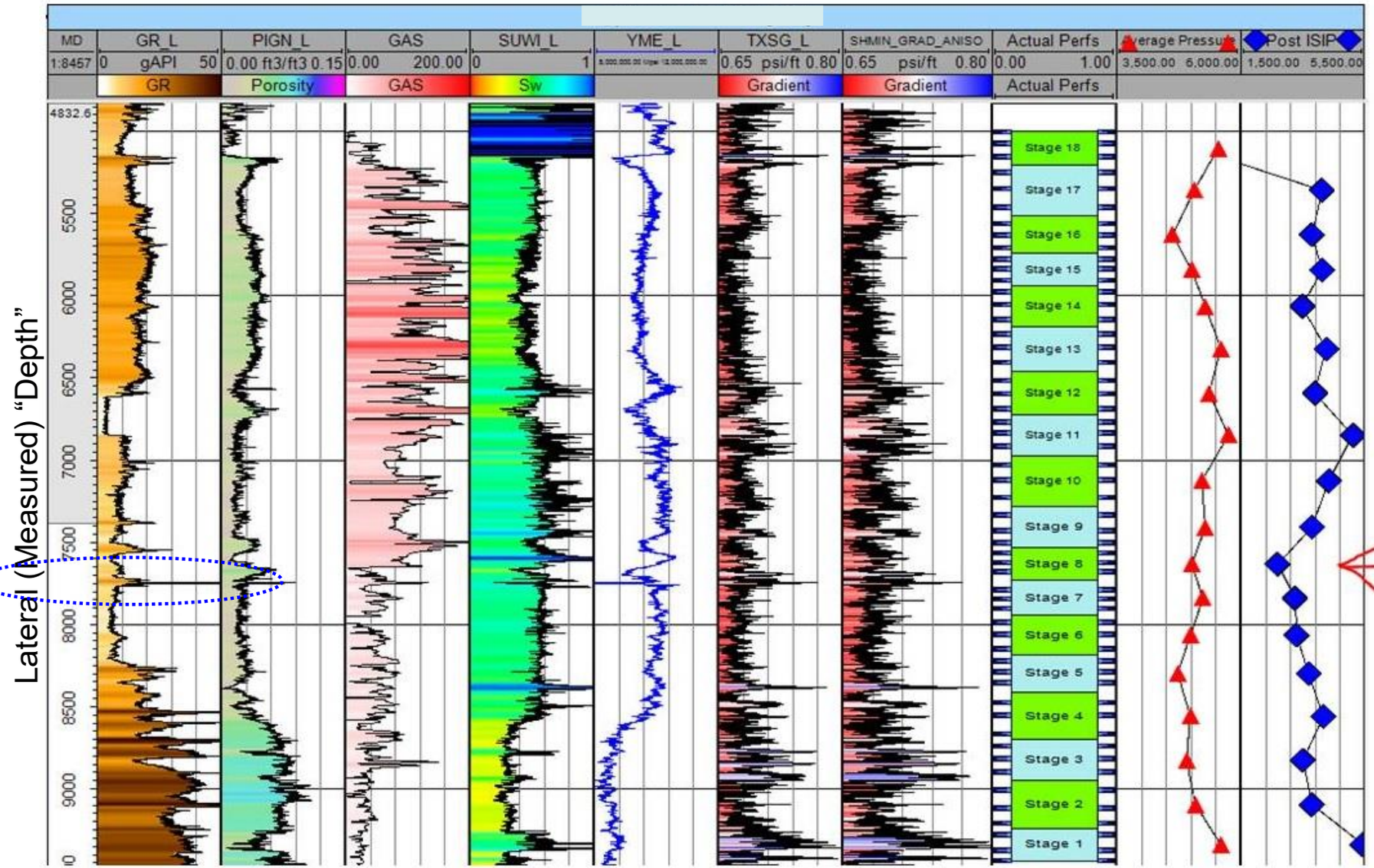
Data Integration Step 2

Adding in the Other Logs and Frac Data



Stage 8 of the Frac Job
(Greatest Bleedoff of Pressure)

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Step 3

Production Data Integration

Martin Water Laboratories, Inc.

Analysts & Consultants since 1953
Bacterial & Chemical Analysis

TO:		LABORATORY NO.	16-08-69
ADDRESS:		SAMPLE RECEIVED:	2016
COMPANY:		RESULTS REPORTED:	2016
LEASE:	Listed	COUNTY, STATE:	Gaines, TX
FORMATION:	SA	FIELD OR POOL:	

DESCRIPTION OF SAMPLES

No. 1 Submitted water sample - taken 8/4/16 from Well #1
No. 2 Submitted water sample - taken 8/4/16 from Well #2
No. 3
No. 4

Chemical and Physical Properties (milligrams per liter)	No. 1	No. 2	No. 3	No. 4
Specific Gravity @ 60°F.	1.0260	1.0225		
pH When Received	6.80	6.70		
Bicarbonate as HCO_3	952	1,098		
Total Hardness, as CaC03	7,300	6,800		
Calcium, as Ca	2,120	1,840		
Magnesium, as Mg	486	535		
Sodium and/or Potassium	12,009	11,126		
Sulfate, as SO4	3,456	3,420		
Chloride, as Cl	20,590	18,815		
Iron, as Fe	20	10		
Barium, as Ba	0	0		
Total Dissolved Solids, Calculated	39,613	36,834		
Hydrogen Sulfide	466	445		
Resistivity, ohms/m @ 77°F.	0.212	0.226		

REMARKS: The undersigned certifies the above to be true and correct to the best of his knowledge and belief.

By: Greg Ogden, B.S.

(432) 683-4521 * 709 W. Indiana, Midland, Texas 79701 * (fax) 682-8819
Remit to Address: P.O. Box 98, Midland, Texas 79702

Anomalously Low Produced Water TDS

Remembering…. this is a Laterally Flushed ROZ with Source Water from the Surface 100 miles away

Step 3 (Cont'd)

Production Data Integration

SPL

Certificate of Analysis
Number: 1030-17010715-001A

Houston Laboratories
8820 Interchange Drive
Houston, TX 77054
Phone 713-660-0901

Analysis Date: 2017

Sample ID:
Station Name:
Station Number:

Sampled By:
Sample Of: Liquid Spot
Sample Date: 2017
Sample Conditions:

Analytical Data

Test	Method	Result	Units	Detection Limit	Lab Tech.	Analysis Date
API Gravity @ 60° F	ASTM D-287	27.30	°		FM	01/27/2017
Specific Gravity @ 60/60° F	ASTM D-287	0.8911			FM	01/27/2017
Density @ 60° F	ASTM D-287	0.8902	g/ml		FM	01/27/2017
Viscosity - Kinematic @ 104°F	ASTM D-445	10.39	cSt		FM	01/27/2017
Viscosity - Kinematic @ 104°F	ASTM D-445	60.21	SUS		FM	01/27/2017
Calculated Dynamic Viscosity @ 104°F		9.25	cP			

Anomalously High Oil Viscosity

Aggregating the Case History Conclusions (1)

- The Horizontal Well Encountered a 6’ Wide Fracture Zone
- The San Andres Documented Fracture Appears to be Related to a Basement Lineament (One of a Series of PB Left-Lateral Strike Slip Faults) that has Likely moved Repeatedly Over Geologic time
- The Well (Fracture?) Produces Low Salinity Formation Water and the Multi-Pore Volume Lateral Sweep has Lowered the Oil Gravity and Raised the Viscosity of the Oil in the Formation

Aggregating the Case History Conclusions (2)

- The Well Had the Advantage of Thru Pipe Image and Sonic Scanner Logging
- The Wells Making Anomalously Low Salinity Water and High Viscosity Oil Proved to be Uneconomic
- Has this “Failed” Well Opened the Door to a Greater Understanding?
- With a Mass Spectrometry Mud Log to Find the Fractured Interval and Applying Completion Engineering, Could the Well’s Economics Been Saved?

Section 6:

Mass Spectrometry Mud Logging's Potential to Add Valuable Contributions to Reservoir Understanding and Completion Engineering?

Why Mass Spectrometry (MS) Mud Logs?

- MS has become “Portable” and Can go Now to the Field for Real Time Mud Gas Observations
- With Proper Placement of the Gas Collector, the Range of the Various Components in Mud Gas Sensing is Dramatically Improved
  - Key Compounds
    - Full spectrum of C1-C10
    - Helium
    - Sulfur (e.g. H_2S)
    - Hydrogen
- Analysis of Those Components and Ratios of Various Components Can be Illuminating Since Oils in the San Andres Laterally Swept ROZs are Quite Different than Our Experience with the Main Pay Zone Oils
- Can Some of the Same Observations in San Andres Laterals be Applied and Add Value to the Shale Plays?

One Specific Application May Involve Our New Found Ability to Get Real Time Measurements of Helium from the Mud Gas (1)

- The Theory is that Helium Must First Come from the Crust
- It is a Decay Product of “Primordial” Uranium and Thorium (Plus Minor Contributions from a Few Other Radioactive Elements {Isotopes})
- Uranium is Soluble in Water
- Uranium Loves to Attach to Carbonaceous Matter (e.g., Oil, Coal)
- Upon Decay, Ur & Th Emit an Alpha Particle (Helium) and also a Gamma Ray of Specific Energy

One Specific Application May Involve Our New Found Ability to Get Real Time Measurements of Helium from the Mud Gas (2)

- You May Recall, We Have Used this Gamma Emission Property in our Spectrometry Gamma Logs to Identify what Common Element(s) are Emitting the Gamma Rays (Potassium, Thorium, Uranium)

- Advances in Mud Logging Can Also Record any Helium Present in the Mud Gas

Theory: A Direct Pathway to the Basement Can Offer an Anomaly in both Helium and Uranium Gamma Readings. Coupling this with Our Other Logging Tools (Image, Porosity, Sonic), can we Now Identify Transmissive Fractures to the Crust?

For Separate Reading Later (if needed)…

Background on Uranium Decay Products

- Uranium-238 decays by alpha emission into Thorium-234, which itself decays by beta emission to Protactinium-234, which decays by beta emission to Uranium-234, and so on…
- After several more alpha and beta decays, the series ends with the stable isotope lead-206

- Alpha decay or α-decay is a type of radioactive decay in which an atomic nucleus emits an alpha particle **(helium nucleus)** and thereby transforms or 'decays' into a different atomic nucleus, with a mass number that is reduced by four and an atomic number that is reduced by two.
- When an atom emits an alpha particle, the atom's mass number decreases by four due to the loss of the four nucleons in the alpha particle. The atomic number of the atom goes down by exactly two, as a result of the loss of two protons – the atom becomes a new element. Examples of this are when uranium becomes thorium, or radium becomes radon gas due to alpha decay.

- Alpha particles are commonly emitted by all of the larger radioactive nuclei such as uranium, thorium, actinium, and radium, as well as the transuranic elements. Unlike other types of decay, alpha decay as a process must have a minimum-size atomic nucleus which can support it. The smallest nuclei which have to date been found to be capable of alpha emission are the lightest nuclides of tellurium (element 52), with mass numbers between 106 and 110. **The process of emitting an alpha sometimes leaves the nucleus in an excited state, with the emission of a gamma ray removing the excess energy.**

As We Have Already Observed…

- In a San Andres ROZ Case History, We have Identified a Large Natural Fracture that had Abundant Characteristics of a Transmissive Fracture Connected to the Crustal Rocks
  - Uranium Gamma Ray Anomaly
  - ROP ‘Chatter’
  - Image Log Showing Evidence of Gouge Fill
  - Sonic Velocity Anomaly
  - Anomalously Low Salinity Formation Water and Higher than Normal Oil Viscosity
  - Located Over Documented Deep Structures and Near a Documental Left Lateral Recurrent Fault

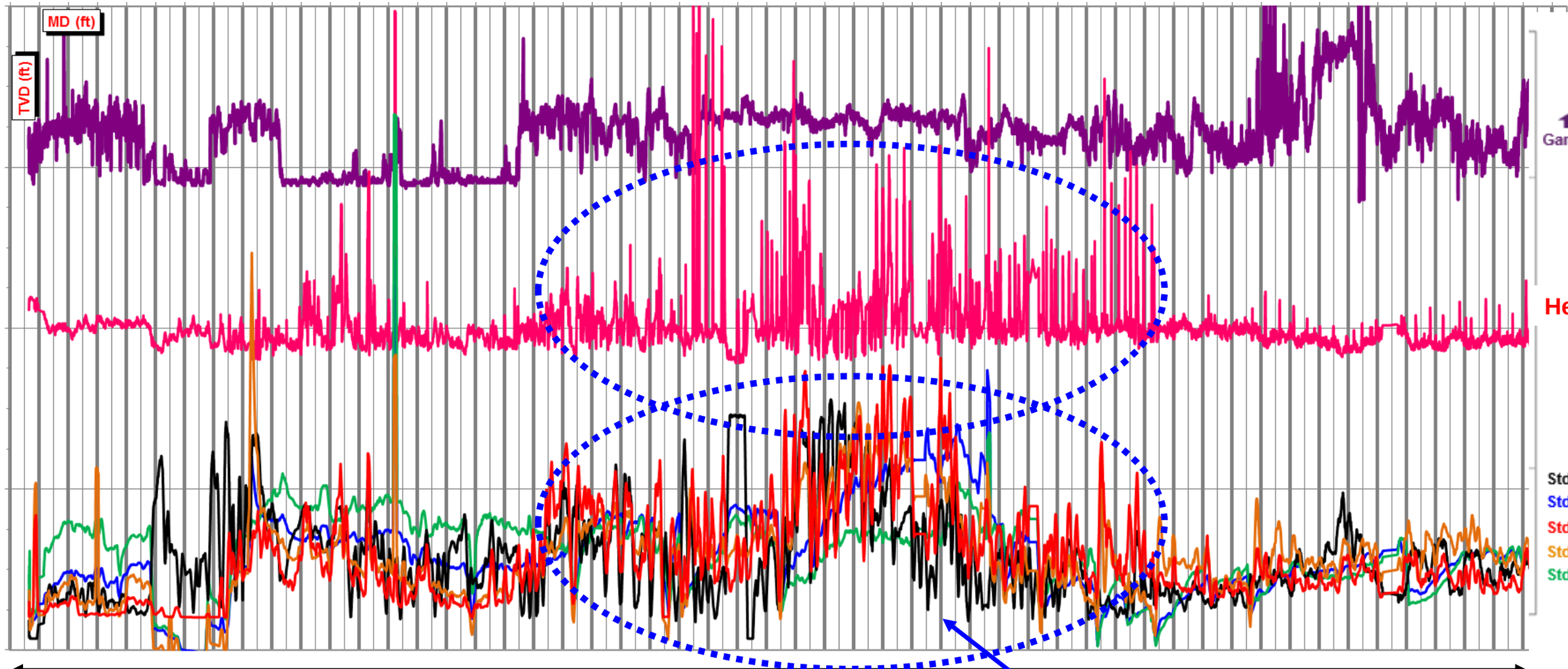
Had we Had a Helium Detector, Would we have Completed the Story of a Connection to the Crust Implied by the Uranium Gamma Spectrometry Log?

So….What Does this Matter to Shales?

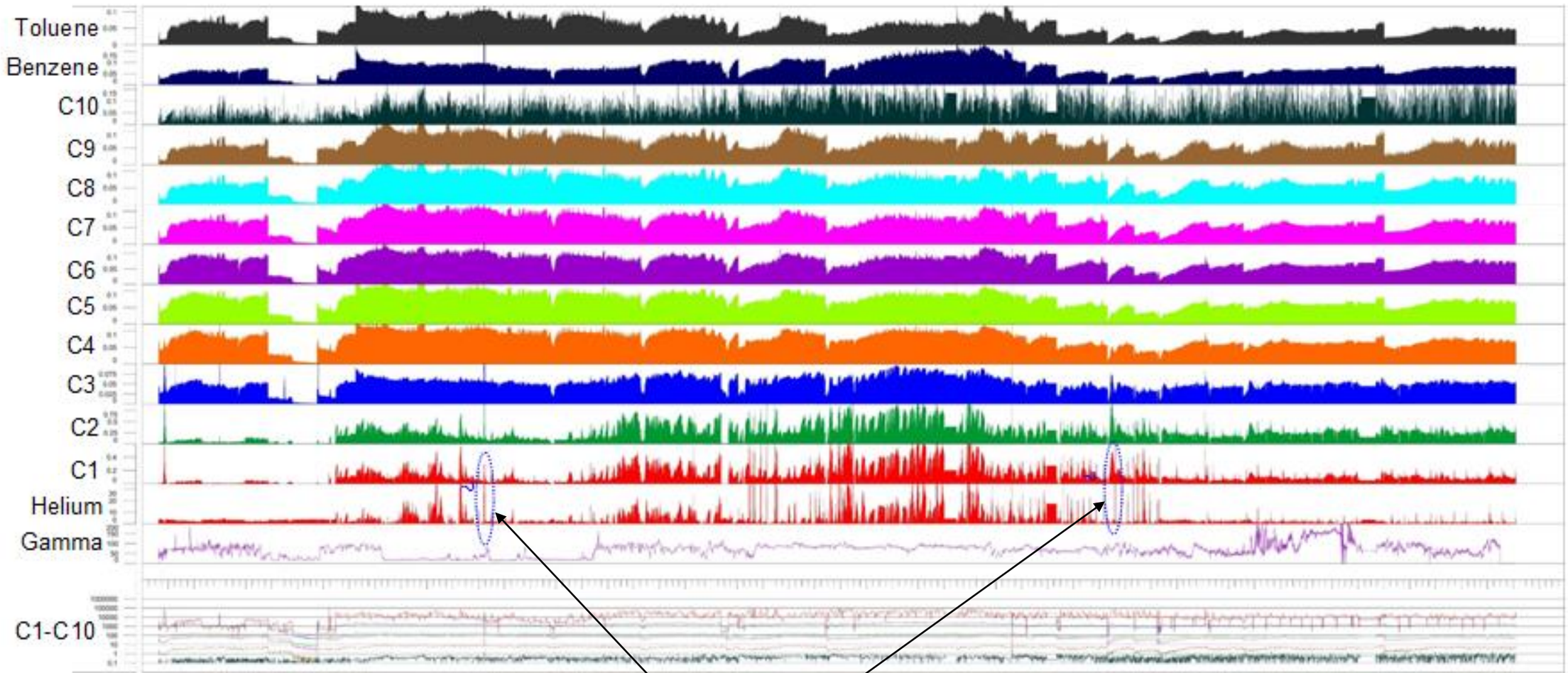
Wrapup Section (7):

Crustal Connections and Sour Wells in the Shales

We Also Occasionally See Helium in the Shales: Mass Spec Mud Log in a Shale Lateral – Example



Mass Spec Mud Log Strip Along Lateral - Example 2



Excessive Helium Readings (Shown Here with a Truncated Peak)

In a Shale Well

- We Occasionally (Randomly?) Produce Sour Oil and Gas
- These can Even Occur Adjacent to a Sweet O&G Well
- For the H_2S Generation BioChemistry to Work, We have to Have the Source of Sulfur but there is no $CaSO_4$. However there is FeS_2 (Pyrite) and some organo-sulfides available to Make the H_2S
- MSL Would Keep the Oil & Gas Sweet Absent a Transmissive Fracture Flow Field to Disseminate the H_2S
- Does a Crustal Connected Transmissive Fracture Explain the Sour O&G When Correlated with a Helium Anomaly?

Where Should this Go?…Ideas to Examine in Further Detail

- Look Now at the Sour Shale Wells
- Does the H_2S Come from Microbes Modifying the Iron Sulfides &/or Organo-sulfides?
- Prioritize Regions with Enhanced Seismicity from TexNet/NMT Network
- Try to Identify the Transmissive Fractures in the Lateral
- Develop Trend Maps
- Extrapolate to Suggest Higher Risk Areas for:
  - 1) Minimizing New Sour O&G and Higher Water Cut Shale Wells,
  - 2) Requiring a Greater Need for Careful Completion Engineering, and
  - 3) Taking More Regionally-Based Care in Disposal Well Permitting

Are We Getting Closer to Answering the Perplexing Questions?

Can we explain why one horizontal well in a shale produces sweet oil while the adjacent lateral, landing at the same depth, produces sour oil?

Can we now locate the transmissive fractures in our laterals and begin to map those – maybe with the added aid of 3-D seismic surveys?

…and w*ill that help us to….*

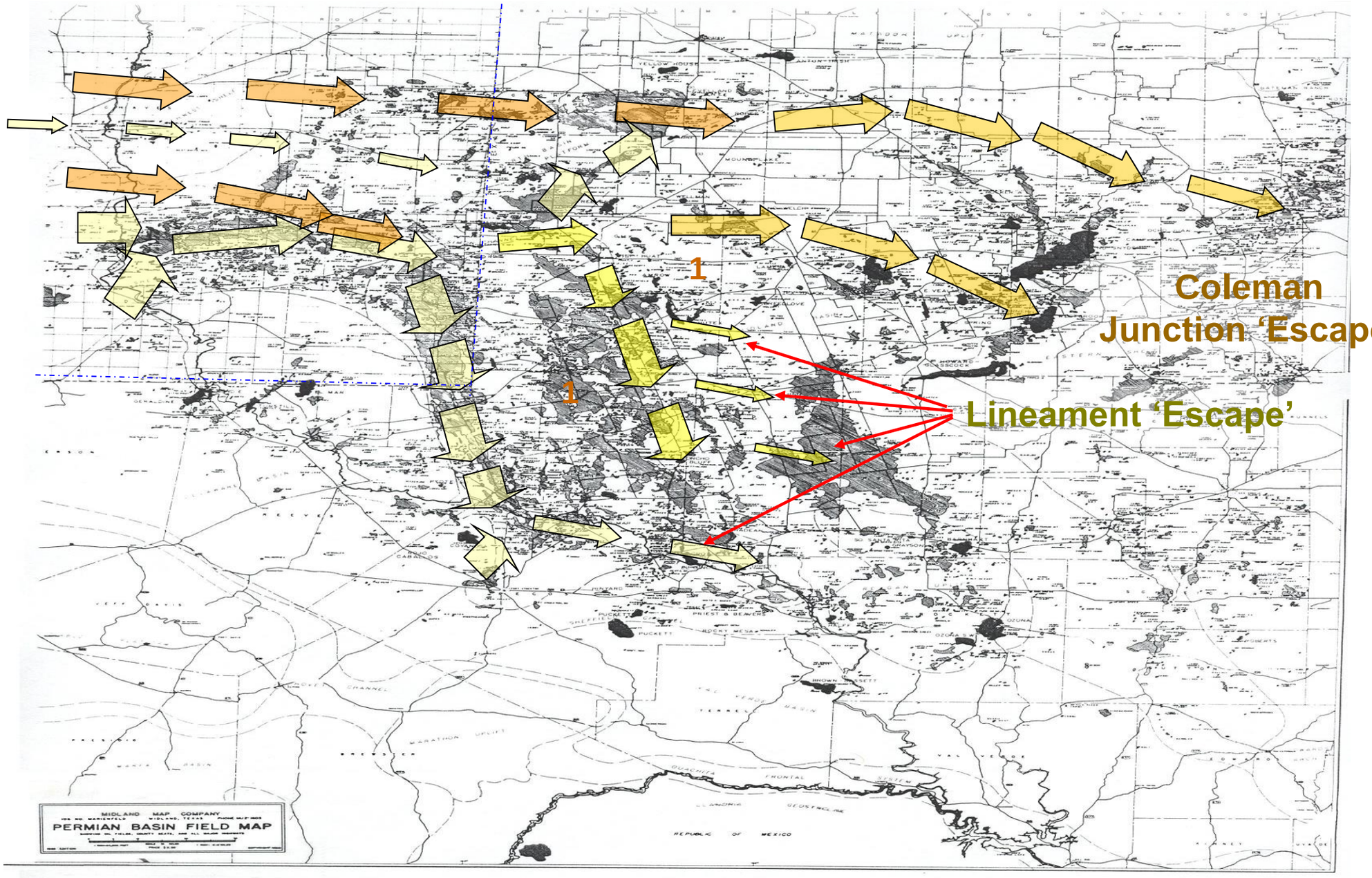
1) Cut the percentage of high water cut wells and disposal volumes?
2) Cut the percentage of sour shale oil wells?
3) Rate areas for SWD Drilling for Low and High Risk Induced Seismicity?

Thank You

Time for Questions?

Backup Slides

PERMIAN BASIN SAN ANDRES ROZ FAIRWAY FLOW MAP



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AAPG EXPLORER
February 2019

More Background on Helium

February 2019

18 By JON GLUYAS

Historical Highlights

Helium Shortages and Emerging Helium Provinces

The History of Helium Exploration Part 2

The search for new sources of helium is of paramount importance as a combination of declining production and increasing demand have made helium prices soar.

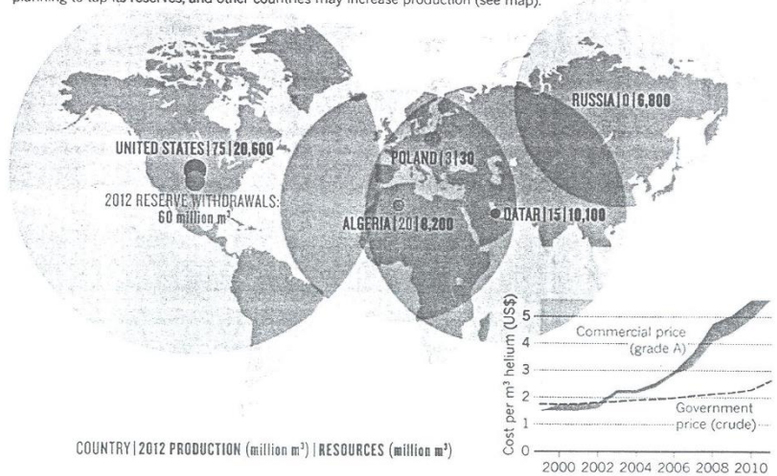
This follows a century in which the United States had a near monopoly on helium reserves and U.S. production met global demand. Although most of the helium production story has taken place in the United States, there are other nations that have produced and are producing helium. Details of production and exploration in these regions are scant, however.

Helium Beyond the United States

In a 2014 issue of the journal "Minerals," New Zealanders Steve Mohr and James Ward published "Helium Production and Possible Projections," in which they attempted to build the history of helium production for countries other than the United States. The data they assembled comes from documents published by the U.S. Geological Survey Mineral Resources Program, which enabled them to collate the production from countries other than the United States. Helium has been produced

FLOATING SKYWARD

The price of helium from a US government stockpile has not kept pace with commercial prices (see graph). Most helium currently comes from the United States, but with price rises expected to continue, Russia is planning to tap its reserves, and other countries may increase production (see map).



Helium producing countries. Image from Mark Peplow's "Helium Reserves Under Pressure" from a 2013 issue of "Chemistry World."

Jon Gluyas is a geologist who has worked in both the petroleum industry and in academia. Gluyas specialized in oil field redevelopment as rehabilitation, learning his trade first in eastern Venezuela and subsequently the states of the former Soviet Union. In the mid-'90s he returned to his native UK and with others, founded his first oil company. Acorn Oil and Gas became the first company working in the North Sea to reactivate a completely abandoned oil field, the original one, Argyll. He then went on to found Fairfield Energy before moving to the academic sector in 2009, joining Durham University in the UK. Recently he has worked on carbon capture and storage and geothermal energy. He co-organized the first ever geothermal/petroleum crossover meeting for the AAPG in Durham in 2016 and is currently working on decarbonizing the UK's heat demand, which accounts for half of all energy used and around 30 percent of all UK greenhouse gas emissions.

It was back in 1999 that Gluyas first

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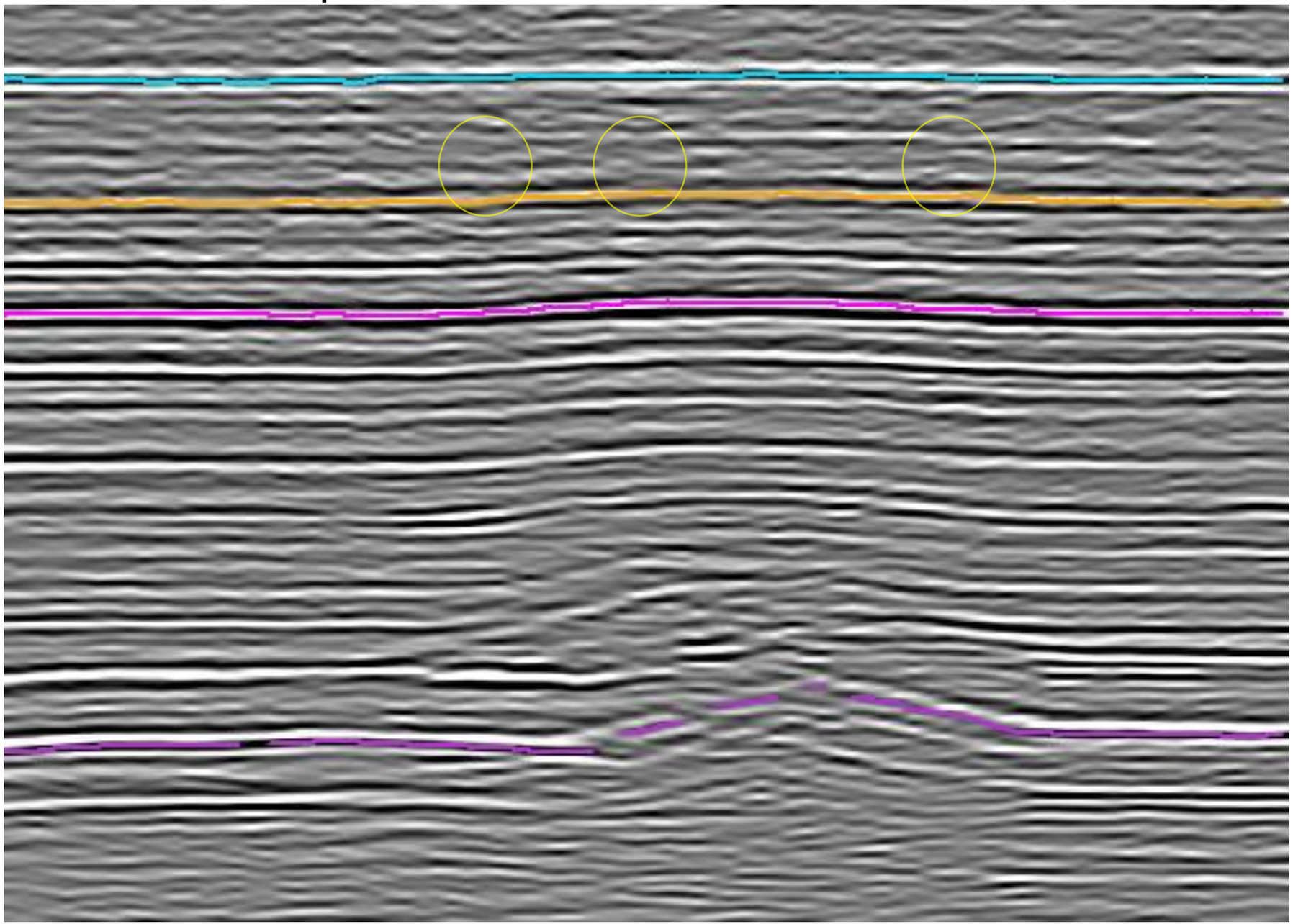
Deep Structure Effects within the San Andres Section (1)



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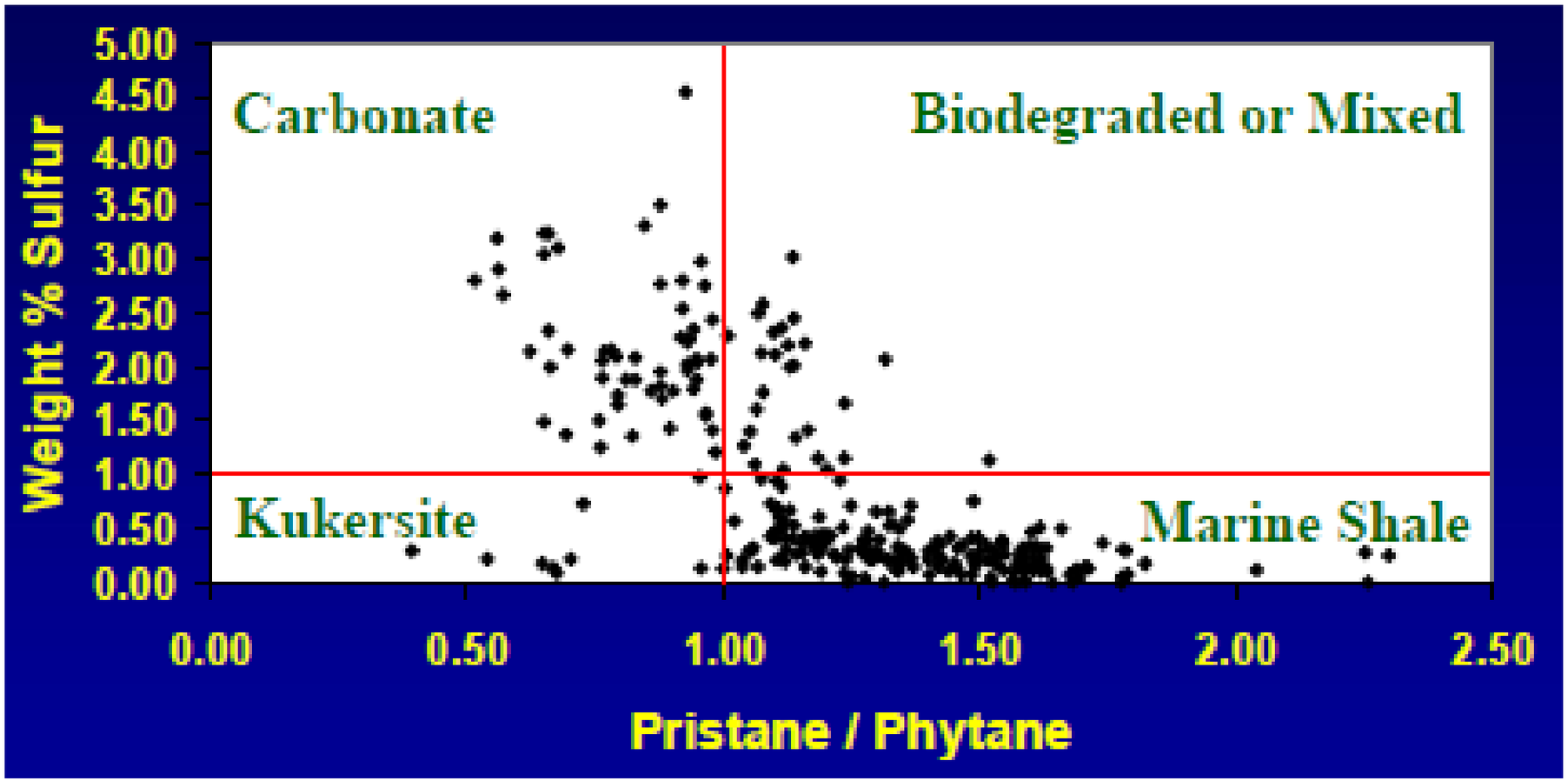
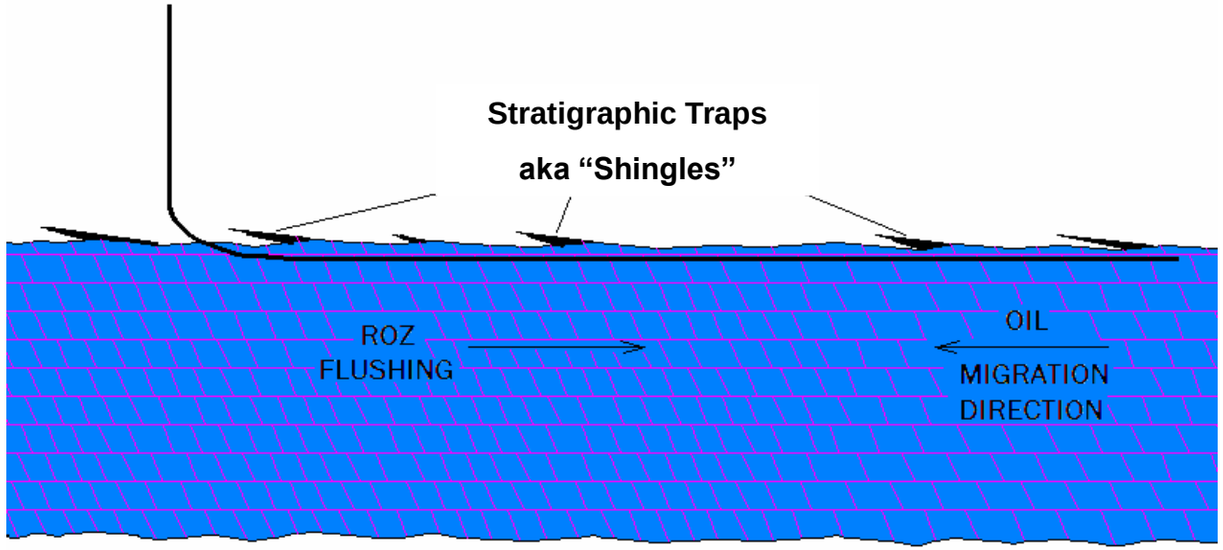
Sulfur Content of Permian Basin Oils as a Functon of Source Facies*



* Source: USGS and Humble Geochemical Services Division

Landing High in the San Andres ROZ Can Have a Bonus of Early Oil Production



Cross Sectional View

Plan View