SOCIETY OF INDEPENDENT PROFESSIONAL EARTH SCIENTISTS

SAN ANDRES FORMATION RESIDUAL OIL ZONES AND THEIR RELATIONSHIP TO THE HORIZONTAL CARBONATE PLAY ON THE NORTHERN SHELF

L. Stephen Melzer, Melzer Consulting

SIPES # 1081

and Dr. Robert Trentham, UTPB

and with invaluable contributions from

David Vance, Arcadis

April 20, 2016

Abstract

The new understanding of the origins of residual oil zones (ROZs) is providing insights as to the explanation for the growing number of commercial horizontal well exploitation projects in the San Andres formation of the northern shelf area in the Permian Basin. The case will be made that what started out as a tight carbonate play, using production concepts analogous to the shale plays, has morphed into a 'greenfield' ROZ play at considerable distances away from the San Andres fields and in places where the landscape has been dotted with dry or disappointing vertical wells over the course of 60 years.

To understand the targeted reservoir requires a study of the processes involved in the natural sweep (lateral water flood) of a huge paleo oil entrapment in the San Andres formation. The ROZ related studies began as an attempt to explain the abnormal thicknesses and properties of intervals of residual oil beneath main pay zones (MPZs) as in the Seminole and Wasson fields. The studies have now evolved to include the understanding that these residual oil resources exist in large fairways and can be made commercially attractive targets. It was first believed that enhanced oil recovery methods would be required to liberate the oil. And, to that end, several successful projects are underway in the Permian Basin proving the concept of using CO_2 as the injectant to enliven and displace the oil via miscible flooding techniques. But more recently, the concept of depressuring the upper ROZ intervals has been introduced, is proving commercial at surprisingly low oil prices, and is offering insights into a process of recovery of immobile oil only conjectured in the past.

What is required for producing residual oil via depressuring are the technologies and commercial developments involved in horizontal drilling and completion methods. The same revolution that occurred in the unconventional shales is being extended into carbonates and into more conventional reservoirs with no mobile oil. An analogous process has been called dewatering in Oklahoma (e.g., Hunton, Mississippian Lime) but is called depressuring here in Texas. The play's linkage to the ROZ studies in the San Andres formation has occurred and, for that reason, is being dubbed "Depressuring the Upper ROZ" or DUROZ.

The author suspects that the Oklahona plays were most generally categorized as producing the large volumes of water that freed up the mobile oil to move. Others believed the mobile oil existed in isolated reservoir compartments and that the horizontals intersected enough compartments to make the contacted rock volume commercial. Still others believed both mobile oil and water coexisted in the pore space but that the water moves first by the relative permeability nature of the two fluids. This latter concept can be reframed to the scientific principles involved with reservoir fluid depressuring and that solution gas expansion allows the hydrocarbons to expand in the pore and effectively liberate a portion of the oil and most of the gas. We believe that this scientific formulation, (as contrasted to the mathematical 'rel perm' one), forms the basis for explaining how gassy residual oil can be liberated.

Both the EOR and DUROZ projects currently underway and producing residual oil will be presented.

San Andres ROZs

- The Horizontal San Andres Play
- What Kind of a Play is it?
- ROZ Science – Some “New” Processes at Work
- Two Ways to Exploit Residual Oil: Case Histories

34599

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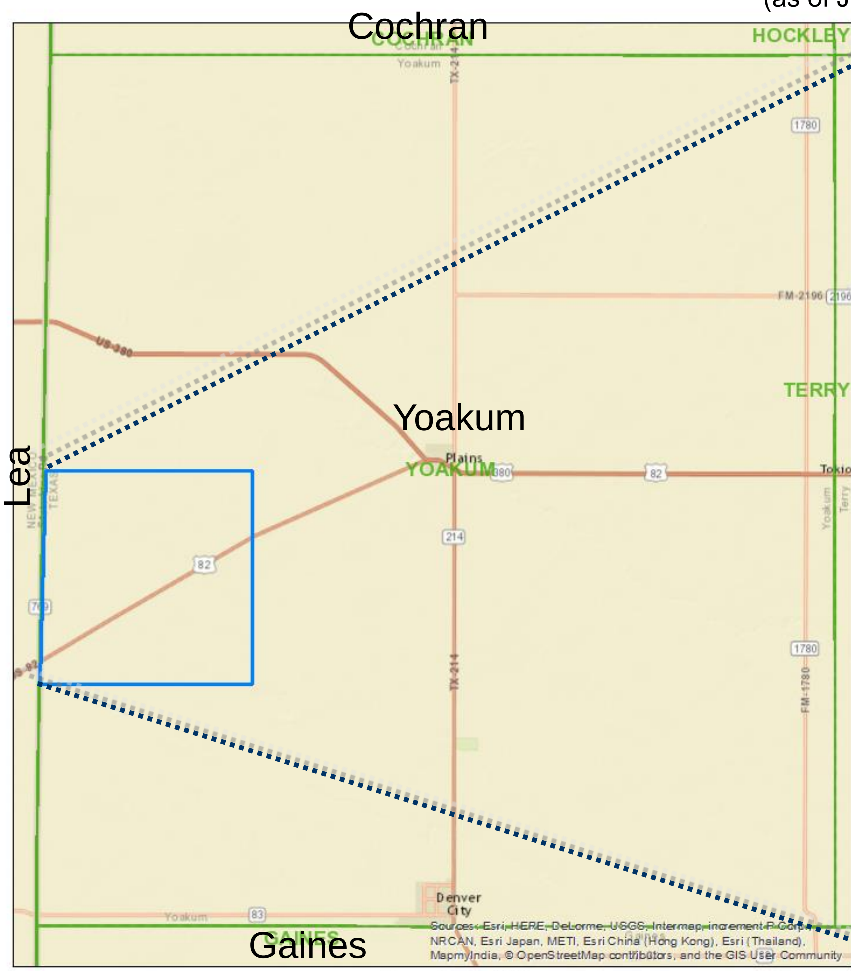
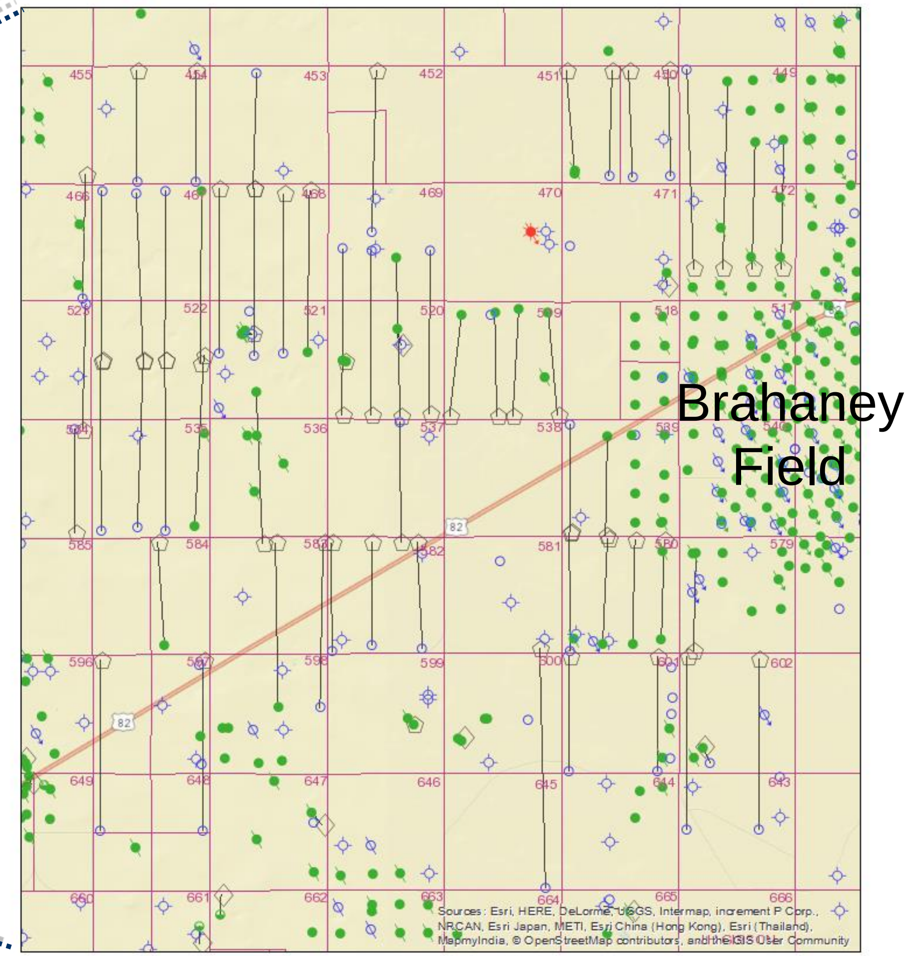
W. Yoakum San Andres Horizontal Wells

(as of Jan '16)





November 24, 2015

1 inch = 24,075 feet

PREPARED BY:

RAILROAD COMMISSION of TEXAS

P.O. BOX 12967
AUSTIN,TX 78711-2967

0 2.5 5 7.5 10 Miles

0 13,000 26,000 52,000 78,000 104,000 Feet

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Source: RRC Public GIS Viewer

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0 0.6 1.2 1.8 2.4 Miles

0 3,350 6,700 13,400 20,100 26,800 Feet

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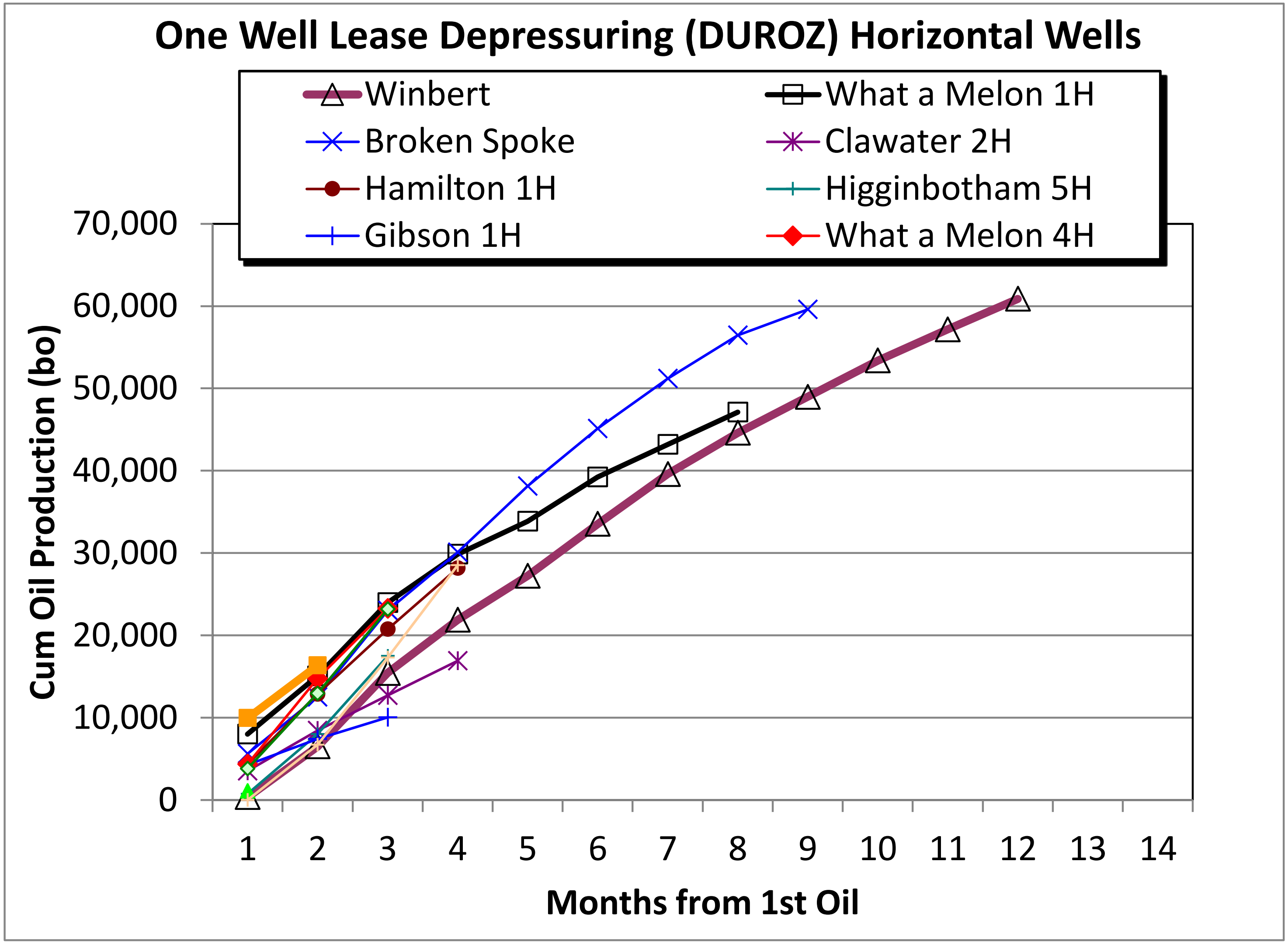
Oil Cumulatives of the First Wells in the N Shelf Play



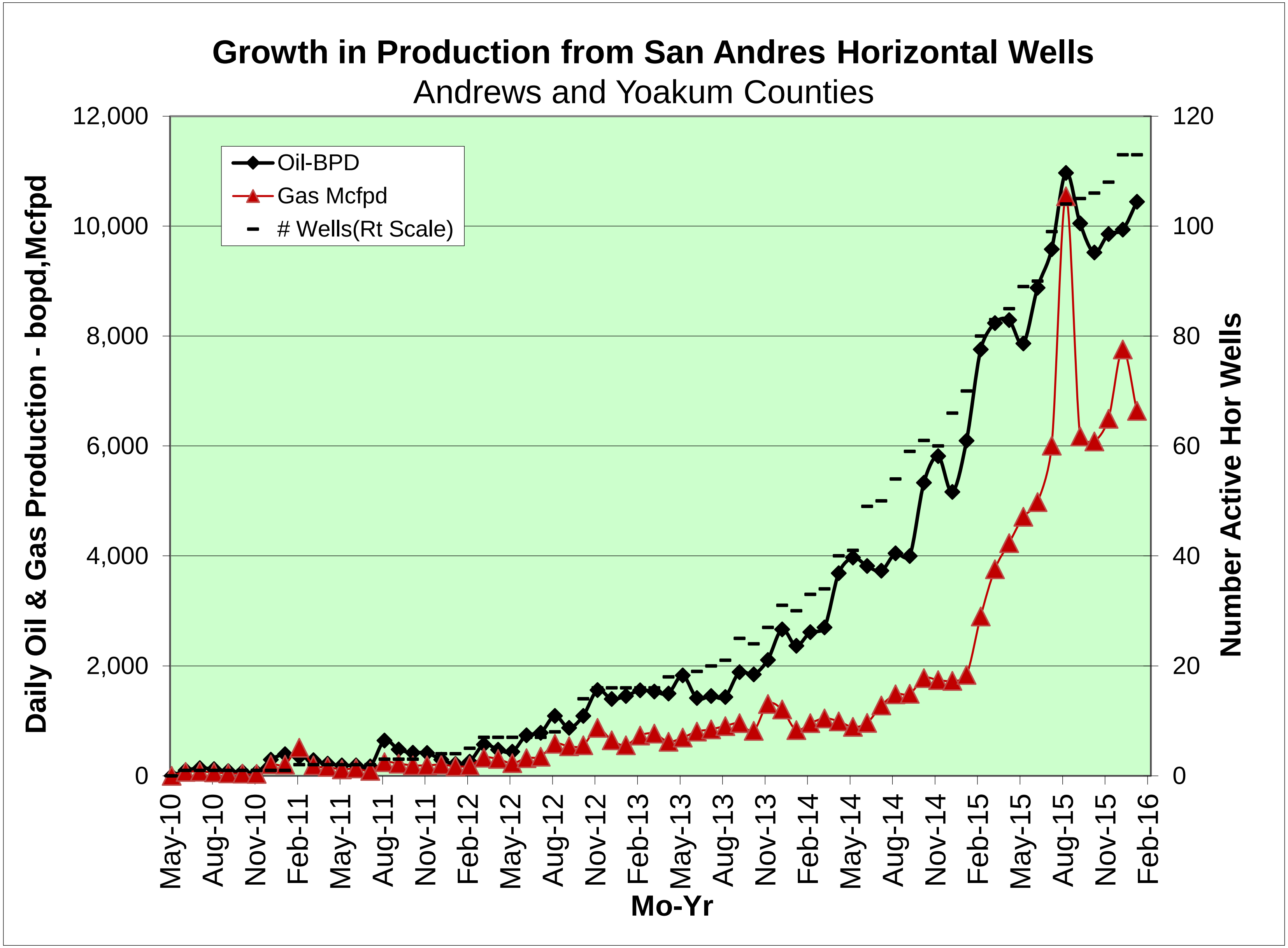
The 'Players'

- NW Shelf
  - Manzano, Walsh, Riley, Apache, ER Operating, Henry, Silver Creek, Stewart, Element, Wishbone
- Andrews County
  - Forge, Pacesetter

The ‘Big Five’ Operators*

Company	bopd	Mcfpd	# Wells
Forge	3840	2385	71
Manzano	3070	3100	14
Walsh	2150	275	18
Riley	250	840	4
Pacesetter	510	220	7
TOTALS	**9820**	**6820**	**114**

* Stats as of Jan ‘16

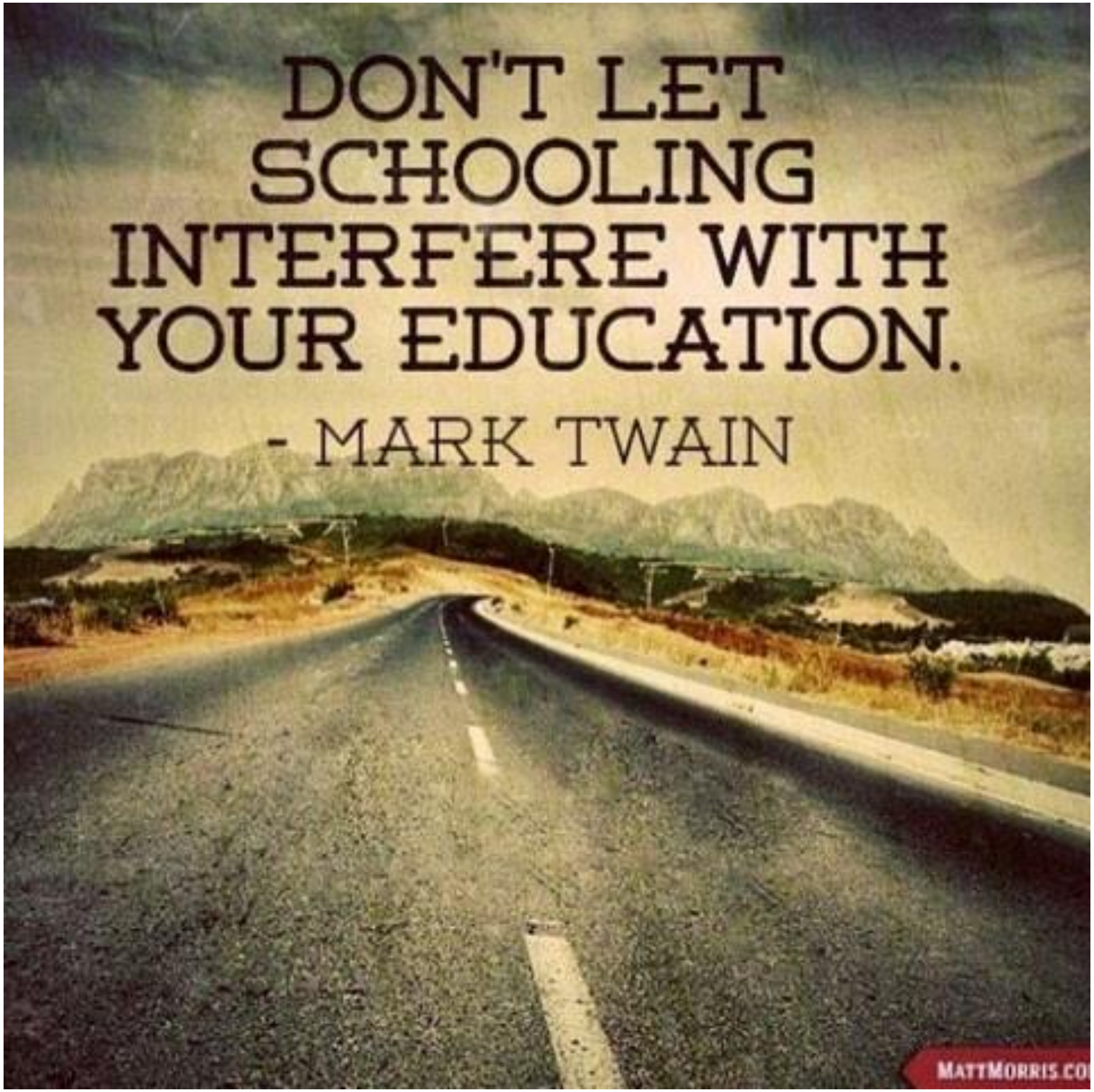


Growth in Production from San Andres Horizontal Wells
Andrews and Yoakum Counties
Oil-BPD
Gas Mcfpd
Wells(Rt Scale)
Daily Oil & Gas Production - bopd,Mcfpd
Number Active Hor Wells
Mo-Yr
0
2,000
4,000
6,000
8,000
10,000
12,000
0
20
40
60
80
100
120
May-10
Aug-10
Nov-10
Feb-11
May-11
Aug-11
Nov-11
Feb-12
May-12
Aug-12
Nov-12
Feb-13
May-13
Aug-13
Nov-13
Feb-14
May-14
Aug-14
Nov-14
Feb-15
May-15
Aug-15
Nov-15
Feb-16

What is this Play All About?

Is it Just the Carbonate Equivalent to the Shales or Something Else?

The Next Few Slides May Test Your Imagination

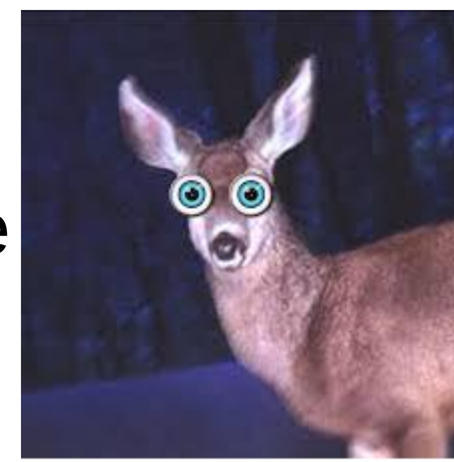

DON'T LET
SCHOOLING
INTERFERE WITH
YOUR EDUCATION.
- MARK TWAIN
MATTMORRIS.CO

The “Camps”

1. Compartmentalized Pods of Mobile Oil (Main Payzones)

2. Tight Oil – Some Mobile Oil but Low Perm Rocks

3. Depressuring a Residual Oil Zone (Relative Permeability)



Which Camp are you in?

The ‘Mobile Oil Compartments’ Camp

- Everybody knows carbonates are badly compartmentalized
- A horizontal well is perfectly suited for connecting those compartments
- For Play success, we:
  - Will need to mildly stimulate but in selective intervals
  - Will see oil come quick with minimal water
  - Do not need a gassy oil

The ‘Tight Oil’ Camp

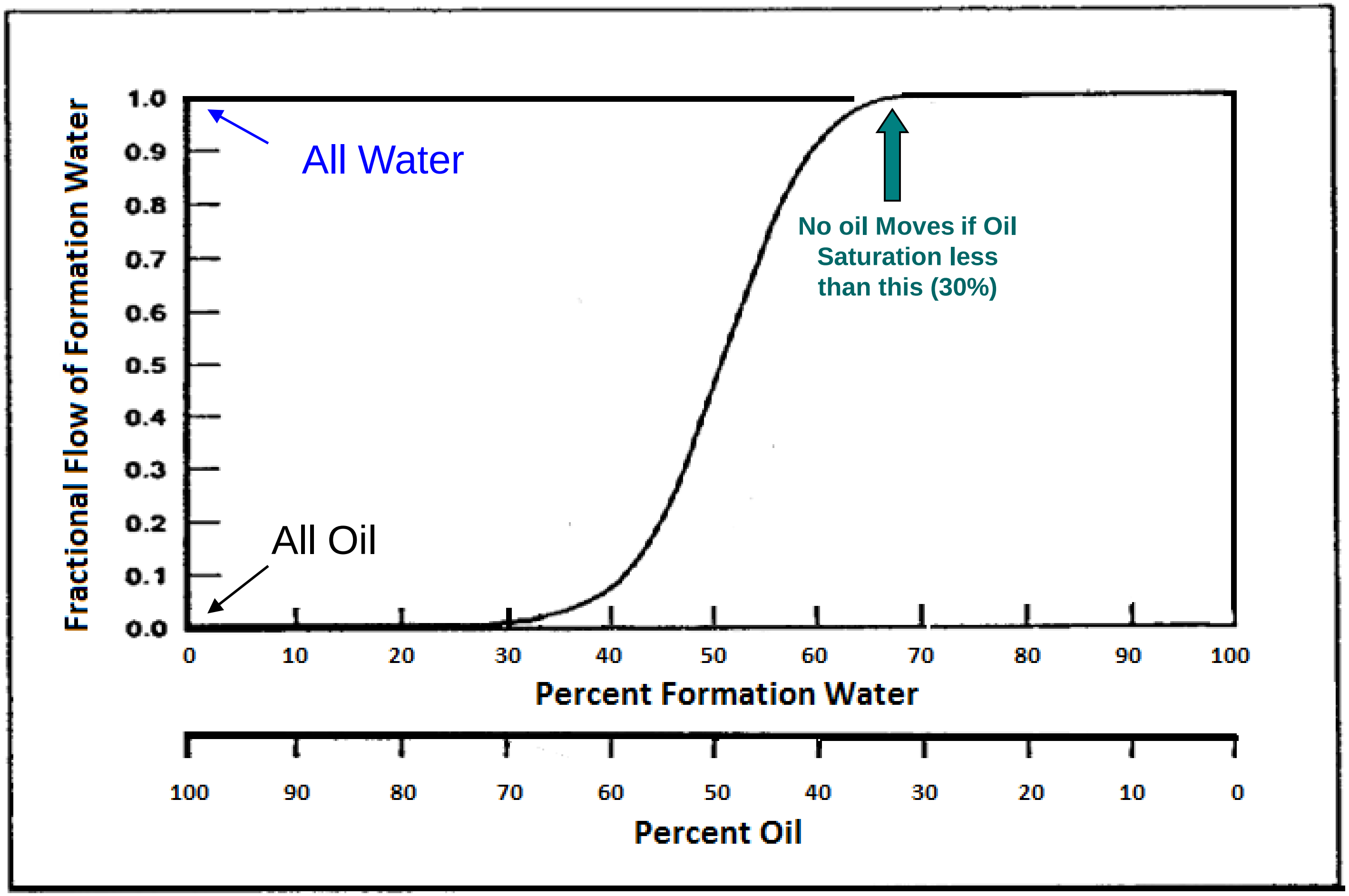
- If we can get oil out of shales, why not out of tight carbonates?
- For Play success, we:
  - Need to find thick zones with same kind of shows as the shales
  - Need to fracture treat like the shales
  - Will see the oil come right away
  - Will see the oil and water deplete pretty rapidly

The 'ROZ' Camp

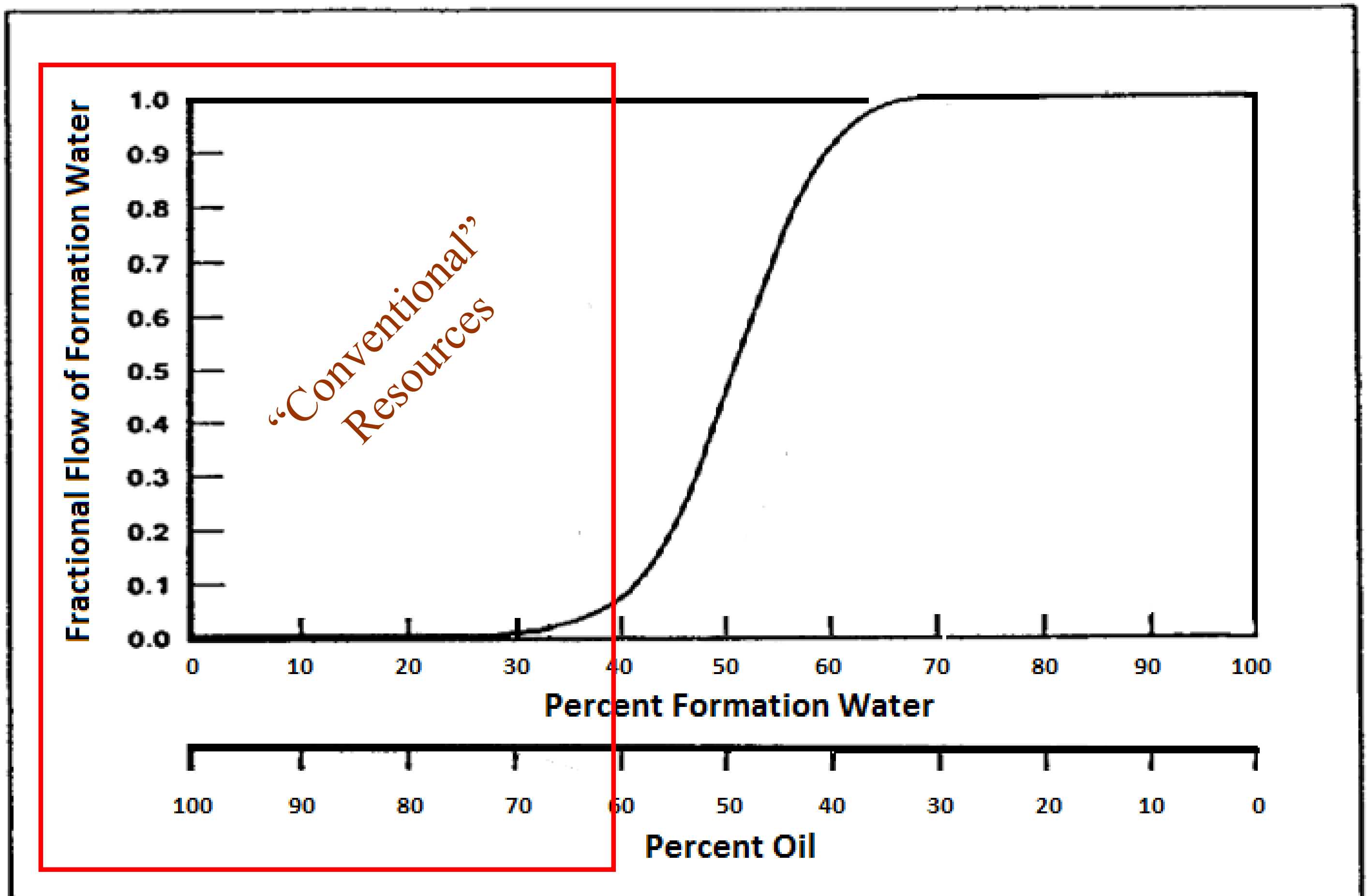
- All the Oil is Immobile!
- As Water is Removed and the Reservoir is Depressured, the Gas in the Oil Expands and the Oil and Gas Occupy Greater %age of the Pore Space
- Some of the Oil Becomes Mobile and Moves into the Flowstream
- Water Dominates all the Production for a Period of Time until the Pressures Fall Past a Threshold Level
- Works Best with a Gassy Oil & Oil- or Mixed-Wet Rocks
- Can be Modeled with Relative Permeability Curves

A Frame of Reference

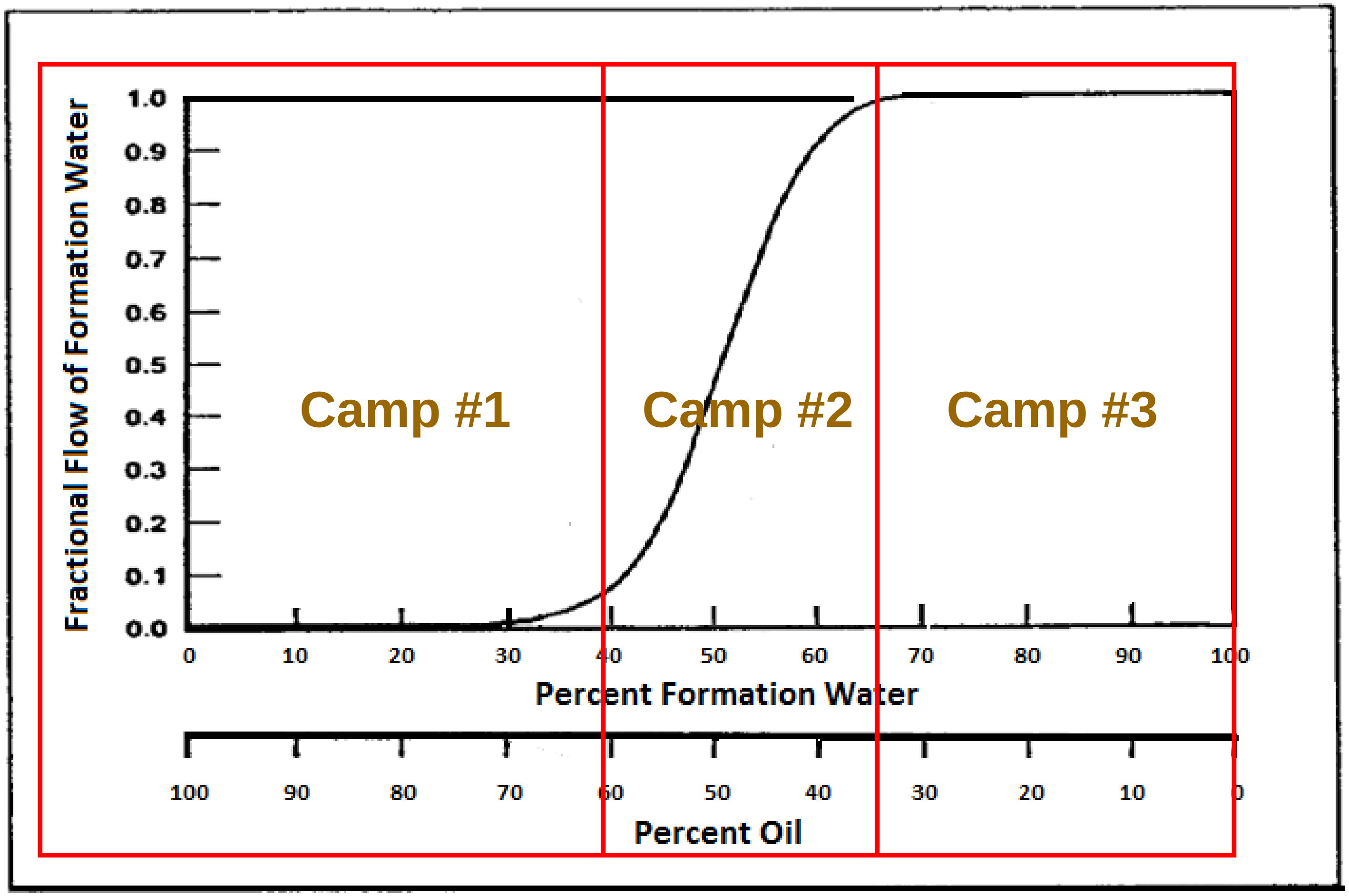
Fractional (Water) Flow as a Function of Oil/Water Saturation



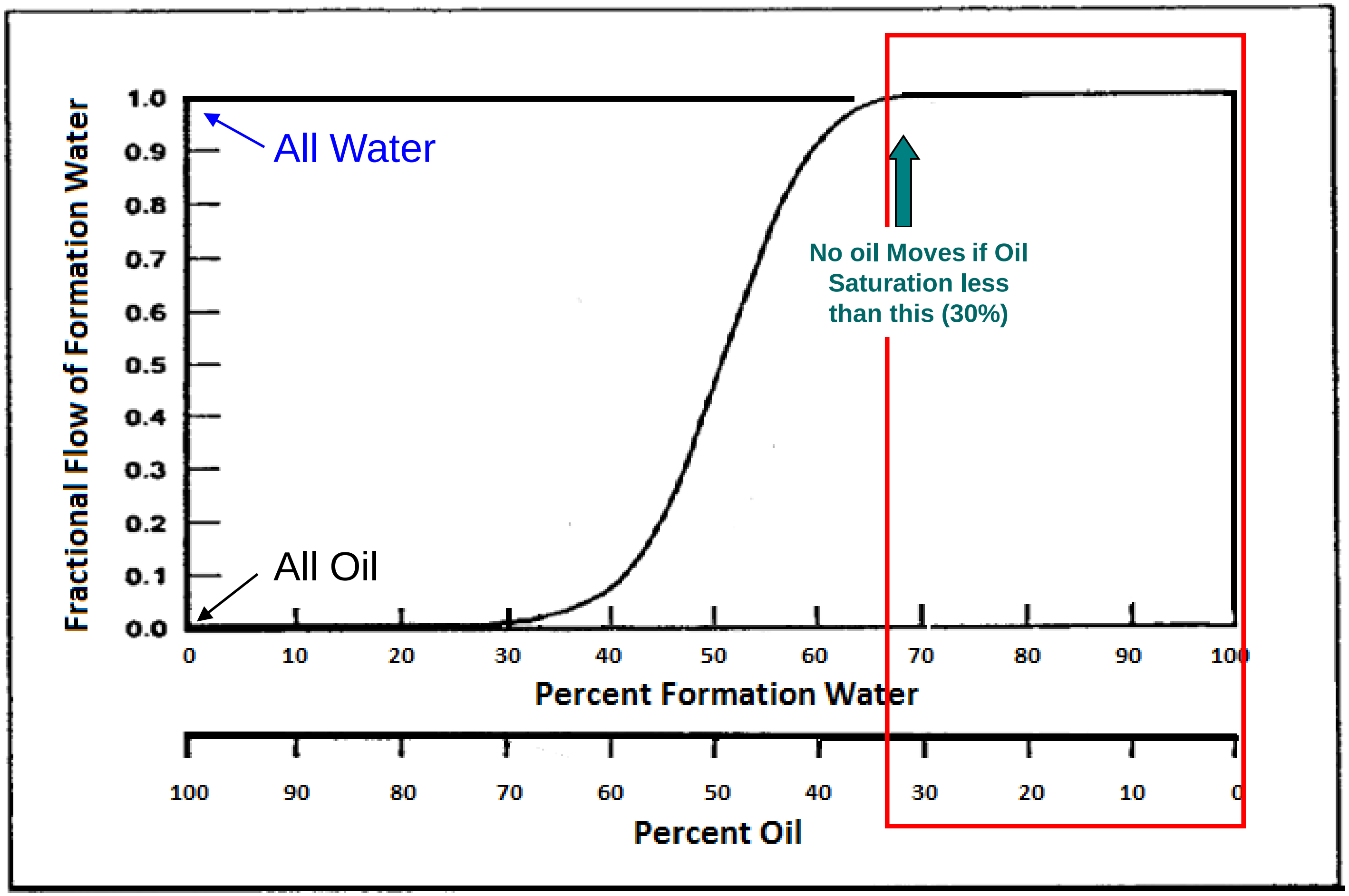
150 Years of Looking for These Reservoirs!



Our Industry Has Moved Beyond the "Conventional" Into Two "New" Camps



Fractional (Water) Flow as a Function of Oil/Water Saturation



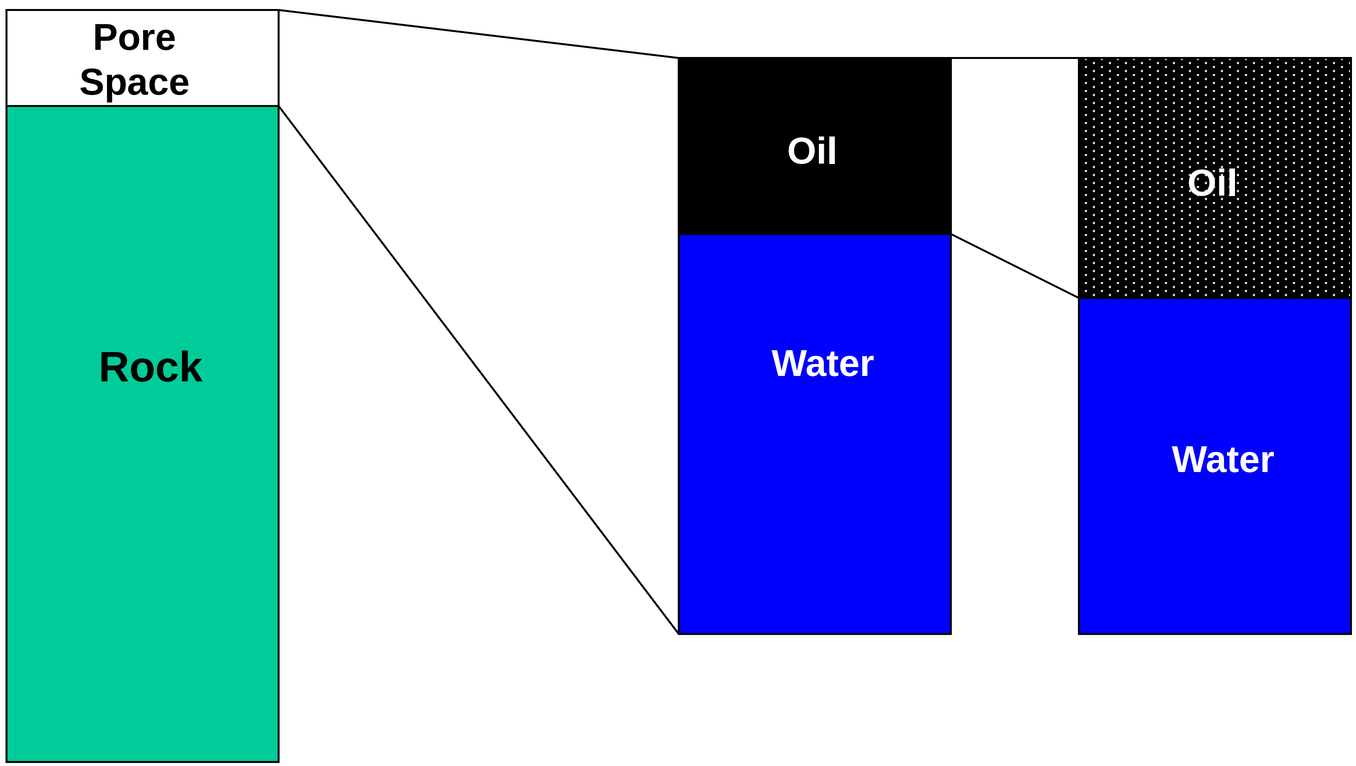
Really? Camp #3?

So what can cause the oil to start moving?

Depressuring Production Mechanics

The pore Fluids

De-pressured State

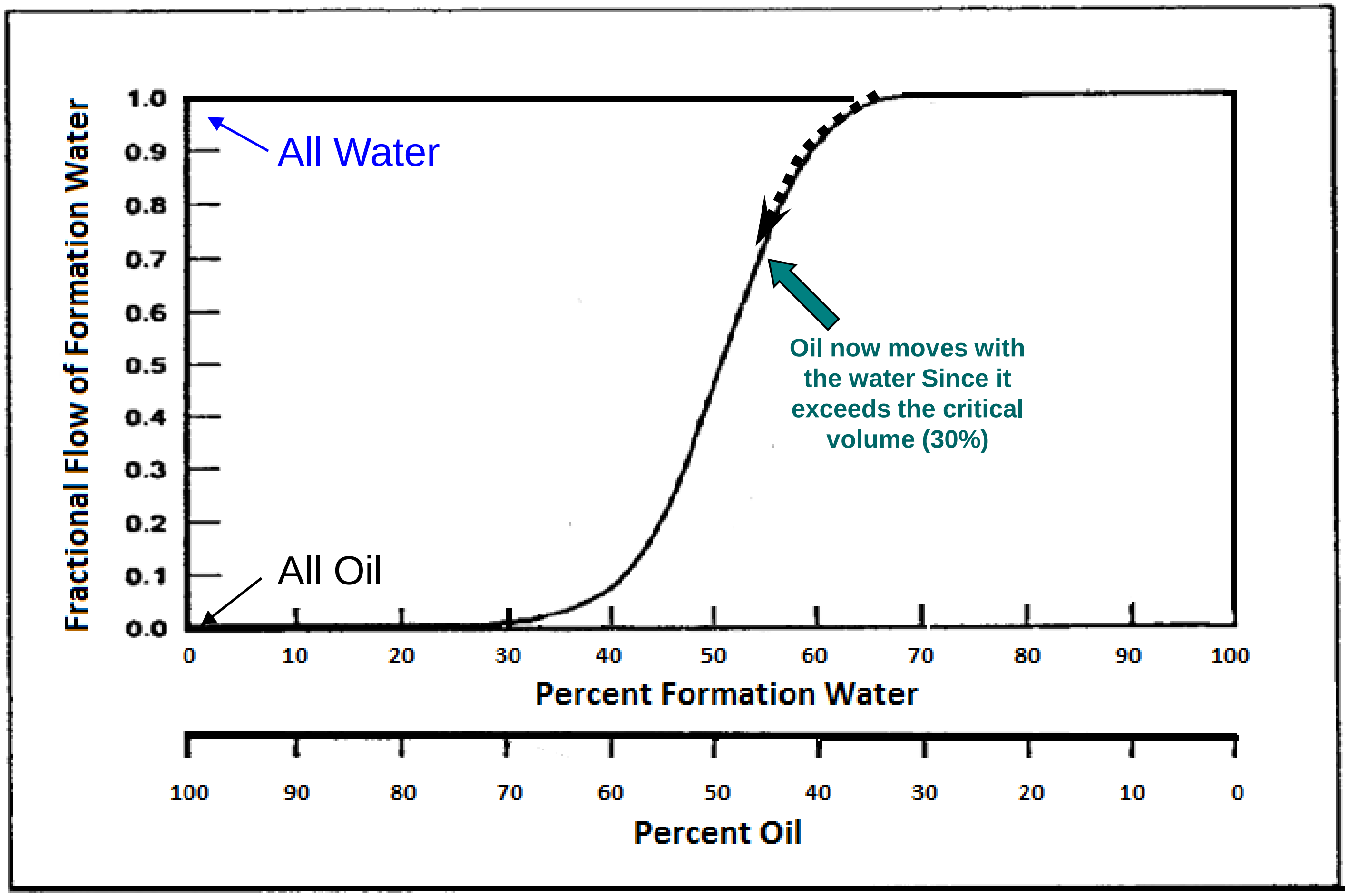


P_i = 2000 psi (in-situ)

P_i = 2000 psi (in-situ)

P_n = 1000 psi (in-situ)

Fractional (Water) Flow as a Function of Oil/Water Saturation



Oil Begins to move as the Oil Volume Grows

Cautionary Note:

That Fractional Flow Curve was Idealized!

The Critical ("Irreducible") Sor Value can Vary Due to Variable Reservoir and Fluid Properties

In Other Words, Water Flooding Can Leave Behind a Lot of Oil in the Swept Zone and the Sorw Values Left Will be a Function of the Reservoir and Oil Properties

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It is that Sorw that we are Targeting and, if it was Mother Nature's Water flood, the Oil has Never Been Depressured

Back to this Slide
"The ROZ Camp"

- All the Oil is Immobile
- As Water is Removed and the Reservoir Depressured, the Gas in the Oil Expands and the Oil and Gas Occupy Greater %age of the Pore Space
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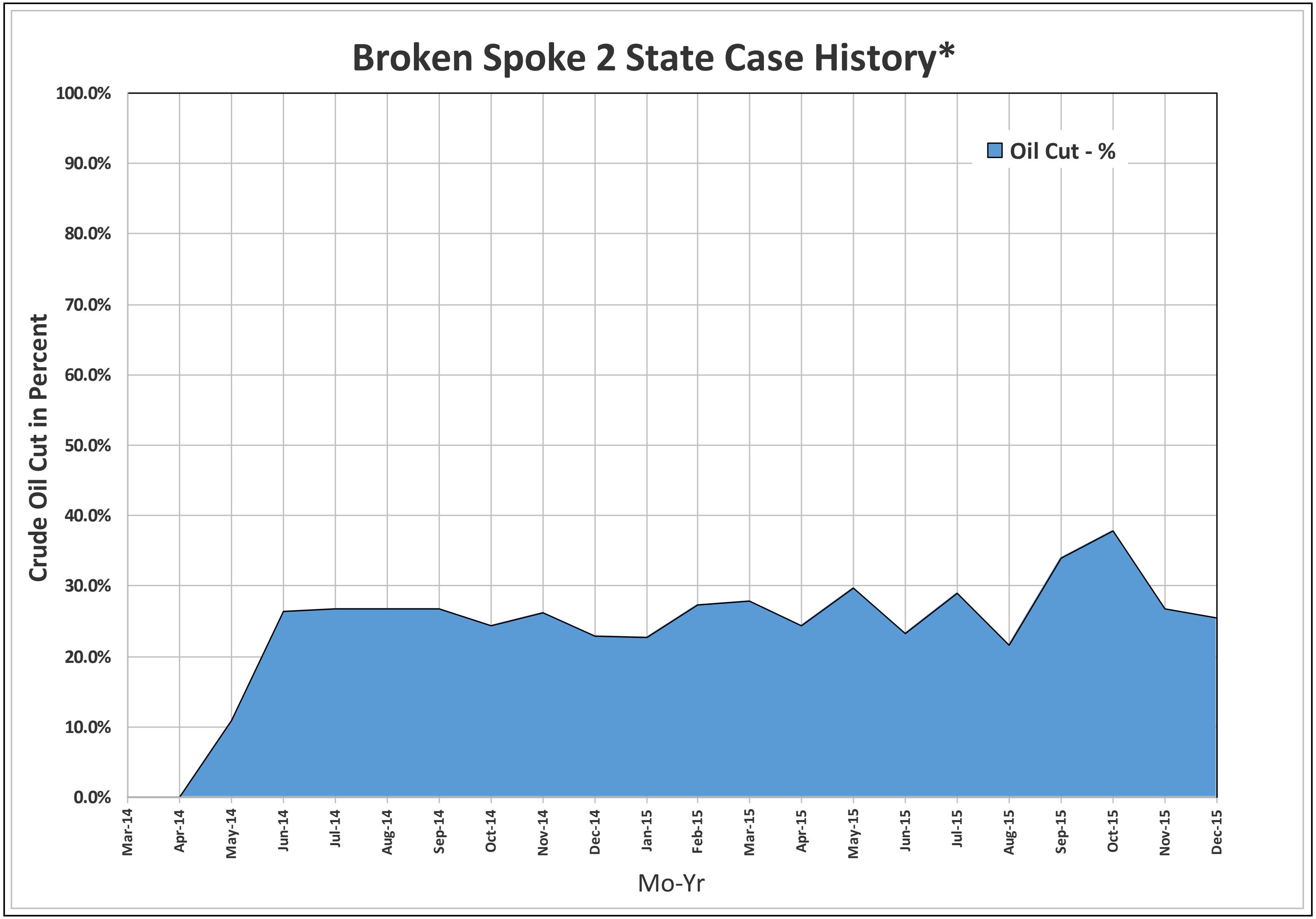
Case History: Water Cut vs. Time



* North Shelf Discovery Well (Lea Co.)

DUROZ Case Histories Pressure Characteristics

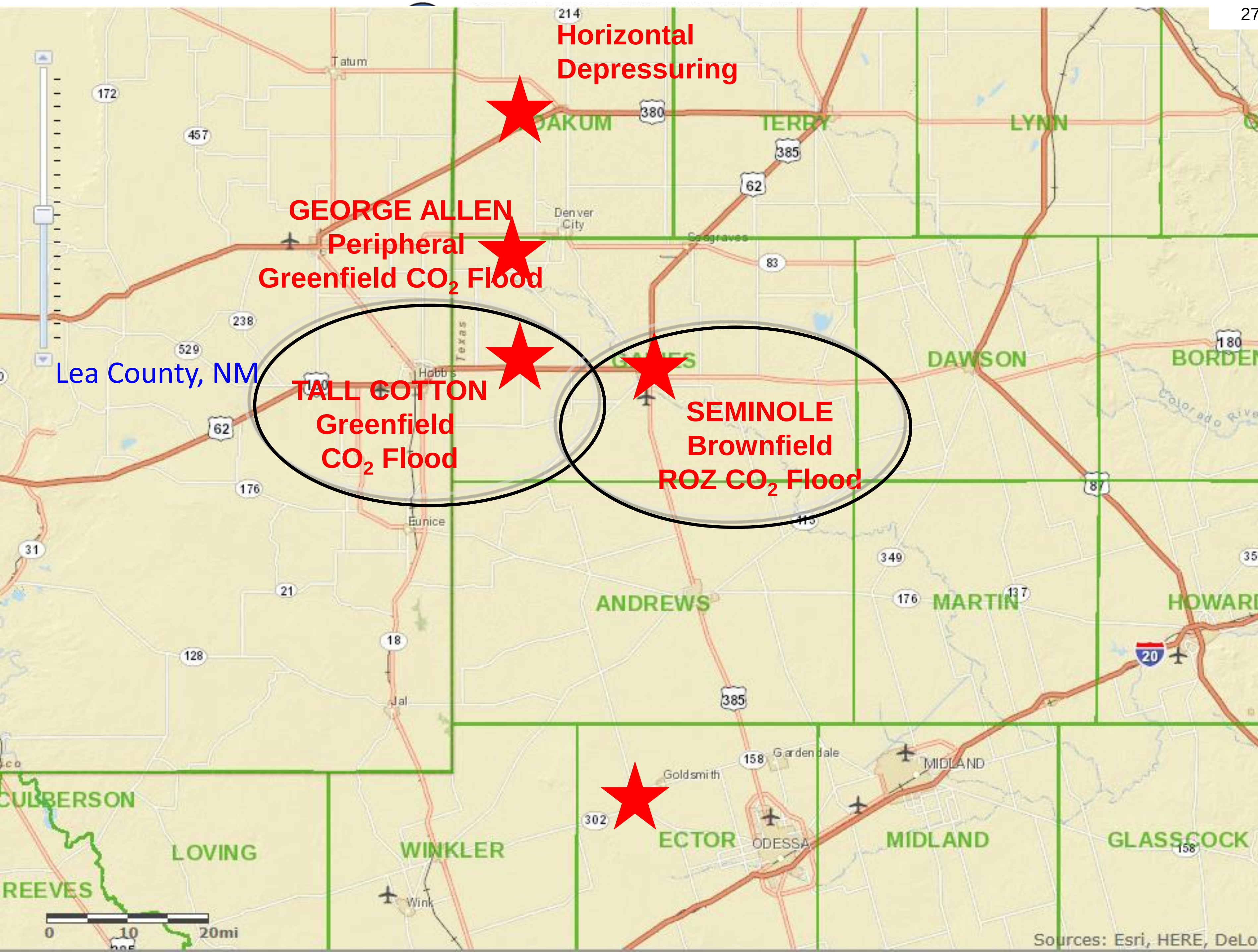
DUROZ WELLS: YOAKUM CO., TX

	Well	Initial Intake Pressure	First Oil Cut Intake Pressure	Lateral Length	Day	Days Until First Production	Ave BOPD since 1st Oil
1	What A Melon 1H	1745	1225	1 mile	393	26	166
2	Well #2	2120	1315	1 mile	378	31	202
3	Well #3	1700	1270	1 mile	195	6	203
4	Well #4	1975	1090	1.5 mile	170	32	313
5	Well #5	2030	1200	1 mile	151	22	126
6	Well #6	2225	1150	1 mile	122	32	243
7	Well #7	2053	1260	1 mile	83	25	228
8	Well #8	2110	1635	1 mile	42	30	142
9	Well #9	1820	No Oil Cut Yet	1.5 mile	20		
10	Well #10	2040	No Oil Cut Yet	1.5 mile	20		
11	Well #11	1750	No Oil Cut Yet	1 mile	1		

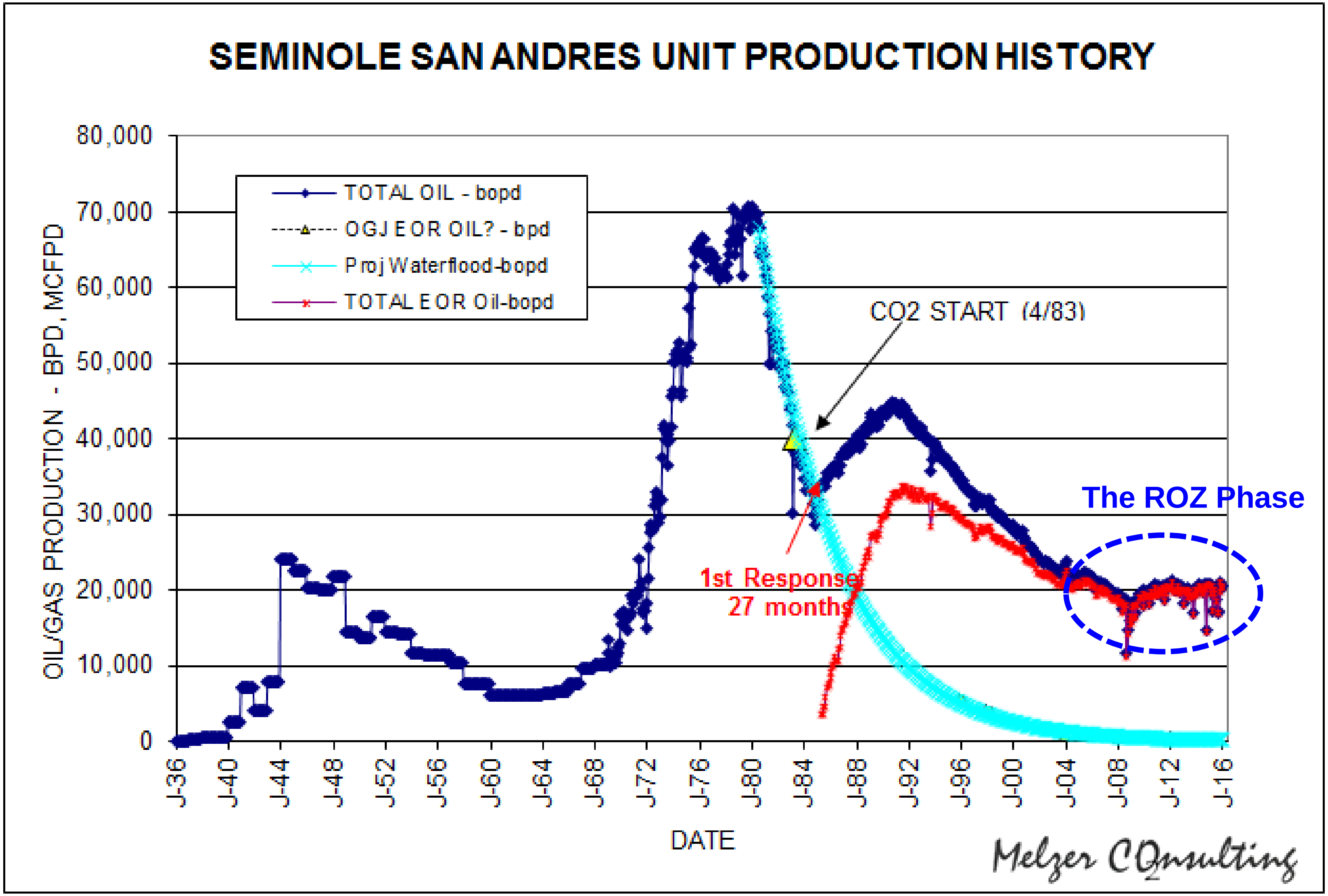
Note Also the Trend to Longer Laterals – Some 2-mile Laterals now

ROZs and EOR

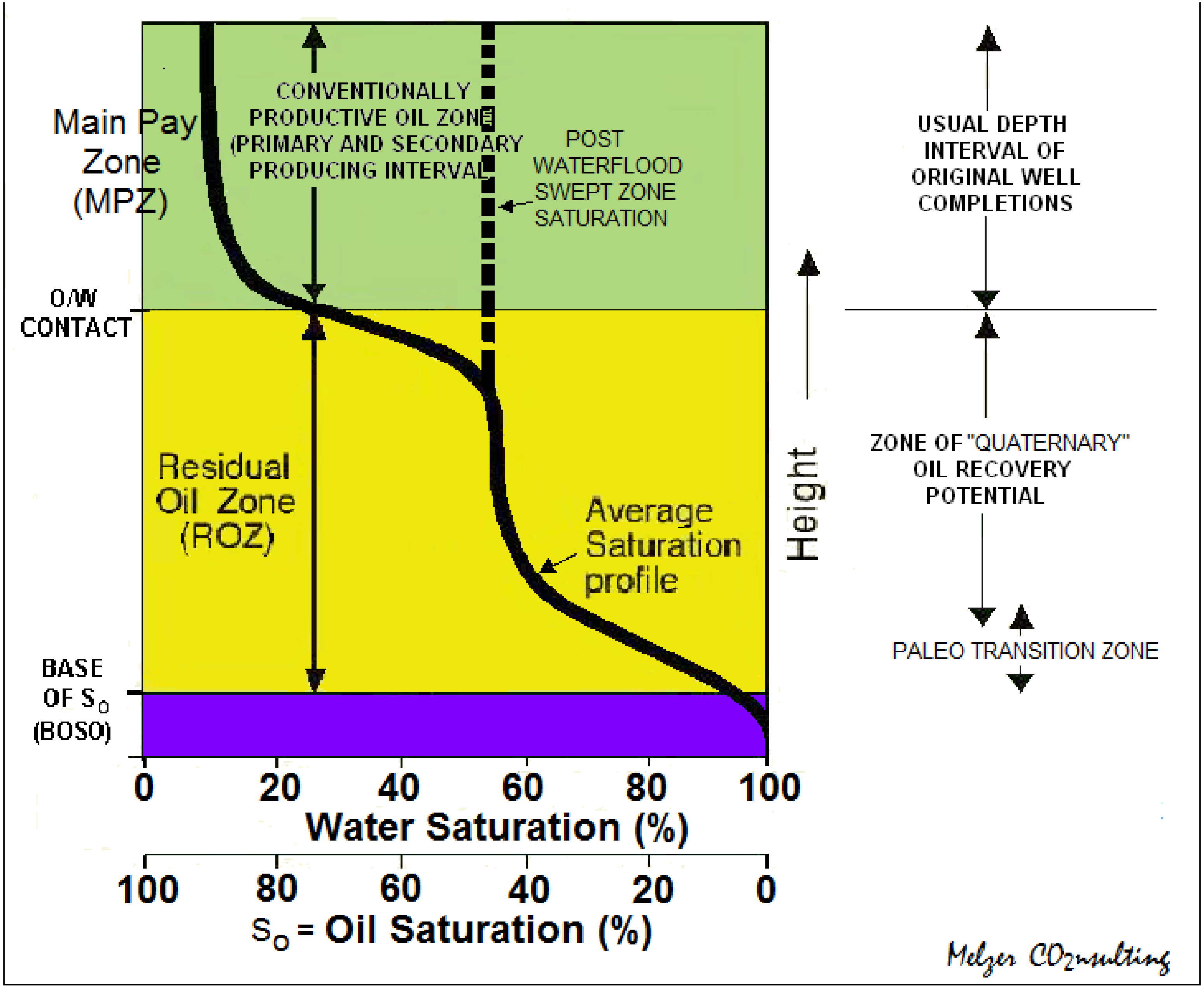
A Progress Update


Horizontal Depressuring
GEORGE ALLEN Peripheral Greenfield CO_2 Flood
TALL COTTON Greenfield CO_2 Flood
SEMINOLE Brownfield ROZ CO_2 Flood
Lea County, NM
YOAKUM
TERRY
LYNN
DAWSON
BORDEN
GAINES
ANDREWS
MARTIN
HOWARD
CULBERSON
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
REEVES
Tatum
Denver City
Seagraves
Hobbs
Eunice
Jal
Goldsmith
Gardendale
ODESSA
Wink
0 10 20mi
Sources: Esri, HERE, DeLorme

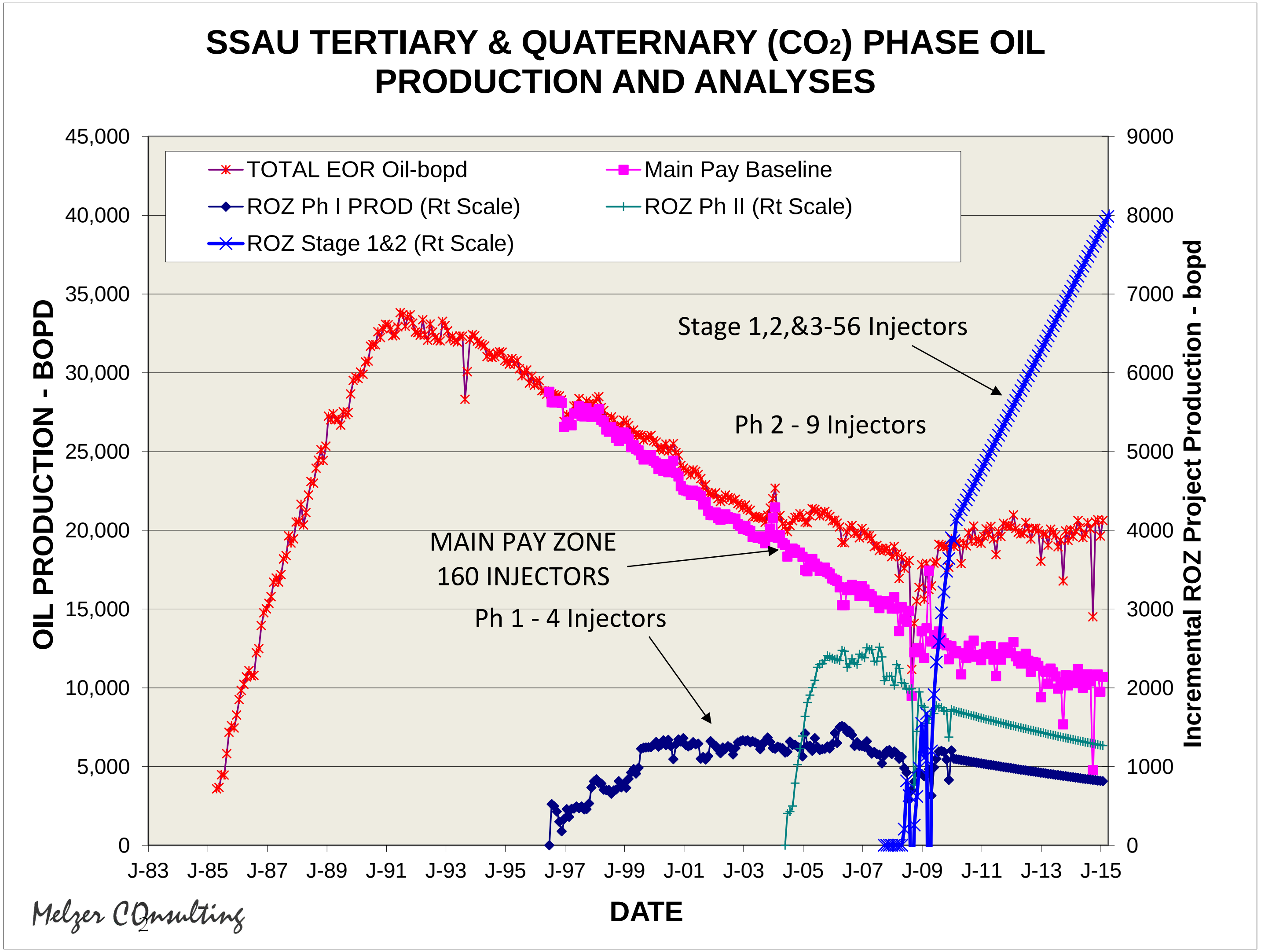
SSAU FIELD HISTORY



Original & Post Waterflood Seminole Field Saturation Profile

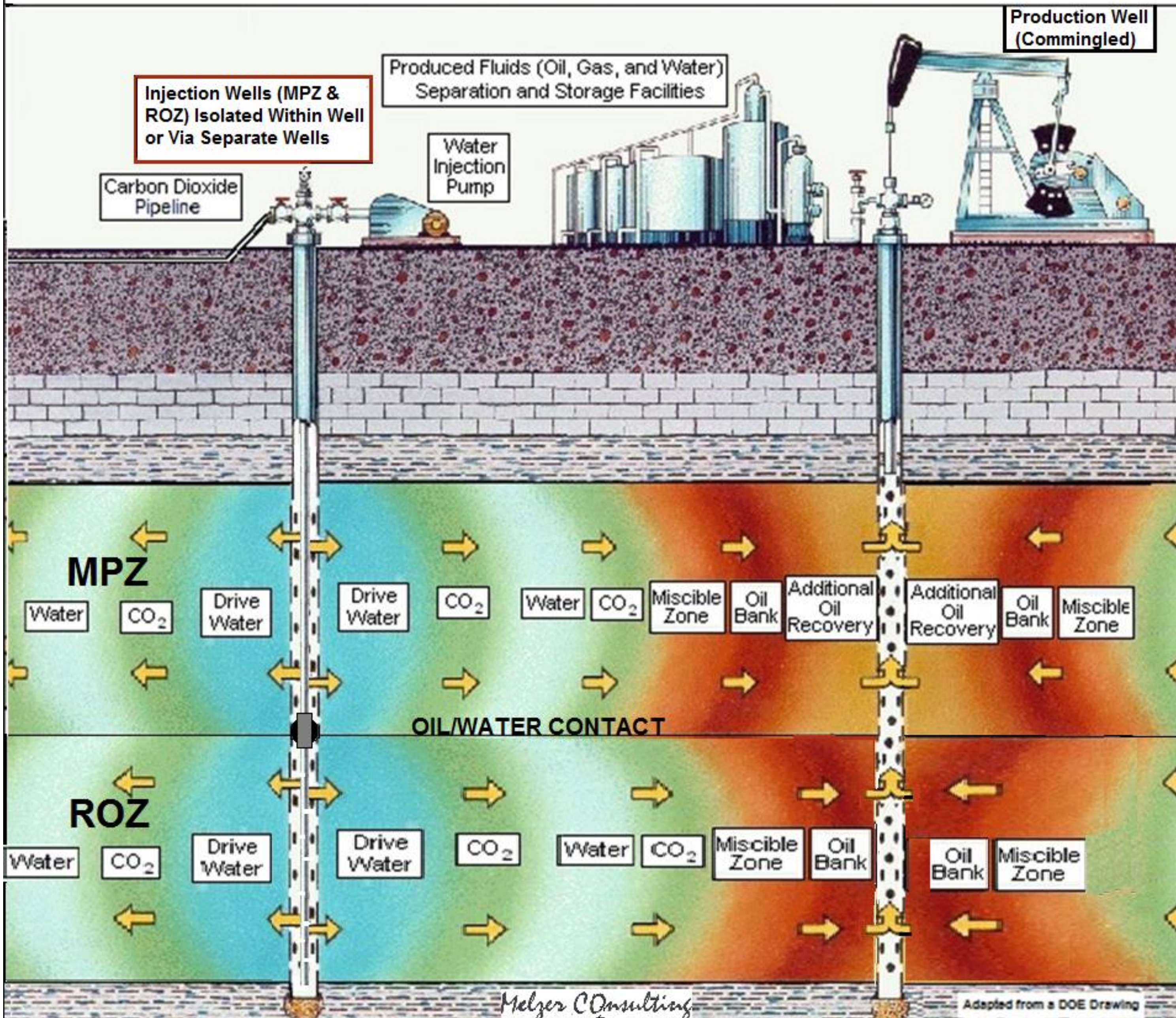


SSAU CO_2 EOR & ROZ Era Production



THE CLASSIC CO_2 ENHANCED OIL RECOVERY AND WAG SCHEMATIC

WITH A COMMINGLE RESIDUAL OIL ZONE DEPLOYMENT



PB ROZ Research

Forming a ROZ

Greenfields and Fairways

Within a Hydrocarbon Basin

- First Stage
  - Deposition and Burial
  - Generation of Hydrocarbons, Expulsion of Some Oil/Gas from the Source Rock
  - Migration to a Trap
- Second Stage
  - Moving Oil and Water Around within a Trap (Mother Nature's Waterflood)
- And Sometimes….third…fourth Stages

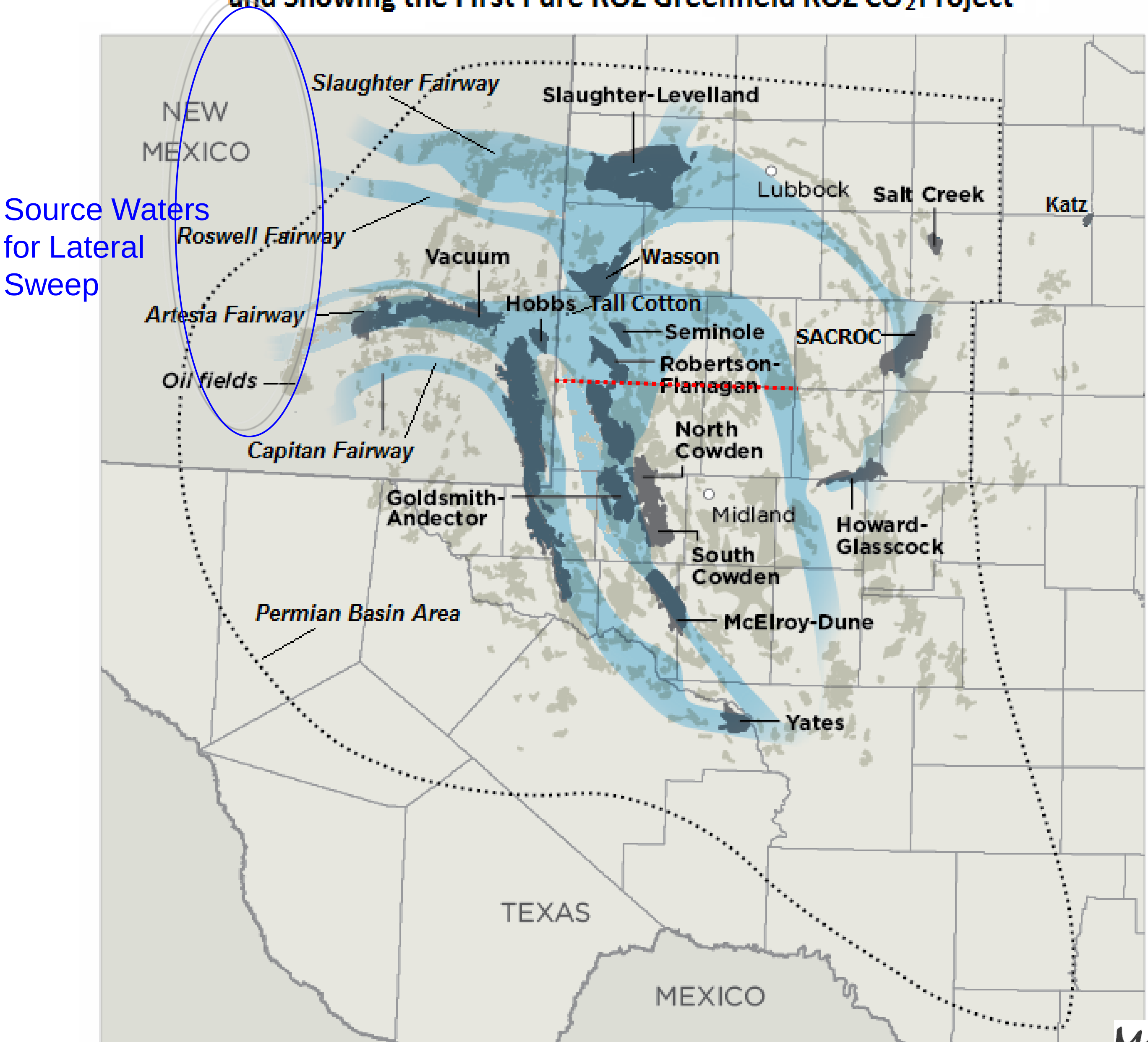
Is this all that happens in a Basin?

Types of Second Stage Adjustments

1. Basin-wide Tilt
2. Basement Readjustments and/or 'Leaky Seals'
3. Asymmetric Uplift and Lateral Sweep
   - Reservoir Outcrop and Meteoric Derived Water Sweep (aka Lateral Sweep)
   - Salt Diapirs

Residual Oil Zone Fairway Mapping with Superimposed Major Permian and Pennsylvanian Oilfields

and Showing the First Pure ROZ Greenfield ROZ CO_2 Project



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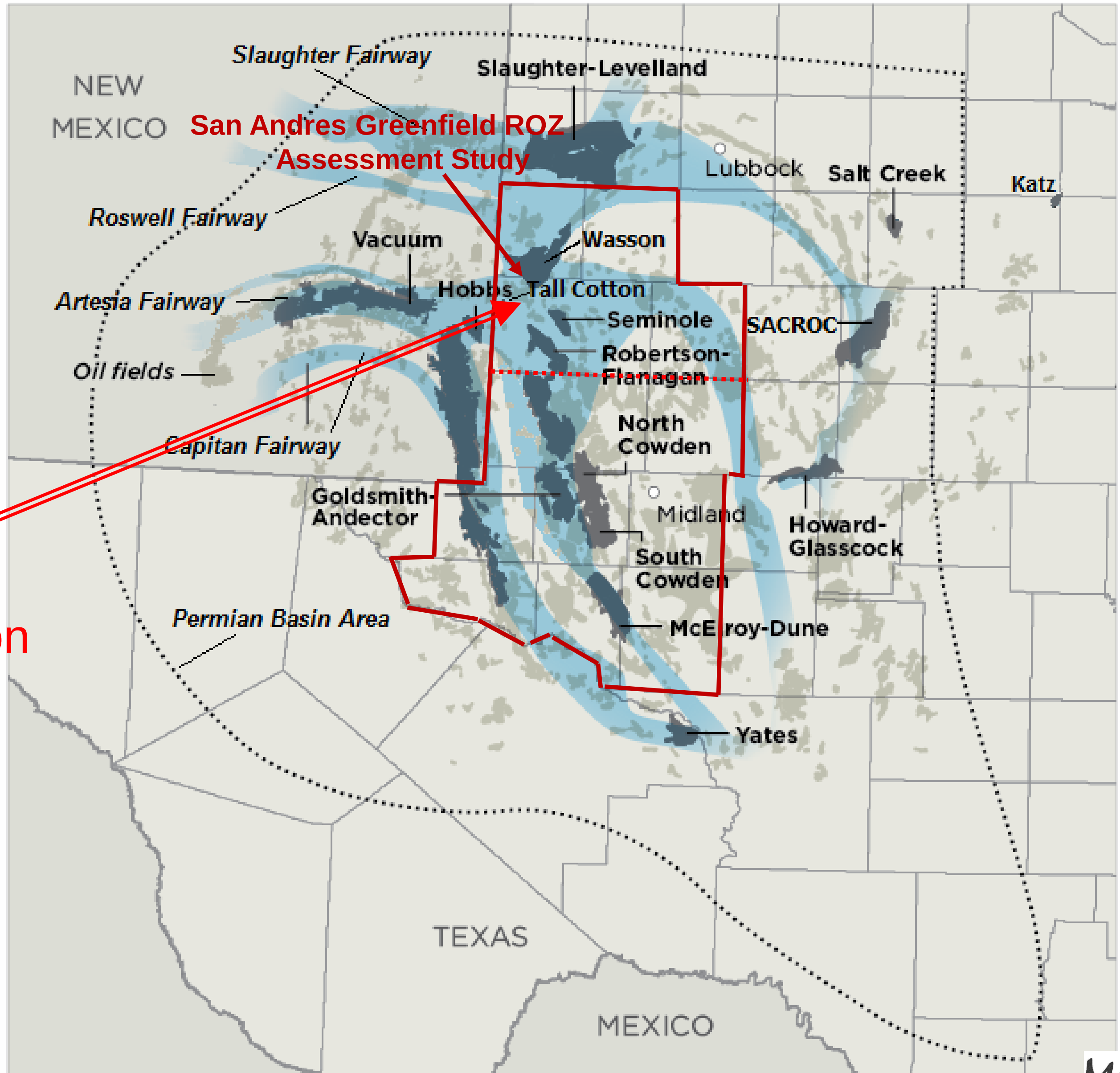
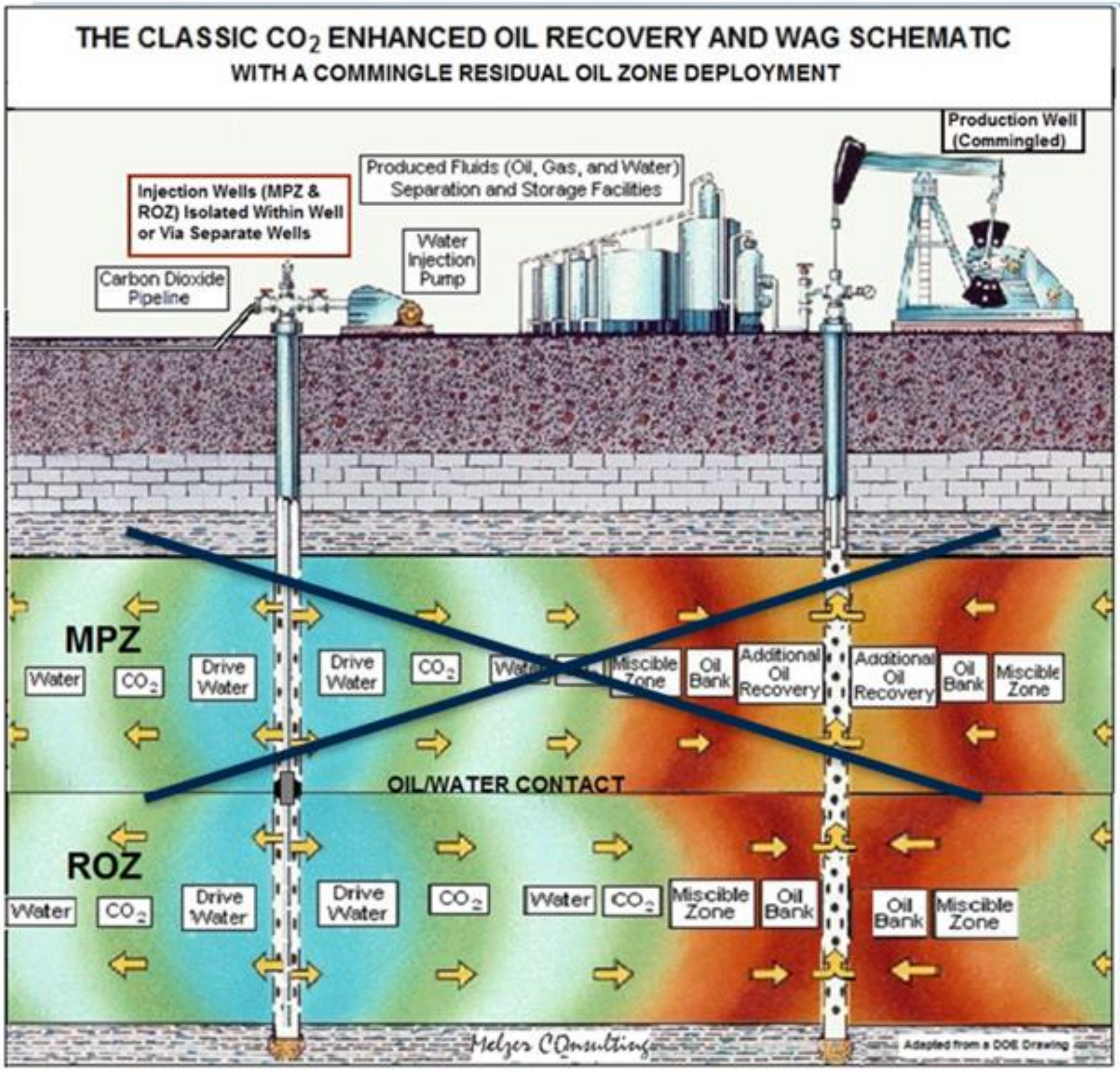


Kinder Morgan's Tall Cotton Project

Melzer CO2nsulting

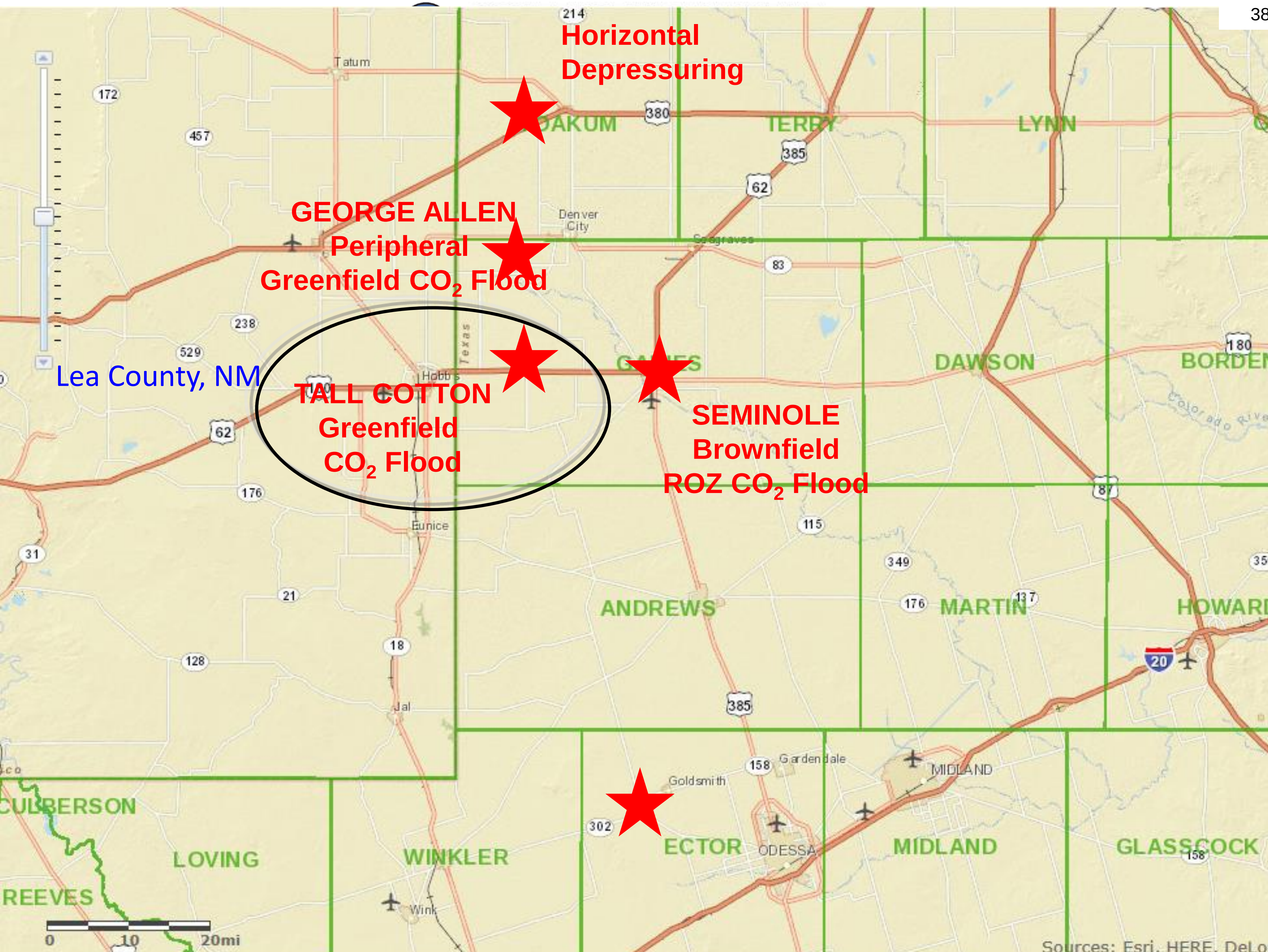
What is a Greenfield ROZ?



X NO MPZ!

-------OWC------

Greenfield ROZ


Horizontal
Depressuring
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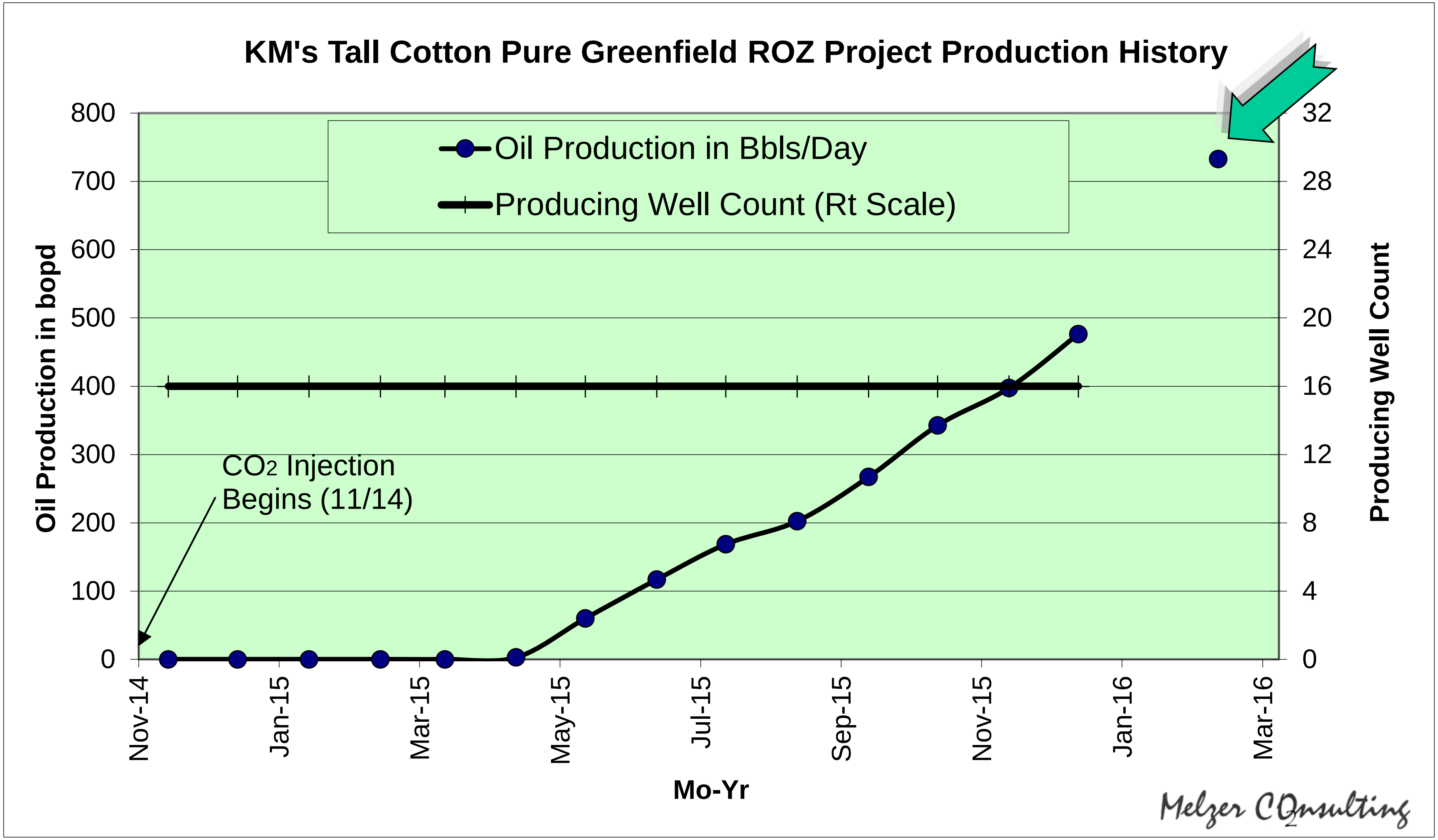
Peripheral
Greenfield CO_2 Flood
TALL COTTON
Greenfield
CO_2 Flood
SEMINOLE
Brownfield
ROZ CO_2 Flood
Lea County, NM
YOAKUM
TERRY
LYNN
DAWSON
BORDEN
ANDREWS
MARTIN
HOWARD
CULBERSON
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
REEVES
Tatum
Denver City
Seagraves
Hobbs
Eunice
Jal
Wink
Goldsmith
Gardendale
ODESSA
MIDLAND
Texas
Colorado River
0
10
20mi
Sources: Esri, HERE, DeLorme

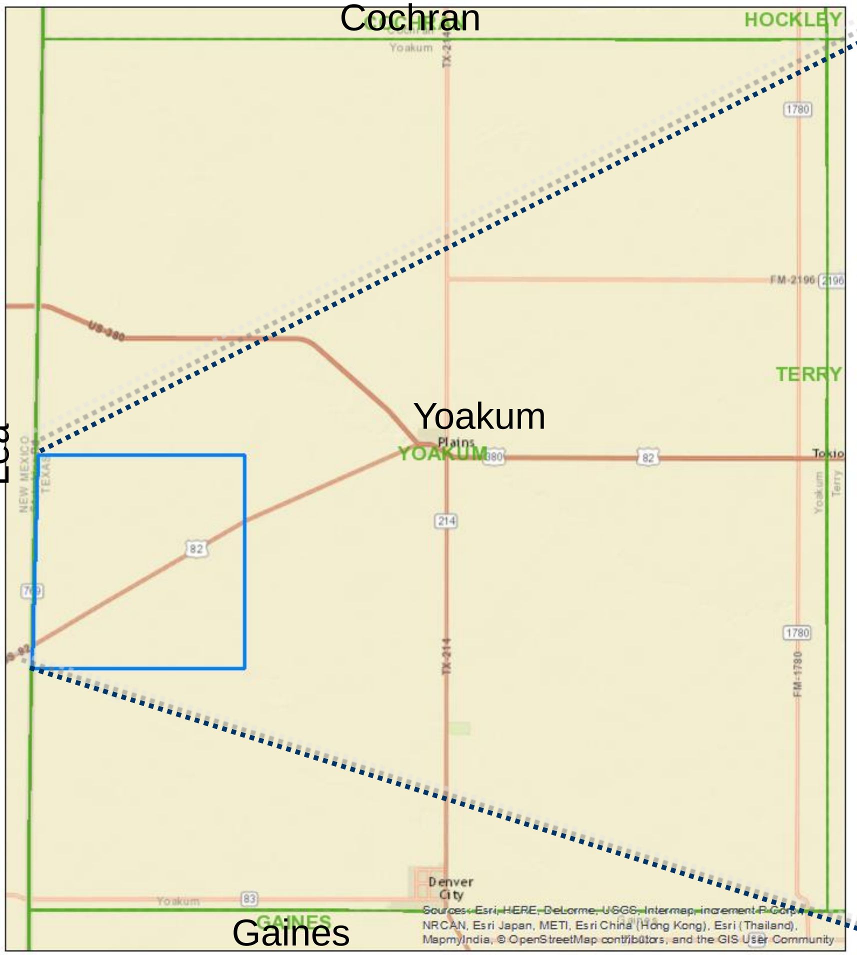

KM's Tall Cotton Pure Greenfield ROZ Project Production History
Oil Production in Bbls/Day
Producing Well Count (Rt Scale)
CO2 Injection Begins (11/14)
Oil Production in bopd
Producing Well Count
Mo-Yr
800
700
600
500
400
300
200
100
0
32
28
24
20
16
12
8
4
0
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
Melzer COnsulting

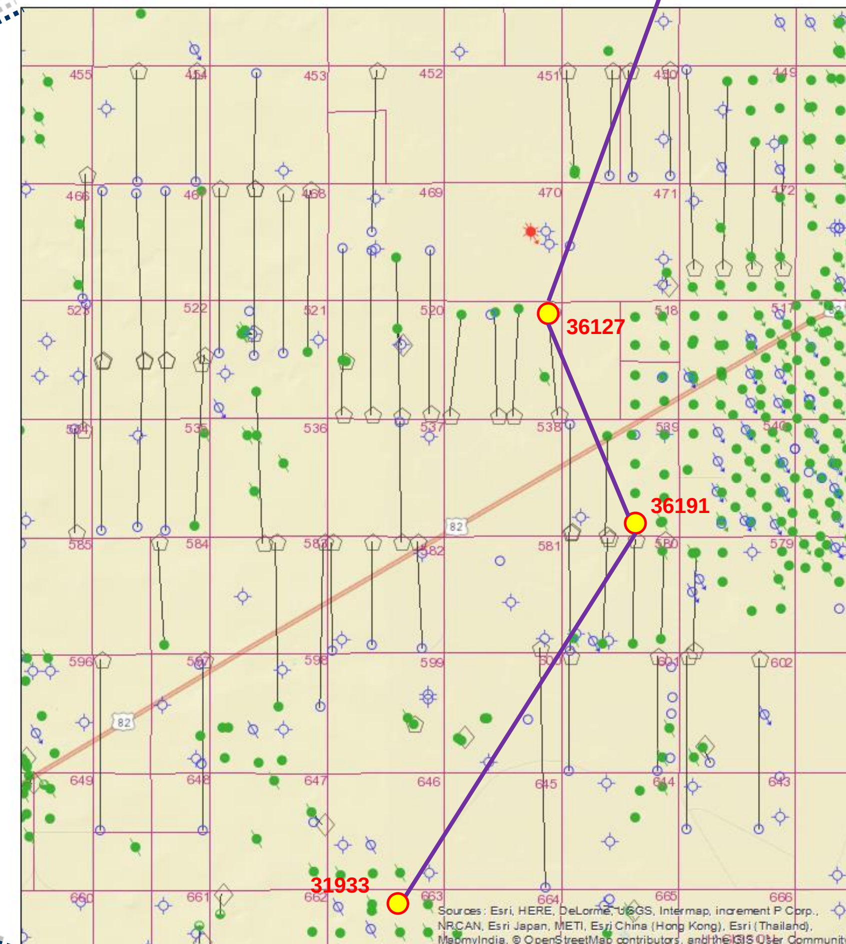
Back to the Horizontals

The Upper Bow

W. Yoakum San Andres Horizontal Wells

(as of Nov '15)





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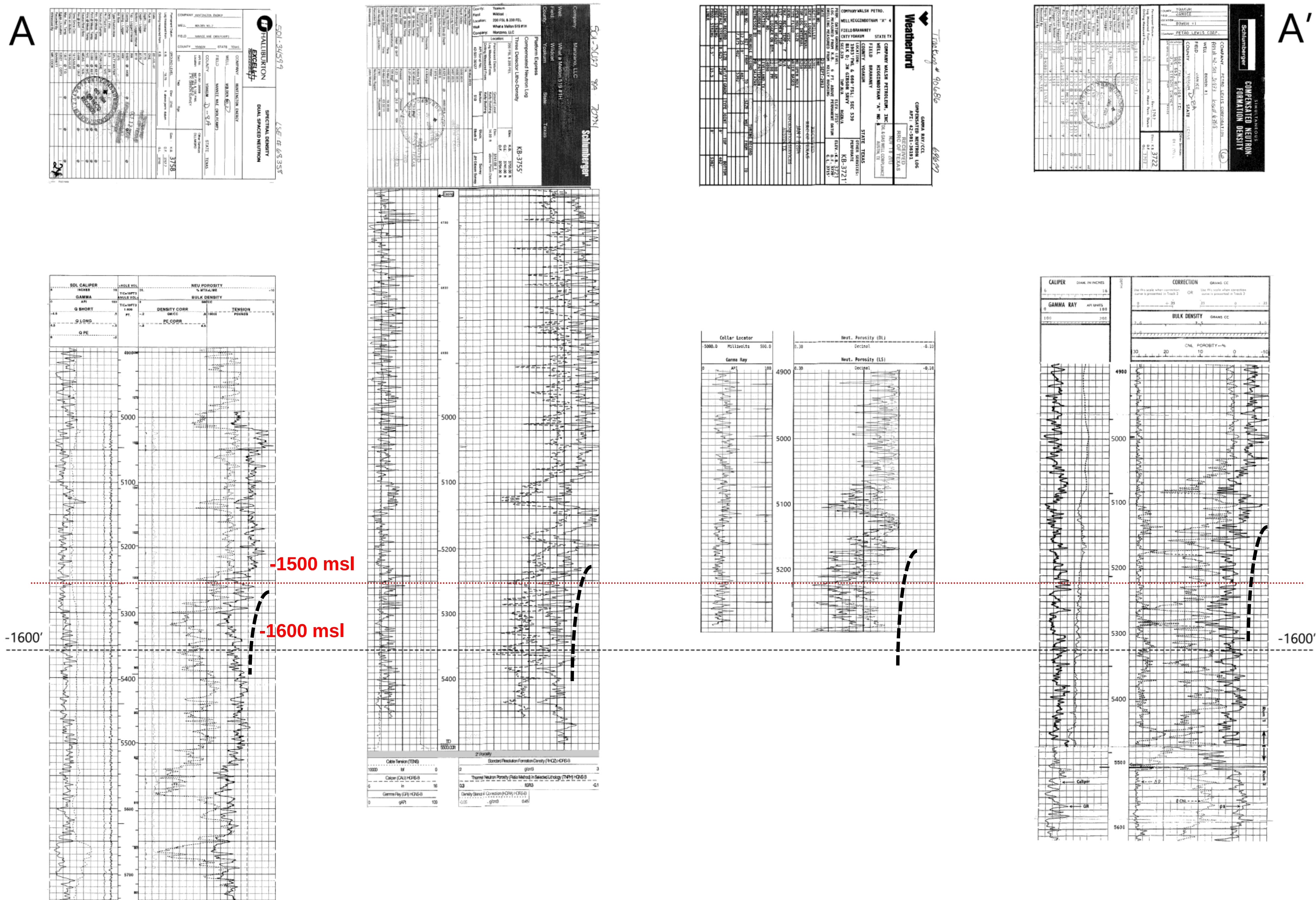
Manzano-Walsh Cross Section A-A’ (N-S)



San Andres Horizontals and the "Camps"

Prod Characteristic	Pods Camp 1	Tite Res Camp 2	ROZ Camp 3
Offset Wells	A new Ball Game	Variable Results	Consistent
Onset of Oil	Immediate	Quick	Delayed
Need for Gassy Oil	No	Yes	Yes
Requires Dolomites	No	No	Yes
Requires Sour Oil	No	No	Yes
Resource* Play	No	No	Yes

* My Definition – not SPEE's

Thankyou

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