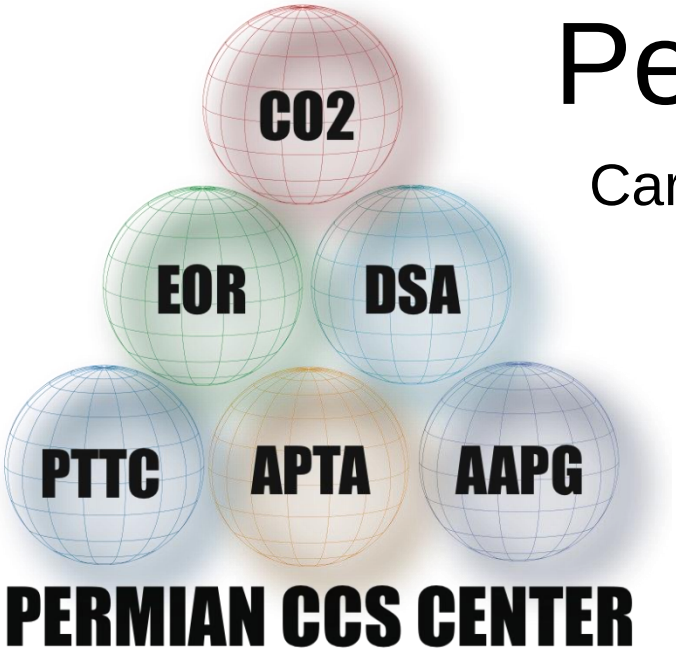


Permian CCS Center

Carbon Capture & Storage Technology

Southwest Petroleum Short Course

April 20 – 21, 2011

Robert D. Kiker

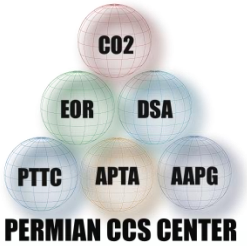
Applied Petroleum Technology Academy

TOPIC OUTLINE

- What is the Permian Basin Carbon Capture and Storage Training Center?
- Training Media
- Other CCS Training Centers
- Changing Focus
- Operations Workshop Highlights

About Permian CCS Center

- World class training in carbon capture and storage (and EOR) for and by industry professionals, focusing on individuals in the Permian Basin but through online presence available to individuals throughout the U.S. and the world
- Stimulated by a grant for the National Energy Technology Laboratory of the DOE and the American Recovery and Reinvestment Act of 2009
- Efforts guided by and Industry Advisory Board



Permian Basin CCS Approach

- By and For Industry – Industry organizations instructing industry professionals
- Targeted audience of wide range of energy professionals potentially involved in CCS, engineers, geoscientists, regulators, academia
- Its all about the money: for the individuals to advance, for PBCCS to become self-sustaining

Three World Class Organizations

Petroleum Technology Transfer Council

Tech Transfer, Workshops, Newsletter, Tech Alerts

American Association of Petroleum Geologists

37,000 Members, Publications and Conferences

Distance Learning

Applied Petroleum Technology Academy

CO_2 Course, CO_2 Conference

PERMIAN CCS CENTER

Applied Petroleum Technology Academy

- The Applied Petroleum Technology Academy ("APTA") is a non-profit organization created to teach energy companies how to apply cost-effective technology in order to extend the lives of aging oil and gas fields around the world. APTA's mission statement is simple:

  "To provide practical training of oilfield practices in a mature oilfield environment emphasizing cost savings with ample opportunity for field visitation."

- Headquartered in Midland, Texas - in the heart of the Permian Basin
  - APTA can provide access to hands-on practical training based on decades of CO_2 experience. Curricula can be customized to meet the specific needs of clients with respect to both their levels of experience and to the types of fields they are dealing with. APTA's curricula are designed to cover all aspects of petroleum production.

Petroleum Technology Transfer Council

- PTTC provides a forum for technology transfer and learning
- The Petroleum Technology Transfer Council (PTTC) is a national not-for-profit organization led by an independent Board of Directors and managed by the American Association of Petroleum Geologists. PTTC was established to provide a forum for transfer of technology and best-practices within the producer community. Local Producer Advisory Groups ensure that PTTC activities in a particular region address the technology needs of producers in that area.
- PTTC is a partnership to connect independents with the technology and knowledge to safely and responsibly develop the nation's CCS and oil and gas resources. As such, it is an important part of America's energy solution

PERMIAN CCS CENTER

American Association of Petroleum Geologists

- Founded in 1917, the American Association of Petroleum Geologists is currently the world's largest professional geological society.
- The membership of AAPG includes geologists, geophysicists, CEOs, managers, consultants, students and academicians. The purpose of the organization is to foster scientific research, advance the science of geology, promote technology and inspire high professional conduct.

Major Elements of Permian Basin CCS

- Week-Long Short Course (APTA) – Industry Professionals instructing Industry Professionals
- Series of One-Day Workshops and Webinars (PTTC)
- E-Certificate (AAPG) and free Open Courseware
- Augmented by www.permianbasinccs.org, Newsletter, e-alert

www.permianbasinccs.org

CARBON CAPTURE & STORAGE TECHNOLOGY

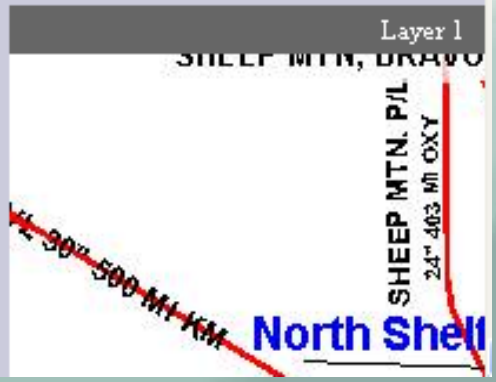
"World Class CCS Training for & by Industry Professionals"

Imparting the needed skill sets to realize CCS opportunities

Developed & Delivered by PTTC, APTA & AAPG with Grant Funding
from the American Recovery and Reinvestment Act of 2009 through DOE

- Elements of the Program
- Calendar of CCS Events
- Newsletter/Tech Alerts
- CCS News of Interest
- Other DOE Regional CCS Training Programs
- DOE's regional Carbon Sequestration Partnerships

CCS-related layer maps of Permian Basin



Carbon Capture and Storage Technology

Catch & STORE

World Class CCS Training for and by Industry Professionals

pttc.org aptapb.org aapg.org permianbasinccs.org VOLUME 1, NUMBER 2 AUGUST 2010

Residual Oil Zones

BY STEVE MELZER

Our first issue described pervasively dolomitized intervals (PDI) in the Permian Basin (PB). PDIs stem from a slow lateral invasion of water from outcrops on the western side of the PB that pervasively altered the limestone to dolomite resulting in a laterally continuous, moderately porous and permeable zone that provides a large potential

What does a Residual Oil Zone (ROZ) look like?

BY BOB TRENTHAM, UTPB/CEED

Research is documenting the evidence for and characteristics of ROZs below the major San Andres reservoirs in the Permian Basin (PB). There is significant anecdotal evidence for the presence of ROZs from exploration wells in "goat pasture" both adjacent to, and at distance

Characteristics. Rock properties include: the presence of sulfur crystals associated with gypsum in the swept interval (ROZ) of carbonate reservoirs; evaporites that are dissolved in the ROZ or altered in the lower part of the main pay; sample shows of oil and/or gas (odor, cut, fluorescence in

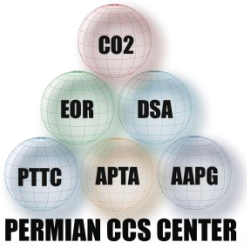
Permian CCS Workshops

Extended Length Workshop (4 ½ days) contains most of the aggregate material found in the 1 day works listed below

- Overview of the Elements of CCS – CCS (and CO_2 Flooding in the Permian Basin)
- Site Selection and Operations – The Reservoir – Characterization, Modeling and Monitoring
- CO_2 Flood Operations & Surface Facilities – CO_2 Sources and Capture Technology
- Business of CO_2 Flooding and Moving Forward with CCS

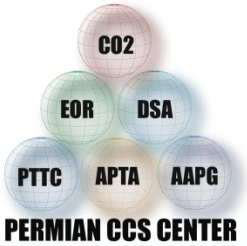
Webinars – Slides and Voice

- The Promise and Performance of Next Generation CO_2-EOR by Advanced Resources International with Vello Kuuskraa and Michael Godec
- CCS (and CO_2 Flooding) in the Permian Basin – An Overview of the Science and Training Program with Steve Melzer and Dwight Rychel
- CCS in the Permian Basin, The Reservoir – Characterization, Modeling and Monitoring with Steve Melzer and Bob Trentham



Free Open Courseware - AAPG

- Carbon Capture and Sequestration: An Introduction
- Geological Models in CO_2 Separation
- CO_2 Supply, Demand: Legal and Regulatory Issues
- CO_2 Separation, Compression, Transportation and Marketing



Permian CCS e-Cert Program

- Online program
- Proceed at your own pace
- Certification after demonstrated learning
- Similar topics as short courses
- Structure the same as recent AAPG Solar Energy Program

Other CCS Training Organizations

Midwest Geological Sequestration Consortium – Sequestration Training and Education Center – MGSC-STTC (http://sequestration.org/step/index.html) by Illinois State Geological Survey.

Carbon Capture and Storage Training (CCST) Northwest – Carbon Tech Alliance (www.carbontechalliance.org) by Environmental Outreach and Stewardship Alliance.

Southwestern United States CO_2 Sequestration Training Center – CO2TC (New Mexico Institute of Mining and Technology) www.southwestcarbonpartnership.org/default.aspx.

Southeast Regional CO_2 Sequestration Technology Training Program – SECARB-Ed (www.sseb.org/secarb-ed.php) by Southern States Energy Board (www.sseb.org).

Sequestration Training, Outreach, Research & Education – STORE (www.storeco2now.com) by University of Texas at Austin..

Wyoming CCS Technology Institute – WCTI (http://wcti.uwyo.edu) by University of Wyoming.

Permian Basin CCS Training Center

What Has Worked

- Highly Qualified and Responsive Advisory Board
- Newsletter and e-Alert Informative, hundreds of readers
- Broad Encompassing Curriculum
- Structure in place for first two short Courses and Webinars

Permian Basin CCS Training Center

Challenges

- Lack of congressional action regarding climate control providing incentives to capture and sequester CO_2 causing otherwise interested parties to lose interest
- Targeted Oil and Gas Professionals in Permian Basin have skills in place for sequestration via CO_2 EOR and little interest in geological storage in saline formations
- Consequently low interest in early produced workshops and webinars

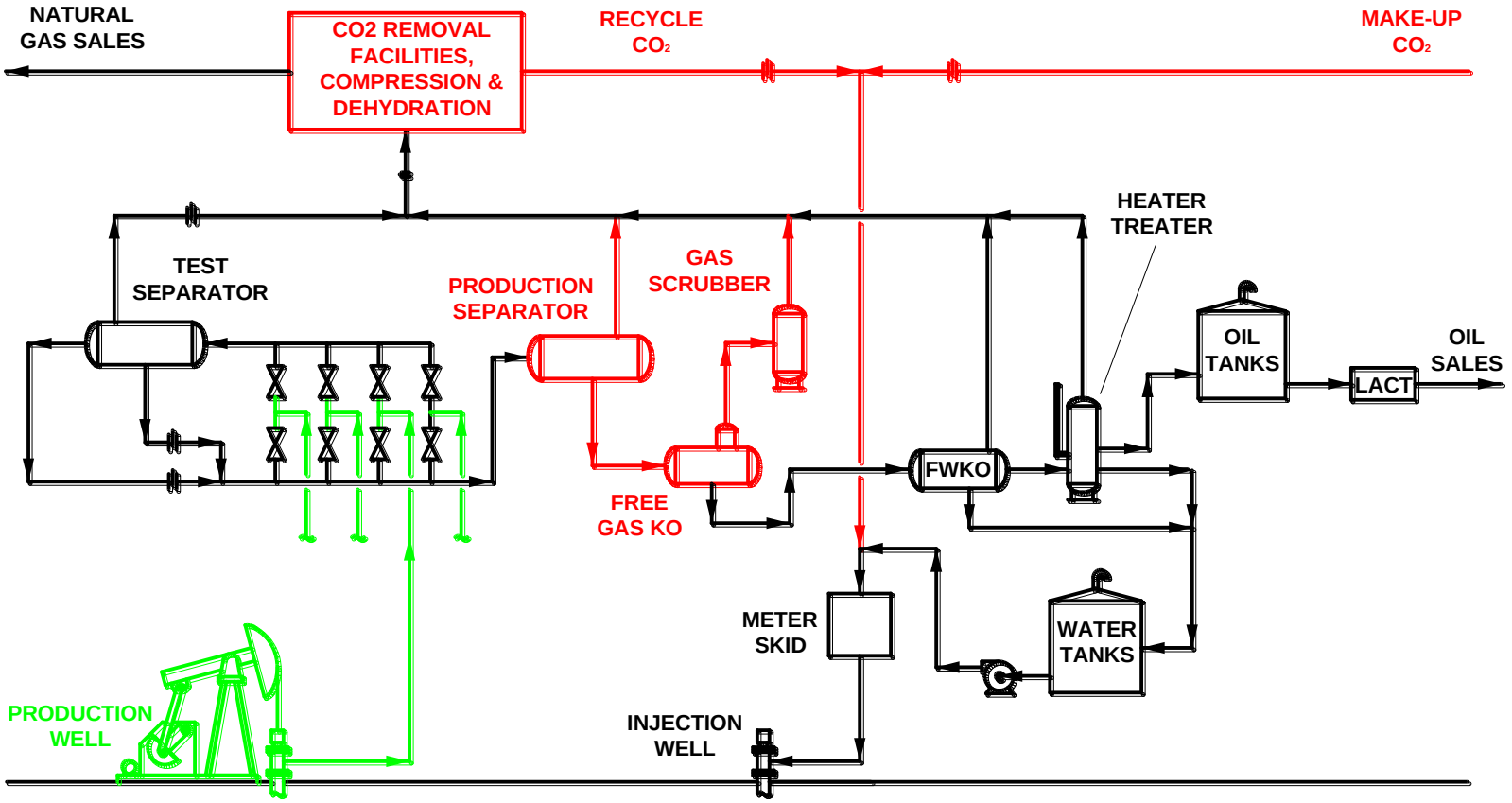
Where We Are Today

- Broadened targeted audience to include regulators, environmentalists, scientists, electric generating industry and other CCS stakeholders
- Slowed the pace of delivery somewhat until the audience is broadened and some hope of legislation emerges
- Focused more on electronic delivery, versus the local workshops

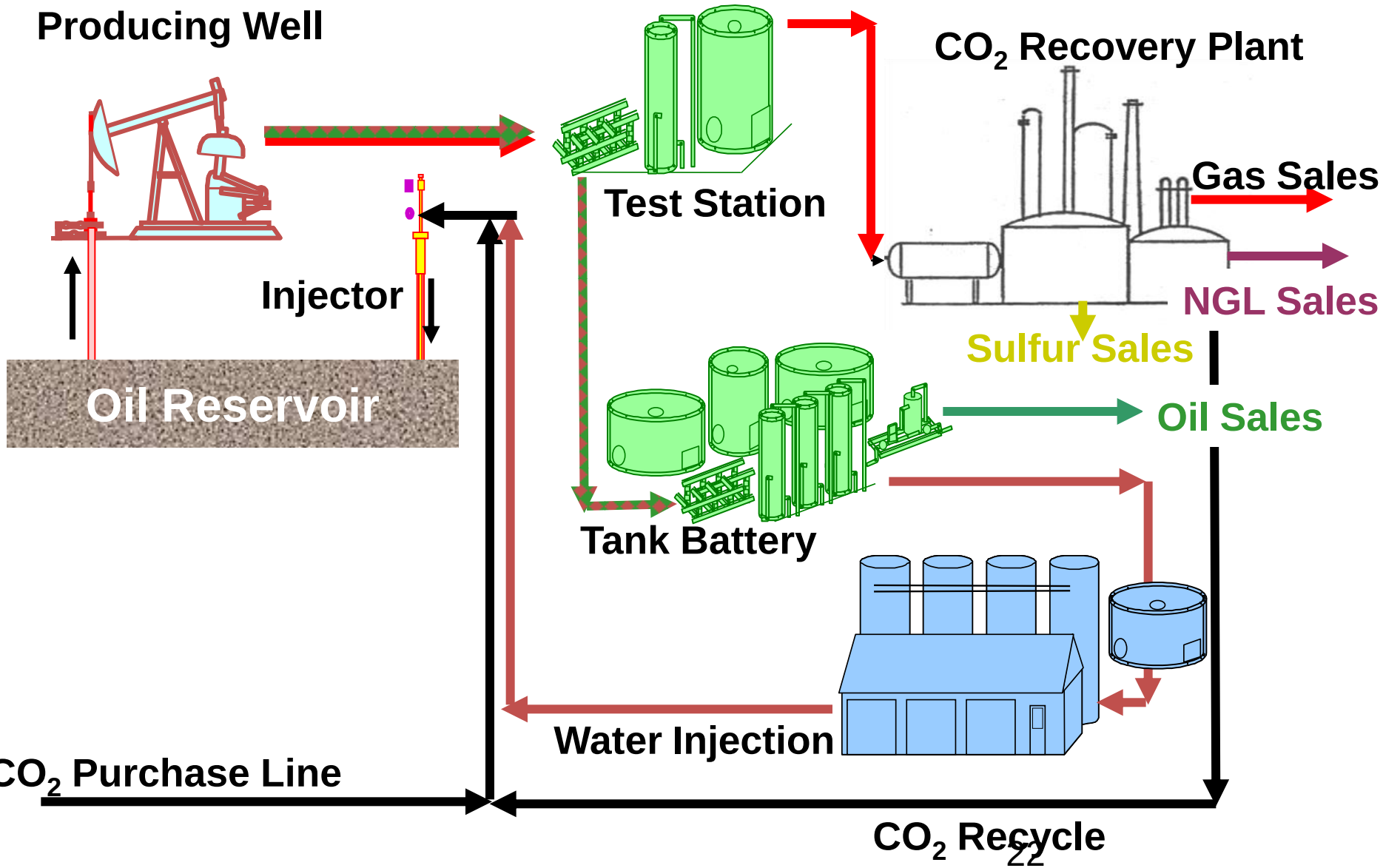
Operations Workshop Topics

- CO_2 Flood Operations
- Wellsite Surface Equipment
- Downhole Design and Considerations
- Operational Features Peculiar to CO_2 Injection Projects
- Examples of Operator Differences
- Review of Anthropogenic Sources and Existing and Future Capture Technologies
- Dehydration Processes
- Compression Facilities
- Sulfur Removal
- Recycle Plants

Typical CO_2 / Waterflood Operation



Field Flow Diagram



Field Flow Diagram

Gas/CO_2

Gas Sale

NGL Sale

Sulfur Sale

Gas/CO_2

Oil, Wtr, Gas/CO_2

Oil Sale

Water

CO_2 Recycle

CO_2 Purch

Water

Surface Equipment

Design Considerations

- Production Equipment/Vessels
  - Headers
  - Separators-2 & 3 phase
  - FWKO
  - FGKO
  - Tanks
    - Oil & Water
  - Vapor Recovery
- Water Injection Equipment

Production Equipment - Vessels

- Production Separator
  - 2-phase
  - Eliminates large gas volumes at test site
  - Disperses slugs and surges
- Free Gas Knock Out
  - 2-phase
  - Eliminates large gas volumes
  - Regulates fluid delivery to FWKO

Production Equipment - Vessels

- Free Water Knock Out
  - 2-phase (fluid packed), or
  - 3-phase
- Heater-Treater
  - 3-phase
  - Vertical or horizontal
  - Oil/water separation
- Gas Scrubber
  - 2-phase
  - Separates carry over fluids

Production Equipment - Vessels

- Design Considerations
  - Operating pressure
  - Operating temperature
  - Production flow rates throughout life of project
- Materials
  - Internally coated carbon steel

Production Equipment - Tanks

- Working Tank
- LACT Tanks
  - Circulation system
  - Agitators (mixers)
- Design Considerations
  - Daily production rates
  - Operator response time
- Materials
  - Carbon steel
  - Partial internal coating

Production Equipment - Vapor Recovery

- Design Considerations
  - Gas volumes
  - Oxygen
  - Regulatory compliance
- Materials
  - Vessels: CS hot side / SS cold side
  - Piping & Valves: CS hot side / SS cold side

Downhole Design Considerations

Tubulars- Both Production and Injection Wellbores
Metallurgy for Pumps and Packers
Artificial Lift

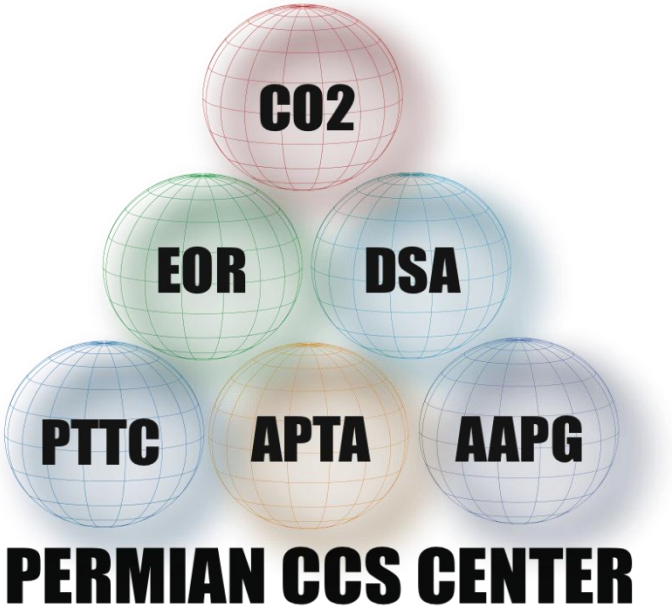
$C0_2$ Operations Features/Operator Differences

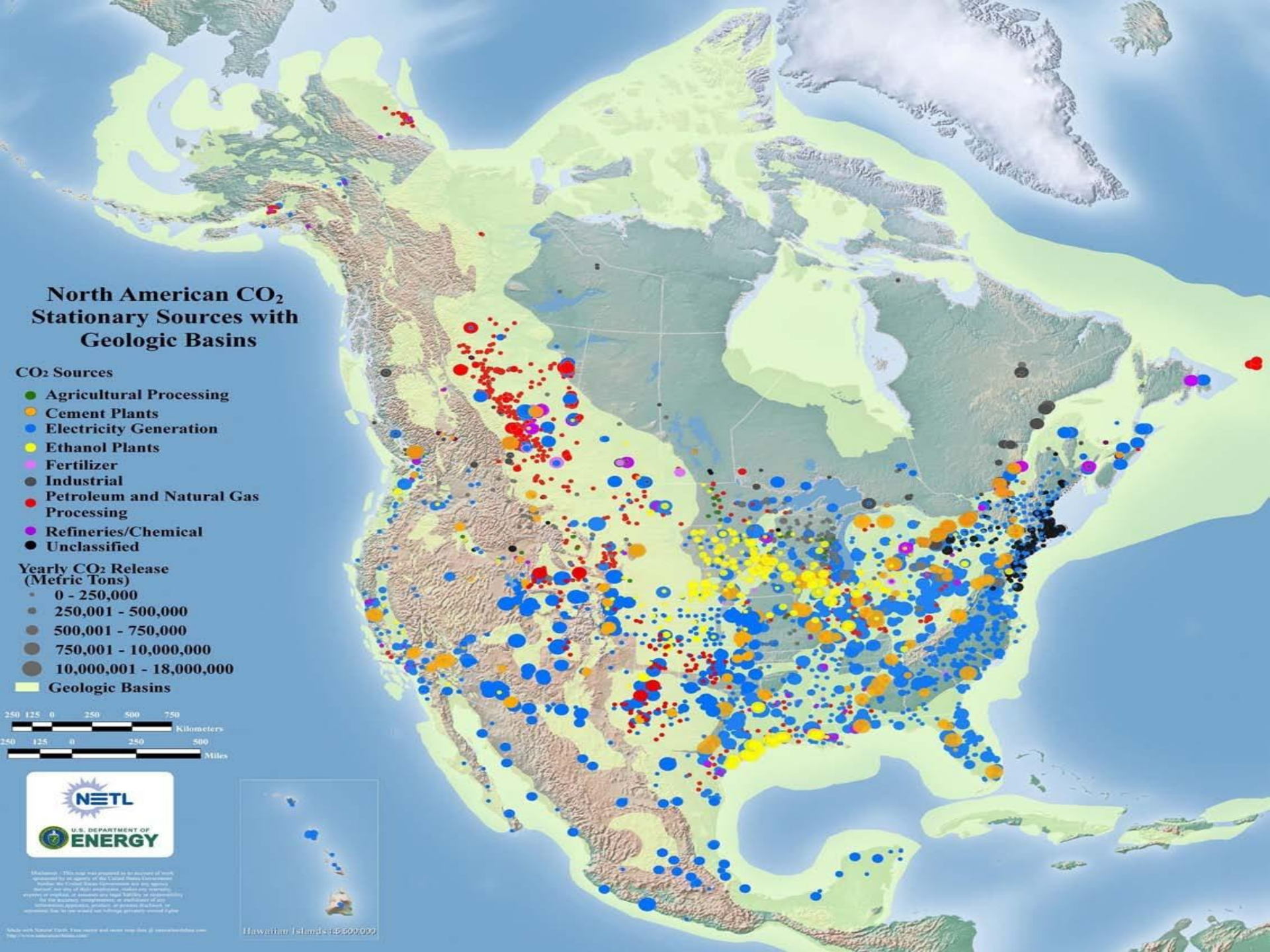
- Review operational feature differences and similarities in regard to production practices including artificial lift.
- Review operational differences in the handling of the produced gas stream for the flood injection.

Surface Facilities Options

- Reinjection of associated gas produced (Often Referred to as Blood, Guts, and Feathers {BGF})
  - Compression and usually dehydration
- Reinjection of associated gas stream coupled with C_4+ extraction for sales
  - Compression, dehydration, rough hydrocarbon cut, CO_2 removal
- Processing of the associated gas stream into C_2+ for sales and CO_2 for reinjection
  - Compression, dehydration, hydrocarbon recovery (distillation, CO_2 membranes, etc.)

Anthropogenic Sources and Separation Technologies




North American CO_2 Stationary Sources with Geologic Basins
CO_2 Sources
Agricultural Processing
Cement Plants
Electricity Generation
Ethanol Plants
Fertilizer
Industrial
Petroleum and Natural Gas Processing
Refineries/Chemical
Unclassified
Yearly CO_2 Release (Metric Tons)
0 - 250,000
250,001 - 500,000
500,001 - 750,000
750,001 - 10,000,000
10,000,001 - 18,000,000
Geologic Basins
250 125 0 250 500 750
Kilometers
250 125 0 250 500
Miles
NETL
U.S. DEPARTMENT OF ENERGY
Hawaiian Islands

Industrial Sources of CO2

Source	Flue Gas % CO2	CO2 Capture/yr (MM tons)	CO2 MMSCF/D
• Coal Power Plant[1]	13.3	4.6	222
• Natural Gas Turbine[2]	4.0	1.5	72
• Cement Plant[3]	14-33	1.2	56
• Steel Mill[4]	15-20	3.85	184
• Ammonia Plant[5]	98+	0.62	30
• Hydrogen Plant[6]	95+	0.50	24
• Ethylene Oxide[7]	98+	0.18	9
• Ethanol Plant[8]	98+	0.14	7

1- 546 MW(net) Supercritical Plant @ 85% Capacity Factor, 90% Capture
2 - 482 MW (net) Nat Gas Combined Cycle Plant @ 85% Capacity Factor, 90% Capture
3 - 1.1 MM ton/yr cement plant @ 92% Capacity Factor and 80% Capture
4 - Oil & Gas Journal, 10-4-2010, p.108: Original Source (IFP)
5 - 1500 ton/day NH3 plant base on steam reforming of methane, 95% Capacity Factor
6 - Based on 100 MMSCF/D hydrogen production from SMR @ 95% Capacity Factor
7 - 350,000 ton/ye Ethylene Oxide plant
8 - 50 MM gallon/year ethanol plant

Blue Strategies, 2010

CO_2 Capture Technologies

- Pre-Combustion
  - IGCC – FutureGen
  - Membranes
- Oxy-Combustion and Chemical Looping
  - Pure Oxygen vs. Air in Boiler
- Post Combustion
  - Adsorption
  - Solvent

Integrated Environmental Control Model – WWW.iecm-online.com

Discuss and Evaluate all CO_2 Capture Processes

CO2 Capture Demonstration Projects

Coal Fired Power Plants

Performer, Location, Capture Technology ,Capture Rate (tonnes/year) , Start Date

Pre-Combustion Capture

Summit Texas Clean Energy Odessa, TX Selexol 3,000,000 2014

Southern Company Kemper County, MS Selexol 2,000,000 2014

Hydrogen Energy California Kern County, CA Rectisol 2,000,000 2016

Post-Combustion Capture

Basin Electric Beulah, ND Amine 5,00,000 - 1,000,000 2014

NRG Energy Thompson, TX Amine ~500,000 2015

American Electric Power New Haven, WV Chilled Ammonia 1,500,000 2015

Oxy-Combustion Capture

FutureGen 2.0 Meredosia, IL Oxy-Combustion 1,000,000 2015

Gas Plant Processing

Dehydration/Compression
Sulfur Removal/Recycle Plants

Gas Handling - Dehydration

- Design Considerations
  - Is dehydration necessary?
  - Wet CO_2 flow rates
  - Operating pressure
  - Operating temperature
- Materials
  - Contactor: Stainless steel
  - Regeneration Skid: Carbon steel and stainless steel

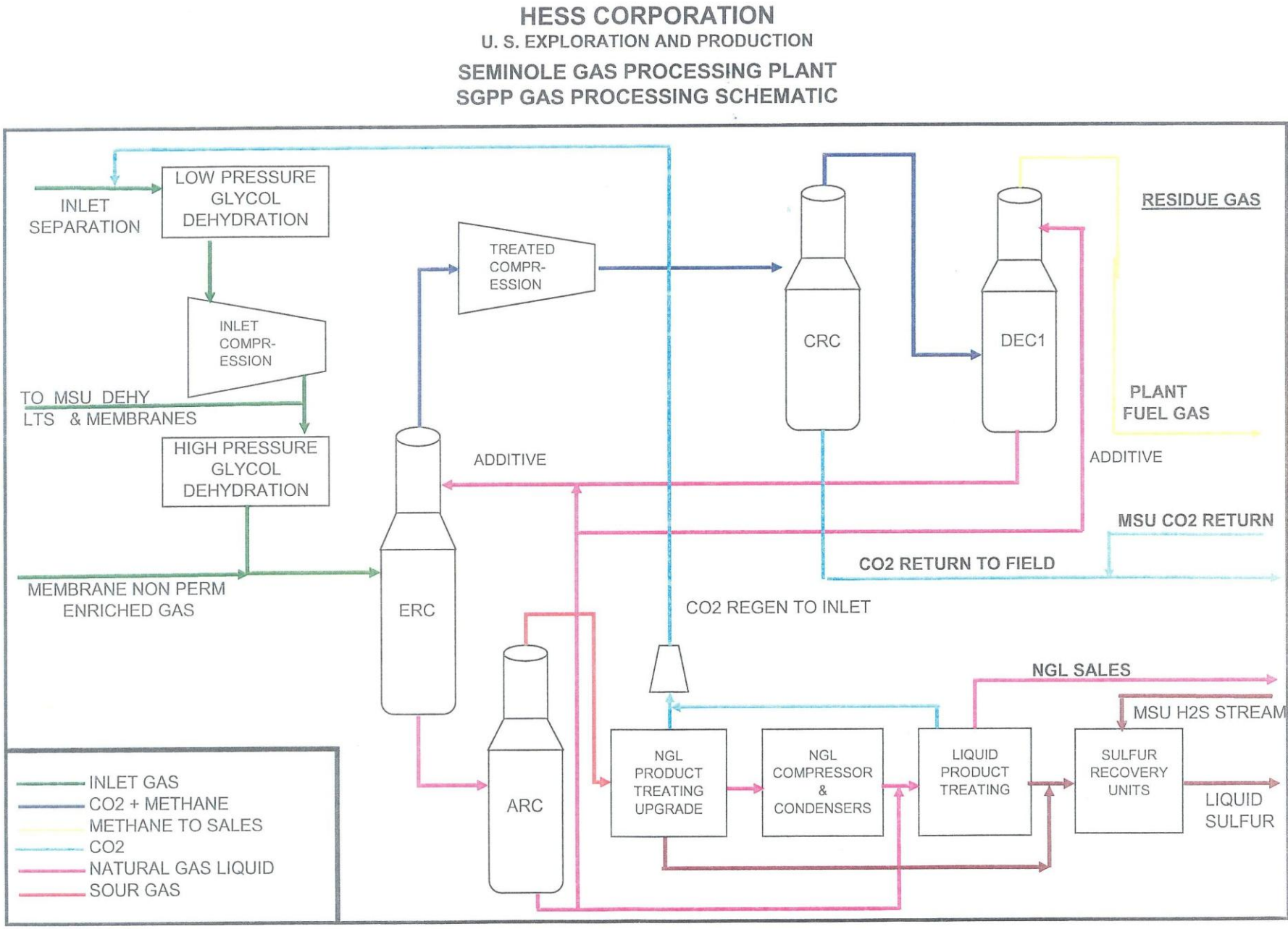
NCG
NICHOLAS CONSULTING GROUP, INC.

Gas Handling - Compression

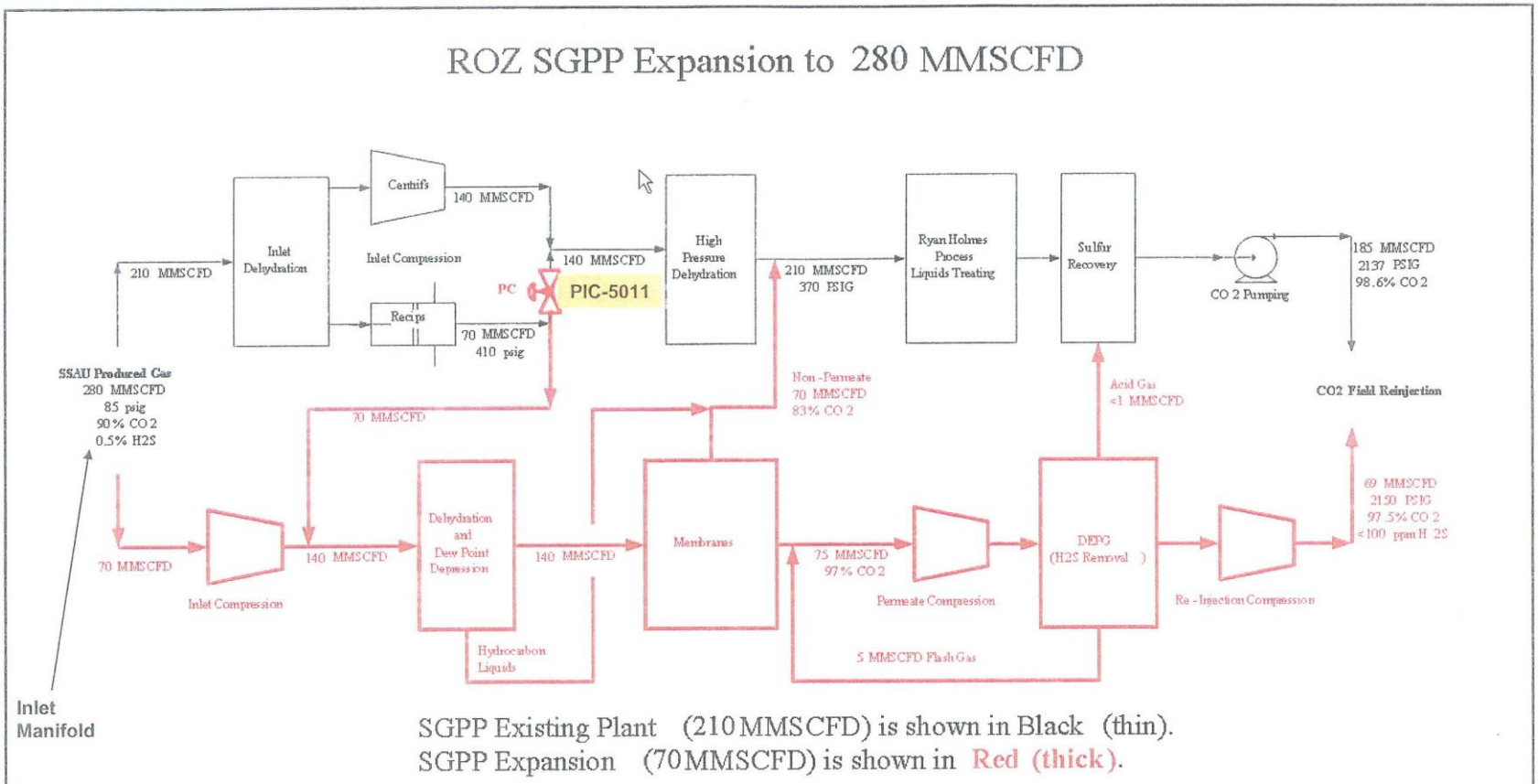
- CO_2 compression differs significantly from natural gas compression
  - Materials
  - Compressor Speed
  - Drivers
  - Cooler Design

NICHOLAS CONSULTING GROUP, INC.

Hess Seminole Plant Schematic



Hess Seminole Plant Expansion Schematic



The nominal capacity of the ROZ expansion is 70 MMSCFD inlet gas, though design allowances and equipment margins should result in a throughput capacity of 75 to 80 MMSCFD (Dehydration through Membrane Separation is ~2 times to incorporate the SGPP gas). ROZ is designed to run on the common SGPP inlet system, analogous to trains 1-3. A new 30" inlet header around the NW corner of SGPP connects the new ROZ inlet to the existing inlet laterals and manifold. The three fixed-speed ROZ centrifugal compressors work in series, and are designed to run in complement with each other. Inlet Gas fluctuations will be absorbed by the existing SGPP I/T compressors and pressure control valves (PV-9301 and PV-5547).

The throughput of ROZ is controlled primarily by the flow-control valves on the inlets to the membrane skids (FV-03141A/B). During normal operation, it is expected that these valves will have local set-points higher than attainable, in order to maximize throughput. Variations between the ROZ Inlet and Permeate Compressors are controlled by the pressure control valves on the SGPP inlet compression discharge header (PV-5011-1/2), allowing excess inlet gas from the Reciprocating compressors to revert to the High Pressure TEG Dehydration.

ROZ (Residual Oil Zone Development)

The following slides have been added to report a new development that the Permian Basin $C0_2$ APTA group has been actively involved in.

Further information on the research and actual demonstration work that is going on in the ROZ zones is available at the website http://www.residualoilzones.com

Origins of Residual Oil Zones and Mother Nature's Waterflood

Background and Understanding

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.

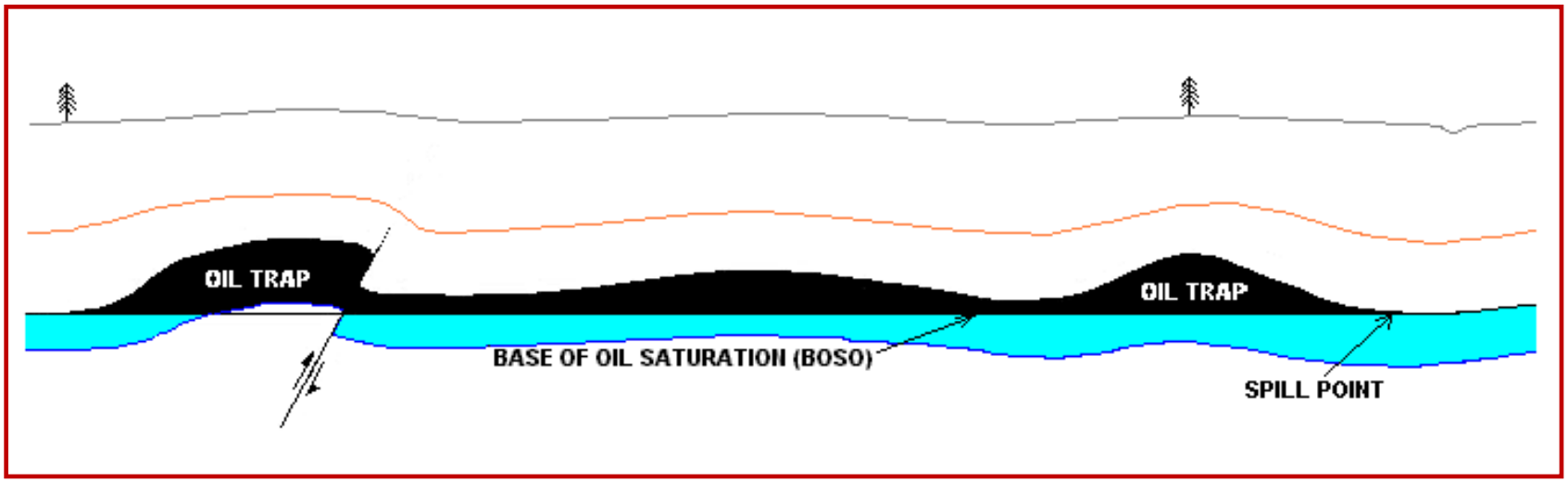
- ROZ's have historically been interpreted as being long Transition Zones. Although the upper portions of TZ's/ROZ's have long been assumed to contribute to production in some fields, until recently their potential as a CO2 recovery target has not been exploited.

- 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.

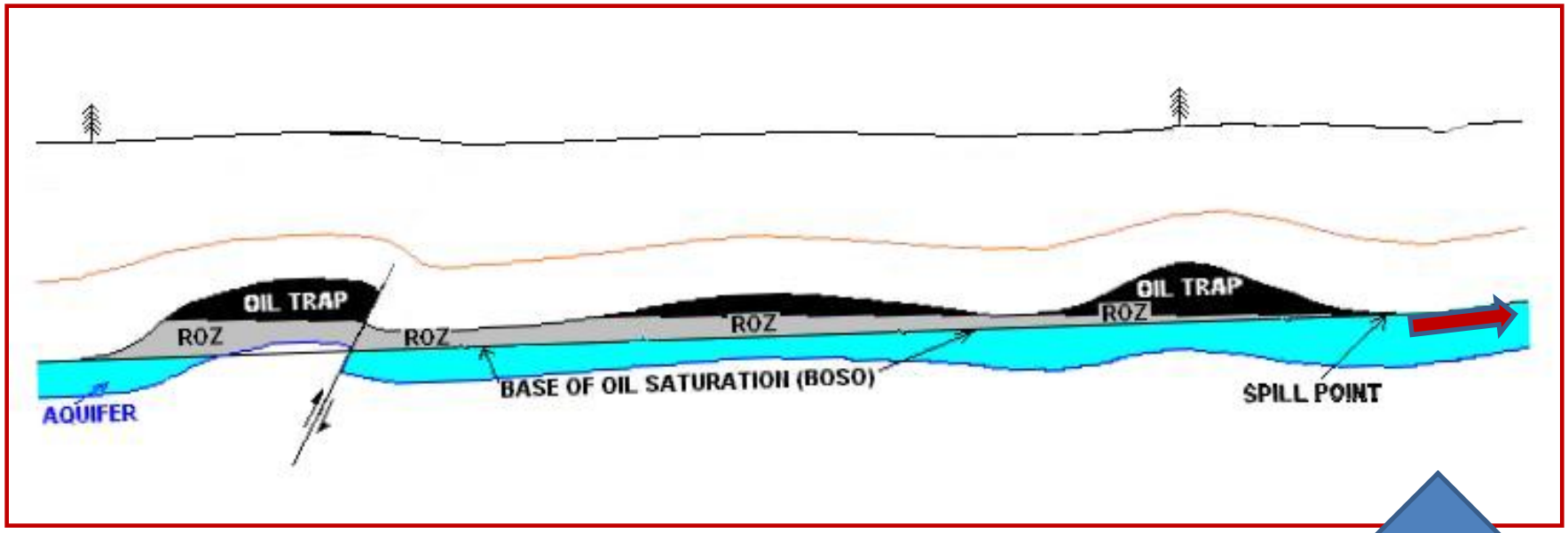
Where we are today

- 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 CO_2 projects underway at Wasson, Seminole, Vacuum, Means, Goldsmith, and Hanford Fields, with others 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.

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

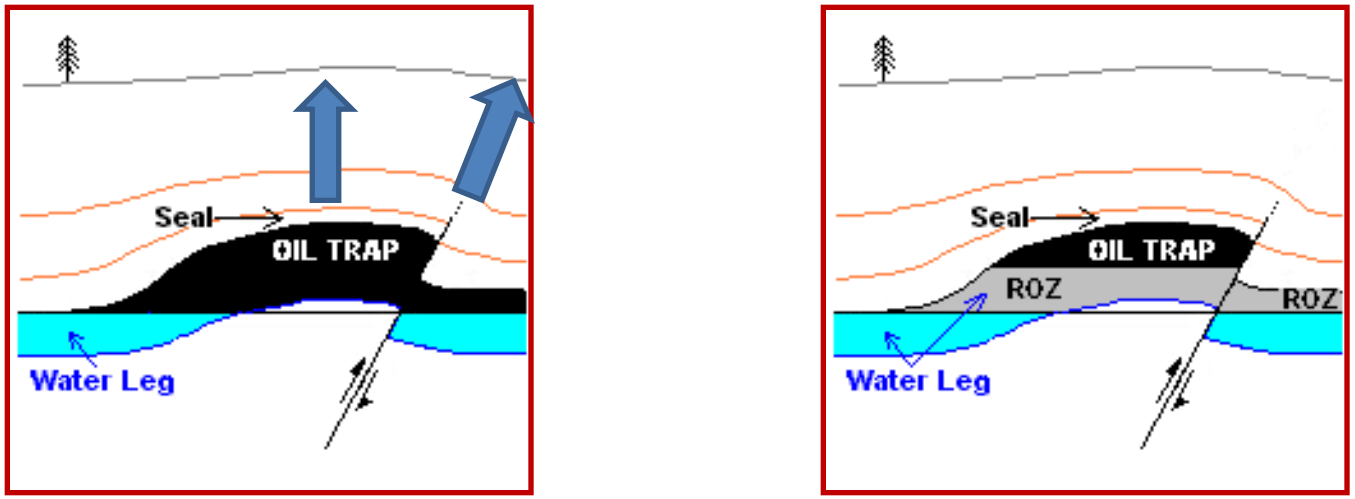


TYPE 1. Original Accumulation Subject to a Eastward Regional Tilt & Forming a ROZ.
The new O/W contact is horizontal
The base of the ROZ is tilted
Oil would have migrated out of the basin.



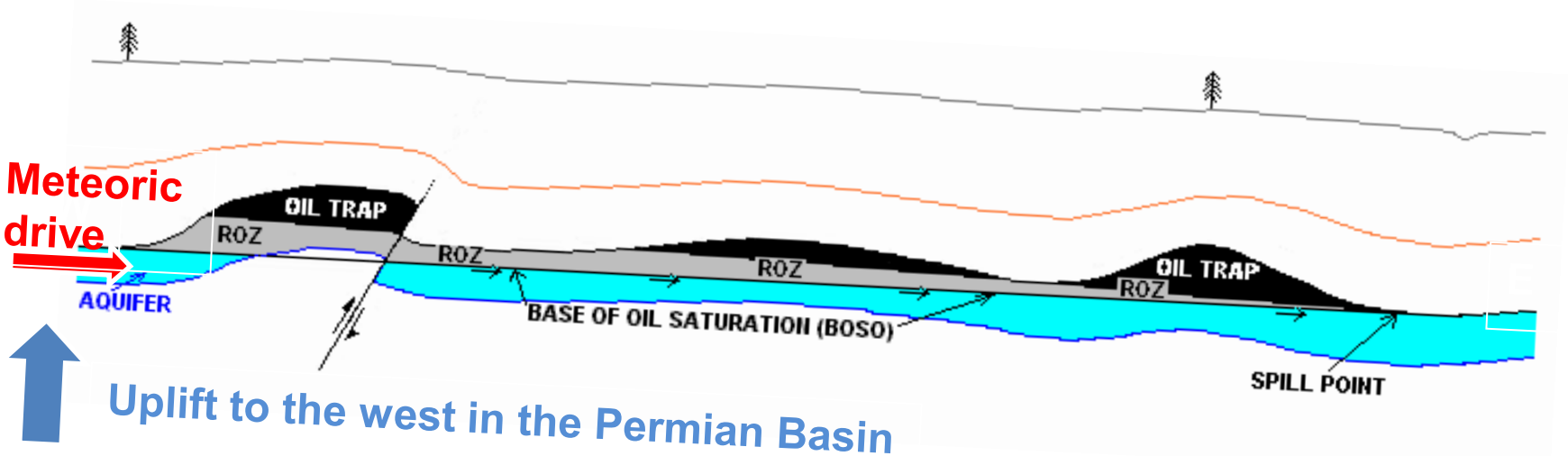
Static System

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.

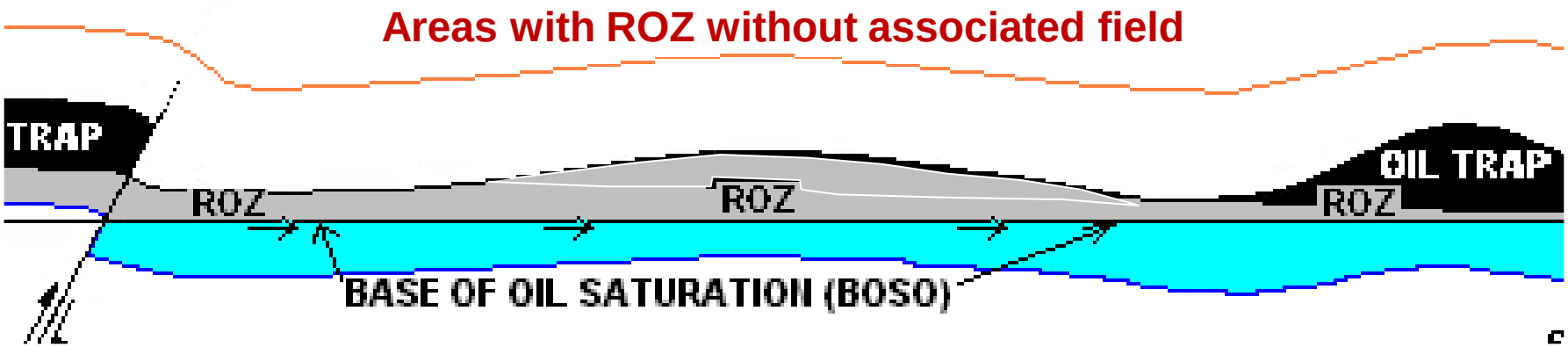


Static System

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.

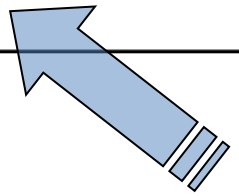


Dynamic System

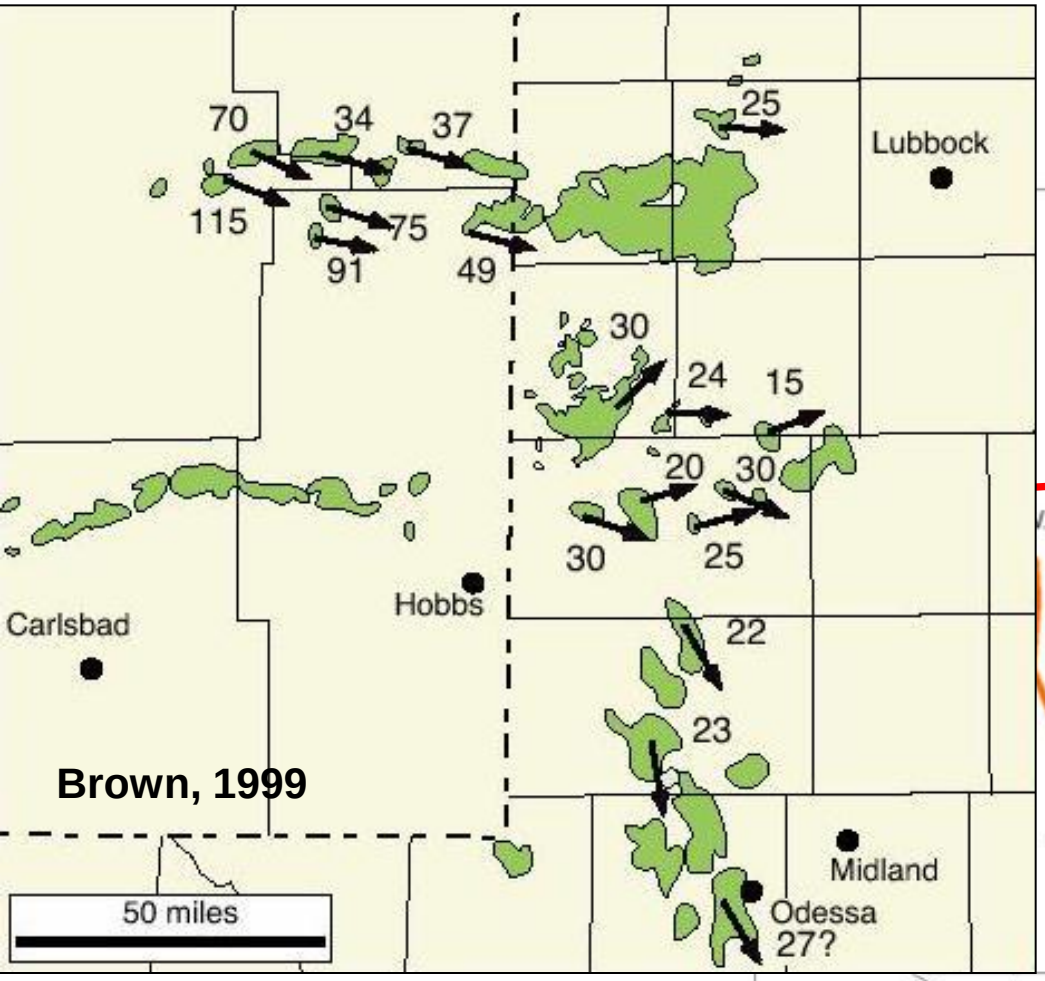


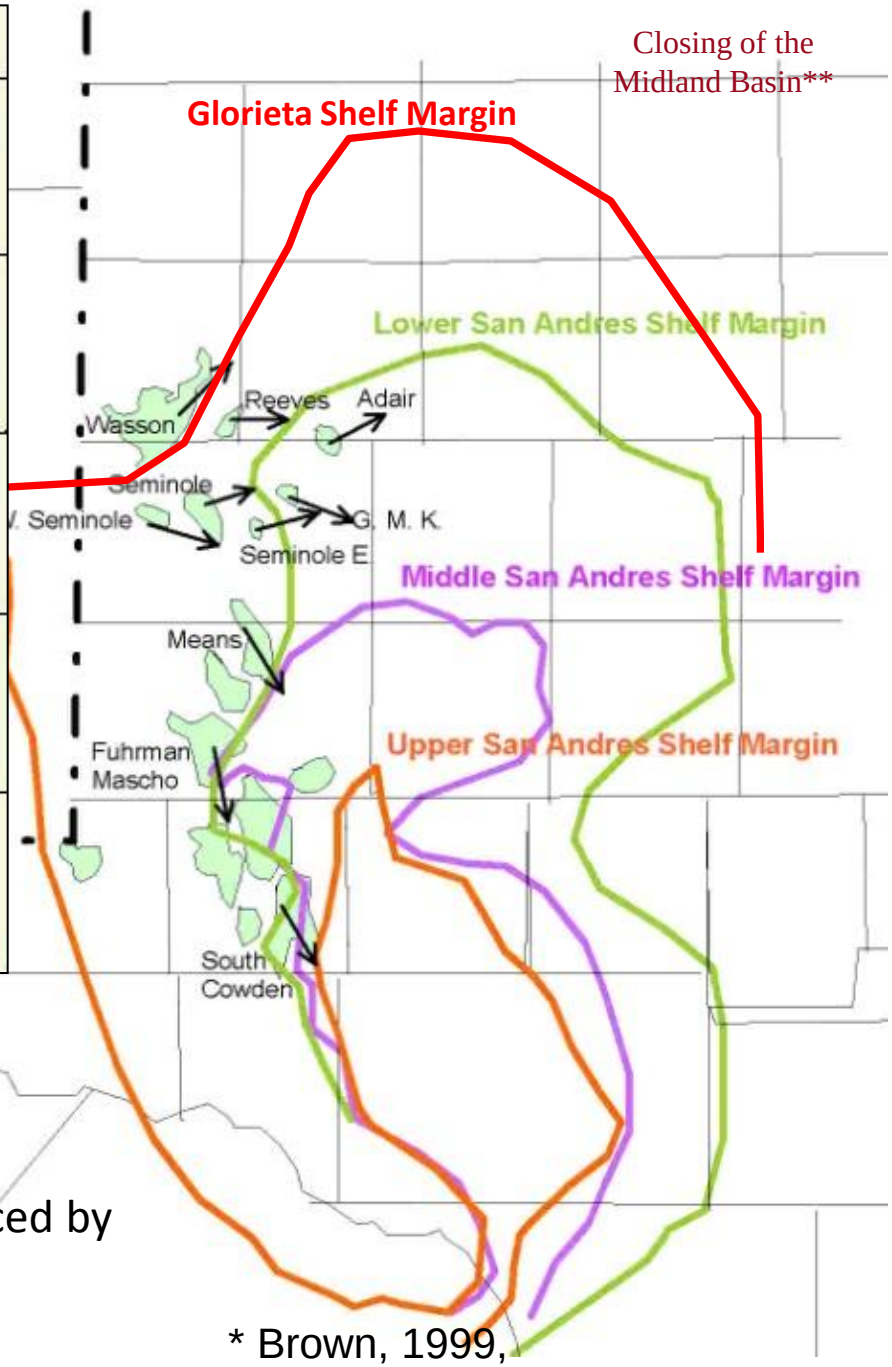
Attributes of the ROZ Types

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





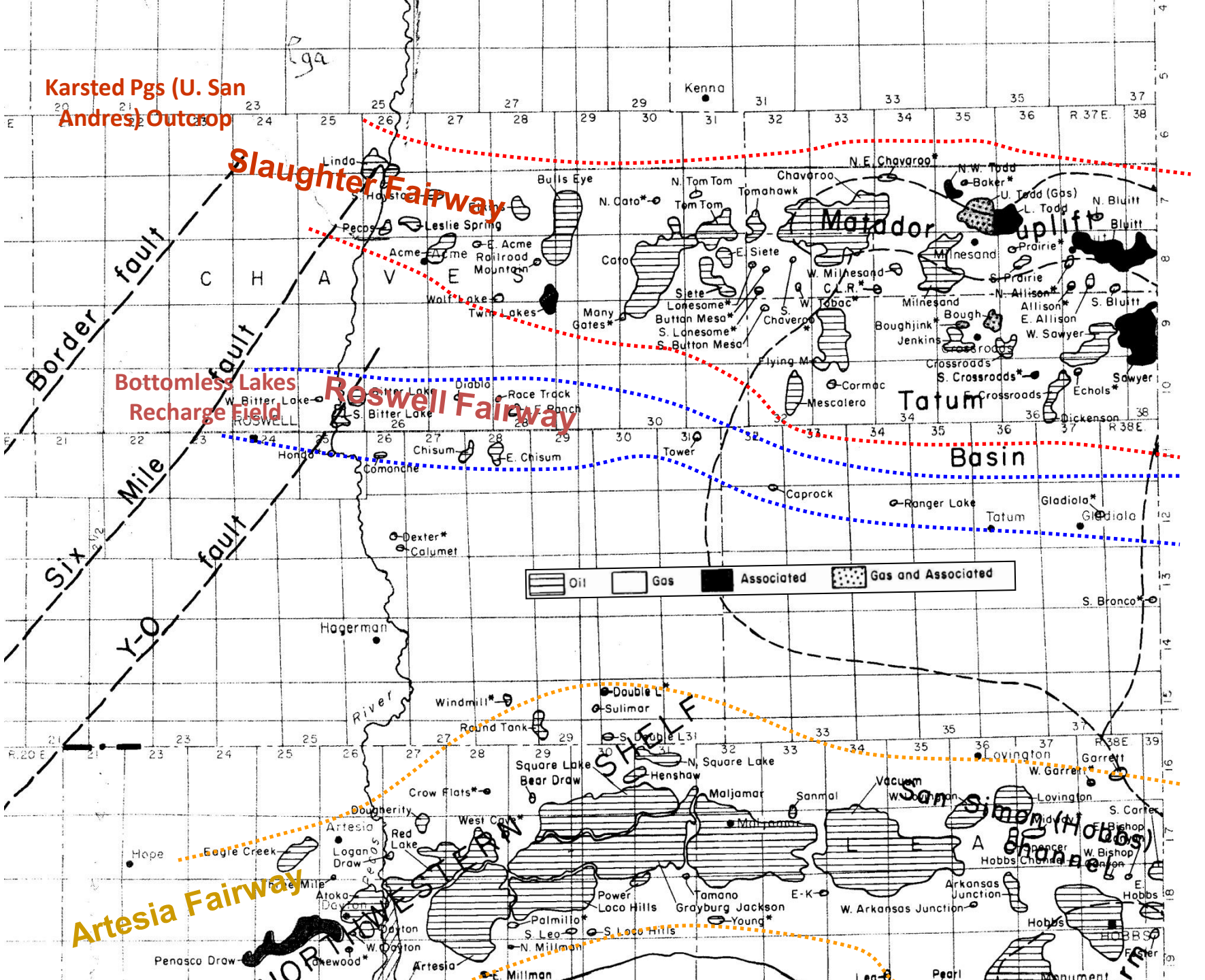
Distribution of Tilted Oil-Water Contacts in the Northern Shelf and Central Basin Platform Areas of the Permian Basin*

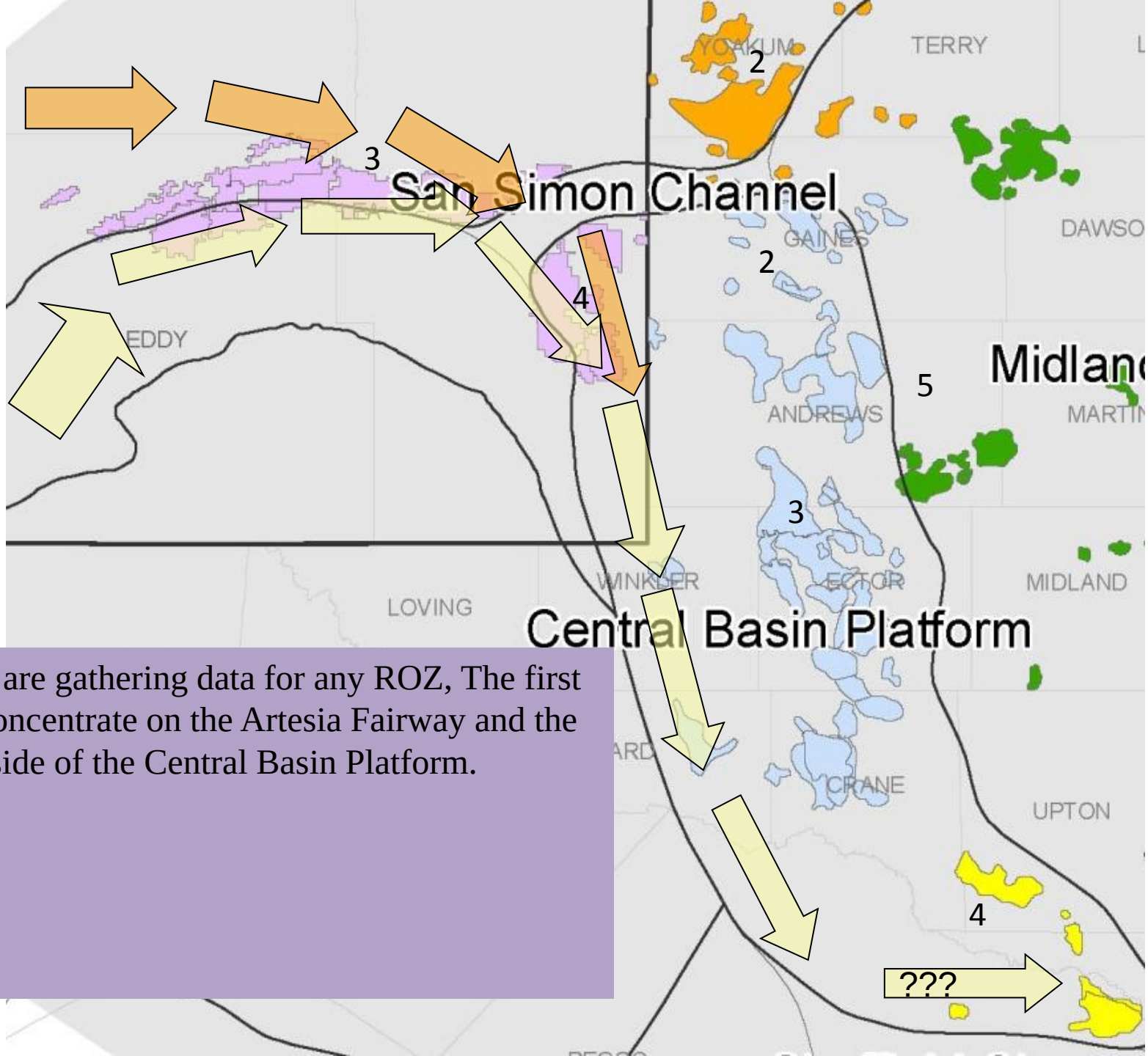
The direction of OWC tilt may be influenced by the age of the producing interval and it's relationship to the shelf margin

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

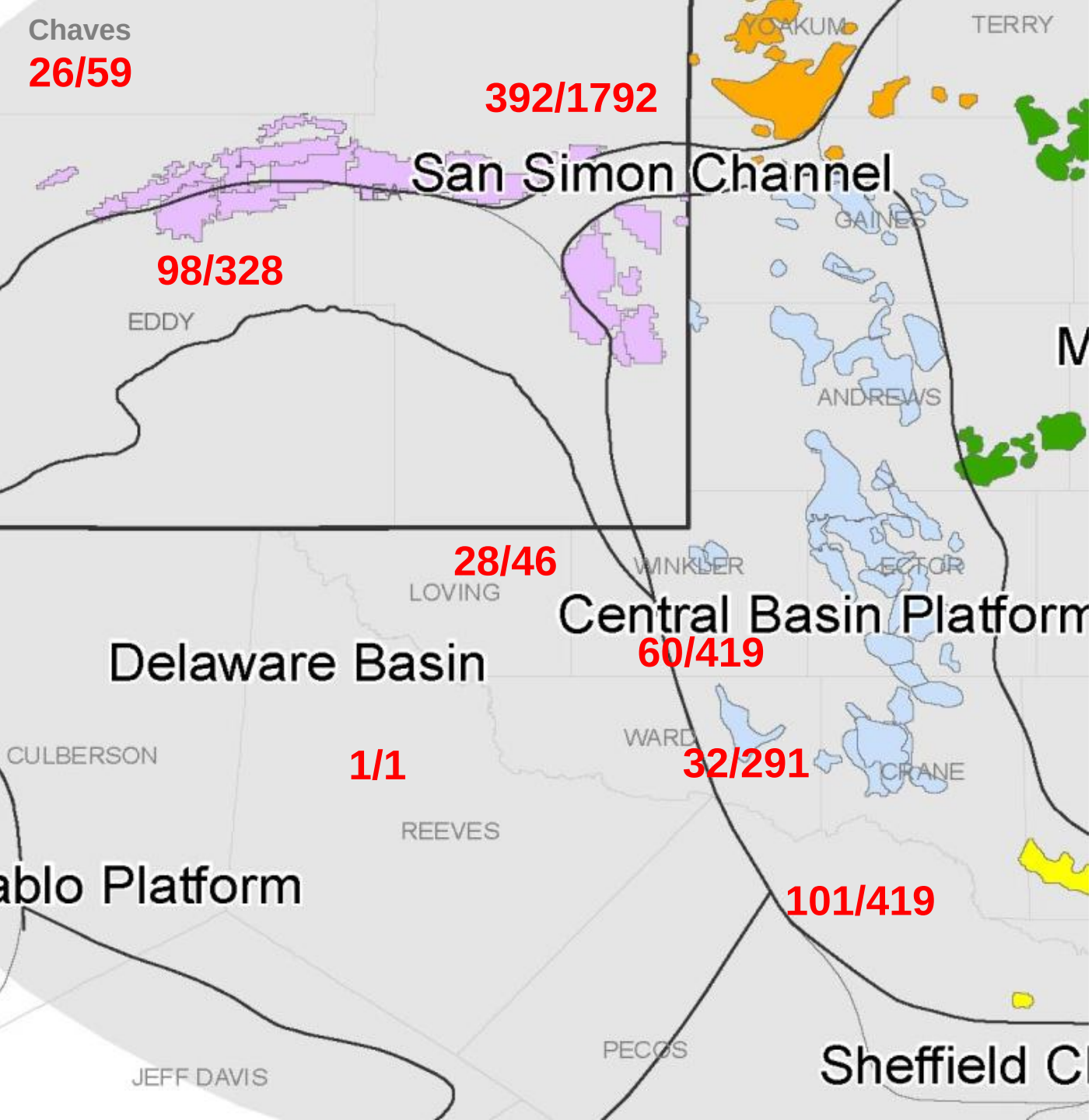
Tilted Oil Water Contacts

- 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 CO_2.
- Be prepared for big hug from royalty owner.


Karsted Pgs (U. San Andres) Outcrop
Slaughter Fairway
Bottomless Lakes Recharge Field
Roswell Fairway
Artesia Fairway
Border fault
Six Mile fault
Y-O fault
CHAVES
ROSWELL
Kenna
Linda
Bulls Eye
Haystack
Pecos
Leslie Spring
Acme
E. Acme
Railroad Mountain
Wolf Lake
Twin Lakes
N. Cato*
N. Tom Tom
Tom Tom
Tomahawk
Chaveroo
N.E. Chaveroo*
N.W. Todd
Baker*
U. Todd (Gas)
L. Todd
N. Bluitt
Bluitt
Prairie*
Motador uplift
Cato
E. Siete
Siete
Lonesome*
Button Mesa*
S. Lonesome*
S. Button Mesa
Many Gates*
W. Milnesand
C.L.R.*
S. W. Tobac*
S. Chaveroo*
Milnesand
S. Prairie
N. Allison*
Allison*
E. Allison
S. Bluitt
W. Sawyer
Boughjink*
Bough
Jenkins
Crossroads
S. Crossroads*
E. Crossroads
Flying M
Cormac
Mescalero
Tatum
Sawyer
Echols*
Dickenson
Basin
Diablo
Race Track
E. Ranch
W. Bitter Lake
S. Bitter Lake
Bitter Lake
Hondo
Chisum
E. Chisum
Comanche
Tower
Caprock
Ranger Lake
Gladiola*
Gladiola
Tatum
Dexter*
Calumet
Oil
Gas
Associated
Gas and Associated
S. Bronco*
Hagerman
Windmill*
Double L*
Sulimar
S. Double L
Round Tank
Square Lake
Bear Draw
N. Square Lake
Henshaw
SHELF
Crow Flats*
Maljamar
Sanmal
Vacuum
W. Vacuum
Lovington
W. Garrett
Garrett
S. Carter
Dougherty
Artesia
Red Lake
West Cave*
Hope
Eagle Creek
Logan Draw
Four Mile
Atoka
Dayton
W. Dayton
Penasco Draw
Lakewood*
Artesia
Power
Loco Hills
Tamano
Grayburg Jackson
Young*
E-K
Palmillo*
S. Leo
S. Loco Hills
N. Millman
E. Millman
Arkansas Junction
W. Arkansas Junction
Hobbs
HOBBS
Pearl
Monument
Foster
San Simon Channel (Hobbs)
NORTHWESTERN
SHELF
R.20 E
R 37 E.
R 38 E.
R 38E



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.



DST and Water Chemistry Data collected from various sources, by county

Wells by County

346/1563

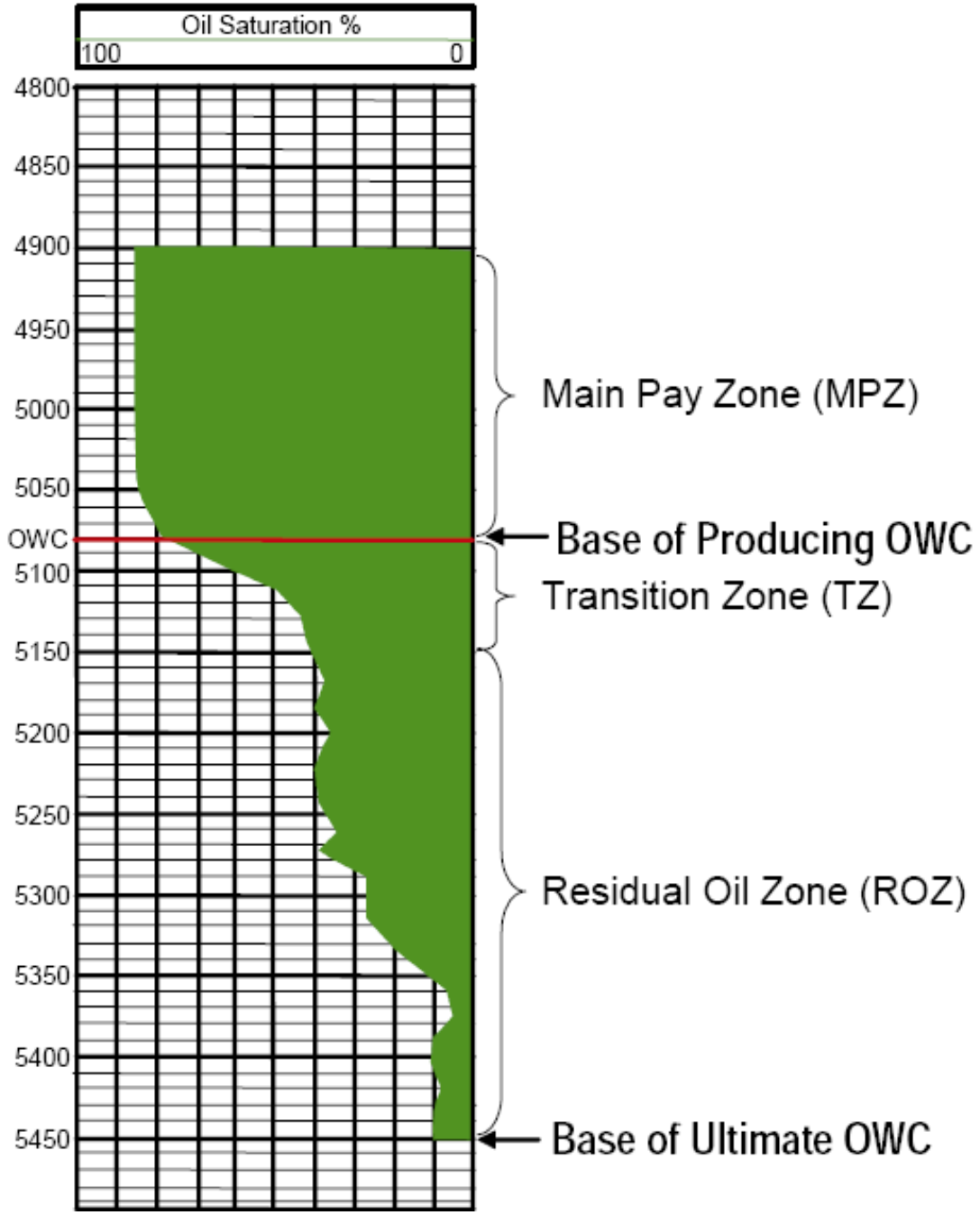
DST / Water Chem

Permian Basin Plays, Dutton et al (2005)

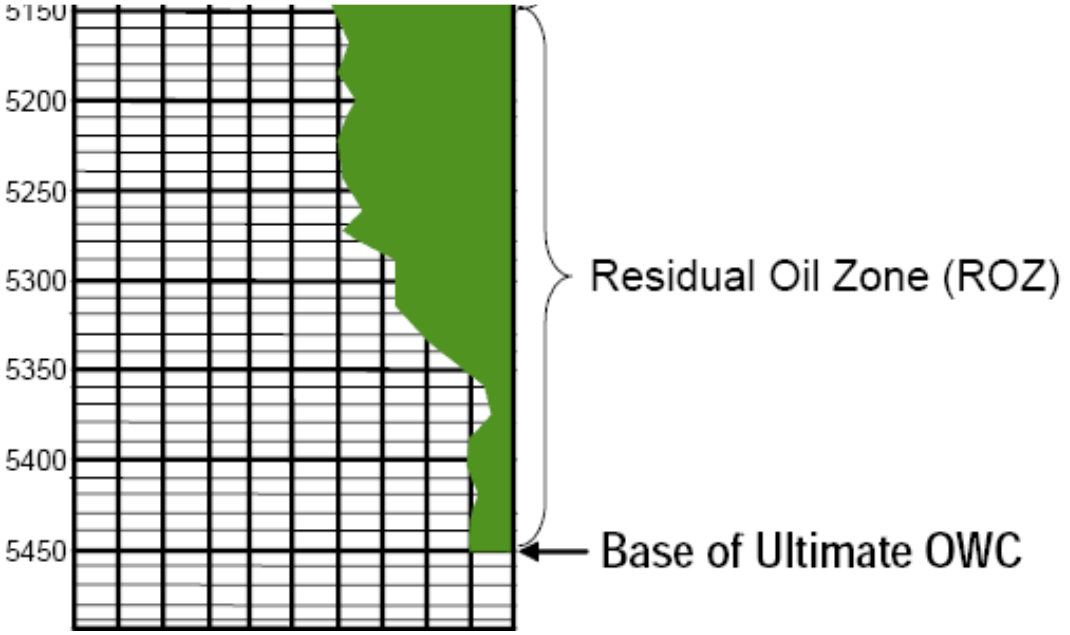
The new Residual Oil Zone Paradigms

- 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.

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



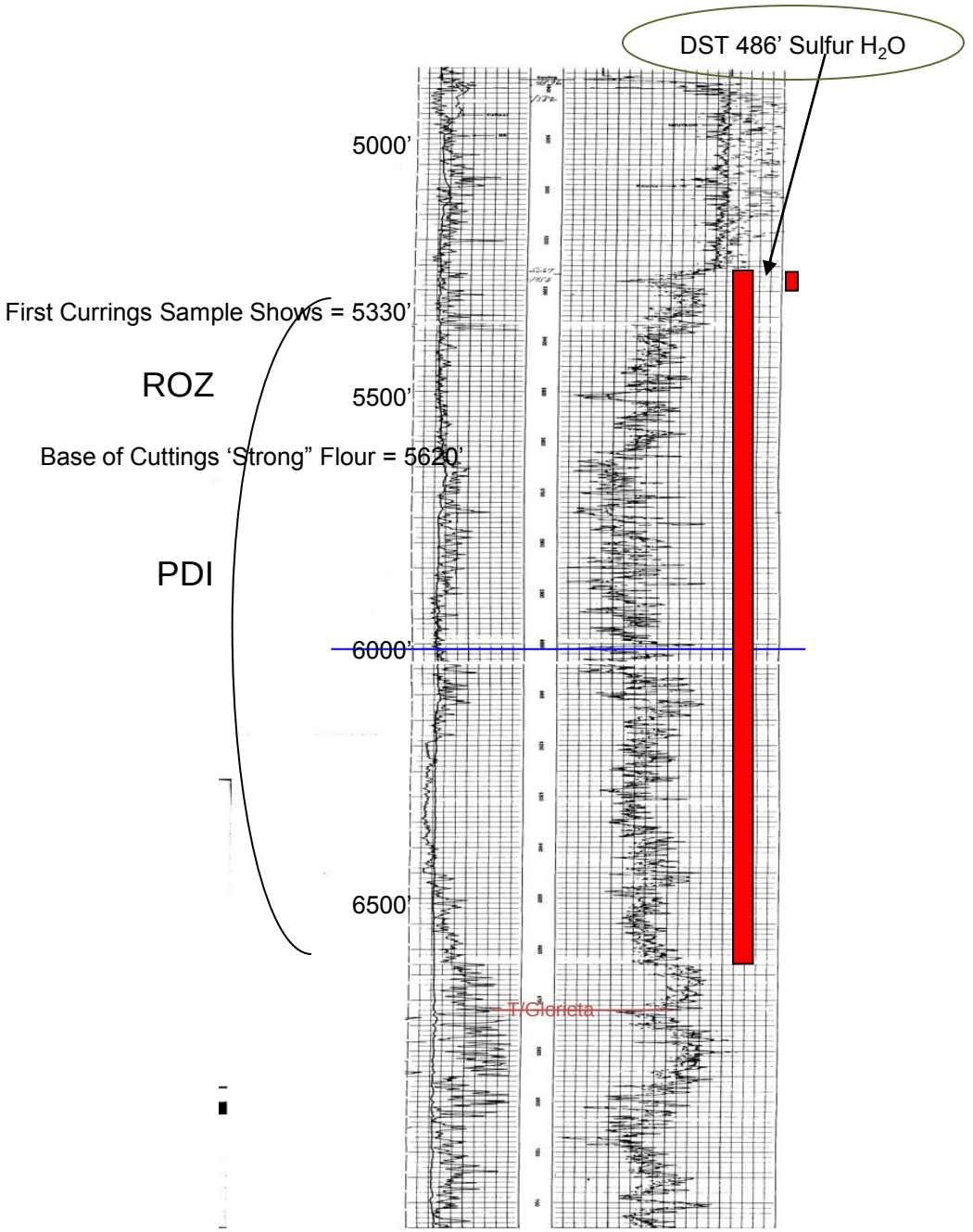
Your left with a tertiary recovery target.



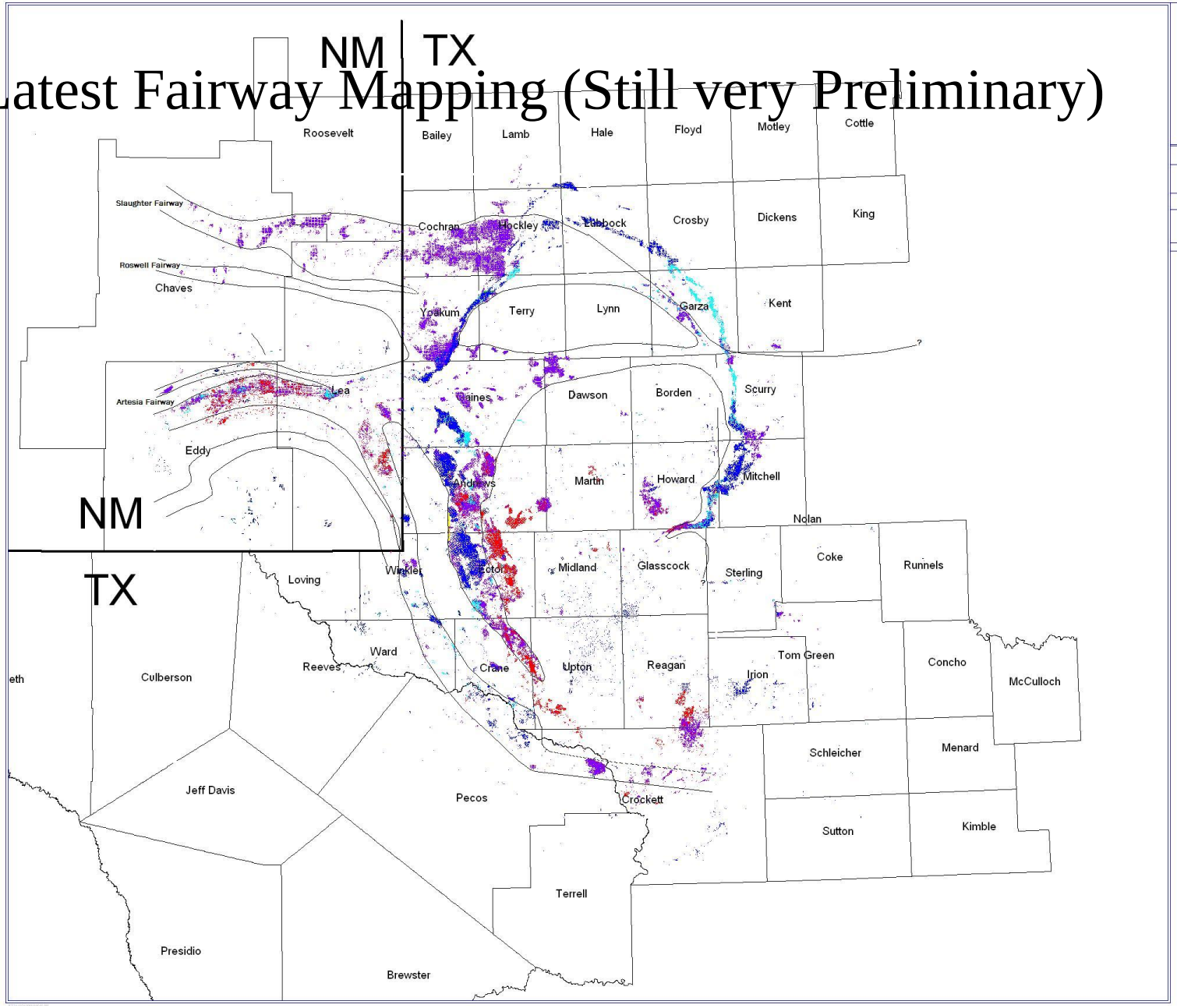
What We Are Learning About the Characteristics of ROZs

Mud log and Cutting Shows, Sulfur and Sulfur Water, Leached Fractures, Pervasive Dolomitization, Bow Shape Logs, Comparisons to MPZs, Nature of Reservoir Fluids, etc.

Northern Central Basin Platform Area



Latest Fairway Mapping (Still very Preliminary)



Permian Basin

RPSEA
Research Partnership to Secure Energy for America

NINE ROZ PROJECTS ARE ACTIVE

(ALL IN PERMIAN BASIN TO DATE)

Melzer CO_2nsulting

TABLE 3 - ROZ CO_2 EOR PROJECTS

Confidential Information

	Type and operator	Field	State	County	Top MPZ Depth, ft	Pay zone	Form-ation	MPZ Start date	ROZ Start date	Strategy	Gross MPZ Thickness	Gross ROZ Thickness	Net ROZ Perforated	Area, acres	Satur. % start
	Active CO_2 miscible														
1	Chevron	Vacuum San Andres Grayburg Unit	NM	Lea Co.	4,550	San Andres/Grayburg	Dolo.	2007	2007	Commingle			150		35
2	Fasken	Hanford	Tex.	Gaines	5,500	San Andres	Dolo.	7/86	8/09	Deepen				1,120	
3	Hess	Seminole Unit-ROZ Phase 1	Tex.	Gaines	5,500	San Andres	Dolo.	7/83	7/96	Deepen	160	250	200	500	32
4	Hess	Seminole Unit-ROZ Phase 2	Tex.	Gaines	5,500	San Andres	Dolo.	7/83	4/04	Deepen (Dedicated*)	160	250	200	480	32
5	Hess	Seminole Unit-ROZ Stage 1 Full Field Dev	Tex.	Gaines	5,500	San Andres	Dolo.	7/83	10/07	Deepen	160	250	200	2,320	32
6	Legado	Goldsmith-Landreth Unit	Tex.	Ector	4,200	San Andres	Dolo.	8/09	8/09	Commingle	80	175	175	80	
7	Occidental	Wasson Bennett Ranch Unit	Tex.	Yoakum	5,250	San Andres	Dolo.	6/95	2000	Commingle	100	78	150		
8	Occidental	Wasson Denver Unit	Tex.	Yoakum	5,200	San Andres	Dolo.	4/83	1995**	Deepen	230	230	150	1000	
9	Occidental	Wasson ODC	Tex.	& Gaines	5,200	San Andres	Dolo.	11/84	?	Deepen			150		
	Planned CO_2 miscible														
10	Conoco	East Vacuum (GSA) Unit	NM	Lea Co.	4,550	San Andres/Grayburg	Dolo.	Feb-81	* 2011	Deepen			150?		35?
11	SandRidge Tert	George Allen	TX	Gaines		San Andres	Dolo.	N/A	2010	Commingle			?		

* Dedicated ROZ Pilot

** Initial Dev called Transition Zone Sweetspot, now followed by Phases 1-4

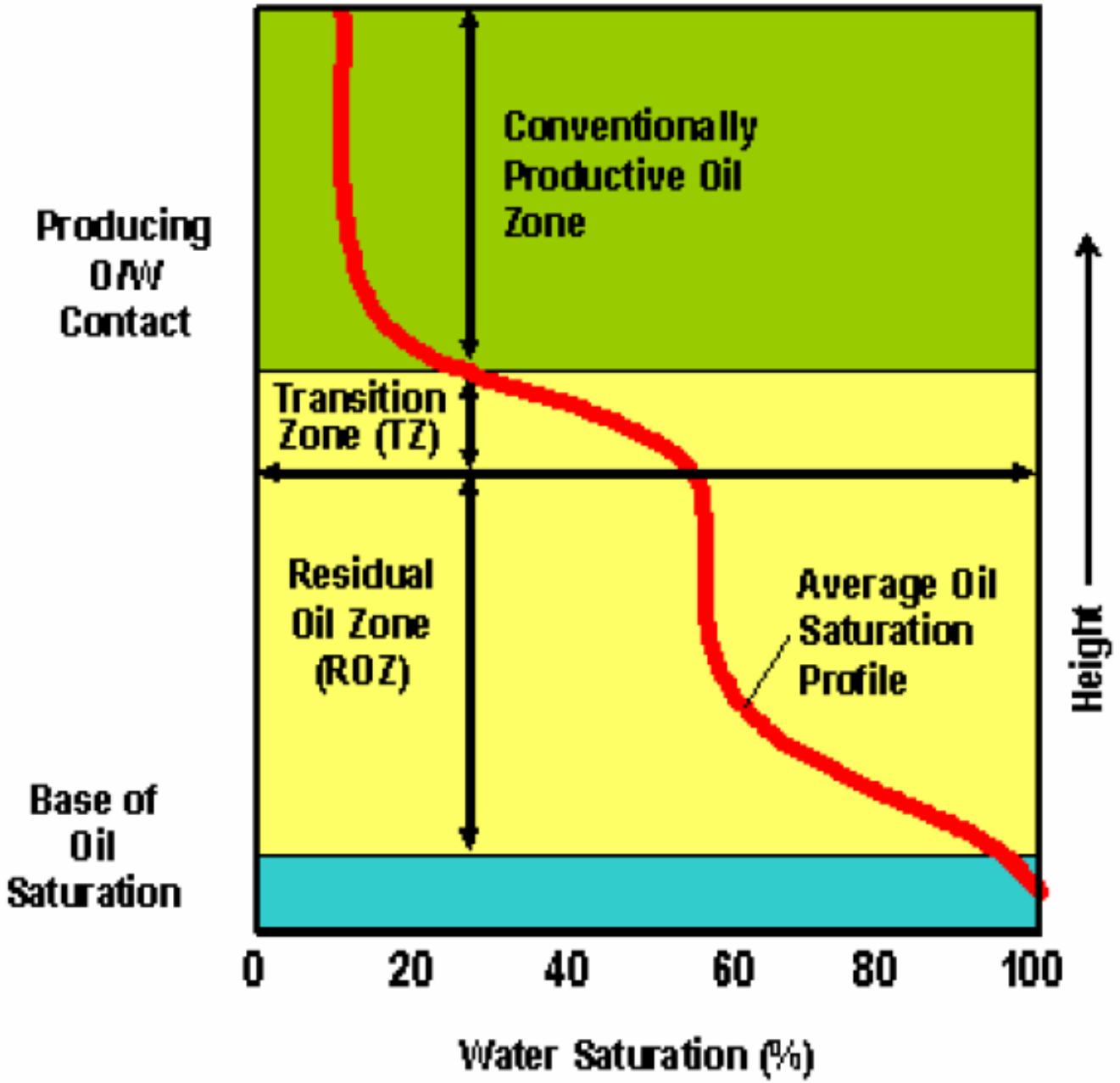
References: Oil & Gas Journal Annual Production Report, Apr 19, 2010, and Melzer Consulting (May 2010)

Our ROZ Conclusions to Date

- Intervals Below the OWC with Shows Are More Appropriately Viewed as Residual Oil Zones and Owe Their Origins to a Variety of Causes Beyond Transition Zones
- PB ROZ Prevalent Type is Type 3: Laterally Flushed
- ROZs Can be Very Thick and Contain Huge Amounts of Oil
- New Paradigm: "Look at Intervals with 'Shows' Below the OWC as Targets for EOR" and, also, Look Between Fields
- Considerably More Research is Needed; We Aren't Starting Over but Because These Targets are Present, Very Large and Commercial, There Are a Lot of New Concepts to Grasp

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)



Calibrating the Oil Recovery Models and EstimatingTechnically Recoverable ROZ Oil – MPZ and TZ/ROZ Oil in Place

Advanced Resources International, Inc.

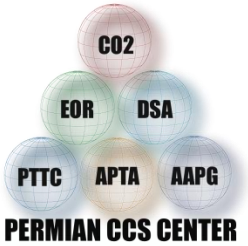
56 fields in five major Permian Basin oil plays that have potential for significant TZ/ROZ resources were identified by ARI.

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 CO2-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**

Conclusions

- Absent meaningful climate control legislation and breakthrough on the cost of separation, interest in CCS is waning
- The market is oversaturated in CCS training offerings
- CCS training is clearly price sensitive
- The CCS training market is demanding more online, self-paced, less expensive alternatives to traditional face to face course work
- CO_2 EOR as storage is an important aspect of CCS



Permian Basin CCS Training Center

Questions?

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