Optimizing CO2 Sweep based on Geochemical, and Reservoir Characterization of the Residual Oil Zone of Hess's Seminole Unit

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Presentation Outline

- Benefit to the Program
- Project Overview: Goals and Objectives
- Expected Outcomes

- Technical Status
- Accomplishments
- Summary

Benefit to the Program

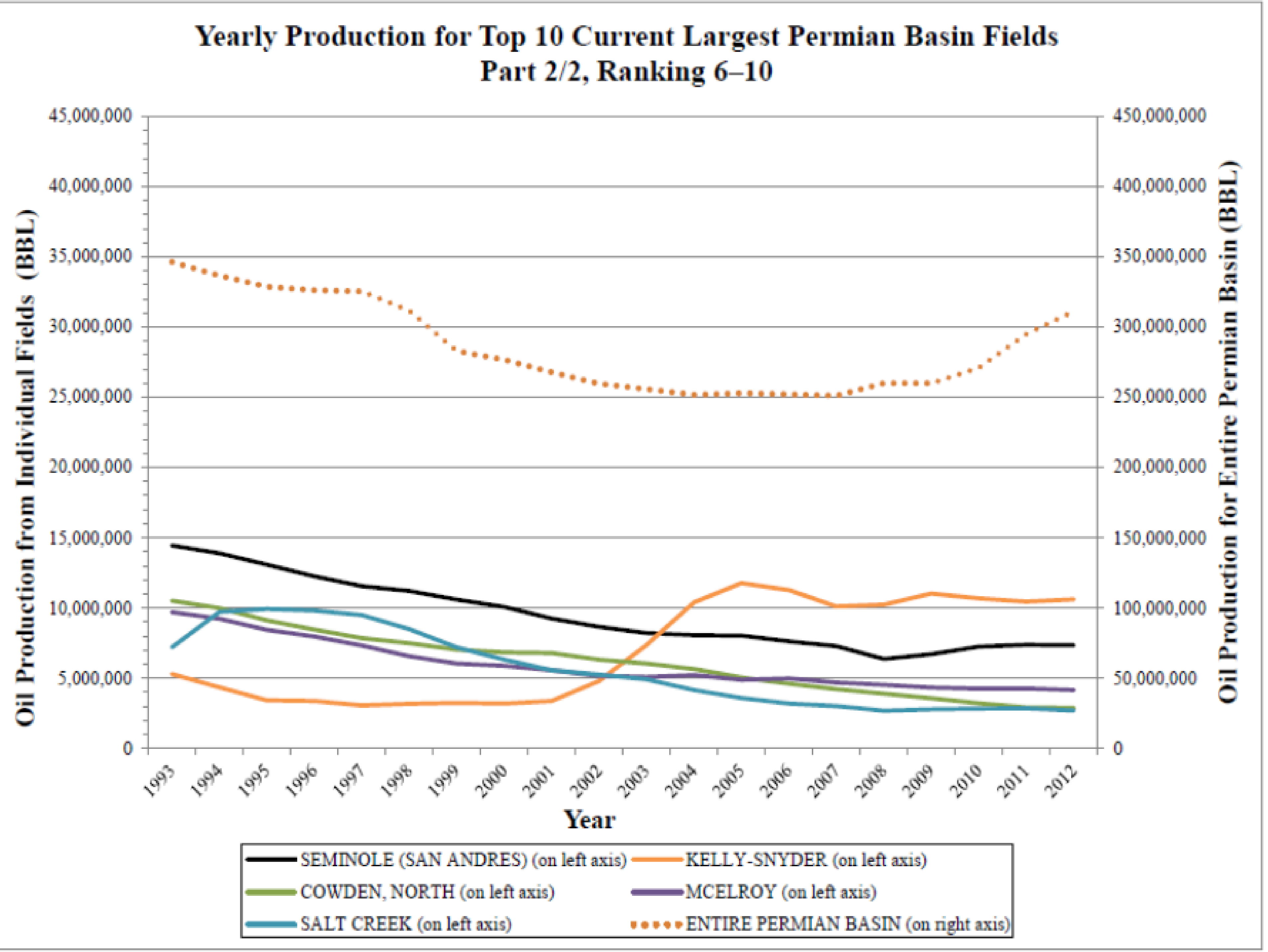
- Supports DOE's Programmatic goal No. 2, to "Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness".

Project Overview:
Goals and Objectives

Project objective: “To improve the understanding of how much CO_2 can be stored in residual oil zones (ROZ) given current practice and how much this could be increased, by using strategies to increase sweep efficiency”.

These same strategies will increase the efficiency of oil production.

Technical Status


Yearly Production for Top 10 Current Largest Permian Basin Fields
Part 2/2, Ranking 6–10
Oil Production from Individual Fields (BBL)
Oil Production for Entire Permian Basin (BBL)
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
450,000,000
400,000,000
350,000,000
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
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0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year
SEMINOLE (SAN ANDRES) (on left axis)
KELLY-SNYDER (on left axis)
COWDEN, NORTH (on left axis)
MCELROY (on left axis)
SALT CREEK (on left axis)
ENTIRE PERMIAN BASIN (on right axis)

Middle San Andreas Paleogeography with Location of Industry Documented ROZ

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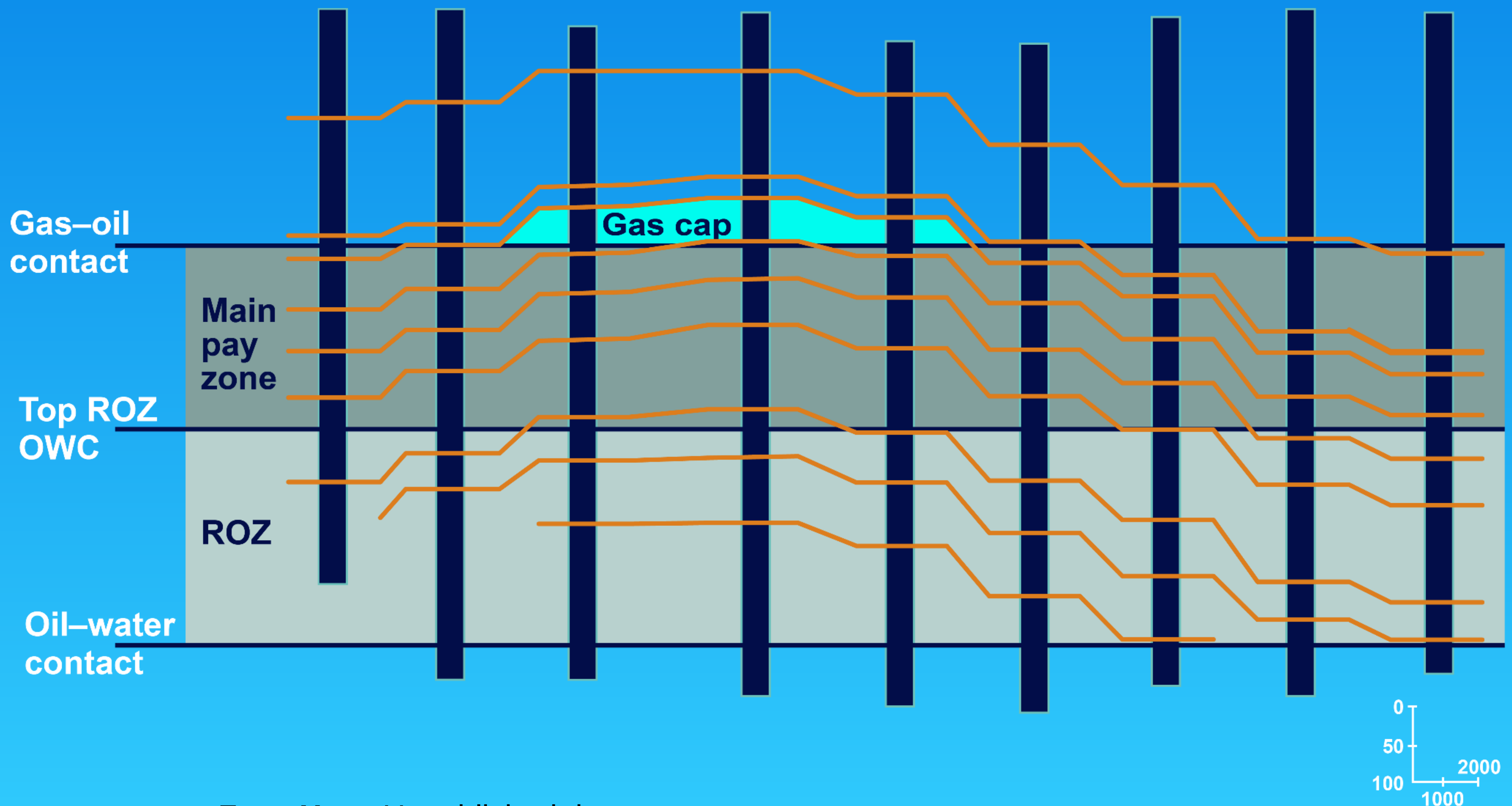
GEOLOGY of SEMINOLE UNIT

Seismic and geological analysis show that Seminole a **carbonate ramp reservoir**, one of several isolated platforms built during the lower San Andres and became linked with the rest of the platform during progradation of the upper San Andres sequence.

The lower 750 ft. of the San Andres contains skeletal grainstone and packstone and an open-marine fauna. The highstand systems tract is represented by (1) 300 ft. of fusulinid wackestones and packstones, and (2) 150 ft. of upward-shallowing, peloidal, shallow subtidal to peritidal cycles. The upper 350 ft. of the San Andres at Seminole is largely anhydritic peritidal deposits.

Structural Cross-Section
East to West



From **Hess** Unpublished data

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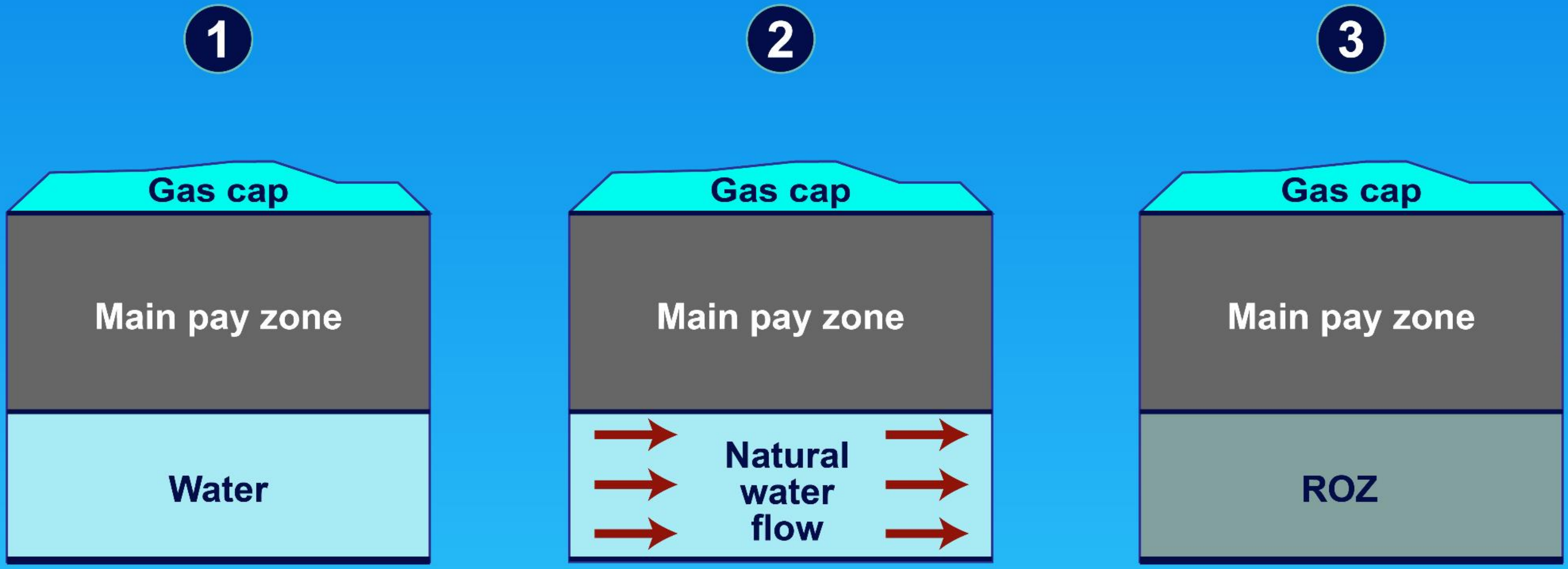
ROZ Genesis



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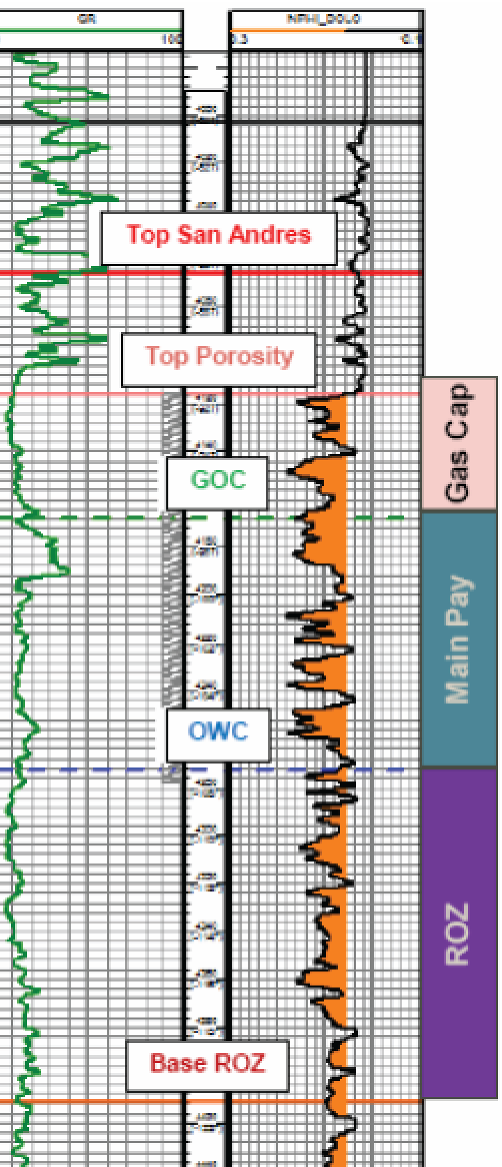
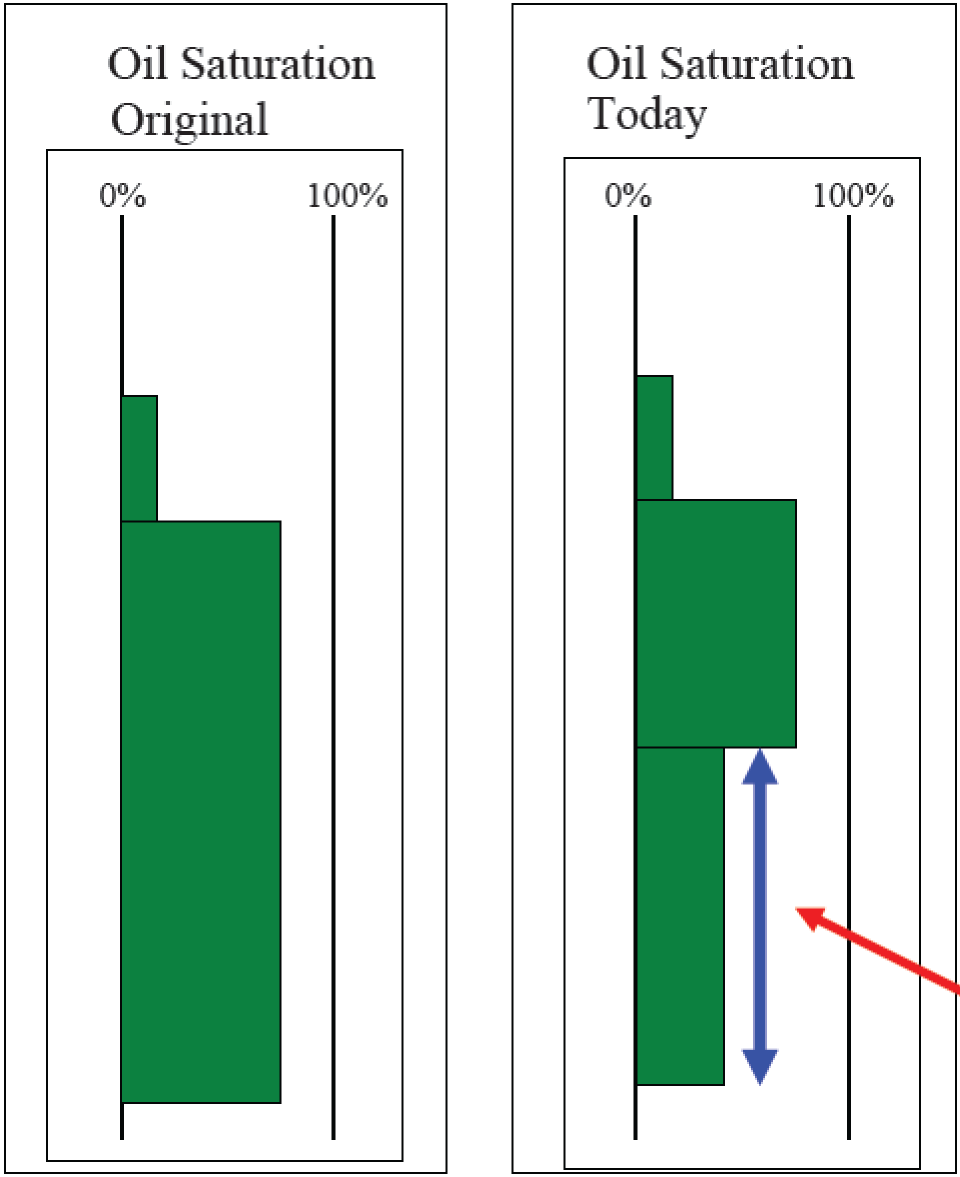
Permian Basin (Residual Oil Zone - ROZ)

ROZ - Oil Saturation Profile





Note:

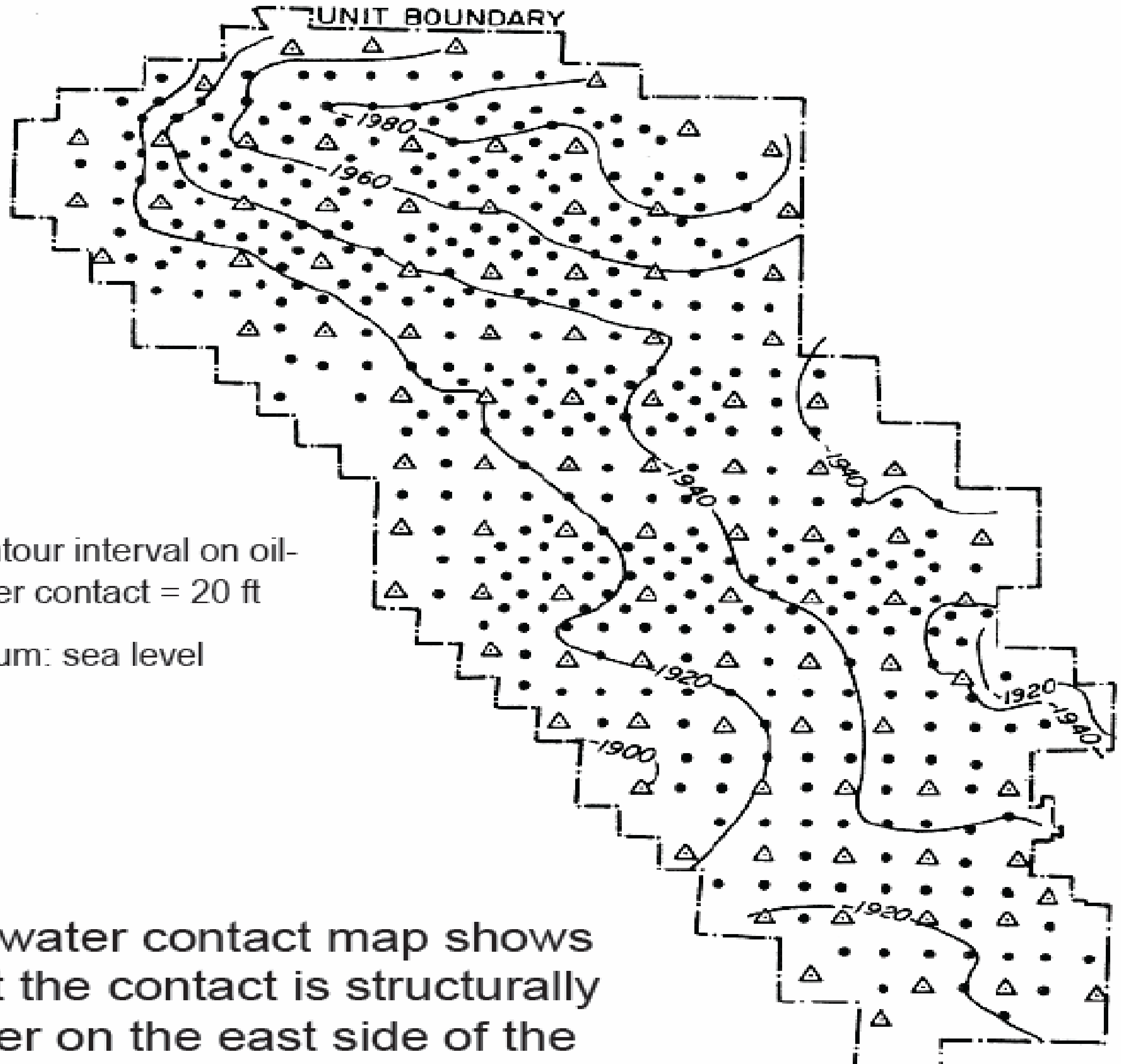
Reservoir originally contain full column of oil

Oil migrated elsewhere in ba

A Residual Oil Saturation remained afterwar

Note: ROZ Pay Zones do not exist in all Basins

Sloping Oil/Water Contact Seminole Field



Contour interval on oil-water contact = 20 ft

Datum: sea level

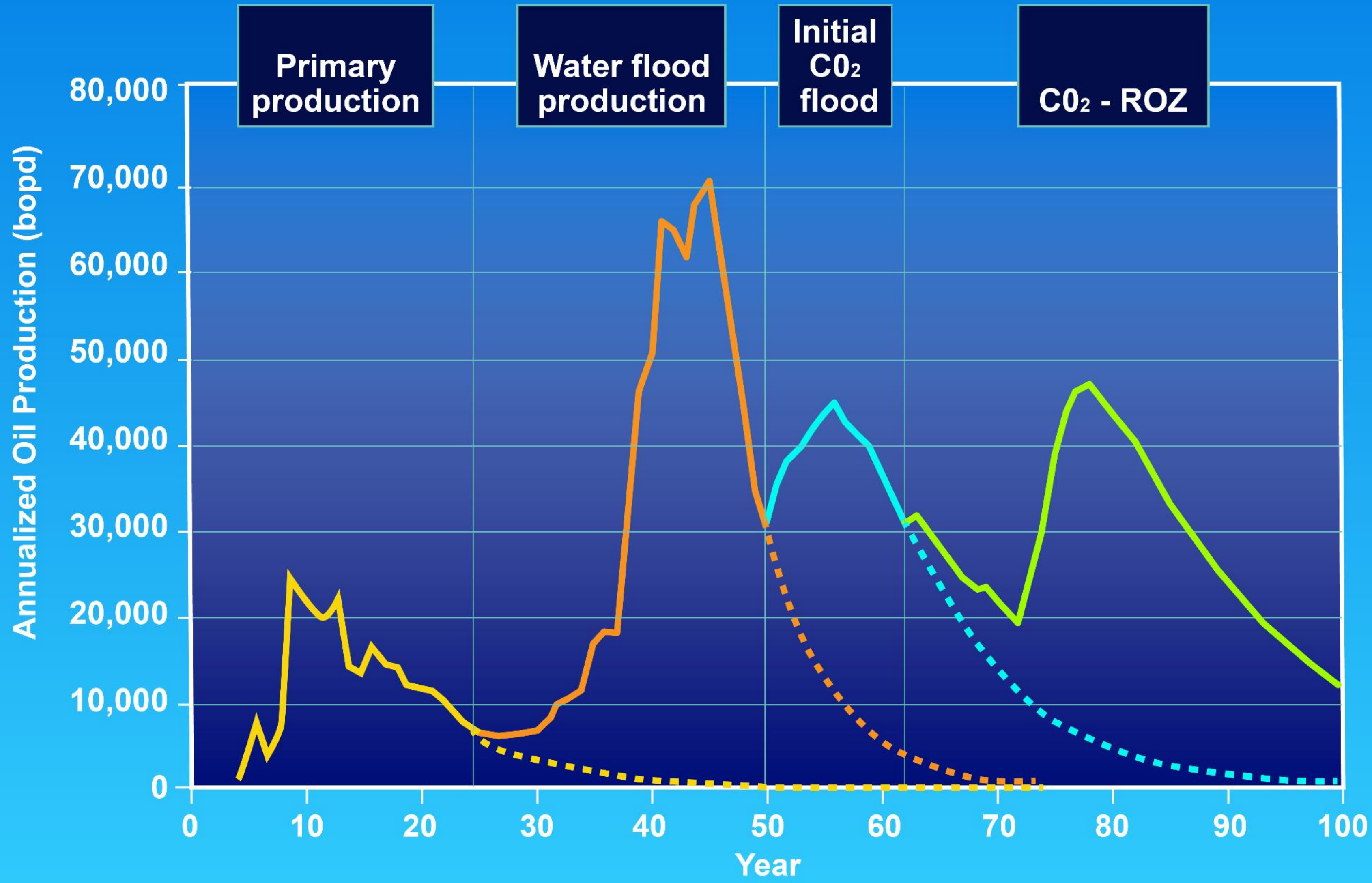
Oil-water contact map shows that the contact is structurally lower on the east side of the field than on the west side.

From: **Koperna** (2006)

Main Pay Zone Characteristics	Residual Oil Zone Characteristics
Thickness: 126 ft	Thickness: 197 ft
Average Porosity: 12%	Average Porosity: 12.8%
Permeability: 0.8 to 120 md	Permeability: 0.5 to 270 md
Original Oil in Place: 1 billion barrels	Original Oil in Place: 0.96 billion barrels
Initial oil saturation: 0.84	Initial oil saturation: 0.32

Modified from: **Trentham** (2011)

Phases of Production



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Dr Loucks and Prof. Kerans Examine Project Core

Pyrite halos surrounding Stylolite

Seminole Unit core being logged

Accomplishments to Date

Accomplishments

Job Searches

- Three formal job searches for Post Doc
- Screened over 70 applicants
- Three rounds of interviews
- Dr. Lei Jiang (carbonate geologist) starts next month.
- A second post doc with skills in using Petrel to create static reservoir models currently being processes
- Some 27 PhD reservoir simulation post doc candidates being considered

Accomplishments

Well Core Acquisition

- Over 30 well cores from the Seminole Unit identified and available to the project
- Additional cores located in Midland core warehouse located and available
- Over 480 existing thin sections of core have been assembled and are being catalogued

Accomplishments

Data Acquisition

- Gas, oil, water production information for over 480 producer wells and nearly 250 CO_2 injector wells covering Seminole Unit have been downloaded into Arc GIS
- Well logs are being assembled in a Petra project
- A Petrel model of the reservoir will be built when our second post doc arrives.

Accomplishments

A first draft of a review paper on CO_2 sequestration incidental to CO_2 EOR has been started by the PI and should be completed in the next quarter.

An extensive literature study of residual oil zones has been completed and will be written up as review paper.

A search for available well cores has been completed and cores located within several core warehouses in Austin, Houston, and Midland. Over 30 well cores from the Seminole Unit identified and available to the project. In addition over 500 existing thin sections of core have been assembled and are being catalogued. Preliminary logging of two cores has been initiated.

Our core logging thus far has been guided by Dr. Robert Loucks (who has extensive experience in reservoir characterization in the Permian Basin including very similar reservoirs to this one) and Professor Charles Kerans, who was the lead scientist on the first detailed reservoir characterization of the upper portion of Seminole unit some quarter century ago. Loucks time on the project is part of the BEG cost share.

Accomplishments

Conclusions from our preliminary core examination include:

1) We believe that the lithologic subdivisions of facies previously developed by Kerans and his co-workers can be applied successfully to our study. These will be modified if this becomes necessary but they provide a useful starting point.

2) There is extensive evidence for late stage pyrite formation above the ROZ zone that has not been previously studied. Pyrite is typically observed as a halo of grains (with dimensions of a 1 to 6 mm) around stylolites. These halos have a typical widths of 3 to 5 cms. It is possible that this pyrite formed in response to H2S created in the formation of the ROZ when the widespread breakdown of anhydrite and the formation of replacement calcite is observed. A search for similar halos around rare vertical fractures has thus far been unsuccessful. Our new incoming post-doc Dr. Jiang has published several papers on this type of diagenesis in international journals.

3) An apparent late stage diagenetic rimming of large dolomite crystal and aggregated by calcite has been observed in stained core samples. The significance of this diagenetic event is not clear. We plan to carry out stable isotope analyses of these cements and anticipate that we will be able to address this issue.

Synergy Opportunities

– Discuss how collaboration among projects could have a synergistic effect on advancing the carbon storage technology described during the session in which you are presenting.

Summary

– Key Findings

BEGs previous facies classification scheme for the San Andres appears viable for our project based on logging so far.

There is extensive evidence of H2S migration apparently between the ROZ and the overlying main pay zone reservoir.

Summary

– **Lessons Learned**

Even in an industry downturn PhDs with experience in reservoir characterization are in great demand… hence our recruiting problems.

Sulfur isotopes will likely be needed to resolve origin of pyrite along fluid pathways in main payzone and test connection to large scale anhydrite dissolution in ROZ

Summary

– **Future Plans**

We plan to:

(1) complete our post doc search

(2) Develop our Petrel model of the reservoir

(3) Extend our logging to newly drilled cores in the ROZ

(4) Complete Review paper in sequestration incidental to EOR.

(5) Late stage replacement of dolomite by calcite occurs in the main pay zone. We will be looking for this in ROZ core

Appendix

– These slides will not be discussed during the presentation, but are mandatory

Organization Chart

Project Director Ian Duncan	
Task 1 Management	**Task 2 through 6**
Task Leader/Back-up Duncan/Ambrose	**Task Leader/Back-up** Duncan/Loucks/Ambrose

Gantt Chart

	Yr1 Q1	Yr1 Q2	Yr1 Q3	Yr1 Q4	Yr2 Q1	Yr2 Q2	Yr2 Q3	Yr2 Q4	Yr3 Q1	Yr3 Q2	Yr3 Q3	Yr3 Q4
2	X	X	X	X	X	X	X	X	X	X D7	X	
2.1	x	x	x D3	x	x	x	x	x				
2.2		x	x	x	x	x D11	x	x				
2.3			x	x	x	x	x	x	x			
2.4				x	x	x	x	x D8				
2.5				x	x	x	x	x	x	x D9		
3		X	X	X	X D4							
4		X	X	X	X	X	X D5	X	X D6	X	X	
4.1				x	x	x						
4.2			x	x	x	x	x					
5		X	X	X	X	X	X	X	X	X	X D10	
6						X	X	X D12	X	X	X	X D13

Bibliography