

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

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Eric Potter

Associate Director

**Bureau of Economic Geology, University of
Texas at Austin**

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Presentation Outline

- Benefit to the Program
- Project Overview: Goals and Objectives
- Methodology
- Expected Outcomes
- Communication Plan
- Task/Subtask Breakdown
- Deliverables / Milestones / Decision Points
- Risk Matrix
- Proposed Schedule
- 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 CO₂ 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.

Project Overview:

Goals and Objectives

Other objectives include improving understanding of:

- (1) stratigraphic faces variations,
- (2) the impact of diagenesis on the ROZ,
- (3) the variation fluid and oil chemistry within the reservoir
- (4) The impact reaction transfer in the ROZ on multi-phase fluid flow.

Project Overview:

Goals and Objectives

Melzer and Trentham refer to the Seminole Unit as...

“The Gold Standard for ROZ fields”

Our project sets out to create a detailed model for the reservoir character, geochemistry, fluid flow properties etc. of the reservoir

Project Overview:

Goals and Objectives

ARI have estimated that on the order of 12 billion barrels of oil could be extracted from ROZ in the Permian Basin of Texas alone....

Assuming 2.5 barrels of oil for each metric ton of CO₂ stored this will result in:

4.8 billion metric tons of CO₂ stored....

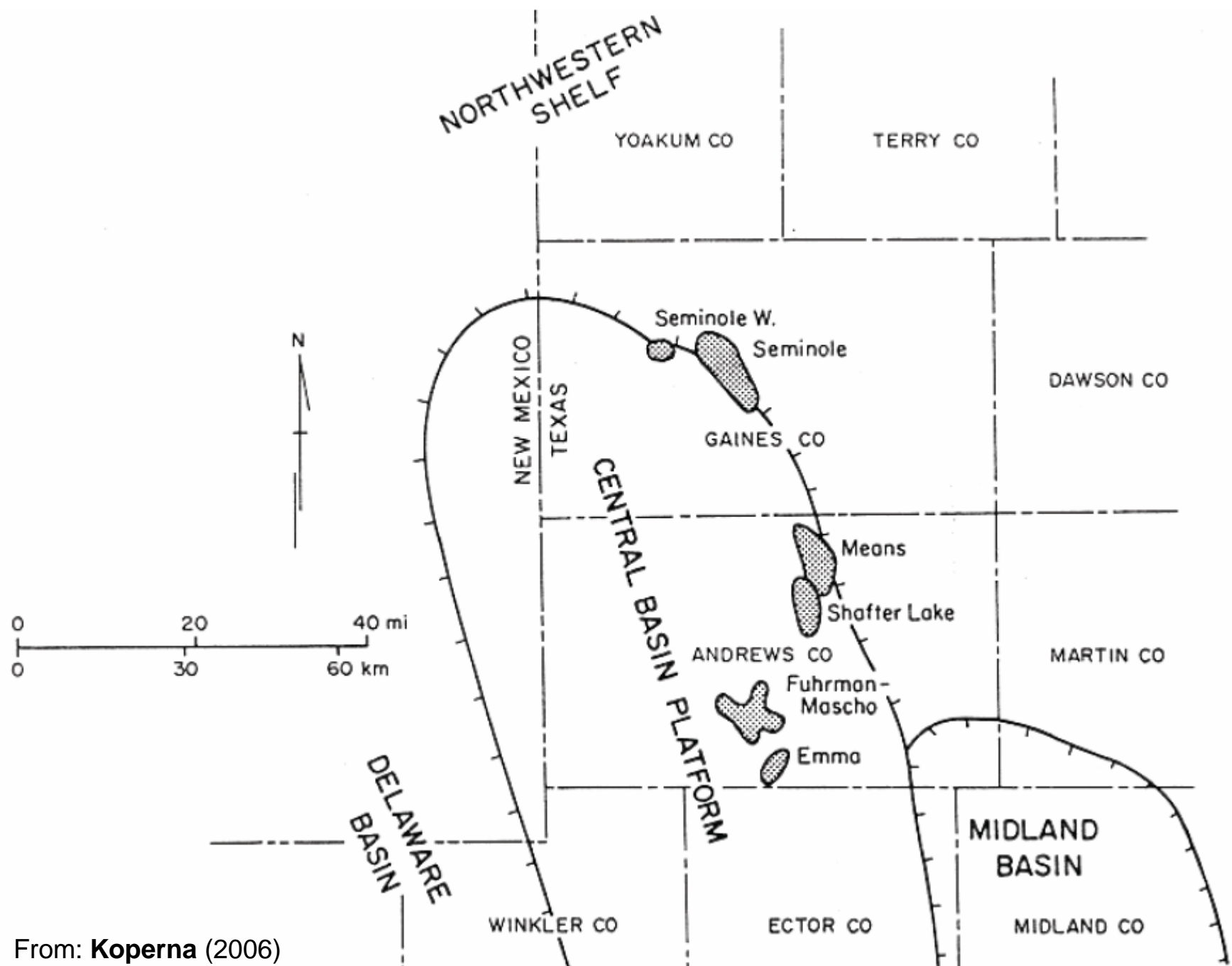
Methodology

- Only through a better understanding of the nature of ROZ reservoirs can we make accurate estimate of the CO₂ storage potential. A detailed reservoir characterization of the largest producing ROZ, Hess's Seminole San Andres Unit is proposed.
- To support the reservoir simulation modelling to investigate sweep efficiency (and hence CO₂ storage) in the ROZ

GEOLOGY of SEMINOLE UNIT

The Seminole San Andres Unit lies on the northern Central Basin Platform immediately south of the San Simon Channel. It covers approximately 23 square miles and contains more than 600 wells.

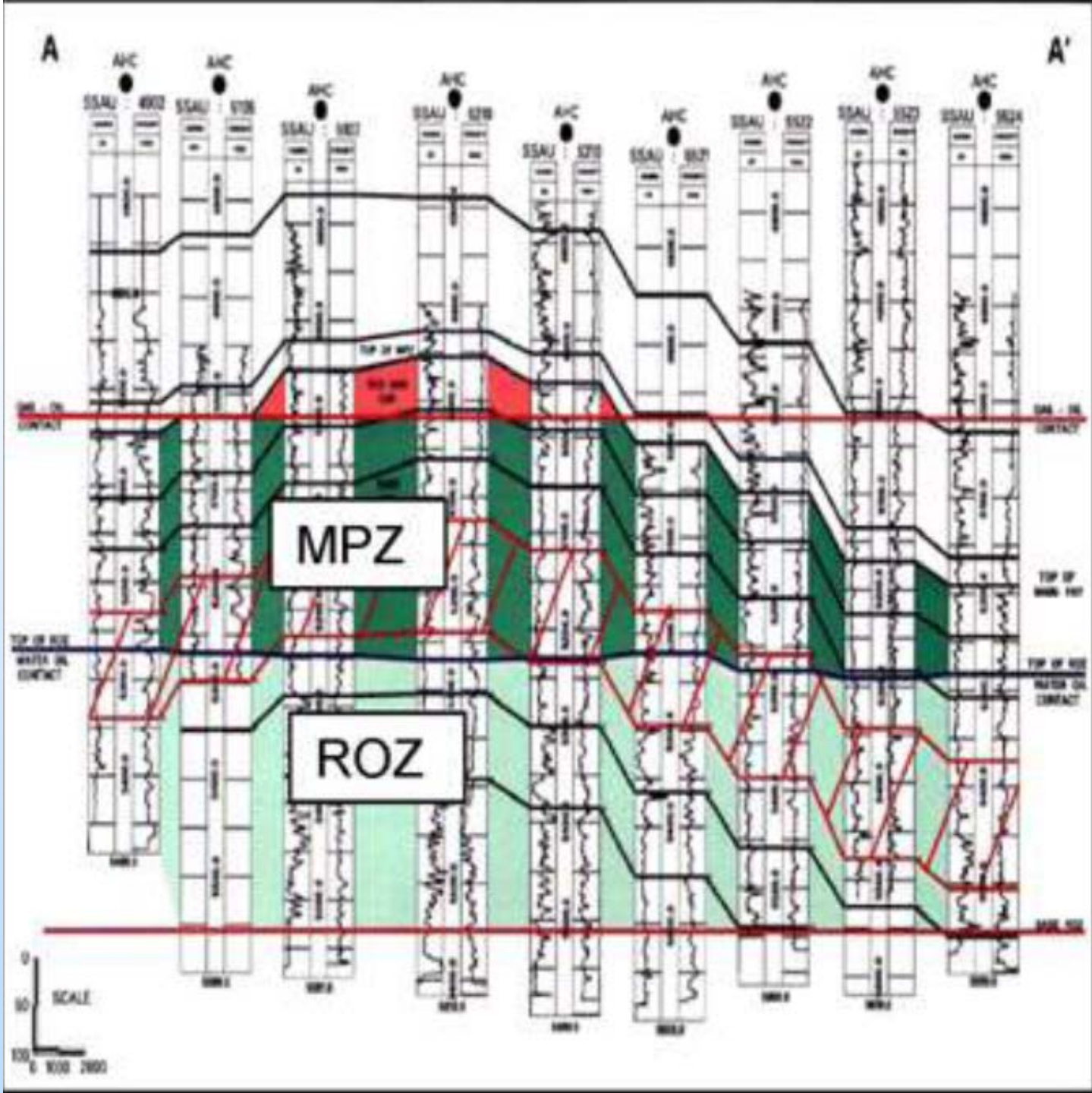
Discovered in 1936, the original oil in place was estimated as 1,100 MSTB (Galloway and others, 1983). Waterflooding was initiated in 1970 and CO₂ flooding of the main pay zone began in 1985.



GEOLOGY of SEMINOLE UNIT

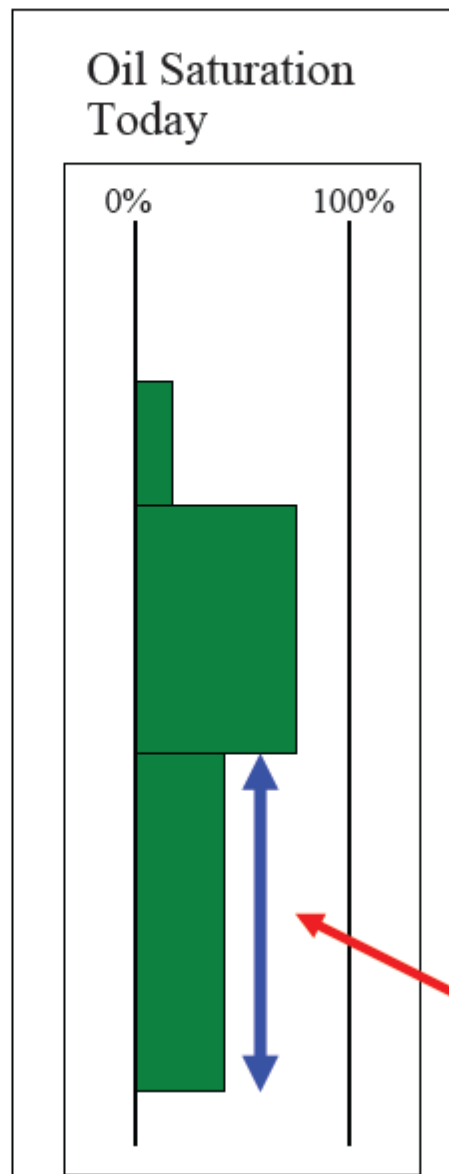
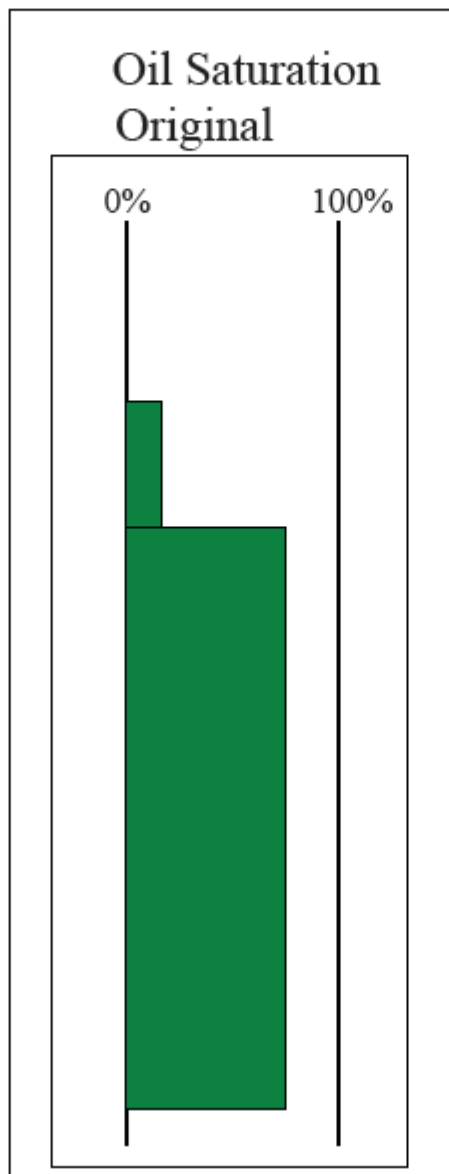
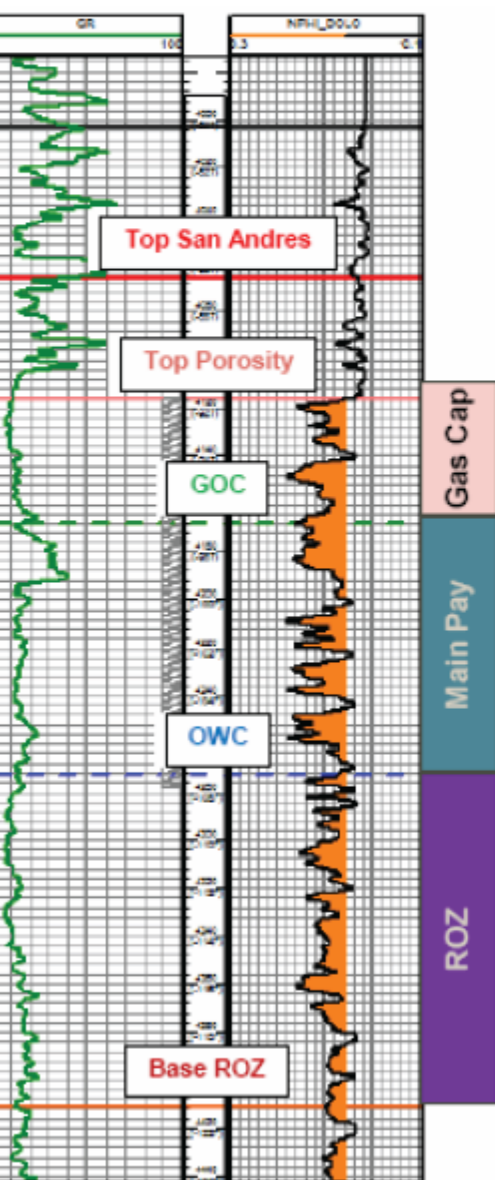
Seismic and geological analysis show that Seminole a **carbonate ramp reservoir**, one of several isolated platforms built during the lower San Andres and became linked with the rest of the platform during progradation of the upper San Andres sequence.

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.



From Hess
Unpublished
data

ROZ - Oil Saturation Profile



Note:

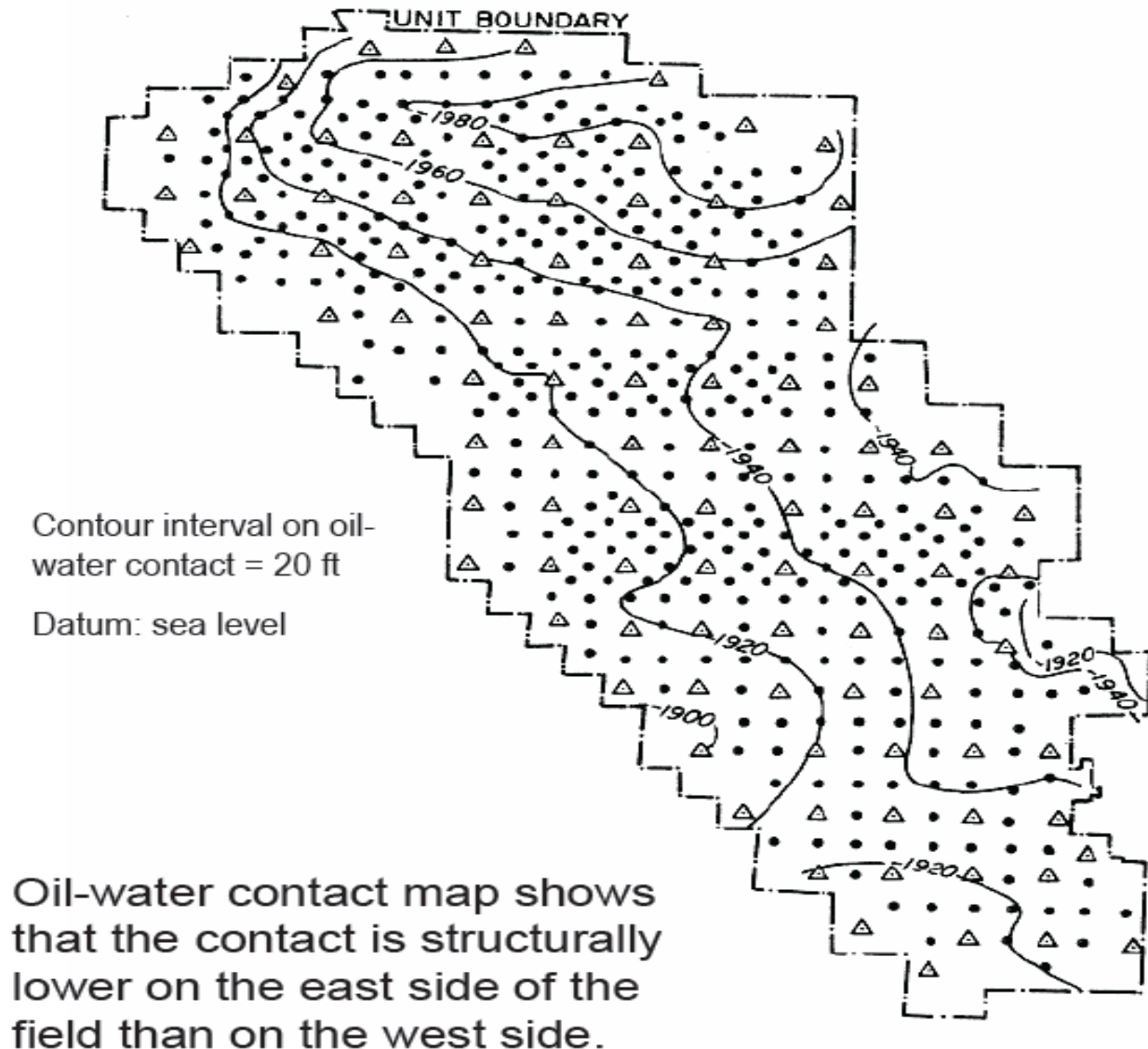
Reservoir originally contained full column of oil

Oil migrated elsewhere in basin

A Residual Oil Saturation remained after migration

Note: ROZ Pay Zones do not exist in all Basins

Sloping Oil/Water Contact Seminole Field



Seminole Main Pay Zone versus ROZ

	<u>Net Thickness</u>	<u>Average Permeability</u>	<u>Initial Oil Saturation</u>
Main Pay Zone (MPZ):	126'	9 md	84%
Residual Oil Zone (ROZ):	213'	12 md	32%

From: **Koperna** (2006)

Water flooded Main Pay

20 to 40% S_o

Brine reservoir fluids

Enhanced high perm streaks

Mixed wettability

Residual Oil Zone

20 to 40% S_o

Sulfur water – lower TDS

Potentially more homogeneous

Wettability uncertain

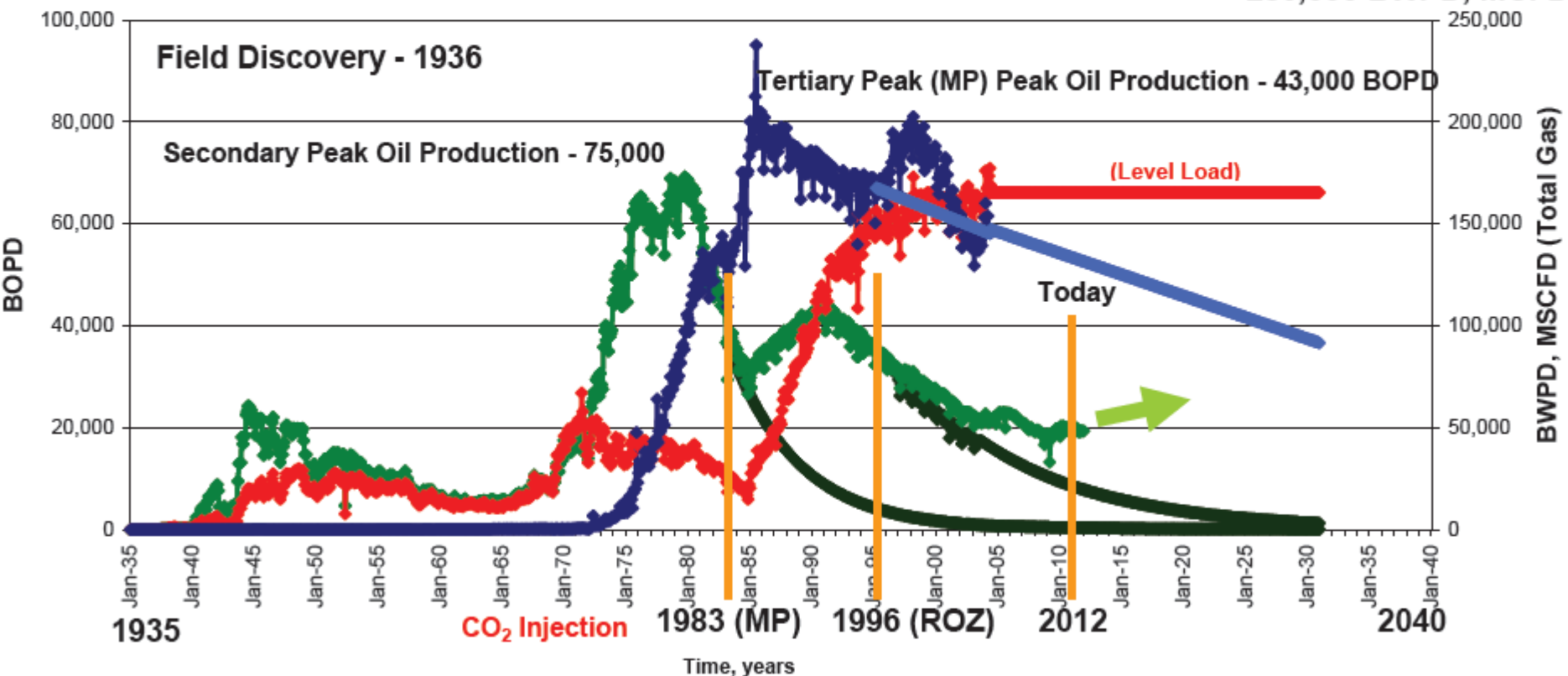
Modified from: **Trentham** (2011)

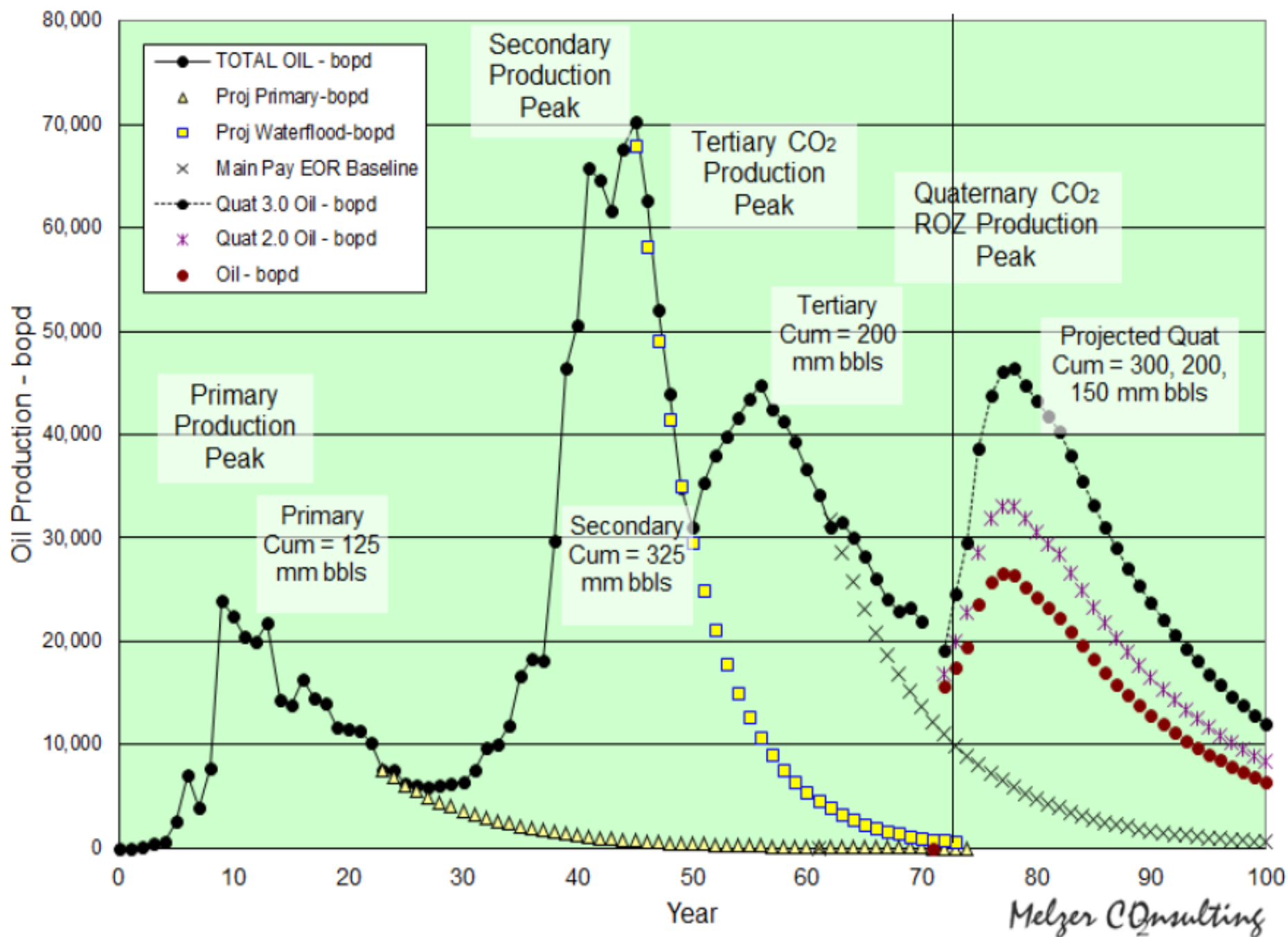
Tertiary Recovery (ROZ Addition)

Total Unit Performance

250,000 BWP, MC

250,000 BWPD, MC





Estimating Ancillary Storage CO₂

- For traditional WAG based CO₂-EOR, one metric ton of CO₂ stored for every 2.5 barrels oil recovered
- If the Seminole ROZ ultimately produces 200 to 300 million barrels of oil, then **estimated CO₂ storage** would be:

80 to 120 million metric tons.

Expected Outcomes

There is currently no detailed, publicly-available geologic description of a ROZ... this project will supply a detailed characterization.

There is currently no detailed multi-phase, fluid flow modelling to evaluate the nature of CO₂ storage in Permian Basin ROZs.

Expected Outcomes


- Include expected outcomes and results of the project.
- Include the 'products' of the project (i.e. new technique, data, new modeling tools, etc.)
- Be specific and include discussion of how this project furthers the overall body of work within the research community.

Expected Outcomes

Products from the Project

- 1) Digital static reservoir model
- 2) Evaluation of different injection geometries on optimizing CO₂ sweep
- 3) Evaluation of different CO₂ injection strategies such as WAG, continuous CO₂ injection etc. on optimizing CO₂ sweep
- 4) Evaluation of the chemistry of oils and reservoir fluids from ROZ as possible tracers of fluid flow.

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

Communication Plan

The PI and the project team will **communicate with DOE/NETL project manager** on an ongoing basis on all aspects of the project. Quarterly Progress Reports will include the status of project milestones.

Quarterly reports will include: (1) the actual status and progress of the project; (2) progress made on project's milestones; and (3) any proposed changes in the project's schedule required to complete milestones.

Communication Plan

We will have at least monthly **communications with Hess** either by phone or face-to-face.

We will **communicate with other stakeholders** through **presentations at SPE meetings** and the **annual CO₂ Conference in Midland**.

We will also **post talks, reports and papers generated by the project on our web site**.

Task/Subtask Breakdown

Task 1.0 – Project Management and Planning

Task 2 – Detailed Site Characterization of the San Andres Seminole Unit

detailed site characterization of the San Andreas Seminole Unit including geological core logging, improved interpretation of wireline logs, analyses of oil geochemistry, analyses of diagenetic changes, analyses of formation brines for geochemical and microbiological activity/impacts.

Subtask 2.1 – Geological Core Logging

Subtask 2.2 -- Improved Interpretation of Wireline Logs

Subtask 2.3 – Characterization of Oil Geochemistry of Hydrocarbons in ROZ

Subtask 2.4 – Diagenetic Characterization of ROZ

Subtask 2.5 – Geochemical and Microbiological Characterization of In-Situ Brine Fluids in ROZ

Task/Subtask Breakdown

Task 3- 3D static reservoir model: utilizing characterization data gathered in Task 2 to create a detailed three dimensional stratigraphic and porosity-permeability model of the ROZ volume

Task 4 – Fluid Flow Reservoir Simulations of CO₂ mobility controls:

Use the static reservoir model to perform numerical simulations of CO₂ injection, using commercial software to model increased oil production due to the injection of CO₂, and the pattern of CO₂ storage in the reservoir.

Subtask 4.1 Simulation of wellbore configuration on CO₂ mobility controls:

Subtask 4.2 Simulations of Operational CO₂ Mobility Controls:

Task 5– Reaction Transfer Simulations

Deliverables / Milestones

Task 1 Deliverable 1: **Project Management Plan (PMP)** (Year 1 Q1)

Task 1 Deliverable 2: **Data Submitted to NETL-EDX**. Will include: 1) various datasets and files as appropriate, 2) metadata, 3) software/tools, and 4) articles (Year 3 Q4)

Task 2 Deliverable 3: **Core Logging Summary Report** (Year 1 end Q3)

Task 3 Deliverable 4: **Draft reservoir model paper** (Year 2 end Q1)

Deliverables / Milestones

Task 4 Deliverable 5: **Preliminary Report Reservoir Simulation Results** (Year 2 end Q3)

Task 4 Deliverable 6: **Draft paper on reservoir fluid flow during CO₂-EOR in the ROZ** (Year 3 end Q1)

Task 2 Deliverable 7: **Draft paper on geochemistry of oil from the ROZ** (Year 3 end Q2)

Task 2 Deliverable 8: **Draft paper on diagenesis of the ROZ** (Year 2 end Q4)

Task 2 Deliverable 9: **Draft paper chemistry and microbiology ROZ fluids** (Year 3 end Q2)

Deliverables / Milestones / Decision Points

Task 5 Deliverable 10: **Draft paper on reaction transfer within the ROZ** (Year 3 end Q3)

Task 2 Deliverable 11: **Draft paper improved wireline log interpretation of the ROZ** (Year 2, end Q2)

Task 6 *Deliverable 12*: **At least 4 preliminary recommendations to improve sweep efficiency made to industry partner** (Year 2 Q4)

Task 6 Deliverable 13: **Draft paper on sweep efficiency and controls over CO₂ storage in the ROZ** (Year 3, Q4)

Risk Matrix

Risk (1): Possible Failure to complete the static reservoir model in time for fluid flow simulation- We believe that this is a very low risk because of our Teams extensive experience in core logging and creating reservoir models. If this happened our risk mitigation plan is to add some more STARR research geologists to the task to get this done.

Risk (2): Possible failure to focus project resources on the tasks that require the most attention- We will proactively manage this risk through our monthly project meetings.

Risk (3): Possible Loss of PI- If the PI (Duncan) becomes unavailable then Ambrose and Loucks could readily take over as PI's of the project.

Risk Matrix

Risk (4) Breakdown of the cooperative Agreement with Hess to allow us access to core and reservoir data- We judge this risk to be low. We are confident that we could get one of several other operating large San Andres ROZ-CO₂ injections.

Risk (5) Numerical Fluid Flow Modeling will not prove useful in investigating CO₂ sweep- Our risk management strategy would be to access help and advice of the very talented and experienced modeling groups on our campus.

Risk (6) Failure to adequately communicate results to stakeholders and to do effective outreach- A major problem with some research projects is that the results do not get effectively communicated to the stakeholders. We have a strong communications plan based on targeted presentations at venues attended by industry.

Proposed Schedule

Shown in next slide

	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 D13	X

Summary

- **First detailed characterization of a ROZ**
- **Application of oil chemistry and fluid chemistry as tracers of fluid movement**
- **Optimization of CO₂ sweep for a ROZ based on detailed reservoir model**

Thanks!

Appendix: Funding Tables

Federal Project Costs

(Only DOE Costs)

(Fill in Budget Period Spaces Below will Automatically Populate Total Federal Project Costs)

Category	Task No. 1.0	Task No. 2.0	Task No. 3.0	Task No. 4.0	Task No. 5.0	Task No. 6.0	Total
Personnel	\$13,673.69	\$207,326.92	\$145,329.85	\$147,082.40	\$44,578.75	\$86,933.75	\$644,925.35
Fringe Benefits	\$3,965.37	\$60,124.81	\$42,145.66	\$42,653.90	\$12,927.84	\$25,210.79	\$187,028.35
Travel	\$35,183.00	\$0.00	\$0.00	\$0.00	\$0.00	\$10,409.00	\$45,592.00
Supplies	\$500.00	\$30,744.08	\$0.00	\$0.00	\$0.00	\$0.00	\$31,244.08
Other	\$291.00	\$9,290.40	\$6,925.20	\$7,371.60	\$1,882.80	\$3,999.00	\$29,760.00
Total Direct Charges	\$53,613.05	\$307,486.21	\$194,400.70	\$197,107.90	\$59,389.39	\$126,552.53	\$938,549.78
Indirect Charges	\$29,487.18	\$169,117.41	\$106,920.39	\$108,409.35	\$32,664.16	\$69,603.89	\$516,202.38
TOTAL AWARD BUDGET	\$83,100.23	\$476,603.62	\$301,321.09	\$305,517.25	\$92,053.55	\$196,156.42	\$1,454,752.16
TOTAL ESTIMATED PROJECT COST	\$83,100.23	\$476,603.62	\$301,321.09	\$305,517.25	\$92,053.55	\$196,156.42	\$1,454,752.16

Budget Period 1 Costs							
Category	Task No. 1.0	Task No. 2.0	Task No. 3.0	Task No. 4.0	Task No. 5.0	Task No. 6.0	Total
Personnel	\$8,491.32	\$153,731.08	\$101,689.30	\$101,932.92	\$20,475.40	\$27,531.67	\$413,851.68
Fringe Benefits	\$2,462.48	\$44,582.01	\$29,489.90	\$29,560.55	\$5,937.86	\$7,984.18	\$120,016.99
Travel	\$35,183.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$35,183.00
Supplies	\$0.00	\$30,744.08	\$0.00	\$0.00	\$0.00	\$0.00	\$30,744.08
Other	\$184.80	\$7,069.20	\$4,914.00	\$5,224.20	\$890.40	\$1,265.40	\$19,548.00
Total Direct Charges	\$46,321.60	\$236,126.38	\$136,093.20	\$136,717.67	\$27,303.66	\$36,781.25	\$619,343.75
Indirect Charges	\$25,476.88	\$129,869.51	\$74,851.26	\$75,194.72	\$15,017.01	\$20,229.69	\$340,639.06
TOTAL AWARD BUDGET	\$71,798.48	\$365,995.88	\$210,944.46	\$211,912.38	\$42,320.67	\$57,010.93	\$959,982.81
TOTAL ESTIMATED PROJECT COST	\$71,798.48	\$365,995.88	\$210,944.46	\$211,912.38	\$42,320.67	\$57,010.93	\$959,982.81

Budget Period 2 Costs							
Category	Task No. 1.0	Task No. 2.0	Task No. 3.0	Task No. 4.0	Task No. 5.0	Task No. 6.0	Total
Personnel	\$5,182.37	\$53,595.84	\$43,640.54	\$45,149.48	\$24,103.35	\$59,402.08	\$231,073.67
Fringe Benefits	\$1,502.89	\$15,542.79	\$12,655.76	\$13,093.35	\$6,989.97	\$17,226.60	\$67,011.36
Travel	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$10,409.00	\$10,409.00
Equipment	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Supplies	\$500.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$500.00
Other	\$106.20	\$2,221.20	\$2,011.20	\$2,147.40	\$992.40	\$2,733.60	\$10,212.00
Total Direct Charges	\$7,291.45	\$71,359.83	\$58,307.50	\$60,390.24	\$32,085.73	\$89,771.28	\$319,206.03
Indirect Charges	\$4,010.30	\$39,247.91	\$32,069.13	\$33,214.63	\$17,647.15	\$49,374.21	\$175,563.32
TOTAL AWARD BUDGET	\$11,301.75	\$110,607.74	\$90,376.63	\$93,604.86	\$49,732.87	\$139,145.49	\$494,769.35
TOTAL ESTIMATED PROJECT COST	\$11,301.75	\$110,607.74	\$90,376.63	\$93,604.86	\$49,732.87	\$139,145.49	\$494,769.35

Cost Share Project Costs

Only Cost Share Costs)

(Fill in Budget Period Spaces Below will Automatically Populate Total Cost Share Project Costs)

Category	Task No. 1.0	Task No. 2.0	Task No. 3.0	Task No. 4.0	Task No. 5.0	Task No. 6.0	Total
Personnel	\$10,195.60	\$98,784.35	\$58,761.31	\$4,530.93	\$0.00	\$6,284.52	\$178,556.71
Fringe Benefits	\$2,956.72	\$28,647.46	\$17,040.78	\$1,313.97	\$0.00	\$1,822.51	\$51,781.45
Other	\$240.00	\$3,150.00	\$1,800.00	\$240.00	\$0.00	\$270.00	\$5,700.00
Total Direct Charges	\$13,392.33	\$130,581.81	\$77,602.10	\$6,084.90	\$0.00	\$8,377.03	\$236,038.16
Indirect Charges	\$7,365.78	\$71,820.00	\$42,681.15	\$3,346.69	\$0.00	\$4,607.37	\$129,820.99
TOTAL AWARD BUDGET	\$20,758.11	\$202,401.80	\$120,283.25	\$9,431.59	\$0.00	\$12,984.39	\$365,859.14
TOTAL ESTIMATED PROJECT COST	\$20,758.11	\$202,401.80	\$120,283.25	\$9,431.59	\$0.00	\$12,984.39	\$365,859.14

Budget Period 1 Costs							
Category	Task No. 1.0	Task No. 2.0	Task No. 3.0	Task No. 4.0	Task No. 5.0	Task No. 6.0	Total
Personnel	\$7,520.05	\$66,410.48	\$38,033.67	\$2,773.33	\$0.00	\$2,506.27	\$117,243.80
Fringe Benefits	\$2,180.81	\$19,259.04	\$11,029.77	\$804.27	\$0.00	\$726.82	\$34,000.70
Other	\$180.00	\$2,160.00	\$1,155.00	\$150.00	\$0.00	\$105.00	\$3,750.00
Total Direct Charges	\$9,880.86	\$87,829.52	\$50,218.44	\$3,727.60	\$0.00	\$3,338.09	\$154,994.50
Indirect Charges	\$5,434.47	\$48,306.23	\$27,620.14	\$2,050.18	\$0.00	\$1,835.95	\$85,246.97
TOTAL AWARD BUDGET	\$15,315.34	\$136,135.75	\$77,838.58	\$5,777.77	\$0.00	\$5,174.03	\$240,241.47
TOTAL ESTIMATED PROJECT COST	\$15,315.34	\$136,135.75	\$77,838.58	\$5,777.77	\$0.00	\$5,174.03	\$240,241.47

Budget Period 2 Costs							
Category	Task No. 1.0	Task No. 2.0	Task No. 3.0	Task No. 4.0	Task No. 5.0	Task No. 6.0	Total
Personnel	\$2,675.55	\$32,373.87	\$20,727.64	\$1,757.60	\$0.00	\$3,778.25	\$61,312.91
Fringe Benefits	\$775.91	\$9,388.42	\$6,011.02	\$509.70	\$0.00	\$1,095.69	\$17,780.74
Other	\$60.00	\$990.00	\$645.00	\$90.00	\$0.00	\$165.00	\$1,950.00
Total Direct Charges	\$3,511.46	\$42,752.29	\$27,383.66	\$2,357.30	\$0.00	\$5,038.94	\$81,043.66
Indirect Charges	\$1,931.31	\$23,513.76	\$15,061.01	\$1,296.52	\$0.00	\$2,771.42	\$44,574.01
TOTAL AWARD BUDGET	\$5,442.77	\$66,266.05	\$42,444.67	\$3,653.82	\$0.00	\$7,810.36	\$125,617.67
TOTAL ESTIMATED PROJECT COST	\$5,442.77	\$66,266.05	\$42,444.67	\$3,653.82	\$0.00	\$7,810.36	\$125,617.67