



April 3, 2020

Ms. Mary Sullivan, Program Manager
U.S. Department of Energy
National Energy Technology Laboratory
3610 Collins Ferry Road PO Box 880
Morgantown WV 26507-0880

Dear Ms. Sullivan,

The Southern States Energy Board (SSEB) is honored to lead the U.S. Department of Energy National Energy Technology Laboratory-funded project entitled, "Southeast Regional Carbon Storage Partnership: Offshore Gulf of Mexico" (SECARB Offshore GoM), Cooperative Agreement No. DE-FE0031557. I am writing to document completion of the Task 2 Milestone, "Host Offshore CO2 Storage Workshop."

On March 26-27, 2020, SSEB hosted the SECARB Offshore GoM and GoMCarb's 2nd Annual Joint Partnership Meeting. The event was originally scheduled over these dates as an in-person meeting in New Orleans, Louisiana. Due to the COVID-19 pandemic, we were able to transition the location to a "Virtual Venue" using our web meeting system. The agenda and presentations are provided as enclosures. Participation over the two days ranged from 70 to 109 individual log-ins. While this situation was not ideal, we were able to generate interest from a broad group of stakeholders.

Further, we were able to invoke the Force Majeure clause in our contract with the Royal Sonesta hotel in New Orleans. Therefore, no expenses were incurred for the event cancellation, and they refunded our deposit.

Please let me know if you have any questions or if additional information regarding the joint meeting.

Sincerely,

A handwritten signature in black ink that reads "Kimberly Gray". The signature is fluid and cursive.

Kimberly Gray
Managing Director

Enclosure



SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting March 26 – 27, 2020

Web Conference Information Provided Below for Each Day

***Eastern Daylight Time**

March 26, 2020

WebEx Link

<https://ssenergyboard.my.webex.com/ssenergyboard.my/j.php?MTID=m55fd5df800810ef22f6ae36293c721f4>

Meeting number (access code): 627 750 865

Password: GOM2020

Join by phone

+1-510-338-9438 USA Toll

Tap here to call (mobile phones only, hosts not supported): tel:%2B1-510-338-9438,,*01*627750865%23%23*01*

Global call-in numbers

<https://ssenergyboard.my.webex.com/ssenergyboard.my/globalcallin.php?MTID=mafc4a3a38c8bbd2b75b0bd21bd08bafa>

Join by video system

Dial 627750865@ssenergyboard.my.webex.com

You can also dial 173.243.2.68 and enter your meeting number.

Join using Microsoft Lync or Microsoft Skype for Business

Dial sip:627750865.ssenergyboard.my@lync.webex.com

March 26 GoMCarb Project Updates and Discussion

9:45 AM – 10:00 AM Log In and Trouble Shooting

10:00 AM – 10:05 AM Overview of GoMCarb Program and Key Accomplishments this Year – Susan Hovorka

10:05 AM – 11:05 AM Task 2 – Offshore Storage Resource Assessment

- Offshore Capacity Mapping Approach, Status of Mapping, Results of Seismic Interpretation – Dallas Dunlap, BEG
- Net Sandstone, Reservoir Architecture Depositional Facies, and Phi-h: Goals and Progress – Iulia Olariu, BEG-GCCC
- Progress on Characterization of the Chandeleur Area – Marcie Purkey-Phillips, UTIG
- Buoyant CO₂ Storage Assessment: Methodology and Estimating Input Distributions – Sean Brennan, USGS
- Discussion, questions, and next steps

11:05 AM – 11:10 AM BREAK

11:10 PM – 12:10 PM Task 3 – Risk Assessment, Simulation, and Modeling

- Well Blowout Simulations – Curt Oldenburg, LBNL
- Reservoir Modeling – Sahar Bakhshian, BEG-GCCC
- Analytical Model – Larry Lake, UT PGE
- Fault-Conforming Model for Geomechanical Simulations – Antoine Mazuyer and Josh White, LLNL and Total
- Discussion, questions and next steps

12:10 PM – 12:15 PM BREAK

12:15 PM – 12:45 Task 4 – Monitoring, Verification, and Assessment (MVA)

- Distributed Acoustic Sensors – Jonathan Ajo-Franklin, Rice University
- P-Cable Update – Tip Meckel, BEG-GCCC
- Discussion, questions, and next steps

12:45 PM – 1:30 PM LUNCH BREAK

1:30 PM – 2:00 PM Task 5 – Infrastructure, Operations, and Permitting

- CO₂ Transport and Delivery – Trimeric
- Tracy Benson, Lamar University
- Discussion, questions, and next steps

2:00 PM – 3:00 PM Task 6 – Knowledge Dissemination

- Stakeholder Outreach – Rachel Lim, UT Stan Richards School/UT PGE/GCCC
- Technical Outreach – Emily Moskal, BEG-GCCC
- Offshore Workshop 2020 – Alex Bump, BEG-GCCC
- Discussion, questions and next steps

3:00 PM – 3:15 PM Wrap-up and comments

PRIVATE: 3:30 PM – 5:00 PM GoMCARB Advisors Session

March 27, 2020

WebEx Link

<https://ssenergyboard.my.webex.com/ssenergyboard.my/j.php?MTID=m2999a4493d17b4e636d954e03e18373e>

Meeting number (access code): 623 597 455

Password: GOM2020

Join by phone

+1-510-338-9438 USA Toll

Tap here to call (mobile phones only, hosts not supported): tel:%2B1-510-338-9438,,*01*623597455%23%23*01*

Global call-in numbers

<https://ssenergyboard.my.webex.com/ssenergyboard.my/globalcallin.php?MTID=m8341dbb2417be73a23d2b364243bf62c>

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Join using Microsoft Lync or Microsoft Skype for Business

Dial sip:[623597455.ssenergyboard.my@lync.webex.com](tel:623597455.ssenergyboard.my@lync.webex.com)

March 27 SECARB Offshore GoM Project Updates and Discussion

9:45 AM – 10:00 AM Log In and Trouble Shooting

10:00 AM – 11:00 PM

- Status of Characterization of CO₂-EOR Offshore Resource Potential – Matt Wallace, ARI (30 mins)
- Status of Risk Characterization Activities and Data Development – Michael Godec, ARI (30 mins)

11:00 AM – 11:15 AM BREAK

11:15 AM – 12:15 PM

- Status on Work on Characterizing Legal and Regulatory Frameworks and Key Considerations – Ingvild Ombudstvedt, IOM Law and Michael Godec, ARI (30 mins)
- Overview of Offshore CO₂-EOR/Storage Case Studies – Vello Kuuskraa, ARI (30 mins)

12:15 PM – 1:15 PM LUNCH BREAK

1:15 PM – 2:05 PM

- Risk Assessment Gas Hydrates – Camelia Knapp (20 Mins)
- SECARB Offshore evaluating the salt structures and deep-water reservoirs in the central Gulf of Mexico – Pashin (30 mins)

2:05 PM – 2:20 PM BREAK

2:20 PM – 3:00 PM

- Offshore Well Integrity – Andrew Duguid (20 mins)
- 45Q – Brian Hill (20 mins)

3:00 PM – 3:15 PM Wrap up and Comments

March 26, 2020

GoMCarb Project Updates and Discussion

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Agenda continued on next slide...



Experiencing Technical Difficulties?

Emily Moskal

Emily.Moskal@beg.utexas.edu

(281) 796-9834

March 26, 2020

GoMCarb Project Updates and Discussion

Agenda continued...

12:15 PM – 12:45 PM

Task 4 – Monitoring, Verification, and Assessment (MVA)

Distributed Acoustic Sensors – Jonathan Ajo-Franklin, Rice University
P-Cable Update – Tip Meckel, BEG-GCCC
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Wrap up and Comments



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Emily Moskal

Emily.Moskal@beg.utexas.edu

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Overview of GoMCarb Program and Key Accomplishments This Year



Susan Hovorka

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Discussion via chat

Put Q- and your question in chat on WebEx.



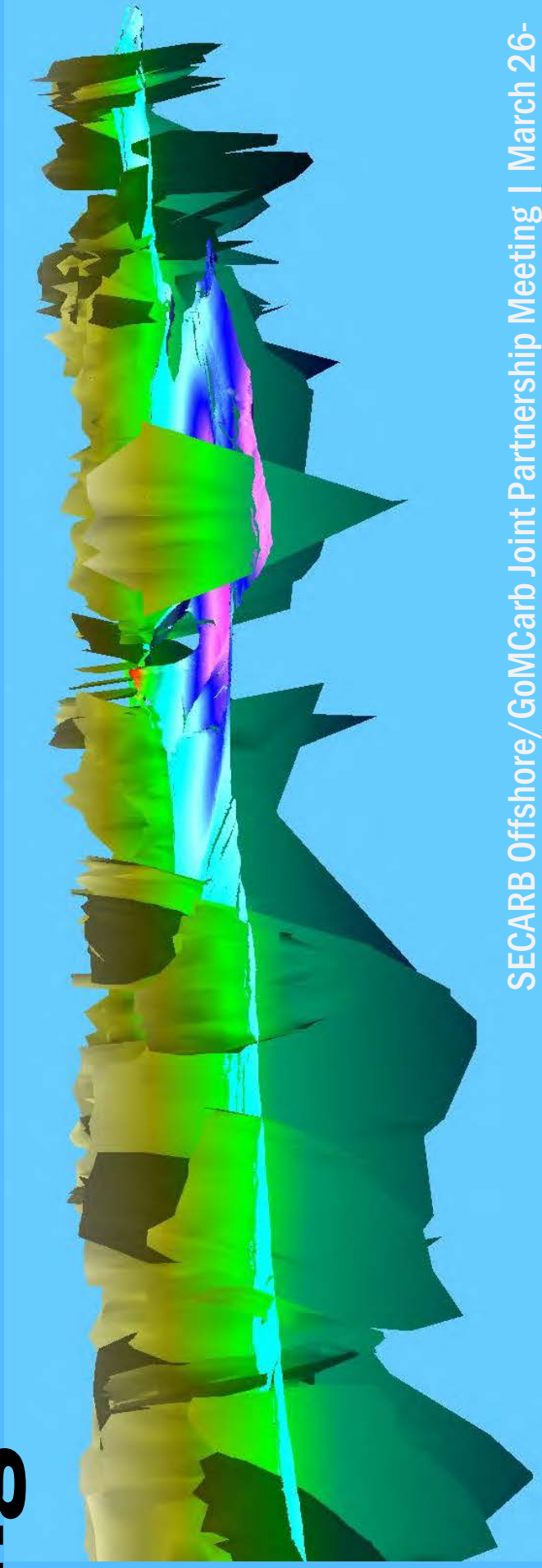
Offshore Texas/Louisiana Seismic Structural Framework and Capacity Mapping

Micheal DeAngelo
Dallas B. Dunlap
Reynaldy Fifariz
Tip A. Meckel
Ramon Trévino



HALLIBURTON

SEI[®] SEISMIC
EXCHANGE

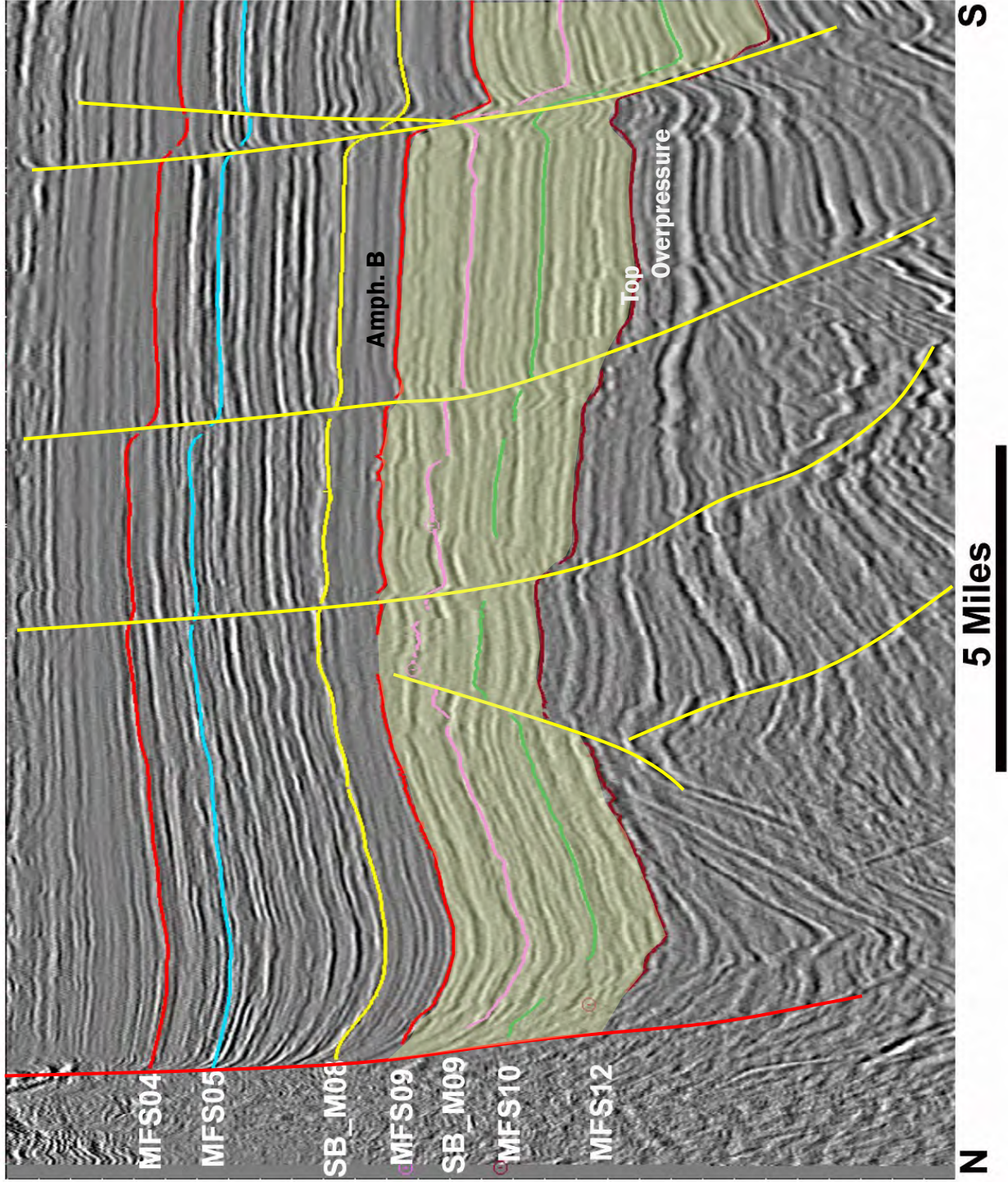


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Seismic Stratigraphic Framework

Northern Texas Coast
Amplitude Dip Line
(TWT)

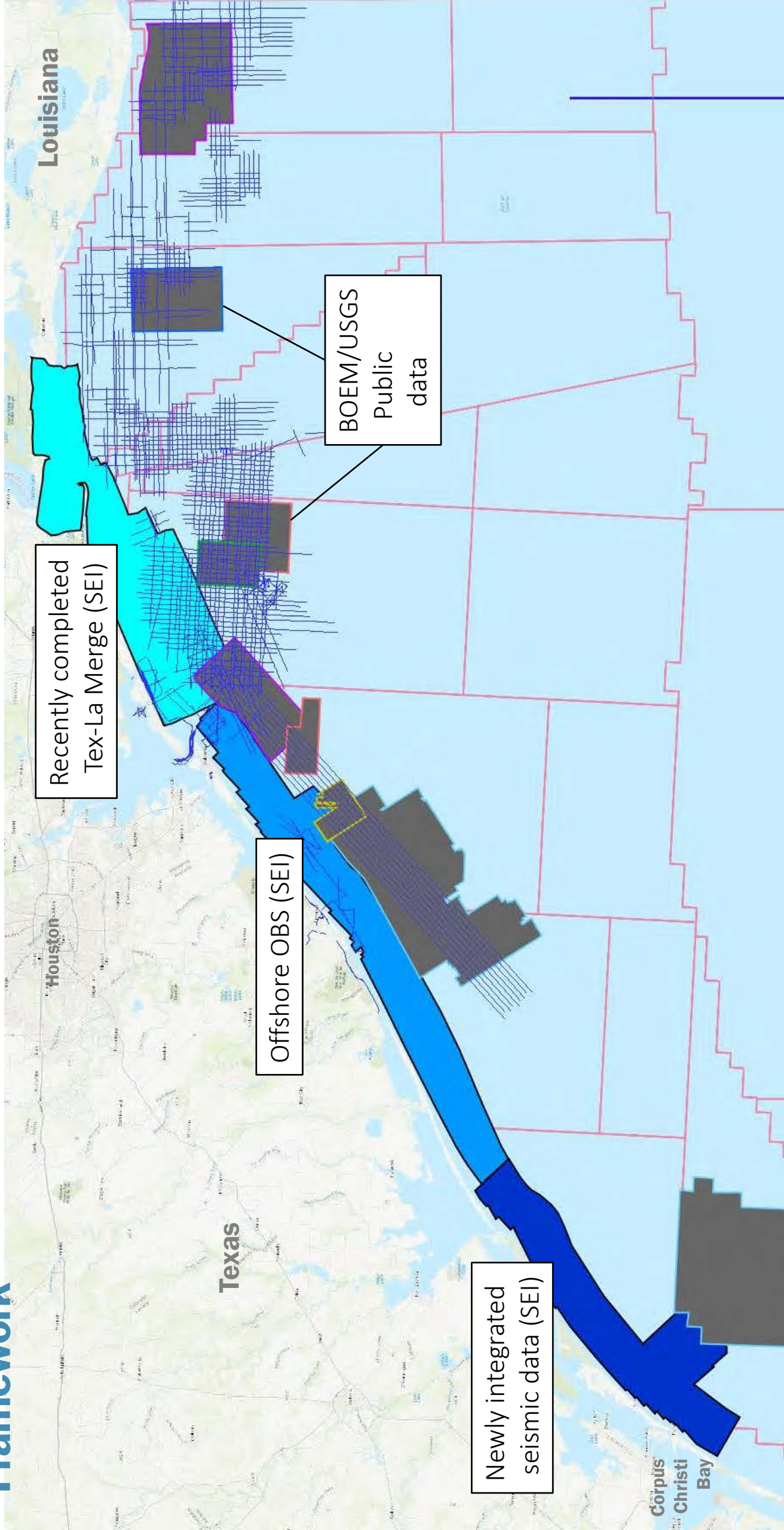
Amphistegina B - Lower Miocene (LM2)
Maximum Flooding Surface 9 (MFS09)



Seismic data owned or controlled
by Seismic Exchange, Inc.
Interpretation is that of the
University of Texas

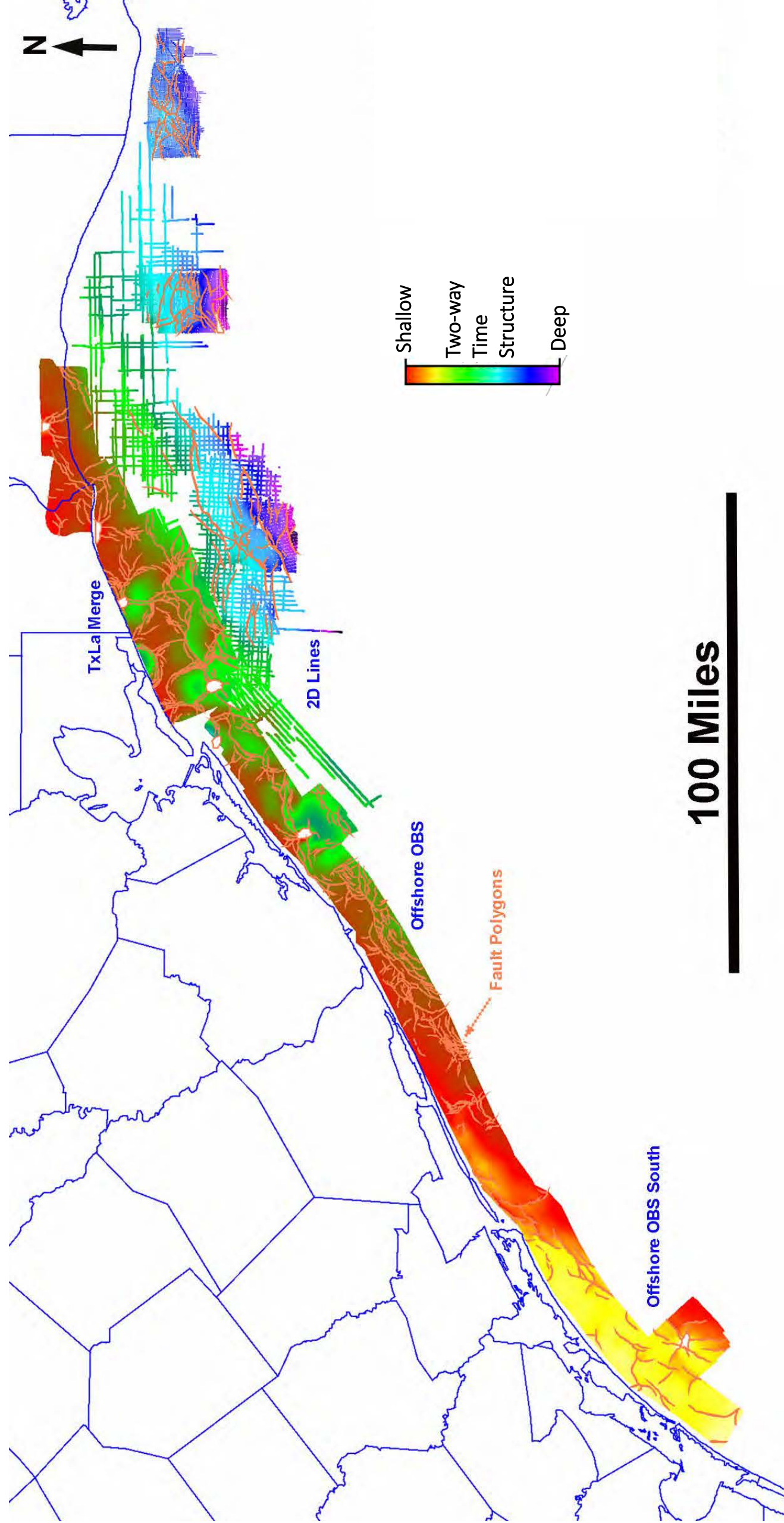
Seismic Stratigraphic Framework

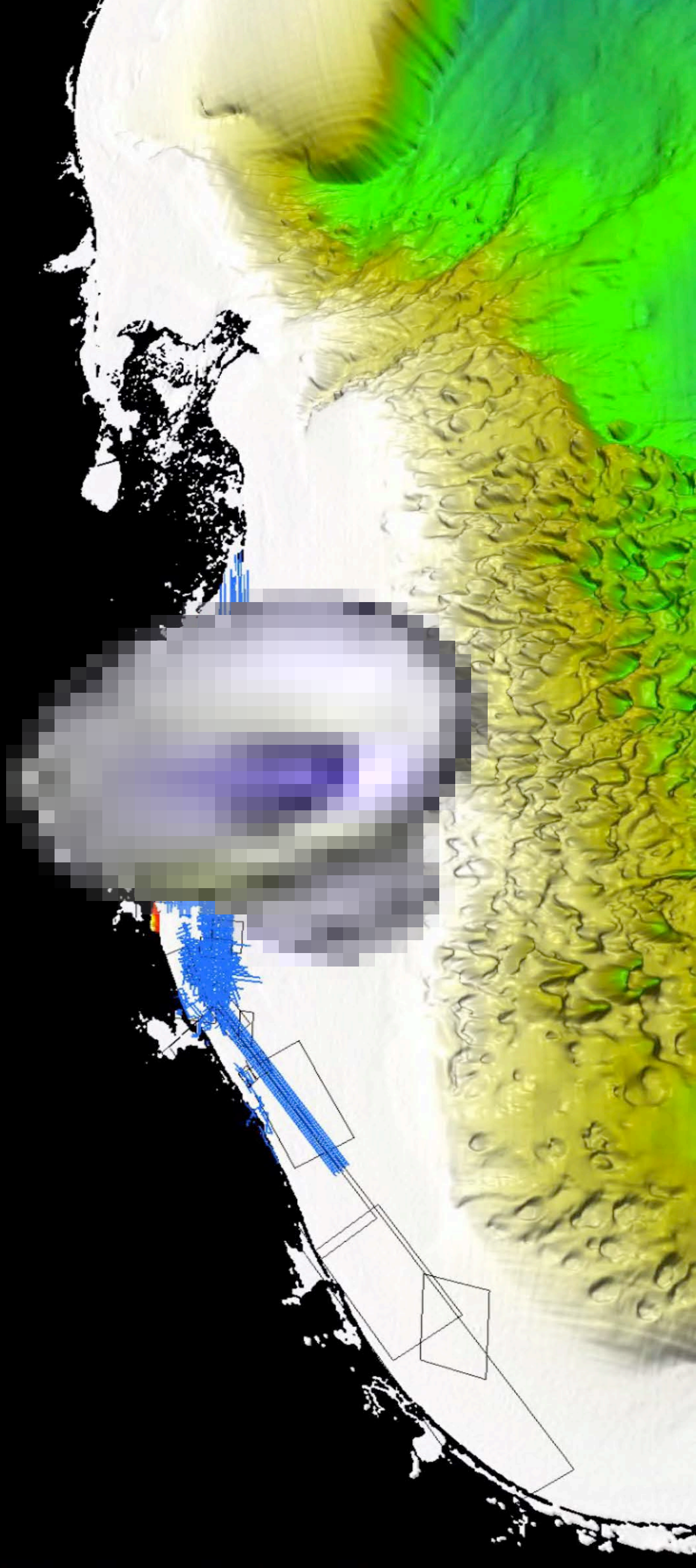
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MFS09 Structure map

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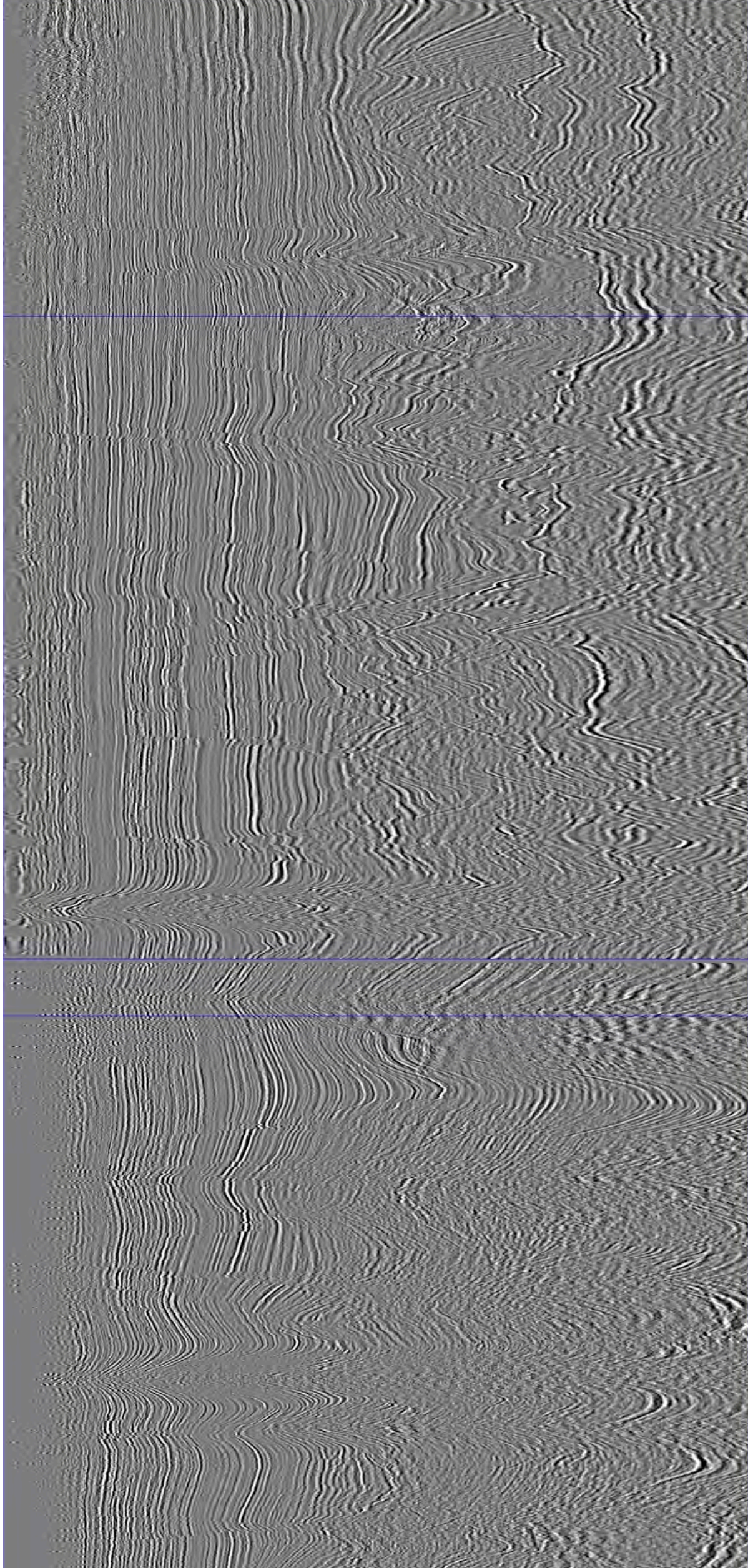


Objectives for the Seismic Interpretation

- 1) Expanding existing seismic framework into new areas of state waters
- 2) Expand the existing time/depth model into these emerging study areas
- 3) Develop workflows and initial inventory of offshore storage opportunities

Composite Seismic Image Louisiana to Middle Texas Coast

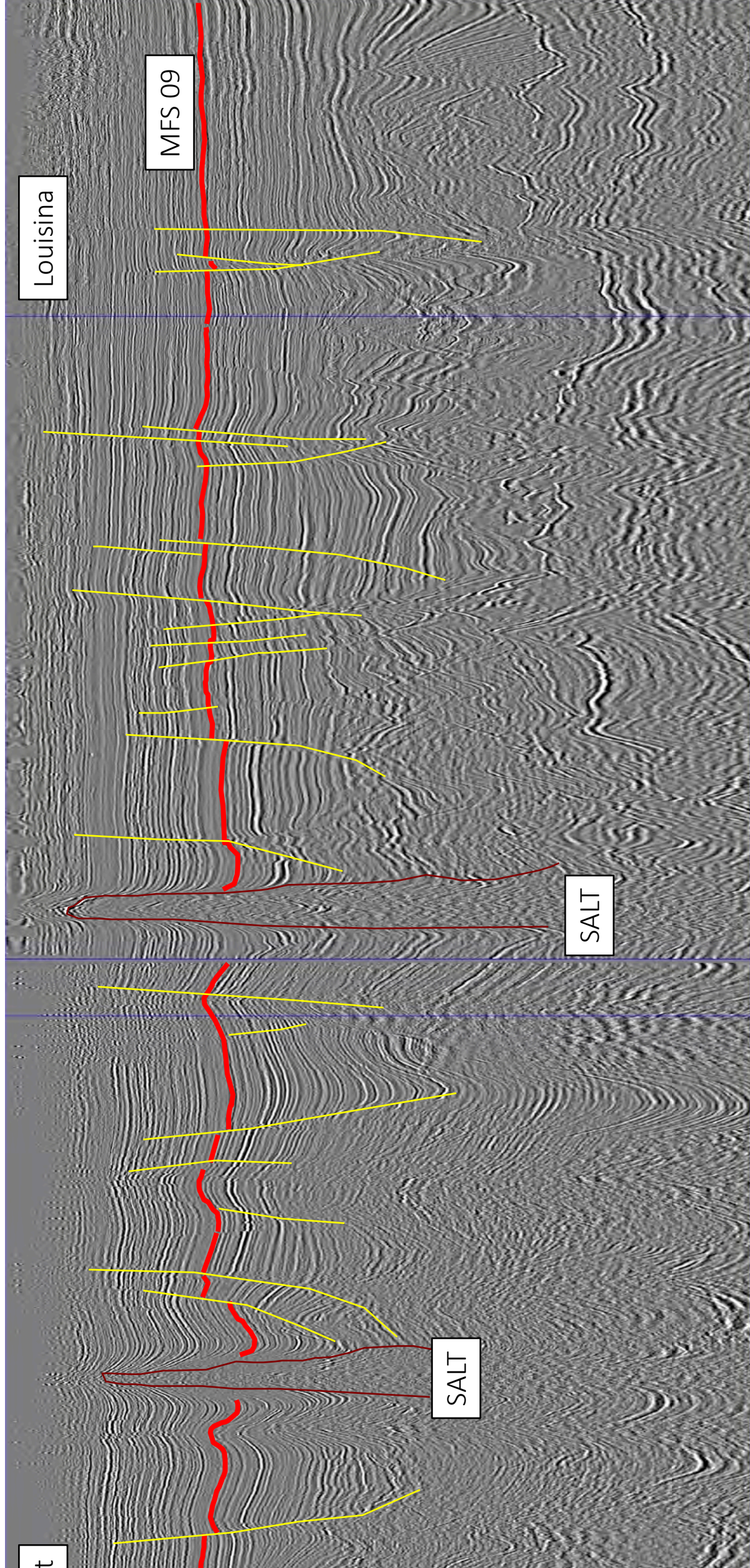
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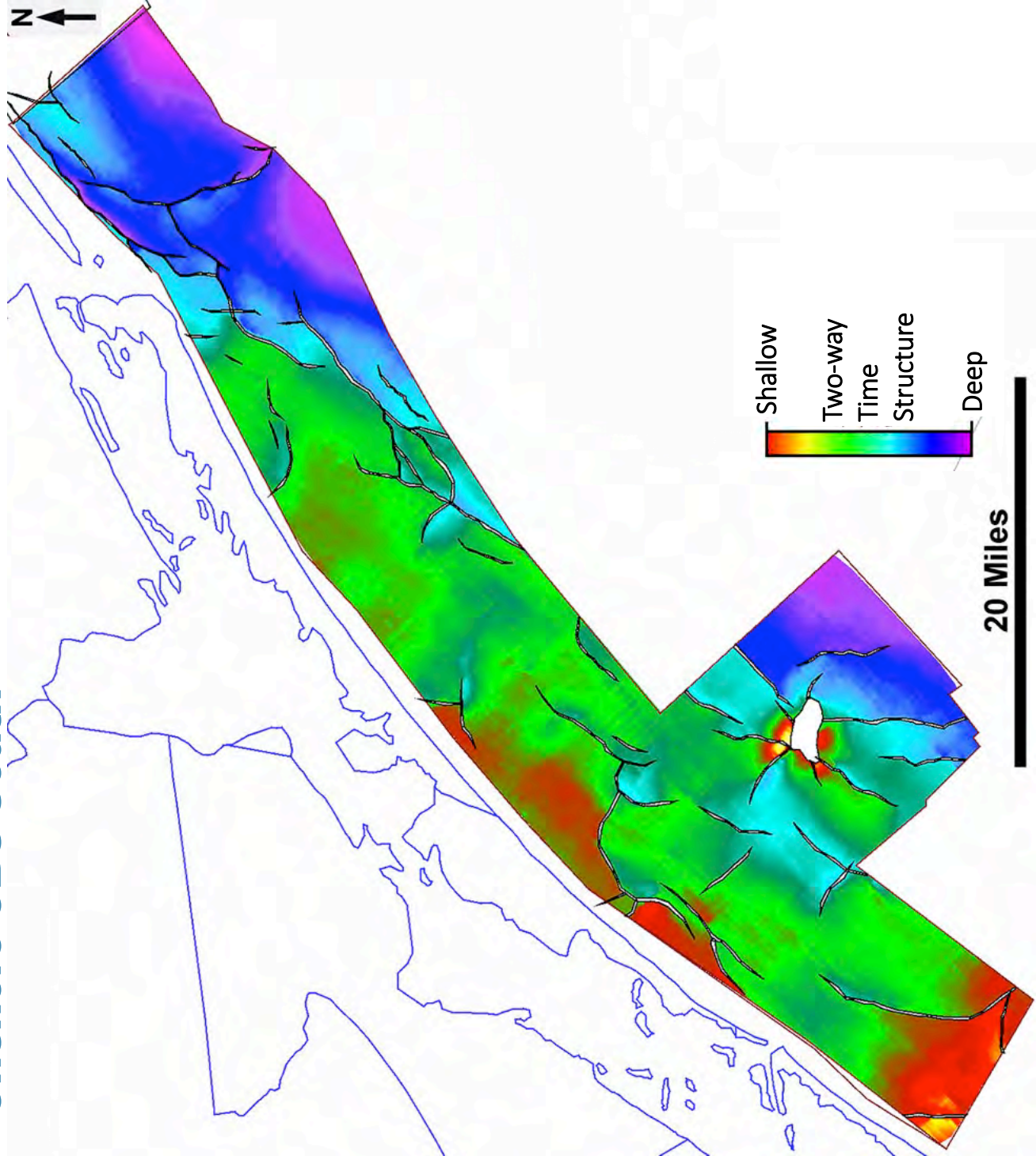
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Composite Seismic Image Louisiana to Middle Texas Coast

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**Amphistegina B - Lower Miocene (LM2)
Maximum Flooding Surface 9 (MFS09)**

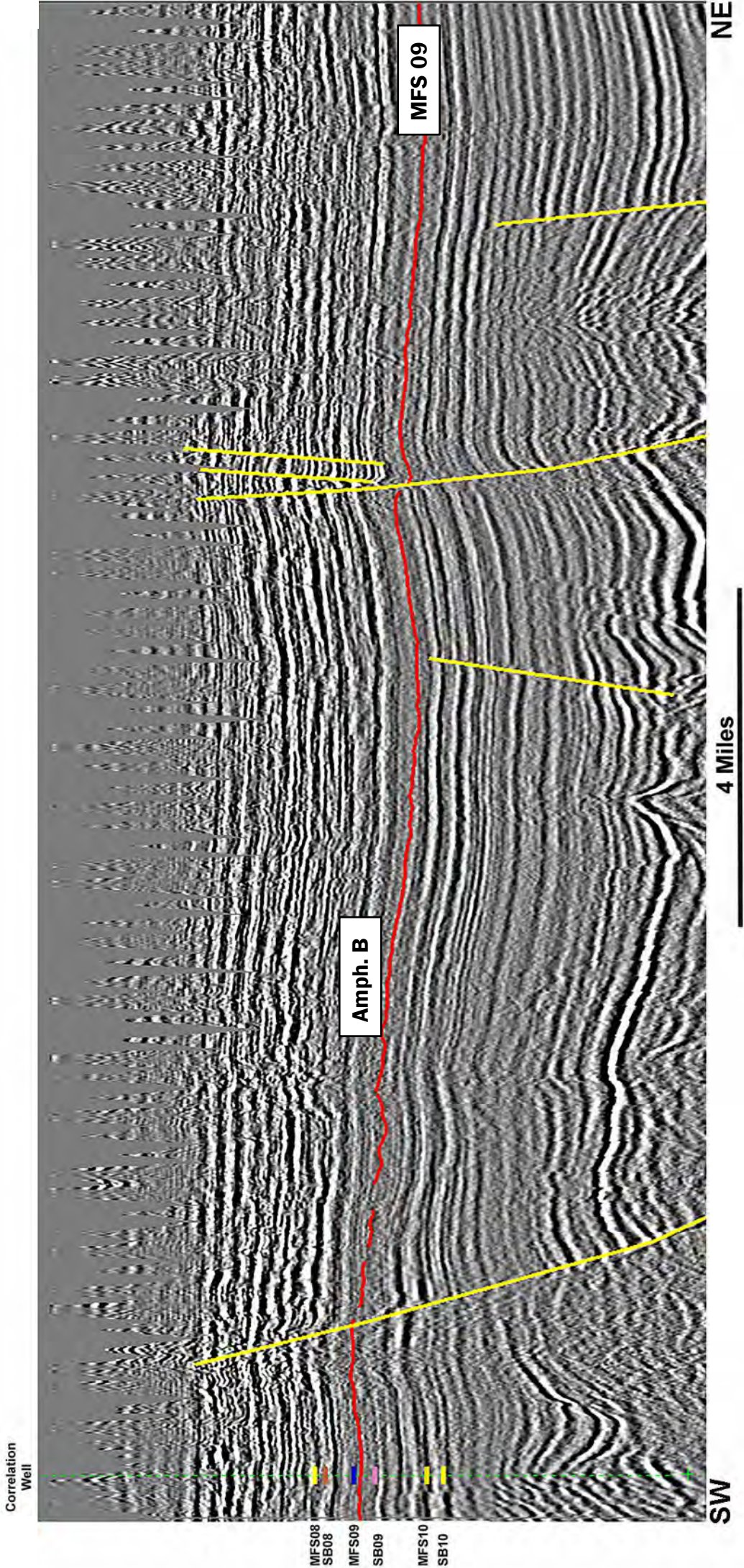
Fully interpreted in New Volume

**Interpreted or documented:
Numerous faults sets,
Incised valleys,
salt domes,
and areas of mass-wasting.**

**In process of expanding structural
framework stratigraphically down to
Top-Overpressure (~MFS12)**

Seismic Section Middle Texas Shelf

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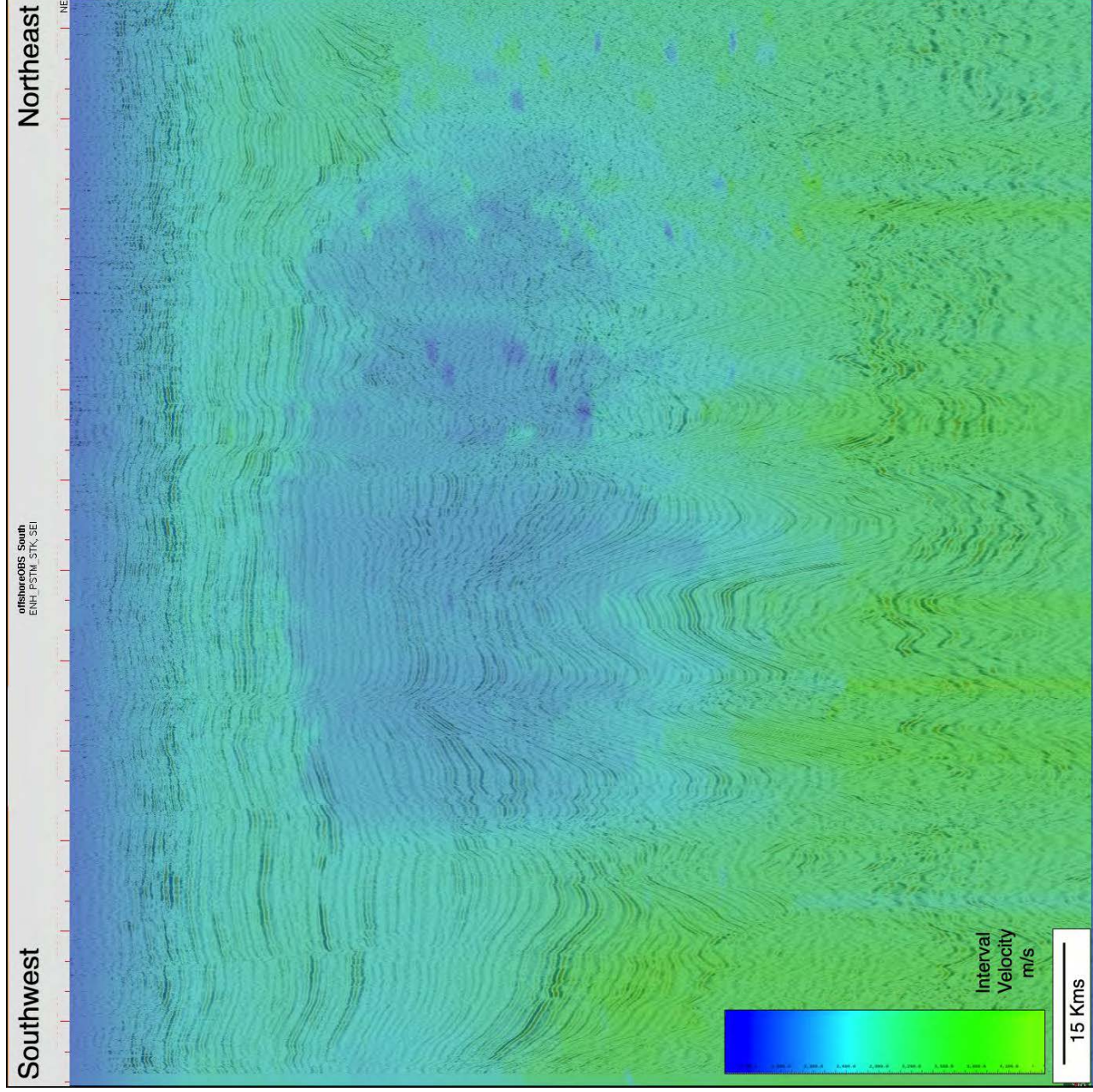
Time/Depth Velocity Model

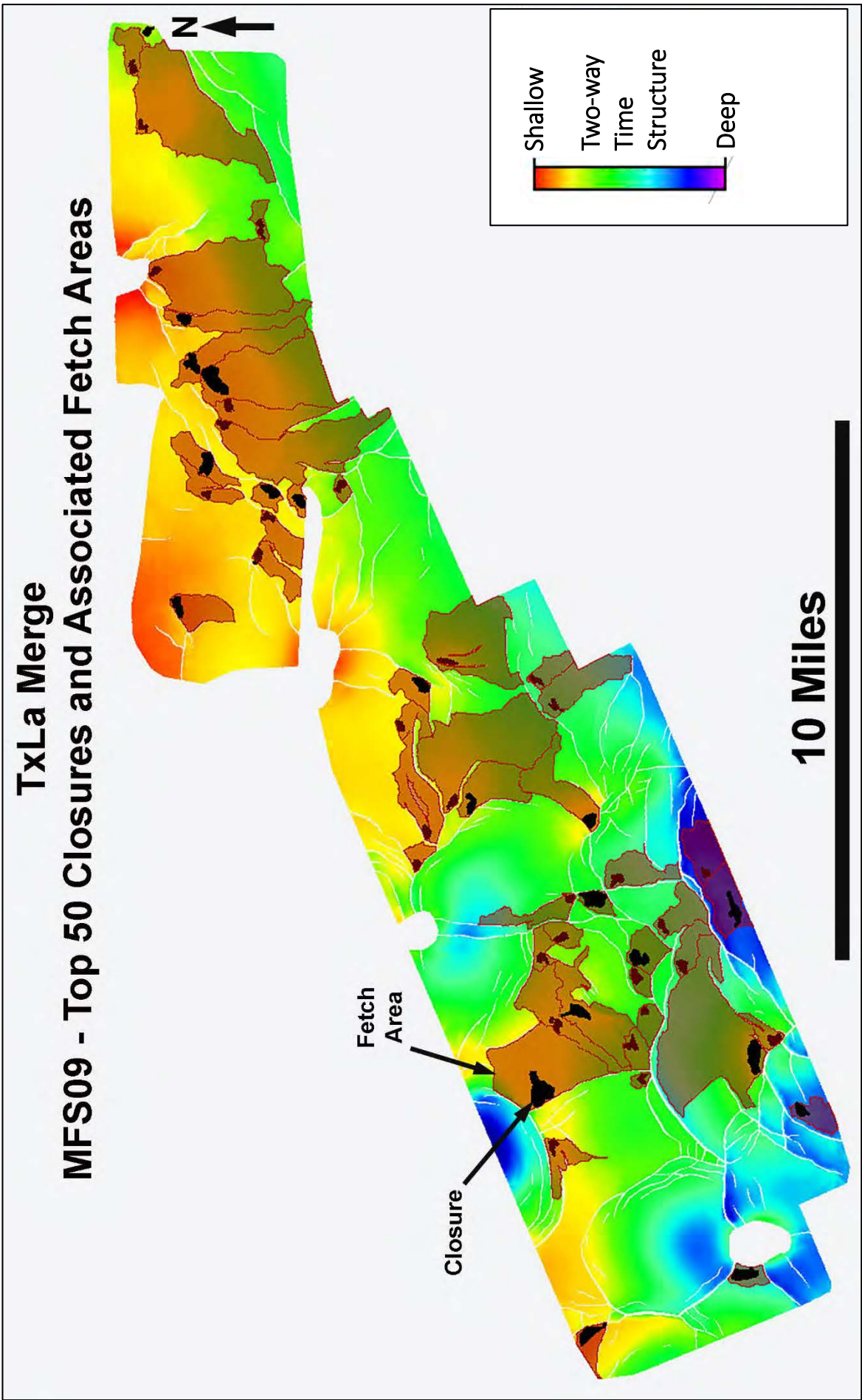
Generated and merged velocity models in Offshore OBS South and Offshore OBS

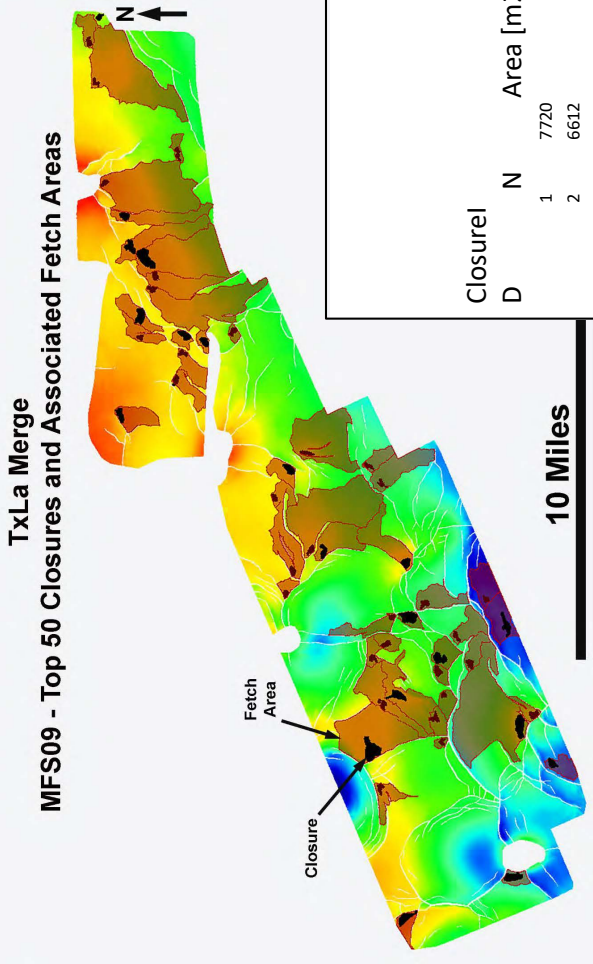
Produced from PSTM stacking velocities to generate a first-pass velocity model

Dynamic velocity model now spans Western Louisiana to Corpus Christi Bay used in seismic Interpretation and storage assessment

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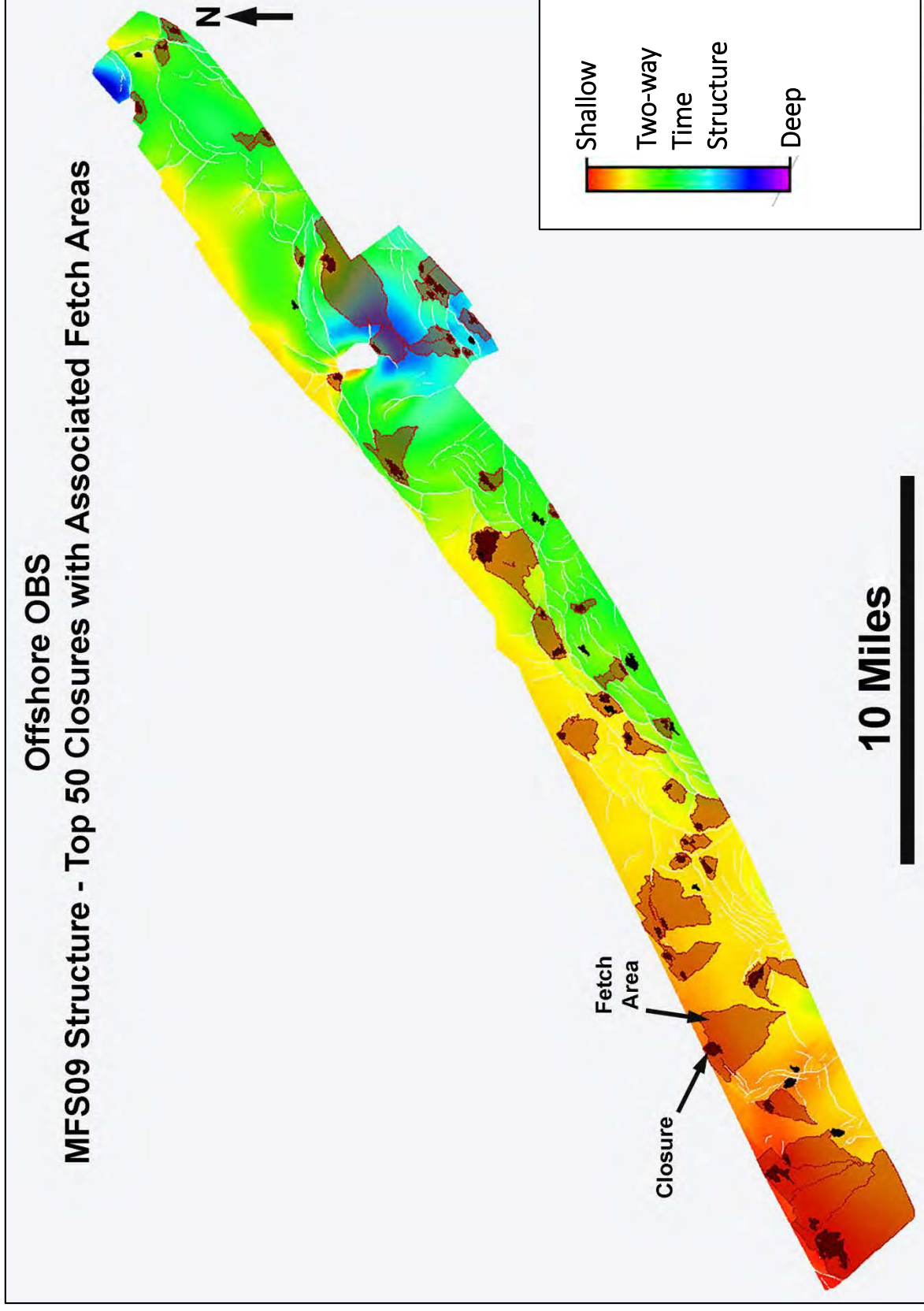


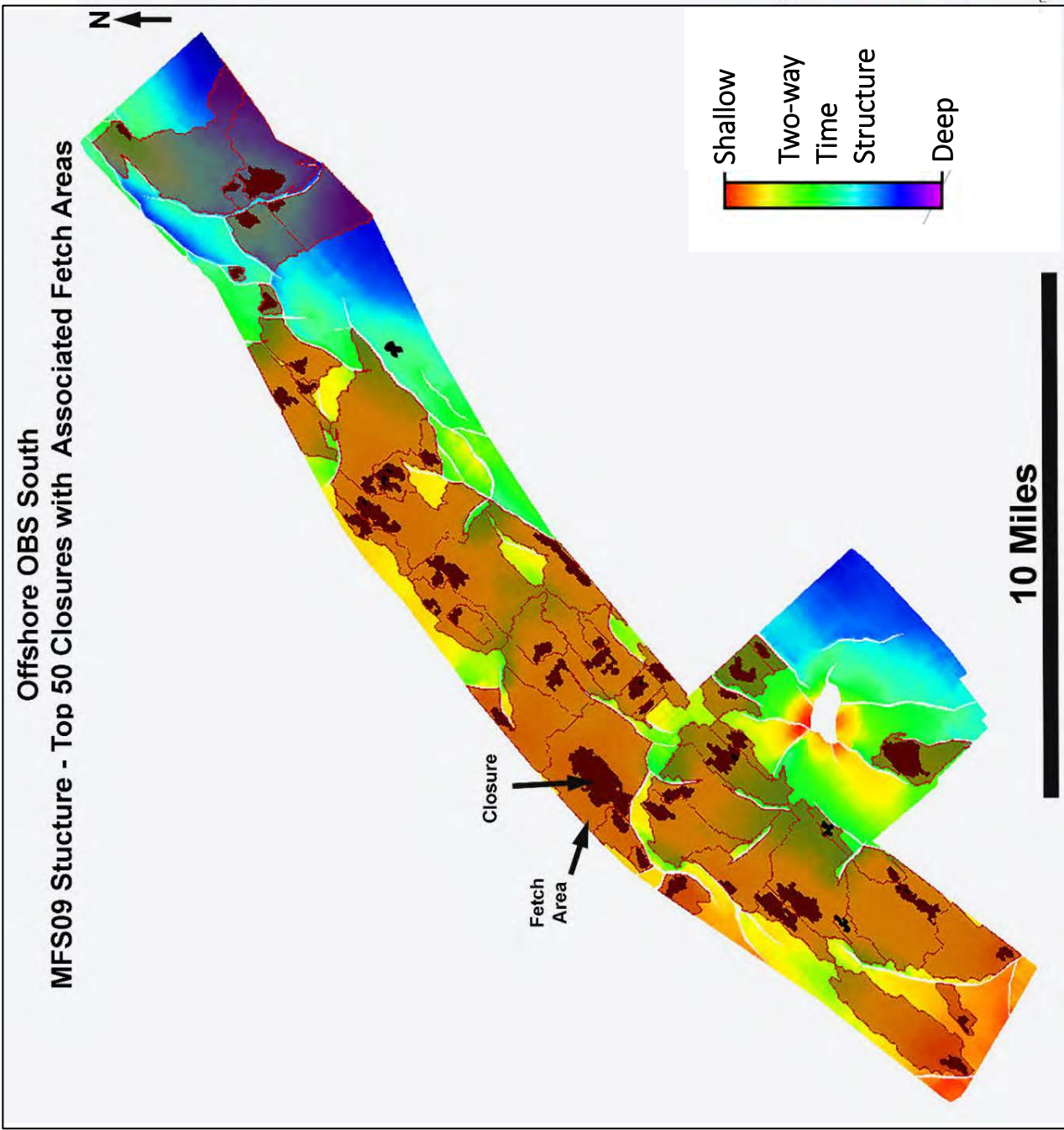


Closure and Fetch Results for TxLa Merge

Closure#	Area [m2]		Area [km2]		Apex Depth [m]		Spill Depth [m]		Max Closure Height [m]		Fluid Depth [m]		Actual Column Height [m]		Bulk Rock Volume[m3]	
	D	N														
	1	7720	8680780	2093.16	8.68078	2149.61	2149.61	56.4512	2149.61	56.4512	2149.61	2149.61	56.4512	56.4512	191385000	1.12E+08
	2	6612	7.43E+06	2215.04	7.43488	2249.88	2249.88	34.8457	2249.88	34.8457	2249.88	2249.88	34.8457	34.8457	40.4067	1.09E+08
	3	6331	7.12E+06	2505.44	7.11891	2545.85	2545.85	40.4067	2545.85	40.4067	2545.85	2545.85	40.4067	40.4067	31.0833	9.10E+07
	4	6277	7058190	2060.37	7.05819	2091.45	2091.45	31.0833	2091.45	31.0833	2091.45	2091.45	31.0833	31.0833	74628800	1.12E+08
	5	6253	7.03E+06	2310.69	7.03121	2361.69	2361.69	51.0005	2361.69	51.0005	2361.69	2361.69	51.0005	51.0005	52.5996	1.13E+08
	6	5367	6.03E+06	2044.53	6.03494	2097.13	2097.13	52.5996	2097.13	52.5996	2097.13	2097.13	52.5996	52.5996	46.2325	9.03E+07
	7	4889	5.50E+06	2022.39	5.49745	2068.62	2068.62	46.2325	2068.62	46.2325	2068.62	2068.62	46.2325	46.2325	53.0925	8.20E+07
	8	4787	5.38E+06	2441.85	5.38276	2491.12	2491.12	49.261	2491.12	49.261	2491.12	2491.12	49.261	49.261	53.9392	1.19E+08
	9	4496	5.06E+06	2213.1	5.0554	2266.2	2266.2	53.0925	2266.2	53.0925	2266.2	2266.2	53.0925	53.0925	39.8977	5.84E+07
	10	4468	5.02E+06	2238.12	5.02406	2290.88	2290.88	52.7593	2290.88	52.7593	2290.88	2290.88	52.7593	52.7593	39.0054	4.38E+07
	11	4020	4.52E+06	2157.73	4.5203	2205.96	2205.96	48.2361	2205.96	48.2361	2205.96	2205.96	48.2361	48.2361	23.4622	3.15E+07
	12	3995	4.49E+06	2162.74	4.49219	2216.68	2216.68	53.9392	2216.68	53.9392	2216.68	2216.68	53.9392	53.9392	56.176	1.02E+08
	13	3775	4.24E+06	2393.28	4.24481	2433.18	2433.18	39.8977	2433.18	39.8977	2433.18	2433.18	39.8977	39.8977	52.2917	5.83E+07
	14	3368	3.79E+06	2465.76	3.78716	2504.77	2504.77	39.0054	2504.77	39.0054	2504.77	2504.77	39.0054	39.0054	4.30E+07	4.30E+07
	15	3267	3.67E+06	2083.85	3.67359	2107.31	2107.31	23.4622	2107.31	23.4622	2107.31	2107.31	23.4622	23.4622	1696.08	4.91E+09
	16	3254	3.66E+06	2283.97	3.65897	2340.14	2340.14	56.176	2340.14	56.176	2340.14	2340.14	56.176	56.176	7.48E+07	7.48E+07
	17	2957	3.33E+06	2432.68	3.32501	2484.97	2484.97	52.2917	2484.97	52.2917	2484.97	2484.97	52.2917	52.2917	51.0293	5.51E+07
	18	2824	3.18E+06	2124.53	3.17546	2162.67	2162.67	38.1392	2162.67	38.1392	2162.67	2162.67	38.1392	38.1392	52.6321	3.21E+07
	19	2696	3031530	2040.35	3.03153	2091.39	2091.39	51.0385	2091.39	51.0385	2091.39	2091.39	51.0385	51.0385	50487500	5.04E+07
	20	2674	3.01E+06	2171.51	3.00679	2211.7	2211.7	40.1873	2211.7	40.1873	2211.7	2211.7	40.1873	40.1873	1696.08	4.91E+09
	21	2618	2.94E+06	2303.92	2.94382	4000	4000	1696.08	4000	1696.08	4000	4000	1696.08	1696.08	51.052	5.10E+07
	22	2548	2.87E+06	2189.78	2.86511	2240.83	2240.83	51.052	2240.83	51.052	2240.83	2240.83	51.052	51.052	52.6321	3.21E+07
	23	2528	2.84E+06	2203.13	2.84262	2254.16	2254.16	51.0293	2254.16	51.0293	2254.16	2254.16	51.0293	51.0293	52.251	4.37E+07
	24	2485	2.79E+06	2469.56	2.79427	2522.19	2522.19	52.251	2522.19	52.251	2522.19	2522.19	52.251	52.251	6.36E+07	6.36E+07
	25	2454	2.76E+06	2075.48	2.75941	2127.73	2127.73	52.251	2127.73	52.251	2127.73	2127.73	52.251	52.251	5.72E+07	5.72E+07
	26	2337	2.63E+06	2244.4	2.62785	2295.42	2295.42	51.0166	2295.42	51.0166	2295.42	2295.42	51.0166	51.0166	5.09E+07	5.09E+07
	27	2072	2.33E+06	2392.32	2.32987	2443.33	2443.33	51.0117	2443.33	51.0117	2443.33	2443.33	51.0117	51.0117	3.71E+07	3.71E+07
	28	2061	2.32E+06	2270.99	2.3175	2322	2322	51.0066	2322	51.0066	2322	2322	51.0066	51.0066	2.86E+07	2.86E+07
	29	1922	2.16E+06	2168.46	2.1612	2219.46	2219.46	51.0015	2219.46	51.0015	2219.46	2219.46	51.0015	51.0015	2.86E+07	2.86E+07
	30	1871	2.10E+06	2258.74	2.10385	2296.13	2296.13	37.3887	2296.13	37.3887	2296.13	2296.13	37.3887	37.3887	2.86E+07	2.86E+07

Based on a 50ft minimum closure height





Large number of closures in the OBS South volume

These have greater closure areas and associated fetch areas than in the northern volumes

In the process of integrating well penetrations, production histories, and outlines of producing/non-producing fields

Next Steps

- 1) Build out the stratigraphy from MFS09 down to the top of overpressure in the middle Texas Shelf
- 2) Refine the southern extent of the depth model to more accurately constrain the volumetrics of offshore storage opportunities
- 3) Correlate offshore field locations and well production results with locations of predicated geologic closure and fetch

Questions?

Acknowledgements:

Landmark Graphics for the use of the Landmark Software Interpretation Suite and Permedia

SEI for granting the display of SEI Seismic reflection data.

Undergraduate and graduate students for their efforts in this interpretation

BEG/UT Institute of Geophysics IT for software and hardware support



Task #2



Offshore Storage Resource Assessment

Iulia Olariu, Tucker Hentz
BEG UT

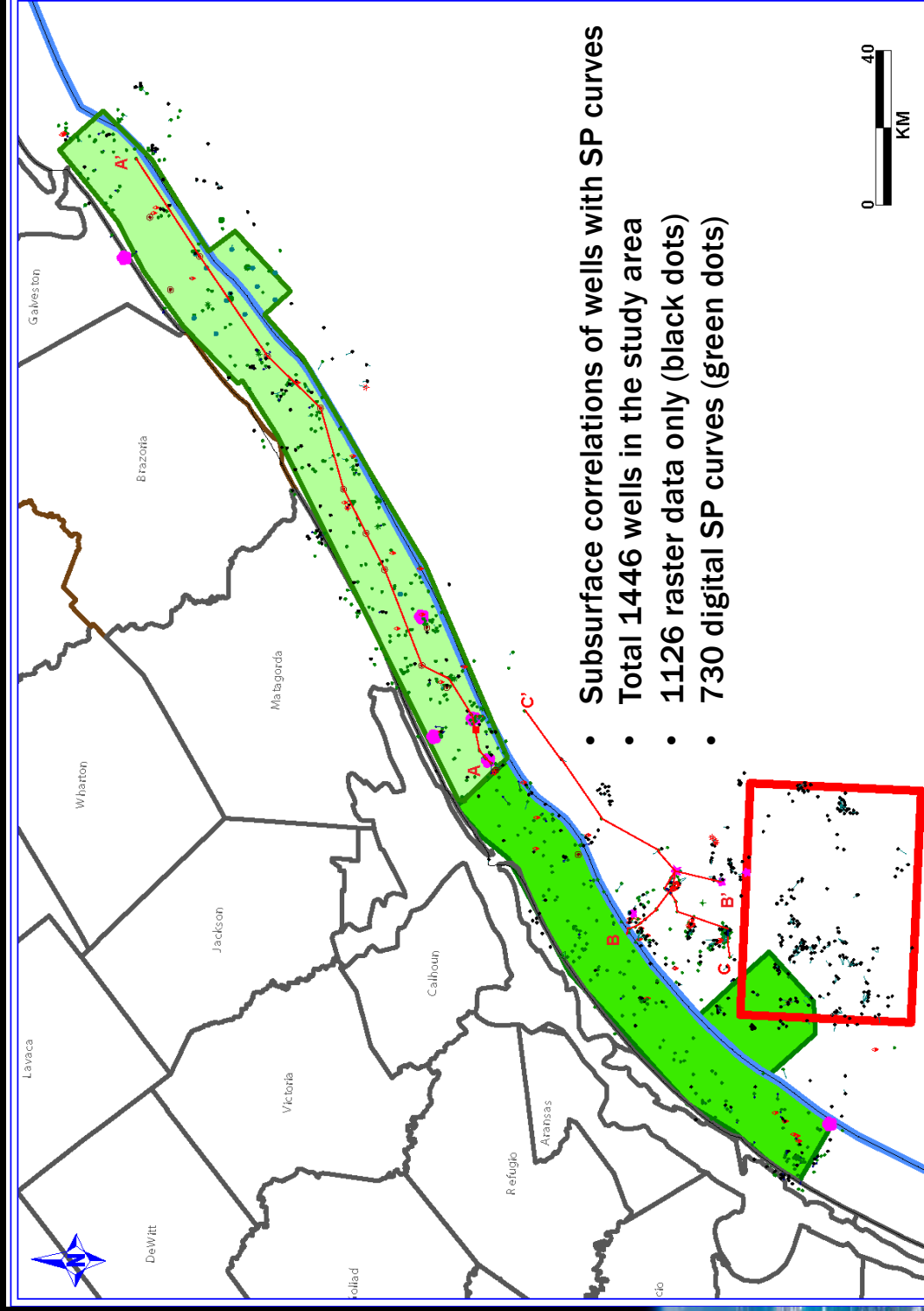
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Problem

- Identify potential CO₂ storage intervals (between the supercritical depth and the top of the overpressure)
- Well-log database development offshore mid Texas coast from Galveston to Corpus Christi Bay
- Net sandstone maps - calculation of the sandstone thickness for the prospective interval of interest
- Estimate static regional capacity

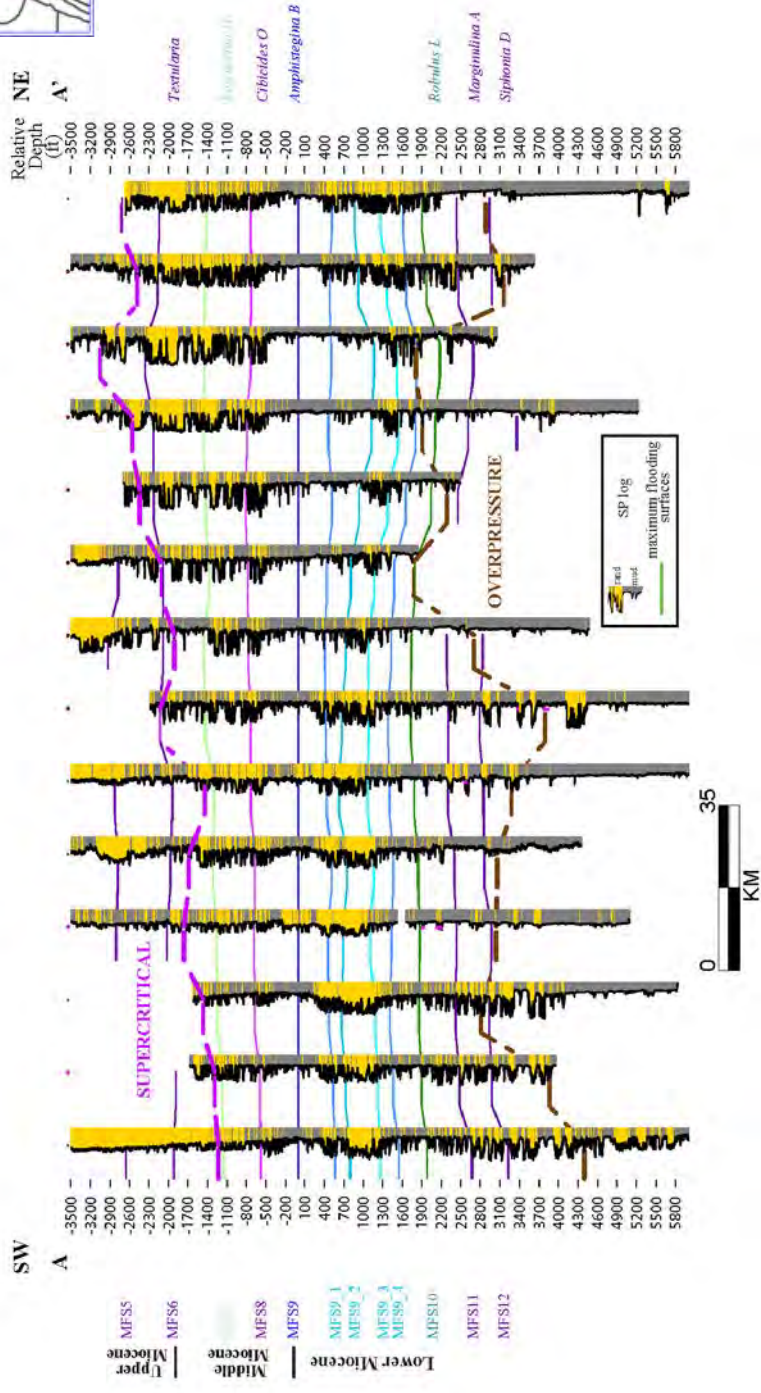


Approach

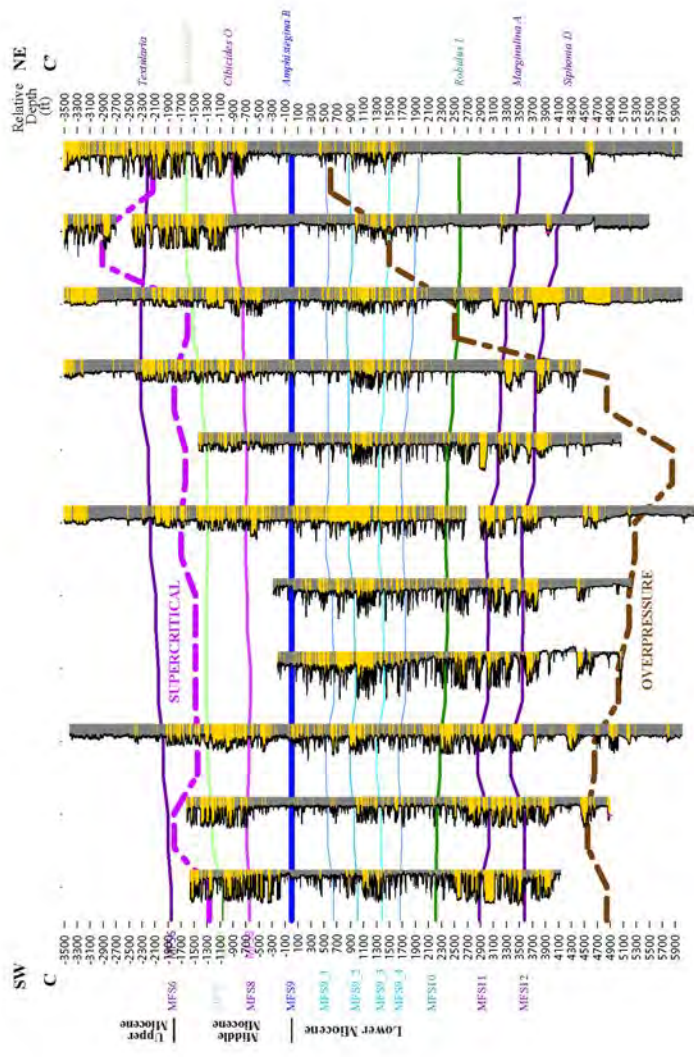
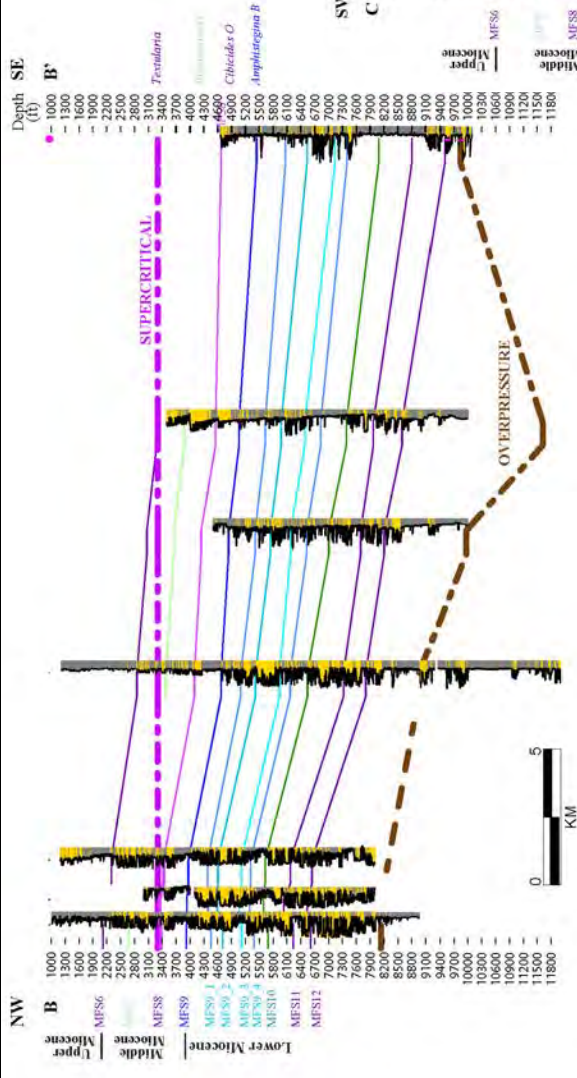


Status and Results

The interval for CO2 sequestration is the sandy section above the top of the overpressure between MFS 9 and MFS 10.



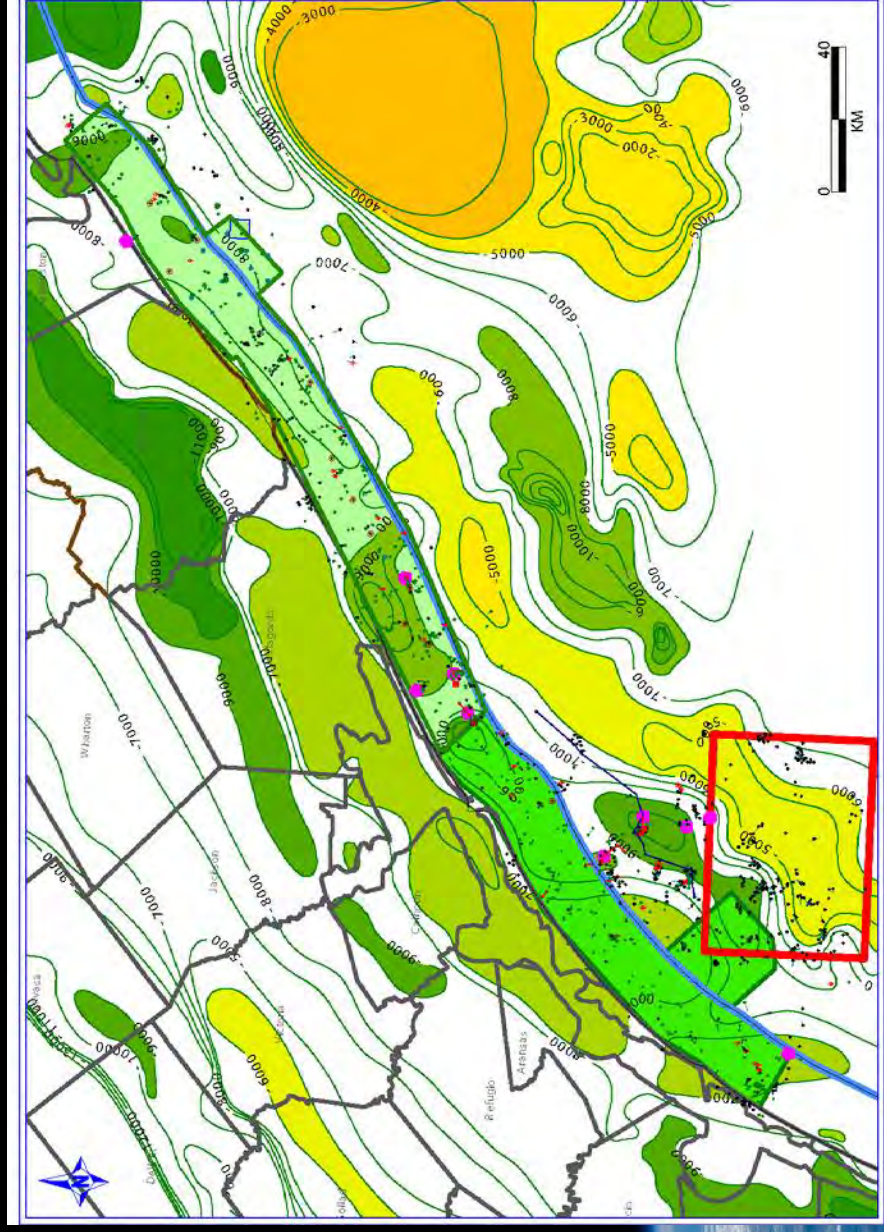
Status and Results



The interval for CO2 sequestration is the sandy section above the top of the overpressure between MFS 9 and MFS 10.



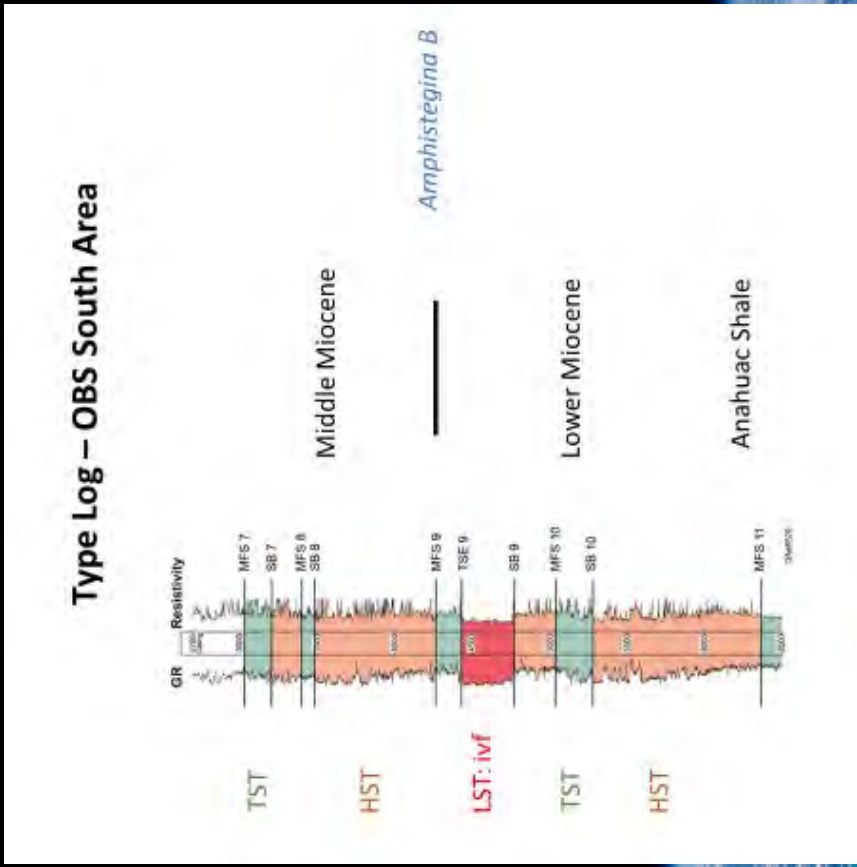
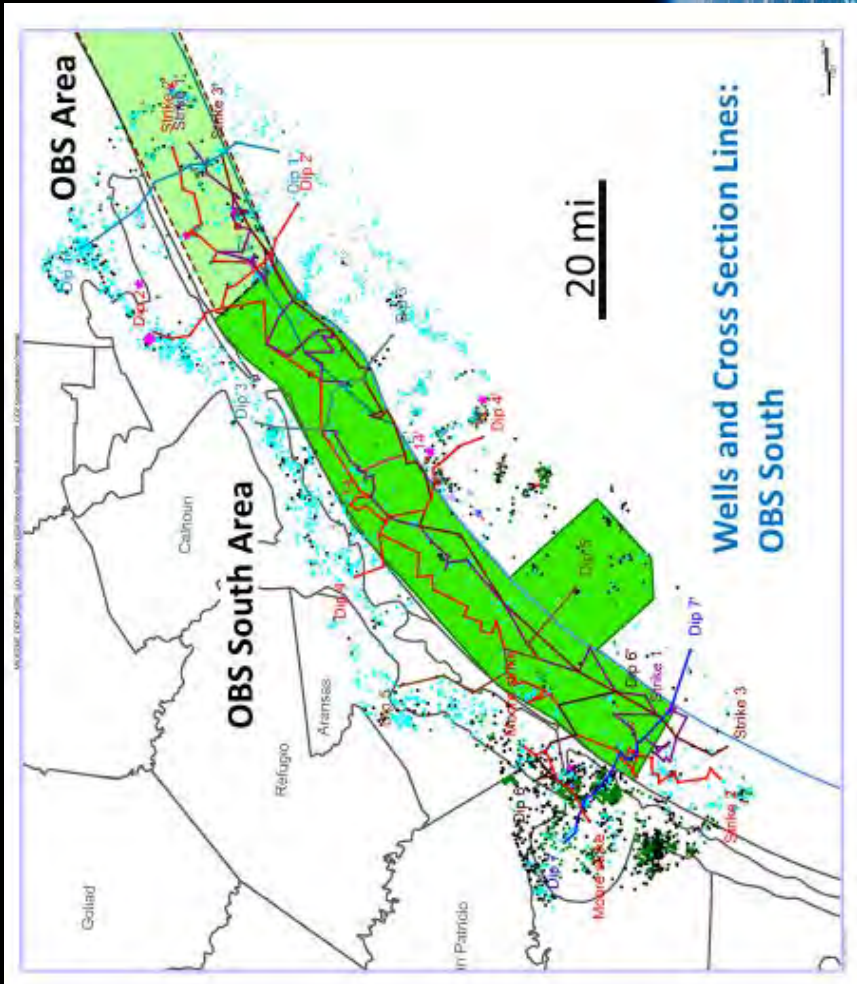
Status and Results



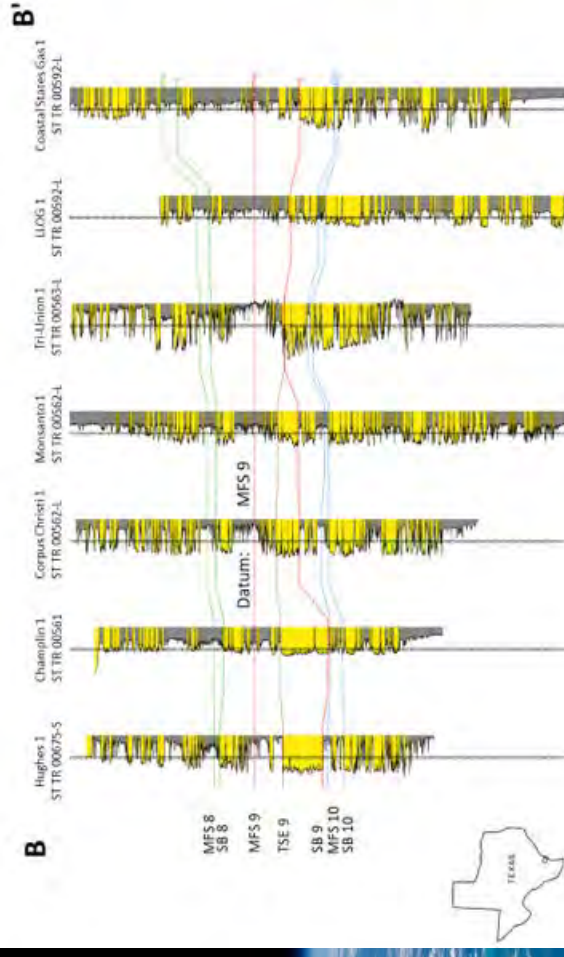
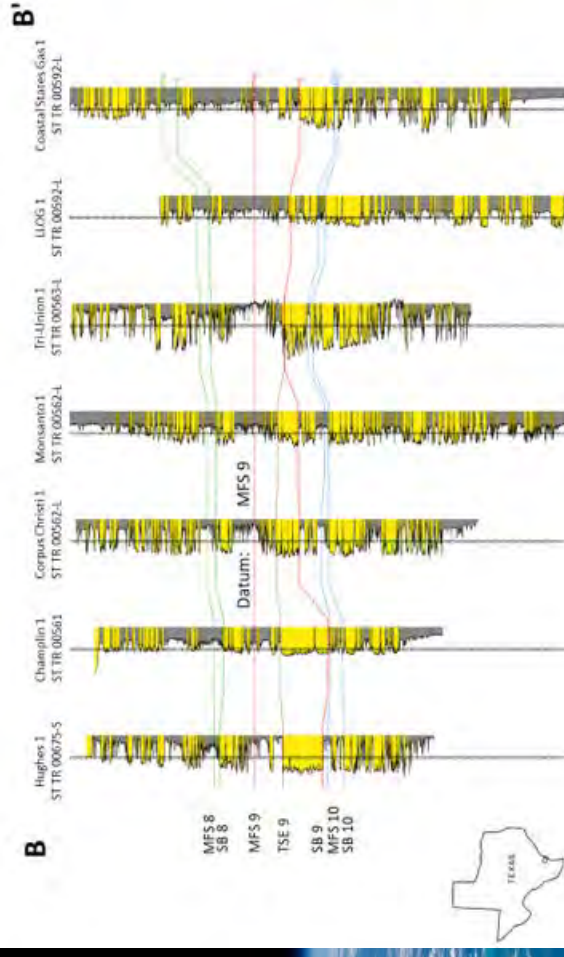
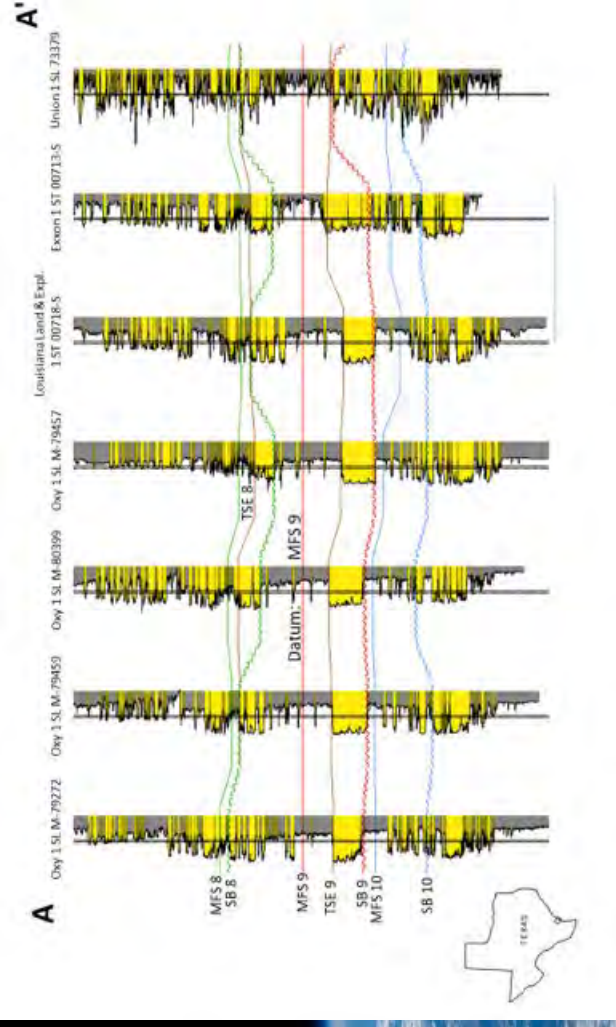
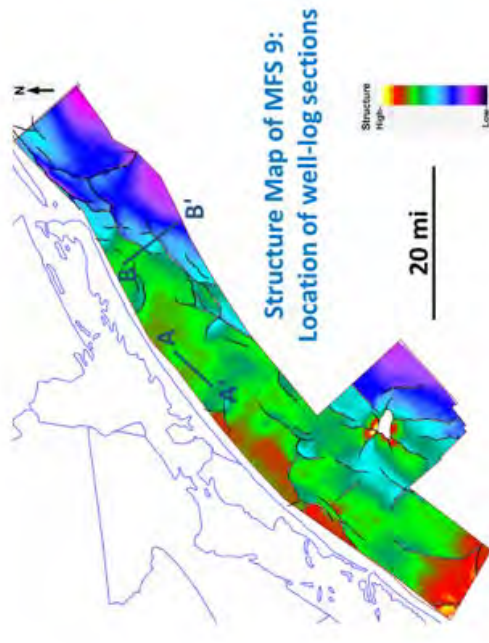
Top of the overpressure very shallow (4000-5000 ft) in the federal waters just south of the state waters offshore Matagorda and Corpus Christi Bay.

(from Pitman, 2011)

Status and Results

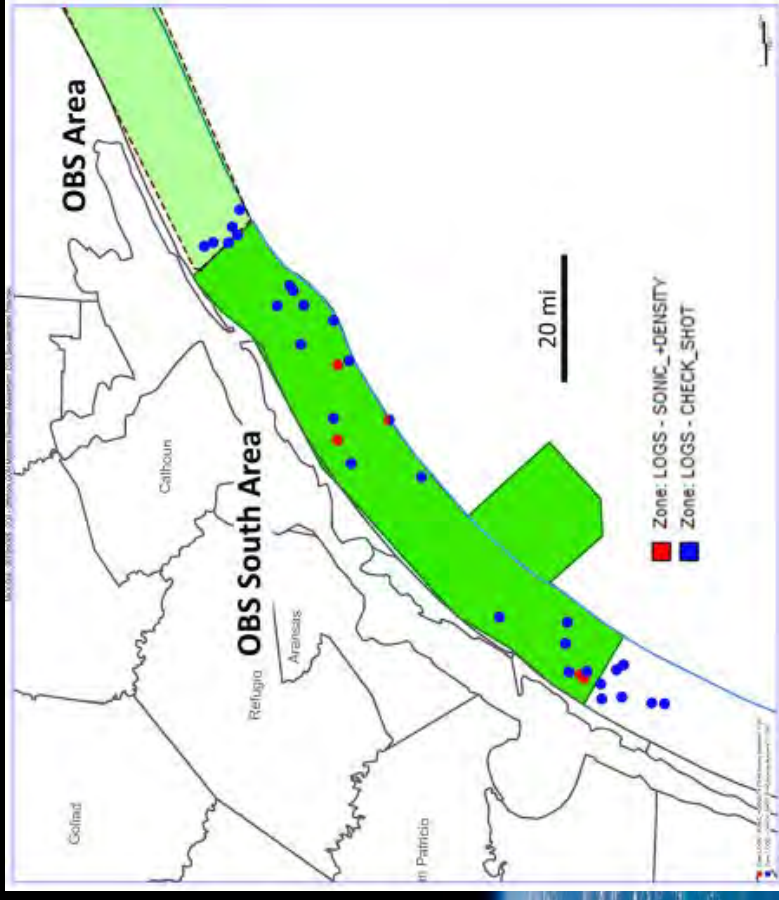
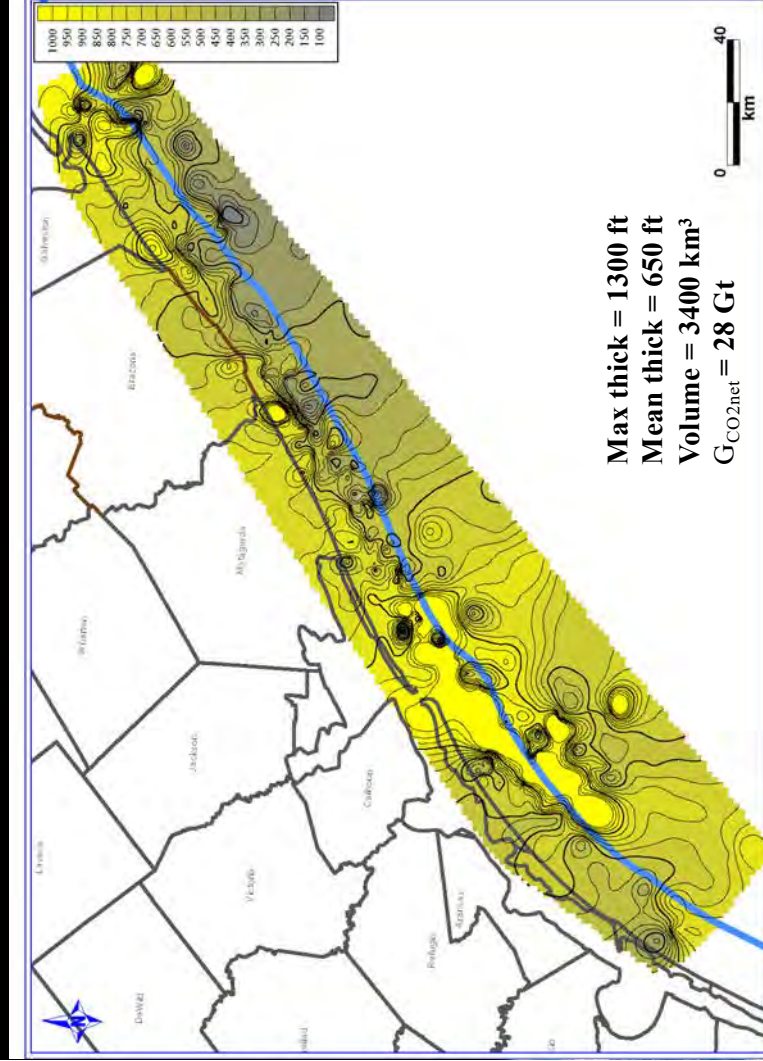


Status and Results

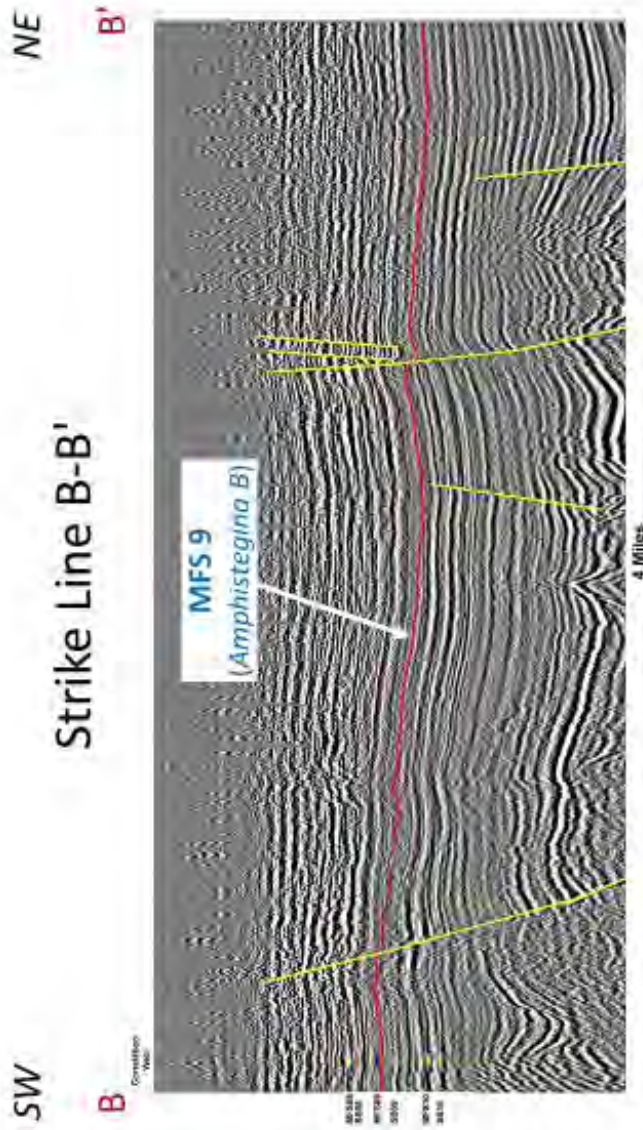
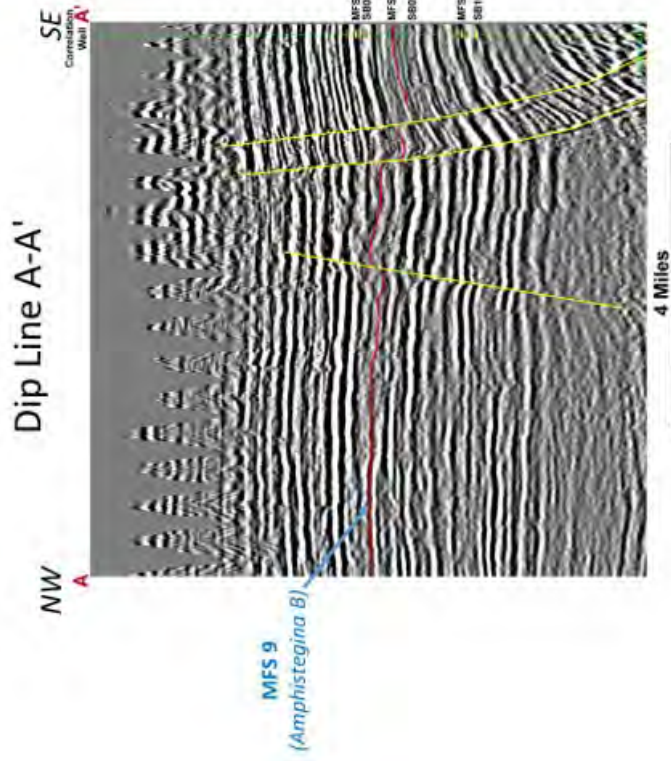
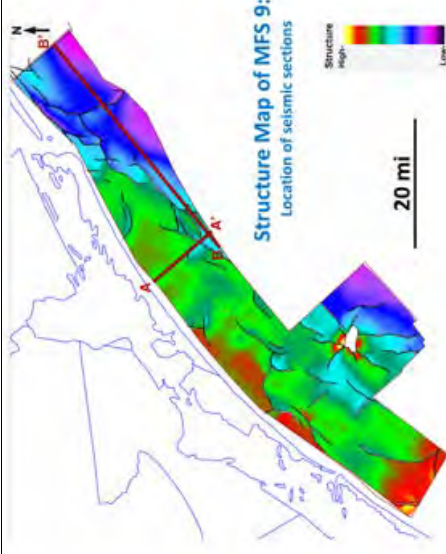


Next Steps

- Estimate static regional capacity - the distribution of storage capacity is influenced by the net sandstone thickness, total porosity and CO2 density
- Sandstone thickness map for the stratigraphic interval from *Amphistegina* B (MFS9) to *Robulus* L (MFS10)
- Integrate well log interpretation with seismic



Next Steps



Discussion via chat

Links to other tasks?

Suggestions/next steps?

Other resources?

Chandeleur Island CCS Potential

Update about offshore Louisiana

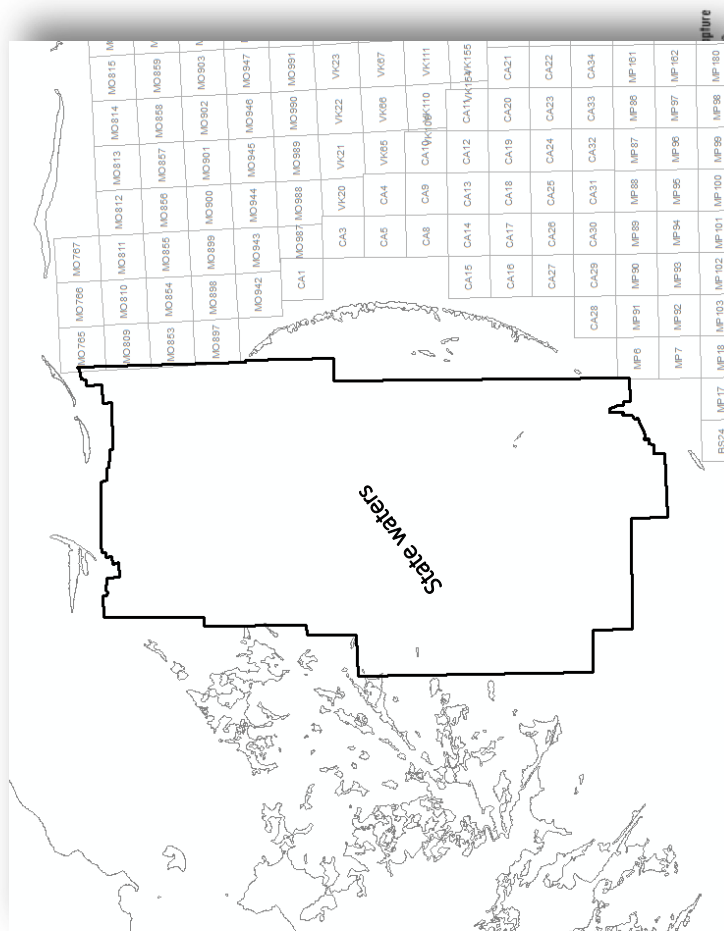
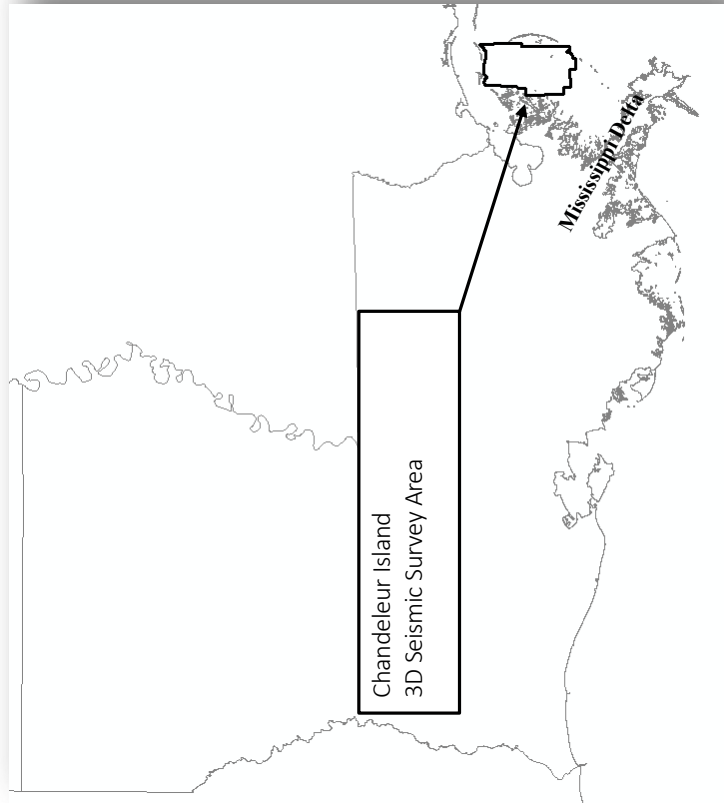


Marcie Purkey Phillips

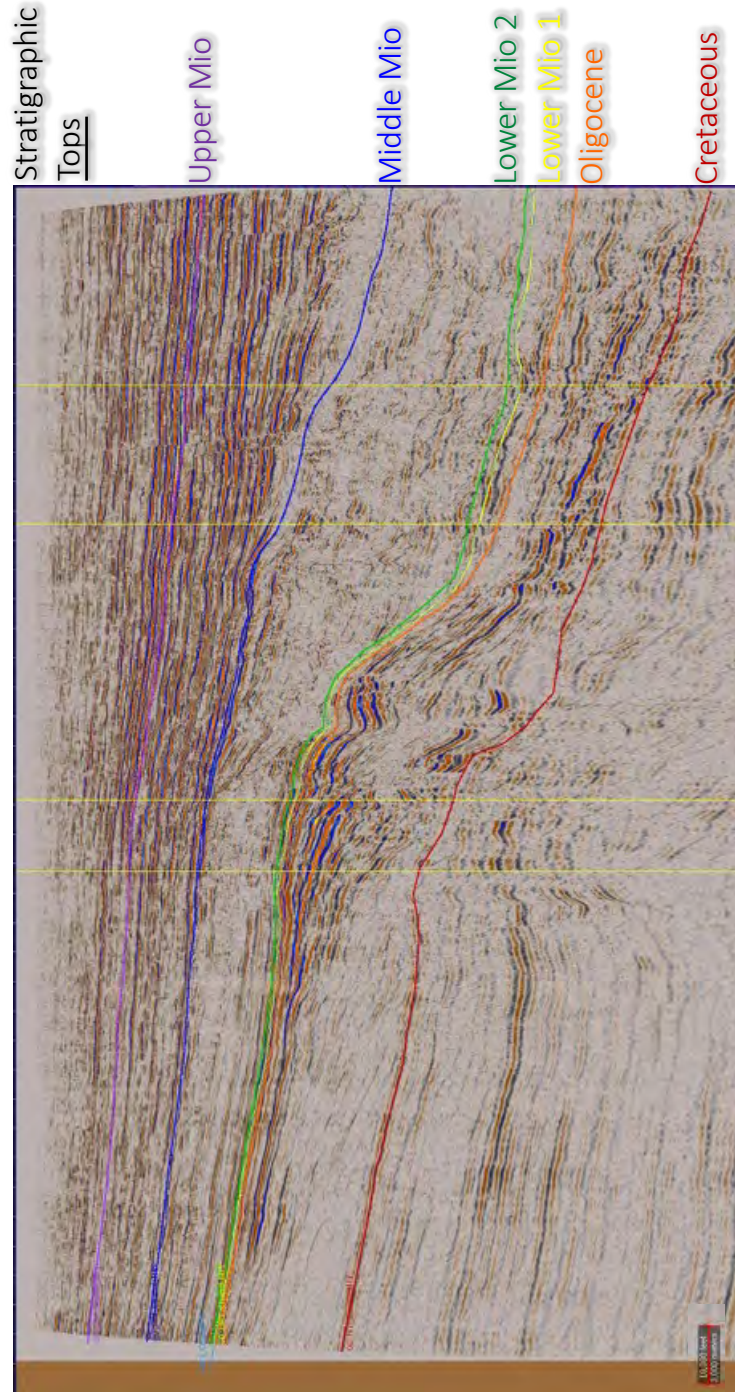
University of Texas at Austin Institute
for Geophysics

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Chandeleur Study Area

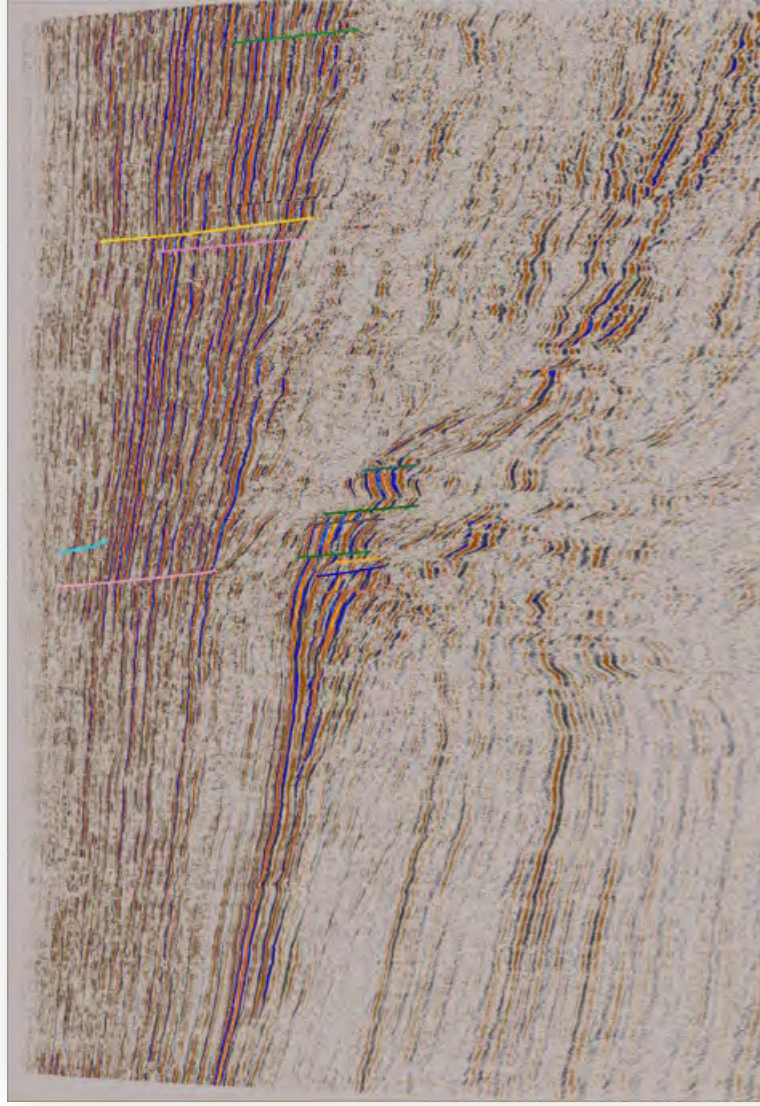


Stratigraphic Interpretation – 2nd Iteration

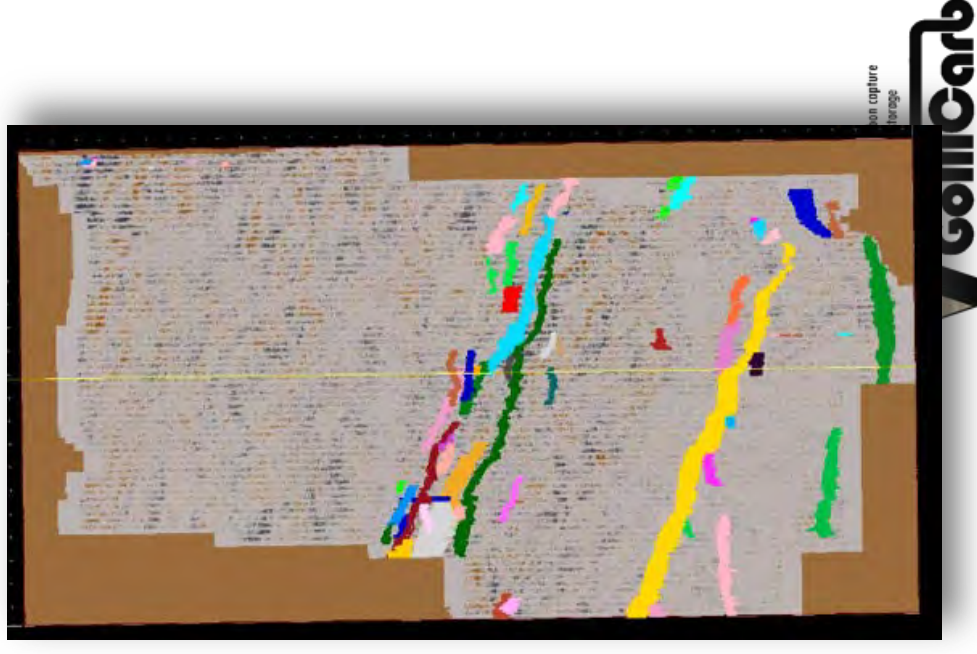


Seismic data owned or controlled by Seismic Exchange, Inc. (SEI). Interpretation is that of the University of Texas.

Fault Interpretation



Seismic data owned or controlled by Seismic Exchange, Inc. (SEI). Interpretation is that of the University of Texas.

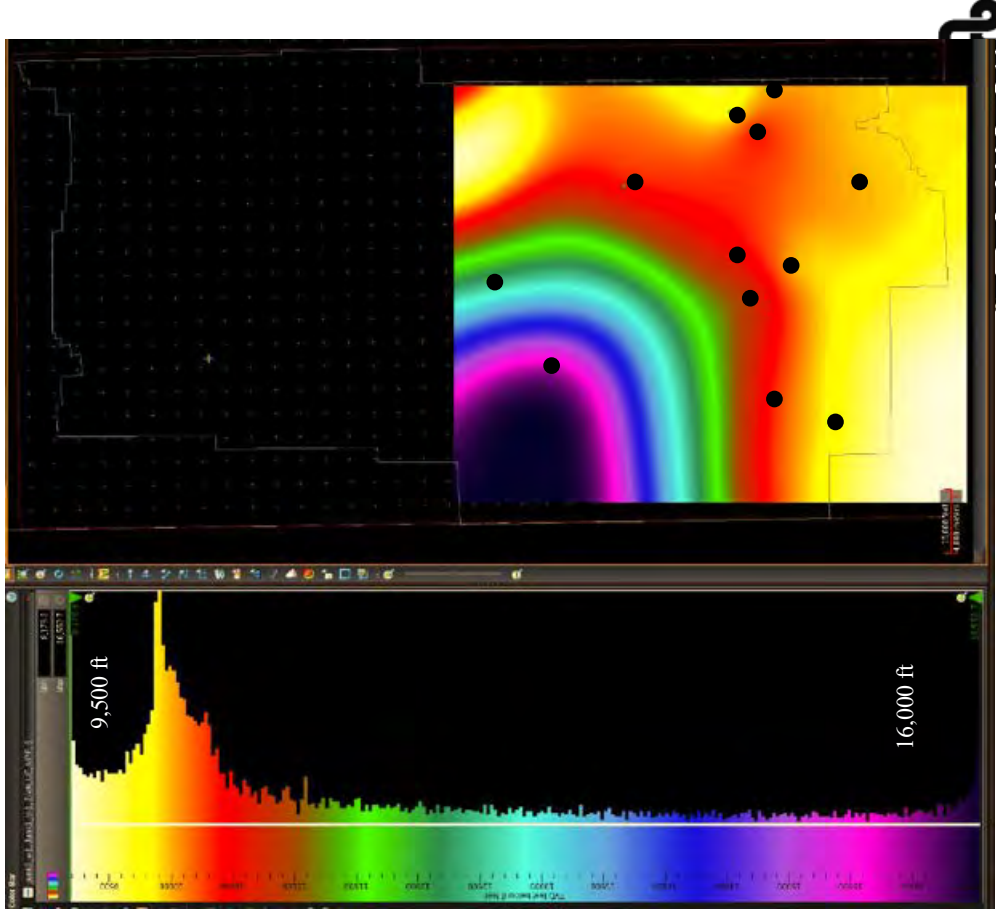


son capture
storage

GoMCarb

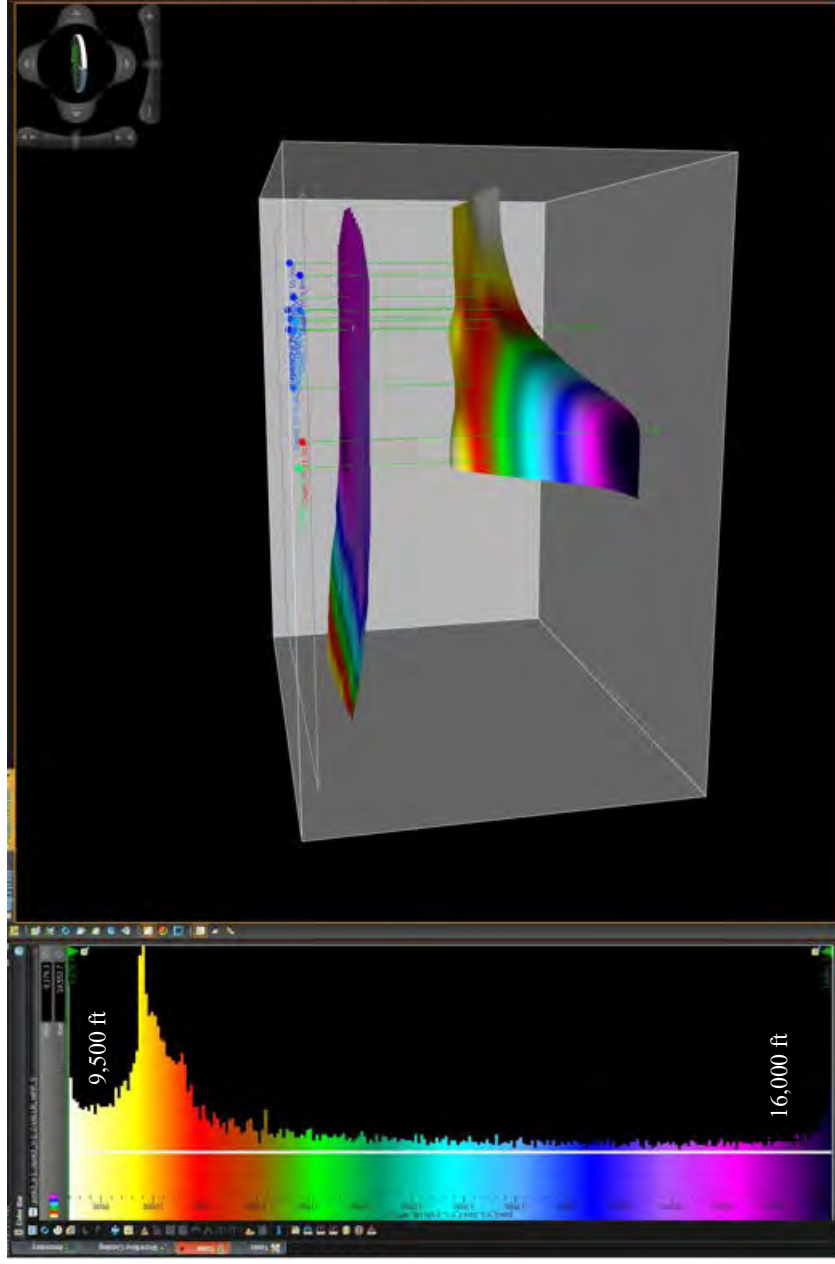
Pressure Gradient

- Top of overpressure = 0.70 psi/ft
 - $P = MW/c_2$ (Burke et al., 2012)
- 12 wells reached overpressure
 - 170 total wells
 - 122 w/logs



Seismic data owned or controlled by Seismic Exchange, Inc. (SEI). Interpretation is that of the University of Texas.

Pressure Gradient – Cube View



Supercritical cutoff
~1000' or top UM

Top of Overpressure

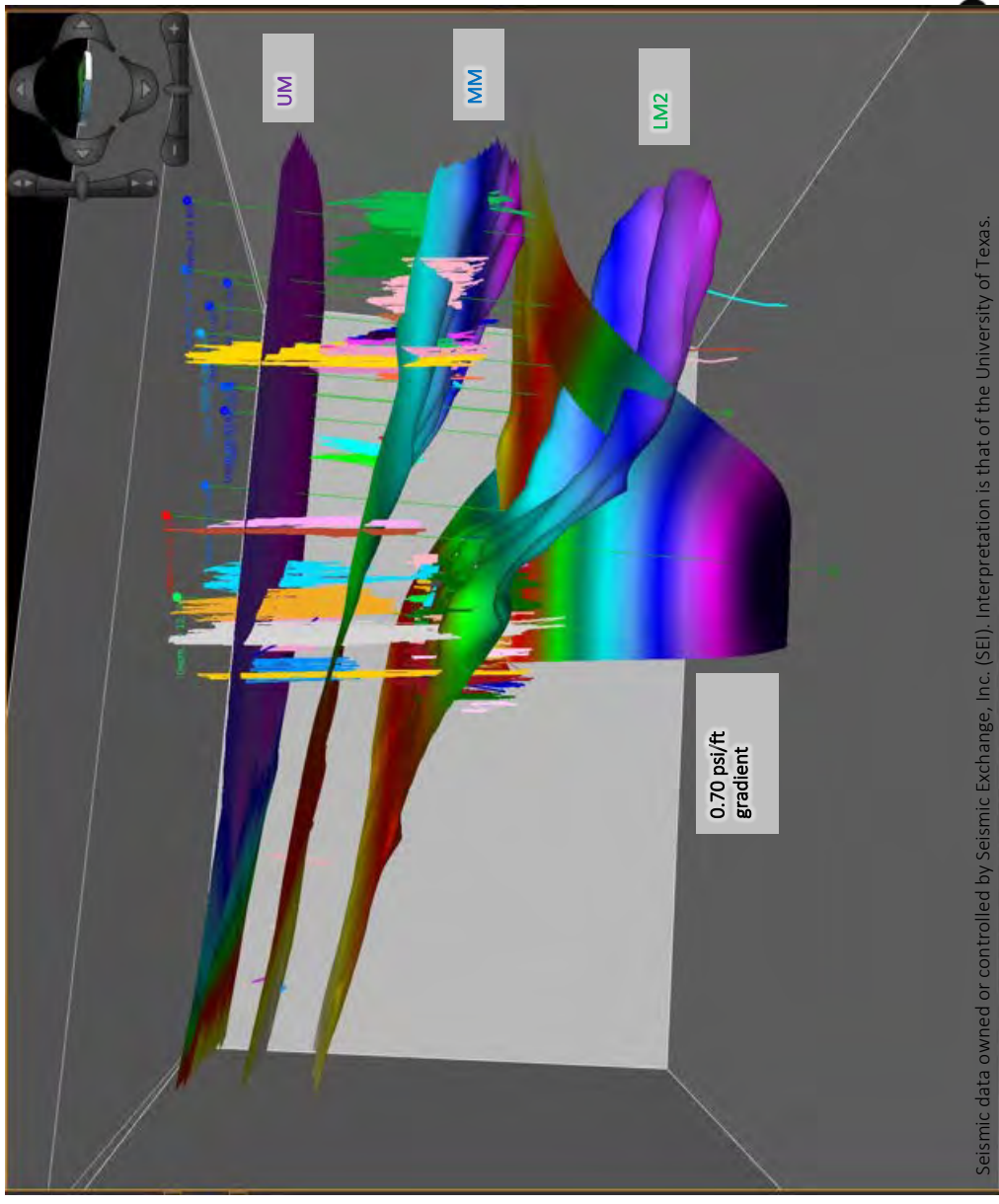


Seismic data owned or controlled by Seismic Exchange, Inc. (SEI). Interpretation is that of the University of Texas.

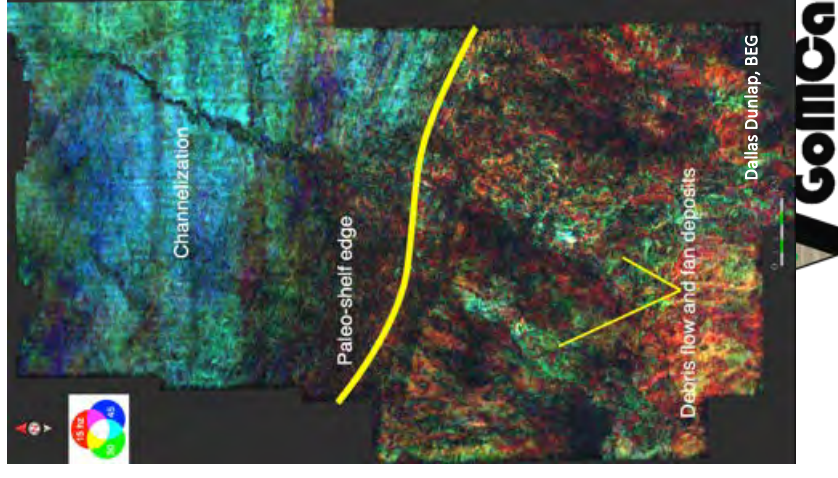
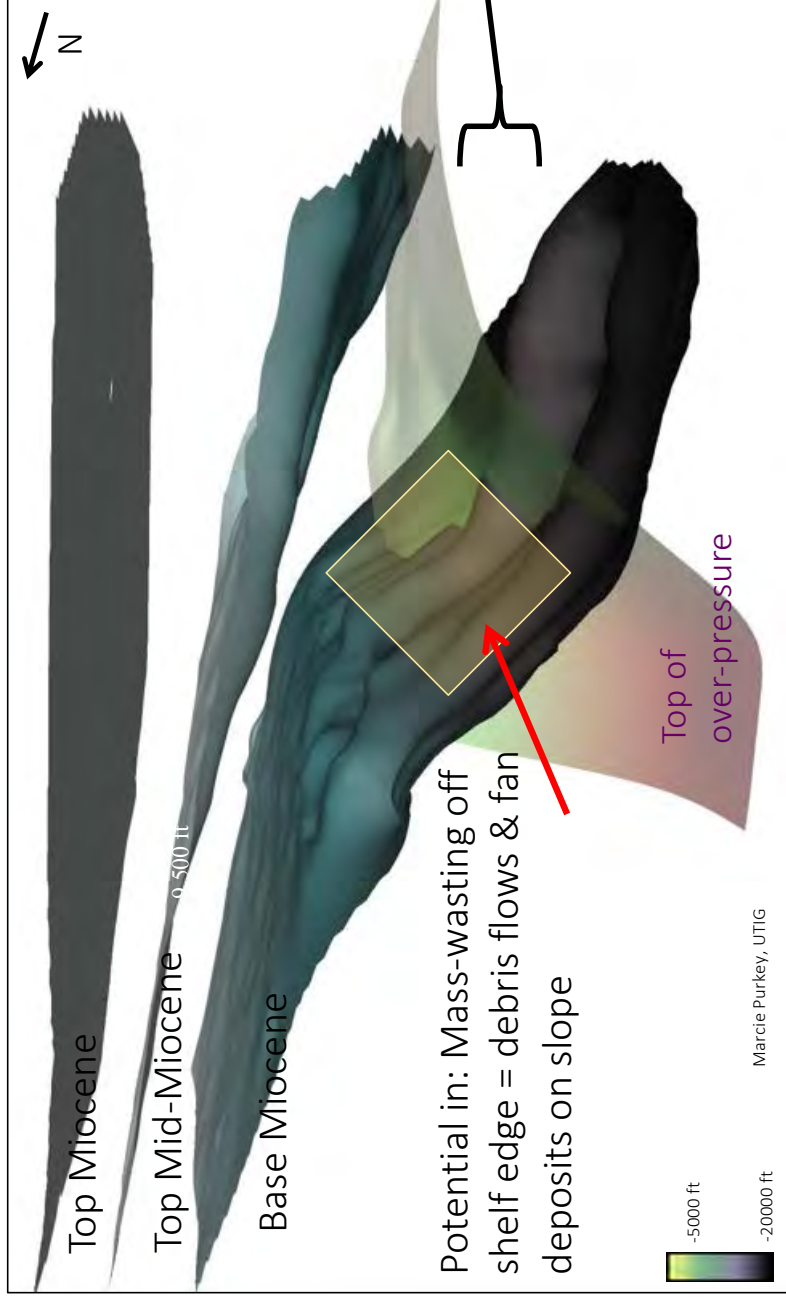
Cube View – Chandeleur Stratigraphy

- Miocene tops
- Pressure Gradient
- Faults

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Storage Potential



Seismic data owned or controlled by Seismic Exchange, Inc. (SEI). Interpretation is that of the University of Texas.

Ongoing Work

- ✧ Estimate storage potential of debris-flow deposits in Chandeleur
- ✧ Identify shales and determine seal efficacy
- ✧ Determine which faults, if any, would be sufficient seals



Discussion

Task 2

Buoyant CO₂ Storage

Assessment: Methodology and Estimating Input Distributions

Sean T. Brennan

**U.S. Geological Survey, Eastern Energy Resources
Science Center**



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Problem

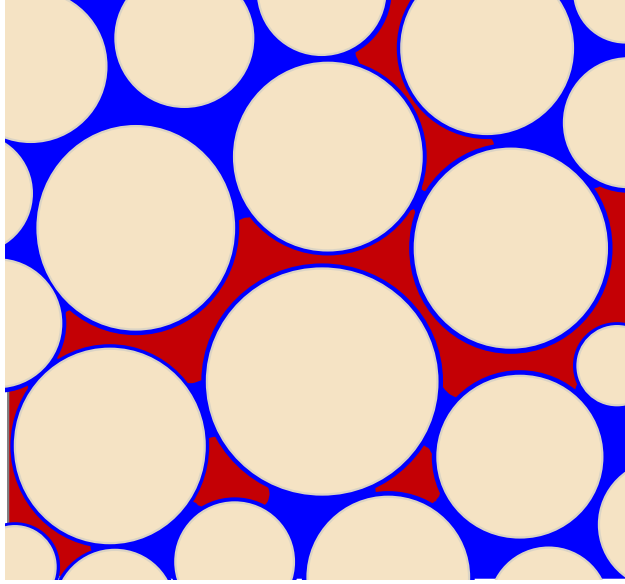
- The goal is to assess the buoyant CO₂ storage resource for the western portion of the Gulf of Mexico.
- The plan is to use a modified version of the U.S. Geological Survey CO₂ storage resource assessment methodology.
- The method was first applied to the lower Miocene strata as test using real data and some gross estimates.
- Realize that the buoyant storage resources is a small relative to the residual storage resource.
 - Pore volume within traps are orders of magnitude less than pore volume of saline formations
 - However more CO₂ will be stored in a smaller region relative to residual storage in saline formations



Buoyant Storage

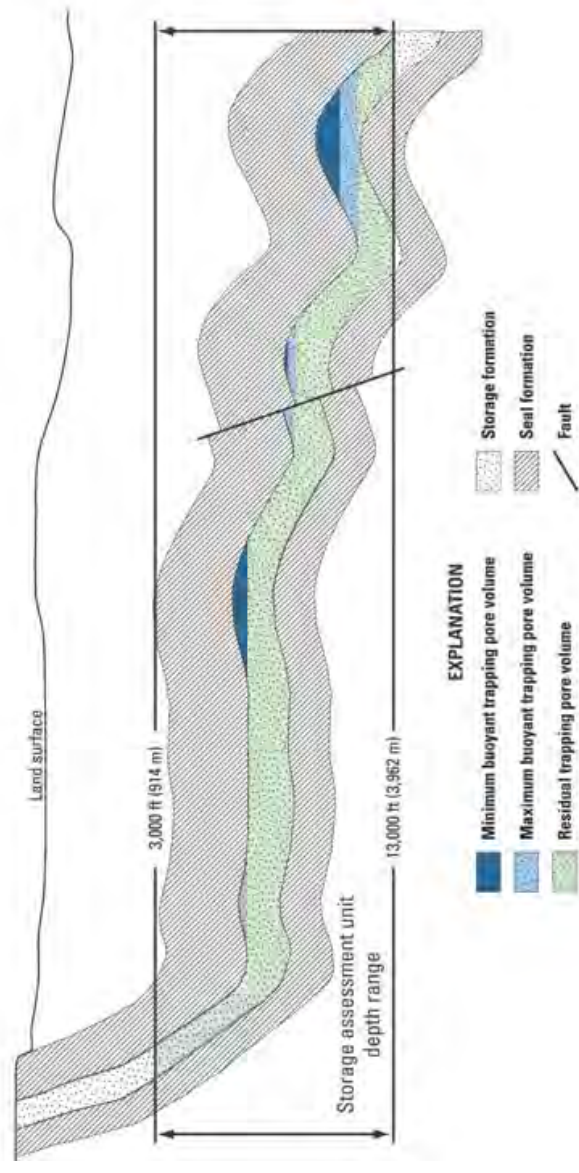
Buoyant Trapping

CO₂ fills pore space, held in place by top and lateral seals



Beige = sand grains, Blue = water, Red = CO₂

Schematic Storage Formation Model
Storage Assessment Unit, Cross Section



Approach

- The USGS buoyant CO₂ storage assessment methodology, like all USGS assessments, is fully probabilistic.
- This means that we use ranges for all inputs, and use those ranges to create probability distributions.
- These distributions are then sampled using a Monte Carlo simulator that chooses values from those distributions for inputs into the storage equation.

The equation that is used here is basic:

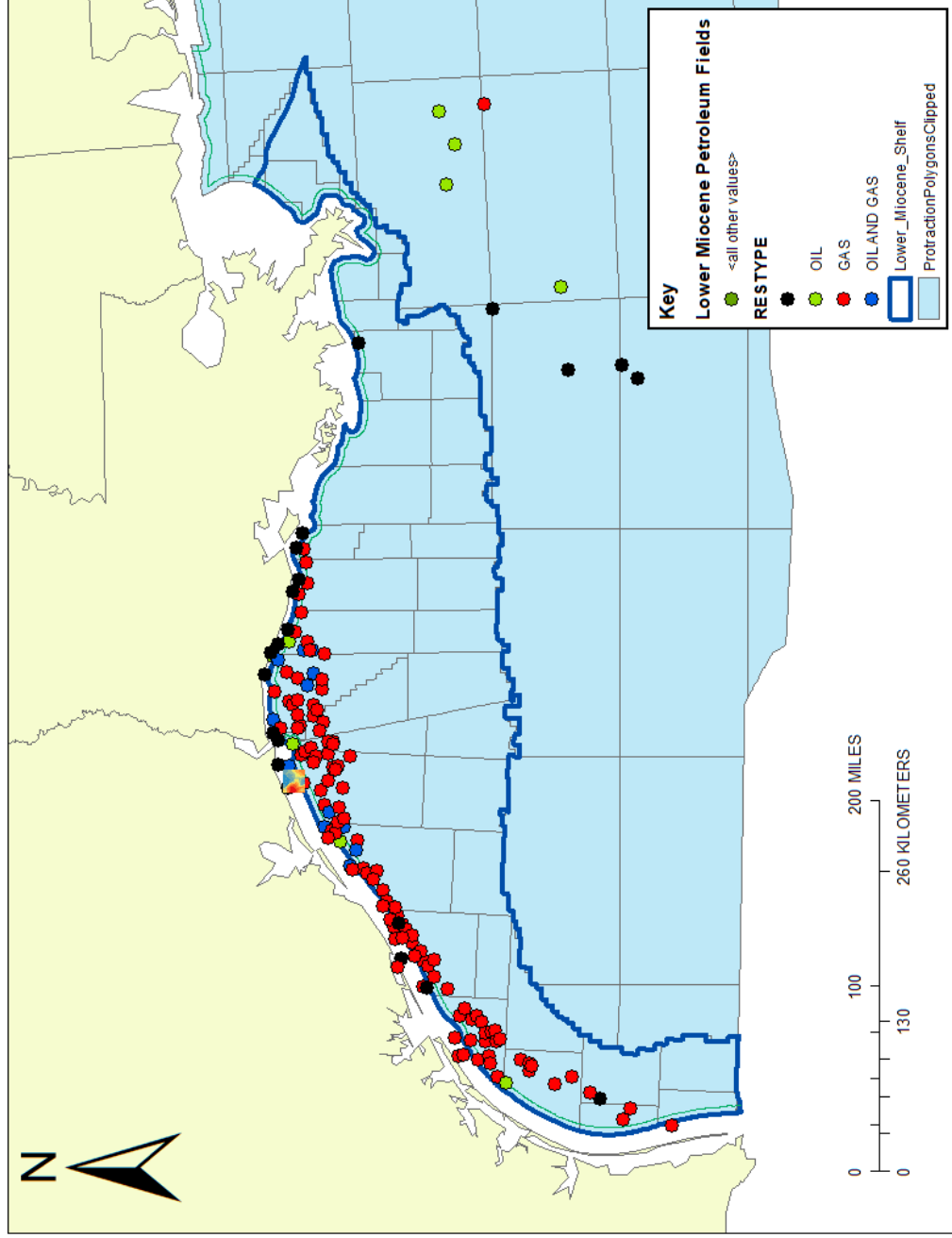
$$\text{Buoyant CO}_2 \text{ storage} = \text{pore volume} \times \text{storage efficiency} \times \text{CO}_2 \text{ density}$$

- To get to these values we use data from existing petroleum production fields, structural maps, well logs, seismic, or any other available data.



Estimation of input values

The initial stage of estimating the buoyant storage is to use data from petroleum fields from the same strata in the assessment area.



Estimation of input values

Buoyant pore volumes are estimated using known petroleum production values, estimates of undiscovered petroleum, and estimates of maximum possible pore volumes.

Production volumes are given at surficial conditions typically, so they need to be transformed into subsurface or in situ volumes.

Titles		Calcs
Input		Outputs

Volumetric worksheet

1) Oil KR	MBBLS	Min	83,600	Most likely	Max	
2) Gas KR	MMcf		13,700,000			
3) NGL KR	MBBLS		320,000			
4) Oil FVF	Units	Min	1.05	Most likely	Max	@Risk F(x)
5) Gas FVF	Dec. Frac		0.0037	1.4	1.9	1.41661922
6) NGL FVF	Dec. Frac		1.5	0.0047	0.009	0.006669978
				2.5	5	3.43088099
Oil - In Situ Volume (ft ³)		Min	664388745.6	Most likely	Max	
Gas - In Situ Vol (ft ³)			91786980680	1748391436	7947233799	
NGL - In Situ Vol (ft ³)			6159117550	1.33996E+11	1.1725E+12	
Total In Situ Volume			98610486976	9238676325	2.1172E+10	
				1.44983E+11	1.2016E+12	



Estimation of input values

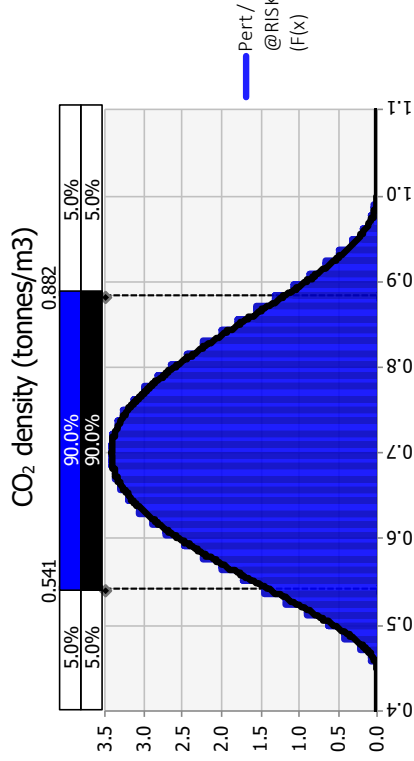
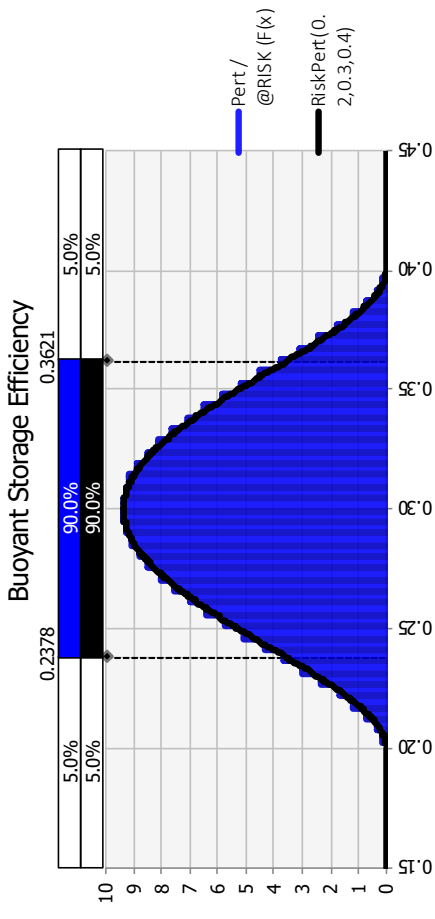
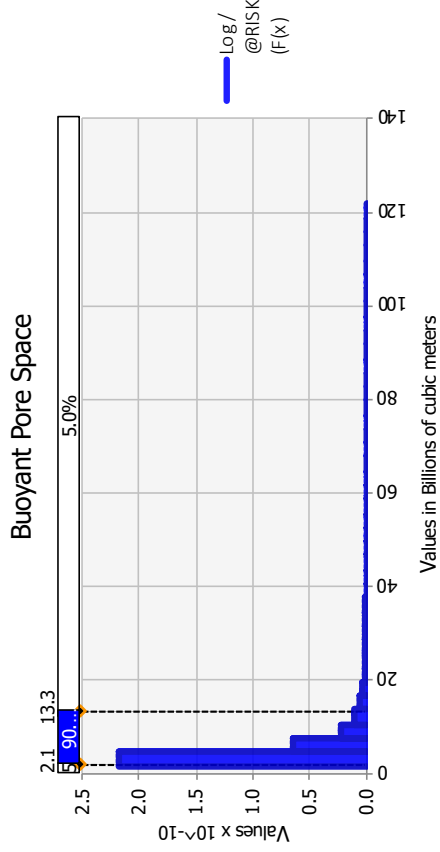
Once the buoyant volumes are transformed into subsurface volumes, they can be used to create the distributions that go into the Monte Carlo model to estimate buoyant CO₂ storage resource.

Titles		Calcs	
Input		Outputs	
Min		Most likely	
		Max	
		μ	σ
		mean	sd
		@RISK (F(x)	
Buoyant Pore Volume	2,710,124,641	3,987,976,112	33,031,019,188
Storage Efficiency	20%	30%	40%
	0.450	0.700	1.000
CO2 Density			

	21	1	1,277,833,448	2,945,019,542	5,795,173,450 m3
storage efficiency					0.300 (fraction)
					0.658 tonne/m3



Input value distributions



Status and Results

- Currently I only have known petroleum production and undiscovered volumes to work with
- I will be getting more data on maximum possible buoyant pore volumes, which will help define the entire distribution
- If we decide to use a method that attempts to capture the total thickness of porous strata within traps I realized that I will need more data to estimate the most likely value for that buoyant pore volume. Using data from master's theses on the High Island 10-L and 24-L blocks, as well as structural maps of the entire assessment area, should help estimating these pore volumes.



Add status and results here

Using the known produced and undiscovered petroleum in the assessment area, and an estimate of the maximum buoyant pore volumes the buoyant CO₂ storage resource for the lower Miocene in this assessment area in Gt is:

Mean	P95	P50	P5
1.11	0.39	0.77	2.89

If the most likely value of natural gas is increased from 20 TCF to 50 TCF, while keeping all the other inputs the same, the buoyant storage resource values would be:

Mean	P95	P50	P5
1.24	0.46	1.04	2.69



Next Steps

- A more accurate accounting of most likely buoyant pore volume and estimates for maximum buoyant storage are needed to complete the assessment
- Once the lower Miocene is assessed, we need to move on to the other stratigraphic intervals and complete those assessments



Discussion via chat

Links to other tasks?

Suggestions/next steps?

Other resources?



**Energy
Geosciences**
EARTH & ENVIRONMENTAL SCIENCES AREA



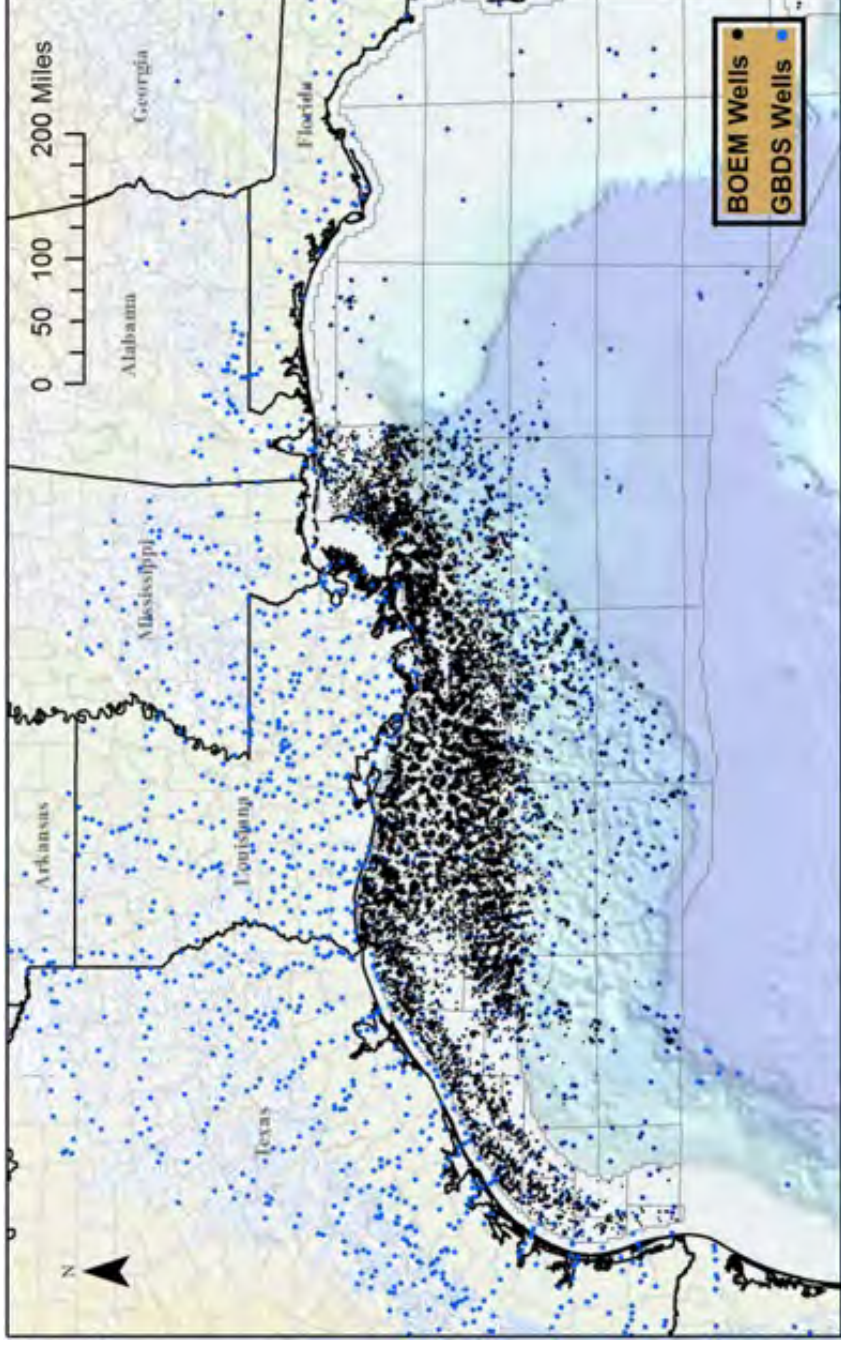
Mechanistic modeling of CO₂ leakage into the water column from off-shore CO₂ wells or pipelines

Curtis M. Oldenburg

Presented @ SECARB-GoMCarb Virtual Meeting March 26, 2020

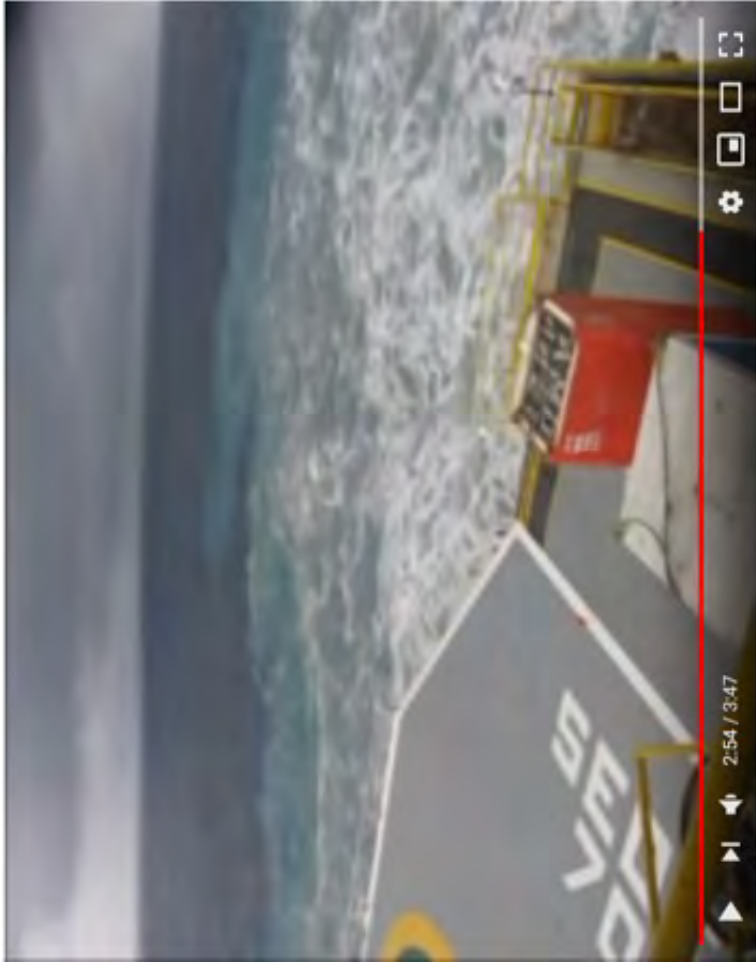


Numerous wells in near-offshore region bring hazard of leakage through wells



Main Questions Being Addressed for CO₂ wells:

- Under what blowout conditions will leaking CO₂ make it to the sea surface (not dissolve in the water column)?
 - Water depth, leakage rate, orifice, ...
- What are the possible blowout flow rates for given reservoir-well conditions?
 - Orifice size, reservoir depth, water content, composition, ...
- If CO₂ is emitted into the atmosphere, what are expected downwind safety distances?
 - CO₂ emission rate, wind, ...



Sedco 700 Shallow Gas Blow Out 6 June 2009 11 35am

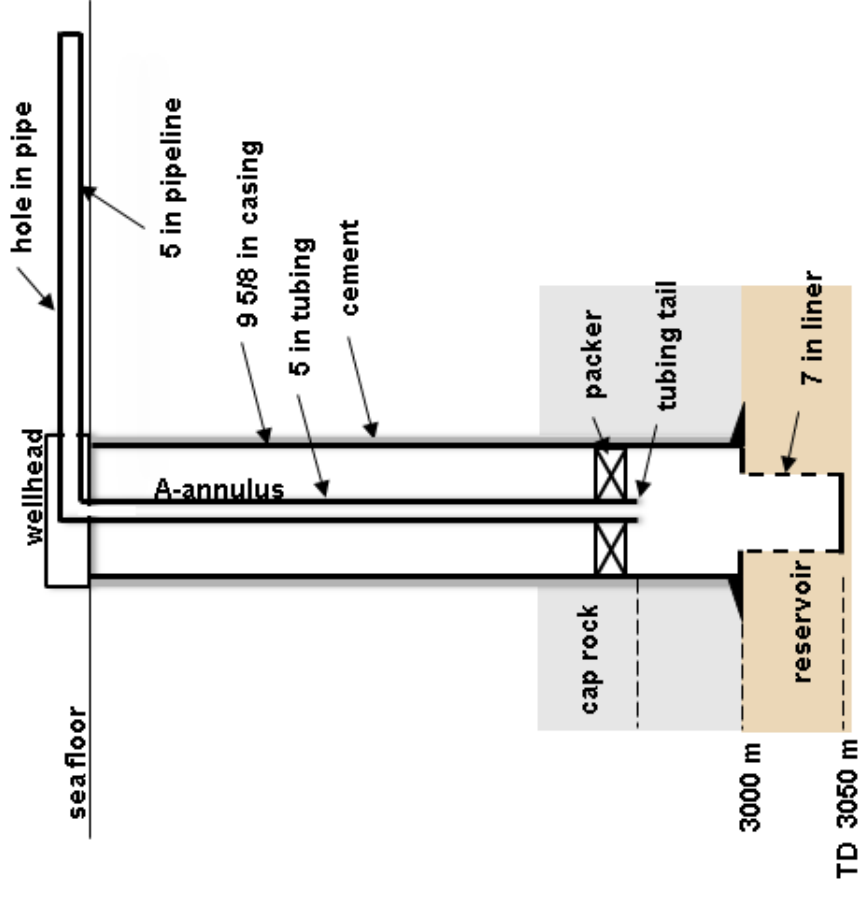
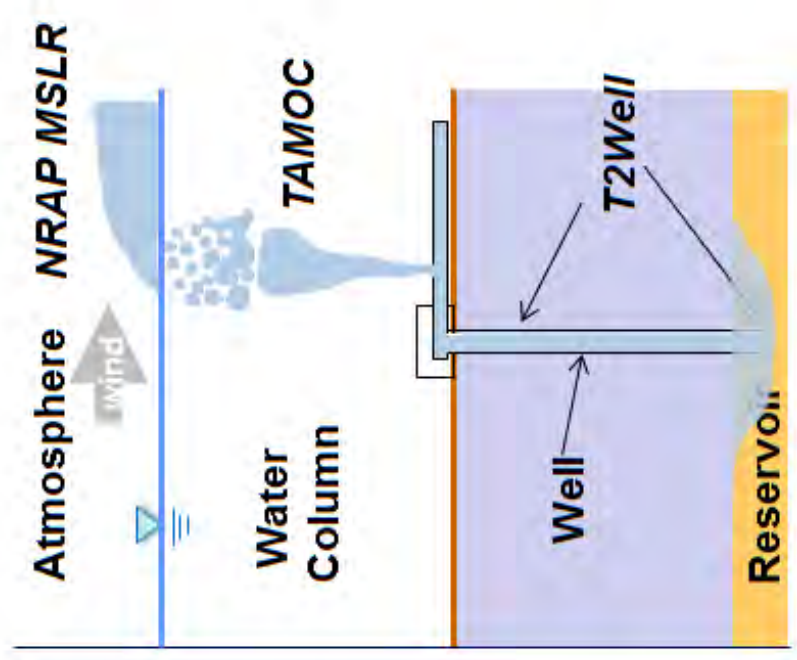
Nigeria

<https://www.youtube.com/watch?v=NJiBS64RVVQ>



EARTH AND ENVIRONMENTAL SCIENCES • LAWRENCE BERKELEY NATIONAL LABORATORY

Approach: Simulate offshore CO₂ blowout using T2Well and pass output to TAMOC



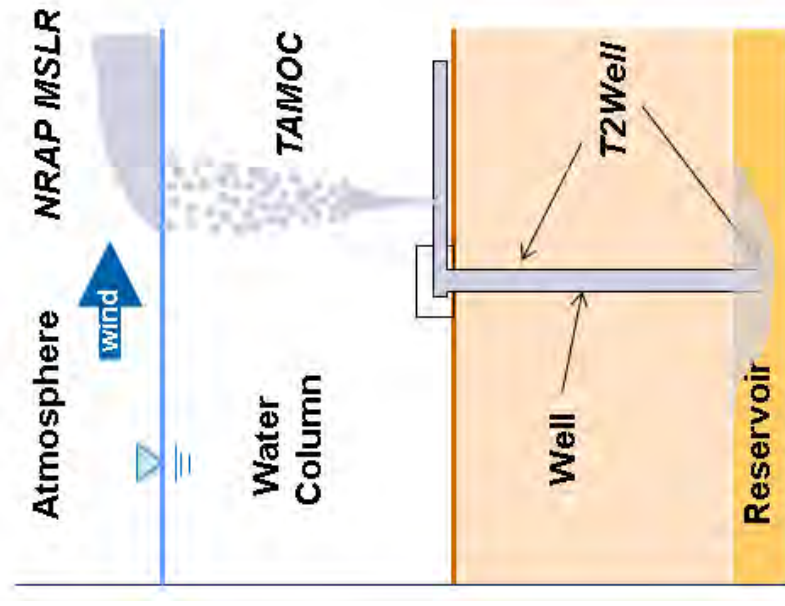
Offshore CO₂ well blowouts are strongly controlled by transport processes in the water column

Relative to ambient air, the water column provides

- More resistance to flow
- Positive buoyancy for CO₂
- Vast source of heat to counter cooling caused by decompression
- Vast sink for CO₂ dissolution

Loosely couple two existing models to understand consequences of sub-sea CO₂ leaks and blowouts

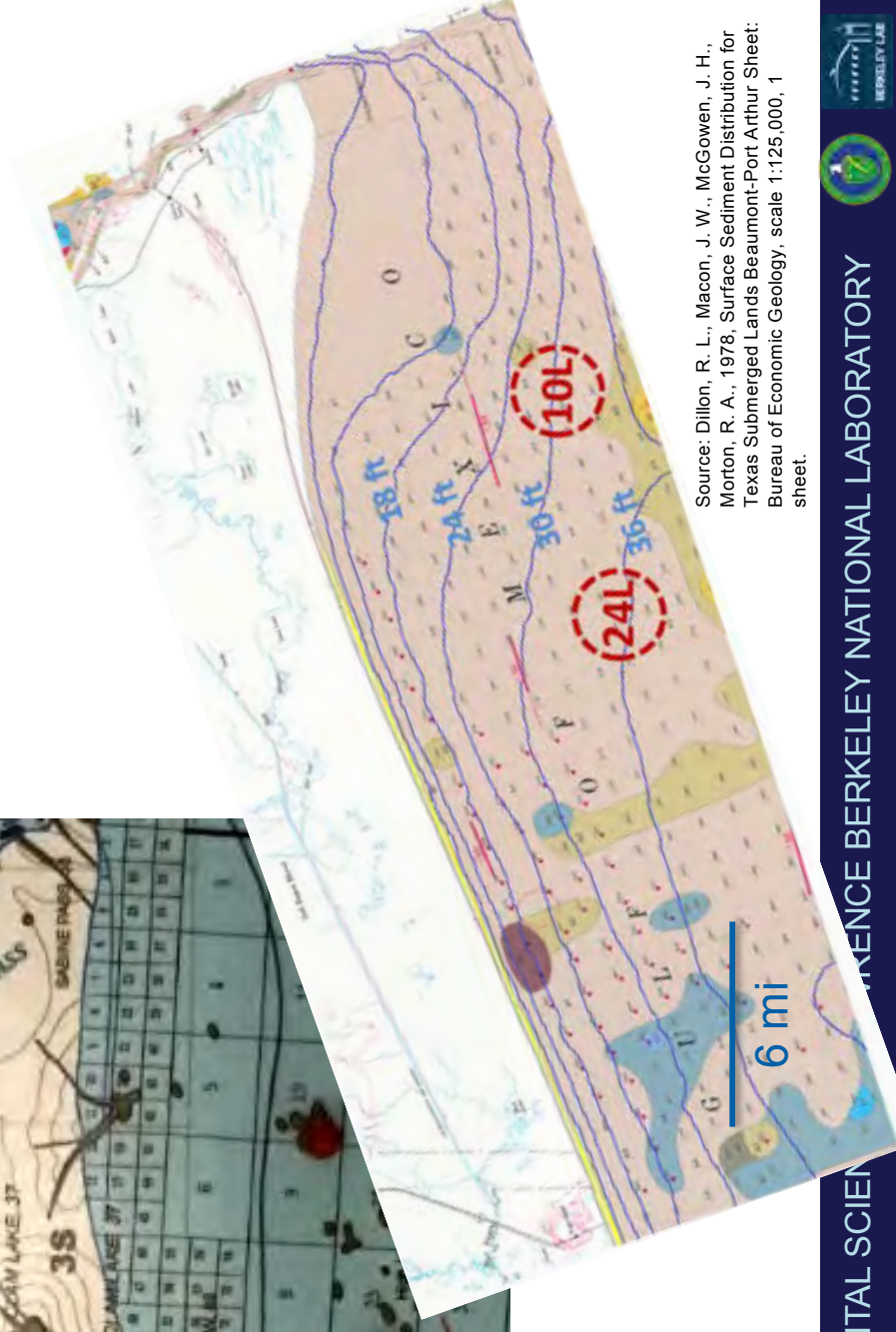
- Reservoir-well flow (T2Well)
- Jet and buoyant plume flow in the water column (TAMOC)



GoMCarb focus is on the High Island 10L and 24L blocks where the water depth is approximately 30-40 ft



Source: Gulf Coast Geomap Company, 2009, Extended Area Reference Map 380: Geomap Company.



Source: Dillon, R. L., Macon, J. W., McGowen, J. H., Morton, R. A., 1978, Surface Sediment Distribution for Texas Submerged Lands Beaumont-Port Arthur Sheet: Bureau of Economic Geology, scale 1:125,000, 1 sheet.

Approach to simulating CO₂ rise in the water column: TAMOC (integral model for gas jets and bubble plumes by Scott Socolofsky, Texas A&M)

TAMOC models complex physical processes using an integral approach:

- Jet flow of gas into water column
- Transition from jet flow to bubbly flow
- Top-hat velocity profiles with fluid entrainment
- **Buoyant bubble rise w/ dynamics based on bubble-size distribution**
- Equations of state for multiple gases and gas mixtures
- Crossflow of seawater
- Stratification of seawater
- Salinity, pressure, temperature effects on density and solubility

<https://www.marine.usf.edu/c-image/component/k2/texas-a-m-oilspill-calculator-tamoc-modeling-suite-for-subsea-spills>

Dissanayake, A. L., Gros, J., and Socolofsky, S. A. (2018). "Integral models for bubble, droplet, and multiphase plume dynamics in stratification and crossflow." Environ Fluid Mech, 18(5), 1167-1202.

The Rosin-Rammler distribution is used to describe the bubble-size distribution

Workflow to calculate bubble distribution:

Use discharge rate q (kg/s), density, and aperture to calculate U_a

$$U_a = u_g \sqrt{\frac{\rho_g}{\rho_a}}$$

Calculate M , B , l_M , to find We_m

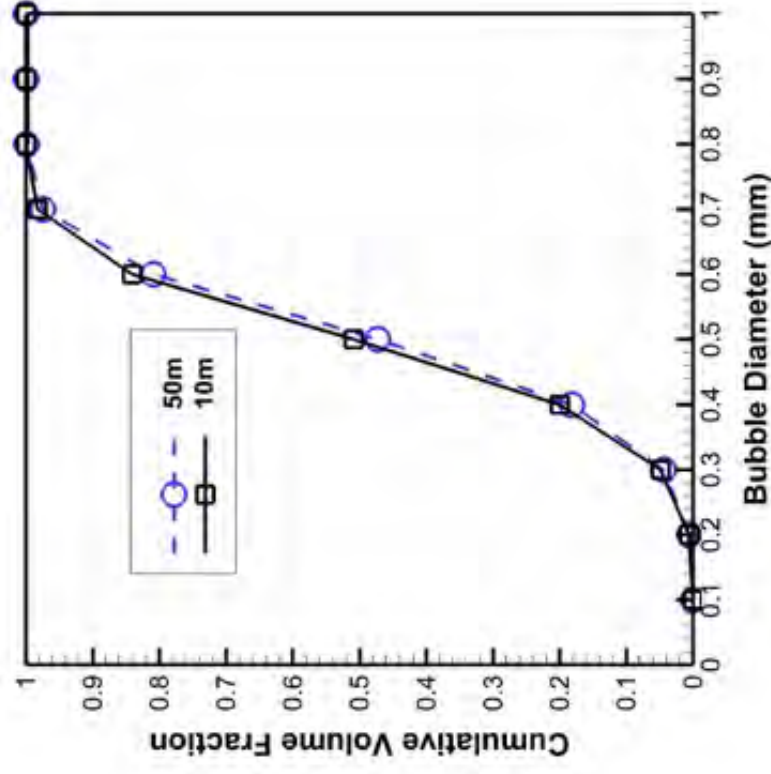
$$M = \frac{m_0}{\rho_a} \quad B = \frac{b_0}{\rho_a} \quad l_M = \frac{M^{3/4}}{B^{1/2}} \quad We_m = \frac{U_a^2 l_M \rho_m}{\sigma}$$

Calculate d_{50}

$$d_{50} = l_M 4.3 We_m^{-3/5}$$

Calculate $V(d)$

$$V(d) = 1 - \exp \left[-k_{50} \left(\frac{d}{d_{50}} \right)^\alpha \right]$$



The well blowout is simulated using T2Well for the coupled reservoir-well flow

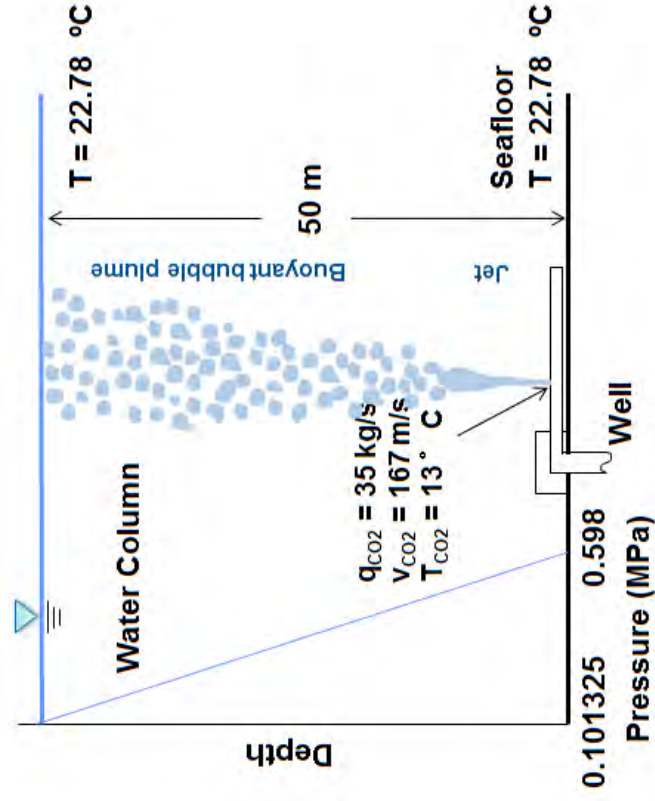
- T2Well models three-phase flow in the reservoir and in the well for this problem
- Three-phase Darcy's law for flow in the reservoir
 - Drift-flux model for flow in the well pipe
 - Friction in the well is a function of roughness and flow rate (Re)
 - Continuous range of flow regimes depending on phase saturations and Re
 - Equation of state for CO₂-brine mixtures was used here
 - Salinity, pressure, temperature effects on density and solubility

<https://tough.lbl.gov/licensing-download/tough-related-codes-licensing-download/>

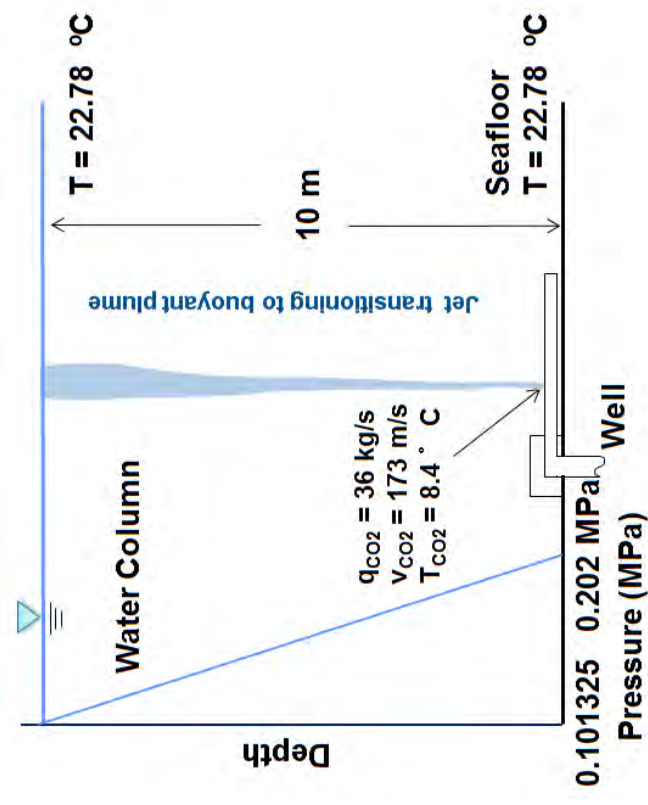
Pan, L. and Oldenburg, C.M., 2014. T2Well—an integrated wellbore–reservoir simulator. Computers & Geosciences, 65, pp.46-55.

To understand effects of water column (depth), we simulated a CO₂ blowout for two cases

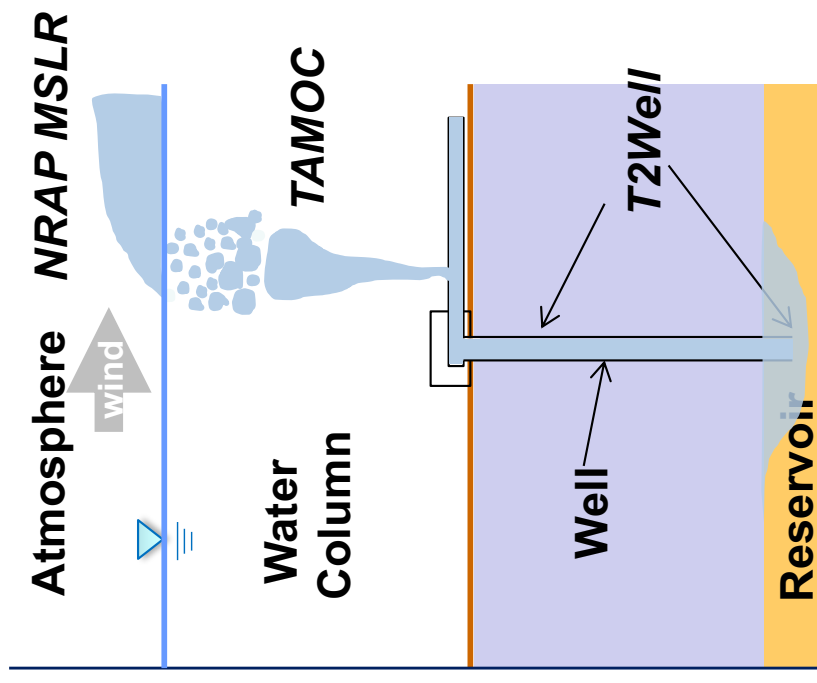
Case I (50 m)



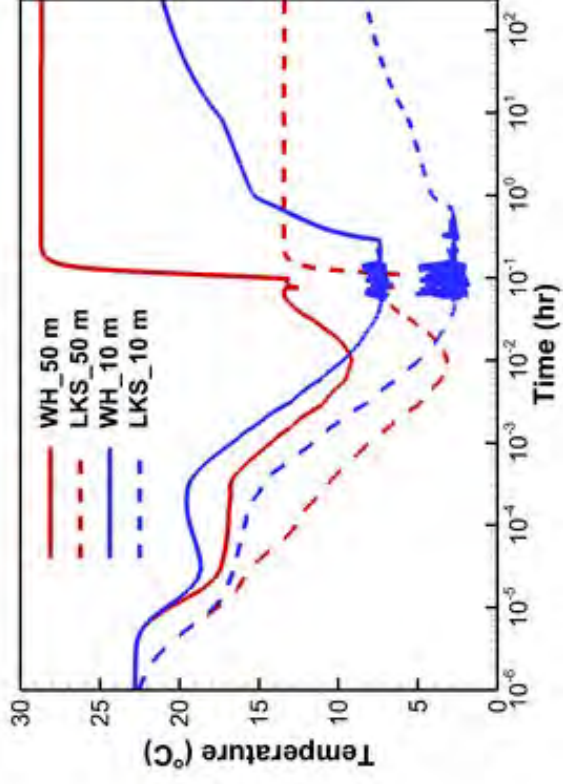
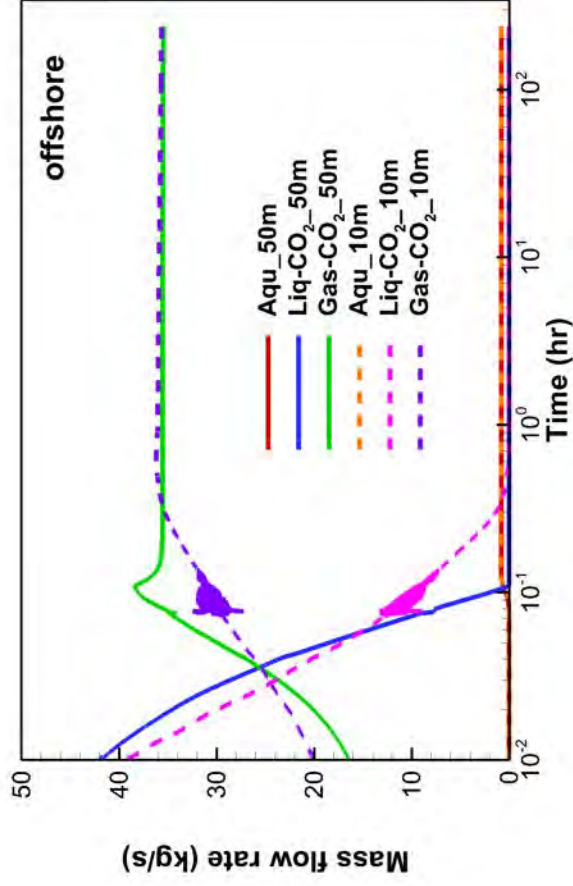
Case II (10 m)



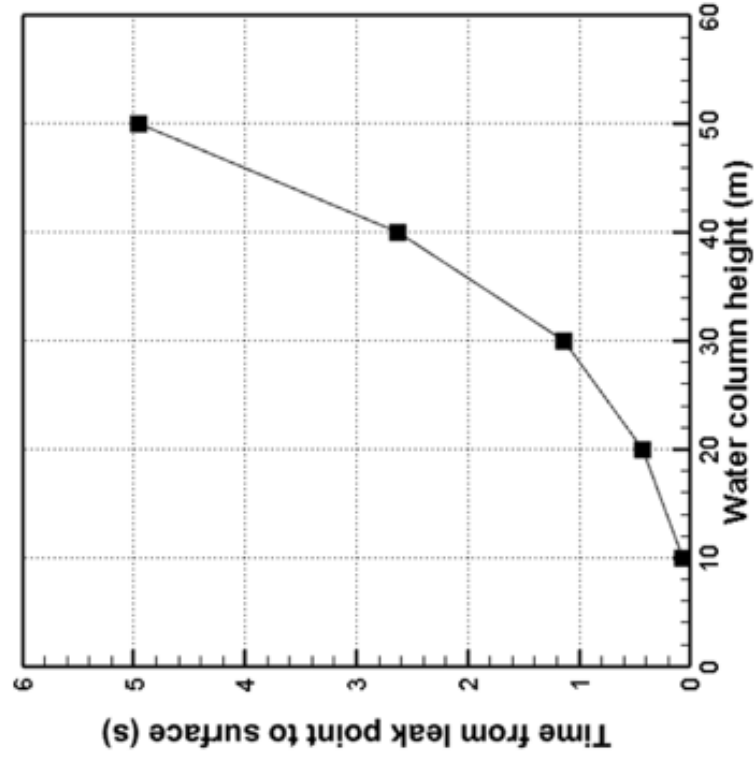
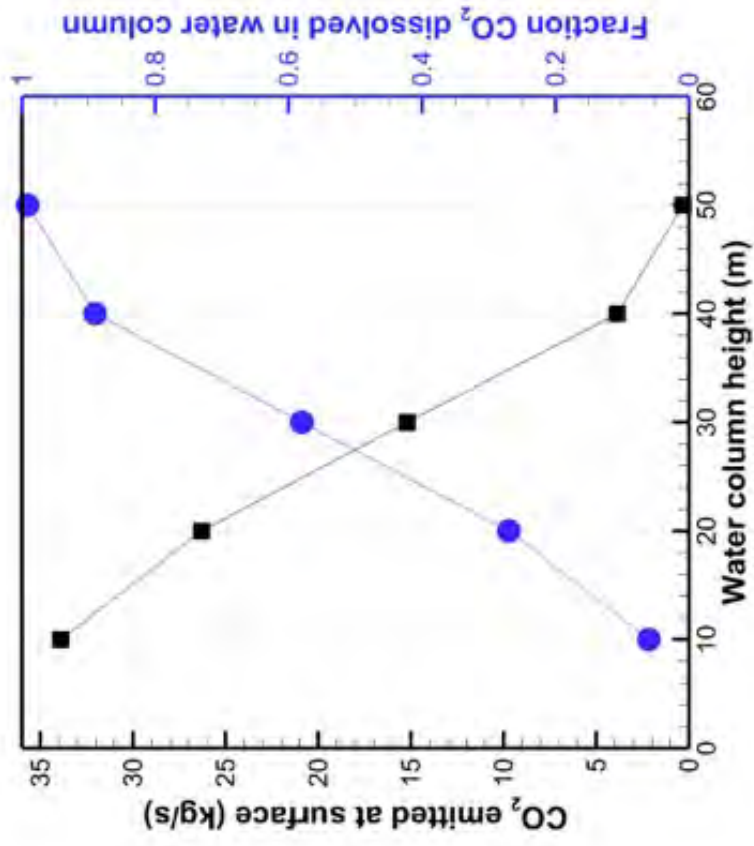
Results



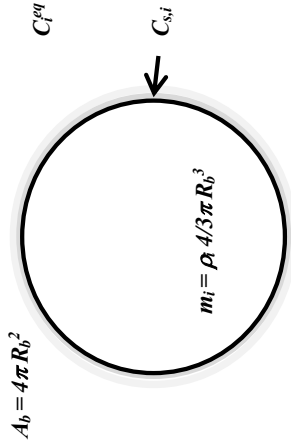
T2Well Results for Offshore CO₂ Blowout in 50 m and 10 m Depth



CO₂ blowout plume is almost entirely attenuated by seawater column if 50 m deep

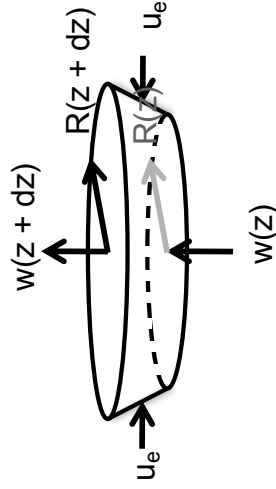


Simplified bubble mass transfer and seawater entrainment analysis confirms results



$$\frac{dm_i}{dt} = -A_b \beta_i (C_{s,i} - C_i^{eq}) \longrightarrow \Delta t = \frac{\Delta m_i}{A_b \beta_i (C_{s,i} - C_i^{eq})}$$

- Using independently estimated mass transfer coefficients and solubility of CO₂ in seawater, the time to dissolve the median-sized bubble is 1.14 s.
- Rise time for 50 m water column is 5 s. Therefore the median-sized bubble easily dissolves during rise through water column.



$$U_e = \alpha w \quad (\alpha \approx 0.1)$$

- 36 kg CO₂/s * m³ seawater / 2 kg CO₂ = 18 m³ seawater/s (need to entrain at this rate to dissolve all of the CO₂)
- Dividing this vol. flow rate by the surface area of the conical plume, we get a required entrainment velocity. It turns out the actual entrainment velocity is ~70 times larger, i.e., easily enough seawater is entrained to dissolve the leaking CO₂.

Conclusions

- Offshore sites are being considered for GCS in the Texas Gulf Coast
- There is a need to understand risks of CO₂ blowouts at offshore sites
- Offshore CO₂ blowouts will behave differently from onshore blowouts because of the strong effects of the water column
- We loosely coupled two models for simulations of this system:
 - T2Well (reservoir and well or pipeline)
 - TAMOC (water column)
- Results for large blowout (~1 Mtonne/yr) show
 - Median bubble size diameter is estimated to be 0.5 mm
 - 99% of the CO₂ is dissolved in the seawater for a blowout at 50 m depth
 - 94% of the CO₂ is emitted at the sea surface for a blowout at 10 m depth
- TAMOC results can be rationalized independently by estimates of
 - Mass transfer rate from median-size bubble
 - Seawater entrainment rate needed to dissolve leaked CO₂
- The results agree qualitatively with model results from another group using totally different methods



Acknowledgments

We thank Scott Socolofsky (Texas A&M) and Jonas Gros (GEOMAR Helmholtz Centre for Ocean Research Kiel) for help with using TAMOC, and Margaret Murakami, Tip Meckel, Ramon Trevino, and Susan Hovorka (Texas BEG) for assisting with characterization of the near-offshore region in the Gulf of Mexico.

This work was supported by the GoMCarb Project funded by the Assistant Secretary for Fossil Energy (DOE), Office of Clean Coal and Carbon Management, through the National Energy Technology Laboratory (NETL), and by Lawrence Berkeley National Laboratory under Department of Energy Contract No. DE-AC02-05CH11231 .



Oldenburg, C.M., and L. Pan, Major CO₂ blowouts from offshore wells are strongly attenuated in water deeper than 50 m, *Greenhouse Gases: Science and Technology*, 10, 15-31, 2020. DOI: 10.1002/ghg.1943



Task # 3



CO₂ dissolution trapping in saline aquifers

Sahar Bakhshian

**Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin**

SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

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Outline

- **Problem statement**
- **Background**
- **Approach**
- **Results and current status**
- **Prospective directions**



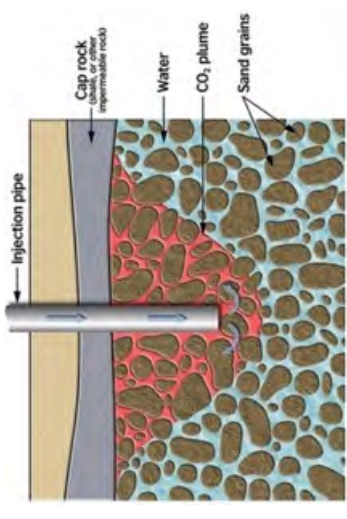
Problem Statement

- Dissolution trapping of supercritical CO_2 (scCO_2) in reservoir brine
- Dynamic dissolution of injected scCO_2 occurring within CO_2 plume during injection period
- Pore-scale simulation of multicomponent mass transfer (CO_2 and brine) in heterogeneous reservoirs
- Our study **benefit**: help us in risk assessment and capacity estimation



Background

- Accurate prediction of the long-term storage of CO₂ through understanding of trapping mechanisms
- Dissolution trapping is critical to the permanent containment of injected scCO₂ in saline aquifers.
- Dissolution of CO₂ into brine occurs during 3 stages:
 - Dissolution of scCO₂ plume by local phase partitioning during injection period
 - Beneath scCO₂ plume under the caprock by convection
 - Along immobile, tailing edges of the scCO₂ plume during post-injection period



- More accurate prediction of CO₂ plume extent

Approach

Two-phase multicomponent pore-scale simulation:

- Direct numerical simulation of the Navier-Stokes and advection-diffusion equations
- Volume-of-fluid (VOF) method



Approach

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- Momentum equilibrium

- Solving Navier-Stokes equation for multiphase flow using volume-of-fluid (VOF) method

$$\rho \left(\frac{\partial u}{\partial t} + u \cdot \nabla u \right) = -\nabla P + \nabla \cdot (\mu (\nabla u + \nabla u^T)) + \rho g + f_{st}$$

u : velocity P : pressure
 μ : viscosity ρ : density
 f_{st} : interfacial forces

- Concentration equation (Advection-diffusion):

$$\frac{\partial C_b}{\partial t} + \nabla \cdot (C_b \cdot u_b) = \nabla \cdot (D_b \nabla C_b)$$

C_b : concentration of species
 D_b : diffusion coefficient

- Continuity of mass fluxes and chemical potentials at the fluid-fluid interface

- Using a partitioning relation such as Henry or Raoult laws

- **Simulation tool:** Implementation of mathematical model in the open source Computational Fluid Dynamics toolbox OpenFOAM.



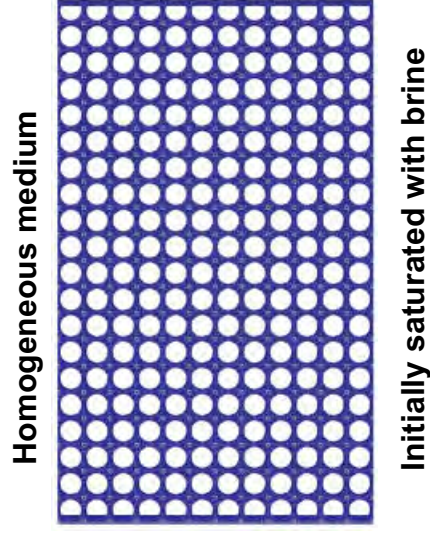
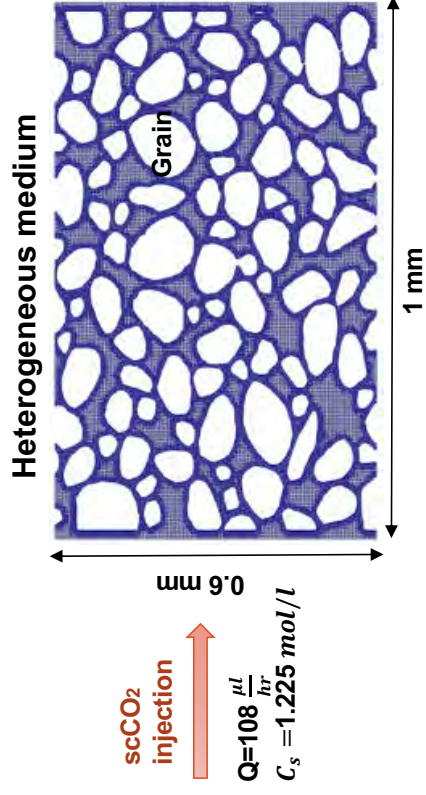
Status and Results

- Non-equilibrium scCO_2 dissolution during drainage (injection period)
- Upscaling of scCO_2 dissolution in brine



Results

• Non-equilibrium scCO₂ dissolution during injection period



Property	scCO ₂	Brine
Density (kg/m ³)	280	992
Viscosity (m ² /s)	2.3e-05	5.5e-04
Diffusivity (m ² /s)	0.0	1.6e-9
Interfacial tension(mN/m)		35
Wettability		45°
Henry's constant		1
Porosity		45

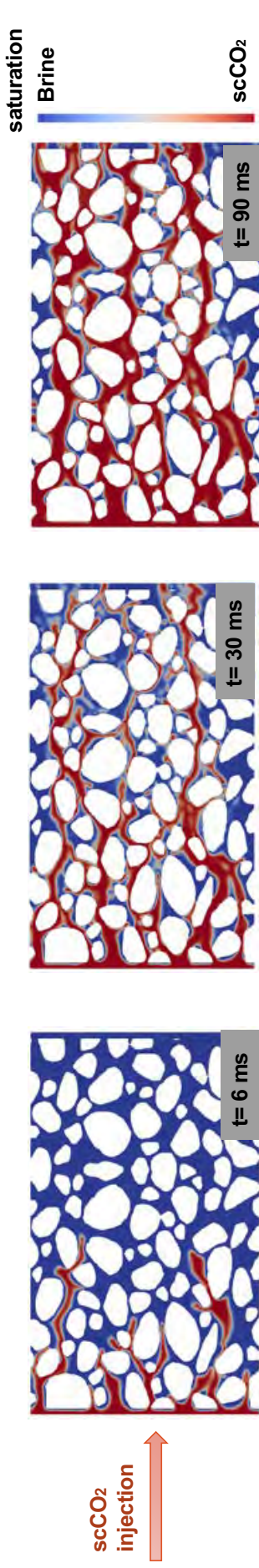
Goals:

- Transient scCO₂ dissolution and mass transfer process at the pore-scale
- Effect of fine-scale rock heterogeneity on the dissolution process

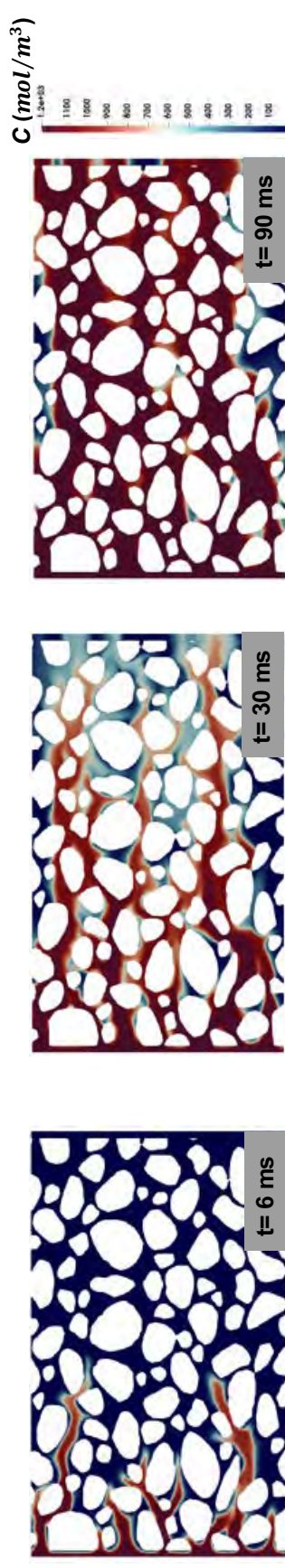
Results

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- ❖ Phase distribution during drainage of scCO₂ into the heterogeneous pore space initially saturated with brine



- ❖ Concentration distribution during drainage of scCO₂

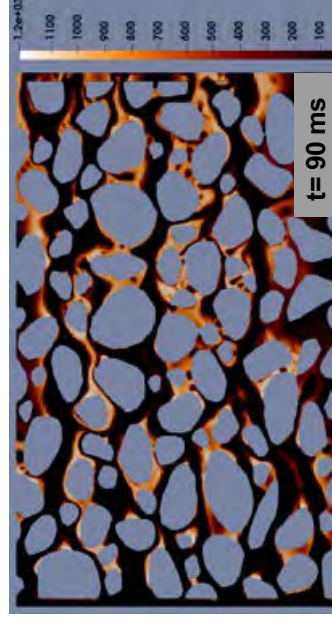
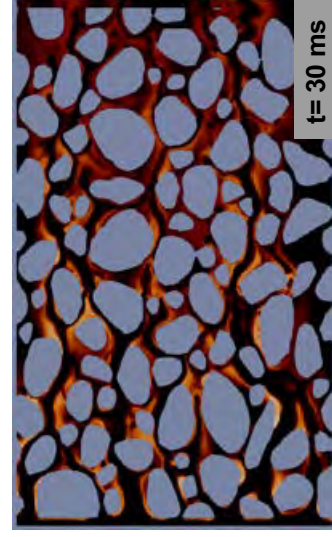
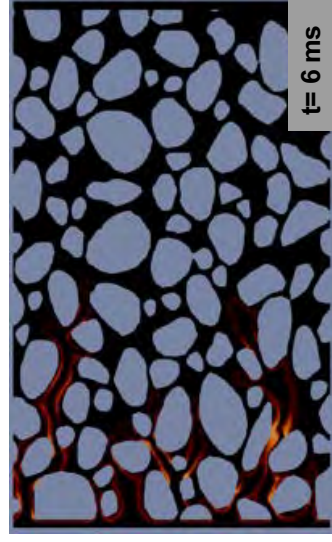


- ❖ CO₂ changes from supercritical state to the dissolved CO₂ (dsCO₂) at the scCO₂-brine interface.
- ❖ dsCO₂ mass transfer happens as it transports away from the interfaces to water-filled pores.

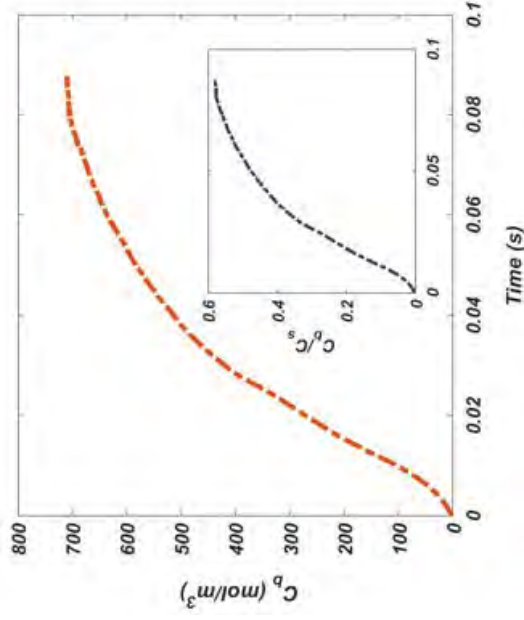
Results

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❖ Evolution of dissolved CO₂ concentration in brine during injection



C_b (mol/m³)

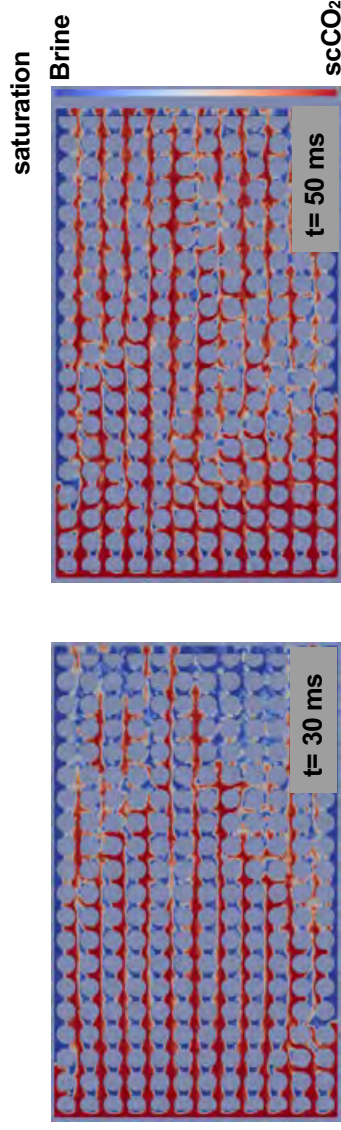
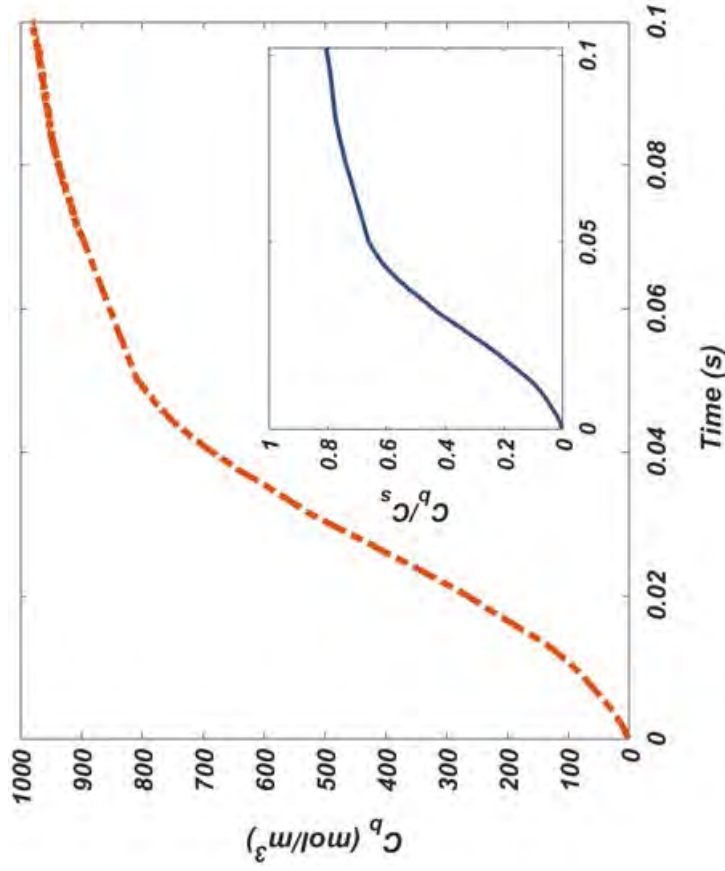


- ❖ Faster scCO₂ dissolution and phase equilibrium occurs around the percolating fingers as the advection is more effective.
- ❖ The process for dissolved CO₂ concentration to reach the solubility value at the pore scale is not instantaneous.
- ❖ The observed non-equilibrium dissolution can be attributed to the limited interactions between scCO₂ and brine at the scale of individual pores and pore clusters.

Results

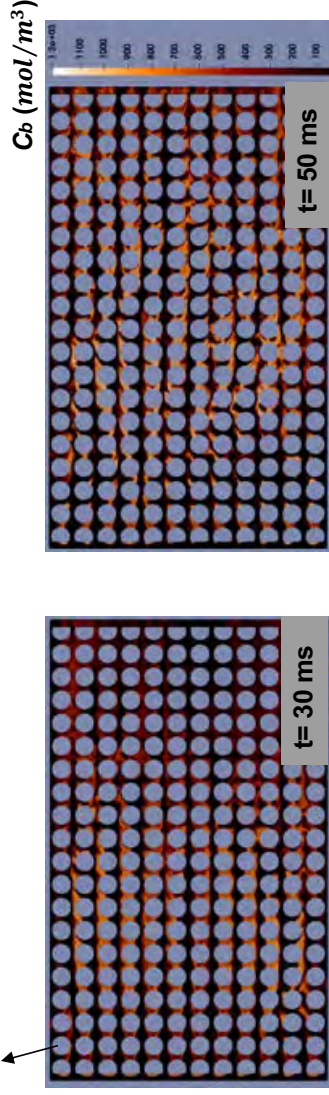
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❖ Homogeneous medium:



Phase distribution of scCO₂ (red) and brine (blue)

grain



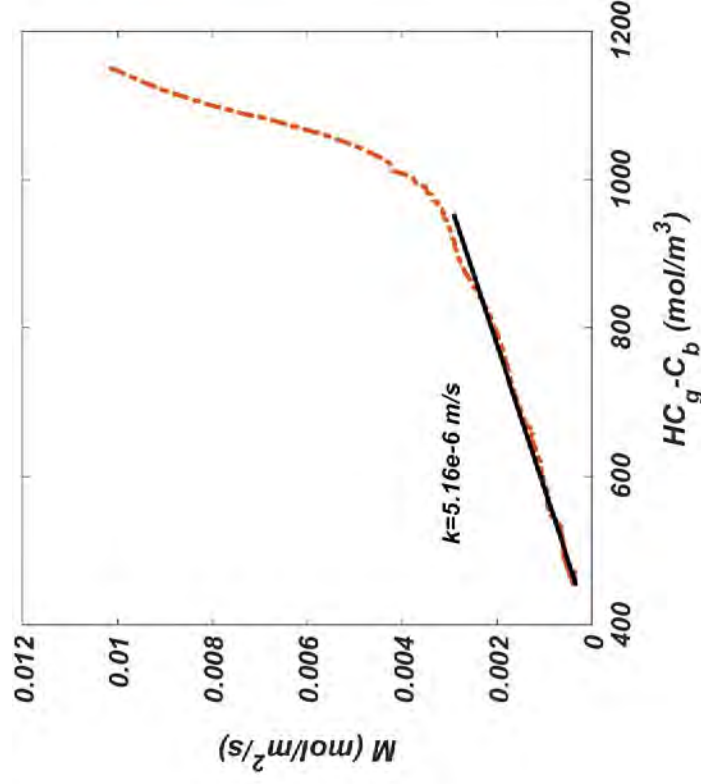
Dissolved CO₂ concentration in brine

❖ Homogeneous sample displays a better mixing and higher dissolution of CO₂ in brine.



Results

❖ Upscaling of CO₂ dissolution in brine



Mass transfer per interfacial area versus the concentration gradient in the heterogeneous sample

❖ Slope of the curve is representative of the mass transfer coefficient.

❖ The small mass exchange coefficient demonstrates the effect of incomplete mixing and non-equilibrium dissolution.

$$M = k (HC_g - C_b)$$

M : mass transfer per interfacial area

k : mass transfer coefficient

H : Henry's constant

Key takeaways

- ❖ Our study helps to capture the complexity of scCO_2 dissolution process in brine reservoirs.
- ❖ scCO_2 dissolution process is dynamic rather than an equilibrium state.
- ❖ scCO_2 dissolution and mass transfer depend on the heterogeneity of rock.
- ❖ Subsurface heterogeneity leads to the incomplete mixing and non-equilibrium dissolution of CO_2 in resident brine.



Prospective directions

- ❖ Investigate the effect of injection rate, wettability and salinity on CO₂ dissolution dynamics



Thank you!

Questions?

The Effect of Compressibility and Boundaries on Displacement Stability

Aura N. Araque and Larry W. Lake
Hildebrand Department of Petroleum and
Geosystems Engineering

The Mobility Ratio

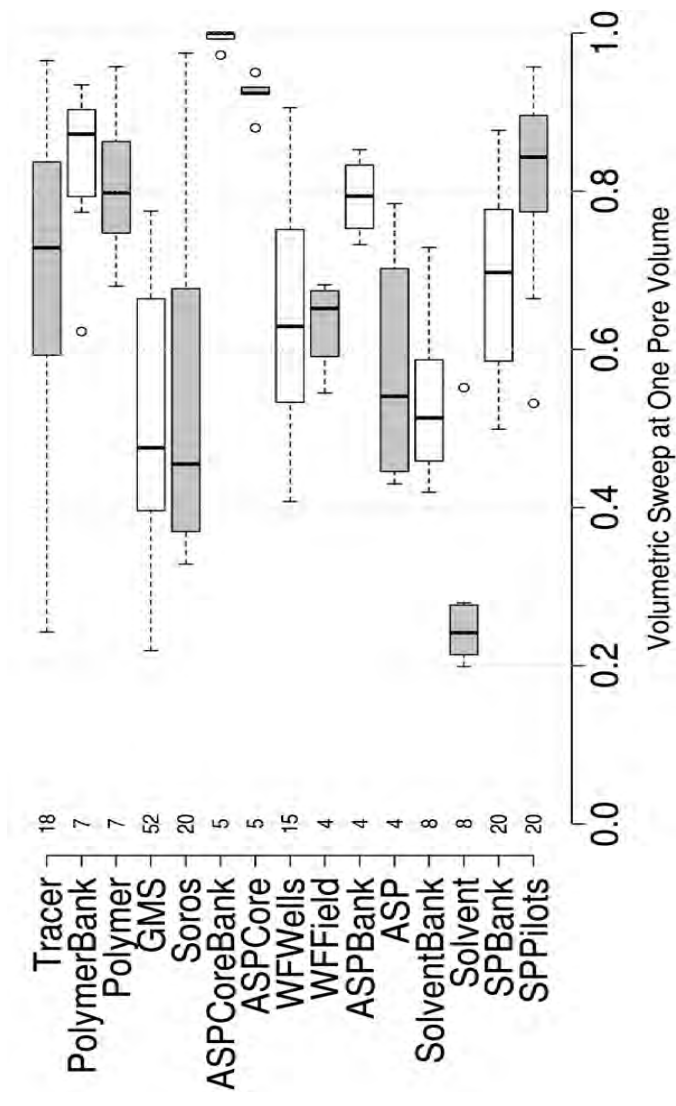
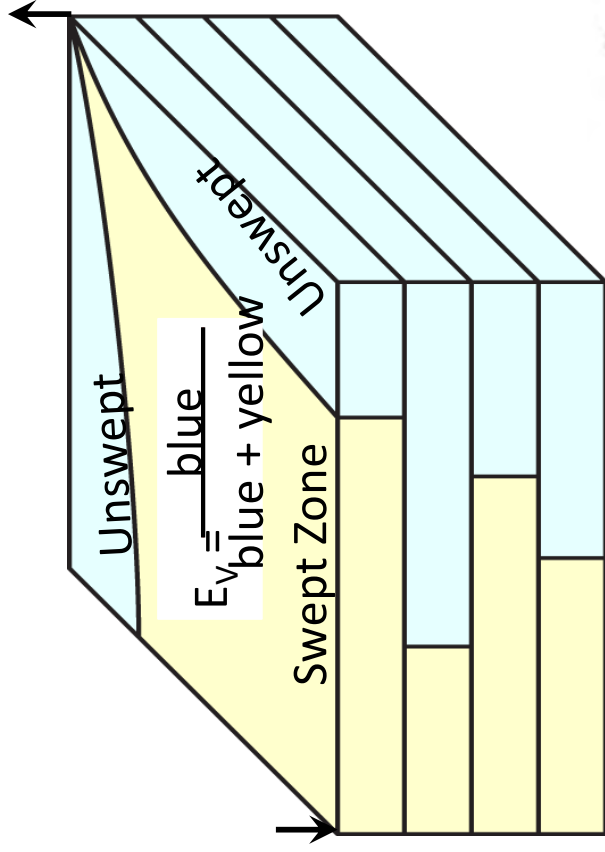
Definition $M = \frac{\text{Mobility displacing fluid}}{\text{Mobility displaced fluid}}$

$$M = \frac{(\text{Relative perm.} / \text{viscosity})_{\text{displacing}}}{(\text{Relative perm.} / \text{viscosity})_{\text{displaced}}}$$

$$M = \begin{cases} 0.5 - 10 & \text{Light oil waterflood} \\ 10 - 20 & \text{CO}_2 \text{ flood} \\ 20 - 50 & \text{Methane flood} \end{cases}$$

No compressibility in this definition

Volumetric Sweep Efficiency Field Scale...



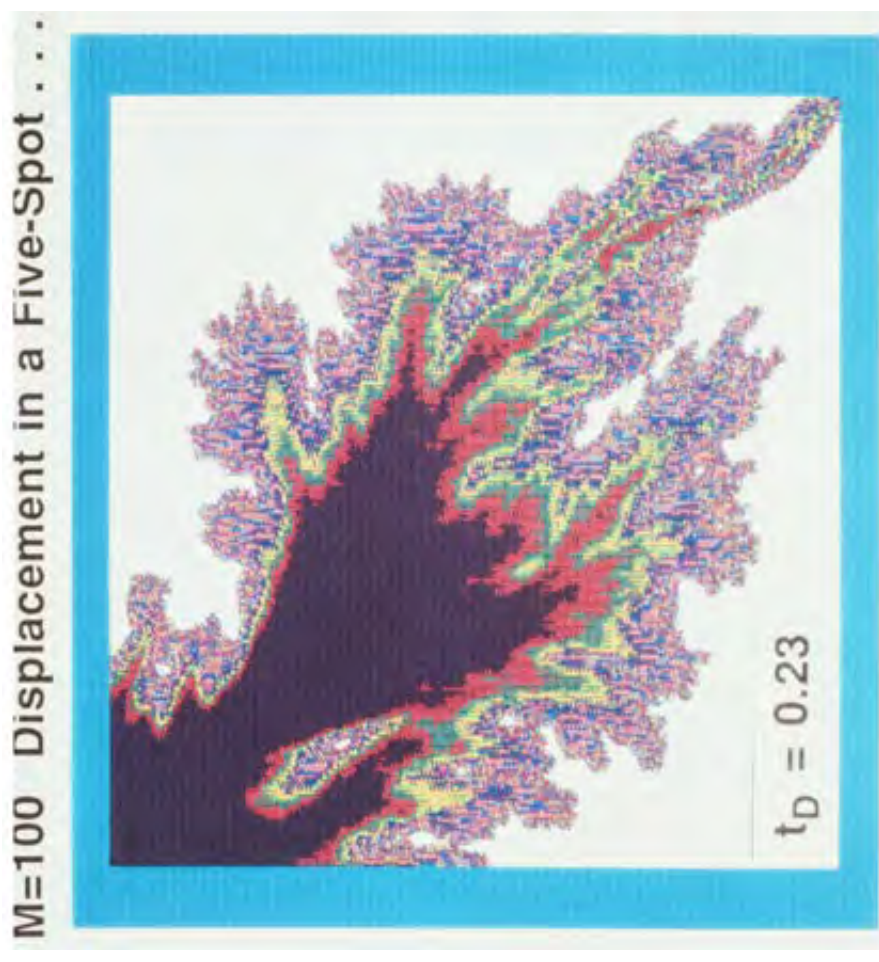
Simulated

Incompressible fluids (Simulation results from previous work)

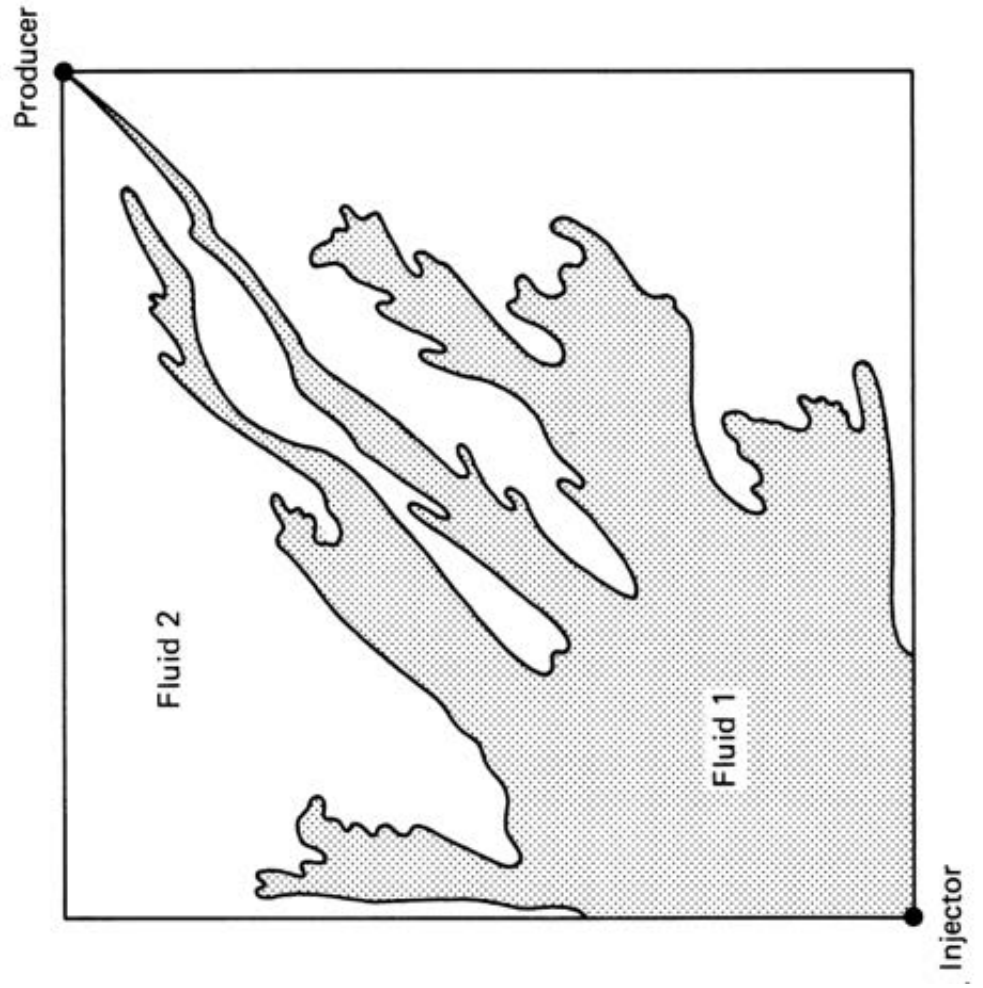
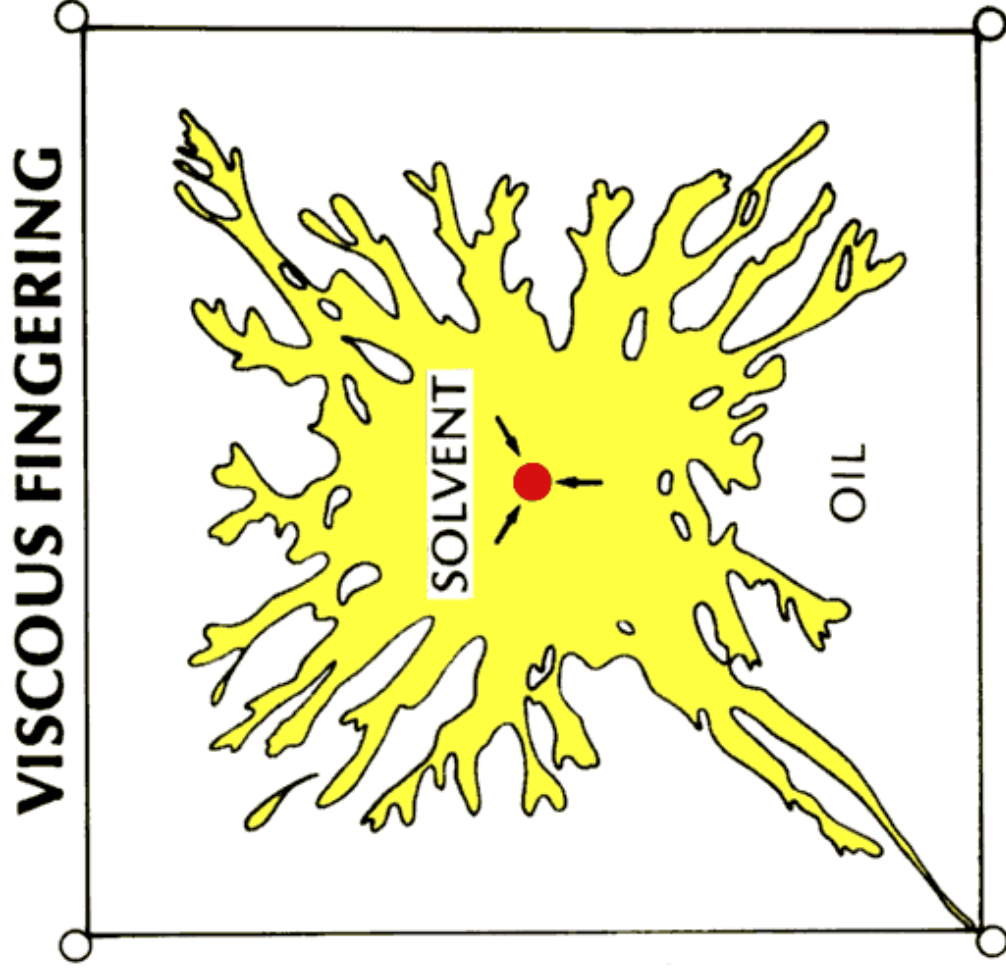
Injector



Producer



Experimental Left Hele Shaw; Right $M=17$



The penetration of a fluid into a porous medium
or Hele-Shaw cell containing a more
viscous liquid

BY P. G. SAFFMAN AND SIR GEOFFREY TAYLOR, F.R.S.
Cavendish Laboratory, University of Cambridge

(Received 17 January 1958—Read 17 April 1958)

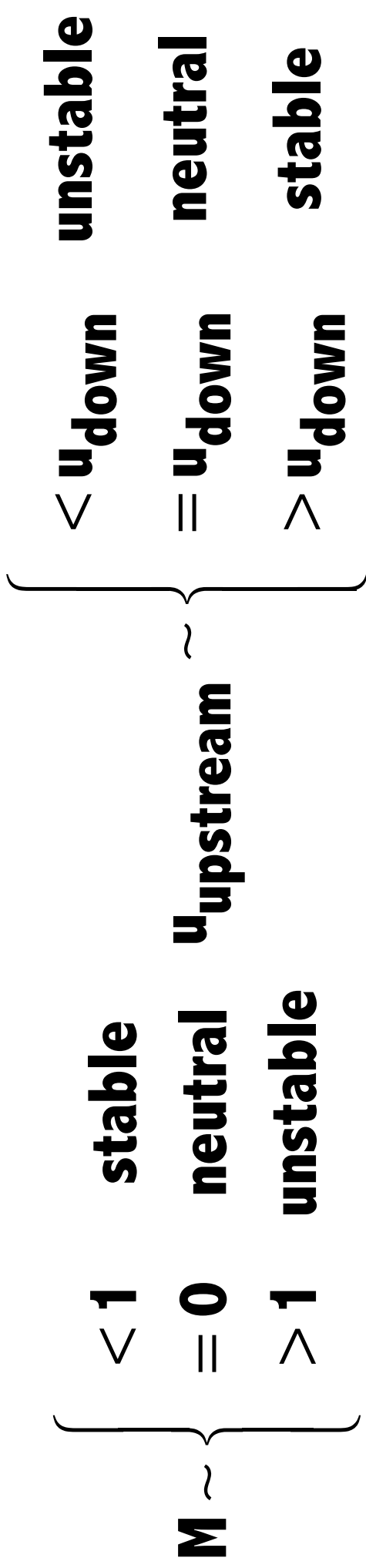
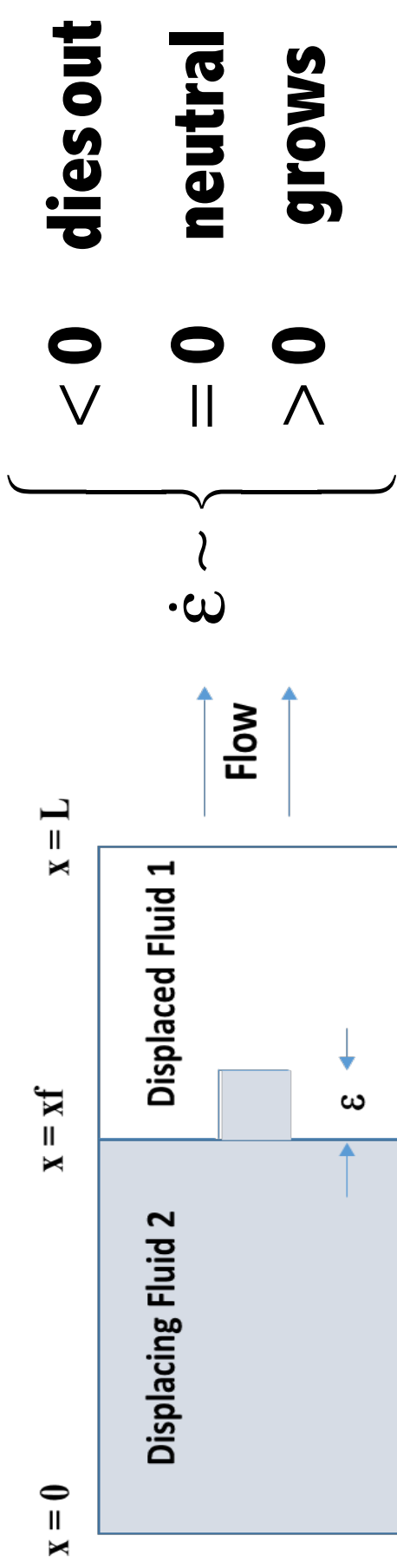
•
Channelling in packed columns

S. HILL, M.A., F. Inst. P., F.S.S.

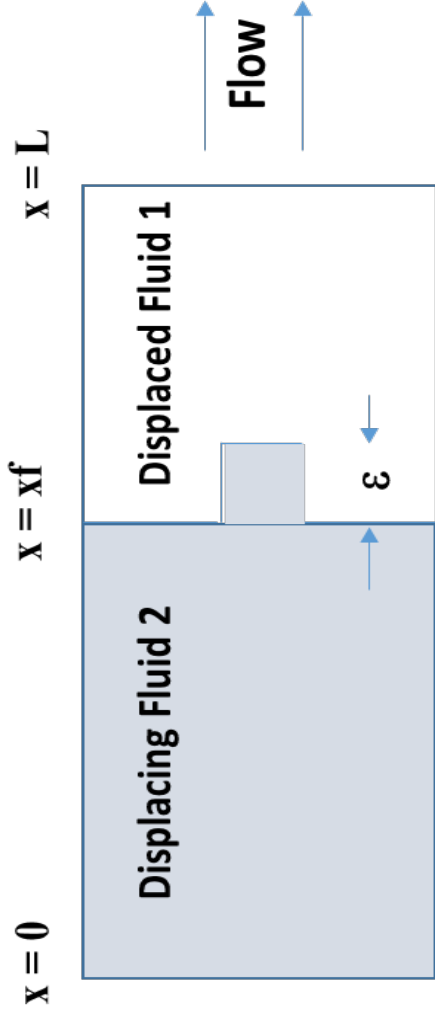
Tate & Lyle Research Laboratory, Keston, Kent
(Received August 1952)

Chemical Engineering Science

ST Instability



ST Instability



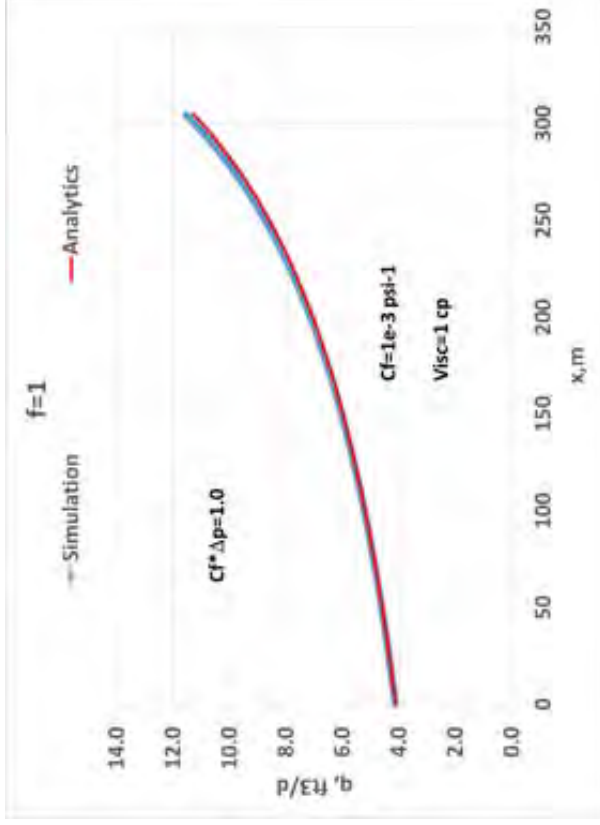
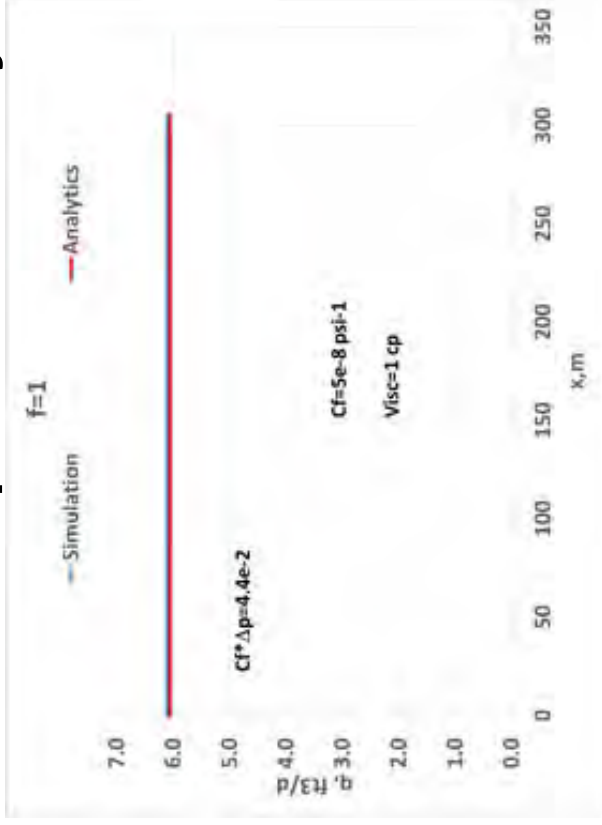
$$\left. \begin{array}{l} < u_{\text{down}} \\ = u_{\text{down}} \\ > u_{\text{down}} \end{array} \right\} \begin{array}{l} \text{unstable} \\ \text{neutral} \\ \text{stable} \end{array}$$

u_{upstream}

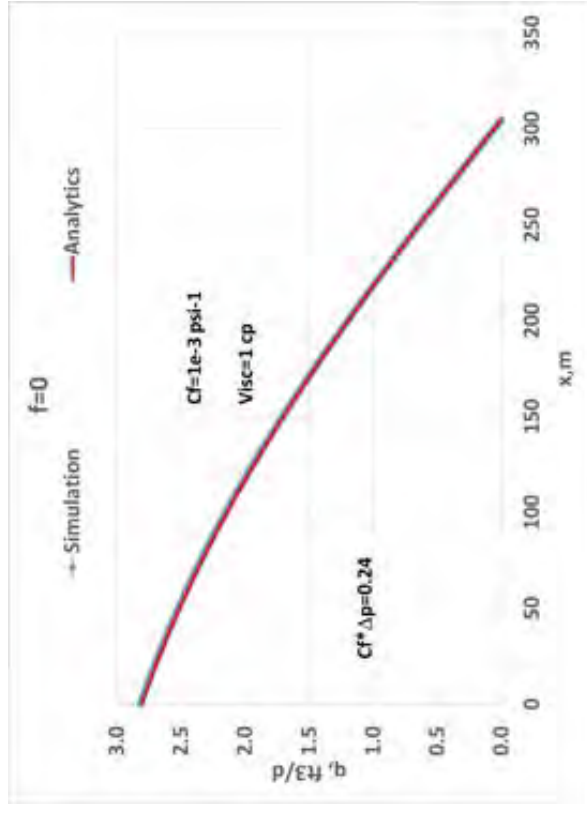
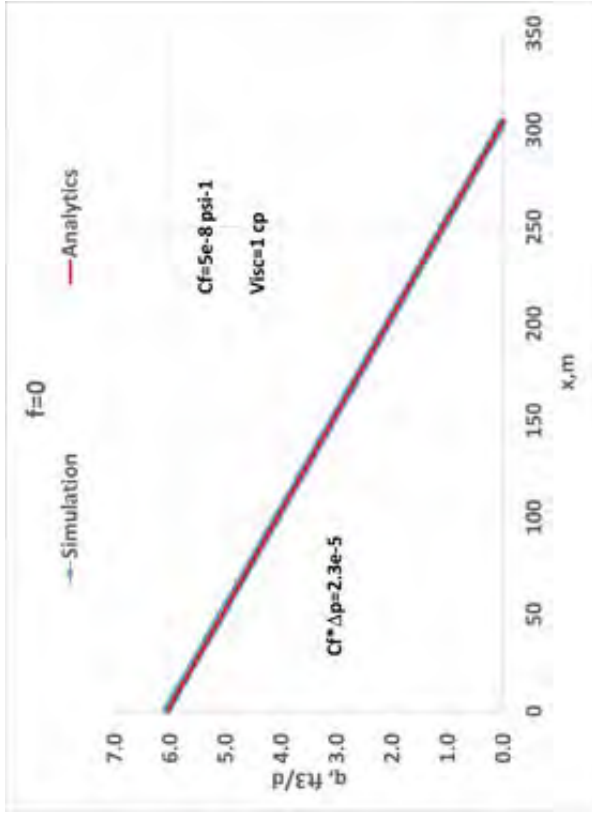
$$f = \frac{(\rho u)_{\text{outlet}}}{(\rho u)_{\text{inlet}}} = \left\{ \begin{array}{ll} 0 & \text{sealed (SS)} \\ 0 < f < 1 & \text{partially sealed} \\ 1 & \text{transparent (SSS)} \end{array} \right.$$

Velocity Profiles

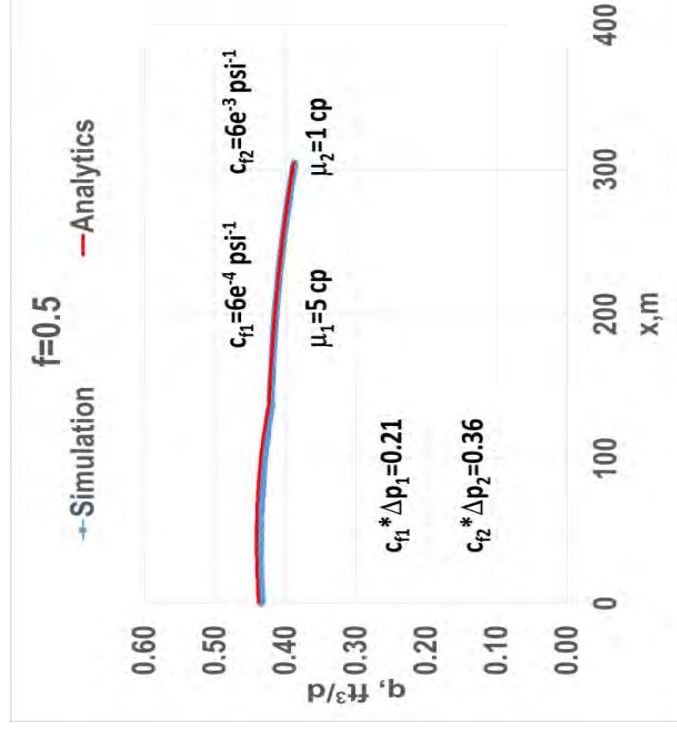
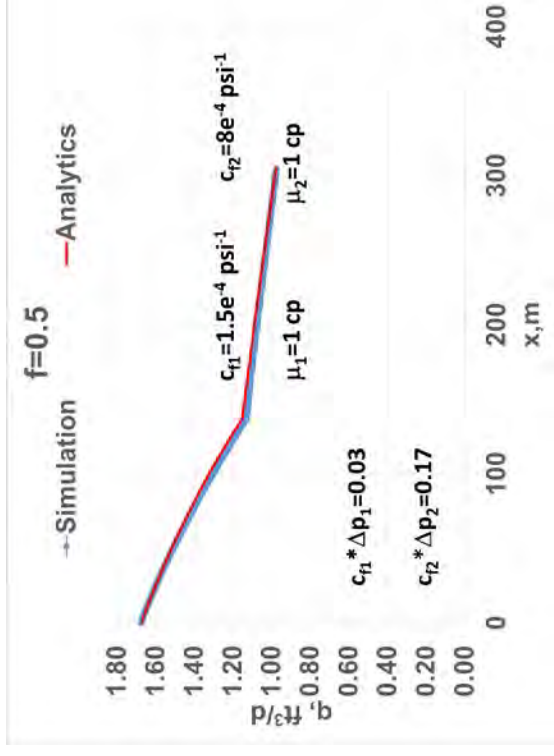
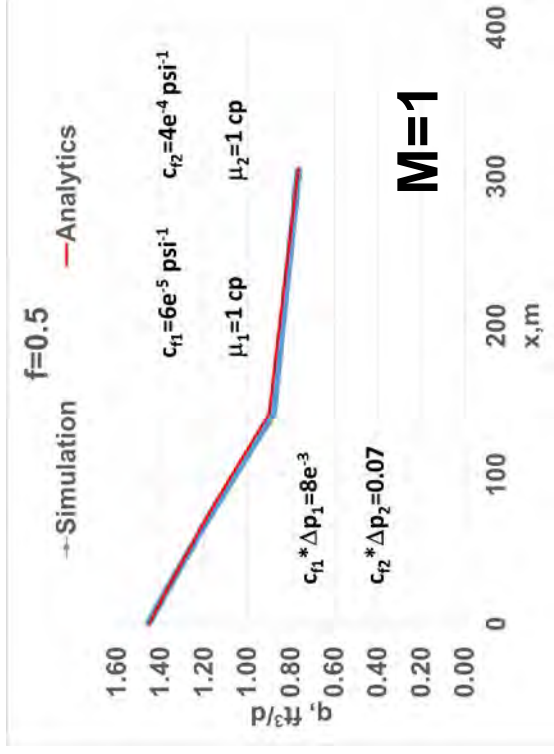
Transparent Boundary



Sealed Boundary



Velocity Profiles, partially sealed



Conclusions

- Derived an analytic solution for ST instability in compressible flow; agrees with simulation
- Behavior of fluid velocity is equivalent to perturbation analysis
- Increasing velocity toward external boundary leads to ST instability
- Open boundary compressibility always destabilizes
- Partially sealed external boundary stabilizes flow
- Sweep efficiency in CO₂ storage (no producers) should be greater than for CO₂-EOR
- Commercial simulators do not work well in the high compressibility limit

The Effect of Compressibility and Boundaries on Displacement Stability

Aura N. Araque and Larry W. Lake
Hildebrand Department of Petroleum and
Geosystems Engineering

Fault-conforming model for geomechanical simulation

Example of the HI24L block, Gulf of Mexico



Antoine Mazuyer, Josh White, Hervé Gross, François Hamon

Task 3: Risk Assessment, Simulation, & Modeling SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020



Lawrence Livermore
National Laboratory



TOTAL



Overall objective

Develop a geomechanical hazard assessment for potential storage targets in the Gulf-of-Mexico

Specific objectives

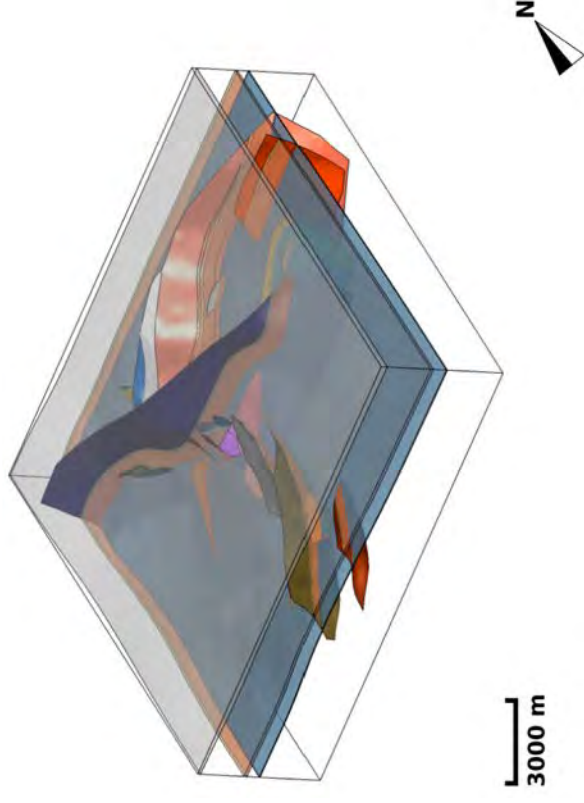
1. Estimate potential deformation of poorly-consolidated Miocene-age rocks
2. Refine understanding of how fault bounded structures could respond to injection
3. Make recommendations regarding further characterization efforts and geophysical monitoring designs

A key tool in this effort is a data-constrained geomechanical modeling.



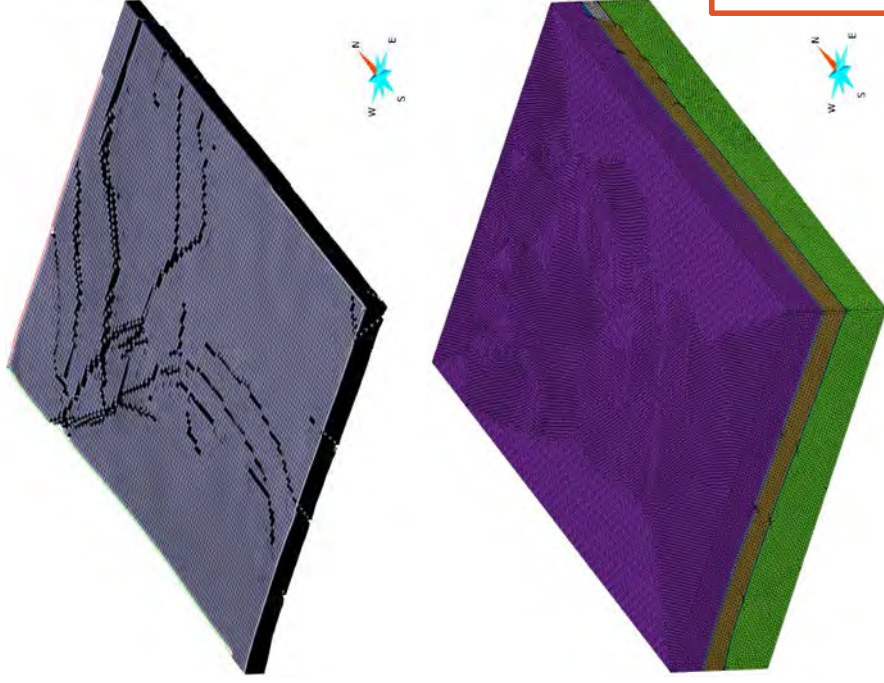
Problem statement

- Area of interest : **reservoir + overburden + underburden + sideburden**
- Flow simulation (track CO₂ saturation and **pressure evolution**)
- Mechanical simulation (**fault reactivation, deformation**)
- Accurate geological representation (**structures + property filling**)



How to create a reliable geological model and mesh for this kind of simulation?

Limit of the “classical” workflow



- Only the reservoir part is considered (no overburden, underburden)
- Faults with small throw can be ignored in the modeling process
- Stair steps makes contact mechanics impossible and geology is approximated

Proposition : generate a conformal tetrahedral mesh to solve both mechanical and flow equations

The example of HI24L

- Analog model for CO2 sequestration, Gulf of Mexico
- Original dataset comes from UT Austin, BEG... Thanks for the data !

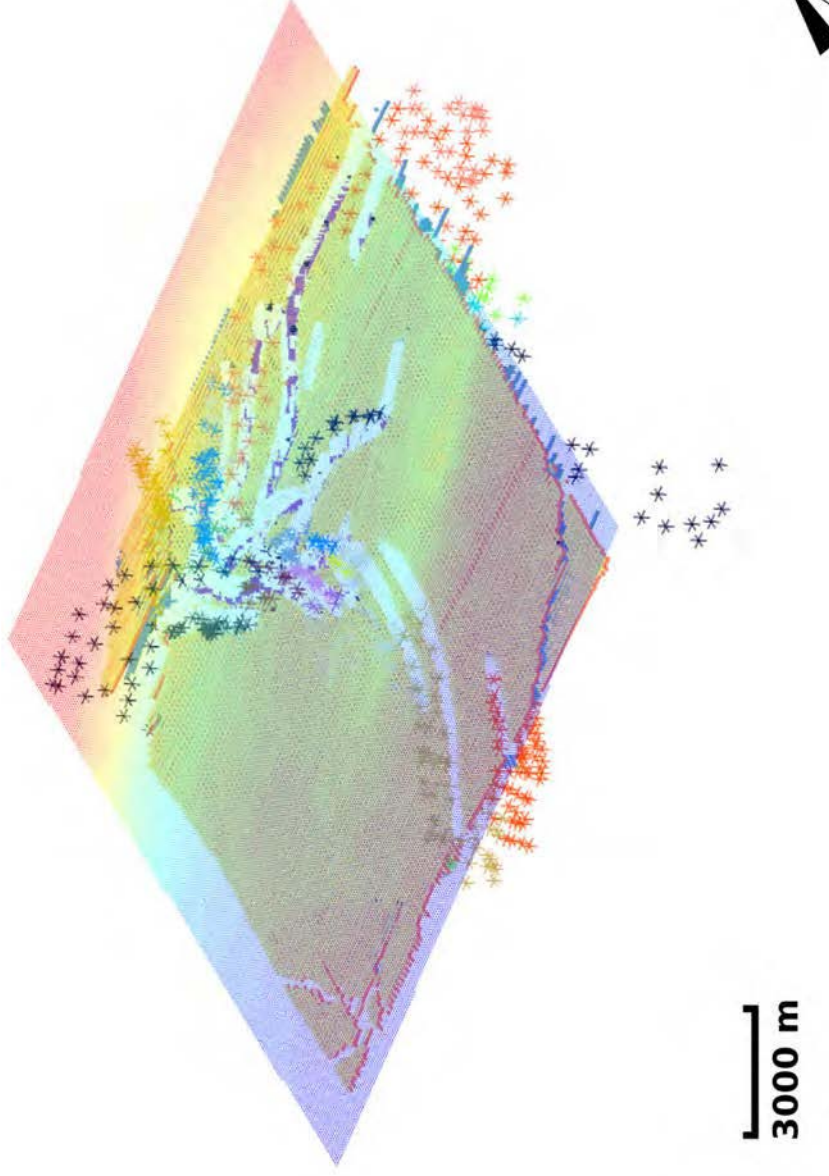


We highlight with this examples the challenges to generate a model suitable for multiphysics simulations

Input data

[DeAngelo et al., 2019, *Int. J. of Green. Has Ctrl.*]

[Olario et al., 2019, AAPG convention]



- 4 horizons

- 51 faults

- 35 wells

[UT Austin, BEG]

- 1 DEM

[National Oceanic and Atmospheric administration]

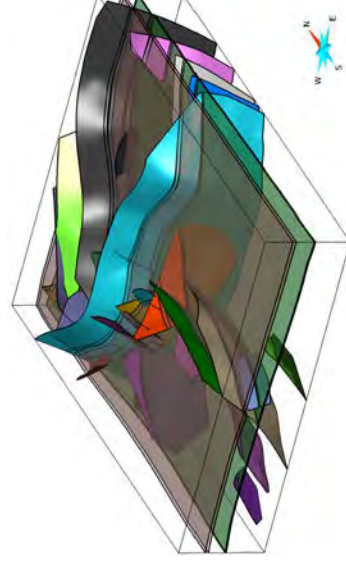
Implicit and explicit modeling



Data

- Pointset, seismic picking, etc..

[UT Austin, BEG]



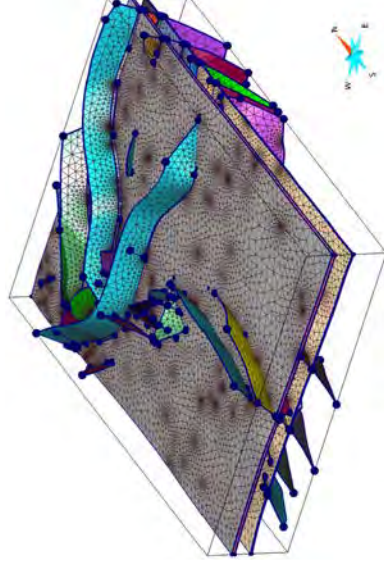
Implicit model

- Horizons = isovalues of a scalar field
- Easy to edit faults/horizons connexion

[Mallet, 2002, *Geomodelling*]

[Caumon et al., 2009, *Math. Geos.*]

[Collon et al., 2016, *Interpretation*]



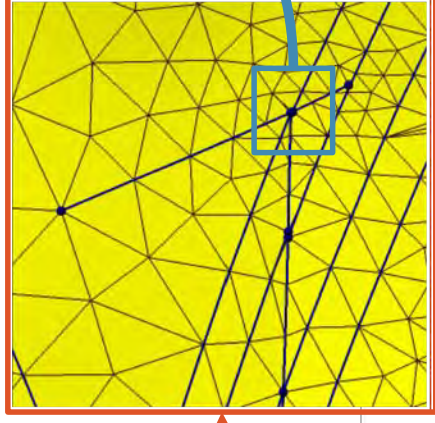
Explicit model

- Horizons = triangulated surfaces
- Support of the tetrahedral mesh

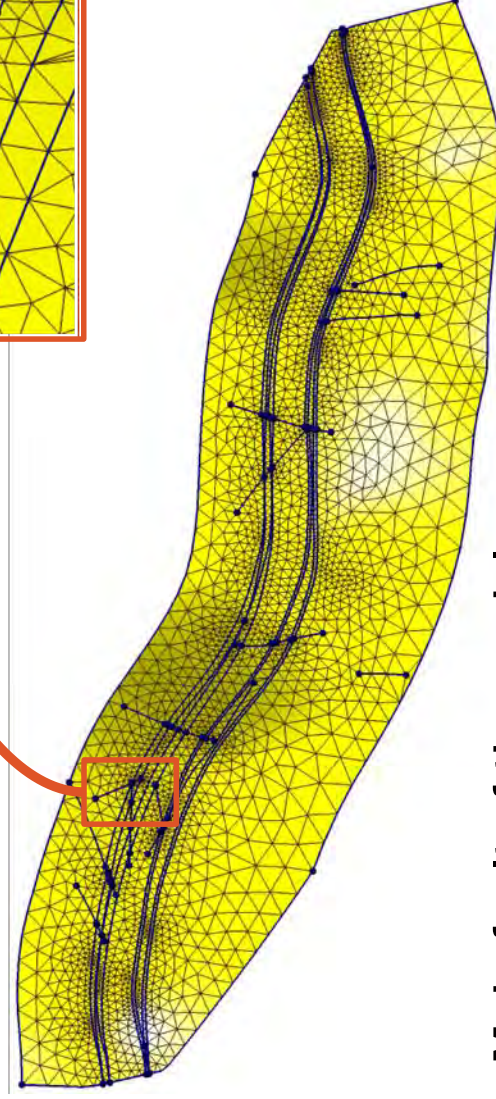
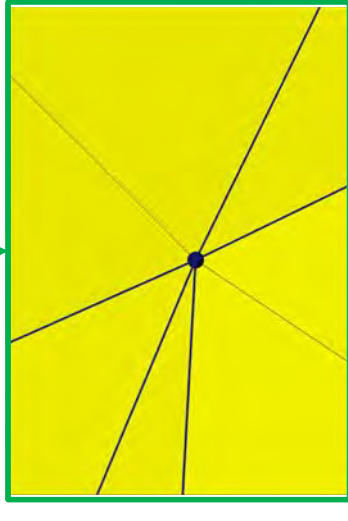
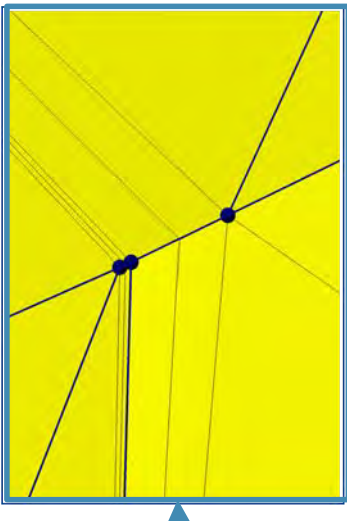


Explicit modeling: quality control

- Model simplifications must be done to properly mesh the model with tetrahedra



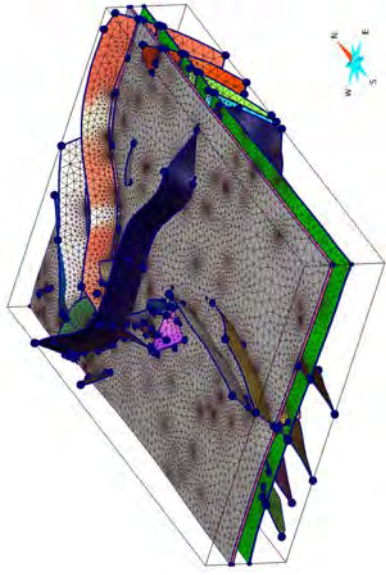
Topology simplification



Main fault of the model

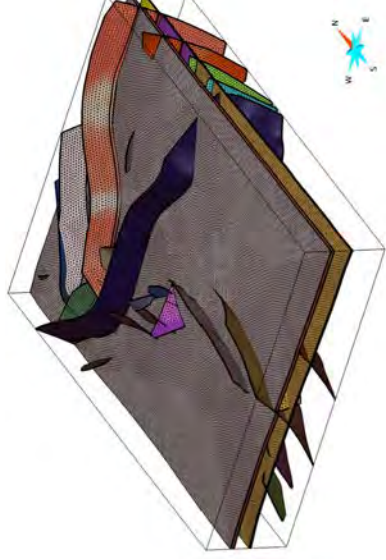
50 cm between the corners !

Volume meshing



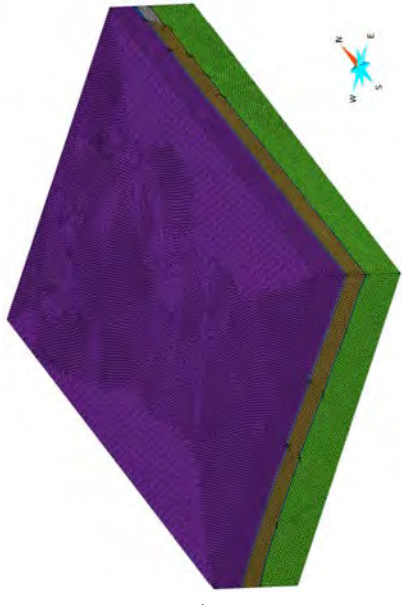
Surface remeshing

- Mesh will be conformal to surfaces
→ need of good surface mesh
- Reparameterization method [Beaufort et al., 2020]
- Voronoi approach [Pellerin et al., 2016]

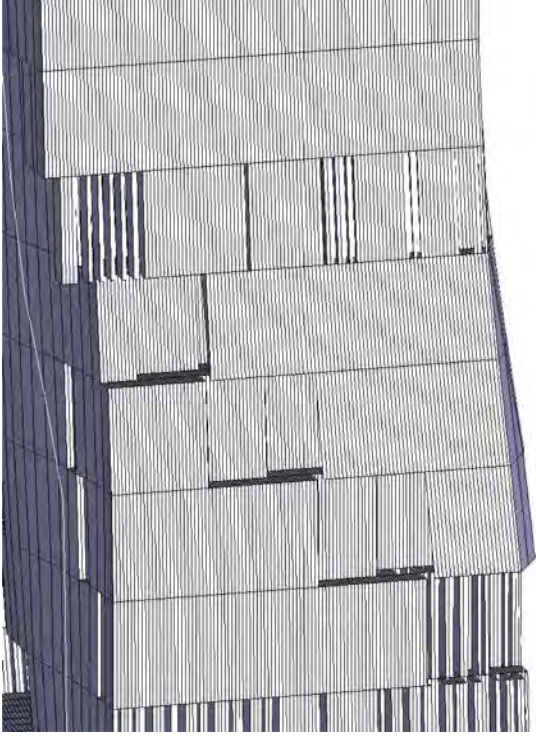


Volume meshing

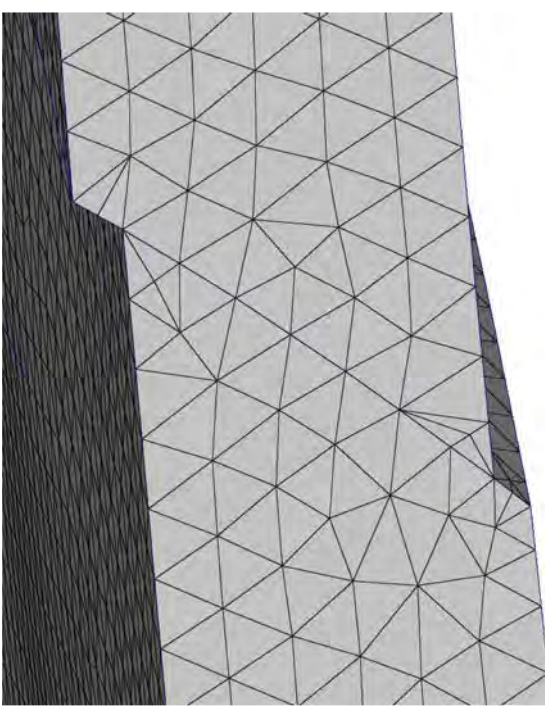
- Easy if we start from a good quality surface mesh
- Tetrahedral mesh is conformal to fault and horizons surfaces



Volume remeshing



Both ~ 800K
cells



Corner Points Grids

- 6 m vertical resolutions
- Good enough to represent geological vertical heterogeneities

Tetrahedral mesh

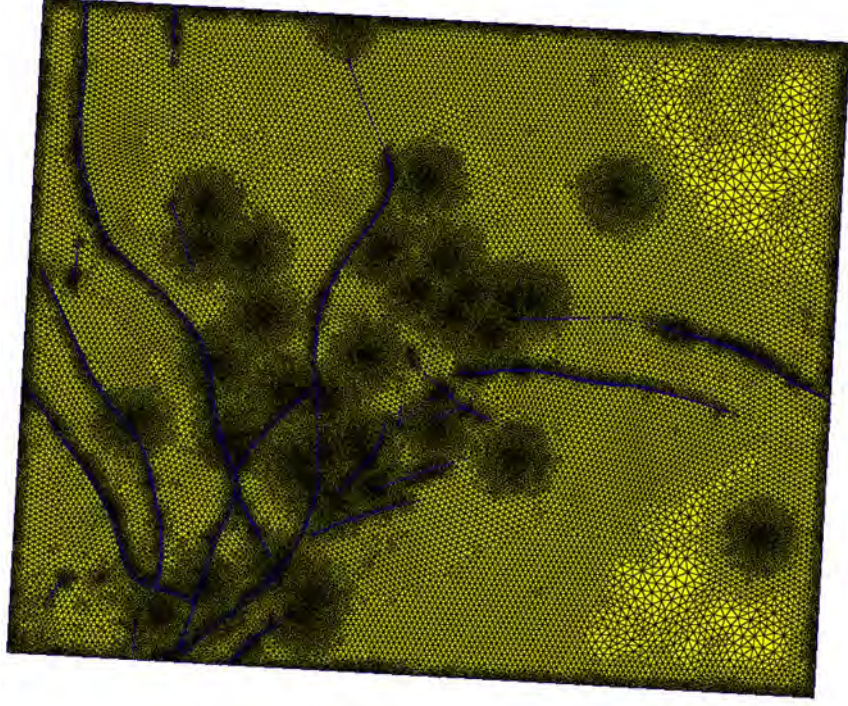
- 100 m vertical resolutions

Proposition : generate a tetrahedral mesh with an anisotropic mesh size

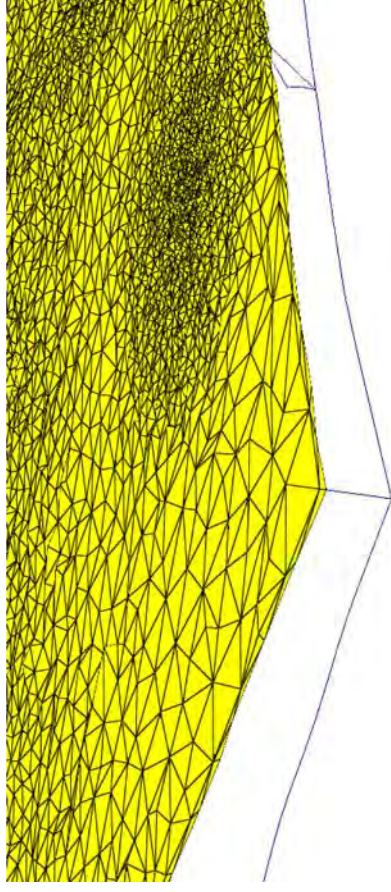


Volume (re)meshing

Remeshing done using the mmg
software, prescribing an
anisotropic metric tensor



Top View



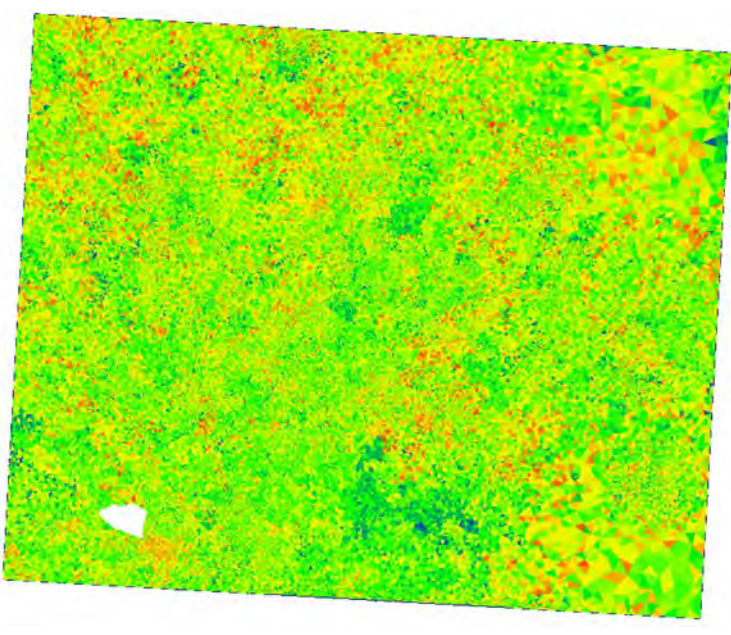
Horizontal slice

~ 6M cells

Geostatistical method adapted for unstructured grid

- No structured grid → Challenge for geostatistical algorithms
- Use of a novel method suitable for unstructured grid

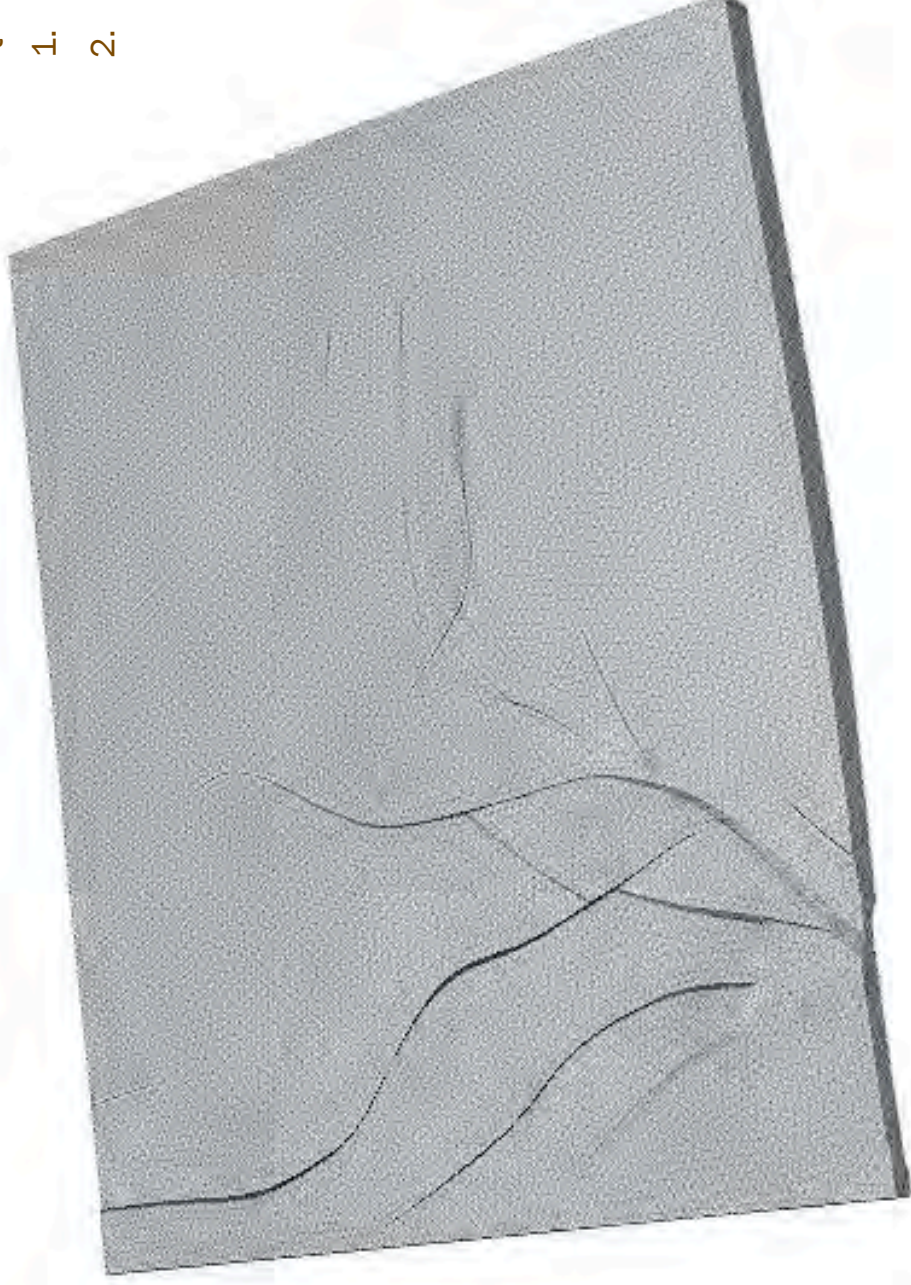
[Biver et al., 2016, *Intl. Geostat. Congress*]
[Zaytsev et al., 2016, *Math. Geos.*]
[Biver et al., 2019, *Petroleum Geostats*]



Porosity

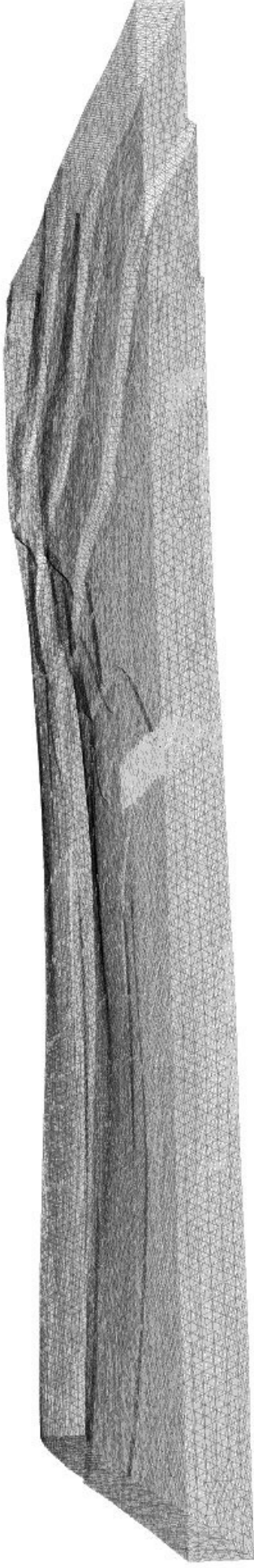
Quick check simulation ... **not realistic!**

1. Injecting in all wells
2. Faults are transparent



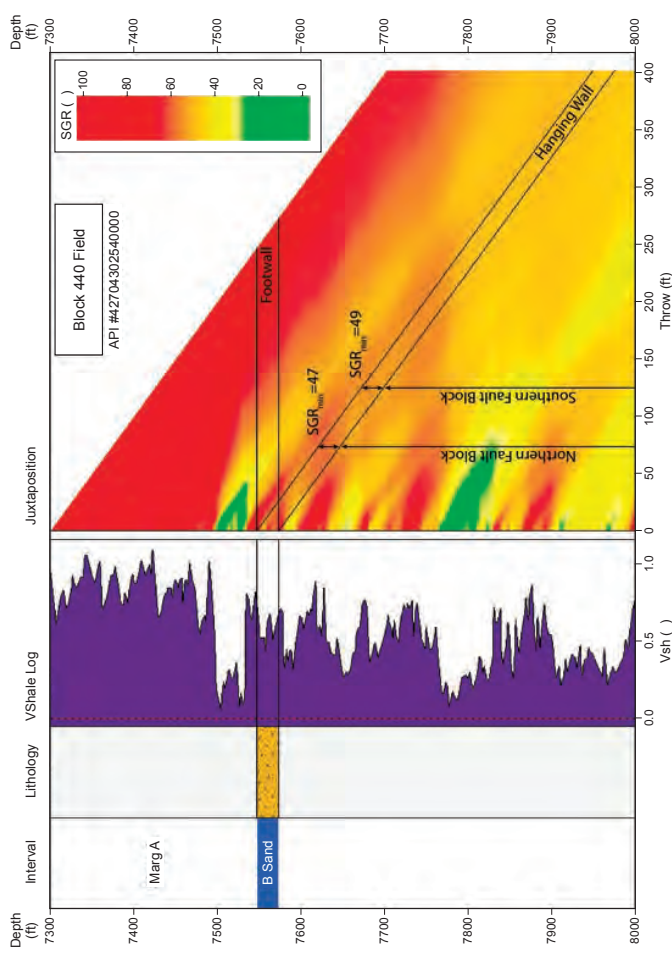
Quick check simulation ... **not realistic!**

1. Injecting in all wells
2. Faults are transparent



Next steps

1. Need to decide on target injection scenarios (wells and volumes).
2. Need to constrain fault seal behavior.
Can leverage existing GCCC work.
3. Working on constraining geomechanical properties, but we will need to accept high uncertainties.



Fault juxtaposition analysis [Meckel et al.]

Extra Slides



Key Model Inputs

Input	“Path Forward”	Sources
Lithology + structure	Clear	GCCC Framework Model
Absolute perm + porosity	Clear	GCCC Framework Model
Relative perm	Maybe	Wallace et al. 2017
Fault seal behavior	Clear	Meckel et al. 2017, Nicholson 2012
Formation pressure, temp, salinity	Maybe	Well data?
Static elastic moduli	Clear	GCCC Framework Model (with dynamic/static correlation)
Inelastic properties	Unclear	Vastar and Atlantic Richfield Core? Analogue data?
Fault friction properties	Clear	Correlations + Limit Analysis
Stress orientation	Maybe	Regionally consistent
Stress magnitude	Unclear	Local stress indicators? Gas-trap and faulting constraints.

TOWARDS INTEGRATED SEISMIC MVA FOR NEAR-SHORE GCS: SEAFLOOR DAS FOR MONITORING

Jonathan Ajo-Franklin^{1,2}, Nate Lindsey³, Feng Cheng¹, Benxin Chi¹



Jonathan



Nate



Feng



Benxin

1



Rice
University

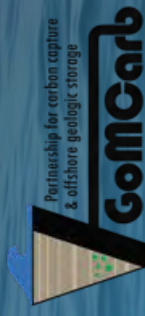
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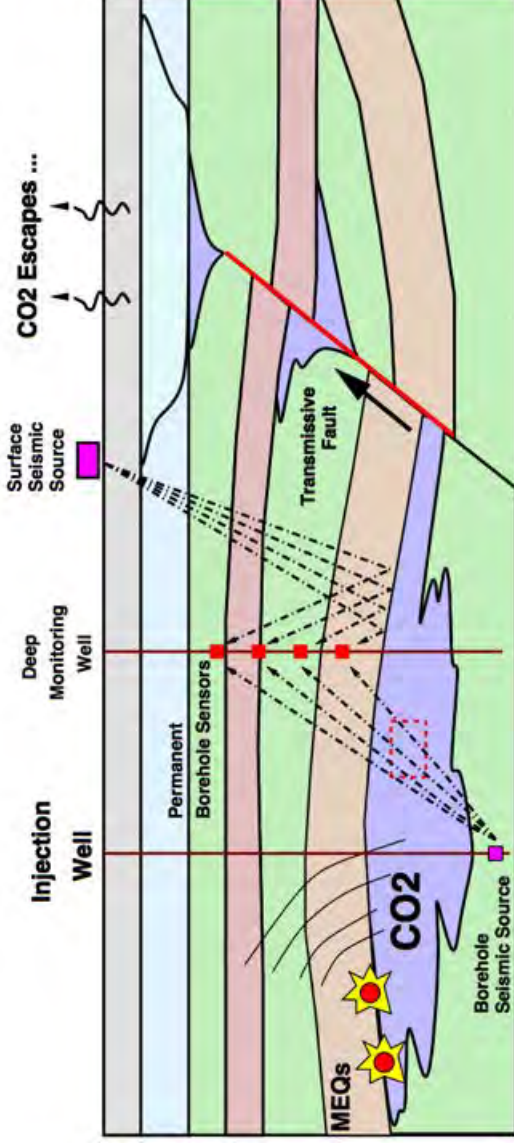
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Stanford



MVA Challenges in Shallow Offshore Environments

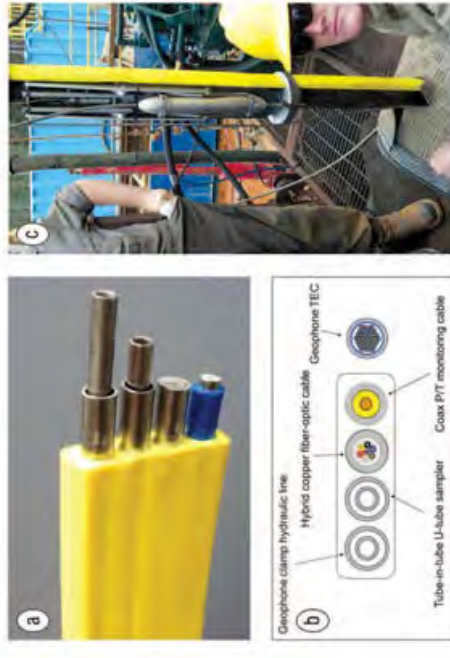
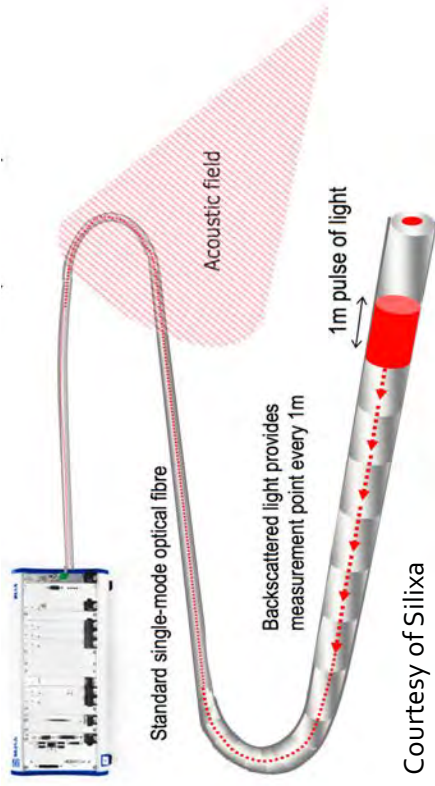


Challenges for GomCARB include

- Need to consider deep CO₂ movement (reservoir), intermediate/shallow leakage, seafloor expression, and water column (+ pipeline?).
- All in the context of a petroleum province with a dynamic seafloor, abundant natural gas seeps, storm impacts.
- Expensive wells (& completion ops) suggests less dependence on borehole monitoring beyond injector.
- Seafloor environment hostile to traditional long-term sensing (as well as costly), particularly for high sensor densities. Consider maintenance.
- Need to monitor seafloor and deep subsurface without direct access besides shallow draft vessel and ROV.
- One plus : Marine 4D simpler/high S/N than land.

Two New(ish) Technologies for MVA : DAS & Persistent Seismic Sources

- **Distributed Acoustic Sensing [DAS]** is a rapidly advancing approach for measuring the seismic wavefield using commercial fibers (SM, telecom)
- Easy to deploy in wells, behind casing, seafloor, 1000s to 100,000s of channels available (big data) over 10+ km
- *Very low cost per "sensor"*: \$/ft for cable
- *Rugged*: handles high/low T, high pressures, aquatic environments.
- Once fibers are there, other sensing modalities simple (DTS, DSS etc).
- **LBNL Strengths**: unique deployment packages, cable modifications, system integration, application domains, processing & inversion strategies.



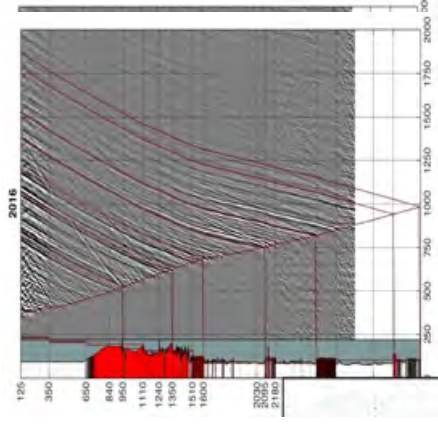
For GCs:

Past LBNL deployments at Citronelle, Aquistore, Otway, CaMI, ADM for VSP (ADM only surface test, rest are borehole)

GoMCarb:

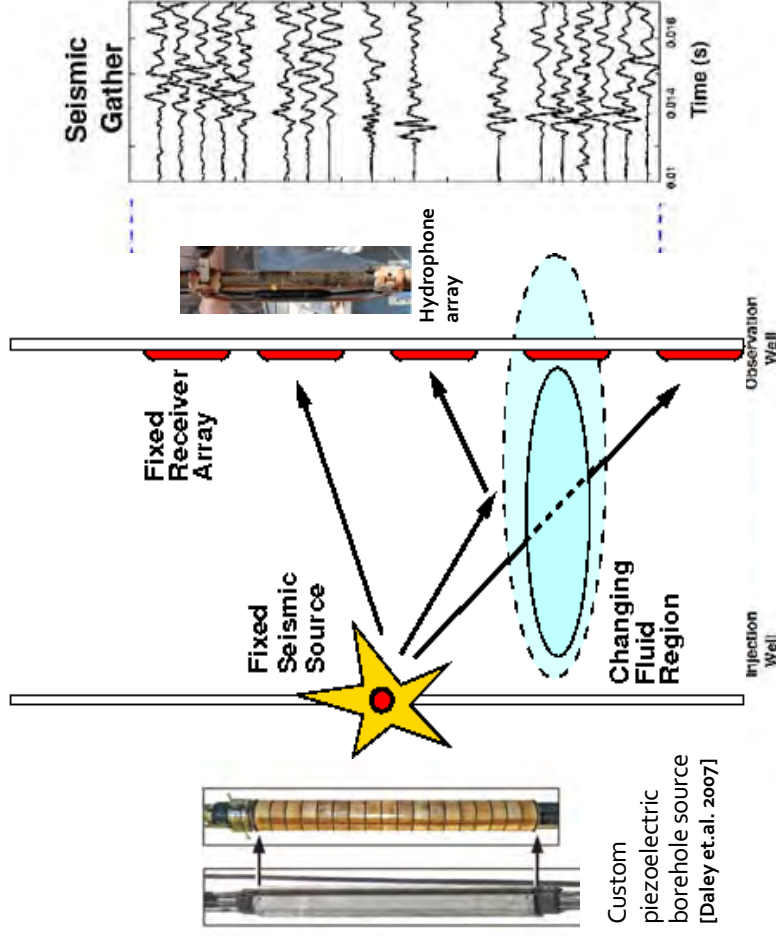
- First time we are considering offshore
- First exploration of seabed
- First exploration of shallow/deep imaging combined

Daley et. al. 2016 (Geop Prosp.), Miller et al. 16, Daley et.al. 2013, (TLE)



Two New(ish) Technologies for MVA : DAS & Persistent Seismic Sources

- Large permanent seismic arrays (DAS) require sources (!).
- Need matching high-temporal resolution measurements in the field.
- For MVA, need sources to illuminate both deep (reservoir), near seabed, and water column perturbations.



Custom piezoelectric borehole source [Daley et al. 2007]

CASSM :

Continuous Active Source Seismic Monitoring

Fixed repeatable source & receiver array. LBNL has worked on piezoelectric and rotary source designs

- Temporal Resolution (< 5 min)
- Precise repeatability (~ 10 ns)
- Stacking $\rightarrow$ Excellent S/N
- Real-time Acquisition
- Borehole & surface sources.
- Deployment to 10,500 ft & 120 C
- Largest deployment 22 S x 72 R
- Moving towards real-time seismic tomography

LBNL/EESA developed and fielded at 12+ sites to date.

GCS tests at Frio 2, Cranfield Phase 3 (borehole), Otway, ADM (surface) [Daley et al. 2007, Daley et al. 2011, Marchesini et al. 2017, Zhu et al. 2018, Zhu et al. 2019]

GoMCARB :

- Opportunity to consider **water column** broadband sources
- Mount near platform for combined surface (shallow/deep) and VSP monitoring?
- Provide time points between 4Ds

Concept :

Integrating DAS + Marine Persistent Sources (CASSM) Near-Offshore MVA

- **Use DAS on the seafloor (and wellbore) as linear seismic array for imaging**
 - Near-surface anomalies (CO₂ leakage), Deep subsurface (CO₂ migration) & microseismic
 - Noise from relevant processes (bubble emission etc).
 - **Ambient noise imaging**
 - Replaces OBS or seafloor hydrophone deployments.
 - Better time resolution than repeat streamer surveys, much cheaper than LoFS using cabled OBS. Also permanent receivers for 4D

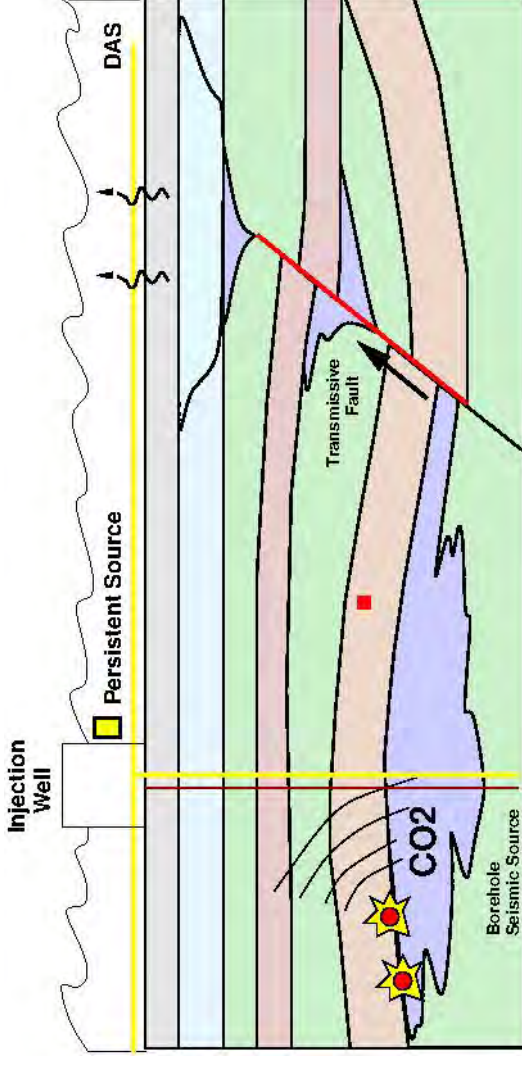
[note : technology also has a potential role for pipeline monitoring in future tests]

- **Use fixed seismic source in the water column for high repeatability imaging (Marine CASSM)**

- highly repeatable timelapse monitoring of the near-seabed sediment, water column, and deep subsurface.
- Considering novel swept source with resonance for combined reflection/transmission/VSP.

- **Combined system for seismic MVA with high (minute) time resolution in marine environment**

- Unique aspect is combination of shallow (leakage) and deep (reservoir) targets.
- Challenges are understanding deployment challenges for system elements

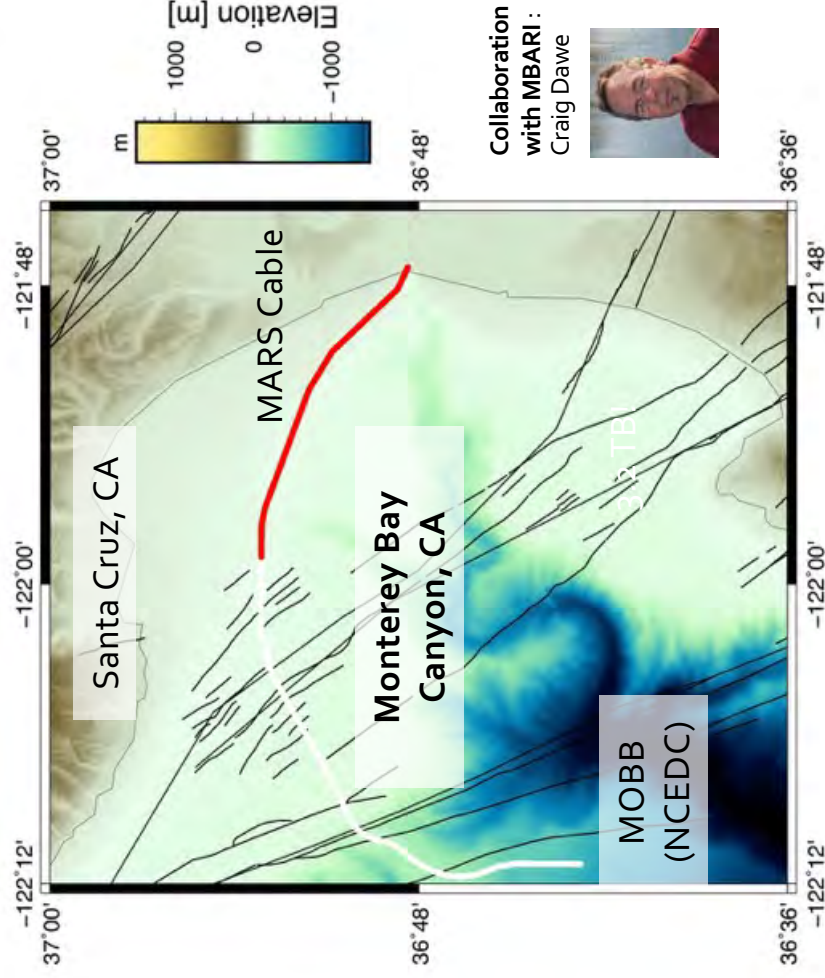
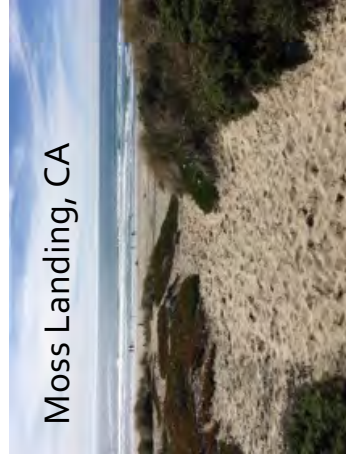


LBNL MVA Tasks (5 years)

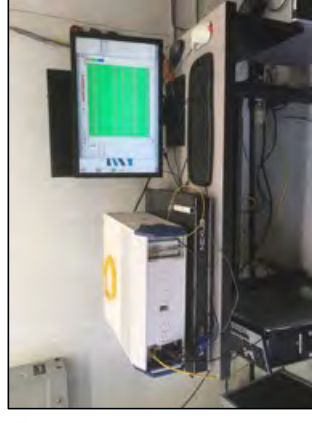
- **Task 1 : Design and Modeling Stage**
Design and modeling of the proposed source & integrated source/DAS system in a marine environment for CO₂ leakage tracking.
- **Task 2 : Source Construction and Laboratory Tank Testing**
Construction of prototype source/tank tests. Evaluate for (a) water column, (b) near-seafloor, and (c) deep subsurface imaging targets.
- **Task 3 : Analysis of Seafloor DAS Dataset**
Analysis of a DAS dataset acquired on an existing seafloor cable to examine noise characteristics and response in a near-shore environment. (datasets of opportunity!)
- **Task 4 : Broad MVA Support**
Collaborate with TX BEG more broadly to develop fit-for-purpose monitoring suited for the near offshore environment.
- **Task 5 : Design and Execution of a Shallow Water Field Test**
Near-offshore field test. Similar water depths to pilot. Possible short N₂ bubble release along a DAS profile illuminated by the persistent source, designed to test monitoring (a) near-seafloor subsurface velocity perturbations, (b) acoustic noise from release (c) changes in acoustic transmission in the water column.
- **Task 6 : Evaluation of Fiber Optic Cables in the GoM Available for DAS**
Our last task is evaluation of existing fiber optic cables in the GoM which might be leveraged for DAS recording as part of a near-shore GCS monitoring network.

DAS on Offshore Seabottom Cables? MBARI Evaluation Dataset (Task 3)

- A dataset of opportunity – 1st offshore cable DAS dataset (that I know of) processed for seismic.
- Umbilical cable to MOBB – offshore tethered observatory
- Explore passive signals recorded with ~20km MARS cable with Silixa iDAS at Moss Landing (MBARI headquarters)



Collaboration
with MBARI :
Craig Dawe

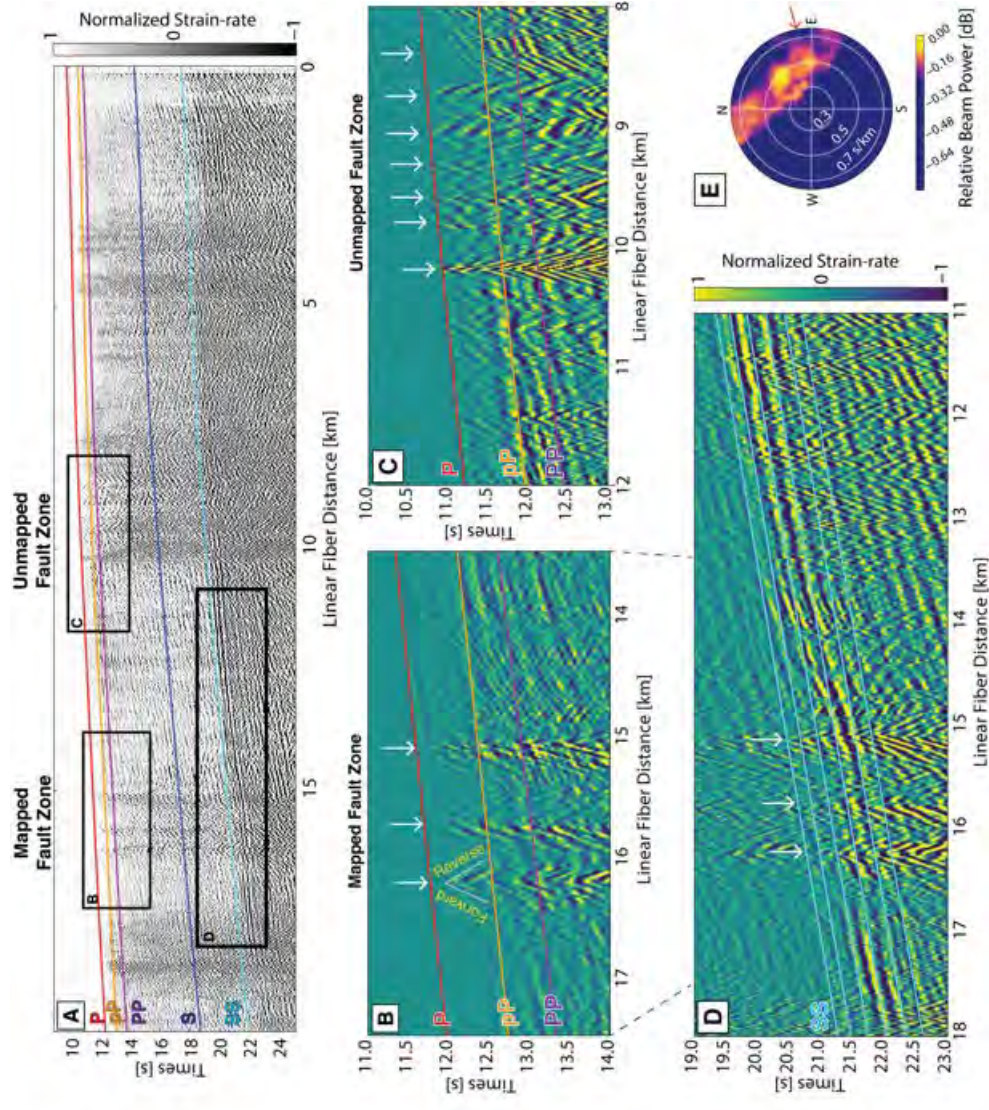


Detecting Seismicity & Faults Using Marine Dark Fiber

- Several on-shore EQs detected during short deployment. M3.4 in Gilroy (~30 km).
- Signal cleaner than on-shore recordings for local events.
- Smaller regional events (~M2) also detected.
- Body-wave scattering features which may correspond to offshore fault systems
- Fault locations validated on one profile using existing USGS seismic lines.
- Will be a powerful tool for probing near- offshore fault systems & **induced seismicity**.
- Densest OBS (ever?)

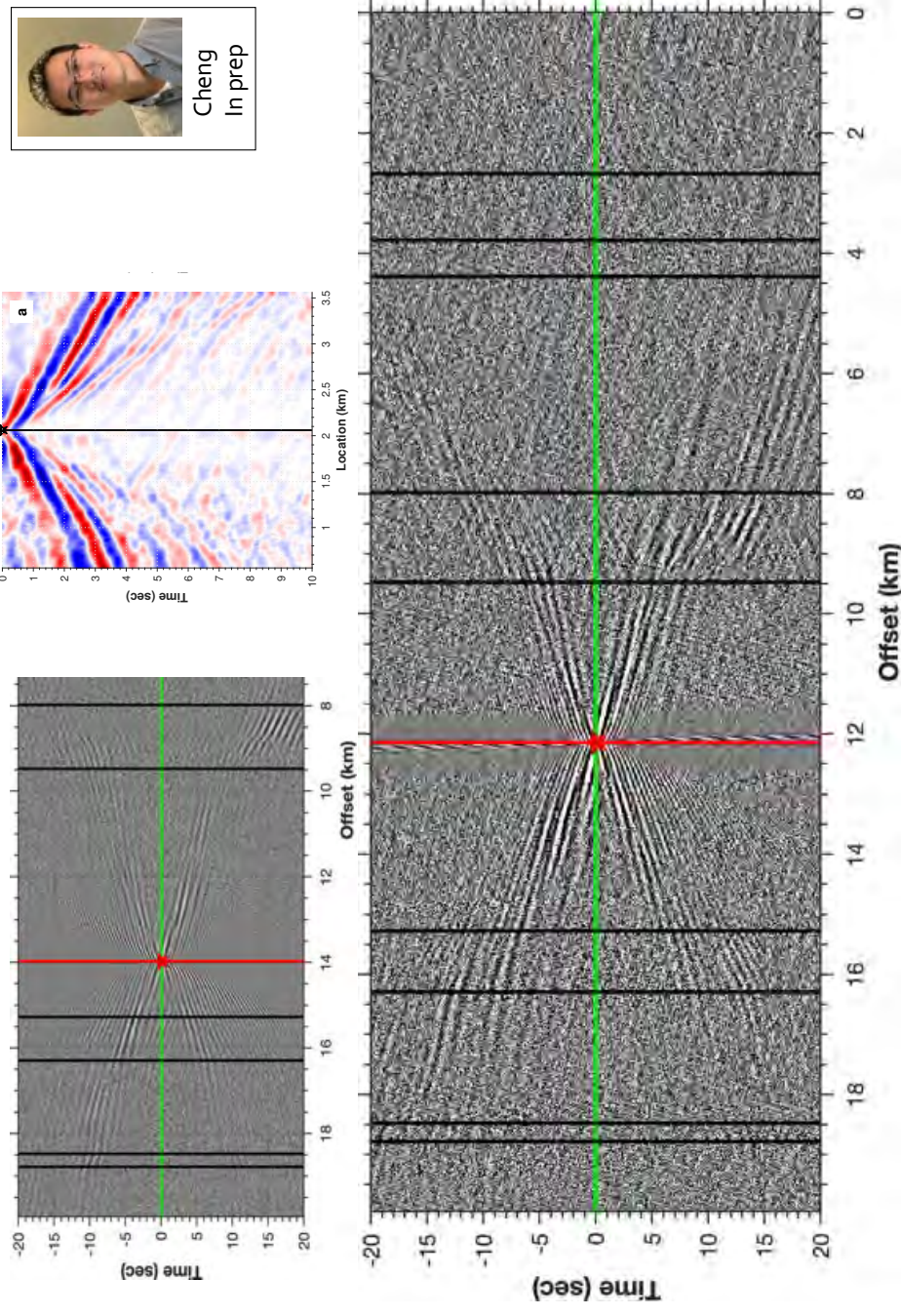
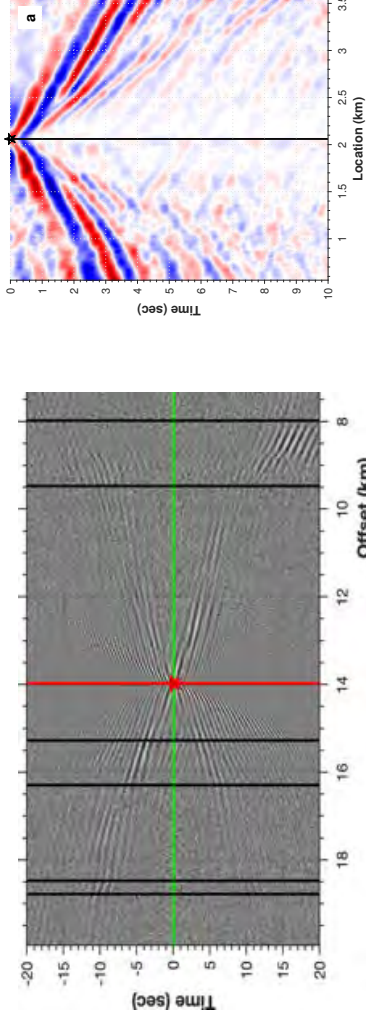


Lindsey et al.
2019



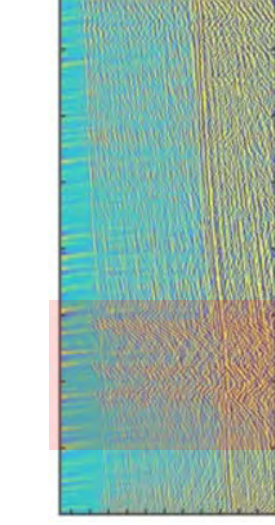
Ambient Noise Analysis for Offshore Structure?

- Since no CASSM source was deployed in this test, analyzing ambient noise Green's functions for evaluation of imaging.
- Approach utilizes cross-correlation of noise recordings to replicate what an active shot looks like – limited by noise spectrum & recorded modes.
- Targets are velocity variability and scattering features from seafloor fault zones.
- Computed 1000 gathers on sequential 20 m src points
- High-quality dispersive Scholte waves – perfect for Vs inversion.
- Evidence of Scholte wave scattering within fault zones – a potential imaging target.



Scholte Wave Velocity Inversions : Seafloor V_s Variability

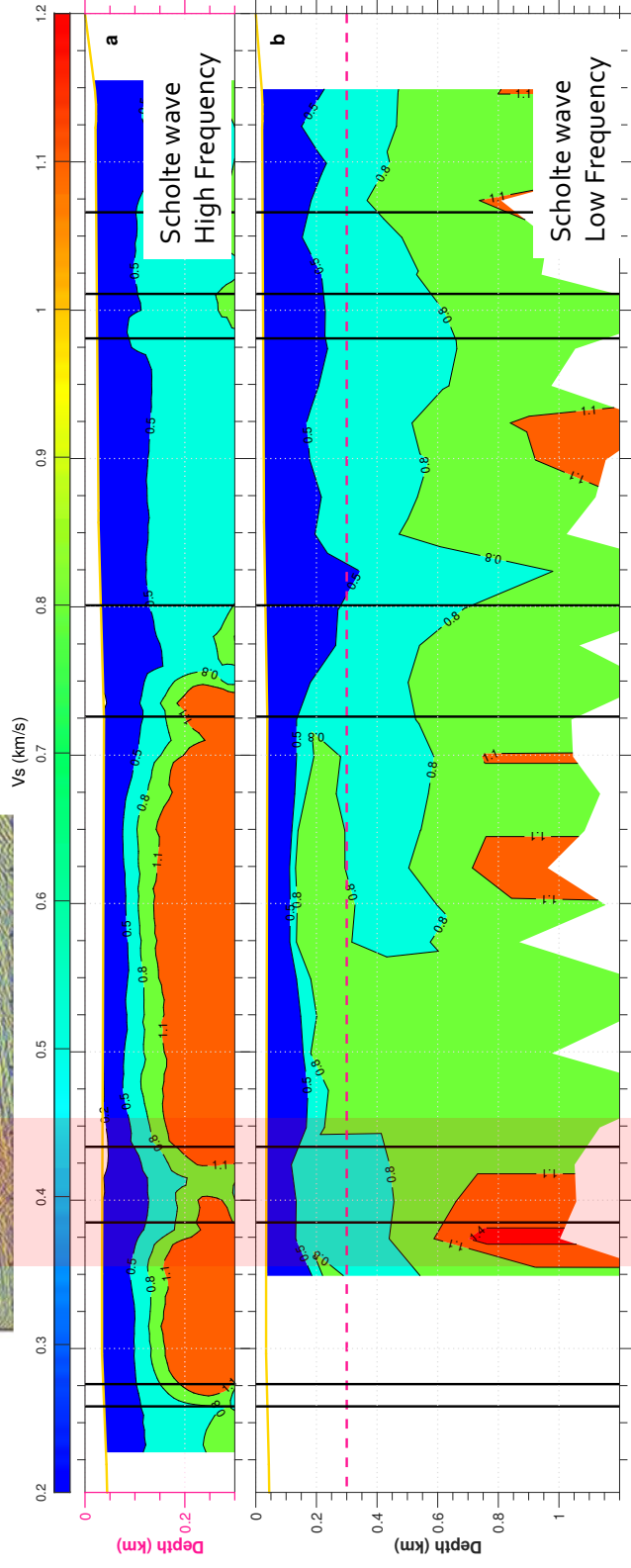
- Ambient noise gathers inverted for 1.5 D shear wave velocity (V_s) profiles in two frequency bands.
- Provide V_s model for near-surface structure from 0-250 m (high resolution) and coarser resolution to 1.2 km.
- Comparison of scattering observed from regional EQ (top) to Scholte wave velocity inversion (two frequency bands).
- Low V_s zone and reflection discontinuities **consistent**.
- Further verification of fault zone ID.



Regional seismic event showing scattering features.

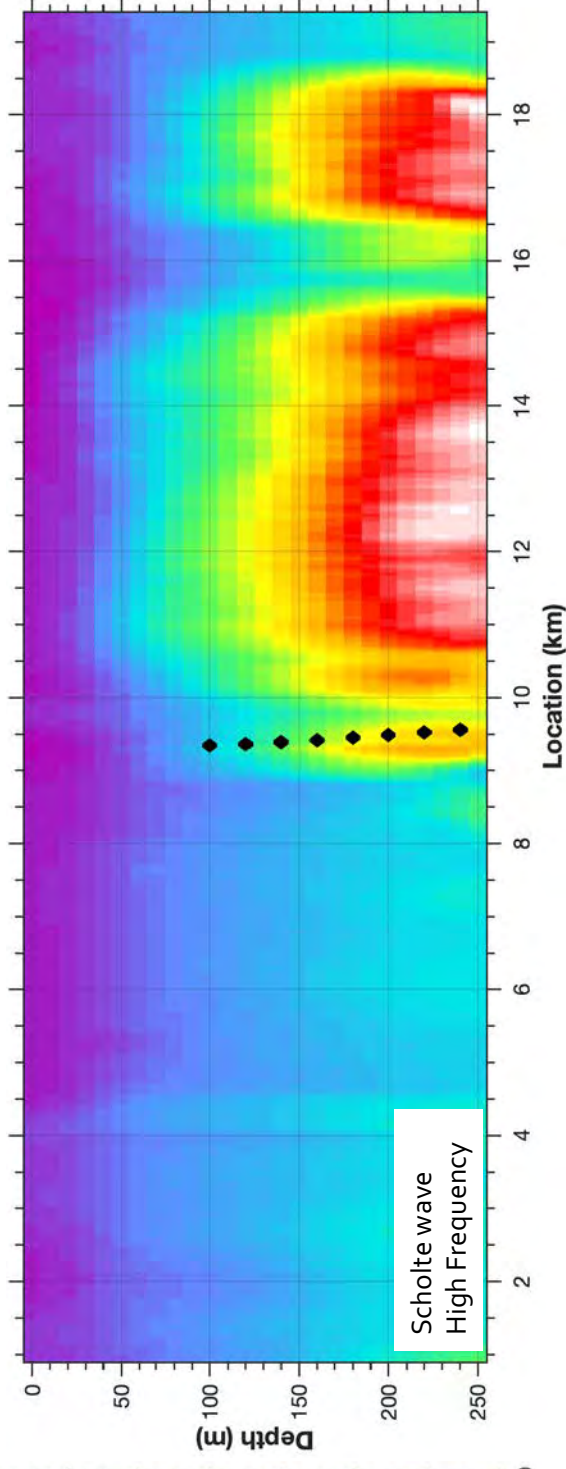
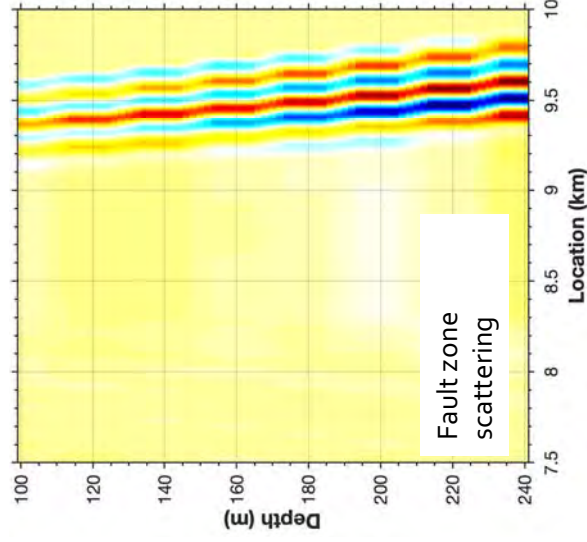
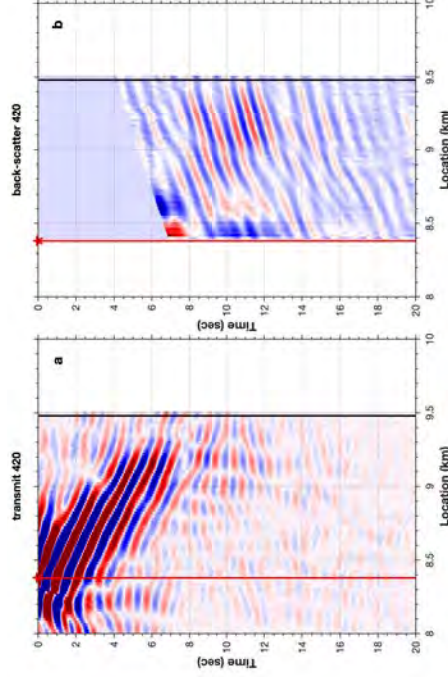


Cheng
In prep



Scholte Wave Scattering for Fault Imaging?

- Observed significant scattering of Scholte waves from fault zones in ambient noise Green's functions.
- Extracted scattered wavefield and performed 2D migration in XY plane, wavelength to depth-conversion using Vs model.
- Provides higher resolution profile of the fault plane, potential *possibilities for timelapse imaging of fluid perturbations.*



Moving Forward

- Initial seafloor DAS data seems to have potential for seismic recording
 - Demonstrated regional EQ recording
 - Ambient noise imaging of seafloor velocity structure at a range of resolutions
 - Identification and imaging of seafloor faults using scattered surface waves
 - Characterization of oceanic noise levels.
- Exploring how ambient noise approaches might be utilized in offshore monitoring context.
- Considering source & DAS cable design in the context of initial offshore DAS data (offset, install).
- Exploring options for acquiring offshore GoM DAS cable dataset for continued task 3 – temporary installation of near-shore cable.
- Developing persistent multi-purpose source design for water tank testing (Task 2) – work delayed by (1) lab build at Rice (finished in February) and now (2) COVID.
- Considering DAS design in context of possible “model” pilot sites



Thanks For Listening!

This work was supported by the GoMCarb Project funded by the Assistant Secretary for Fossil Energy (DOE), Office of Clean Coal and Carbon Management, through the National Energy Technology Laboratory (NETL), and by Lawrence Berkeley National Laboratory under Department of Energy Contract No. DE-AC02-05CH11231 .



Laboratory Directed
Research and
Development Program

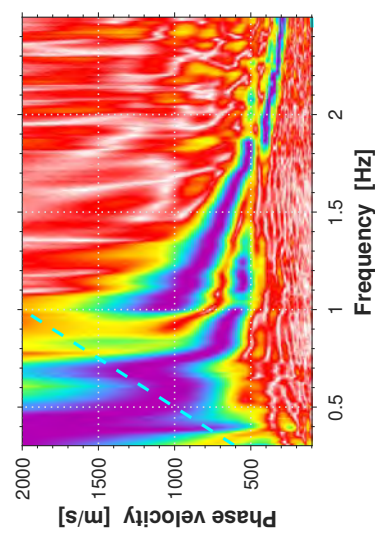
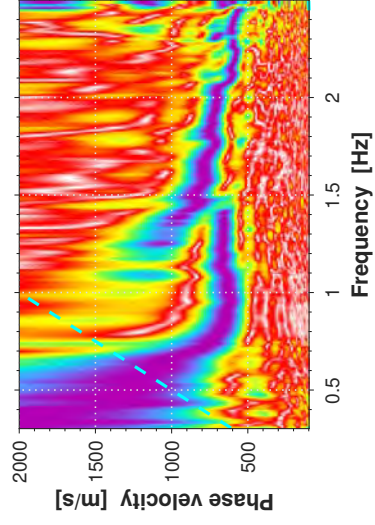
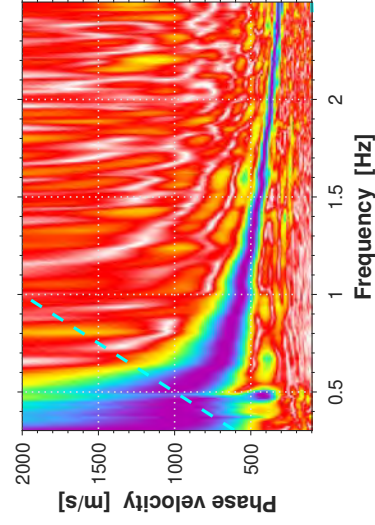
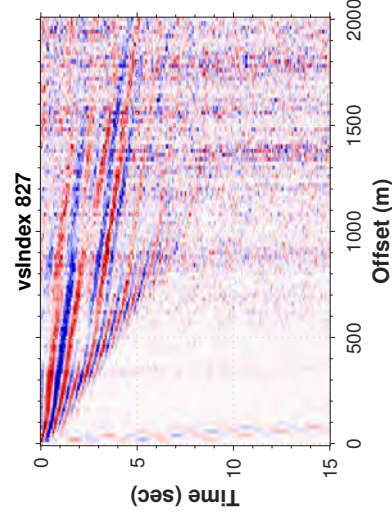
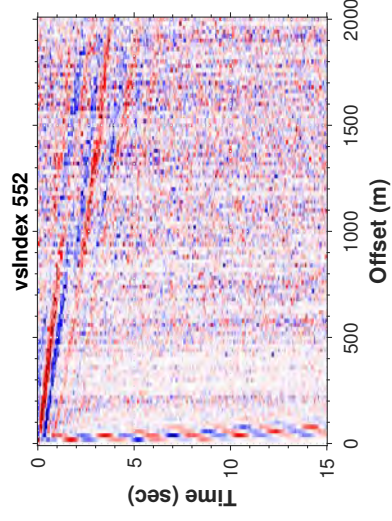
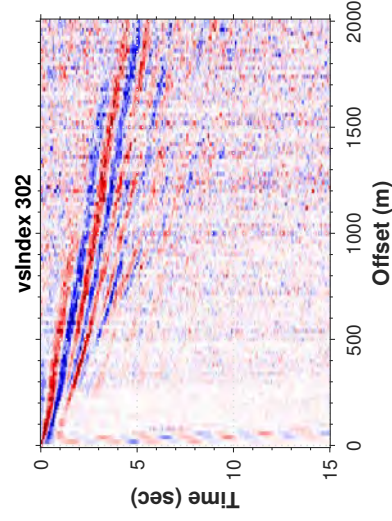
MBARI Acquisition



BACKUP

Ambient Noise Analysis for Offshore Structure?

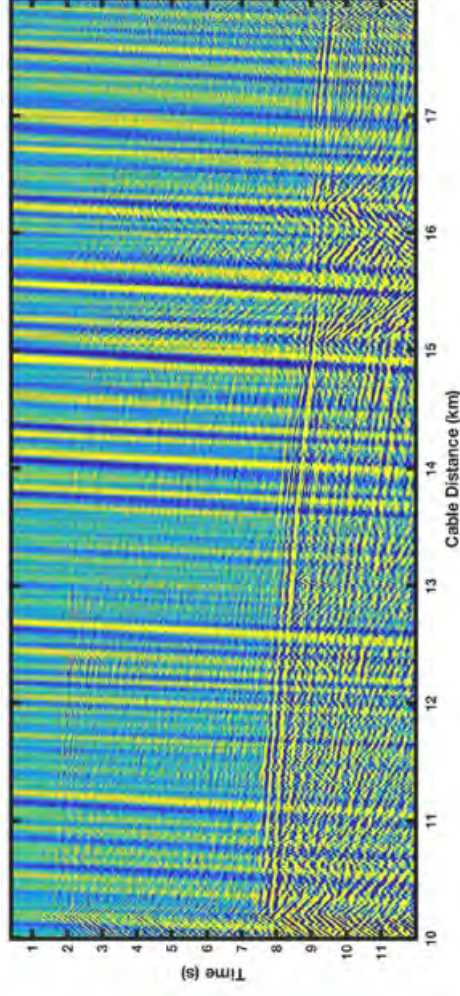
- Since no CASSM source was deployed in this test, analyzing ambient noise Green's functions for evaluation of imaging.



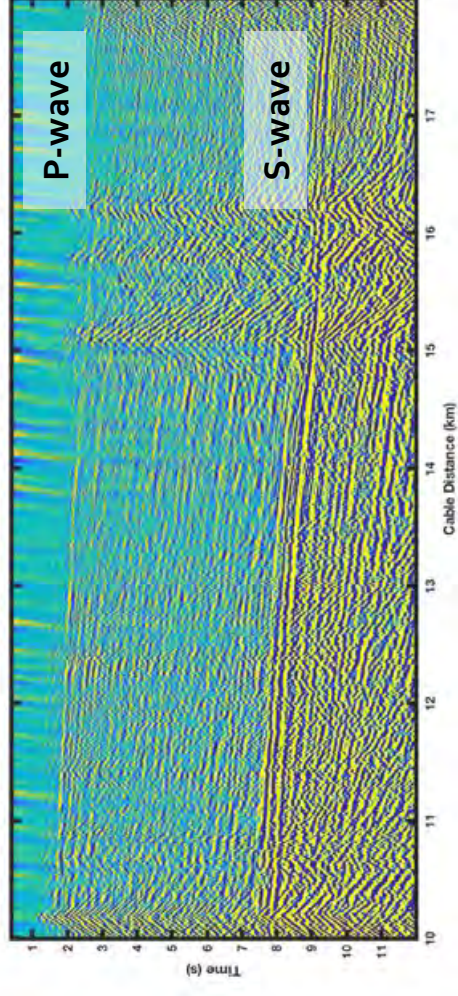
Results from Last Year : Detecting Seismicity Using Marine Seabed Fiber & DAS



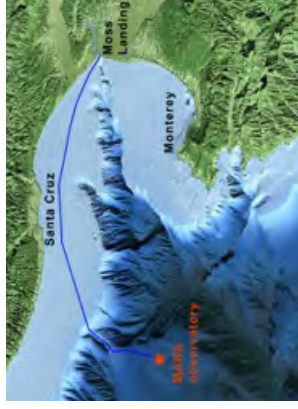
- Several on-shore EQs detected during short deployment. M3.4 in Gilroy (~30 km). Also picked up several smaller (M2) events, same hypocenter.
- Signal cleaner than on-shore recordings for local events.
- Wave motion (primary/secondary microseisms) overprint – easily removed.
- Scattering features which may correspond to offshore fault systems?
- Will be a powerful tool for probing near- offshore fault systems & potential **induced seismicity**.



[2 m channel spacing, 10 m gauge, 20 km array, 10 k channels, 500 hz recording,
Densest OBS recording ever?]



Ocean bottom seismology is a costly endeavor



Ocean Bottom Seismometer Deployments

NSF 2016 OBS Pool = 247 (37% SP)

European 2014 OBS Pool = 450 (71% SP)

OBS battery life = 14 month +/-6 month

Data Delay (seconds to months)

Annual costs?

Cabled Observatories

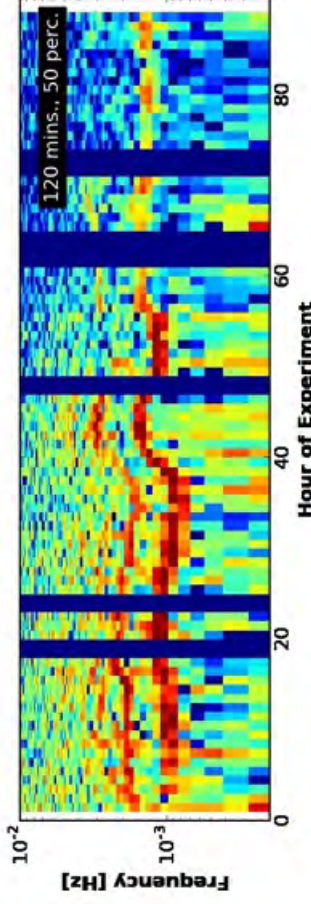
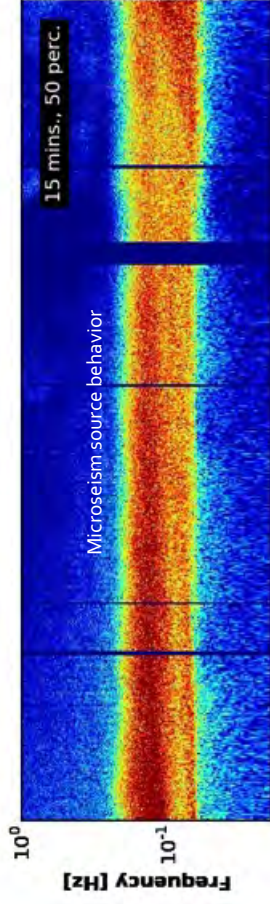
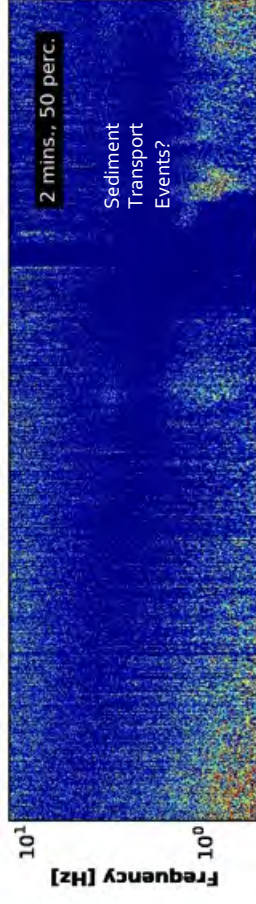
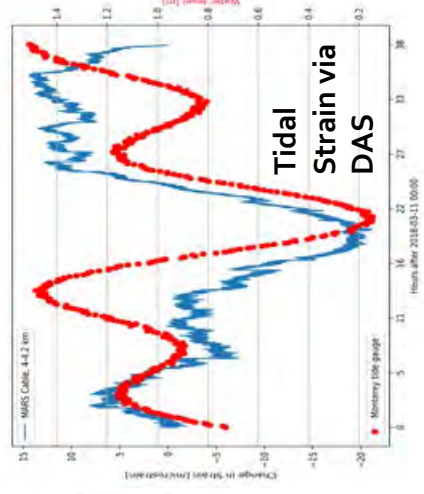
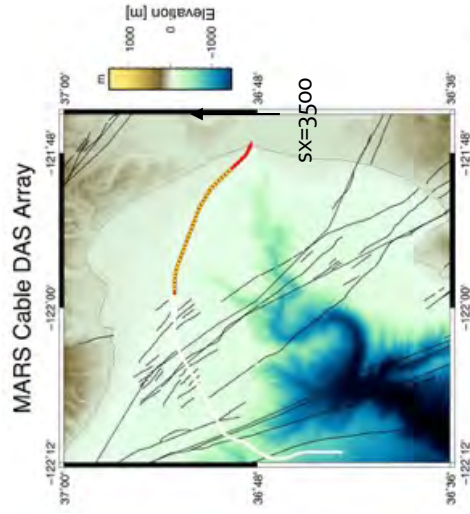
MARS Cable Laying 2002 – 2007

\$11.75M investment

2 GB/s data transfer over 52km

Oceanographic Process Observations via Seafloor DAS?

- Surprisingly broadband (mHz to 100 Hz)
- Signal of oceanic wave processes down to the mHz range (1000 s)
- Can see microseism source behavior, infragravity waves (long period swell groups).
- HF noise which might be useful for imaging.
- Storm & tidal signals.
- A possible GCS target, seafloor bubble emissions
- Ambient noise from platform another possibility, or deformation



Lab for future tank testing



TASK 4.0: Monitoring, Verification, and Assessment (MVA)



P-Cable Update

High-resolution 3D marine seismic applications for offshore CCUS

TIP MECKEL

GoMCarb Task 4 – Monitoring, Verification, and Assessment (MVA)

SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

Problem

How can we evaluate the subsurface features and processes in the overburden between an injection reservoir and the seafloor?

- 1) Pre-injection characterization - identify and reduce risk (seal, fault)
- 2) Monitoring during injection - conformance, retention
- 3) Post-injection assurance - end of project & liability transfer



Approach

Identify a location for testing some combination of technology and geologic target at an analog injection site to provide insight into capabilities and optimization strategies.

Collect dataset: design, acquire, process, interpret.



Approach:

High-resolution 3D Seismic

Closely spaced short (25m) streamers allows for dense array and higher horizontal resolution ($\sim 6 \text{ m}^2$).

Recovery of high frequencies for relatively shallow intervals (< 1 km) allows for higher vertical resolution (2-5 m).

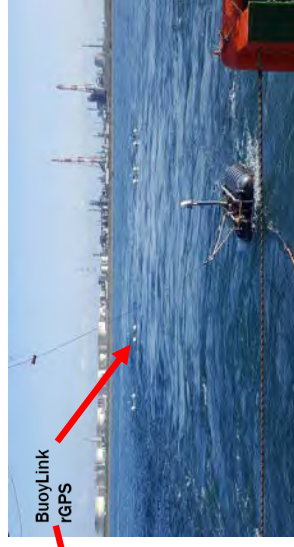
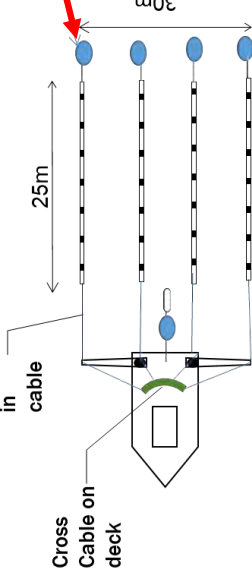
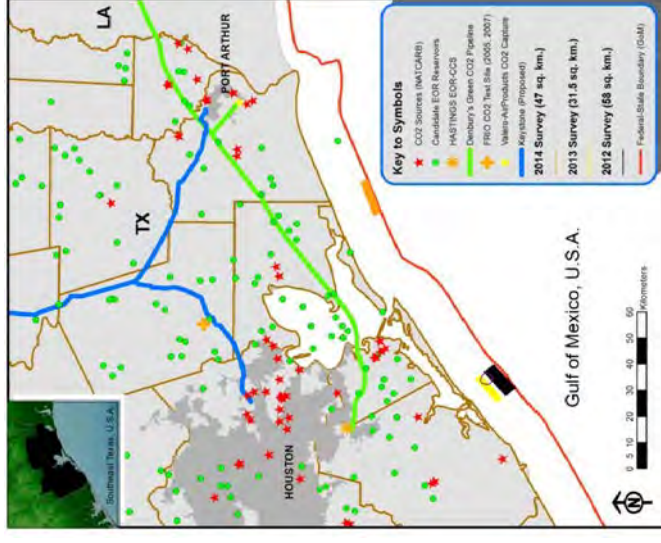
Technique developed and tested under prior DOE funding: 3 surveys in the inner shelf Gulf of Mexico (2012, 2013, 2014).

Technique deployed at an active injection site at Tomakomai Project in Japan (2018).

Meckel and Trevino, 2013, GHGT-12

Meckel and Mulcahy, 2016, Interpretation

Meckel and Feng, 2018, IJGC



Subtask 4.1: MVA Technologies and Methodologies

This subtask will **identify a suite of MVA technologies and methodologies** for large-scale storage projects and evaluate suitability for the unique characteristics of the environments expected to be encountered in the region. Adaptations of existing, and novel-technologies will all be considered.

Subtask 4.1.1.1 Geochemical Monitoring of Seabed Sediments.

Subtask 4.1.1.2 Geochemical Monitoring of Seawater Column.

Subtask 4.1.3 UHR3D Seismic. The Recipient will **refine concepts** related to utilization of novel UHR3D (ultra-high resolution 3D) seismic for characterization and monitoring of injection reservoirs and overburden.

Subtask 4.1.4 Distributed Acoustic Sensors.

Subtask 4.1.5 Pipeline MVA.



Refine HR3D concepts for characterization and monitoring

Use pre-injection survey to de-risk sites: faults and fluids

Draft Manuscript: *Use of high-resolution 3D seismic data for imaging the geologic overburden above typical prospective CO₂ storage sites offshore Texas, U.S.A.*

Unique processing workflows using multiple software strengths: optimal imaging

Merging conventional (deep reservoir) seismic with HR3D (shallow overburden): single data product

Potential for AUV deployment for streamers.



Subtask 4.2: Plans for Testing of MVA Technologies

This subtask will incorporate the knowledge and lessons learned from previous and current offshore storage efforts (including international collaboration) to develop plans for testing of MVA technologies to support the most likely offshore geologic storage scenarios.

Based on the lessons learned from this subtask, a summary of MVA lessons learned will be developed in collaboration with the other awarded project from FOA1734 to ensure safe, long-term, economically viable carbon storage in offshore environments.

Subtask 4.2.1 A **priority list for MVA technologies** and their testing methods will be developed.

Subtask 4.2.1.1 High-resolution 3D seismics (HR3D). This subtask will **assess locations and design modifications** for deploying HR3D technology for MVA. Sites initially evaluated will be in the Texas State waters.

Subtask 4.2.1.2 Geochemical monitoring in the Seawater Column.



Assess locations and design modifications

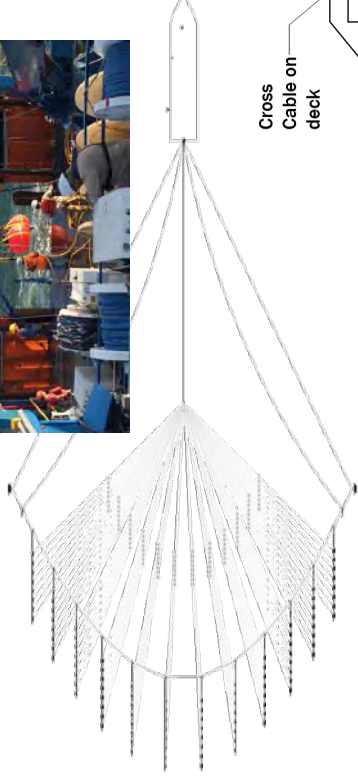
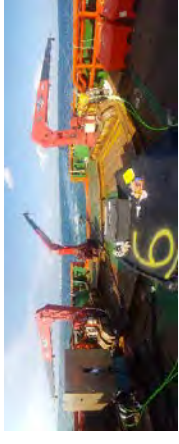
LOCATIONS:

1. Shallow salt dome (return to San Luis Pass area) – understand geology of **salt flank seal**.
 - Inner-shelf setting typical of near onshore and near offshore prospective storage sites on salt flanks.
 - Compare to existing field studies (La Popa, Mexico)
2. Fluid migration in Auger Basin – **Natural hydrocarbon seep setting**; Deep overpressure and migration. Lots of existing published research to leverage.
3. Taylor Energy **MC20 site** – Worst case scenario for CCS? **Leaky well site**; Accessibility?
4. Other sites



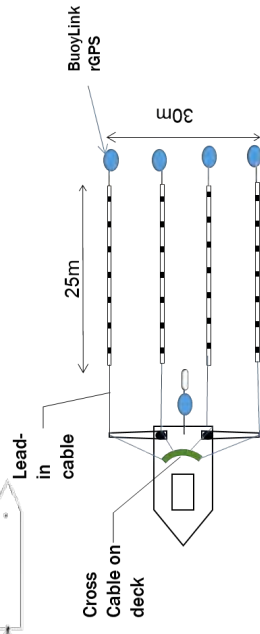
Assess locations and design modifications

DESIGN MODIFICATIONS:



Full array to compact array

Outrigger boom design



Positioning: Tail buoy design and construction

Hardware: cable voltage, GPS

Data stream management



Subtask 4.3: Plans for Testing of MVA Technologies

Subtask 4.3 Testing MVA technologies

This subtask includes all activities to **permit, contract a vessel, and acquire, process and interpret two to three (2-3) HR3D seismic datasets** for CO₂ storage analog sites identified in Subtask 4.2.1.1.

Operational considerations

Research partner TDI-Brooks using vessel *R/V Brooks McCall*.

Vessel currently operational, but conversations regarding scheduling are ongoing.



Status

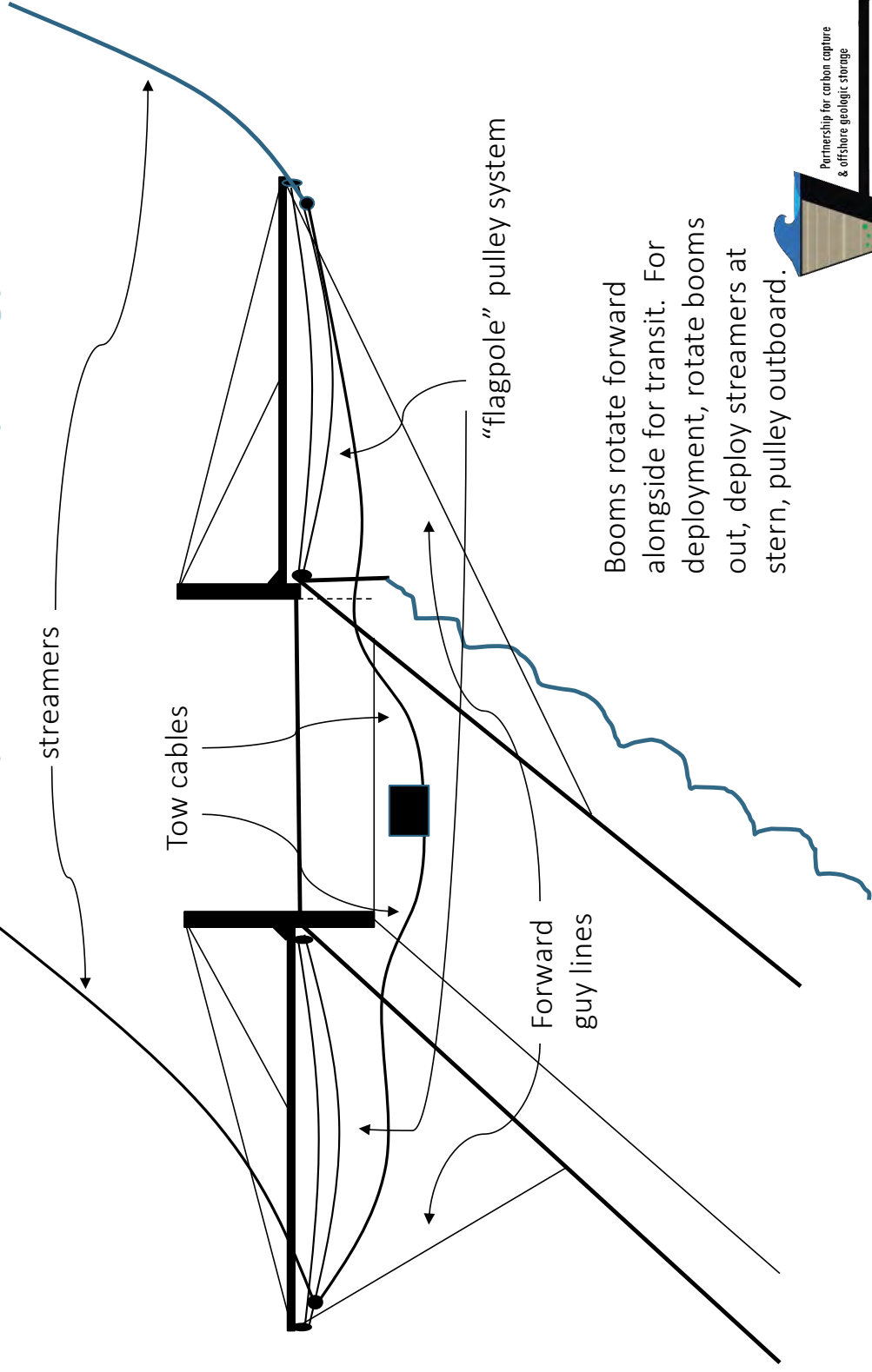
Currently identifying optimal location for survey

- Technology test – positioning, new tail buoy design.
- Target – leverage prior research and knowledge at a site
 - Geologic fluid system
 - Fault setting
 - Well setting



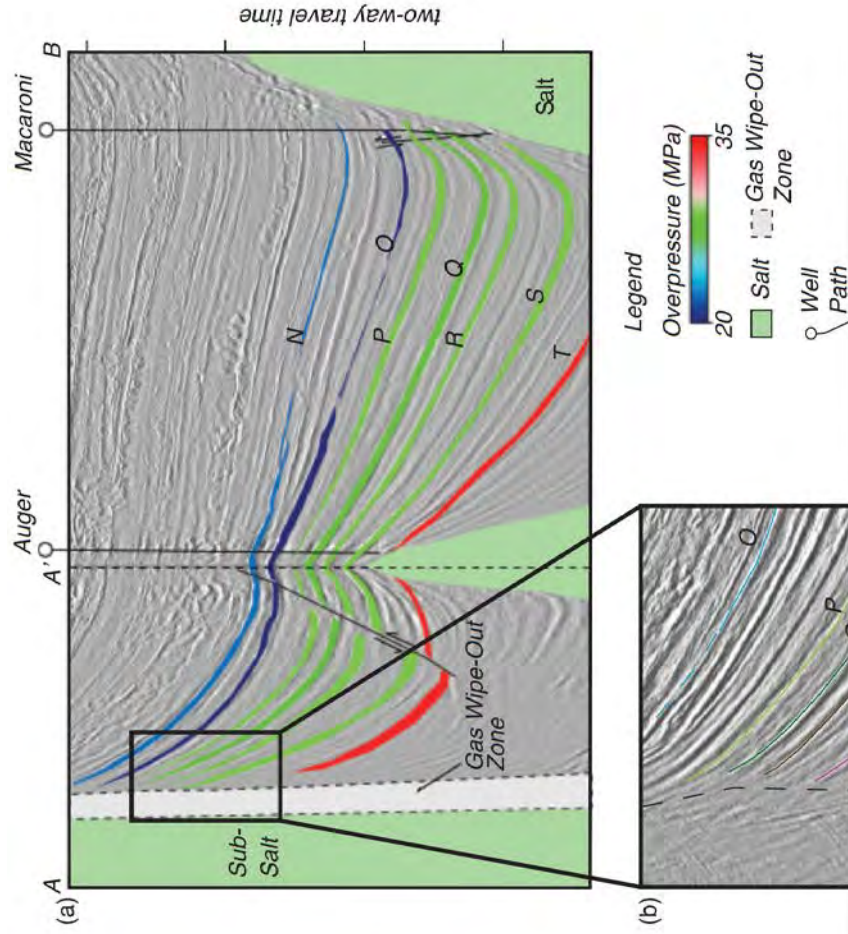
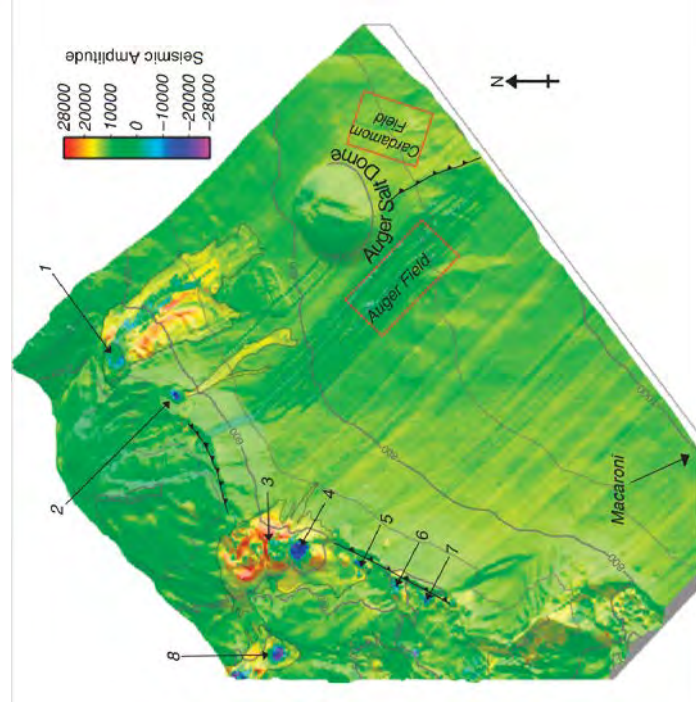
Discussion

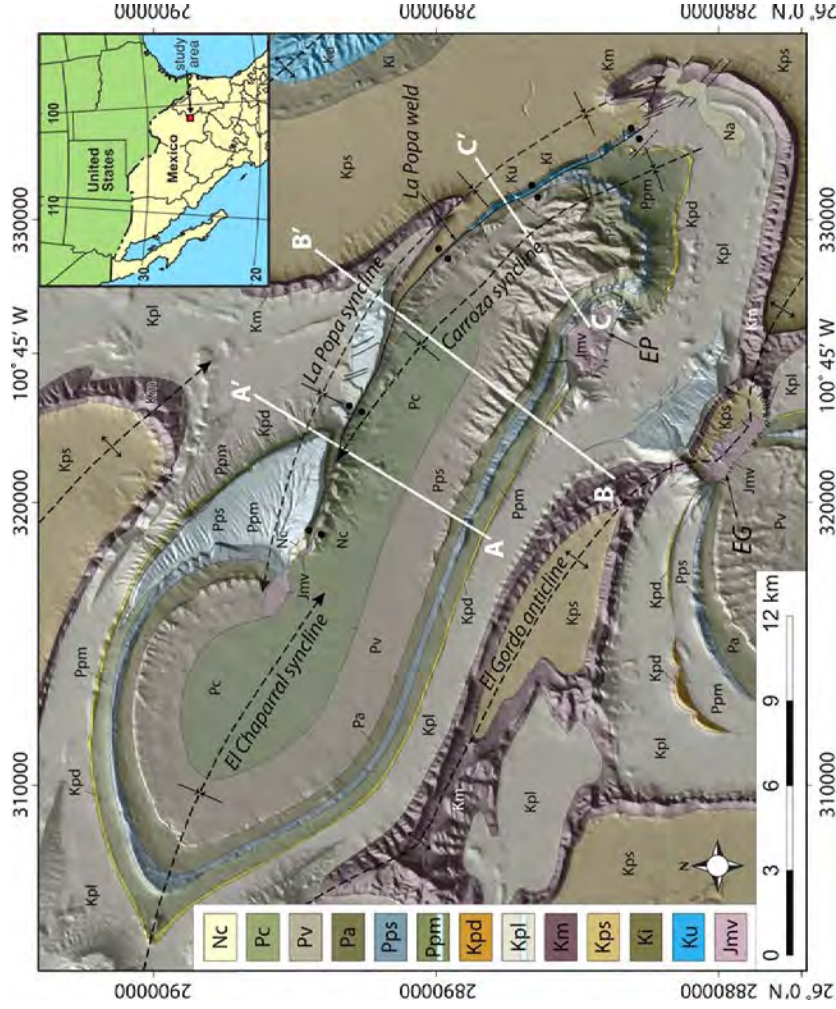
Vessel



Booms rotate forward
alongside for transit. For
deployment, rotate booms
out, deploy streamers at
stern, pulley outboard.

Auger Basin setting





Near-salt deformation in La Popa basin, Mexico, and the northern Gulf of Mexico: A general model for passive diapirism

Mark G. Rowan; **Timothy F. Lawton**; Katherine A. Giles; Robert A. Ratliff

AAPG Bulletin (2003) 87 (5): 733–756.

<https://doi.org/10.1306/01150302012>

Taylor Energy MC-20 Site

Analog for worst-case scenario for CCS

The longest oil spill in U.S. history

Destruction of a **Taylor Energy oil platform** during Hurricane Ivan.

This resulted in between 25 and 28 leaking wells being buried beneath the sea floor, approximately 475 feet (145 m) below the surface.

BSSE Enforcement



<https://www.bsee.gov/newsroom/library/incident-archive/taylor-energy-mississippi-canyon/ongoing-response-efforts>

CO₂ Transport and Delivery

Progress for the Infrastructure Subtask

Darshan Sachde, PhD
Katherine Dombrowski, PE
Ray McKaskle, PE
Joe Lundeen, PE

Trimeric Corporation
Task 5 - Infrastructure



SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

Disclaimer

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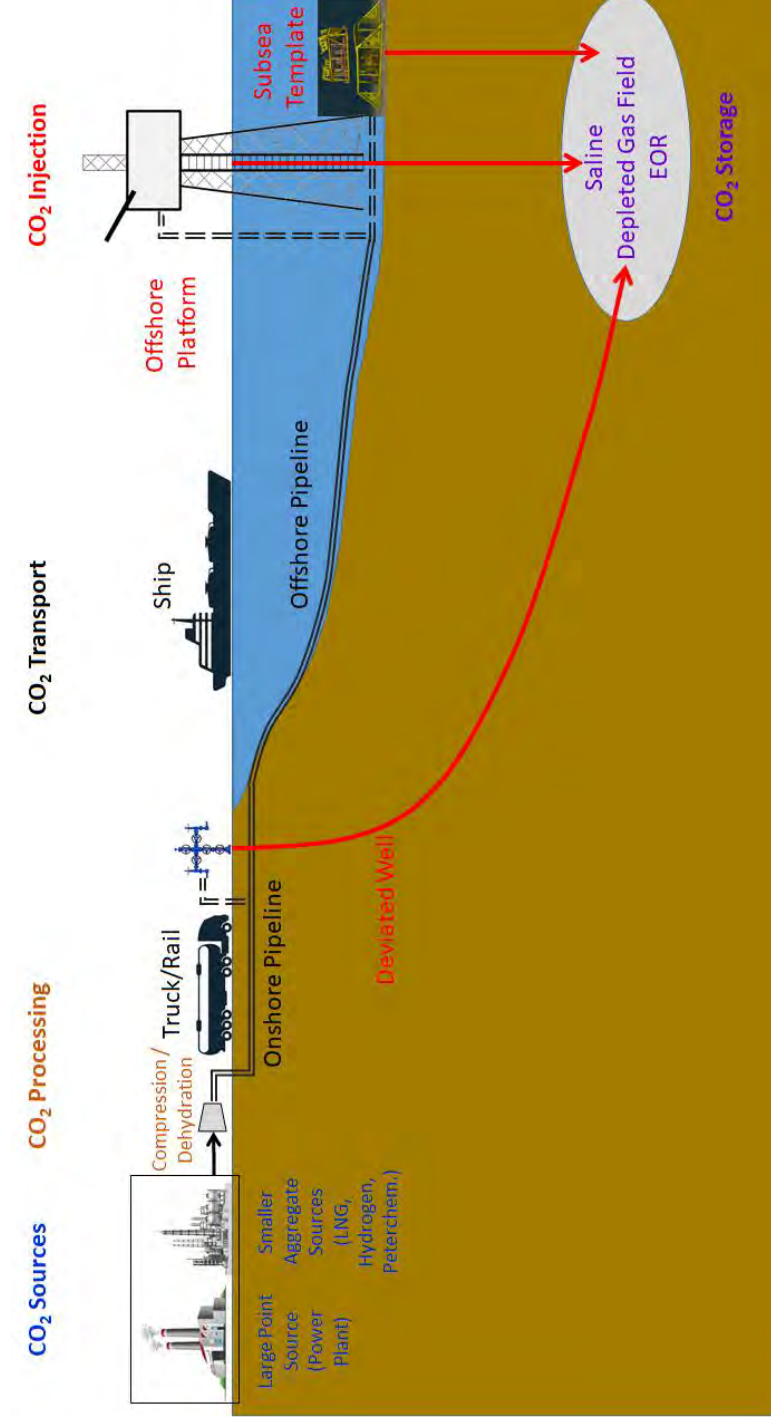


Background

- Task 5: Infrastructure, Operations & Permitting (Trimeric, Lamar U., Aker)
 - Identify/evaluate existing infrastructure (pipelines, wells, platforms) for re-use
 - Feasibility of subsea templates in GoM
 - Risk assessment of early stage CO₂ transport operations (truck & barge)
 - Generate source-transport-sink networks for scenario optimization
 - Use analog sites (e.g., High Island area) to develop methods and analysis
- Trimeric
 - We provide Chemical and Process Engineering services to industry, government agencies, and consortia
 - 18 Chemical Engineers
 - Founded in 2003
 - Austin / Buda, TX location



Outline of Near-Offshore Storage



Infrastructure Re-Use Assessment



Infrastructure Re-use

- Wells, Pipelines, and Platforms for Oil and Gas Production = Potential Re-use Targets
- Goals:
 - Develop screening criteria to assess the scale of the opportunity
 - Identify high priority opportunities for more detailed assessment
 - Identify data gaps/needs/challenges
- For today's presentation – Focus on Pipelines as an example
 - Represent a high value re-use opportunity
 - Represent general challenges of re-use

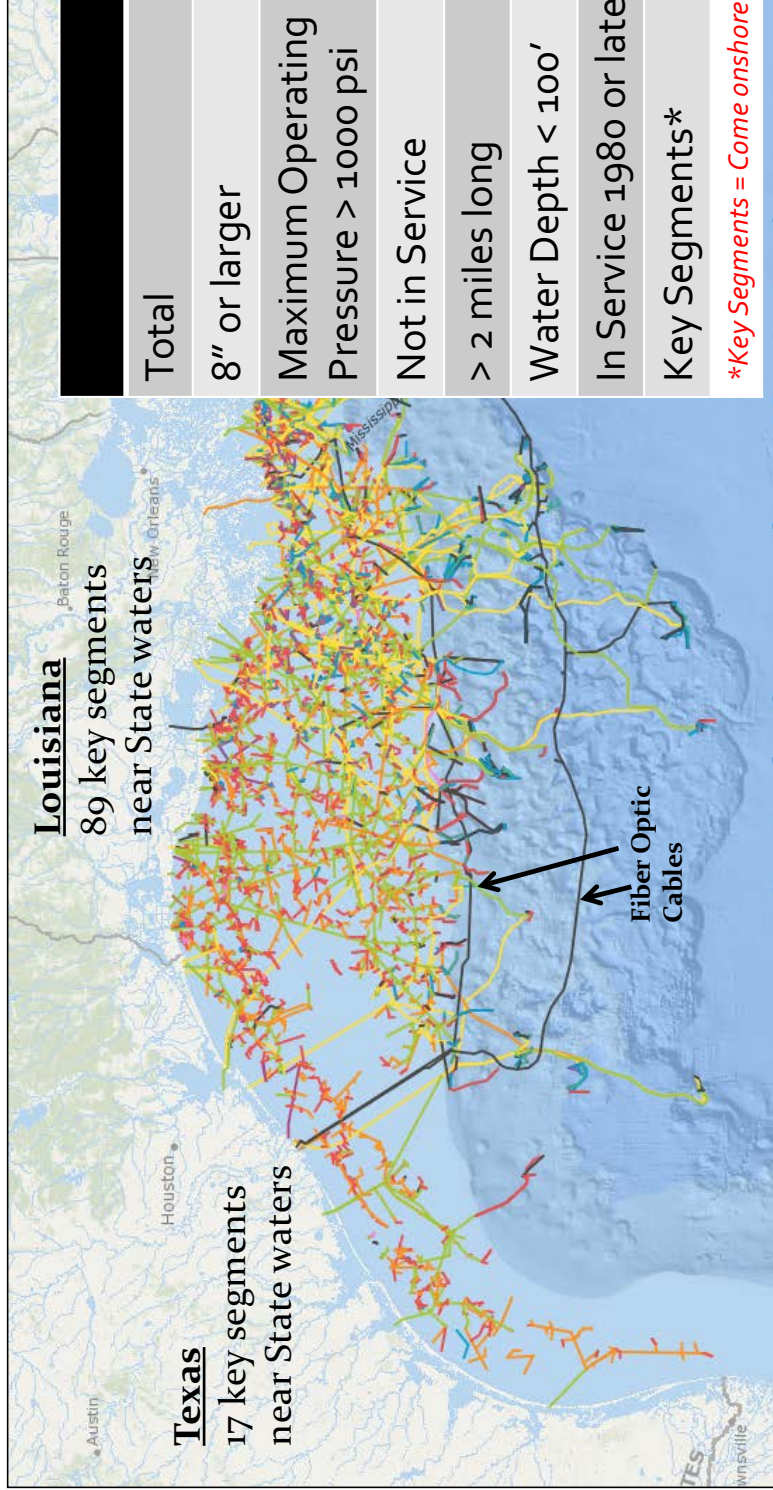


Pipeline Re-Use: Phase 1 - Screening

- Scope:
 - State and Federal Waters
 - Texas and Louisiana Coastline
- Screening Criteria
 - Age
 - Pressure Rating (keep CO₂ in supercritical state)
 - Diameter
 - Water Depth
 - Length
- Darrell Davis – O&G Industry – Lead on this effort



Pipeline Opportunity: Federal Waters



Sources: BSEE/BOEM
Prepared by Darrell Davis for Trimeric Corporation

u l f o f M e x i c o



	# Segments
Total	20,274
8" or larger	4,614
Maximum Operating Pressure > 1000 psi	3,875
Not in Service	1,927
> 2 miles long	951
Water Depth < 100'	520
In Service 1980 or later	355
Key Segments*	11

Pipeline Re-Use : Phase II - Workflow

- Goal: Develop framework to assess specific lines for re-use
- Industry Input
 - Operator: Provided Detailed Pipeline Evaluation Criteria
 - Broker: Useful life of pipelines up to 85 years
- Review Individual Pipelines for Public Data
 - Decommissioning procedures
 - As-Built/Survey Drawings
 - Leak/repair records
 - **Identify Lines for “Case Study” or deeper dive**

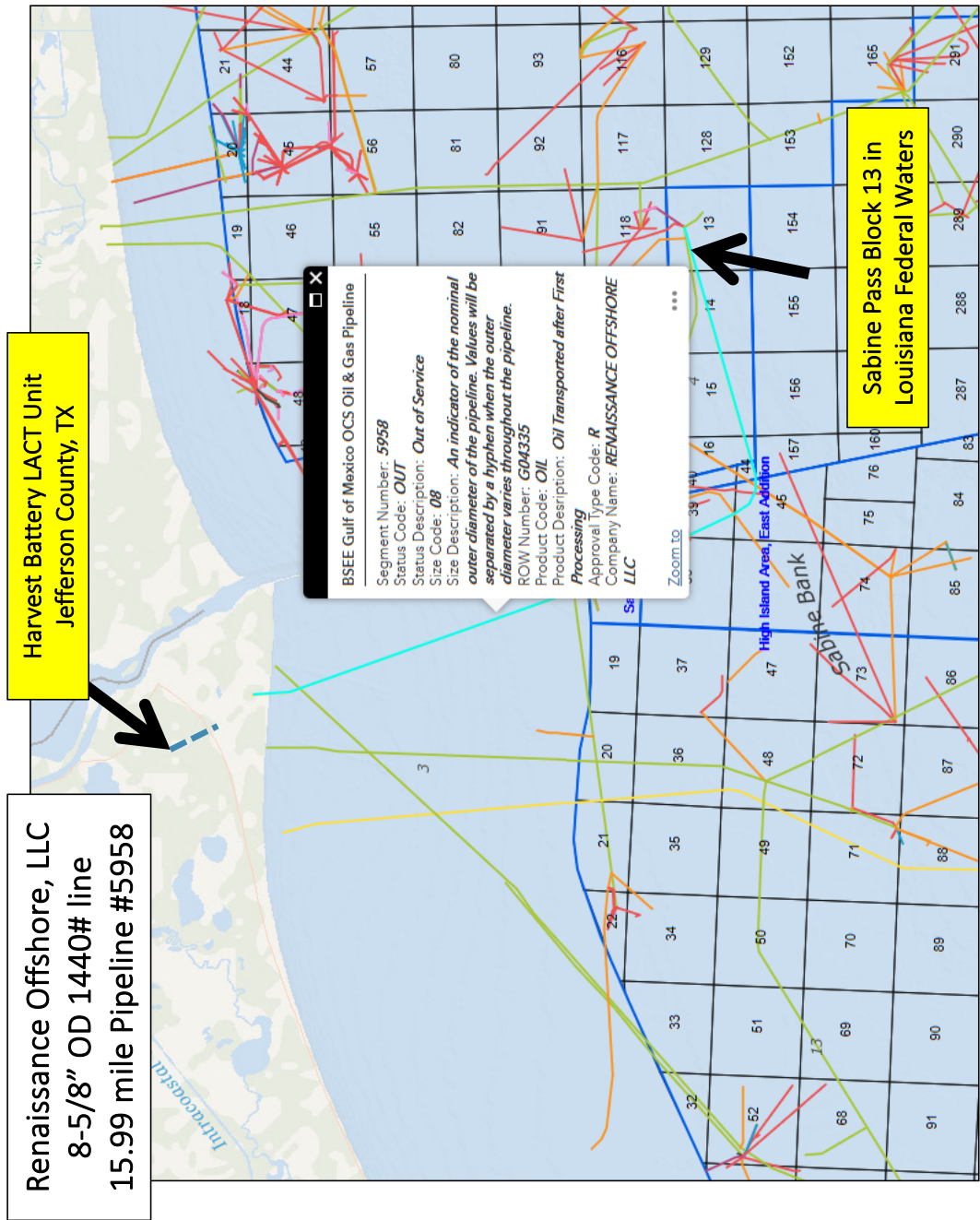


Pipeline Re-Use : Phase II - Workflow

- Three Specific Lines for Initial Deep Dive:

Region/Location	Line ID	Last Owner	In Service Date	Size	Max Oper. P (psig)	Length (miles)	Water Depth (feet)	Status
Louisiana (Vermillion/ White Lake)	5434	Columbia Gas Transmission	11/14/1984	36"	1253	6.27	10 - 32	Abandoned In Place
Texas (High Island)	5958	Renaissance Offshore	5/28/1981	8"	1440	15.99	39 - 50	OOS
Texas (Galveston)	7199/ 3489	Black Marlin	12/1984	16"	1367	23.87	48 - 61	Proposed Abandon







Next Steps



Task 5 : Infrastructure – Next Steps

- Continue parallel efforts into well, pipeline, platform re-use screening and workflow development
- Engage industry review/input of work products as they are developed
 - Leverage expertise of Aker
- Longer term:
 - Extend efforts into other transport options
 - *Shipping, deviated wells, subsea templates etc.*
 - Source/sink optimization with analog sites

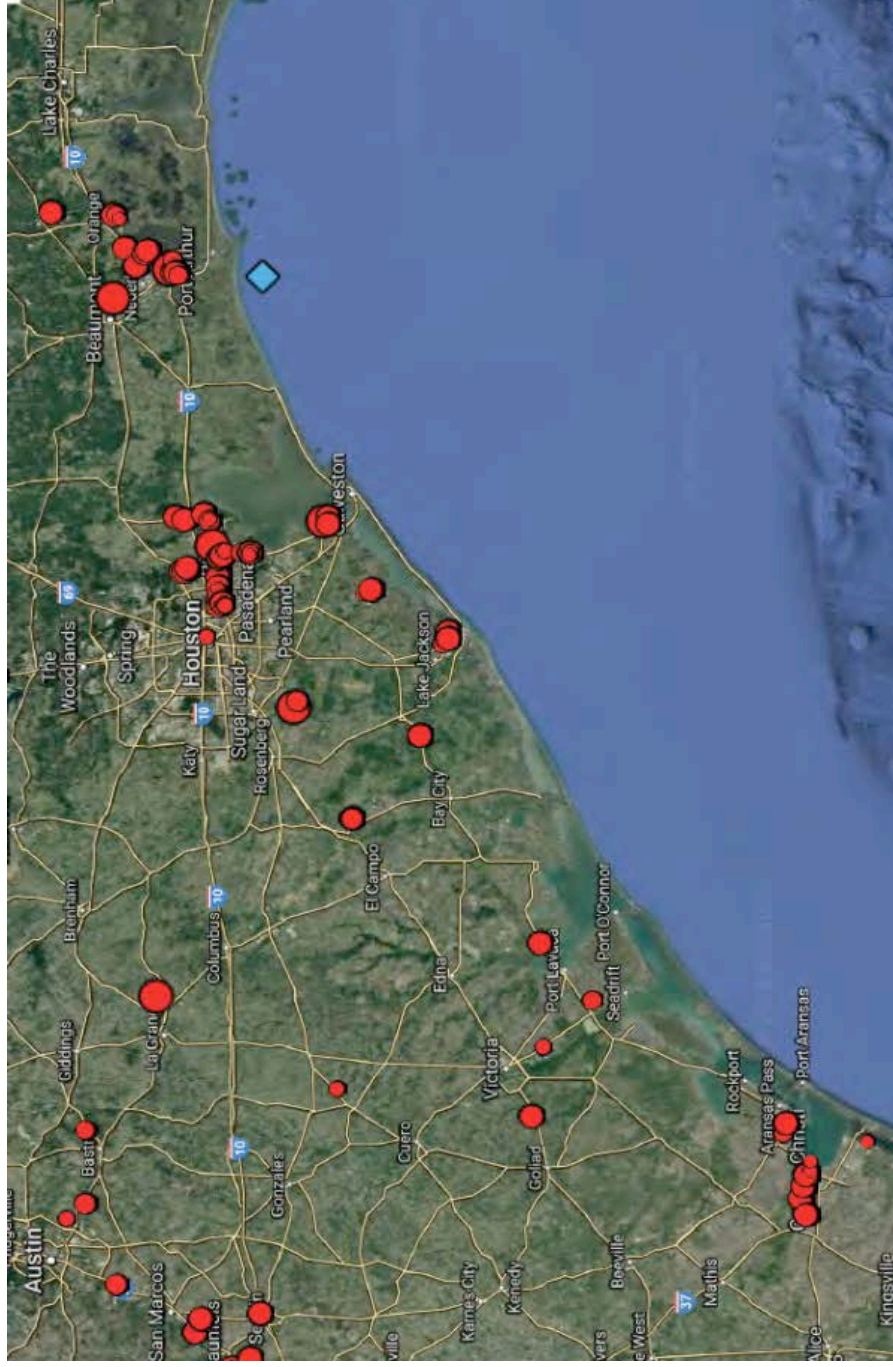


Discussion

Backup Slides



Potential CO₂ Sources: Texas Gulf Coast



- » Large Source = 400k+ tonnes CO₂/yr
 - Size of dot indicates scale of emissions)
- » 148 Large Sources in Texas
 - ~75 within 50 miles of coastline
- » Regions of Focus
 - Beaumont/Port Arthur
 - Greater Houston
 - Corpus Christi
- » Data from EPA GHGRP 2017

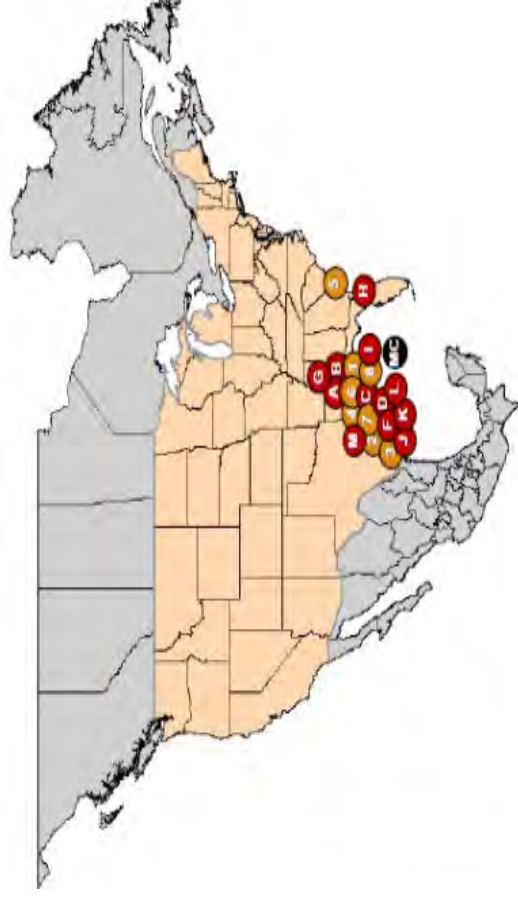
CO₂ Sources: 45Q Tax Credits (2018 Revised)

- Capture and Sequestration Requirements
 - 500,000 tonnes/yr (Power Plant)
 - 25,000 tonnes/yr (Utilization)
 - 100,000 tonnes/yr (All Others)
- Progressive Tax Credit
 - U.S. \$20 - \$35+ for EOR/EGR and Utilization
 - U.S. \$32 - \$50 for Non-EOR
- Construction must start by 1/1/2024

LNG Facilities: Emerging Opportunity?

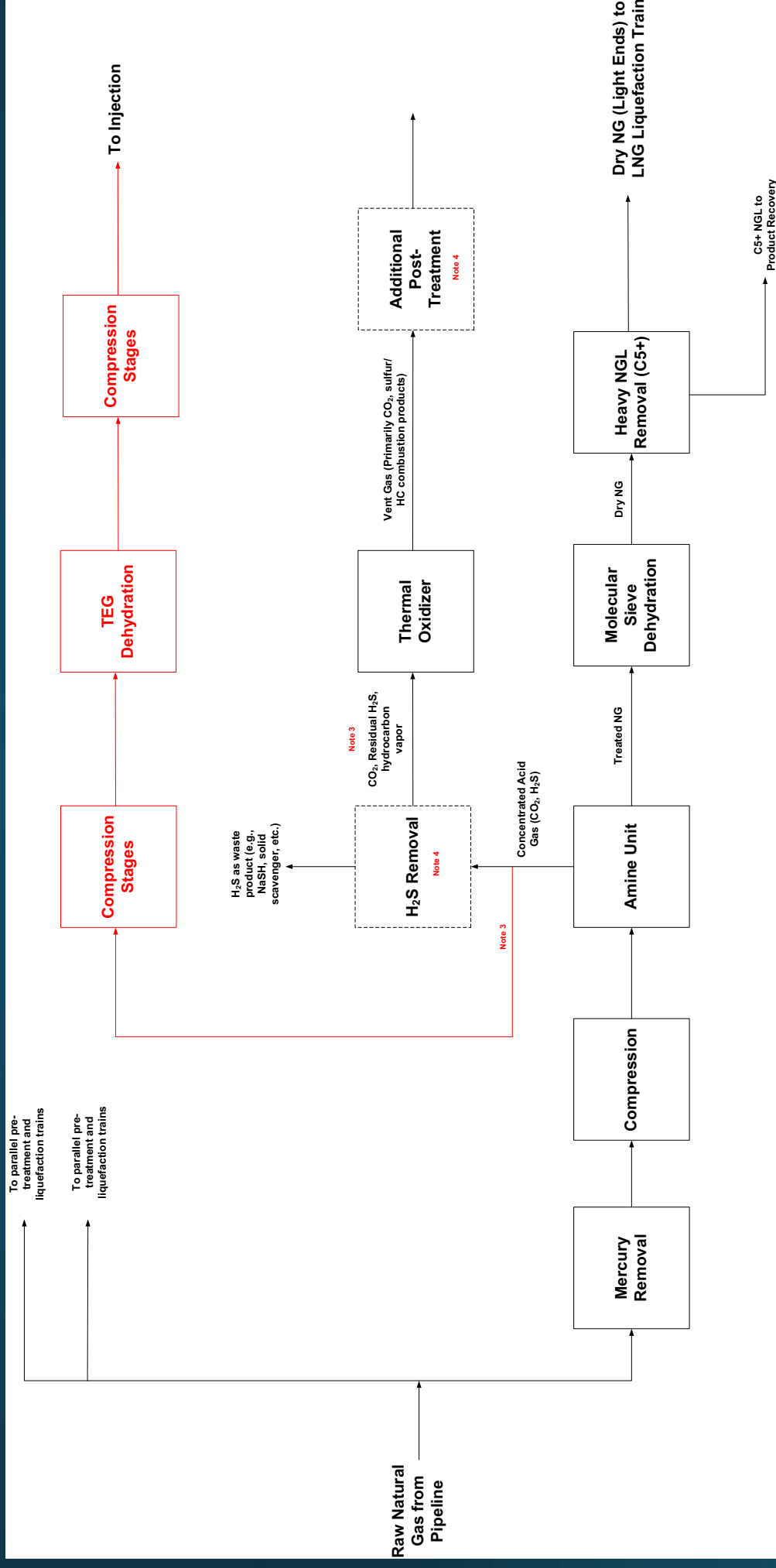
- High-purity CO₂ source
 - CO₂ generated as part of the purification of LNG
- Large CO₂ source
 - Public GHG PSD Application LNG Facility = 3 LNG trains
 - CO₂ emissions > 1.5 million tonnes/year
 - ~2 sources: gas turbines (dilute CO₂), AGRU (concentrated CO₂)
- Several facilities/projects in near-shore GoMCarb region
 - Trimeric tracking >10 facilities/projects
 - Operators have indicated openness to engagement with GoMCarb
- Potential benefits to LNG operators
 - 45Q tax credits
 - Eliminate/reduce load on pre-treatment processes (e.g., thermal oxidizer)

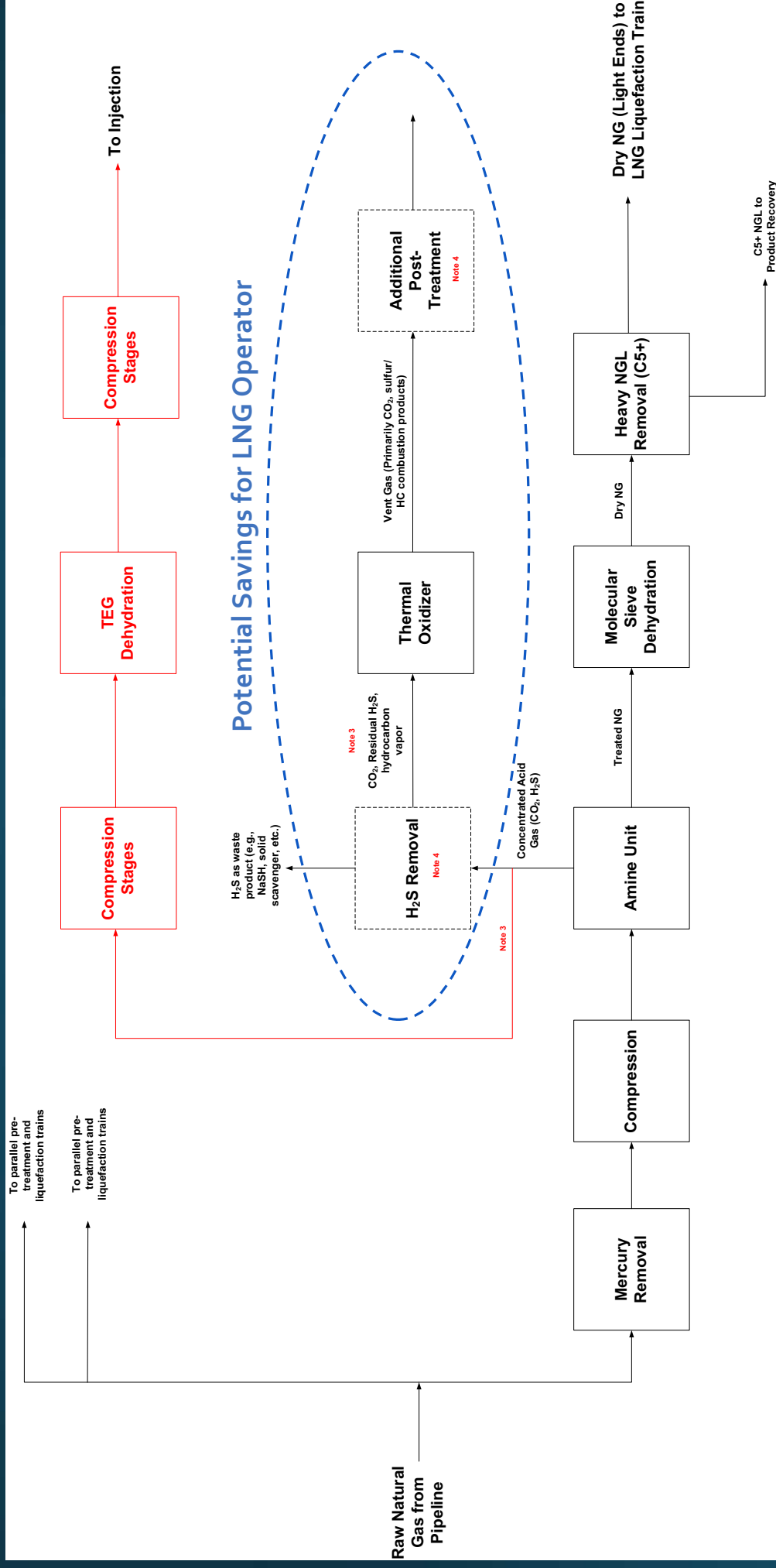
North American LNG Export Terminals *Approved, Not Yet Built*



Source: FERC

UTCCS-5 Meeting, Jan. 28, 2020, Austin, TX





LNG Facilities: Challenges

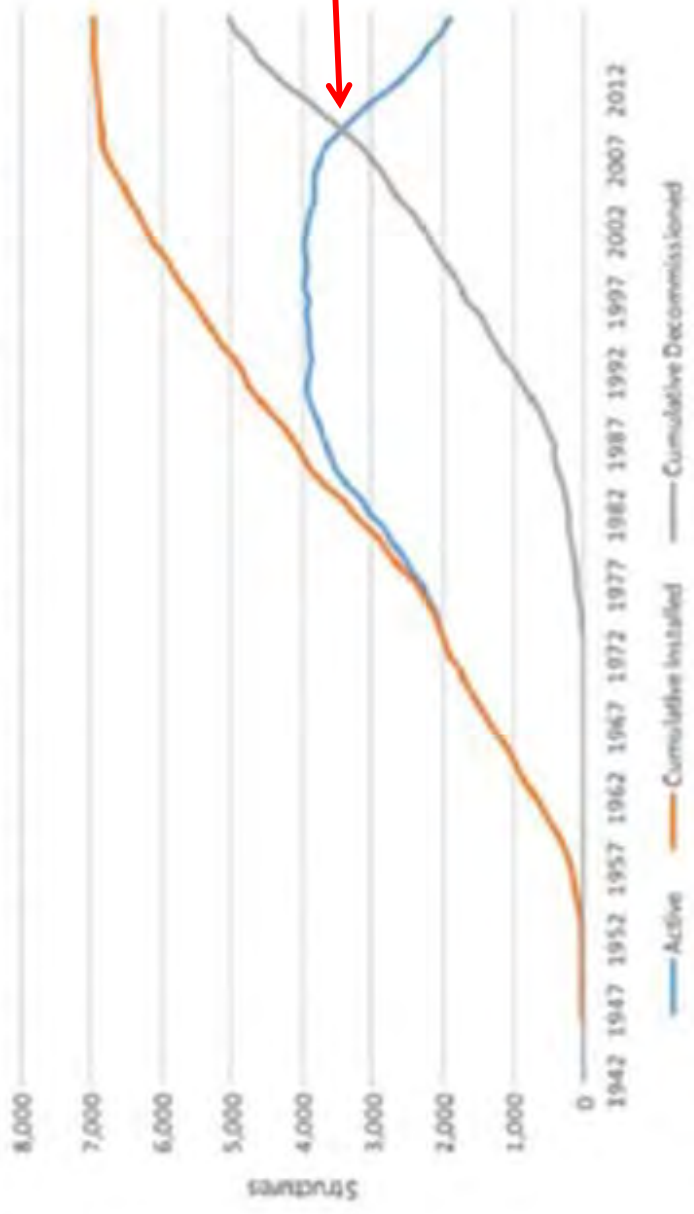
- Impurities in AGRU CO₂
 - Hydrocarbons (e.g., methane, benzene, etc.), H₂S
 - Additional processing for transport offsets benefits of AGRU gas offtake
- Impact to LNG Facility
 - LNG Operators: Focus is on LNG production – ideally, CO₂ transaction handled separately by third party
 - CO₂ capture plan needs to start early in investment planning for LNG facility
 - Impact to production
 - What happens if CO₂ transport/storage goes offline? Design flare to handle AGRU offgas?

UTCCS-5 Meeting, Jan. 28, 2020, Austin, TX



Re-Use Challenges- Future Stock of Reusable Infrastructure

Active structures in water depth less than 400 ft, 1942-2017E.



Source: Data from BOEM/ISSEI, February 2018.

Inventory for Re-use
Decreasing

Source: Kaiser and Narra, LSU
Center for Energy Studies;
Offshore Magazine, March 2018

- Well map from TX RRC GIS
- TX RRC database is not complete and not easy to search
- UT has access to proprietary databases that are more complete
- HI-10L
 - 34 wells in TXRRC
 - 9 additional wells listed in UT database
 - None are operational
 - Half are plugged
 - Half are dry holes

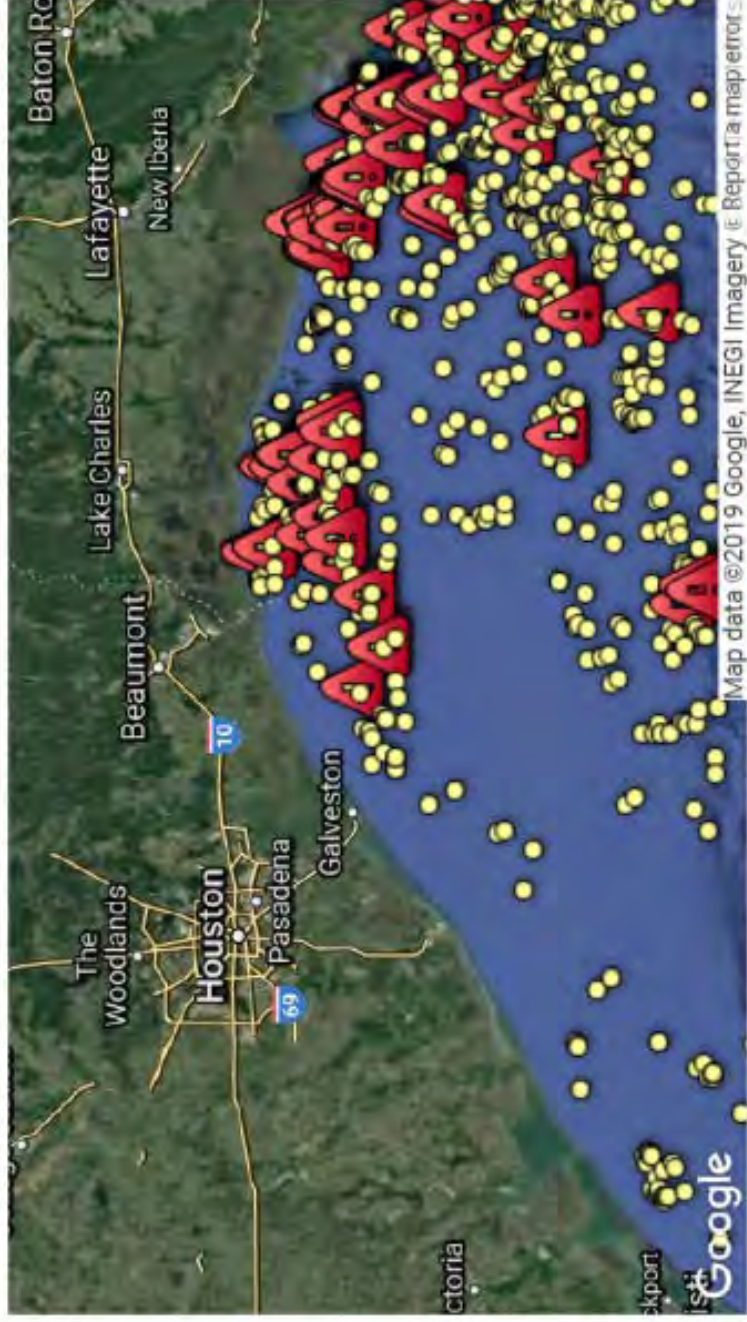
Well Screening Criteria

1 st Pass Criteria: Readily Available, such as from Databases	
Construction Date > 1970	Modern well construction HI-10L: 13 of 43 wells were pre-1970
Full API Number	Older wells do not have full API number HI-10L: 11 wells did not have full API in RRC GIS
Total Vertical Depth	Deeper wells = more expensive HI10L: wells terminate at 5,800-14,000 ft
Casing Diameter	Larger diameter accommodates modern tools HI10L: 5.5" to 10.8", 5.5" sufficient for 3/8" tubing
2 nd Pass Criteria: Available with more effort, such as Permit Searches	
Well design/completion history	Determine pressure specification Look for problems in completion
3 rd Pass Criteria: Incur Significant Costs, such as Well Integrity Tests	
Well integrity tests: Make measurement/re-test upon re-entering well	All wells in field must have integrity assured Fewer wells reduces cost for assuring well integrity

Platform Re-Use

- Repurposing platforms for CO₂ storage could help offset cost of decommissioning idled platforms
- Potential platform re-use criteria
 - Location/proximity to preferred injection site
 - Age/general condition of platform
 - Space on platform (including slots for wells)
 - Regulatory/legal considerations
 - How does liability/decommissioning responsibility transfer?
 - “Rigs to Reefs” and other programs may be starting point
- **Platform re-use unlikely to be a project driver**
 - Reservoir, pipeline, and in some cases, wells will be prioritized ahead of platforms

Idle Iron Data – Existing Stock of Reusable Infrastructure



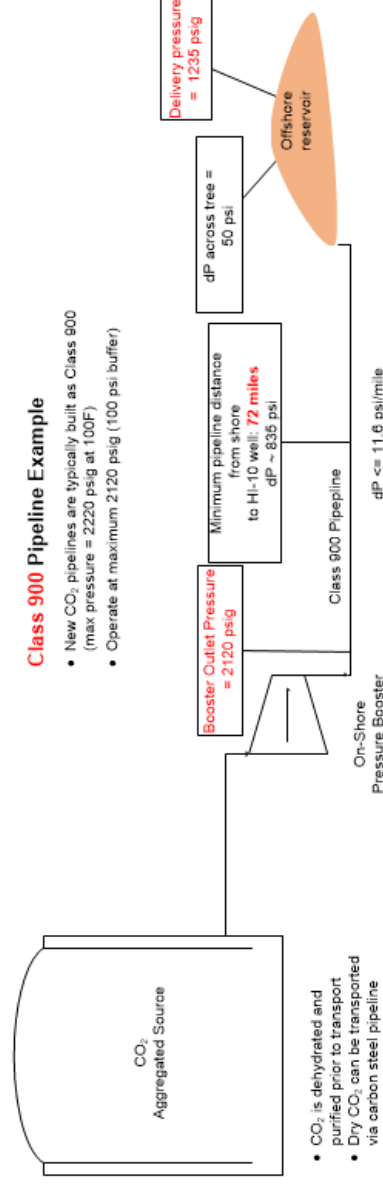
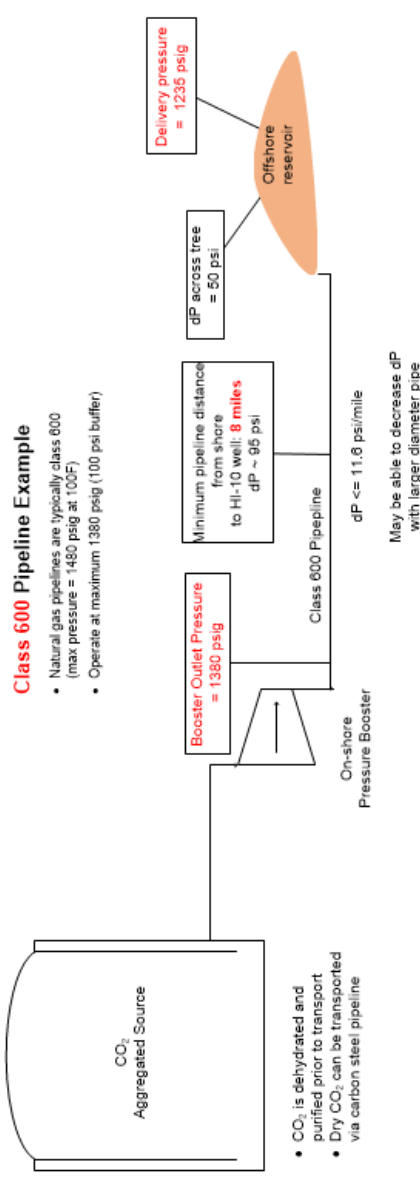
- Red Triangles = “Idle Iron”
- Yellow Dots = All other standing platforms
- Federal water only; state does not have robust platform data

Source: Plough, A. (2017, August 3). American Idle: Decommissioning costs sink offshore drillers into latest crisis. *Debtwire Investigations*.

Pipeline Opportunity: New Offshore Pipeline Costs

Source	Fluid	Cost (\$/in-mile)		Offshore Multiplier
		Onshore	Offshore	
NATGAS.INFO website	Natural Gas		\$40,000 - \$64,000	
Kaiser 2016	Oil, Natural Gas		\$45,000 - \$418,333	
JRC (Serpa, Morbee and Tzimas 2011)	CO ₂		\$67,600 - \$89,600	
USAID and SARI/Energy 2006	Oil, Natural Gas			1.96
Brito and Sheshinski 1997	Natural Gas	\$40,000	\$100,000	2.50
Global CCS (Vermeulen 2011)	CO ₂	\$103,000	\$144,800	1.41
Scottish Power Longannet	CO ₂	\$12,900	\$49,900	3.87
IPCC 2005	CO ₂			2
ZEP 2011	CO ₂			1.38
JRC 2011	CO ₂			2
NETL 2013 via Kinder Morgan	CO ₂	\$50,000	\$700,000	14
Average				3.64

Pipeline Challenges: Pressure Rating



Assessment of Large CO₂ Point Sources from Four Refineries of SE TX



Adhish Madugula and Tracy Benson, Lamar University

GoMCarb Task 5 – Infrastructure, Operations, and Permitting

Name

GoMCarb Task

SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

OBJECTIVE

Evaluate the annual CO₂ production within a refinery (both from an overall perspective and from specific units within the refinery)



Motiva, Port Arthur, TX

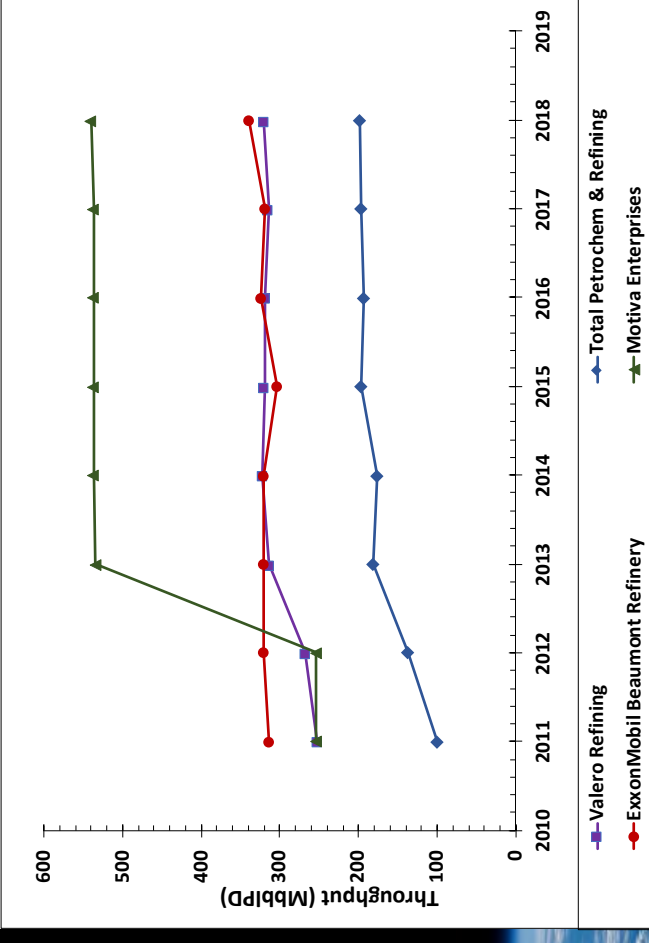
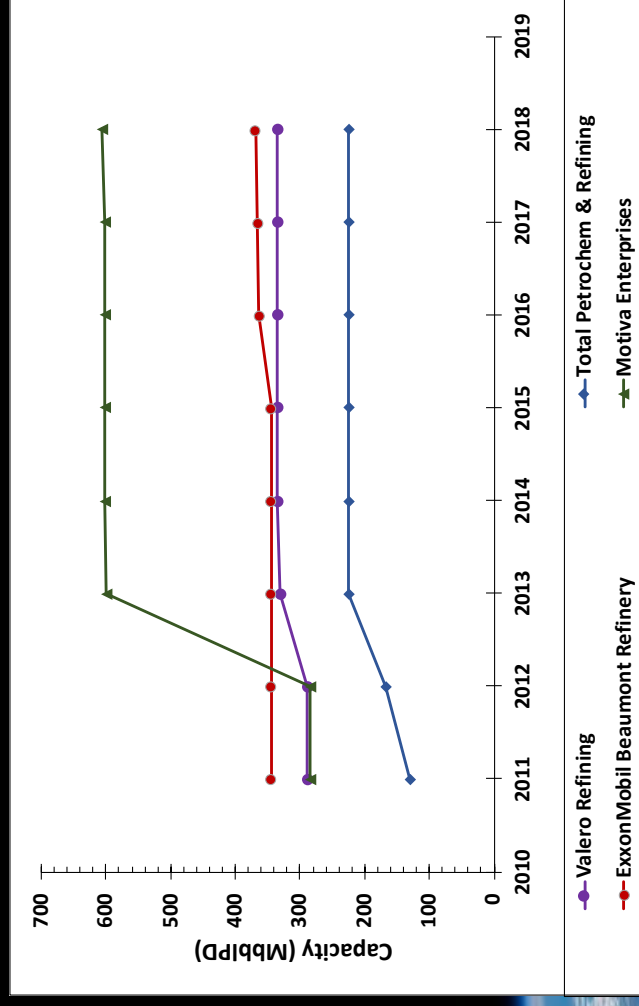


ExxonMobil, Beaumont, TX

Total, Port Arthur, TX



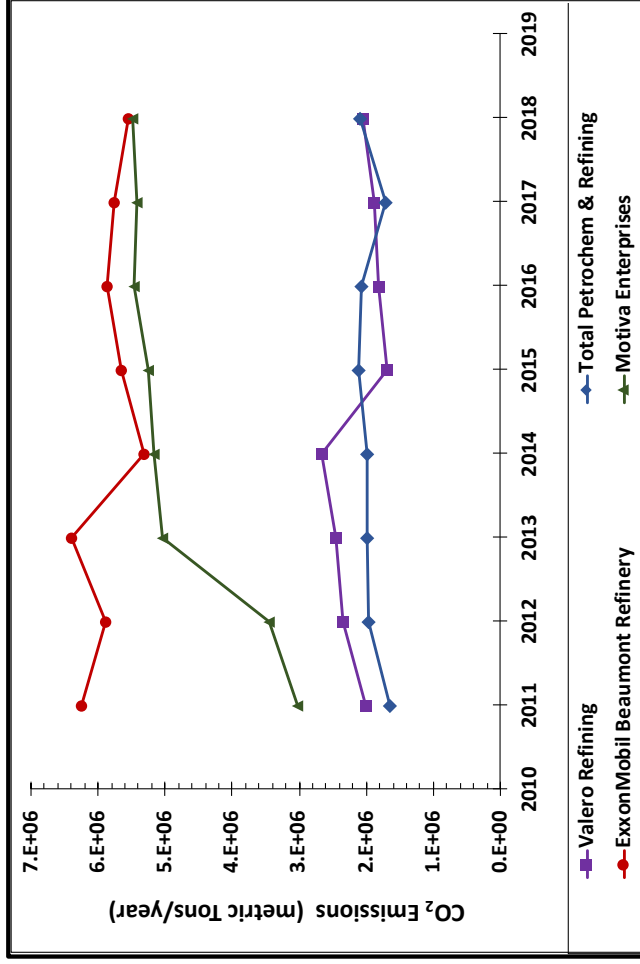
Refinery Capacity vs Actual Production



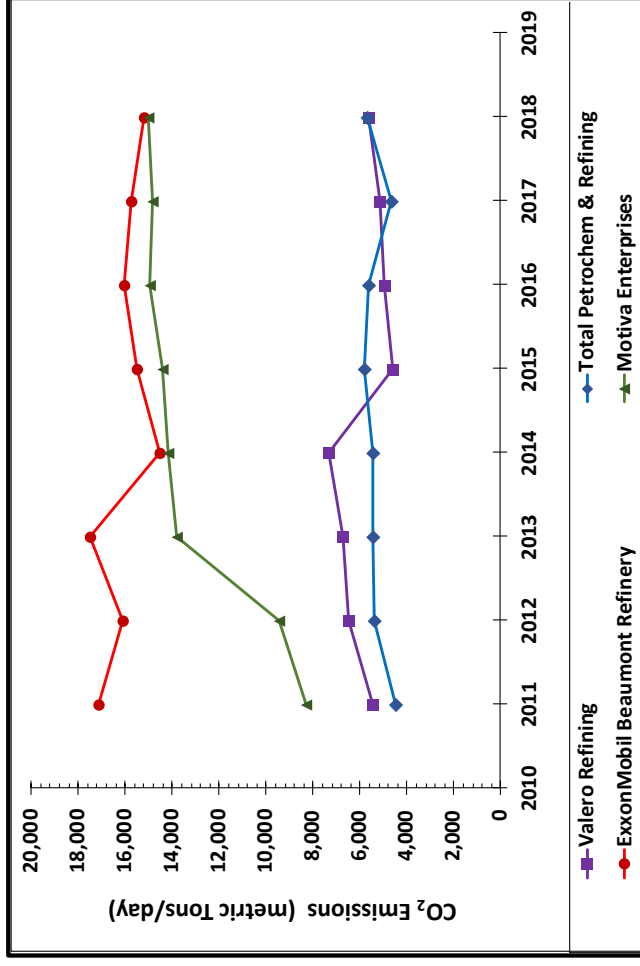
Corporate quarterly and annual reports

Overall CO₂ Emissions

YEARLY



DAILY

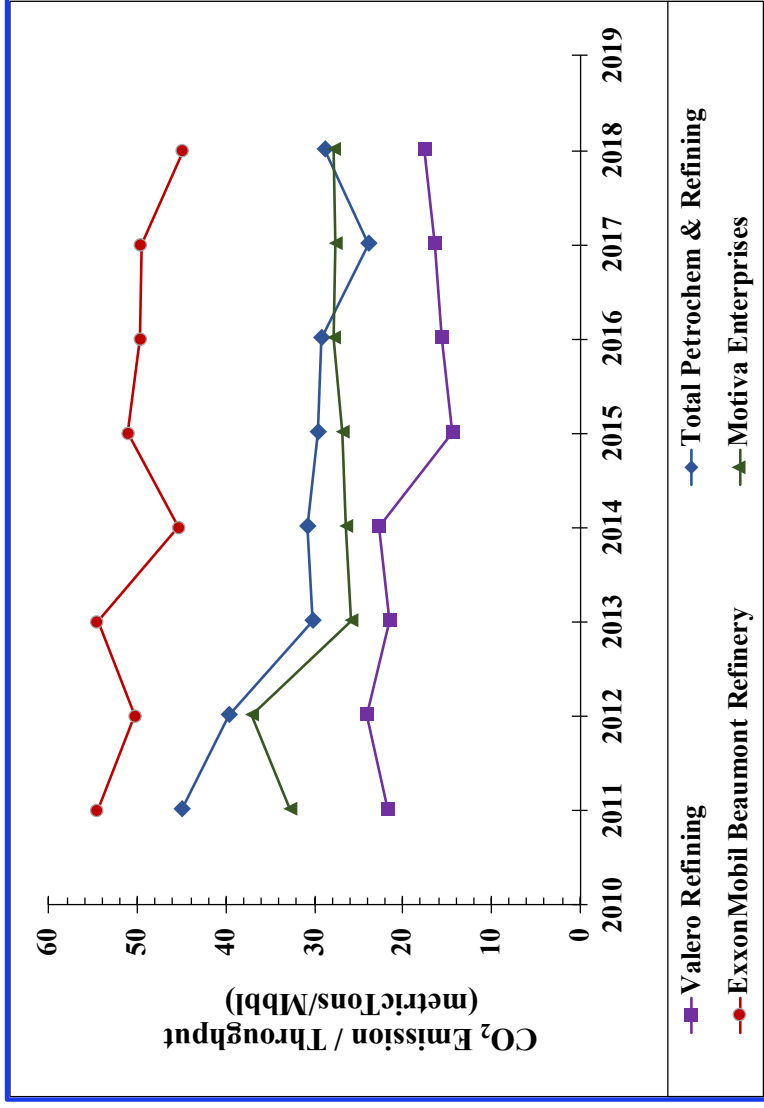


<https://ghgdata.epa.gov/ghgp/main.do#>

Types of CO₂ Emission Sources

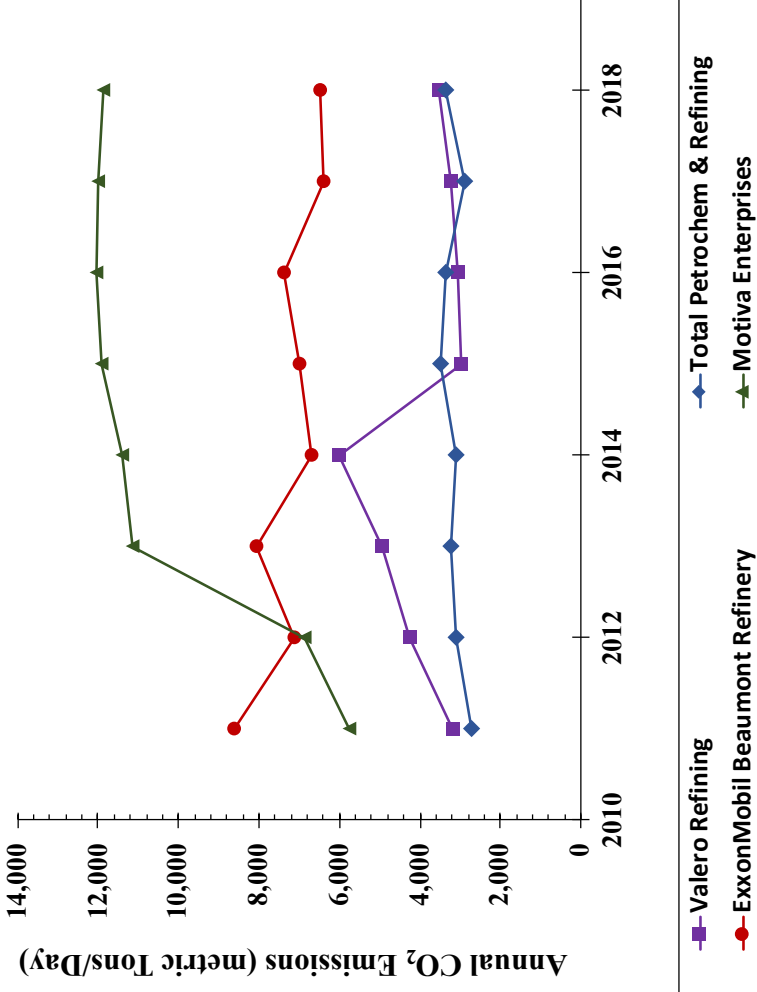
Unit Type	% of CO ₂ Produced
Stationary Fuel Combustion Sources	55 - 60
Catalytic Cracking & Reforming	25
Sulfur Recovery	7 - 10
Flares	minimal
Electric Power Generators	^a
Process Vents	^a

^a Only reported by ExxonMobil.
No correlation to production.

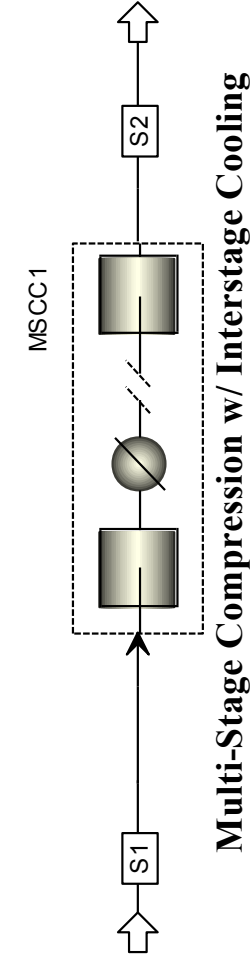


Stationary Fuel

Combustion



Next Stage: Compressor Sizing and Energy Requirements



Steam Methane Reforming Operations

0.5 MM tonnes CO₂/yr
1 – 54 atm

Optimal # Stages: 6

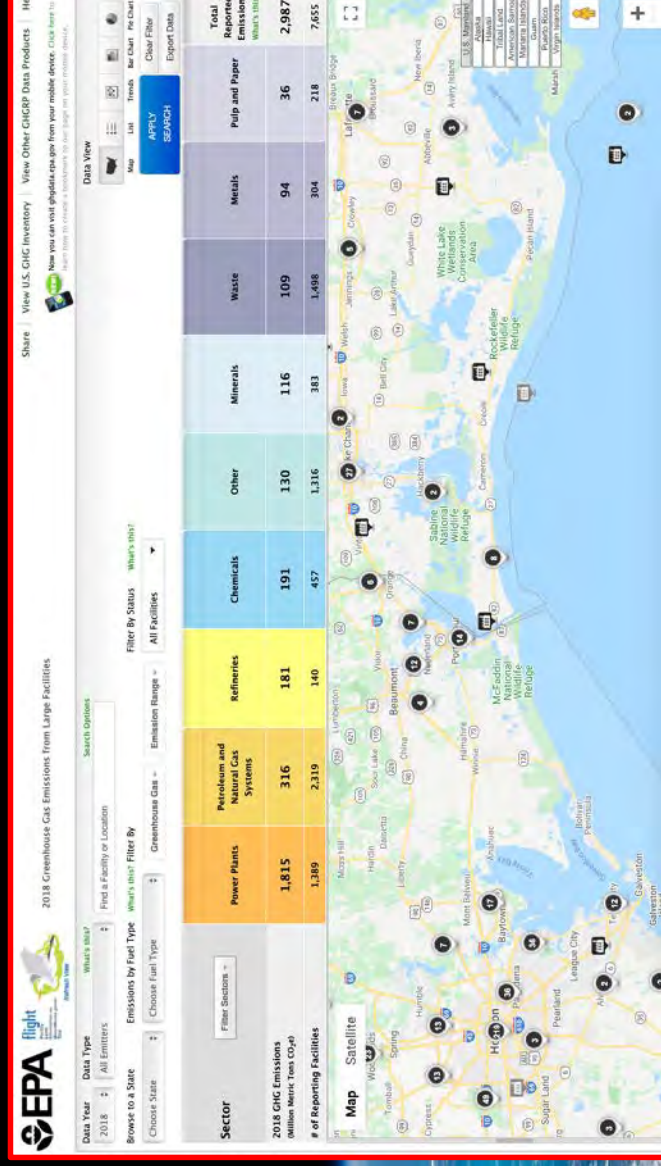
Stage	Temp.	Press.	Compres sion ratio	Horse- power
	°F			hp
1	182	1.95	1.95	1,043
2	218	3.79	1.95	1,101
3	219	7.38	1.95	1,091
4	219	14.36	1.95	1,070
5	220	27.95	1.95	1,031
6	221	54.40	1.95	952

$$CR = (PR_T)^{1/N}$$

Centrifugal Compressor: CR → 1.5 - 2

Closing Thoughts

- Neglecting hurricanes, CO₂ production is predictable, steady, and correlates with refinery capacity
- Motiva doubled its capacity in 2012 to 600,000 BPD
- ExxonMobil will edge out Motiva as largest refinery in the 2021 expansion



Discussion

CFD Simulations of CO₂ Wellhead Failure and
Dispersion from an Analog Injection Well at the
High Island 10L Field
GoMCarb Webinar, March 26, 2020

Daniel Chen & Napoli Rosario, Lamar University, Beaumont, TX

SUMMARY

- Collected available data for the purpose of estimating the CO₂ wellhead failure and dispersion from an analog injection well at the High Island 10L Field.
- Performed ANSYS Fluent CFD simulations of CO₂ wellhead failure from an High Island 10L injection well.

High Island 10L, a hydrocarbon field suitable for CO₂ storage, is located in the Gulf of Mexico, long-94.00 and lat 29.554, Figure 1.

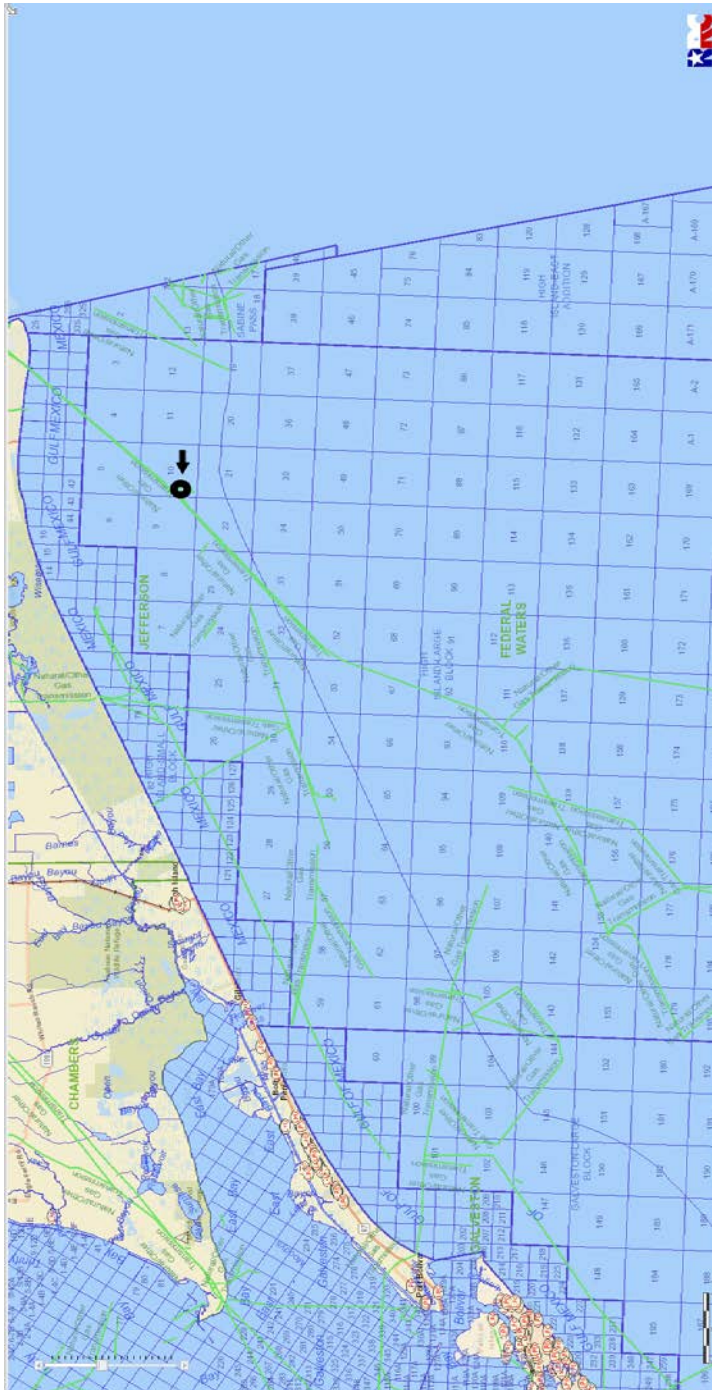


Figure 1 Location of the High Island 10L

According to the Gulf of Mexico bathymetric map, the depth around High Island 10L is 20 meters. Furthermore, the terrain at High Island 10L is essentially flat, Fig. 2.

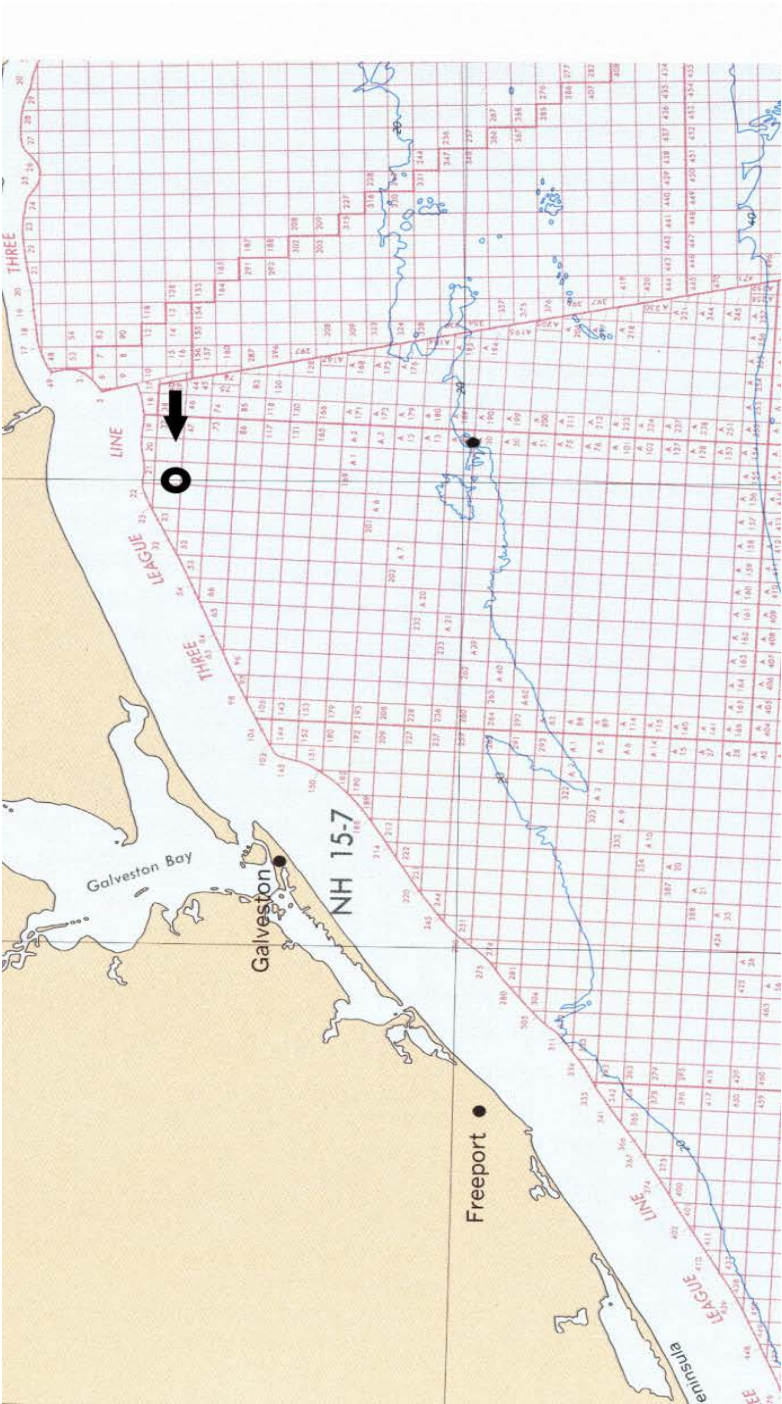
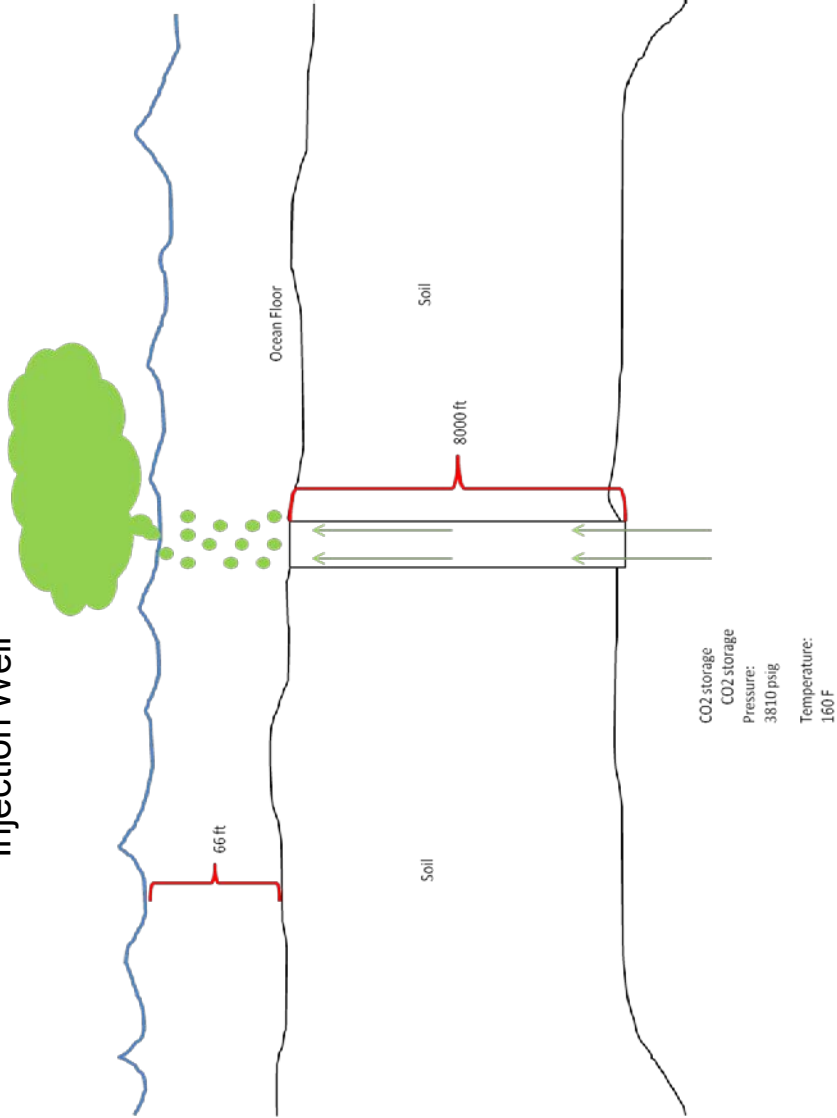


Figure 4.1.5.5 Gulf of Mexico Bathymetric Map, High Island 10L Location

ANSYS Fluent Simulation of CO2 Wellhead Failure from an High Island 10L Injection Well



Pipe Size (in) sch 40	CO2 Choke flow (lb/hr)	Choke Velocity (ft/s)
3.00	202000	21.43
4.00	426059	27.29
6.00	1257993	32.175
8.00	2574963	41.1
10.00	4581550	48.31

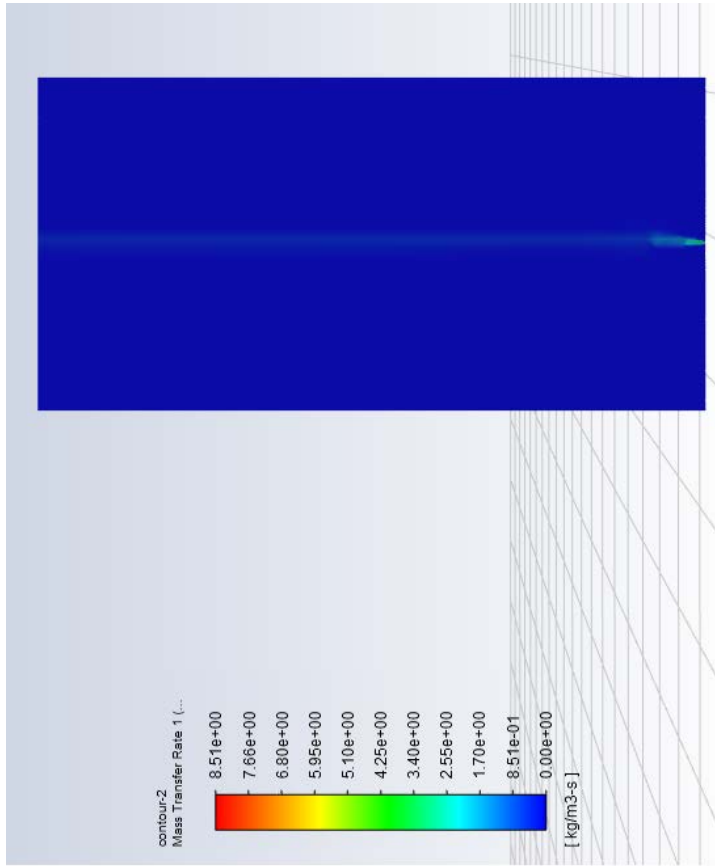
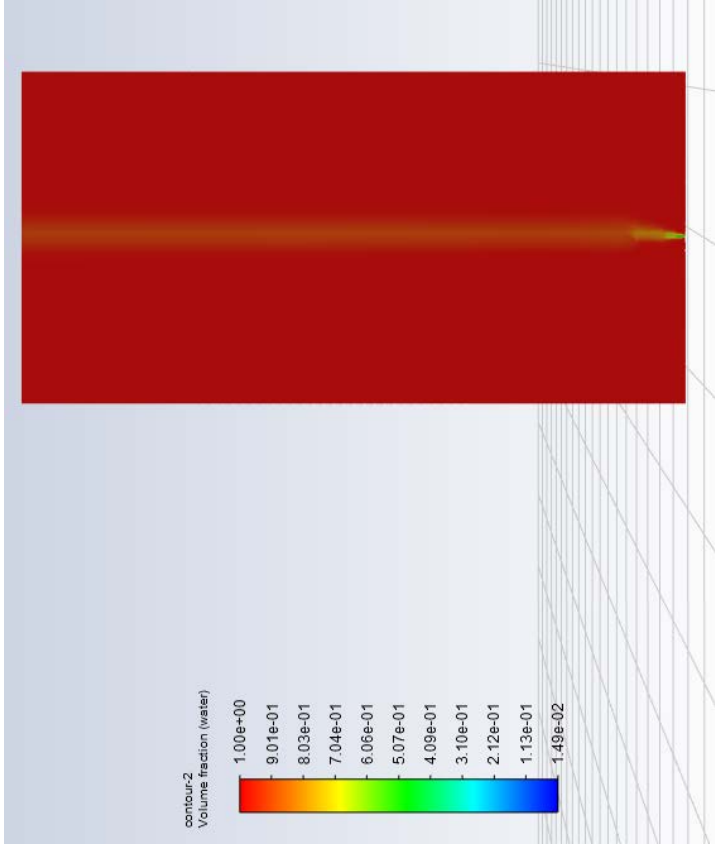
Figure 3 CO₂ Leakage from High Island 10L Injection Well

The data available from each station is summarized in Figures 4. The speed and direction of surface sea currents are monitored only in the Sabine Bank Channel LBB 34.



Figure 4 Galveston Bay Entrance Station (L) Sabine Pass North Station (R) data

Pipe size 4 in, CO2 velocity 9.8 m/s; flow, 52.16 Kg/s, Temp. 97.2 F, Press. 1218.97 psig, Vol. Mass transfer .00865 s-1, surface tension .072 n/m. Conditions of CO2 close to choke conditions (only gas phase flow)



$$k_L a = \left[\frac{0.99}{B} - \frac{V_L R T}{Q_G H} \right]^{-1}$$

Equation utilized to calculate the volumetric mass transfer.

Aqueous phase CO2 Dissolution Rate =9.37 kg/s

Future Work

- Use mass transfer coefficient under Gulf current, salinity (including Ca^{2+}), and pH conditions to estimate ΔpH .
- Add atmospheric phase dispersion
- Computational Fluid Dynamics (Fluent) modeling for onshore CO₂ pipeline ruptures



Acknowledgement

- Useful interactions with GoMCarb team members, [Curtis Oldenburg](#) at the Lawrence Berkeley National Laboratory (LBL), and [Margaret A Murakami](#) at the University of Texas, Austin (UT), regarding marine environmental data near 10L and 24L lease blocks in Texas State Waters are acknowledged.



The University of Texas at Austin
Stan Richards School of
Advertising & Public Relations
Moody College of Communication



Task 6.

CCS Communication Research

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LUCY ATKINSON, PH.D. Associate Professor, The University of Texas at Austin
LEE ANN KAHLOR, PH.D. Associate Professor, The University of Texas at Austin
HILARY CLEMENT OLSON, PH.D. Senior Lecturer, The University of Texas at Austin
EMILY MOSKAL, Research Program Coordinator, The University of Texas at Austin

SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

Motivation

Two audiences in CCS communication

- ✓ Key stakeholders: stakeholders directly involved in or impacted by CCS technology
- ✓ Lay citizens

Key stakeholders are important

- ✓ Engaging key stakeholders is imperative for the success of the CCS project
- ✓ Impact lay citizens perspectives on CCS technology



CCS Communication Approach

Objectives

- ✓ Understand CCS benefits and risks relevant to key stakeholders (Qualitative)
- ✓ Build CCS messages that resonate with key stakeholders (Quantitative)



Result. Rank Order Perceived Benefit

<u>CCS Benefits</u>		<u>N</u>	<u>M</u>	<u>SD</u>
1	Addressing climate change by reducing CO2 emissions into the atmosphere	69	2.96	2.16
2	Reducing air pollution	79	2.47	1.33
3	Achieving environmental goals (e.g., Paris agreement)	56	3.96	2.24
4	Presenting economic opportunities for new businesses (e.g., sustains current jobs and creates new ones)	57	5.00	2.01
5	Keeping the US at the forefront of energy technology	47	5.11	2.46
6	Being ready to go now; there's no need for extensive R&D	42	6.48	2.38
7	Bringing about better air quality by reducing conventional air pollutants that threaten human health	79	2.81	1.55
8	Reducing asthma rates	48	4.83	1.72
9	Effectively managing heavy metals (mercury) and particulate matter	44	4.84	2.03

Focus group and in-depth interviews with stakeholders in Beaumont and Port Arthur, TX
 Online survey (collected from mTurk) (N=81; the general public in the US)

** 1- most important, 9- least important*



Result. Rank Order Perceived Risk

<u>CCS Risks</u>		<u>N</u>	<u>M</u>	<u>SD</u>
1	Well blow outs and CO2 leakage through caprock	64	3.88	1.76
2	Uncertainty of demonstrating 1000 years CO2 storage security	47	4.23	2.37
3	Micro-seismicity (small earthquakes)	53	4.38	2.50
4	High cost (e.g., individuals might see added surcharges to their energy bills)	62	4.21	2.62
5	Unclear liabilities on managing geological storage sites. (e.g., Legal repercussions from using private land and legal liabilities)	48	5.38	2.12
6	Uncertainty in long-term maintenance of facilities and stored CO2	59	3.86	1.90
7	Delay in transition to renewable energy	45	5.20	2.71
8	Affecting underground water from storage leakages	72	2.86	1.73
9	A large inadvertent release of CO2 and its effects on a local area	72	3.10	2.03

Focus group and in-depth interviews with stakeholders in Beaumont and Port Arthur, TX
 Online survey (collected from mTurk) (N=81; the general public in the US)
** 1- most important, 9- least important*



Next Step: Online Experiment

Benefit and risk messages

- ✓ Framing CCS benefits and risks relevant to key stakeholders (from qualitative work)

Source of information

- ✓ Source may impact how people view the information (from qualitative work)

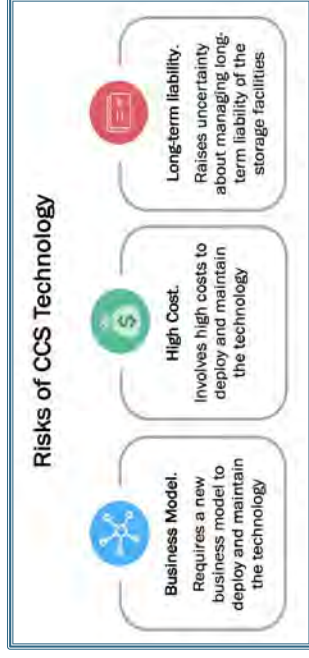
Individual factors

- ✓ Psychological proximity of climate change affect how people engage into issues related to climate change (literature)





Benefits



Economic risks



Environmental / technology risks

Pretest: Stimuli Development

- **Preparing for the main test**
 - ✓ Testing stage
 - ✓ Constructing appropriate messages
 - ✓ Preliminary relationships
- **N=112 (student sample)**
- **Measurements**
 - ✓ Manipulation check questions
 - ✓ DVs. CCS support, concern toward CCS technology

Manipulation pretest results

- Messages were significantly different in terms of the manipulation scale (6-point scale):

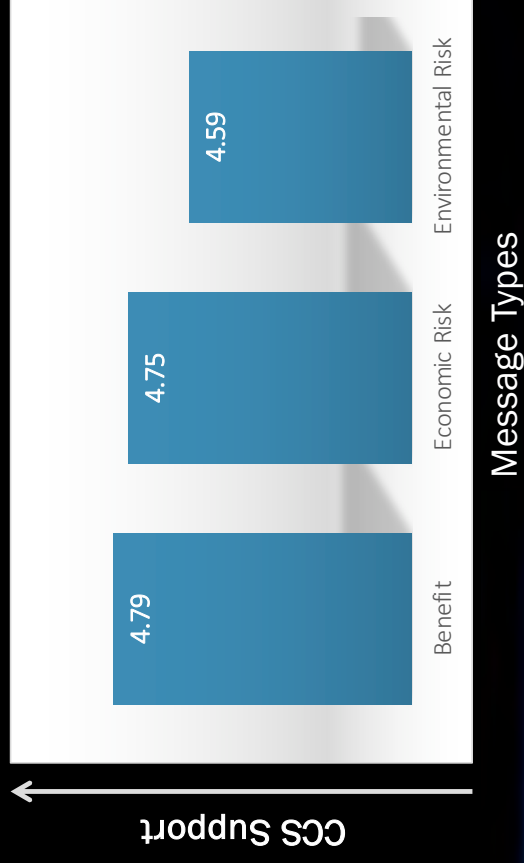
“This message communicated about the _____ of CCS technology.”

- Risks = 1, Benefits = 6
- Negatives = 1, Positives = 6
- Concerns = 1, Advantages = 6
- Harm = 1, Value = 6

	Message Category	N	Mean	SD	df	F
Manipulation Check Scale	Benefit	38	5.57	0.77	1, 109	102.35***
	Economic Risk	40	2.69	1.39		
	Env / Tech Risk	34	2.02	1.14		

Pretest results

- **No significant differences among messages** on participants' intention to support CCS technology.
- A similar pattern is shown in perceived concern toward CCS technology.



Trusted Source

	Mean	SD
Oil & Gas	2.33	1.17
University Scientists	4.27	0.70
Industry Scientists	4.24	0.88
White House	2.61	1.13
EPA	3.80	1.03
DOE	3.62	0.98
State Gov.	2.89	0.99
Environmental Nonprofits	3.88	0.86
Local Gov.	2.92	0.93
Members of my community	2.76	1.00

How much do you trust each of the following as a source for information about carbon capture and storage?



Individual factors

Psychological proximity to climate change

- ✓ The extent to which a person perceives that the event of climate change is psychologically close/ distant to the self
- ✓ Psychological proximity impacts how people process information and engage with the issue

CCS is a climate change mitigating technology

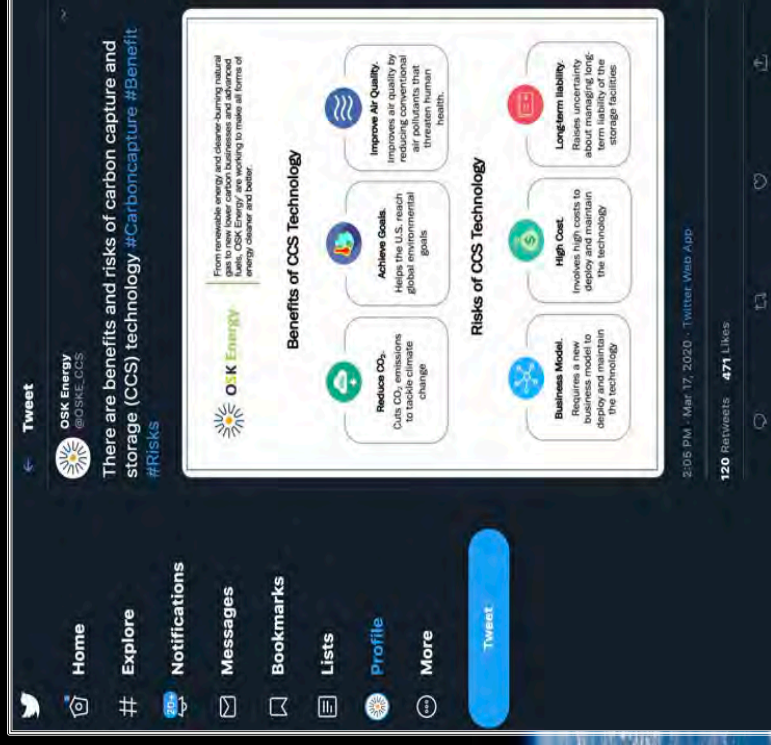
- ✓ How people view CCS messages may be impacted by a person's perceived proximity of the climate change issue



Next Steps

- Online survey. 900+ N
- Messages. Benefit vs. Risk vs. Balanced messages (benefit-risk, risk-benefit)
- Sources. Oil & Gas Industry, University Scientist, Government
- Individual factors. Psychological proximity to climate change

➤ To understand the extent to which messages, sources, psychological factors impact stakeholder response to CCS communication



Thank you!
Questions?



Technical Outreach

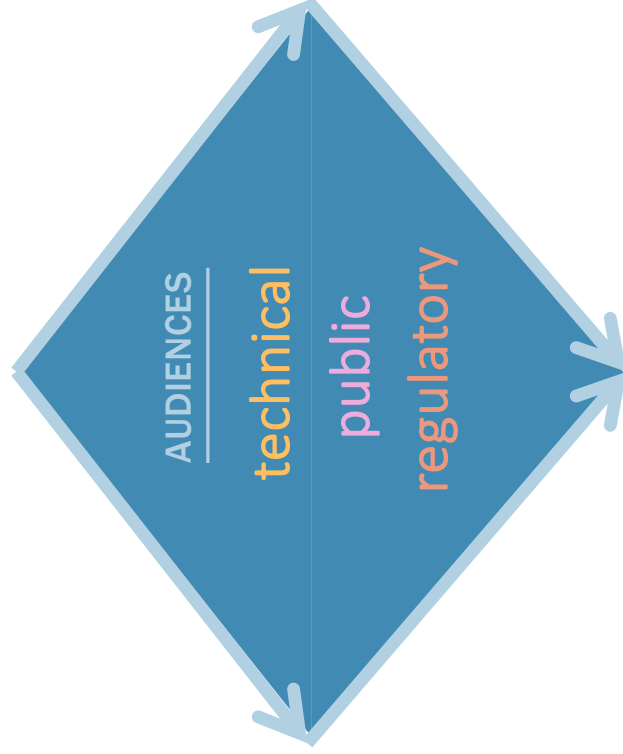
Gulf of Mexico Partnership for Offshore Carbon Storage (GoMCarb)

Emily Moskal
Gulf Coast Carbon Center,
Bureau of Economic Geology
Task 6: Outreach

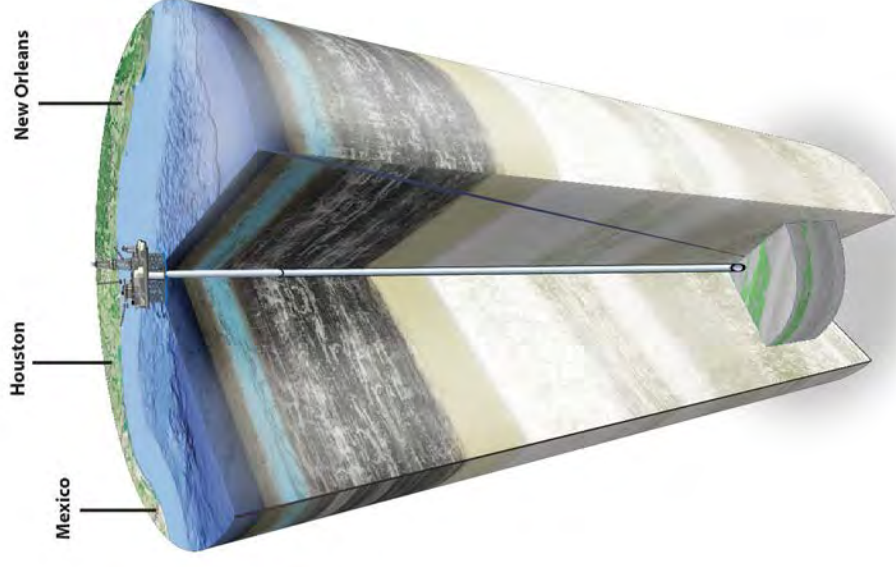
SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

The Goal

KNOWLEDGE



source industries engaged with large-
volume storage resources



Meetings

Trading technical expertise and connecting with new groups loosely or directly engaged with CCS



Opportunities to share knowledge

- Oil & Gas Climate Initiative ([OGCI](#))
[Investments Day](#) (GCCC)
- [iCCUS](#) (GCCC)
- Carbon Capture, Utilization, and Storage at the D3 Revival - Energy Disruption Conference (GCCC)
- Port Arthur Chamber of Commerce 45Q meeting (Lamar University, GCCC)
- Also, AGU (LBNL, GCCC), SEG (GCCC), NETL (GCCC), Texas A&M (LBNL)



More opportunities

- Offshore Technology Conference (LBNL, Trimeric, GCCC)
- Gordon Research Conference on CCUS (GCCC)
- [CLIMIT Summit](#) (GCCC)
- [American Beach and Shoreline Preservation Association](#) and American Shoreline Podcast (GCCC)
- Alex Bump will talk about STEM-CCS and the 4th international offshore workshop

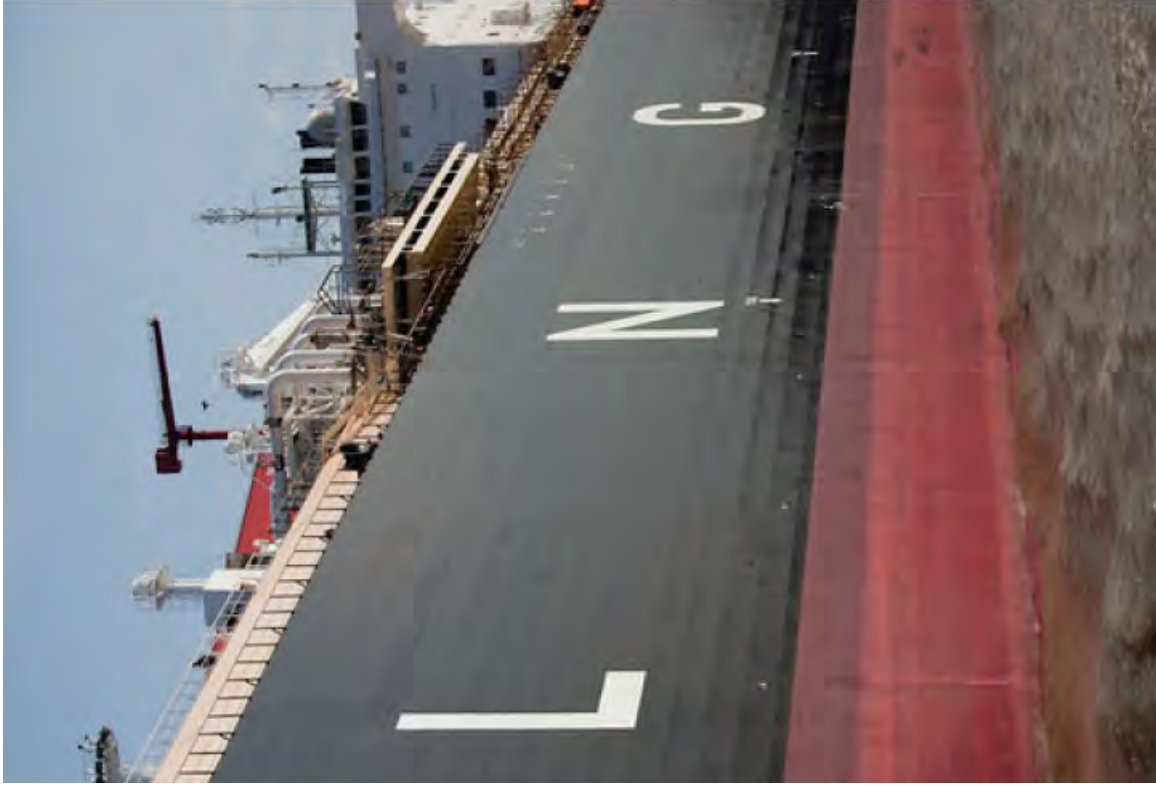


Source Industries & Regulatory Agencies

Trimeric: Several LNG facilities are starting up in TX and LA. LNG is a good source for CO₂.

Trimeric: Insight gained from expert interviews includes: large pipelines are in use already and pipelines reused for EOR require multiple booster stations to limit pressure during transport, which would increase project costs.





PIPELINE RE-USE



work done by:

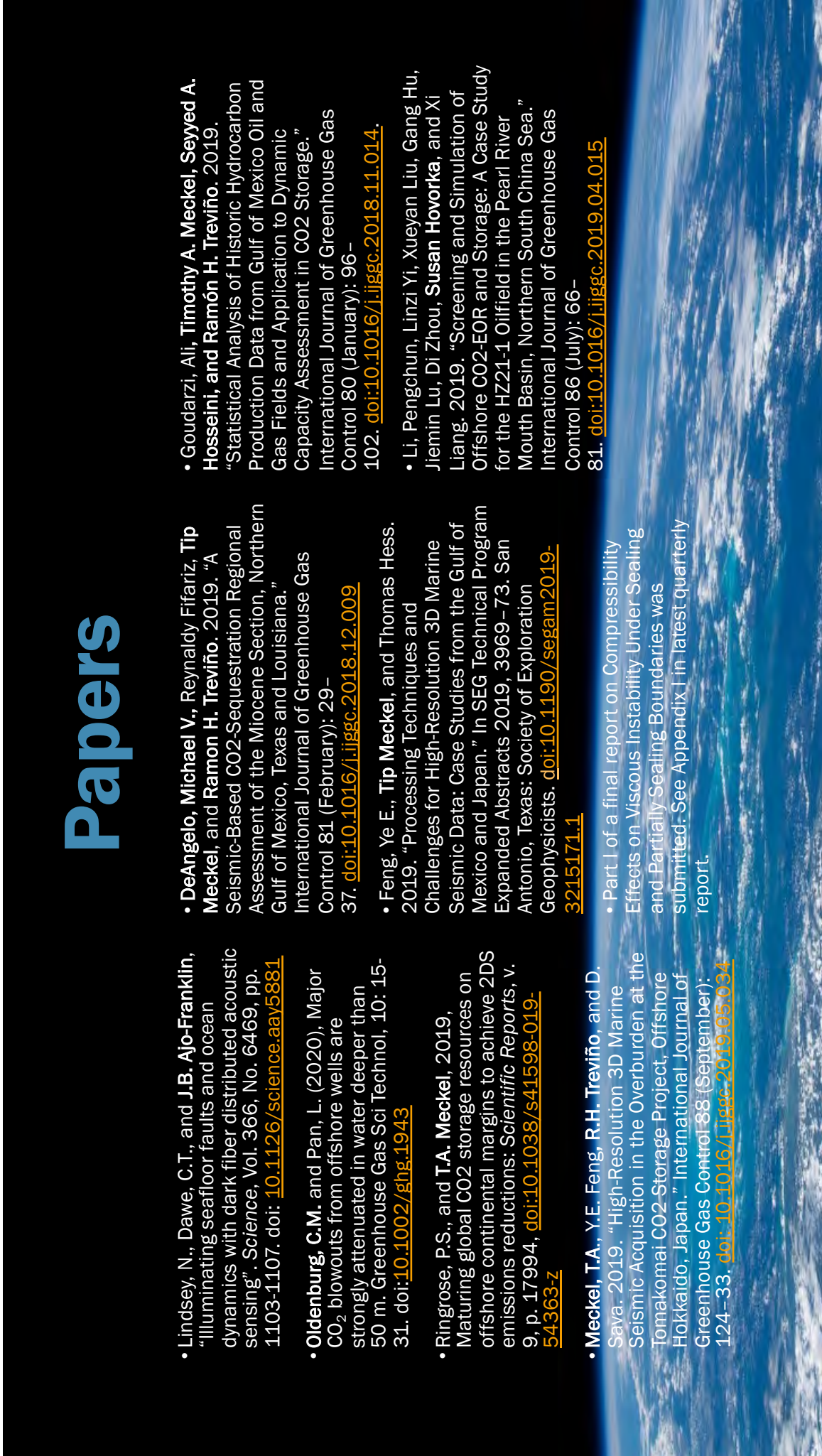


TRIMERIC CORPORATION



Papers

- Lindsey, N., Dawe, C.T., and J.B. Ajo-Franklin, “Illuminating seafloor faults and ocean dynamics with dark fiber distributed acoustic sensing”. *Science*, Vol. 366, No. 6469, pp. 1103-1107. doi: [10.1126/science.aay5881](https://doi.org/10.1126/science.aay5881)
- Oldenburg, C.M. and Pan, L. (2020), Major CO₂ blowouts from offshore wells are strongly attenuated in water deeper than 50 m. *Greenhouse Gas Sci Technol*, 10: 15-31. doi:[10.1002/ghg.1943](https://doi.org/10.1002/ghg.1943)
- Ringrose, P.S., and T.A. Meckel, 2019, Maturing global CO₂ storage resources on offshore continental margins to achieve 2DS emissions reductions: *Scientific Reports*, v. 9, p. 17994, doi:[10.1038/s41598-019-54363-z](https://doi.org/10.1038/s41598-019-54363-z)
- Meckel, T.A., Y.E. Feng, R.H. Treviño, and D. Sava. 2019. “High-Resolution 3D Marine Seismic Acquisition in the Overburden at the Tomakomai CO₂ Storage Project, Offshore Hokkaido, Japan.” *International Journal of Greenhouse Gas Control* 88 (September): 124–33. doi: [10.1016/j.jggc.2019.05.034](https://doi.org/10.1016/j.jggc.2019.05.034)
- DeAngelo, Michael V., Reynaldy Fifariz, Tip Meckel, and Ramon H. Treviño. 2019. “A Seismic-Based CO₂-Sequestration Regional Assessment of the Miocene Section, Northern Gulf of Mexico, Texas and Louisiana.” *International Journal of Greenhouse Gas Control* 81 (February): 29–37. doi:[10.1016/j.jggc.2018.12.009](https://doi.org/10.1016/j.jggc.2018.12.009)
- Feng, Ye E., Tip Meckel, and Thomas Hess. 2019. “Processing Techniques and Challenges for High-Resolution 3D Marine Seismic Data: Case Studies from the Gulf of Mexico and Japan.” In *SEG Technical Program Expanded Abstracts* 2019, 3969–73. San Antonio, Texas: Society of Exploration Geophysicists. doi:[10.1190/segam2019-3215171.1](https://doi.org/10.1190/segam2019-3215171.1)
- Part I of a final report on Compressibility Effects on Viscous Instability Under Sealing and Partially Sealing Boundaries was submitted. See Appendix I in latest quarterly report.
- Goudarzi, Ali, Timothy A. Meckel, Seyyed A. Hosseini, and Ramón H. Treviño. 2019. “Statistical Analysis of Historic Hydrocarbon Production Data from Gulf of Mexico Oil and Gas Fields and Application to Dynamic Capacity Assessment in CO₂ Storage.” *International Journal of Greenhouse Gas Control* 80 (January): 96–102. doi:[10.1016/j.jggc.2018.11.014](https://doi.org/10.1016/j.jggc.2018.11.014).
- Li, Pengchun, Linzi Yi, Xueyan Liu, Gang Hu, Jiemin Lu, Di Zhou, Susan Hovorka, and Xi Liang. 2019. “Screening and Simulation of Offshore CO₂-EOR and Storage: A Case Study for the HZ21-1 Oilfield in the Pearl River Mouth Basin, Northern South China Sea.” *International Journal of Greenhouse Gas Control* 86 (July): 66–81. doi:[10.1016/j.jggc.2019.04.015](https://doi.org/10.1016/j.jggc.2019.04.015)



Going Forward

Engaging Hispanic communities





GoMCarb Newsletter

Exploring the Gulf of Mexico subsurface for CO₂ storage
April 1, 2018 - March 31, 2023

February 2020

New Quarterly Report Summaries Via Email

Starting this year, the quarterly reports for GoMCarb will be released to partners via this newsletter. The goal is to share research findings across tasks so that other GoMCarb researchers keep up-to-date on the latest findings as we move forward in the year. The aim is to provide a newsletter with each quarterly report release. To orientate you to the goings-on of other researchers, the newsletter will provide a brief overview and then the amended report (removing proprietary data) will be attached. You can always find a list of all quarterly reports and other meeting materials on the GoMCarb Partner Portal on the right sidebar of the GCCC website.

Save the login:



If you have a research update, paper, or event you'd like to share with the group, please send the update to GCCC research program coordinator Emily Moskal, the newsletter curator:

emily.moskal@beg.utexas.edu



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Discussion in Chat

Report on STEMM-CCS & 4th International Offshore Workshop

Held in Bergen, 11-12 February, 2020



**Alex Bump
Task 6: Outreach**

SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

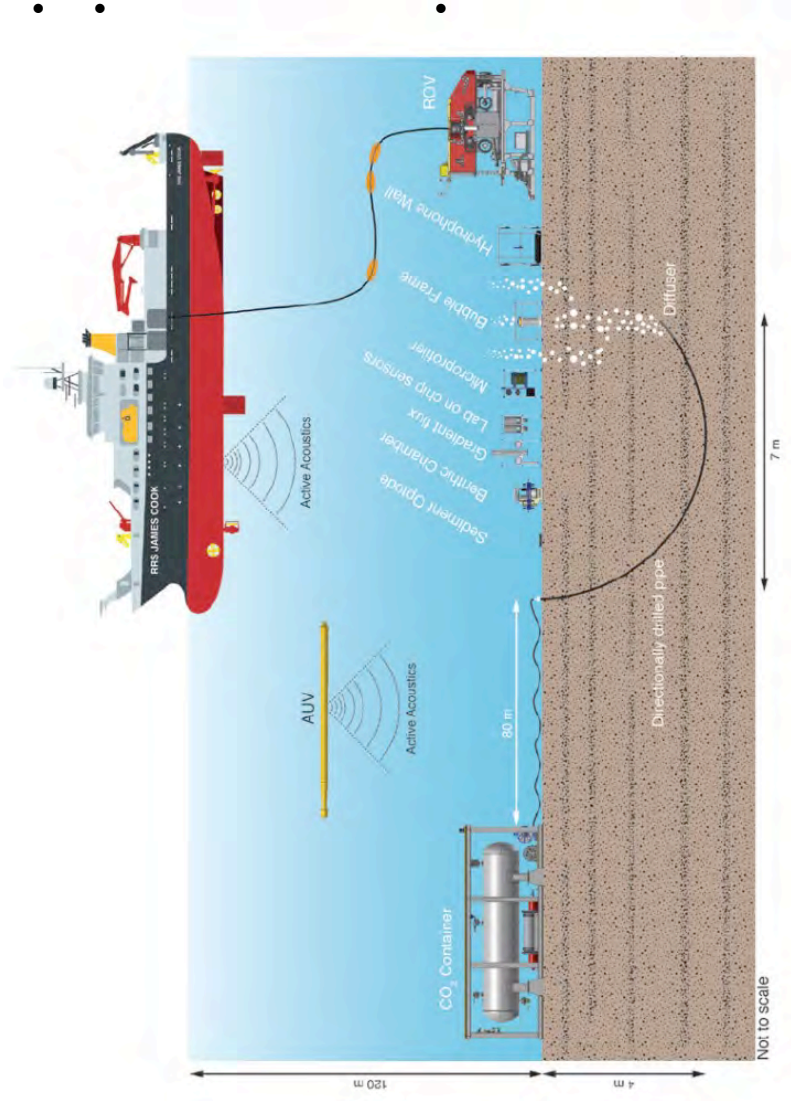
SECARB Offshore/GoMCarb Joint Partnership Meeting | March 26-27, 2020

2 days, 10 sessions, ~150 people



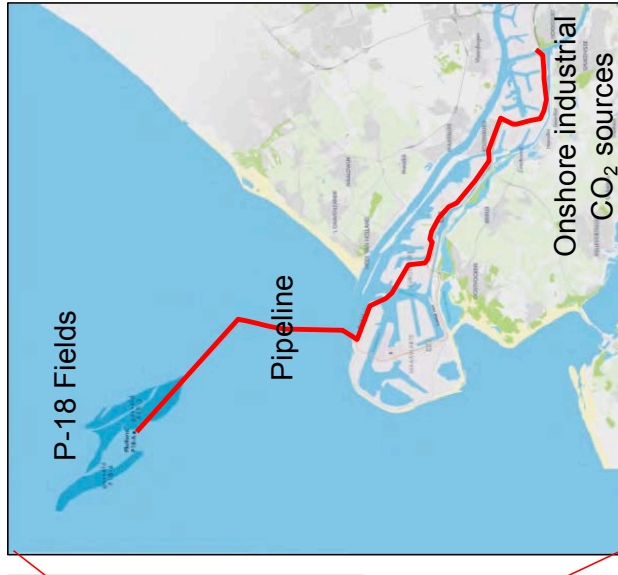
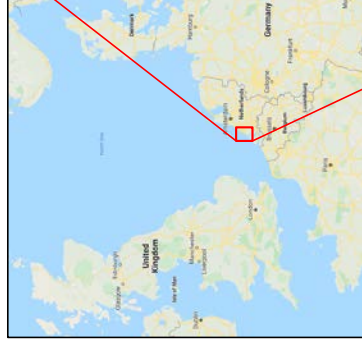
Monitoring: STEMM-CCS Project

- 14-day controlled release of CO₂ sub-seabed
- Monitor dispersal, experiment with detection
- Accomplishments
 - Development of “lab on chip” sensors
 - Quantification of chimney permeability
 - Acoustic quantification of leakage
 - CSeep method for stoichiometric leakage source attribution
- Application
 - Many tools for reliable leak detection
 - To be cost-effective, monitoring needs to be risk-based, tiered and triggered



Commercial Offshore CCS: Porthos

- Part of Dutch effort to cut GHGs by 95% by 2050
- Joint venture: Port of Rotterdam, EBN & Gasunie
- CAPEX ~ € 450M
- Commercial CO₂ transport and storage business
- Open access to onshore suppliers
 - Shell, ExxonMobil, Air Liquide and Air Products currently interested
- Transport via 54 km pipeline
- Storage in P-18 fields with capacity of ~37 Mt
- Currently in permitting and FEED studies
- EIA and agreements with CO₂ suppliers due in 2020
- Formal FID 2021, operational 2023
- EU recognition as a Project of Common Interest

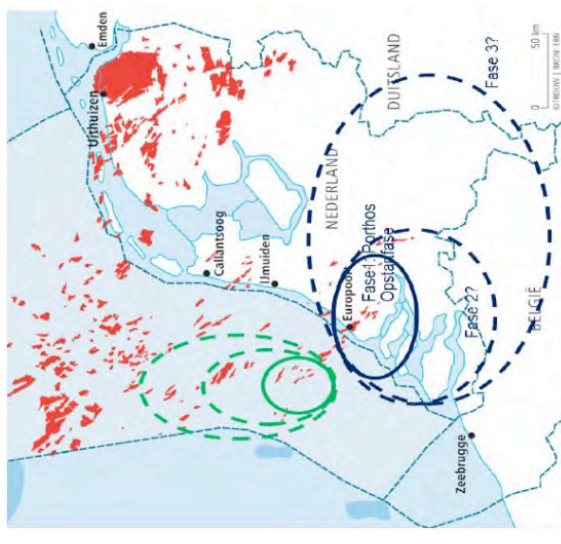


(Filip Neele, TNO; <https://www.rotterdamccus.nl/en/the-project/>)



Phased Design: Porthos

- Porthos positioned as a future CCS hub
 - Initial injection of 2-2.5 Mt/yr; design capacity of 10 Mt/yr
 - Transport system is deliberately over-sized for Phase 1
 - Phase 2: domestic sources beyond Port of Rotterdam
 - Phase 3: foreign sources, including Belgium, Germany
 - Updates to London Protocol now permit export of CO₂
 - Storage would expand into neighboring depleted fields as needed
 - Plan to learn and adapt as business grows
- Other projects following a similar model
 - Athos, Northern Lights, Net Zero Teeside, Acorn
 - Potential for broad applicability



(Filip Neele, TNO; <https://www.rotterdamccus.nl/en/the-project/>)



Global Offshore CCS Challenges

- Re-use of infrastructure
 - Financially attractive, technically difficult
 - How to extend use beyond design life? Adapt to handling different fluids?
 - How to assess and mitigate risk of legacy well leakage
- Monitoring
 - Must be efficient and cost-effective but also trustworthy
 - Risk-based with further monitoring triggered by exceptions
- Legal
 - CCS is a new use of the sea, not covered by international oil and gas law
 - How to align existing O&G licensing, facilities, decommissioning laws with CCS?
 - Parallel licenses? How to transfer facilities and liabilities?
 - What if there is a time gap between production and storage? Who is responsible in the interim? Who maintains the facilities?



Conclusions and Recommendations

Insights and trends

- Moving from decarbonizing just oil and gas to broader energy systems and industries
- More and more offshore projects are being planned
- Many projects are considering hubs with phased sources –need to oversize the transport initially

Recommendations

- Change our language to be more positive, e.g. “containment” instead of “leakage”
- Develop a road map for CCS implementation of CCS and work backward to identify research needs
- Educate regulators and legislators on CCS—benefits, boundaries and framework are needed
- Work to create an investment-friendly framework for CCS (i.e., de-risk investment)

One to watch

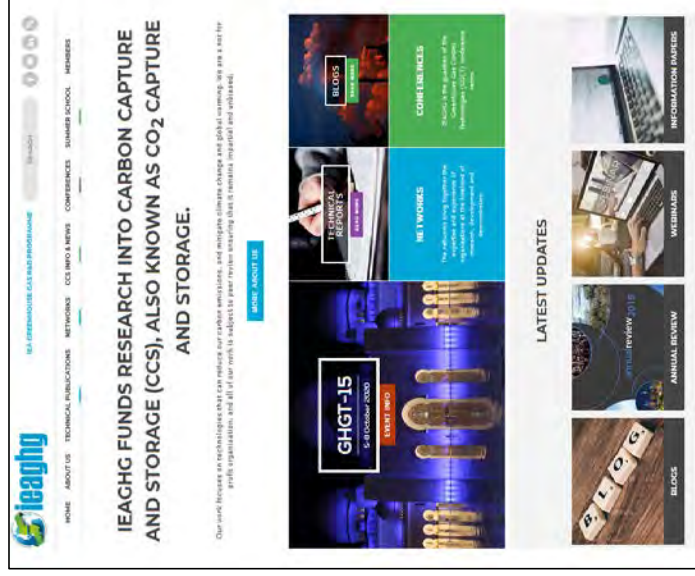
- Role of CCS in country updates to the Paris Agreements (due in mid-2020)



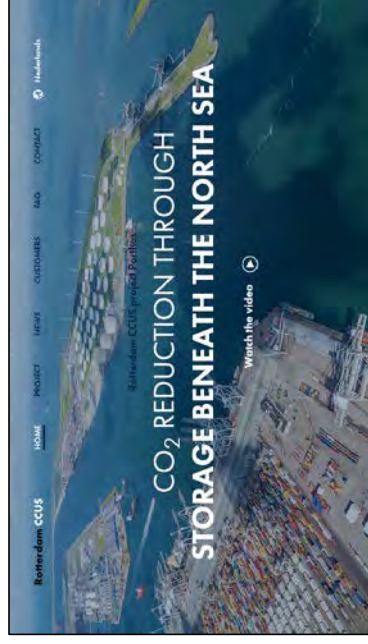
More Information



<http://www.stemm-ccs.eu/>



www.ieaghg.org



<https://www.rotterdamccus.nl/en/>



March 27, 2020

SECARB Offshore GoM Project Updates and Discussion

9:45 AM – 10:00 AM

Log In and Trouble Shooting

10:00 AM – 11:00 PM

Status of Characterization of CO₂-EOR Offshore Resource Potential – Matt Wallace, Advanced Resources International, Inc.
Status of Risk Characterization Activities and Data Development – Michael Godec, Advanced Resources International, Inc.

11:00 AM – 11:15 AM | BREAK

11:15 AM – 12:15 PM

Status on Work on Characterizing Legal and Regulatory Frameworks and Key Considerations – Michael Godec, Advanced Resources International, Inc., and Ingvild Ombudstvedt, IOM Law
Overview of Offshore CO₂-EOR/Storage Case Studies – Vello Kuuskraa, Advanced Resources International, Inc.

12:15 PM – 1:15 PM | LUNCH BREAK

1:15 PM – 2:05 PM

Risk Assessment Gas Hydrates – Camelia Knapp, Oklahoma State University
SECARB Offshore evaluating the salt structures and deep-water reservoirs in the central Gulf of Mexico – Jack Pashin, Oklahoma State University

2:05 PM – 2:20 PM | BREAK

2:20 PM – 3:00 PM

Offshore Well Integrity – Andrew Duguid, Battelle Memorial Institute
45Q – Brian Hill, Crescent Resource Innovation

3:00 PM – 3:15 PM

Wrap up and Comments



Experiencing Technical Difficulties?

Emily Moskal

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Experiencing Technical Difficulties?

Emily Moskal

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Thank you for joining us!

Presentations are available online.

gulfcoastcarbon.org/news/2020

March 26-27: <https://www.sseb.org/news-and-events/>

After March 27: <https://www.sseb.org/news-and-events/past-events/>



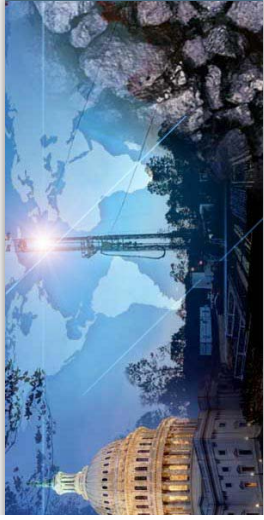


Characterization of Offshore CO₂ EOR Resource Potential

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace, Project Manager
Advanced Resources International, Inc.

March 26-27, 2020



Outline of Presentation

1	Purpose of Study
2	Offshore GOM OCS Oil Resources
3	Offshore Oil Field Database
4	Offshore CO ₂ EOR Resource Potential
5	Next Steps

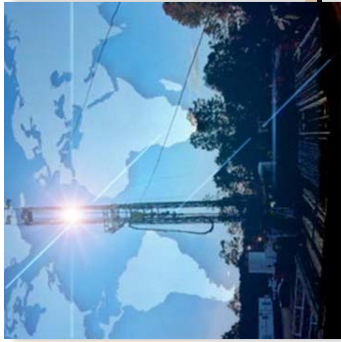
Purpose Of Study

The primary purpose of this resource characterization is to identify the Offshore GOM OCS oil resource that is potentially viable for CO₂ enhanced oil recovery (CO₂ EOR).

This study includes characterization of oil fields in both the Shallow Water Lease Areas and Deep Water Protraction Areas in the Central Planning Area of the GOM OCS.

This resource characterization included several tasks:

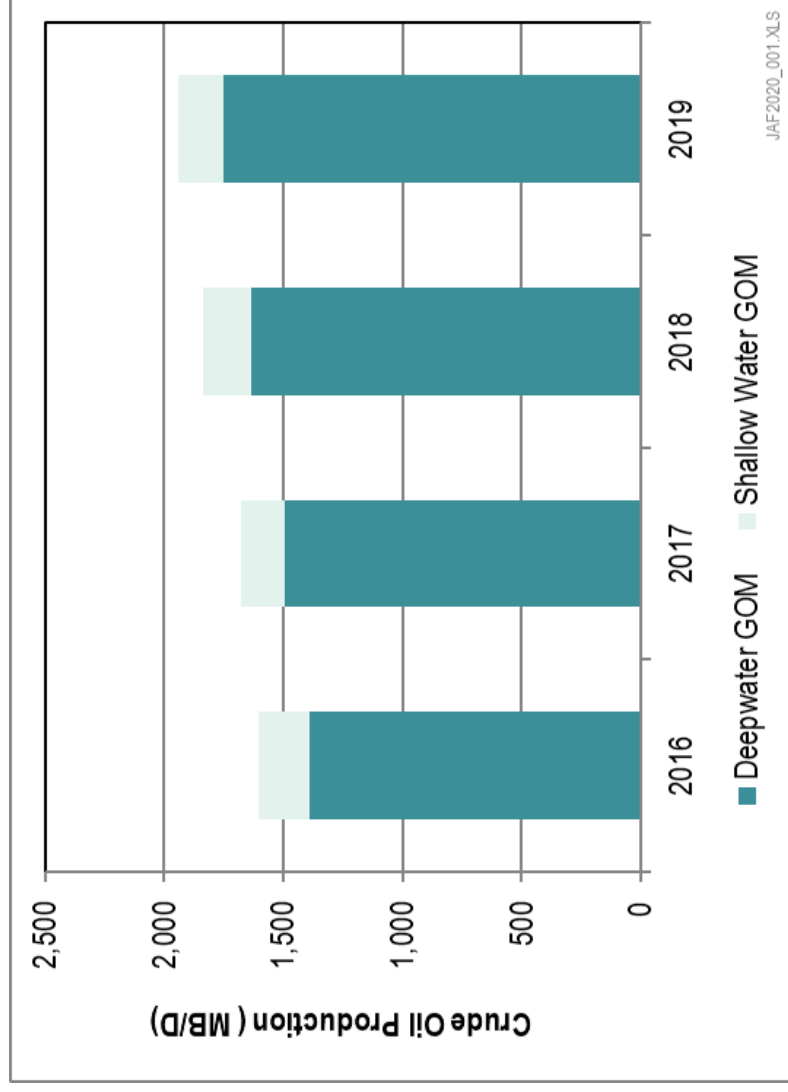
1. **Offshore GOM OCS Oil Resource.** Establish the oil resource in-place and remaining reserves for oil fields in the GOM OCS Central Planning Area.
2. **Offshore Oil Field Database.** Develop a database of Offshore GOM OCS oil reservoirs viable for CO₂ EOR.
3. **Offshore CO₂ EOR Resource Potential.** Calculate the remaining oil reserves and resource in place for Shallow and Deep Water oil fields that are likely candidates for CO₂ EOR.



Offshore GOM OCS Oil Resource

Status of Offshore GOM OCS Oil Production

Offshore GOM: Crude Oil Production



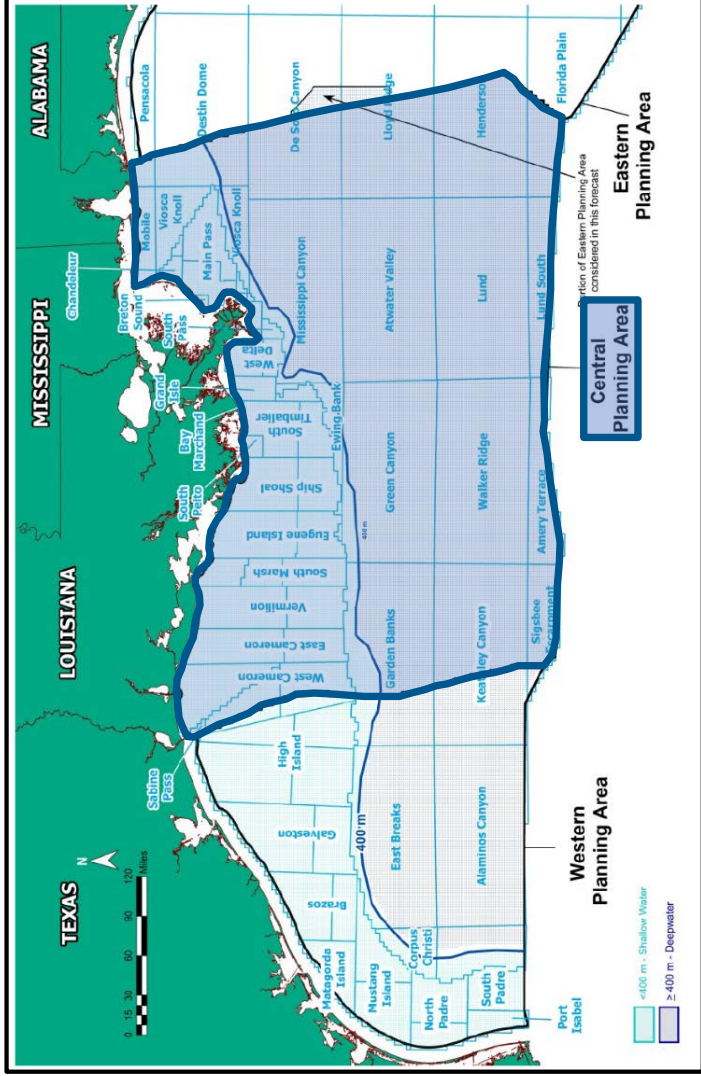
Oil production from offshore GOM OCS oil fields has increased for the last several years, enabling production to reach 1.9 MMB/D in 2019.

We expect oil production to continue to grow in 2020 as new deep water oil fields come on-line and existing fields, like Thunder Horse South and Atlantis, undergo expansion.

Given the increased production from offshore oil resources, many leases nearing depletion will require advanced production practices (like CO₂ EOR) to extend their productive life.

Offshore GOM OCS Resource

GOM OCS Central Planning Area



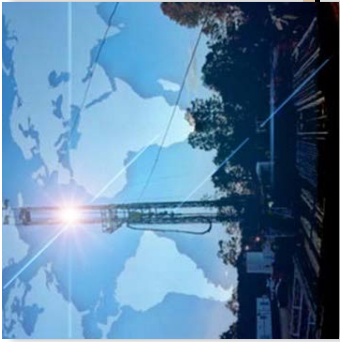
Source: Modified from BOEM 2017-082, OCS Report.

Area	Fields	Original Reserves (MMBOE Equivalent)
Central Planning Area	966	51,850
Western Planning Area	353	7,530
Total GOM OCS	1,319	59,380

This Offshore CO₂ EOR resource characterization focuses on Shallow and Deep Water resources in the GOM OCS Central Planning Area.

As of EOY 2017 the Central Planning Area contains 966 of the 1,319 total GOM OCS oil and gas fields.

These 966 fields contain 51,850 MMBOE of the 59,380 MMBOE in the GOM OCS (87%).



Offshore Oil Field Database

2018 BOEM Sands Oil Resource Data

The foundation for establishing the ARI Offshore Oil Reservoir Database is the Bureau of Ocean Management (BOEM) 2018 Oil Sands database.

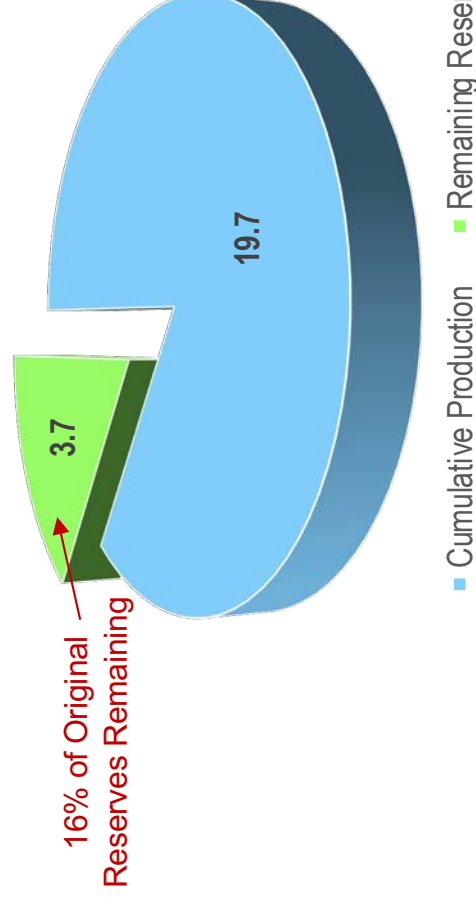
This data set includes production history, well counts, volumetric data, and reservoir characteristic data for all Offshore oil and gas reservoirs.

Of the 966 fields in the Central Planning Area 241 are designated oil fields. These 241 oil fields contain 23.4 billion barrels of Original Reserves, with only 3.7 billion barrels of Remaining Reserves.

Central Planning Area Oil Resources

CPA Resources	Oil Resources (MMBbl)
Oil Fields	241
Original Reserves	23,410
Cumulative Production	19,660
Remaining Reserves	3,750

Central Planning Area Remaining Reserves



Building the ARI Offshore Oil Field Database

The 2018 BOEM Sands reservoir data provided the foundation for the ARI Offshore Oil Field Database, however a number of updates were required to adapt the data for evaluating CO₂ EOR viability.

1. Volumetric Consistency – The 2018 Sands Database includes a reservoir OOIP, however this value is not always consistent with the reported reservoir volumetric data (area, net pay, porosity, So, and Bo). ARI adjusted the OOIP value to be volumetrically consistent, which added a significant volume of resource to the database.

2. Additional Reservoir Data – The 2018 Sands Database includes primarily volumetric and reservoir characteristic data, however ARI calculated a number of additional reservoir data points required for modeling CO₂ EOR in the future. These data points include:

- **Current formation volume factor (Bo)**
- **Residual oil saturation (Sor)**
- **Dykstra-Parsons co-efficient of heterogeneity**
- **Reservoir Sweep Efficiency**

Screening Criteria for CO₂ EOR Oil Fields

The 2018 Sands Database was screened to identify oil fields in the Central Planning Area that are likely candidates for CO₂ EOR. Screening criteria included:

- Resource Size: Minimum Original Oil In-Place ≥ 20 MMBbl
- API Gravity: Minimum of 20 degrees
- Depth: TVD $> 2,500$ ft to meet minimum miscibility requirements
- Shallow Water Fields: $< 1,000$ ft water depth
- Deep Water Fields: $\geq 1,000$ ft water depth

ARI Offshore Oil Field Database

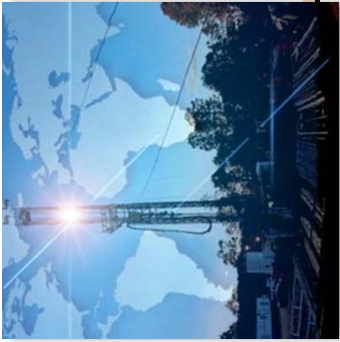
Of the 241 CPA oil fields in the 2018 BOEM Sands database, 168 oil fields met the screening criteria for inclusion in the ARI Offshore Oil Field Database.

These 168 oil fields include 572 reservoirs, which hold 49.7 billion barrels of original oil in-place and 15.3 billion barrels of original reserves (approximately 65% of the 2018 Sands Database total of 23.4 billion barrels).

While the Shallow Water lease areas contain more oil fields and reservoirs, the Deep Water resource contains approximately 70% of the total oil resource in the CPA.

ARI Offshore DB -- Central Planning Area Oil Resources

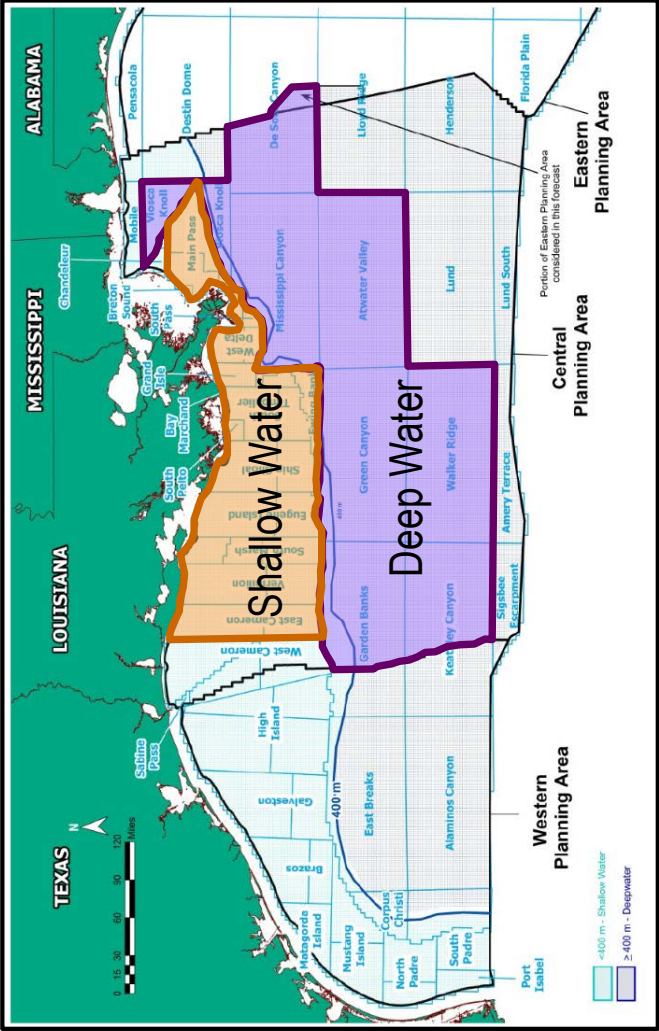
	Oil Fields	Reservoirs	OOIP (BBbl)	Orig. Reserves (BBbl)
Shallow Water	90	310	14.7	6.0
Deep Water	78	262	35.0	9.3
Total	168	572	49.7	15.3



Offshore CO₂ EOR Resource Potential

Central Planning Area CO₂ EOR Resource

Central Planning Area CO₂ EOR Oil Resources



The CPA holds 34.3 billion barrels of remaining oil in-place available for targeting by CO₂ EOR.

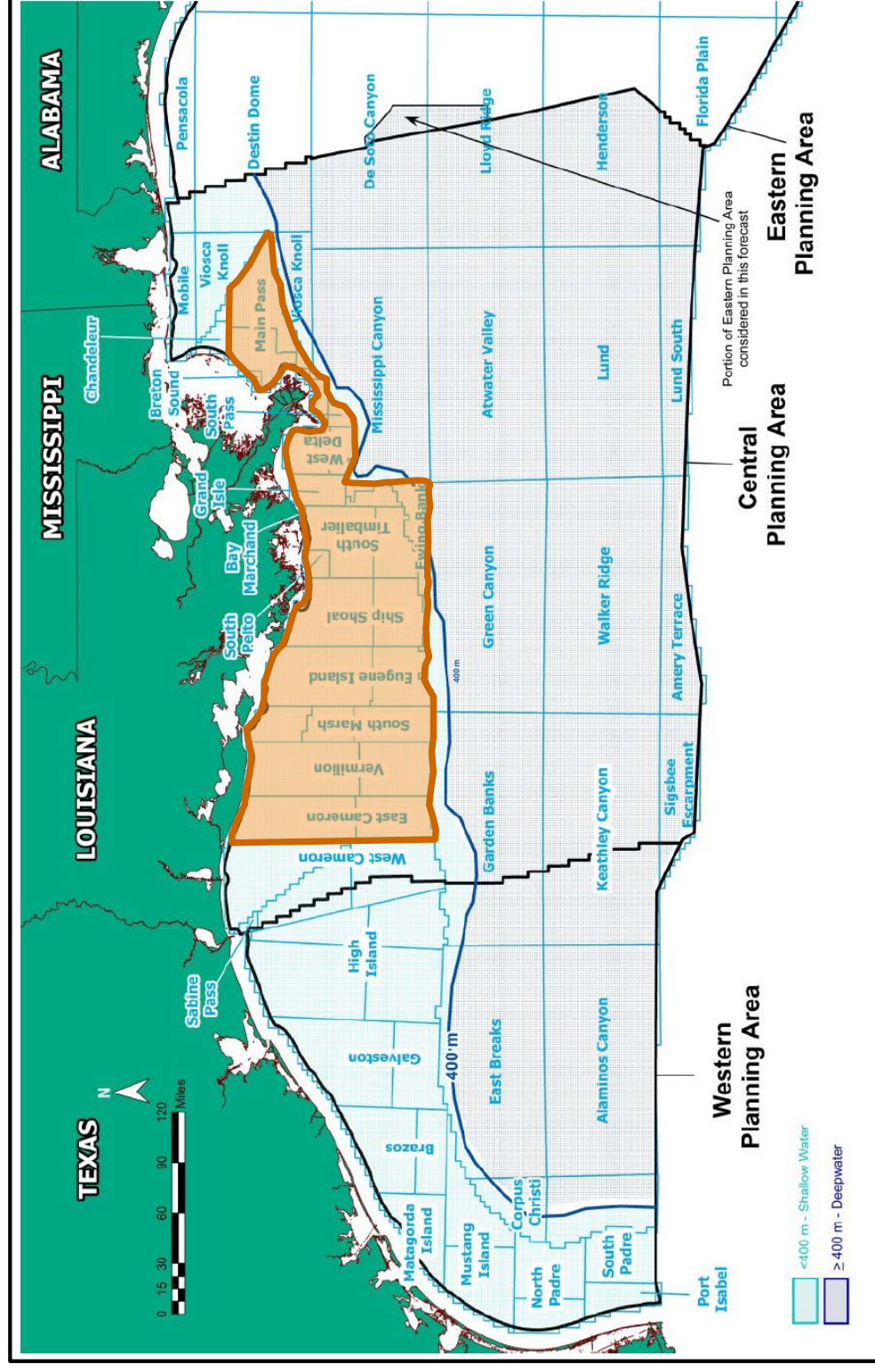
The shallow water area has only 100 million barrels of remaining reserves, and many fields are effectively depleted. However, there are 8.6 billion barrels of remaining oil in-place available for targeting by CO₂ EOR.

The deep water area has 3 billion barrels of remaining reserves, however it holds a significant volume of remaining oil in-place of 25.7 billion barrels that could be targeted by CO₂ EOR.

	OOIP (BBbl)	Orig. Res. (BBbl)	Cum. Prod (BBbl)	Rem. Res. (BBbl)	ROIP (BBbl)
Shallow	14.7	6.1	6.0	0.1	8.6
Deep	35.0	9.3	6.3	3.0	25.7
Total	49.7	15.3	12.2	3.1	34.3

Shallow Water Lease Areas

The ARI Offshore Oil Field Database includes oil resources for eleven shallow water lease areas.



Viable Shallow Water CO₂ EOR Resources

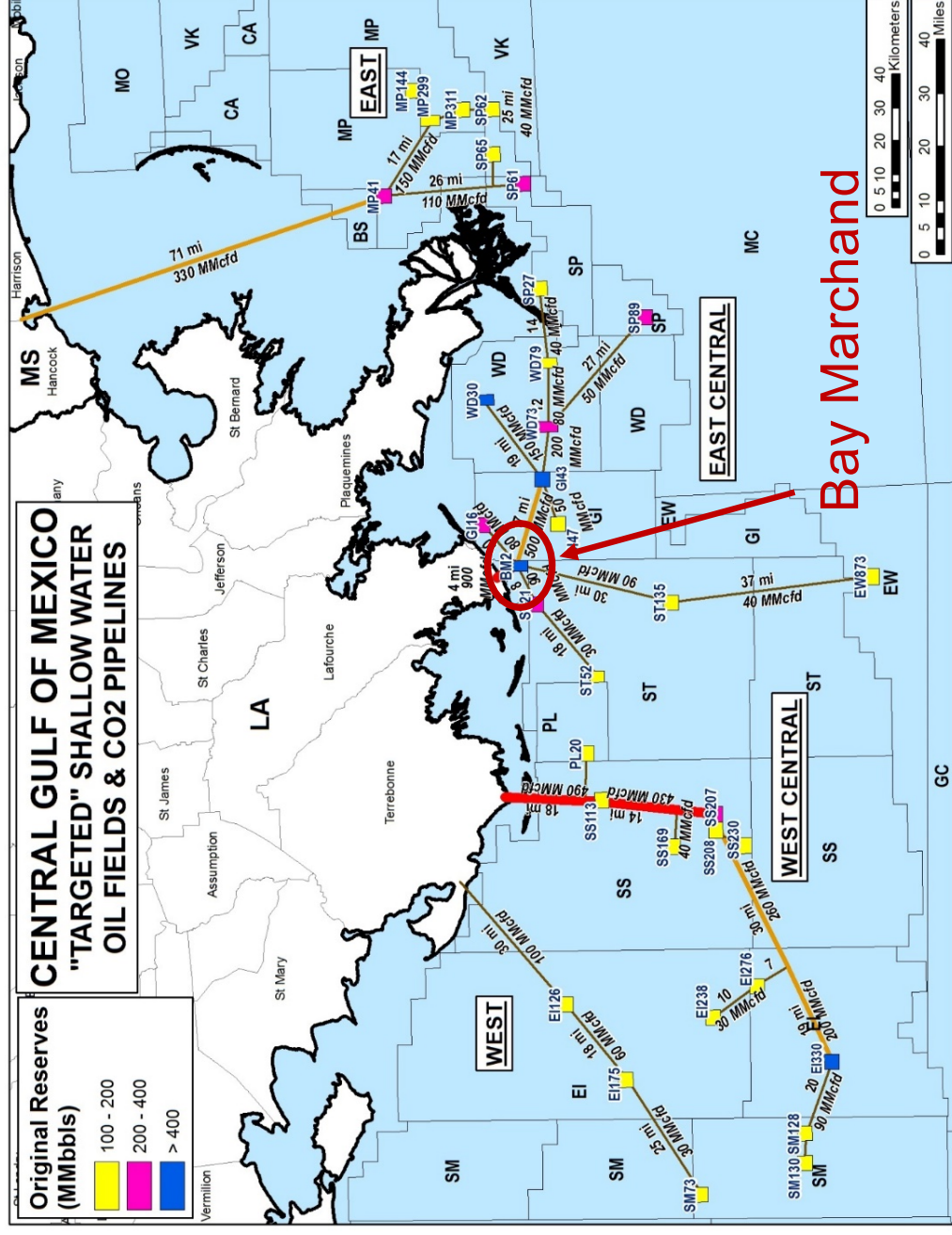
The shallow water lease areas contain just over 100 million barrels of remaining reserves. Original reserves in each lease area are nearing depletion, particularly in South Pass, West Delta, and South Timbalier which have produced over 99% of original reserves.

South Timbalier, which includes the large Bay Marchand field, has over 1 billion barrels of ROIP and is particularly attractive for CO₂ EOR.

Area	OOIP	Resources (Million Barrels)		
		Original Reserves	Cumulative Production	Remaining Reserves
South Pass	1,902	702	699	4
West Delta	1,790	859	859	4
South Timbalier	1,975	998	910	6
South Marsh	1,160	435	426	9
Main Pass	2,270	817	807	10
Ship Shoal	1,272	597	586	12
Grand Isle	1,573	645	631	14
Eugene Island	1,769	774	754	20
Other*	999	320	296	24
Total	14,709	6,147	5,968	102
				8,639

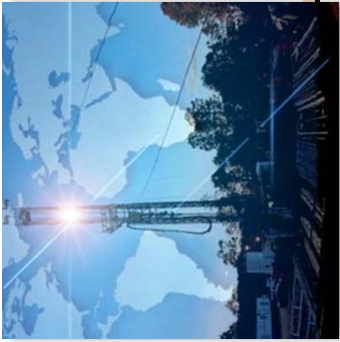
*Ewing Bank, Vermillion, East Cameron

Shallow Water CO₂ Pipeline Network



This diagram represents a theoretical offshore CO₂ pipeline network connecting oil fields to onshore sources of CO₂ for CO₂ EOR.

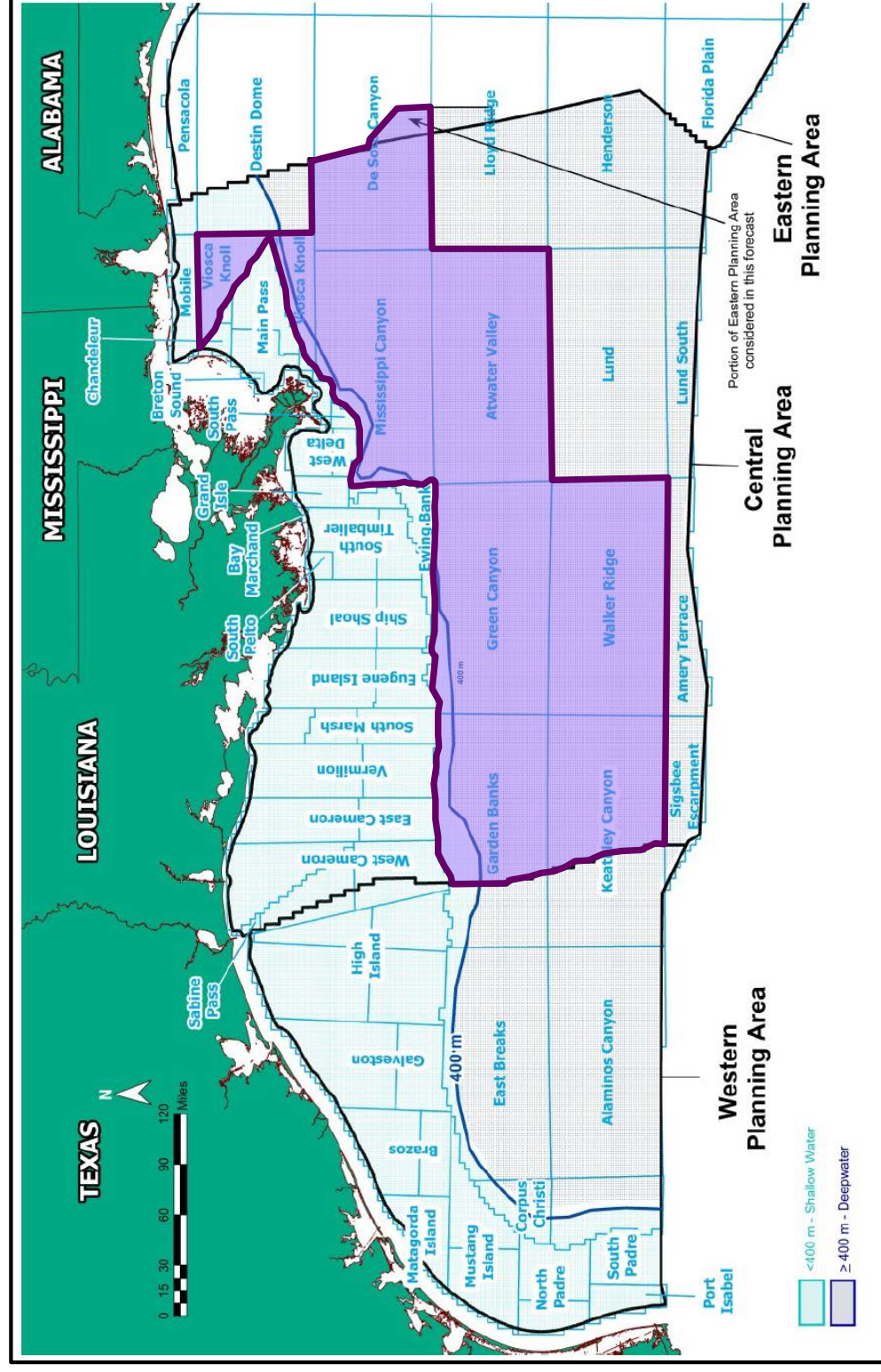
The large Bay Marchand field, which is located close to shore, would serve as a "hub" location distributing CO₂ through smaller transportation lines.



Deep Water Oil Field Resource

Deep Water Protraction Areas

The ARI Offshore Oil Field Database includes oil resources for eight whole or partial deep water protraction areas.



Viable Deep Water CO₂ EOR Resources

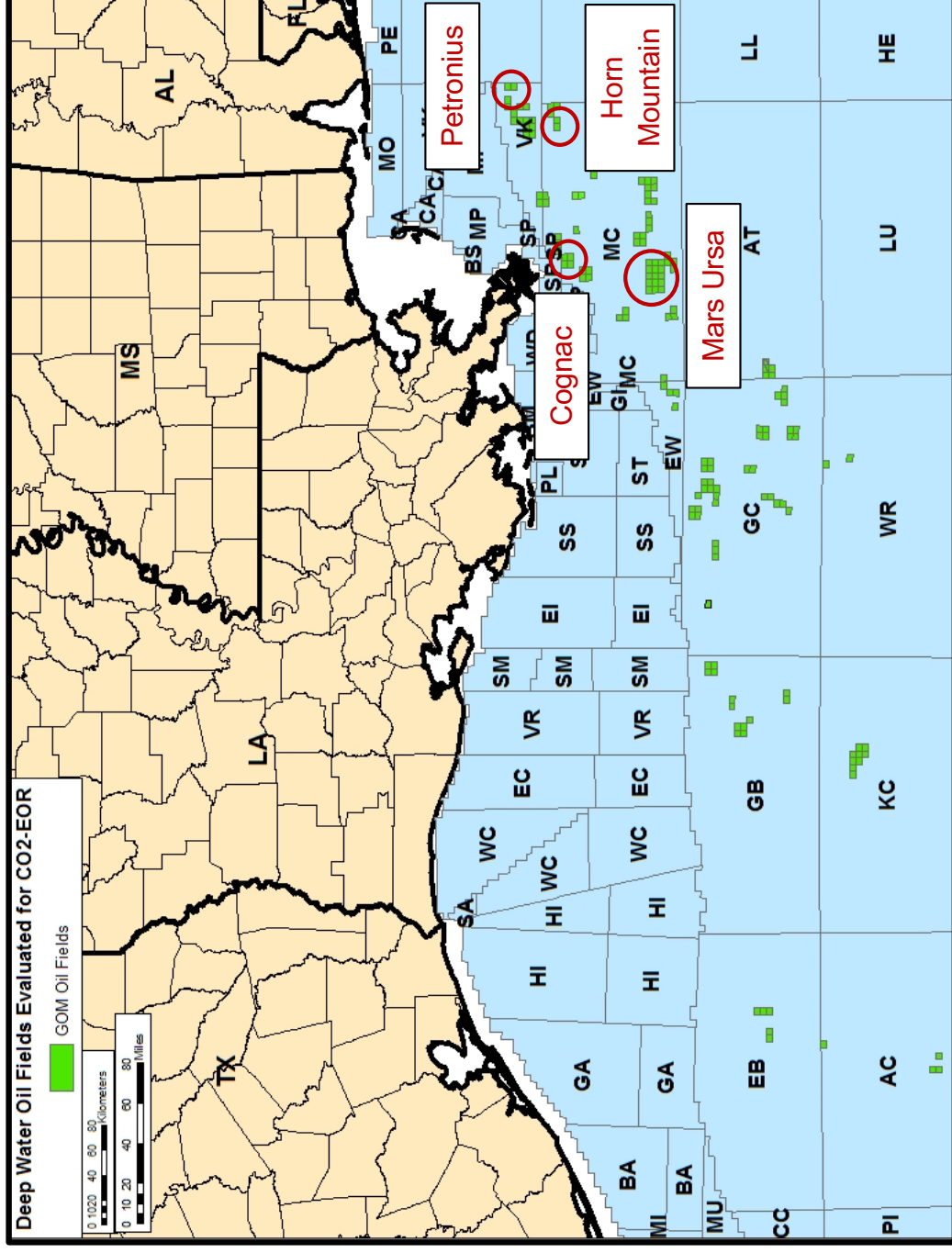
The deep water protraction areas contain just over 3 billion barrels of remaining reserves. Original reserves in several lease areas, like Viosca Knoll, are nearing depletion while others, like Mississippi Canyon and Green Canyon, have significant volumes of remaining reserves.

Viosca Knoll, which includes several large fields like Ram Powell and Petronius that are located relatively close to shore, holds 700 million barrels of ROIP that could be targeted for CO₂ EOR.

Area	Original OIP	Resources (Million Barrels)		
		Original Reserves	Cumulative Production	Remaining Reserves
Viosca Knoll	1,193	461	441	20
Garden Banks	1,729	662	604	58
Walker Ridge	4,837	591	117	473
Mississippi Canyon	12,549	4,002	2,859	1,143
Green Canyon	14,280	3,393	2,168	1,224
Other*	384	154	68	86
Total	34,972	9,262	6,258	3,004
				25,709

*Keathley Canyon, Atwater Valey, De Soto Canyon

Nearshore Deep Water Oil Fields



A number of large deep water oil fields that are viable for CO₂ EOR are located relatively near shore – particularly in the Viosca Knoll and Mississippi Canyon protraction areas.

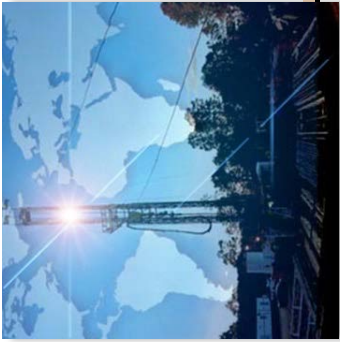
Cognac, Petronius, Horn Mountain, and Mars Ursa, among a number of other fields, are located within 80 miles of shore and have a combined ROIP of 3.5 billion barrels.

Emerging Deep Water CO₂ EOR Technology

Significant advancements in technology have moved CO₂ EOR in the Deep Water GOM OCS production areas closer to reality. Aker Solutions is currently developing a network of sea floor processing equipment for CO₂ injection and recycling for CO₂ EOR.



Source: Journal of Petroleum Technology, Aker Sea Floor CO₂ Injection Project



Next Steps

Next Steps Technically Viable Resources

The next step for modeling Offshore CO₂ EOR potential is to determine the technically viable CO₂ EOR resources and overall CO₂ demand.

With availability of appropriate data, the CO₂-PROPHET Model can be used to model CO₂-EOR potential in GOM oil reservoirs. The data required for running CO₂-PROPHET would be assembled from the latest BOEM Sands database, augmented by a variety of estimates and calculations.

Location	State									
	Oil Field Name	Reservoir Name	OOIP (MMBbl)	Reservoir Area (ac)	Net Pay (ft)	Porosity (%)	Initial Oil Saturation (%)	Residual Oil Saturation (%)	Initial Formation Volume Factor	Current Formation Volume Factor
Volumetric Reservoir Data										
Reservoir Characteristics	Depth (ft)									
	Reservoir Temperature (°F)									
	Oil Gravity (° API)									
	Gas-Oil Ratio (scf/Bbl)									
	Reservoir Water Salinity (ppm)									
	Gas Specific Gravity									
	Dykstra-Parsons									
	Permeability (mD)									
	Oil Viscosity (cp)									
	Water Viscosity (cp)									
CO ₂ EOR Flood Data	Injectivity (Bbl/d)									
	Minimum Miscibility Pressure (psi)									
	Injection Pressure (psi)									
Well Data	Production Wells									
	Shut-In Production Wells									
	Injection Wells									
	Shut-In Injection Wells									

Next Steps

Economically Viable Resources

The economically viable Offshore CO₂ EOR oil resource and CO₂ demand would be determined using a modified CO₂ EOR Cost Model. The model will include separate costs for developing offshore CO₂ EOR oil fields in either shallow or deep water areas, and will include several technology options for CO₂ delivery, injection, and recycling.

The Offshore GOM OCS resource contains significant potential for increased volumes of domestic oil production and secure storage of CO₂, yet the technical challenges will require significant collaboration from multiple stakeholders.



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Building the Foundation for Assessing GOM Offshore CO₂ EOR and Associated CO₂ Storage

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace
Anne Oudinot
Advanced Resources International, Inc.

March 26-27, 2020





Outline of Presentation

1	Purpose of the Case Studies
2	Petronius Offshore Oil Field Case Study
3	Cognac Offshore Oil Field Case Study
4	Observations and Findings

Purpose Of Case Studies

The primary purpose of the “Offshore Oil Field Case Studies” is to assess the ability of the NETL CO₂ PROPHET Model to represent the performance of an offshore CO₂ flood, including appropriately capturing the geologic complexity and irregular well spacings typical of offshore oil fields.

For this, the Study conducted seven tasks:

1. **Geologic Model.** Build representative geologic models for the oil fields, including capturing structural setting and associated aquifer.
2. **Reservoir Model.** Assemble the key reservoir properties of the oil reservoir, including its volumetric data, fluid flow capabilities, and oil composition.
3. **Field Development.** Establish the locations of the existing oil/gas production wells producing from the oil reservoir.

Purpose Of Case Study (Cont'd)

4. **History Matching Using Compositional Simulations.** Use GEM compositional simulator to provide a “first-order” history match of fluid production from the oil reservoir.
5. **Assessing CO₂ Flooding Using Compositional Simulation.** With a calibrated geologic/reservoir description, appraise the performance of a post-primary CO₂ EOR project in the oil reservoir using the GEM compositional simulator.
6. **Assessing CO₂ Flooding Using CO₂ PROPHET.** In parallel with the GEM compositional simulator, use the NETL CO₂ PROPHET Model to appraise the performance of a post-primary CO₂ EOR project in the oil reservoir.
7. **Comparing GEM and CO₂ PROPHET Modeling.** Compare the results of GEM and CO₂ PROPHET modeling of CO₂ EOR to determine whether the NETL CO₂ PROPHET model could reasonably represent the performance of the CO₂ flood compared to the more sophisticated GEM compositional simulator.

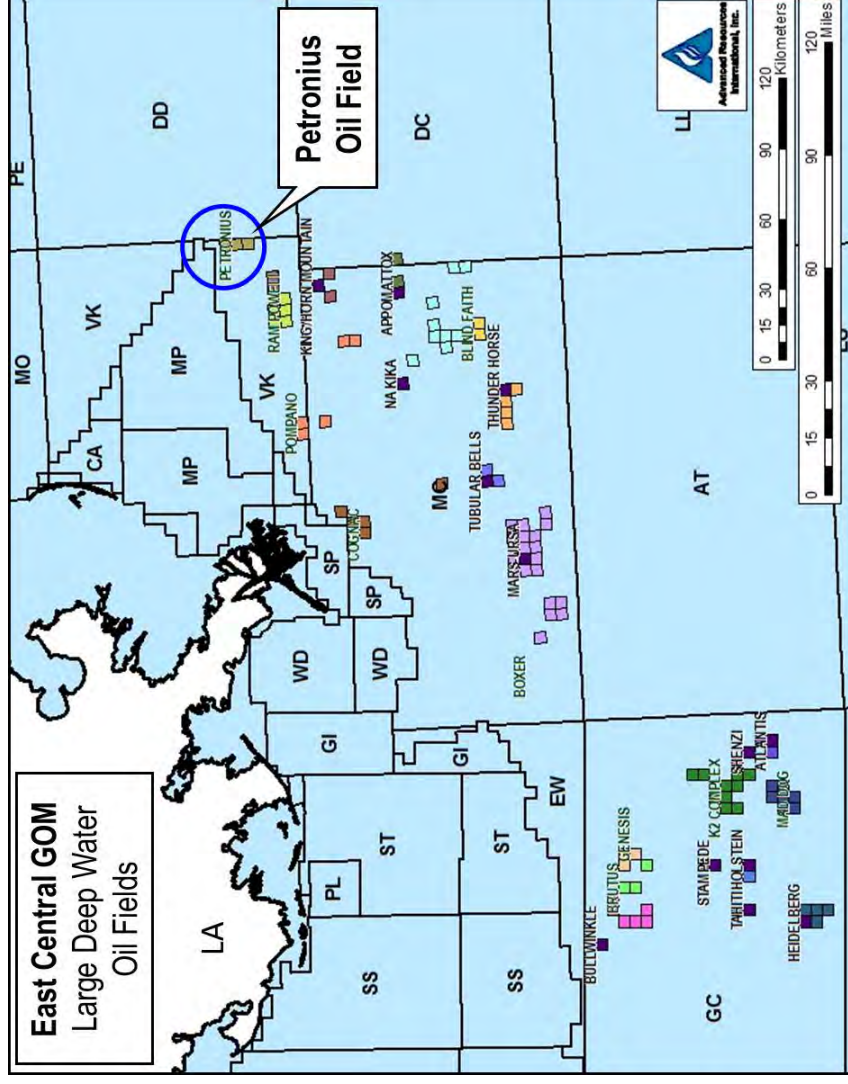


Petronius Offshore Oil Field Case Study

Background

The Petronius deepwater oil field (VK 786) is located in 1,790 feet of waters of the East Central Gulf of Mexico.

Location of Petronius Oil Field, Eastern Gulf of Mexico



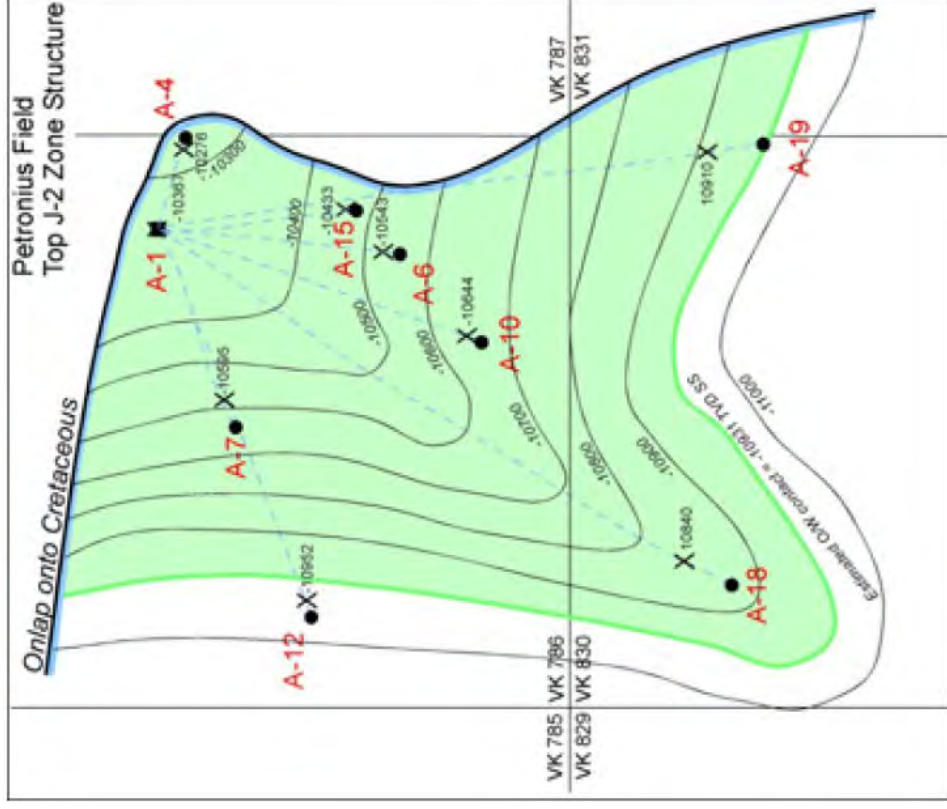
Petronius, with 162 million barrels of original oil reserves, has produced over 96% of its original reserves, as of the end of 2016.

Oil production that peaked at 70,000 B/D in 2003 but has declined to 6,600 B/D in 2016, placing Petronius on a list of oil fields facing near-term abandonment.

A notable feature of Petronius is its early installation of a waterflood due to a relatively weak underlying aquifer.

Petronius J-2 Sand Geologic Model

Structure of the Petronius J-2 Sand



Source: Duan, 2013

The Petronius J-2 Sand reservoir is a Middle Miocene sheet sand, providing a structurally simple setting.

There is little faulting within the Petronius oil field and the J-2 Sand reservoir is judged to be relatively continuous.

The illustration provides the structure of J-2 reservoir, its oil-water contact (OWC), and the location of its nine production wells.

The Petronius J-2 Sand

The Petronius oil field contains two major sands, the Miocene-age Upper (J-1) Sand and Middle (J-2) Sand, as well as a series of smaller oil sands, shown below.

Petronius Original Oil Resources, Production and Remaining Reserves

Sands	Area (Acres)	Original Oil In- Place (MMB)	Cumulative Oil Production* (MMB)	Remaining Oil Reserves* (MMB)
1. Major Sands				
▪ J-1	3,438	124.8	69.6	4.0
▪ J-2	5,288	104.7	52.0	1.3
2. Minor Sands				
▪ J-3	1,352	24.5	6.1	1.0
▪ J-4	1,398	39.2	17.8	0.9
▪ J-5	389	18.2	7.8	1.5
▪ Other (13)	-	0.7	0.2	-
Total	11,865	312.1	153.5	8.7

*As of end of 2016. JAF2019_014.XLS

Volumetric and Other Reservoir Properties: Petronius J-2 Sand

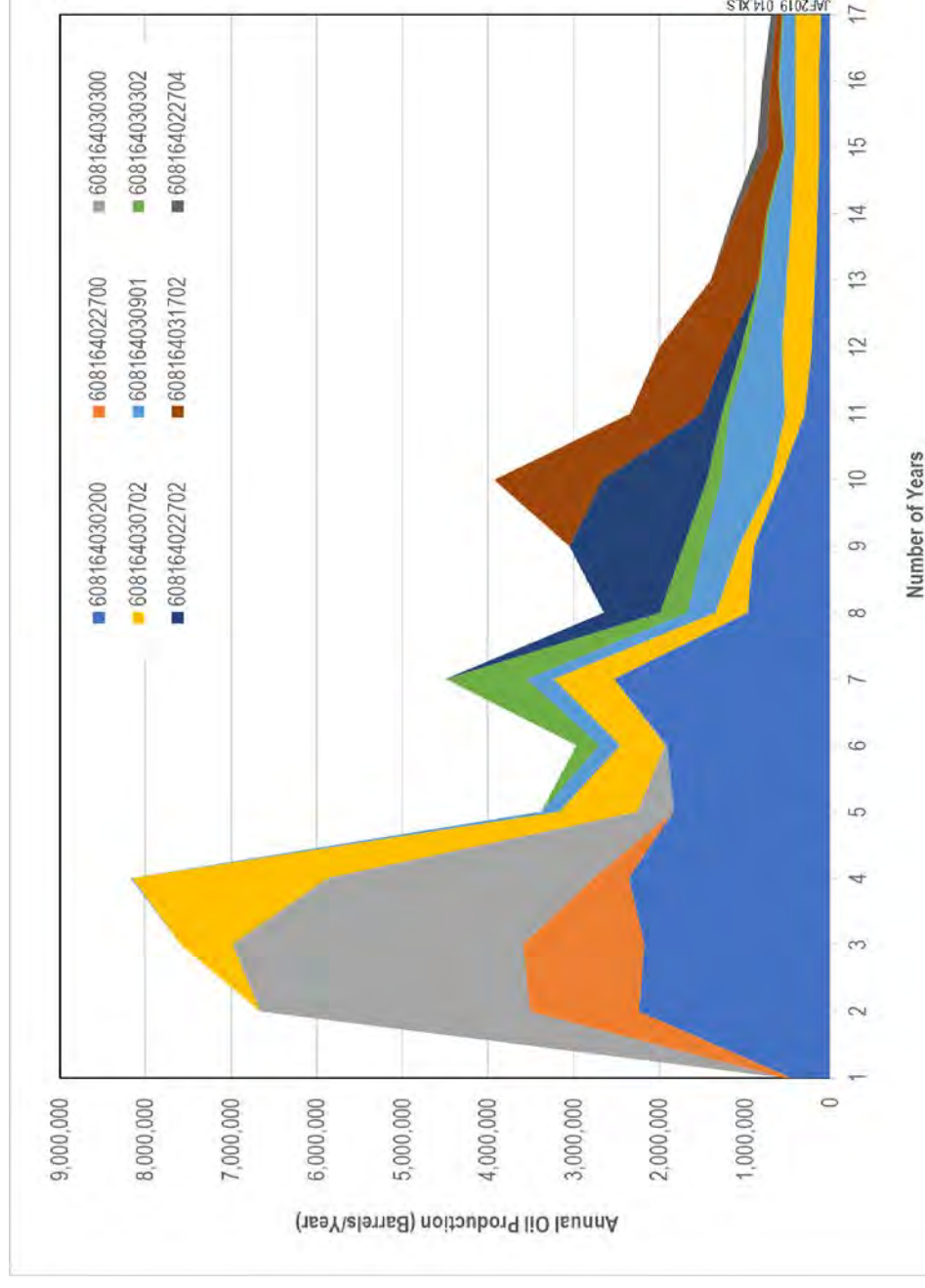
Reservoir Properties	Value
Oil Area	
▪ Total	5,288 Acres
▪ Quarter*	1,290 Acres
Porosity	30%
Depth	10,900 to 11,100 ft
Permeability	398 mD
Net Pay	16.5 ft
Oil Gravity	31 API
Swi	0.24
Boi	1.45
OOIP	104 MM bbls
Initial Pressure	5,287 psia
Pressure Gradient (@ 10,560 ft)	0.5 psi/ft
Initial Temperature	182 °F

*After including gas cap area.

The key volumetric and reservoir properties for the Petronius J-2 Sand are derived from information provided in the BOEM Offshore GOM database and from the technical literature on the Petronius oil field.

Petronius J-2 Sand

Annual Oil Production 2000-2016

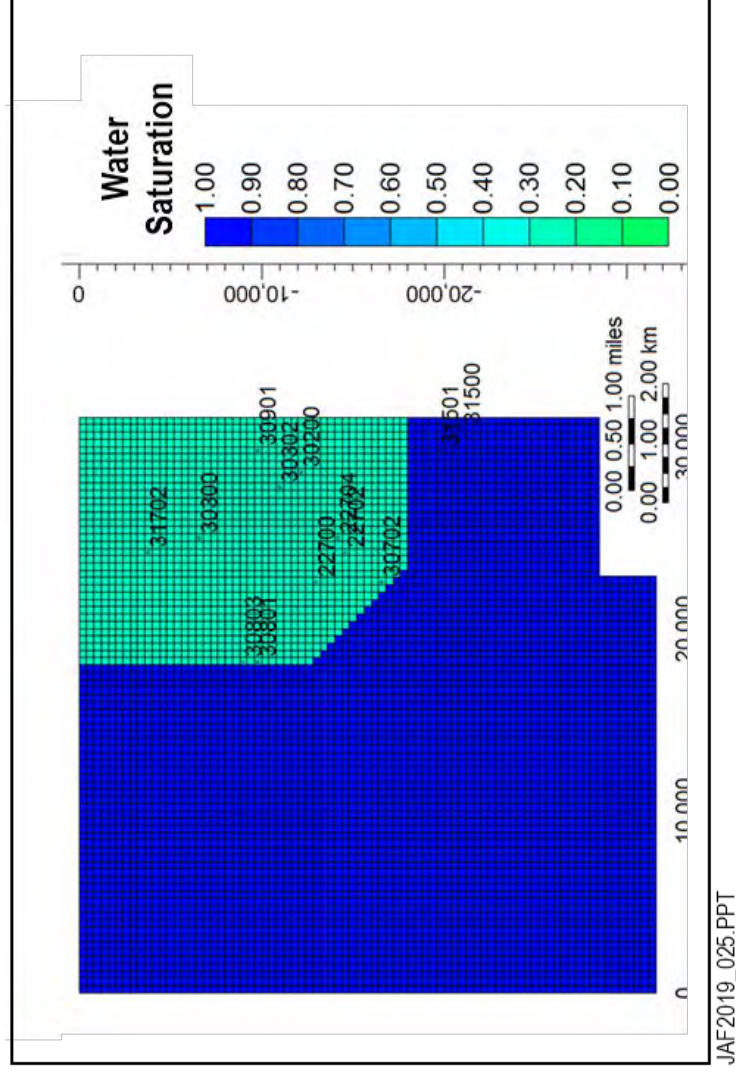


After a peak of 22,400 B/D (8.2 MMBbl/yr) in 2003, oil production from the J-2 Sand declined to 1,900 B/D (0.7 MMBbl/yr) in 2016.

The oil production history for the nine production wells drilled into the Petronius J-2 Sand is shown.

Reservoir Model for Petronius J-2 Sand

J-2 Sand Reservoir Model and Grid Blocks

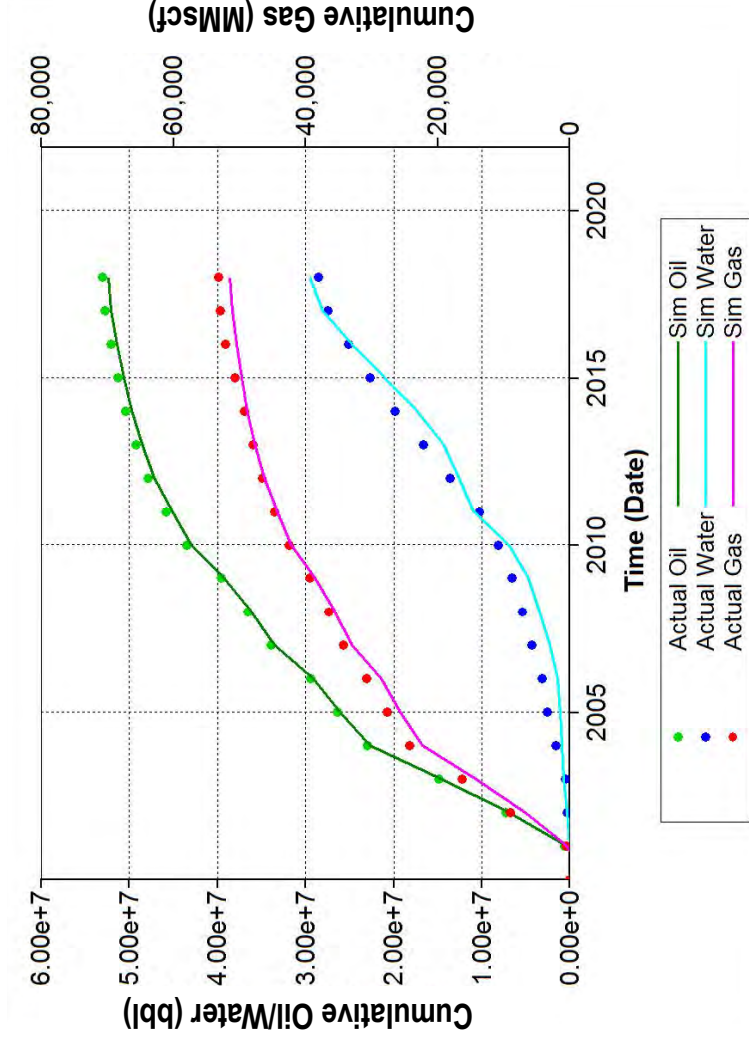


The reservoir model for the Petronius J-2 Sand contains 79 grid blocks in the X direction and 79 grid blocks Y direction, with each grid block set at 400 feet by 400 feet.

The up-structure portion of the reservoir model represents the oil reservoir. The down-structure portion of the reservoir model represents the underlying aquifer.

Source: Advanced Resources International, 2019

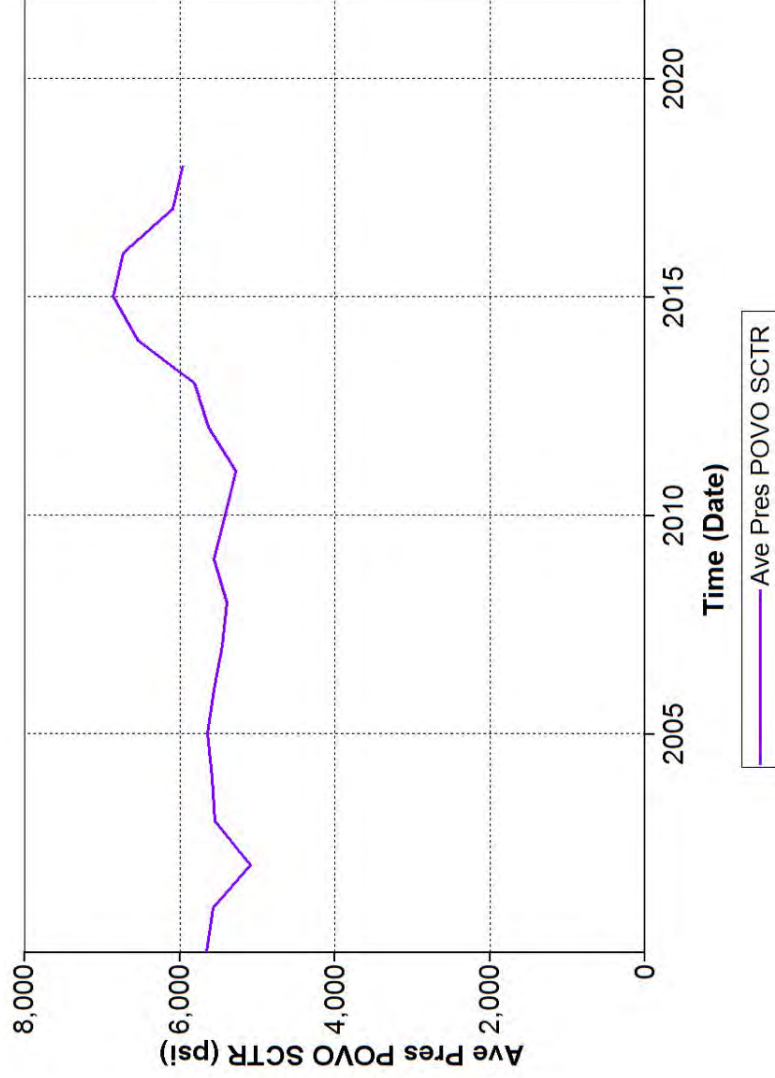
History Match of Fluid Production, Petronius J-2 Sand



Excellent history matched results were obtained for oil production, gas production and water production.

Source: Advanced Resources International, 2019

History Match of Fluid Production, Petronius J-2 Sand



An important output of the history match was the estimate of J-2 Sand reservoir pressure at the end of the waterflood.

Source: Advanced Resources International, 2019

GEM Compositional Modeling of the Performance of the CO₂ Flood, Petronius J-2 Sand

CO₂ Flood Design. Given the structural dip of the formation, its high permeability, and the strong bottom waterdrive, the design of the CO₂ flood was as follows:

- Drill an updip CO₂ injection well on the crest of the fault block.
- Inject continuous CO₂ at a rate of 25 MMcfd into the J-2 Sand for 40 years.
- Shut-in the one previously drilled, still active water injection well; operate the CO₂ flood using a bottom hole back pressure of 4,000 psi.
- Operate the CO₂ flood using a quarter of a five-spot pattern, with three closely spaced, active wells representing one production well and the other two closely spaced, active wells representing the second production well.

CO₂ PROPHET Modeling of the NETL CO₂ Flood, Petronius J-2 Sand

In parallel with the GEM compositional simulator, the study modeled the CO₂ flood in the Petronius J-2 Sand using NETL CO₂ PROPHET.

To capture the heterogeneity of the J-2 Sand, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the J-2 Sand were modeled (with CO₂ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO₂ producer and operate the CO₂ flood using a quarter of a five-spot pattern.
- Inject continuous CO₂ at a rate of 25 MMcfd for forty years, reaching a cumulative injection of CO₂ of 365 Bcf, equal to CO₂ injected in the GEM Model.

Comparative Analysis of GEM and CO₂ PROPHET Modeling of CO₂ Flood, J-2 Sand

The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

	CO ₂ Flood Performance GEM Compositional Simulator	CO ₂ Flood Performance CO ₂ PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	106	106	106
CO ₂ Injection (Bcf)	365	365	365
CO ₂ Production (Bcf)	226	238	190
CO ₂ Storage (Bcf)	139	127	175
Cumulative Oil Recovery			
▪ (million barrels)	14.3	10.8	17.4
▪ % of OOIP	13.5%	10.2%	16.4%
CO ₂ /Oil Ratio (Mcf/B)			
▪ Gross	25.5	33.8	21.0
▪ Net	9.7	11.8	10.1

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.

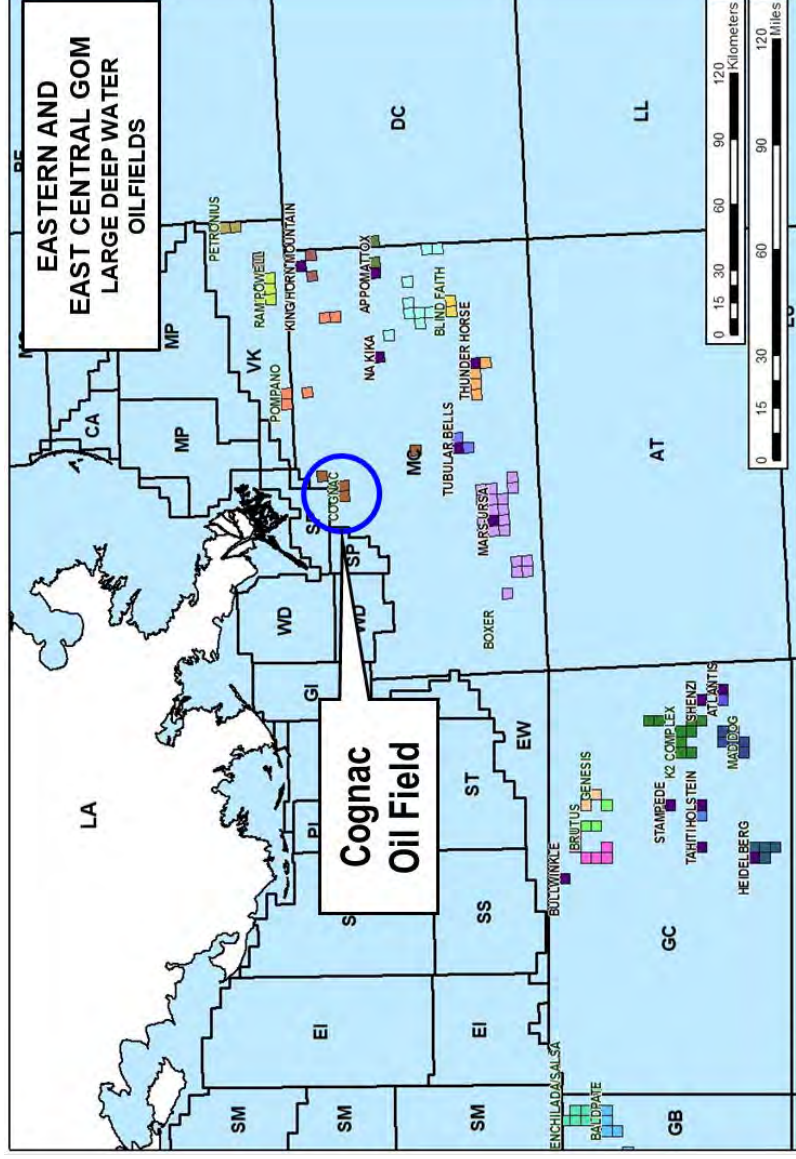


Cognac Offshore Oil Field Case Study

Background

The Cognac deepwater oil field (MC 194) is located in 1,022 feet of water in the Central Gulf of Mexico.

Location of Cognac Oil Field, Eastern Gulf of Mexico

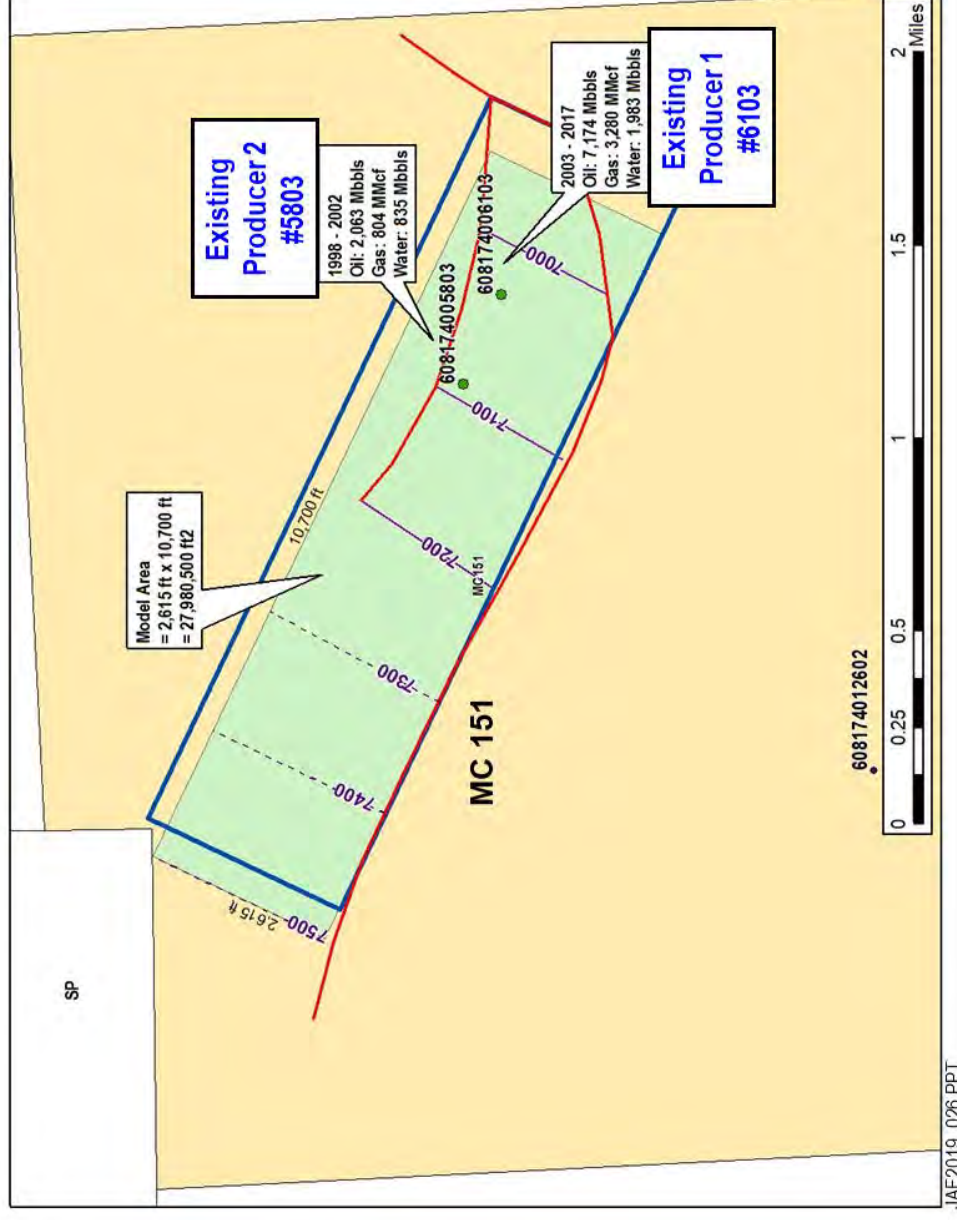


Cognac, with 184 million barrels of original oil reserves, has produced essentially all of its reserves, as of the end of 2017.

Oil production that peaked at 83,000 B/D of oil in 1983 has declined to about 2,000 B/D of oil in 2016, placing Cognac on a list of oil fields facing abandonment.

Cognac J Sand/NE Fault Block Geologic Model

Outline of NE Fault Block, Cognac Field



The NE Fault Block in MC 151 contains two oil producing wells – Well #5803 and Well #6103 – producing from a fault bounded area of about 384 acres.

A simplified representation of the NE Fault Block, including its structure, the location of the bounding faults, and the location of the two producing wells is shown.

Cognac J Sand

The J Sand in the Cognac oil field, selected for the Case Study, holds 136 million barrels of OOIP and has a remaining oil target of 79 MMB. The NE Fault Block (J Sand) holds about 18% of the OOIP in the total J Sand.

Cognac Original Oil Resources, Production and Remaining Reserves

Sands	Oil Area (Acres)	Original Oil In-Place* (MMB)	Cumulative Oil Production** (MMB)	Remaining Oil Reserves (MMB)
1. Major Sands				
▪ I	3,560	191.5	91.7	0.1
▪ J	2,240	135.6	56.9	0.3
2. Minor Sands				
▪ J-1	1,740	23.3	6.6	***
▪ Others	n/a	n/a	16.0	3.2
Total	7,540	350.4	171.2	3.6

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*Volumetrically adjusted by Advanced Resources Intl., **As of end of 2016.
***Less than 0.05 MMB.

Volumetric and Other Reservoir Properties

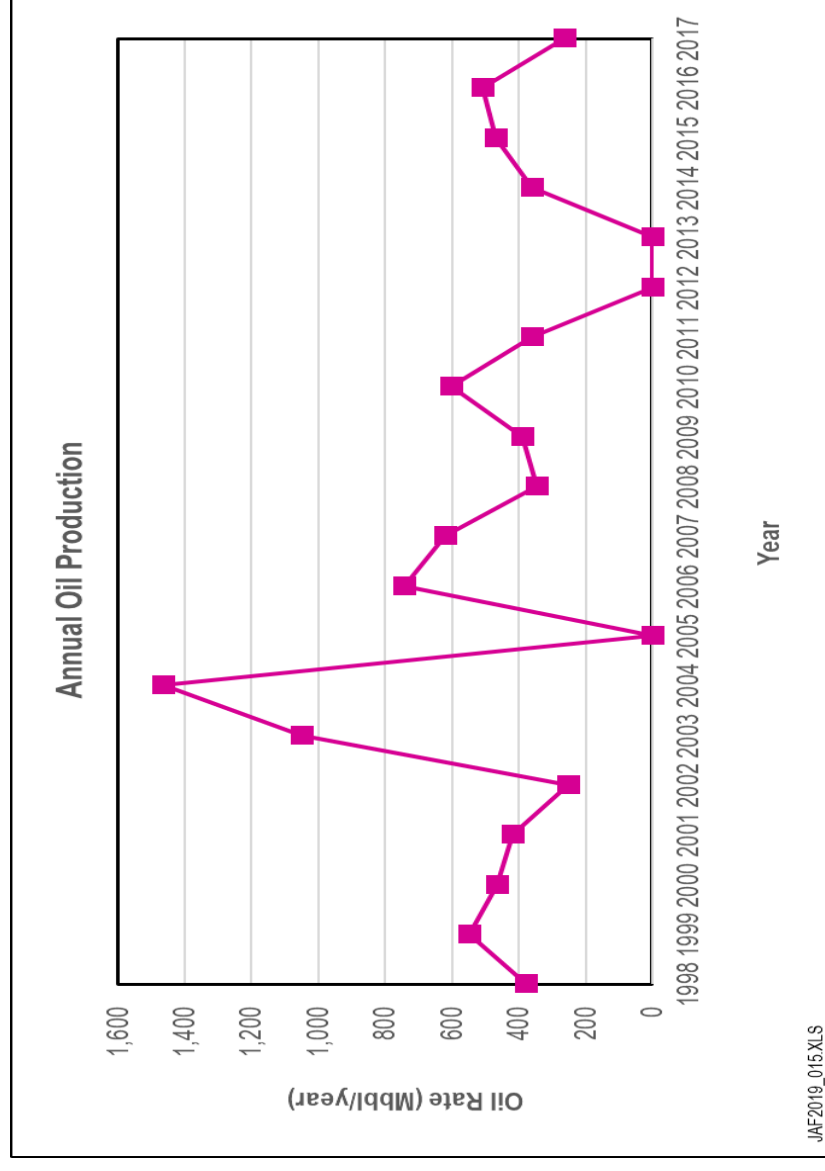
Cognac J Sand/NE Fault Block

Reservoir Properties	Value
Accessible Oil Area	384 Acres
Porosity	32%
Permeability	794 mD
Net Pay	42 ft
Oil Gravity	34.6 API
Soi	0.73
Sor	0.45
Boi	1.21
OOIP	24.2 MMbbls
Initial Pressure (@ 8,297 ft)	4,412 psia
Initial Reservoir Temperature	130 °F

The key volumetric and reservoir properties for the Cognac J Sand in the NE Fault Block are derived from information provided in the BOEM Offshore GOM data base and from the technical literature on the Cognac oil field.

Cognac J Sand/NE Fault Block

Annual Oil Production, Cognac J Sand, NE Fault Block



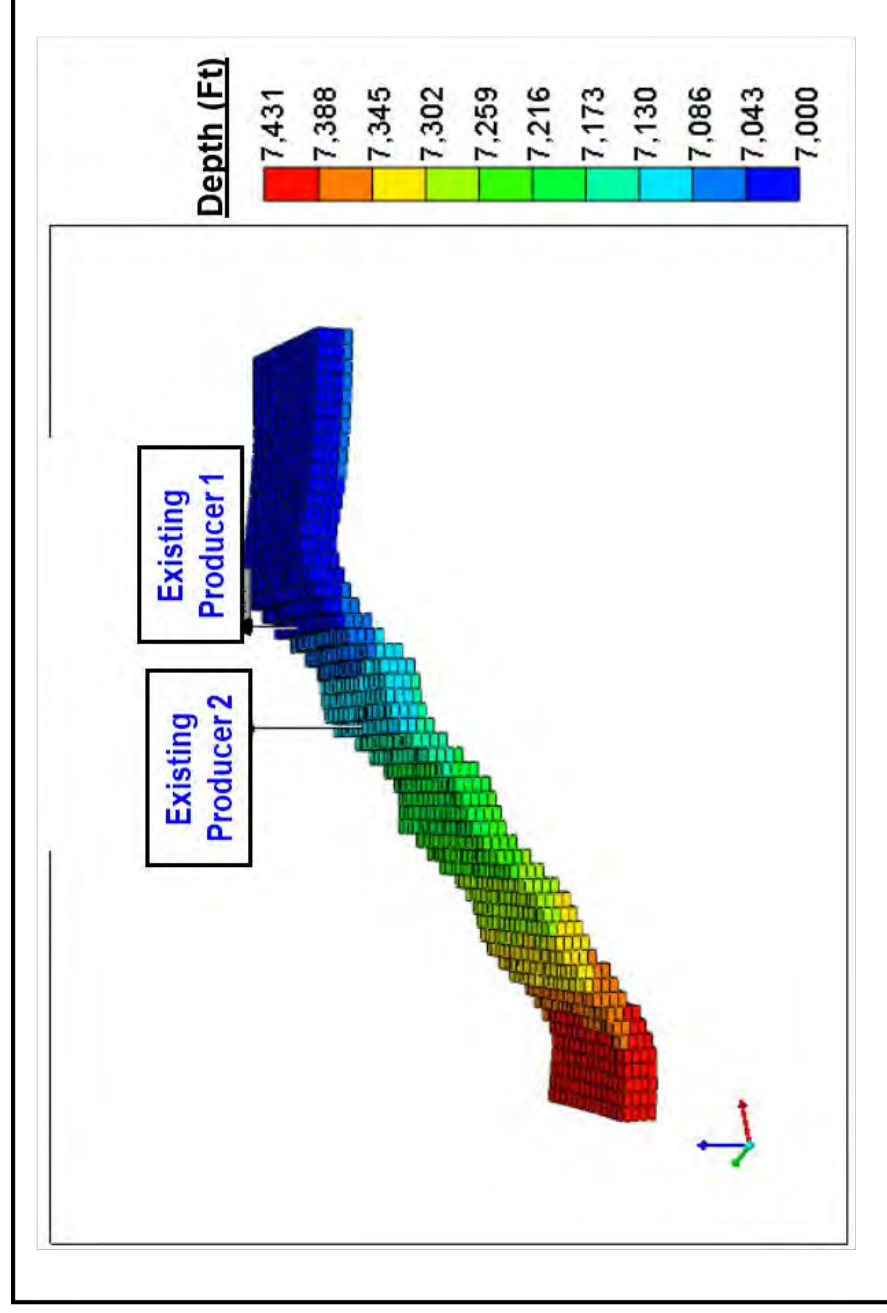
Source: Advanced Resources Int'l using DrillingInfo data, 2019

As of mid-2017, the J Sand of the NE Fault Block has produced 9.25 million barrels of oil, equal to 38 percent of OOIP.

The annual oil production history of the NE Fault Block J Sand from inception in mid-1998 to mid-2017 is shown.

Reservoir Modeling for Cognac J Sand

NE Fault Block, Cognac J Sand, 3D Model, Side View

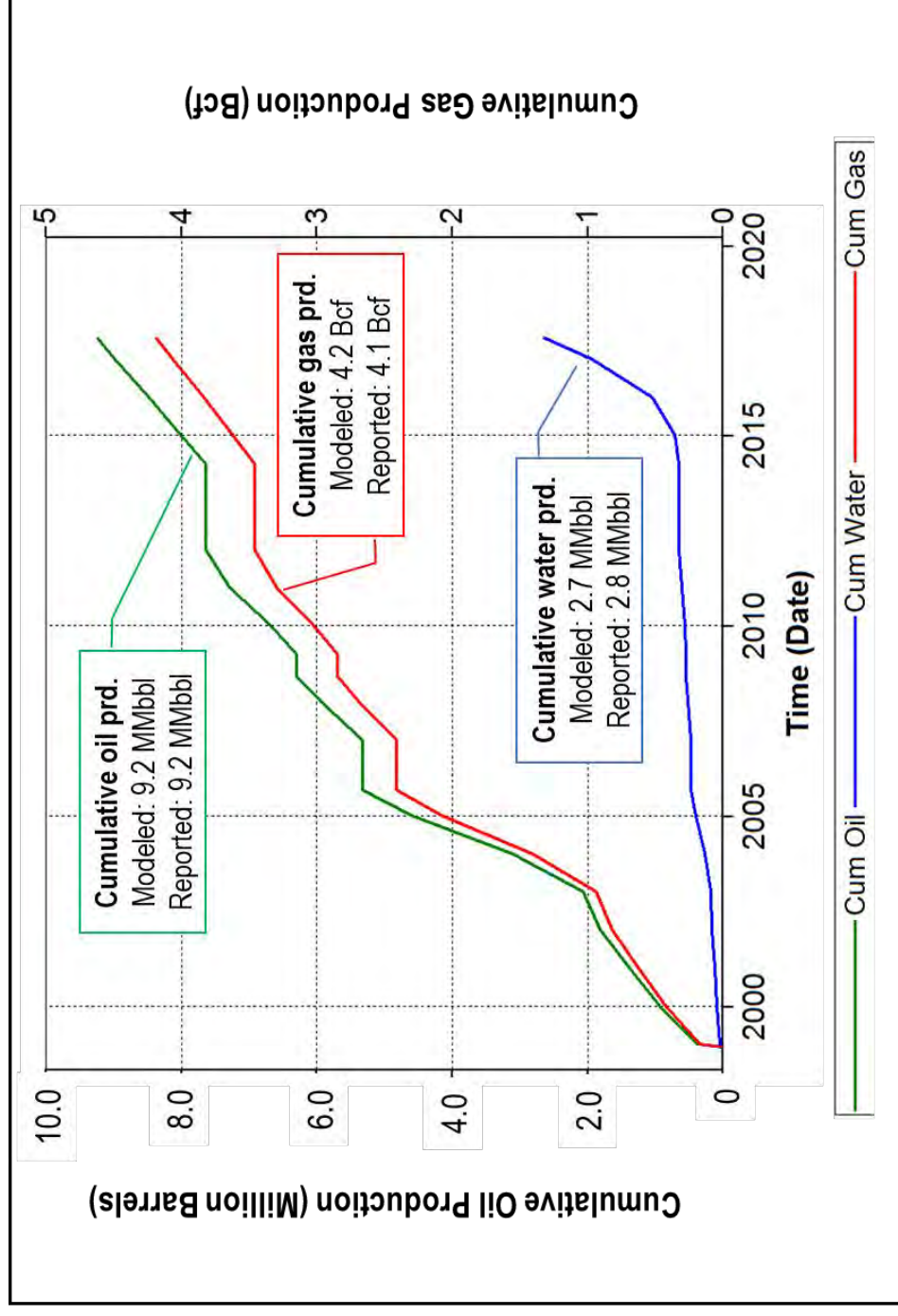


The reservoir model for the surface of NE Fault Block J Sand contains 702 grid blocks (54 x 13) each having a dimension of 200 ft in the X and Y directions.

The vertical dimension of the J Sand is represented by four layers (grid benches), each having a thickness of 10.5 feet.

History Match of Fluid Production, Cognac

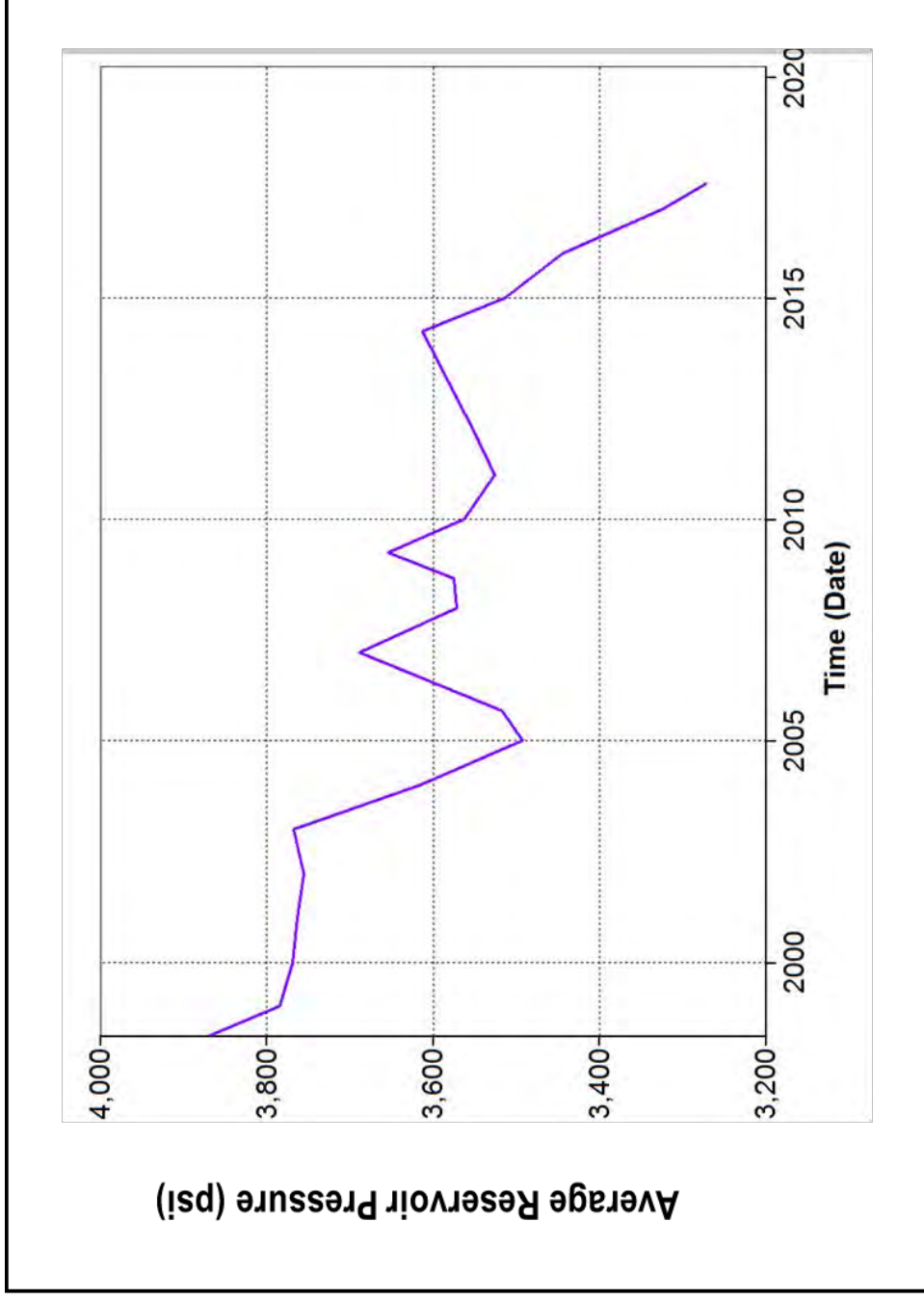
J Sand, NE Fault Block



History Match of Fluid Production, Cognac

J Sand, NE Fault Block

An important output of the history match was the estimate of J Sand reservoir pressure at the end of primary production.



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GEM Compositional Modeling of the Performance of the CO₂ Flood, Cognac J Sand, NE Fault Block

CO₂ Flood Design. Given the structural dip of the formation, its high permeability and the strong bottom waterdrive, the design of the CO₂ flood was as follows:

- Drill an updip CO₂ injection well on the crest of the fault block.
- Inject continuous CO₂ at a rate of 24 MMcfd into the J Sand for 10 years and 20 years.
- Shut-in the producing wells for 12 months to raise reservoir pressure; operate the CO₂ flood using a bottom hole back pressure of 3,000 psi.
- Initially produce from updip production well (Prd #1) until CO₂ breakthrough; shut in updip production well and open downdip production well (Prd #2) and produce until end of the CO₂ flood.

CO₂ PROPHET Modeling of the NETL CO₂ Flood, Cognac J Sand, NE Fault Block

In parallel with the GEM compositional simulator, the study modeled the CO₂ flood in the Cognac J Sand, NE Fault Block, using NETL CO₂ PROPHET.

To capture the heterogeneity of the J Sand in the NE Fault Block, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the NE Fault Block's J Sand were modeled (with CO₂ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO₂ producer and operate the CO₂ flood in a two well line drive configuration.
- Inject continuous CO₂ at a rate of 24 MMcfd for ten years, reaching a cumulative injection of CO₂ of 88 Bcf equal to CO₂ injected in the GEM Model (a HCPV of 1.2).

Comparative Analysis of GEM and CO₂ PROPHET Modeling of CO₂ Flood, NE Fault Block J Sand

The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

	CO ₂ Flood Performance GEM Compositional Simulator	CO ₂ Flood Performance CO ₂ PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	24.2	24.4	24.2
CO ₂ Injection (Bcf)	89.5	87.7	87.7
CO ₂ Production (Bcf)	52.3	55.7	45.3
CO ₂ Storage (Bcf)	37.2	32.0	42.4
Cumulative Oil Recovery			
▪ (million barrels)	8.18	6.33	8.67
▪ % of OOIP	33.8%	26.2%	35.8%
CO ₂ /Oil Ratio (Mcf/B)			
▪ Gross	10.9	13.9	10.1
▪ Net	4.5	5.1	4.9

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.

Observations and Findings

A series of observations and findings have emerged from the GOM offshore case studies:

- Establishing a geologically representative data base for offshore oil fields is a challenge, but one that can be overcome with diligent effort.
- By defining the location and status of existing production and injection wells, reasonable spacing and CO₂ flooding designs can be established for offshore oil fields.
- Miscible CO₂ EOR can provide notable increases in oil recovery – 15% to 30% of OOIP – while storing significant volumes of CO₂.
- The NETL CO₂ PROPHET Model can provide realistic estimates of oil recovery and CO₂ storage in offshore oil reservoirs.



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Initial Risk Characterization and Data Development Activities

Presented at:
**SECARB Offshore GoM & GoMCarb Annual Joint
Partnership Meeting**

Presented by:
**Michael Godec
Caroline Skidmore
Advanced Resources International**

New Orleans, Louisiana, USA
March 25 – 27, 2020

Task 4.0

Risk Assessment, Simulation, and Modeling

- Under Task 4.0, one activity is focused on assessing site-specific risks and developing mitigation strategies in the offshore GOM environment.
 - Involves reviewing published efforts to evaluate onshore and offshore (North Sea, Australia, and Brazil) risk assessment and mitigation strategies and adapt or tailor them to our case.
- Based on this, the project team will:
 - Develop and/or adapt geologic and dynamic flow models that evaluate multiple physical and chemical processes
 - Describe the effects of the processes on CO₂ movement within the storage reservoir and potentially through the caprock, overburden, and water column, defined for representative prospects.
- Among other objectives, the results of these modeling efforts will be used to identify and characterize potential geologic and CO₂ permanence risks and design monitoring programs.

Proposed Approach for Risk Characterization

- **In this effort, we build on two previous risk assessment approaches.**
 - The CarbonSAFE ECO₂S Project Risk Assessment
 - The Shell Goldeneye “Bow-Tie” Risk Assessment
- **From these we have developed a proposed combination process that involves aspects of both.**

Project ECO₂S Approach

- **Compile an initial risk register (pre-workshop)**
 - Project ECO₂S used the SECARB Anthropogenic Test CCS project's risk register as their initial risk register.
- **Identify and discuss project values (pre-workshop)**
- **Divide identified risks into topic groups (pre-workshop)**
- **Identify the elements of the project that fall under the “5 W’s and H” -- Who, What, When, Where, Why, and How. (workshop)**
- **Evaluate each risk scenario in terms of Severity and Likelihood**
- **Determine a “risk” value for each risk scenario**
- **Develop plan for a monitoring program**

Project ECO₂S Workshop

- In October 2017, a workshop was conducted to identify and evaluate the principal risks to the Project ECO₂S storage site
 - 18 project participants
- 102 unique risk scenarios were developed
 - Encompassed five specific topic groups: 1) Geologic; 2) Monitor-Model; 3) Operations; 4) Project-Program Management; and 5) Public Acceptance
- Discussion centered on known risks as well as unknowns that could potentially impede the achievement of project goals.
- Participants provided semi-quantitative risk-evaluation data for analysis and reporting
 - Comprising ‘Likelihood’ and ‘Severity’ values measured on 5-point scales.
 - Aggregated values were displayed in real time during the workshop.
- Scenarios not evaluated during the workshop were later completed through emailed correspondence.

Project ECO₂S Results

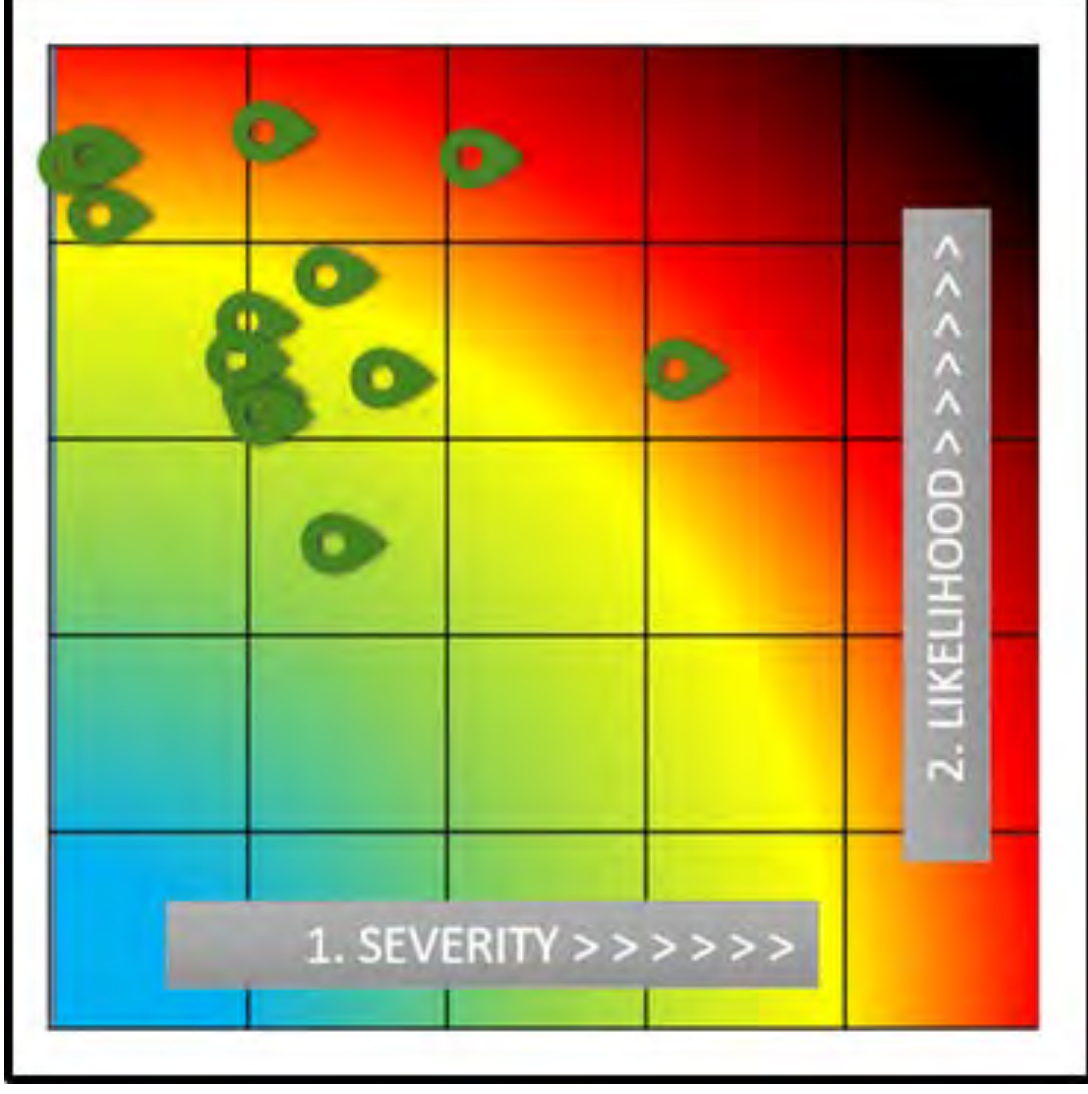
- 102 scenarios were ranked by risk. Strong group consensus identified five - seven program-management scenarios related to CO₂ supply as main sources of project risk.
- Technical risks ranked lower, with concerns about seal (caprock) continuity ranking highest (#23 out of 102, in the “most familiar with the topic” ranking).
- Induced seismicity risks were ranked low.
- Highest monitoring-modeling risks (ranked around #30) focused on prospect that the CO₂ plume might not be confidently observable using available monitoring techniques.
- Overall, risk rankings differed little among participants regardless of familiarity with the subject matter of specific scenarios.

How to select risks to treat? Multiple Screens

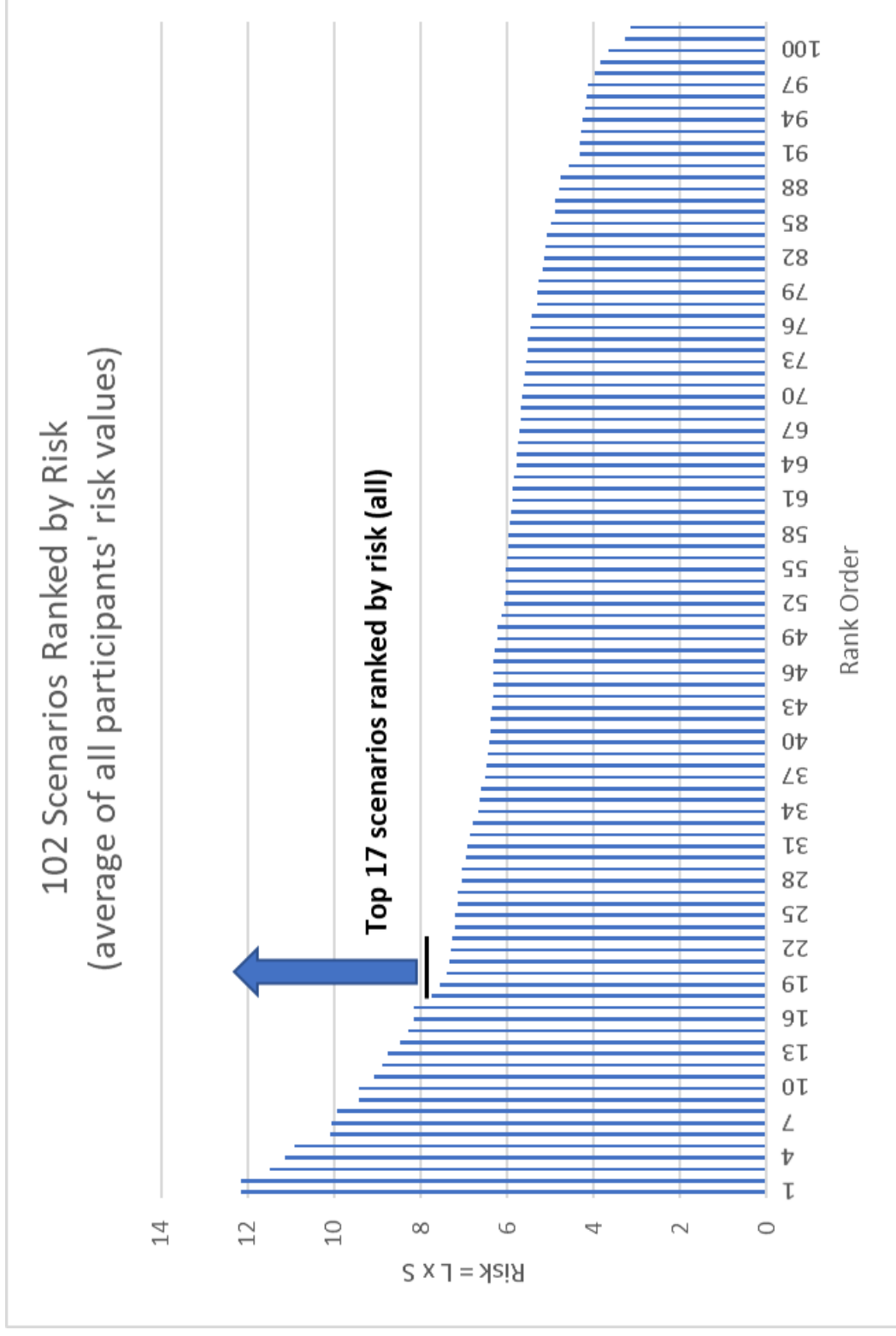
Scen ID	Risk	Rank by Risk (all)	Scenario
P01	12.17	1	Changes in the operational status or commercial viability of CO ₂ source plant prevent meeting project objectives.
P09	12.16	2	Kemper energy facility does not become a source of CO ₂ .
P18	11.48	3	Insufficient CO ₂ supply commitments to support regional storage hub.
U03	11.13	4	Changes in U.S. government personnel or policies result in removal of government support of the CarbonSAFE program.
O15	10.90	5	Operational problems at CO ₂ source plant prevent delivering the CO ₂ needed to show commercial-scale geological storage.
P13	10.10	6	MPC / SOPO management not interested in supporting a regional storage hub.
P12	10.06	7	MPC / SOCO management do not continue to support project during next 2-50 years.
P04	9.92	8	Existing pipeline network not designed to be used as a regional hub.
P14	9.43	9	Pore space rights are insufficient for the project.
P15	9.43	10	Potential CO ₂ sources believe that no mature capture technology is available, so will not commit to project.
P11	9.09	11	Loss of pore space access (due to land sale or other cause) limits the overall storage capacity of the hub.
O14	8.88	12	Oilfield boom drives up project costs and increases lead time for equipment and services.
U11	8.75	13	Local animosity toward MPC leads to vocal opposition of ECO ₂ S project.
O10	8.48	14	Loss of surface access rights in area of existing or planned injection well.
U16	8.30	15	Permitting of a Class VI UIC permit for storage is delayed.
P07	8.17	16	Infrastructure development costs are considerably higher than expected.
O21	8.16	17	Uncertainty in CO ₂ source(s) delays pipeline specifications (sizing, materials, pressure rating).

Example Severity-Likelihood Grid

Live Poll Results (High-Risk Scenario)



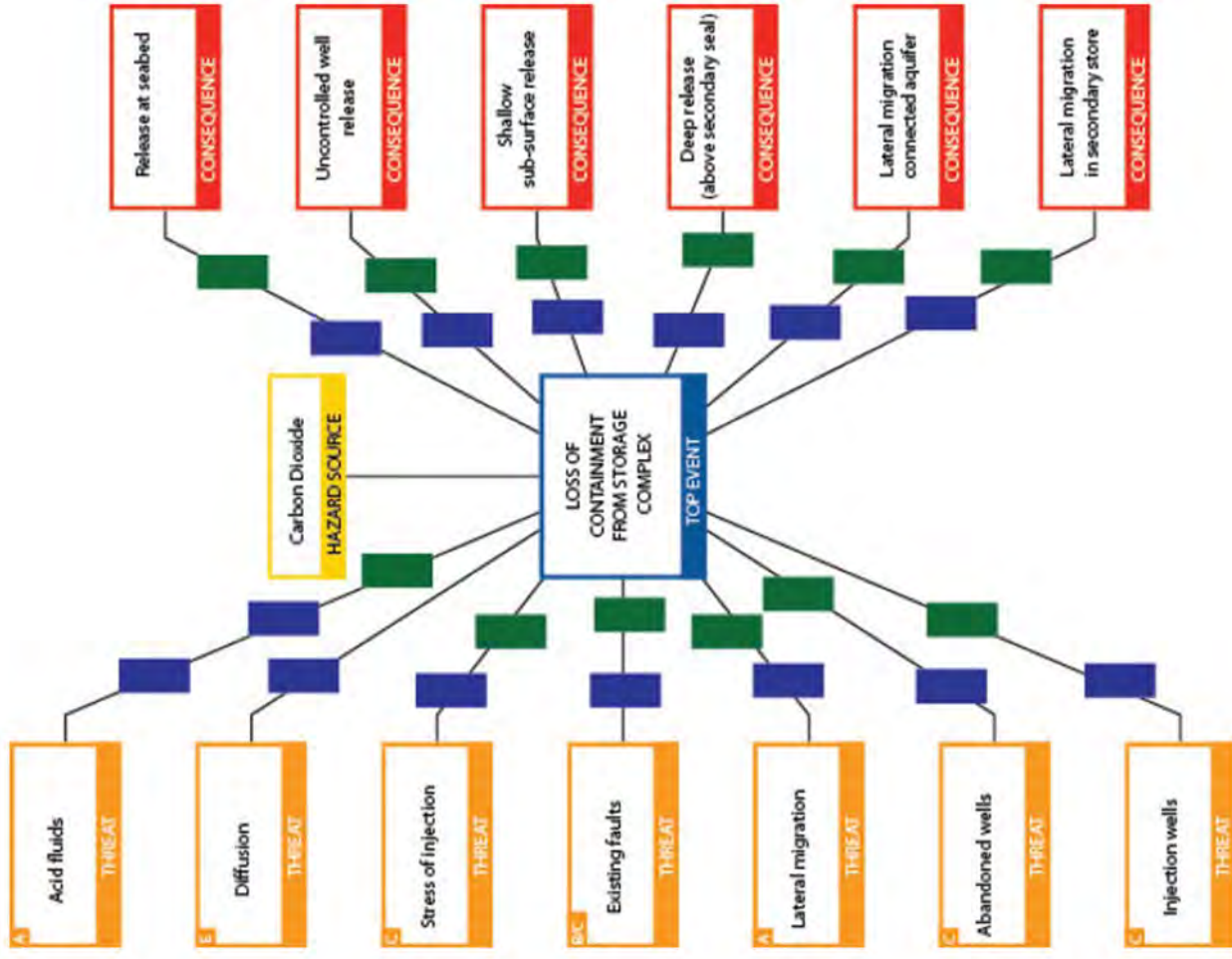
102 Scenarios Ranked By Risk



Shell Goldeneye “Bow-Tie” Approach

- **Identify and describe risks (pre-workshop)**
 - Based on risk identification workshops, experience, past project reviews, regular engagement with key external stakeholders
- **Conduct workshop where project members come together and discuss/create an initial bow-tie risk assessment**
- **Identify the top hazard event(s)**
 - Using initial risk register, identify ‘threats’, based on ways CO₂ could be released
 - Identify the consequence(s) for each threat
 - Identify ‘barriers’ that can prevent the ‘threats’ from causing CO₂ leakage
 - Identify ‘controls’ that can mitigate the consequences if CO₂ leakage does occur
- **Conduct initial bow-tie risk assessment**
- **Perform evaluation of risks**
- **Expand initial bow-tie risk assessment as monitoring program progresses**

Bow-Tie Model for Goldeneye Project





Proposed Approach for SECARB Offshore

The primary objective of this initial risk characterization workshop is to ensure that initial data acquisition and analysis activities are being conducted to ensure the best possible characterization.

- Compile an initial risk register
- Establish one or more workshop working groups
- Assess risks that represent potential ‘real impacts’
- Determine data needs to characterize potential “real impacts,” possibly creating a bow-tie model
 - That includes the risks, the mitigation/controls and consequences that were discussed during their assessment of the risks as material impacts.
 - The overarching main concern initially will be release of CO₂ from the storage complex.

Proposed Approach for SECARB Offshore

(Cont.)

- **Evaluate potential risks in terms of Severity and Likelihood**
 - To discuss the highest-ranked risks and discuss if other risks should be ranked higher or vice versa.
 - These discussions will help pinpoint the data gaps and how those data gaps could be filled and which monitoring efforts would be the best to explore to ensure gaps are filled.
 - Discussions of risk evaluations are likely to continue after the workshop between project members as they determine the appropriate monitoring efforts.
- **Discuss possible additional data acquisition activities**
- **Discuss possible monitoring plans and activities**

Initial Risk Registry

- An excel file has been created to document all potential risks that members of the SECARB Offshore project team identify as initial risks that should be looked into.
- The table will look similar to the table below.

Potential Risks	Severity of Risk	Likelihood of Risk	Data to Characterize Risk	Possible Monitoring Methods	Possible Mitigation Approaches	Links to Sources

Initial Risk Registry (Cont.)

- **Potential Risks:** identify potential risks from experience, past project reviews, and expertise.
- **Severity:** If the risk were to occur how serious are the impacts?
- **Likelihood:** The probability that the potential risk will occur.
- **Data to Characterize:** What data is already available to the project? And what data does the project team need to obtain to better characterize potential risks?
- **Monitoring Methods:** From past experiences and expertise what are the monitoring efforts that could be put in place for the potential risk?
- **Mitigation Methods:** What are the possible mitigation efforts that can diminish the negative impacts if the potential did occur?
- **Links to Sources:** If you have any PDFs, journal article, etc that could be helpful to better explaining/understanding your responses, please include the link(s).

Severity and Likelihood Scales

- We have chosen to use the Severity and Likelihood Scales from Project ECO₂S.
- Each potential risk's severity and likelihood should be evaluated in terms scales featured in the next slides, a 1 through 5 scale.
- After the severity and likelihood values have been determined, those two values will be added together to create the overall potential hazard score.
- Risks with potential hazard score of 7 or greater are considered to have the highest risk potential.
- As the project progresses and more data is collected, we expect the hazard scores to change.

Generic Likelihood Scale

LIKELIHOOD of Impact or Failure Occurring (L)				
1	2	3	4	5
Very Unlikely	Unlikely	50/50	Likely	Very Likely
In 50 ECO ₂ S-like commercial projects, might happen once.	Probably won't happen during this project. In ten such projects, once per decade.	May or may not happen during the project, with roughly equal likelihood.	Probably would occur during the pilot or commercial-scale ECO ₂ S Project. Once per several years.	Nearly sure to occur during the pilot or commercial-scale ECO ₂ S Project. Could happen yearly.

Generic Severity Scale

Examples of negative impacts for generic project values, at each severity level						
	Health & Safety	Environment	Regulatory	Economic-Financial	Reputation	CCS Validation
1	First aid. Minor health effects. Public nuisance.	Insignificant and temporary impact. Small but recordable release of hazardous material.		Equipment damage or production costs <\$5k.	Isolated individual concerns.	Temporary / fixable low injectivity. Ineffectiveness of one monitoring technique.
2	Medical aid, restricted work. Hospital visit. Temporary disability. 1-10 lost person-days. Brief facility evacuation or stand-down.	Reportable release of hydrocarbons or hazardous materials. Minor or one-time cleanup.	Nonconformance with stringent industry practice standards (e.g. ISO, API, ANSI).	\$5k-100k	Local media coverage. Multiple informal complaints. Landowner or community concern.	Capacity somewhat limited for commercial CCUS. Moderate uncertainty in proving containment.
3	Intensive care. 10-100 lost days. Facility evacuation to 2 days.	Onsite release, large or with prolonged cleanup. Offsite release with quick cleanup.	Nonconformance with specific Regional or business unit requirements. Threat of sanctions.	\$100k-1m	Broad media coverage or community concern. Repeated and/or formal complaints.	Injection takes 50% more wells. Models or monitoring questionably demonstrate creditable storage.
4	Permanent injury or disability. Lost days >100. Facility evacuation >2 days.	Offsite release, large or with long cleanup.	Nonconformance with operating company standards and/or reqmts. License suspension.	\$1m-10m	Regional media coverage. Broad community outrage. Litigation.	Injection takes many wells. Suspected leakage; lack of data to show containment.
5	Fatality. Severe health effects. Facility and community evacuation.	Release on, to, or across moving water, potable water, wildlife, national park, state border.	Serious or flagrant nonconformance with regulations or license conditions. License revoked.	>\$10m	National media coverage.	Persistent CO ₂ leak to potable water or surface. Few wells usable at commercial rate.



Next Steps

- **Our initial plan was to conduct a preliminary risk characterization workshop among the SECARB Offshore project team as part of this meeting.**
 - Of course, that plan has been overtaken by events
- **This was to use an initially developed risk registry, for participants to react to, add to, comment on, etc.**
- **We are in the process of evaluating options for continuing.**
 - Delay the preliminary workshop until we can get together again.
 - Conduct the preliminary workshop virtually via a webinar-type format
 - Facilitate input solicitation and data gathering via email communications.



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Characterizing Legal and Regulatory Frameworks

Presented at:
**SECARB Offshore GoM & GoMCarb Annual Joint
Partnership Meeting**

Presented by:
**Michael Godec, Vice President
Advanced Resources International**

New Orleans, Louisiana, USA
March 25 – 27, 2020



Subtask 6.3:

Assessment of Legal and Regulatory Frameworks

- “The Recipient will communicate with BOEM, BSSE, the Coast Guard and other Federal and State regulatory agencies to keep them informed on current project activities, to facilitate a dialogue on permitting requirements, and to compare and contrast with experience/lessons learned elsewhere.
- The project team also will engage with experts on regulatory oversight on offshore CO₂ storage projects from North Sea (UK and Norway and EU), Brazil, Japan.
- Further, the team will coordinate with BOEM, BSSE, DOE, Internal Revenue Service and other Federal and State agencies to develop recommendations to remove barriers and streamline the regulatory process to encourage subsea storage with or without enhanced hydrocarbon recovery and to enable projects to take advantage of any Federal or State incentives.”

Advantages of CO₂ Injection Offshore vs. Onshore?

- May allow surface discharge of produced water.
- Avoids populated areas (minimal NIMBY concerns).
- Minimal issues with surface, pore space, and mineral rights ownership in federal or state waters.
- Avoids issues pertaining to potentially impacting underground sources of drinking water, at a minimum in federal waters.
- Regulatory processes could be more straightforward and expeditious in federal waters (may not be quite the case in state waters)
- E.g., Class VI regulatory requirements are not applicable in federal waters.

BBA Enhancements to IRC Section 45Q -- Highlights

Previous 45Q	Bipartisan Budget Act of 2018
75 million metric ton cap	Eliminates 75 million metric ton cap; applies to new facilities that “break ground” by EOY 2023.
Credit based on “captured qualified CO₂”	- After enactment, credit based on captured “qualified carbon oxide” (CO₂ and other carbon oxides). - Allows for the transfer of qualified credits
\$20/metric ton for CO₂ stored and not used for EOR \$10/metric ton for CO₂ stored and used for EOR	\$50/mt for geologic storage and \$35/mt for EOR (each rate phases up over 10-year period from 2017 to 2026). - Existing qualified facilities would continue to receive the original inflation adjusted \$20 and \$10 credit rates.
Available to <u>facility</u> with capture equipment capturing at least 500,000 metric tons CO₂/year.	- Capture > 500,000 metric tons CO₂/year for electric generating units; > 100,000 metric tons CO₂/year for other. - Credit goes to the owner of the capture equipment. - Available to “direct air capture” and “beneficial use (with 25,000 metric ton threshold)”
Credit available until the 75-million-ton cap is reached.	Credit available for 12 years from the date the carbon capture equipment is placed in service.

Request for Comments by IRS on 45Q

- On 5/20, IRS issued Request for Comments on 45Q enhancements.
- Areas of comment included:
 - Establishing “secure geologic storage”
 - Leakage after credit award – “recapture”
 - Defining “qualifying facilities”
 - Defining “commence construction”
 - Credit transferability, timing, flexibility
 - Allowable structures/partnerships
 - 90+ comments received

■ **Some limited guidance recently released; more pending**

■ **Key question -- is 45Q, as it stands, enough for the offshore GOM?**



Form 8933		Carbon Oxide Sequestration Credit		OMB No. 1545-0123
Department of the Treasury Internal Revenue Service		▶ Attach to your tax return. ▶ Go to www.irs.gov/Form8933 for the latest information.		2018 Attachment Sequence No. 165
Name/Entity shown on return		Identifying number		
Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, nor utilized in a way described in section 45Q(f)(5).				
1a Metric tons captured and disposed of b Inflation-adjusted credit rate c Multiply line 1a by line 1b.				1c
Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or utilized in a way described in section 45Q(f)(5).				
2a Metric tons captured and used b Inflation-adjusted credit rate c Multiply line 2a by line 2b.				2c
Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, nor utilized as described in section 45Q(f)(5).				
3a Metric tons captured and disposed of b Section 45Q(a)(3) applicable dollar amount (see instructions) c Multiply line 3a by line 3b.				3c
Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or used as described in section 45Q(f)(5).				
4a Metric tons captured and disposed of b Section 45Q(a)(4) applicable dollar amount (see instructions) c Multiply line 4a by line 4b.				4c

Regulatory Oversight of CO₂ Storage in the Federal Offshore -- DOI

- Outer Continental Shelf Lands Act (OCSLA), Dept. of Interior (DOI), Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) have authority to regulate development of mineral resources on the OCS:
 - Authority to permit the use and storage of CO₂ for EOR activities on existing oil and gas leases on the OCS.
 - Authority to permit the storage of CO₂ for certain types of projects; though the authority to issue leases for storage remains unclear.
 - No facilities/operations permitted to date
- BOEM finalized research on Best Management Practices (BMPs) for CO₂ offshore transportation and storage on the OCS
 - We are using some of the as a starting point for our study.
 - Specific categories of offshore issues (potential regulatory gaps) were identified.

CCS on the Outer Continental Shelf: Regulatory Framework

- Under Section 8(p)(1)(C) of the OCSLA (43 U.S.C. 1337)(p)(1)(C)), BOEM may issue leases, easements, and rights-of-way for activities that:
 - “produce or support production, transportation, or transmission of energy from sources other than oil and gas”
- In certain circumstances, Section 8(p)(1)(C) allows BOEM to issue leases for sub-seabed CO₂ storage...
 - Only for CO₂ generated as a by-product of electricity production from an onshore coal-fired power plant.
- In 2010, the Presidential Interagency Task Force on CCS examined the existing U.S. regulatory framework and recommended the development of a comprehensive U.S. framework for leasing and regulating sub-seabed CO₂ storage operations on the OCS
- However, this comprehensive framework has yet to be established; therefore, the existing regulatory framework is shared across multiple Federal agencies, and there are several gaps.



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Legal and regulatory analysis

Joint GoMCarb and SECARB Offshore meeting -- 26-27 March 2020

Approach



- Starting point: previous legal analysis of U.S framework
- Desktop review of recent developments
- Comparison with other legal and regulatory frameworks
- Test findings on SECARB Offshore case studies
- Recommendations



Previous legal analysis

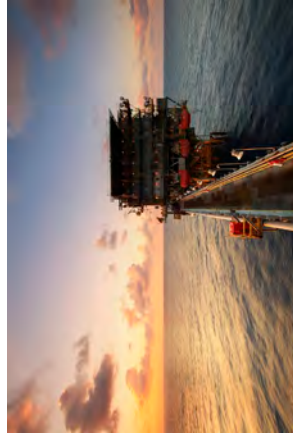
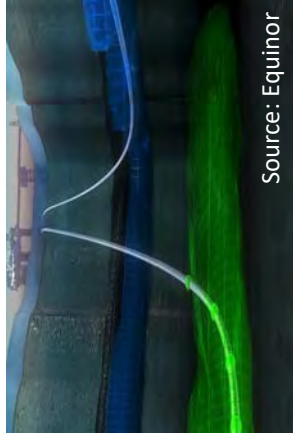


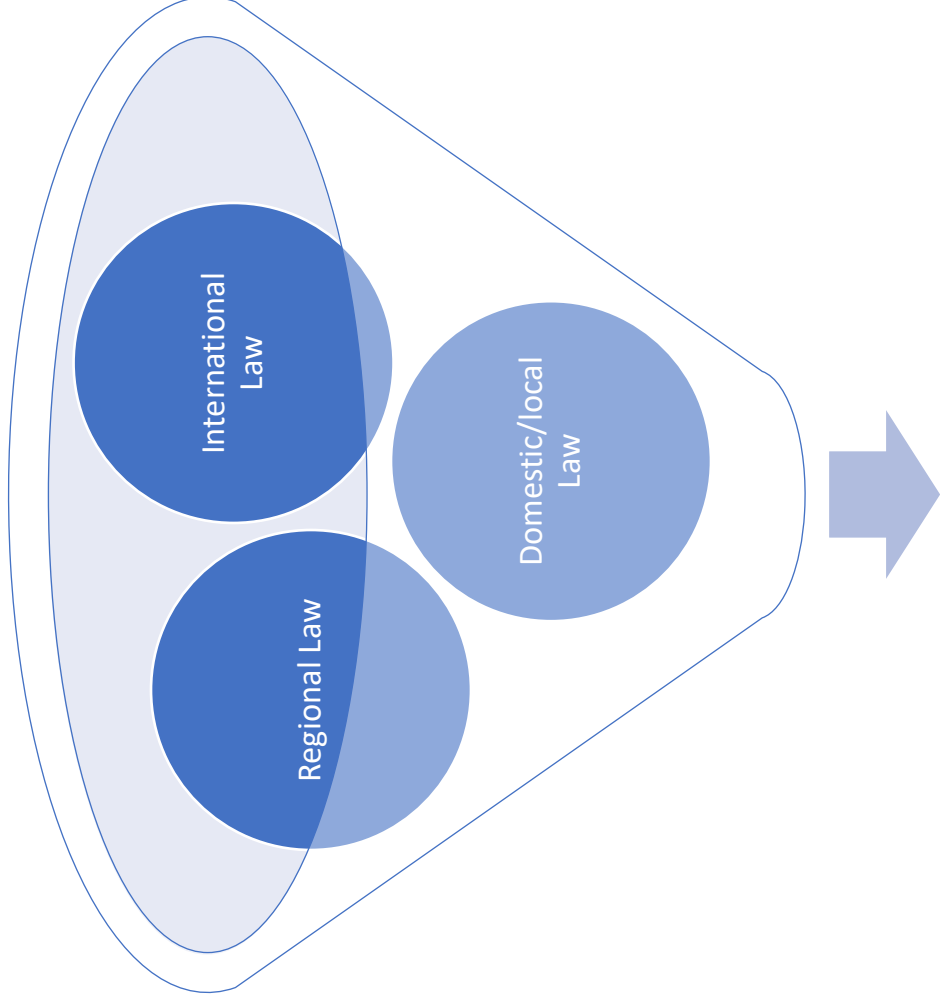
- Storage of Carbon Dioxide in Geologic Structures: A Legal and Regulatory Guide for States and Provinces, 2007
- Interagency Task Force on Carbon Capture and Storage, 2010
- Preliminary evaluation of offshore transport and storage of carbon dioxide, 2013
- Best management practices for offshore transportation and sub-seabed geologic storage of carbon dioxide, 2017
- Overcoming Impediments to Offshore Carbon Dioxide Storage: Legal Issues in the U.S and Canada, 2019

The focus of our analysis



- Prioritized relevant barriers identified in the earlier cited reports
 - Lack of comprehensive legal and regulatory framework
 - Fragmentism
 - Monitoring, reporting, and verification pursuant to subparts RR and UU
 - Liability and long-term stewardship
 - CO₂ as hazardous waste





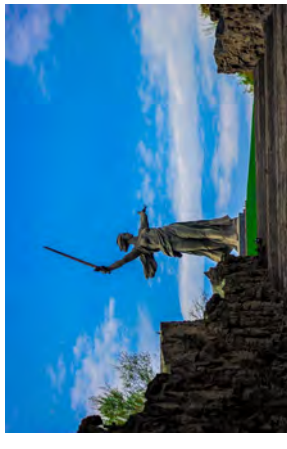
Legal Framework for CCUS

Building on existing U.S legal framework



Some of the most relevant instruments

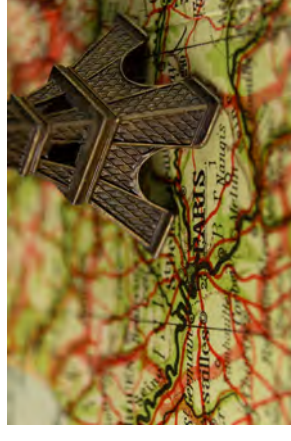
- Outer Continental Shelf Lands Act
 - Oil and Gas Leasing Program
- Coastal Zone Management Act
- Submerged Lands Act
- National Environmental Policy Act
- Safe Drinking Water Act
 - Underwater Injection Control (UIC) Program
- Clean Air Act
 - Greenhouse Gas Reporting Rules



Comparison with International Legal Framework



- The United Nations Convention on the Law of the SEA (UNCLOS)
- The London Convention
- The London Protocol
- OSPAR

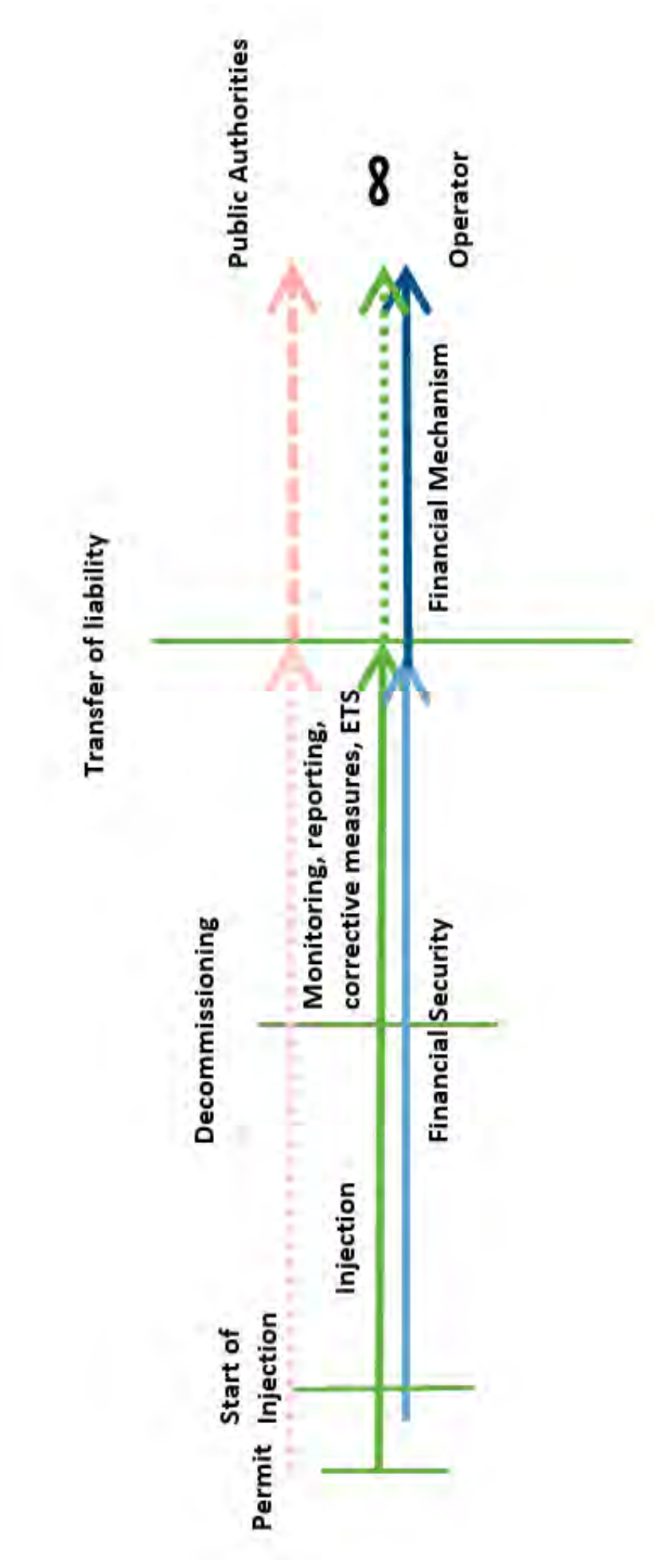


Comparison with European Framework



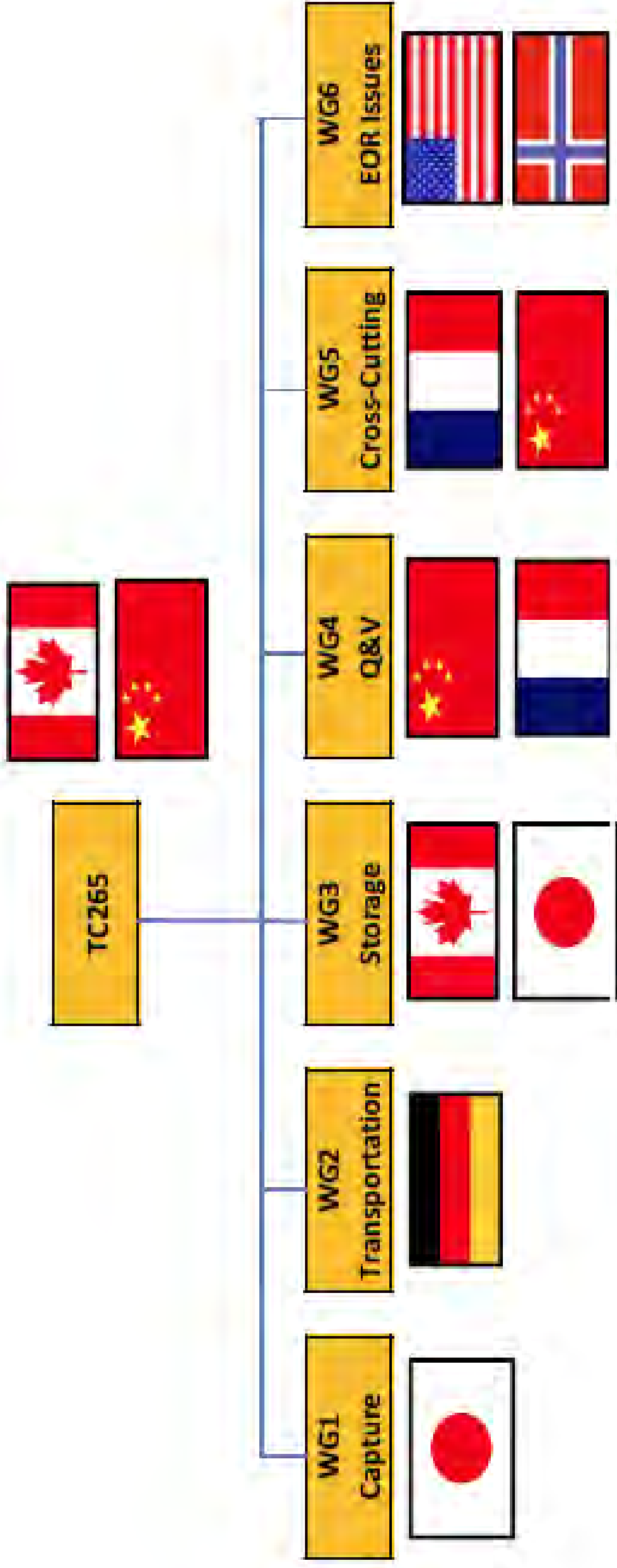
- EU legal framework
 - CCS Directive (2009)
 - Guidance Document 2 (Characterization of the Storage Complex, CO₂ Stream Composition, Monitoring and Corrective Measures)
 - Guidance Document 3 (Criteria for Transfer of Responsibility to the Competent Authority)
 - Guidance Document 4 (Financial Security (Art. 19) and Financial Mechanism (Art. 20))
 - ETS Directive (2003)
 - Environmental Liability Directive (2004)
- Norwegian legal framework
 - Continental Shelf Act (1969)
 - Storage Regulations (2014)
 - Regulations related to safety and working environment in relation to transport and injection of CO₂ on the Norwegian Continental Shelf (2020)
 - Petroleum Act (1996)
 - Petroleum Regulations (1997)
 - Pollution Control Act (1981)
 - Pollution Control Regulations (2004)
 - Guidelines for financial security (2016)

EU liability framework for CO₂ storage at a glance



Other Documents

- EPA Guidance Documents for Class II and Class VI
- IEA Model Regulatory Framework
- ISO TC 265 documents
- European Commission opinions on draft permits for the Netherlands and the United Kingdom
- Norwegian exploitation permit for CO₂ storage (awarded January 2019)



ISO TC265 Carbon Dioxide Capture, Transportation and Geological Storage

General principles of the TC265 standards



- Technology neutrality
 - No patented rights
 - No explicit descriptions of technology or product
 - Fits both onshore and offshore
- Regulatory neutrality
 - Performance-based rather than descriptive
 - No time periods specified
 - No criteria for reporting
 - No criteria for decommissioning
 - No explicit references to, e.g., transfer of liability
- Complements other standards
 - TC265 standards
 - Other ISO standards
 - Specific technical standards from other standardization bodies

ISO standard for CO₂-EOR

- Standard for CO₂-EOR published 31 January 2019
- Provides important tools to
 - assuring containment
 - unlocking access to allowances under e.g. ETS
 - replacing natural with anthropogenic CO₂
- Applies to quantification and documentation of total CO₂ being stored in association with CO₂-EOR
- Contains background data and information about CO₂-EOR globally
- Allows for quantification calculation of natural, anthropogenic and in-situ CO₂



Process for considering recommendations

- Contrast and compare previous work on legal analysis and recommendations
- Compare and contrast with other legal and regulatory frameworks
- Taking new legal and technical developments into consideration
- Taking policy considerations
- Filling gaps using technical international standards
- Reusing known models and mechanisms under US legal framework
- Consultation



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Thank you for your attention!



Building the Foundation for Assessing GOM Offshore CO₂ EOR and Associated CO₂ Storage

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace
Anne Oudinot
Advanced Resources International, Inc.

March 26-27, 2020





Outline of Presentation

1	Purpose of the Case Studies
2	Petronius Offshore Oil Field Case Study
3	Cognac Offshore Oil Field Case Study
4	Observations and Findings

This work was completed under DOE NETL Contract Number DE-FE0025912. This work was performed under MESA Activity 205.002.

Purpose Of Case Studies

The primary purpose of the “Offshore Oil Field Case Studies” is to assess the ability of the NETL CO₂ PROPHET Model to represent the performance of an offshore CO₂ flood, including appropriately capturing the geologic complexity and irregular well spacings typical of offshore oil fields.

For this, the Study conducted seven tasks:

1. **Geologic Model.** Build representative geologic models for the oil fields, including capturing structural setting and associated aquifer.
2. **Reservoir Model.** Assemble the key reservoir properties of the oil reservoir, including its volumetric data, fluid flow capabilities, and oil composition.
3. **Field Development.** Establish the locations of the existing oil/gas production wells producing from the oil reservoir.

Purpose Of Case Study (Cont'd)

4. **History Matching Using Compositional Simulations.** Use GEM compositional simulator to provide a “first-order” history match of fluid production from the oil reservoir.
5. **Assessing CO₂ Flooding Using Compositional Simulation.** With a calibrated geologic/reservoir description, appraise the performance of a post-primary CO₂ EOR project in the oil reservoir using the GEM compositional simulator.
6. **Assessing CO₂ Flooding Using CO₂ PROPHET.** In parallel with the GEM compositional simulator, use the NETL CO₂ PROPHET Model to appraise the performance of a post-primary CO₂ EOR project in the oil reservoir.
7. **Comparing GEM and CO₂ PROPHET Modeling.** Compare the results of GEM and CO₂ PROPHET modeling of CO₂ EOR to determine whether the NETL CO₂ PROPHET model could reasonably represent the performance of the CO₂ flood compared to the more sophisticated GEM compositional simulator.

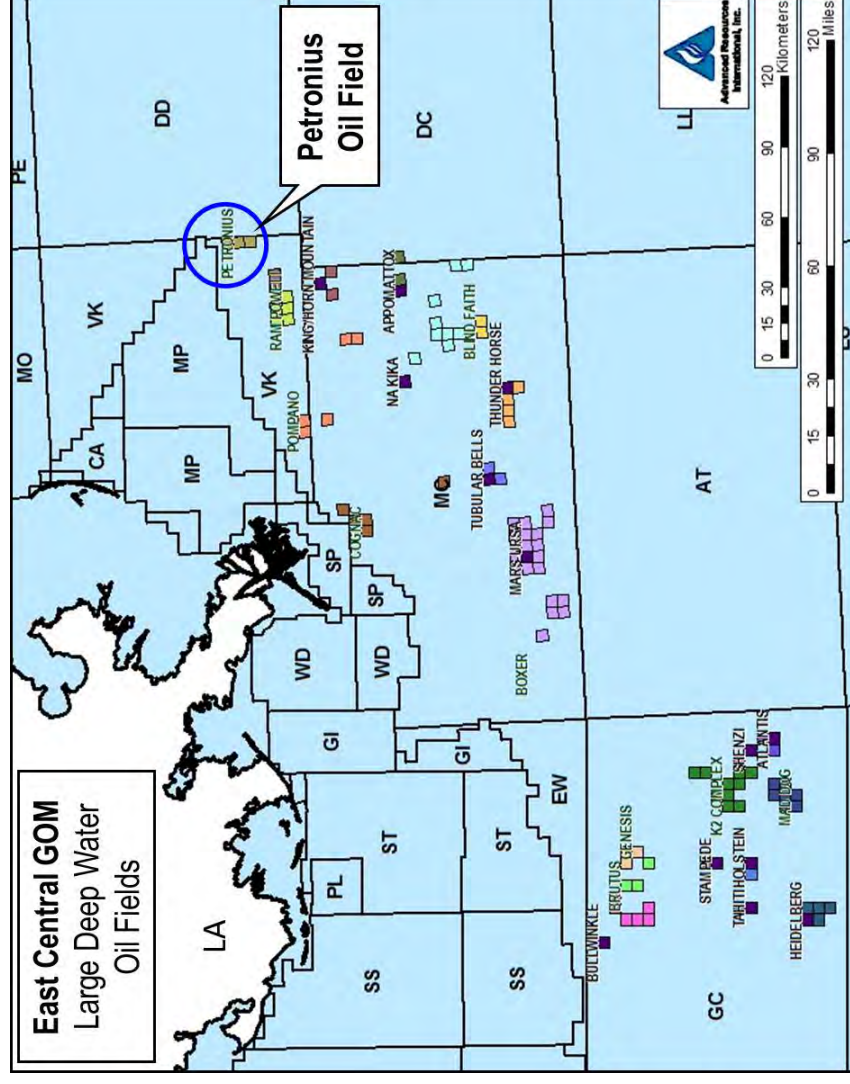


Petronius Offshore Oil Field Case Study

Background

The Petronius deepwater oil field (VK 786) is located in 1,790 feet of waters of the East Central Gulf of Mexico.

Location of Petronius Oil Field, Eastern Gulf of Mexico



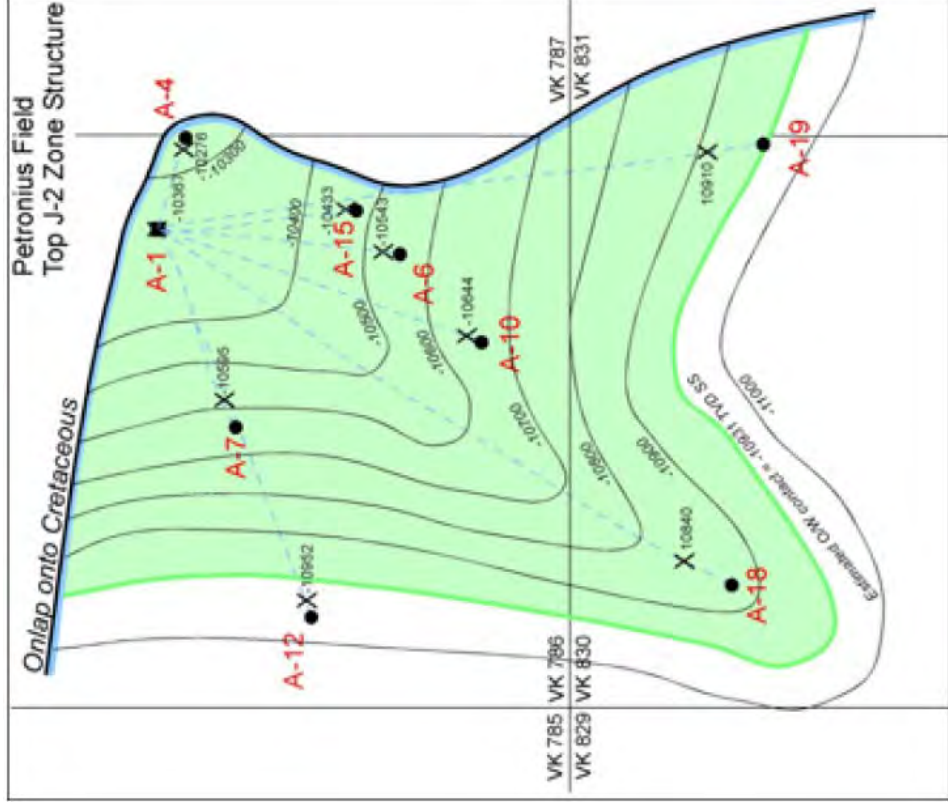
Petronius, with 162 million barrels of original oil reserves, has produced over 96% of its original reserves, as of the end of 2016.

Oil production that peaked at 70,000 B/D in 2003 but has declined to 6,600 B/D in 2016, placing Petronius on a list of oil fields facing near-term abandonment.

A notable feature of Petronius is its early installation of a waterflood due to a relatively weak underlying aquifer.

Petronius J-2 Sand Geologic Model

Structure of the Petronius J-2 Sand



Source: Duan, 2013

The Petronius J-2 Sand reservoir is a Middle Miocene sheet sand, providing a structurally simple setting.

There is little faulting within the Petronius oil field and the J-2 Sand reservoir is judged to be relatively continuous.

The illustration provides the structure of J-2 reservoir, its oil-water contact (OWC), and the location of its nine production wells.

The Petronius J-2 Sand

The Petronius oil field contains two major sands, the Miocene-age Upper (J-1) Sand and Middle (J-2) Sand, as well as a series of smaller oil sands, shown below.

Petronius Original Oil Resources, Production and Remaining Reserves

Sands	Area (Acres)	Original Oil In- Place (MMB)	Cumulative Oil Production* (MMB)	Remaining Oil Reserves* (MMB)
1. Major Sands				
▪ J-1	3,438	124.8	69.6	4.0
▪ J-2	5,288	104.7	52.0	1.3
2. Minor Sands				
▪ J-3	1,352	24.5	6.1	1.0
▪ J-4	1,398	39.2	17.8	0.9
▪ J-5	389	18.2	7.8	1.5
▪ Other (13)	-	0.7	0.2	-
Total	11,865	312.1	153.5	8.7

*As of end of 2016. JAF2019_014.XLS

Volumetric and Other Reservoir Properties: Petronius J-2 Sand

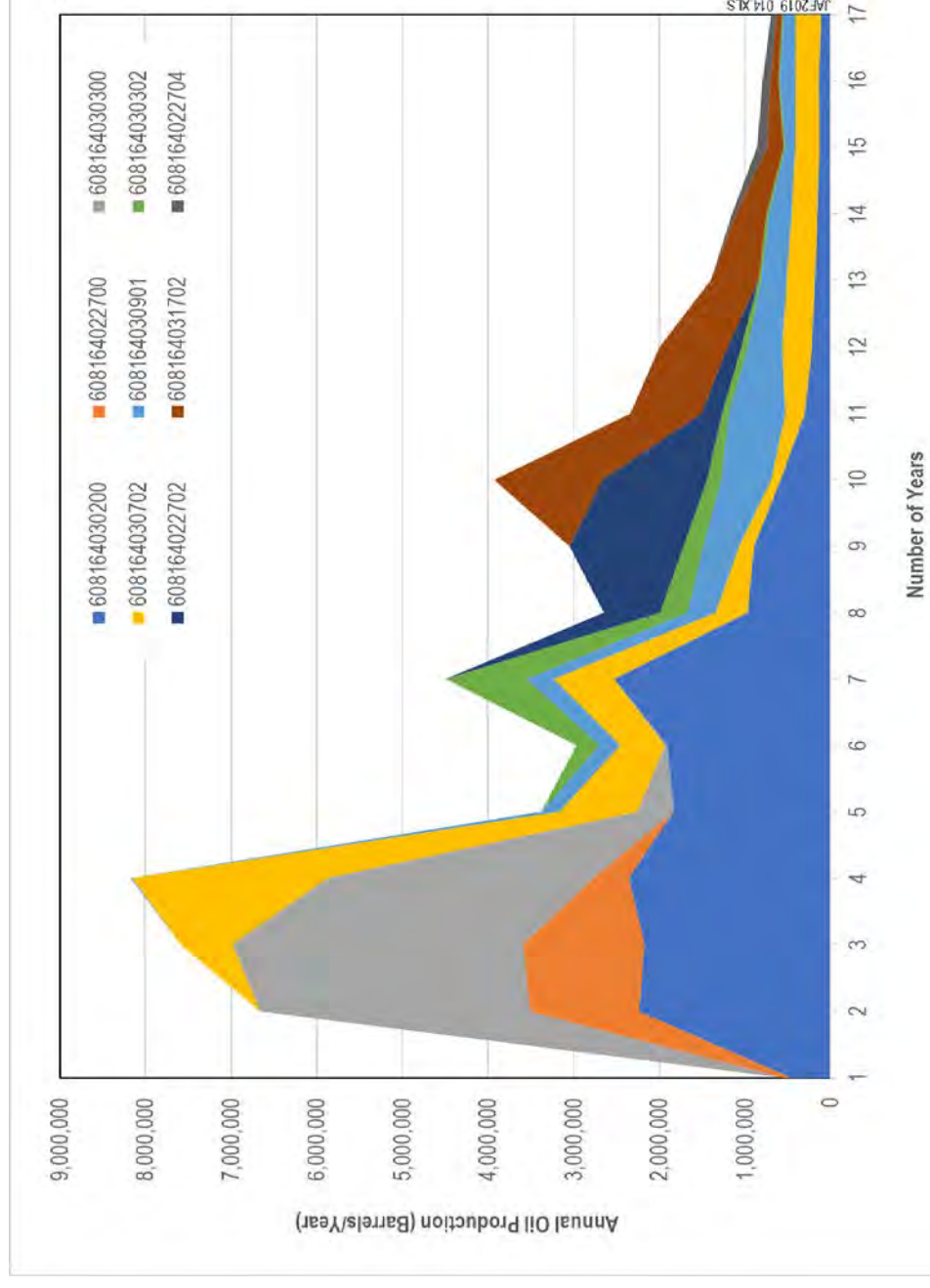
Reservoir Properties	Value
Oil Area	
▪ Total	5,288 Acres
▪ Quarter*	1,290 Acres
Porosity	30%
Depth	10,900 to 11,100 ft
Permeability	398 mD
Net Pay	16.5 ft
Oil Gravity	31 API
Swi	0.24
Boi	1.45
OOIP	104 MM bbls
Initial Pressure	5,287 psia
Pressure Gradient (@ 10,560 ft)	0.5 psi/ft
Initial Temperature	182 °F

*After including gas cap area.

The key volumetric and reservoir properties for the Petronius J-2 Sand are derived from information provided in the BOEM Offshore GOM database and from the technical literature on the Petronius oil field.

Petronius J-2 Sand

Annual Oil Production 2000-2016

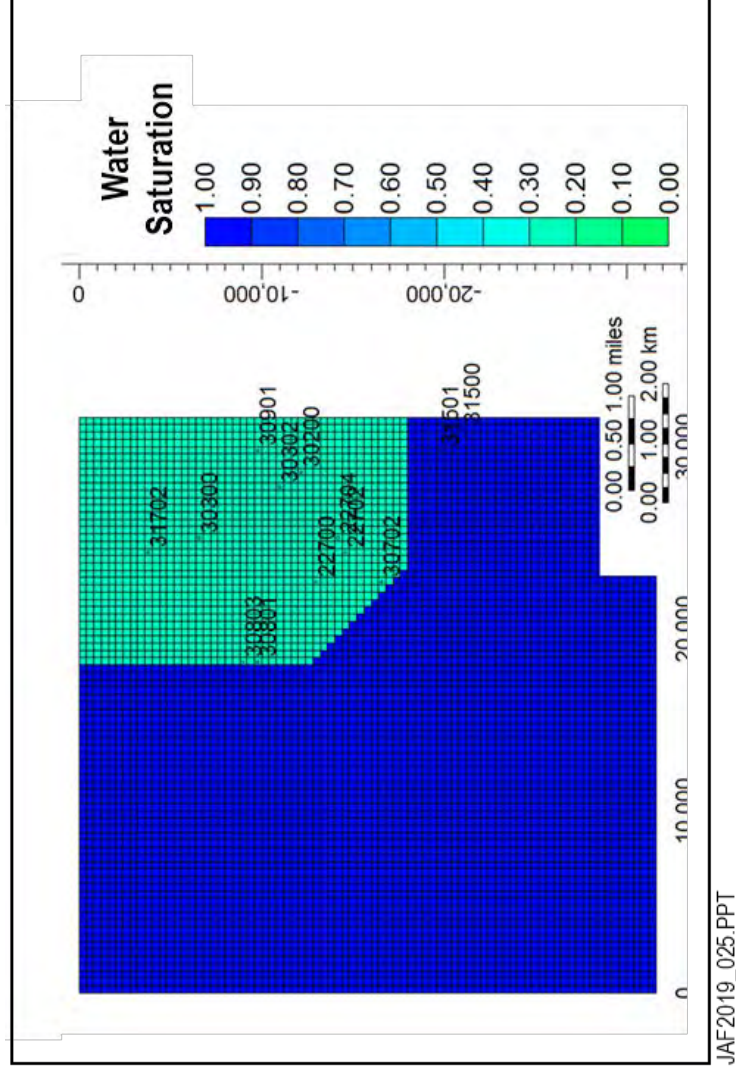


After a peak of 22,400 B/D (8.2 MMBbl/yr) in 2003, oil production from the J-2 Sand declined to 1,900 B/D (0.7 MMBbl/yr) in 2016.

The oil production history for the nine production wells drilled into the Petronius J-2 Sand is shown.

Reservoir Model for Petronius J-2 Sand

J-2 Sand Reservoir Model and Grid Blocks

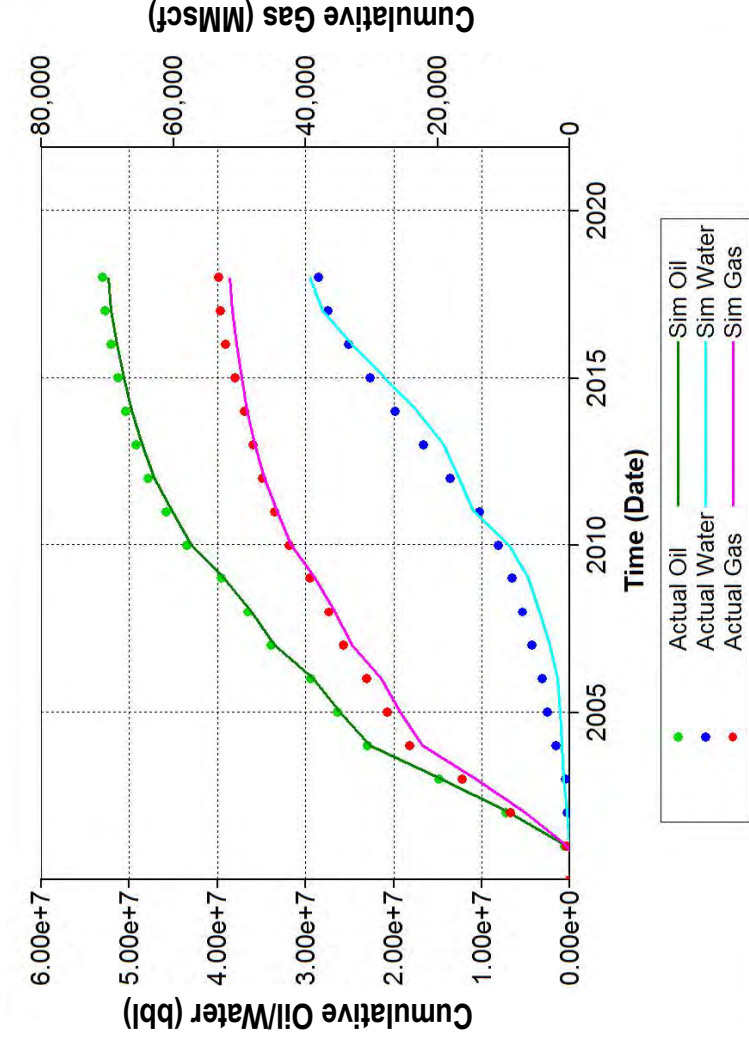


The reservoir model for the Petronius J-2 Sand contains 79 grid blocks in the X direction and 79 grid blocks Y direction, with each grid block set at 400 feet by 400 feet.

The up-structure portion of the reservoir model represents the oil reservoir. The down-structure portion of the reservoir model represents the underlying aquifer.

Source: Advanced Resources International, 2019

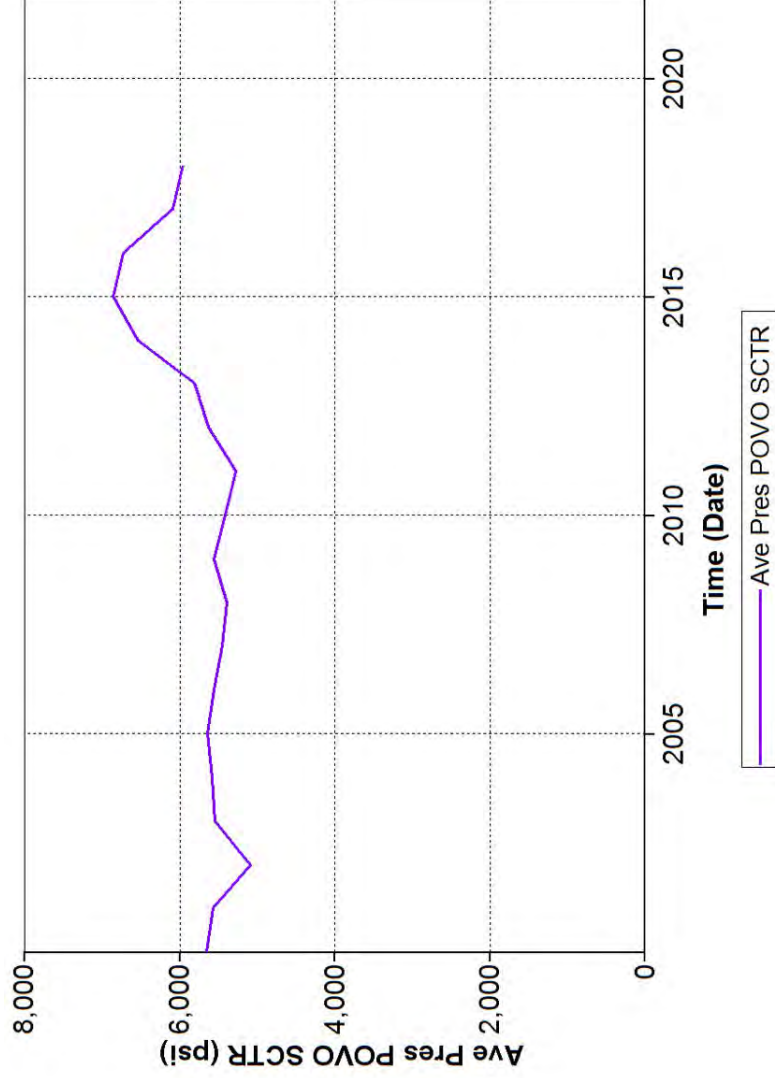
History Match of Fluid Production, Petronius J-2 Sand



Excellent history matched results were obtained for oil production, gas production and water production.

Source: Advanced Resources International, 2019

History Match of Fluid Production, Petronius J-2 Sand



An important output of the history match was the estimate of J-2 Sand reservoir pressure at the end of the waterflood.

Source: Advanced Resources International, 2019

GEM Compositional Modeling of the Performance of the CO₂ Flood, Petronius J-2 Sand

CO₂ Flood Design. Given the structural dip of the formation, its high permeability, and the strong bottom waterdrive, the design of the CO₂ flood was as follows:

- Drill an updip CO₂ injection well on the crest of the fault block.
- Inject continuous CO₂ at a rate of 25 MMcfd into the J-2 Sand for 40 years.
- Shut-in the one previously drilled, still active water injection well; operate the CO₂ flood using a bottom hole back pressure of 4,000 psi.
- Operate the CO₂ flood using a quarter of a five-spot pattern, with three closely spaced, active wells representing one production well and the other two closely spaced, active wells representing the second production well.

CO₂ PROPHET Modeling of the NETL CO₂ Flood, Petronius J-2 Sand

In parallel with the GEM compositional simulator, the study modeled the CO₂ flood in the Petronius J-2 Sand using NETL CO₂ PROPHET.

To capture the heterogeneity of the J-2 Sand, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the J-2 Sand were modeled (with CO₂ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO₂ producer and operate the CO₂ flood using a quarter of a five-spot pattern.
- Inject continuous CO₂ at a rate of 25 MMcfd for forty years, reaching a cumulative injection of CO₂ of 365 Bcf, equal to CO₂ injected in the GEM Model.

Comparative Analysis of GEM and CO₂ PROPHET Modeling of CO₂ Flood, J-2 Sand

The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

	CO ₂ Flood Performance GEM Compositional Simulator	CO ₂ Flood Performance CO ₂ PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	106	106	106
CO ₂ Injection (Bcf)	365	365	365
CO ₂ Production (Bcf)	226	238	190
CO ₂ Storage (Bcf)	139	127	175
Cumulative Oil Recovery			
▪ (million barrels)	14.3	10.8	17.4
▪ % of OOIP	13.5%	10.2%	16.4%
CO ₂ /Oil Ratio (Mcf/B)			
▪ Gross	25.5	33.8	21.0
▪ Net	9.7	11.8	10.1

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.

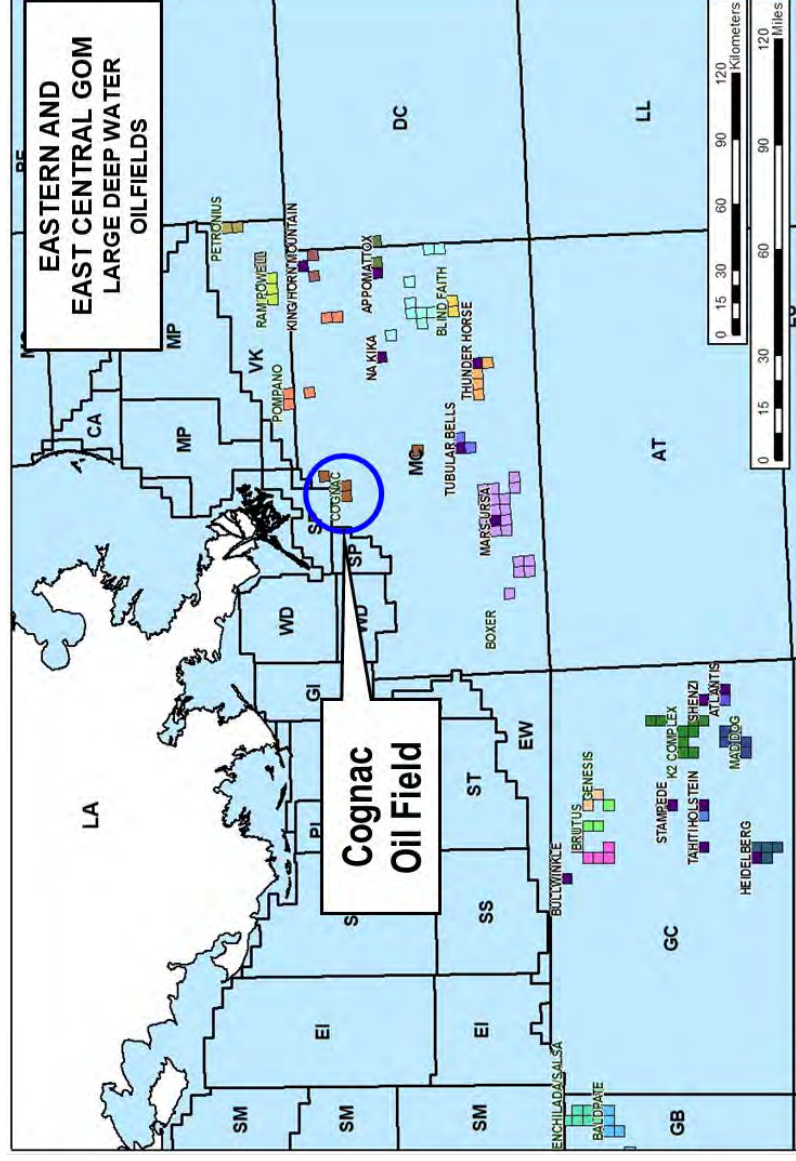


Cognac Offshore Oil Field Case Study

Background

The Cognac deepwater oil field (MC 194) is located in 1,022 feet of water in the Central Gulf of Mexico.

Location of Cognac Oil Field, Eastern Gulf of Mexico

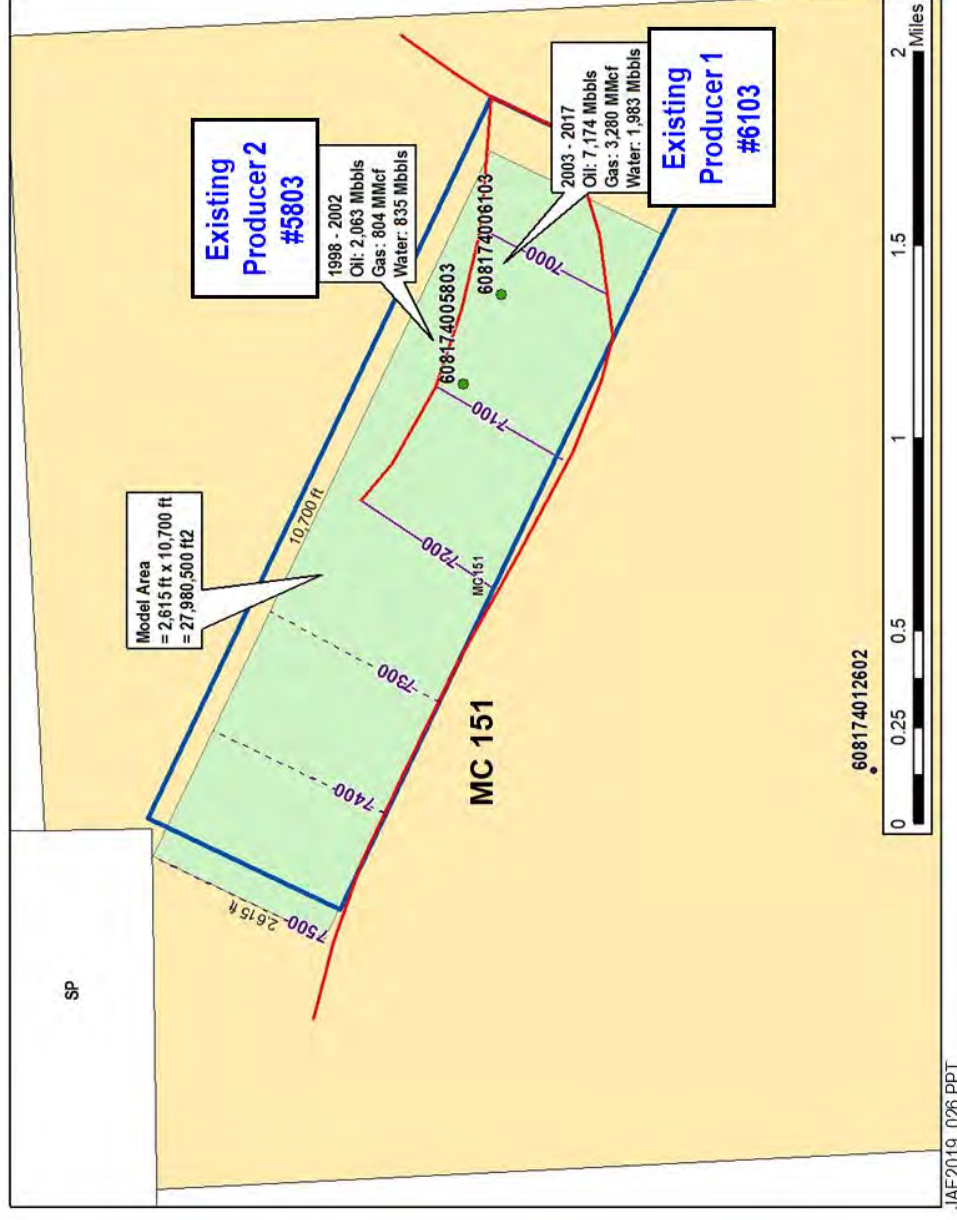


Cognac, with 184 million barrels of original oil reserves, has produced essentially all of its reserves, as of the end of 2017.

Oil production that peaked at 83,000 B/D of oil in 1983 has declined to about 2,000 B/D of oil in 2016, placing Cognac on a list of oil fields facing abandonment.

Cognac J Sand/NE Fault Block Geologic Model

Outline of NE Fault Block, Cognac Field



The NE Fault Block in MC 151 contains two oil producing wells – Well #5803 and Well #6103 – producing from a fault bounded area of about 384 acres.

A simplified representation of the NE Fault Block, including its structure, the location of the bounding faults, and the location of the two producing wells is shown.

Cognac J Sand

The J Sand in the Cognac oil field, selected for the Case Study, holds 136 million barrels of OOIP and has a remaining oil target of 79 MMB. The NE Fault Block (J Sand) holds about 18% of the OOIP in the total J Sand.

Cognac Original Oil Resources, Production and Remaining Reserves

Sands	Oil Area (Acres)	Original Oil In-Place* (MMB)	Cumulative Oil Production** (MMB)	Remaining Oil Reserves (MMB)
1. Major Sands				
▪ I	3,560	191.5	91.7	0.1
▪ J	2,240	135.6	56.9	0.3
2. Minor Sands				
▪ J-1	1,740	23.3	6.6	***
▪ Others	n/a	n/a	16.0	3.2
Total	7,540	350.4	171.2	3.6

JAF2019_015.XLS

*Volumetrically adjusted by Advanced Resources Intl., **As of end of 2016.
***Less than 0.05 MMB.

Volumetric and Other Reservoir Properties

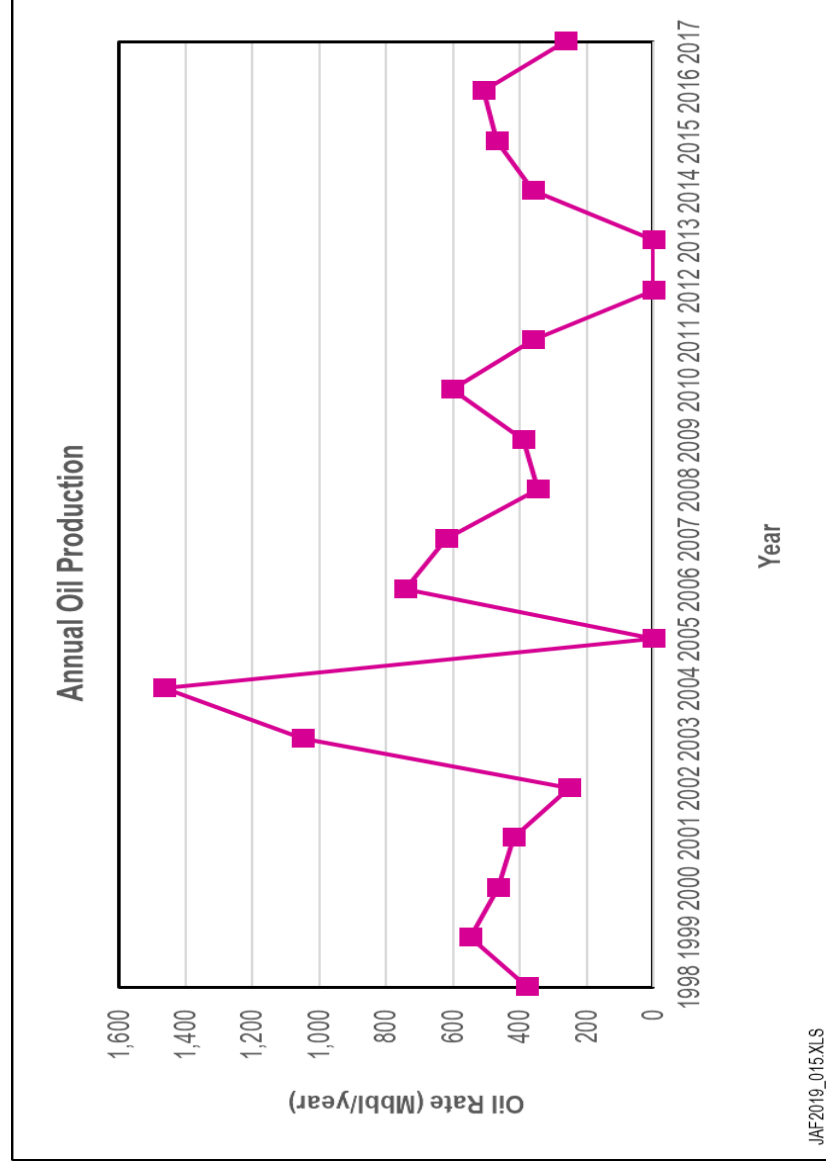
Cognac J Sand/NE Fault Block

Reservoir Properties	Value
Accessible Oil Area	384 Acres
Porosity	32%
Permeability	794 mD
Net Pay	42 ft
Oil Gravity	34.6 API
Soi	0.73
Sor	0.45
Boi	1.21
OOIP	24.2 MMbbls
Initial Pressure (@ 8,297 ft)	4,412 psia
Initial Reservoir Temperature	130 °F

The key volumetric and reservoir properties for the Cognac J Sand in the NE Fault Block are derived from information provided in the BOEM Offshore GOM data base and from the technical literature on the Cognac oil field.

Cognac J Sand/NE Fault Block

Annual Oil Production, Cognac J Sand, NE Fault Block



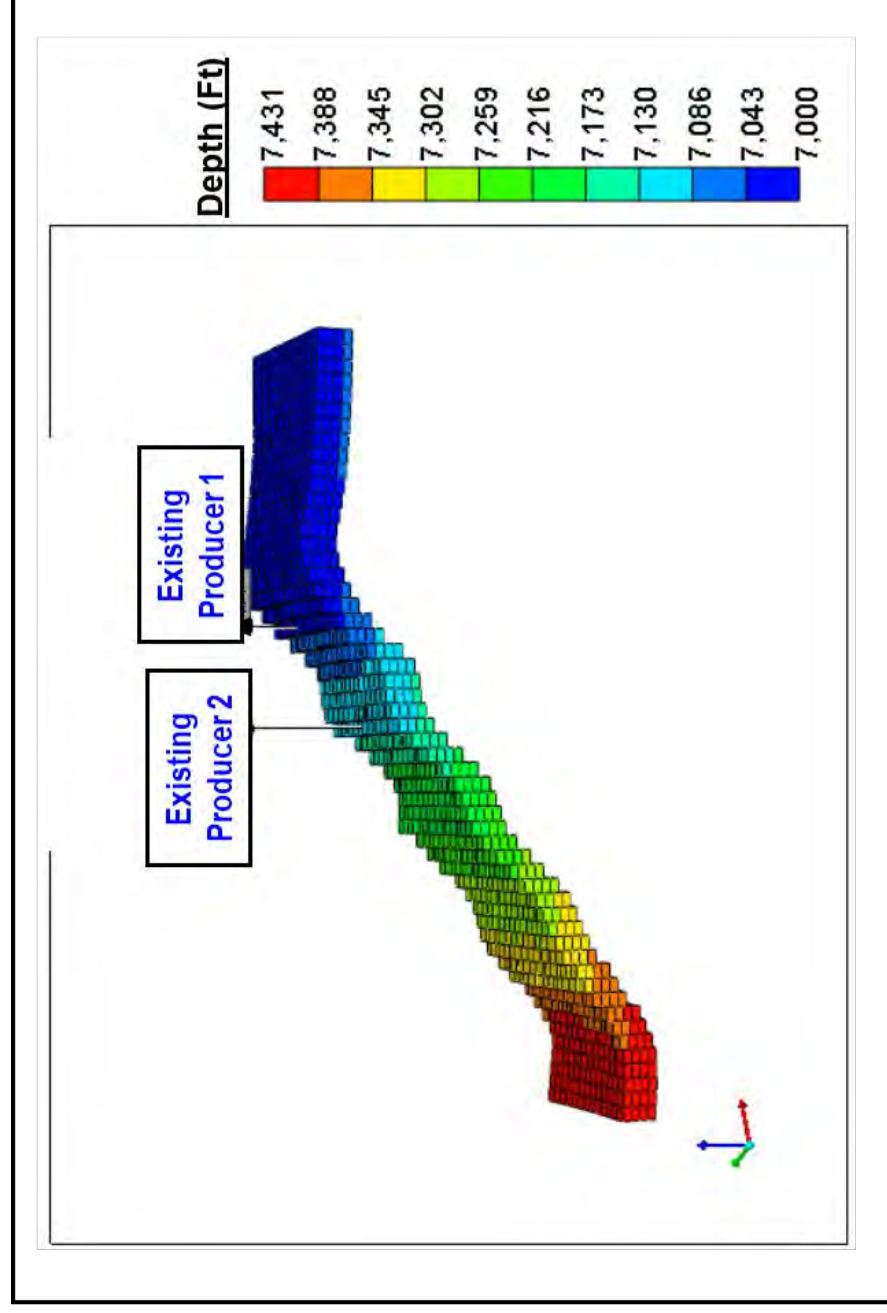
Source: Advanced Resources Int'l using DrillingInfo data, 2019

As of mid-2017, the J Sand of the NE Fault Block has produced 9.25 million barrels of oil, equal to 38 percent of OOIP.

The annual oil production history of the NE Fault Block J Sand from inception in mid-1998 to mid-2017 is shown.

Reservoir Modeling for Cognac J Sand

NE Fault Block, Cognac J Sand, 3D Model, Side View

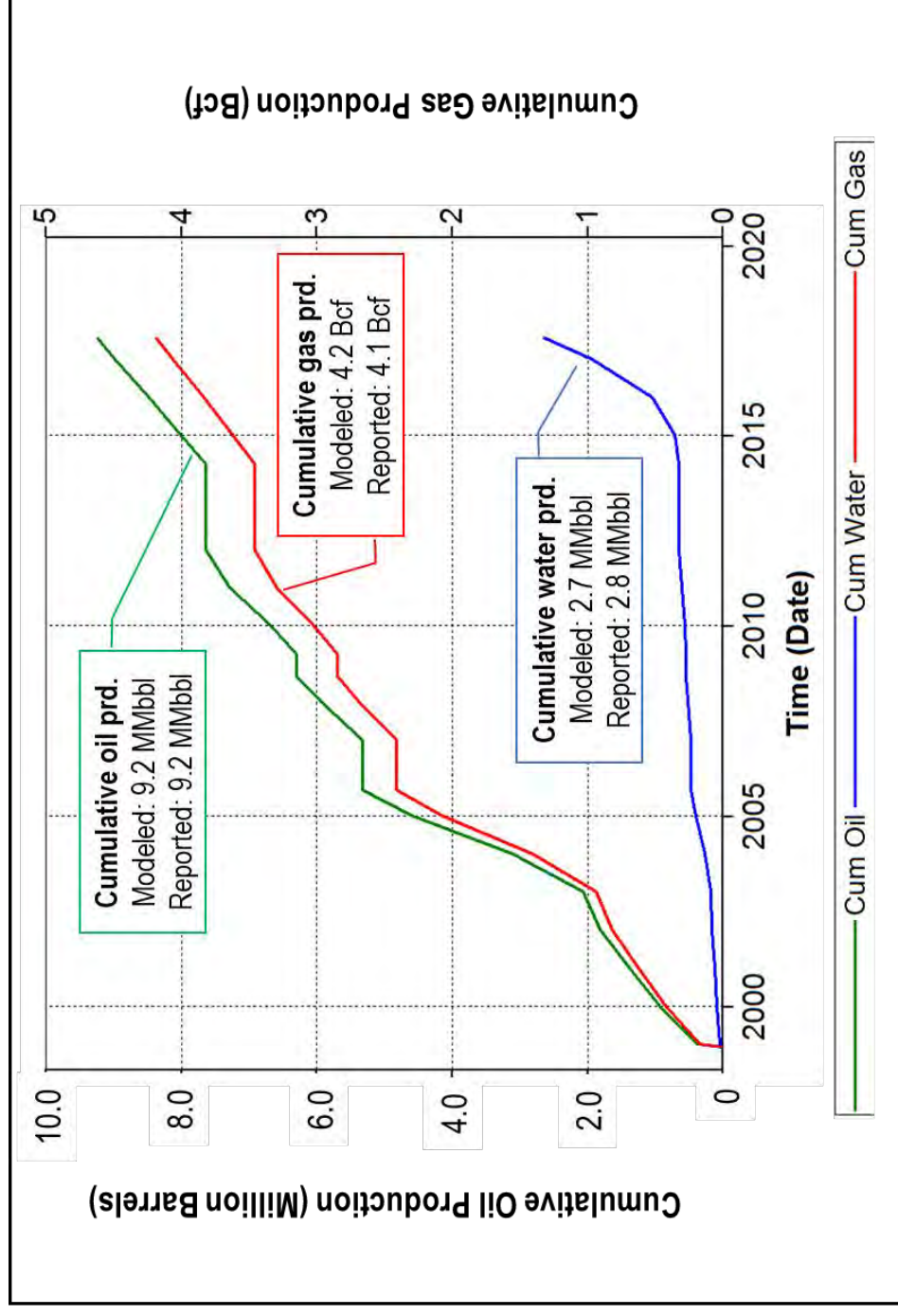


The reservoir model for the surface of NE Fault Block J Sand contains 702 grid blocks (54 x 13) each having a dimension of 200 ft in the X and Y directions.

The vertical dimension of the J Sand is represented by four layers (grid benches), each having a thickness of 10.5 feet.

History Match of Fluid Production, Cognac

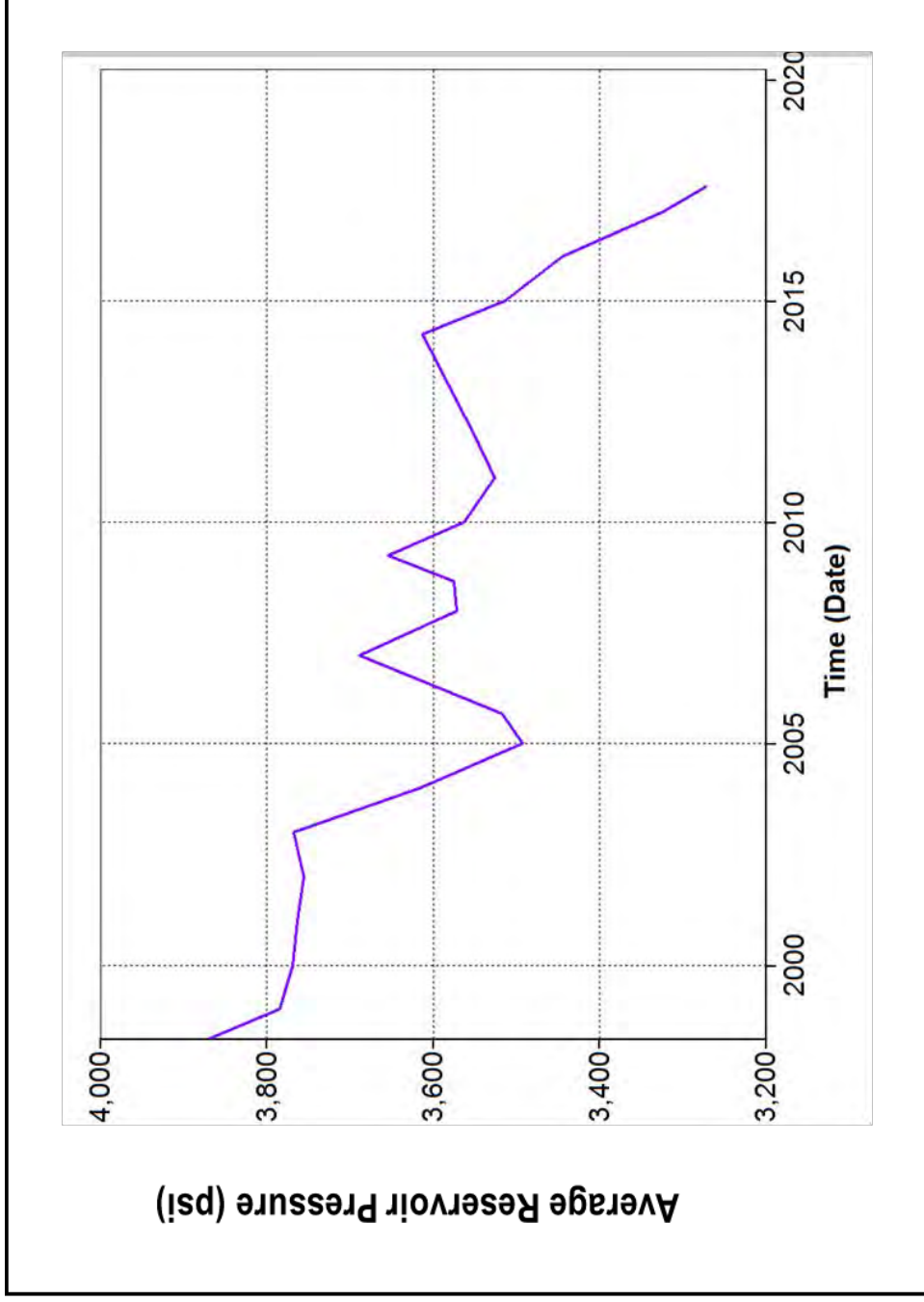
J Sand, NE Fault Block



History Match of Fluid Production, Cognac

J Sand, NE Fault Block

An important output of the history match was the estimate of J Sand reservoir pressure at the end of primary production.



JAF2019_026.PPT

GEM Compositional Modeling of the Performance of the CO₂ Flood, Cognac J Sand, NE Fault Block

CO₂ Flood Design. Given the structural dip of the formation, its high permeability and the strong bottom waterdrive, the design of the CO₂ flood was as follows:

- Drill an updip CO₂ injection well on the crest of the fault block.
- Inject continuous CO₂ at a rate of 24 MMcfd into the J Sand for 10 years and 20 years.
- Shut-in the producing wells for 12 months to raise reservoir pressure; operate the CO₂ flood using a bottom hole back pressure of 3,000 psi.
- Initially produce from updip production well (Prd #1) until CO₂ breakthrough; shut in updip production well and open downdip production well (Prd #2) and produce until end of the CO₂ flood.

CO₂ PROPHET Modeling of the NETL CO₂ Flood, Cognac J Sand, NE Fault Block

In parallel with the GEM compositional simulator, the study modeled the CO₂ flood in the Cognac J Sand, NE Fault Block, using NETL CO₂ PROPHET.

To capture the heterogeneity of the J Sand in the NE Fault Block, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the NE Fault Block's J Sand were modeled (with CO₂ PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO₂ producer and operate the CO₂ flood in a two well line drive configuration.
- Inject continuous CO₂ at a rate of 24 MMcfd for ten years, reaching a cumulative injection of CO₂ of 88 Bcf equal to CO₂ injected in the GEM Model (a HCPV of 1.2).

Comparative Analysis of GEM and CO₂ PROPHET Modeling of CO₂ Flood, NE Fault Block J Sand

The CO₂ PROPHET streamtube model was able to reasonably represent the performance of the CO₂ flood compared to the GEM compositional simulator.

	CO ₂ Flood Performance GEM Compositional Simulator	CO ₂ Flood Performance CO ₂ PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	24.2	24.4	24.2
CO ₂ Injection (Bcf)	89.5	87.7	87.7
CO ₂ Production (Bcf)	52.3	55.7	45.3
CO ₂ Storage (Bcf)	37.2	32.0	42.4
Cumulative Oil Recovery			
▪ (million barrels)	8.18	6.33	8.67
▪ % of OOIP	33.8%	26.2%	35.8%
CO ₂ /Oil Ratio (Mcf/B)			
▪ Gross	10.9	13.9	10.1
▪ Net	4.5	5.1	4.9

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO₂ PROPHET model) provide results that bracket the performance of the CO₂ flood from the GEM compositional simulator.

Observations and Findings

A series of observations and findings have emerged from the GOM offshore case studies:

- Establishing a geologically representative data base for offshore oil fields is a challenge, but one that can be overcome with diligent effort.
- By defining the location and status of existing production and injection wells, reasonable spacing and CO₂ flooding designs can be established for offshore oil fields.
- Miscible CO₂ EOR can provide notable increases in oil recovery – 15% to 30% of OOIP – while storing significant volumes of CO₂.
- The NETL CO₂ PROPHET Model can provide realistic estimates of oil recovery and CO₂ storage in offshore oil reservoirs.



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RISK ASSESSMENT GAS HYDRATES

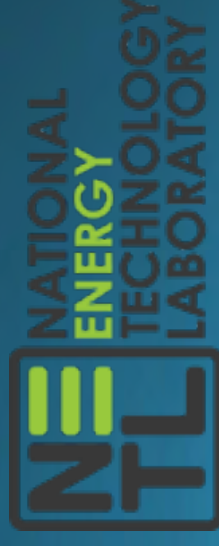


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SECARB Offshore GoM

**CAMELIA KNAPP, JIM KNAPP,
GOKCE ASTEKIN, SAIFUL ALAM**
Boone Pickens School of Geology
Oklahoma State University
Task 4.0

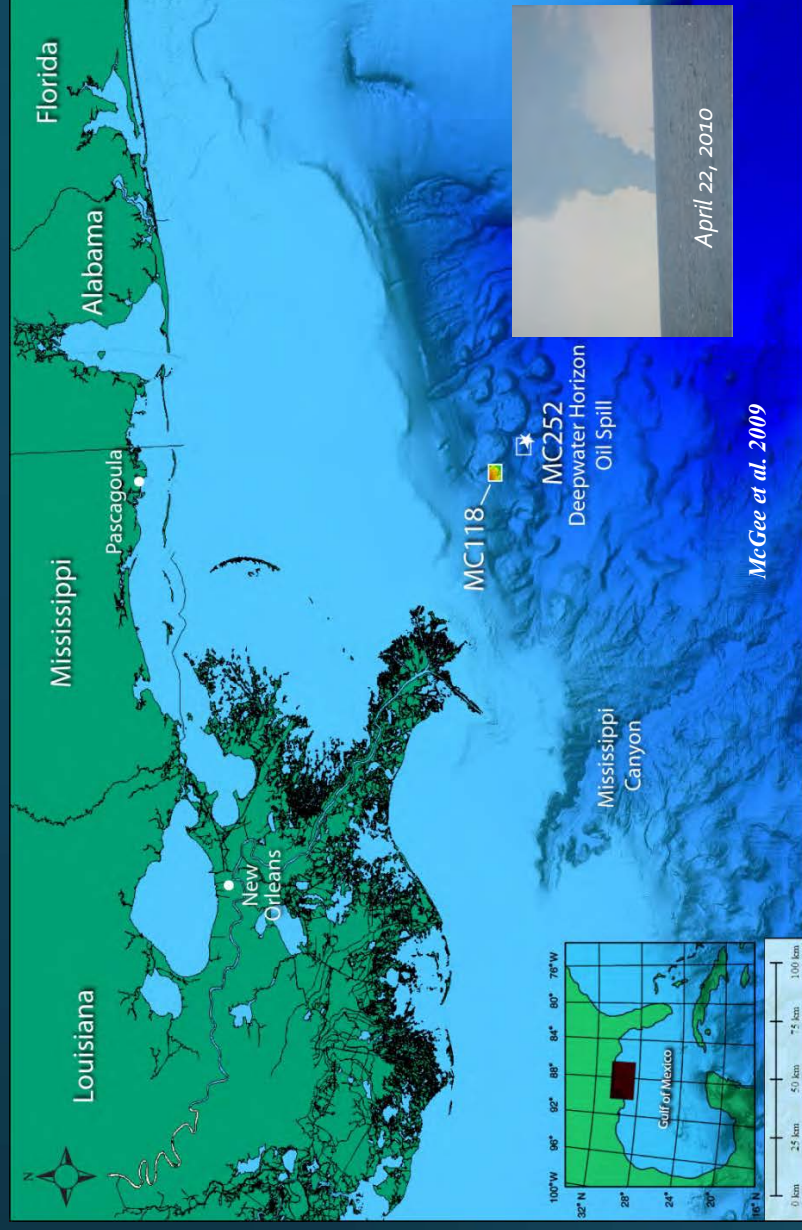




Task 4.0

- Risk Assessment, Simulation, and Modeling. Going beyond the traditional NRAP process, this Task encompasses activities related to the refinement and adaption of existing data mining, analysis, and machine learning tools (SAS Viya decision system; Subtask 3.2), simulation tools, geologic models, and **risk assessment and mitigation strategies for site-specific assessments of storage prospects in the offshore environment**. To aid in a formalized process for characterizing prospects with high potential for commercial CO2 storage development, supported, to the extent possible and practical, by the SAS Viya platform, the project team will perform a robust characterization of risk, geologic technical risk, operational risk, and commercial risk related to the full, integrated system (source, transport, and storage utilization). Results will be used to highlight possible physical regulatory and or commercial barriers, and mechanisms to overcome those barriers. This activity is directly dependent on the outcome of Task 3.0, namely the defined characteristics of representative storage opportunities.
- Subtask 4.3.2: Seismic Hazard Assessment and Earthquake Risk Analysis. Perform seismic hazard assessment and earthquake risk analysis in the study area, assess the evolution of gas hydrate-bearing systems and their temporal and spatial response to natural perturbations, based on lessons learned from the active Woolsey Mound cold seep at Mississippi Canyon 118.

Woolsey Mound - CSHS



- 900 m WD on the N continental slope of the GOM.
- Slope highly discontinuous, intersected by slumping, folding and faulting mainly driven by salt tectonics and sediment load delivered by the Mississippi River.
- Deepwater Horizon rig, Mississippi Canyon 252, April 22, 2010.



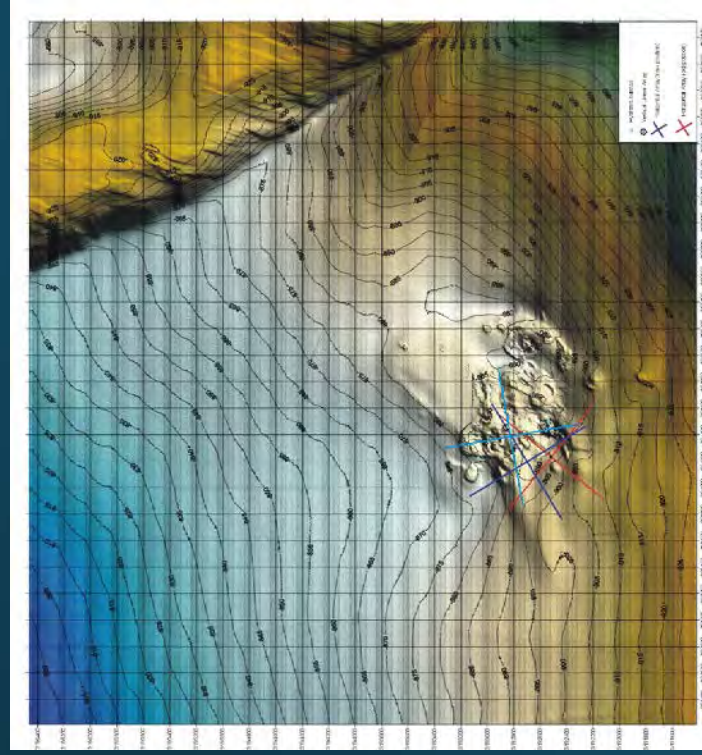
Woolsey Mound Hydrates

- Do not exhibit the classic regional BSRs on seismic sections.
- Seem to form around salt-related faults that provide likely migration pathways for the thermogenic hydrocarbons.
- Other methods need to be implemented in order to detect them and provide estimates of their volumetric extent.



MC 118, (Lutken et al., 2011)

Woolsey Mound: Fault-Controlled, Transient, Thermogenic Hydrate System

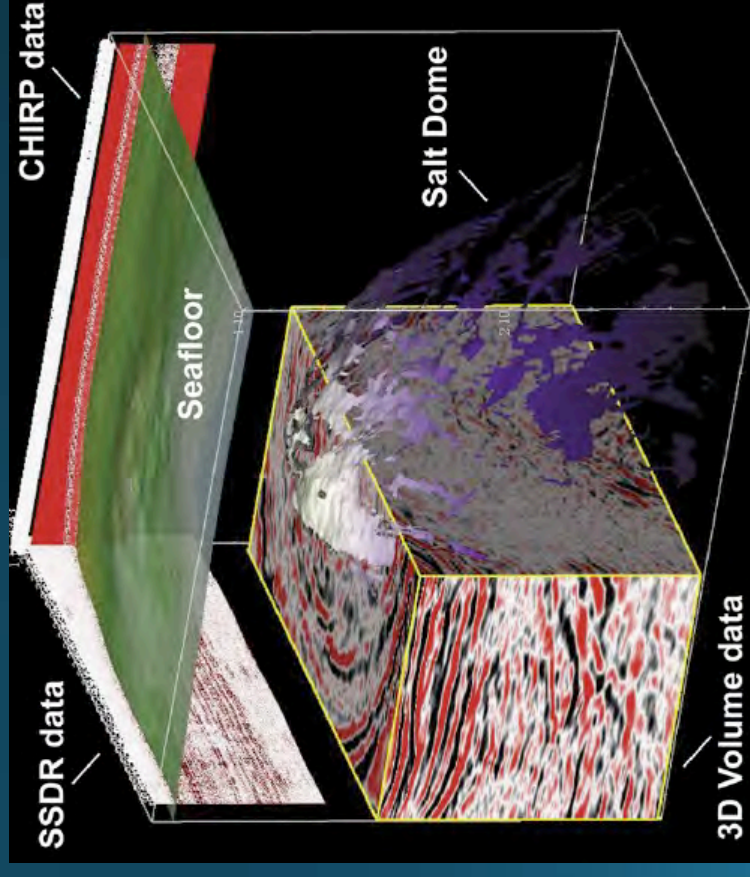


Macelloni et al., 2012

- Mid-slope of GOM
- Salt tectonically driven cold seep
- Gas venting at the seafloor
- Outcropping hydrate chemosynthetic communities, carbonate mounds, and bubble plumes
- Chemosynthetic communities
- Relatively shallow water depth (<1000 m).

Hypotheses

- GH are genetically related to the salt system through active normal faults, conduits for thermogenic gas
- GH formation and dissociation vary temporally in the vicinity of active faults, and can temporarily seal them as conduits for thermogenic fluids.
- GH at WM are controlled by a highly heterogeneous stability field leading to the general paucity of BSRs.
- AVO analysis is a good indicator of hydrates in the absence of well defined BSRs.
- Apparent temporal changes in seismic images of the subsurface are correlated with periodic fluid expulsion and hydrate dissociation.



Macelloni et al., 2012

Available Data

Standard 3-D data from TGS-Nopec, acquired in 2000; time domain data; 3 s TWTT

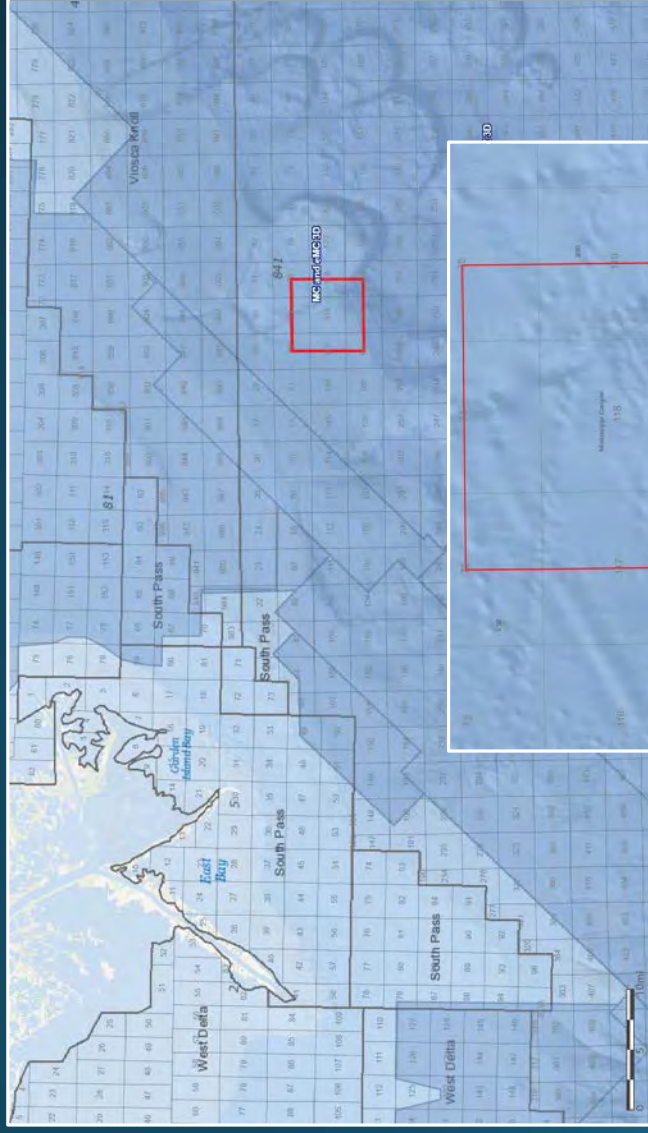
Standard 3-D data from Western Geco, acquired in 2003; time domain data; 10 s TWTT

Wide Azimuth (WAZ) 3-D data from TGS-Nopec, acquired in 2010; time and depth domain data; 10 s TWTT, 16 km depth

Wide Azimuth (WAZ) 3-D data from TGS-Nopec, acquired in 2014; time and depth domain data; 10.4 s TWTT, 18 km depth

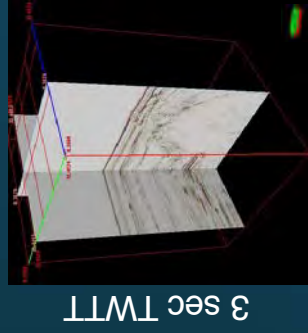
Single-channel 2D AUV-borne Chirp Sub-bottom Profiler data, acquired in 2005;

Single-channel pseudo 3D Surface Source Deep Receiver data (SSDR), acquired in 2006.



TGS Nopec

4-D SEISMIC ANALYSIS

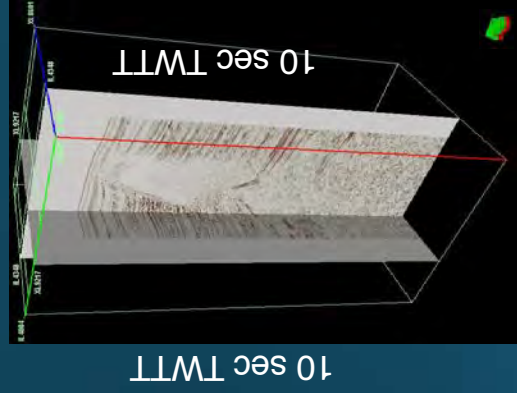


TGS 2000

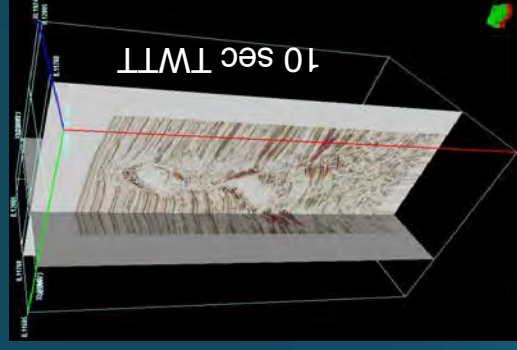
4-D PROCESSING SEQUENCE

(cross-equalization):

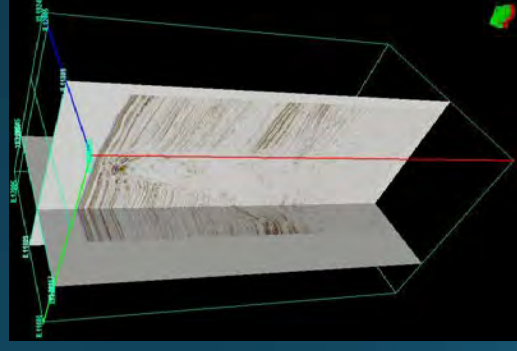
- ✓ re-sampling
- ✓ 3D geometry re-binning
- ✓ phase matching
- ✓ shaping filter
- ✓ gain x-normalization
- ✓ residual amplitude map



WesternGeco
2003



Justice
2010



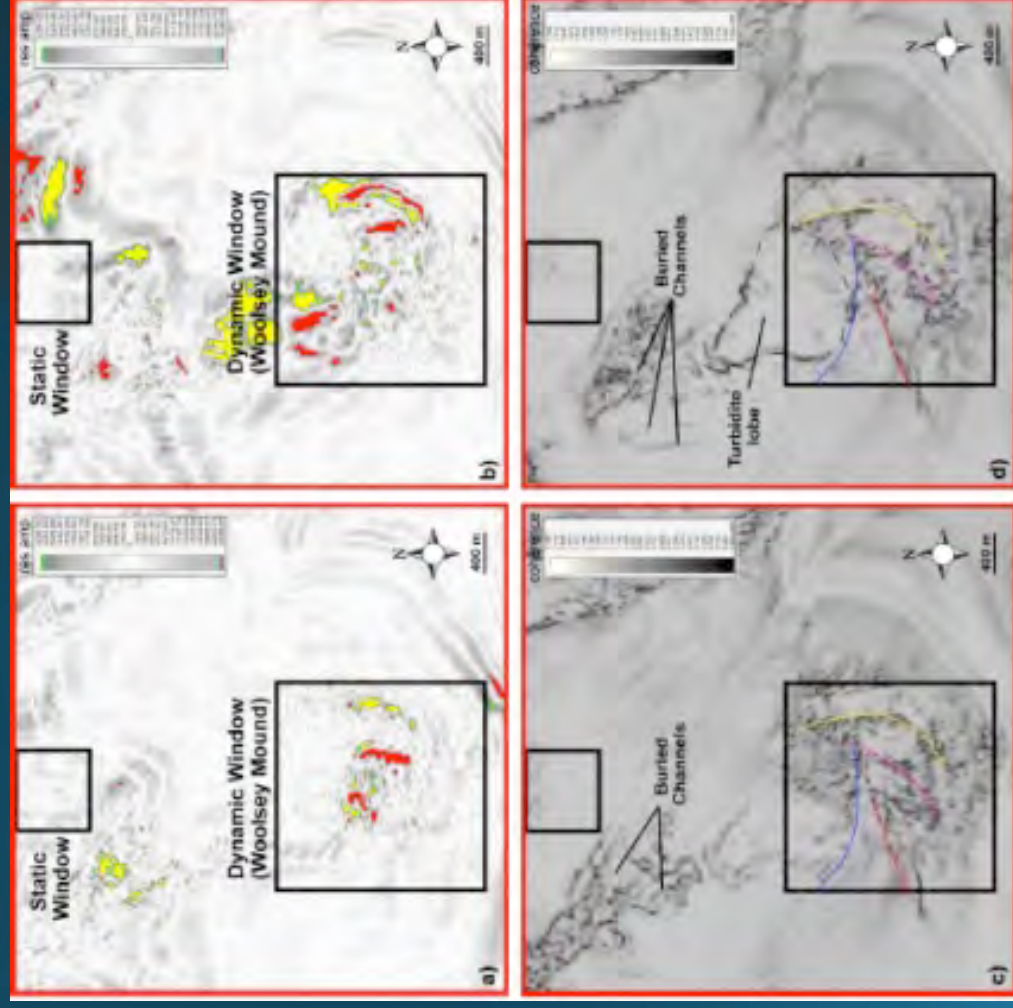
Declaration
2014

Time-lapse seismic monitoring involves comparing the results of 3-D seismic surveys repeated at considerable time intervals: time is the fourth dimension.

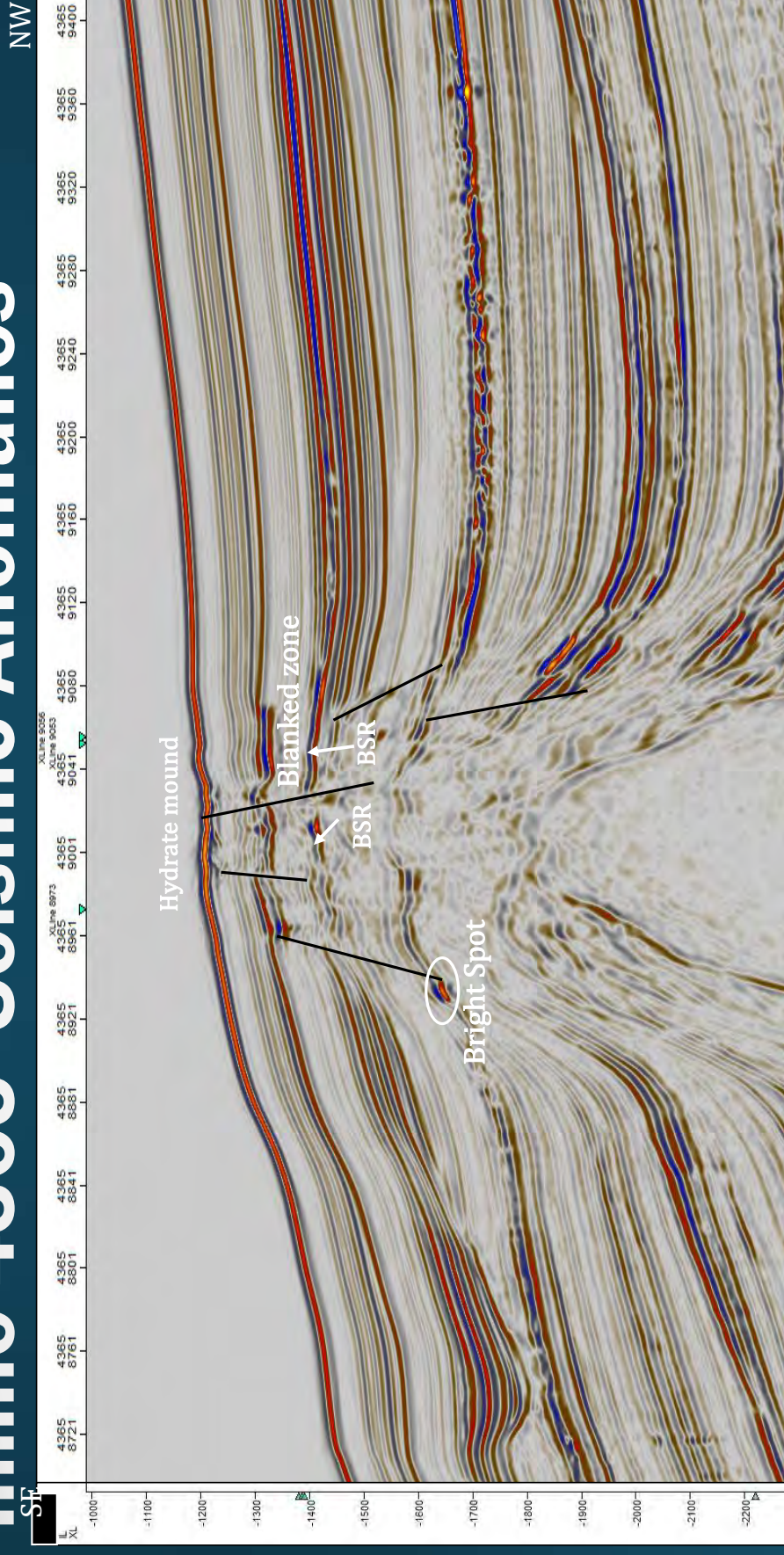
4-D seismic anomalies (time
slices near the BHSZ)

Subsurface Structures
(time slices near the BHSZ)

Simonetti et al., 2015



Inline 4365- Seismic Anomalies



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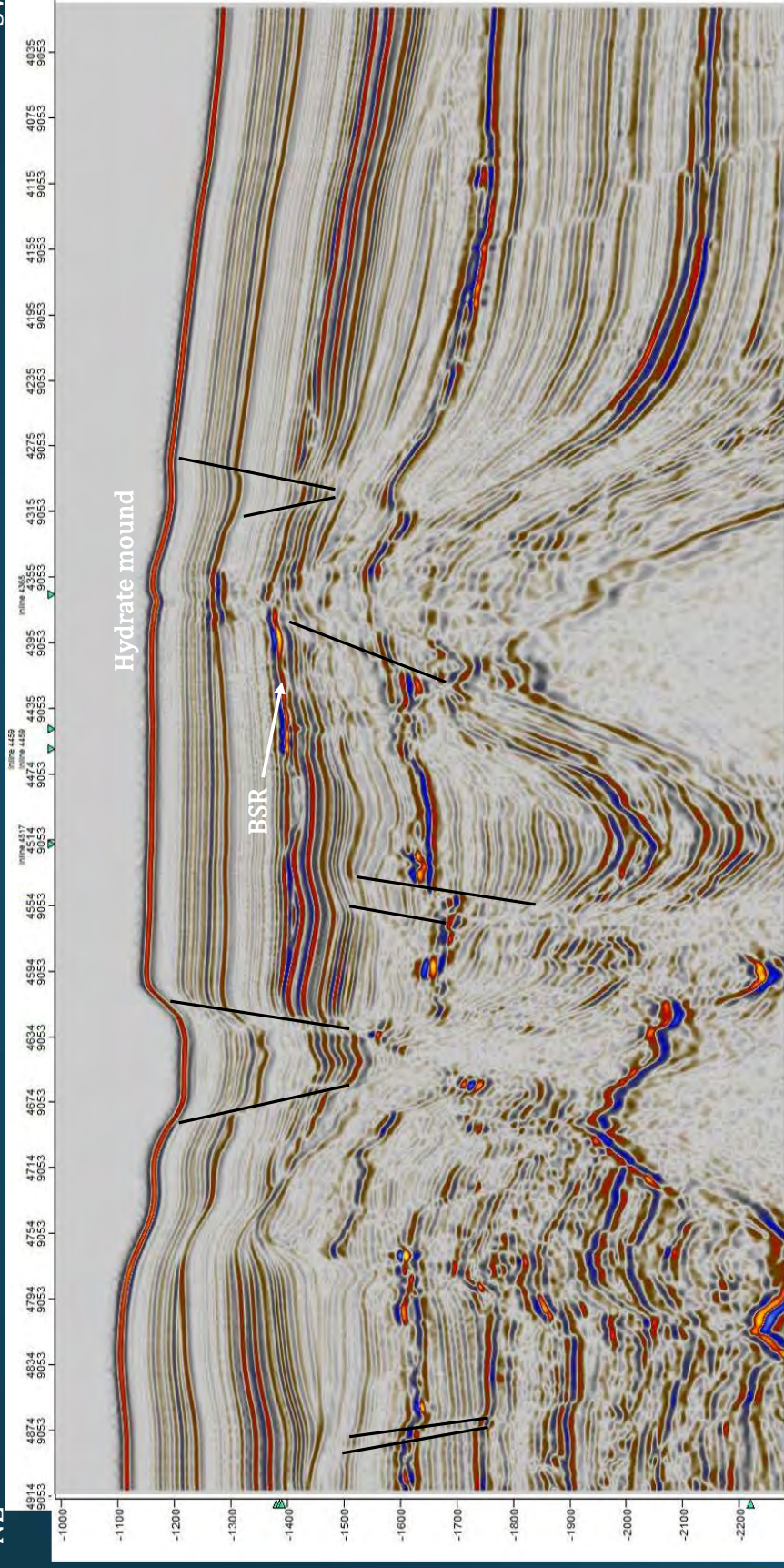
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Crossline 9053 - Seismic Anomalies

NE

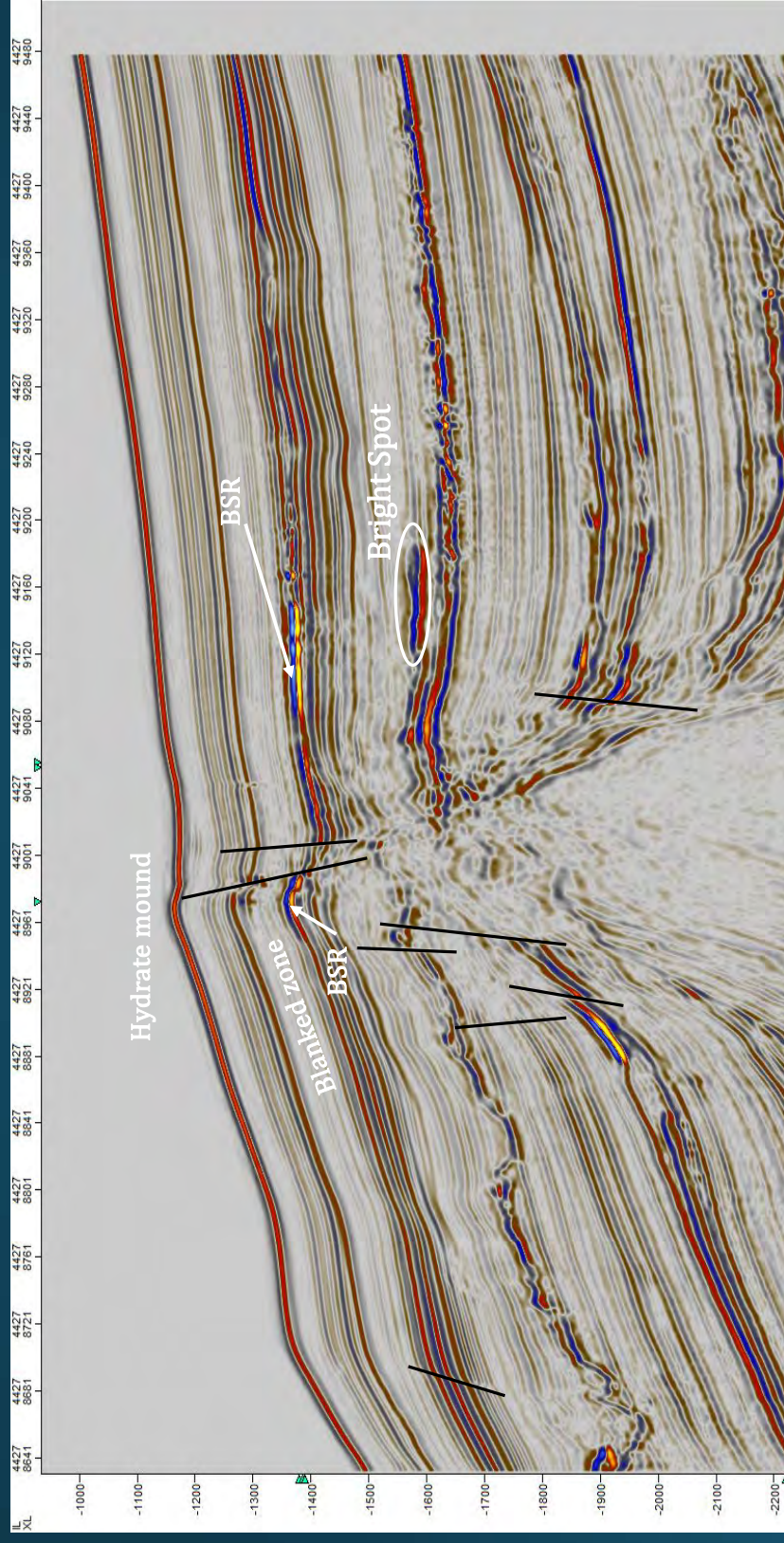
SW



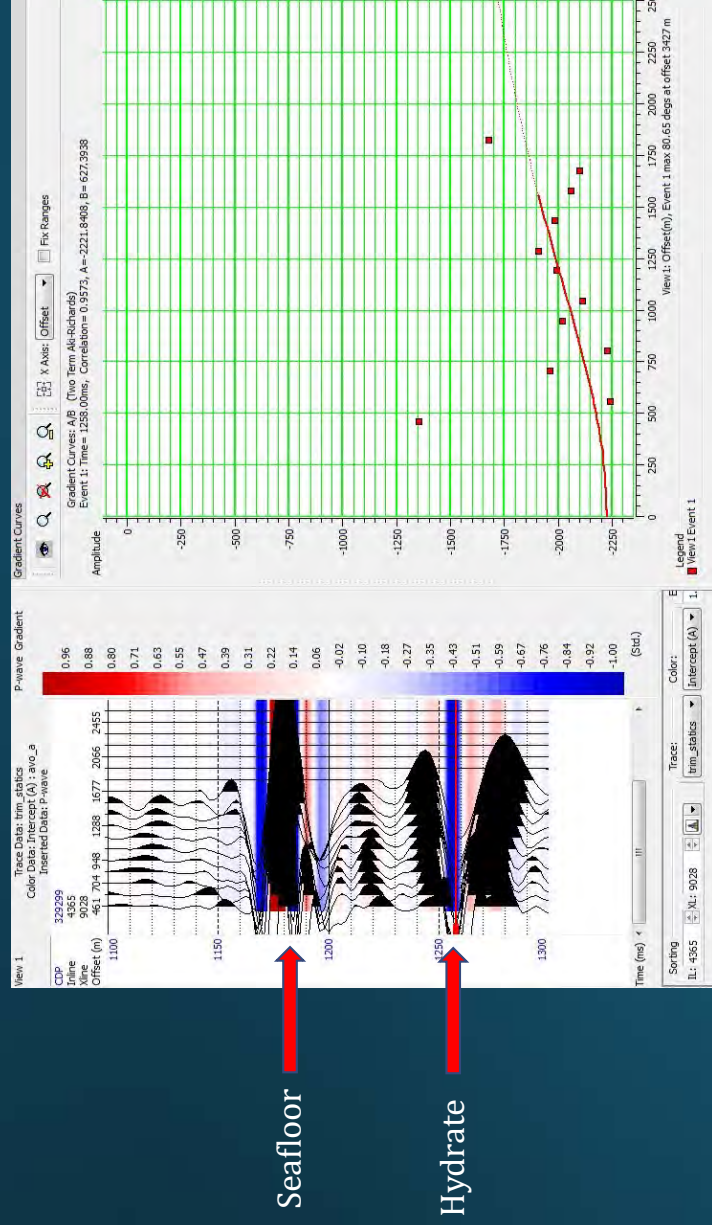
Inline 4427 – Seismic Anomalies

SE

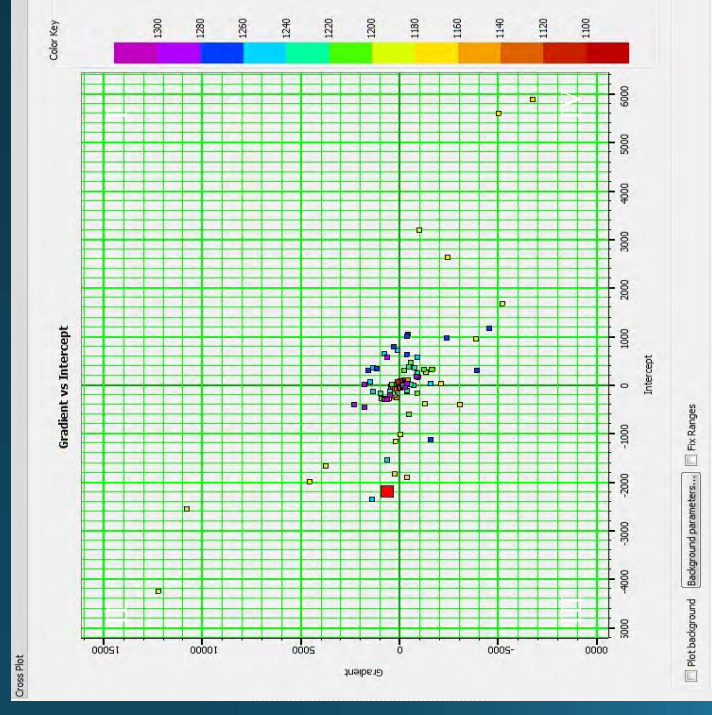
NW



Base of the Hydrate Layer 1 - Inline 4365

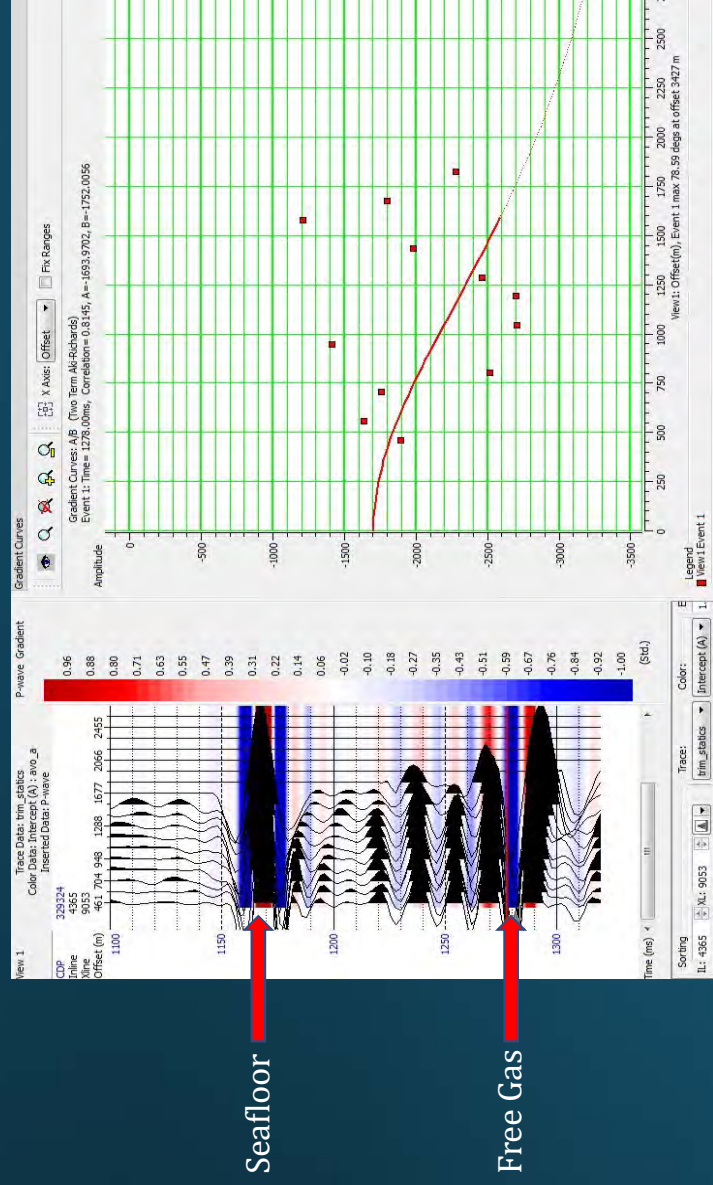


a) Variation of Reflected Amplitude with offset

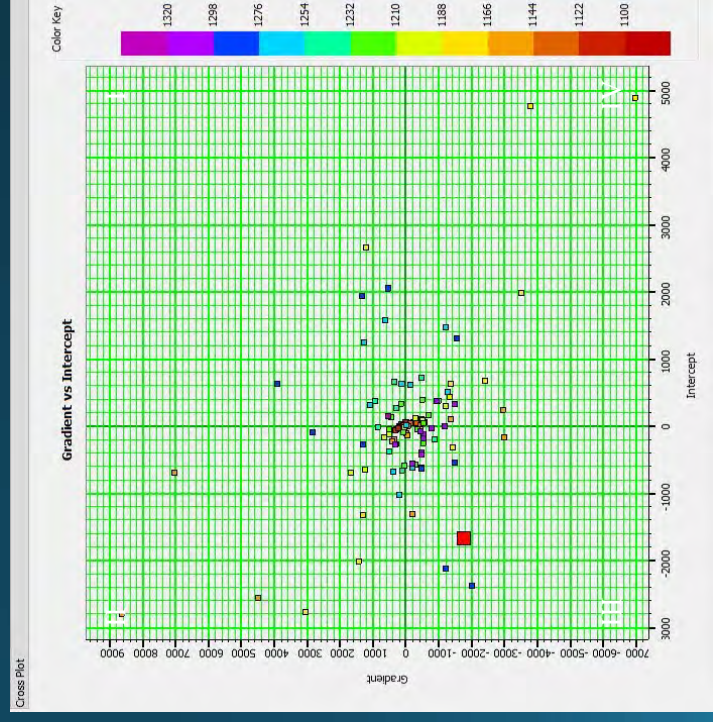


b) AVO Crossplot of data- Gradient vs Intercept

Free Gas Saturated Layer 1 - Inline 4365

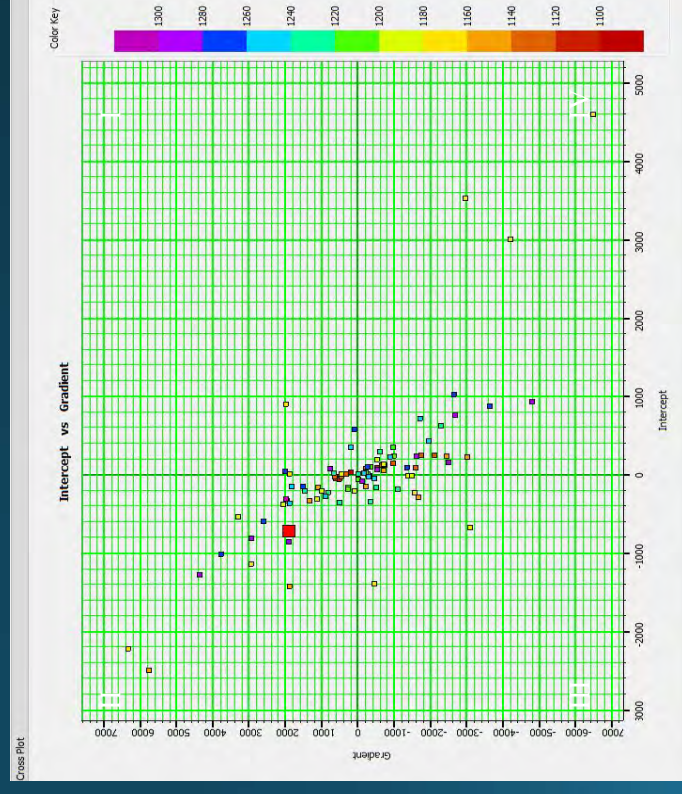
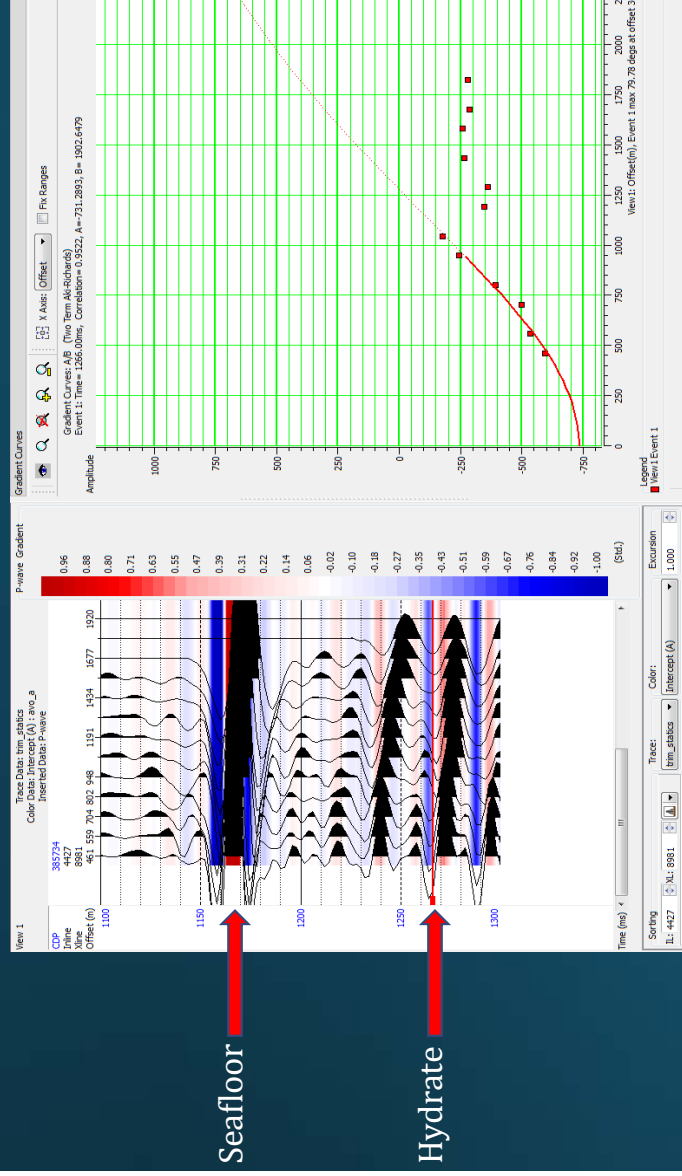


a) Variation of Reflected Amplitude with offset



b) AVO Crossplot of data- Gradient vs Intercept

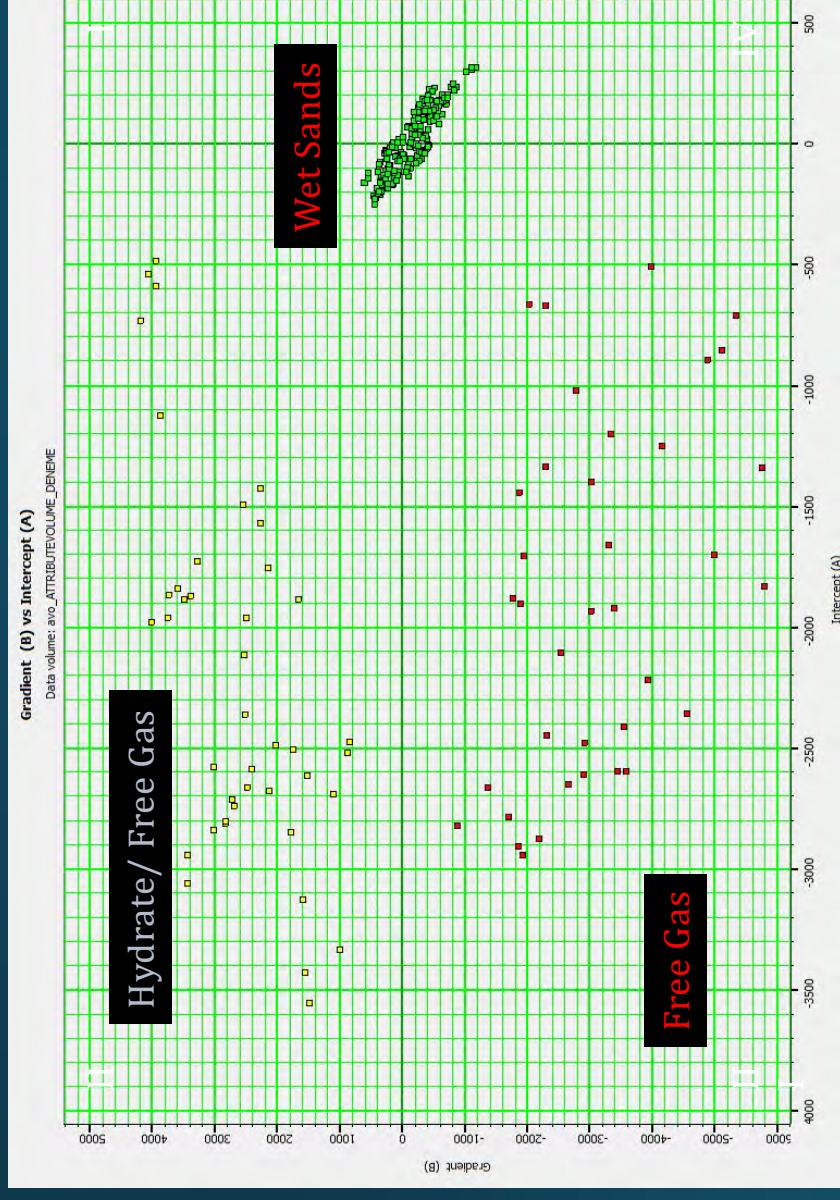
Base of the Hydrate Layer 2 - Inline 4427



a) Variation of Reflected Amplitude with offset

b) AVO Crossplot of data- Gradient vs Intercept

Gradient vs Intercept Crossplots

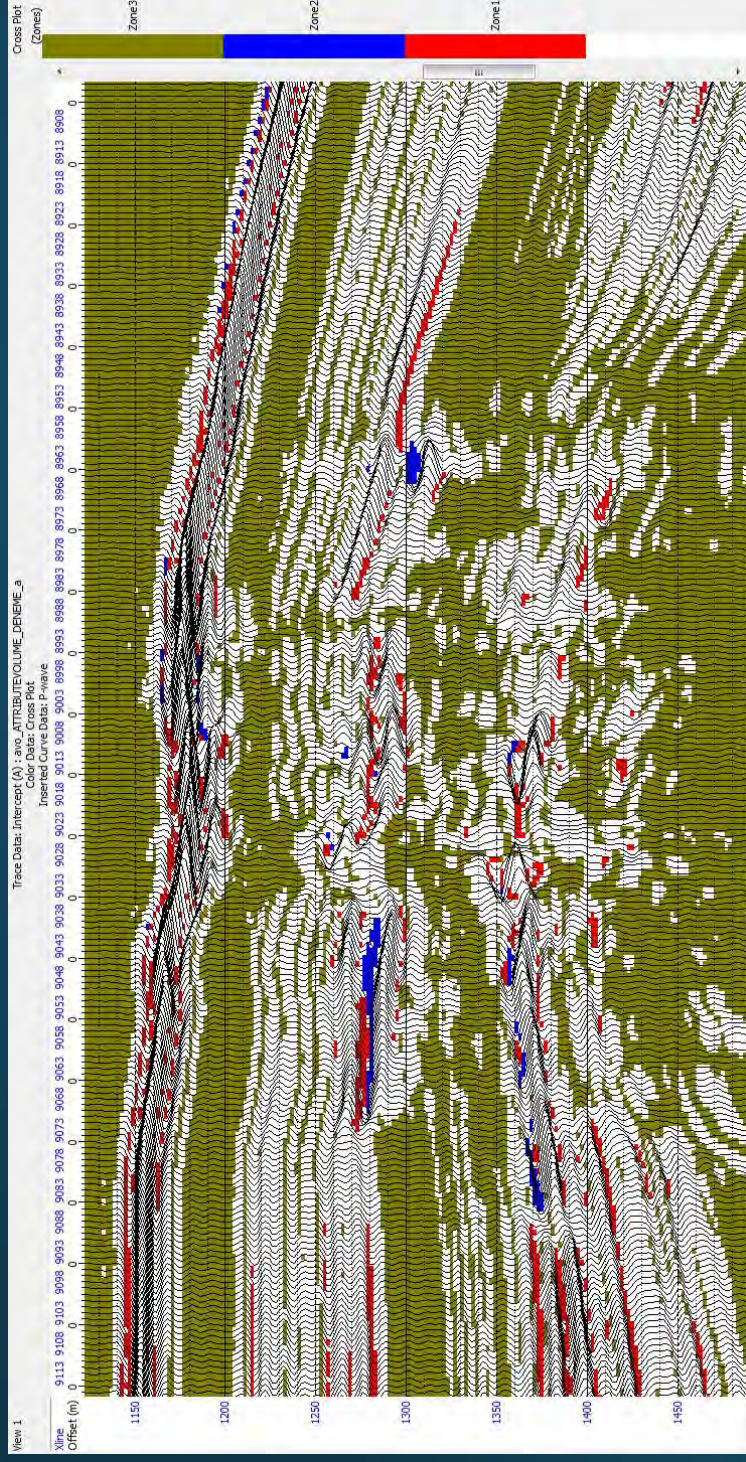


Yellow cluster: Hydrate/Free Gas
Located in Quadrant 2

Red cluster: Free Gas
Located in Quadrant 3

Green cluster: Wet Sands
Follows Background Trend

Defined Zones for AVO

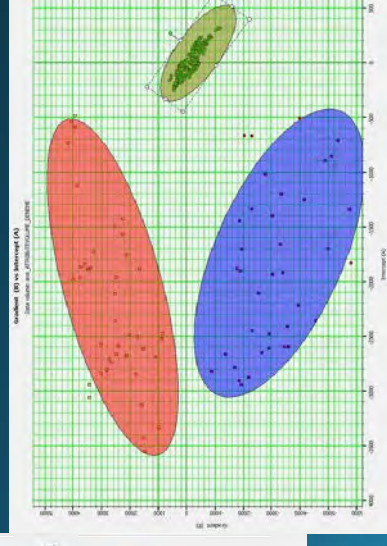


Zones of colors represent:

Red Zone: Hydrated sediments

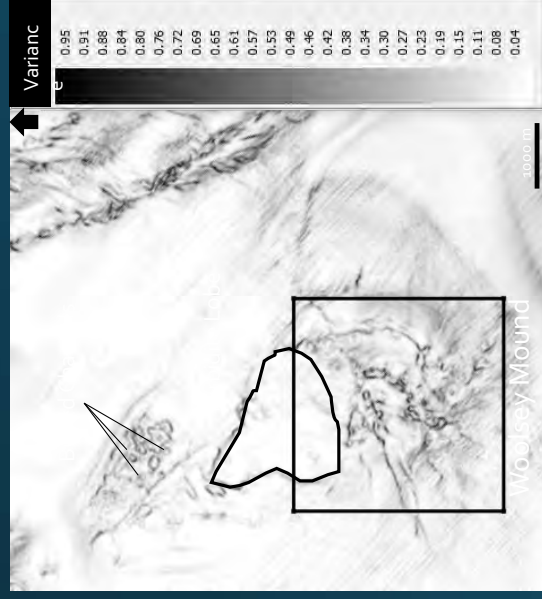
Green Zone : Wet sands

Blue Zone: Gas sands



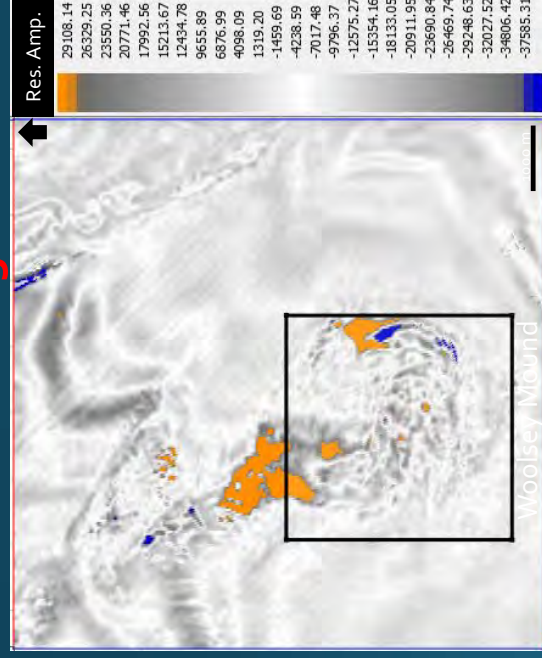
4-D SEISMIC – RESULTS

2000 - 2003

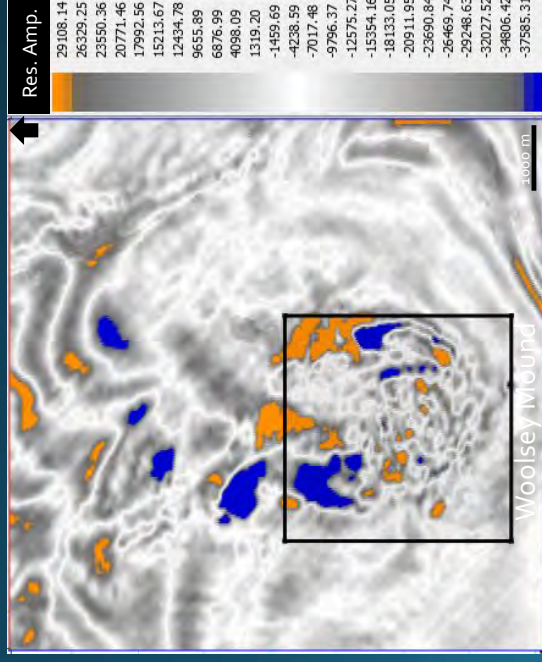


Variance slice

2000 - 2010



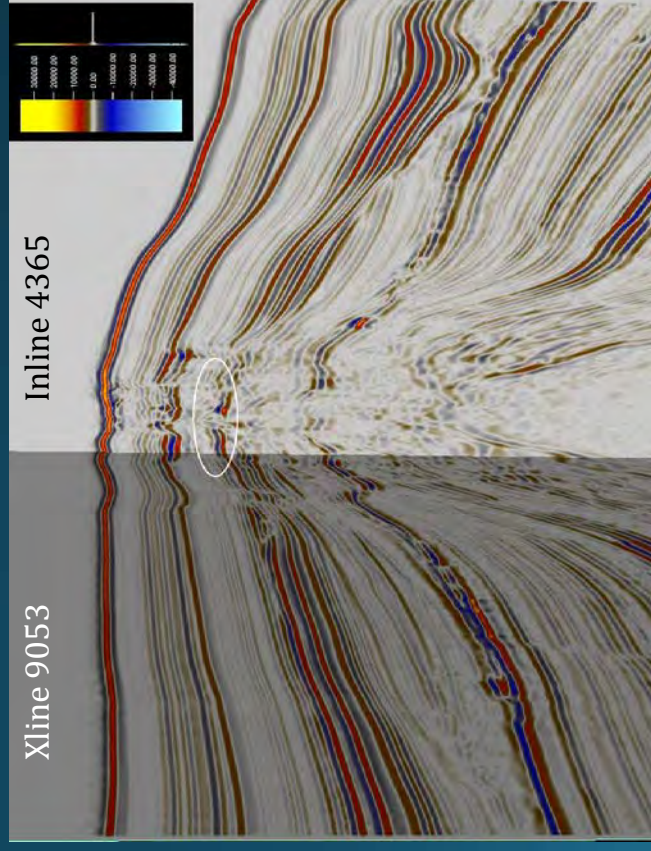
Residual amplitude slice



Residual amplitude slice

4-D SEISMIC – FUTURE WORK

- Apply 4-D processing sequence on Declaration 2014 data.
- Investigate the time-lapse changes that occur between year 2000 and 2014.
- Build a 4-D model that shows Gas Hydrate destabilization in Woolsey Mound between year 2000 and 2014.





Summary

- The hydrate stability field is highly fluctuating through time and space at Woolsey Mound.
- 4-D seismic anomalies are spatially associated with faults and may represent changes in the subsurface pore-fluid content.
- AVO analysis proves to be a reliable tool to identify hydrates in the absence of clearly defined BSRs.
- Results will provide fundamental numerical parameters of the development and evolution of a gas hydrate-bearing system and its response to natural perturbations over a time window comparable to human scale processes (14 years).



Acknowledgements

- Southern States Energy Board (SSEB)
- U.S. Department of Energy (NETL)
- Gulf of Mexico Gas Hydrate Research Consortium
- Geophysical Exploration/ Tectonics and Geophysics Labs
- TGS-Nopec; WesternGeco
- Bureau of Ocean Energy Management (BOEM)
- Seismic Micro-Technology, Landmark Graphics, Veritas Hampson-Russell, Schlumberger- Petrel

**SECARB OFFSHORE PARTNERSHIP
PROJECT NUMBER: DE-FE0031557**

SALT STRUCTURES, SHELF, AND DEEP-WATER RESERVOIRS, CENTRAL GOM

Jack Pashin, Ali Al-Janabi, Seyi Sholanke, and Justin Spears
Oklahoma State University



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Cost share and research support are provided by the Project Partners and an Advisory Committee.*

GOMCarb-SECARB Offshore Partnership Web Meeting
March 26-27, 2020

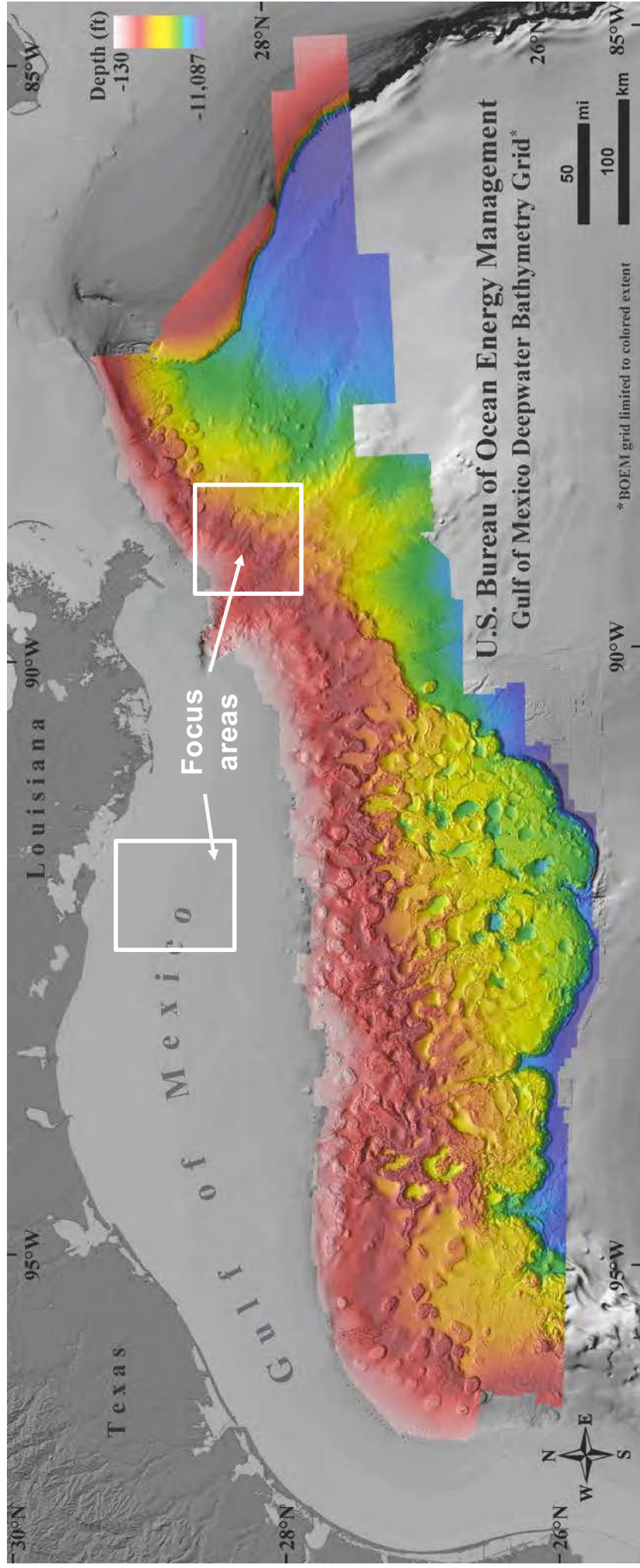
OPENING QUESTIONS

- How do storage and enhanced recovery strategies differ between shelf and continental slope settings?
- What are the critical depositional and tectonic factors that need to be understood when developing storage strategies in salt tectonic settings?
- In what ways can depositional and structural architecture be used to evaluate geologic storage security?
- What does a decision support system look like that integrates geology, engineering, and infrastructure?

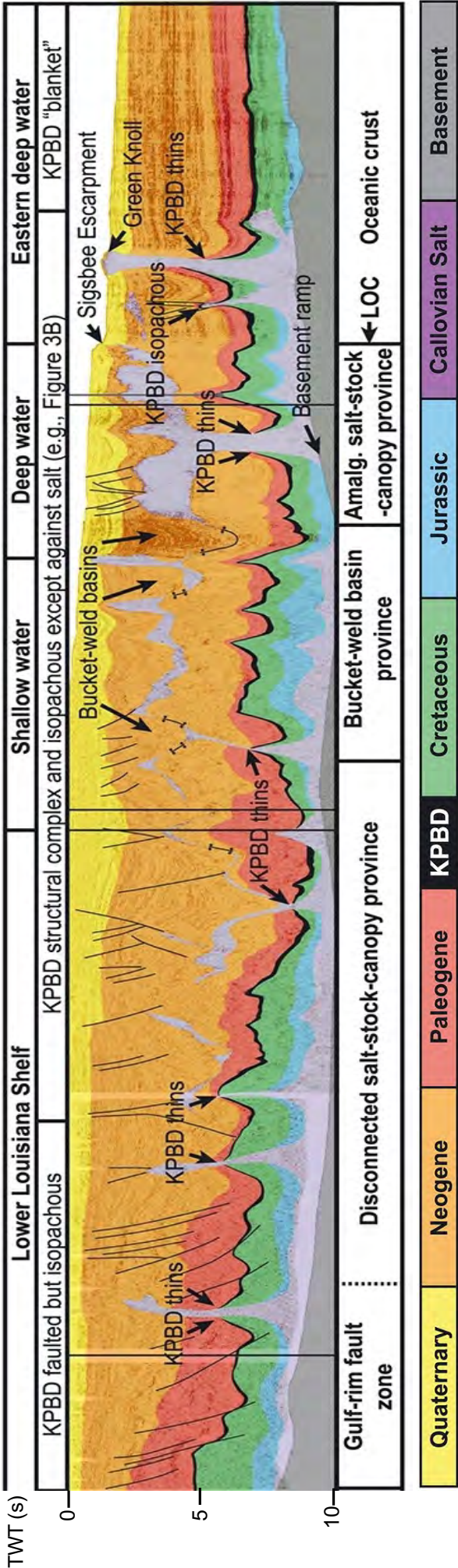
OBJECTIVES

- Geological Characterization (Stratigraphy, sedimentation, structure, hydrodynamic analysis).
- Analyze reservoir properties, storage volumetrics, potential storage mechanisms, migration pathways, and reservoir integrity.
- Understand pressure regime and implications for geologic CO₂ storage and enhanced recovery.
- Design heuristic decision support system using SAS Viya software.

SECARB OFFSHORE PROJECT AREA

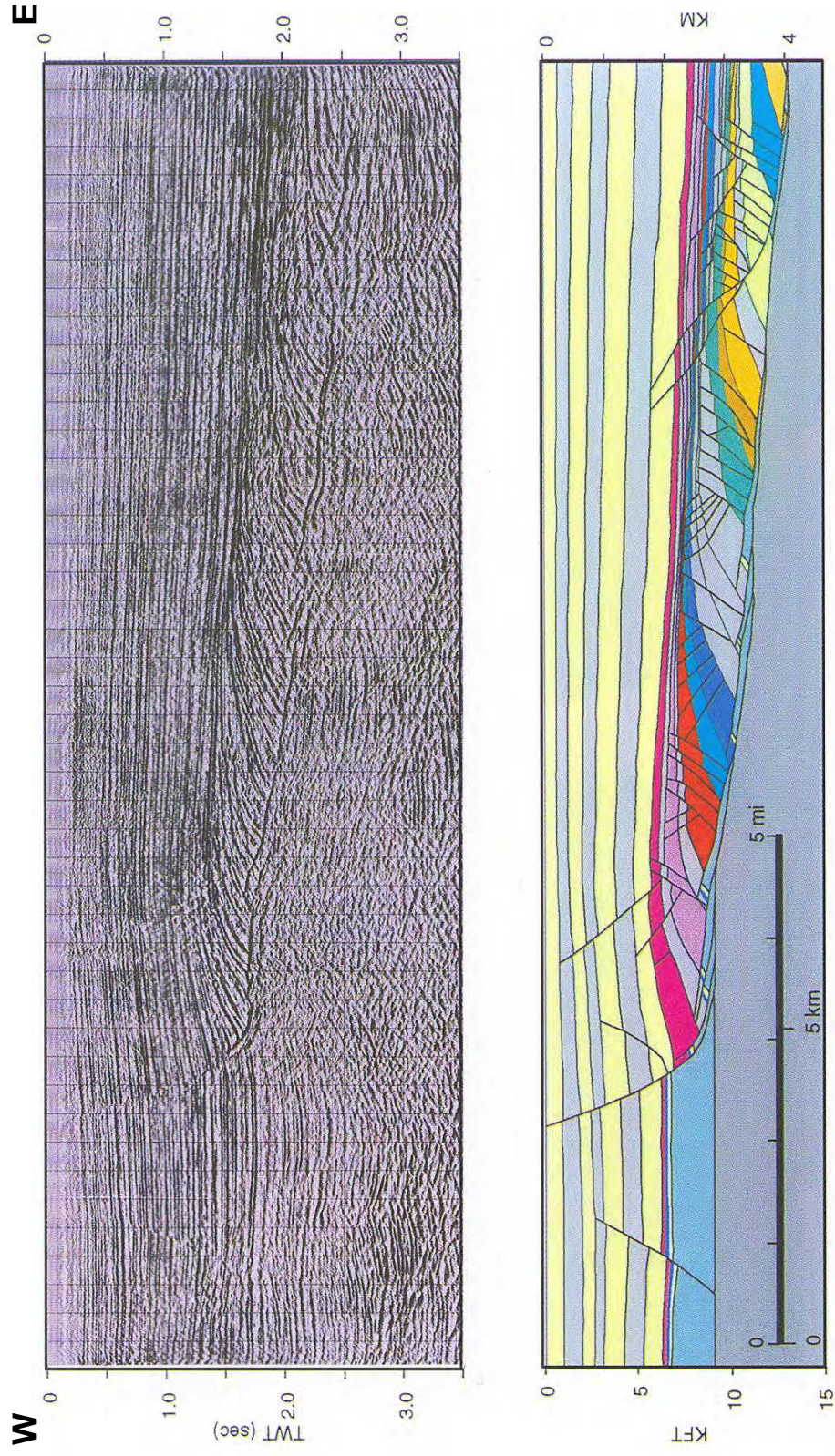


SHELF-SLOPE TRANSECT



Sanford et al., 2016

SHELF EXTENSION — OLIGOCENE-MIOCENE VICKSBURG DETACHMENT, SOUTH TEXAS

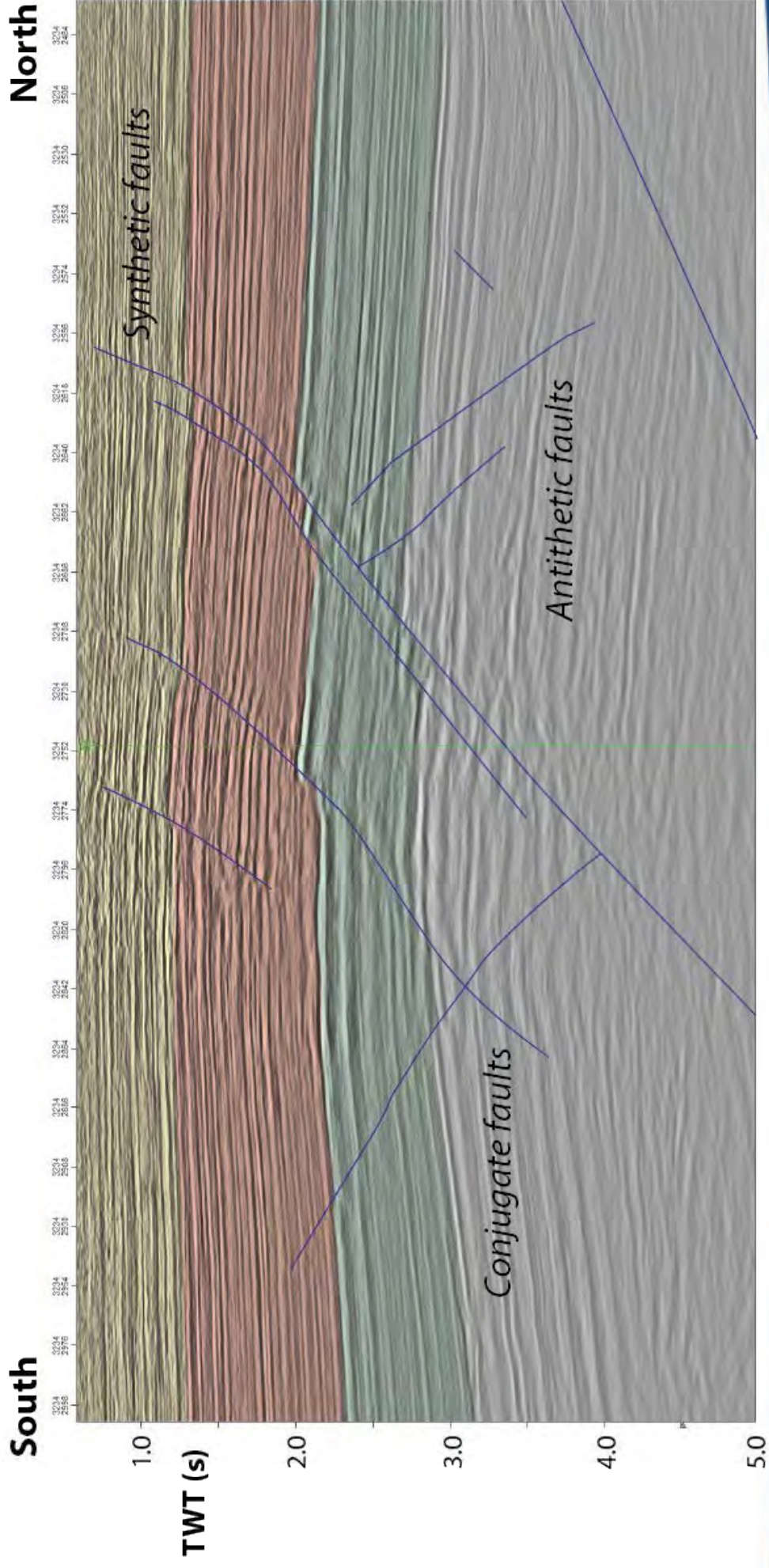


Diegel et al., 1995

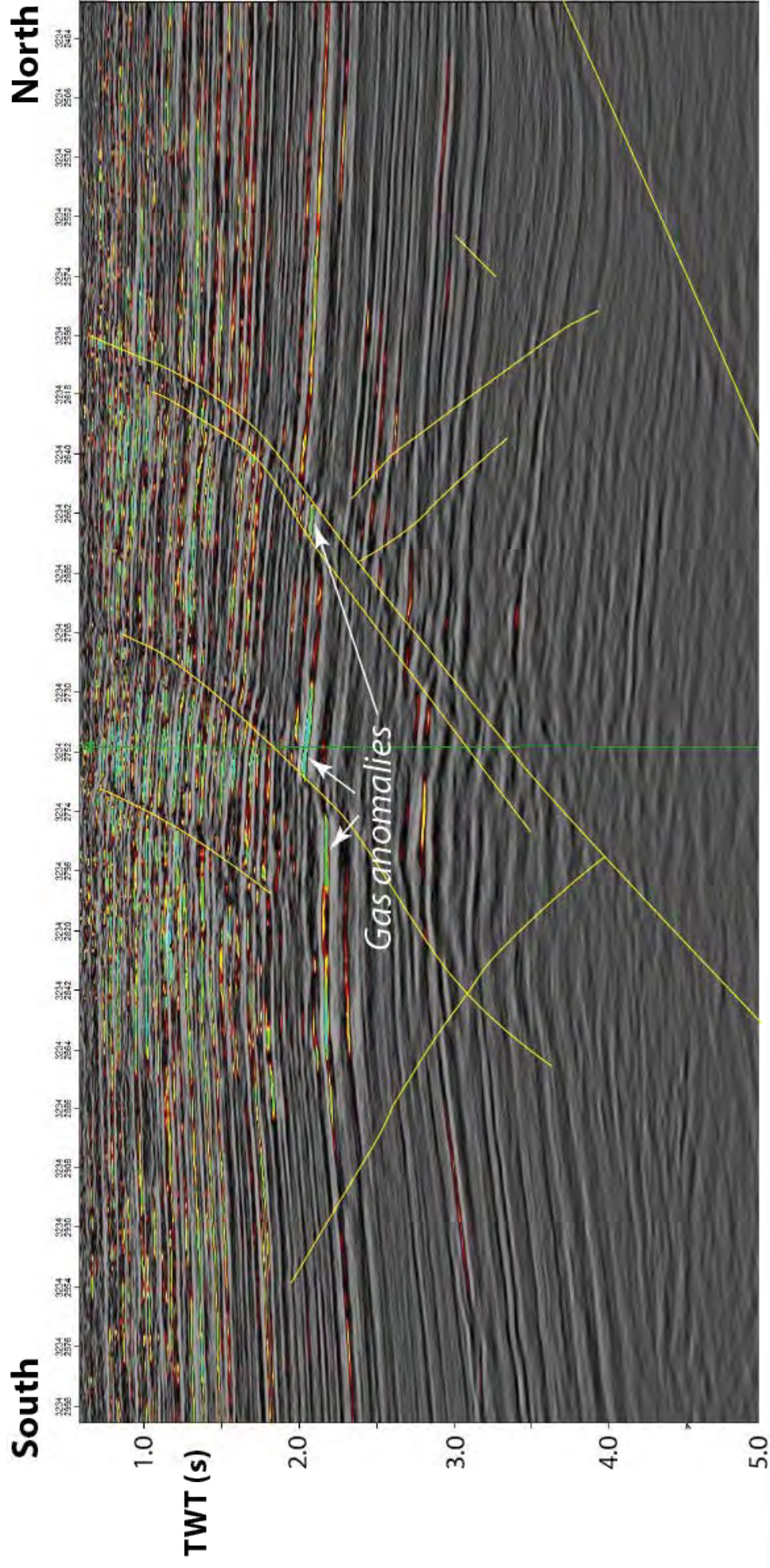
SAND-BOX MODEL – LISTRIC FAULT, ROLLOVER FOLD, AND KEYSTONE GRABEN



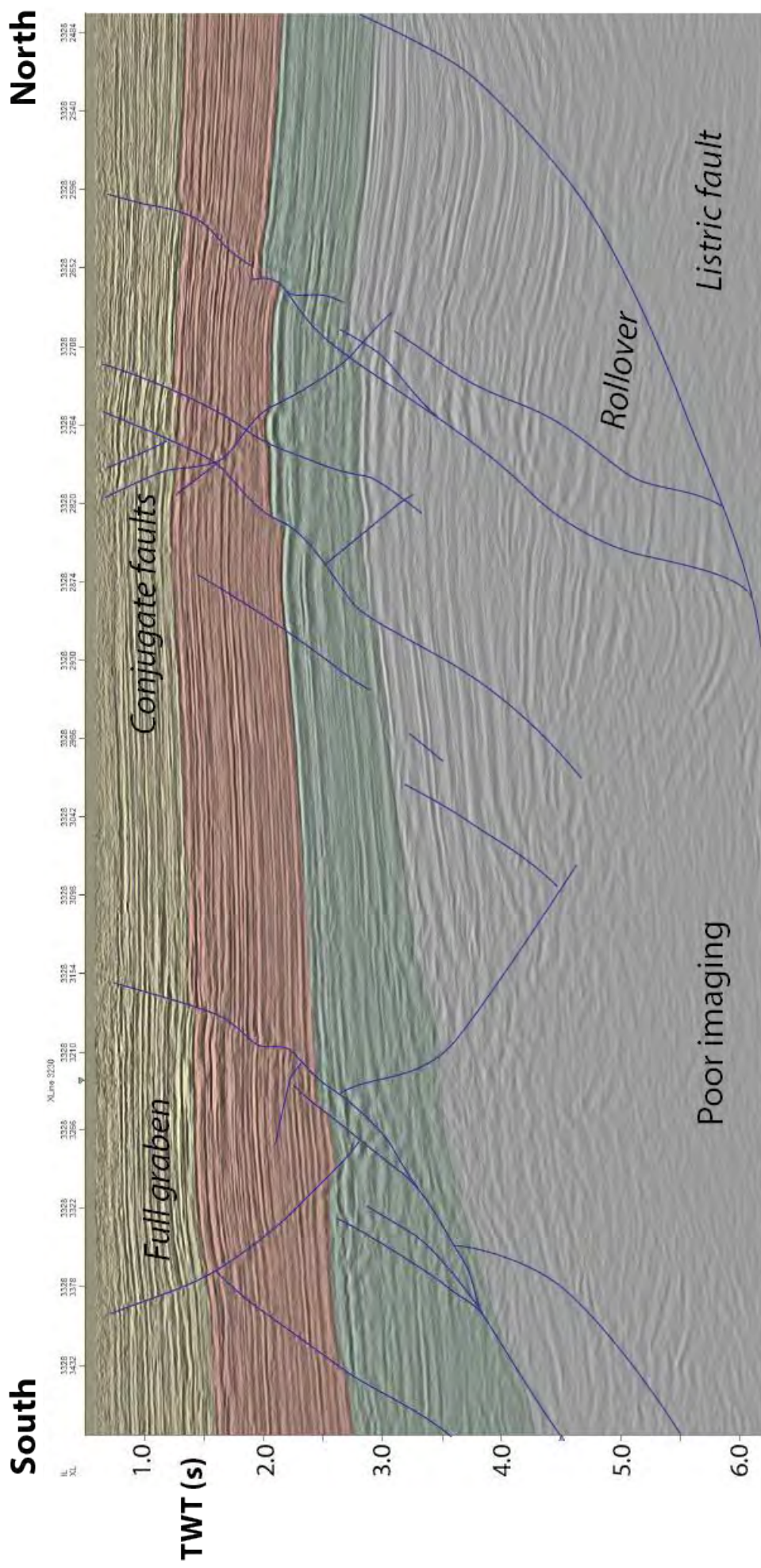
SEISMIC INTERPRETATION: LOUISIANA SHELF ROHO PROVINCE



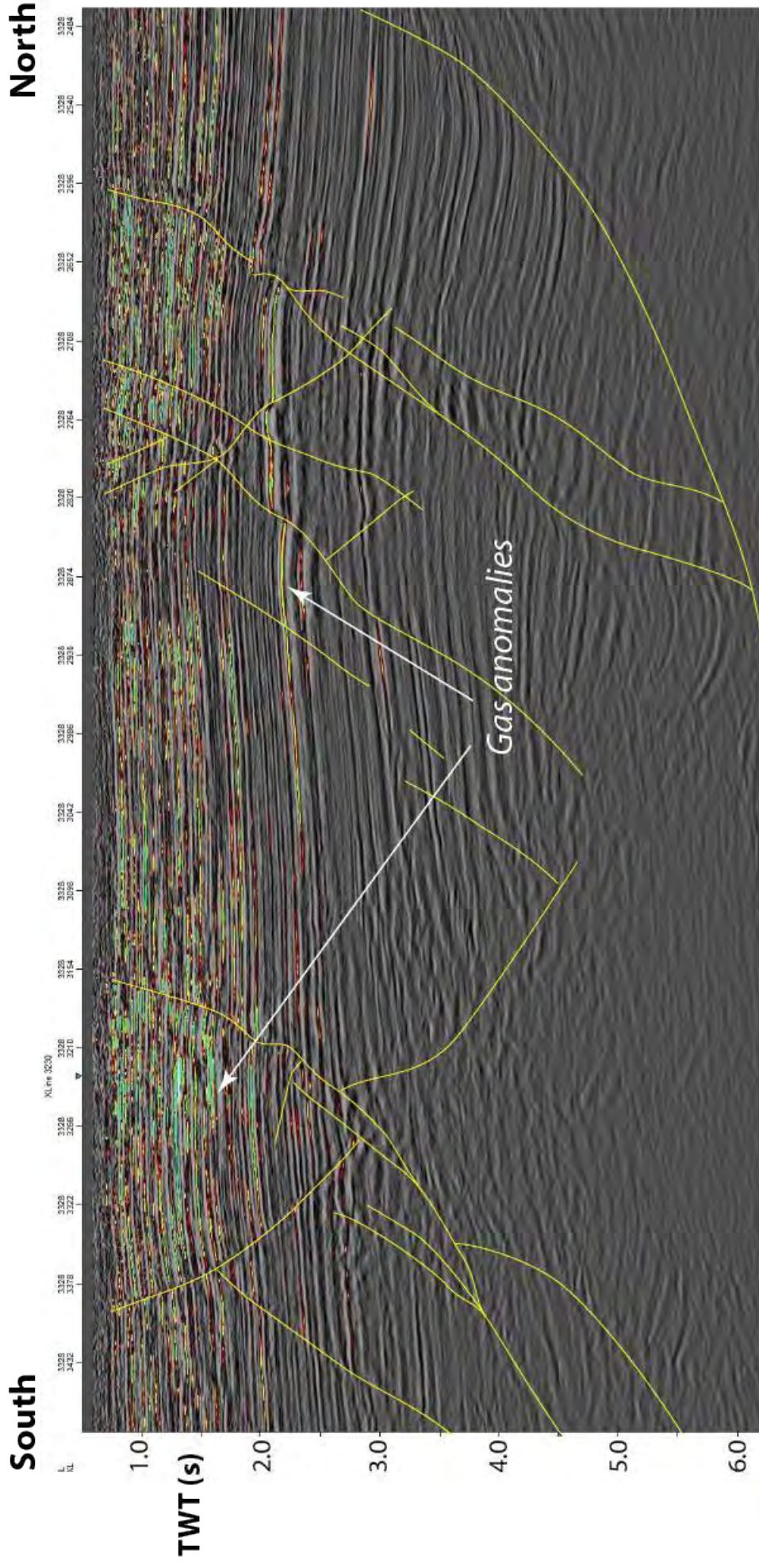
SEISMIC INTERPRETATION: LOUISIANA SHELF



SEISMIC INTERPRETATION: LOUISIANA SHELF



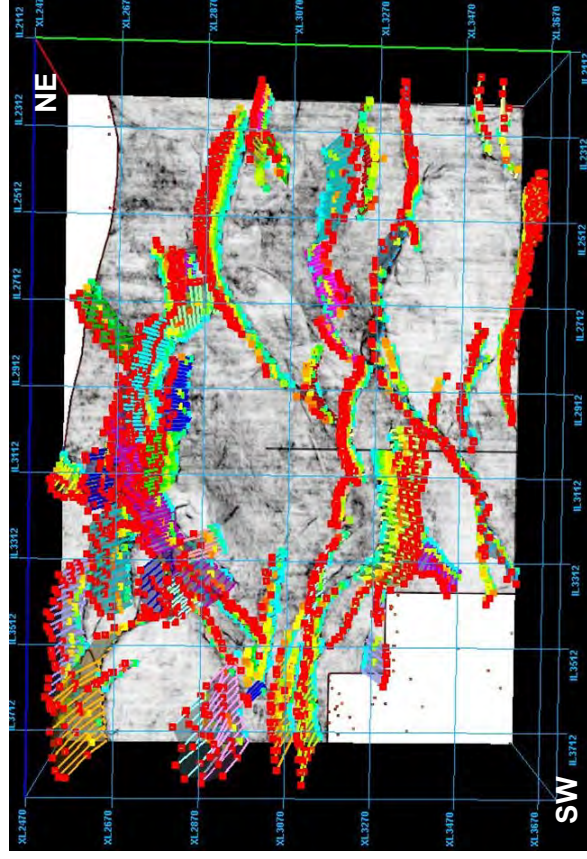
SEISMIC INTERPRETATION: LOUISIANA SHELF



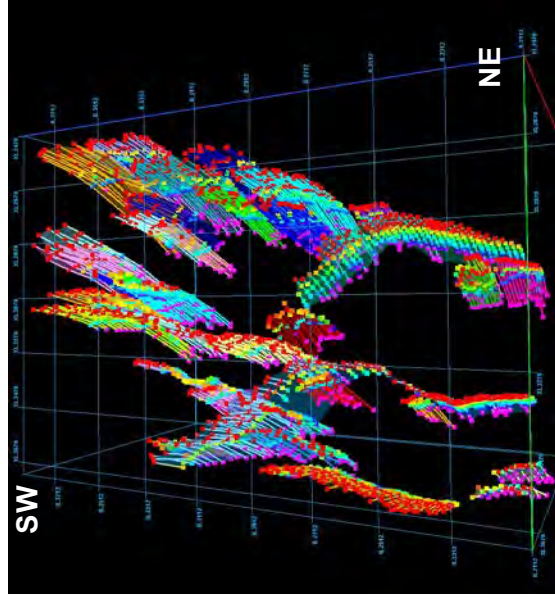
SOCIETY OF EXPLORATION
— GEOPHYSICISTS —

FAULT MODELING

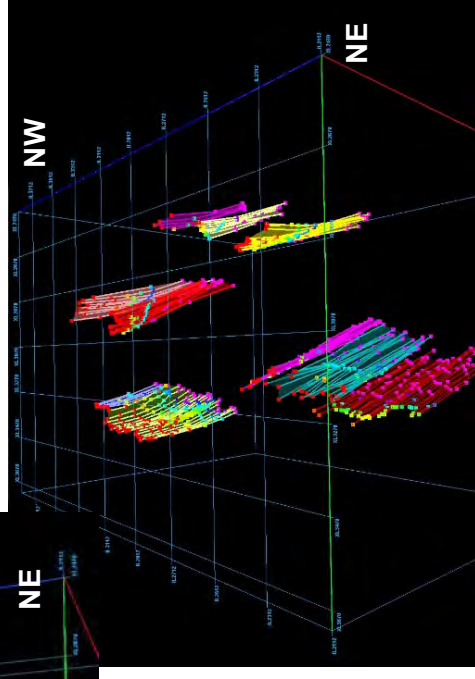
Mappable faults



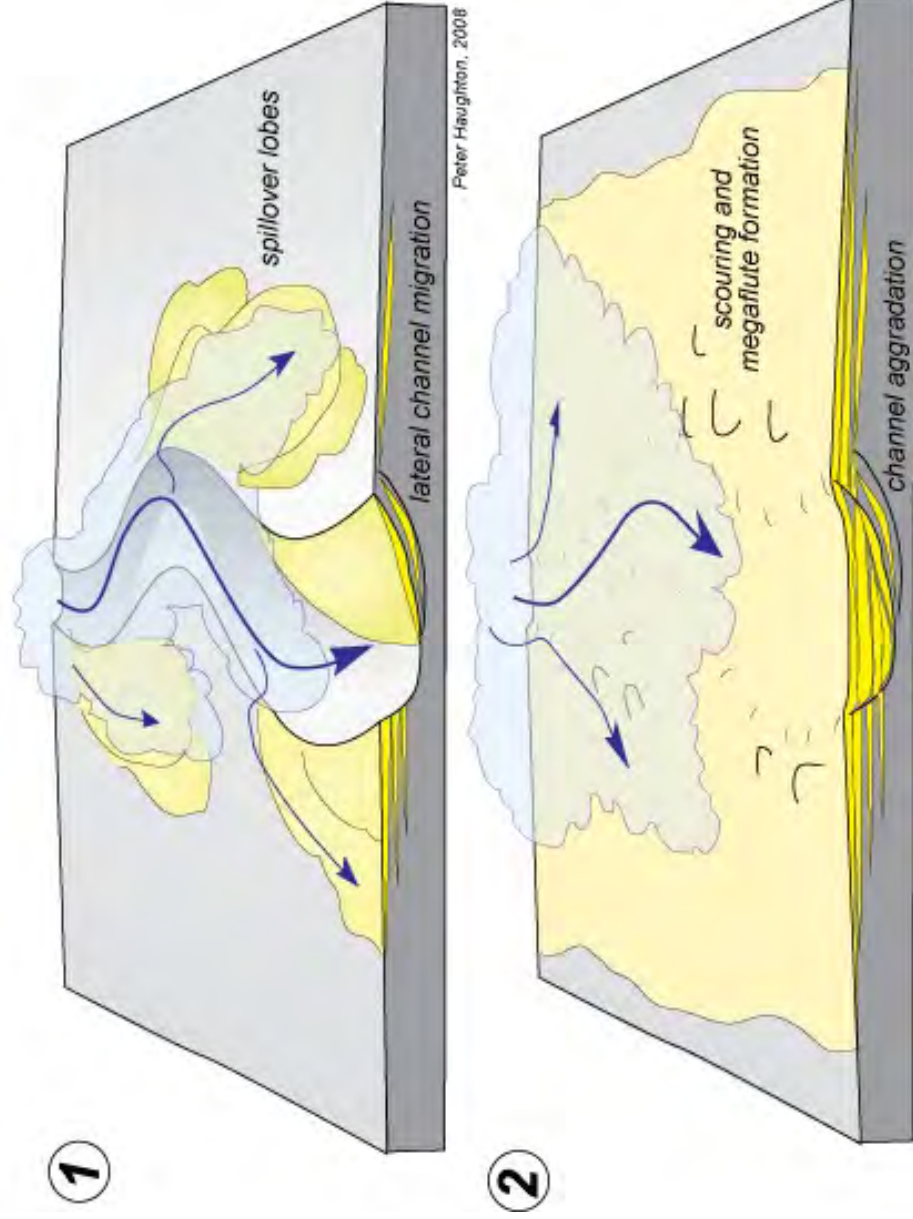
Regional faults



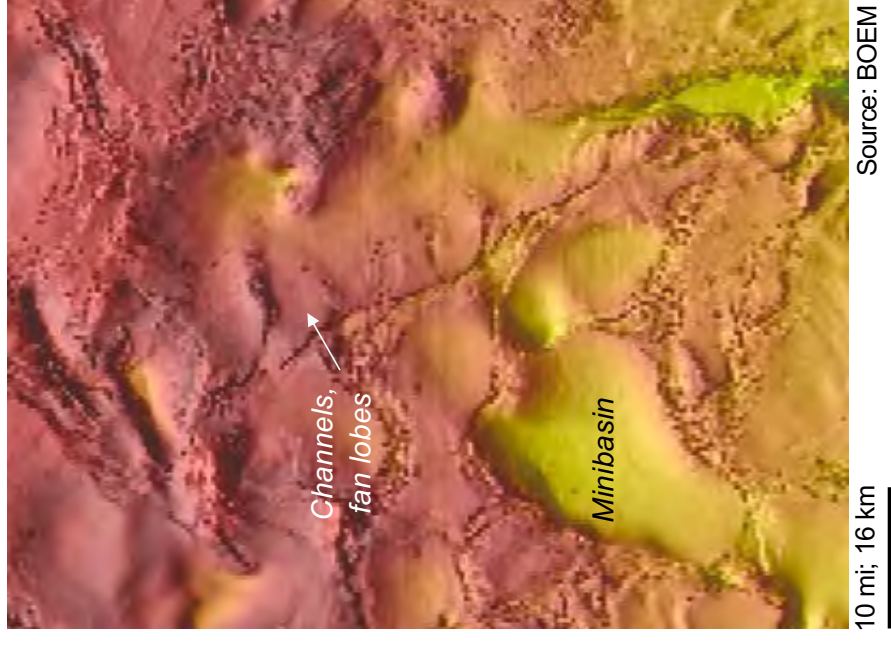
Counterregional faults



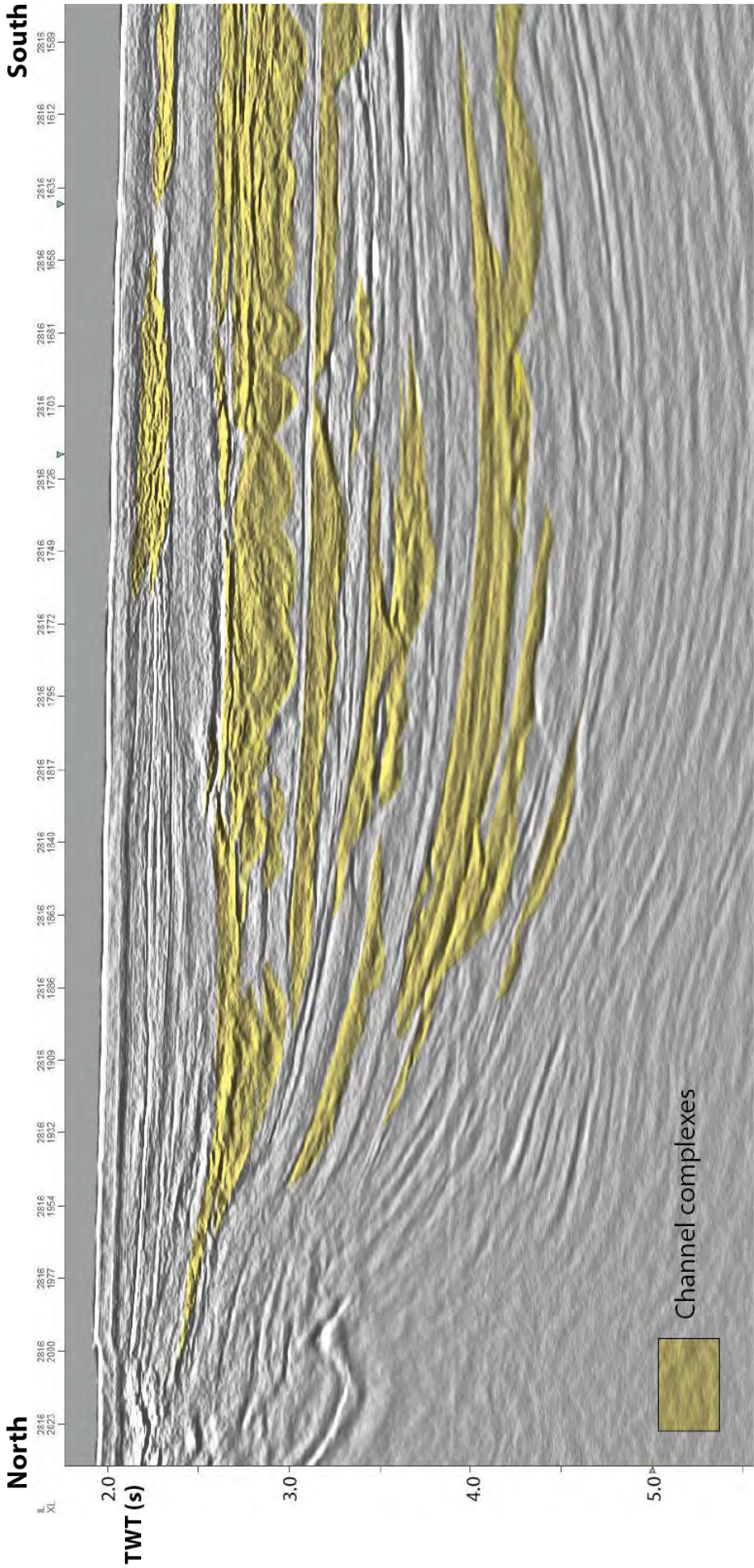
TURBIDITE SYSTEMS



Keathley Canyon bathymetry

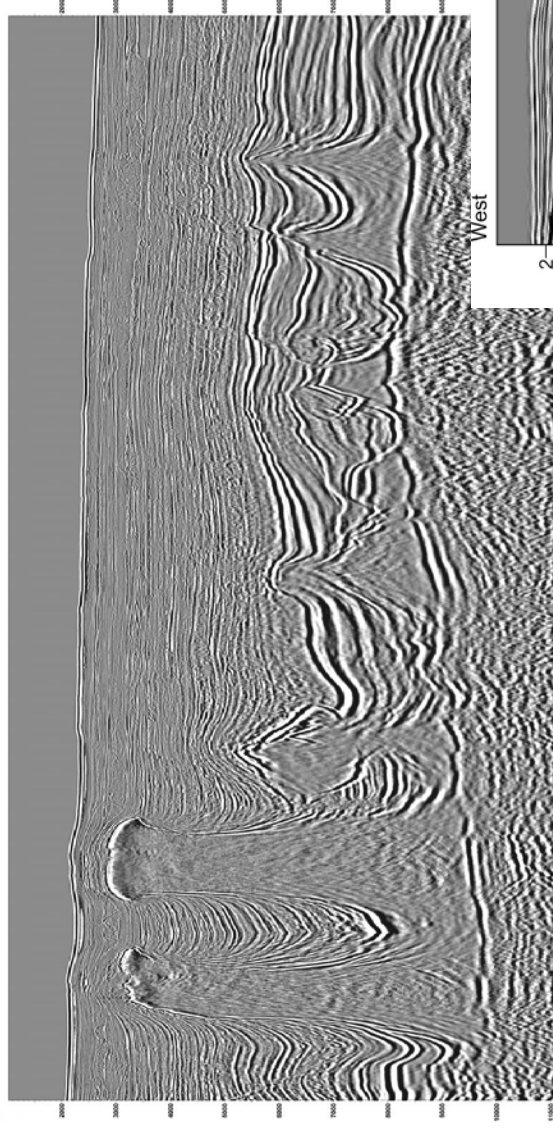


SEISMIC INTERPRETATION: SUBMARINE CHANNEL COMPLEXES, MENSA REGION

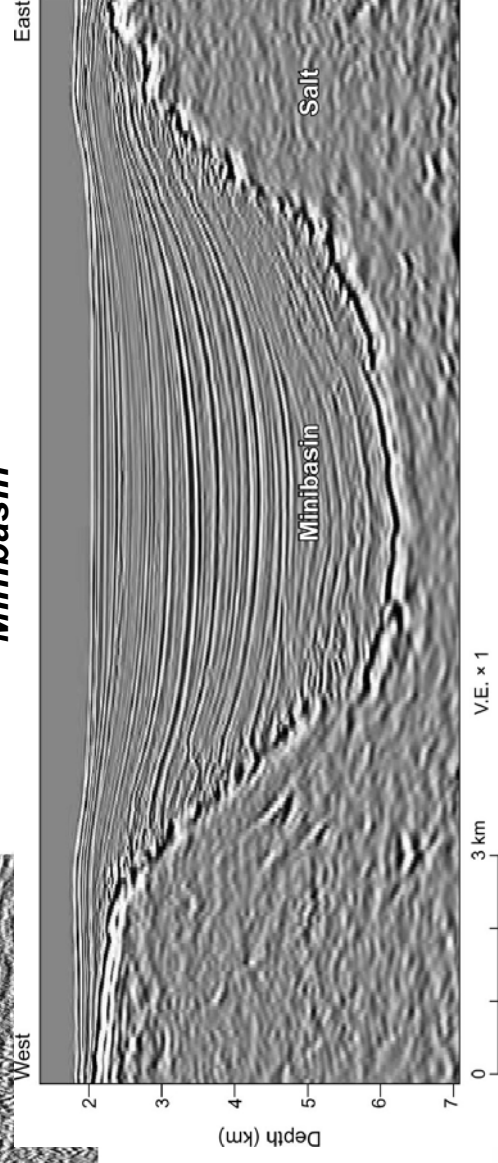


DEEP-WATER SALT TECTONICS

Allochthonous salt sheet with diapirs



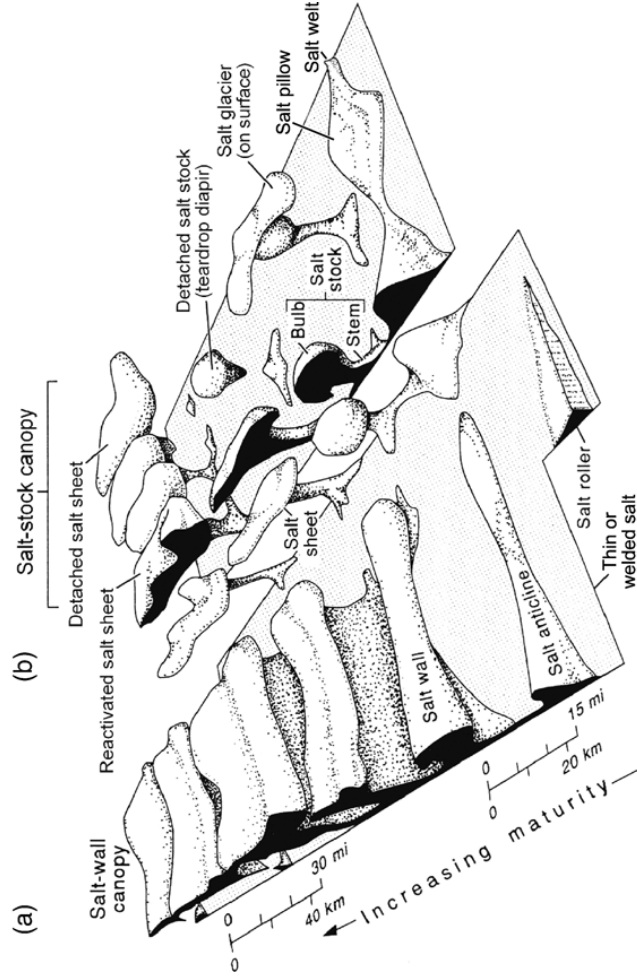
Minibasin



Hudec et al., 2009

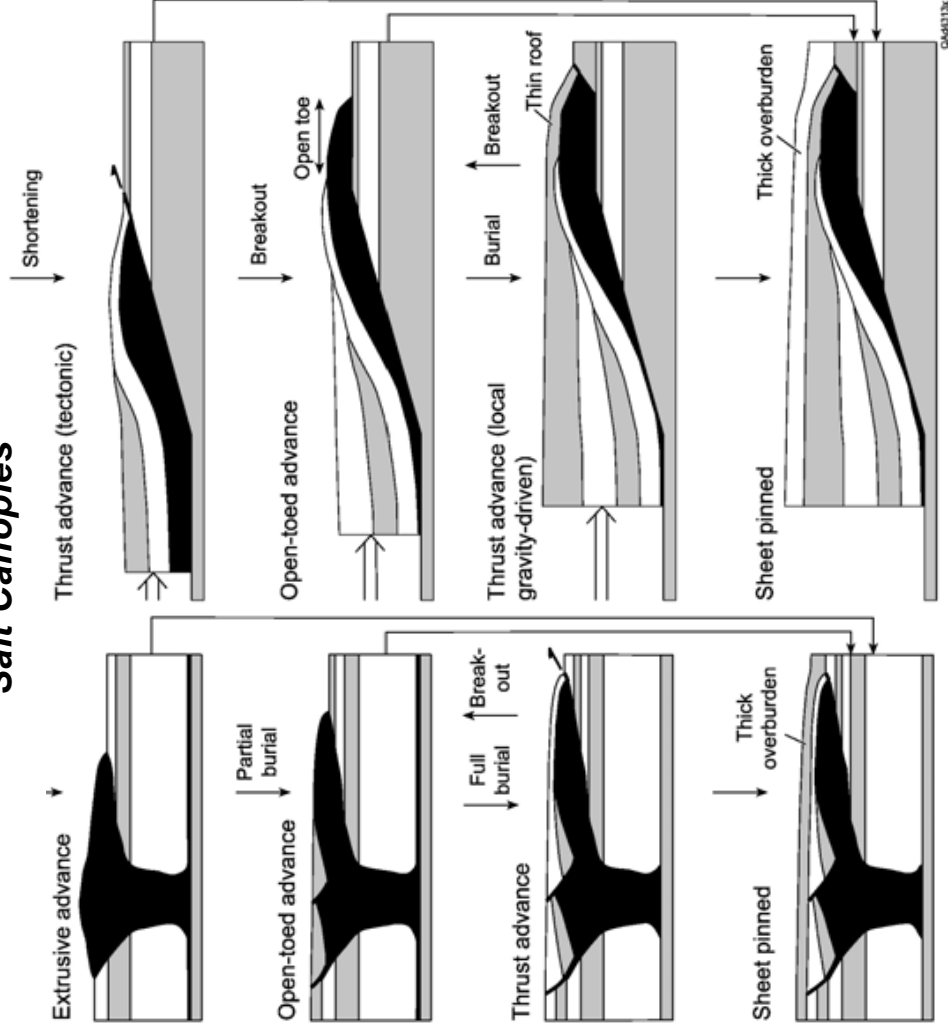
SALT TECTONICS

Salt body geometry

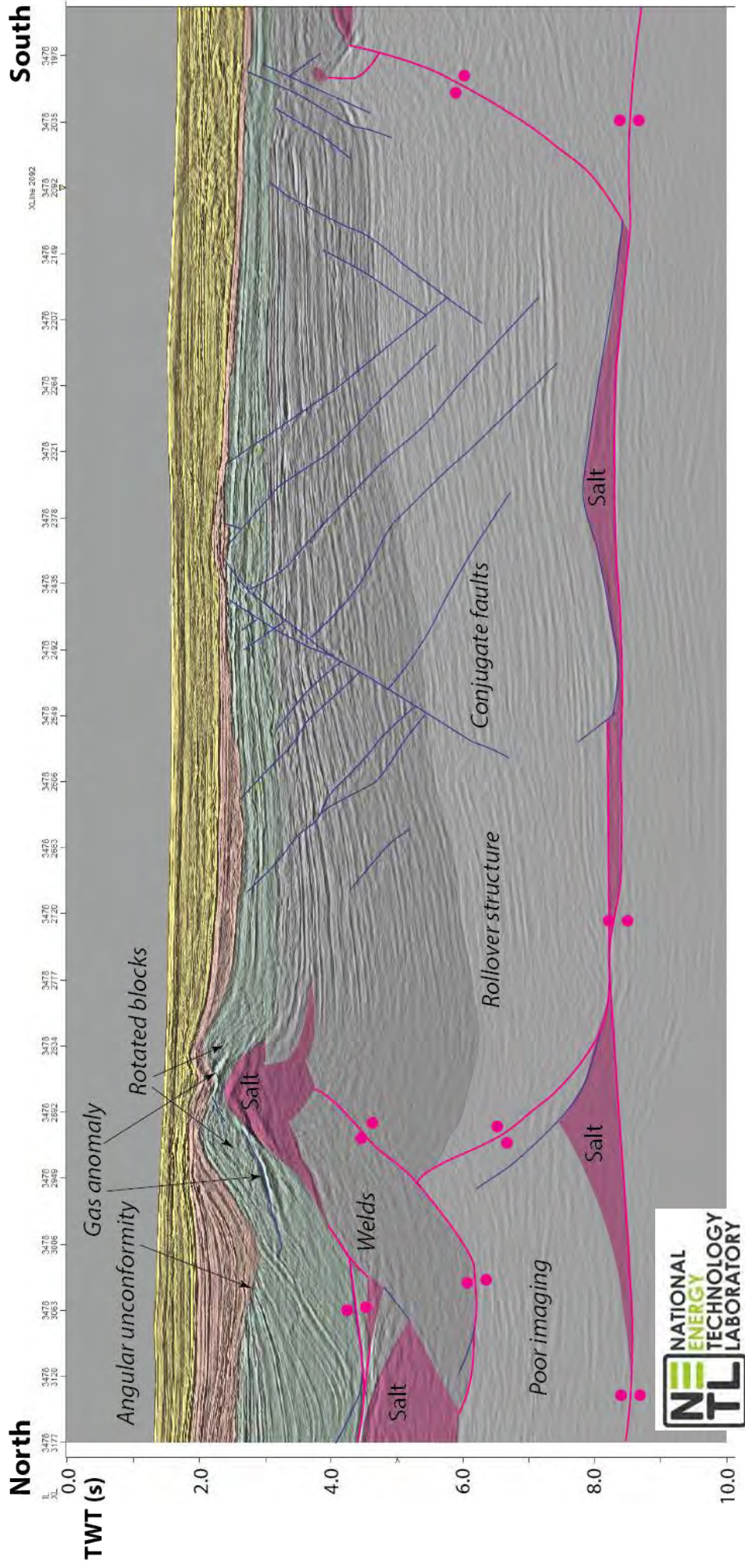


Hudec and Jackson (2007)

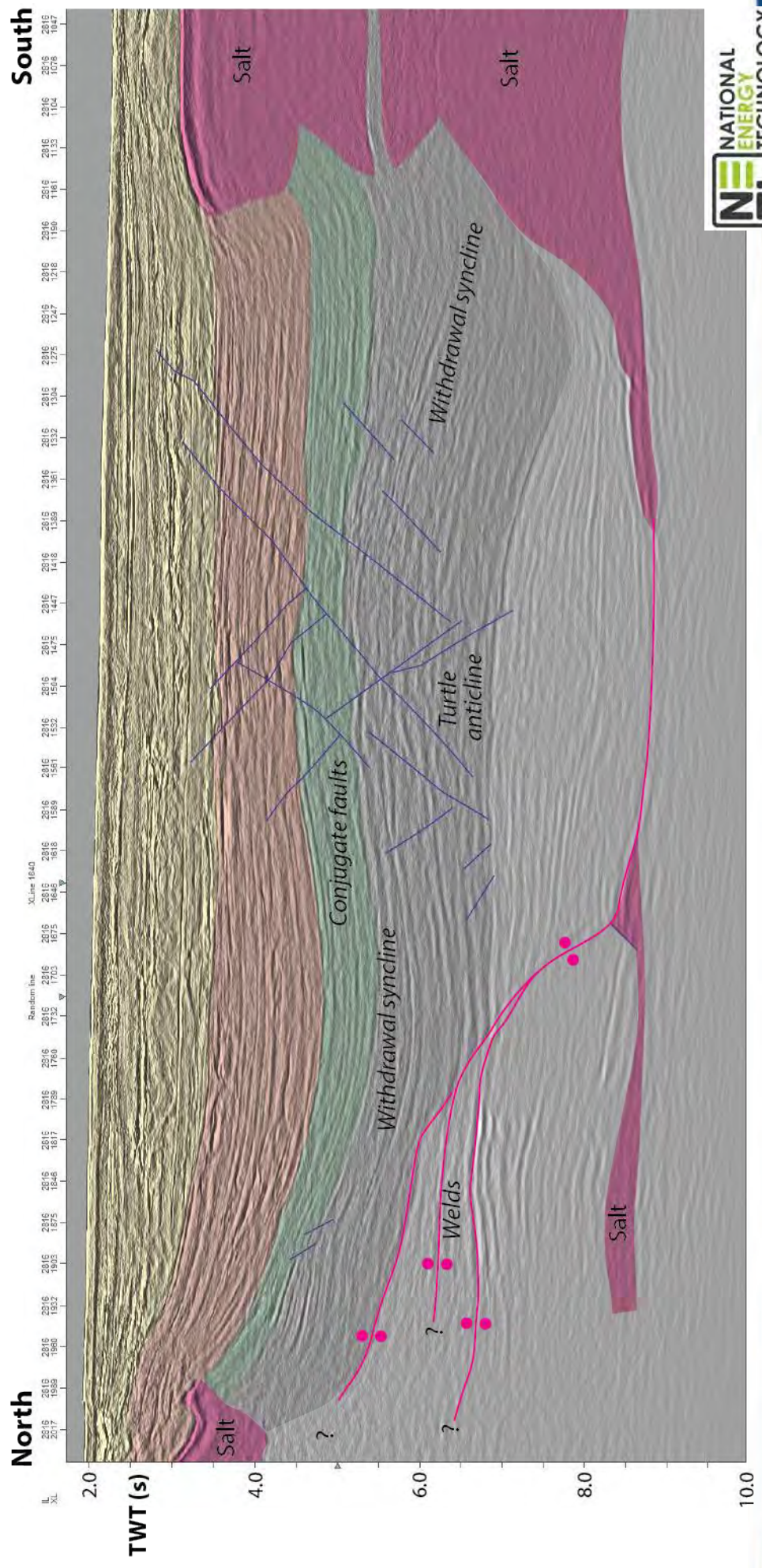
Salt Canopies



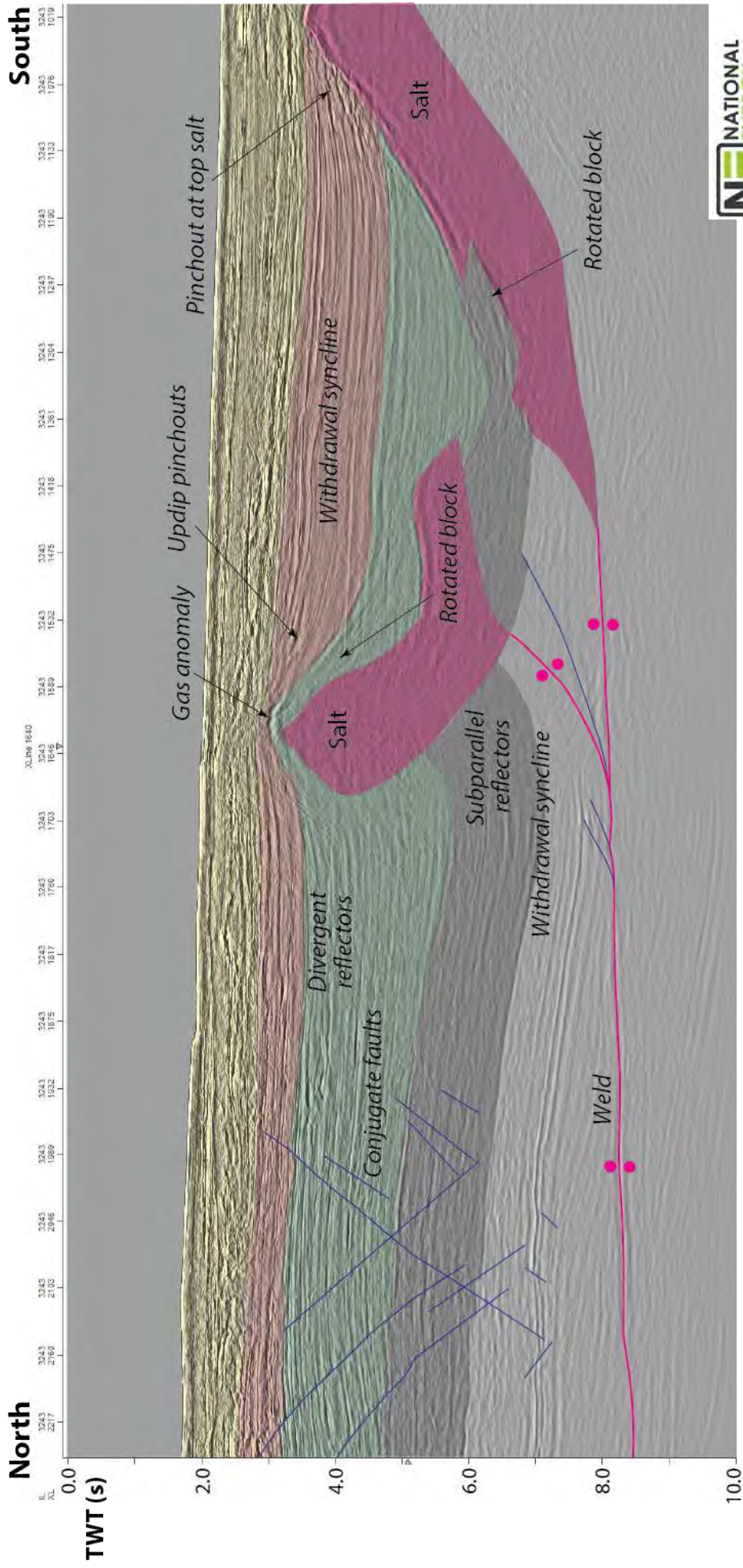
SEISMIC INTERPRETATION: ROLLOVER-SALT WITHDRAWAL STRUCTURE



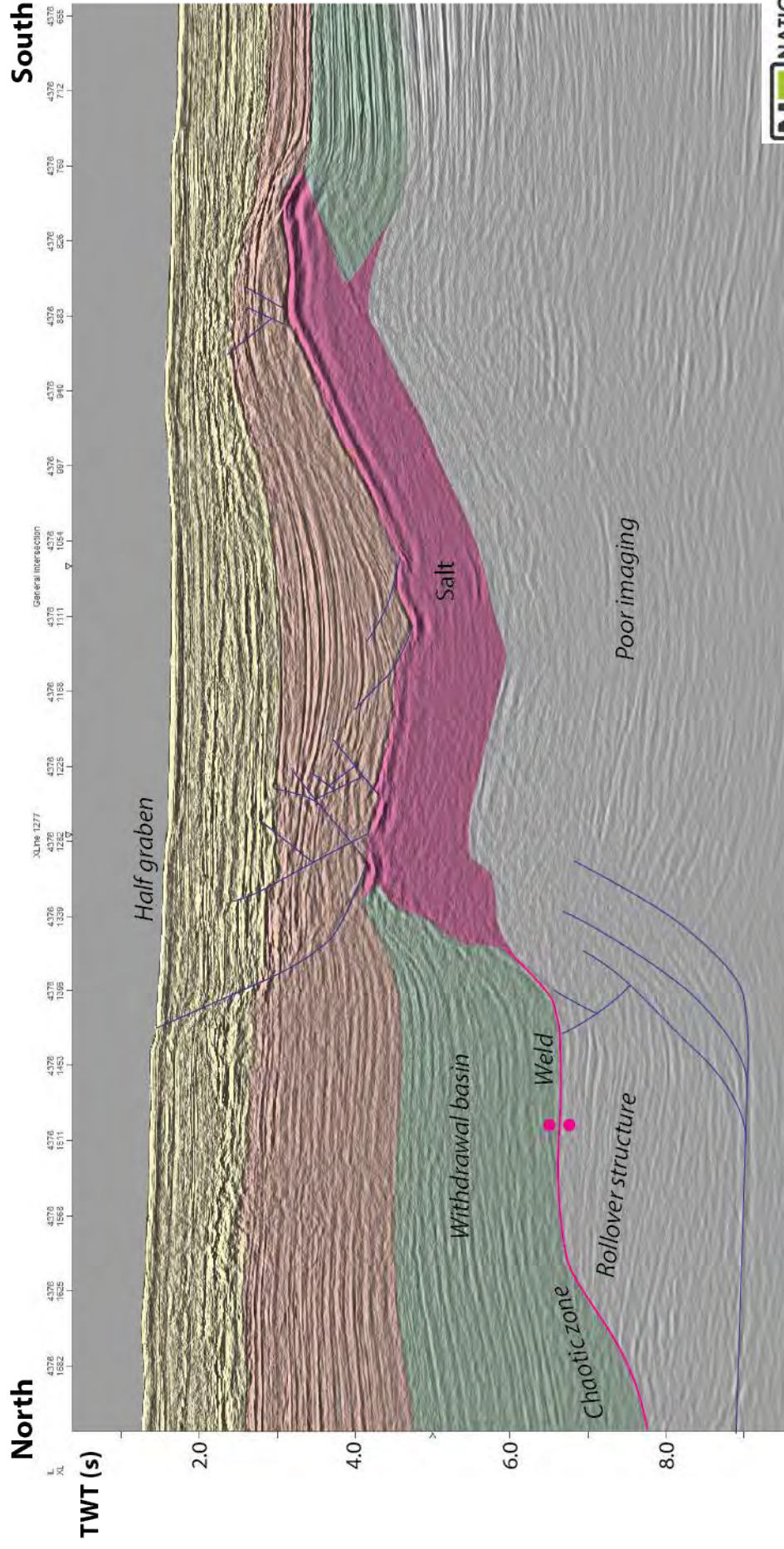
SEISMIC INTERPRETATION: MENSA TURTLE STRUCTURE



SEISMIC INTERPRETATION: DEVIL'S TOWER STRUCTURE



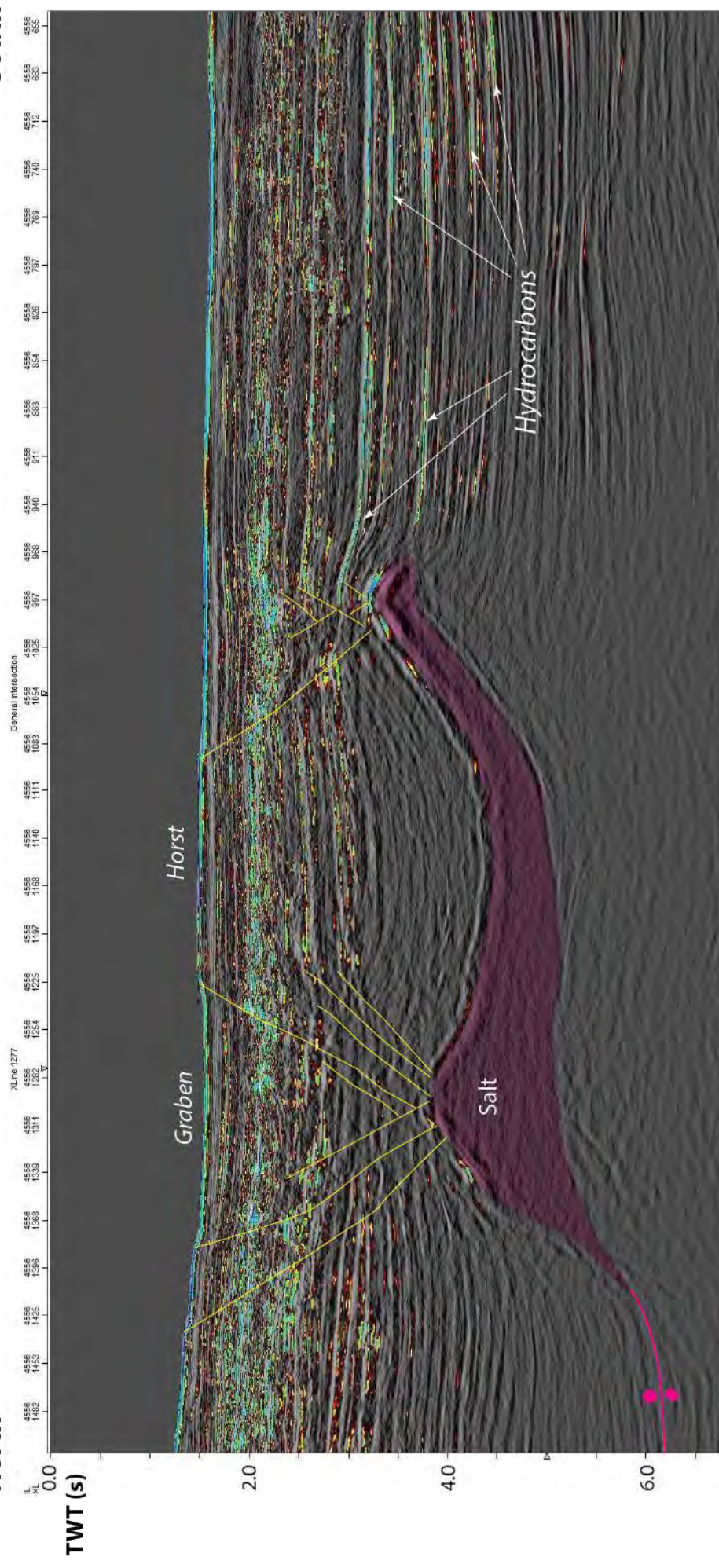
SEISMIC INTERPRETATION: RAMP-FLAT WELD, ALLOCHTHONOUS SALT



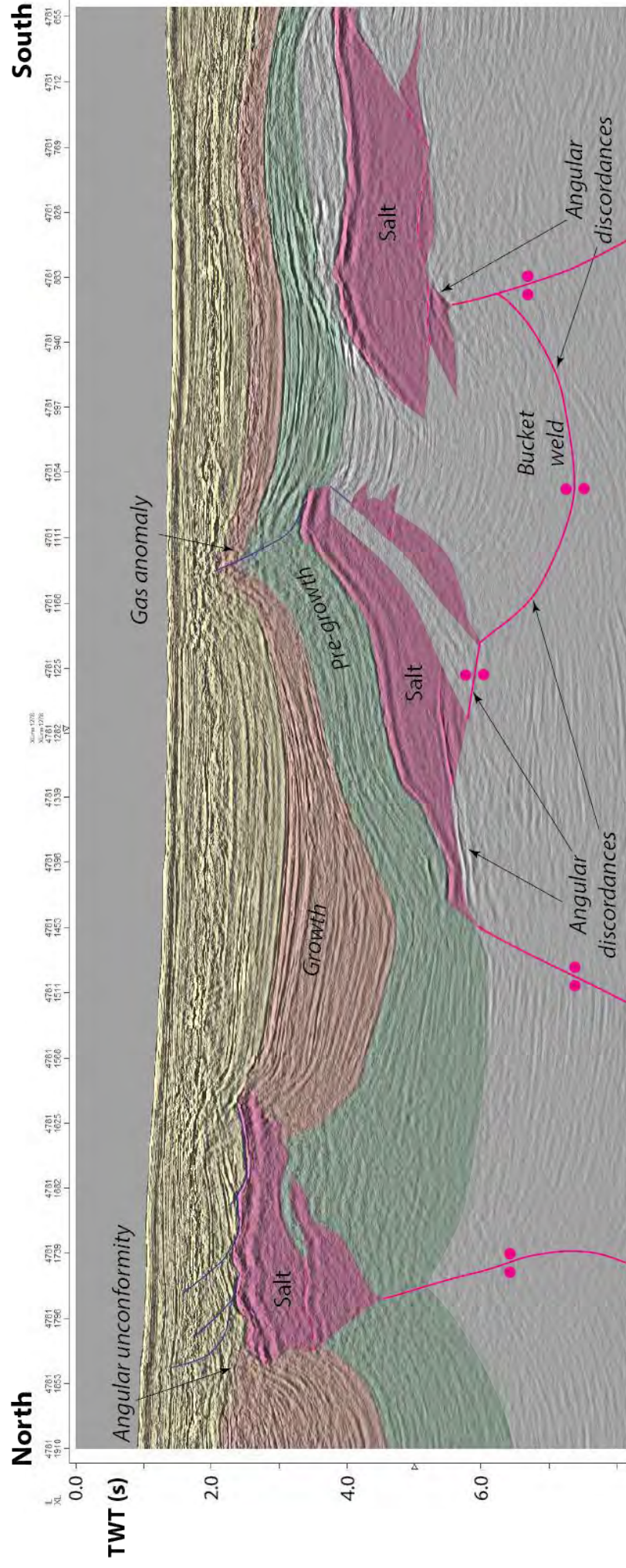
North South



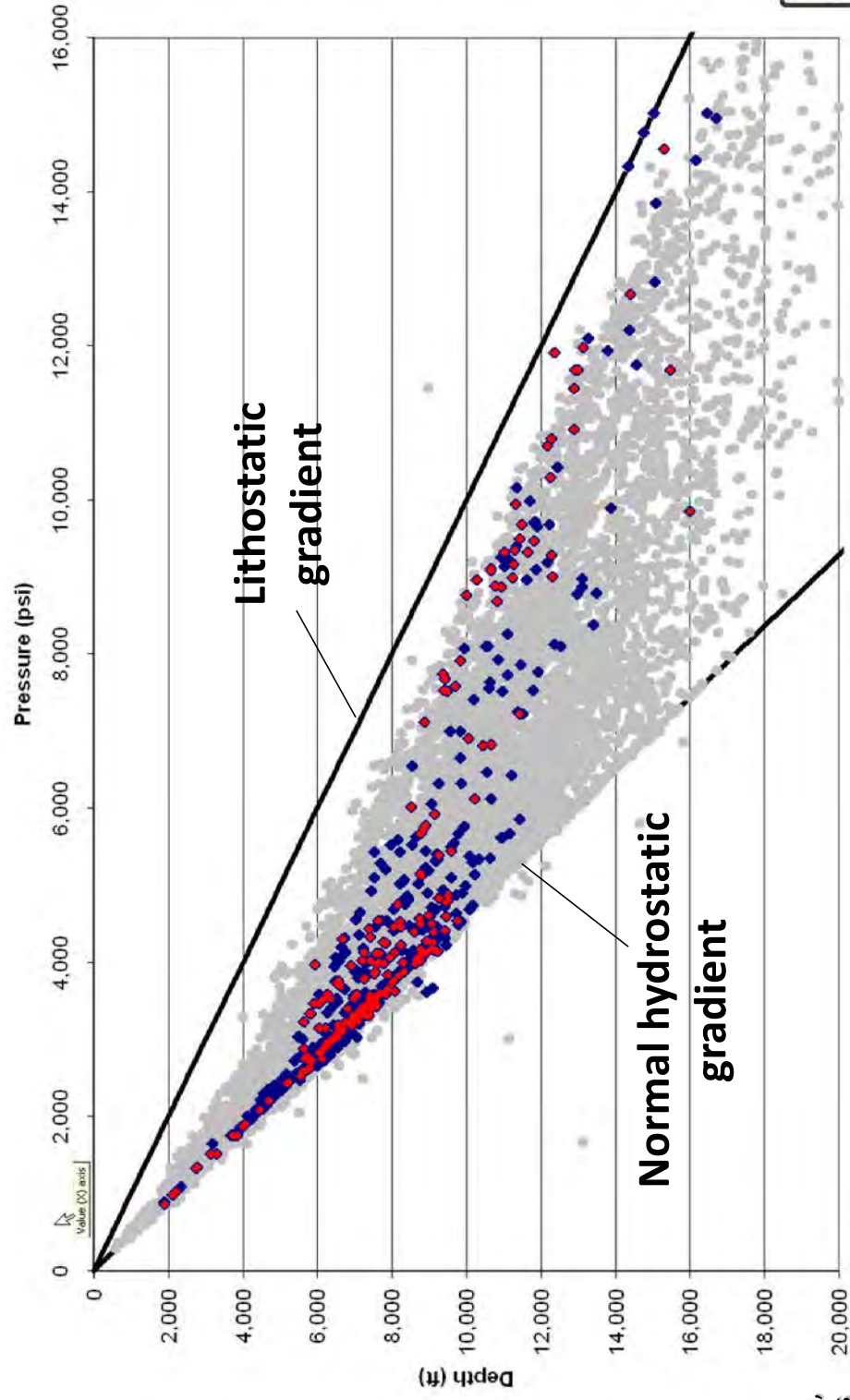
South



SEISMIC INTERPRETATION: MARS MINIBASIN COMPLEX



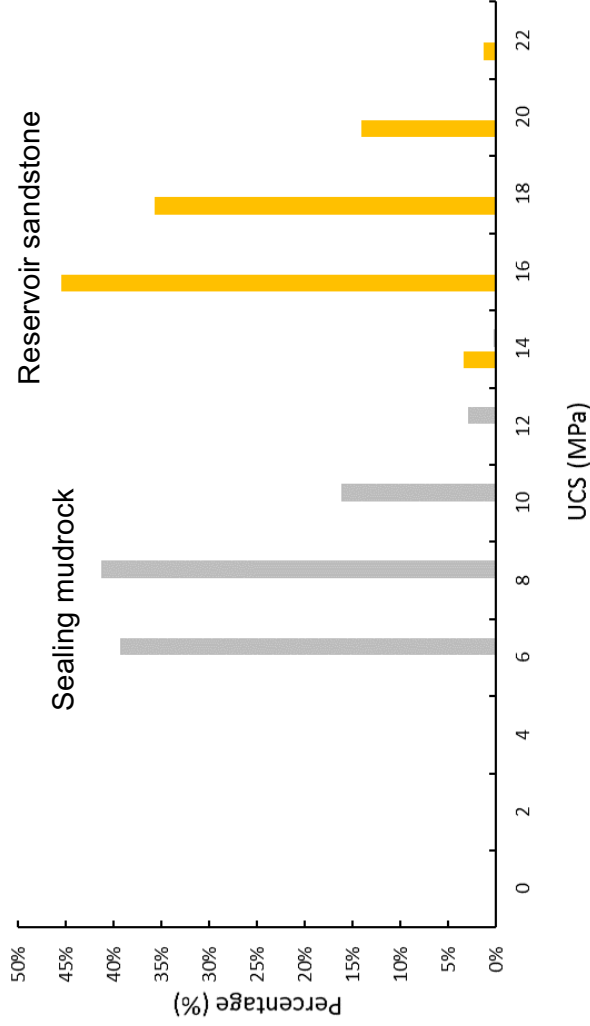
RESERVOIR PRESSURE ENVELOPE



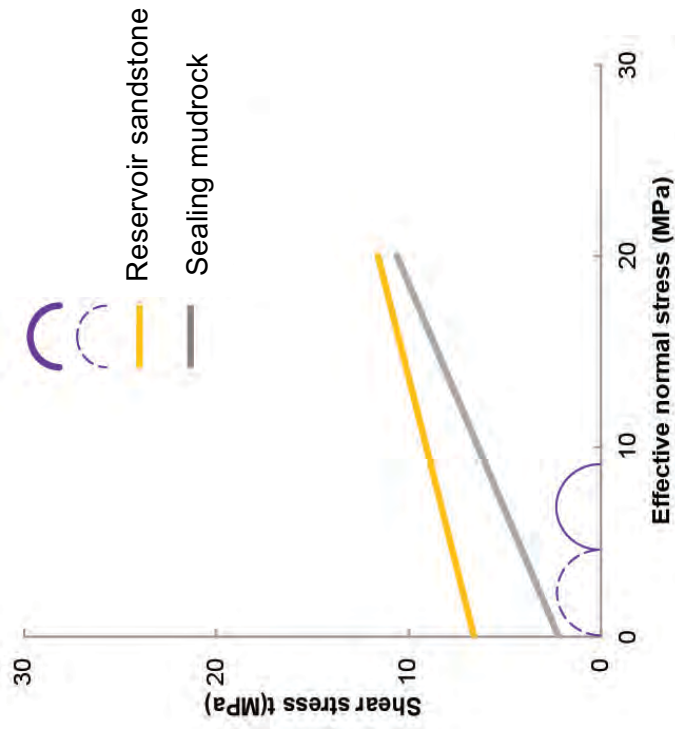
Meckel (2010),
Offshore Texas
Miocene

ROCK STRENGTH (CENOZOIC STRATA)

Unconfined compressive stress

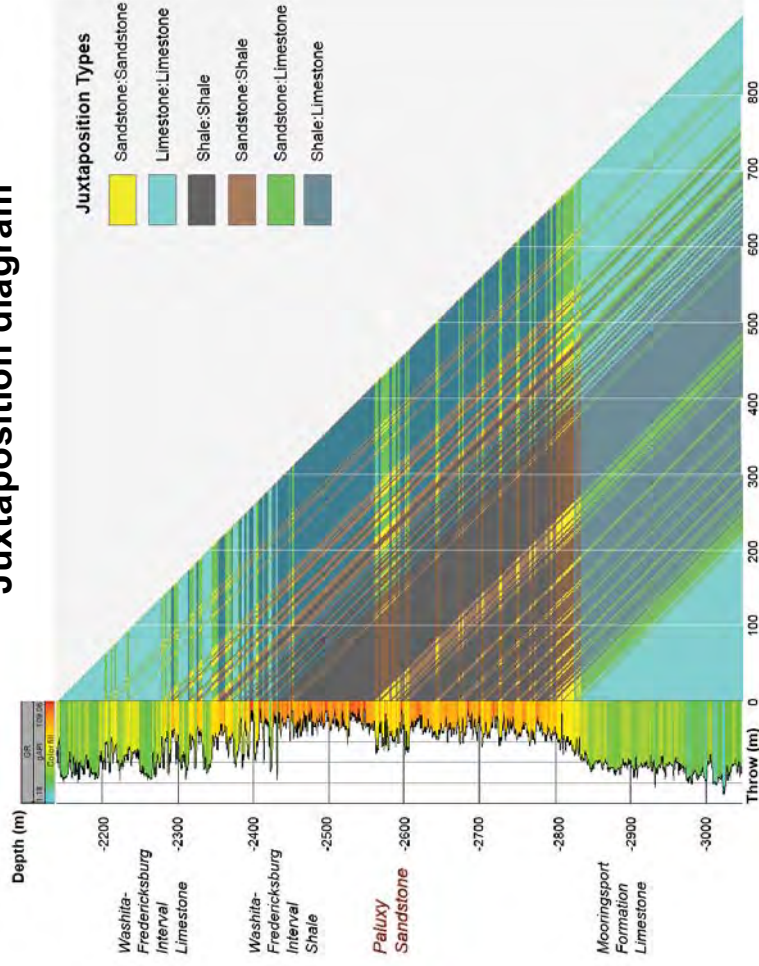


Mohr failure analysis



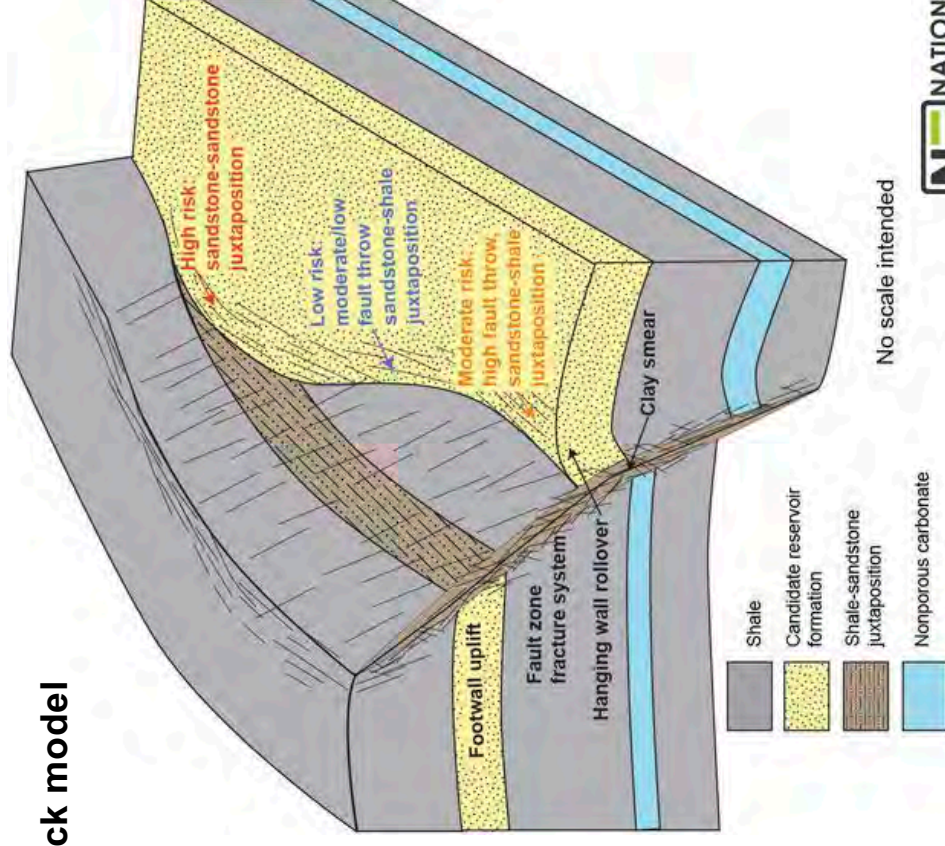
FAULT SEAL ANALYSIS

Juxtaposition diagram



Meng et al., 2020

Block model



HEURISTIC DECISION SUPPORT SYSTEM DESIGN

- **Geologic Information**

- Reservoir location, dimensions
- Rock type
- Depth
- Reservoir thickness
- Structural and depositional geometry
- Trap type

- **Reservoir properties**

- Porosity
- Permeability
- Fluid composition and properties
- Pressure
- Storage resource

- **EOR/EGR information**

- API gravity
- Gas-oil ratio
- Resource/reserve volumes
- Production volumes
- Production history
- Drive type
- Production systems

- **Considerations**

- Quantified factors
- Ranked factors
- Infrastructure
- Fluid transport options

- **What are your objectives?**

- Saline formation storage
- Depleted reservoir storage
- Enhanced oil recovery
- Pressure maintenance

OBSERVATIONS

- Shelf has multiple storage/enhanced recovery options; slope focus on EOR
- Shelf potential principally in fluvial-deltaic, shelf sand, slope potential in turbidites.
- Faulting central consideration on shelf; bright spots show sealing potential.
- Slope presents broad range of subsalt, salt flank, and suprasalt options.
- Pressure envelope can be limiting; pressure depletion increases options in shelf.
- Mudrock weaker than sand, although sand consolidation variable.
- Fault seal analysis critical in many settings; structural position important.
- Data well suited for heuristic decision support system; many variables required for proper decision support; operation is context sensitive.

SECARB Offshore Gulf of Mexico Project: Well Integrity Analysis

SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting
March 26 – 27, 2020

William Garnes, Laura Keister, Andrew Duguid
Battelle. Energy Division



Presentation Outline

Project Overview

- Study Area
- Initial Focus Areas

Methodology Development

- Required Data
- Data Collection
- Data Management

Next Steps

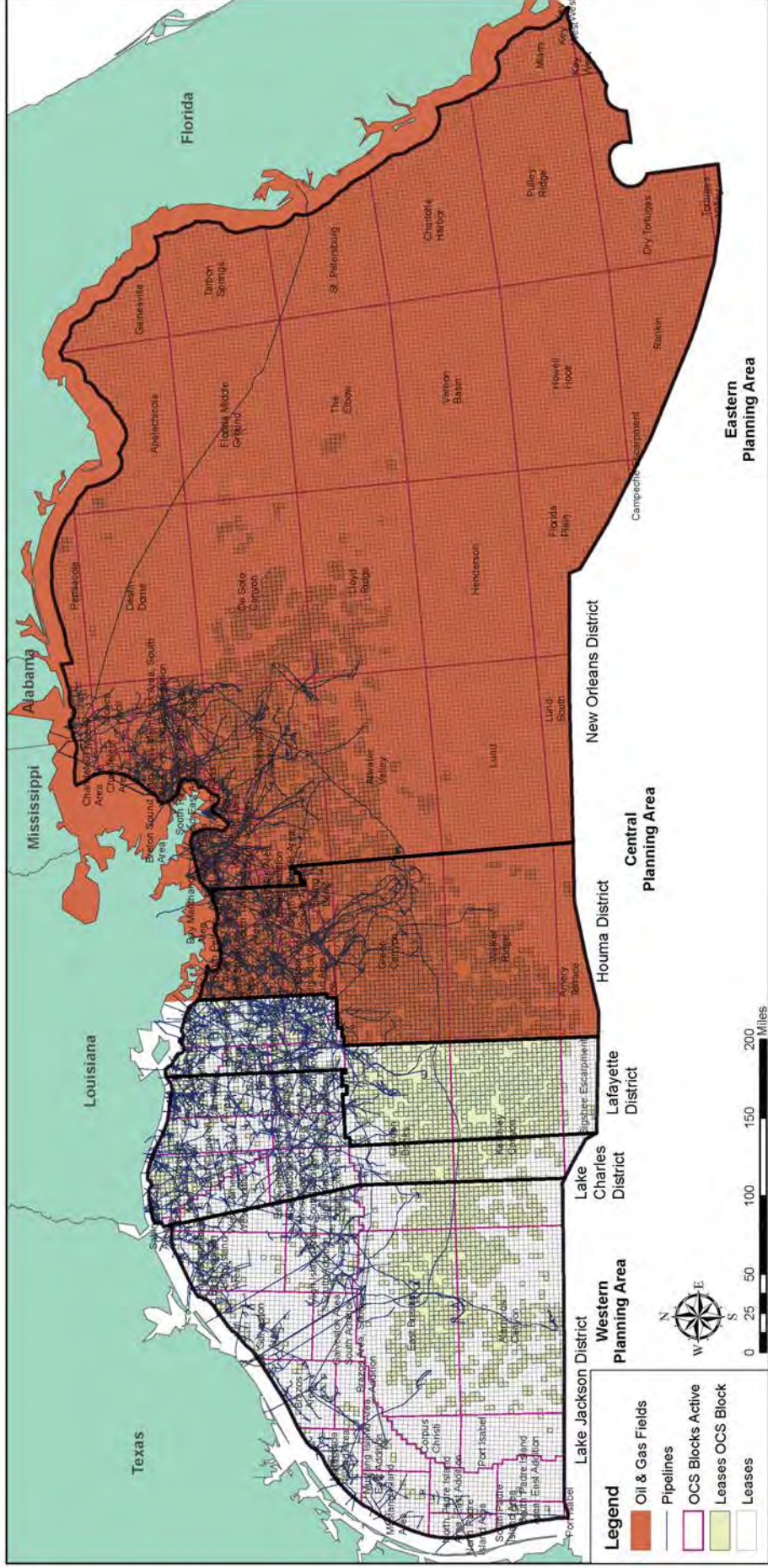
- Filling Data Holes
- Risk Assessment

Project Overview

Gulf Study Area

FEDERAL WATERS		
	Depleted Oil & Gas Fields, and Potentially Associated CO ₂ -EOR	Deep Saline
Western Planning Area	No	No
Central Planning Area	Study Area is East of Houma District's Western Boundary (includes Houma District)	Study Area is East of New Orleans District's Western Boundary (excludes Houma District)
Eastern Planning Area	All	All
STATE WATERS		
	Depleted Oil & Gas Fields, and Potentially Associated CO ₂ -EOR	Deep Saline
Texas	No	No
Louisiana	Partial, Includes State Waters East of Houma District Boundary Extension	Partial, Excludes Chandeleur Sound/Islands
Mississippi	Yes	Yes
Alabama	Yes	Yes
Florida (West Coast)	Yes	Yes

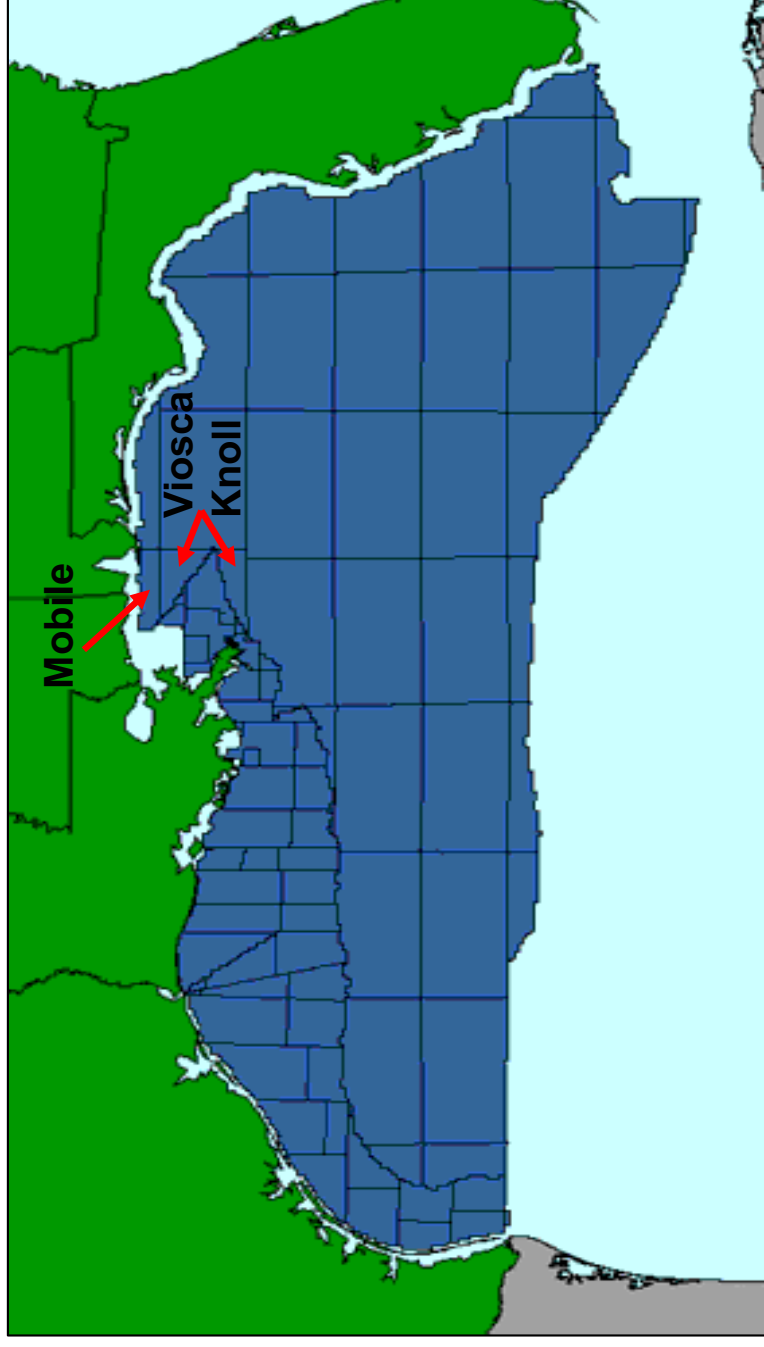
Oil and Gas Fields



This map displays the Gulf of Mexico region, including parts of Texas, Louisiana, Mississippi, Alabama, and Florida. It highlights various planning areas and OCS blocks. The map is divided into several planning areas: Western Planning Area, Central Planning Area, and Eastern Planning Area. The Western Planning Area includes Lake Jackson District, Lake Charles District, and Lake Lafayette District. The Central Planning Area includes Houma District and New Orleans District. The Eastern Planning Area includes the Florida Panhandle. The map shows numerous OCS blocks, some of which are active, and leases. A legend in the bottom right corner defines the symbols: Deep Saline (blue square), Pipelines (black line), OCS Blocks Active (pink outline), Leases OCS Block (yellow outline), and Leases (white outline). A scale bar in miles (0 to 200) and a compass rose are also present.

Initial Focus Areas

- Initial focus is on the Mobile and Viosca Knoll areas of the Gulf of Mexico.
- These areas were chosen to develop a methodology for collecting and analyzing data required for well integrity analyses.
- Once this methodology is established it can be used throughout the rest of the study area.



<https://woodshole.er.usgs.gov/pubs/of2005-1071/htmldocs/catalog.htm>

Methodology Development

Required Data

- Data requirements for a well integrity analysis were established.
- Geologic data
 - Reservoir formations
 - Reservoir characteristics (depth, porosity, permeability)
 - Presence of caprock
- Well ID and Location Data
 - Well API numbers
 - Geographic location of wells
 - Longitude and latitude
- Wellbore data
 - Well construction (age, depth, borehole diameter, casing, cement, BOP, etc.)
 - Well status (producing, abandoned, cement plugs, plug depths)
 - Well history (workovers, well corrosion, blowouts)

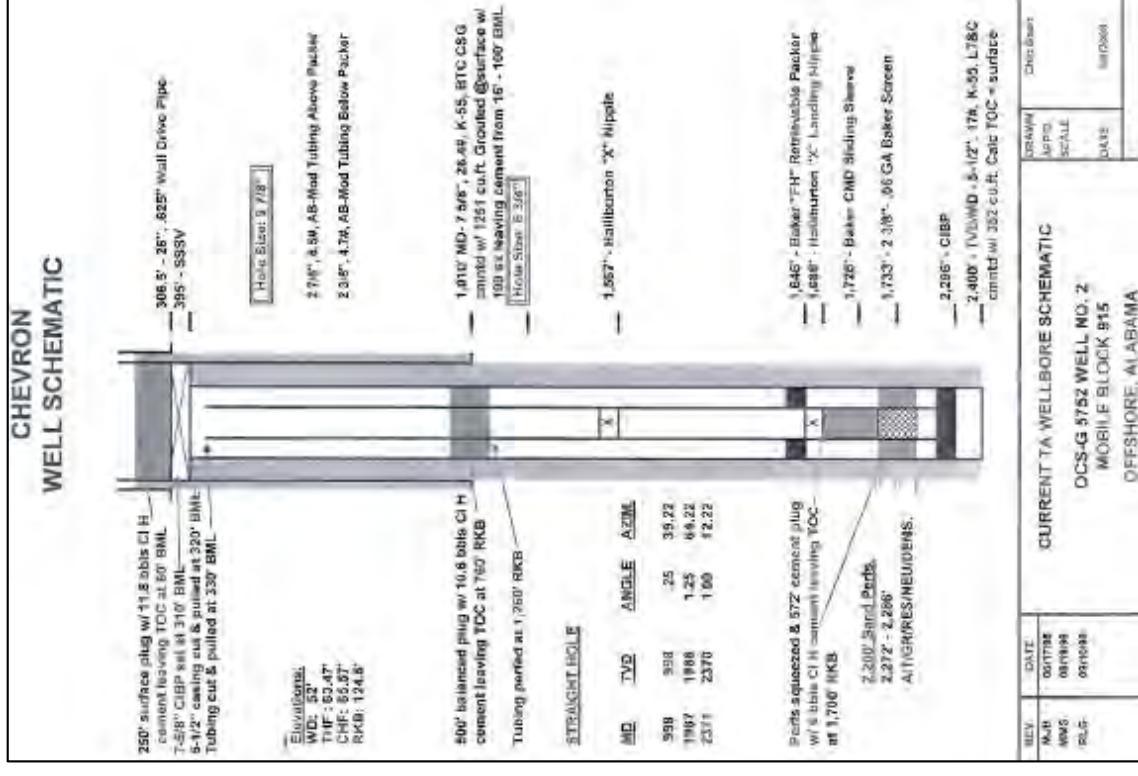
Data Collection

- Geologic data collection
 - Developing a generic geologic stratigraphy in the initial focus areas is being completed by project partners at Oklahoma State University.
- Well location and construction data
 - Provided by the Bureau of Safety and Environmental Enforcement (BSEE).
- Data types and formats
 - Completion reports, drilling permits, operations reports, geophysical logs, etc.
 - Excel files, PDF files, and image files.



Data Collection

- General Well Data
 - API number, long./lat., depth, age, and status data provided by BSEE in an excel file.
- Well construction data
 - Casing, cementing, BOPs, and workover history data was provided in PDF and image files.
- Additional Data Request
 - FOIA request was sent to BSEE to see if any additional well construction data is available in an excel file.



Data Management

- Excel file well data provided by BSEE was organized by API number.

API	Spud Date	BH Total MD	TVD	TD Date	Status Date	Surface Lat.	Surface Long.	Bottom Long.	Bottom Lat.
608154000700	1983/04/14	21736	21736	1983/09/04	1983/11/24	-88.16313	30.189509	-88.16313	30.189509
608154000900	1983/12/20	21720	21717	1984/07/19	1984/08/11	-87.985599	30.165922	-87.985795	30.166176
608154000901	1984/10/22	21575	21391	1984/11/03	1985/06/26	-87.985599	30.165922	-87.988766	30.164665
608154000902	1984/12/15	21728	21663	1985/03/05	1985/06/08	-87.985599	30.165922	-87.984414	30.167837
608154000970	1984/08/11	21628	21430	1984/10/15	1984/10/22	-87.985599	30.165922	-87.988938	30.164557
608154000971	1984/11/26	21583	21396	1984/12/07	1984/12/15	-87.985599	30.165922	-87.988791	30.164607
608154001000	1985/02/27	4270	4270	1985/03/04	2006/06/26	-88.296807	30.042111	-88.296847	30.042063
608154001100	1984/03/14	22422	22420	1984/07/26	2015/10/11	-88.145588	30.148977	-88.145492	30.148895
608154001200	1984/03/27	4120	4120	1984/04/01	1984/04/04	-88.162399	30.034709	-88.162439	30.034669
608154001300	1984/03/17	3620	3620	1984/03/20	2011/06/30	-88.272062	30.042356	-88.272103	30.042333
608154001400	1984/11/13	22092	22087	1985/07/13	1985/07/29	-88.078684	30.086074	-88.07817	30.086761
608154001500	1984/11/04	21645	21644	1985/03/22	1985/08/12	-88.442281	30.119052	-88.442012	30.119238
608154001600	1985/01/10	21995	21899	1985/09/24	2002/01/26	-88.187606	30.184783	-88.188741	30.185978
608154001700	1985/02/27	23153	23149	1986/01/08	1986/03/29	-87.825459	30.023703	-87.825435	30.024097

Data Management

- Image and PDF files
 - Indexed by well API number and document type.
- Total files
 - Mobile: 7,575
 - Viosca Knoll: 23,443

API	File Name	File Type	Data Type	Data in File	Index File Order
608154004170	1332037	tif	WellData	Type=APD-Application for Permit to Drill"	1
	349914	tif	WellData	Type=APD-Application for Permit to Drill"	2
	295515	tif	WellData	Type=Well Completion Report"	3
	350526	tif	WellData	Type=Well Completion Report"	4
	350527	tif	WellData	Type=Sidewall Core Analysis"	5
	350528	tif	WellData	Type=Sidewall Core Analysis"	6
	350530	tif	WellData	Type=Well Completion Report"	7
	350531	tif	WellData	Type=Well Completion Report"	8
	350532	tif	WellData	Type=Well Completion Report"	9
608154004200	350533	tif	WellData	Type=APD-Application for Permit to Drill"	10
	977764	tif	WellData	Type=Sundry Report"	11
	977811	tif	WellData	Type=Well Summary Report"	12
	977812	tif	WellData	Type=Sundry Report"	13
	977813	tif	WellData	Type=Sidewall Core Analysis"	14
	977814	tif	WellData	Type=Sundry Report"	15
	977815	tif	WellData	Type=Well Completion Report"	16
	977816	tif	WellData	Type=Sundry Report"	17
	977817	tif	WellData	Type=APD-Application for Permit to Drill"	18
	mo000522	tif	Logs	Log Type=5in dual induction laterolog long spaced sonic"	19
	mo000523	tif	Logs	Log Type=1in dual induction laterolog"	20
	mo000524	tif	Logs	Log Type=5in dual induction laterolog long spaced sonic log"	21
	mo000525	tif	Logs	Log Type=5in compensated density/neutron log"	22
	mo000526	tif	Logs	Log Type=5in compensated density/neutron log"	23
	mo000527	tif	Logs	Log Type=5in shiva computation six arm dipmeter survey"	24
	mo000535	tif	Logs	Log Type=5in mud log"	25

Next Steps

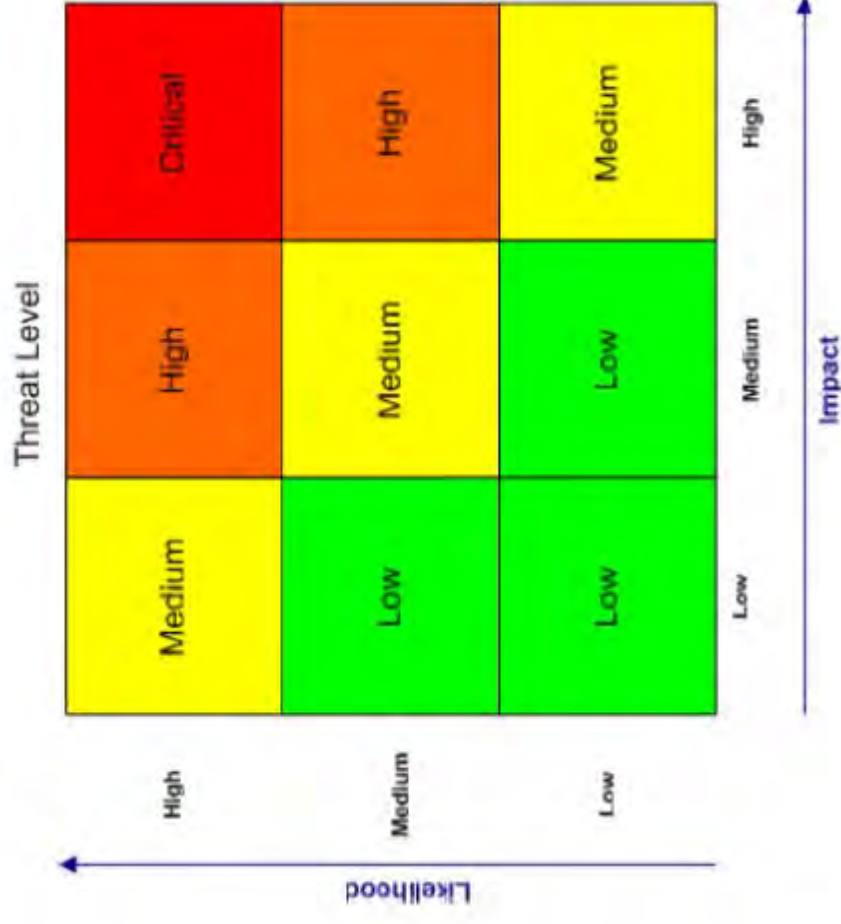
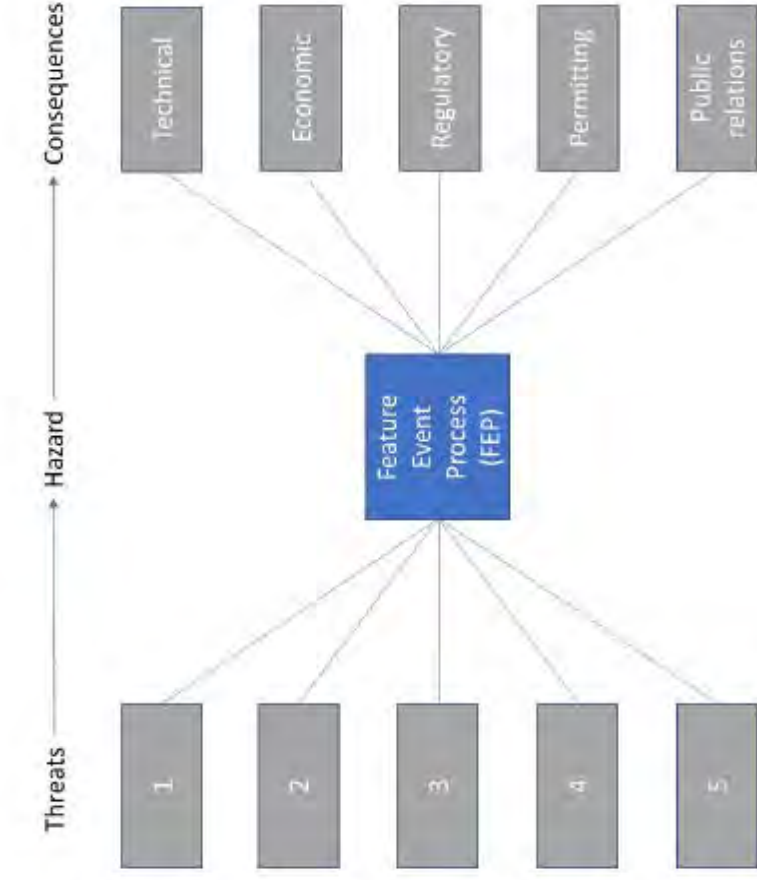
Filling Data Holes

- Data holes
 - Missing data needs to be added.
 - Additional digitized well construction data to be added to the database when it is received from BSEE.
 - Referencing file indices and analyzing PDF and image files to find missing information and fill in the data gaps.

API	Spud Date	BH Total MD	TVD	TD Date	Status Date	Surface Lat.	Surface Long.	Bottom Long.	Bottom Lat.
608164005400	1978/10/20	5260	4524	1978/11/08	1978/11/14	-88.429876	29.227589	-88.42548	29.223335
608164005500	0000/00/00			0000/00/00	0000/00/00	-88.437277	29.271234		
608164005600	0000/00/00			0000/00/00	0000/00/00	-88.424134	29.27051		
608164005700	1978/12/01	10842	7461	1979/01/03	1979/01/12	-88.74278	29.062708	-88.734923	29.043967
608164005701	1979/03/03	10700	7439	1979/04/02	1979/04/02	-88.74278	29.062708	-88.724942	29.056218
608164005800	0000/00/00			0000/00/00	0000/00/00	-88.373232	29.064922		
608164005900	1979/04/03	7057	6843	1979/04/21	1989/03/23	-88.742775	29.062763	-88.739129	29.062641
608164006000	0000/00/00			0000/00/00	0000/00/00	-88.74272	29.062676		
608164006100	0000/00/00			0000/00/00	0000/00/00	-88.742793	29.062749		
608164006200	1979/11/06	5667	5666	1979/11/27	1979/12/06	-88.37949	29.125724	-88.379612	29.125717
608164006300	1980/07/12	15082	15014	1980/11/21	1980/12/05	-88.325986	29.14495	-88.323694	29.145448

Risk Assessment

- Risk = Likelihood * Impact



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It can be done

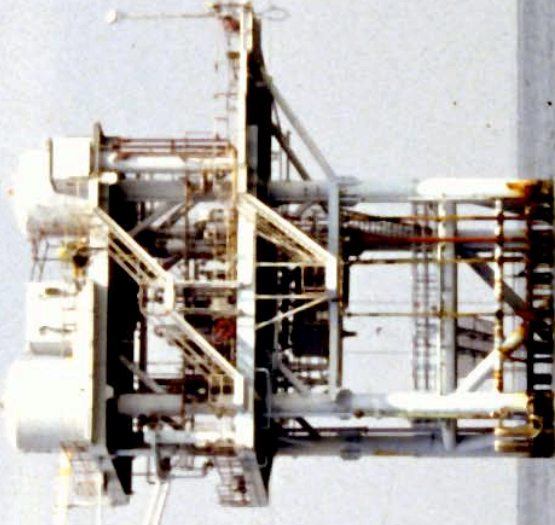
SECARB Offshore Gulf of Mexico Available and Leading Practices



Presented by: Brian Hill, CrescentRI – SSEB Finance & Commercialization Consultant
U.S. Department of Energy | National Energy Technology Laboratory | DE-FOA-0001734
March 27, 2020

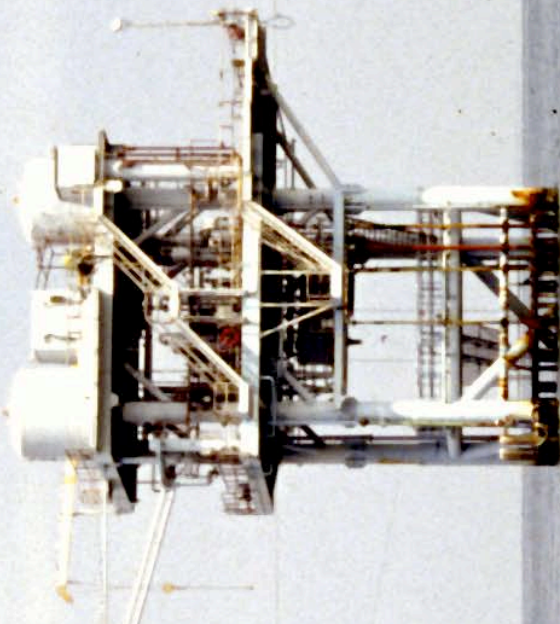
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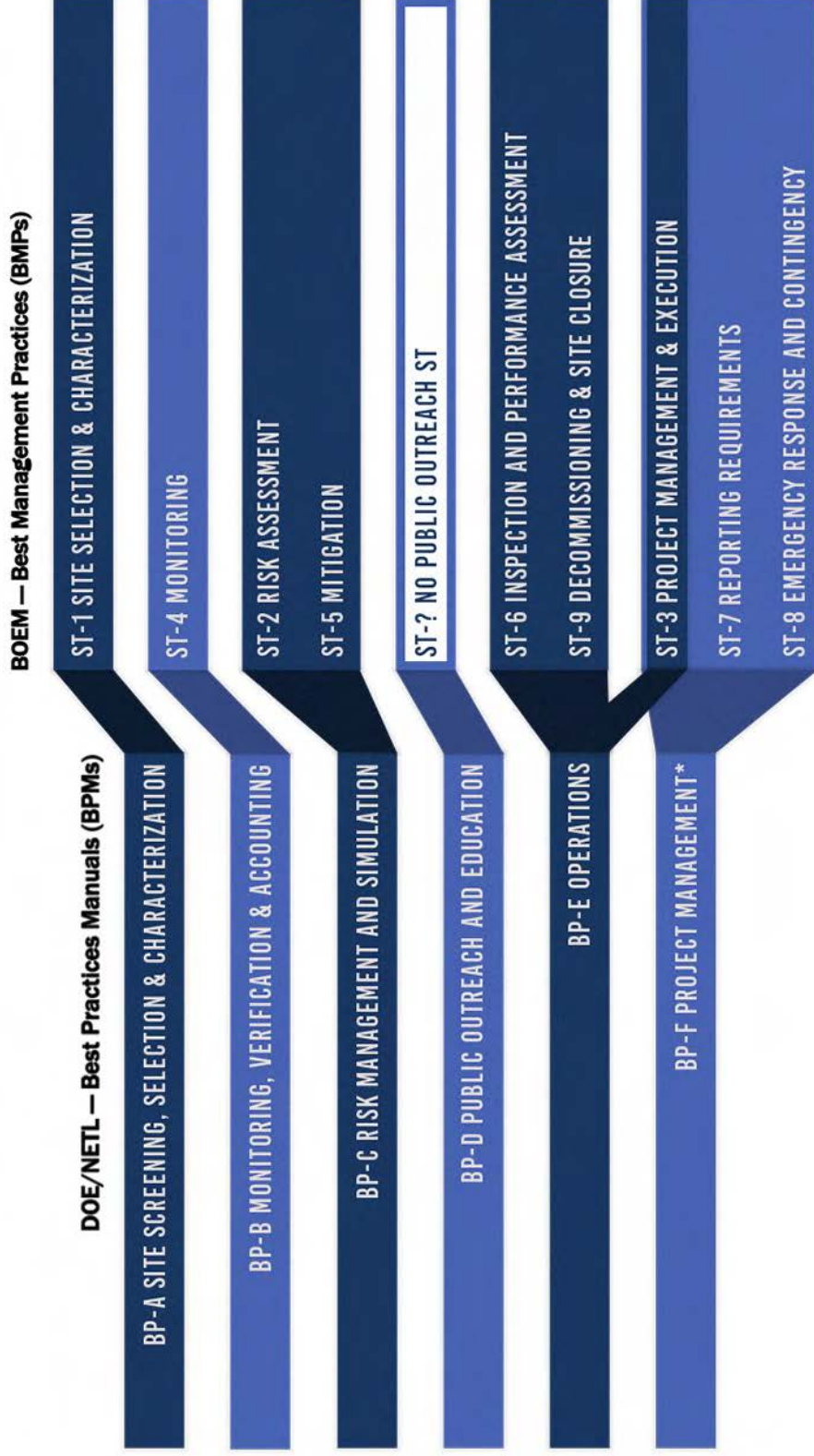
Best Practices: Recent Activities

- Offshore Best Practices for CO₂ Storage & Transportation
 - SSEB and the Interstate Oil and Gas Compact Commission (IOGCC) convened an Offshore Task Force that reviewed laws and regulations for CO₂ capture and storage (2012)
 - Texas BEG prepared a report for BOEM on best management practices for offshore transportation and sub-seabed geologic storage of CO₂ (2017)
 - SSEB prepared a SOSRA T6.1 report that compared DOE/NETL onshore best practices with the BOEM best management practices for offshore CO₂ transportation and storage (2019)
 - SSEB prepared SOSRA T6.2.a report formalizing Available and Leading Practices (2019) instead of Best Practices



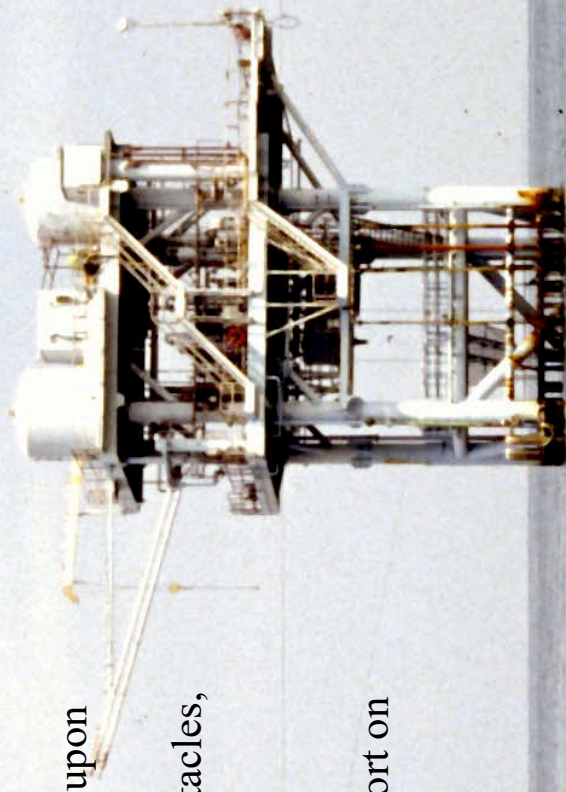
DOE/NETL and BOEM Best Practices Comparison

*Project Management BPM not part of DOE/NETL 2017 update; Under review at SSEB (2020)



SECARB Offshore Planned Activities

- SECARB Offshore (BP1) Action Plan to Expand Available and Leading Practices Explicitly Applicable to the Gulf of Mexico (Mar 2020)
 - Create an action plan to advance offshore practices, based upon SOSRA 6.2 and BOEM work completed
 - Include existing infrastructure, logistical & regulatory obstacles, and decommissioning requirements
- SECARB Offshore (BP2) Final Report (Mar 2023)
 - Incorporate available and leading practices into a final report on “*Assessment of Legal and Regulatory Frameworks*”



SECARB Offshore Planned Activities

INVENTORY OF AVAILABLE PRACTICES: CONCEPTUAL DESIGN

INFRASTRUCTURE COMPONENTS	CHARACTERIZATION			RISK				MONITORING (Atmospheric, Aqueous,)			
	SITE SELECTION	INITIAL SITE EVALUATION	DETAILED SITE EVALUATION	DEVELOPMENT	OPERATIONS	CLOSURE	POST CLOSURE	DEVELOPMENT	OPERATIONS	CLOSURE	POST CLOSURE
Landside Connections CO2 Transport & Corridors Platforms & Sea Floor Connections Well Bores & Wells Geological Seals & Barriers CO2 Storage & Utilization Formations	C1	C2	C3	R1	R2	R3	R4	M1	M2	M3	M4
	C4	C5	C6	R5	R6	R7	R8	M5	M6	M7	M8
	C7	C8	C9	R9	R10	R11	R12	M9	M10	M11	M12
	C10	C11	C12	R13	R14	R15	R16	M13	M14	M15	M16
	C13	C14	C15	R17	R18	R19	R20	M17	M18	M19	M20
	C16	C17	C18	R21	R22	R23	R24	M21	M22	M23	M24
OUTREACH											
Integrate Public Outreach with Project Management Conduct and Apply Social Characterization Develop Outreach Materials Tailored to the Audiences				Identify Outreach Goals with Project Management Establish an Outreach Program Implement and Manage the Outreach Program Needed				Identify Key Stakeholders Develop Key Messages Asses the Performance of the Outreach Program			

C16

SECARB Offshore Planned Activities

Inventory Of Available Practices – C16 CO₂ Storage and Utilization Formations

Phase	Onshore Action	Available Practices	Comparison to Offshore
Site selection	Subsurface Geological Data Analysis Storage Reservoir	Identify storage reservoirs and injection zones within Selected Areas. Develop stratigraphic and structural framework diagrams that illustrate suitable storage reservoirs and injection zones of interest, using all available well and outcrop data.	No difference
Site selection	Subsurface Geological Data Analysis Confining Zone	Analyze confining zones in Selected Areas. Create stratigraphic and structural framework diagrams to illustrate areal extent, thickness, lithology, porosity, permeability, capillary pressure, and structural complexity of suitable confining zones, based on existing data.	No difference
Site selection	Subsurface Geological Data Analysis Trapping	Establish baseline geomechanical characteristics of targeted injection and confining zones.	No difference
Site selection	Subsurface Geological Data Analysis Mechanism	Evaluate trapping mechanisms for Selected Areas using available well, outcrop, and seismic data.	No difference
Site selection	Subsurface Geological Data Analysis Potential	Establish hydrogeological characteristics of injection and confining zones to assure reliable containment of injected CO ₂ .	No difference
Site selection	Subsurface Geological Data Analysis Injectivity	Perform initial estimate of injectivity of candidate injection zones in Selected Areas, using available production history data, hydrologic test data, and analyses of core plugs.	No difference
Site selection	Model development - Modeling parameters	Identify types of models and modeling parameters needed to characterize the storage reservoir, confining zone, and fluid properties for Selected Areas.	No difference
Site selection	Model development - Data Requirements and cost	Identify data requirements to optimize modeling results; conduct cost vs. benefit analysis to determine value of acquiring new data.	Data acquisition costs offshore tend to be significantly higher; data tends to be lower density due to higher cost
Site selection	Model development - Boundary conditions/uncertainty	Identify and characterize uncertainties in modeling results; select boundary conditions which minimize uncertainties in modeling results.	No difference
Site selection	Model development - Existing seismic data	If available, integrate existing seismic data in development of static and dynamic models for Selected Areas.	Offshore seismic data tends to be easier to work with due to no need for topographic corrections and easier avoidance of obstacles.

SECARB Offshore Planned Activities

MATRIX OF LEADING PRACTICES: CONCEPTUAL DESIGN

Project Management												
INFRASTRUCTURE COMPONENTS	CHARACTERIZATION			RISK				MONITORING				
	SITE SELECTION	INITIAL SITE EVALUATION	DETAILED SITE EVALUATION	DEVELOPMENT	OPERATIONS	CLOSURE	POST-CLOSURE	DEVELOPMENT	OPERATIONS	CLOSURE	POST-CLOSURE	
Landside Connections	C1	C2	C3	R1	R2	R3	R4	M1	M2	M3	M4	
CO2 Transport & Corridors	C4	C5	C6	R5	R6	R7	R8	M5	M6	M7	M8	
Platforms & Sea Floor Connections	C7	C8	C9	R9	R10	R11	R12	M9	M10	M11	M12	
Well Bores & Wells	C10	C11	C12	R13	R14	R15	R16	M13	M14	M15	M16	
Geological Seals & Barriers	C13	C14	C15	R17	R18	R19	R20	M17	M18	M19	M20	
CO2 Storage & Utilization Formations	C16	C17	C18	R21	R22	R23	R24	M21	M22	M23	M24	
Outreach and Education												

Onshore to Offshore Relationship
Very little to no difference

Onshore to Offshore Relationship
Small differences

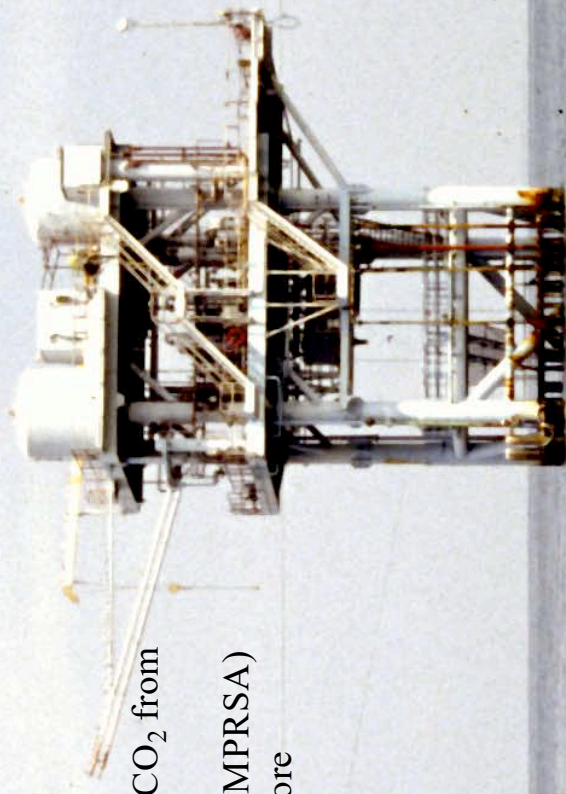
Onshore to Offshore Relationship
Major differences

Onshore to Offshore Relationship
Major differences

Onshore to Offshore Relationship
Not contemplated in Onshore

Challenges for Offshore

- Regulation
 - Regulation needed for offshore development
 - Bureau of Ocean Energy Management
 - Bureau of Safety and Environment Enforcement
 - Pore Space availability
 - Long term Liability
 - Monitoring requirements
 - Under the Outer Continental Shelf Lands Act (OCSLA) only CO₂ from coal fired power plants is allowed
 - Under the Marine Protection, Research, and Sanctuaries Act (MPRSA) CO₂ is considered a waste and prohibited from disposal offshore
- Timing
 - Limited window under existing 45Q
 - Commence Construction date of 12/31/2023
 - 6-year window to complete construction
- Economics
 - Higher costs to operate offshore
 - Current low oil prices
 - Economics of Storage after 45Q – only 12-year credit



THANK YOU!



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LOUISIANA STATE UNIVERSITY



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