Offshore CO₂ Storage Resource Assessment of the Northern Gulf of Mexico (Upper Texas-Western Louisiana Coastal Areas)

"TXLA" DE-FE0026083

Ramon Treviño



Jackson School of Geosciences The University of Texas at Austin Gulf Coast Carbon Center

U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:

Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 1-3, 2017

Presentation Outline

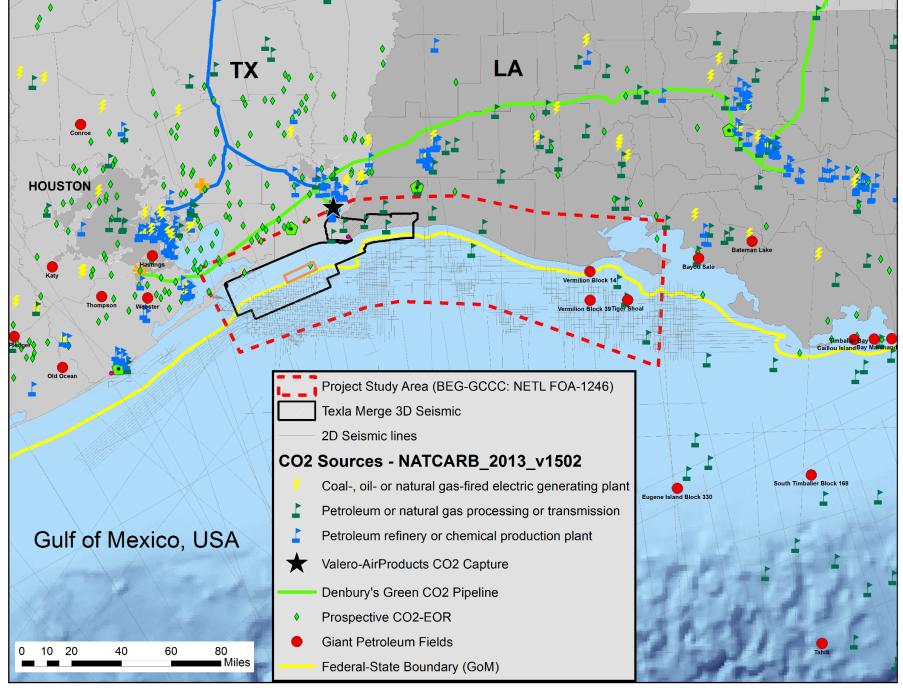
- Project Overview: Goals and Objectives
- Technical Status
- Accomplishments to Date
- Lessons Learned
- Summary
- Acknowledgements





TXLA Goals & Objectives

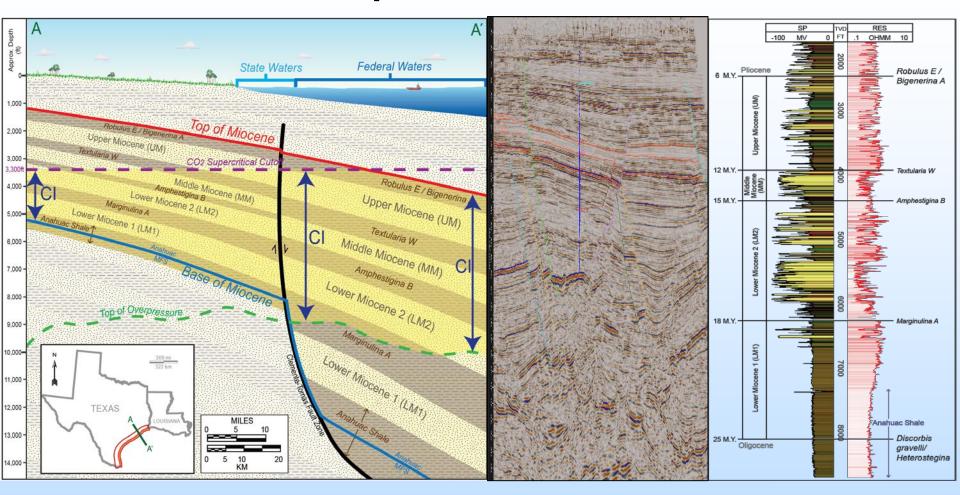
Assess: Depleted oil & natural gas reservoirs' storage capacity Saline formations' ability to store nationally-significant amounts of anthropogenic CO₂ Identify at least one 30 MT site

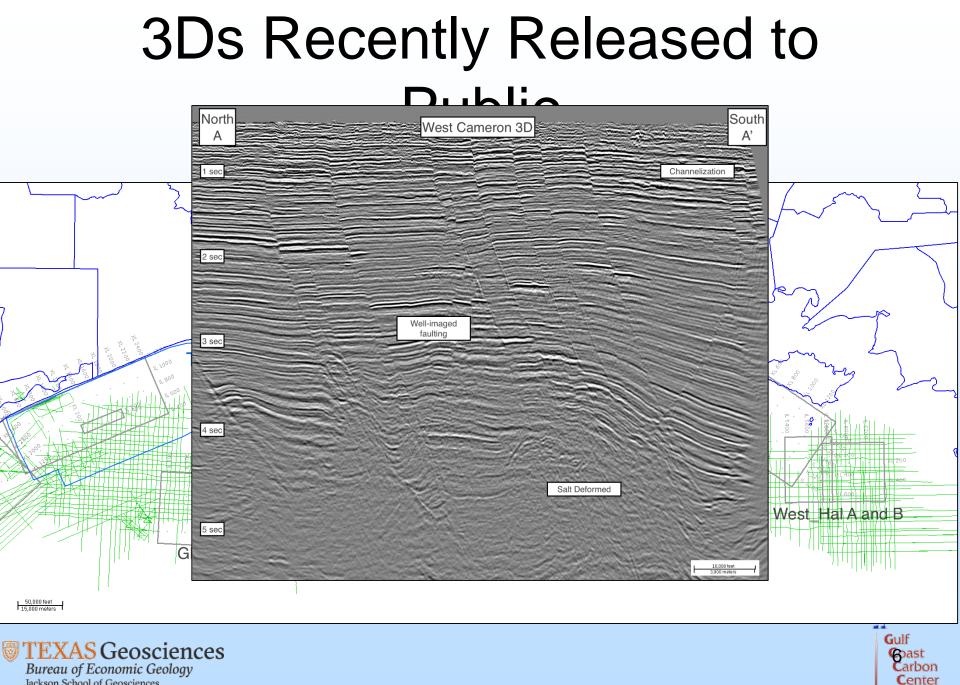


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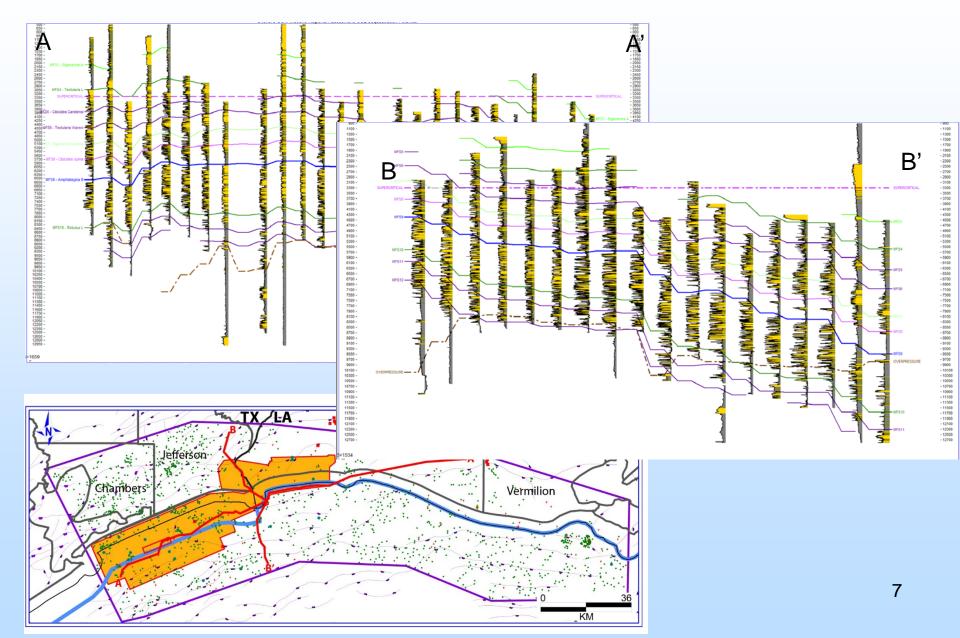
Conceptual Overview



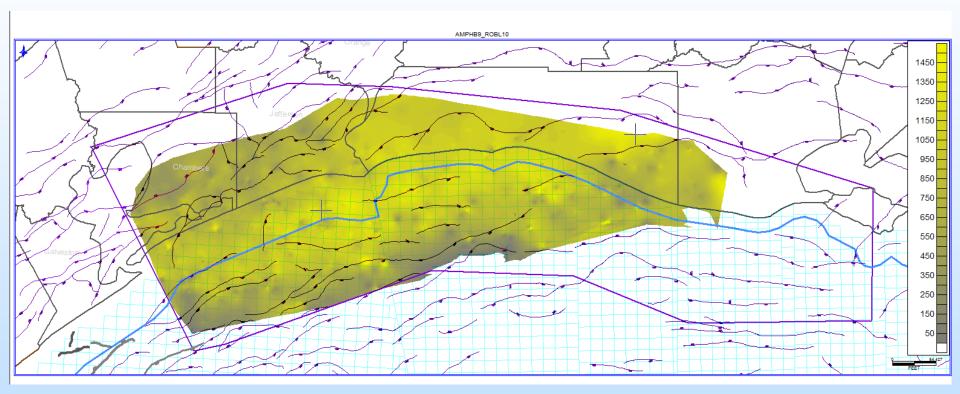


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Regional Well Correlations



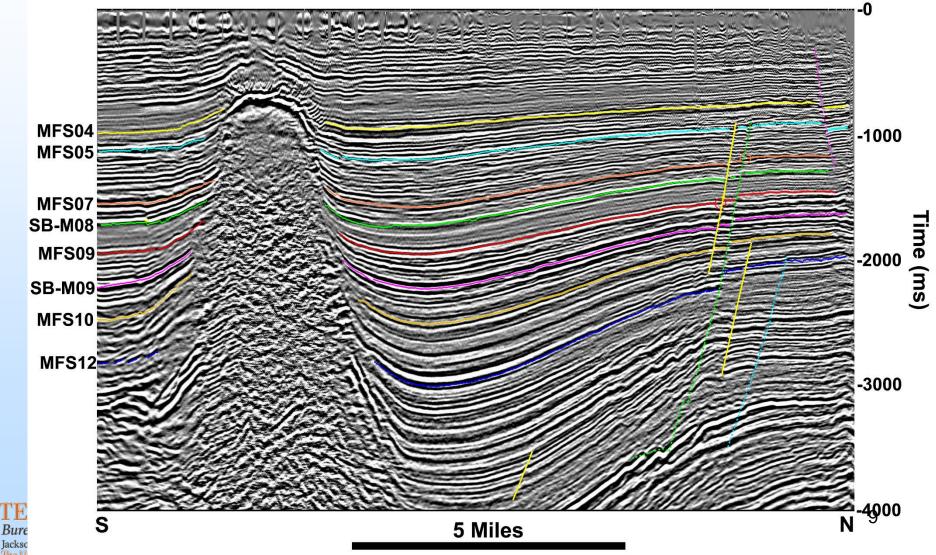
Net Sand Calculations for Static Capacity Estimates

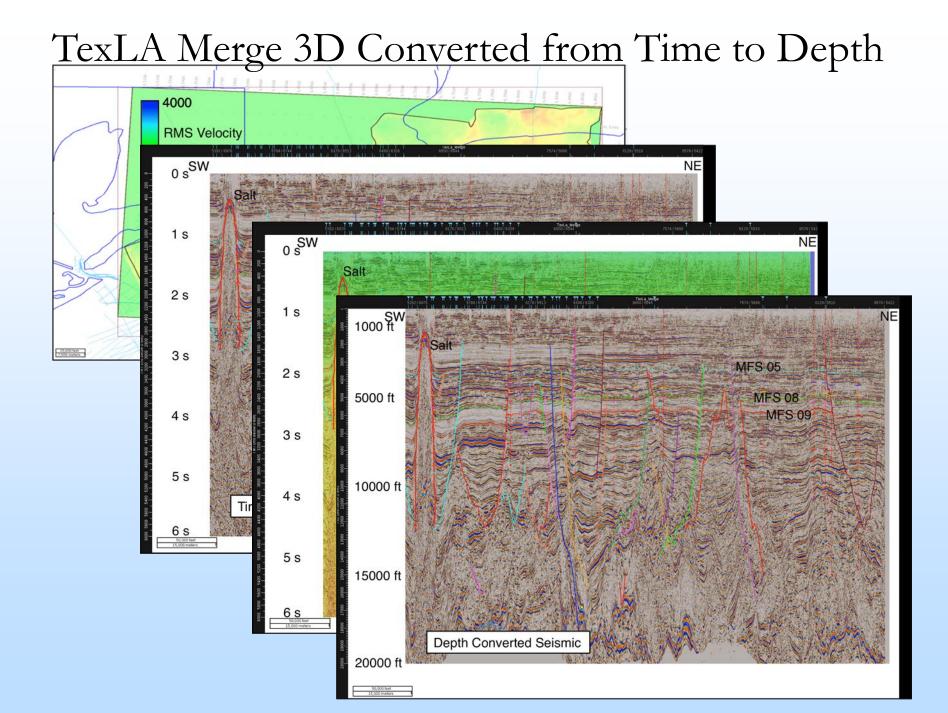




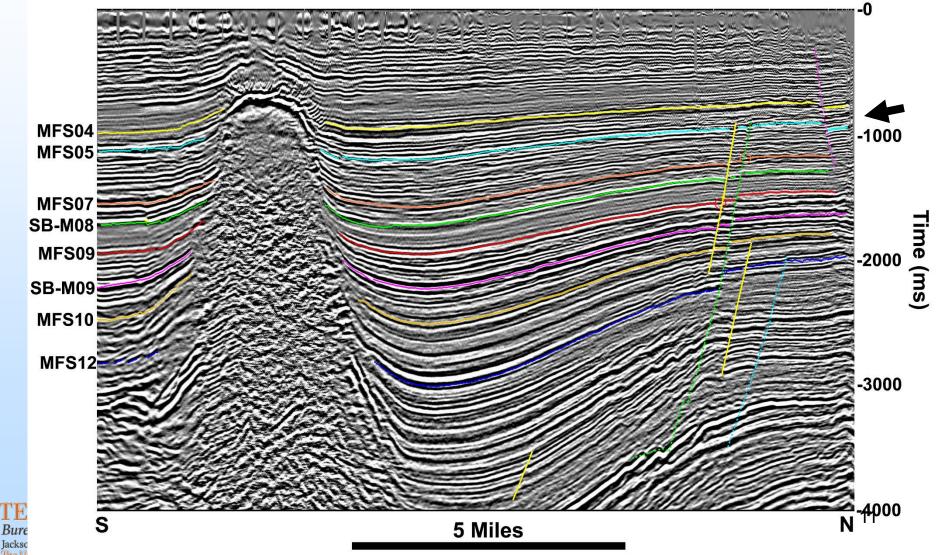


Transect – TexLa Merge 3D Interpreted Horizons

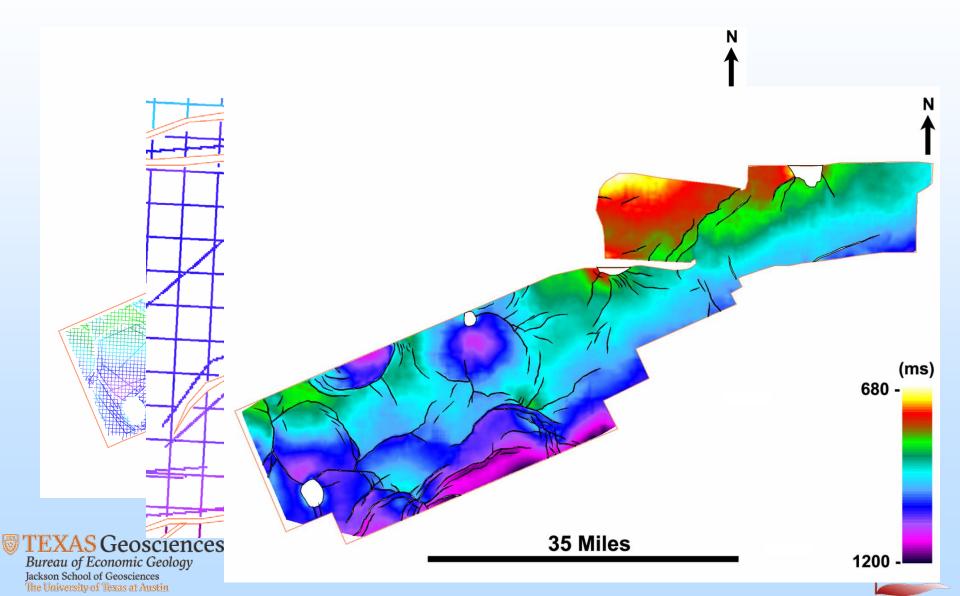


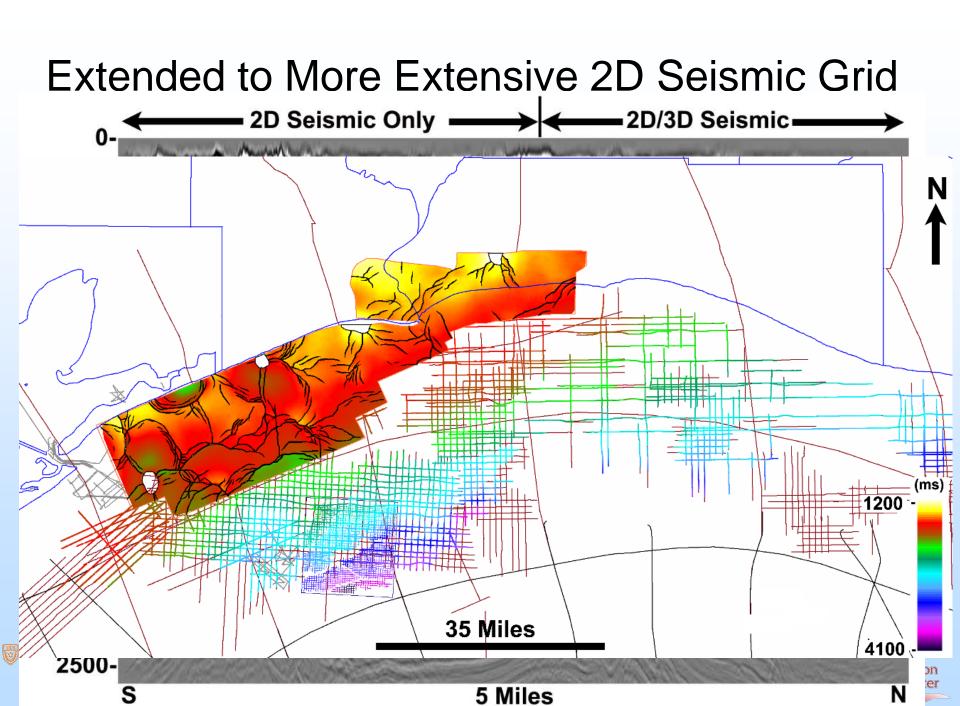


Transect – TexLa Merge 3D Interpreted Horizons

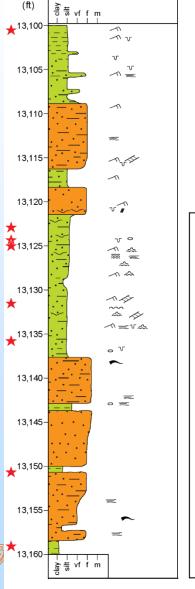


Seismic Interpretation: Horizons & Faults





Assess Confining Zone (Seal) Interval **Characteristics** (Micro-Scale)



weakly laminated.

Cross lamination

Mudstone clast

Plant fragment

Ser bedding

Lenticular bedding Parellel bedding

Shell fragments

So Siderite nodules

burrows

Burrow

Ripple

V

2

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32

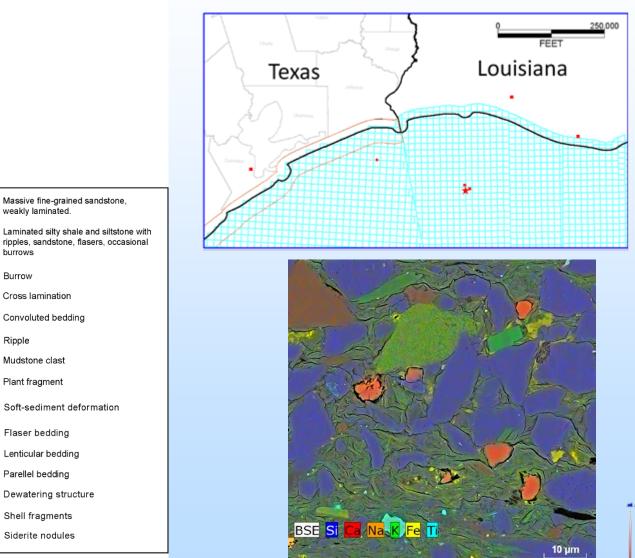
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Depth



Gulf

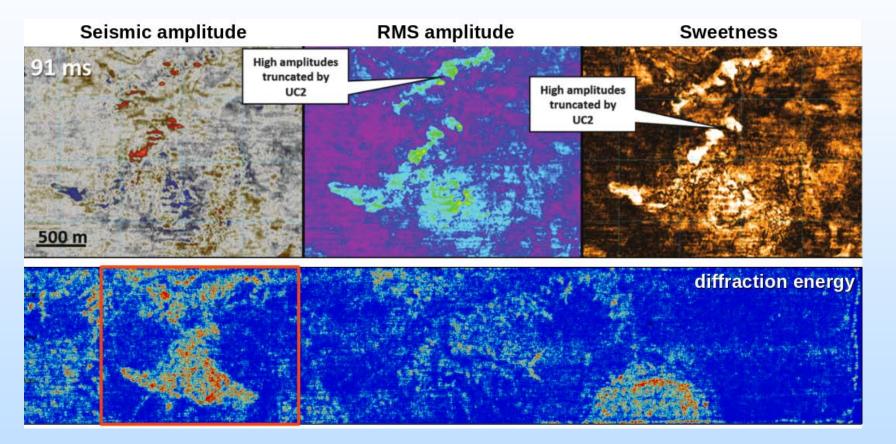
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Assess Confining Zone (Seal) Interval Characteristics (Macro-Scale)



*Using UHR3D datasets





Production Decline Analysis - 22 Offshore Oil & Gas fields: Dynamic Capacity Estimate (EASiTool)

$$CBP = V_o B_o + \frac{V_g}{5.615E_g}$$

CBP = Cum. Bulk Production V_o = total oil production (standard conditions), B_o = oil formation volume factor, V_g = total gas production (standard conditions) E_g = gas expansion factor

> **Equivalent** Mass $(CO_2) = CBP \times \rho_{CO_2}$

Where ρ_{CO_2} represents CO₂ density at reservoir conditions of T_{res} , P_{res} (reservoir temperature and reservoir pressure, respectively)

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Number of Field	Field	Reservoirs	CBP (bbl)	Equivalent Mass of CO ₂ (Million Metric Tons)
1		7500 DISCORBIS B, LO.	1.03E+05 4.63E+03	0.012
	Crystal Beach (TX)	S-1	4.05E+05	1.072
		7700	1.00E+03	0.000
2	Galveston 176-S (TX)	MIOCENE A-12, FB 2	8.20E+04	0.009
		MIOCENE D-1 MIOCENE S-2*	2.46E+05 2.99E+03	0.028 0.000
		MIOCENE S-1	1.63E+06	0.185
3	High Island 10-L (TX)	6950 SD BIG 3	2.00E+03 5.10E+04	0.000
4 5	High Island 14-L (TX) High Island 19-S (TX)	6700°	5.10E+04 1.11E+06	0.005
		8700 10000*	8.50E+06 6.24E+07	0.933 7.920
		36-B SD.	1.28E+05	0.015
6	High Island 20-S (TX)	5800	7.00E+03	0.001
7	High Island 23-L (TX)	LH-10 LH-13	1.49E+06 2.59E+06	0.207 0.350
	High Island 52 (TX)	M26	4.30E+05	0.047
8		M30 M48	2.20E+05 1.71E+06	0.024 0.194
		M49/M50	5.80E+06	0.657
		M50 B	3.17E+07 4.72E+07	4.098
9	High Island 160 (TX)	C	7.60E+07	8.614
	High Island 179 (TX)	G SD H8SD	1.69E+07 1.45E+07	1.812 1.640
		I SD	1.82E+07	2.074
10		J3SD J4SD	2.27E+06 7.78E+06	0.267 0.908
		N SD	1.66E+07	2.032
		60 FB-4, 2-B, UP	7.60E+06 4.70E+04	0.980
	Caplen (TX)	MIOCENE 4000	1.58E+03	0.000
11		MIOCENE 4300 MIOCENE 4430	8.10E+04 1.85E+05	0.005
		MIOCENE 4650	5.60E+04	0.005
		SIPH D, 7250 SD FB-5, 10	4.73E+04 7.19E+05	0.004 0.075
	Hog Bayou Offshore (LA)	AMPHISTEGINA	2.24E+06	2.236
12		DISCORBIS_SANDS	2.29E+05	0.229
		LIEBUSELLA_SANDS	4.00E+06	3.996
13	Creole Offshore	CREOLE_SAND	3.16E+04	0.032
14	East Cameron 4 (LA)	12300_SAND	5.24E+04	0.052
15	East Cameron 14 (LA)	DB-1 DB-2	3.65E+07 3.54E+07	4.201 4.189
	Law Cameron 14 (LA)	M11-3	6.77E+05	0.086
16		CR54#6 NA	1.05E+06 1.36E+07	0.111 1.499
	East Cameron 33 (LA)	12900	6.51E+06	0.825
		MAI#10 NO	7.31E+04 3.10E+07	0.009 3.403
		14000	9.77E+05	0.131
17	West Cameron 28 (LA)	14300 15100	1.09E+07 5.09E+05	1.481 0.078
	West Cameron 33 (LA)	AMPH	5.43E+04	0.005
18		CRIS DIS B1	3.58E+04 1.67E+07	0.004 1.795
		DIS B2		
			1.86E+07	2.014
		AMP5 AMP6	9.52E+05 2.57E+05	2.014 0.099 0.027
		AMP6 AMPH11	2.57E+05 8.08E+05	0.027 0.082
		AMP6	2.57E+05	0.027
19	West Cameron 45 (LA)	AMP6 AMPH11 AMPH13 AMPH14 DISB1	2.57E+05 8.08E+05 1.27E+06 5.90E+05 1.50E+07	0.027 0.082 0.131 0.065 1.614
19	West Cameron 45 (LA)	AMP6 AMPH11 AMPH13 AMPH13 AMPH14 DISB1 DISB2	2.57E+05 8/08E+05 1.27E+06 5.90E+05 1.30E+07 1.17E+07	0.027 0.082 0.131 0.065 1.614 1.203
19	West Cameron 45 (LA)	AMP6 AMPH11 AMPH13 AMPH14 DISB1 DISB1 DISB2 BISB5 E4	2.57E.03 8.08E.05 1.27E.06 5.90E.05 1.59E.07 1.17E.07 4.30E.06 3.14E.06	0.027 0.082 0.131 0.005 1.614 1.203 0.503 0.334
19	West Cameron 45 (LA)	AMP9 AMPH11 AMPH13 AMPH14 DISB1 DISB2 DISB2 E4 E825979	2.578:05 8.058:05 1.278:06 5.508:05 1.508:07 1.378:07 4.508:06 3.148:06 1.968:07	0.027 0.082 0.121 0.085 1.414 1.203 0.503 0.503 0.334 2.147
19	West Cameron 45 (LA)	AMP6 AMPH1 AMPH13 AMPH14 DISB1 DISB2 DISB3 E4 E8E9F9 E914 F6	2.5TE:05 8.05E:05 1.2TE:06 5.50E:05 1.50E:07 1.57E:07 4.58E:06 3.14E:06 1.96E:07 2.66E:07 1.44E:08	0.027 0.082 0.121 0.025 1.414 1.203 0.503 0.503 0.334 2.147 2.913 1.5.884
19	West Cameron 45 (LA)	AMP6 AMPH1 AMPH1 DISB1 DISB2 DISB5 E4 E54 F6 R R	2.578:05 3.088:05 3.958:05 1.558:07 1.78:07 4.858:05 3.188:06 1.968:07 2.968:07 1.488:08 3.388:04	0.027 0.032 0.031 0.055 1.644 1.203 0.030 0.034 2.447 2.943 1.5384 0.054
19	West Cameron 45 (LA)	AMPN AMPHI AMPHI AMPHI BEI DEE DEE E4 E4 E5959 E4 E6 E4 E6 E7 E6 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7	2 538:05 8.088:05 1.278:06 3.984:03 1.178:07 1.18:07 1.18:06 1.984:07 1.266:07 1.48:08 1.984:07 1.48:08 2.286:07	0.027 0.082 0.131 0.054 0.054 0.050 0.334 0.334 2.147 2.913 15.344 0.055 0.555 0.554 0.554 0.554 0.555 0
19 20	West Cameron 45 (LA) West Cameron 66 (LA)	AMPN AMPH1 AMPH1 DKB1 DKB1 DKB2 DKB5 E4 DKB5 E4 F4 F4 F4 F4 F4 F4 F4 F4 F4 F4 F4 F4 F4	2.578:45 8.088:45 1.278:46 5.988:45 1.588:47 1.378:47 1.388:46 1.388:46 1.388:46 1.388:46 1.388:46 1.388:46 1.388:44 1.388:44 1.388:44 1.388:44 1.388:44 1.388:44 1.388:471.388:47 1.388:47 1.388:471.388:47 1.388:47 1.388:471.388:47 1.388:47 1.388:471.388:47 1.388:471.388:47 1.388:471.388:47 1.388:471.388:47 1.398:471.398:47 1.398:471.398:47 1.398:471.398:47 1.398:471.398:47 1.399:471.399:470000	0.027 0.082 0.13 0.055 1.614 0.201 0.201 0.214 2.447 2.447 2.447 0.234 0.234 0.055 0.34 0.247 0.247 0.255 0.25
		AMPN AMPHI AMPHI AMPHI BEI DEE DEE E4 E4 E5959 E4 E6 E4 E6 E7 E6 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7 E7	2 538:05 8.088:05 1.278:06 3.984:03 1.178:07 1.18:07 1.18:06 1.984:07 1.266:07 1.48:08 1.984:07 1.48:08 2.286:07	0.027 0.032 0.131 0.054 0.054 0.050 0.334 0.334 0.34 2.913 15.344 0.050 0.350 0.354 0.354 0.050 0.354 0.050 0.
		AMPs AMPH1 AMPH13 AMPH14 DN881 DN887 DN887 DN87 DN87 DN87 DN87 F6 R R R R R I N N N N N N N N T	2.538.65 8.058.65 8.058.65 1.278.66 1.278.66 1.988.65 1.988.67 1.188.67 1.348.68 1.988.67 1.348.68 3.348.64 3.348.65 3.348.64 3.3	0.027 0.082 0.031 0.053 1.641 0.053 0.034 0.034 2.913 1.534 0.044 0.044 0.054 0.054 0.054 0.055
		AMP6 AMPH1 AMPH1 AMPH1 AMPH14 DN881 DN881 DN88 E E E E E E E E E E E E E E E E E E	2 238:03 8.08:05 1 278:06 3.986:05 1 386:07 1 386:07 1 386:07 1 48:08 1 386:07 1 48:08 3 386:07 1 48:08 3 386:04 5 216:07 6 76:06 6 76:06 8 00 8 00 1	0.027 0.032 0.13 0.035 1.614 0.33 0.334 2.913 1.534 0.004 2.913 1.534 0.004 2.913 1.534 0.004 0.004 0.005 1.625 0.00
		AMPs AMPH1 AMPH1 AMPH1 DEE1 DEE1 DEE1 E4 E4 E4 E4 E4 E4 E4 E4 E4 E4	2 538.65 8.088.65 8.088.65 1.378.66 1.378.66 1.378.66 1.488.67 1.488.67 1.488.67 1.488.67 1.488.67 2.268.67 2.348.67 2.3	0.027 0.032 0.031 0.031 0.031 0.031 0.031 0.033 0.033 0.034 2.147 2.031 1.034 0.034 0.034 0.034 0.035 0.035 0.035 0.035 0.035 0.035 0.035 0.035 0.038
		AMP6 AMPH1 AMPH1 DKB1 DKB1 DKB1 DKB1 DKB3 DKB3 DKB3 DKB3 DKB3 DKB3 DKB3 DKB3	2 238.03 8.08.05 8.08.05 1.278.09 1.386.05 1.366.07 1.366.07 1.366.07 1.346.06 1.966.07 1.346.08 1.986.07 1.346.08 1.986.07 1.346.08 1.986.07 1.346.08 1.986.07 1.346.08 1.986.07 1.346.08 1.986.07 1.346.08 1.986.07 1.946.08 1.996.07 1.946.08 1.996.07 1.946.08 1.996.07 1.946.08 1.996.07 1.946.08 1.996.07 1.946.08 1.946	0.027 0.082 0.031 0.034 1.043 0.035 0.034 0.034 2.913 1.534 0.004 0.004 0.005 0.005 0.005 0.005 1.18 0.005 1.18 0.005 0.05
		AMPs AMPHI AMPHI AMPHI AMPHI DBEB DBEB E4 B1059 E8 B1059 E8 B B1059 E8 B B1059 F B B B B B B B B B B B B B	$\begin{array}{c} 2536.68\\ \pm 0.081.05\\ \pm $	0.027 0.025 0.032 0.031 0.03 0.030 0.030 0.030 0.034 0.030 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.036 0
20	West Cameron 66 (LA)	AMPs AMPH1 AMPH1 AMPH1 DER1 DER2 DER3 E4 E4 E4 E5059 F E4 E4 E4 E4 E4 E4 E4 E4 E4 E4	$\begin{array}{c} 2536.65\\ 8.086.05\\ 1.376.66\\ 3.06.05\\ 1.376.66\\ 3.06.05\\ 1.176.07\\ 1.176.07\\ 1.176.07\\ 1.086.66\\ 1.086.66\\ 1.086.66\\ 1.086.67\\ 1.086.67\\ 1.086.66\\ 1.086.67\\ 1.086.66\\ 1.086.67\\ 1.$	0027 0025 0025 0025 0025 0025 0025 0025
		AMPS AMPHI AMPHI AMPHI AMPHI AMPHI AMPHI BES BES BES BES BES BES BES BES	$\begin{array}{c} 2.576.68\\ \pm 0.081.65\\ \pm 0.081.65\\ \pm 0.081.66\\ \pm$	0.027 0.082 0.031 0.053 0.053 0.053 0.034 0.034 2.047 2.047 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.035 0.
20	West Cameron 66 (LA)	AMPs AMPH1 AMPH1 AMPH1 AMPH1 AMPH1 AMPH1 BES BES E4 BES E4 BES E4 BES E4 BES E4 E4 E4 E4 E4 E4 E4 E4 E4 E4	2236.63 3086.65 326.67 326.67 326.67 338.66 338.64 338.64 338.64 338.64 338.64 338.64 338.64 338.64 338.64 338.64 338.64 338.64 338.64 308.66 308.66 308.66 308.66 308.66 308.66 308.66 308.66 308.66 328.67 338.68	0.027 0.027 0.037 0.011 0.03 0.030 0.030 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.035 0
20	West Cameron 66 (LA)	AMPs AMPH1 AMPH1 AMPH1 BMH	2 238.65 8.088.65 8.088.65 1.278.66 1.388.65 1.278.66 1.388.66 1.388.66 1.388.66 1.388.67 1.448.08 1.388.67 1.448.08 1.388.67 1.388.68 1.388.67 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.68 1.388.67 1.388.67 1.388.67 1.388.68 1.388.67 1.3	0027 0085 0085 0081 0081 0081 0081 0081 0081
20	West Cameron 66 (LA)	AMPS AMPHI AMPHI AMPHI AMPHI AMPHI AMPHI AMPHI AMPHI BES BES BES BES BES BES BES BES	$\begin{array}{c} 2.536.68\\ \pm 0.086.65\\ \pm 0.086.65\\ \pm 0.086.66\\ \pm$	0.027 0.027 0.013 0.022 0.014 0.014 0.014 0.030 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.032 0.032 0.03 0.03 0.03 0.03 0.03 0.
20	West Cameron 66 (LA)	AMPs AMPH1 AMPH1 AMPH1 DEST DEST DEST DEST AMPH1 DEST DE	$\begin{array}{c} 2536.68\\ 8.086.08\\ 8.086.08\\ 1.376.08\\ 1.376.08\\ 1.376.08\\ 1.376.08\\ 1.176.07\\ 1.176.07\\ 1.386.69\\ 1.986.69\\ 1.986.69\\ 1.986.69\\ 1.986.69\\ 1.986.69\\ 1.986.69\\ 1.986.69\\ 1.386.69\\ $	0.027 0.035 0.031 0.031 0.031 0.030 0.030 0.030 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.035 0.036 0.03 0.03 0.03 0.03 0.03 0.03 0.0
20	West Cameron 66 (LA)	AMPS AMPHI A	$\begin{array}{c} 2.536.68\\ \pm 0.086.65\\ \pm 0.086.65\\ \pm 0.086.66\\ \pm$	0.027 0.027 0.013 0.022 0.014 0.014 0.014 0.030 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.031 0.032 0.032 0.03 0.03 0.03 0.03 0.03 0.

Deep Subsurface Geology: Value in Sandstone Pores Offshore CO₂ Storage Resource Assessment of the Northern Gulf of Mexico (Texas-Louisiana)

Outreach



A.Sandstone is a seturiterinary reduced from sandstones Most oil and gas has been produced from sandstones appears very solid, it is really very much like a spong The holes in sandstone are called porosity. Permeab

MEST MFS2

MFS4

MFS5

MFS6

MFS7

MFS8

MES9

MFS10

MESI

LOCATION

demarcated by the ouisiana). A stratig the coastline (NE

CROSS-SECT

MFS

MFS

MFS MFS MFS MES

MFS MEST

MESI

SANDSTONE

MAPS

Mariana I Olarin Dames II -

NETL

RUBEAU OF Offshore CO₂ Storage Resource Assessment of the Northern Gulf of Mexico (Texas-Louisiana) Using Seismic Data to Locate Potential Sites for CO₂ Sequestration Michael DeAngelo, Ramon Treviño, and Dallas Dunlap

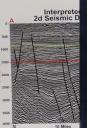
What is Seismic Data? Seismic data is an image of the earth below the near the earth's surface are reflected from und the near surface and are recorded (Figure 1). reflectors. Different rock types, and fluids in th collected in the field, processed in a computer

There is 2, 3, and 4 dimensional seismic data (2 offshore Texas and Louisiana Gulf of Mexico ar of the earth (Figure 4). 4d seismic shows a 3d y data collection today for imaging the earth's su



Figure 2. TexLa study area.

The interpreter can utilize the 3d seismic data mapping features throughout the 3d cube, it's Figure 5 is a compilation of several images that porosity zones) that are important in ranking a



Time structure map

This map highlights areas that are optimal for Structurally high areas can sometimes accum natural gas, CO2) that can be trapped by overly strata (layers). Faults can serve as a leak or es fluids. However, some faults act as traps, barrie All faults must be evaluated for leakage possib

Structural High



Accomplishments to Date

- Correlated ~ 2000 wells
- Interpreted 8 major seismic horizons
 - Sequence boundaries or maximum flooding surfaces
 - Converted seismic to depth
- Analyzed Confining zone (micro & macro)
- Analyzed 500 wells' production data (22 fields)
 Calculate equivalent mass of injected CO2
- Local and regional outreach





Lessons Learned

- Plenty of well data!
 well logs, production data,
- More seismic data than originally anticipated
 ...and probably more released soon
- Lack of rock material (cores) for interval of interest
 Only two whole cores identified / analyzed
- Unanticipated research difficulties
 - Key research staff member recently barred from project
 - international political affairs





Synergy Opportunities

- PI Meckel is participant on Battelle's mid-Atlantic Assessment Project (AAP).
 - Monthly phone conferences

Geosciences

Bureau of Economic Geology Jackson School of Geosciences

- Trevino TXLA presentation SECARB (Atlanta)
 - L. Cummings (AAP); J. Pashin, J. Knapp (SOSRA)
 - SSEB (SOSRA Prime) hosts meeting
- International Workshop on Offshore Geologic CO₂ Storage (June, 2017, Beaumont, TX)
 - Neeraj Gupta (AAP); J. Knapp, J. Pashin (SOSRA)

- SSEB (SOSRA prime): Outreach on TXLA



Project Summary

- Key Findings
 - Large amount of potential reservoir rock
 - Oil & Gas Fields
 - Saline
 - Confining zone adequate
 - Micro-scale: positive results
 - Macro-scale: seismic diffraction energy with UHR3D
 - potential new tool
- Next Steps

Bureau of Economic Geology

Jackson School of Geosciences

- Regional static storage capacity assessment
- Identify Leads & Prospects (candidates)
 - Dynamic capacity assessment (EASiTool)



Acknowledgements

- Jerry Carr (NETL PM)
- Tip Meckel (PI)

Geosciences

Bureau of Economic Geology Jackson School of Geosciences

- Mike DeAngelo (geophysicist)
- Dallas Dunlap (geophysicist)
- Iulia Olariu (geologist)
- Alexander Klokov (geophysicist
- Ali Goudarzi (engineer)
- Reinaldo Sabbagh (GRA)



Appendix

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





Benefit to the Program

- Goal (3) of the Carbon Storage Program: "Support industry's ability to predict CO₂ storage capacity in geologic formations to within ±30 percent" by assessing potential regional storage formations in State and Federally regulated offshore areas of the United States.
- Goal (4) of the Carbon Storage Program: "Develop Best Practice Manuals for monitoring, verification, accounting (MVA), and assessment; <u>site screening, selection, and initial</u> <u>characterization</u>; public outreach; well management activities; and risk analysis and <u>simulation</u>" by producing information that will be useful for inclusion in DOE Best Practices Manuals.
- <u>BENEFITS STATEMENT</u>: The methodology being developed is the assessment of <u>offshore</u> <u>CO₂ storage resources</u> in depleted hydrocarbon field settings or saline aquifers for offshore CO₂ storage applications. This approach will <u>improve the current understanding of CO₂ storage potential for a large area of the Gulf of Mexico adjacent to significant industrial emissions sources. This projects supports Goals 3 & 4 of the Carbon Storage Program Plan by assessing potential regional storage formations in state and/or federally regulated portions of the Gulf of Mexico. The study will also produce information that will be useful for inclusion in DOE Best Practices Manuals, thus supporting Goal 4.</u>





Project Overview

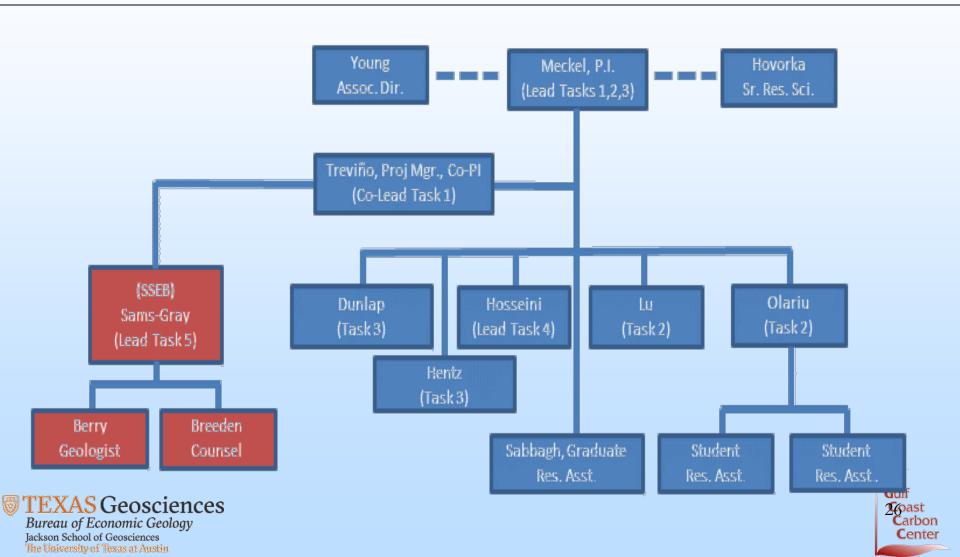
Goals and Objectives

- The objective of this study is to conduct an offshore carbon storage resource assessment of the Gulf of Mexico, Texas – Louisiana study area. This will be completed by:
 - Assessing the CO₂ storage capacity of <u>depleted oil and natural gas</u> <u>reservoirs</u> utilizing existing data (well logs, records and sample descriptions from existing or plugged/abandoned wells, available seismic surveys, existing core samples, and other available geologic and laboratory data) from historical hydrocarbon industry activities in the heavily explored portions of the inner continental shelf portions of the Texas and Louisiana Gulf of Mexico coastal areas; and
 - Assessing the ability and capacity of <u>saline formations</u> in the region to safely and permanently store nationally-significant amounts of anthropogenic CO₂ using existing data. Additionally, the study will identify at least one specific site with potential to store at least 30 million tons of CO₂ which could be considered further for a commercial or integrated demonstration project in the future.
 - The project will also <u>engage the public and other stakeholders</u> for the region through outreach activities to apprise them of the study objectives and results.





Organization Chart



Gantt Chart



Bibliography

- List peer reviewed publications generated from the project per the format of the examples below.
- <u>Klokov, A., R. H. Treviño, and T. A. Meckel, 2017, Diffraction imaging for seal</u> <u>evaluation using ultra high resolution 3D seismic data: Marine and Petroleum</u> <u>Geology, v. 82, p. 85-96.</u>



