Offshore CO_2 Storage Resource Assessment of the Northern Gulf of Mexico (Upper Texas-Western Louisiana Coastal Areas)

TX-LA

DE-FE0026083

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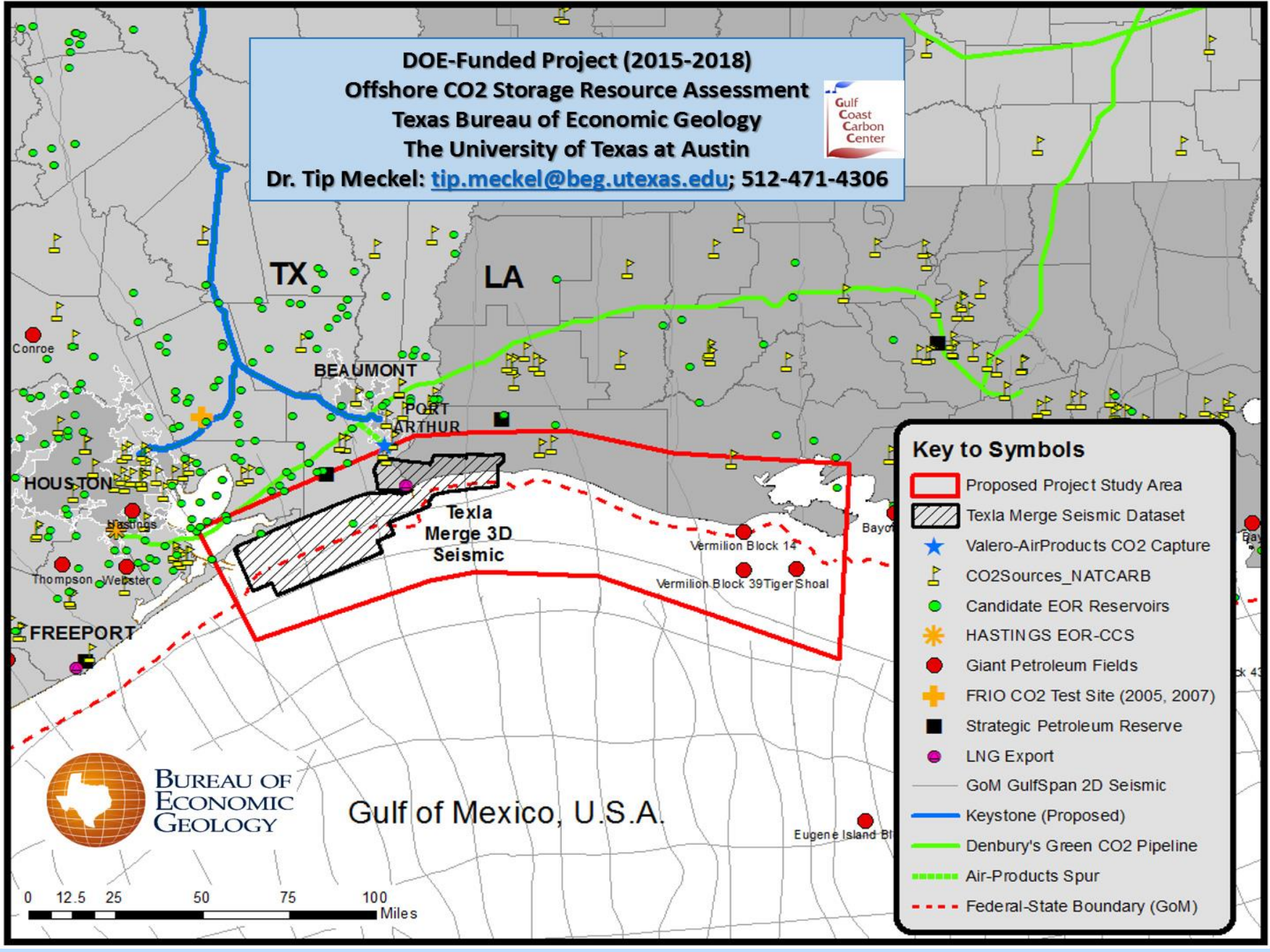
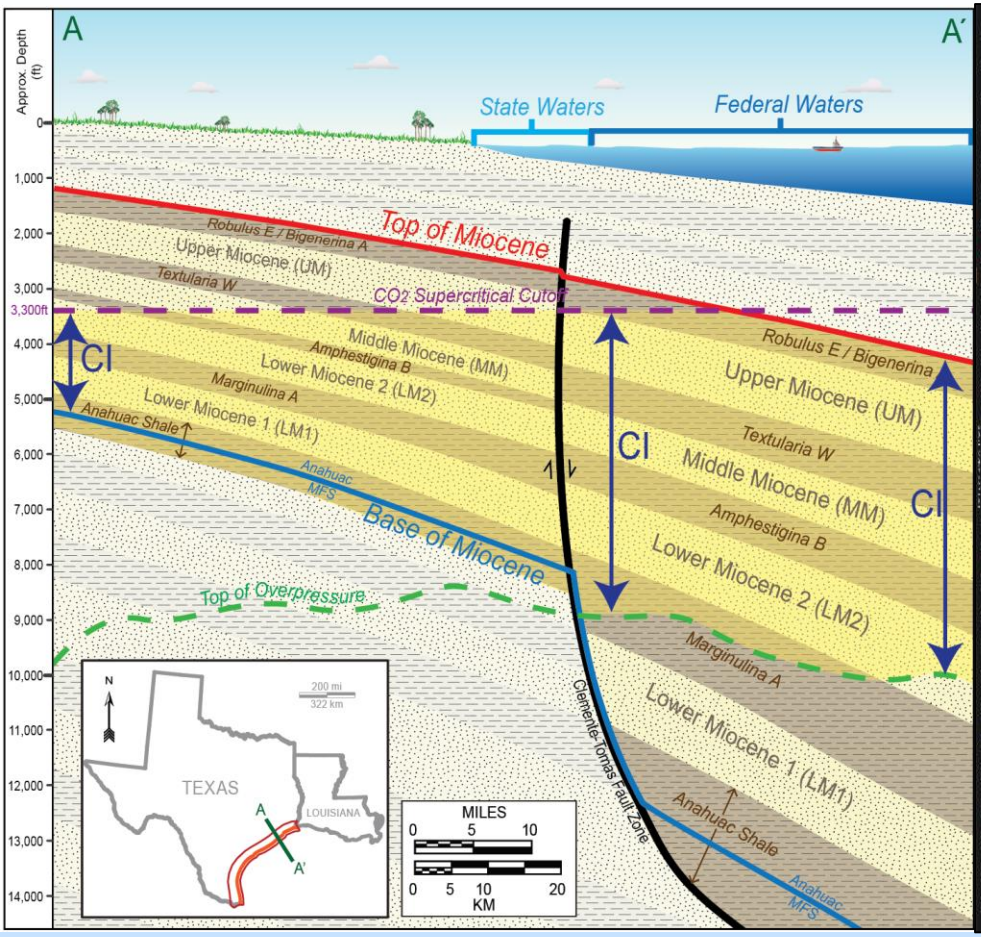
TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

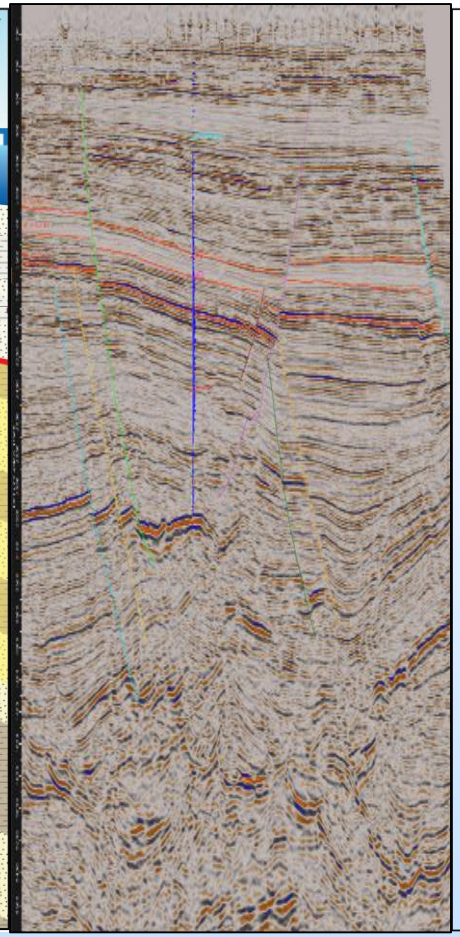
Gulf Coast Carbon Center

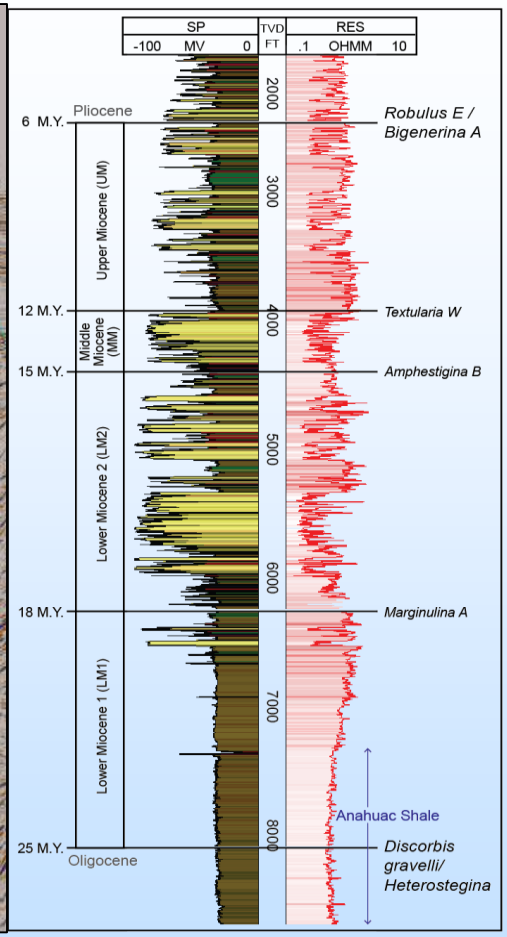
U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology, Innovation and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 16-18, 2016


DOE-Funded Project (2015-2018)
Offshore CO2 Storage Resource Assessment
Texas Bureau of Economic Geology
The University of Texas at Austin
Dr. Tip Meckel: tip.meckel@beg.utexas.edu; 512-471-4306
Gulf Coast Carbon Center
TX
LA
Conroe
BEAUMONT
PORT ARTHUR
HOUSTON
Hastings
Thompson
Webster
FREEPORT
Texla Merge 3D Seismic
Vermilion Block 14
Vermilion Block 39
Tiger Shoal
Eugene Island Bl
Gulf of Mexico, U.S.A.
BUREAU OF ECONOMIC GEOLOGY
0 12.5 25 50 75 100 Miles
Key to Symbols
Proposed Project Study Area
Texla Merge Seismic Dataset
Valero-AirProducts CO2 Capture
CO2Sources_NATCARB
Candidate EOR Reservoirs
HASTINGS EOR-CCS
Giant Petroleum Fields
FRIO CO2 Test Site (2005, 2007)
Strategic Petroleum Reserve
LNG Export
GoM GulfSpan 2D Seismic
Keystone (Proposed)
Denbury's Green CO2 Pipeline
Air-Products Spur
Federal-State Boundary (GoM)

Conceptual Overview







Presentation Outline

- **Benefit to Program**
- **Project Overview: Goals and Objectives**
- **Technical Status**
- **Accomplishments to Date**
- **Synergy Opportunities**
- **Summary**
- **Appendices**
  - **Organization Chart**
  - **GANTT Chart**
  - **Bibliography**

Benefit to the Program

- **Goal (3) of the Carbon Storage Program**: "*Support industry's ability to predict CO_2 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; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation*" by **producing information that will be useful for inclusion** in DOE Best Practices Manuals.

- BENEFITS STATEMENT: The methodology being developed is the assessment of offshore CO_2 storage resources in depleted hydrocarbon field settings or saline aquifers for offshore CO_2 storage applications. This approach will improve the current understanding of CO_2 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.

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 CO_2 storage **capacity of depleted oil and natural gas reservoirs 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 **saline formations** in the region to safely and permanently store nationally-significant amounts of anthropogenic CO_2 using existing data. Additionally, **the study will identify at least one specific site with potential to store at least 30 million tons of CO_2 which could be considered further for a commercial or integrated demonstration project in the future**.
  - The project will also **engage the public and other stakeholders** for the region through outreach activities to apprise them of the study objectives and results.

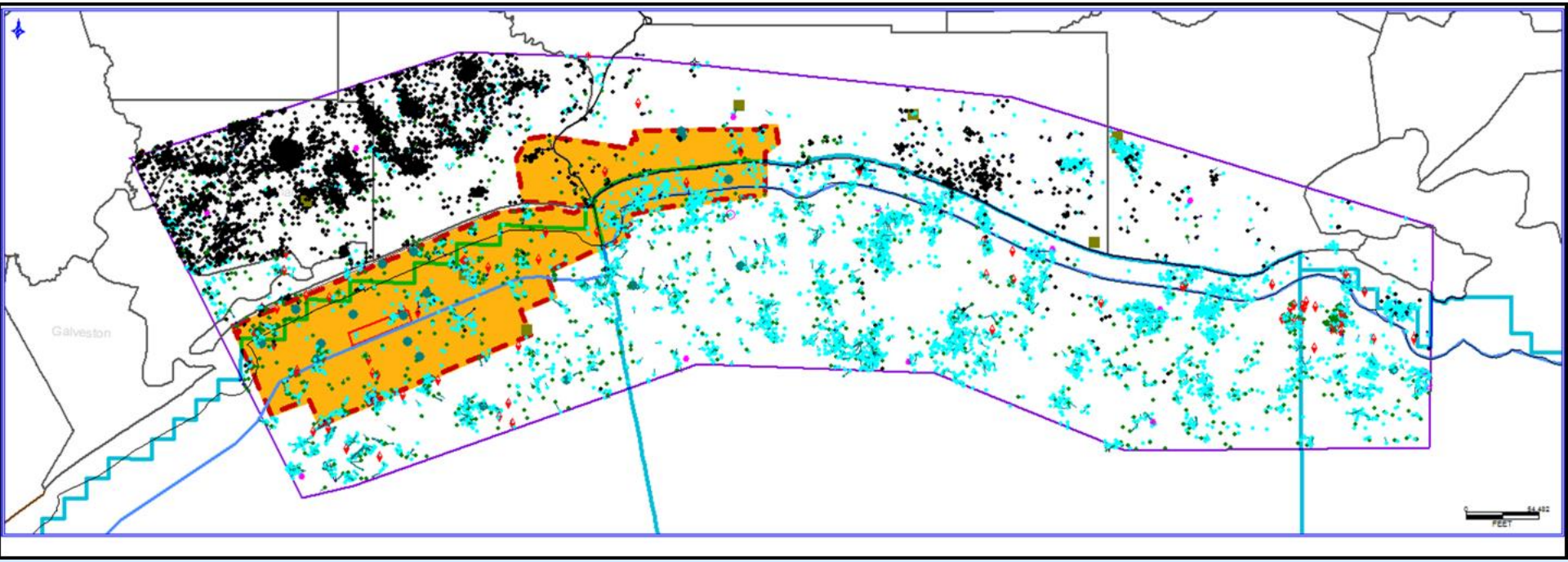
Technical Status

Task	Tasks	BUDGET PERIOD 1				BUDGET PERIOD 2				BUDGET PERIOD 3			
		YEAR 1				YEAR 2				YEAR 3			
		Qtr 1	Qtr2	Qtr3	Qtr4	Qtr 1	Qtr2	Qtr3	Qtr4	Qtr 1	Qtr2	Qtr3	Qtr4
		S-O-N	D-J-F	M-A-M	J-J-A	S-O-N	D-J-F	M-A-M	J-J-A	S-O-N	D-J-F	M-A-M	J-J-A
		2015	2016				2017				2018		
Offshore CO2 Storage Resource Assessment of the Northern Gulf of Mexico(TX-LA)													
1	**Project Management, Planning, and Reporting**	Q = Quarterly Report; M = Milestone; DP = Decision Point; F = Final Report											
	Revision and Maintenance of Project Management Plan	MA; MB											
	Progress Report	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q/F
2	**Conduct RegionalGeologic Assessment**												
2.1	Database Development			MC; MD		MF	MG						
2.2	Develop Comprehensive Data Set for Reservoir Properties							MH					
2.3	Develop Structural Closure Mapping for Reservoirs								MI				
2.4	Assess Seal Interval Characteristics				ME; DP1						MJ		
2.5	Analyze CO2 Prospect Categories											MK	
3	**Static Capacity Estimates**												
3.1	Regional Capacity Assessment												ML
3.2	Local Prospect Resource Assessment												MM
3.3	Data Management												
4	**Dynamic Capacity Assessments**												
4.1	Pressure Decline Analysis												
4.2	EASiTool (Enhanced Analytical Simulation Tool) Application								DP2				MN
5	**Outreach and Stakeholder Engagement**												
5.1	Local Public and Stakeholder Outreach												
5.2	Regional outreach												

- ***Subtask 2.1 – Database Development (Milestones C & D)***
  - ***WELLS***
  - ***SEISMIC***
- ***Subtask 2.2 – Comprehensive Data set for Reservoir Properties***
- ***Subtask 2.4 – Assess Seal Interval Characteristics (Milestone E)***

- ***Task 5: Local and Regional Public and Stakeholder Outreach***

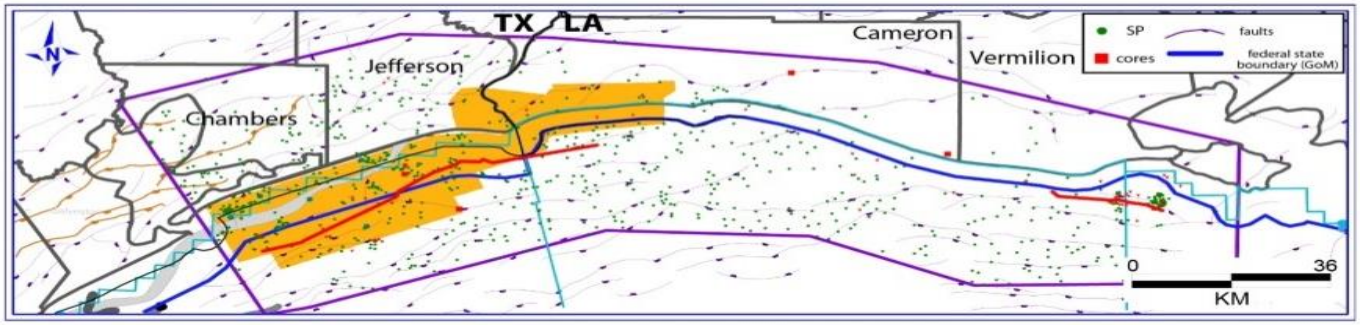
Milestone D – Quick-Look Report Summarizing the Selection of Well Data for Regional Correlation

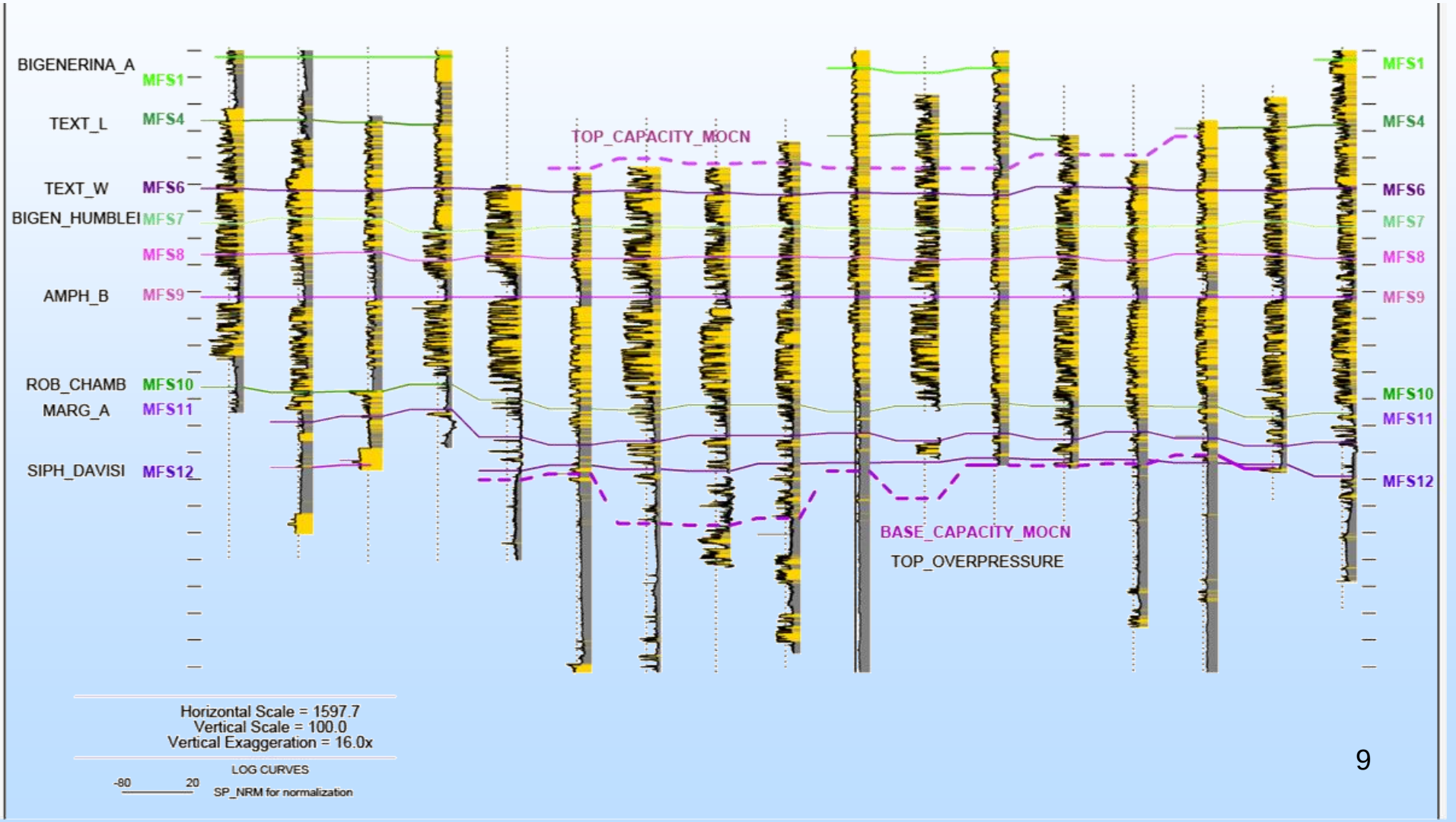


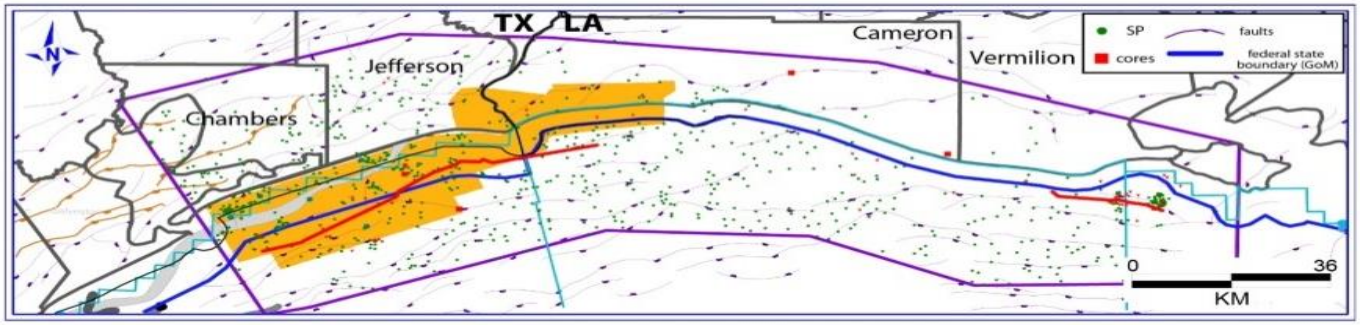
Map of the study area including wells and primary 3D seismic dataset.
Location of the primary 3D seismic dataset (“TexLa Merge”) is highlighted in orange.

- 11,817 wells in the study area, 5250 of which have wireline well log raster data only (black dots);
  Of those, 4337 raster logs were purchased from vendor, MJ Systems.
- 900 wells have digital SP curves (green dots);
- 74 have digital gamma ray (red rhombs) and
- 7 wells have whole core (olive-green squares).

- The cyan colored dots represent wells currently without raster or LAS data.


TX
LA
Cameron
Vermilion
Jefferson
Chambers
SP
cores
faults
federal state boundary (GoM)
0
36
KM


BIGENERINA_A
MFS1
TEXT_L
MFS4
TOP_CAPACITY_MOCN
TEXT_W
MFS6
BIGEN_HUMBLEI
MFS7
MFS8
AMPH_B
MFS9
ROB_CHAMB
MFS10
MARG_A
MFS11
SIPH_DAVISI
MFS12
BASE_CAPACITY_MOCN
TOP_OVERPRESSURE
Horizontal Scale = 1597.7
Vertical Scale = 100.0
Vertical Exaggeration = 16.0x
LOG CURVES
-80
20
SP_NRM for normalization


TX
LA
Jefferson
Chambers
Cameron
Vermilion
SP
cores
faults
federal state boundary (GoM)
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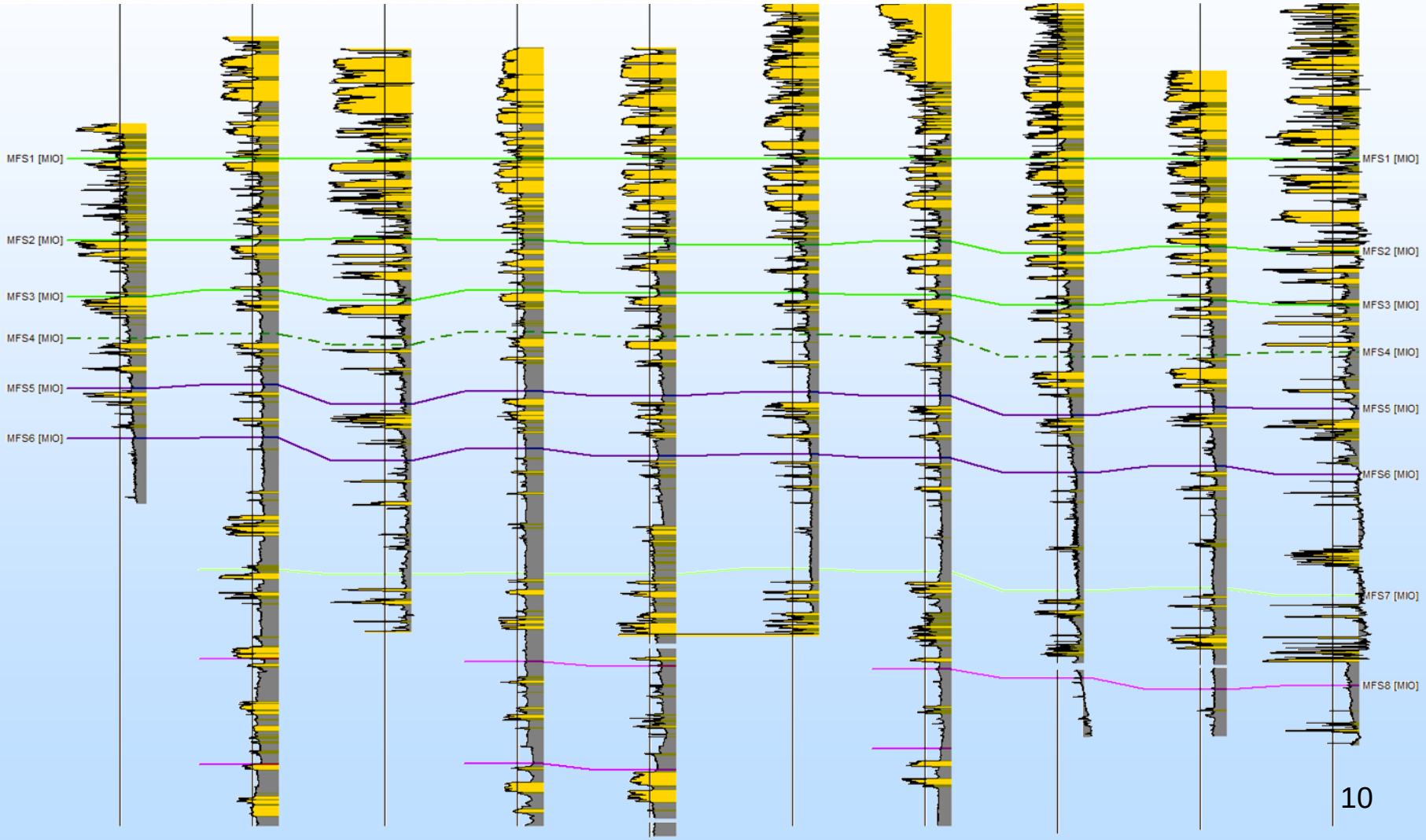
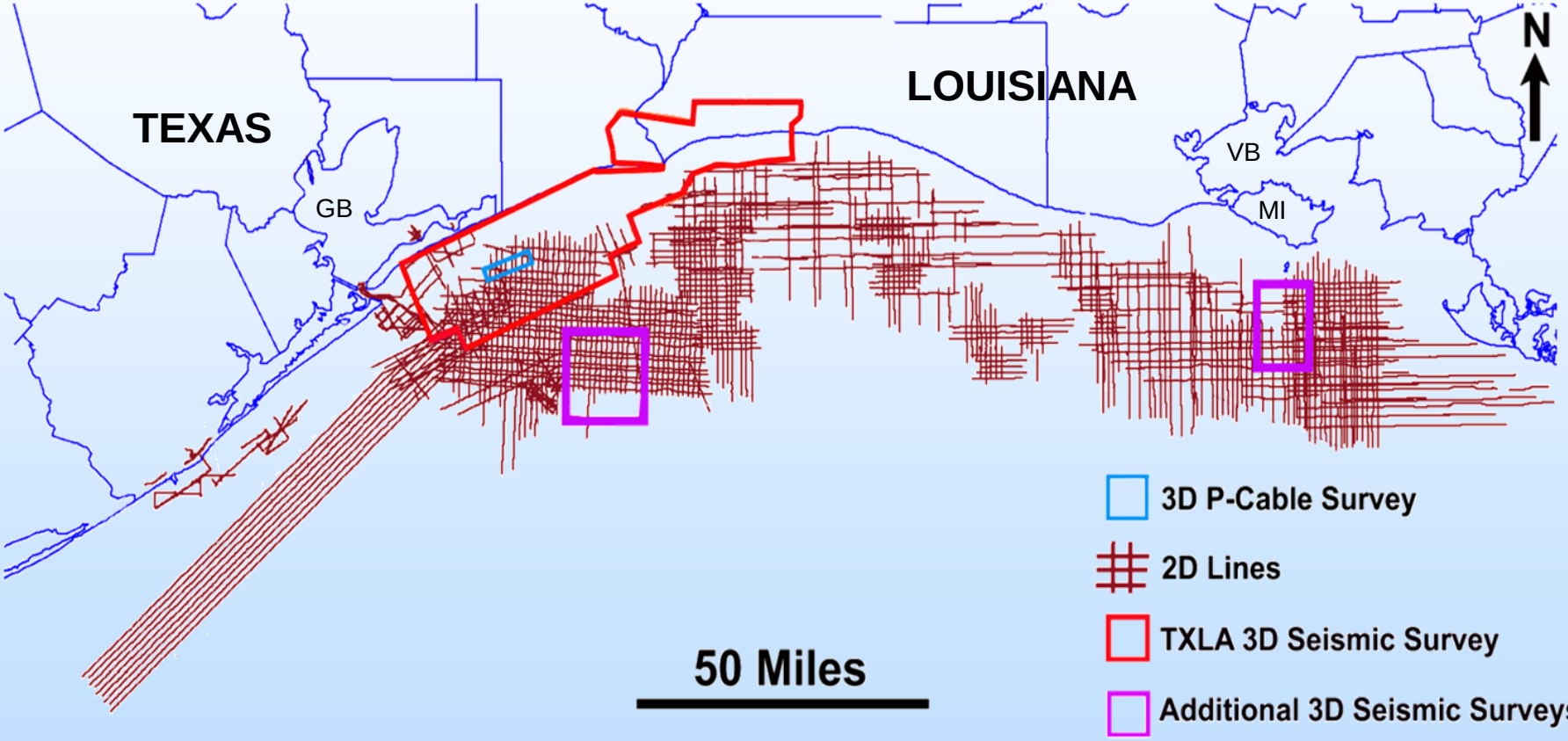
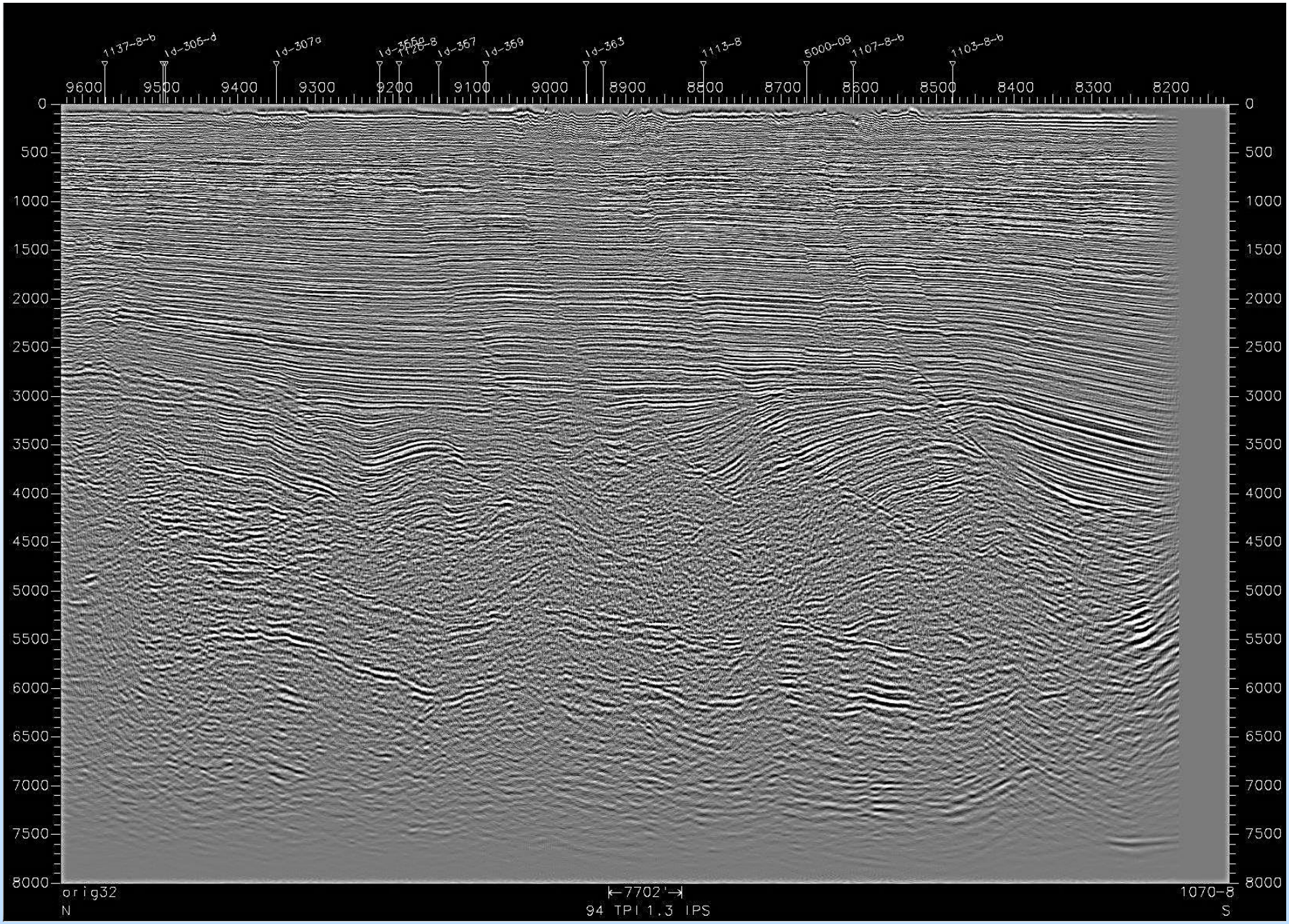
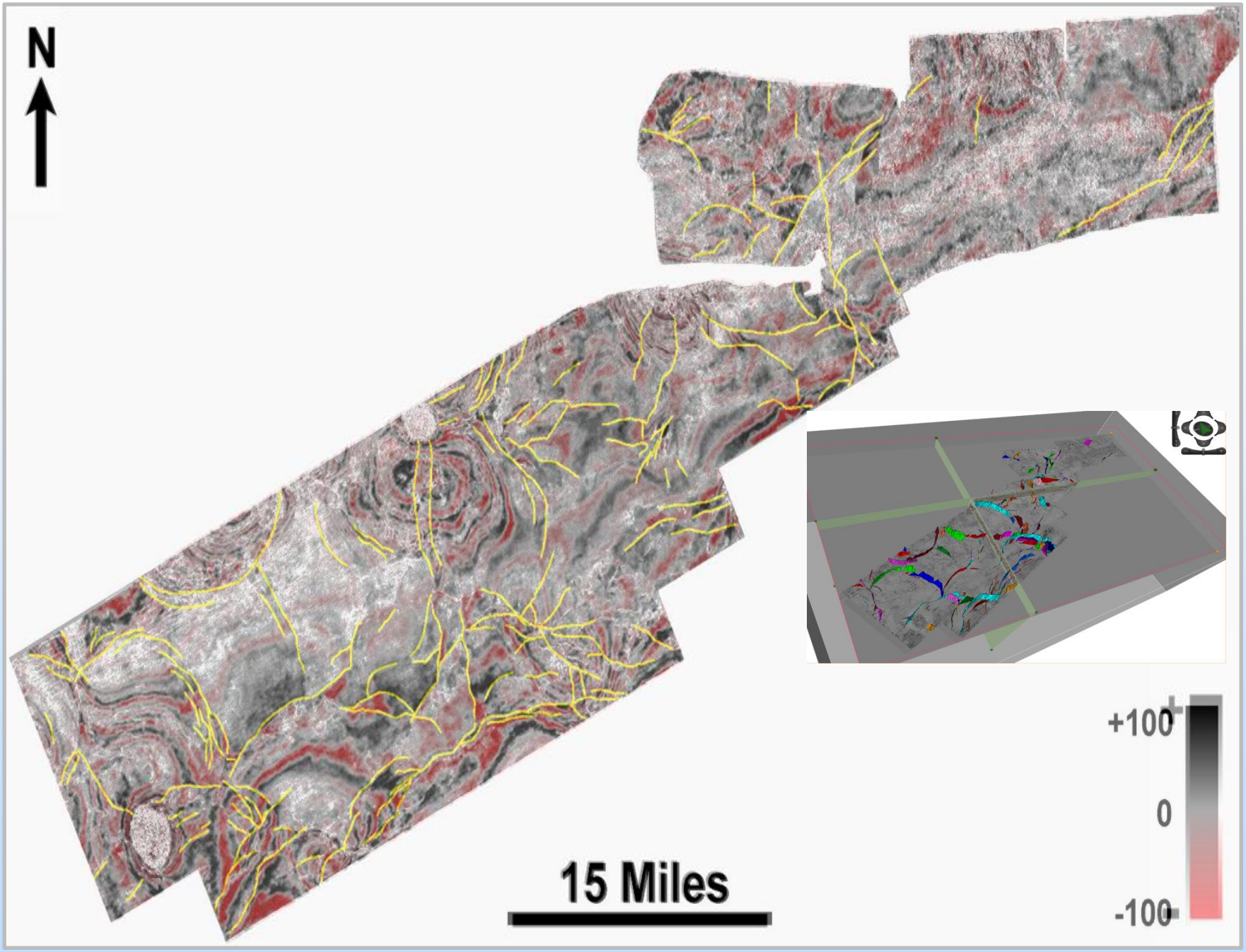
36
KM


MFS1 [MIO]
MFS2 [MIO]
MFS3 [MIO]
MFS4 [MIO]
MFS5 [MIO]
MFS6 [MIO]
MFS7 [MIO]
MFS8 [MIO]

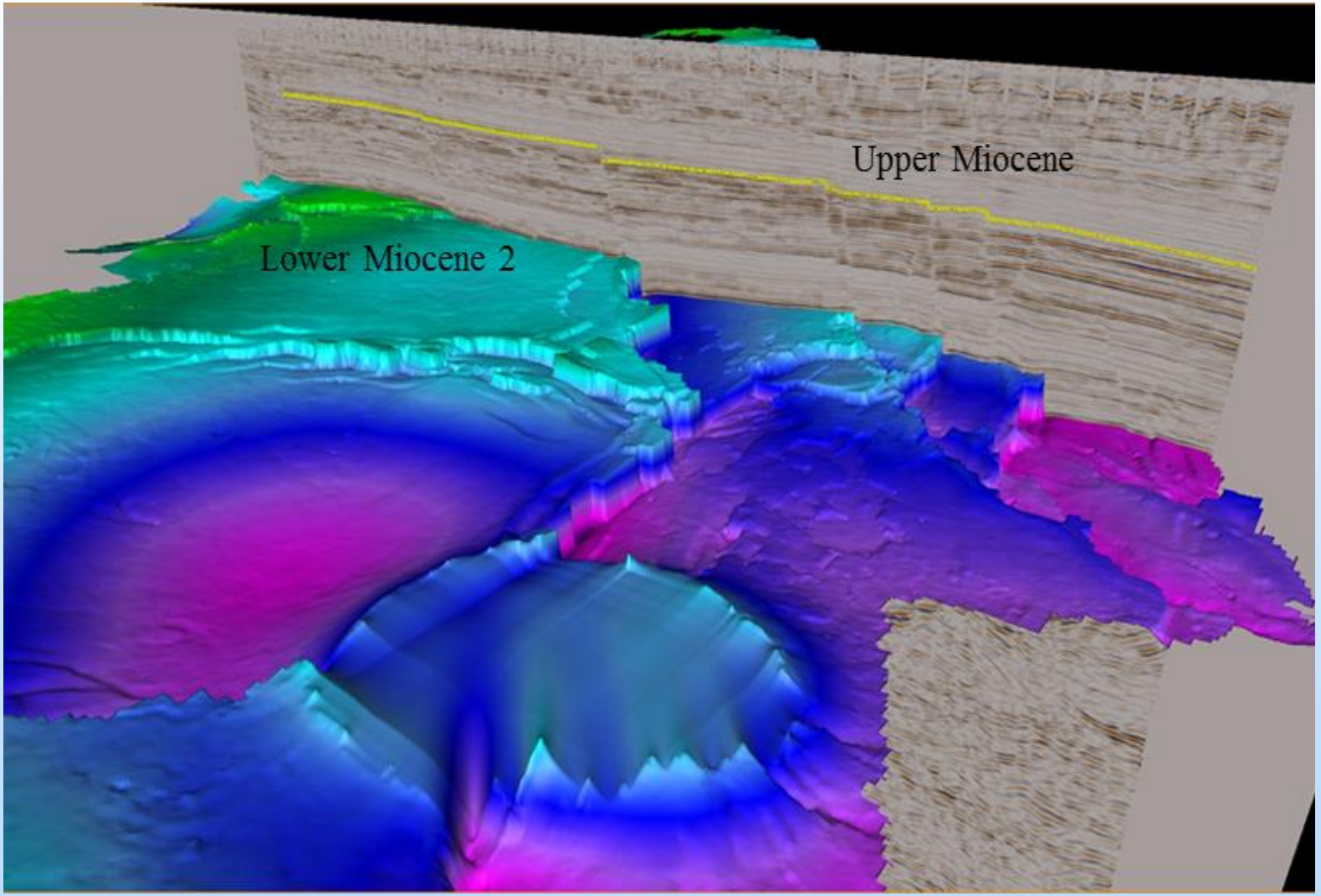
Milestone C - Map of Completed Selection of Seismic Data for Regional Correlation



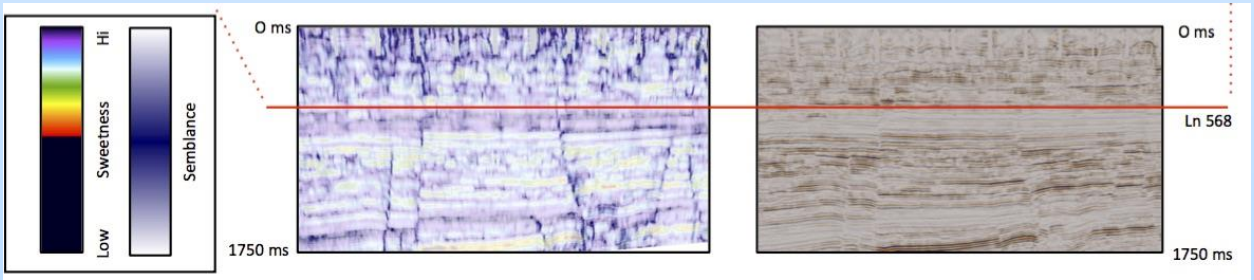

1137-8-b
ld-306-d
ld-307a
ld-356a
1128-8
ld-357
ld-359
ld-363
1113-8
5000-09
1107-8-b
1103-8-b
9600
9500
9400
9300
9200
9100
9000
8900
8800
8700
8600
8500
8400
8300
8200
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
orig32
N
7702'
94 TPI 1.3 IPS
1070-8
S


N
15 Miles
+100
0
-100

Lower Miocene 2 (LM2) surface (approximately equivalent to the *Marginulina A* biozone) is the most extensively mapped surface to date. The manually picked seismic horizon marked by a positive amplitude event at the base of a homogenous seismic event was tentatively designated as Top Lower Miocene 2 (LM2).



Co-rendered sweetness and semblence timeslice (532 ms below MSL) of the sothern portion of the 3D volume showing the complex geomorphology preserved in the dataset.



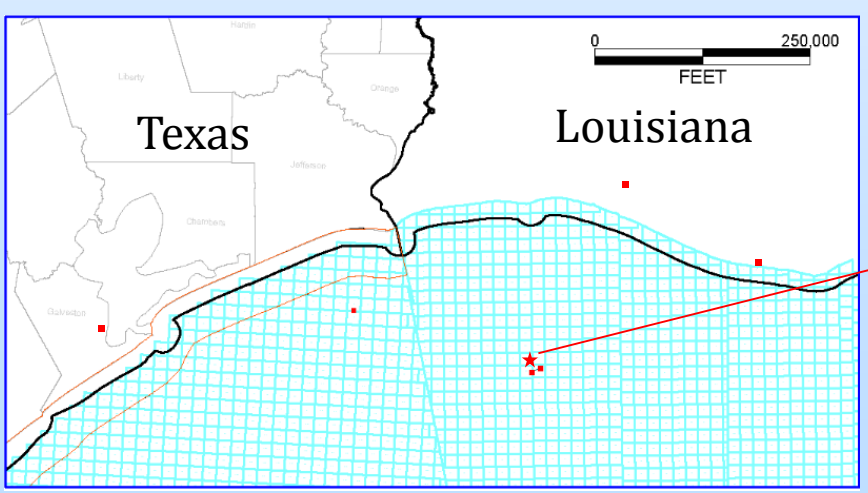
Semblence highlights edges and continuity.
Change in sweetness signals a change in lithology or fluid.

Milestone E – List of Identified Core/Wells for Analyses

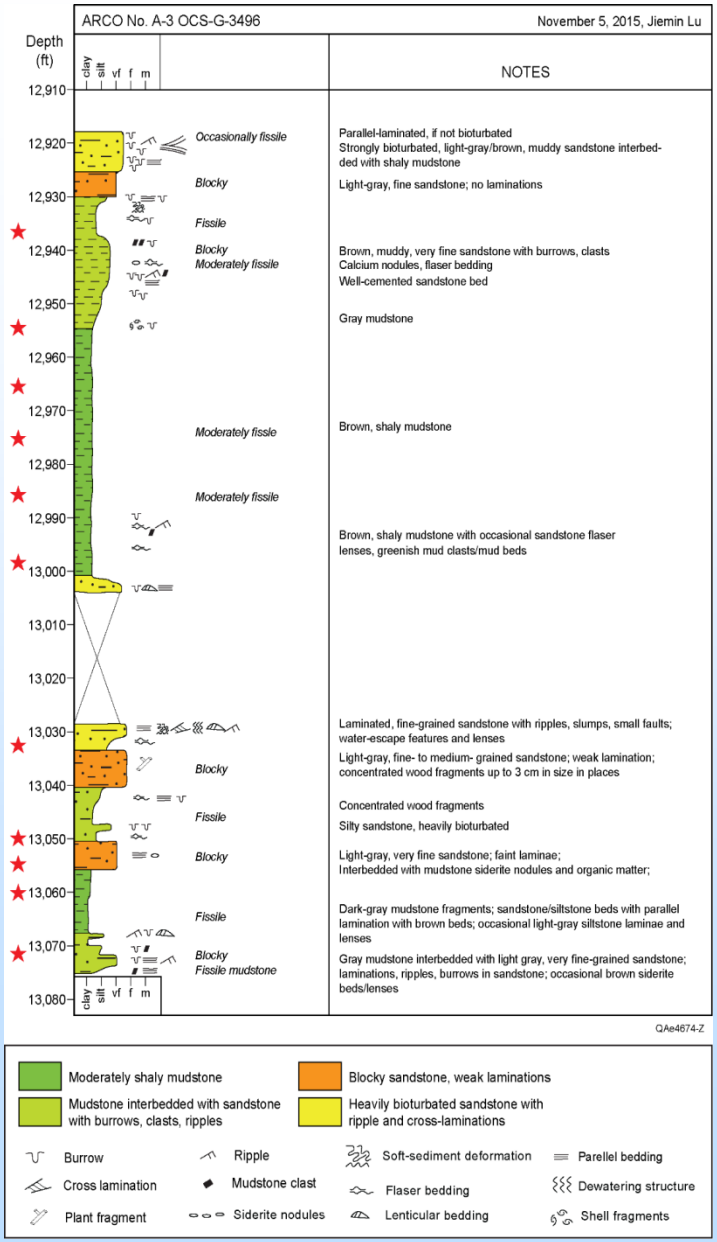
UWI/API	STATE	COUNTY / PARISH	Well ID	OPERATOR	LEASE	ELEV_KB	TD (ft)	Top depth (ft)	Base depth (ft)	Sample Type	Longitude	Latitude
171132160800	LA	VERMILION		AMOCO PROD CO	WATKINS E M	36	10850	7003	7072	SLABBED CORE	-92.59224	29.80006
17023023450000	LA	CAMERON		PAN AMERICAN	SL 04210		18436	17846	17870	SLABBED CORE	-92.6487	29.6035
17023200240000	LA	CAMERON		PAN AMERICAN	GULF LAND A R/A /C/		4588	3843	4433	SLABBED CORE	-93.42716	29.98916
17023202590000	LA	CAMERON		PAN AMERICAN	BRUCE J VINCENT		1706	1588	1701	WHOLE CORE	-93.39067	29.99254
17023202650000	LA	CAMERON		PAN AMERICAN	B LYONS PALMER		1630	1558	1598	SLABBED CORE	-93.3993	29.9952
17023202680000	LA	CAMERON		PAN AMERICAN	AGNES LOWERY		1595	1555	1590	SLABBED CORE	-93.4037	29.9999
17023202730000	LA	CAMERON		PAN AMERICAN	RAY DUHON		2092	1871	1907	SLABBED CORE	-93.3887	29.99089
17023202760000	LA	CAMERON		PAN AMERICAN	GLADYS TRAHAN		1933	1872	1931	SLABBED CORE	-93.3943	29.9885
17023202810000	LA	CAMERON		PAN AMERICAN	M L GRAY		2092	1848	1872	SLABBED CORE	-93.38768	29.99177
17023202820000	LA	CAMERON		PAN AMERICAN	M L GRAY		1753	1737	1750	SLABBED CORE	-93.3873	29.9929
17023202870000	LA	CAMERON		PAN AMERICAN	M L GRAY	16	2094	1848	1939	SLABBED CORE	-93.3858	29.99193
17023216370000	LA	CAMERON		AMOCO PROD CO	SL 00042	18	10087	9266	9382	WHOLE CORE	-93.40507	30.01792
17023220570000	LA	CAMERON		ARCO OIL & GAS CO	RP MIAMI	26	20026	16264	16298	SLABBED CORE	-93.0782	29.87002
17023226220000	LA	CAMERON		VASTAR RESOURCES	INCMIAMI CORP	33	15968	6862	6880	SLABBED CORE	-93.49566	29.88343
17113216240000	LA	VERMILION		AMOCO PROD CO	WATKINS E M	25	7810	7304	7364	SLABBED CORE	-92.59398	29.81337
17113216260000	LA	VERMILION		AMOCO PROD CO	WATKINS E M	25	8816	7401	7448	SLABBED CORE	-92.59376	29.81333
42708303160000	TX	HIGH ISLAND		VASTAR RESOURCES	INCSL 59455	83	10692	8401	8431	SLABBED CORE	-94.14044	29.5371
177004040000	LA	W CAMERON BLK 205	A-3	ARCO OIL & GAS CORP	OCS-G-3496	91	13,505	12918	13074	SLABBED CORE	-93.3312	29.2597
177004063100	LA	W CAMERON BLK 205	C-4	ATLANTIC RICHFIELD COMPANY THE	OCS-G-4392	120	13,829	13100	13160	SLABBED CORE	-93.3317	29.2287
427084032600	TX	HIGH ISLAND-L B	1	ATLANTIC RICHFLD CO	OCS-G-10266	90	12077	10722	10748	SLABBED CORE	-93.989	29.4199
177004061700	LA	WEST CAMERON	C-5	FORCE ENERGY GAS EXPL INCORP		120	17,220	11409	11415	SLABBED CORE	-93.3317	29.2287
421673064500	TX	GALVESTON	30645		SOUTH GILLOCK UNIT #94	100	10,000	9163	9181	SLABBED CORE	-94.9674	29.391
17707400570000	LA	S MARSH	1	AMOCO PROD CO	OCS-G-2305	99	10,246	710	10250	CUTTINGS	-92.14837	29.18225
17707403910000	LA	S MARSH ISLAND BLK 232	1	CONOCO INC	OCS-G-4435	83	11965	8130	10500	CUTTINGS	-92.13898	29.36718
17707402610000	LA	S MARSH ISLAND BLK 260	A-2	AMOCO PRODUCTION CO	OCS-G-2305	89	12,568	11389	12565	CUTTINGS	-92.13627	29.19544
17707400430000	LA	S MARSH ISLAND	1	CHEVRON	OCS-G-2301	40	15,752	920	15730	CUTTINGS	-92.03333	29.22488

CORE

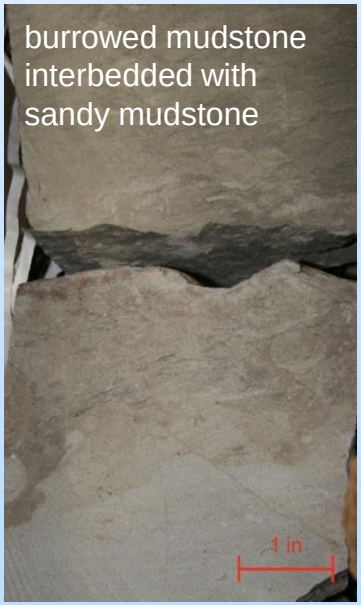
API Number	Well ID	Location	Lease Name	Top Depth (ft)	Bottom Depth (ft)	Sample Type	Reservoir	LON	LAT
177004040000	**A-3**	**County: WEST CAMERON State: LOUISIANA**	**OCS-G-3496**	**12918**	**13074**	**SLABBED CORE**	**WEST CAMERON**	**-93.3312**	**29.2597**
177004063100	C-4	County: WEST CAMERON State: LOUISIANA	OCS-G-4392	13100	13160	SLABBED CORE	198	-93.3317	29.2287
427084032600	1	County: HIGH IS-L B State: TEXAS	OCS-G-10266	10722	10748	SLABBED CORE	Unknown	-93.9890	29.4199
177004061700	C-5	County: WEST CAMERON State: LOUISIANA		11409	11415	SLABBED CORE	WEST CAMERON 212	-93.3317	29.2287
170230234500	02345	County: CAMERON State: LOUISIANA		17846	17870	SLABBED CORE	WILDCAT 17	-92.6487	29.6035
170232205700	D-1	County: CAMERON State: LOUISIANA	MIAMI CORP	16264	16298	SLABBED CORE	HIGH ISLAND	-93.0782	29.8700
421673064500	30645	County: GALVESTON State: TEXAS	SOUTH GILLOCK UNIT #94	9163	9181	SLABBED CORE	GILLOCK S	-94.9674	29.3910



Core description of OCS-G-3496 A-3, West Cameron Block 205, Louisiana



Sample ID	Well	Sample depth (ft)	Lithology
1	OCS-G-3496 A-3	12937	Mudstone
2	OCS-G-3496 A-3	12954.2	Argillaceous silty claystone
3	OCS-G-3496 A-3	12966.8	Mudstone
4	OCS-G-3496 A-3	12975.5	Mudstone
5	OCS-G-3496 A-3	12984.9	Mudstone
6	OCS-G-3496 A-3	12999.5	Argillaceous silty claystone
7	OCS-G-3496 A-3	13033	Mudstone
8	OCS-G-3496 A-3	13050	Siliceous siltstone
9	OCS-G-3496 A-3	13056	Fine-grained sandstone
10	OCS-G-3496 A-3	13060.5	Argillaceous silty claystone
11	OCS-G-3496 A-3	13071.5	Mudstone

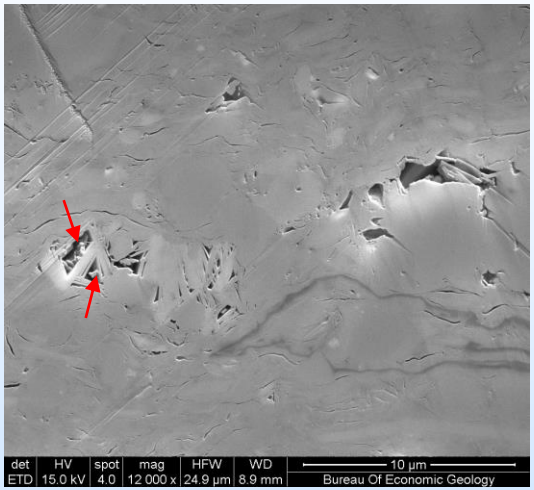


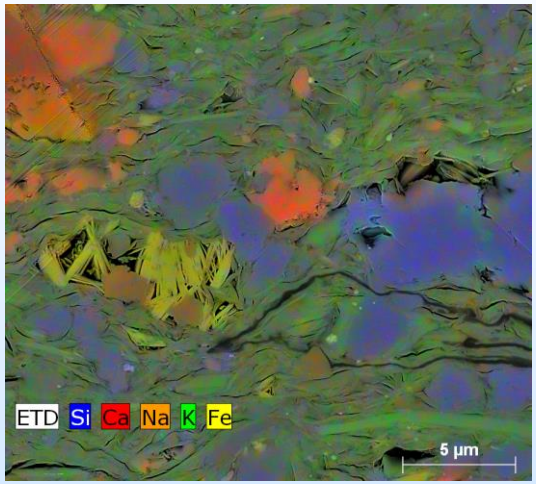
Eleven samples (above) were taken from the core for further analyses, such as scanning electron microscope (**SEM**), X-ray diffraction (**XRD**), mercury intrusion capillary pressure (**MICP**), etc.

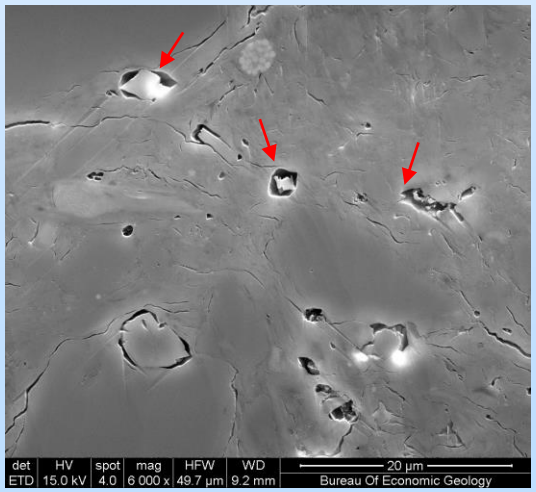
Four have been polished by state-of-the-art ion milling and examined using SEM.

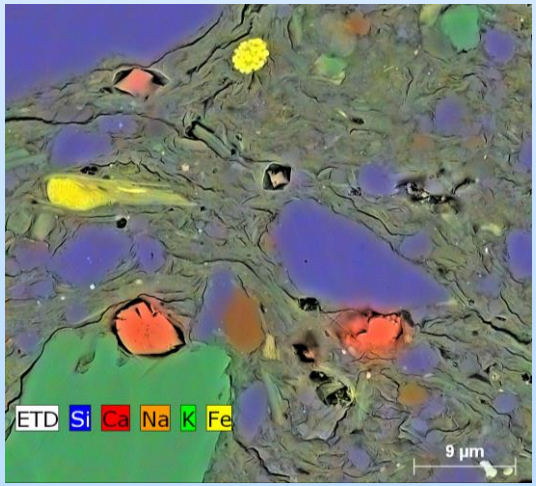
The silty claystone is dominated by extra-basinal siliciclastic detrital grains of quartz, illite, chlorite, mica, and small amounts of plagioclase and K-feldspar

The majority of the observed pores are secondary pores derived from mineral dissolution and later partially filled with diagenetic minerals (chlorite, calcite)









Accomplishments to Date

- A website, was established for the project: http://www.beg.utexas.edu/gccc/osra.php
- **Map of Completed Selection of Seismic Data for Regional Correlation**
- **Quick-Look Report Summarizing the Selection of Well Data for Regional Correlation**
- **List of Identified Core/Wells for Analyses**
- Initial Structural Map of the LM2 Surface
- Initial 3D Fault Network Mapping
- Core identified, sampled, analyzed

Accomplishments to Date

- Local and Regional Local and Stakeholder Outreach
  - SSEB:
    - http://www.sseb.org/programs/sosra/
    - Southern State Energy Board's Executive Committee
    - David Mohler, Deputy Assistant Secretary of Clean Coal and Carbon Management;
    - Elena Melchert, Senior Program Manager, U.S. Department of Energy Office of Oil and Gas
    - Southwestern Electric Power Company
  - BEG
    - Port Arthur, La Porte
    - UT BEG GCCC hosted an "International Workshop on Offshore Geologic CO_2 Storage" (April 19-21, 2016) sponsored by CSLF (Carbon Sequestration Leadership Forum)

Synergy Opportunities

- Meckel is participant on Battelle's Atlantic Assessment Project.
  - Monthly phone conferences
  - Meeting in September
  - Consultation with G. Mountain @ Rutgers on HR3D seismic.
- International Workshop on Offshore Geologic CO_2 Storage (April, 2016): L. Cummings
- Annual Review Meeting

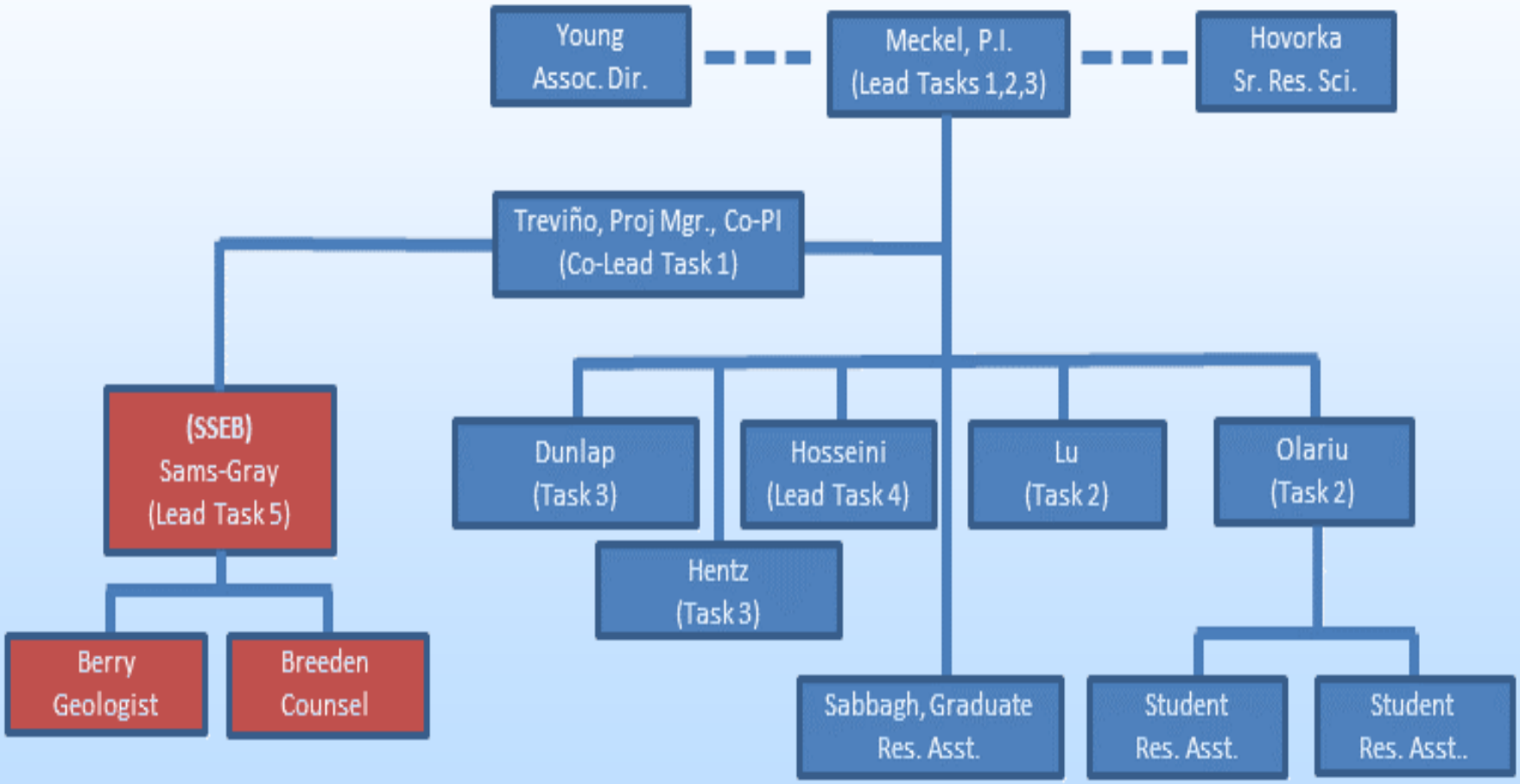
Summary

- **Key Findings:** LM2 surface, Fault polygons, Seal Characterization.
- **Lessons Learned:** Integration of 2D-3D seismic and well logs; Seal material scarce but useful.
- **Future Plans:**
  - Local Prospect Resource Assessment
  - Development of Comprehensive Data Set of Reservoir Properties
  - Regional Capacity Assessment
  - Structural Closure Mapping for Reservoirs
  - Pressure Decline Analysis

Appendix

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

Organization Chart



Gantt Chart

Task	Tasks	BUDGET PERIOD 1				BUDGET PERIOD 2				BUDGET PERIOD 3			
		YEAR 1				YEAR 2				YEAR 3			
		Qtr 1	Qtr2	Qtr3	Qtr4	Qtr 1	Qtr2	Qtr3	Qtr4	Qtr 1	Qtr2	Qtr3	Qtr4
		S-O-N	D-J-F	M-A-M	J-J-A	S-O-N	D-J-F	M-A-M	J-J-A	S-O-N	D-J-F	M-A-M	J-J-A
		2015	2016				2017				2018		
Offshore CO2 Storage Resource Assessment of the Northern Gulf of Mexico(TX-LA)													
1	**Project Management, Planning, and Reporting**	Q = Quarterly Report; M = Milestone; DP = Decision Point; F = Final Report											
	Revision and Maintenance of Project Management Plan	MA; MB											
	Progress Report	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q/F
2	**Conduct RegionalGeologic Assessment**												
2.1	Database Development			**MC; MD**		**MF**	**MG**						
2.2	Develop Comprehensive Data Set for Reservoir Properties							**MH**					
2.3	Develop Structural Closure Mapping for Reservoirs								**MI**				
2.4	Assess Seal Interval Characteristics				**ME**; DP1						MJ		
2.5	Analyze CO2 Prospect Categories											MK	
3	**Static Capacity Estimates**												
3.1	Regional Capacity Assessment												ML
3.2	Local Prospect Resource Assessment												MM
3.3	Data Management												
4	**Dynamic Capacity Assessments**												
4.1	Pressure Decline Analysis												
4.2	EASiTool (Enhanced Analytical Simulation Tool) Application								DP2				MN
5	**Outreach and Stakeholder Engagement**												
5.1	Local Public and Stakeholder Outreach												
5.2	Regional outreach												

Project Milestones

Budget Period	Task/ Subtask	Milestone ID/Description	Planned Completion	Verification Method[1,2]
1	1.0/1.1	A. Updated Project Management Plan	10/30/2015	Project Management Plan file
1	1.0	B. Kickoff Meeting	11/30/2015	Presentation file
1	**2.0/2.1**	**C. Compile map with completed selection of seismic data for regional correlation**	**5/31/2016**	**Map**
1	**2.0/2.1**	**D. Quick-look report summarizing the selection of well data for regional correlation**	**6/30/2016**	**Quick-look report.**
1	**2.0/2.4**	**E. Compile list of identified core/wells for analyses**	**7/31/2016**	**List**
2	**2.0/2.1**	**F. Compile representative data (i.e. cross section) for the integrated well-seismic correlation of major stratigraphic surfaces**	**12/31/2016**	**Representative data**
2	**2.0/2.1**	**G. Quick-look report documenting finalized geologic database**	**3/31/2017**	**Quick-look report**
2	**2.0/2.2**	**H. Quick-look report documenting the finalized reservoir property database**	**6/30/2017**	**Quick-look report**
2	**2.0/2.3**	**I. Quick-look report documenting the structural closure mapping and analyses completed**	**7/31/2017**	**Quick-look Report**
3	2.0/2.4	J. Quick-look report summarizing the seal characteristics determined	1/31/2018	Quick-look Report
3	2.0/2.5	K. Quick-look report describing CO_2 prospect categories determined and analyzed in this work	6/30/2018	Quick-look Report
3	3.0/3.1	L. Quick-look report documenting the static regional capacity estimates determined in addition to supporting data including time/depth structure, porosity, isopach maps used for capacity calculations, as well as maps with capacity estimates gridded at appropriate resolution for the datasets used (nominally 25 km^2)	7/31/2018	Quick-look Report
3	3.0/3.2	M. Complete a summary sheet that describes the 30 Mt site identified	8/31/2018	Summary sheet
3	4.0/4.2	N. Quick-look report documenting the results from the EasiTool analyses including capacity estimates, reservoir performance, summary statistics, and sensitivity analyses	7/31/2018	Quick-look Report

Bibliography

List peer reviewed publications generated from the project

Journal, multiple authors:

- Klokov, A., Trevino, R. and Meckel, T.A., *in review*, Diffraction imaging for sealing evaluation using ultra-high resolution 3D (P-Cable) data (Interpretation).

- Merzlikin, D., Meckel, T.A., and Fomel, S., *in review*, Diffraction imaging of high-resolution P-Cable data from the Gulf of Mexico using azimuthal plane wave destruction (First Break)