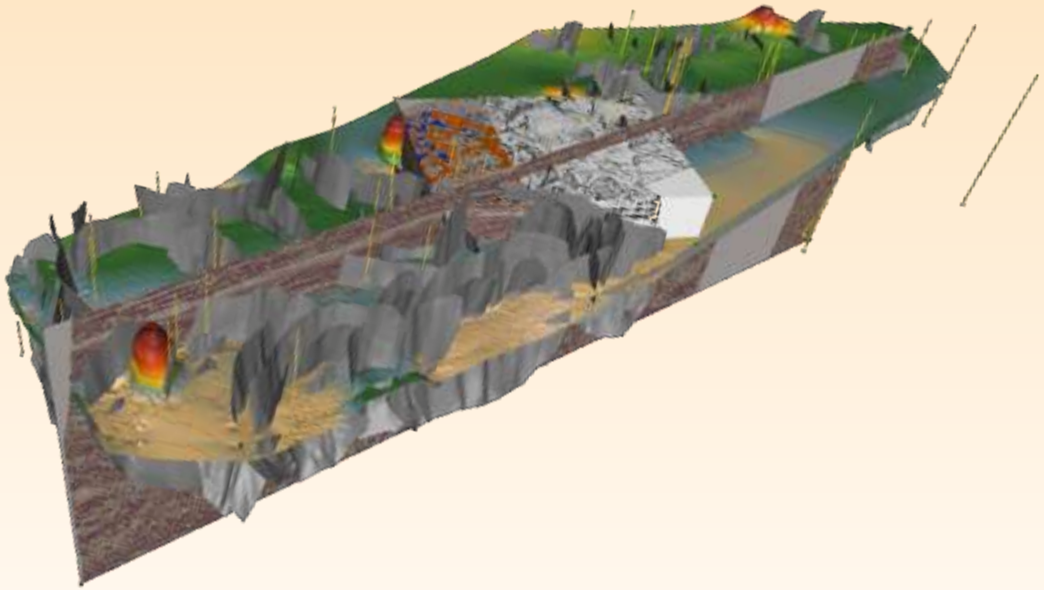
Perspectives of offshore CCS from the northern Gulf of Mexico, USA

<u>Tip Meckel</u>, Ramon Trevino, Susan Hovorka

The University of Texas at Austin

Bureau of Economic Geology

Gulf Coast Carbon Center



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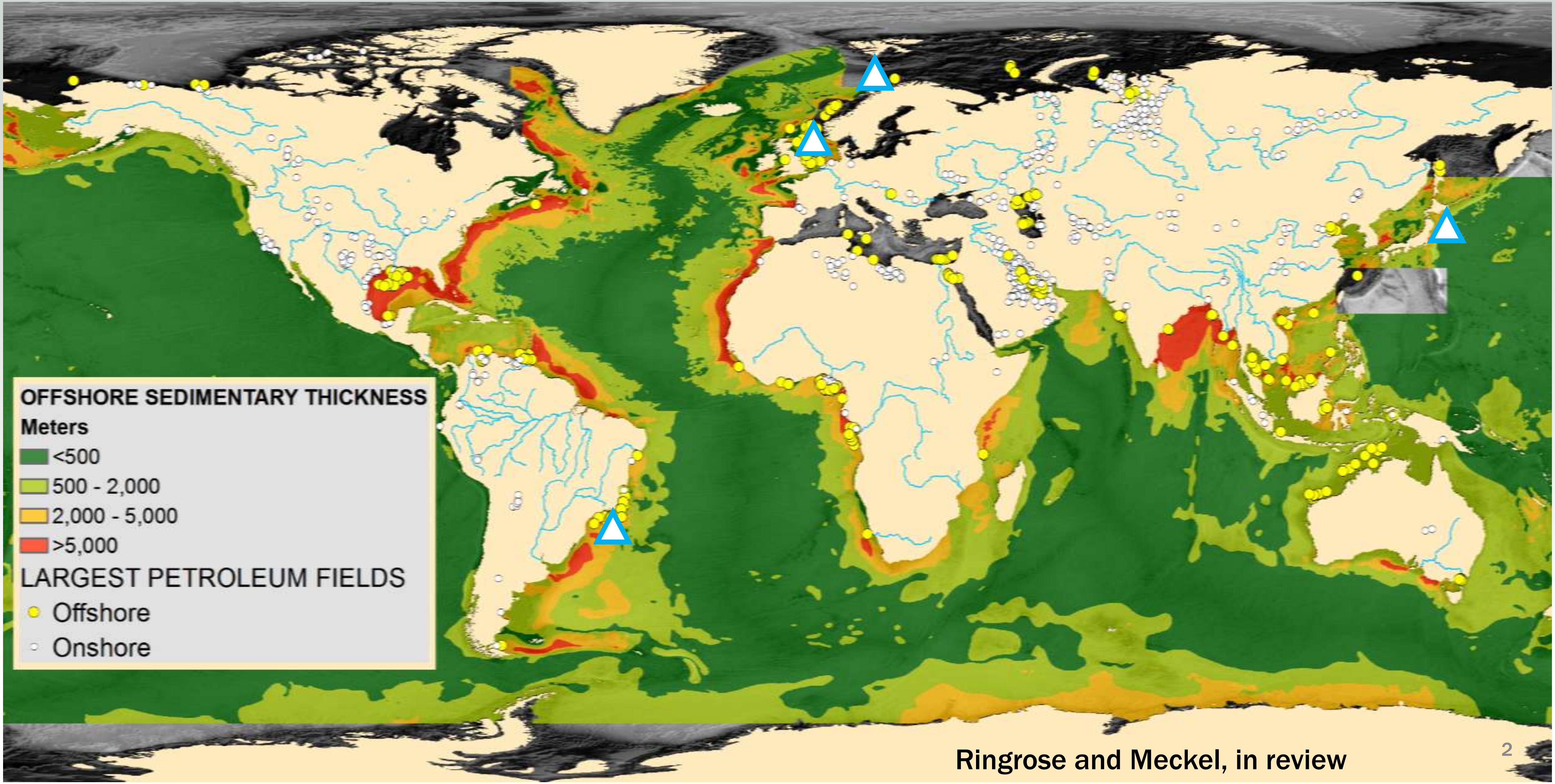
Offshore continental margins are the most promising for near-term Gigatonne-scale storage



Ringrose and Meckel, in review

TOPICS

- What is the maturity of CCS in the northern Gulf Coast?
  - Many prior projects (research/demo, industrial).
  - Existing capture and pipeline transport infrastructure.
  - Current 45Q Tax Credits make CCUS very attractive – generic example.

- Prior and current work to mature near offshore storage
  - Summary of prior geologic storage assessments since 2009.
    - Texas Offshore Atlas publication.
  - **NETL**: Two active Offshore partnerships; Screening & Identification Study

- Examples of Miocene-age reservoir capacity estimates and basin storage implications for meeting 2050 targets.

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Tax Credit Value Available for Different Sources and Uses of CO_2

	Minimum Size of Eligible Carbon Capture Plant by Type ($ktCO_2/yr$)			Relevant Level of Tax Credit in a Given Operational Year ($USD/$tCO_2$)									
Type of CO_2 Storage/Use	Power Plant	Other Industrial Facility	Direct Air Capture	2018	2019	2020	2021	2022	2023	2024	2025	2026	Beyond 2026
Dedicated Geological Storage	500	100	100	28	31	34	36	39	42	45	47	50	Indexed to Inflation
Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35	Indexed to Inflation
Other Utilization Processes[1]	25	25	25	17[2]	19	22	24	26	28	31	33	35	Indexed to Inflation

[1] Each CO_2 source cannot be greater than 500 $ktCO_2/yr$

[2] Any credit will only apply to the portion of the converted CO_2 that can be shown to reduce overall emissions

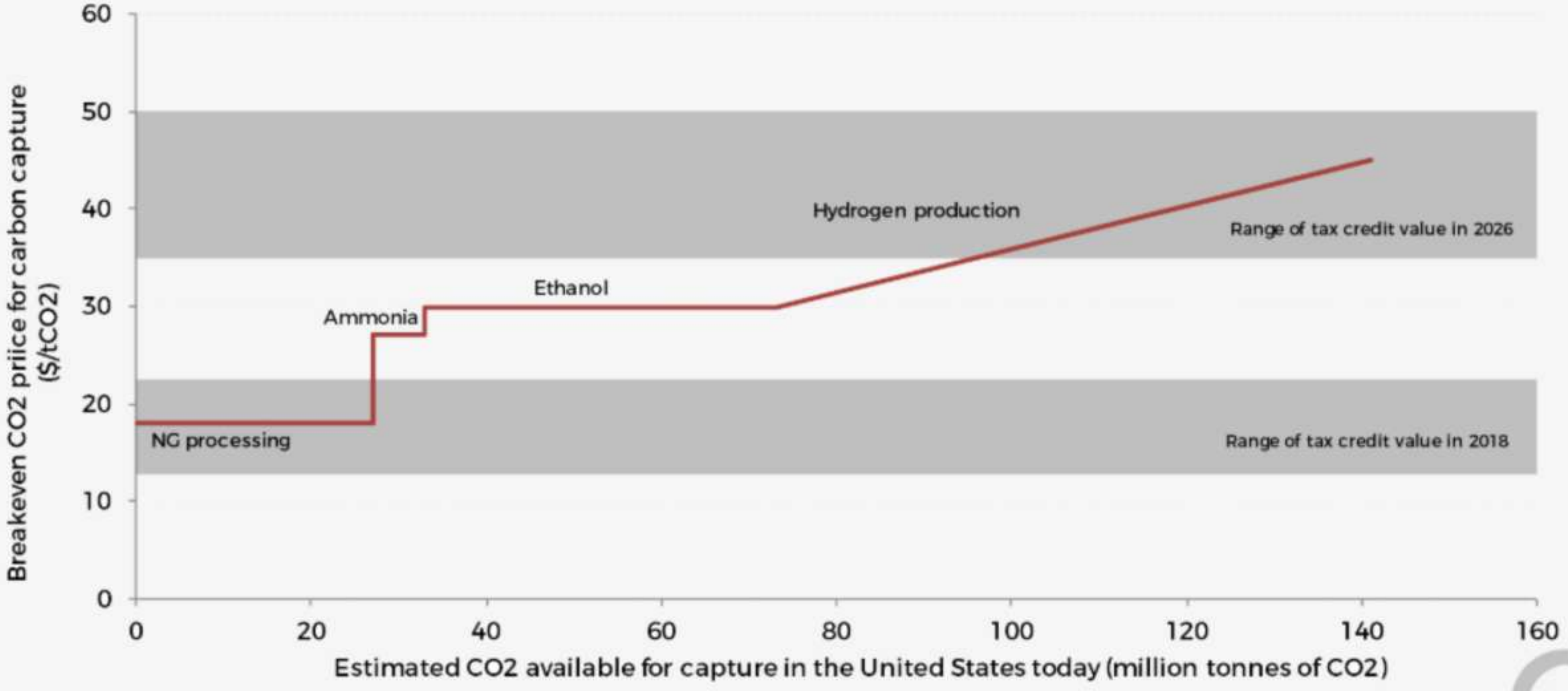
ENERGY FUTURES INITIATIVE

Source: Closely adapted from Simon Bennett and Tristan Stanley, Commentary: US budget bill may help carbon capture get back on track, International Energy Agency.

	CREDIT RATE (USD)		UTILIZATION (tons/yr)			STORAGE (tons/yr)	
YEAR	Utilization	Storage	25,000	100,000	500,000	100,000	500,000
2019	$ 17.76	$ 28.74	$ 444,000	$ 1,776,000	$ 8,880,000	$ 2,874,000	$ 14,370,000
2020	$ 20.22	$ 31.78	$ 505,571	$ 2,022,286	$ 10,111,429	$ 3,177,714	$ 15,888,571
2021	$ 22.69	$ 34.81	$ 567,143	$ 2,268,571	$ 11,342,857	$ 3,481,429	$ 17,407,143
2022	$ 25.15	$ 37.85	$ 628,714	$ 2,514,857	$ 12,574,286	$ 3,785,143	$ 18,925,714
2023	$ 27.61	$ 40.89	$ 690,286	$ 2,761,143	$ 13,805,714	$ 4,088,857	$ 20,444,286
2024	$ 30.07	$ 43.93	$ 751,857	$ 3,007,429	$ 15,037,143	$ 4,392,571	$ 21,962,857
2025	$ 32.54	$ 46.96	$ 813,429	$ 3,253,714	$ 16,268,571	$ 4,696,286	$ 23,481,429
2026	$ 35.00	$ 50.00	$ 875,000	$ 3,500,000	$ 17,500,000	$ 5,000,000	$ 25,000,000
2027	*$ 35.53*	*$ 50.75*	$ 888,125	$ 3,552,500	$ 17,762,500	$ 5,075,000	$ 25,375,000
2028	*$ 36.06*	*$ 51.51*	$ 901,447	$ 3,605,788	$ 18,028,938	$ 5,151,125	$ 25,755,625
2029	*$ 36.60*	*$ 52.28*	$ 914,969	$ 3,659,874	$ 18,299,372	$ 5,228,392	$ 26,141,959
2030	*$ 37.15*	*$ 53.07*	$ 928,693	$ 3,714,772	$ 18,573,862	$ 5,306,818	$ 26,534,089
2031	*$ 37.70*	*$ 53.86*	$ 942,624	$ 3,770,494	$ 18,852,470	$ 5,386,420	$ 26,932,100
2032	*$ 38.27*	*$ 54.67*	$ 956,763	$ 3,827,051	$ 19,135,257	$ 5,467,216	$ 27,336,082
		SUM	**$ 9,859,048**	**$ 39,436,194**	**$ 197,180,970**	**$ 57,059,257**	**$ 285,296,283**

Breakeven CO_2 price vs. estimated CO_2 availability

IEA Analysis, NETL, IEAGHG



Regional Gulf Coast setting for rapid large-scale carbon management in U.S. heavy industry

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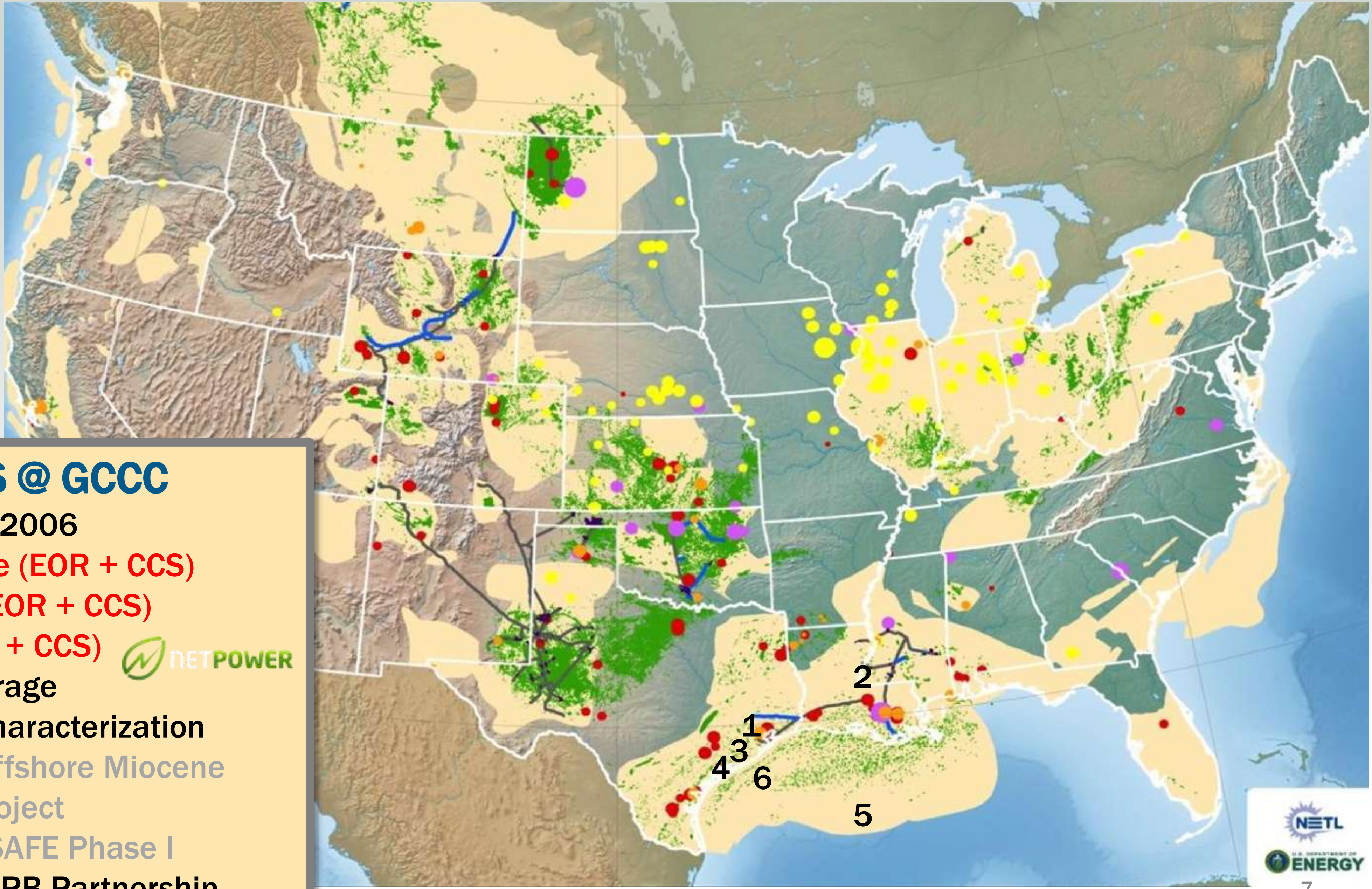

Gulf Coast CCS @ GCCC

1) Frio Saline tests 2004 & 2006
2) Cranfield stacked storage (EOR + CCS)
3) Air Products - Hastings (EOR + CCS)
4) NRG – West Ranch (EOR + CCS)
5) BOEM BPM Offshore Storage
6) Offshore GoM Storage Characterization
    A. 2009-2014 Texas Offshore Miocene
    B. 2015-2018 TXLA Project
    C. 2016-2018 CarbonSAFE Phase I
    D. 2018–2023 GoMCARB Partnership

NETPOWER

NETL

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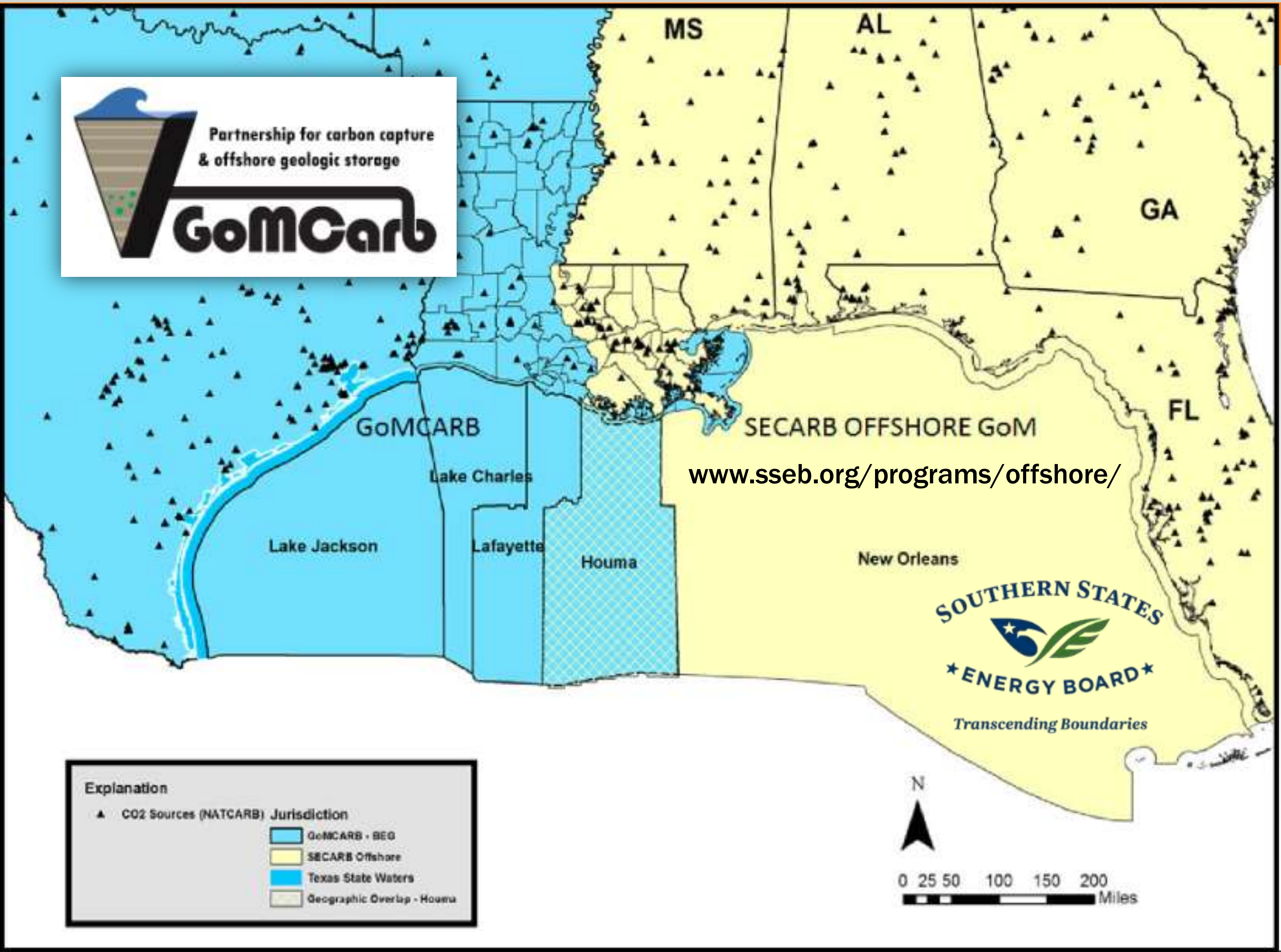


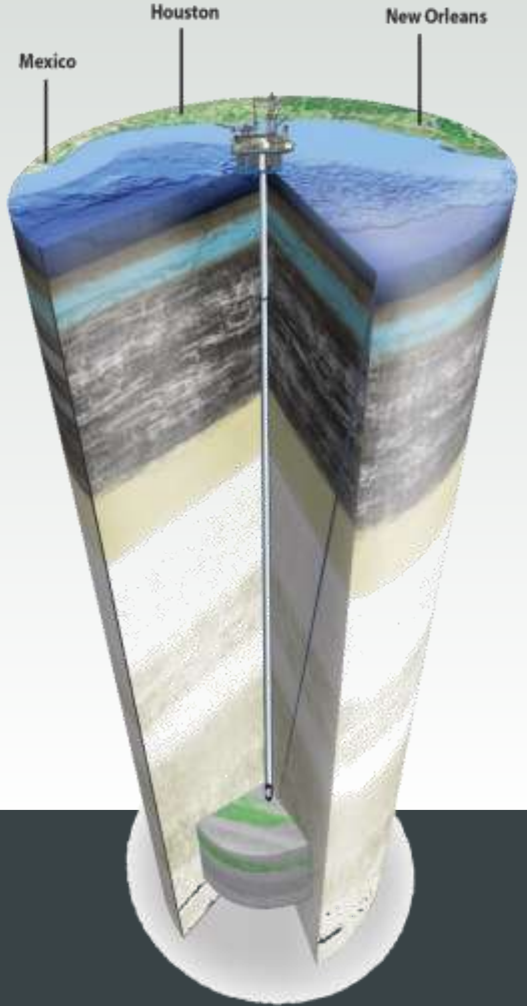
A) Offshore Storage Resources

B) Risk Assessment, Simulation, Modeling

C) Monitoring, Verification, Assessment

D) Infrastructure, Operations, Permitting

E) Outreach



www.beg.utexas.edu/gccc/research/gomcarb

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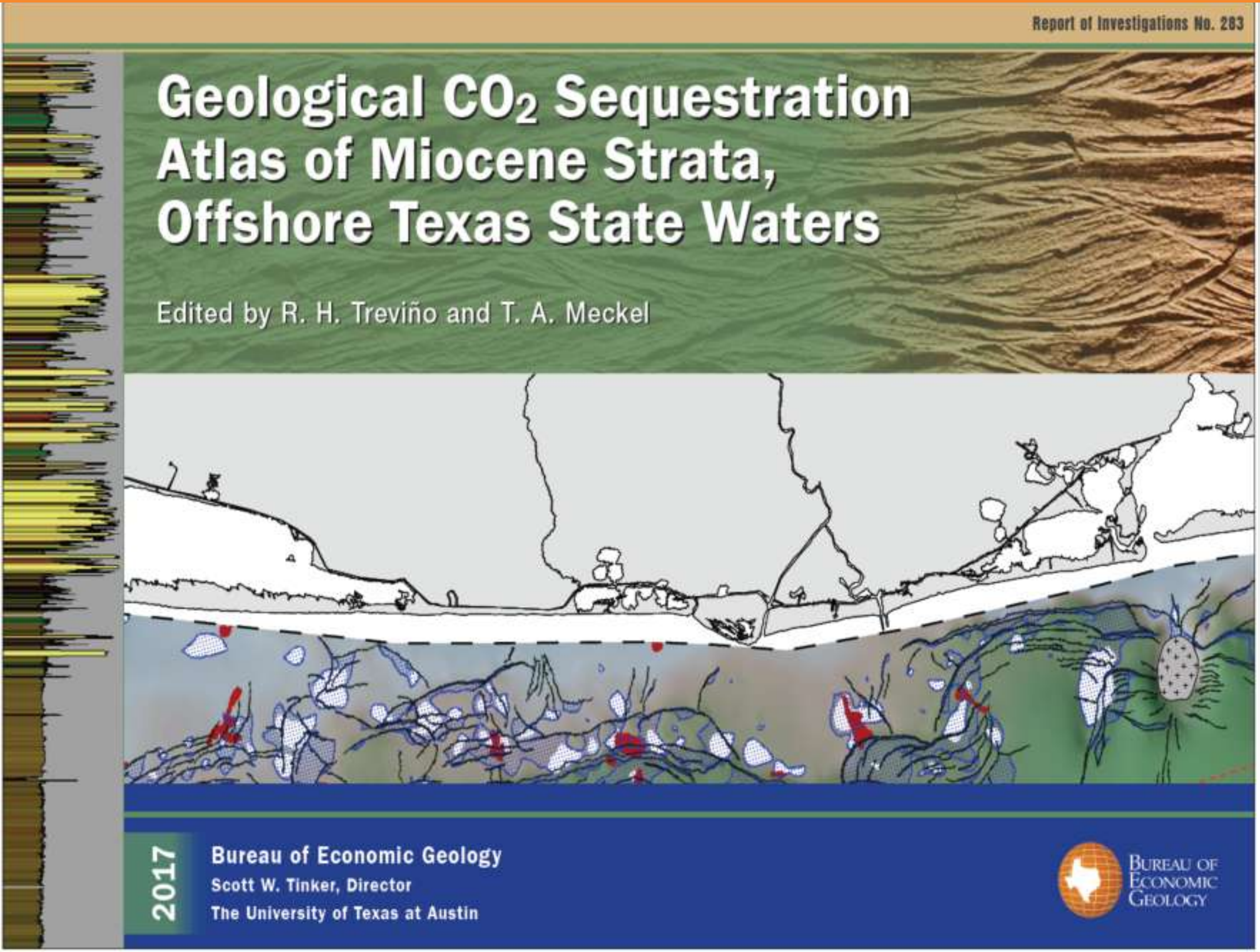
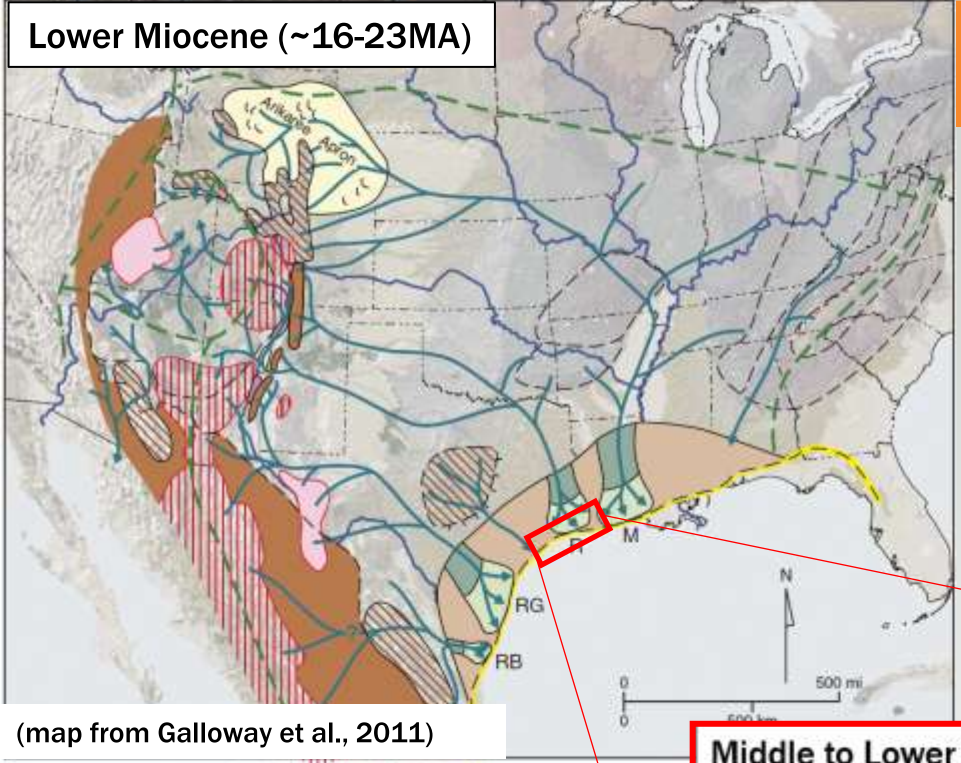
2017 Comprehensive Study of CO_2 Storage in Texas State Waters



1. Regional Geology of the Gulf of Mexico and the Miocene Section of the Texas Near-offshore Waters
2. Implications of Miocene Petroleum Systems for Geologic CO_2 Storage beneath Texas Offshore Lands
3. Evaluation of Lower Miocene Confining Units for CO_2 Storage, Offshore Texas State Waters, Northern Gulf of Mexico, USA
4. Capillary Aspects of Fault-Seal Capacity for CO_2 Storage, Lower Miocene, Gulf of Mexico
5. Regional CO_2 Static Capacity Estimate, Offshore Saline Aquifers, Texas State Waters
6. Field-scale Example of Potential CO_2 Sequestration Site in Miocene Sandstone Reservoirs, Brazos Block 440-L Field
7. Estimating CO_2 Storage Capacity in Saline Aquifer Using 3D Flow Models, Lower Miocene, Texas Gulf of Mexico
8. Appendix A: Regional Cross Sections, Miocene Strata of Offshore Texas State Waters

GOM Paleogeography

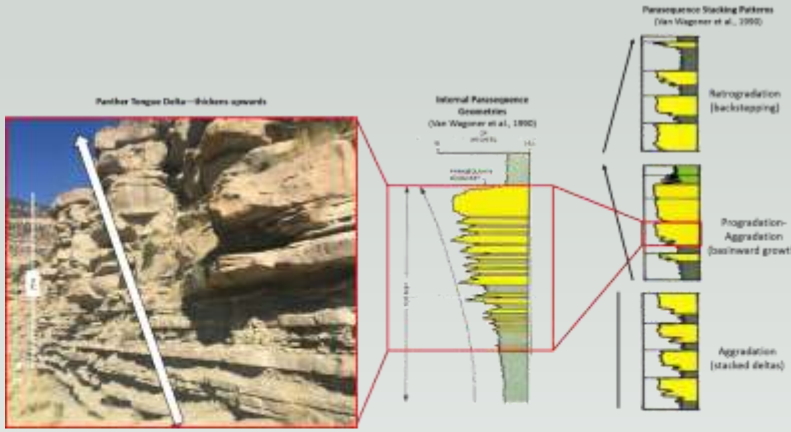


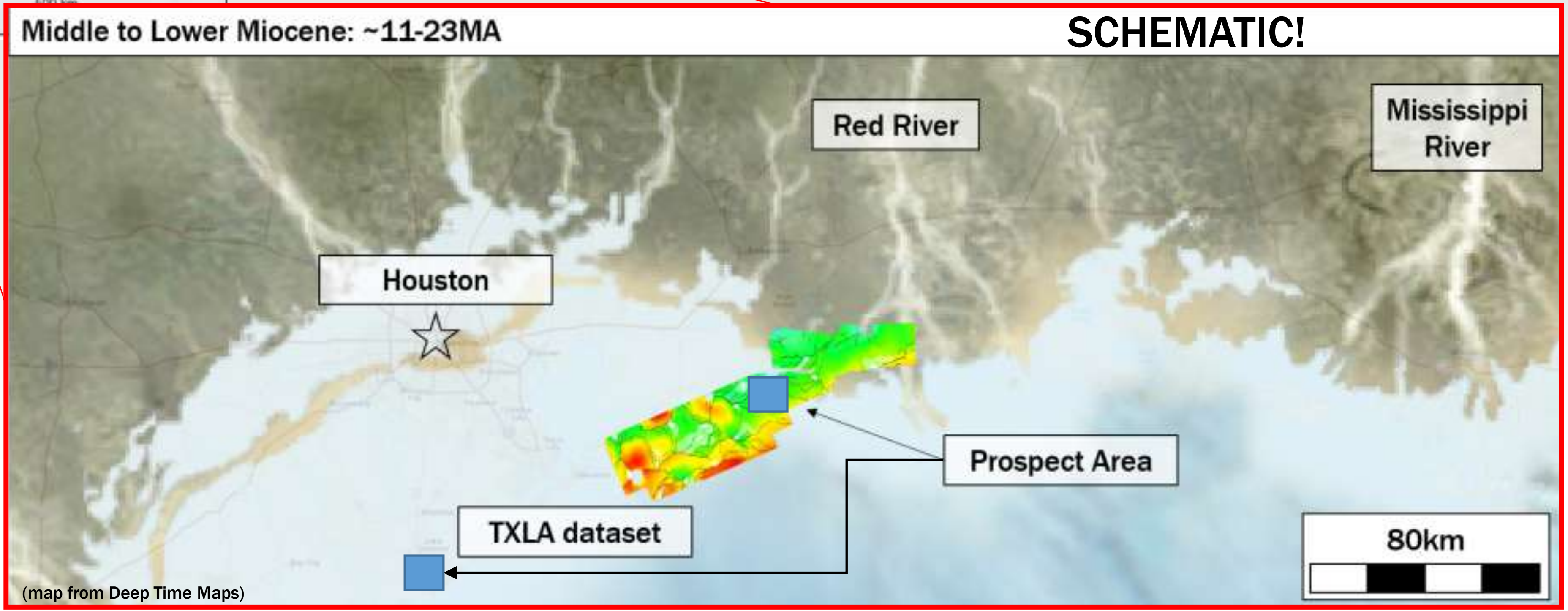
(map from Galloway et al., 2011)

Receiving Basin Elements

- Depositional coastal plain
- Fluvial axes
- Deltaic depocenters
- Max. progradational shoreline

- Dominant environment: Coastal-Deltaic, shallow marine
- Red River merging with Mississippi River





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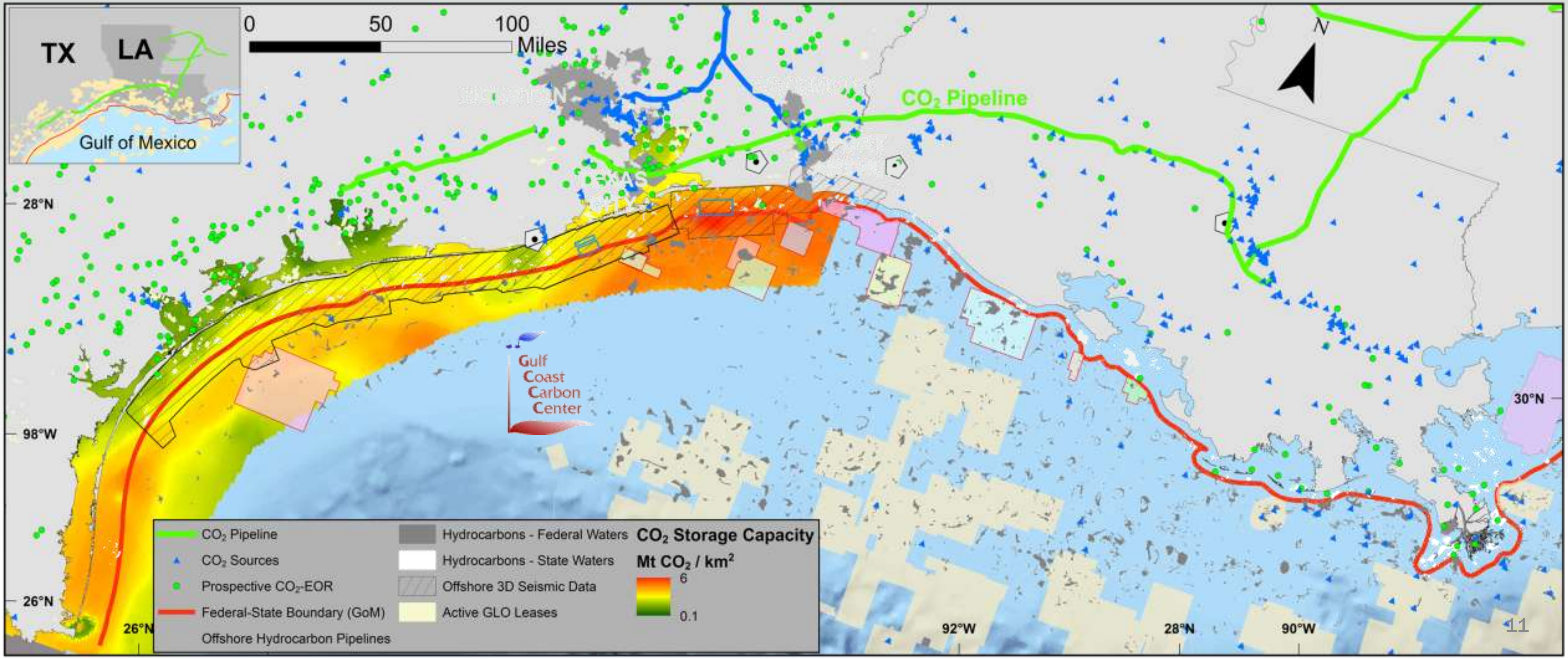
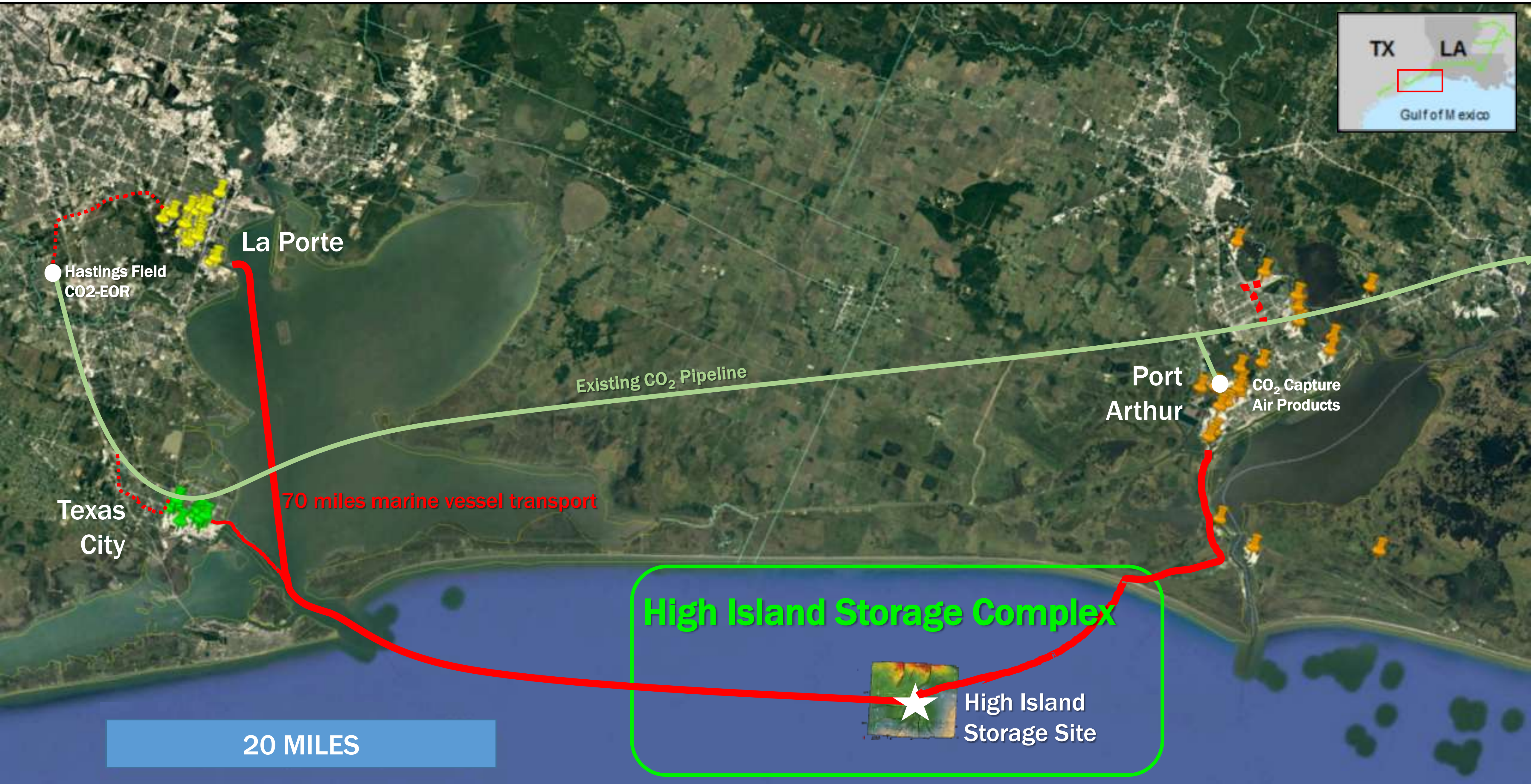
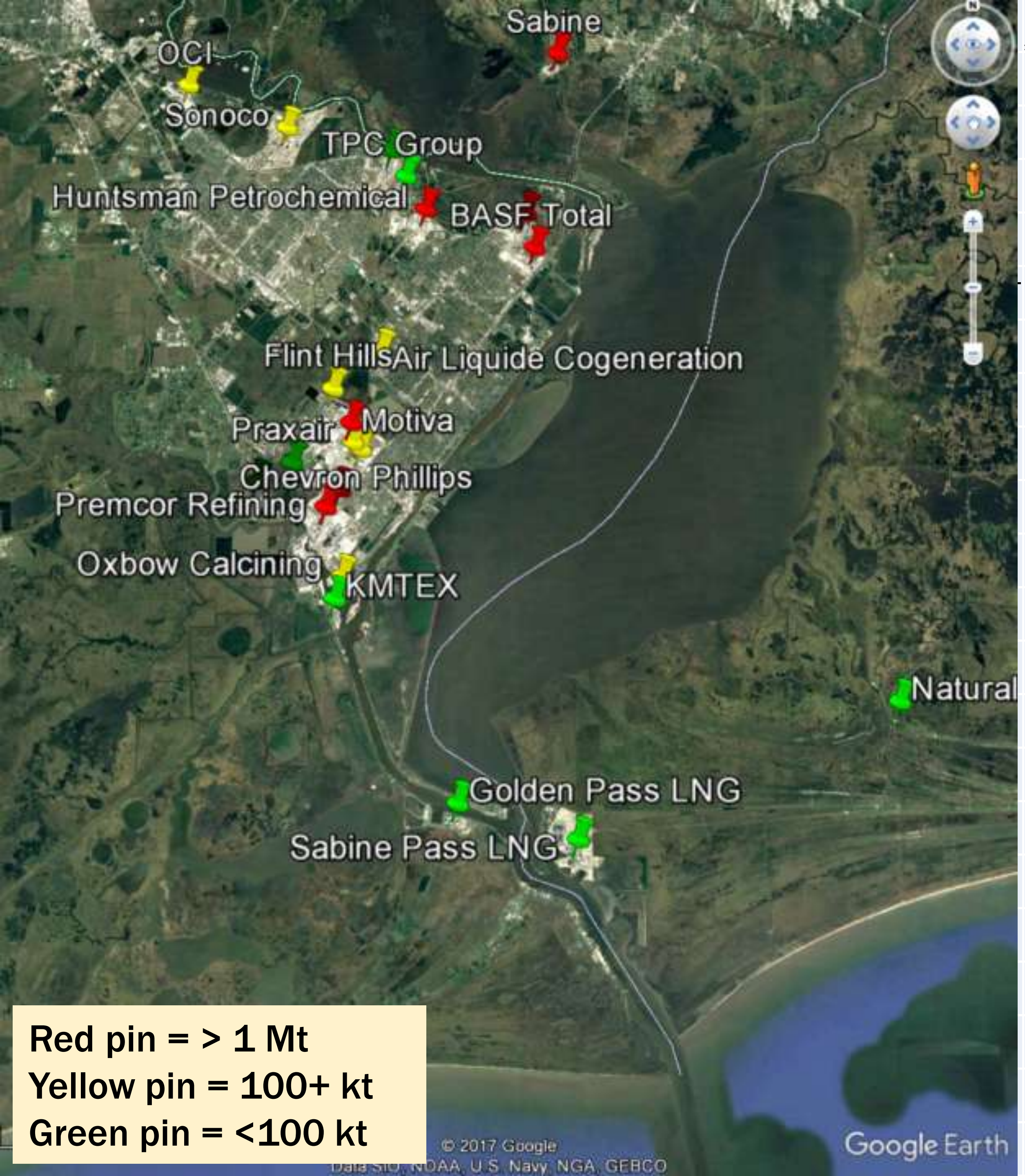
Static Regional Capacity

- NETL Methodology
- 40,000 sq. km.
- 3,300 logs
  - Tops, net sand, porosity
- 172 Gt CO_2 storage total TX State Waters



3 Texas GoM CO_2 Hubs: La Porte, Texas City, Port Arthur

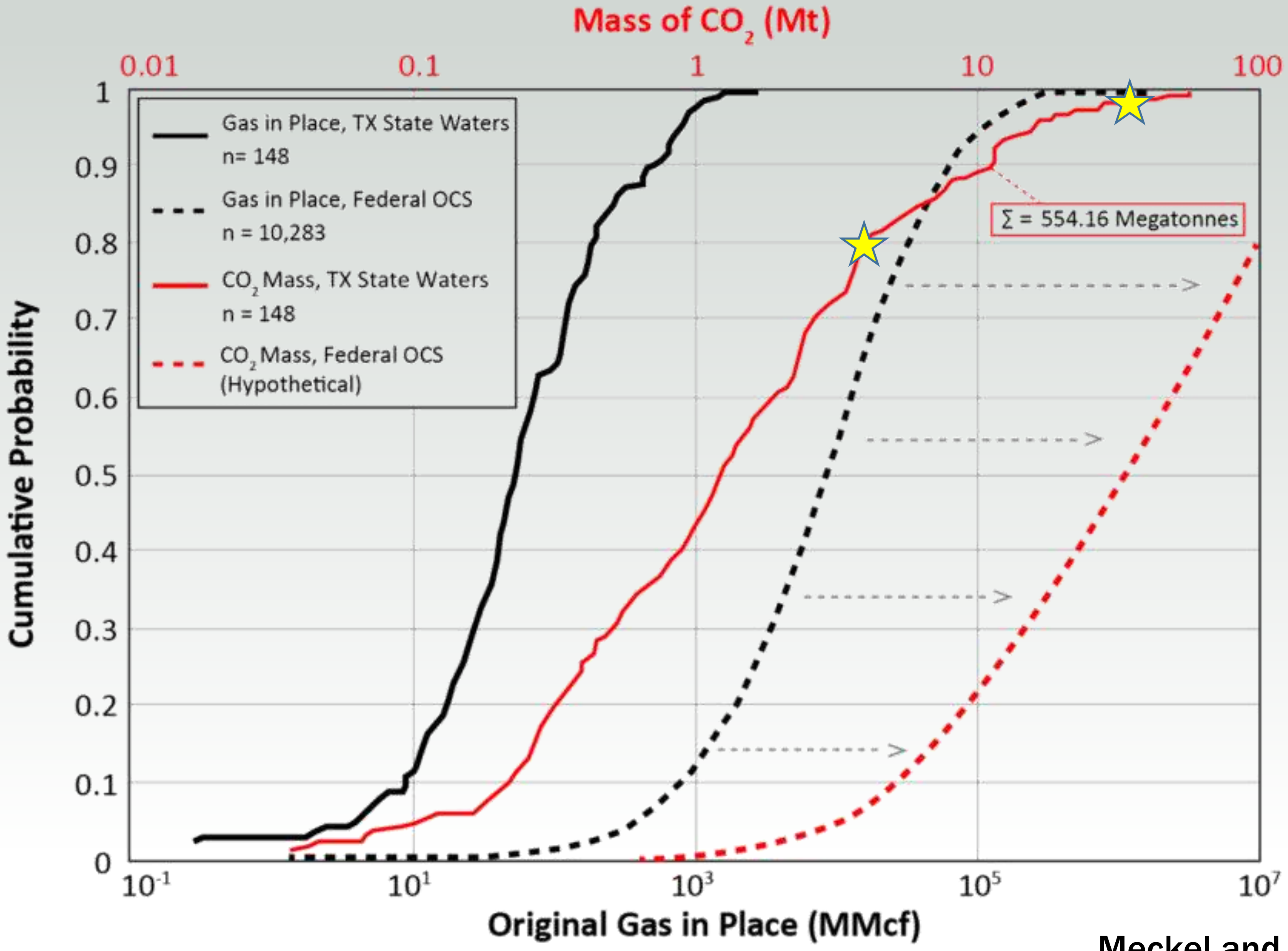




SOURCE_TYPE_COMMON	EPA_SUBPART_CATEGORY	CO2_TONNE
REFINERIES/CHEMICAL	Stationary Combustion	4,590,601
REFINERIES/CHEMICAL	Stationary Combustion	2,463,770
REFINERIES/CHEMICAL	Stationary Combustion	2,359,646
ELECTRICITY	Electricity Generation	2,326,263
REFINERIES/CHEMICAL	Stationary Combustion	1,975,996
REFINERIES/CHEMICAL	Stationary Combustion	1,487,779
REFINERIES/CHEMICAL	Stationary Combustion	1,405,838
REFINERIES/CHEMICAL	Hydrogen Production	781,428
REFINERIES/CHEMICAL	Petrochemical Production	630,161
REFINERIES/CHEMICAL	Stationary Combustion	615,150
REFINERIES/CHEMICAL	Stationary Combustion	263,337
REFINERIES/CHEMICAL	Stationary Combustion	244,469
REFINERIES/CHEMICAL	Stationary Combustion	206,246
REFINERIES/CHEMICAL	Stationary Combustion	78,489
REFINERIES/CHEMICAL	Stationary Combustion	59,440
PETROLEUM/NATURAL GAS	Petroleum and Natural Gas Systems	57,182
REFINERIES/CHEMICAL	Stationary Combustion	38,727
PETROLEUM/NATURAL GAS	Petroleum and Natural Gas Systems	30,766
REFINERIES/CHEMICAL	Stationary Combustion	25,179
PETROLEUM/NATURAL GAS	Stationary Combustion	16,762
PETROLEUM/NATURAL GAS	Stationary Combustion	1,129

Port Arthur Hub, Phase I
~20 Mta total
17 Mta, 7 sources

Converting methane gas accumulation experience to CO_2 storage



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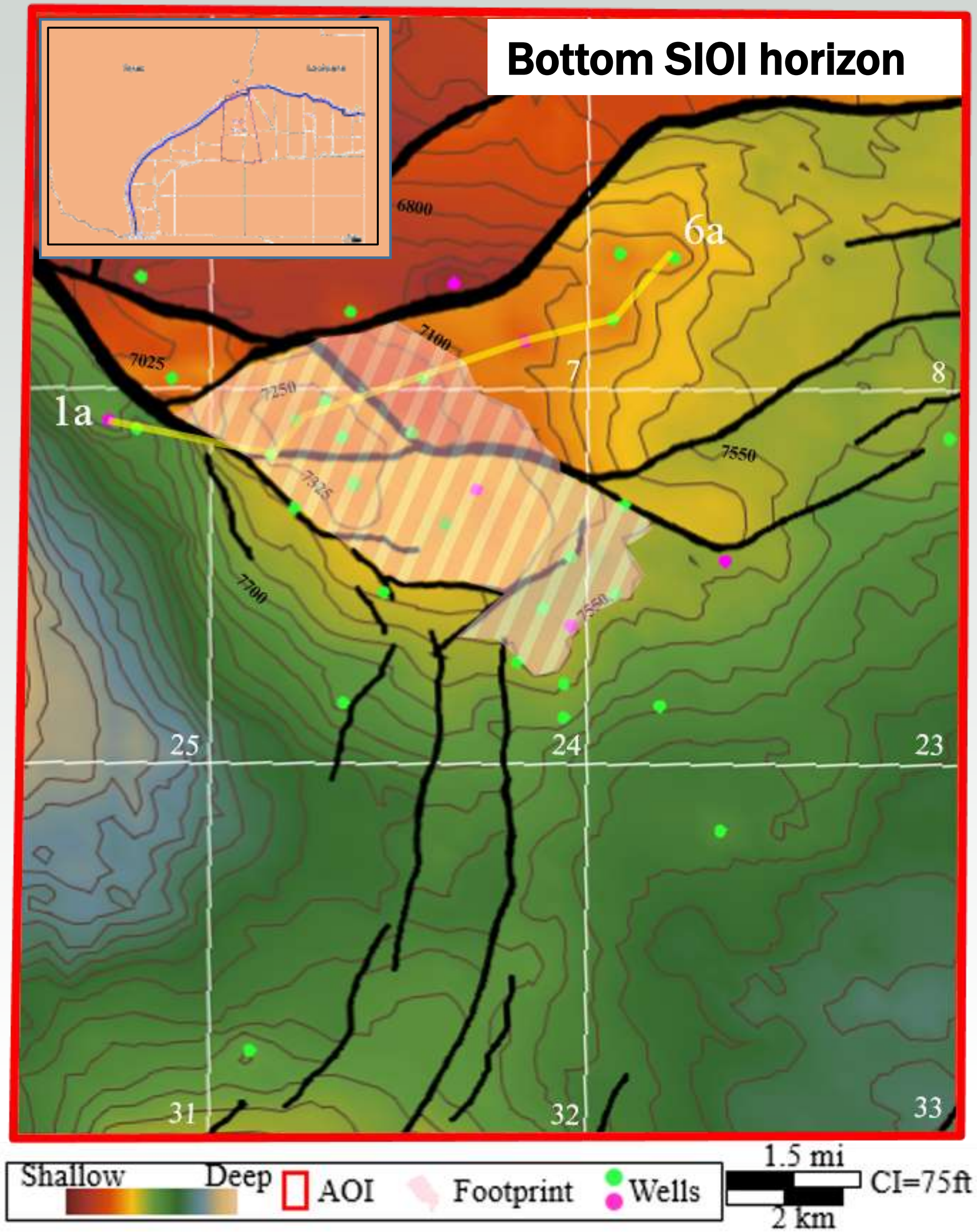
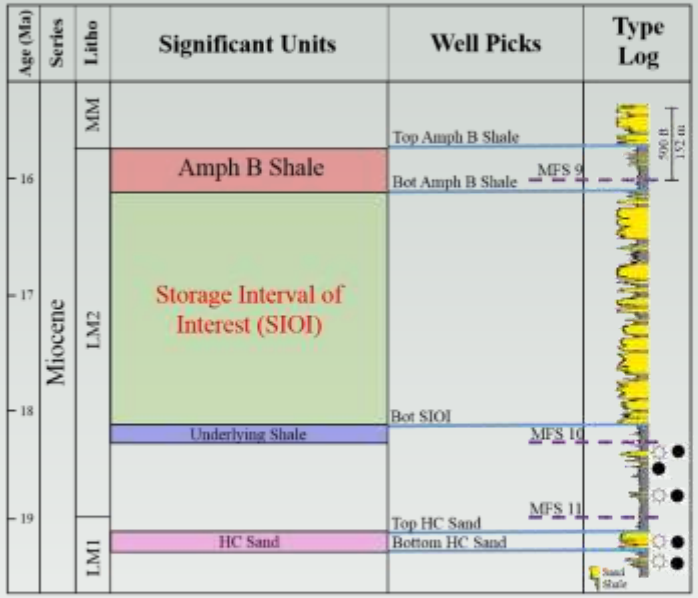
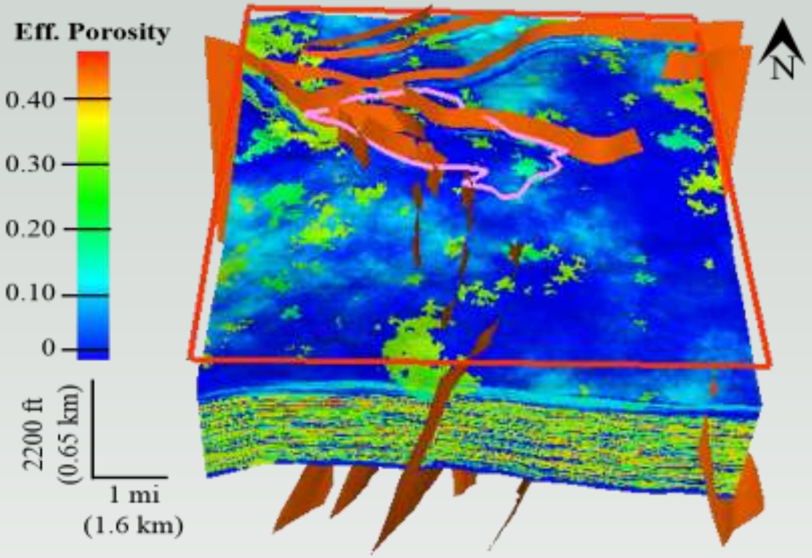
Meckel and Rhatigan, 2017

High Island 24-L Field – Southeast Texas





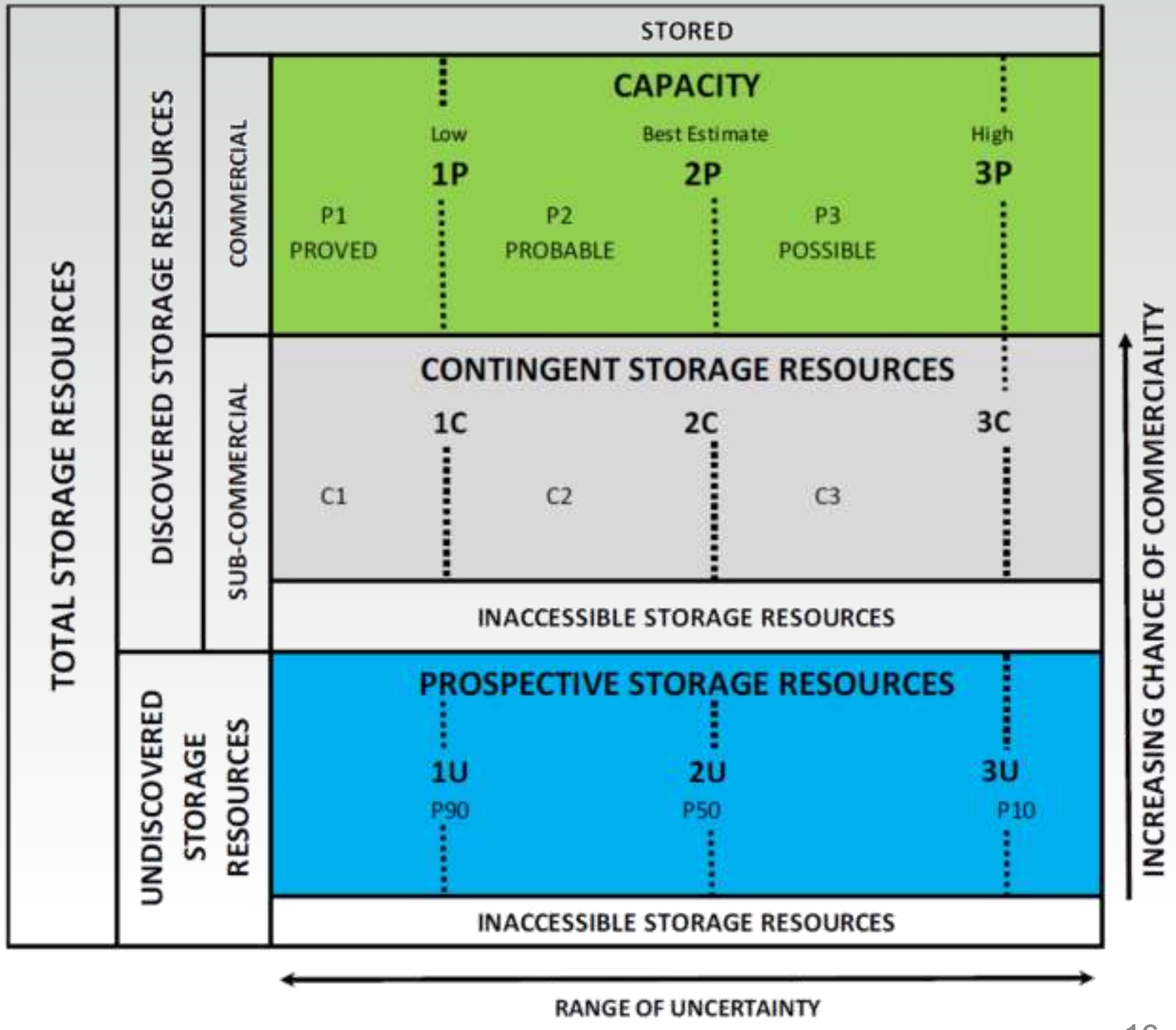


STATIC VOLUMETRIC CALCULATIONS

	P10	P50	P90
$E_{saline} = E_v E_d$	7.4%	14%	24%
SIOI: NETL CO2 Screen (Mt)	63	120	206
SIOI: 3-D Eff. Porosity Model (Mt)	57	108	185
HC Sand: 3-D Constant Avg. Eff. Porosity Model (Mt)	6	12	20

SPE Storage Resources Management System (SRMS)

- Uniformity, clarity, familiarity
- Bookable storage
- Similar to PRMS
  - SRMS exists
  - https://www.spe.org/industry/CO2-storage-resources-management-system.php
  - Guidelines currently being drafted
  - Training workshops to come.



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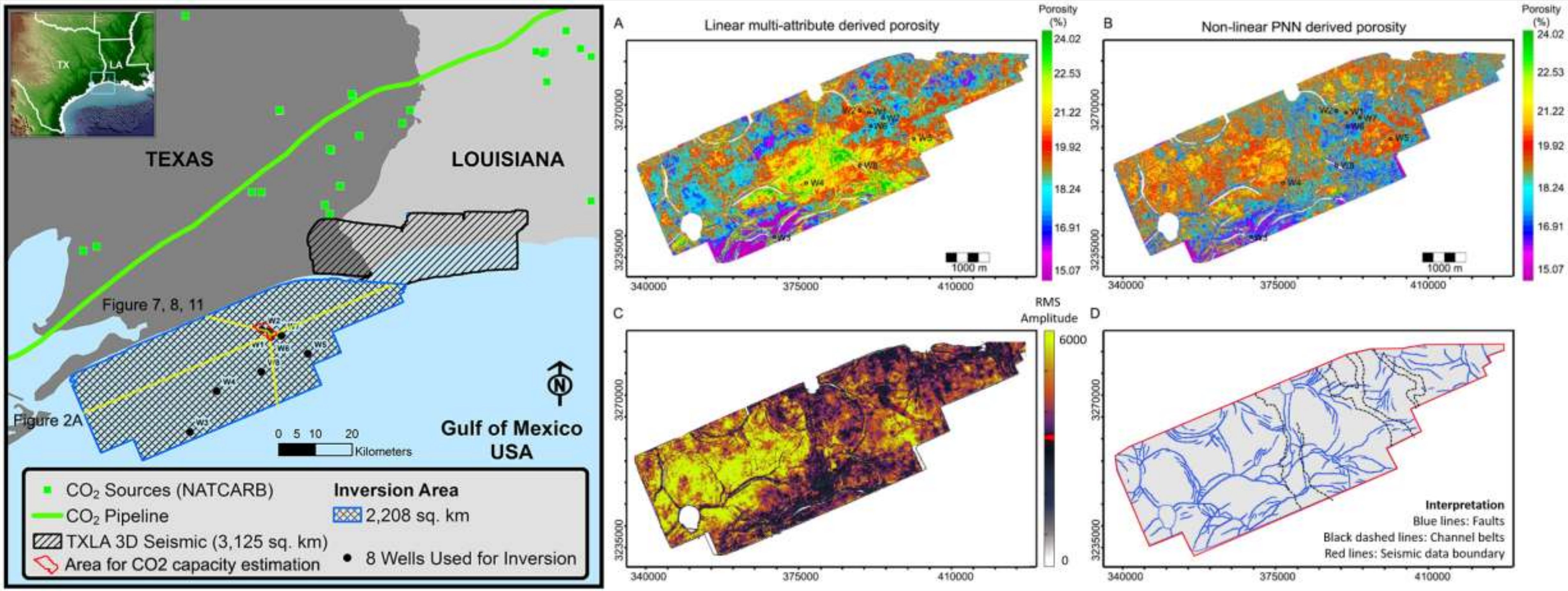
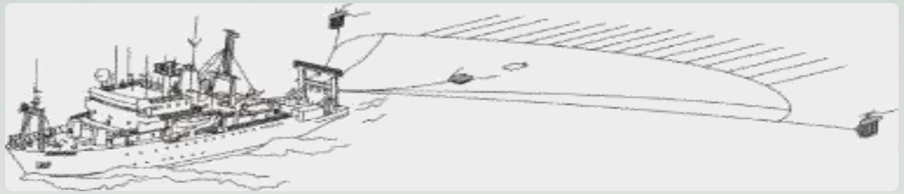
Seismic inversion for porosity volume

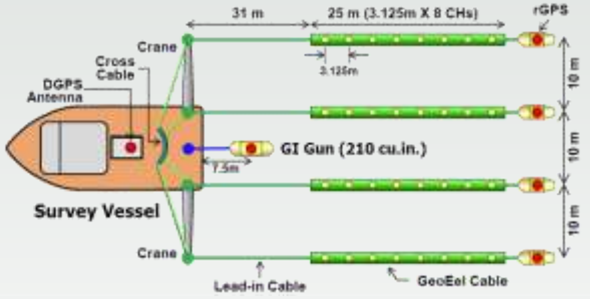


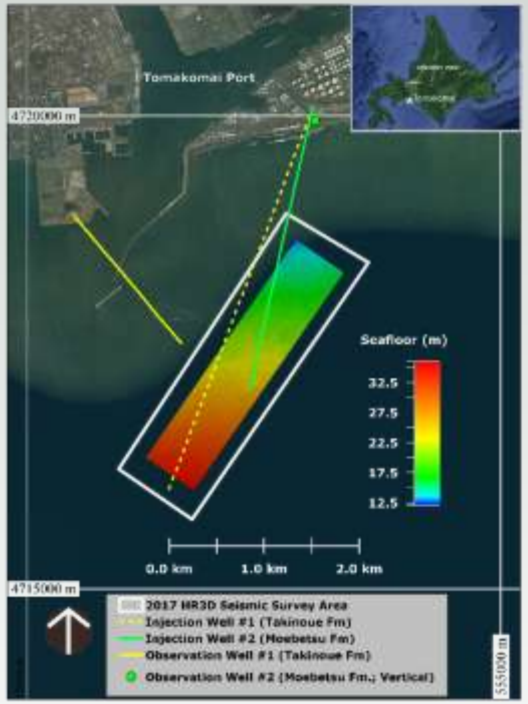
HR3D Seismic Characterization & Monitoring

- 3 GoM Surveys (2012-14)
  - overburden characterization
  - Multiple publications using data

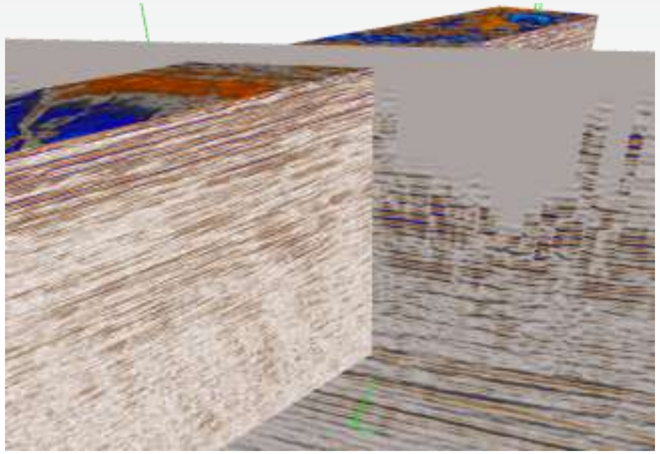


- 1 Japan survey – Monitoring (Tomakomai)
  - IJGGC Volume 88, 2019, Pages 124-133
  - https://doi.org/10.1016/j.ijggc.2019.05.034
  - Repeat survey tentative 2020

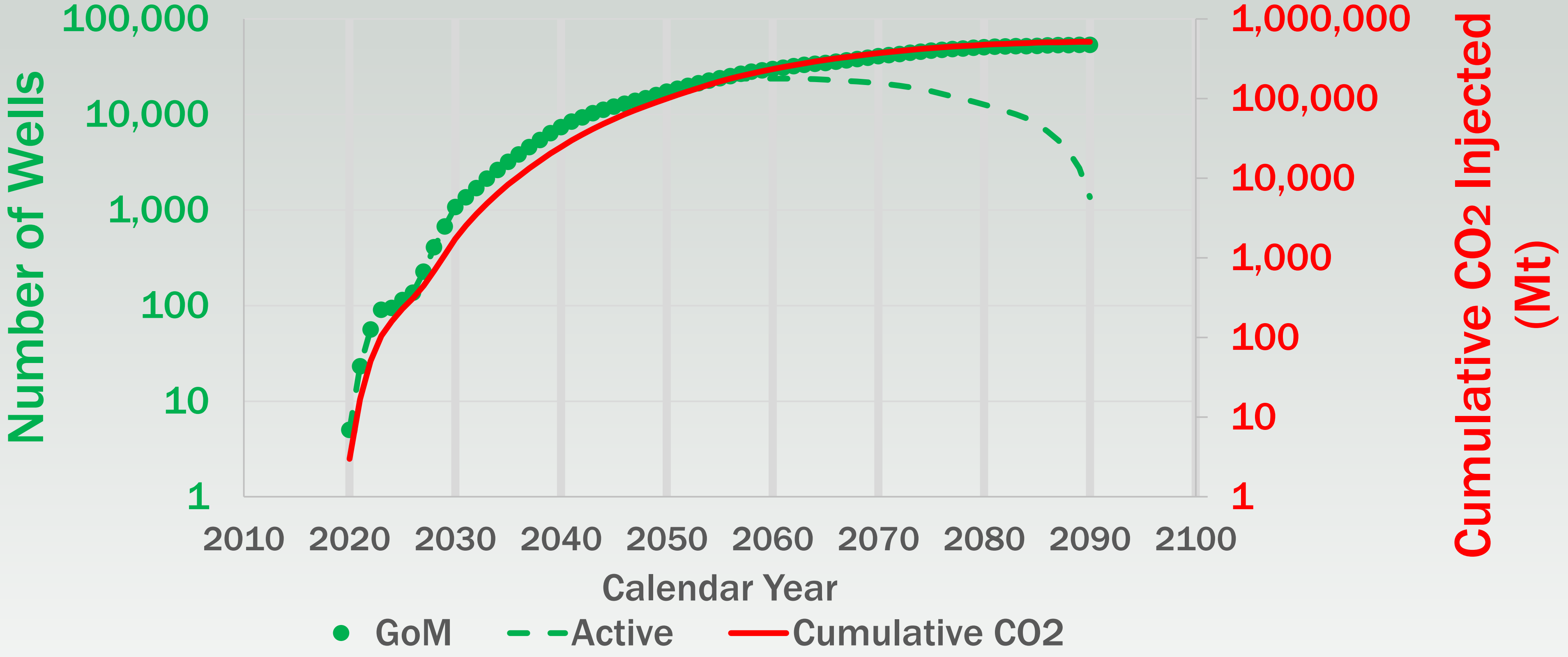




- 1-2 future GoM surveys funded through GoMCARB
  - Targets being evaluated
  - Collaboration possible



Gulf of Mexico – historically-informed CO_2 well development scenario



2020+ SCENARIO	Avg. Well Inj. Rate Mt/yr	Number of active wells in 2050	Incremental Rate in 2050 Mt/yr	Cumulative Mass in 2050 Mt CO2	Comment
GoM	0.6	17,175	10,305	99,946	Unlikely one region will develop this aggressively; Incremental goal exceeded; Close to cumulative goal
GoM	0.41	17,175	7,000	67,891	Injection rate low, not cost effective; Cumulative goal not met

SUMMARY

- The global offshore continental margins represent the best near-term opportunity for Gigatonne-scale CCS.
  - Gulf of Mexico is ideal geologically and geographically.
  - National resource of consequence.
  - **Research needs**: understand hub development and scaling, impact of Gt-scale pressure perturbation, fault performance.
- :
- GoM ready to apply and expand upon the many successful examples.
  - North Sea, Japan, Brazil
  - CC(U)S perspectives benefit from knowing prior petroleum history: capacity, seal, reservoir performance, well development.
- Offshore CCS can deliver needed scales on needed time frames.
- CO_2 storage can be a bookable resource for reassuring investors and evaluating project economics.

Acknowledgements / Thank You / Questions

We gratefully acknowledge:

- **Seismic Exchange, Inc**., for access to regional 3D seismic data.
- **Halliburton** for integrated Decionspace Desktop software license.

Tip Meckel, Ramon Trevino, and Susan Hovorka

tip.meckel@beg.utexas.edu

BACKUP SLIDES
for questions

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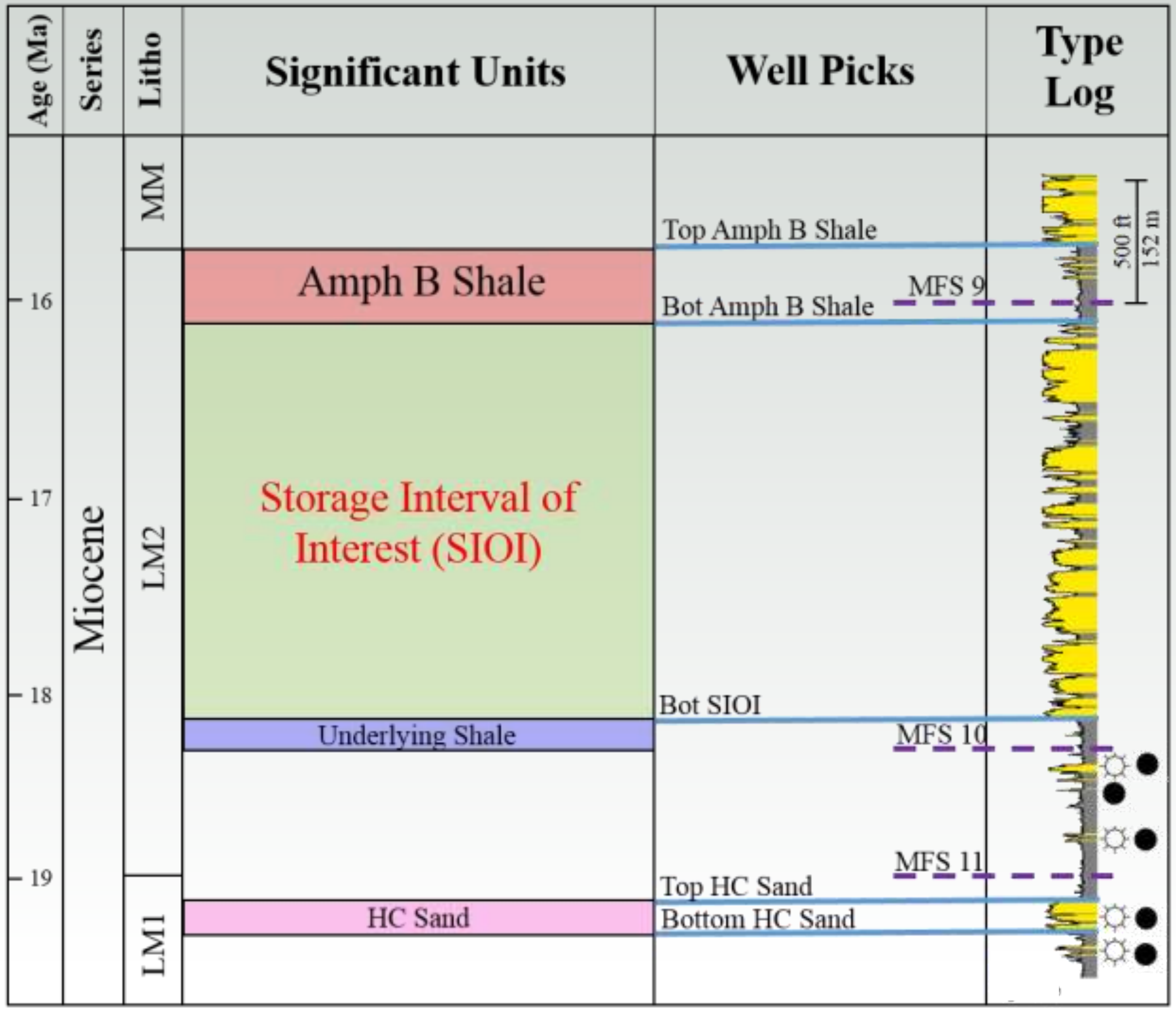
CCS Perspectives Benefit from Knowing Petroleum History

High Island 24-L Field
~10% of all oil and gas from Texas state waters

MFS 9-10 Interval

- 1720’ total thickness
- 1066’ net sand
  - 62%
  - Average of 37 SP curves
- No productive intervals



MFS = Interpreted Maximum Flooding Surface Horizon (Galloway et al., 1989)

Below MFS 10

~0.5 Tcf Gas

- 3625 ft total thick package
- 525 ft net sand (15%)
- 225 ft charged sand (43% of net sand)
- HC Sand most productive

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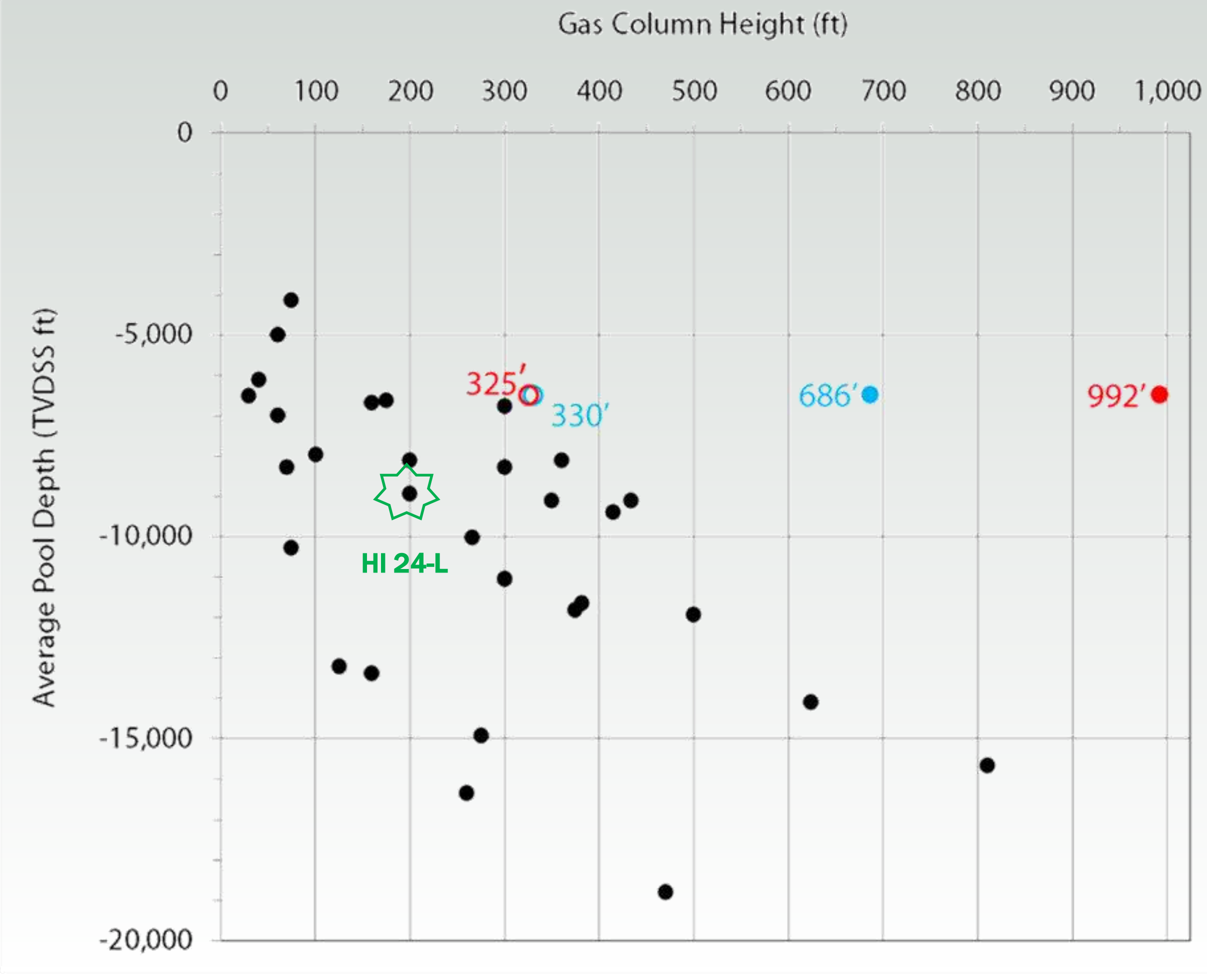
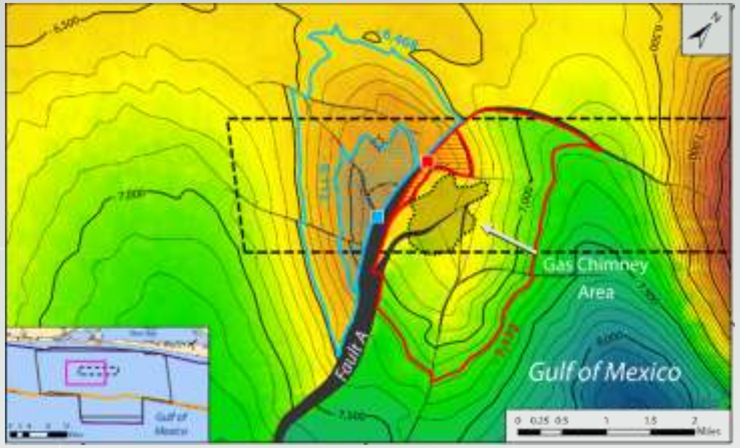
Caveat: Fault Seal Capacity

Estimated Gas Column Heights for the Fault A Structure vs. Regional Data from Seni *et al.*, 1997



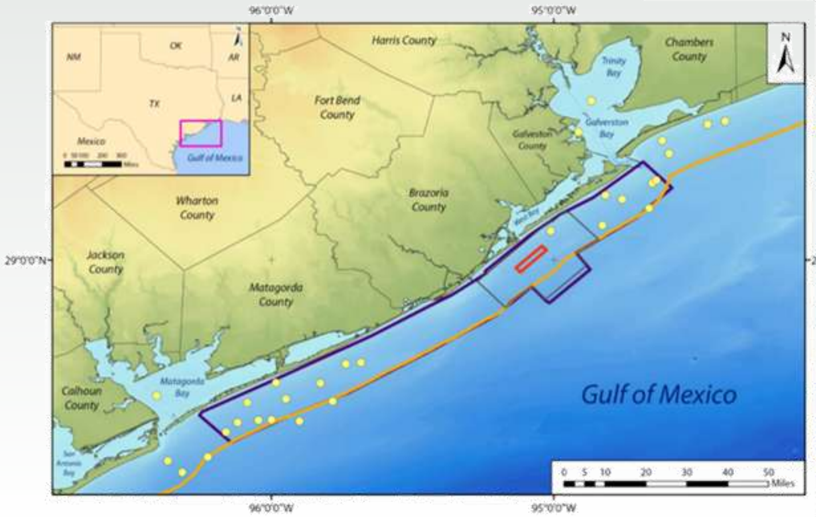
Key to Chart Symbols

- Seni et al., 1997
- Fill-to-Spill: FW
- Fill-to-Spill: HW
- Fault Seal Membrane: FW
- Fault Seal Membrane: HW



Key to Map Symbols

- Accumulation Data Locations from Seni *et al.*, 1997



J. Osmond MS Thesis UT-Austin, 2016

*Average pool depth for San Luis Pass = –6,477 TVDSS ft

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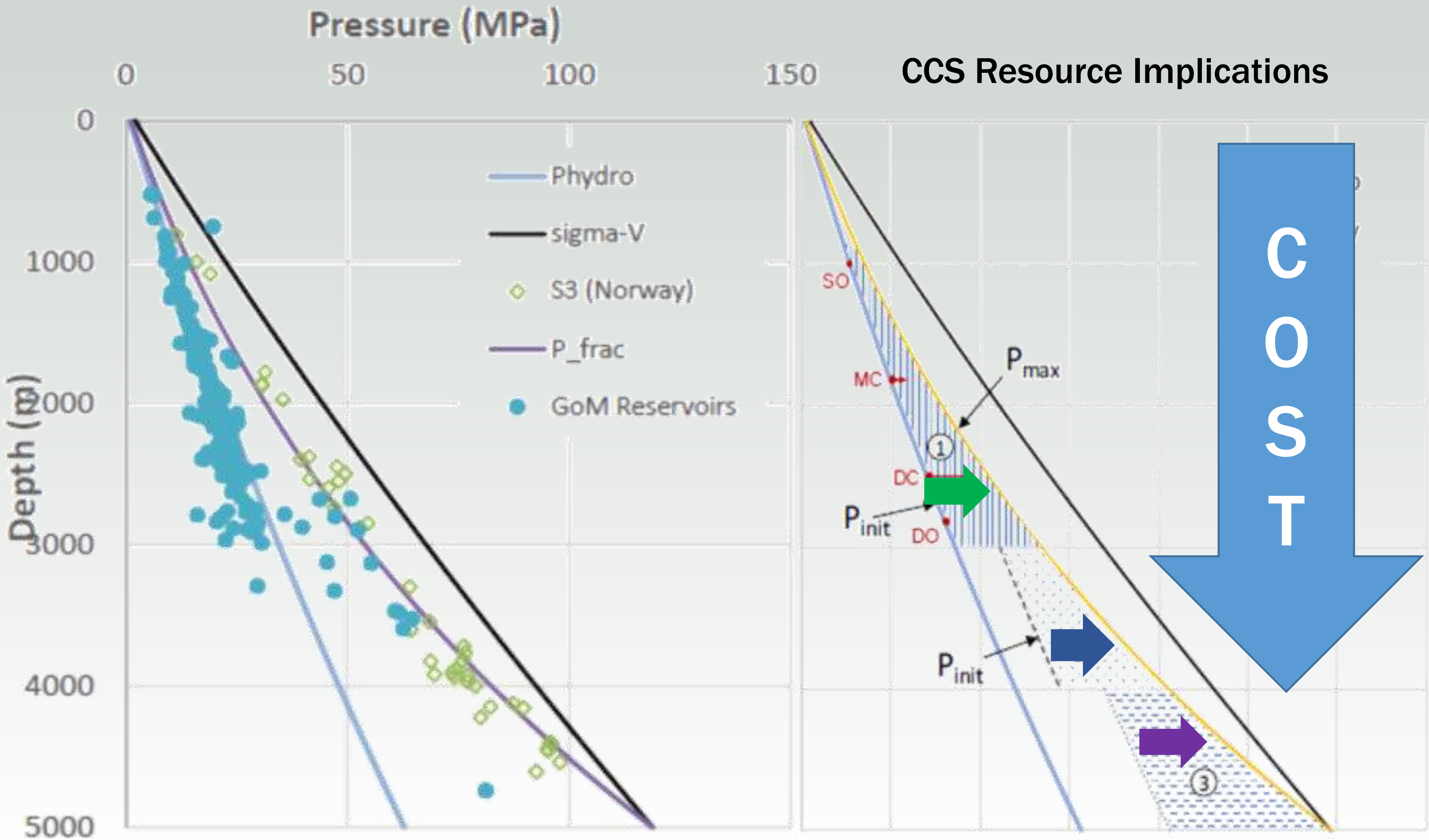
Pressure will be the primary factor limiting capacity



Ringrose and Meckel, in review

Primary:
Normal pressure (CENOZOIC)

Secondary:
Elevated pressure (MESOZOIC)

Tertiary:
High pressure, brine extraction?

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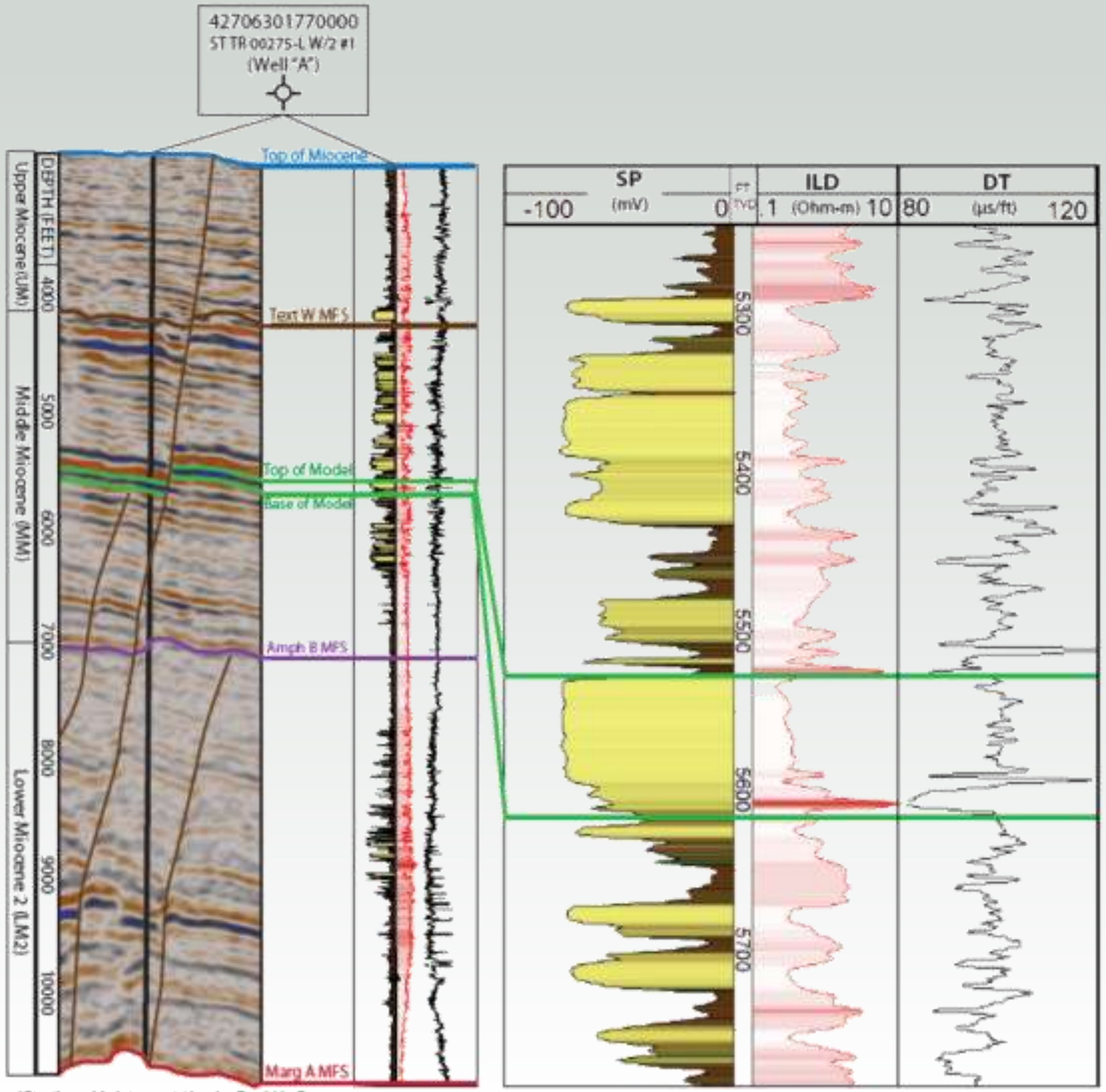
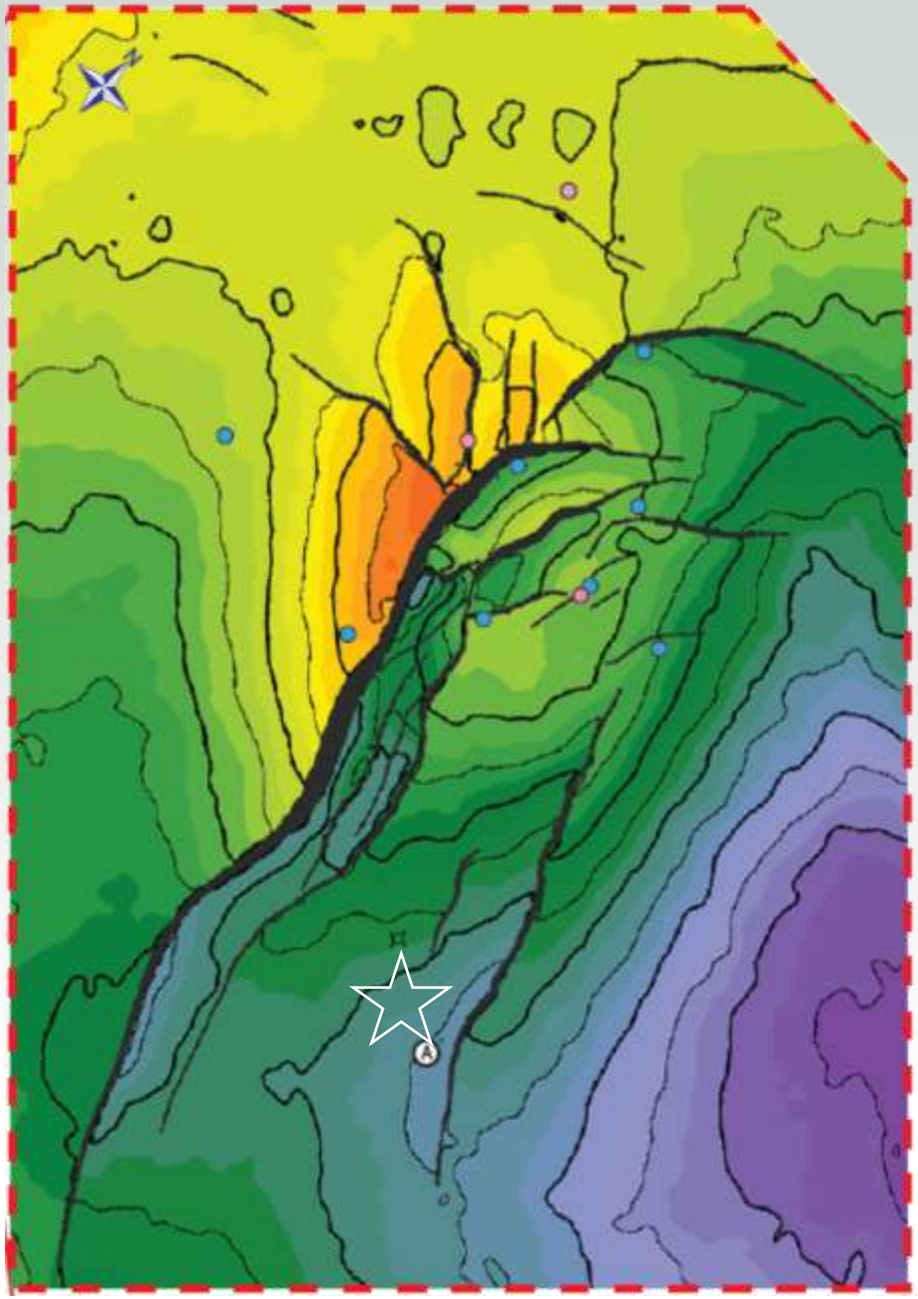
Reservoir Performance – Nonproductive Setting (San Luis Pass)



*Stratigraphic interpretation by David L. Carr
**Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Kerstan Wallace



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Wallace, 2013

Approximately 5 Mt in 90' sand, unless completely open flow boundaries

Cumulative Injection Results for 27 dynamic 3D flow simulations

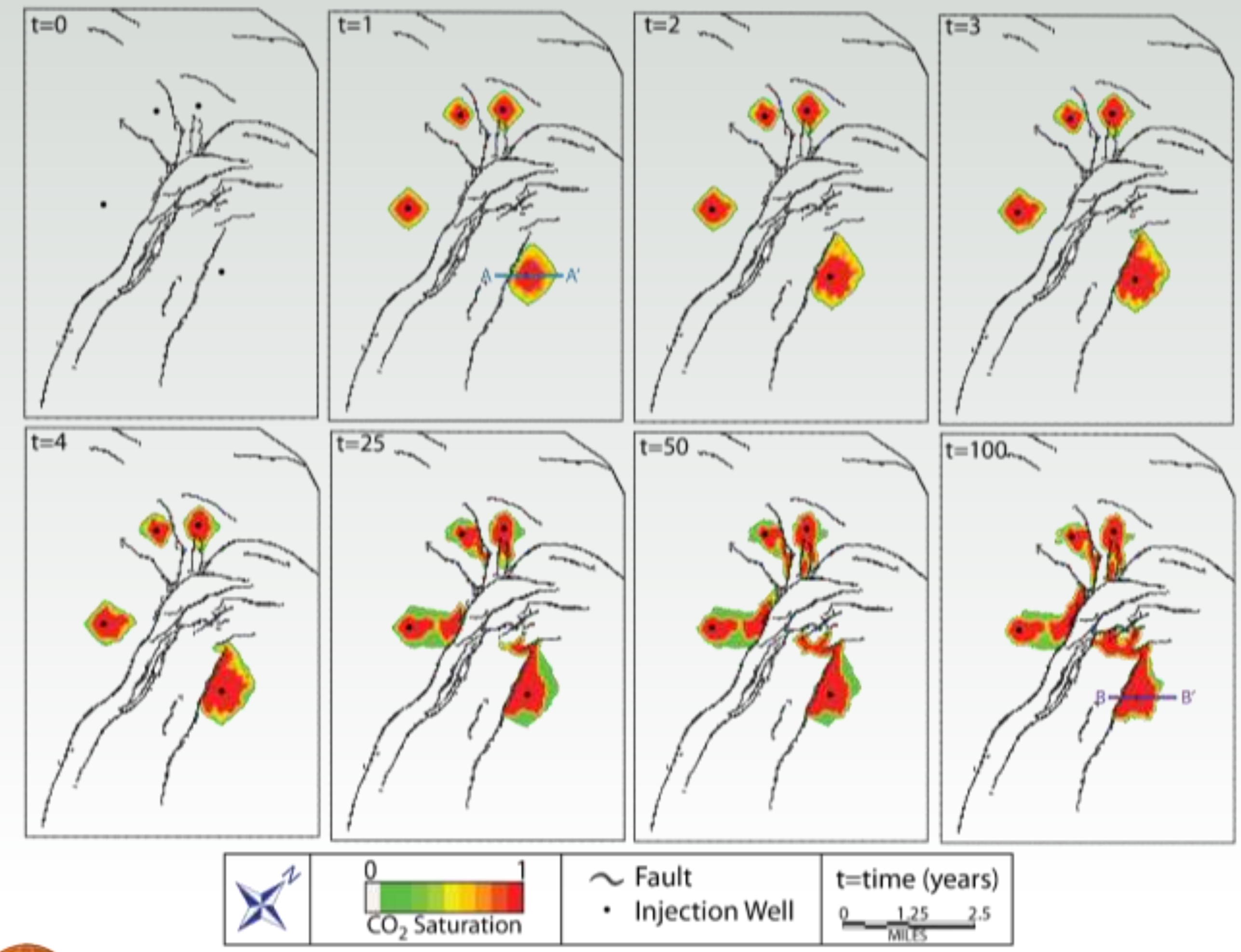
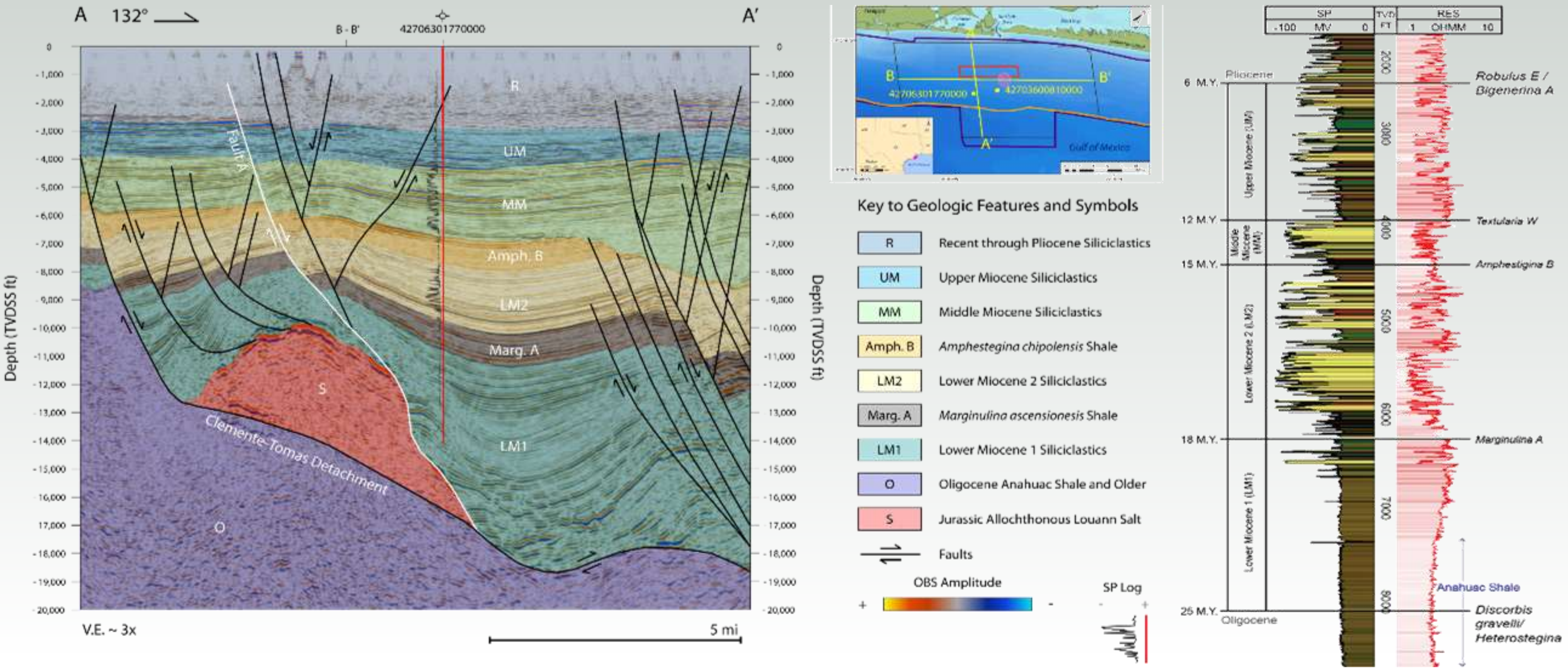


Table 7.2. Cumulative injection results for 27 model cases of dynamic 3D flow model

3D Flow Model Injected-Mass Results (Mt)			
	Homogeneous	Statistic-Based Heterogeneous	Seismically Derived Heterogeneous
Base case	5.4	5.3	4.5
High-quality reservoir	6.9	6.8	5.7
Low-quality reservoir	3.7	3.5	3.1
Open boundaries	116.2	114.4	64.0
Open faults	5.6	5.3	4.6
1 well	6.0	5.7	5.0
15 wells	5.4	5.2	4.8
Optimized array	5.4	5.3	4.9
Constant-rate injection	4.8	5.1	4.5

Typical large growth fault setting on inner shelf – Dip Section



Osmond, 2016

NETL's Offshore CCUS Study:
Screening and Identification of High-Suitability Offshore CCUS Storage Areas in the GOM Using a Multi-Criteria Evaluation Approach

System Engineering and Analysis – Energy Systems Analysis Team

MESA SubCLIN 205: Subsurface Analysis

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