Progress in the Gulf of Mexico

Ramón Treviño & Alex Bump

UTCCS-5 Meeting, January, 2020

Austin, Texas

"Big Plan" Topic 2: Large Volume Injection (aka "BIGFOOT")

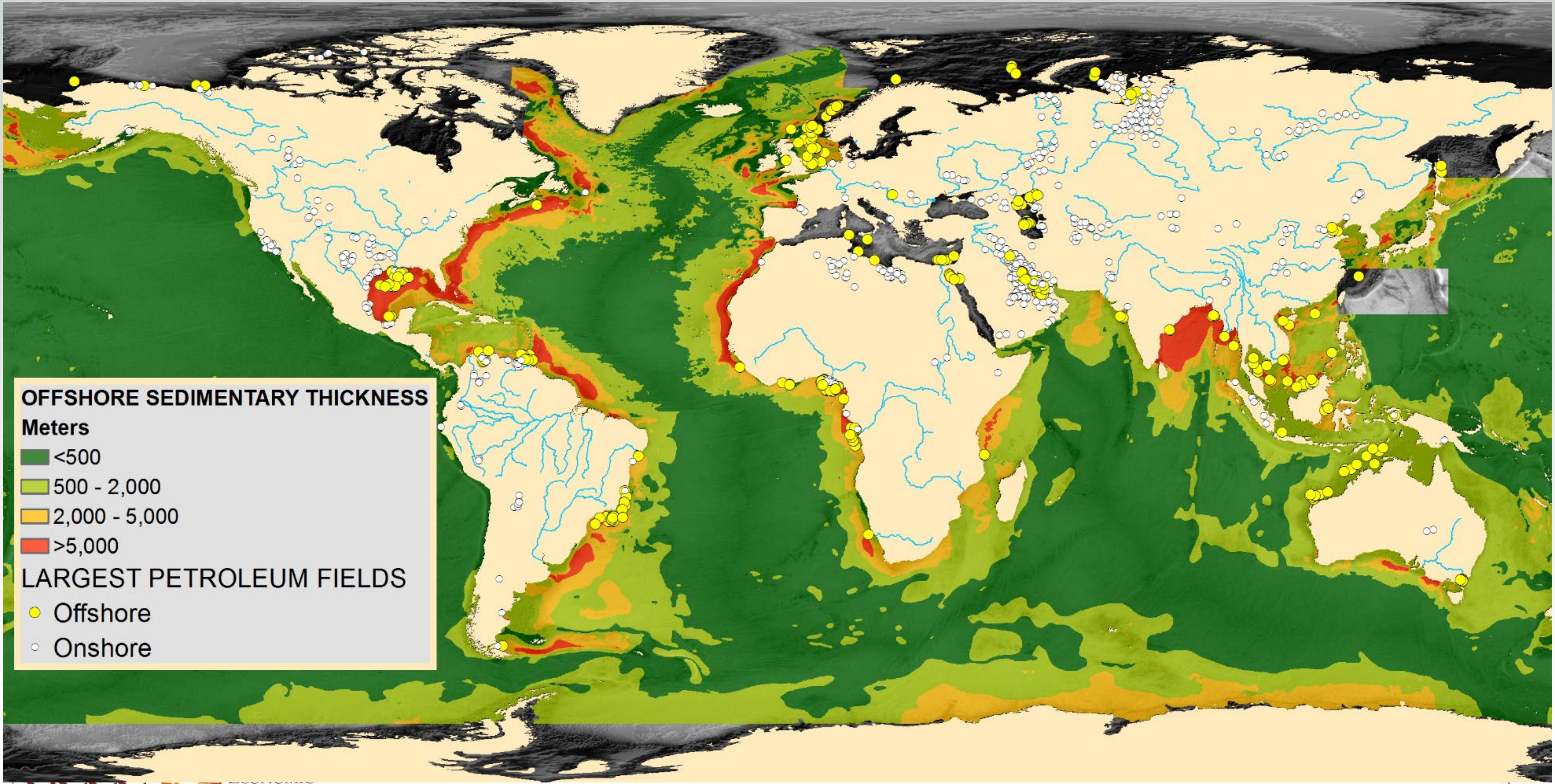
Demonstrate basin-scale characterization workflows
(e.g., pressure's affects on capacity)

Preparation for multiple sites @
maximum injection rates
prolonged time periods
in same region (e.g., GoM)

Benefit (society, industry, govt.):
Increased Retention Assurance

Global continental margins - best near-term <u>Gigatonne-scale CCS</u> opportunity
Gulf of Mexico geologically ideal

Offshore continental margins most promising (near-term Gigatonne-scale storage)



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GEOLOGY

Ringrose & Meckel, 2019 (*after* Divins, 2003; Mann, et al. 2001; Whittaker, 2013)

Overview

- History of GCCC's Offshore studies (including GoM)
  - Expanding scope
    - Geography
    - Research areas
- Storage Play Fairways
- Regional Seismic- & Well-based Mapping
  - Chandeleur Sound
  - Western GoM
    - Upper TX / Western LA Coast
    - Middle TX Coast

Offshore CCS at GCCC

- GULF OF MEXICO
  - GomCARB Partnership
  - CarbonSAFE
  - TXLA
  - Miocene Megatransect
    - HR3D Seismic
    - Geochemistry
  - BOEM
- ATLANTIC
  - Battelle Mid-Atlantic
  - SSEB South Atlantic
- JAPAN
  - Tomakomai
    - HR3D Seismic
    - Geochemistry
- CHINA
  - Pearl River Mouth Basin
- NORTH SEA
  - Scotland ACORN
  - UK Sector
  - IODP GlaciStore
- NIGERIA
  - UNFCC
- GLOBAL
  - CSLF & IEA-GHG
  - International Offshore Storage Workshops
- HR3D SEISMIC
  - 3 GoM surveys 1 Japan survey
  - Service Center

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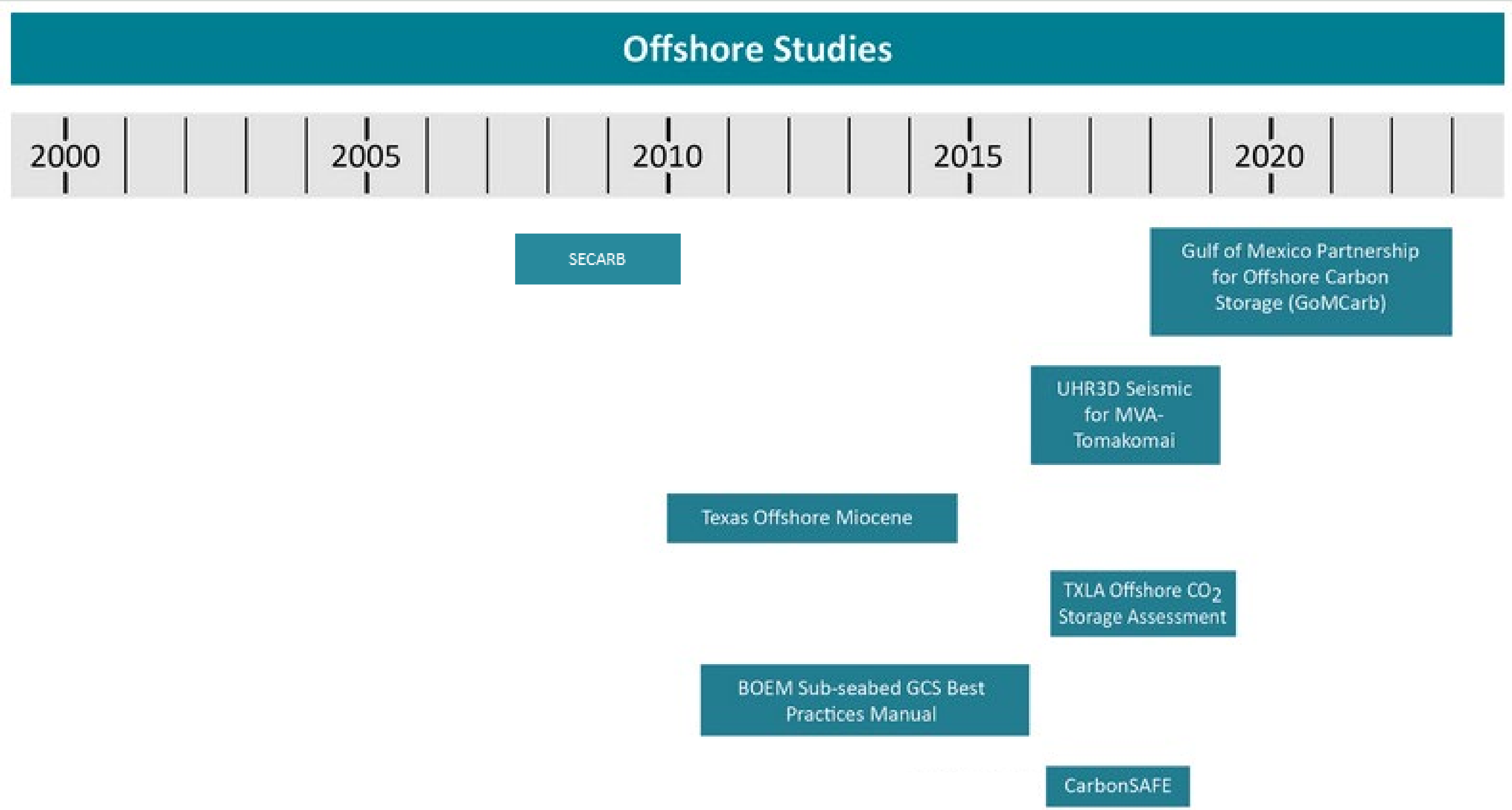
Offshore Studies: *most* in Gulf of Mexico



Student Theses -

1. Ruiz, I., 2019, **Characterization of the High Island 24L Field for modeling and estimating CO2 storage capacity in the offshore Texas State Waters, Gulf of Mexico**, MS Thesis, UT-Austin, 220 p.
2. Garcia, O., 2019, **Geologic characterization and modeling of the High Island 10-L field for CO_2 storage resource assessment in Texas State Waters, offshore Gulf of Mexico**, MS Thesis, UT-Austin, 123 p.
3. Beckham, E., 2018, **CO_2 storage in deltaic environments of deposition: Integration of 3D modeling, outcrop analysis and subsurface application**, MS Thesis, UT-Austin, 220 p.
4. Maciel, R.S., 2017, **Pre-injection reservoir characterization for CO2 storage in the inner continental shelf of the Texas Gulf of Mexico**, MS Thesis, The University of Texas at Austin, 90 p.
5. Osmond, J.L., 2016, **Fault seal and containment failure analysis of a Lower Miocene structure in the San Luis Pass area, offshore Galveston Island, Texas Inner Shelf**, MS Thesis, The University of Texas at Austin, 220 p.
6. Mulcahy, F.J., 2015, **Use of High Resolution 3D Seismic Data to Evaluate Quaternary Valley Evolution History during Transgression, Offshore San Luis Pass, Gulf of Mexico**, MS Thesis, The University of Texas at Austin, 122 p.
7. Wallace, K.J., 2013, **Use of 3-Dimensional Dynamic Modeling of CO2 Injection for Comparison to Regional Static Capacity Assessments of Miocene Sandstone Reservoirs in the Texas State Waters, Gulf of Mexico**, MS Thesis, The University of Texas at Austin, 152 p.
8. Nicholson, A.J., 2012, **Empirical Analysis of Fault Seal Capacity for CO_2 Sequestation, Lower Miocene, Texas Gulf Coast**, MS Thesis, The University of Texas at Austin, 100 p.

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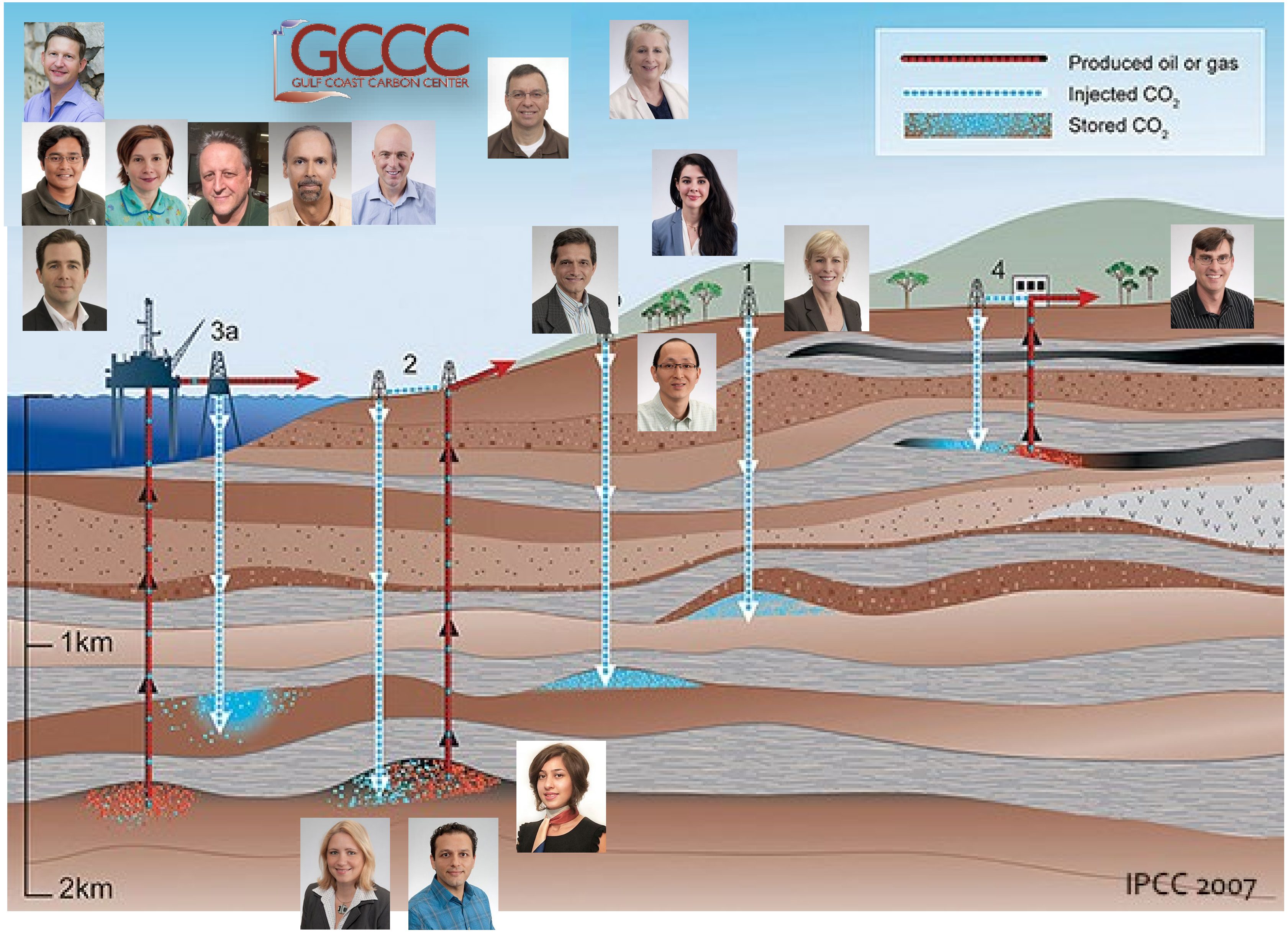
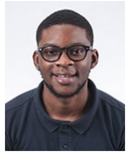
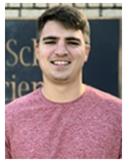
GCCC Team

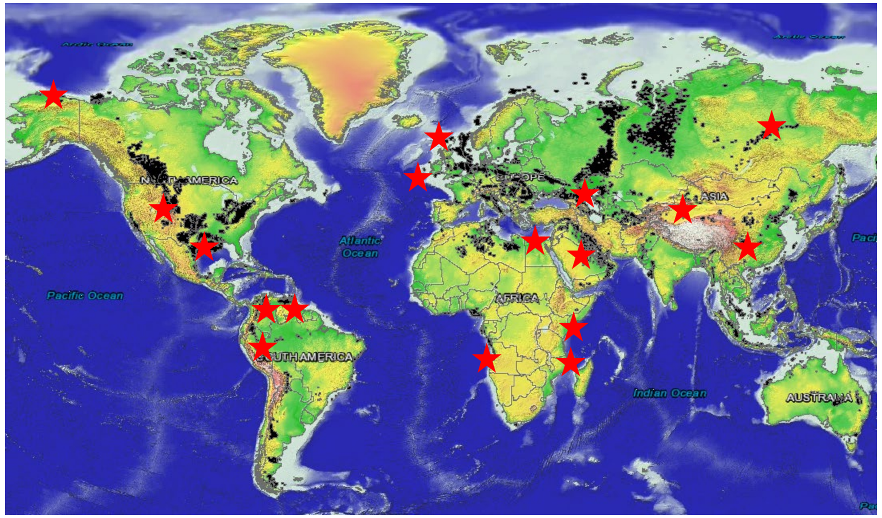

GCCC
GULF COAST CARBON CENTER
Produced oil or gas
Injected CO_2
Stored CO_2
3a
2
1
4
1km
2km
IPCC 2007





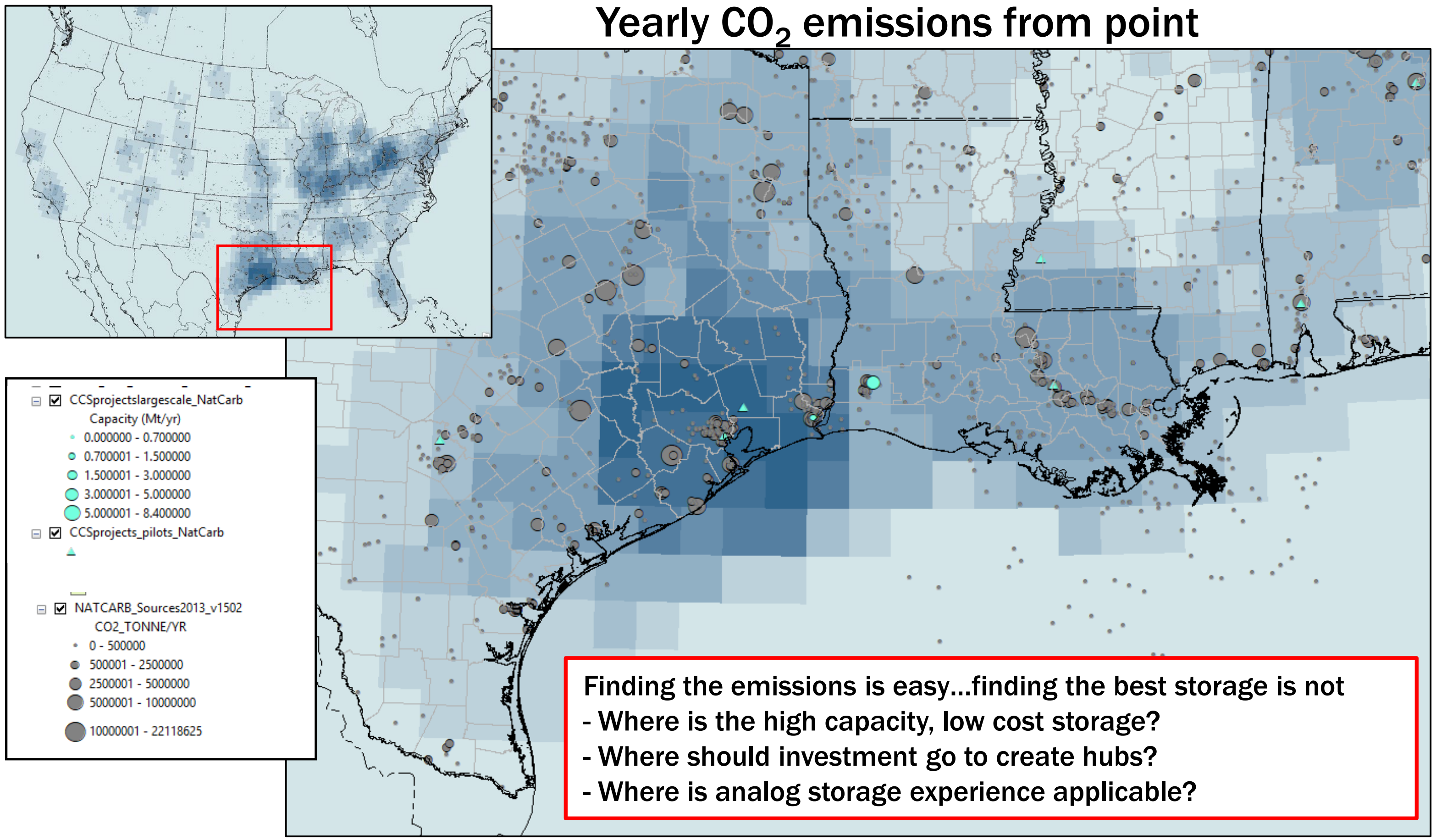
Alex Bump

- University of Arizona PhD, 2001 in structural geology and tectonics
- 16 years in BP Exploration
  - 6 years in Houston, 10 years in London
  - New ventures, drilling prospects, internal consulting
  - Extensive experience teaching and mentoring
  - Last role: Exploration Advisor; Head of Discipline for Structure and Tectonics
    - Global capability
    - Proactive identification and delivery of high-value business
    - Develop and implement new science and tech
- 2018-19 gap year travelling the world
- Joined GCCC October 1, 2019



Storage Play Fairways

Finding the Greatest Emissions is Easy…



Data: NATCARB, 2019; Map: Bump, 2019

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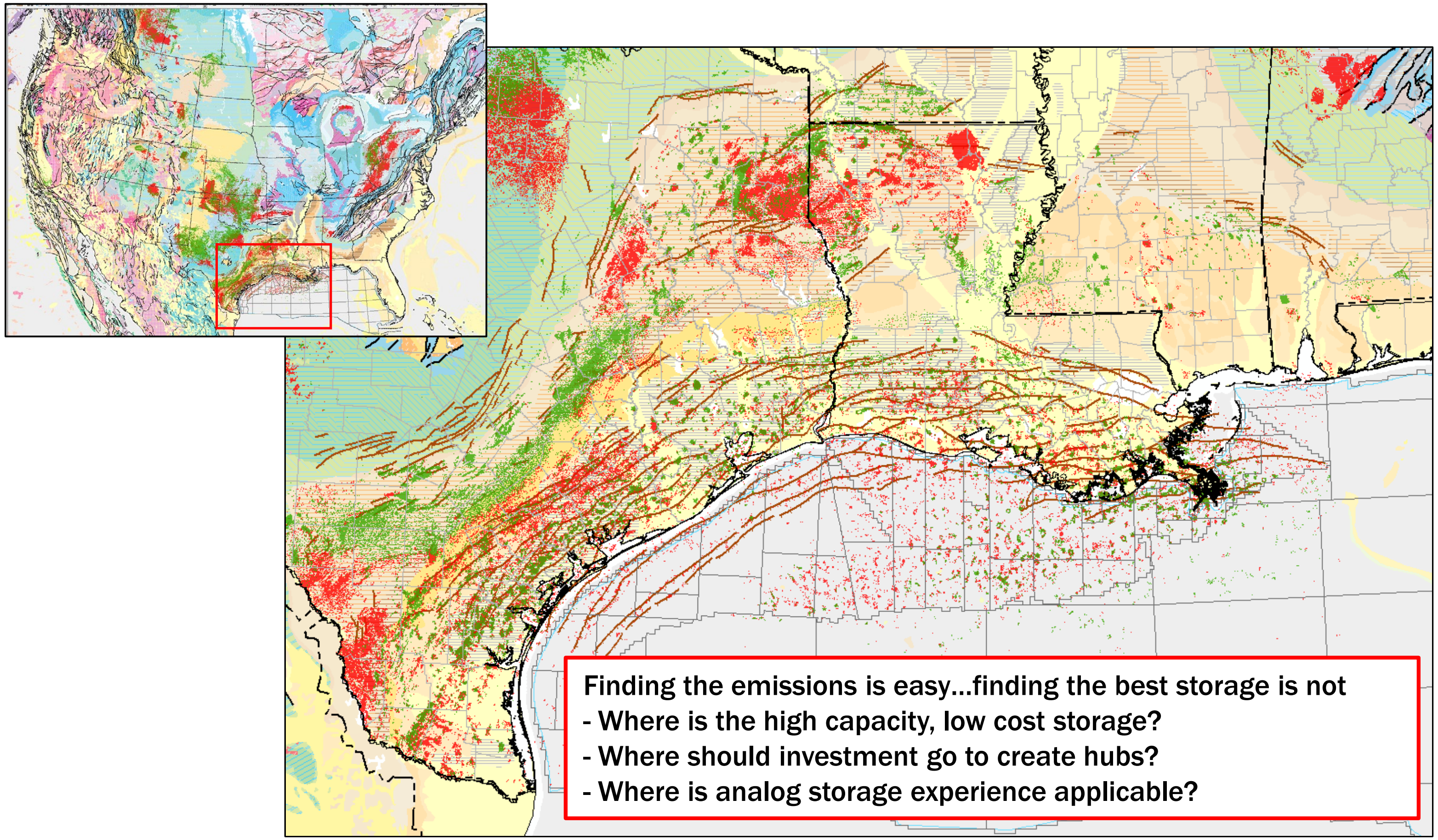
Defining the Best Storage is Not



Geologic Map (USGS) and Hydrocarbon Production (IHS)

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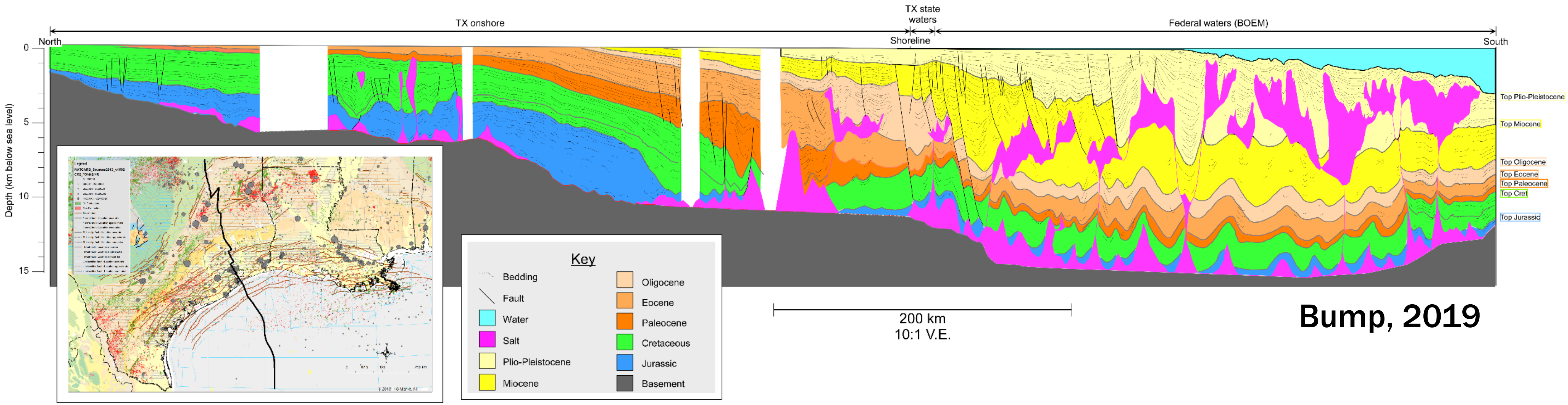
Identifying Storage Plays

Geologic Interpretation



Bump, 2019

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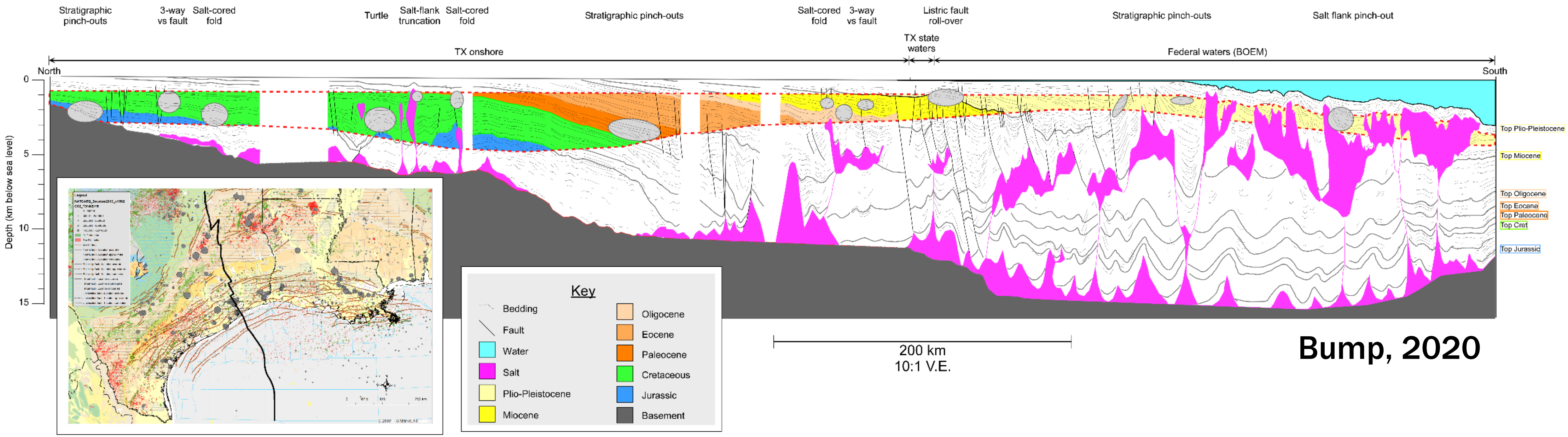
Identifying Storage Plays

Pressure window for injection and potential trap styles



Bump, 2020

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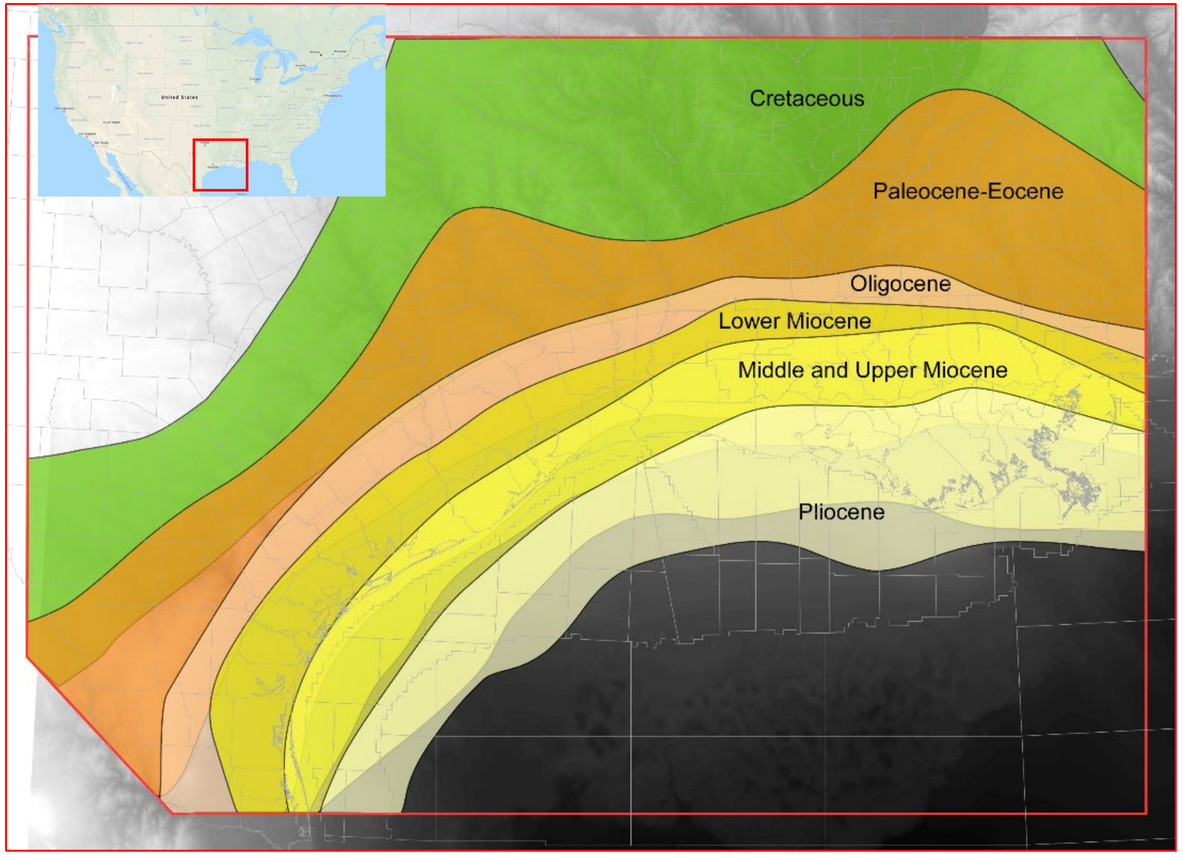
Footprints Within the Storage Window

Geographic extent of CO_2 storage window by stratal age



Bump, 2019

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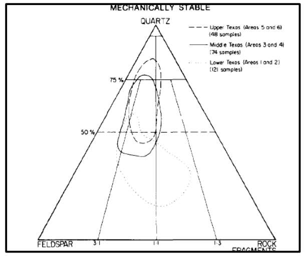
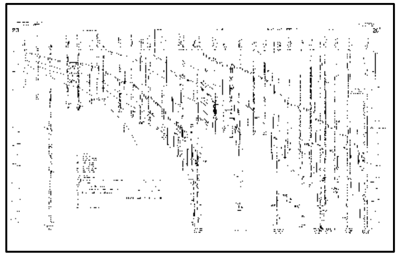
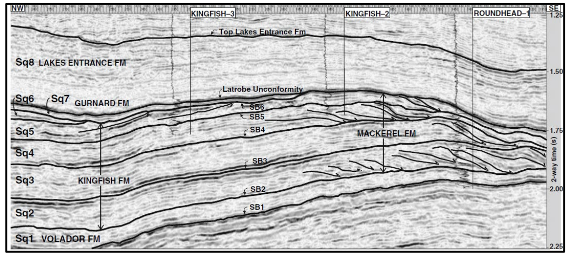
Defining Storage Play Fairways

Example: Oligocene Frio reservoir and Anhuac seal

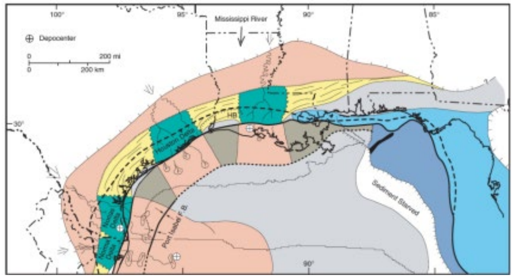
Geologic Data

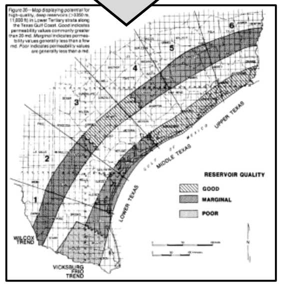


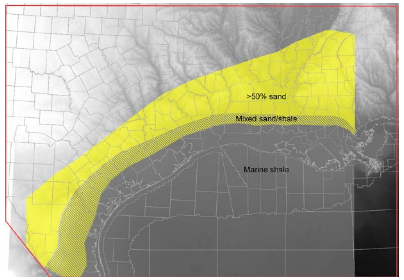




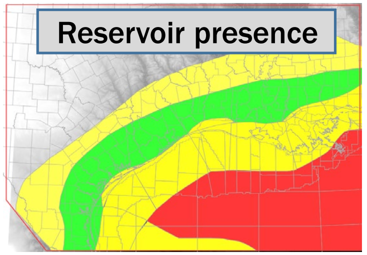
Geologic Interpretations

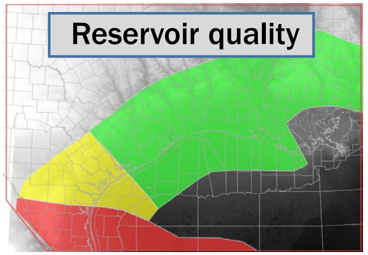


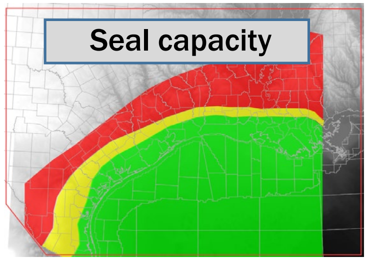




Risk Maps







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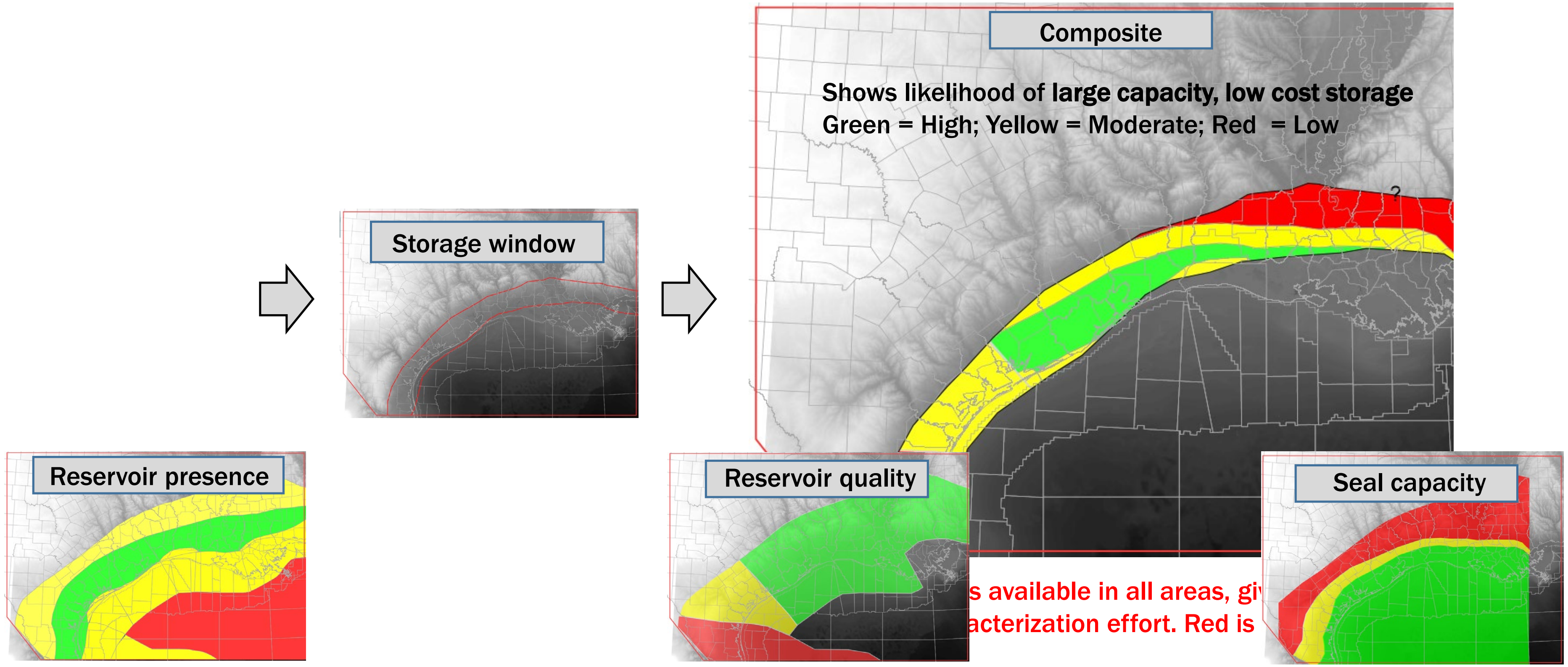
Green on all layers	Green

Defining Storage Play Fairways

Example: Oligocene Frio reservoir and Anhuac seal

Risk Maps

Composite Risk Map



Risk Maps

Bump, 2019

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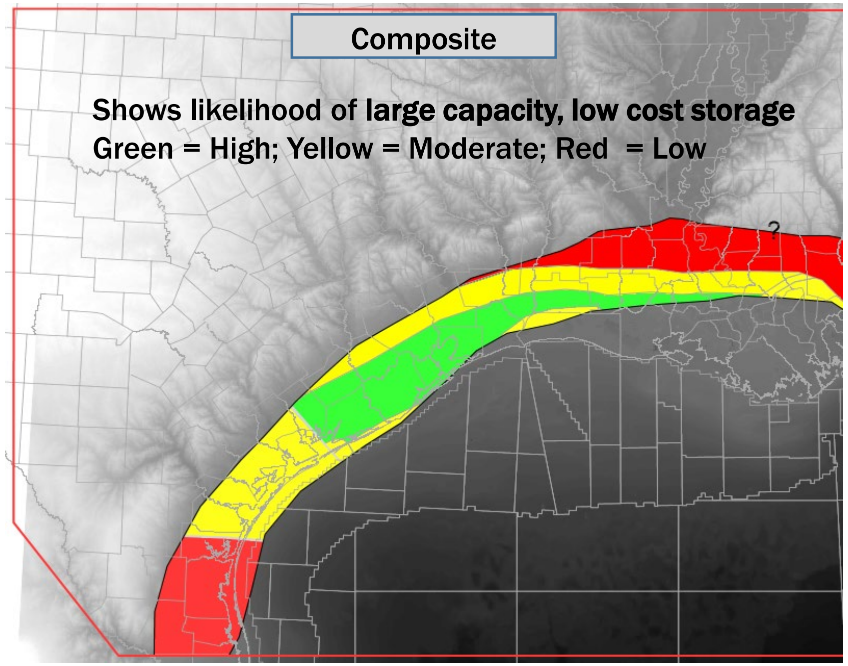
The Prize

- Allows efficient screening
- Ensures focus on opportunities is well placed
- Creates a map for strategic storage investment
- Allows rigorous extrapolation of analog results
- **Do the right thing in the right place**

<u>Composite Risk Map</u>



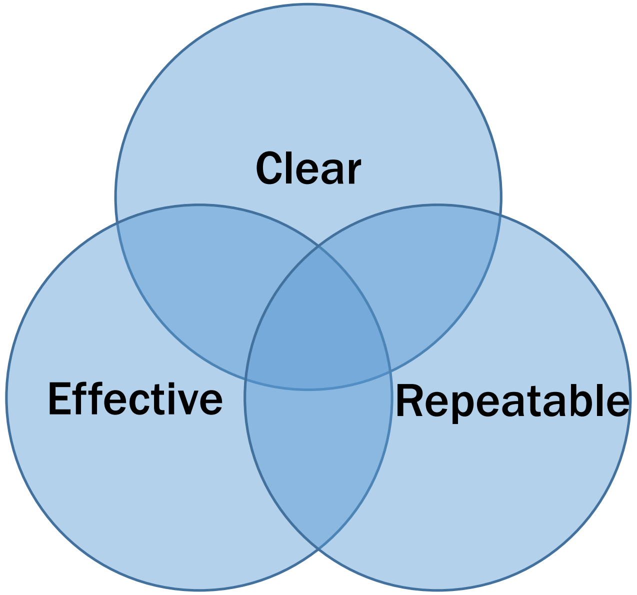
Note: Storage is available in all areas, given enough wells and characterization effort. Red is not a "no go."

The Future

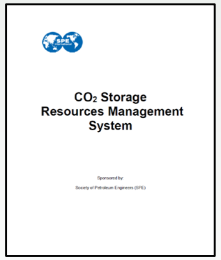
- Next Steps
  - Define Lower and Middle Miocene play fairways
  - Identify structural closures and add storage leads to the maps
  - Use more detailed prospect work and hydrocarbon analogs to validate interpretation and calibrate expected storage costs, efforts and risks

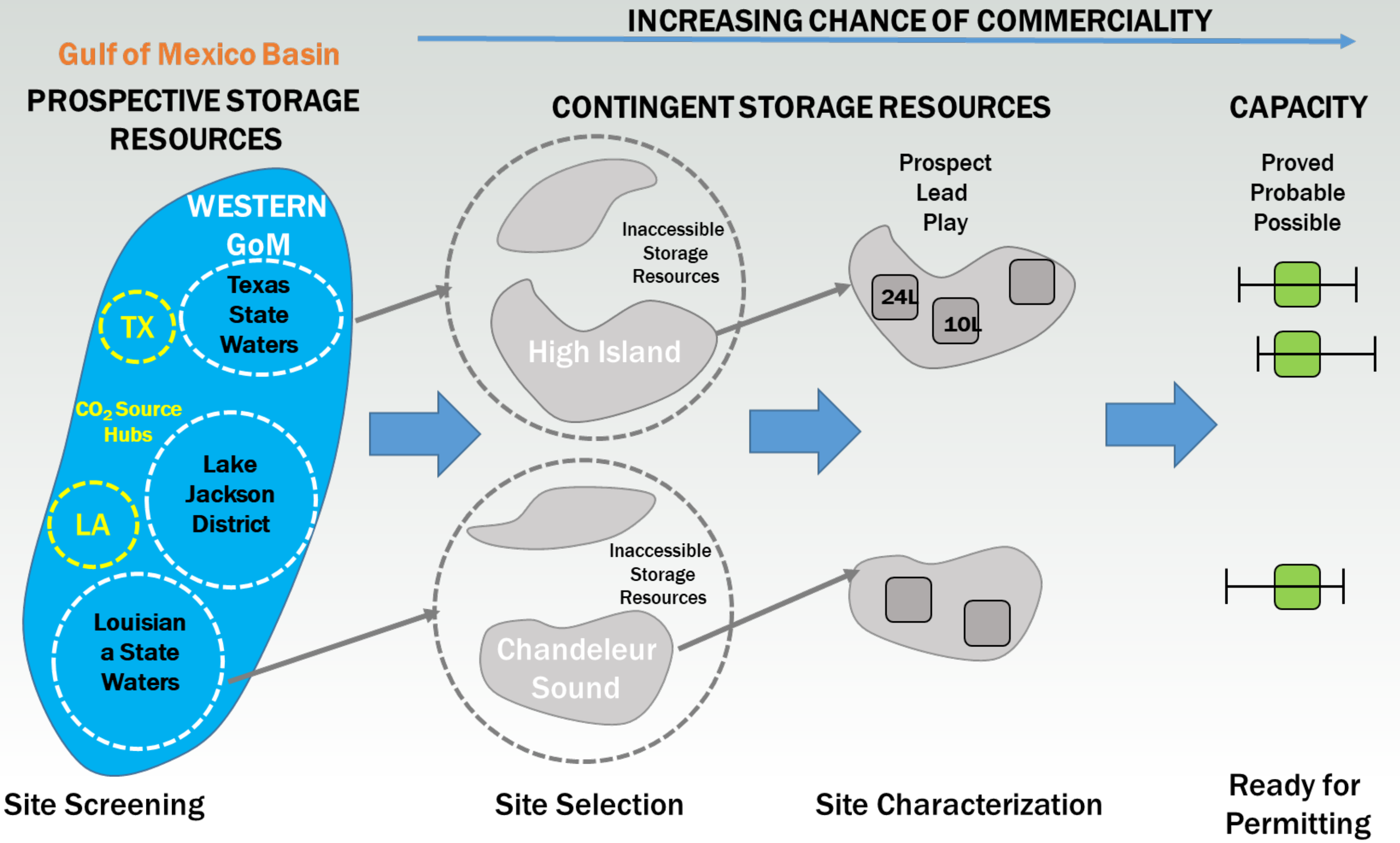
- Research Needs
  - Role of dissolution in subsurface storage
  - Pressure implications of Gigatonne-scale storage

- Learning by doing: Real-world storage experience is key



Prospect Maturation Flow

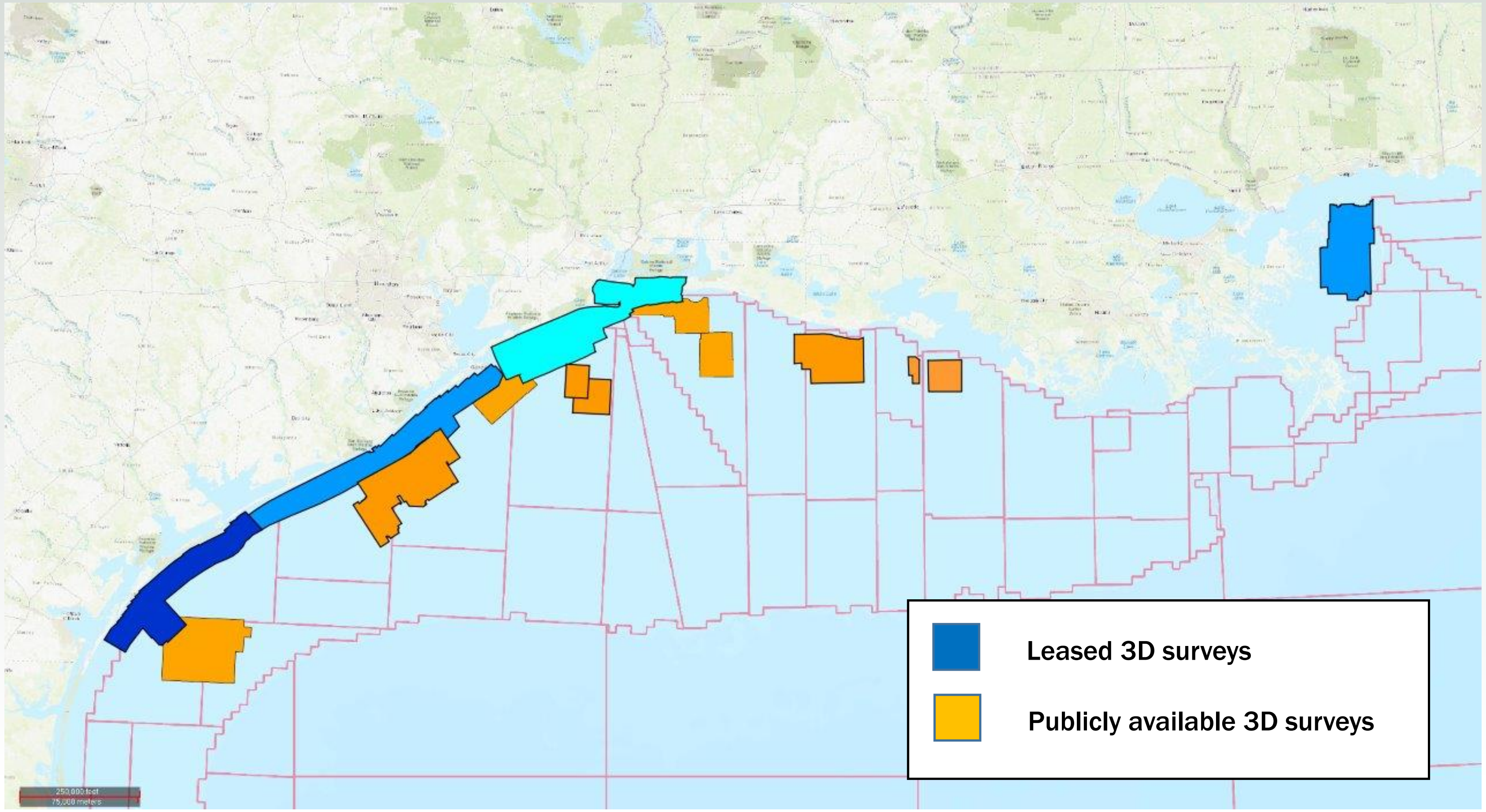




Meckel, 2018

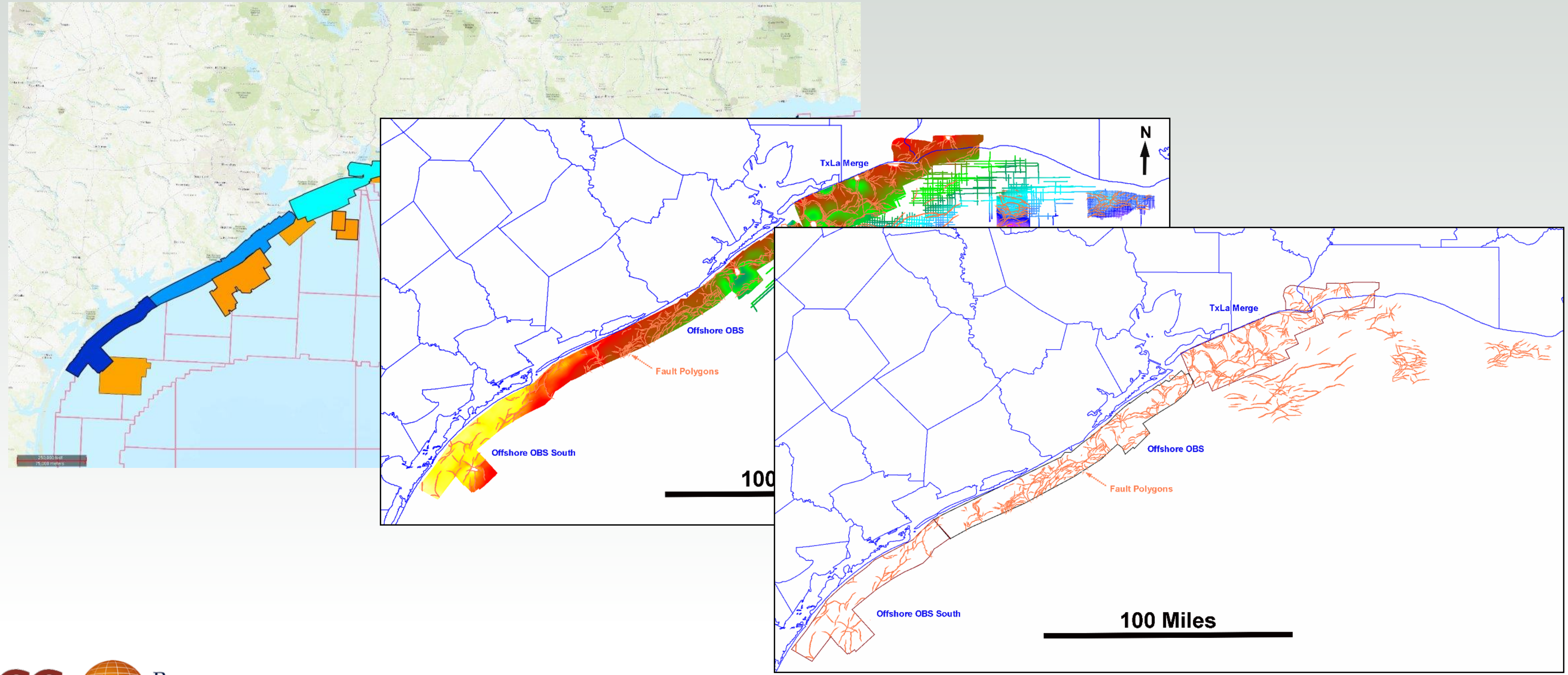
Site Screening

Texas Coast Seismic Mapping



- Near complete 3D seismic coverage of TX state waters
- MFS09 mapped over ~10,000 km^2 on 3D
- 709 interpreted fault polygons.
- TxLA_Merge has 9 surfaces interpreted (mfs4,5,7,8,9,10,12, sb_m8, sb_m9)
- Next step will be to interpret mfs10 or mfs12 throughout the 3D seismic volumes

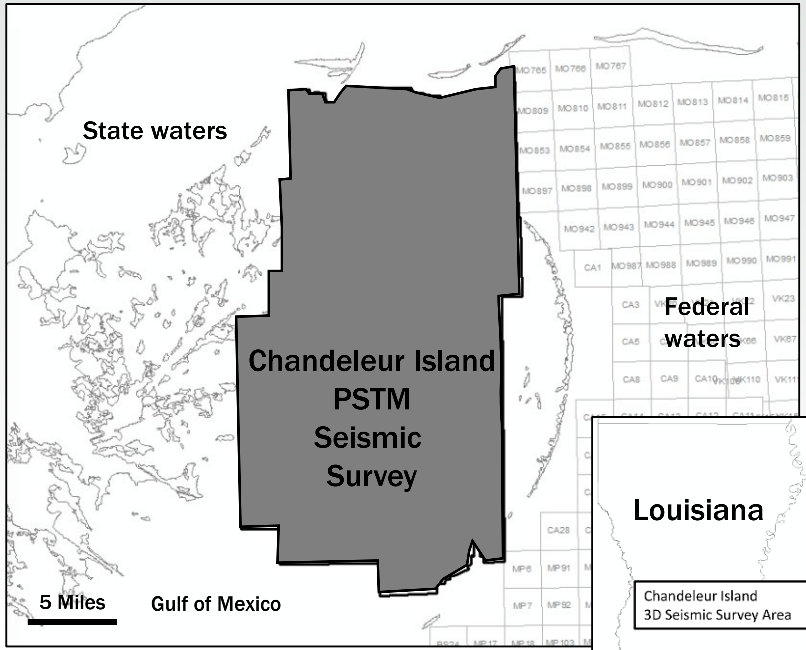
Texas Coast Seismic Mapping

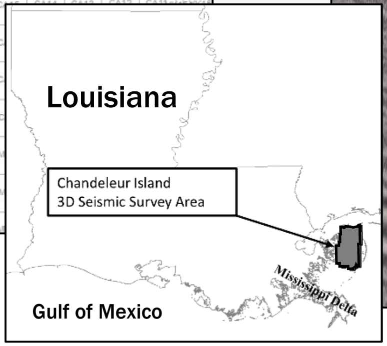


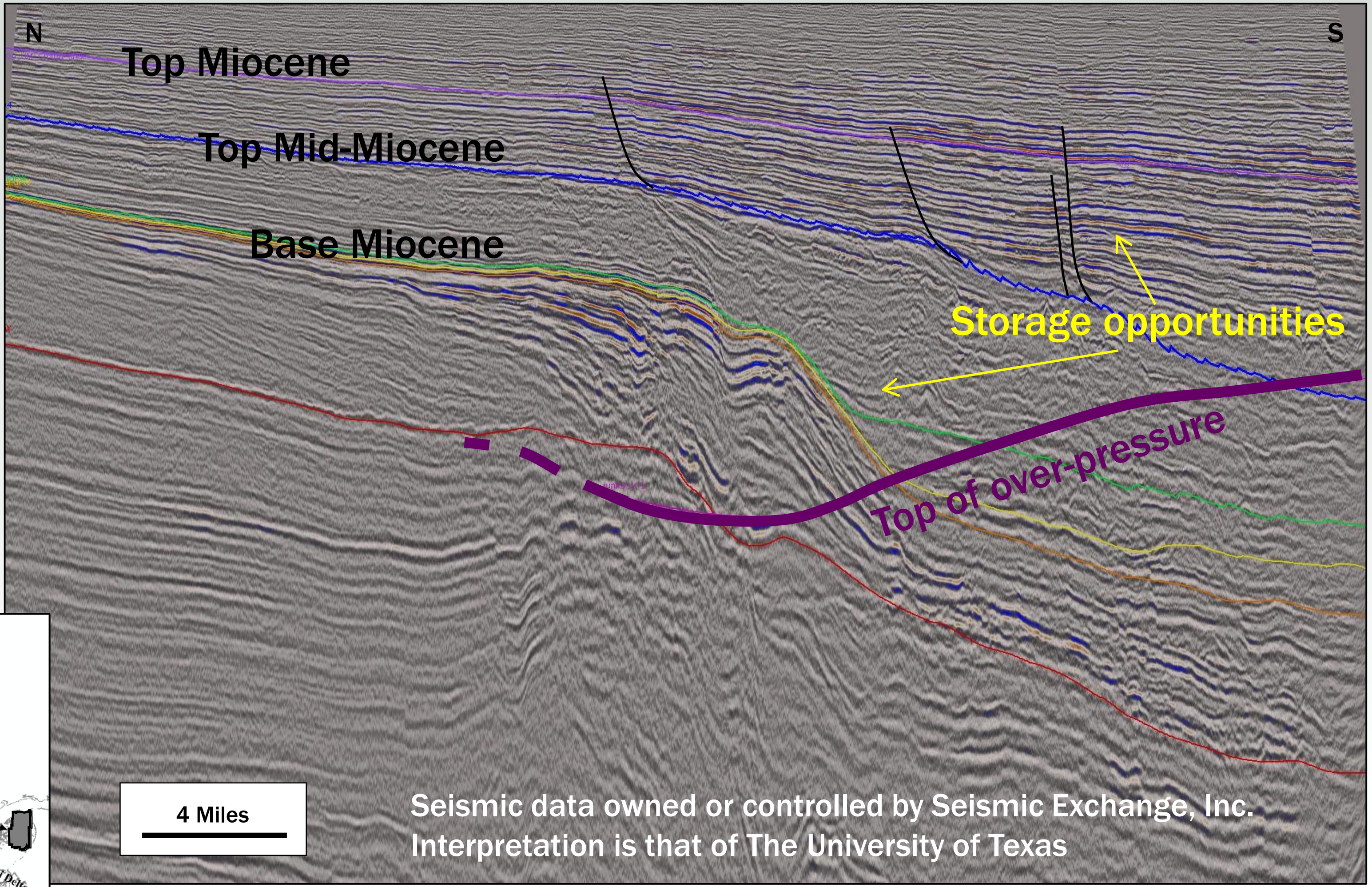
DeAngelo et al, 2020

Offshore GoM (Gulf of Mexico) Studies
Chandeleur Area, Offshore Louisiana

- Storage potential in LA waters
- Partnership with UT-GBDS
- Miocene Interval

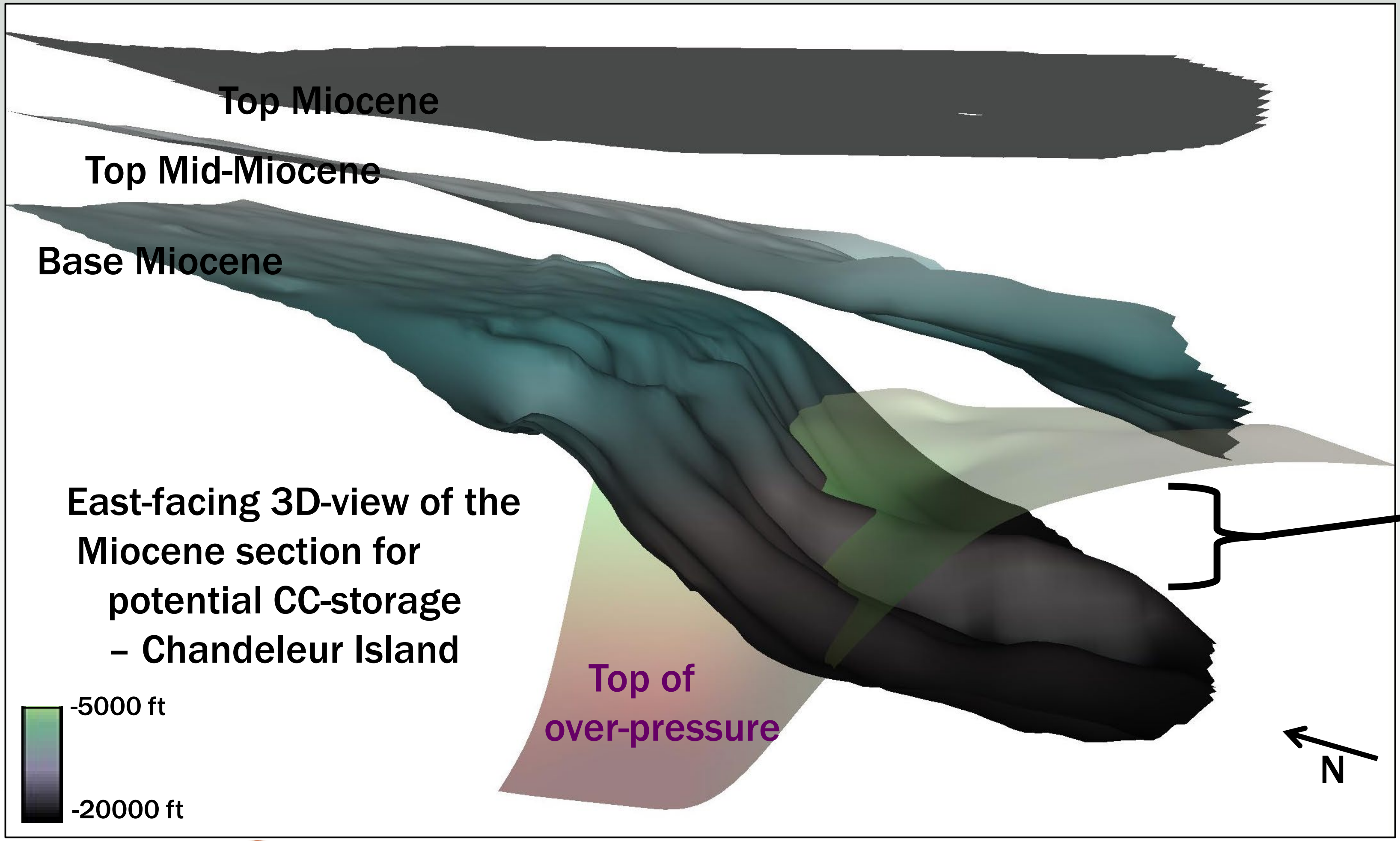


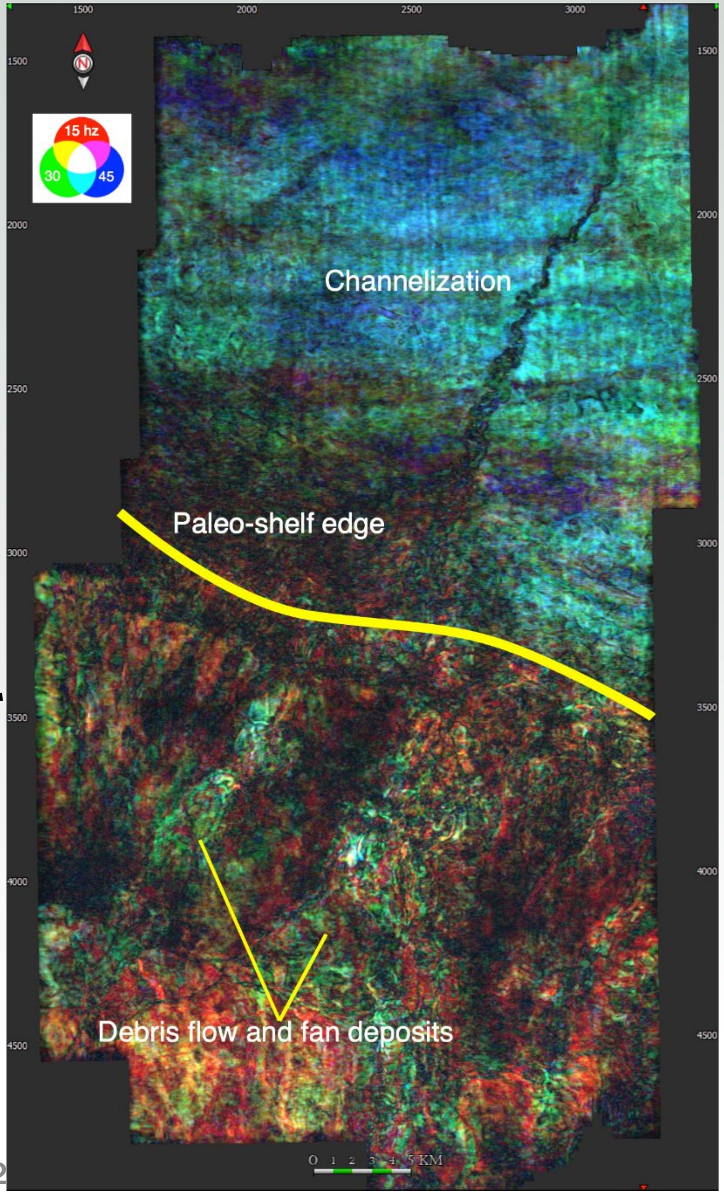




Marcie Purkey Phillips, UTIG

Offshore GoM (Gulf of Mexico) Studies





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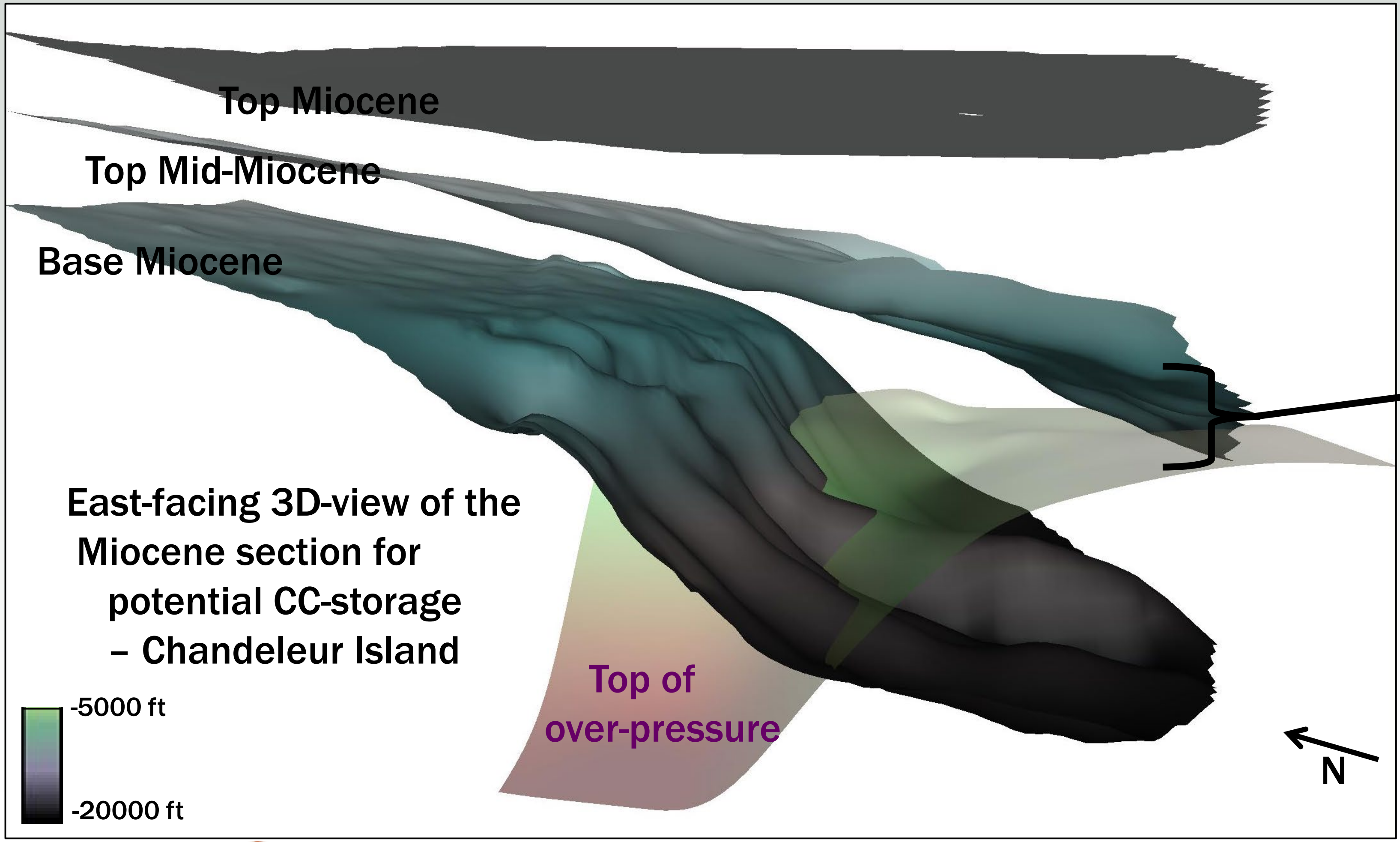
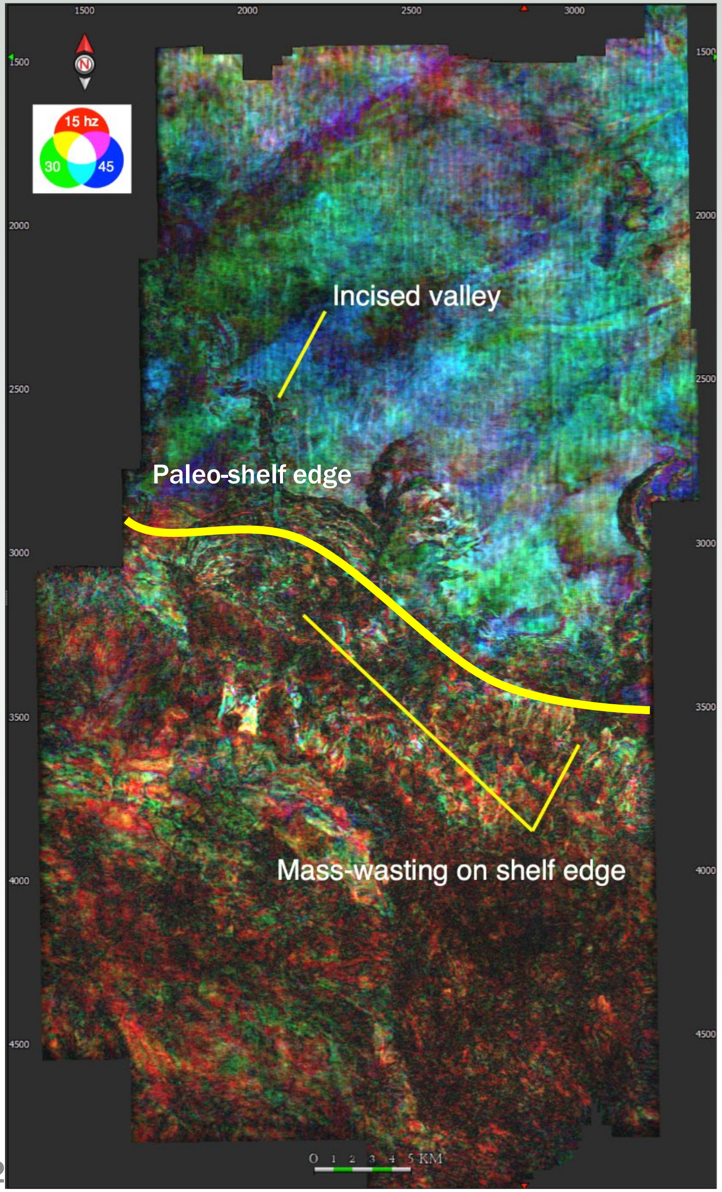
Marcie Purkey Phillips , UTIG
Dallas Dunlap, BEG

Offshore GoM (Gulf of Mexico) Studies





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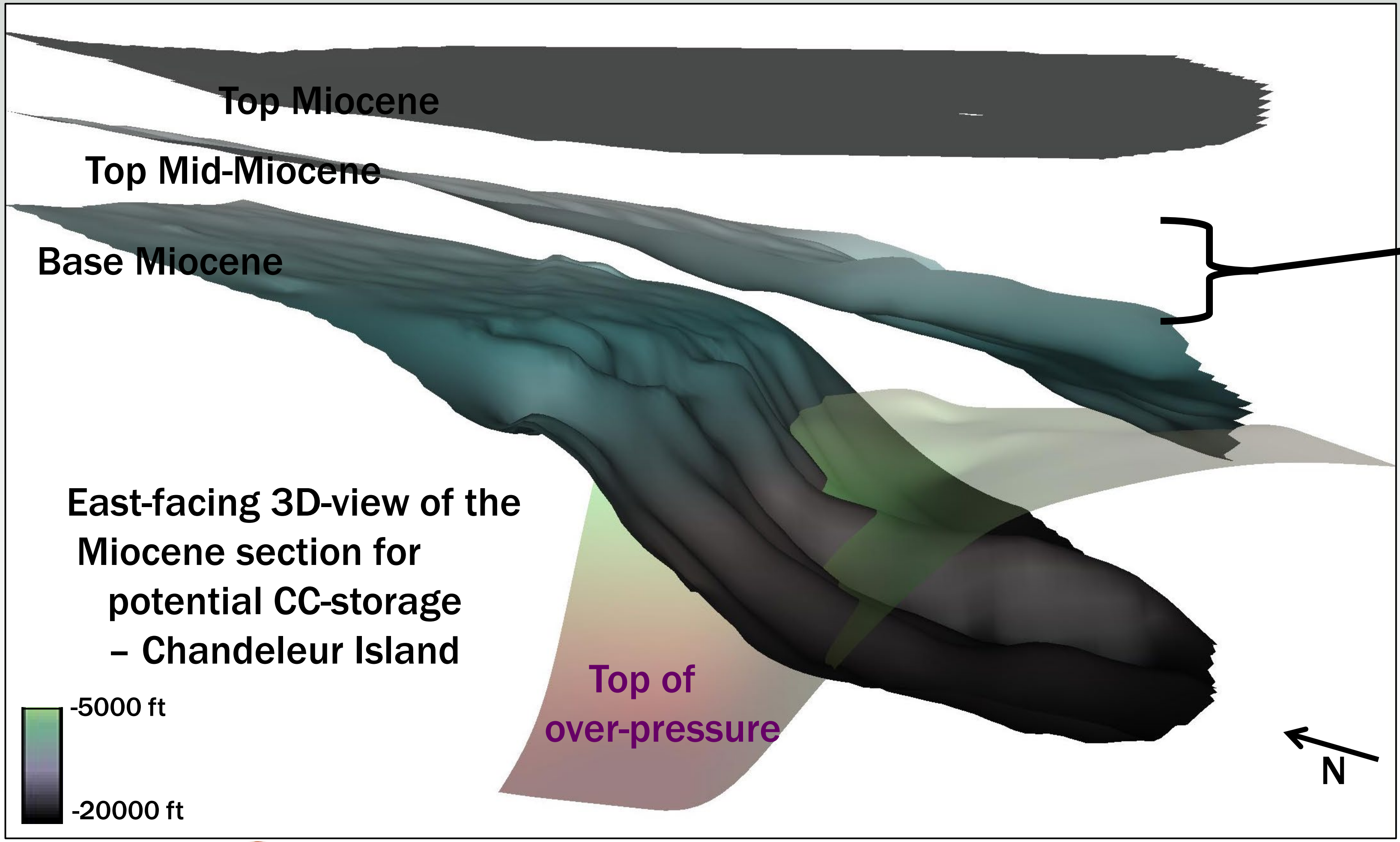

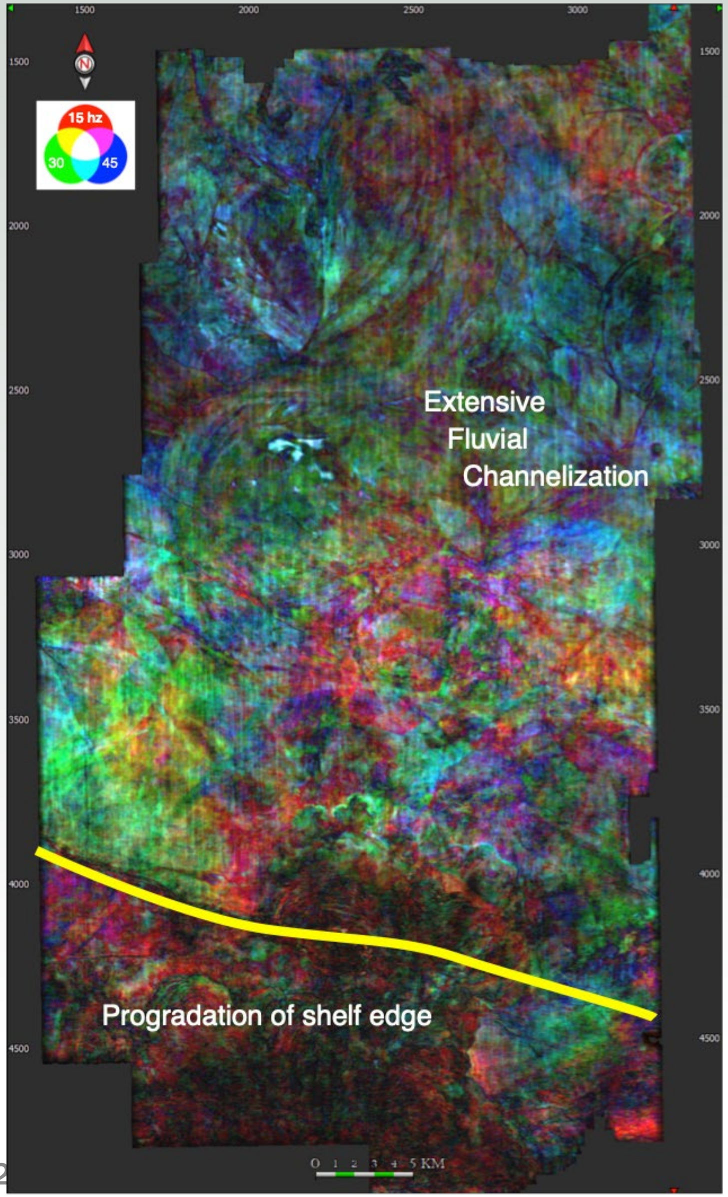

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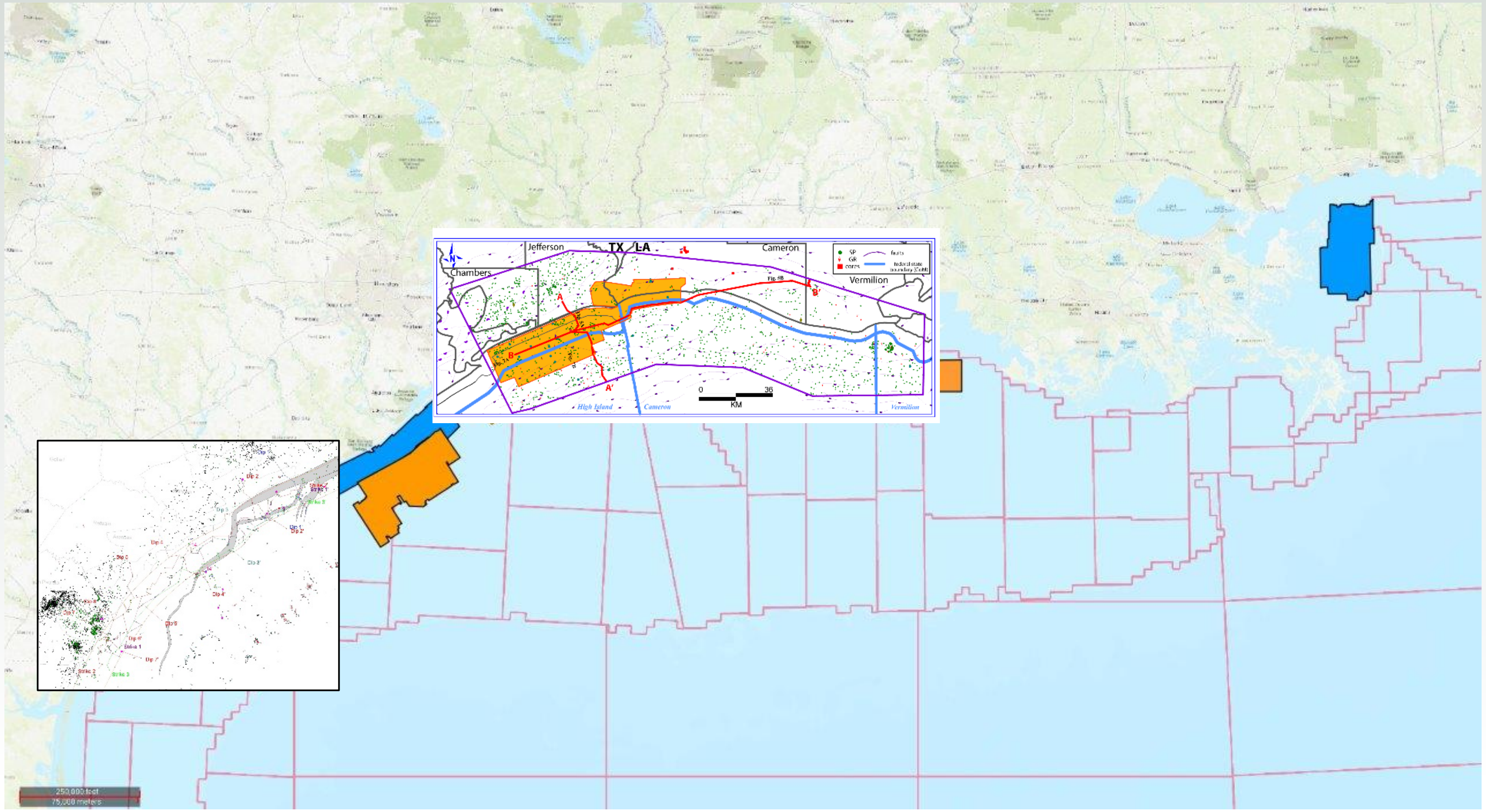
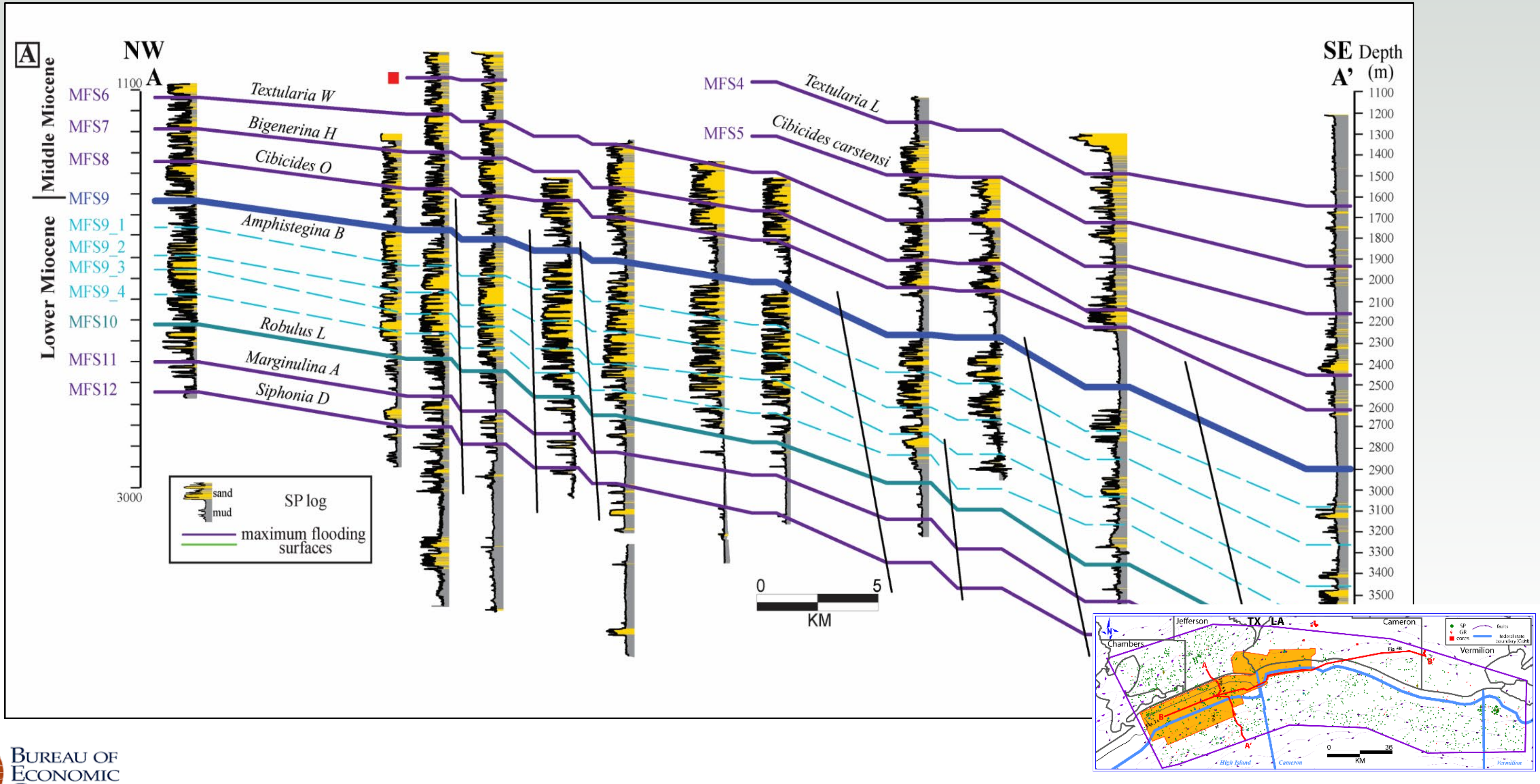
Log Correlations

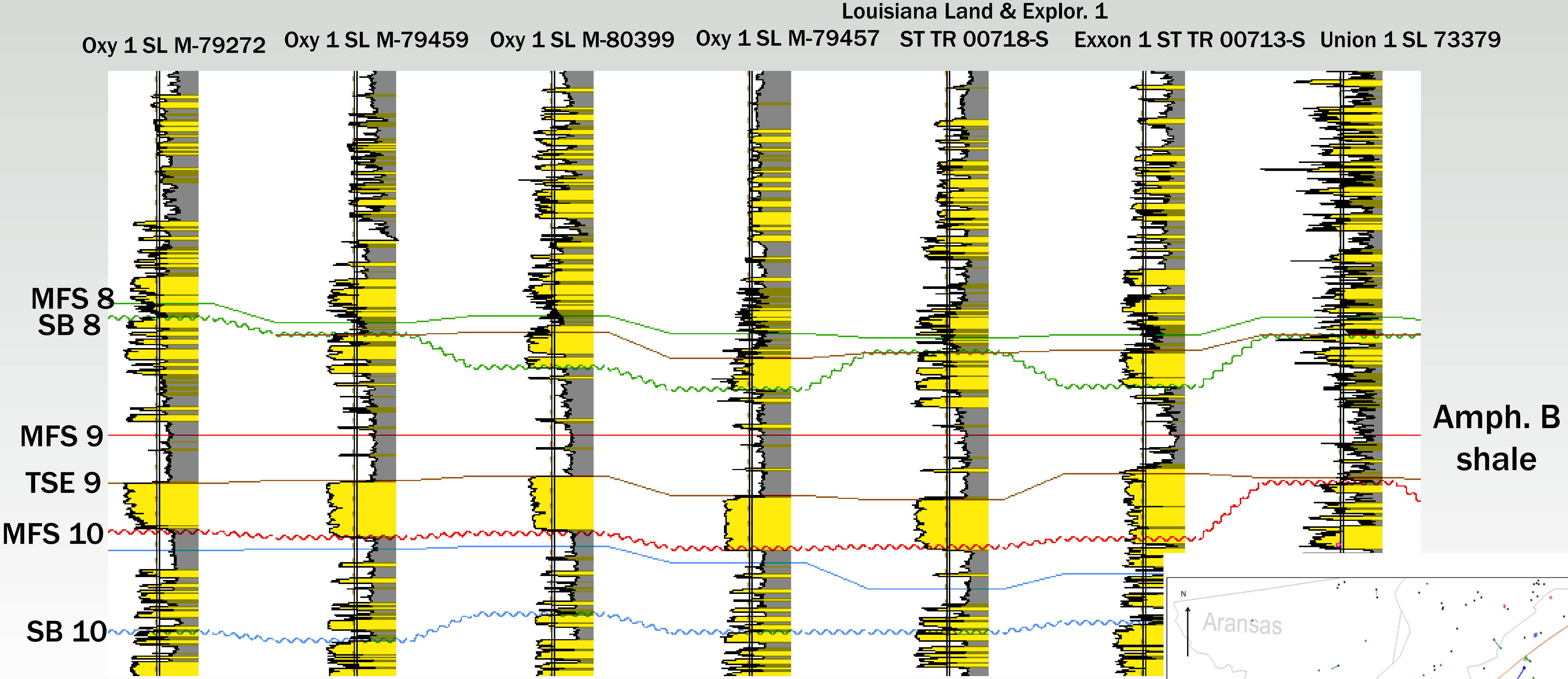


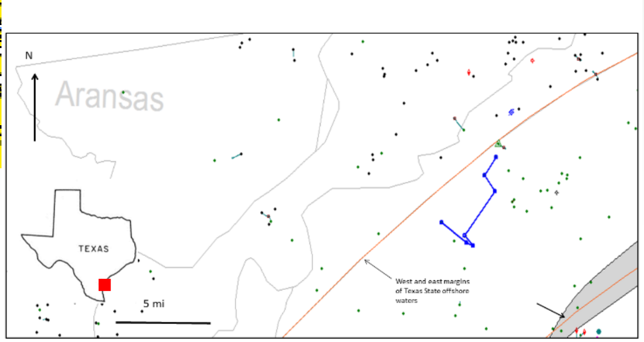
- Adding lithologic detail to seismic mapping
- >5,000 correlated wells (upper coast)
- >1,000 wells correlated (mid-coast)
- Current focus on mid-coast

Log Correlations



Miocene Log Correlations





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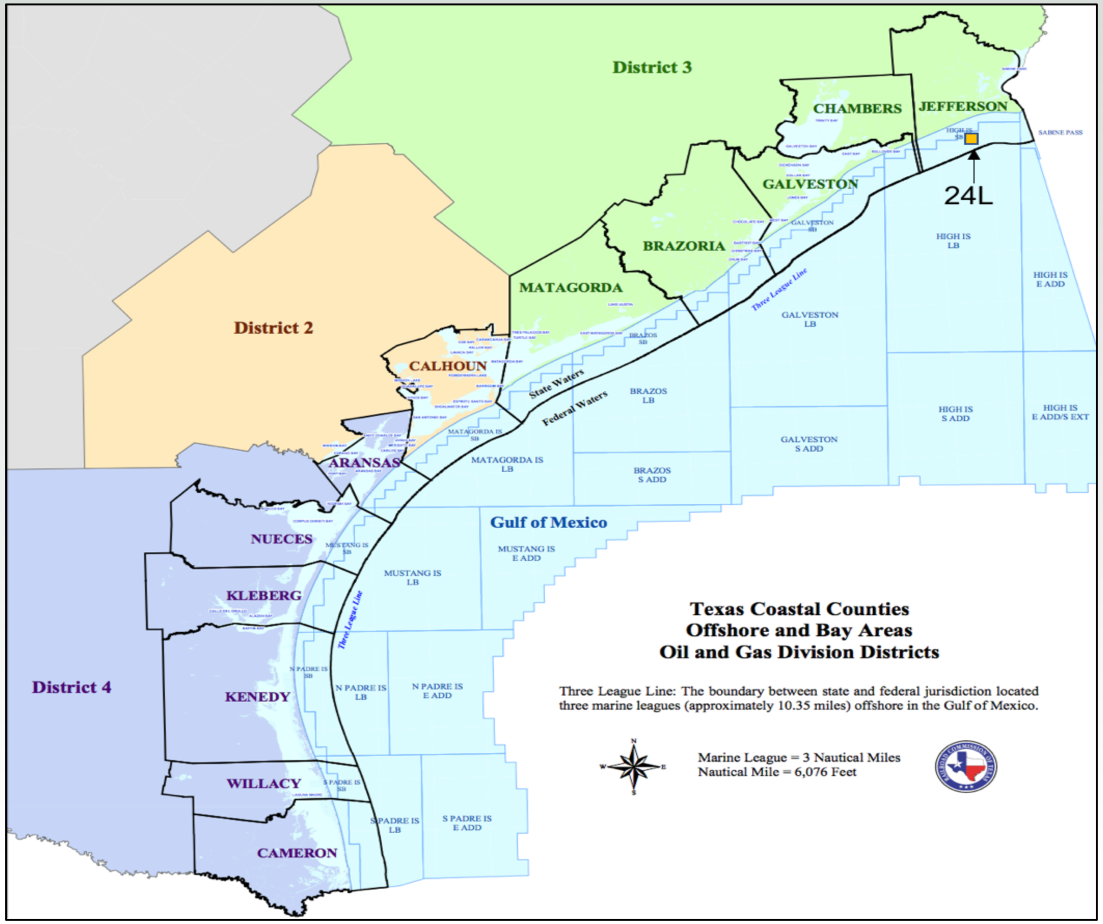
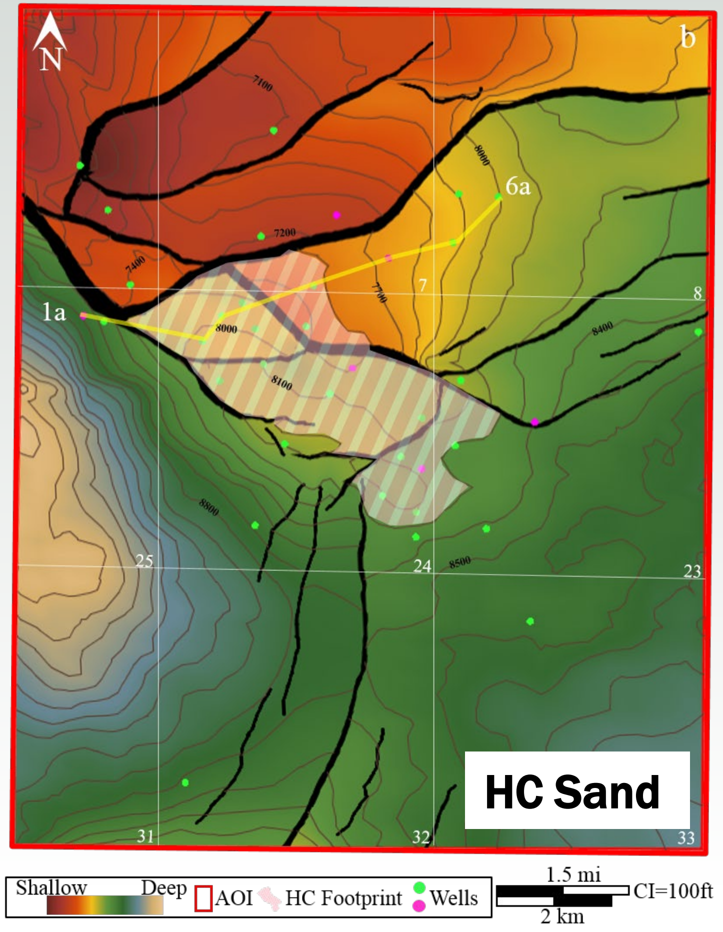
Prospect Description: High Island 24L Field

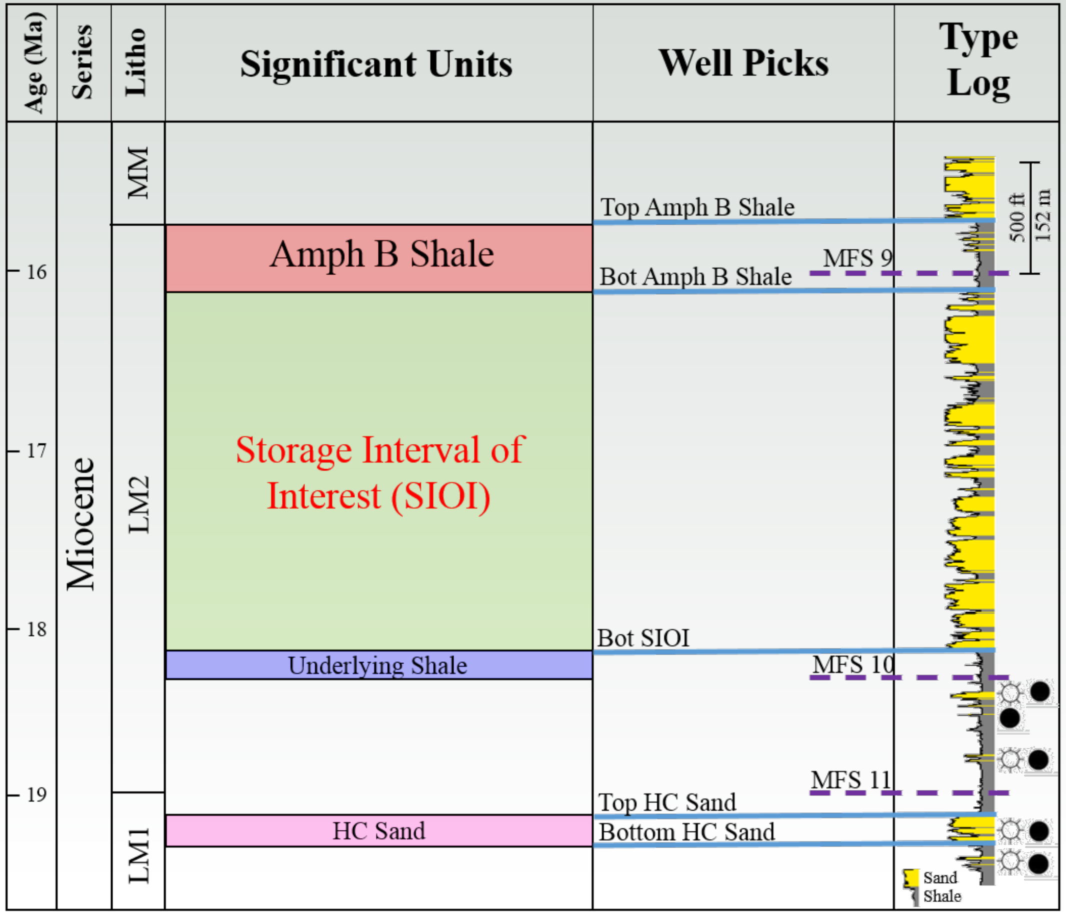
24L

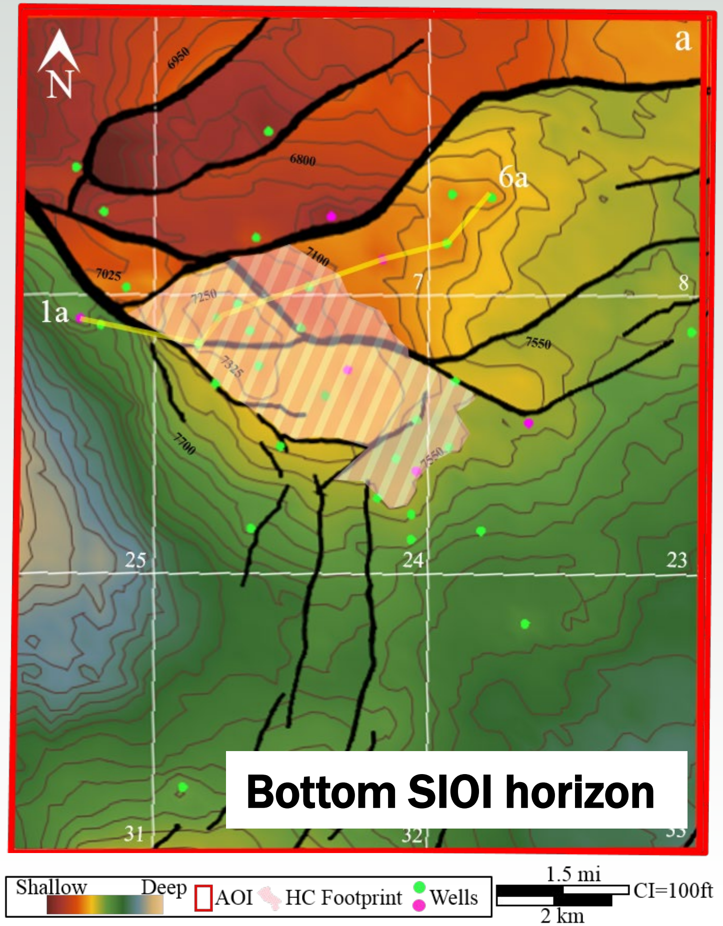




Ruiz, 2019

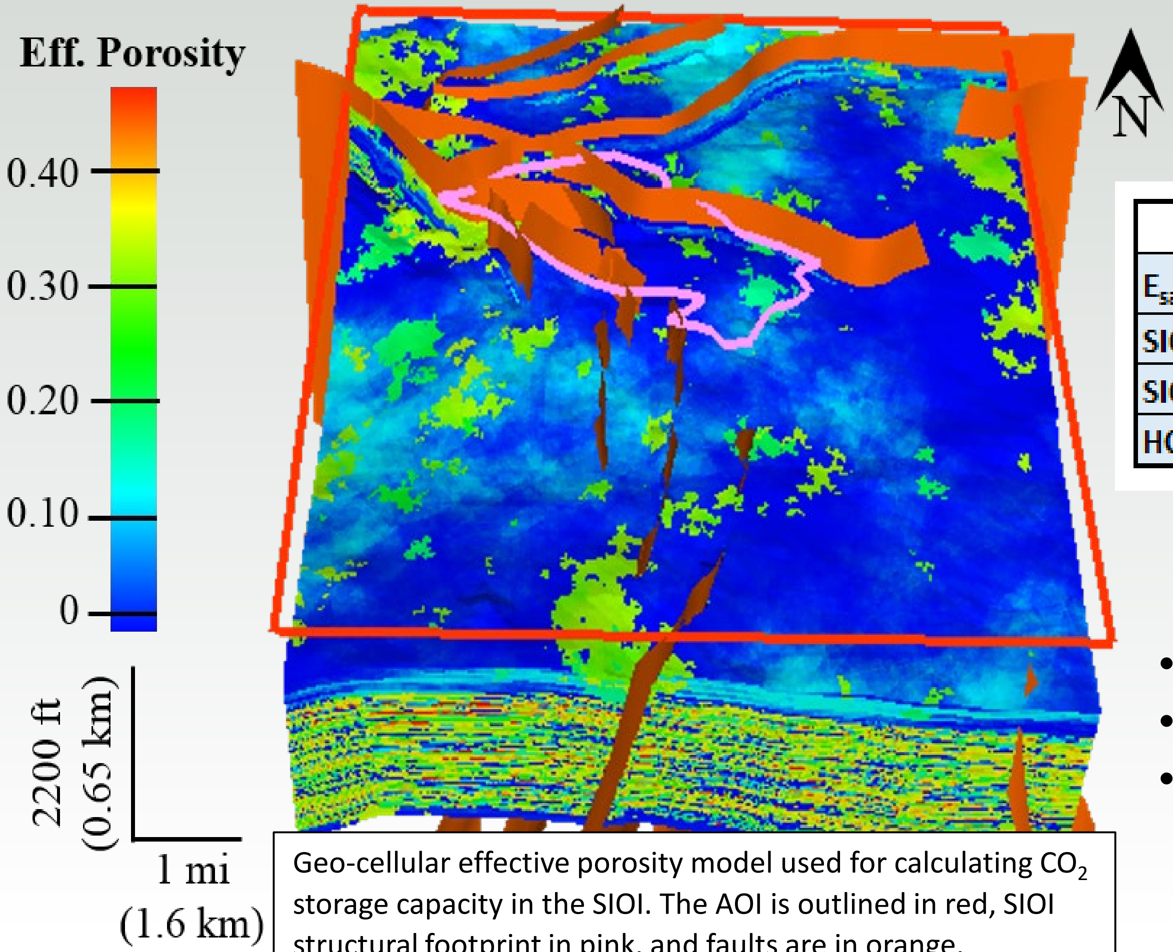
24L Structure





Ruiz, 2019

24L Volumetrics



Geo-cellular effective porosity model used for calculating CO_2 storage capacity in the SIOI. The AOI is outlined in red, SIOI structural footprint in pink, and faults are in orange.

	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

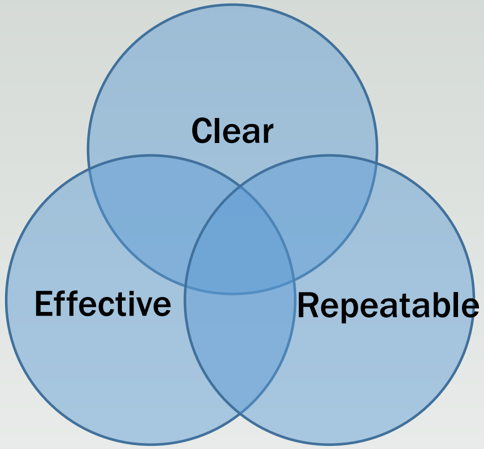
- Exciting prospect
- Near multiple CO_2 sources and existing infrastructure
- One in a growing portfolio of storage prospects

Ruiz, 2019

Summary

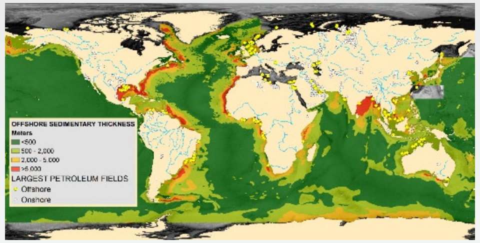
Are there CCS Super Basins, analogous to hydrocarbon basins?

Method to reliably identify and characterize the best opportunities



Global continental margins: Best near-term Gigatonne-scale CCS opportunity

Gulf of Mexico ideally suited to lead the way



Research needs:

- Understand Gigatonne-scale pressure perturbation impact
- Understand the roles of dissolution in storage
- Real-world pilot projects: Learning by doing

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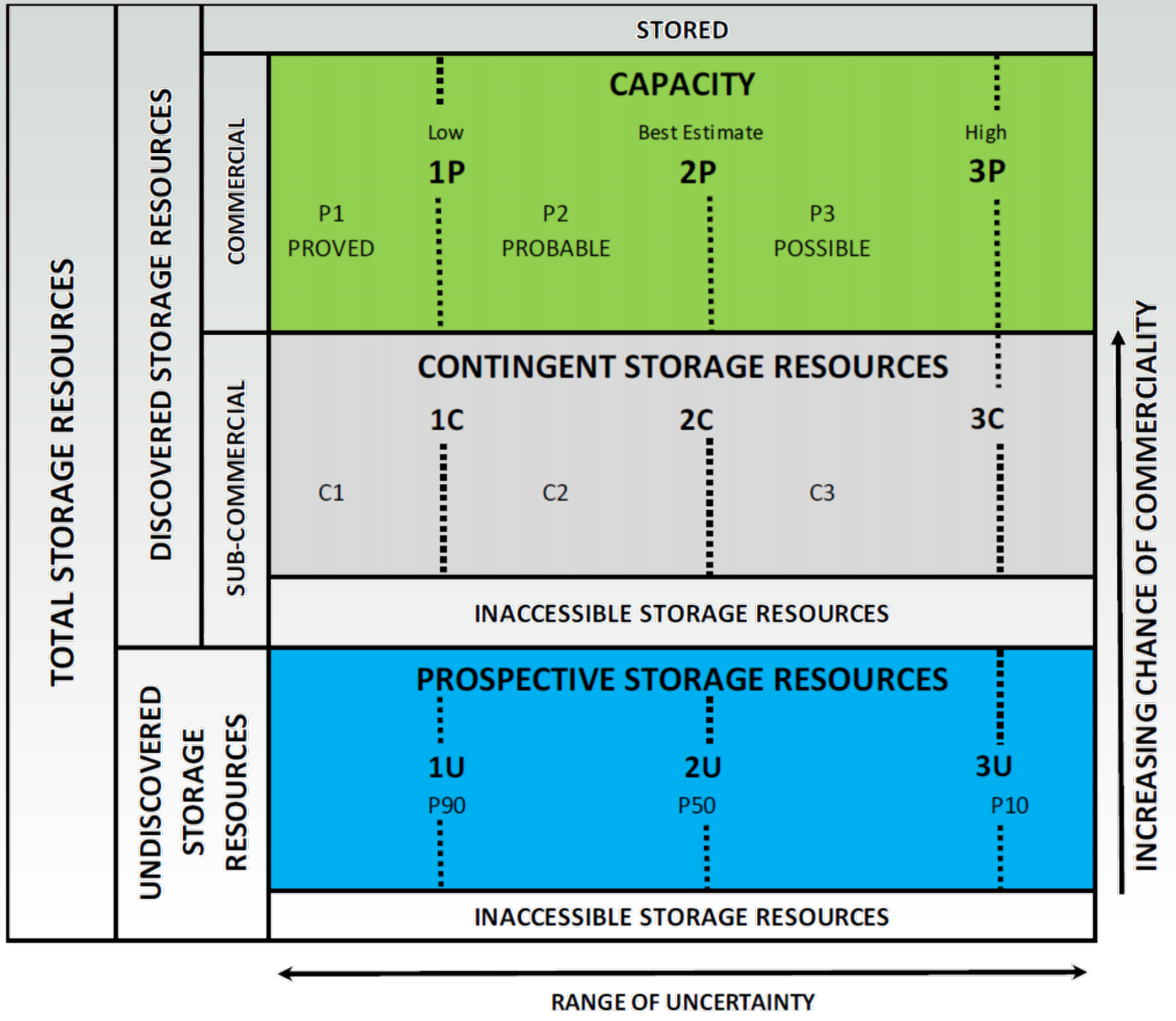
Extra slides

SPE Storage Resources Management System (SRMS)

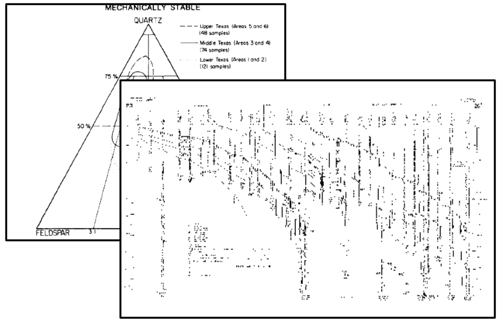
- Bookable storage
- Uniformity, clarity, familiarity
- Similar to PRMS
  - SRMS exists
  - https://www.spe.org/industry/CO2-storage-resources-management-system.php
  - ***Recommendations Generated***



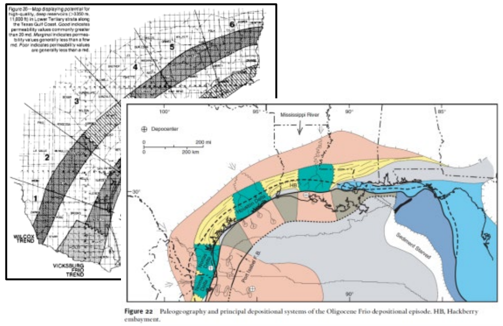
Defining Storage Play Fairways

Example: Oligocene Frio reservoir and Anhuac seal

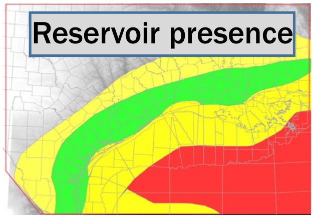
Geologic Data

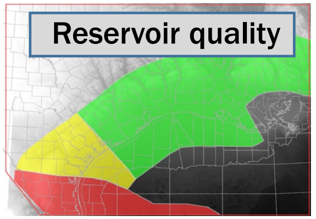


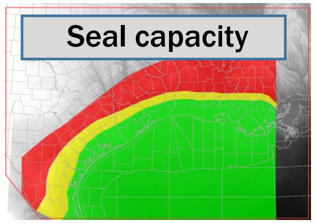
Geologic Interpretations



Risk Maps

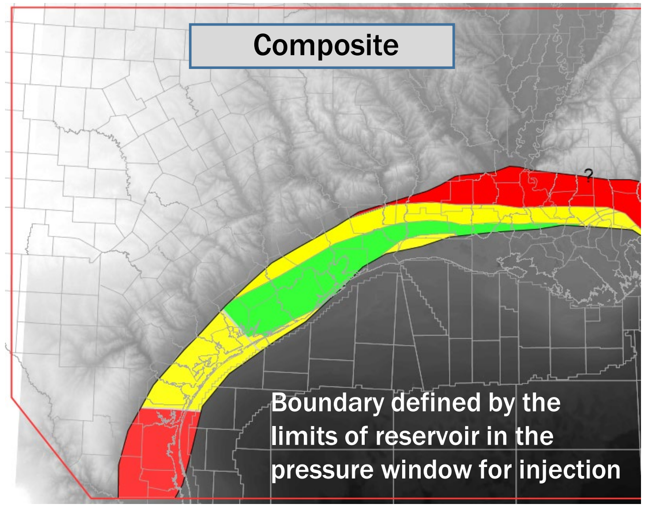






Composite Risk Map

Shows likelihood of **large capacity, low cost storage**
Green = High; Yellow = Moderate; Red = Low
Note: Storage is available in all areas, given enough wells and characterization effort. Map highlights



Input Layers	Composite
Red on any layer	Red
Yellow on any layer but no red	Yellow
Green on all layers	Green

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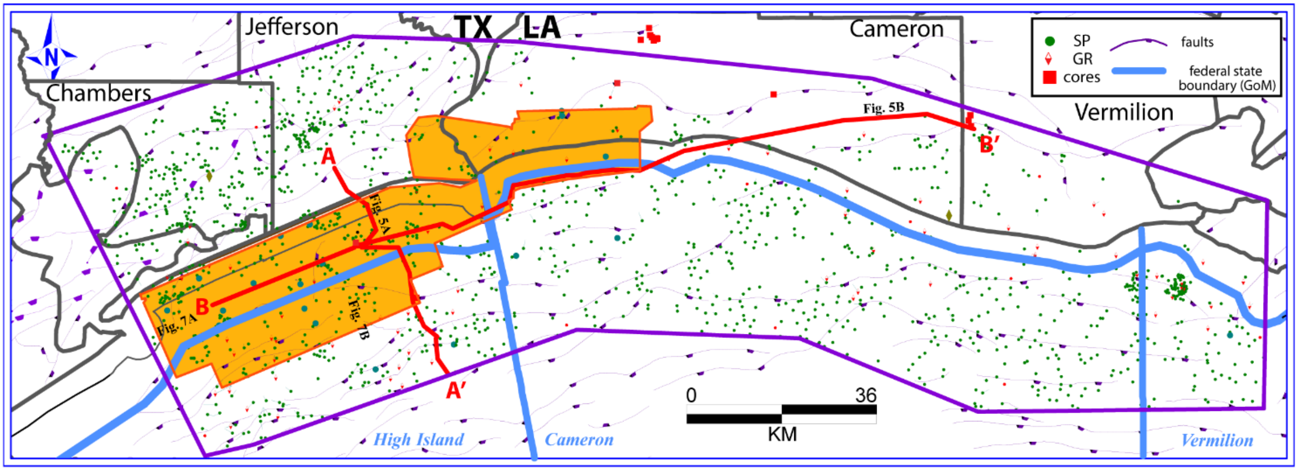

Figure 1. Map of the study area showing wells and primary 3D seismic dataset The state - federal waters boundary is demarcated by the blue line subparallel to the coast. Subsurface control consisted of about 1000 wells with SP curve; dip and strike cross-sections (AA', BB') shown in red.

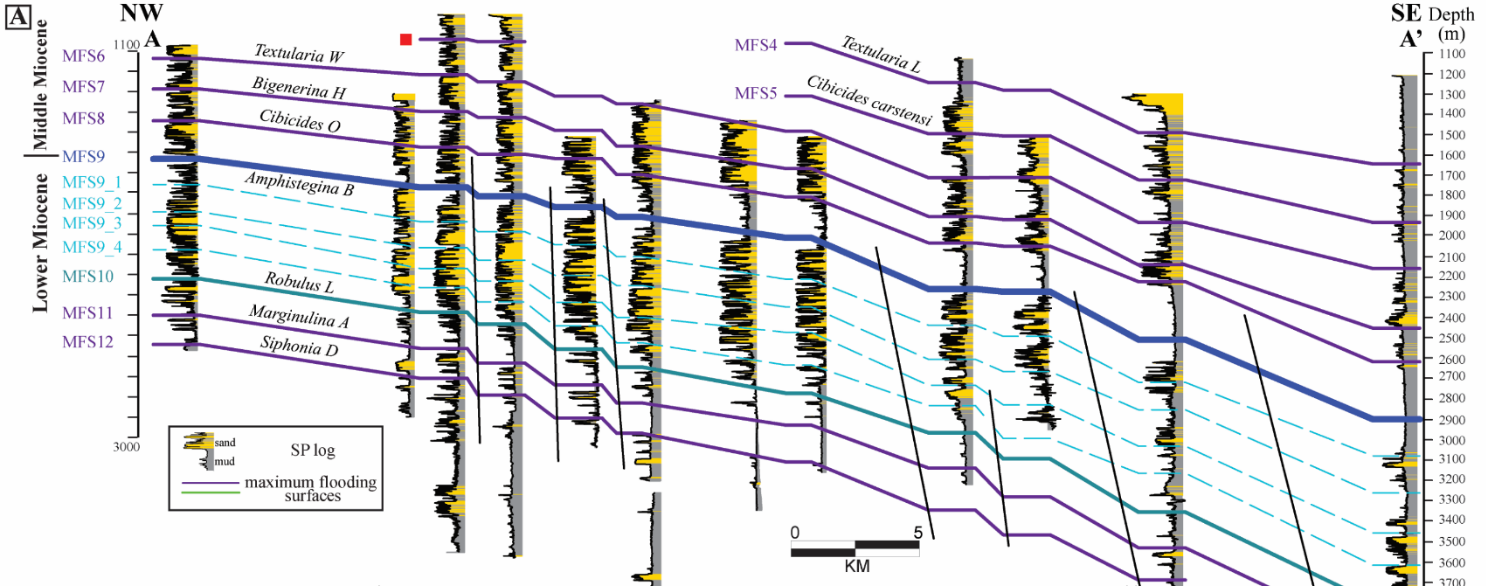

Figure 2. Regional well log cross-sections showing the Miocene succession of the upper Texas and westernmost Louisiana coastal and offshore areas. The interval between MFS 10 (*Robulus L)* and MFS 9 has been subdividided into five 4th order genetic stratigraphic cycles based on flooding surfaces MFS 9_1 to MFS9_4 to provide finer scale stratigraphic detail. A cutoff value of -20 Mv was used to separat from shale in each well. A. Dip-oriented structural cross-section. Multiple normal faults offset the stratigraphy. B. Strike-oriented stratigraphic (flattened at MFS 9) cross-section.

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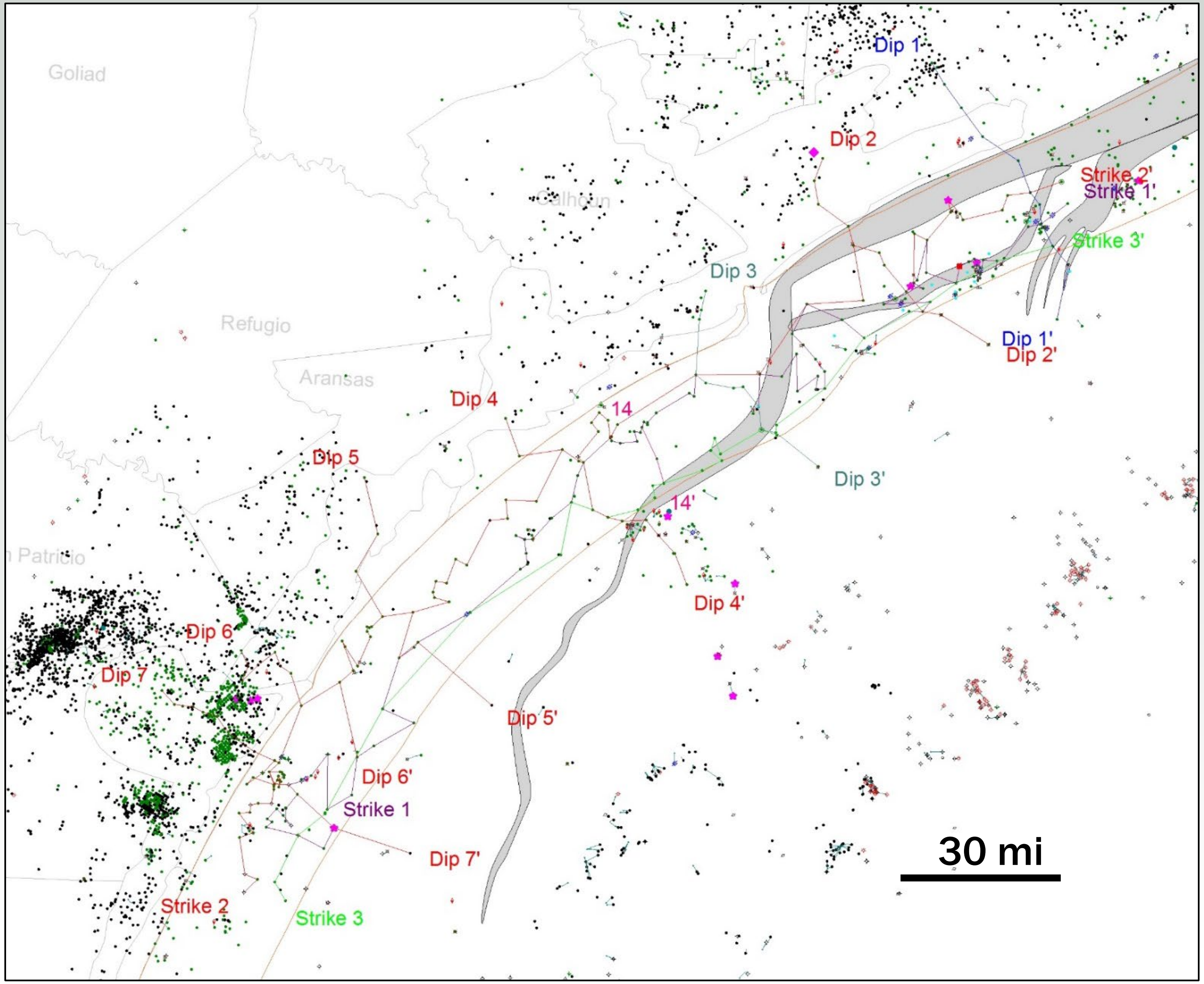

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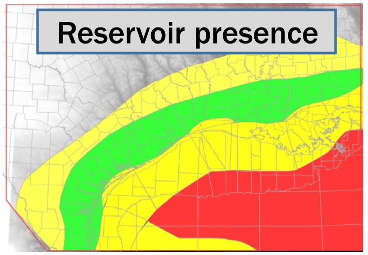
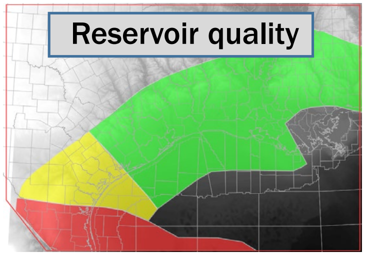
Green on all layers	Green

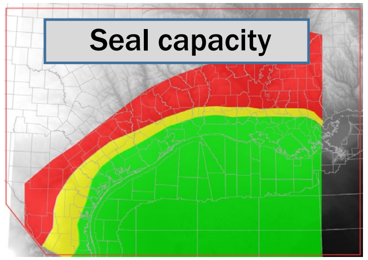
Defining Storage Play Fairways

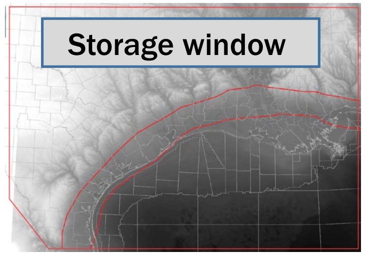
Example: Oligocene Frio reservoir and Anhuac seal

Risk Maps

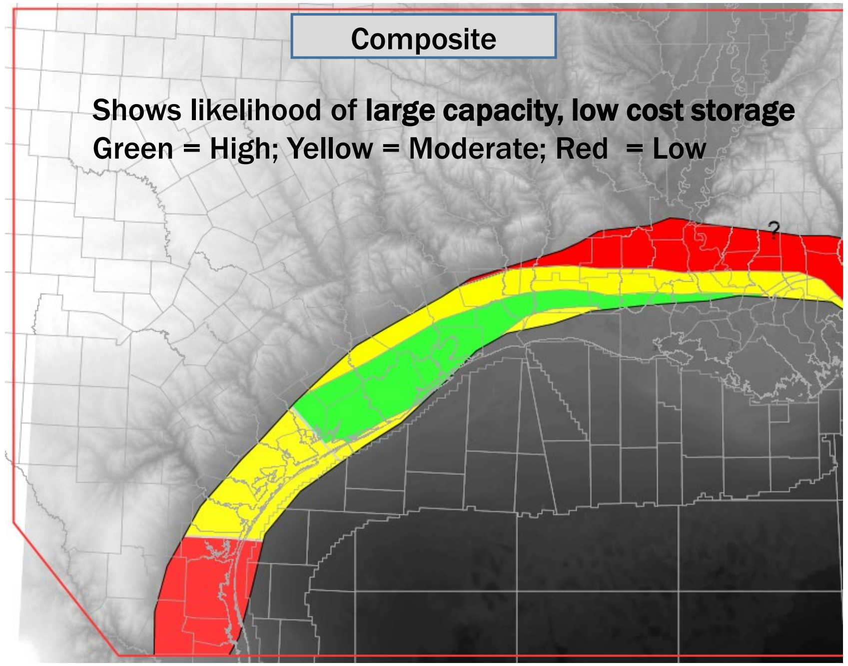






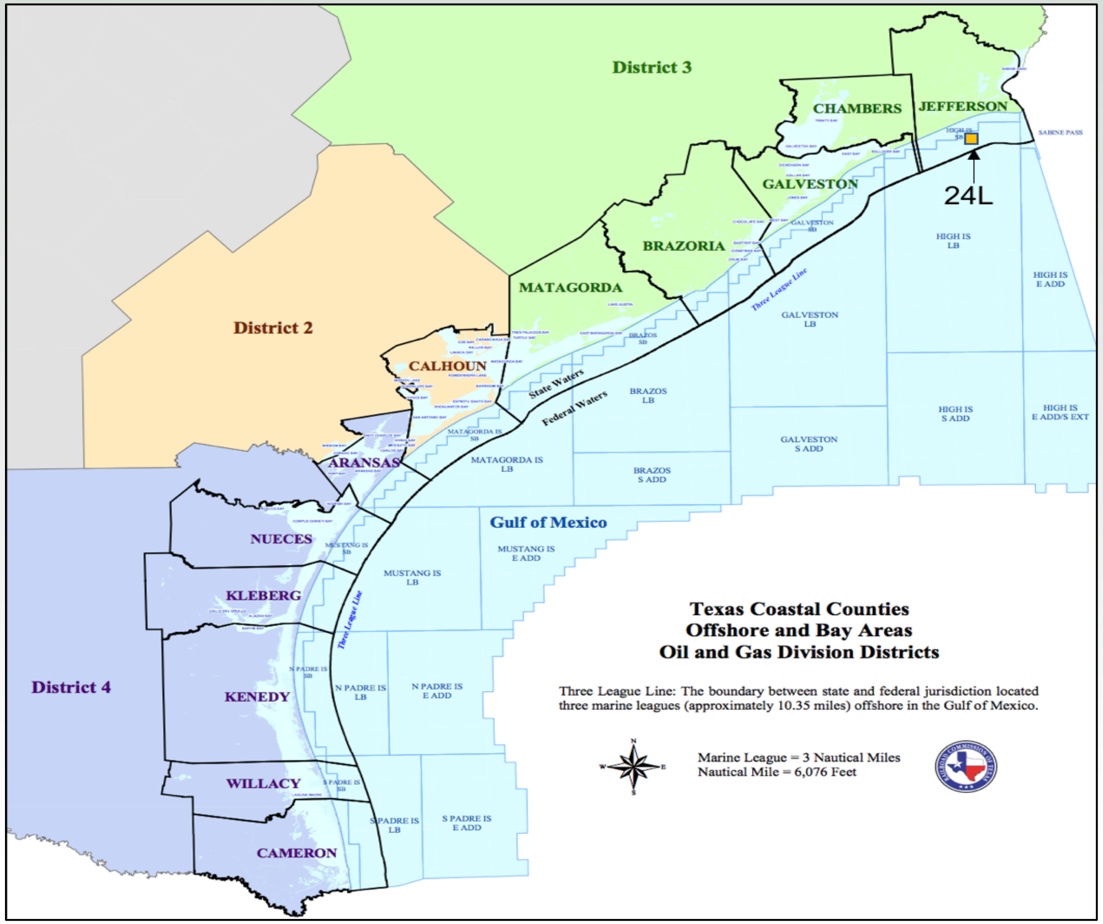


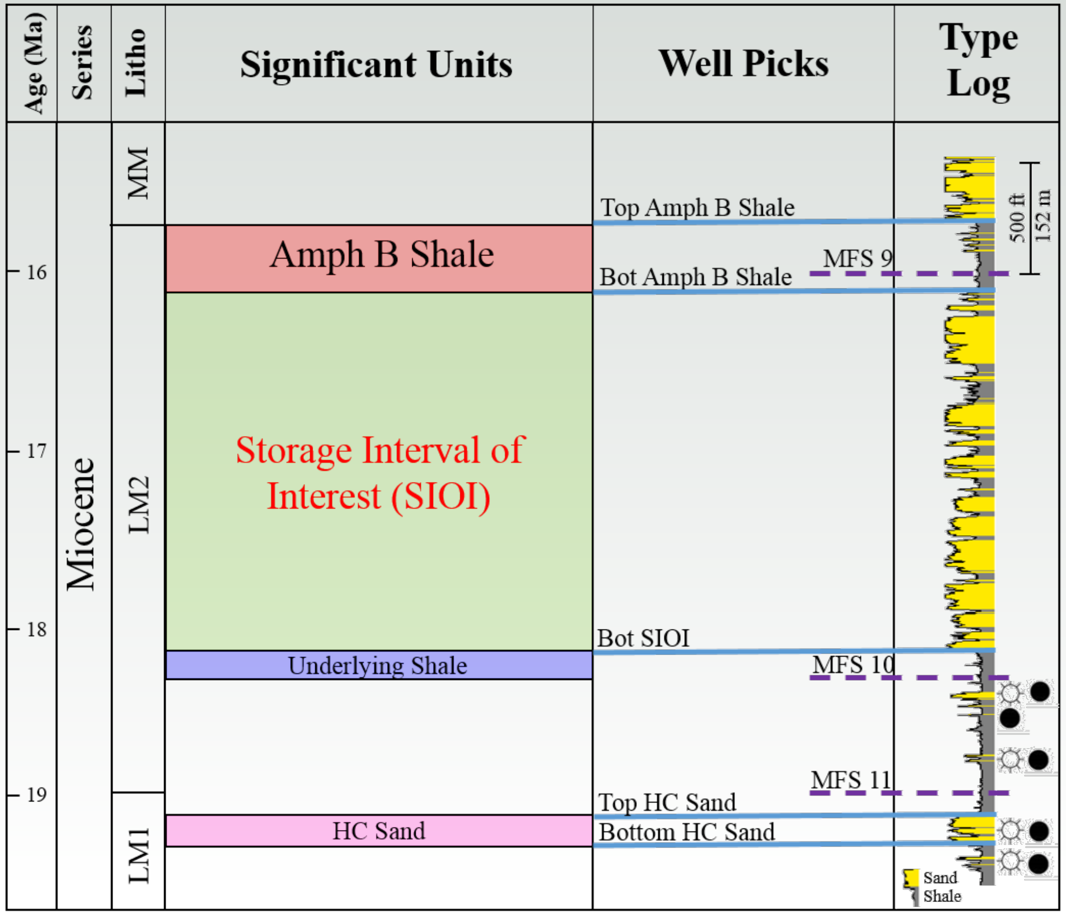
Composite Risk Map



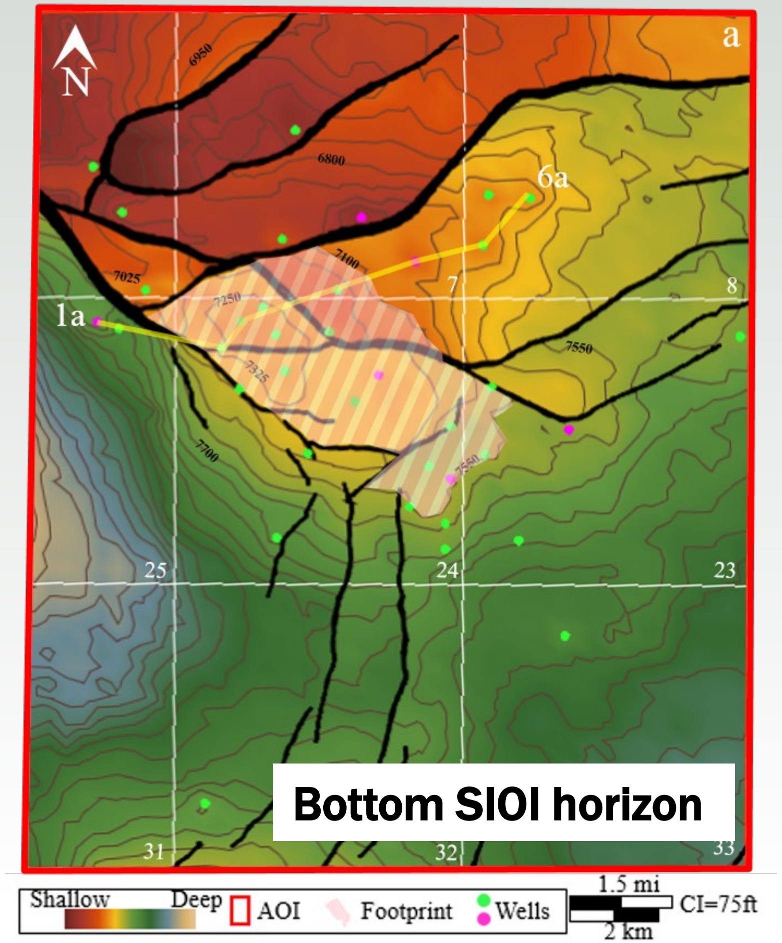
Note: Storage is available in all areas, given enough wells and characterization effort. Red is not a “no go.”

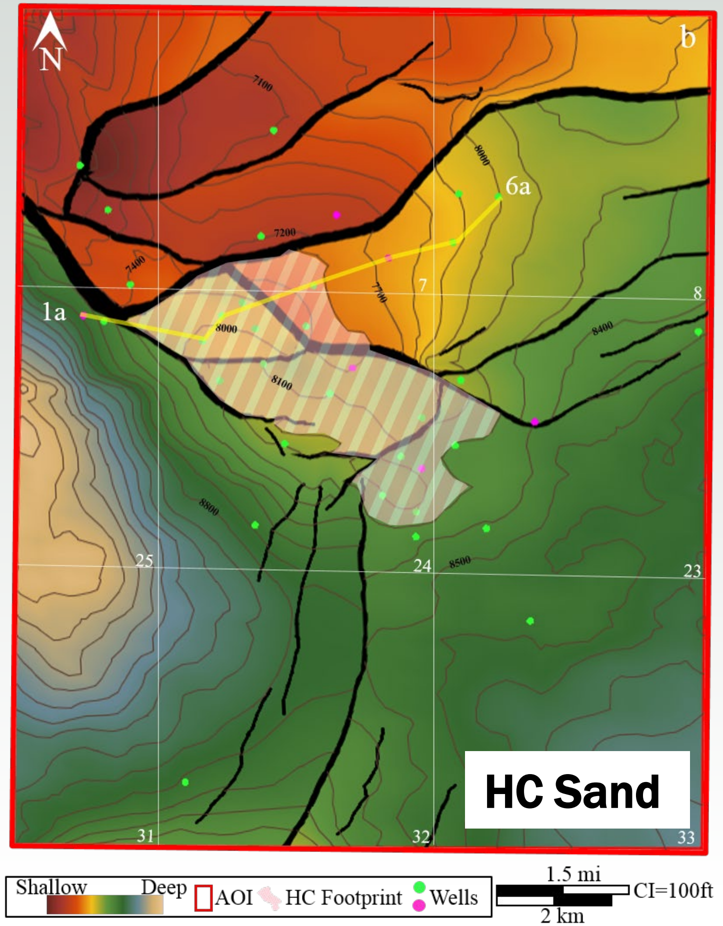
24L


District 3
District 2
District 4
CHAMBERS
JEFFERSON
GALVESTON
BRAZORIA
MATAGORDA
CALHOUN
ARANSAS
NUECES
KLEBERG
KENEDY
WILLACY
CAMERON
24L
State Waters
Federal Waters
Three League Line
Gulf of Mexico
HIGH IS LB
HIGH IS E ADD
HIGH IS S ADD
HIGH IS E ADD/S EXT
GALVESTON LB
GALVESTON S ADD
BRAZOS LB
BRAZOS S ADD
MATAGORDA IS LB
MUSTANG IS LB
MUSTANG IS E ADD
N PADRE IS LB
N PADRE IS E ADD
S PADRE IS LB
S PADRE IS E ADD
SABINE PASS
Texas Coastal Counties
Offshore and Bay Areas
Oil and Gas Division Districts
Three League Line: The boundary between state and federal jurisdiction located three marine leagues (approximately 10.35 miles) offshore in the Gulf of Mexico.
Marine League = 3 Nautical Miles
Nautical Mile = 6,076 Feet


Age (Ma)
Series
Litho
Significant Units
Well Picks
Type Log
16
17
18
19
Miocene
MM
LM2
LM1
Amph B Shale
Storage Interval of Interest (SIOI)
Underlying Shale
HC Sand
Top Amph B Shale
Bot Amph B Shale
MFS 9
Bot SIOI
MFS 10
MFS 11
Top HC Sand
Bottom HC Sand
500 ft
152 m
Sand
Shale

24L Structure





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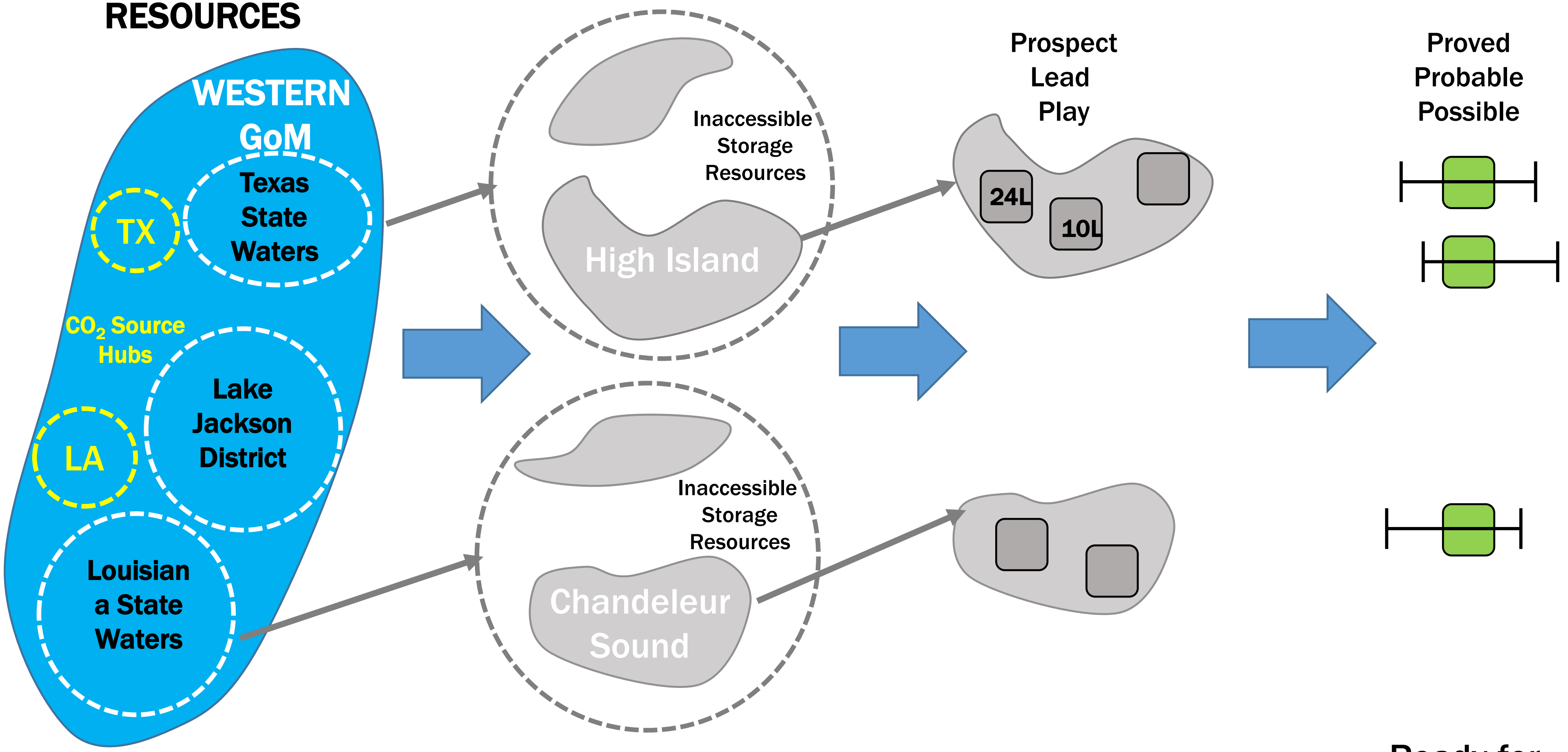
INCREASING CHANCE OF COMMERCIALITY

Gulf of Mexico Basin

PROSPECTIVE STORAGE RESOURCES

CONTINGENT STORAGE RESOURCES

CAPACITY



Site Screening

Site Selection

Site Characterization

Ready for Permitting

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