Gulf of Mexico Miocene CO_2 Site Characterization Mega Transect

DE-FE0001941

Ramon Trevino

Texas Bureau of Economic Geology

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

August 20-22, 2013

Bureau of Economic Geology

The University of Texas at Austin
John A. & Katherine G.
Jackson School of Geosciences

Gulf Coast Carbon Center

Presentation Outline

- Project Overview & Past Accomplishments
- Regional Static Capacity
- Model Area
  - Simple Dynamic Analytical Model
  - Flow Simulation Model Runs
- Hi-Res 3D Seismic (HR3D)
- CO_2 “Plays” Atlas
- Summary & Acknowledgments

Benefit to the Program

Program goals addressed

Develop technologies that:

1. Predict CO_2 storage capacity within ±30%
2. Demonstrate 99% containment

Benefits Statement –

The research will develop 1) an atlas of existing traps (e.g., hydrocarbon fields) and regional data (e.g., existing well data, formation properties, etc.), 2) a best practices manual. The resulting data and techniques will help industry identify and evaluate future sequestration sites. In addition the study is using a new, high-resolution 3D (HR3D) seismic acquisition system to image the shallow geologic section and identify natural leakage pathways (i.e., areas to avoid), which contributes to programmatic goals 1 and 2 (above).

Project Overview: Goals and Objectives

Study Goal – characterize regional Miocene-age geologic section (“formations”) of Texas State Waters.

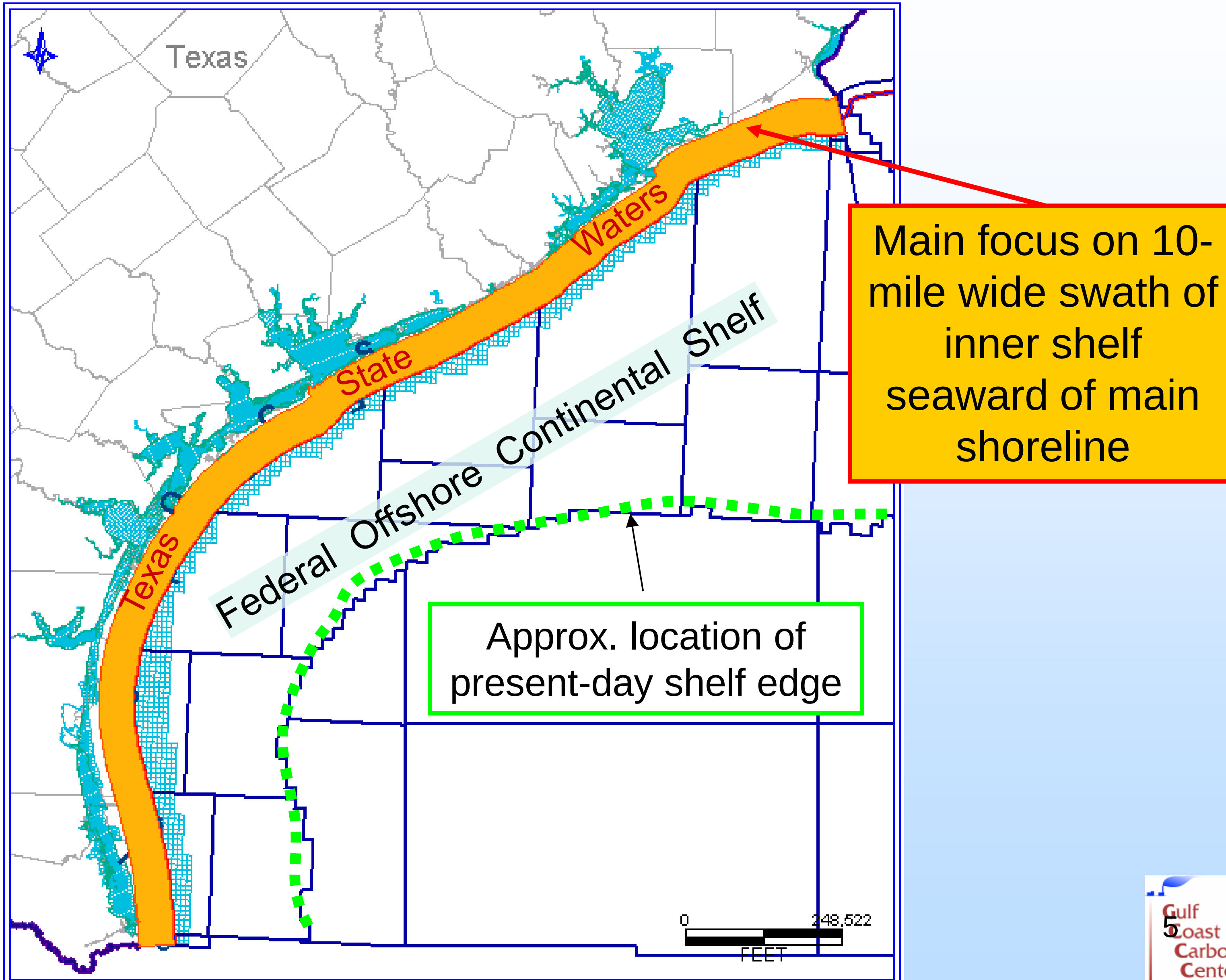
Objectives:

1. Assess & analyze existing energy industry data

2. Verify Miocene strata’s ability to safely and permanently store large amounts of anthropogenic CO_2.

3. Identify at least one specific site (capacity ≥ 30 MT CO_2) for future commercial CCS operations.

Study Area



Bureau of Economic Geology

Gulf Coast Carbon Center

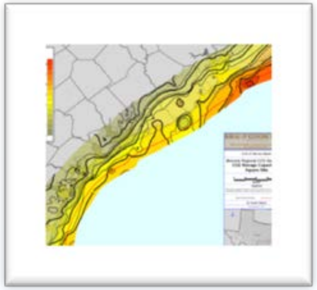
Project Overview:
Goals and Objectives

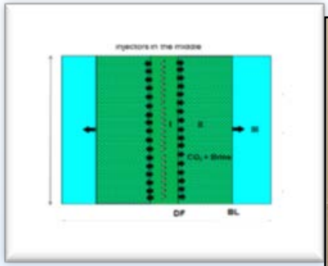
Success Criteria

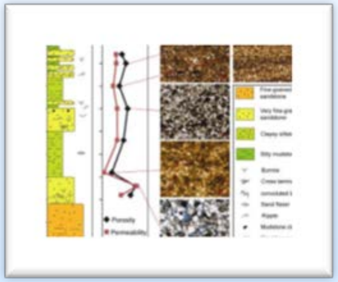
- ✓Minimum necessary data *is* available
- ✓ Identify one or more specific sites
  - Meet / exceed capacity cutoff
  - ✓Complete geologic model(s)
  - ✓Complete flow simulation model(s)

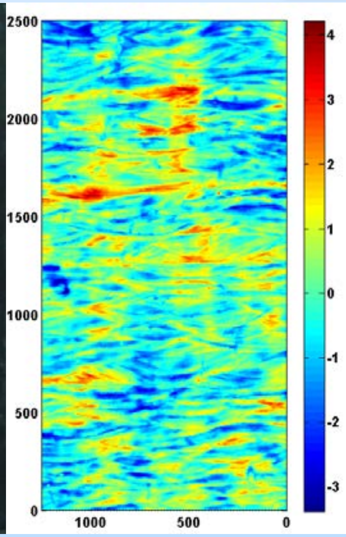
Project Research Scope

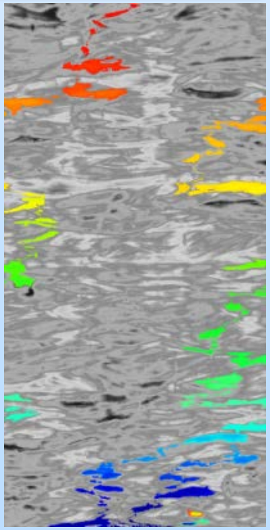
- Static capacity calculations
- Dynamic capacity calculations
  - Analytical & geocellular modeling
- Geochemistry
- Mudrock sealing capacity
- Fluid migration
- Fault seal
- Hi-Res digital model
- HR3D Seismic

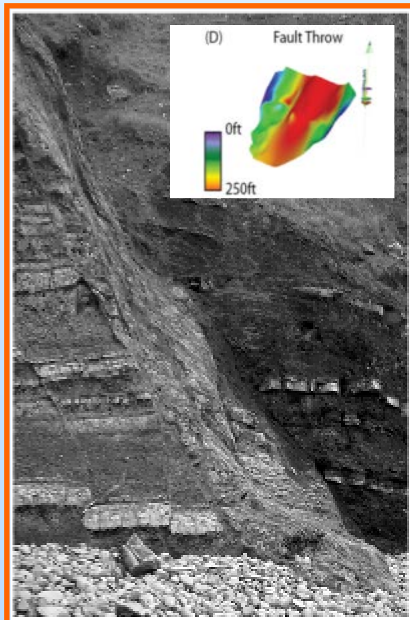












Bureau of Economic Geology

The University of Texas at Austin
John A. & Katherine G.
Jackson School of Geosciences

Accomplishments to Date

- Static regional capacity estimated for Texas State water
- Static regional capacity tested in small portion of study area by:
  - Simple Dynamic Analytical Model
  - 3D flow simulation
- 1st Hi-Resolution 3D (HR3D) Dataset acquired
  - Initial processing complete
  - Re-processing almost complete
  - Field test (land) conducted to verify positional accuracy
- Atlas (draft)

Presentation Outline

- Project Overview & Past Accomplishments
- **Regional Static Capacity**
- Model Area
  - – Simple Dynamic Analytical Model
  - – Flow Simulation Model Runs
- Hi-Res 3D Seismic (HR3D)
- CO_2 Plays Atlas
- Summary & Acknowledgments

Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

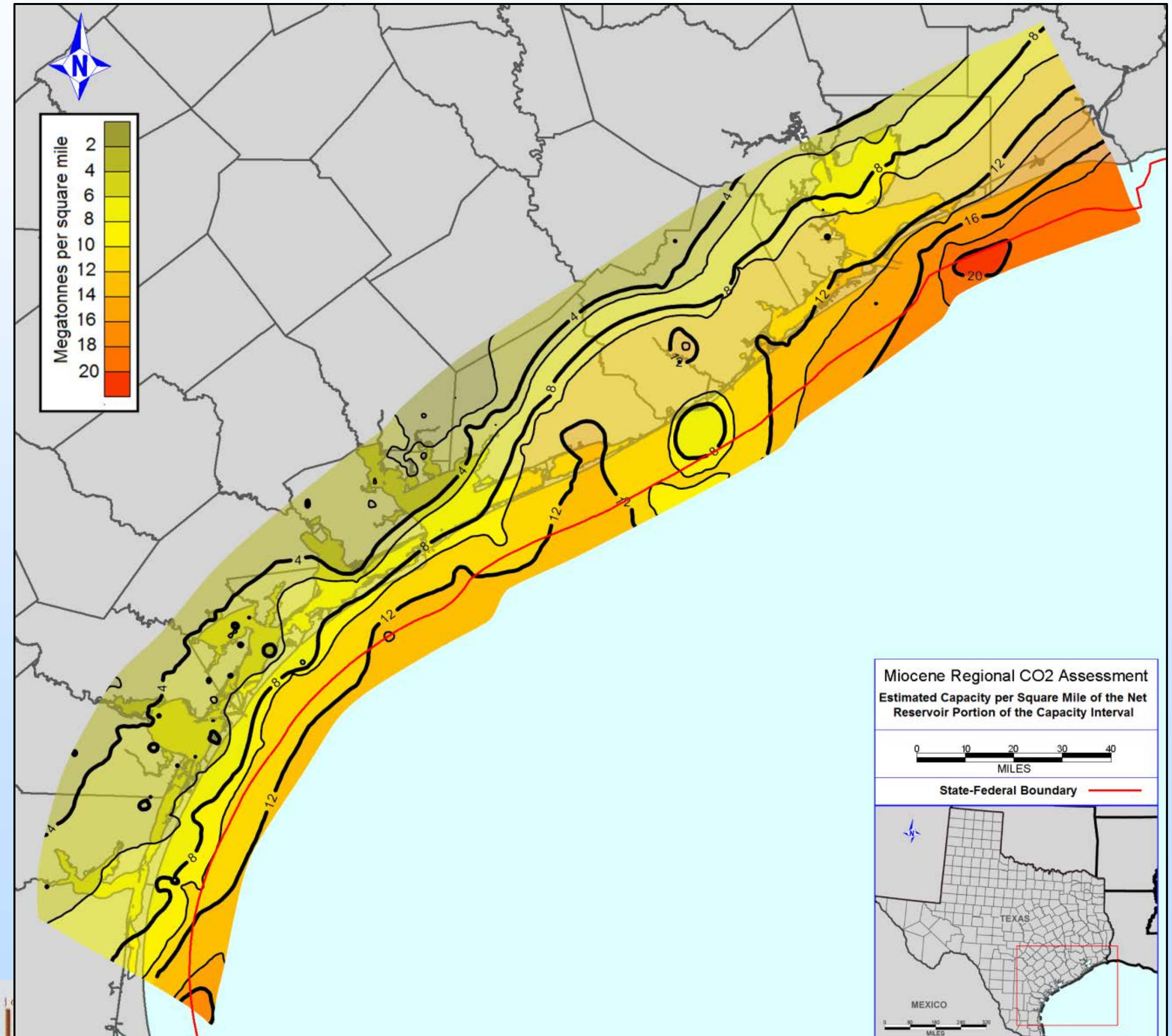
Gulf Coast Carbon Center

Static Storage Capacity Per Sq. Mile

$$G_{CO_2 net} = A_t \, h_{net} \, \varphi_{tot} \, \rho E_{net}$$

Total Net Storage Capacity = **129 GT**

(**86 GT** in study area)



Kerstan Wallace MS Thesis, 2013

(Wallace, et al. *in review*)

BUREAU OF ECONOMIC GEOLOGY

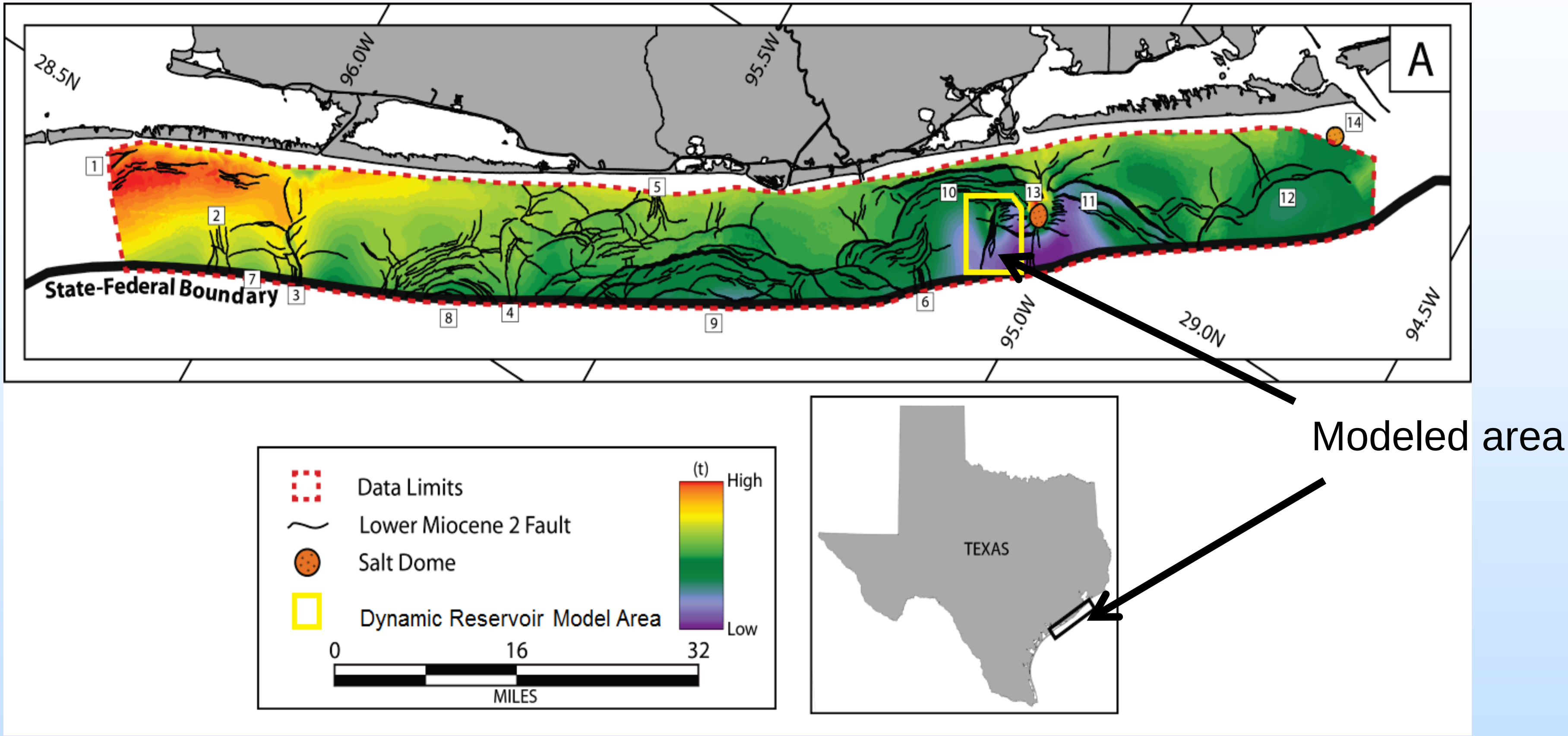
SCHOOL OF GEOSCIENCES

Gulf Coast Carbon Center

Presentation Outline

- Project Overview & Past Accomplishments
- Regional Static Capacity
- **Model Area**
  - **Simple Dynamic Analytical Model**
  - **Flow Simulation Model Runs**
- Hi-Res 3D Seismic (HR3D)
- CO_2 Plays Atlas
- Summary & Acknowledgments

Simple Dynamic Analytical Model

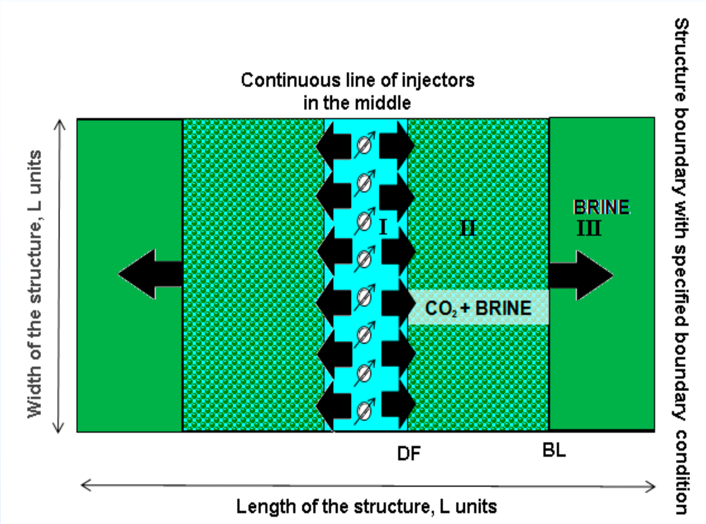


Kerstan Wallace
MS Thesis, 2013

Bureau of Economic Geology
The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences
Gulf Coast Carbon Center

Simple Dynamic Analytical Model, Jain and Bryant (2011)

Summary of Simple Dynamic Analytical Model Inputs			
Parameter	**Property**	**Value**	**Source**
S_{wirr}	Irreducible Water Saturation	10-78%	6,206 Miocene reservoirs
Φ	Porosity	0.12-0.37	6,206 Miocene reservoirs
T	Temperature	135.6° F (57.6° C)	11 log headers in DRMA
P	Pressure	2,105 psi (14.5 Mpa)	Hydrostatic gradient
Z	Depth	4,828 feet (1,472 meters)	Seismic mapping
κ	Permeability	0.08-3686 mD (7.9×10^{-17} - 3.6×10^{-12} m^2)	6,206 Miocene reservoirs
h	Thickness	99.5 feet (30.3 meters)	Seismic mapping
A	Area	4742 acres (19.2 km^2)	Closure analysis
μ_w	Water Viscosity	0.8177 cP (0.8177 mPa·s)	CREWES calculator
μ_g	Gas Viscosity	0.0467 cP (0.0467 mPa·s)	NIST calculator
k	Salinity	190,000 ppm	ILD and DT (well A)
n	Corey exponent (gas)	2.6	Inter-comparison project
m	Corey exponent (water)	10	Inter-comparison project
K^o_{rg}	End point gas saturation	1	Inter-comparison project
P_l	Pressure limit	3,527 psi (24.3 Mpa)	80% of lithostatic pressure
ρ	CO_2 density	.792 g/cc	NIST calculator



<u>Model Assumptions</u>

- Properties Homogeneous
- Structure not considered, BUT *model inputs require accurate depth-structure map*

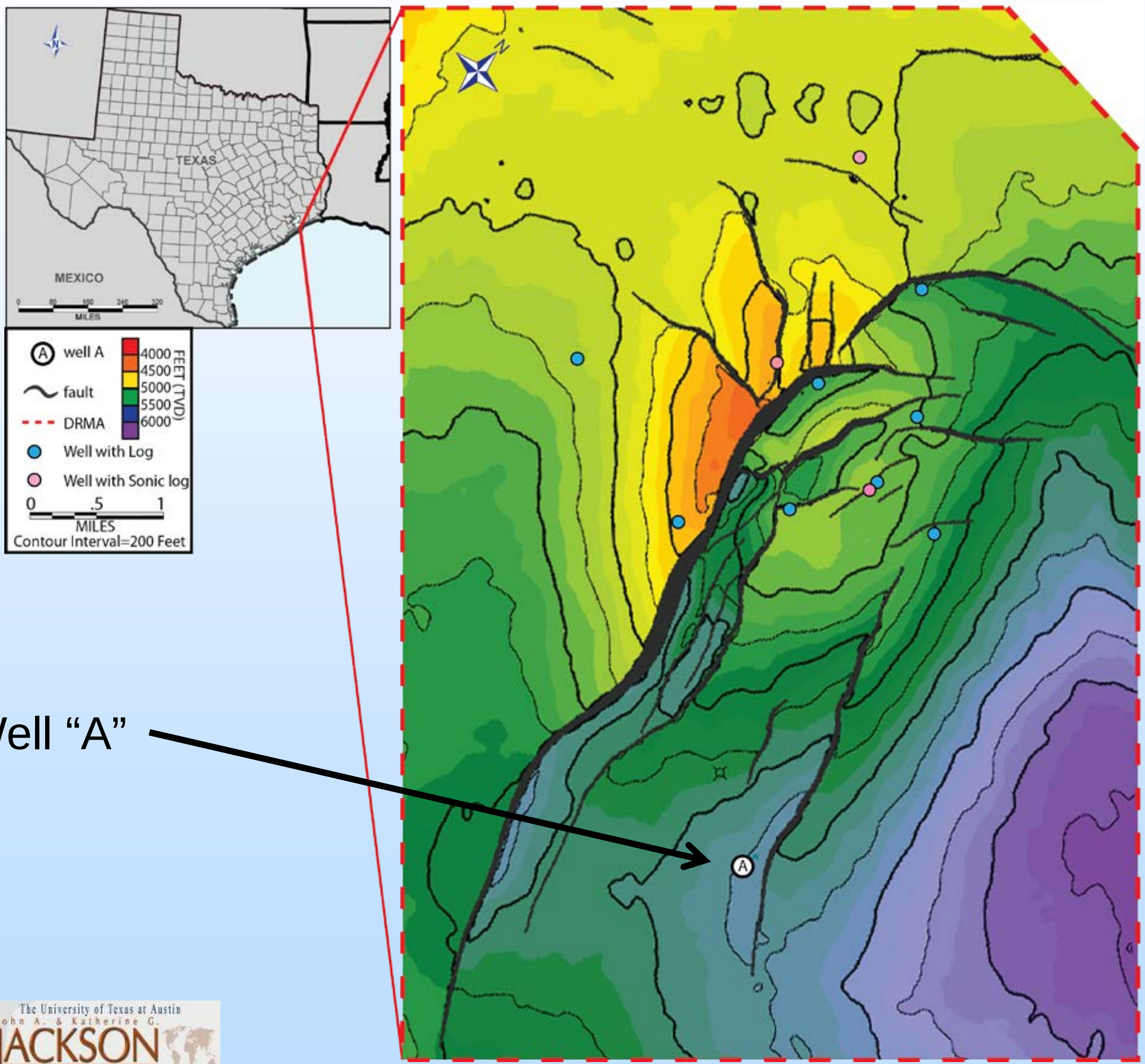
Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

Kerstan Wallace
MS Thesis, 2013

Gulf Coast Carbon Center

Simple Dynamic Analytical Model
Modeled Area



Note Well "A"

Kerstan Wallace
MS Thesis, 2013

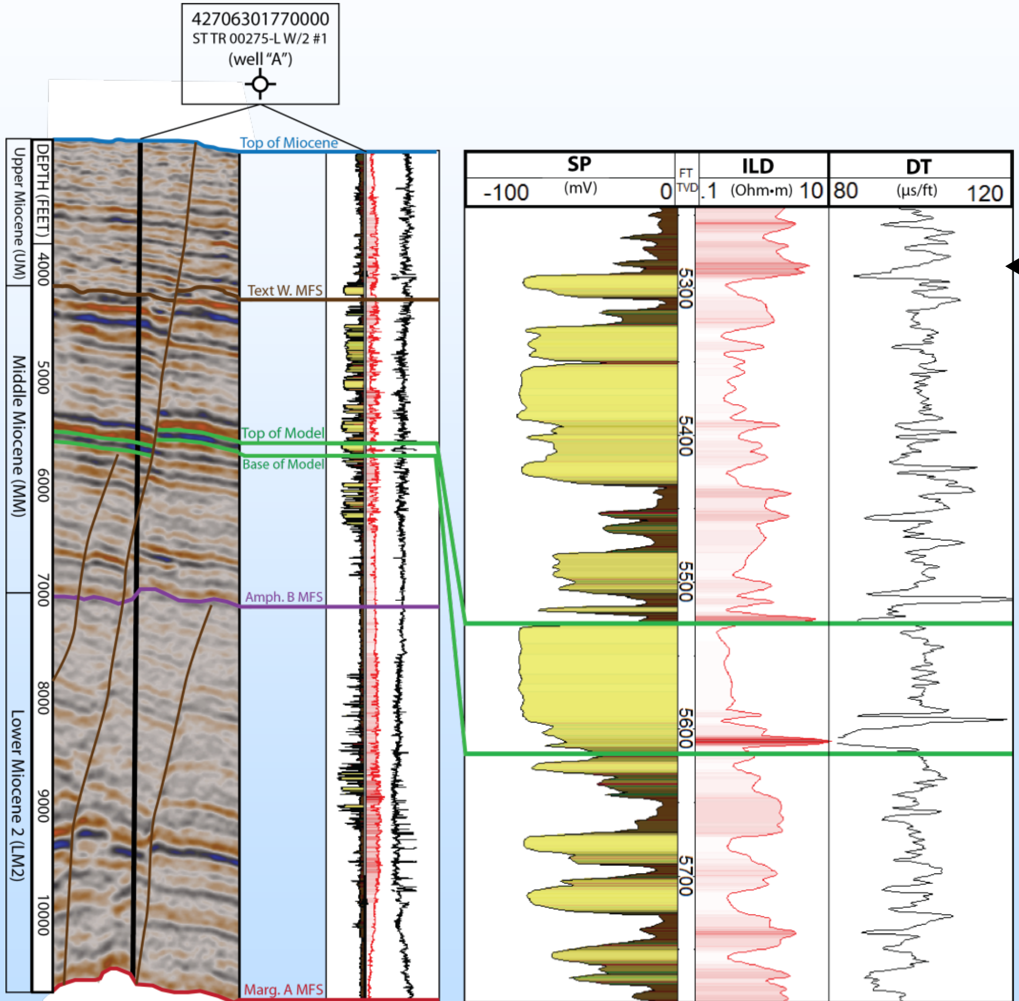
Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

Gulf Coast Carbon Center

Simple Dynamic Analytical Model
“Well A”

Seismic Column and corresponding Well Log



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

Φ Derived from DT

Reservoir Interval

Kerstan Wallace MS Thesis, 2013

Simple Dynamic Analytical Model Results

6,206 samples of:

φ, κ, and S_{wirr}

Only conditions

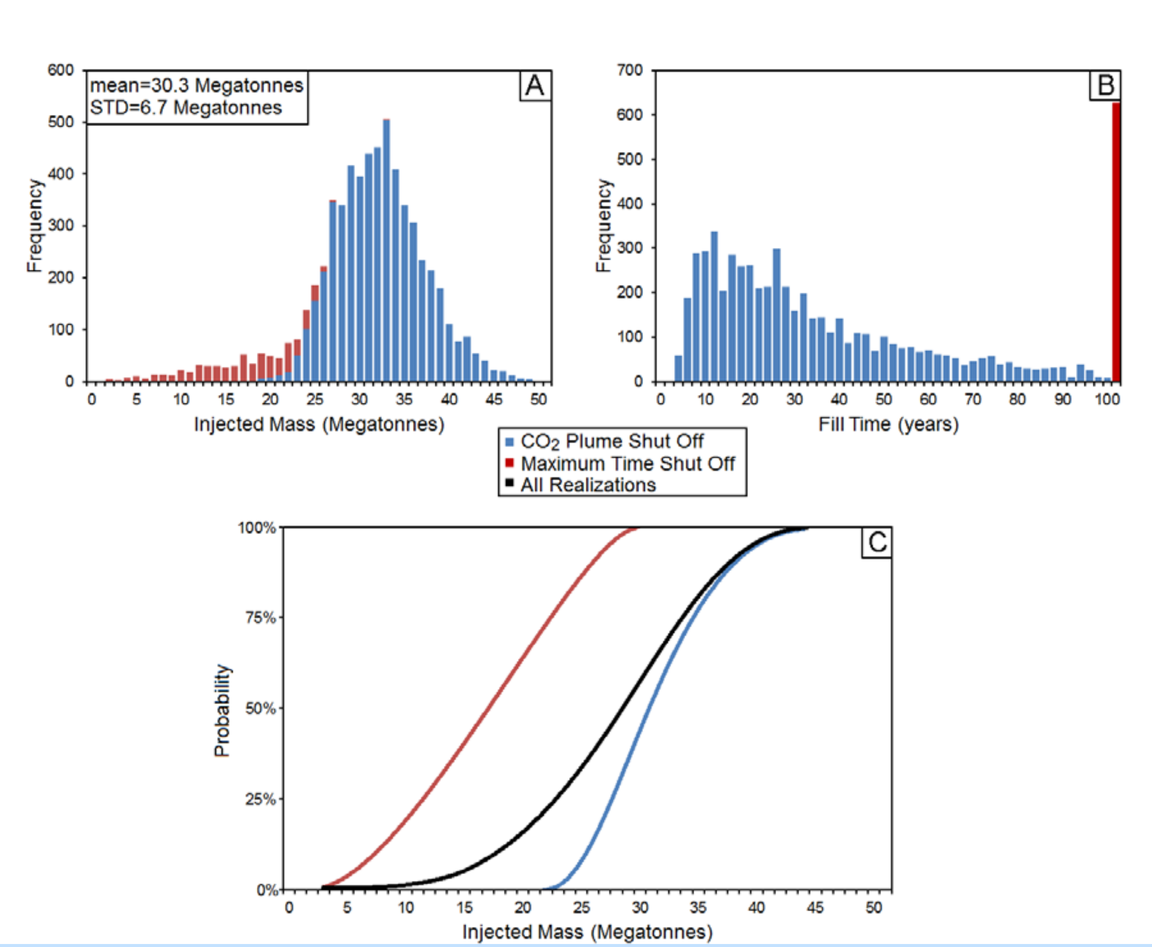
1 (***plume shutoff***) and

3 (***time shutoff***) are met.

Condition 2 (***pressure limit***) not reached.

Avg. capacity = 30.3 MT

Avg. fill-time = 38.3 years



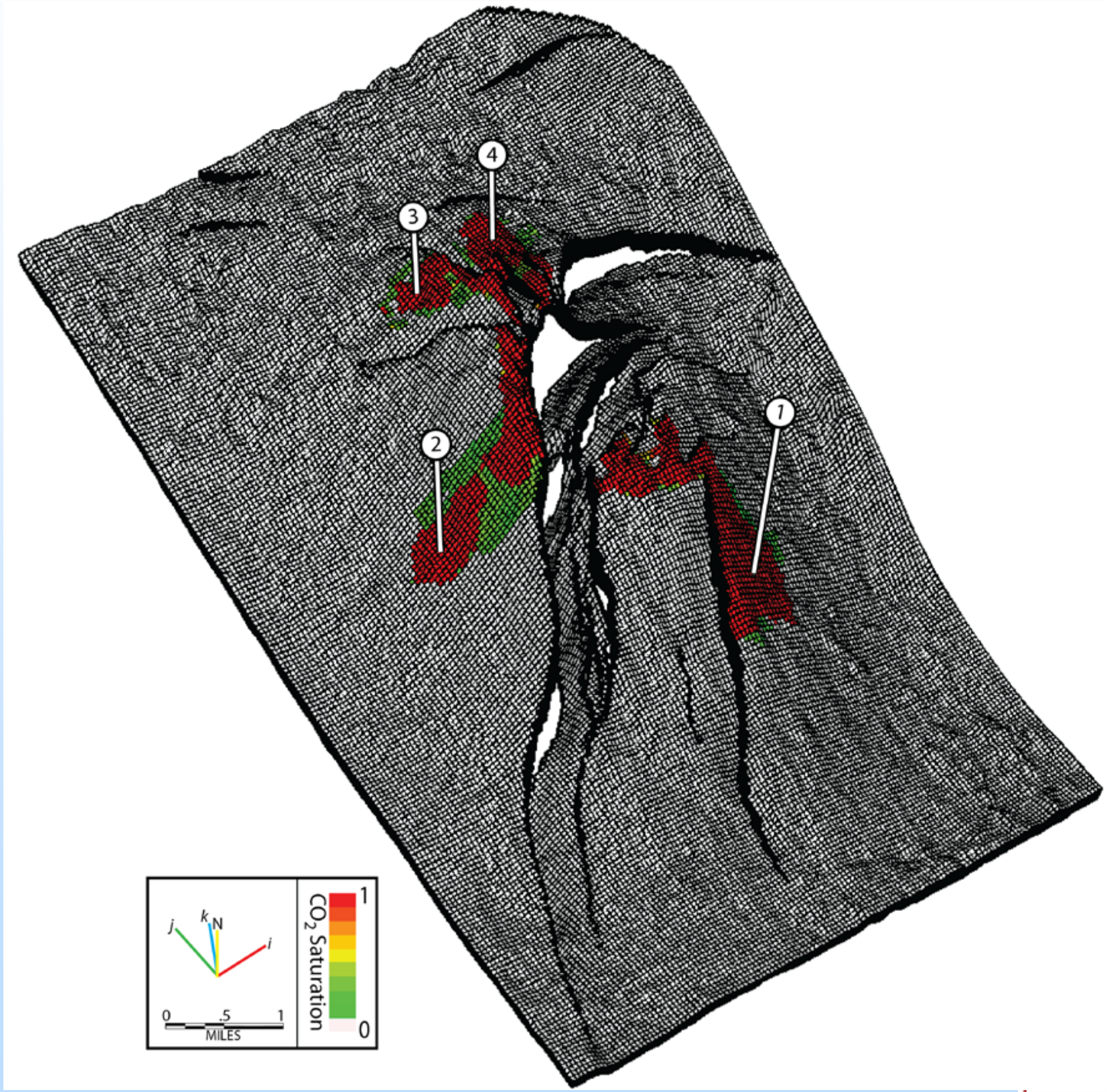
Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

Gulf Coast Carbon Center

3D Dynamic Fluid Flow Simulation Homogeneous Base Case

- 27 model cases
- 9 each of 3 scenarios
  - Homogeneous (shown here)
  - Statistical Heterogeneous
  - Seismic-based Heterogeneous



BUREAU OF ECONOMIC GEOLOGY

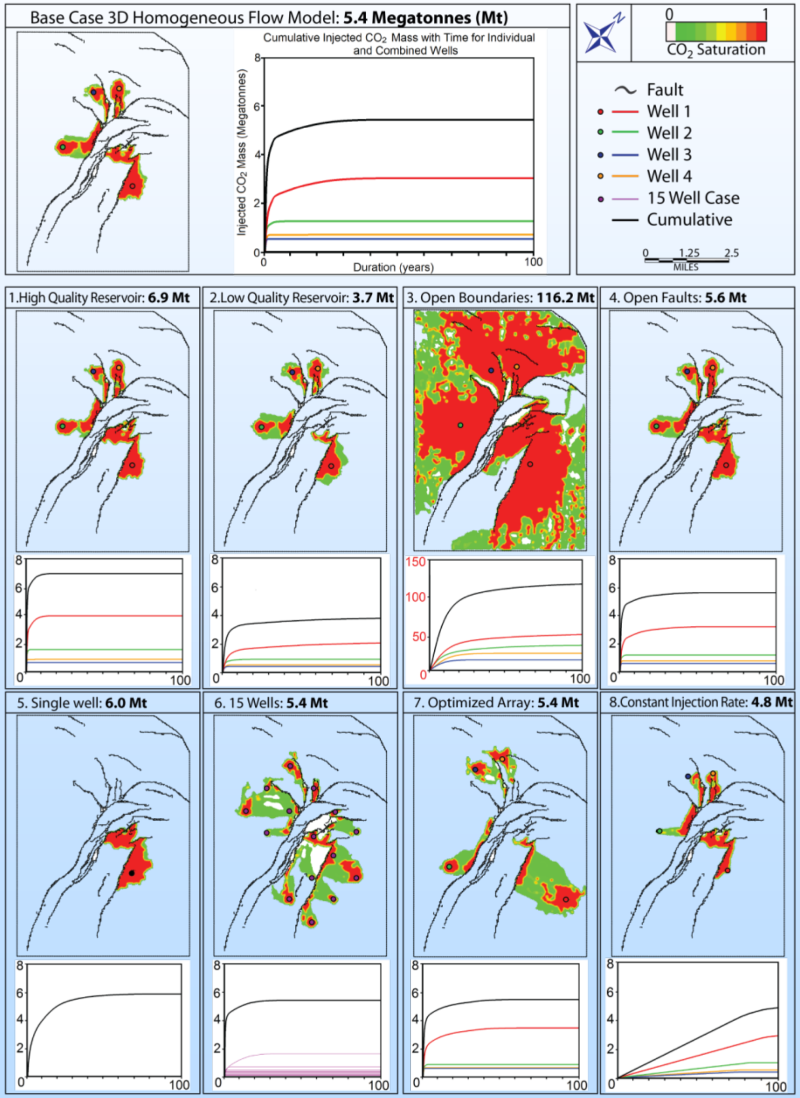
The University of Texas at Austin
John A. & Katherine G. JACKSON SCHOOL OF GEOSCIENCES

Homogeneous 3D Flow Model Scenario

- Cases 1-8 final plume geometries

Open boundaries effect (case #3) ***by far*** the most significant variable parameter

(Note scale change in case #3)



Presentation Outline

- Project Overview & Past Accomplishments
- Regional Static Capacity
- Model Area
  - Simple Dynamic Analytical Model
  - Flow Simulation Model Runs
- **Hi-Res 3D Seismic (HR3D)**
- CO_2 Plays Atlas
- Summary & Acknowledgments

Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

Gulf Coast Carbon Center

Fluid System Analysis Strategy using HR3D

- DOE goal to find secure 30 Mt CO_2 storage site(s)
  - Collect data to reduce barriers to near-term commercial utilization
  - Map storage geometries: compartmentalization.
  - ***Characterize traps and seals***

HR3D insight:
Shallow interval
Poor conventional coverage

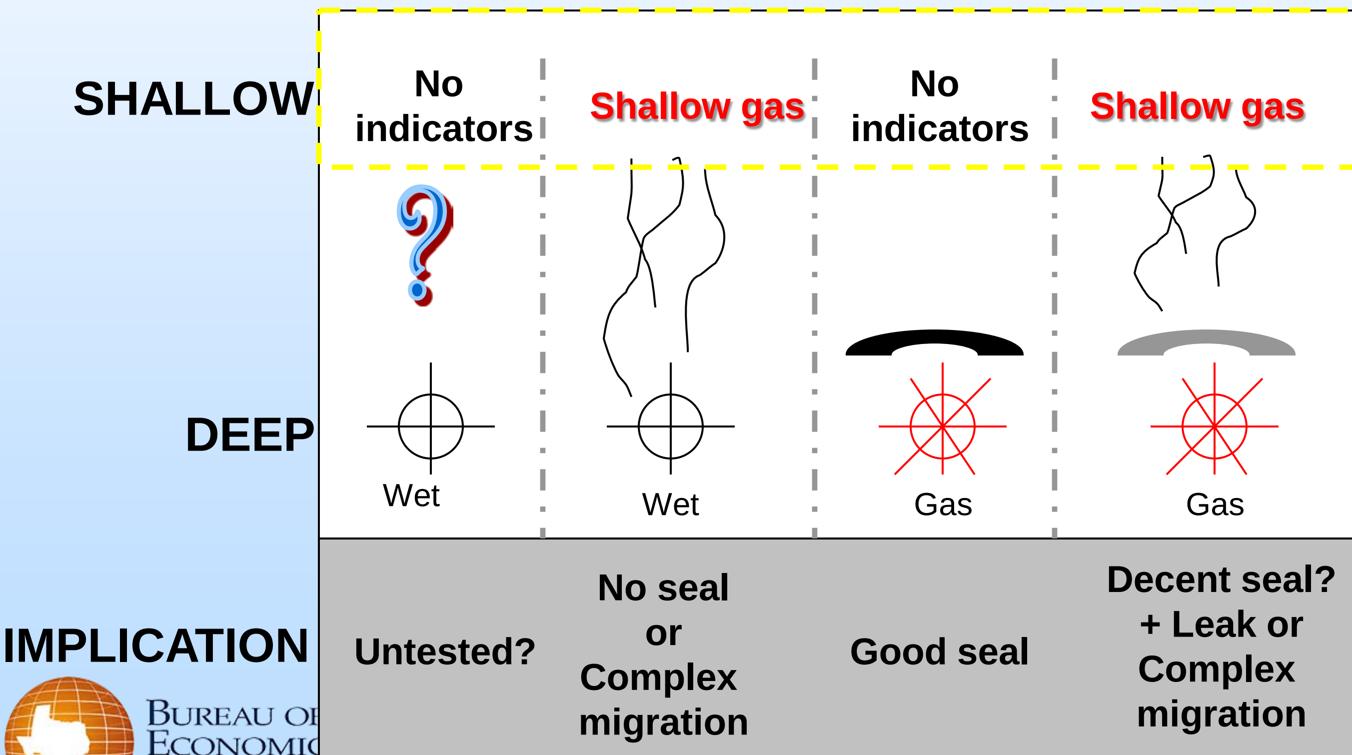


Figure omitted due to proprietary nature of the data presented.

Bureau of Economic Geology
School of Geosciences
Gulf Coast Carbon Center


acer
acer

Hi-Res 3D (HR3D) Seismic

- 1st P-Cable HR3D Survey
  - Dataset Successfully Acquired
  - Initial processing challenges
  - Field testing resolved issues related to receiver position accuracy
  - Re-processing almost complete

Conventional 3D

Vertical Resolution

HR3D - PCable

$$= \left(\frac{1}{25\ hz} * 1500\ m/s\right)/4$$

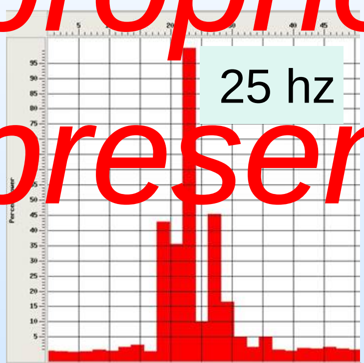
$$= \left(\frac{\mathbf{1}}{\boldsymbol{f}} * \boldsymbol{V}\right)/\mathbf{4}$$

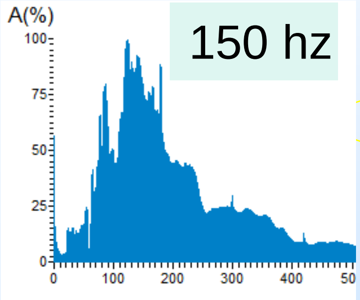
$$= \left(\frac{1}{150\ hz} * 1500\ m/s\right)/4$$

$= \mathbf{15}\ \boldsymbol{meters}$

$= \mathbf{2.5}\ \boldsymbol{meters}$

Figure omitted due to proprietary nature of the data presented.



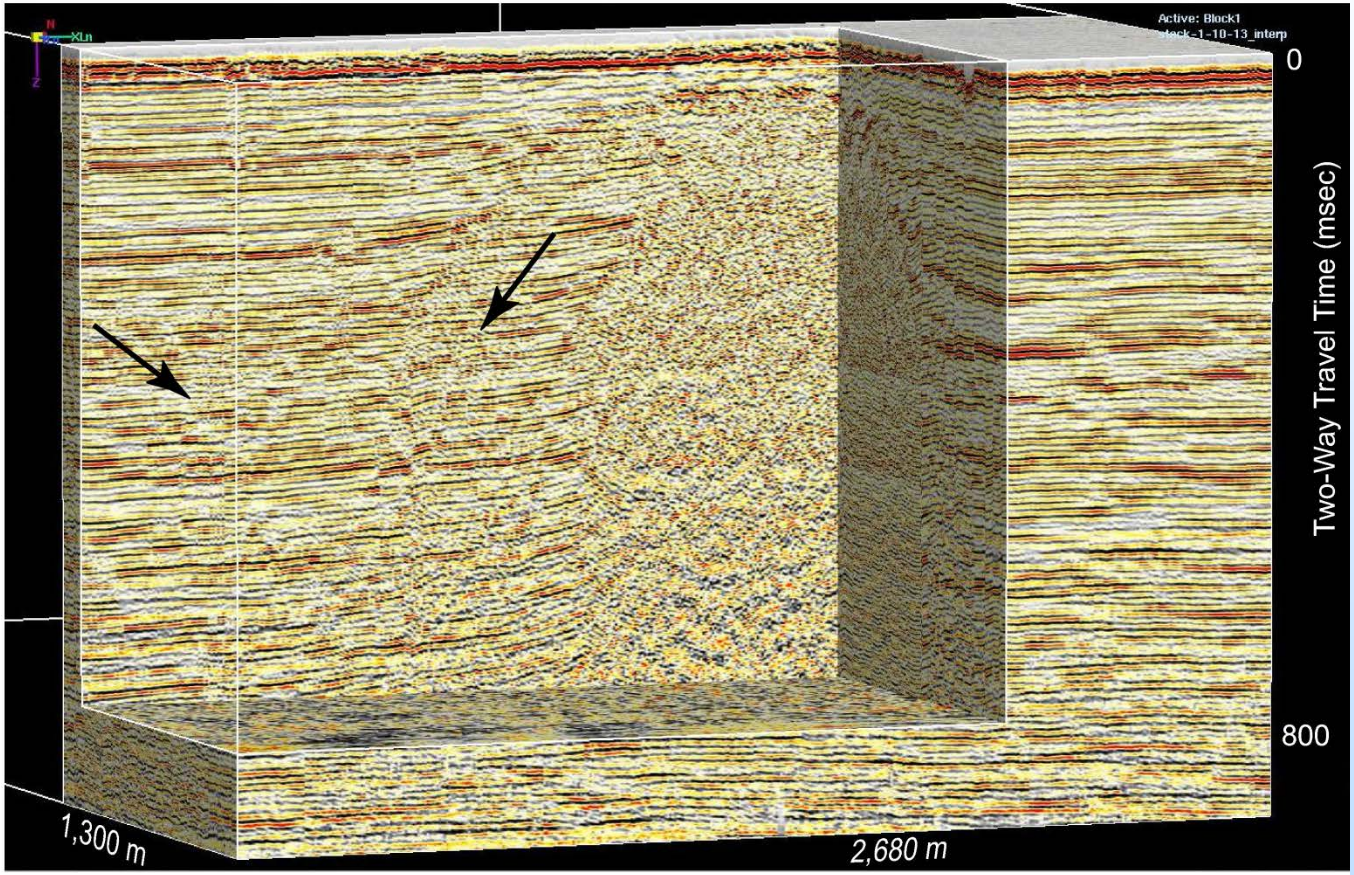


1500 ms ~ 2250 meters depth

Bureau of Economic Geology

The University of Texas at Austin
John A. & Katherine G. Jackson School of Geosciences

Challenges – Initial Processing

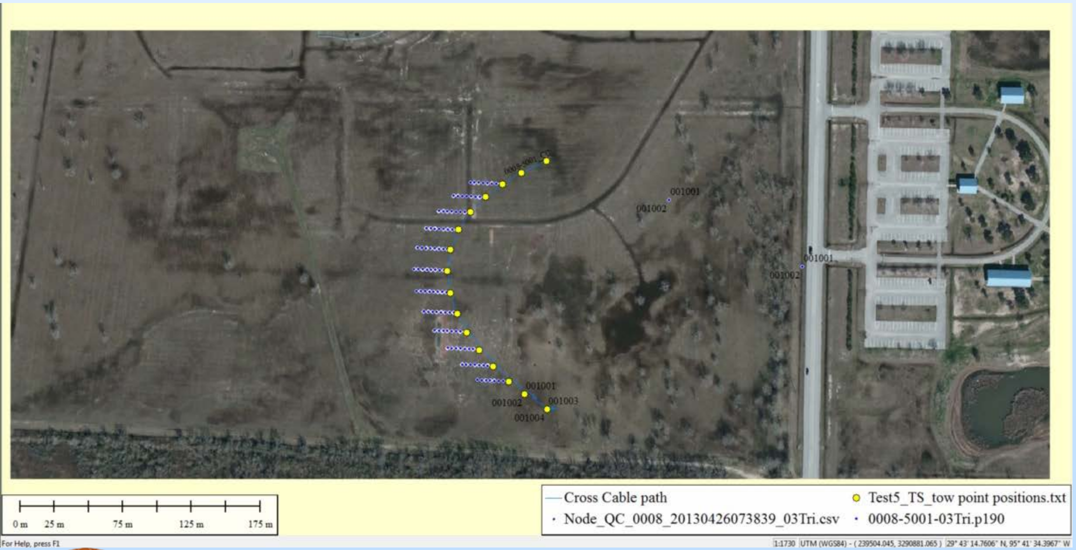


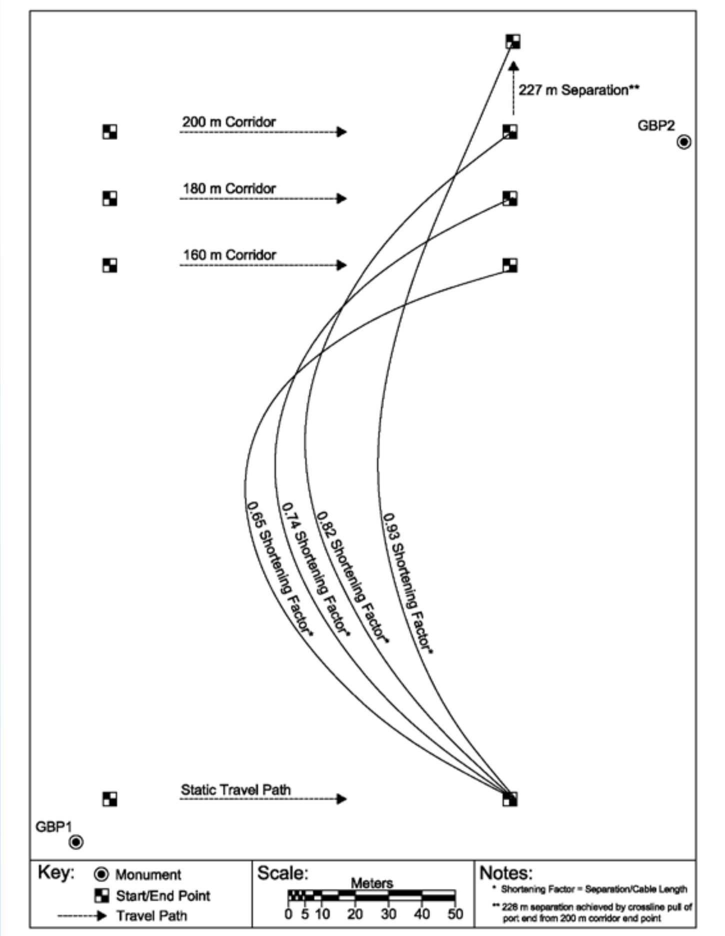
Hi-Res 3D (HR3D) Seismic

- 1st P-Cable HR3D Survey
  - Dataset Successfully Acquired
  - Initial processing challenges
  - Field testing resolved issues
  - Re-processing almost complete

Static Field Test: Compare Calculated Receiver Positions with known (surveyed) positions

1. Software solution (receiver positions) – Robust, and sensitive to:
   - Cross-cable GPS's location distance to 1st junction box and tow point
2. Offsets used for initial processing were less than they should have been.





BUREAU OF ECONOMIC GEOLOGY

The University of Texas at Austin John A. & Katherine G. JACKSON SCHOOL OF GEOSCIENCES

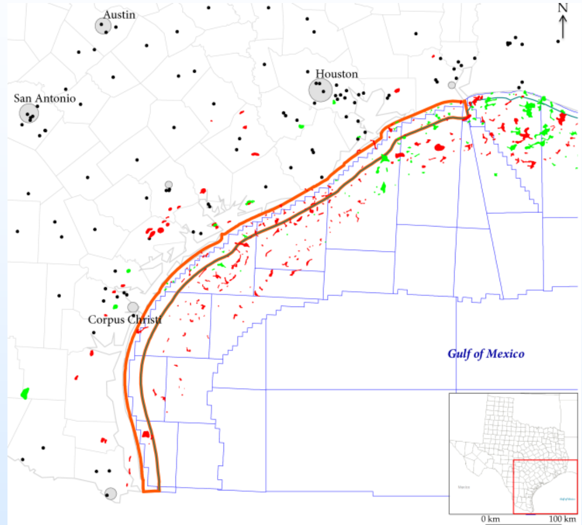
Gulf Coast Carbon Center

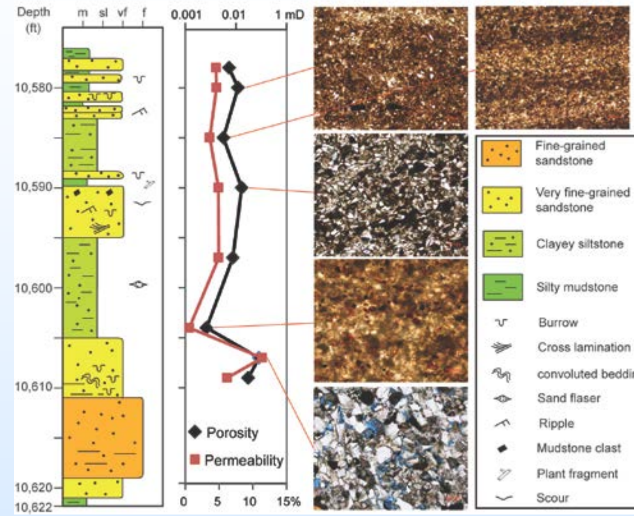
Presentation Outline

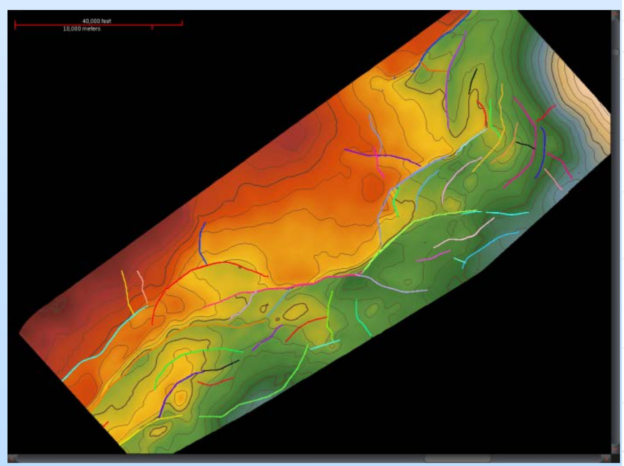
- Project Overview & Past Accomplishments
- Regional Static Capacity
- Model Area
  - Simple Dynamic Analytical Model
  - Flow Simulation Model Runs
- Hi-Res 3D Seismic (HR3D)
- **CO_2 Plays Atlas**
- Summary & Acknowledgments

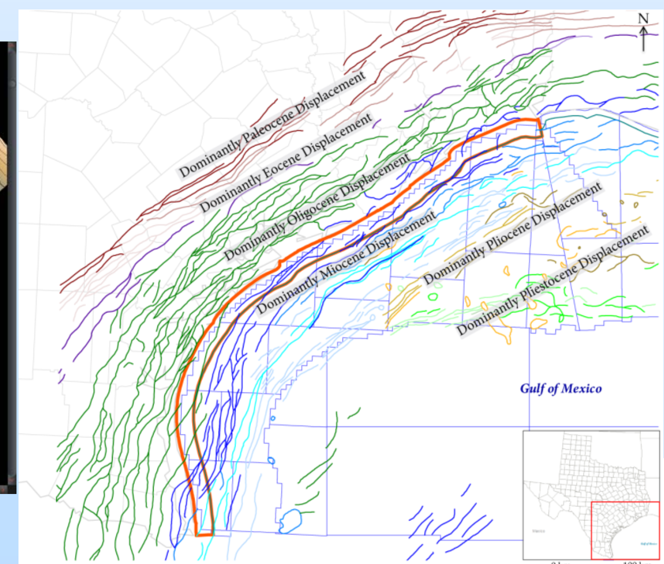
CO_2 Atlas First Draft – Nearing Completion (Focus of Poster)

- Regional geology & petroleum systems (CO_2 analog)
- Confining system overview
- Regional capacity estimate
- CO_2 "plays" prospective storage sites









Bureau of Economic Geology

The University of Texas at Austin
John A. & Katherine G.
Jackson School of Geosciences

Summary

<u>Key Findings</u>

- Estimated Regional Static Capacity per sq. mile probably over-estimates actual storage potential
- Miocene top seals able to trap CO_2
- CO_2 backfilling preferable alternative to capillary flow fingering
- Geochemical experiments' results as expected

Summary

Lessons Learned

- Calculated receiver positions sensitive to cross-cable GPS's location (distance to 1st junction box and tow point)
- P-Cable seismic acquisition cruises logistically complicated but achievable, data-rich and worthwhile

Summary

Future Plans

- 2 more P-Cable surveys
  - Establish subcontract with marine vessel / science partner organization
    - Test different pneumatic sources
  - Test calculated receiver positions / improve processed dataset result
- Publish 2-5 peer-reviewed articles
- Publish atlas
- Characterization best practices manual
- Final report

Acknowledgments

- Landmark Graphics (a Halliburton Co.)
  - University grant program
  - Full suite of geoscience interpretation software
- IHS Petra geoscience interpretation software
- Project PI, Dr. Tip Meckel
- Sandia Tech, LLC

Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

UTIG

NETL National Energy Technology Laboratory

General Land Office · The State of Texas · 1836

Gulf Coast Carbon Center

Disclaimer: This report was prepared as an account of work sponsored by an agency of the United states Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Appendix

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

Organization Chart

The Univ. of Texas at Austin project team comprises:

- **Dr. Tip Meckel**, PI (Principal Investigator) / Geologist, science research leader.
- **Ramon Trevino**, Co-PI / Project Manager (Geologist), leads administrative and managerial tasks.

  (Both co-PI's also participate in various parts of the research.)
- **David Carr**, Geologist, leads a group that concentrates on geologic interpretation using well data supplemented with leased seismic data. An atlas of CO_2 prospects will result from this research. Assisted by **Jordan Taylor, Caleb Rhatigan** and four **undergraduate research assistants**.

Bureau of Economic Geology

The University of Texas at Austin John A. & Katherine G. Jackson School of Geosciences

Gulf Coast Carbon Center

Organization Chart (cont.)

- **Dr. Nathan Bangs**, Geophysicist / seismic processor, leads the acquisition and processing of high-resolution, shallow 3D seismic data using the Study's P-cable system.
- **Tom Hess**, Geophysicist / seismic processor assists processing of high-resolution, shallow 3D seismic data using the Study's P-cable system.
- **Dr. Hongliu Zeng**, Geophysicist / seismic interpreter, assists with post-stack processing and time-depth conversion of leased, regional, petroleum industry 3D seismic data.

Organization Chart (cont.)

- **Drs. Changbing Yang, Katherine Romanak, Tongwei Zhang, Jiemin Lu** and **Patrick Mickler** focus on geochemical research of Miocene aged rocks and brines of the Gulf of Mexico.
- **Dr. Jiemin Lu** also conducts petrologic analyses of reservoir and especially seal (caprock) samples.
- **Dr. Lorena Moscardelli**, Geologist, assisted with acquisition of high-resolution, shallow 3D seismic data using the Study's P-cable system.

Organization Chart (cont.)

- Graduate research assistants:

1. **Julie Ditkof** works under the direction of Dr. Meckel and with Dr. Bangs on seismic processing.
2. **Erin Miller** (recently graduated) worked under the direction of Dr. Meckel on capacity related problems.
3. **Kerstan Wallace** (recently graduated) worked under the direction of Dr. Meckel on structure related problems.
4. **Ravi Priya Ganesh** (recently graduated) worked under the direction of Dr. Meckel and **Dr. Stephen Bryant** on fluid flow related problems.
5. **Andrew Nicholson** (recently graduated) worked under the direction of Dr. Meckel and Ramon Trevino on fault seal research.

Organization Chart (cont.)

At Southern Methodist University:

- **Dr. Mathew Hornbach** and his graduate research assistant, Ben Phrampus, concentrate on advection / diffusion models that incorporate active faulting and fluid flow.

At Los Alamos National Laboratory:

- **Dr. J. William Carey** and his team assessed reservoir capacity and injectivity and developed a cost-optimized model for connecting onshore CO2 sources via pipelines to potential sequestration.

Organization Chart (cont.)

At Sandia Technologies, LLC:

- **Dan Collins**, PI, and **Norma Martinez** are evaluating the well construction of 37 wells in the study area near Galveston Island, Texas. The work sometimes involves directing the work of subcontractors who access records from the Railroad Commission of Texas.

Gantt Chart

The image part with relationship ID rId3 was not found in the file.

Bibliography

List peer reviewed publications generated from project per the format of the examples below

- <u>Journal, one author</u>:
  - Meckel, T.A., 2013, DIGITAL RENDERING OF SEDIMENTARY-RELIEF PEELS: IMPLICATIONS FOR CLASTIC FACIES CHARACTERIZATION AND FLUID FLOW: Journal of Sedimentary Research, v. 83, p. 495-501.
- <u>Journal, multiple authors</u>:
  - Middleton, R. S., Keating, G. N., Stauffer, P. H., Jordan, A. B., Viswanathan, H. S., Kang, Q. J., Carey, J. W., Mulkey, M. L., Sullivan, E. J., Chu, S. P., Esposito, R., and Meckel T. A., 2012, The cross-scale science of CO2 capture and storage: from pore scale to regional scale. Energy & Environmental Science, v. 5(6), p. 7328-7345, available at: www.rsc.org/ees.