# Carbon Dioxide Sealing Capacity: Textural or Compositional Controls? Project #: DE-FE0002028

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**Dept. of Earth and Environmental Sciences**

*U.S. Department of Energy*
*National Energy Technology Laboratory*
*Carbon Storage R&D Project Review Meeting*
*Developing the Technologies and Building the Infrastructure for $CO_2$ Storage*
*August 21-23, 2012*

# Presentation Outline

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- Benefits of the program
- Project Overview: Goals and Objectives
- Technical Status
- Accomplishments to Date
- Summary – Key Findings
- Summary – Lessons Learned
- Summary – Future Plans
- Appendix

# Benefit to the Program

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- The Program goal being addressed:
  - *Develop technologies to demonstrate that 99 percent of injected $CO_2$ remains in the injection zones.*
- The research project is investigating the role of compositional and structural properties of caprock on sealing capacity of a $CO_2$ sequestration site. The research, when finished, will advance our knowledge of the sealing capacity of rocks such as shales and anhydrites and, in turn, will provide a better understanding of the processes that take place in geologic reservoirs that are subject to $CO_2$ injection.
- This research contributes to the Carbon Storage Program's effort of ensuring 99% $CO_2$ storage permanence in the sequestration zones.

# Project Overview:
## Goals and Objectives

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**Major Objective**

- The major objective of this research is to test whether textural parameters (e.g., the pore-throat size, distribution, geometry, and sorting, grain size, etc.) or compositional parameters (e.g., compaction, mineralogical content, cementation, organic matter content, carbonate content, etc.) of cap rocks control their $CO_2$ sealing capacity.

# Project Overview: Goals and Objectives

- Advancing scientific discovery and understanding through proposed activity that will be intimately related to promoting teaching, training and learning activities at Brooklyn College.
- I teach an upper tier core course, titled *"Climate Change – Torn between Myth and Fact"*. During course lectures and practice activities, undergraduate students from various departments will learn about the most important environmental issues raised by increased concentration of $CO_2$ in the atmosphere and the efforts taken by many countries, including USA, to reduce the amount of $CO_2$. One of the efforts, namely carbon dioxide sequestration, will be exemplified by our anticipated results.

# Project Overview: Goals and Objectives

- Students get trained in incorporating new data from our database in existing databases that will be provided to them during the course and practice activities.

# Technical Status

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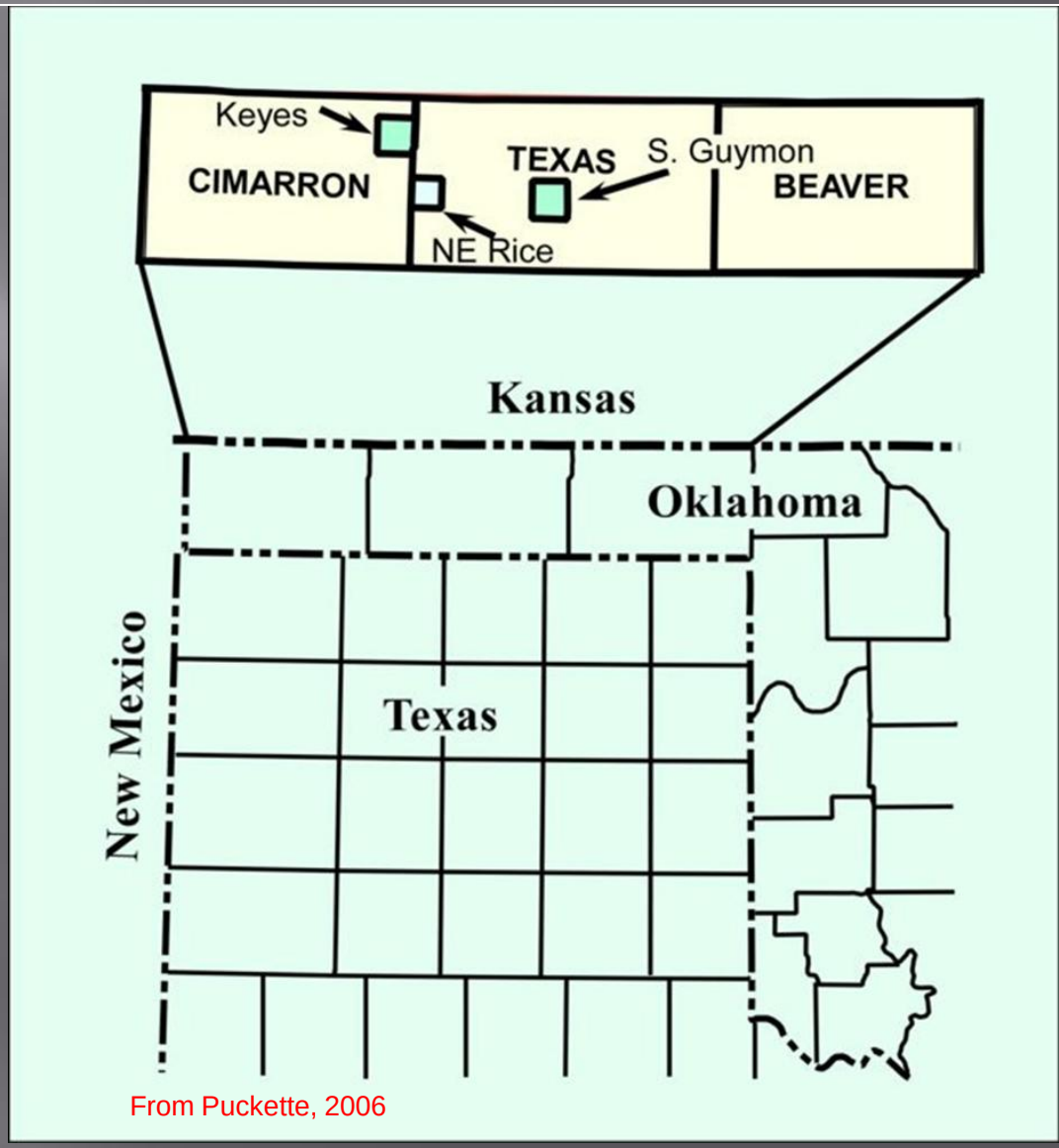
The three gas fields (Keys, NE Rice, and S. Guymon) investigated in this project




From Puckette, 2006

# Technical Status

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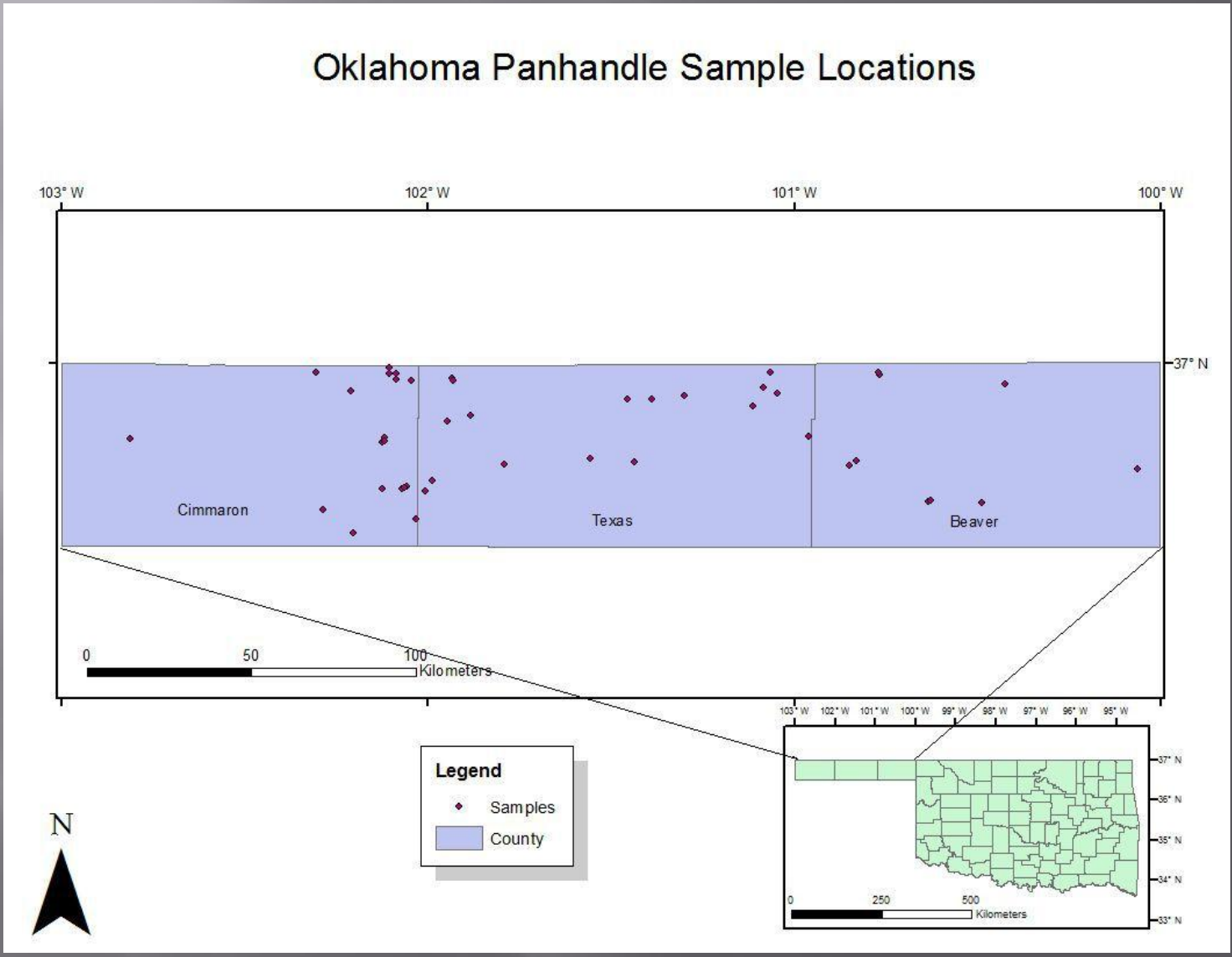

# Technical Status

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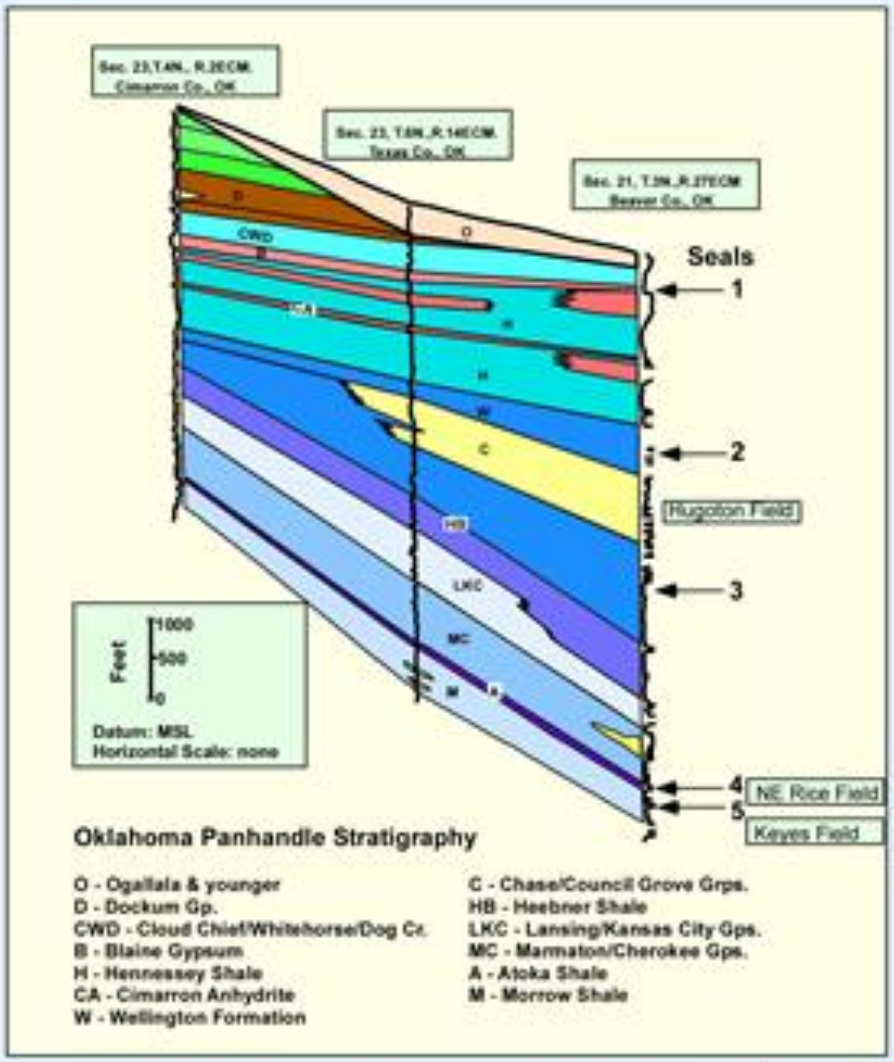


From Puckette, 2006

## Regional Stratigraphy

## Major Seal Intervals

1 - Hennessey Shale
2 - Wellington Formation
3 - U. Morrow/Atoka Shales
4 - L. Morrow Shales

# Technical Status

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| ID # | FILE # | COUNTY | Formation | Top (ft) | Bottom (ft) | Lat | Long | Sample Image | Sample Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 120 | TEXAS | Morrowan | 4419 | 4466 | 36.84006 | -101.94854 | Pic | Gray medium grained quartz sandstone |
| 2 | 163 | TEXAS | Morrowan | 4410 | 4459 | 36.84413 | -101.93947 | pic | Light brown medium to coarse grained sandstone |
| 3 | 239 | BEAVER | Marmaton | 6720 | 6839 | 36.61827 | -100.4896 | Pic | Black fine grained lime mudstone |
| 4 | 269 | BEAVER | Des Moinesian | 6430 | 6533 | 36.62177 | -100.63258 | Pic | Black fine grained lime mudstone |
| 5 | 328 | BEAVER | Permian | 866 | 1030 | 36.50206 | -100.94257 | pic | reddish waxy anhydrite |
| 6 | 334 | BEAVER | Marmaton | 6646 | 6676 | 36.61827 | -100.4896 | Pic | Black fine grained lime mudstone |
| 7 | 868 | TEXAS | Purdy | 4524 | 4547 | 36.95927 | -101.93526 | Pic | Black fine grained Fissile shale |
| 8 | 874 | TEXAS | Morrowan | 4559 | 4569 | 36.95239 | -101.91719 | pic | dark gray fine graineded limestone |
| 9 | 878 | TEXAS | Cherokee | 4524 | 4600 | 36.6806 | -101.98941 | Pic | Black fine grained lime mudstone |
| 10 | 900 | CIMARRON | Morrowan | 4496 | 4557 | 36.92432 | -102.21267 | Pic | Light brown fine grained quartz sandstone |
| 11 | 946 | BEAVER | Marmaton | 6627 | 6741 | 36.61796 | -100.48026 | pic | Black fine graineded mudstone |
| 12 | 953 | BEAVER | Marmaton | 6403 | 6462 | 36.62537 | -100.50748 | pic | Black fine graineded mudstone |
| 13 | 3152 | CIMARRON | Morrowan | 4817 | 4916 | 36.53576 | -102.20474 | Pic | Black fine grained layered calcareous shale |

# Technical Status

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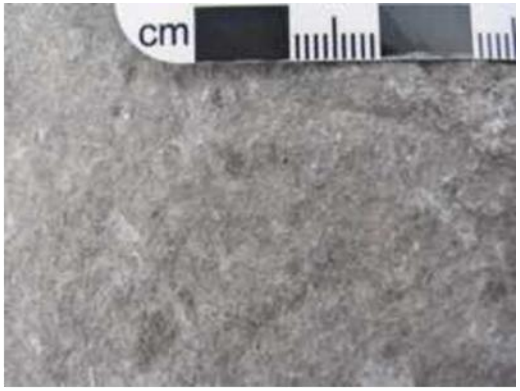
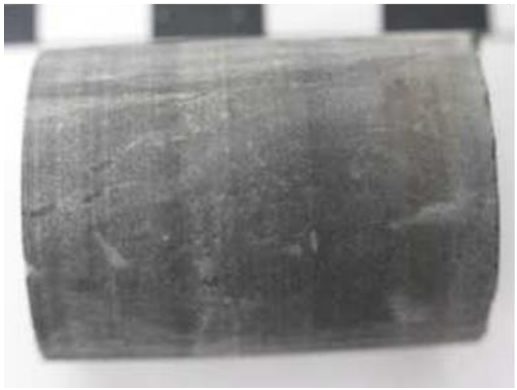
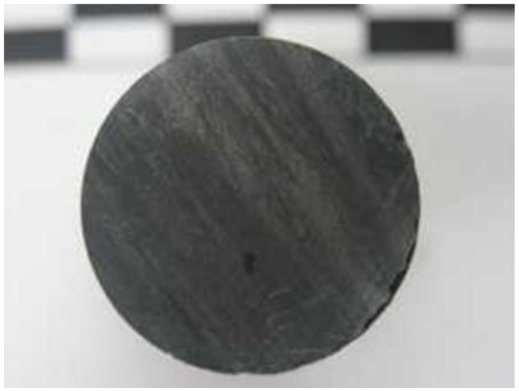
**Sample #601-6 (Depth 3,847-3,850 ft)**
**Gray Limestone (Fine – Medium Grain)**







# Technical Status

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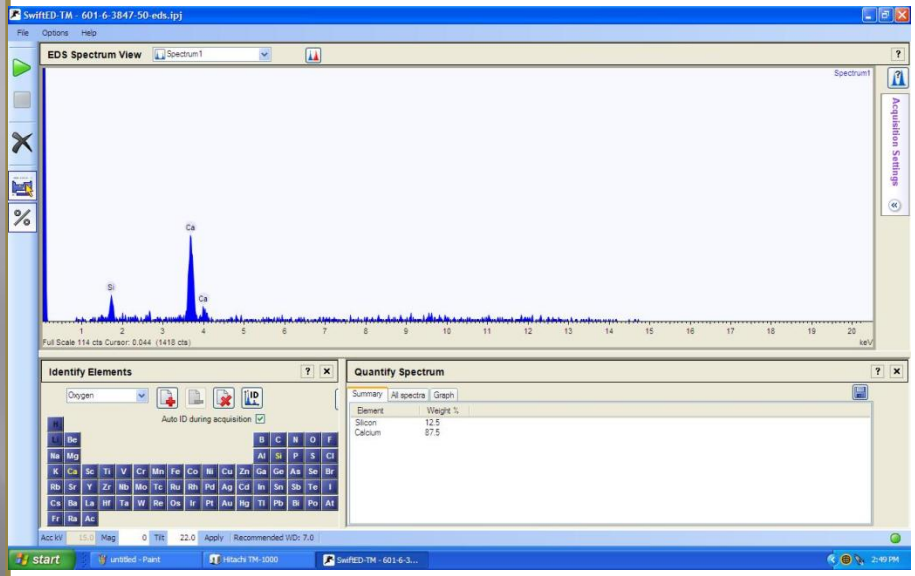
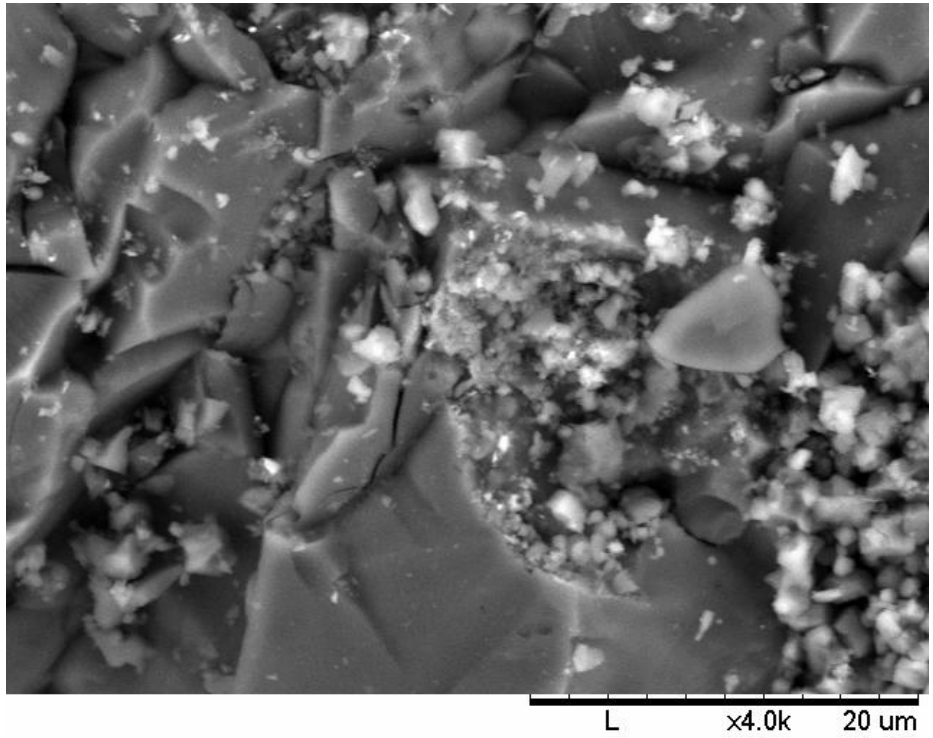
## Sample #601-6 (Depth 3,847-3,850 ft)
## Gray Limestone (Fine – Medium Grain)




**EDS analysis** indicating the predominance of Ca. An XRD analysis indicates 96.7% calcite

**SEM microphotograph**. Calcite crystals are abundant. Intercrystalline porosity

# Technical Status

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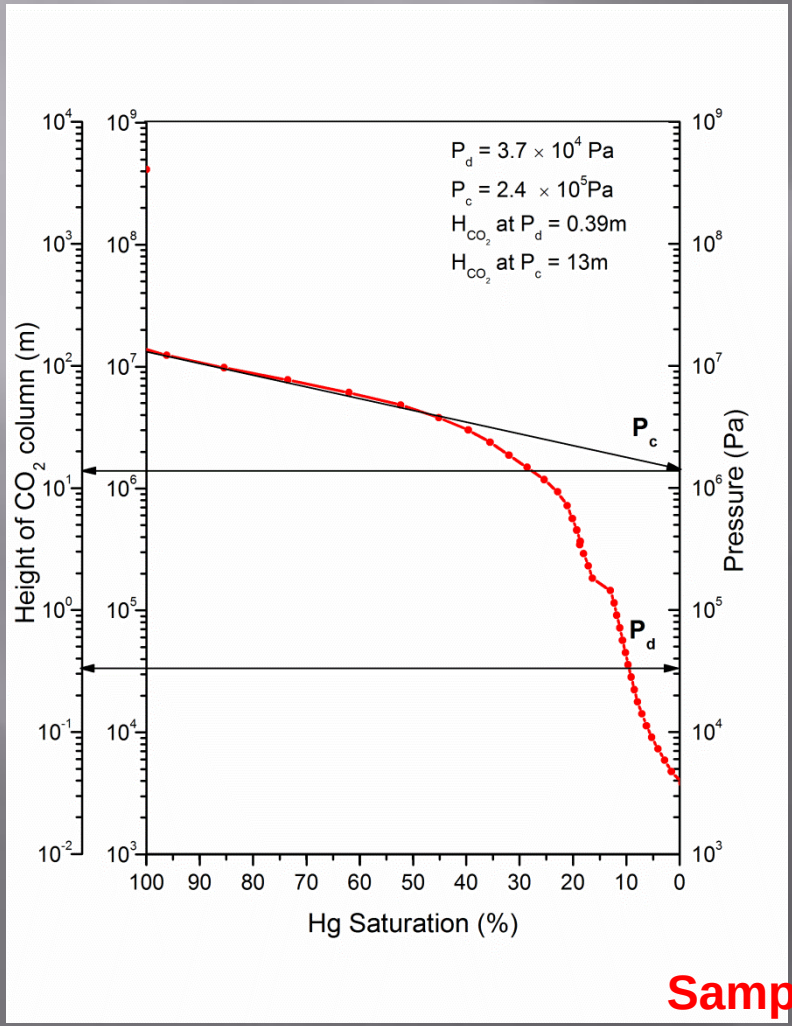
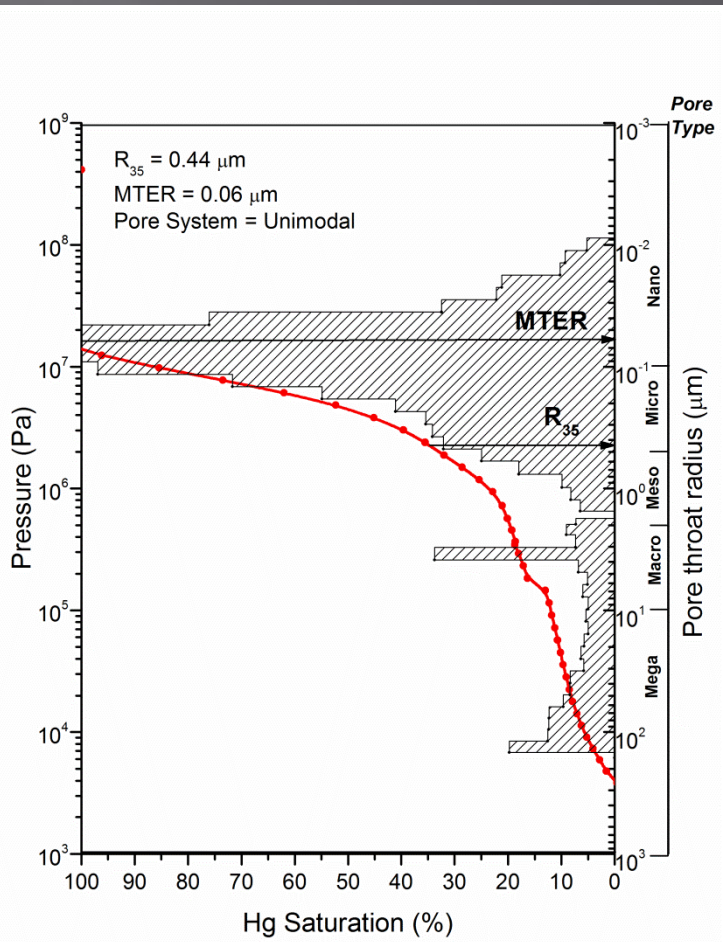
## Mercury Intrusion Porosimetry Measurements




**Sample #601-6**

# Technical Status

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## Surface Area Measurements

MICROMERITICS ANALYTICAL SERVICES — The Particle Testing Authority

TriStar II 3020 V1.03 (V1.03) Unit 2 Port 3 Serial #: 571 Page 1

Sample: 601 F3
Operator: IAR/AT
Submitter: Brooklyn College
File: C:\...\06JUN\1103991.SMP

Started: 6/23/2011 10:09:32AM
Completed: 6/23/2011 12:45:41PM
Report Time: 6/23/2011 1:15:17PM
Warm Free Space: 6.6564 cm³ Measured
Equilibration Interval: 10 s
Sample Density: 1.000 g/cm³

Analysis Adsorptive: N2
Analysis Bath Temp.: 77.350 K
Sample Mass: 4.0348 g
Cold Free Space: 16.1008 cm³ Measured
Low Pressure Dose: None
Automatic Degas: No

Comments: Degas at 110 C for 16h

**Summary Report**

**Surface Area**

Single point surface area at P/Po = 0.300999242: 0.5840 m²/g

BET Surface Area: 0.6087 m²/g

**Sample #601-6**

# Technical Status

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## Grain Size Measurements

MICROMERITICS ANALYTICAL SERVICES The Particle Testing Authority

**Micromeritics Instrument Corporation**

Saturn DigiSizer II 5205 V1.01 Saturn DigiSizer II 5205 V1.01 5200 LSHU V3.00 S/N 127 Page 1

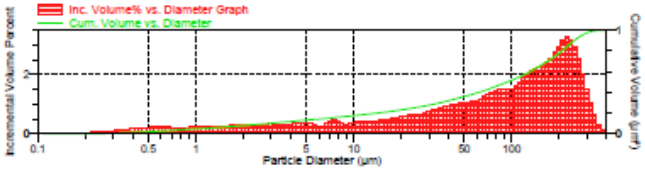
Sample: 601
Operator: TN
Submitter: Brooklyn College of CUNY
File: C:\...\06JUN\1103991.SMP

Test Number: 2
Analyzed: 6/22/2011 2:42:38PM
Reported: 6/22/2011 3:32:49PM
Background: 6/22/2011 2:23:08PM

Model: (1.570, 0.1000000), 1.331
Material: Sediment / Water
Background: Water RI 1.331
Smoothing: Medium

**Combined Report**

**Incremental Volume Percent vs. Particle Diameter Graph**




**Summary Report**

**Analysis Conditions**

FlowRate: 12.0 l/m
Circulation time: Not Used
Ultrasonic intensity: 100 %
Ultrasonic time: 60 sec

**Sample**

Sample Concentration: 0.02676 %
Obscuration: 37.2 %

**Weighted Statistics (Volume Distribution)**

| | | Std Dev of 2 | | | Std Dev of 2 |
|---|---|---|---|---|---|
| Mean | 112.136 | 1.907 | Mode | 223.600 | 0.000 |
| Median | 93.794 | 2.285 | | | |

**Selected Percentiles by Volume**

| Percent Finer | Diameter (µm) |
|---|---|
| 90.0 | 249.193 |
| 50.0 | 93.794 |
| 10.0 | 2.888 |

**Sample #601-6**

# Technical Status

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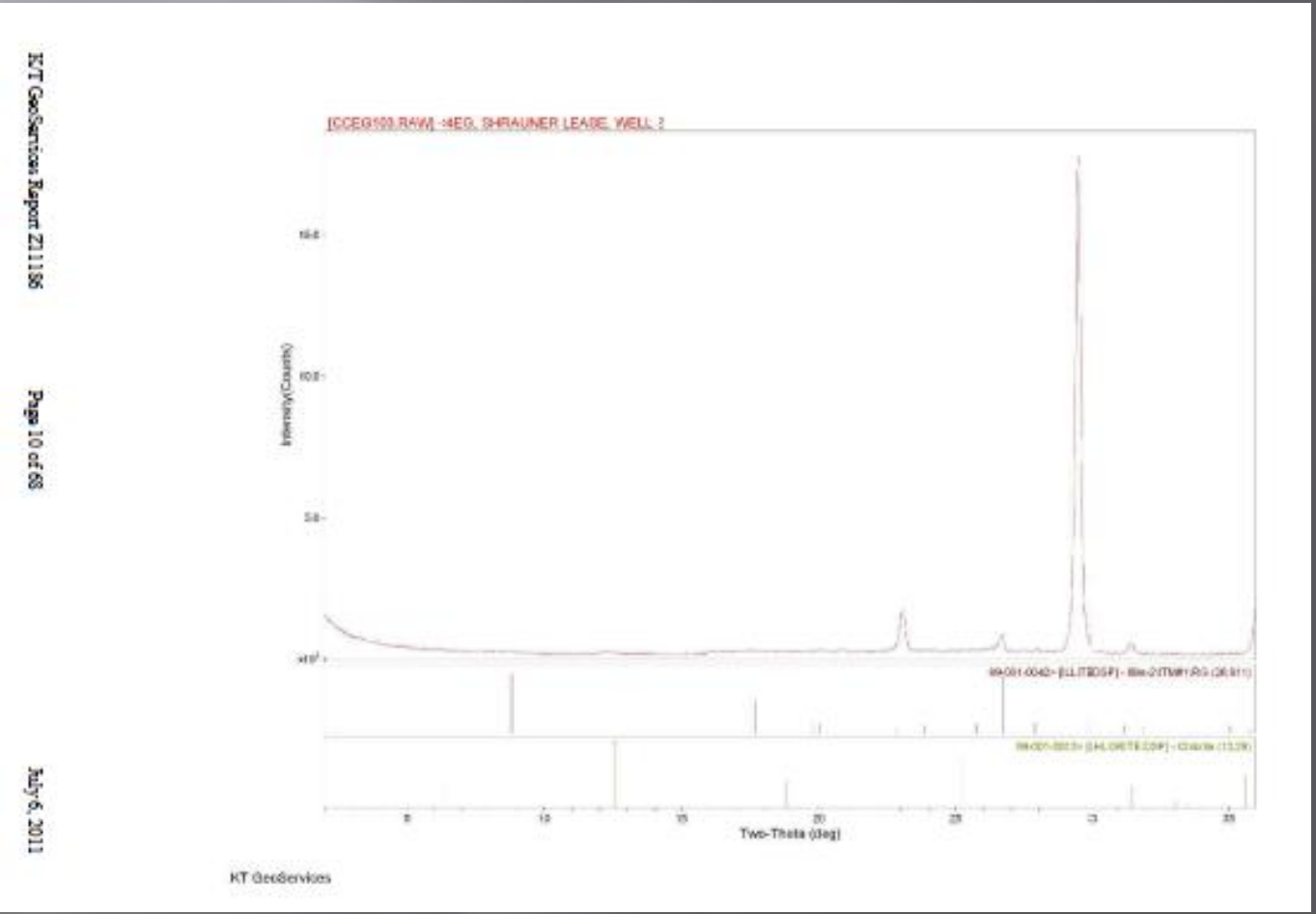
## XRD Measurements




Sample #601-6

# Technical Status

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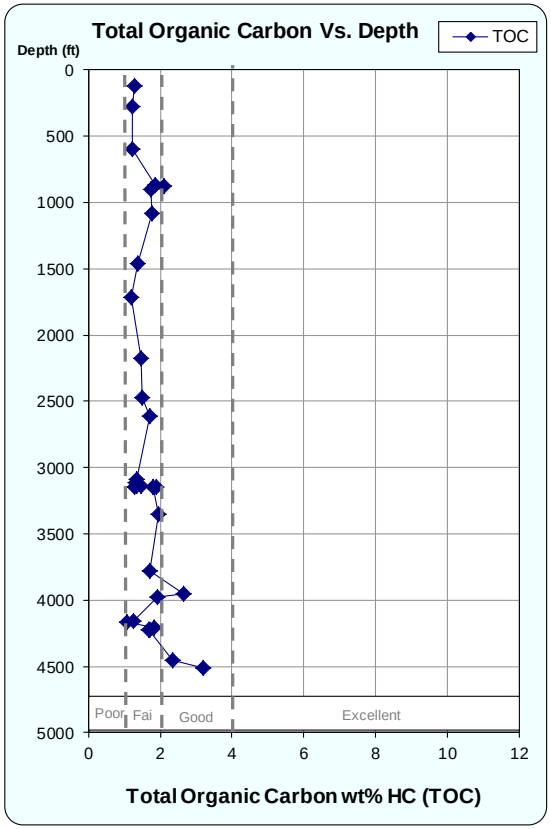
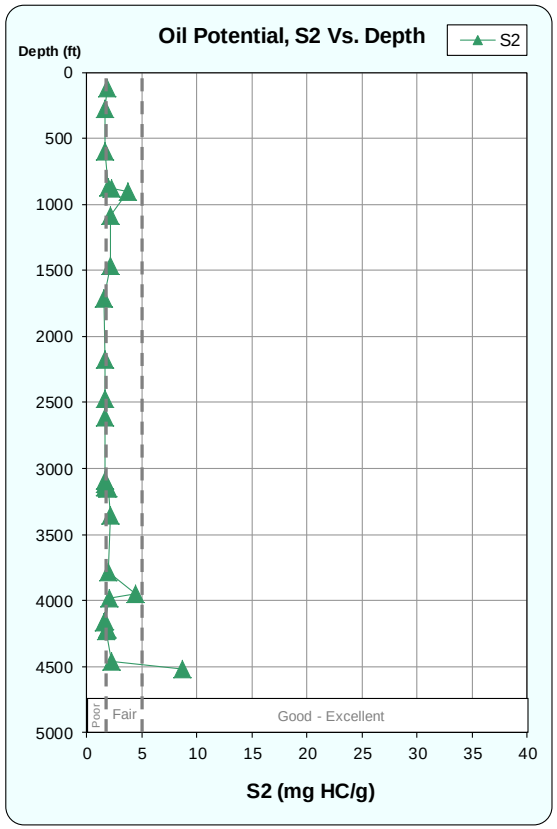
## Source-Rock Analysis and Total Organic Carbon

Job Number: 110558G

Core Lab RESERVOIR OPTIMIZATION



# Technical Status

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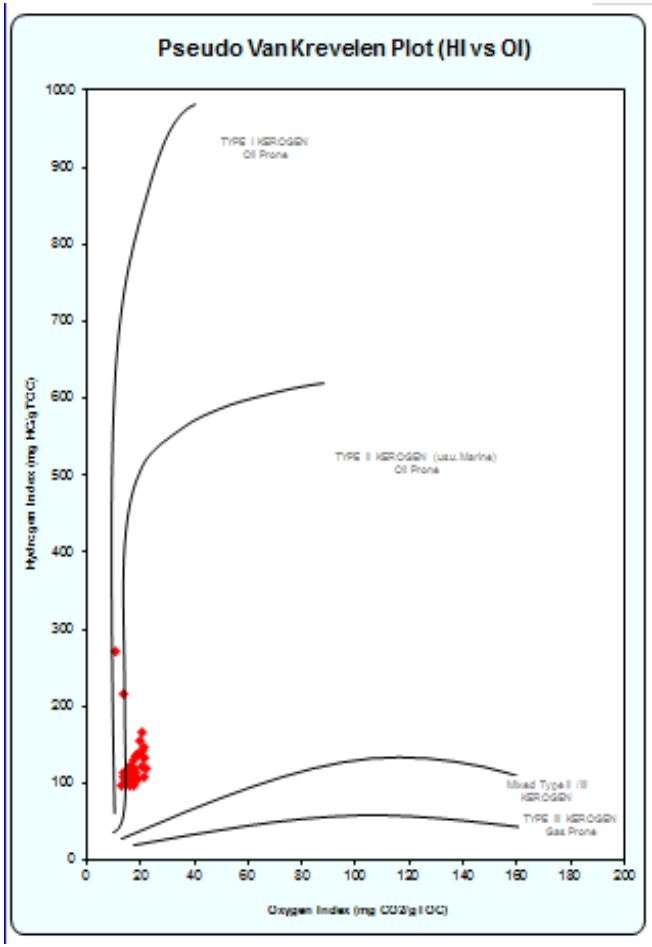
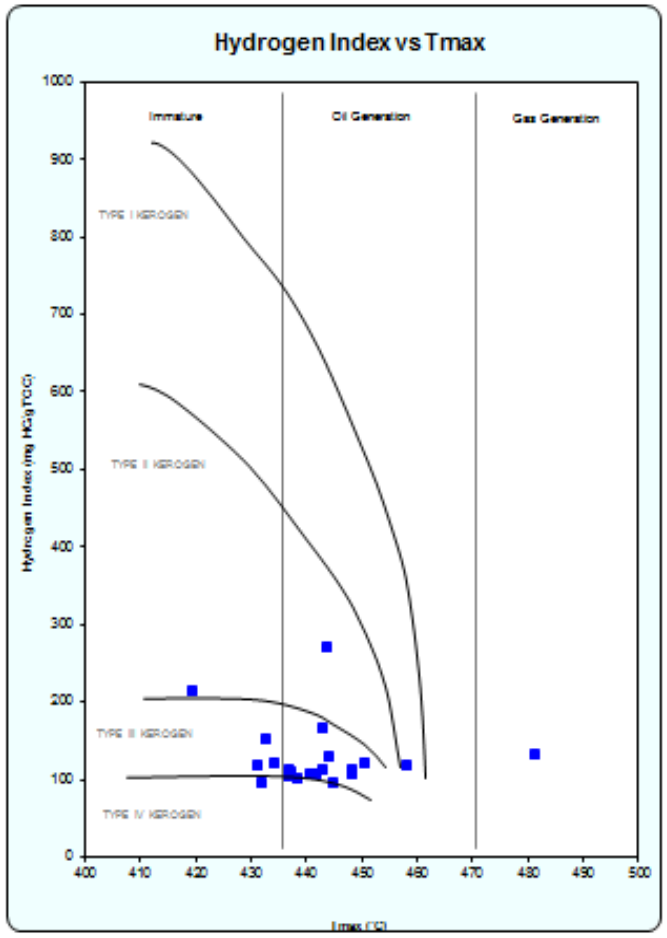
## Source-Rock Analysis and Total Organic Carbon



# Accomplishments to Date

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- 30 samples of caprock from three depleted gas fields in Oklahoma Panhandle have been collected.
- For each sample the following measurements have been performed:
  - Mercury Intrusion Porosimetry
  - SEM microphotography
  - EDS analysis
  - Surface area
  - Grain size
  - Source rock analysis and Total Organic Carbon
  - XRD
  - Lithological descriptions

# Summary
# Key Findings

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- We estimated the sealing capacity of caprocks in the Oklahoma Panhandle in terms of $CO_2$ column height that can be held back by a given seal.
- The range of $CO_2$ column height for the samples used in this research is between 2 ft – 3,596 ft (0.6 – 1,096 m)
- The average $CO_2$ column height is 945 ft (291 m)
- The depth interval between approximately 3,500 – 5,500 ft exhibits the largest values of $CO_2$ column height.
- The above mentioned interval is comprised of mainly Cherokee and Morrowan formations (shale seals).

# Summary
# Key Findings

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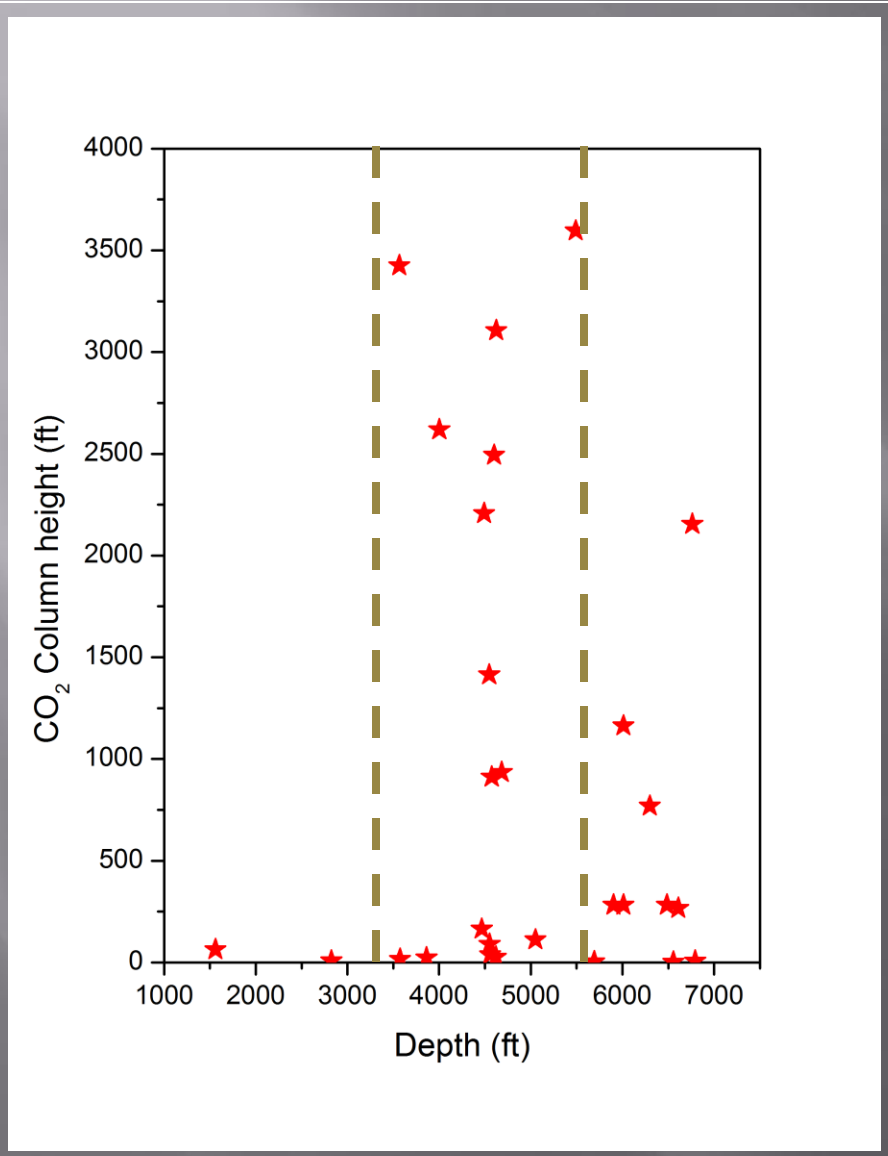


The distribution of $CO_2$ column height value with sample depth

# Summary
# Lessons Learned

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The students learned how to organize research, from developing research questions to crafting a proposal, to working with scientific literature, to designing the research plan.

The students applied a potential method for learning and exploring a topic of interest, like carbon dioxide sequestration as a way of mitigating the current global warming trend.

The students learned that responsibility and integrity in the research program are essential components of their process of becoming future scientists.

# Summary
# Future Plans

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- We are planning to incorporate permeability measurements (both absolute and relative) as a new structural/compositional variable in our model of caprock sealing capacity.
- We will run sensitivity test to estimate the importance of other parameters on $CO_2$ column height:
  - contact angle $CO_2$/brine (0 , 10 , 20 , or 60 )
  - pressure at sample depth
  - temperature at sample depth
  - brine concentration at sample depth
  - $CO_2$ density
  - brine density
  - interfacial tension

# Appendix
# Organization Chart

- PI: Prof. Constantin Cranganu
- Sadiqua Azad, PhD student
- Kieva Watson, Undergraduate student

- With over 16,000 students, Brooklyn College has an impressive racial, ethnic, religious, and minority diversity. From its founding seventy-six years ago, the College has offered men and women – immigrants or the children of immigrants, often the first in their families to go to college – the opportunity to receive a first-rate education that leads to productive careers and satisfying lives. As researchers and educators at Brooklyn College, we are committed to broaden opportunities and enable participation of all students in research projects, as an essential way to maintain the health and vitality of science and engineering.

# Appendix
# Gantt Chart

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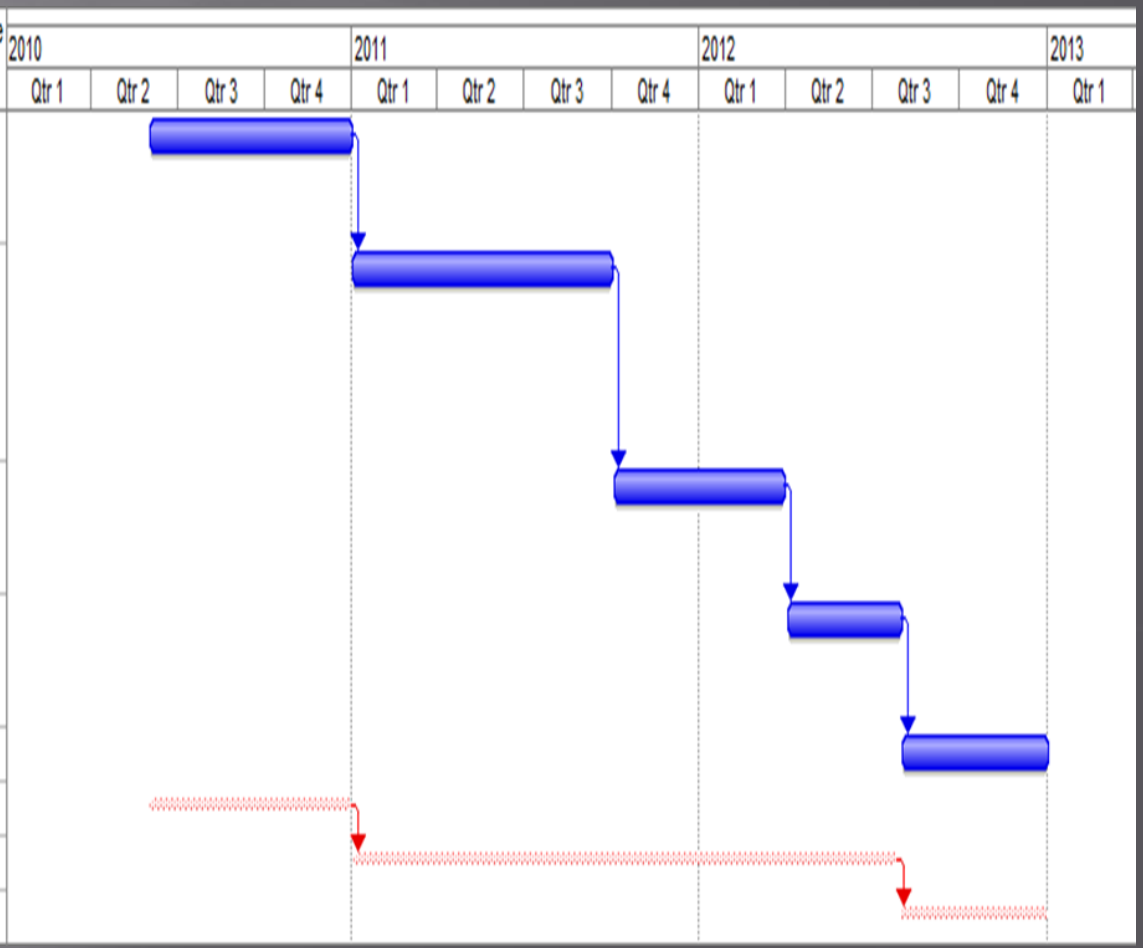
The City University of New York

| ID | Task Name | Duration | Start | Finish | Predecess | Resource Names |
|---|---|---|---|---|---|---|
| 1 | 1.1. Project Management and Planning - Sample Collection | 7.7 mons | Tue 6/1/10 | Fri 12/31/10 | | |
| 2 | 2.1 Data Collecting - MIP measurements | 197 days? | Sat 1/1/11 | Fri 9/30/11 | 1 | |
| 3 | 2.2 Data Collecting - Conduct other textural measurements | 130 days? | Mon 10/3/11 | Fri 3/30/12 | 2 | |
| 4 | 2.3. Data Collecting - Conduct compositional measurements | 87 days? | Mon 4/2/12 | Tue 7/31/12 | 3 | |
| 5 | 3.3 Testing Hypotheses | 109 days? | Wed 8/1/12 | Mon 12/31/12 | 4 | |
| 6 | Milestone - Phase I | 154 days? | Tue 6/1/10 | Fri 12/31/10 | | |
| 7 | Milestone - Phase II | 412 days? | Sat 1/1/11 | Fri 7/27/12 | 6 | |
| 8 | Milestone - Phase III | 111 days? | Mon 7/30/12 | Mon 12/31/12 | 7 | |



# Appendix Bibliography

Puckette, J., 2006, Naturally Underpressured Compartments And the Geologic Sequestration of Carbon Dioxide, http://www.searchanddiscovery.com/documents/2006/06088houston_abs/abstracts/puckette.htm?q=%2BtextStrip%3Apuckette

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# Thank you for your attention!