Electrical Property Investigation of Potential Carbon Sequestration Formations*

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Abstract

In a carbon conscious world steps are being taken to decrease the amount of CO₂ being released into the atmosphere. Geological sequestration has been proposed as a viable option for mitigating the vast amount of CO₂ being produced daily. Test sites for CO₂ injection have been appearing across the world to ascertain the feasibility of capturing and sequestering carbon dioxide. Ohio’s deep saline reservoirs are currently being investigated for their injection potential. The Mountaineer power plant, located on the Ohio River, was a pilot site for a capture and injection.

Geophysical methods, seismic and electromagnetic, play a crucial role in monitoring the subsurface pre- and post-injection. Seismic techniques have been the most popular but electromagnetic methods are gaining interest. The goal of our research is to study the effectiveness of electromagnetic methods as a monitoring tool in Ohio. We gathered core samples from numerous wells around Ohio. Specific interest was placed on reservoir targets (Mt. Simon, Middle Run, and Eau Claire) and cap rocks (Point Pleasant and Utica). The employed methods involve making resistivity and permittivity measurements on the samples in the laboratory.

We designed our own experimental core holders to make electrical measurements on brine saturated samples at ambient pressure. We collected resistivity measurements with a 4-electrode array utilizing frequencies from DC through 100 kHz. The permittivity measurements were made using a coaxial probe with frequencies ranging from 300 kHz to 3 GHz. Our research outlines the range of resistivity and permittivity values for rocks found throughout Ohio’s subsurface. This data gave us the ability to illustrate the limits of using electromagnetic methods to monitor CO₂ injection projects in Ohio.
References


Knight, R., and A. Nur, 1987, The Dielectric Constant of Sandstones 60kHz to 4 MHz, Geophysics, v. 52/5, p. 644-654.


Electrical Property Investigation of Potential Carbon Sequestration Formations

Kyle Shalek
Dr. Jeff Daniels and Dr. David Cole
Project Overview

Ohio Coal Development Office (OCDO):
Geophysical and Geochemical Properties of Reservoir and Cap Rock for Carbon Sequestration in Ohio

Ohio Division of Natural Resources (ODNR) Geological Survey

DOE/NETL ARRA Grant:
Modeling and Evaluation of Geophysical Methods for Monitoring and Tracking CO$_2$ Migration in the Subsurface

Subsurface Energy Materials Characterization and Analysis Laboratory:
Combined Project Outline

• Characterize potential Ohio injection site:
  – Well logs
  – Conduct Porosity and Permeability measurements on rock core

• Collect Electrical Property Data:
  – Conduct 4-electrode Resistivity measurements on core
  – Calculate Dielectric data

• Software Development:
  – Well log analysis
  – Electromagnetic and Seismic forward modeling

• Numerically model and analyze collected data for Geophysical Applications in Ohio
Ohio Geology


Test Case: Warren Co. 2627

Top Devonian Shale to surface
Top Knox to Top Devonian Shale
Top Basal Sandstones to Top Knox
Cambrian Basal Sandstones
Precambrian
Test Case: Warren Co. ODNR 262
Test Case: Warren Co. 2627

Eau Claire Formation

Mt. Simon Sandstone

Middle Run Formation

2915'
3130'
3350'
3570'
### Physical Properties

**Laboratory Data**

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**Mercury Porosimeter**

**Probe Permeameter**

Mike Murphy  
Nick Leeper  
Matt Hawrylak  
Brad Hull
Physical Properties

Mercury Porosimeter
- % Porosity

Corrected Neutron Log Porosity

Eau Claire Formation

Mt. Simon Sandstone

Middle Run Formation
Electrical Property Measurements

4-electrode resistivity technique

NaCl brine based on SCA guidelines. Core is evacuated and then saturated.

LabView controls the measurements and calculates the resistivity.

4 platinum ring electrodes attached to the core

Constant current source Keithley 6221

PCI-6289 card with SCB-68 box Voltmeter
### Electrical Property Measurements

**Log Resistivity**

**Core Resistivity**

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<th>Lithology</th>
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Electrical Property Measurements

Dielectric

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<td>Saturated Sandstone</td>
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</table>

**Complex Refractive Index Method (CRIM):**

\[
K^* = K' - iK''
\]

\[
\sqrt{K^*} = \sum_i V_i \sqrt{K_i^*}
\]

\[
\sqrt{K^*} = [1 - \Phi_t (1 - S_{w0})] \sqrt{K_{wr}^*}
+ (S_w - S_{w0}) \Phi_t \sqrt{K_{bw}^*}
\]

\[
\sqrt{K^*} = (1 - \Phi) \sqrt{K_S^*} + \Phi S_w \sqrt{K_w^*}
+ \Phi (1 - S_w) \sqrt{K_a^*}
\]

- $K_a^*$ = Permittivity wetted rock
- $K_{wr}^*$ = Permittivity wetted rock
- $K_{bw}^*$ = $K_s^*$ = Permittivity water
- $\Phi$ = Total porosity
- $S_w$ = Water saturation
- $S_{w0}$ = Critical Saturation point

R. Knight, A. Nur, The Dielectric Constant of Sandstones 60kHz to 4 MHz, Geophysics, Vol. 52, No. 5 (May 1987)

Electrical Property Measurements

Log Calculated Dielectric

Core Resistivity

<table>
<thead>
<tr>
<th>Depth</th>
<th>Unit</th>
<th>Lithology</th>
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Preliminary Data Estimation:
Presently collecting more dielectric data on the brine and core.
Will be making laboratory dielectric measurements
Software Development

Open-source software package that utilizes well log, laboratory, Electromagnetic, and Seismic data for analysis and forward modeling.

- Forward Modeling
- Top Control & Input
- Display & Interpretation
- Field Data: Well Logs, Seismic data, EM data, & Lab Measurements
- Seismic (MADASGAR)
- EM (PFDTD)
- Interactive Interface To Change Models

Interactive Interface to Change Models
Software Development
Electromagnetic Modeling

Input to Computational Cluster

Sub-block Generation

Interface Output

PFDTD Computation

2D Output Plots

3D Diagnostic Plots

Interface

Model

Diagnosis Plots
Utilize the data collected from the well logs and core samples to numerically model Ohio’s potential carbon sequestration formations.

Model various borehole geometries and conditions to determine effectiveness of Electromagnetic Monitoring of a CO$_2$ injection.
Software Development
Seismic Modeling

Interface:
Model Building

Madagascar Forward Modeling

OpendTect Processing, Imaging, and Interpretation
Software Development
Well Logs

Will be combined and correlated with Seismic and EM 3D blocks
Future Work

• Perform resistivity measurements at subsurface temperatures and pressures while injecting CO$_2$

• Improve dielectric calculations and develop dielectric lab measurements at subsurface temperatures and pressures while injecting CO$_2$

• Develop the software package as an interconnected 3-dimensional geophysical tool

• Explore other locations throughout Ohio
Questions?

Acknowledgments