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 CO_2 being released into the atmosphere. Geological sequestration has been proposed as a viable option for mitigating the vast amount of CO_2 being produced daily. Test sites for CO_2 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 CO_2 injection projects in Ohio.

References

Knight, R., and A. Endres, 1991, A New Concept in Modeling the Dielectric Response of Sandstones: Defining a Wetted Rock Bulk Water System, Geophysics, v. 55/ 5, p. 586-594.

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

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Wickstrom, L.H., 2009, Geologic Challenges for Carbon Sequestration in the Midwest, Advancing the Science of Geologic Carbon Sequestration, unpublished talk given at Oklahoma State University (OSU) March, 2009.

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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

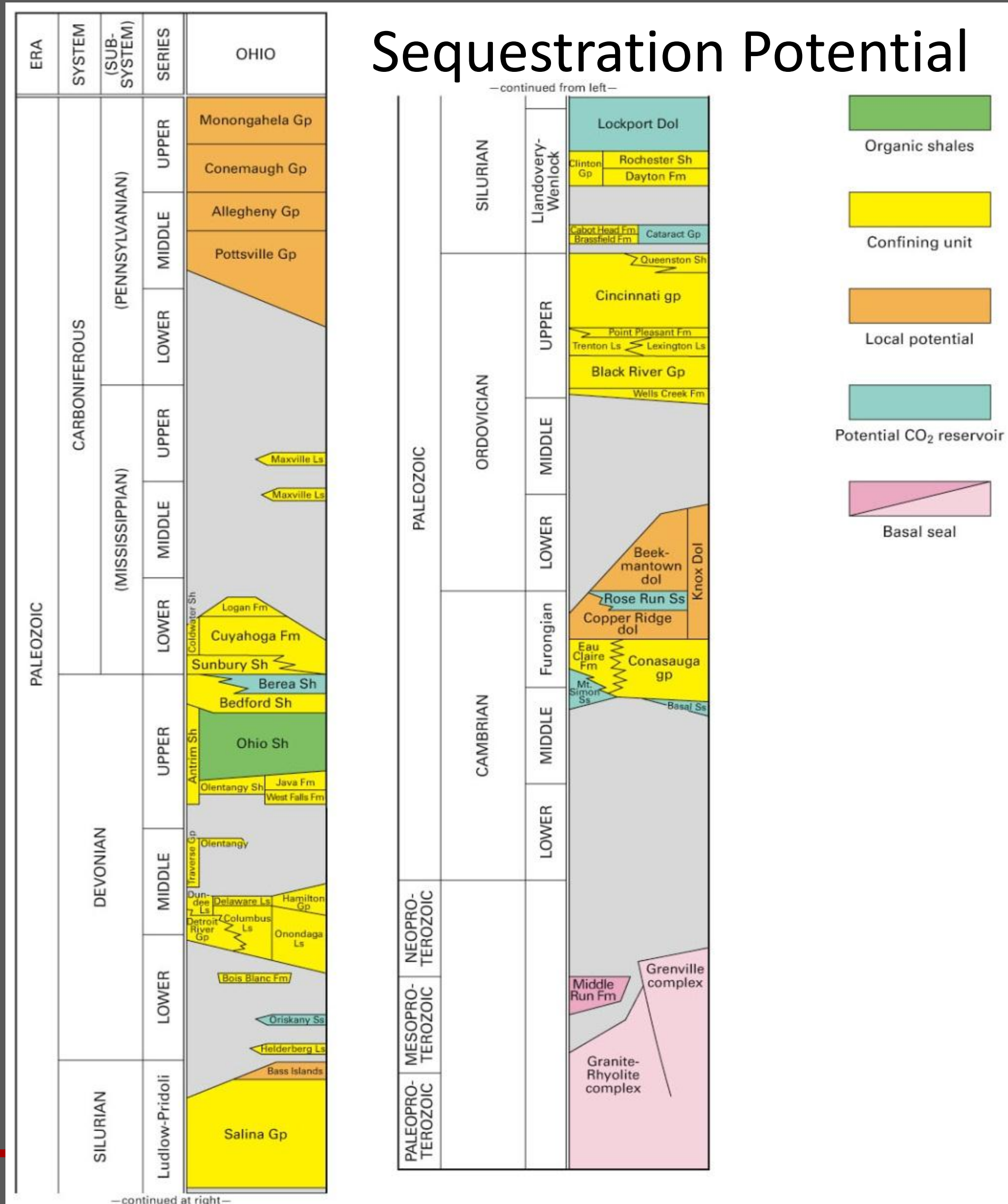
DOE/NETL ARRA Grant:
Modeling and Evaluation of Geophysical Methods for Monitoring and Tracking CO_2 Migration in the Subsurface

Subsurface Energy Materials Characterization and Analysis Laboratory:

Combined Project Outline

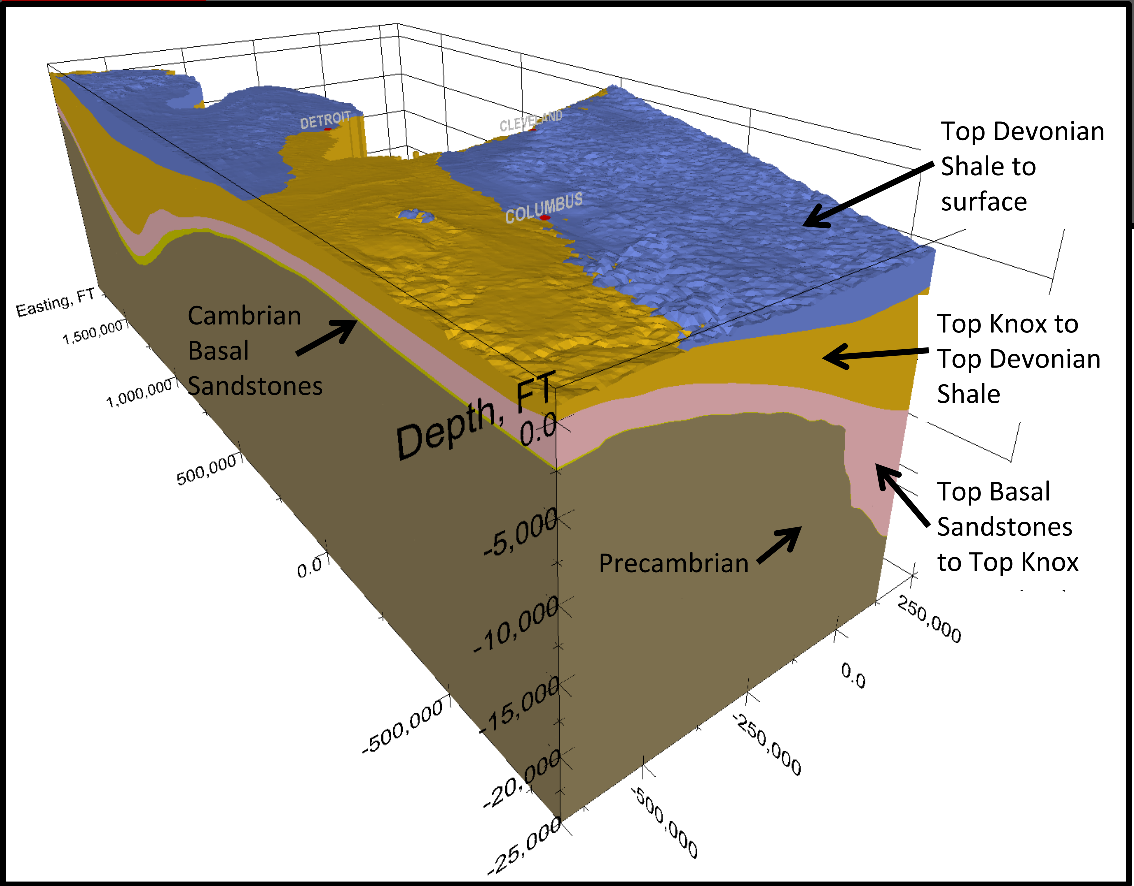
- Characterize potential Ohio injection site:
  - Well logs
  - Conduct Porosity and Permeability measurements on rock core
- Collect Electrical Property Data:
  - Conduct 4-electrode Resistivity measurements on core
  - Calculate Dielectric data
- Software Development:
  - Well log analysis
  - Electromagnetic and Seismic forward modeling
- Numerically model and analyze collected data for Geophysical Applications in Ohio

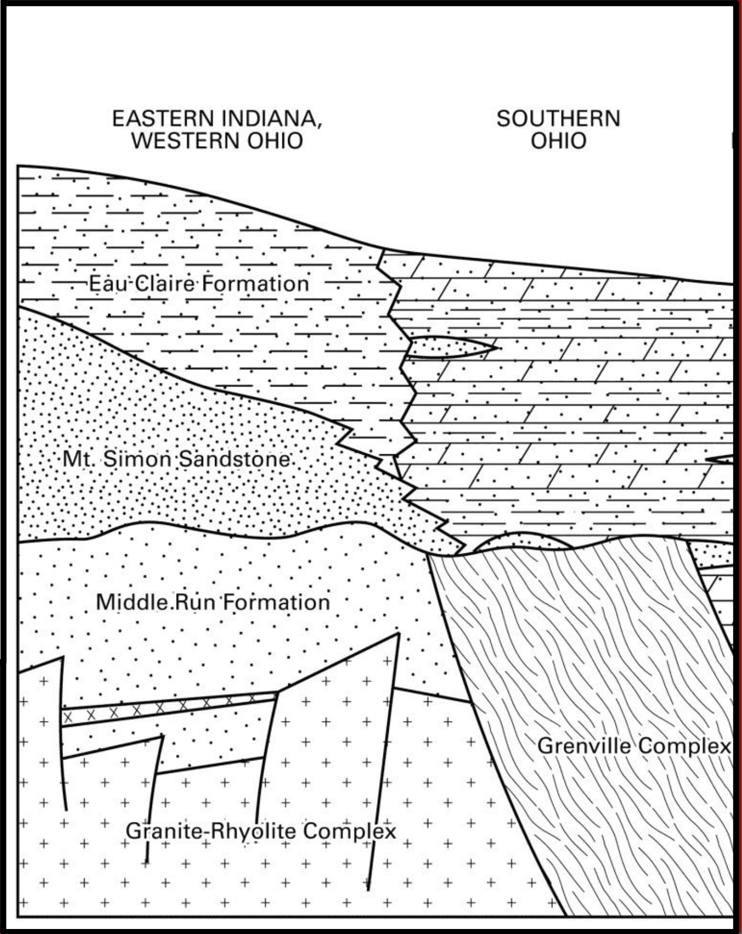
Ohio Geology



L. Wickstrom, et. al., Characterization of Geological Sequestration Opportunities in the MRCSP Region, Task Report, 2010.

Ohio Geology





L. Wickstrom, Geologic Challenges for Carbon Sequestration in the Midwest, Advancing the Science of Geologic Carbon Sequestration, OSU March, 2009.

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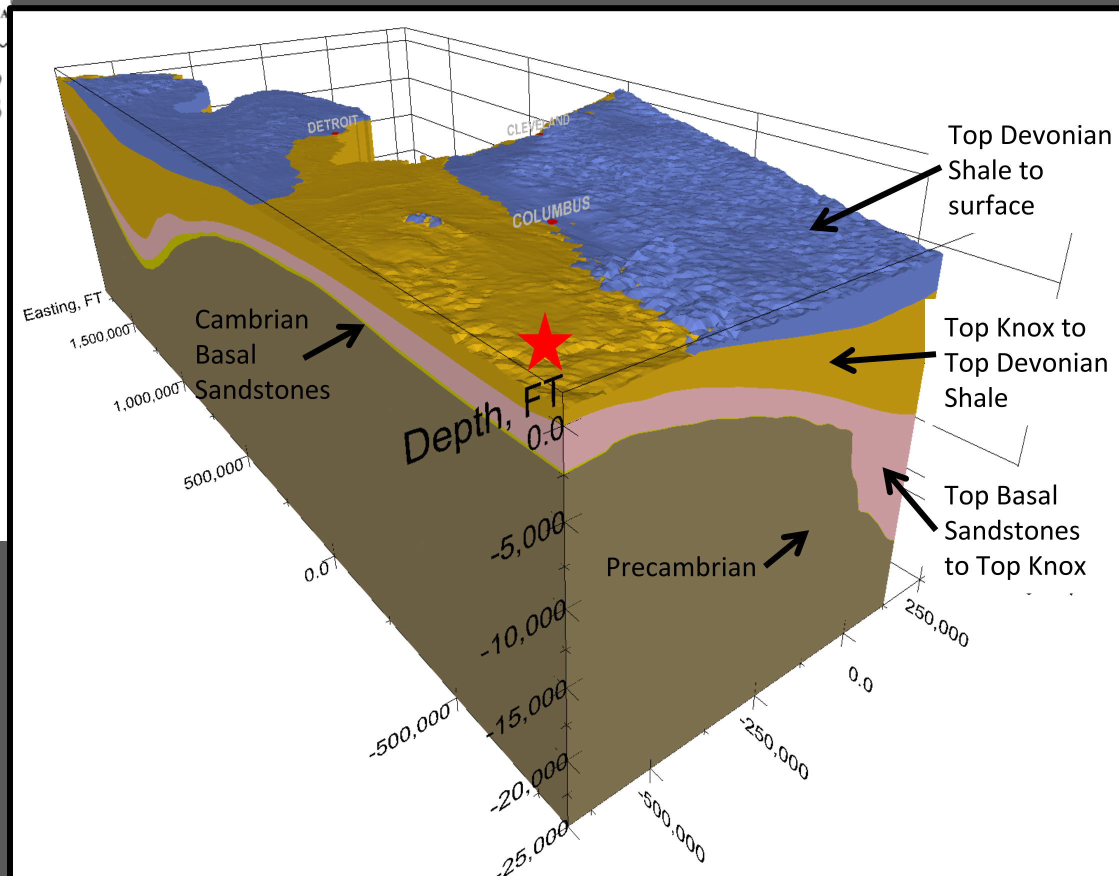
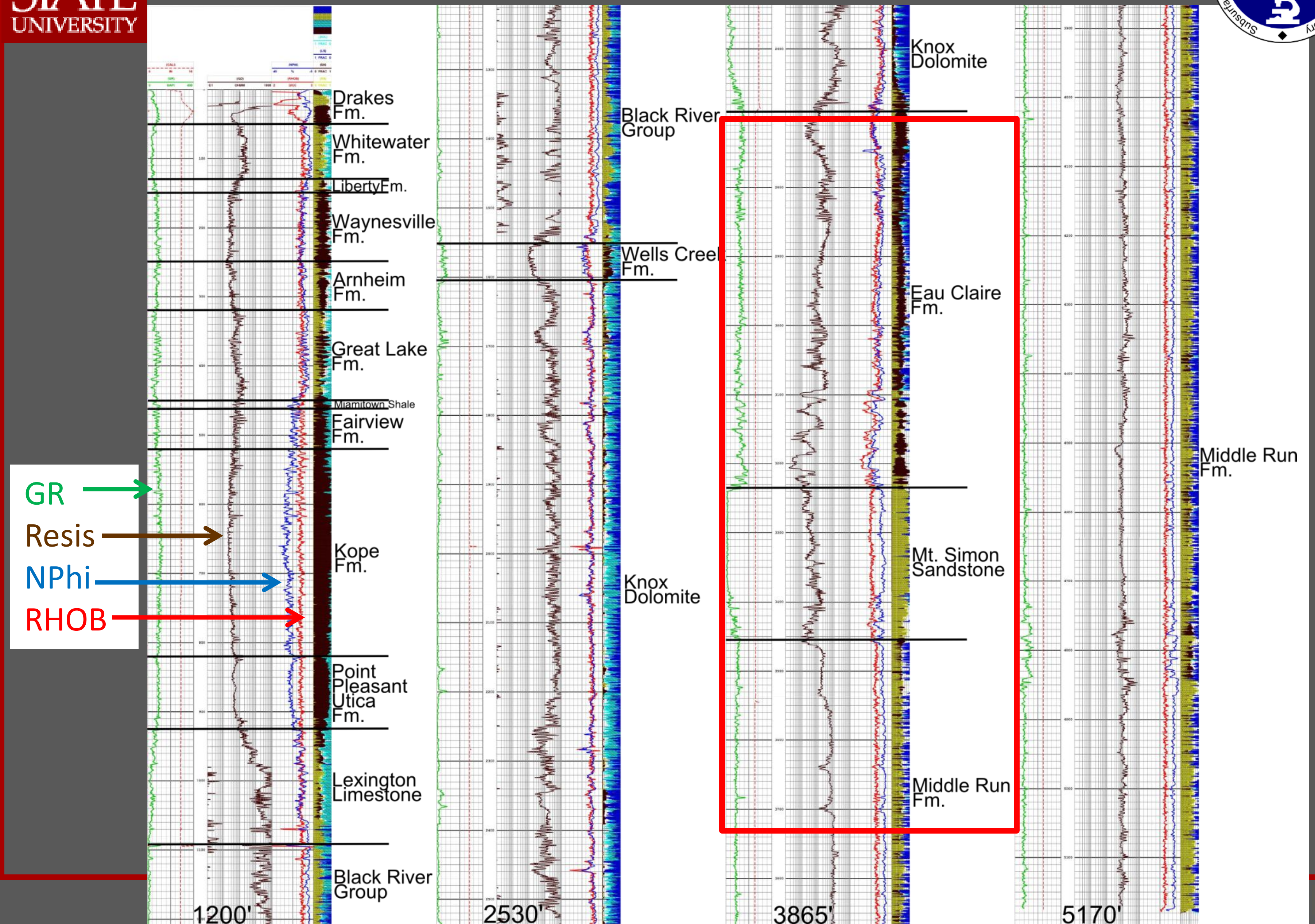
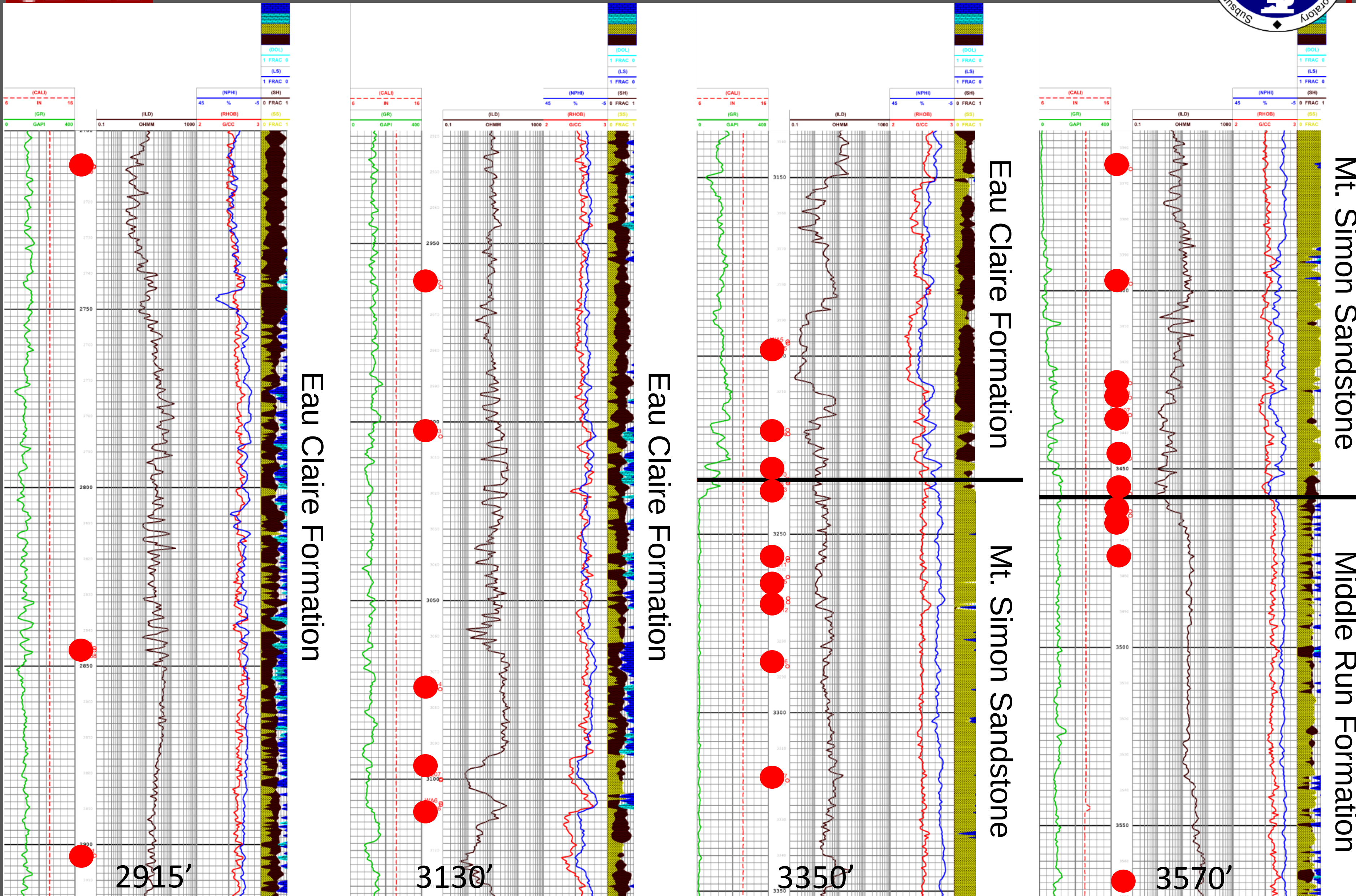
Test Case: Warren Co. 2627



Test Case: Warren Co. ODNR 262



Test Case: Warren Co. 2627



Physical Properties

Laboratory Data

						Porosity	Permeability mD		
	Sample ID	Depth	Formation	Lithology	Core Size	Hg Por	Probe Perm H	Probe Perm V	Hg Perm
26	WA3-6	3287.3	Mt. Simon	sandstone	Quarter	8.4	23.0	74.3	14.1
27	WA3-7	3319	Mt. Simon	sandstone	Quarter	4.4	108	1.60	5.7
28	WA3-8	3366	Mt. Simon	sandstone	Quarter	9.5	0.39	0.05	16.8
29	WA3-9	3398	Mt. Simon	sandstone	Quarter	2.5	X	0.02	6.8
30	wa109	3426.35	Mt. Simon	sandstone	Quarter	13.3	3.14	1.91	8.7
31	wa108	3430.4	Mt. Simon	sandstone	Quarter	5.0	0.08	0.29	13.0
32	wa107	3435.8	Mt. Simon	sandstone	Quarter	4.7	0.13	X	9.0
33	wa106	3447.4	Mt. Simon	sandstone	Quarter	15.4	1.81	X	0.1
34	wa105	3457.8	Middle Run	sandstone/gran. cong.	Quarter	5.1	0.30	X	21.0

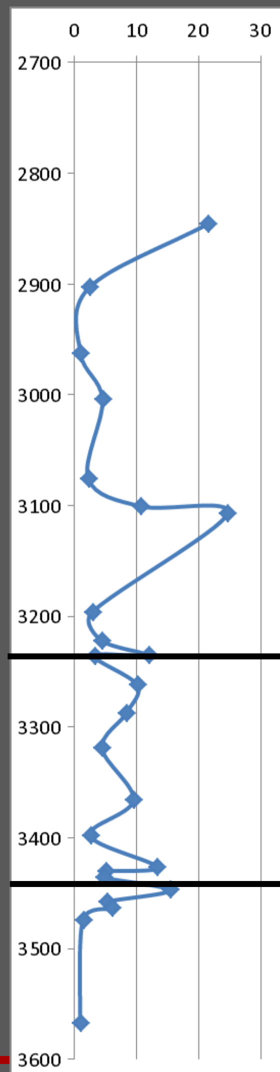
Mercury Porosimeter

Probe Permeameter

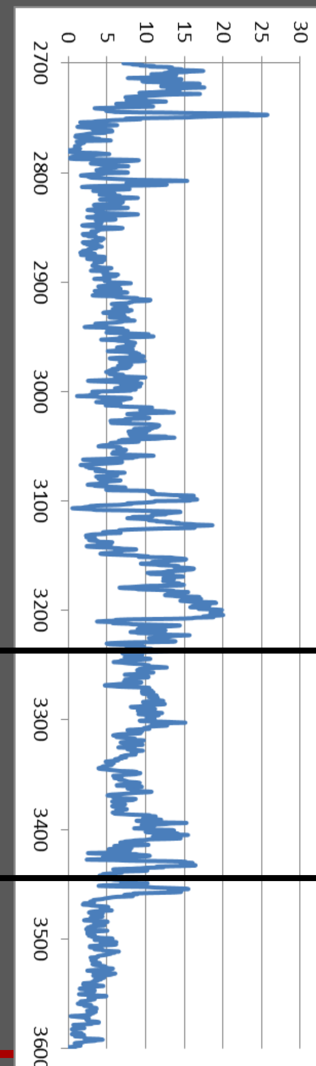
Mike Murphy
Nick Leeper
Matt Hawrylak
Brad Hull

Physical Properties

Mercury Porosimeter
% Porosity



Corrected Neutron
Log Porosity



Eau Claire
Formation

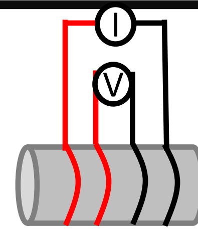
Mt. Simon
Sandstone

Middle Run
Formation

Electrical Property Measurements

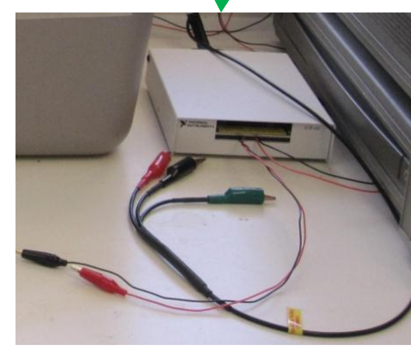
4-electrode resistivity technique

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

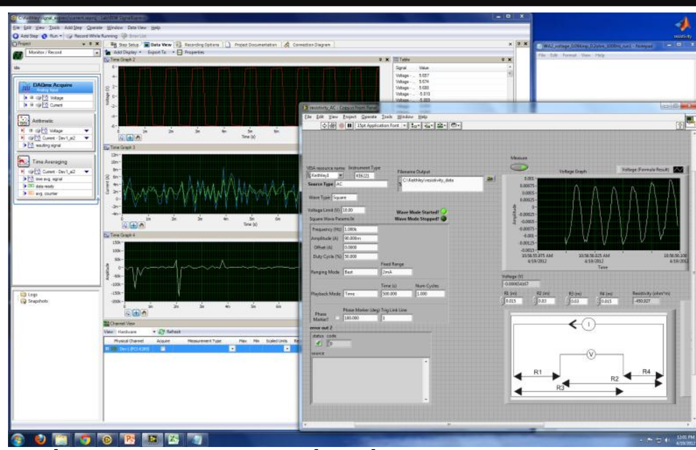


4 platinum ring electrodes attached to the core

Constant current source Keithley 6221



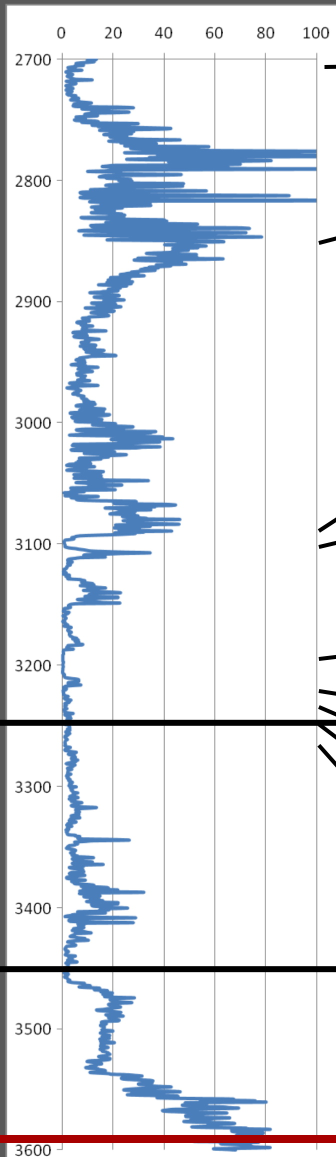
PCI-6289 card with SCB-68 box Voltmeter



LabView controls the measurements and calculates the resistivity

Electrical Property Measurements

Log Resistivity



Eau Claire Formation

Mt. Simon Sandstone

Middle Run Formation

Core Resistivity

Depth	Unit	Lithology	Resistivity (ohmm)
2710.1	Eau Claire	Mudstone	22.0
2845.75	Eau Claire	Siltstone	23.8
3100.7	Eau Claire	Siltstone	23.5
3107.7	Eau Claire	Sandstone	10.0
3196.2	Eau Claire	Sandstone	5.9
3221.95	Eau Claire	Mudstone	21.8
3235.8	Eau Claire	Siltstone	10.9
3257.4	Mt. Simon	Sandstone	11.5
3269.45	Mt. Simon	Sandstone	12.3

Electrical Property Measurements

Dielectric

Substance	K*
Quartz	4.5-4.7
Calcite	7-8
Shale	13-15
Clay	10
Water	81
Sandstone	4.5
Saturated Sandstone	~10-40

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

Complex Refractive Index Method (CRIM):

$$K^* = K' - iK''$$

$$\sqrt{K^*} = \sum_i V_i \sqrt{K_i}^*$$

$$\sqrt{K^*} = [1 - \Phi_t(1 - S_w^0)]\sqrt{K'_{wr}} + (S_w - S_w^0)\Phi_t\sqrt{K^*_{bw}}$$

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

$K_a^* =$ Permittivity wetted rock

$K'_{wr} =$ Permittivity wetted rock

$K^*_{bw} = K_s^* =$ Permittivity water

$\Phi =$ Total porosity

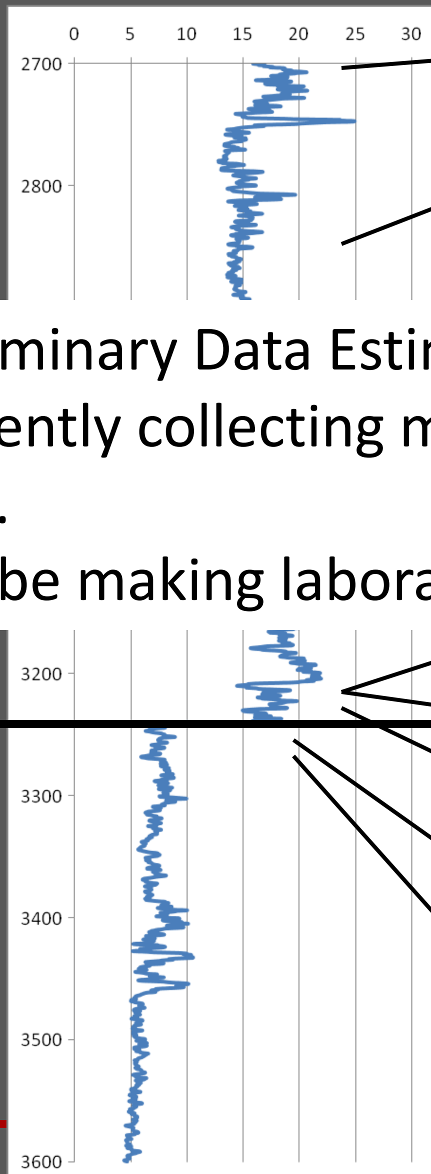
$S_w =$ Water saturation

$S_w{}^0 =$ Critical Saturation point

R. Knight, A. Endres, A New Concept in Modeling the Dielectric Response of Sandstones: Defining a Wetted Rock Bulk Water System, Geophysics, Vol. 55, No. 5 (May 1991)

Electrical Property Measurements

Log Calculated Dielectric



Eau Cl
Forma

Mt. Simon
Sandstone

Core Resistivity

Depth	Unit	Lithology	Dielectric
2710.1	Eau Claire	Mudstone	17.1
2845.75	Eau Claire	Siltstone	20.6
3100.7	Eau Claire	Siltstone	15.4
3221.95	Eau Claire	Mudstone	16.8
3235.8	Eau Claire	Siltstone	12.3
3257.4	Mt. Simon	Sandstone	7.9
3269.45	Mt. Simon	Sandstone	7.9

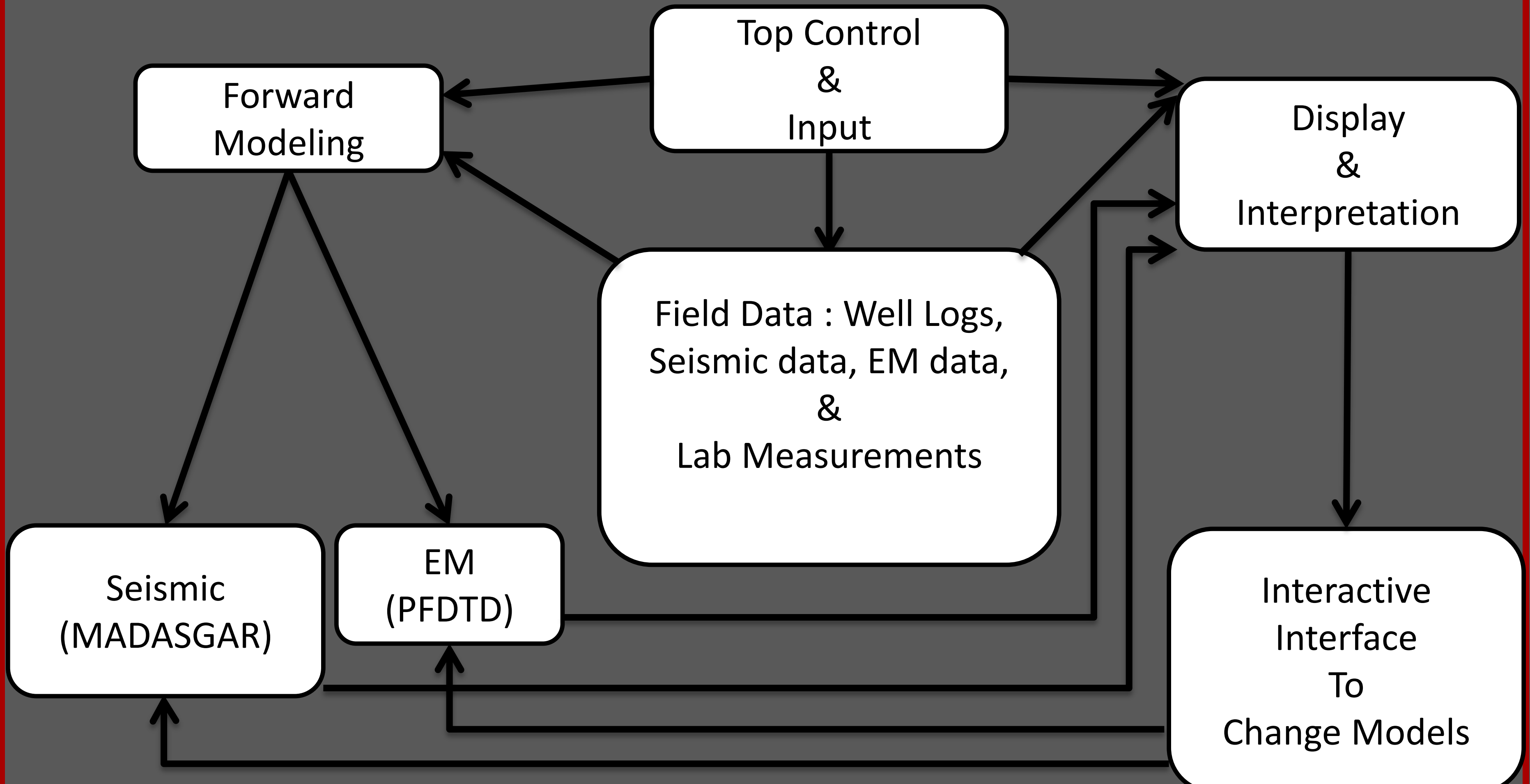
Preliminary Data Estimation:

Presently collecting more dielectric data on the brine and core.

Will be making laboratory dielectric measurements

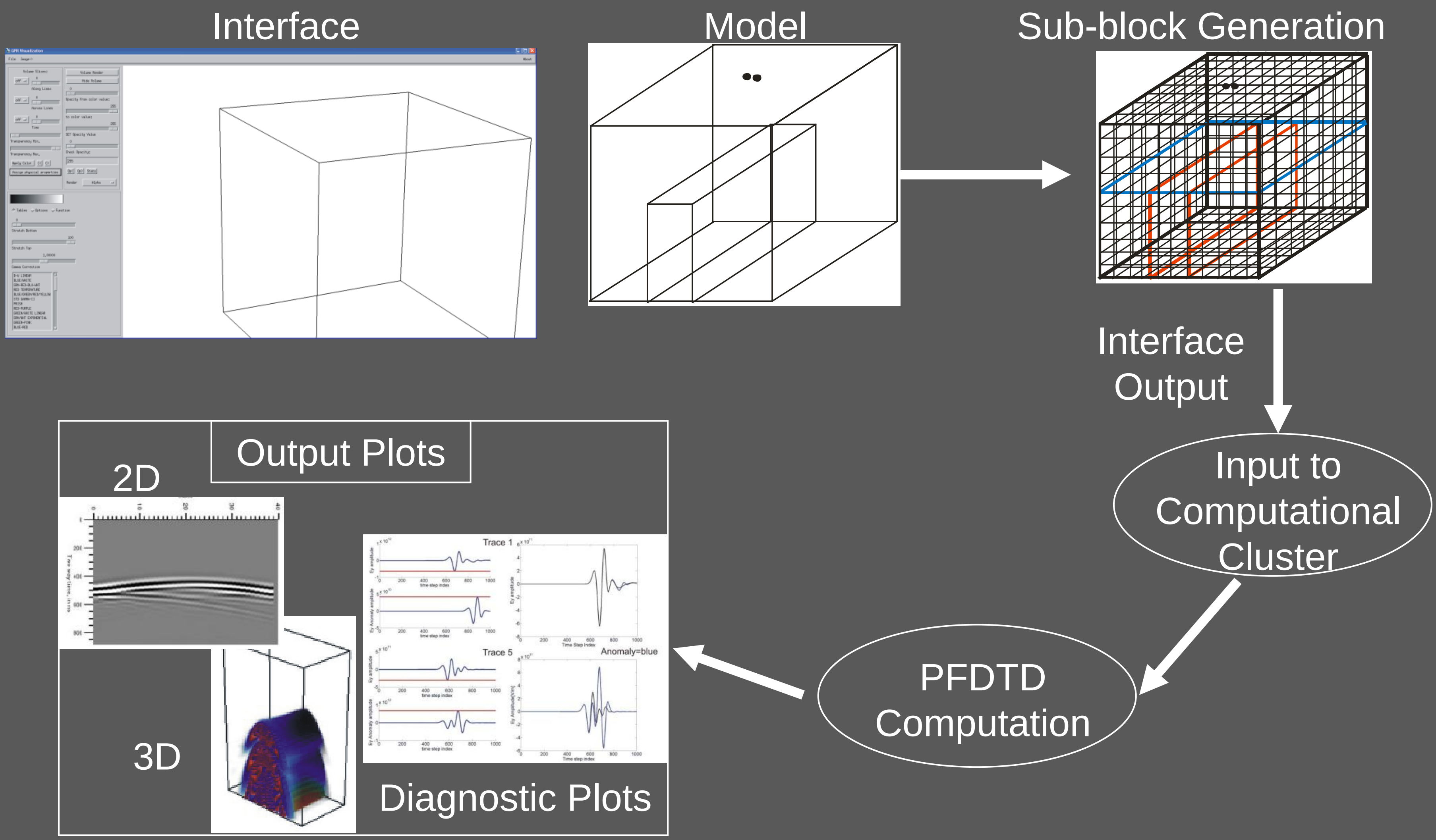
Software Development

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



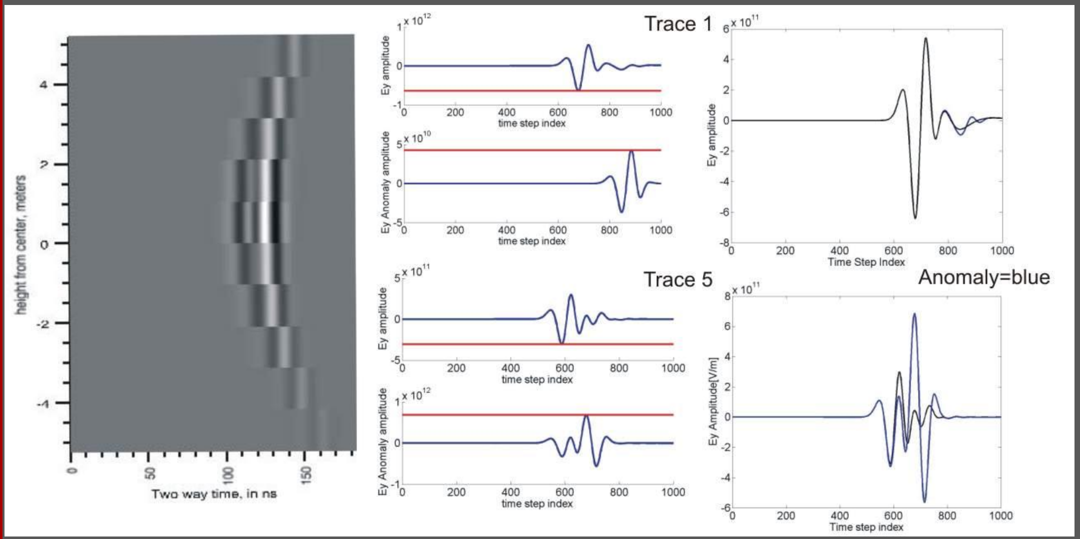
Software Development

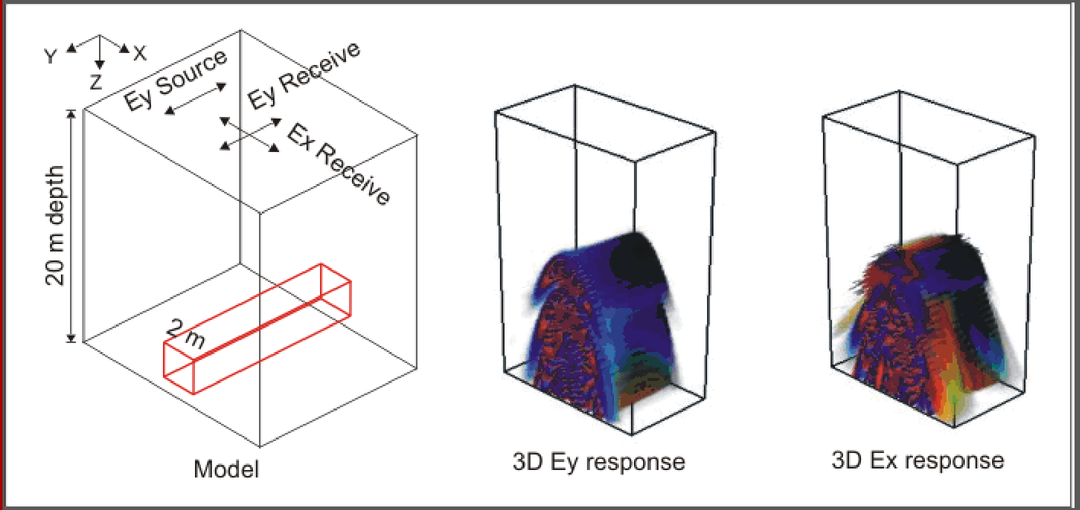
Electromagnetic Modeling



Software Development

Electromagnetic Modeling





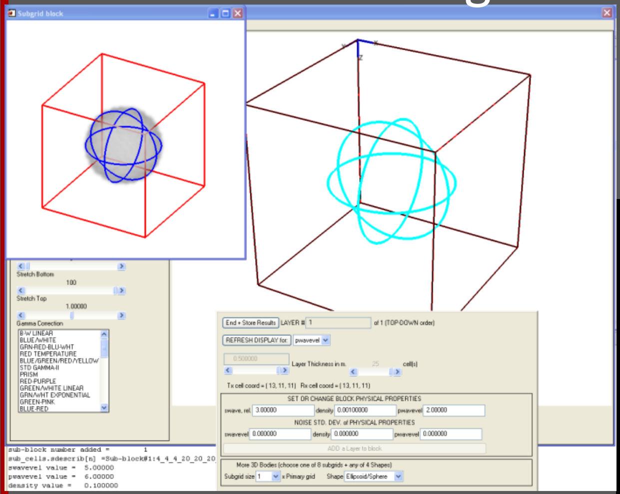
Utilize the data collected from the well logs and core samples to numerically model Ohio's potential carbon sequestration formations.

Model various borehole geometries and conditions to determine effectiveness of Electromagnetic Monitoring of a CO_2 injection

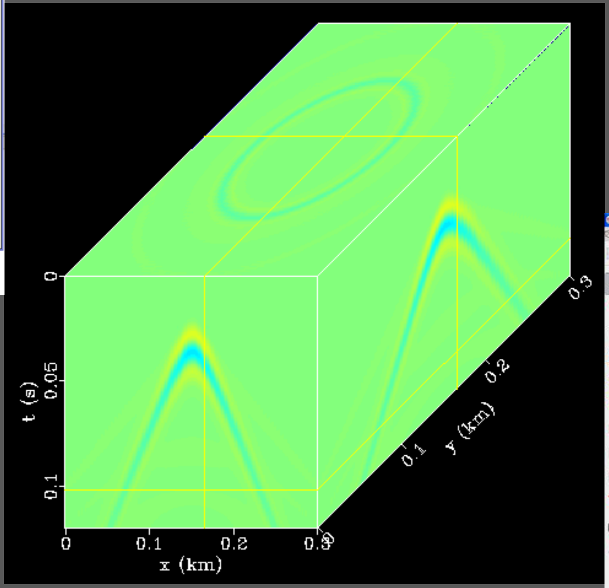
Software Development

Seismic Modeling

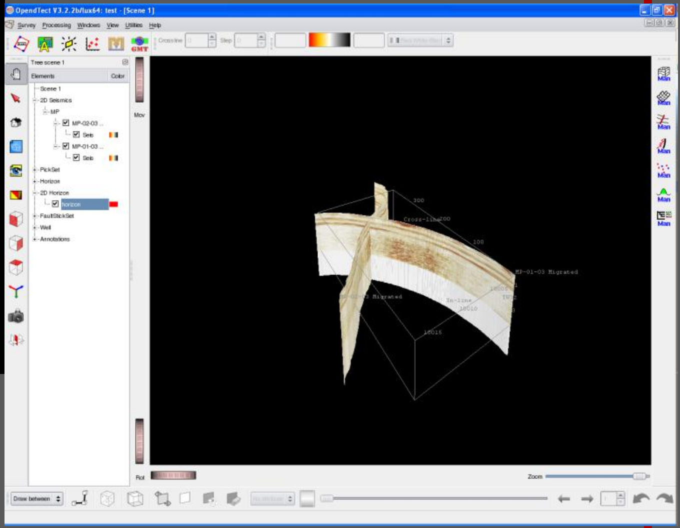
Interface:
Model Building



Madagascar Forward Modeling

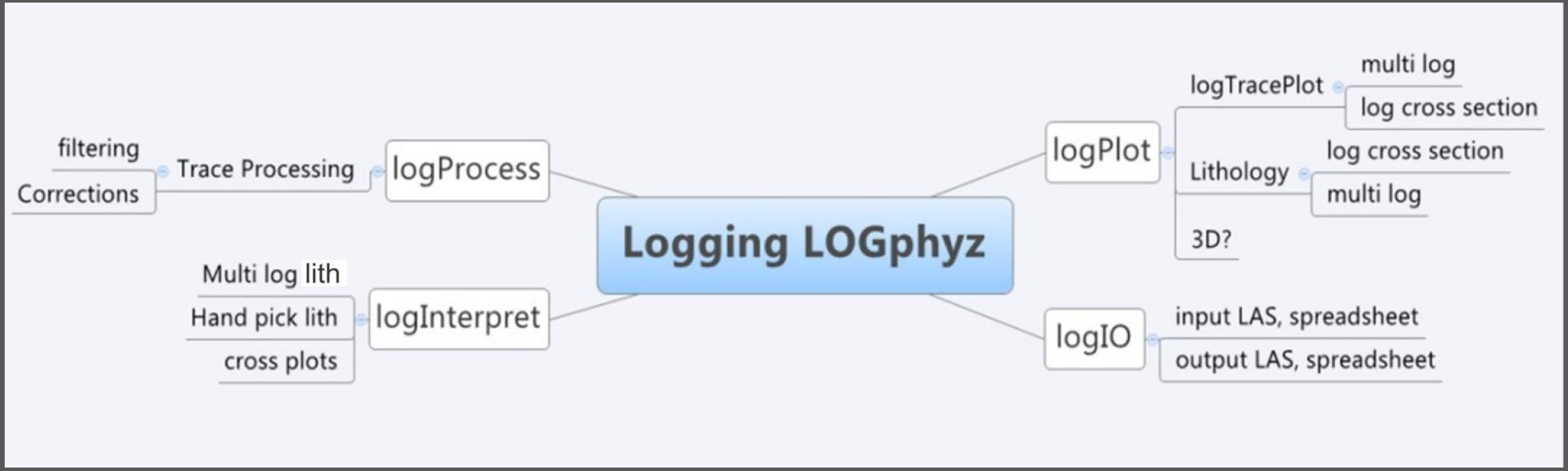


OpendTect Processing, Imaging, and Interpretation



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?

<u>Acknowledgments</u>