Geomechanical Framework for Secure CO_2 Storage in Fractured Reservoirs and Caprocks for Sedimentary Basins in the Midwest U.S.

DE-FE0023330

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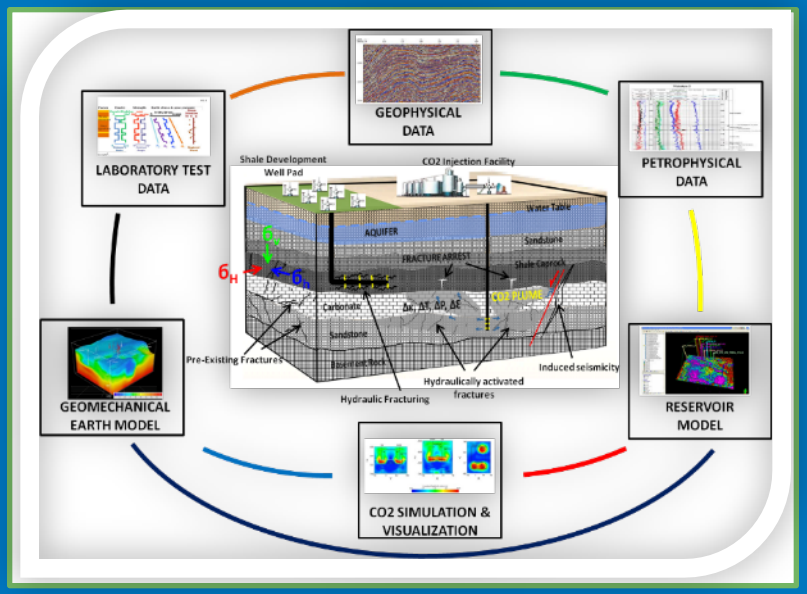

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Transforming Technology through Integration and Collaboration
August 18-20, 2015

Ohio Development Services Agency

U.S. DOE/NETL

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Outline

1. Benefit to Program
2. Project Overview
3. Technical Status
4. Accomplishments to Date
5. Synergy Opportunities
6. Summary

- Appendix Material

Lockport Dolomite, National Lime & Stone Company, Lima, Ohio

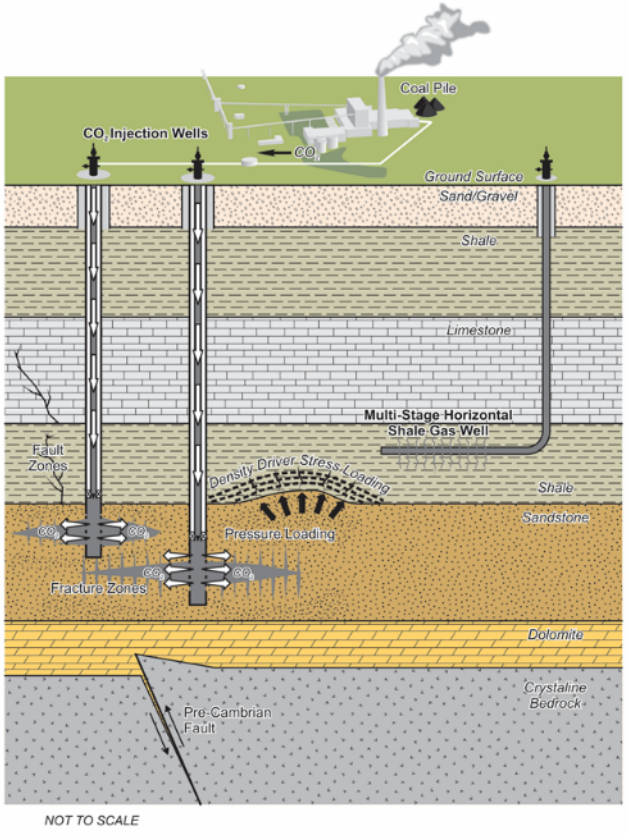
Acknowledgements

- The project was funded by the U.S. DOE / National Energy Technology Laboratory under their program on technologies to ensure permanent geologic carbon storage (Contract DE-FE0023330).
  Project Manager – William O'Dowd, NETL Sequestration Division.
- Co-funding provided by Ohio Development Services Agency Agreement Ohio Coal Development Office (Grant CDO-D-14-17).
- Project team includes Ola Babarinde, Jackie Gerst, Mark Kelley, Glen Larsen, Srikanta Mishra, Nat Voorhies, and many more.

U.S. DOE/NETL

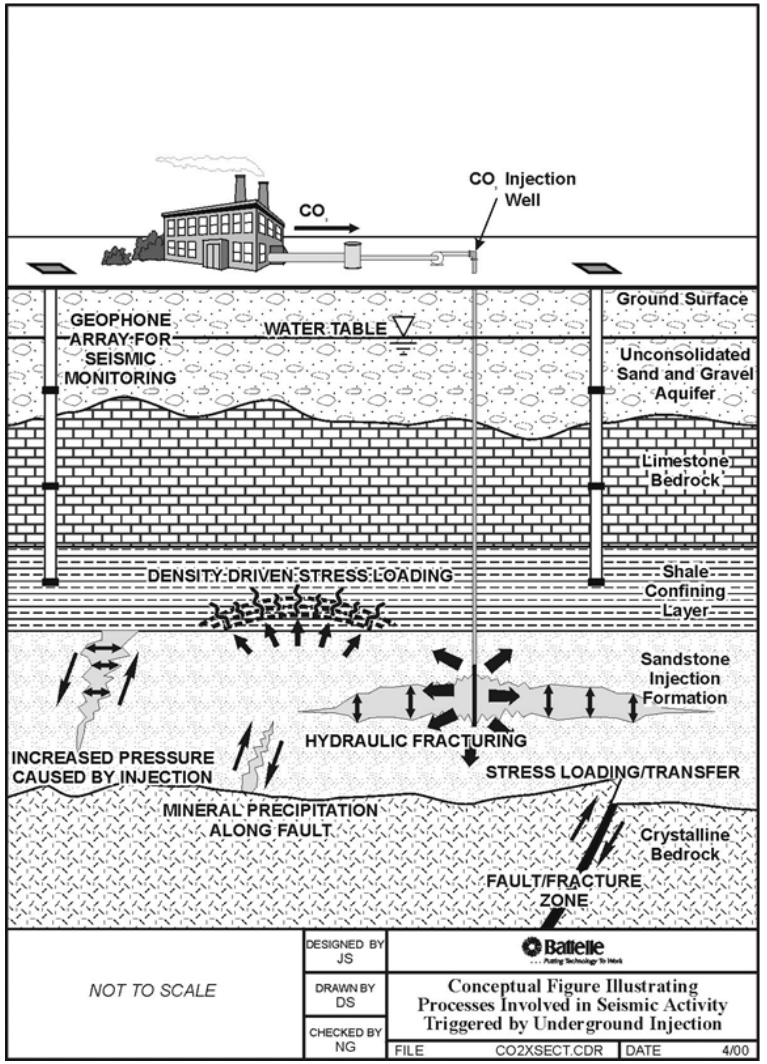
Benefit to Program

- The project addresses FOA 1037 Area of Interest 1-Geomechanical Research.
- Specifically, research impacts include:
  - characterizing the paleo-stress/strain setting in the Midwest U.S.,
  - defining geomechanical parameters,
  - evaluating the potential for (and effects of) subsurface deformation,
  - assessing CO_2 storage processes based on rock core tests and geophysical logging in the regions being considered for large-scale CO_2 storage.



Benefit to Program

- Geomechanical stability of rock formations has been identified as a major challenge to large-scale carbon capture and storage applications.
- Faults, fractures, seismic stability can affect CO_2 injection potential and storage security.

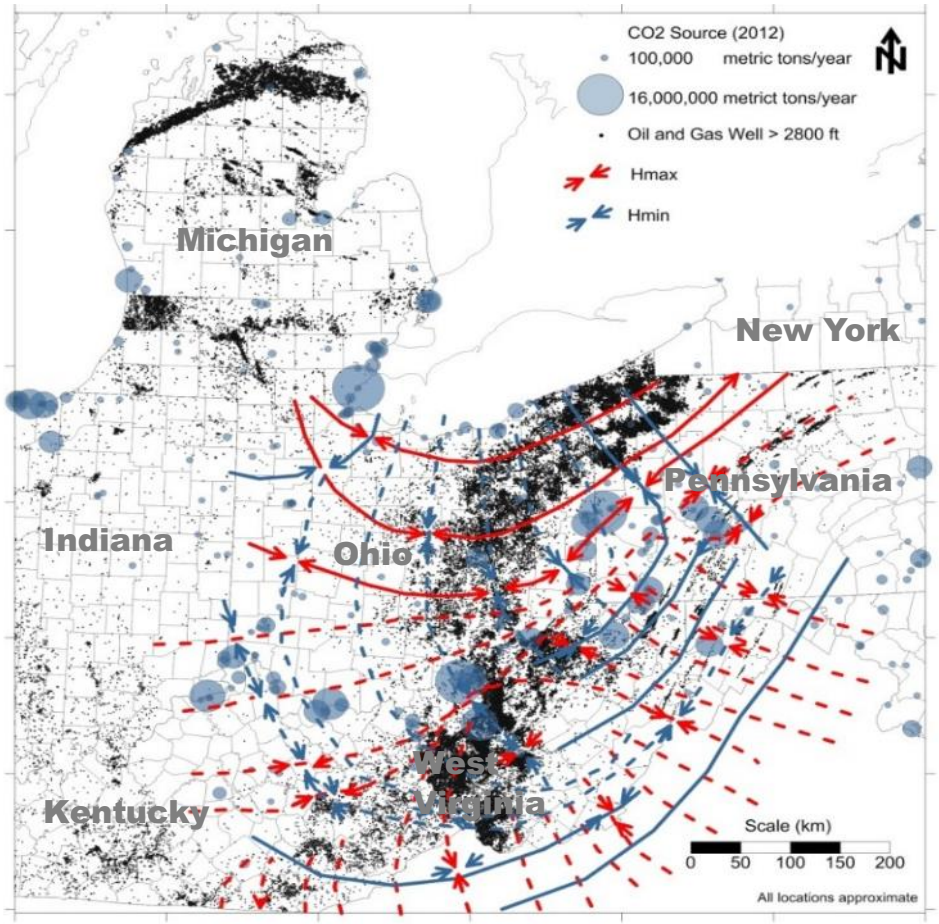


Sminchak, J.R., and Gupta, N. 2003. *Aspects of induced seismic activity and deep-well sequestration of carbon dioxide*. Environmental Geosciences, v. 10, n. 2, pp. 81-89.

Benefit to Program

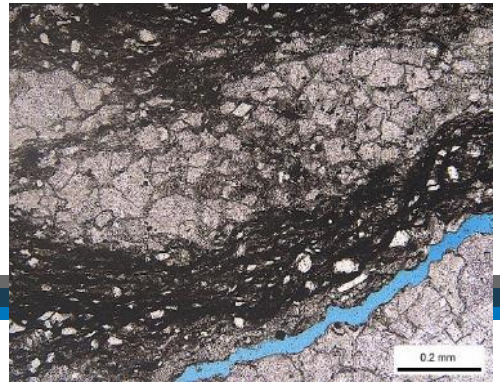
- Geomechanical processes are especially important in Appalachian Basin due to geologic structural setting and nature of deep rock formations.

Conceptual Geomechanical Stress-Strain Setting in Appalachian Basin In Relation to Large CO_2 Sources and Oil & Gas Wells



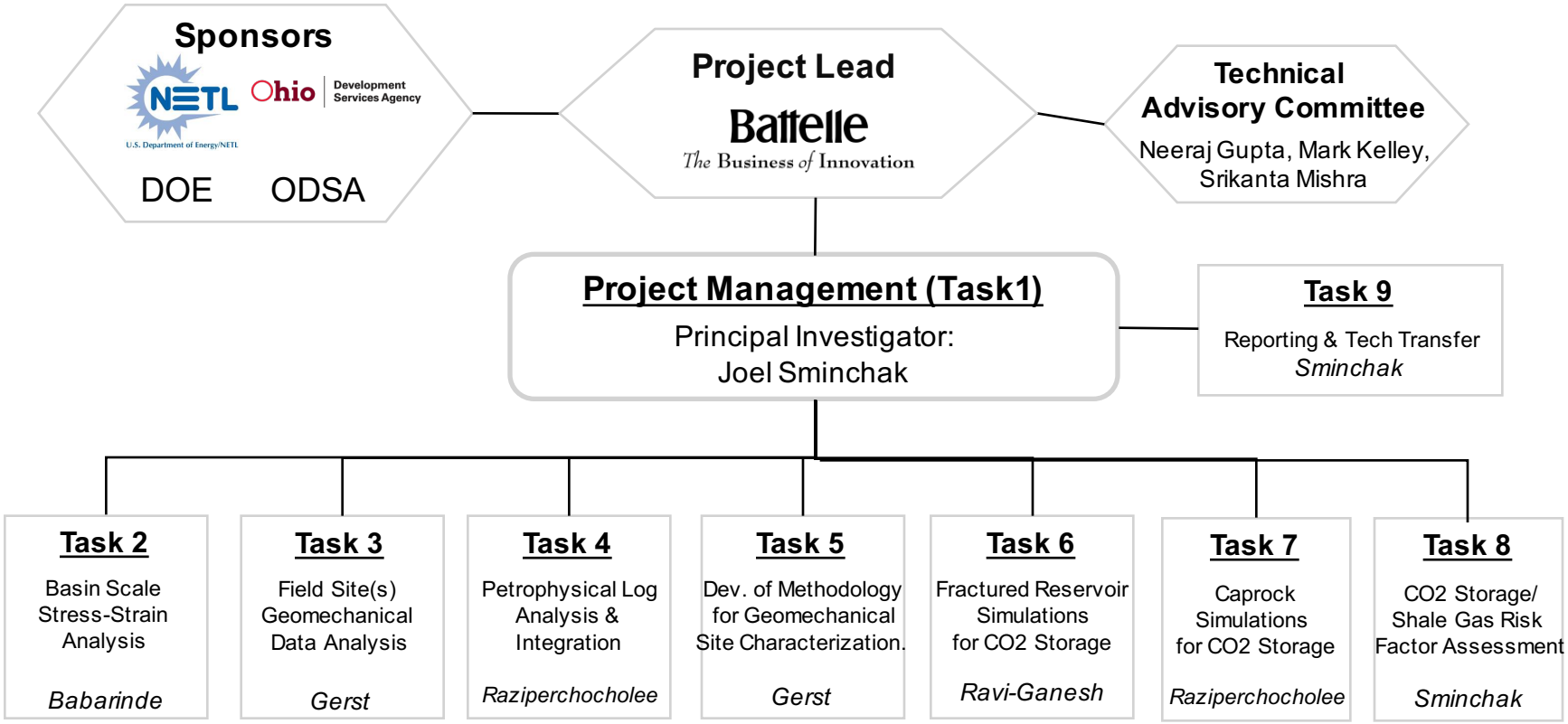
Benefit to Program

- This work was designed to perform realistic analysis of geomechanical risk factors related to CO_2 storage:
  - Which reservoir rock formations are more fractured in the region?
  - Which caprocks have larger risk factors related to fracturing?
  - What are the key methods and tools for evaluating fractured zones in deep layers?
  - How can these methods be safely and cost effectively employed?
  - How can we better understand basin-scale stress-strain regime to more accurately define stress magnitude at depth?



Project Overview

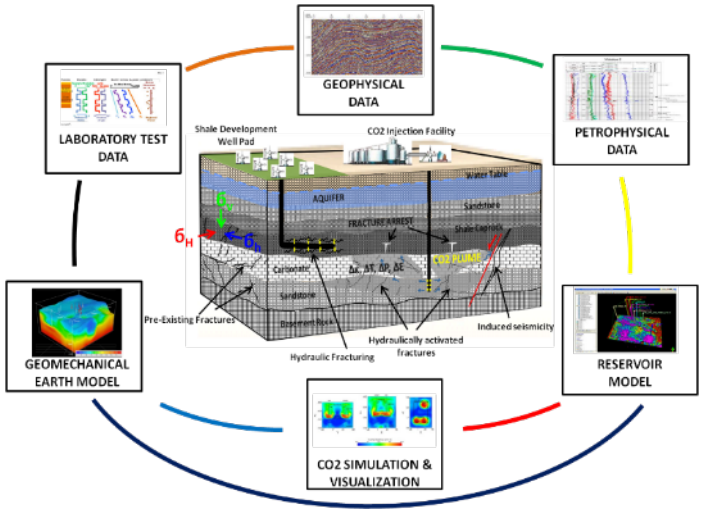
- 3 year project from October 2014-September 2017.
- Project is divided into seven main technical tasks.

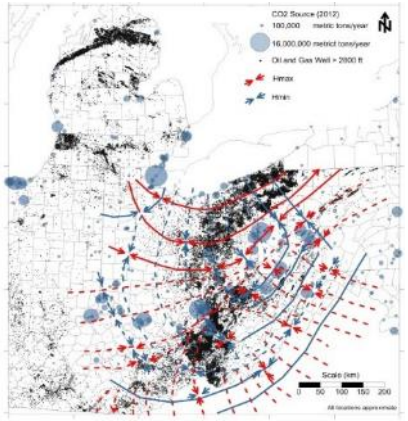


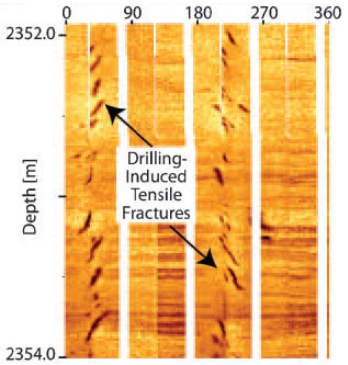
Project Overview: Objectives

Objectives

- Characterize fractured reservoirs stress/strain setting in Appalachian Basin region.
- Assess CO_2 storage processes based on rock core tests and geophysical logging.
- Evaluate the potential and effects of subsurface geomechanical deformation.







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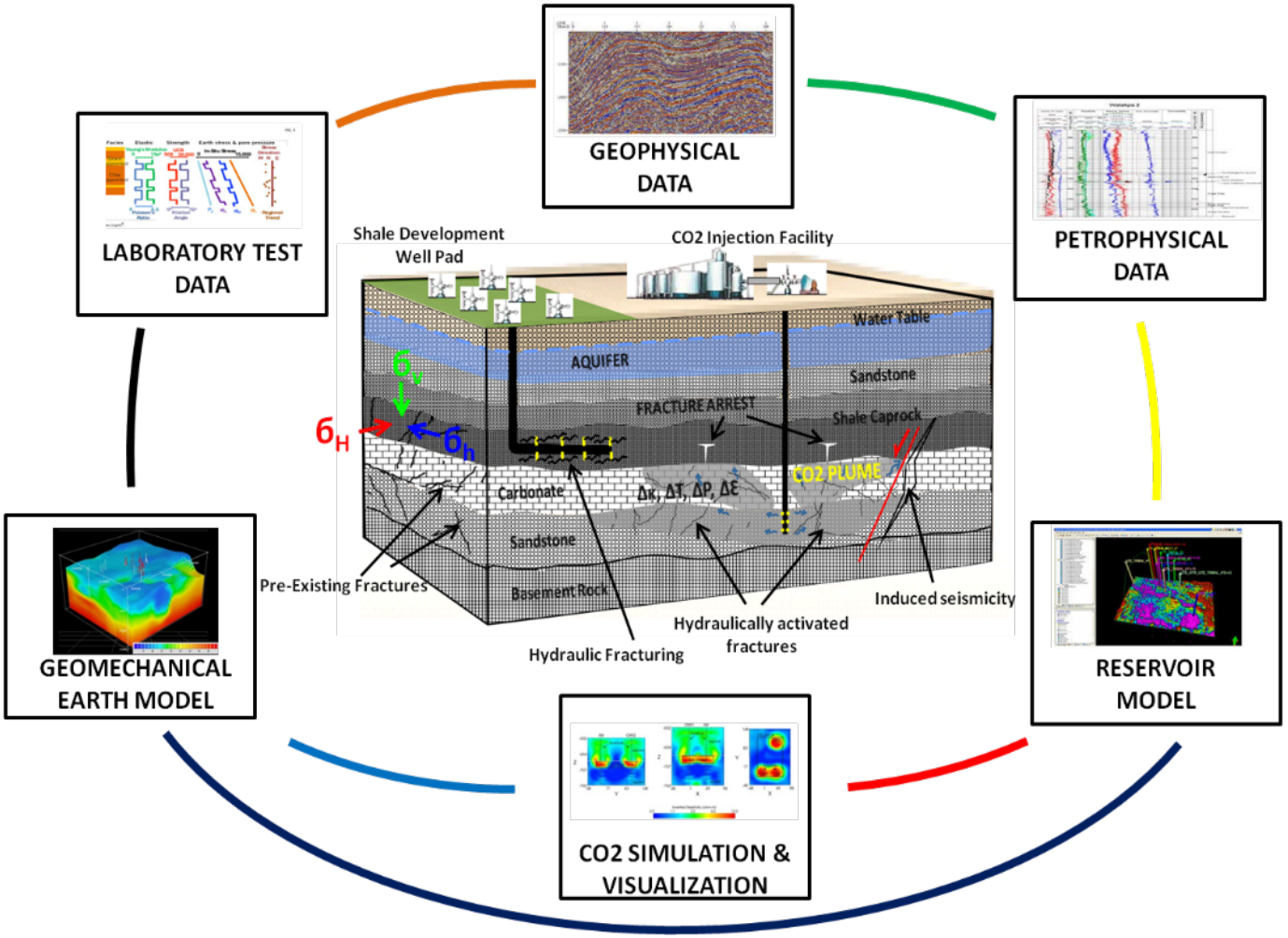
Project Overview: Objectives



Technical Status

2. **Systematic assessment of the stress-strain setting for geologic formations in the Appalachian Basin,**
3. **Compile geomechanical parameters & data analysis,**

Year 1

4. Petrophysical log analysis and integration,
5. Methodology for evaluating potential geomechanical stress at CO_2 storage sites,
6. Reservoir simulations to evaluate geomechanical deformation in geologic reservoirs in the region,

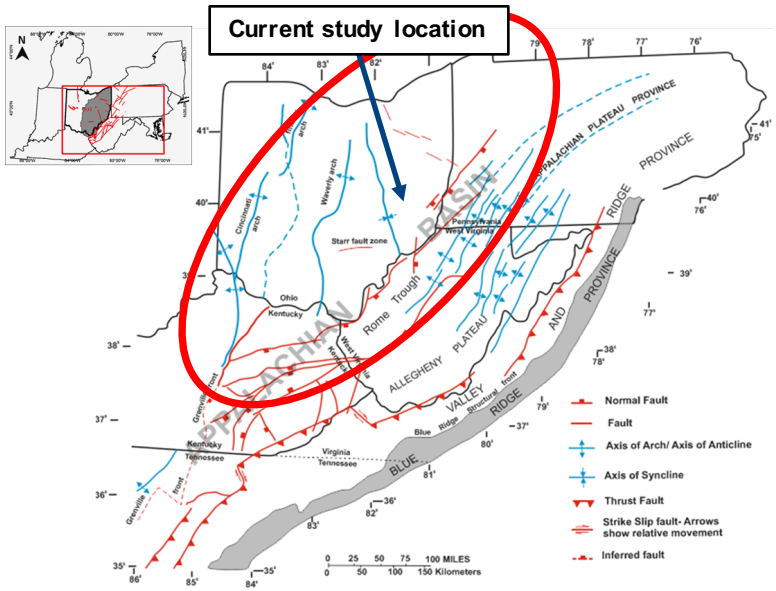
Year 2

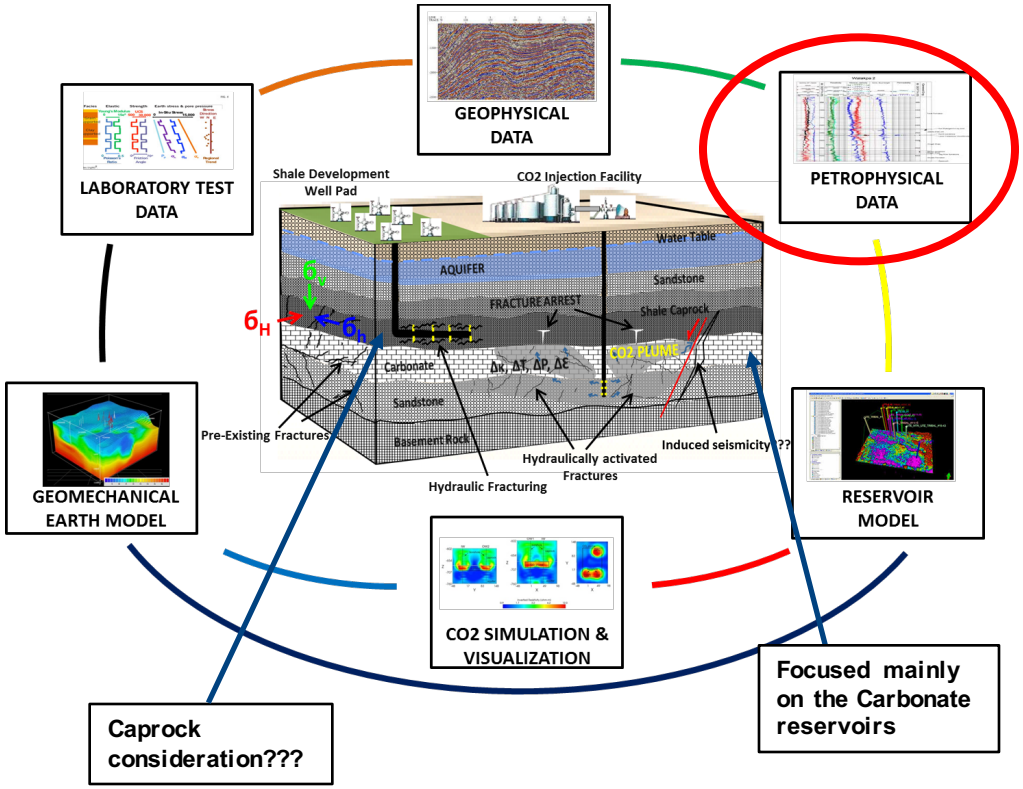
7. Caprock simulations, and
8. Assessment of CO_2 storage in areas with hydraulic fracturing for shale gas development.

Year 3

Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

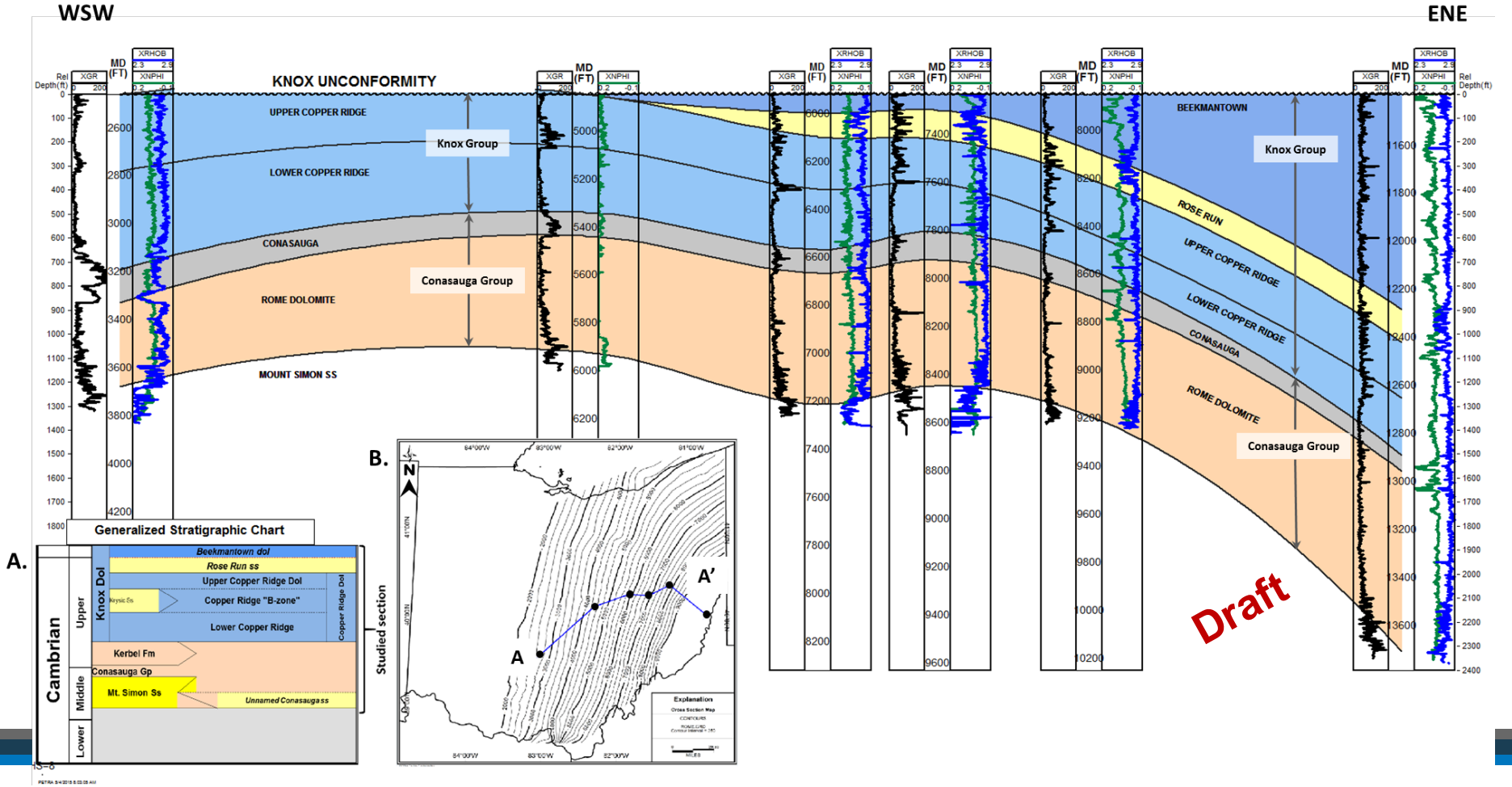
- So far most assessment has primarily been based off geophysical log data





Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- Ordovician-Cambrian geologic cross section across study area provides framework for analysis of geomechanics in region.



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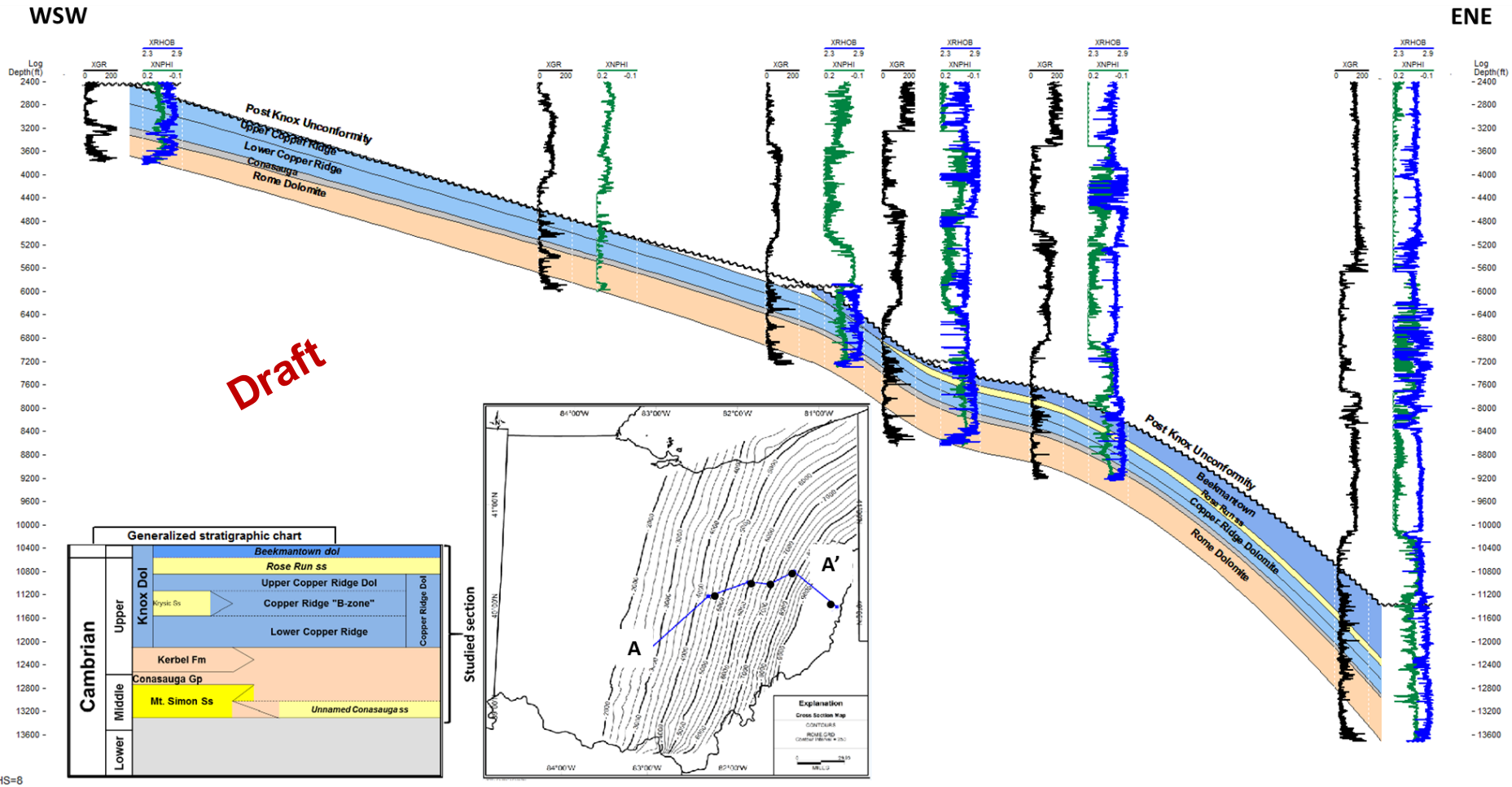
Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- Ordovician-Cambrian geologic cross section (true structure).



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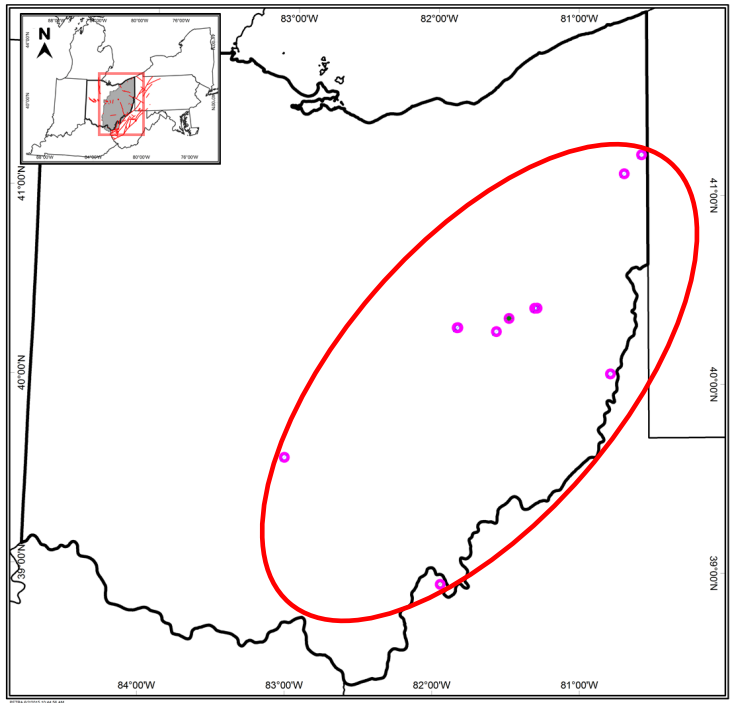
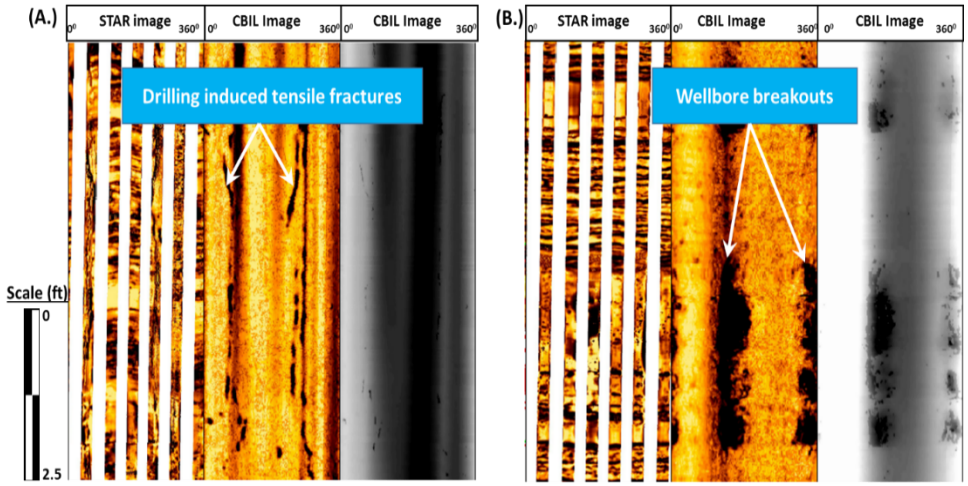
Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

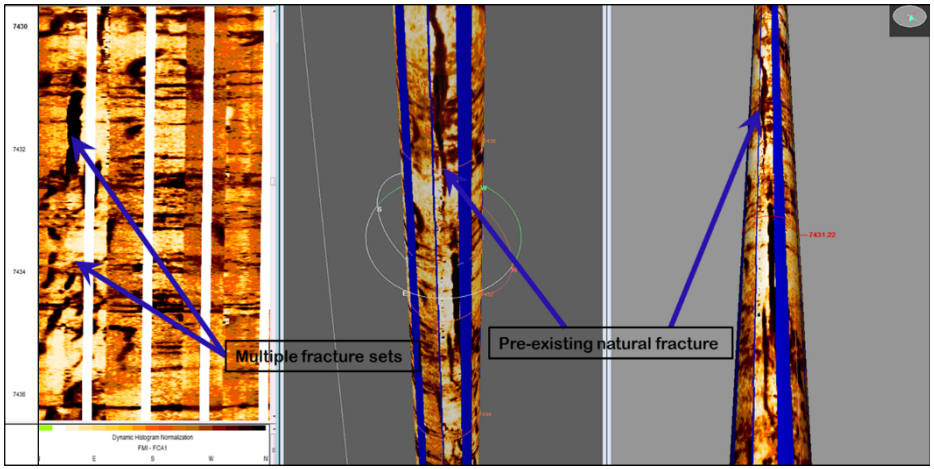
- Ten wells available with acoustic and resistivity image log data
- Same wells have cross-dipole acoustic log data
- Core data are currently been compiled for multiple locations for log Calibration



Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- 1,760 fractures/breakouts analyzed from geophysical image logs.
- Fractures were interpreted on acoustic and resistivity image log data:
  - Fracture intensity variation spatially
  - Studying predominant orientation of these fractures.





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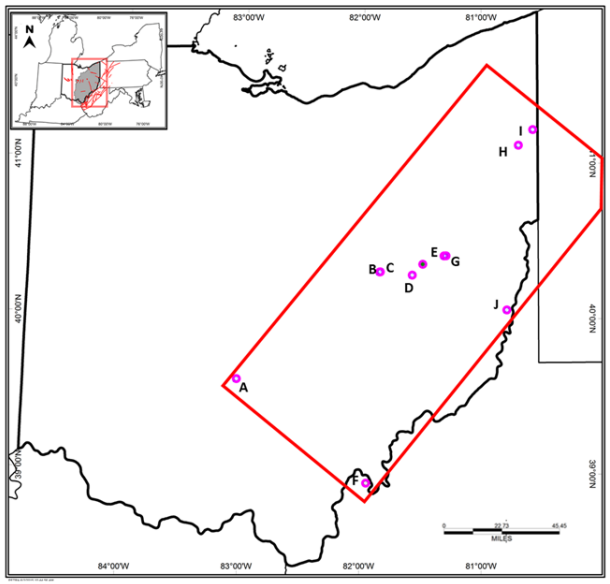
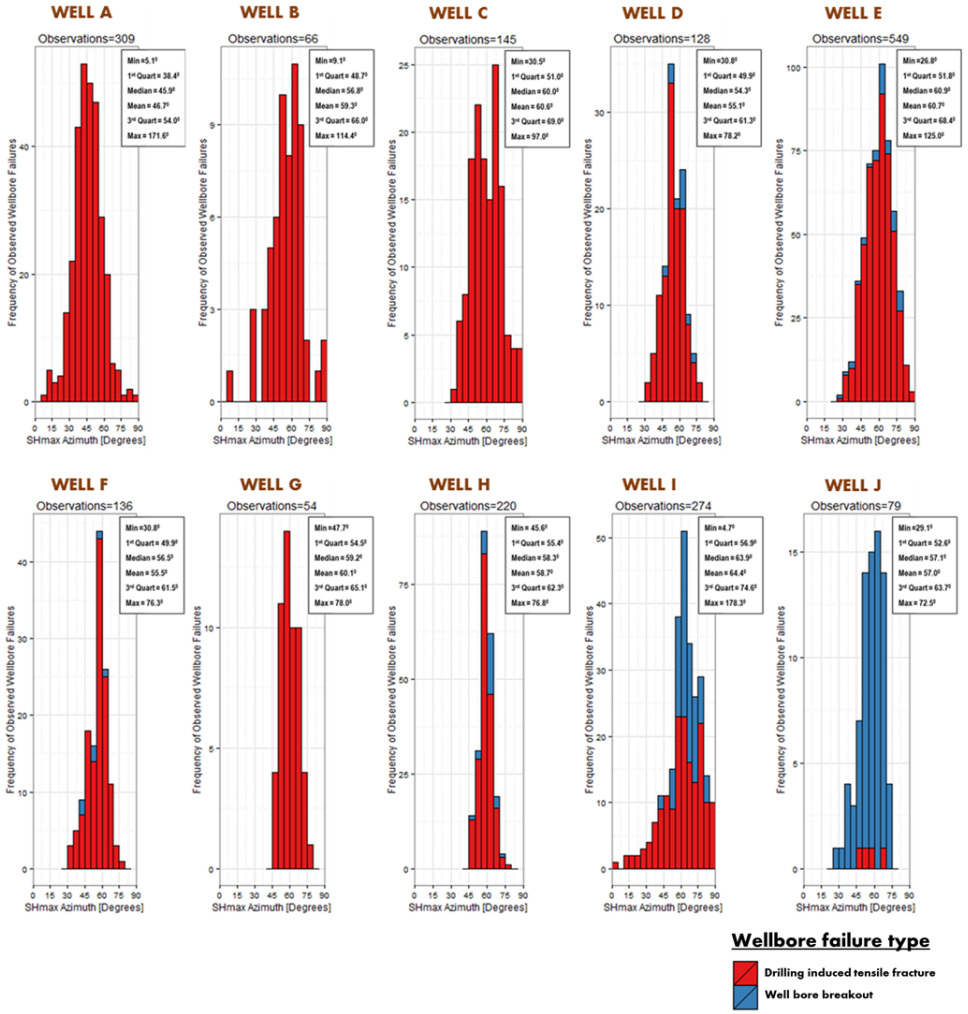
Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

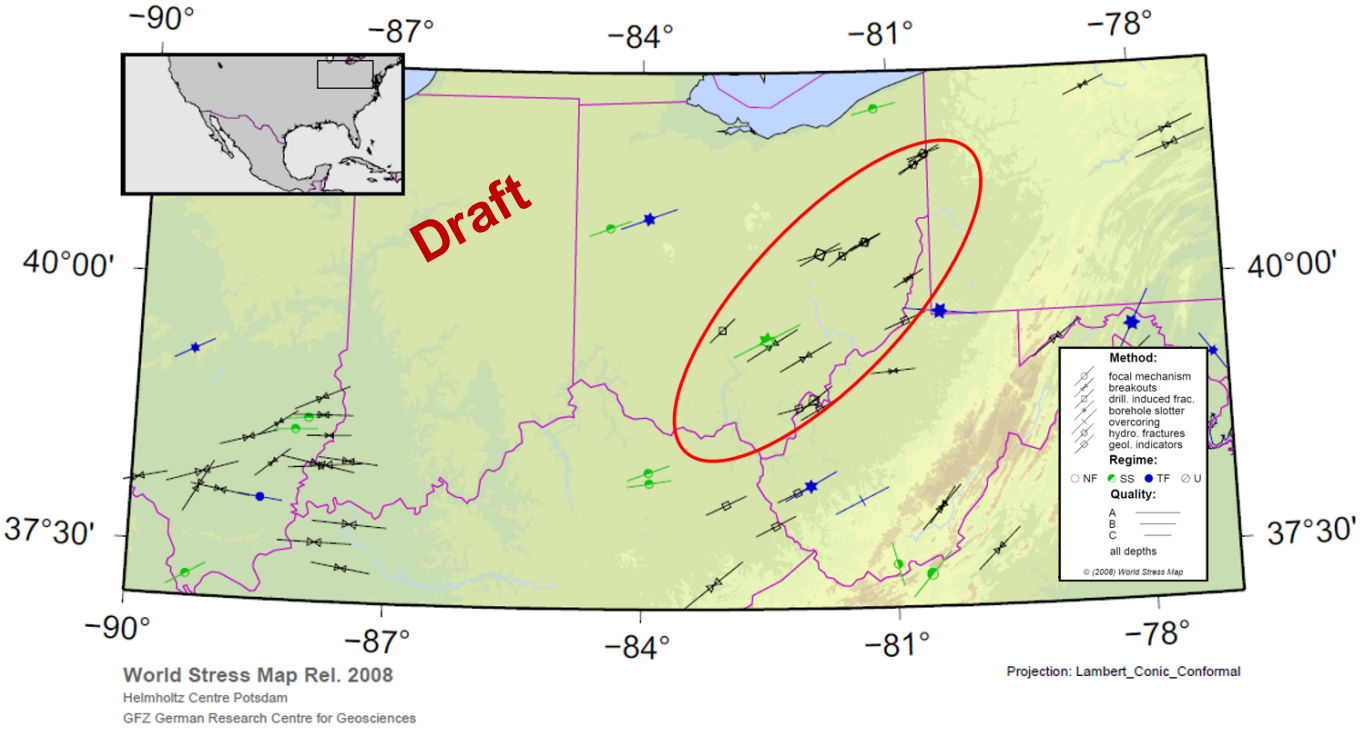




- Fracture orientation statistical results ranges between 45-64 degrees.

Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- Results from stress orientation determination was used in updating stress map of the region
- Results were consistent with pre-existing results in the region



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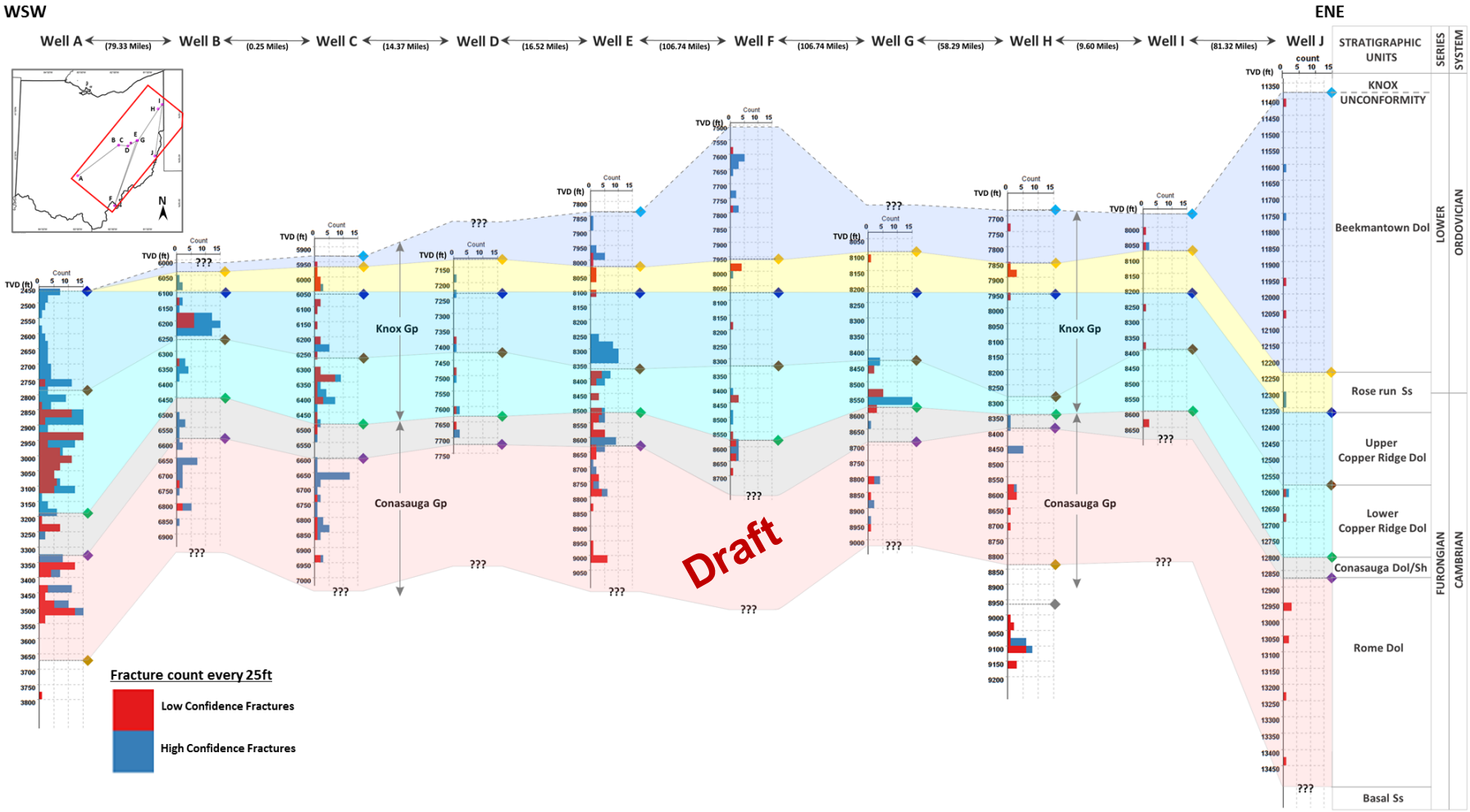
Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- Fracture analysis- fracture intensity cross sections.



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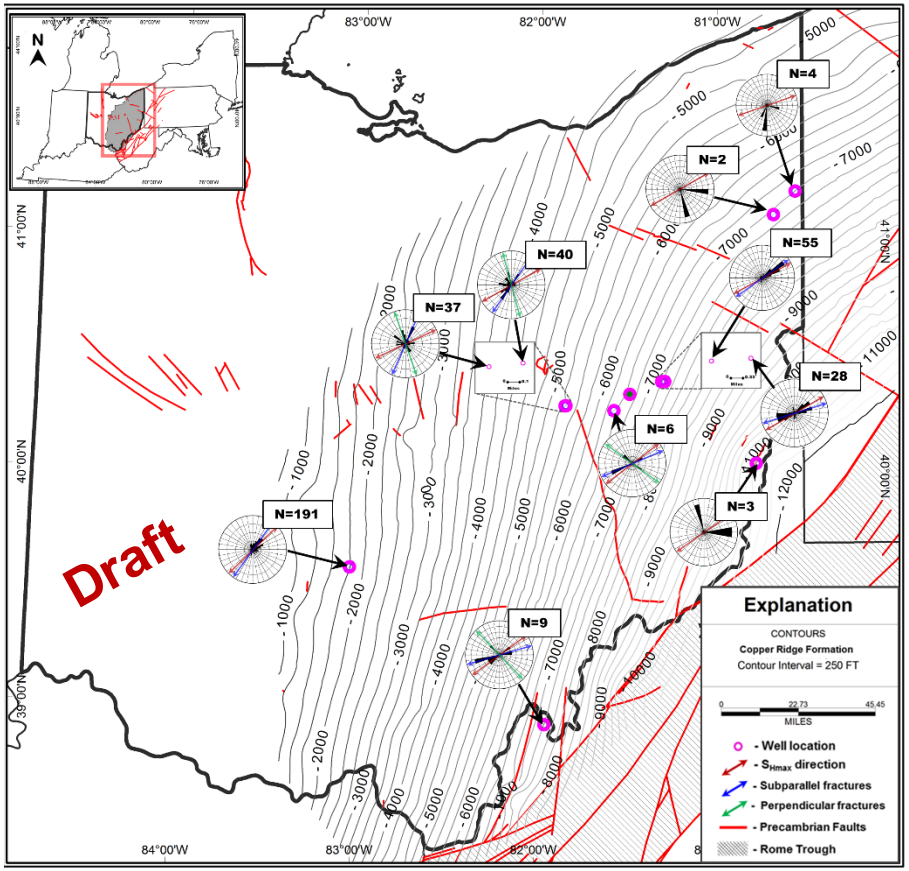
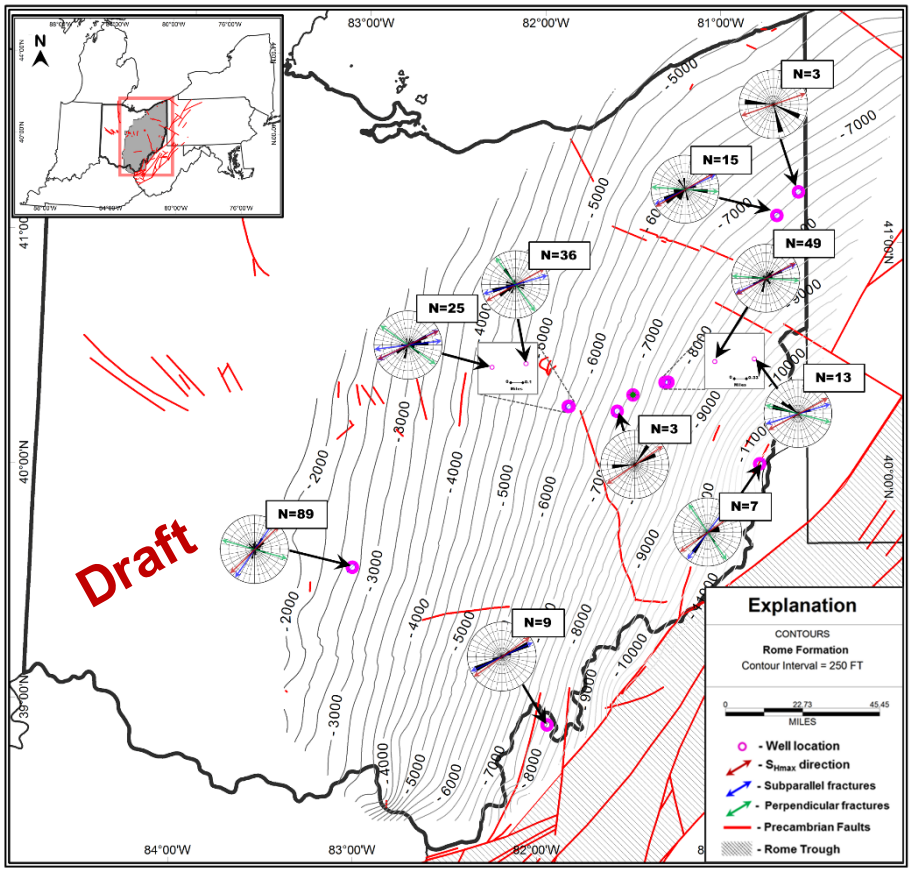
Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- Fracture analysis- fracture orientation maps.



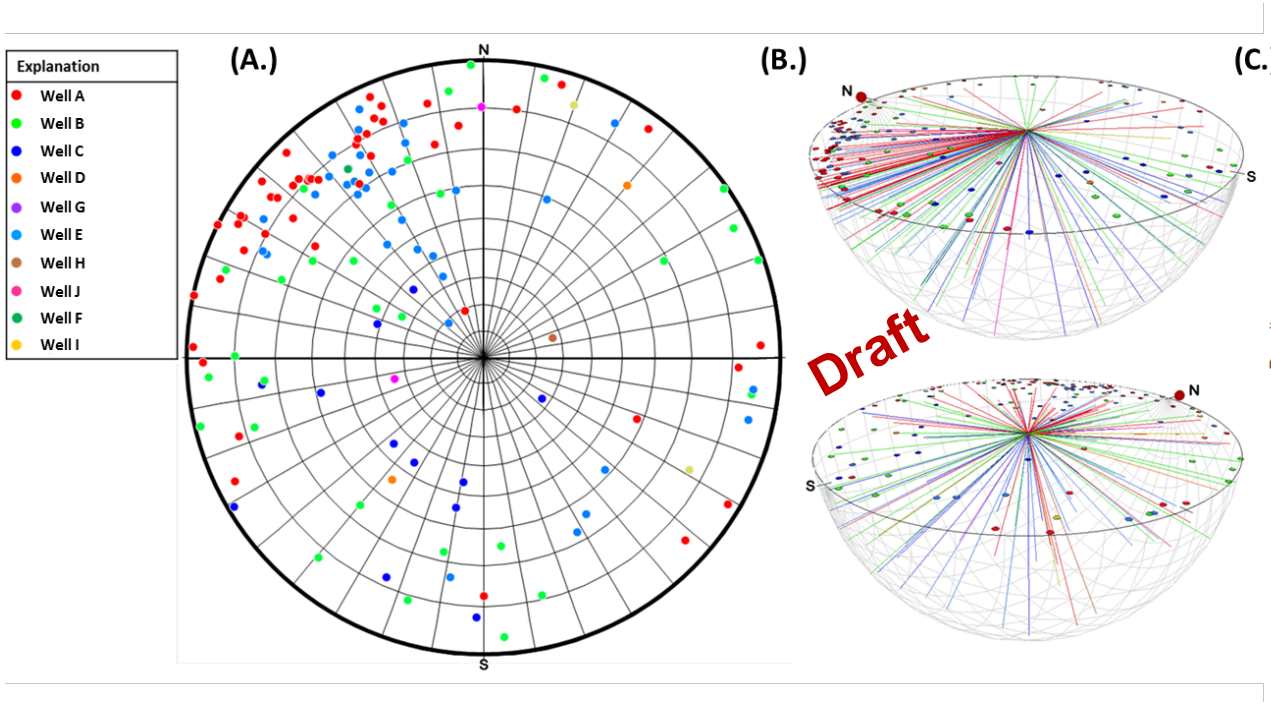
Knox Group



Conasauga Group

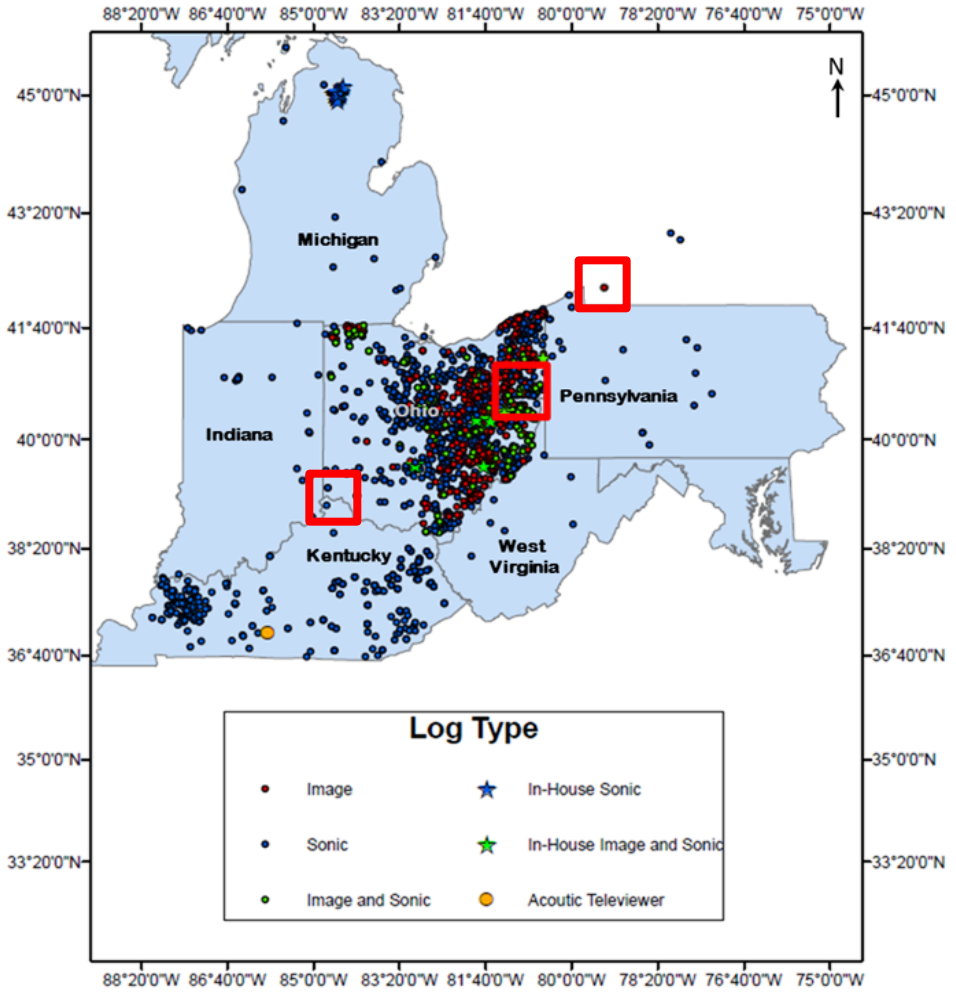
Accomplishments to Date
Task 2: Basin Scale Stress-Strain Analysis

- Fracture analysis- stereonet analysis.



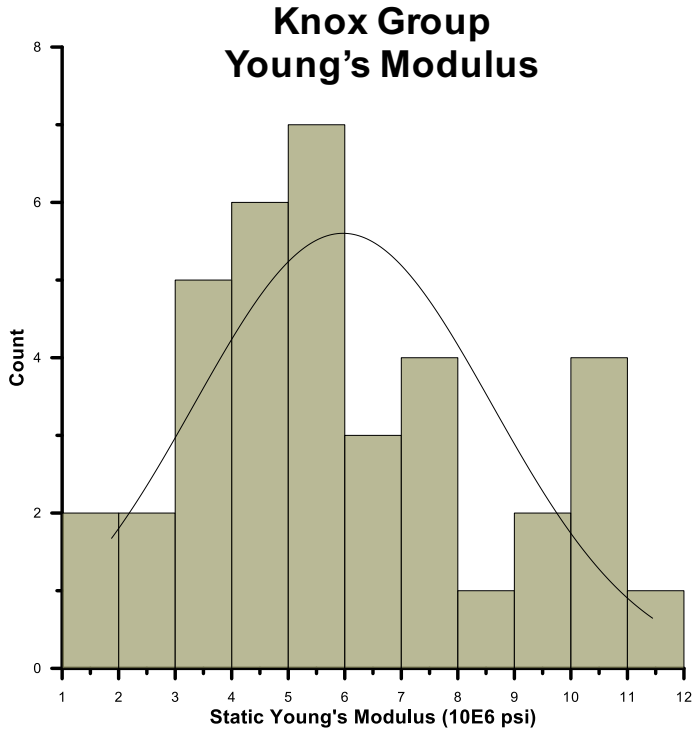
Accomplishments to Date
Task 3: Site Geomechanical Analysis

- 3 sites identified for detailed analysis of geomechanical parameters for reservoirs of interest.
- Objective= characterization of fractured reservoir and in some occasions identifying multiple fractures with different orientation pattern at depth.



Accomplishments to Date
Task 3: Site Geomechanical Analysis

- 8 key rock core samples selected for testing on geomechanical parameters.
- Other geomechanical data for region being analyzed for population distribution.



Synergy Opportunities

Synergy to DOE-NETL C-Storage Program

- Project has significant synergies with other ongoing work on carbon storage technologies (carbon capture & storage), shale gas developments, other CO_2 storage research.
- Provides a better understanding of geomechanical stress parameters for Midwest U.S., a key issue for CO_2 storage in the region's deep rock formations.
- Reduces uncertainty related to existing/future power plant locations by mapping key geomechanical items.

Summary/Results and Conclusions

- First year of the project focused on Paleo Stress-Strain analysis for the Midwest U.S. region.
- Horizontal stress appears to be consistent in the region.
- Analysis on fracture distribution indicates variation in fracture intensity:
  - More fractures were observed on acoustic and resistivity images collected in the western part than eastern part of the study area.
  - Factors influencing variation is under study.
- Analysis on natural fracture orientation indicates a complex pre-dominant northeast-southwest trend.

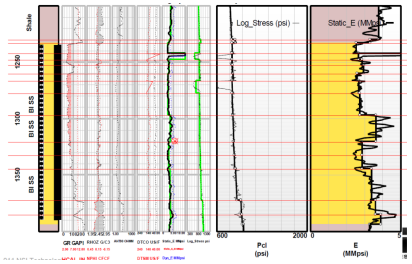
Summary/Results and Conclusions

- Predominant fracture orientation appears to coincide with the orientation of present day S_{Hmax}
  - Factors controlling fracture orientation include
    - Direction of tectonic transport
    - Basin architecture
    - Paleo-stress.
- Above-mentioned factors are challenging to interpret.
- Rock core and image log analysis in progress will contribute to understanding of geomechanics in region and support further work in next 2 years of project.

Summary- Future Work

Task 4: Petophysical Log Analysis & Integration

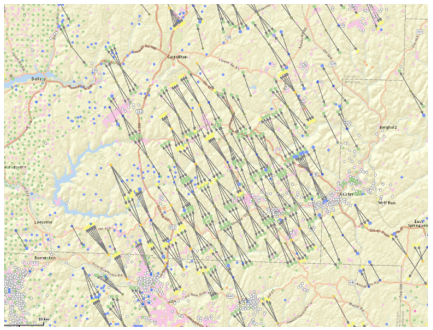
- Translation of petrophysical log data to geomechanical parameters
- Calibration of logs with static geomechanical test data.



Task 5: Development of Methodology for Geomechanical Site Characterization

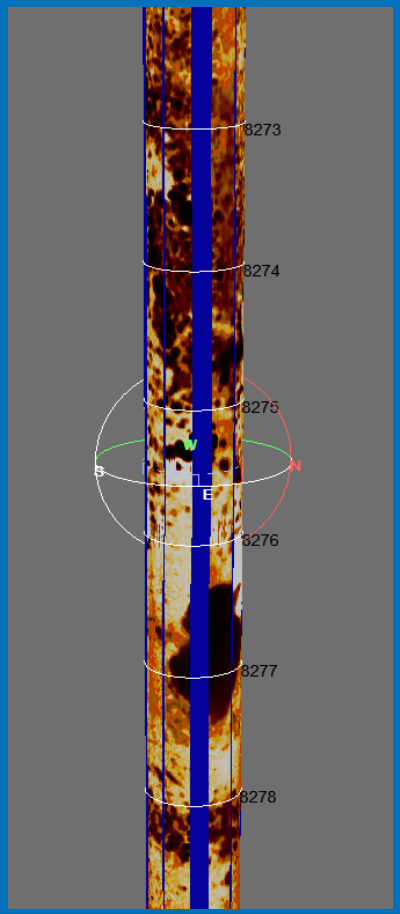
- Describe options and steps for operators drilling CO_2 injection wells, preparing Class 6 UIC permits, and monitoring CO_2 storage sites.

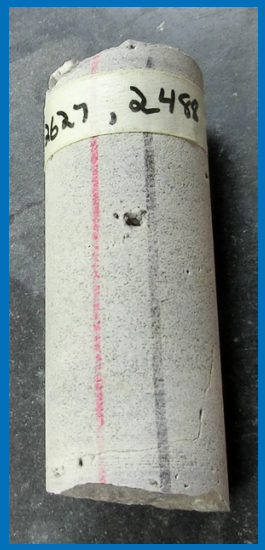
Task 6-7: CO_2 injection simulations for fractured reservoirs and caprock simulations

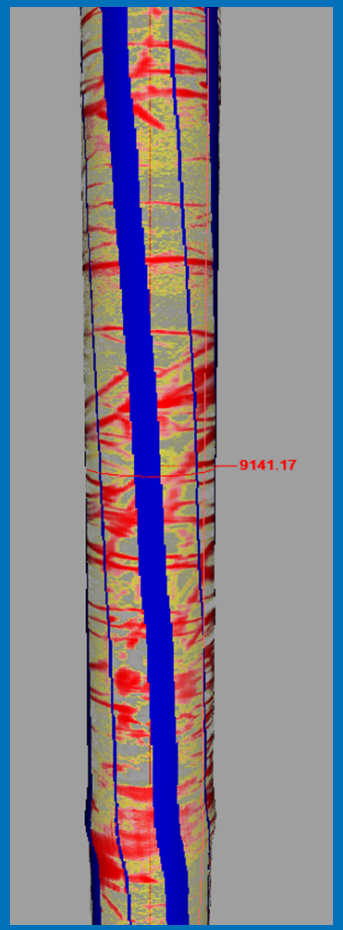


Task 8: CO_2 Storage Site/Shale Gas Risk Factor Assessment

The End. Thank You.







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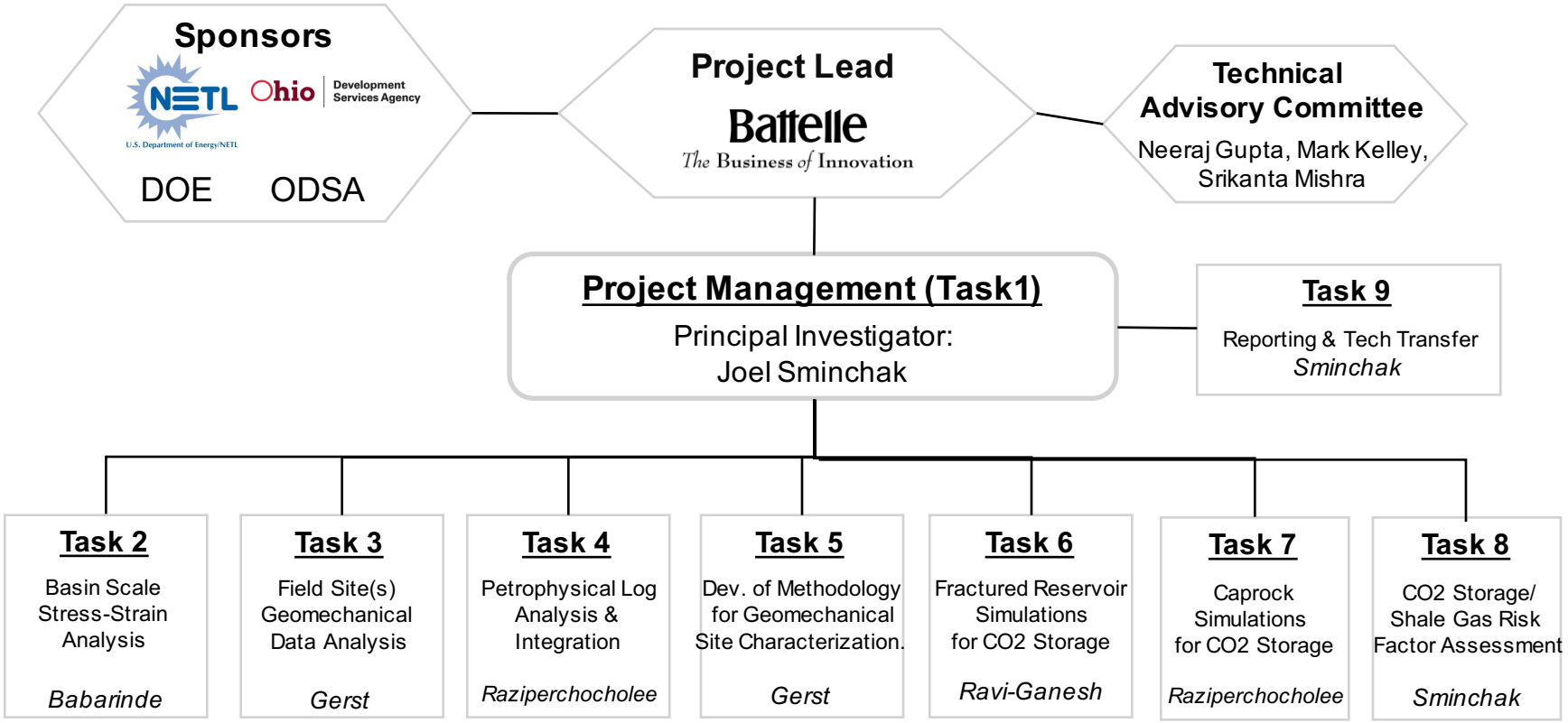
Additional Project Information

Project Organization Chart

- Project organized into 7 main technical tasks.



Gantt Chart

- Project is designed with a sequential series of tasks over 3 years.

Task Name	BP1				BP2				BP3			
	FY2015				FY2016				2017			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Project Management & Planning												
1.1 Update Project Mgmt. Plan												
1.2 Project Management												
1.3 Project Controls												
1.4 NEPA Reporting												
Task 2: Basin Scale Stress-Strain Analysis												
2.1 Tectonic Setting Def. for Midwest U.S.												
2.2 Reg Analy. of Paleo-Stress Orien. & Mag												
2.3 Sys. Rev. of Geomech & Petophys Prop.												
Task 3: Geomech. Data Analysis												
3.1 Data Proc from Well Logs/tests												
3.2 Geo and Geomech Des of Well Sites												
3.3 Static Geomech Rock Core Test&Analys.												
Task 4: Petrophys Log Analysis & Integra.												
4.1 Trans. Petrop Log Data to Geomech Para												
4.2 Calibr. of Logs with Static Geomech Data												
Task 5: Dev. Meth for Geomech Site Char												
5.1 Geophys. Logging Options for CO_2 Sites												
5.2 Geomech Rock Core Test Options												
5.3 Inj Test Options for CO_2 Storage Sites												
5.4 Geomech Mon Options for CO_2 Sites												
Task 6: Fractured Res. Sims for CO_2 Stor.												
6.1 Numerical Model Definition/Setup												
6.2 Caprock Simulation Scenario Runs												
6.3 Simulation Results Processing/Visualiz												
Task 7: Caprock Sims for CO_2 Stor.												
7.1 Numerical Model Definition/Setup												
7.2 Caprock Simulation Scenario Runs												
7.3 Simulation Results Processing/Visualiz												
Task 8: CO_2 Stor/Shale Gas Risk Factors												
8.1 Mapping CO_2 Stor Zones & Shale Gas												
8.2 Class. of Risk Factors Rel to CO_2-Sh Gas												
Task 9: Reporting and Tech Transfer												
9.1 Progress Reporting												
9.2 Technical Summary Reports												
9.3 Final Reporting												
9.4 Project Meetings												

Deliverables/Milestones

Milestones

Budget Period	Milestone Description	Planned Due Date	Verification Method
1	Submit Updated Project Management Plan to DOE	30 days after initial award	Project Management Plan
1	Collect and Analyze Geotechncial Data for Basin Scale Paleo-Stress/Strain Analysis	September 2015	Topical Report
2	Acquire and Process 3-4 Advanced Geophysical Logs from Key Wells in the Region	September 2016	Annual Report, Upload data to EDX
2	Complete Testing of 10 Rock Cores for Geomechanical Parameters	September 2016	Annual Report, Upload data to EDX
3	Complete Development of a Methodology for Geomechanical Site Characterization for CO_2 Storage Sites	March 2017	Summary Technical report
3	Complete Reservoir Simulations for fractured reservoirs and caprocks	June 2017	Topical Report with Simulation Results
3	Develop maps and identify risk factors for CO_2 Storage/Shale Gas Zones in the Region	June 2017	Summary Technical Report
3	Preparation of final technical report detailing all test data, analysis, and project results	90 days after end of the project	Final Technical Report

Deliverables/Milestones

Deliverable List

Deliverable	Task	Description	Deliverable Due Date
Project Management Plan	1	Updated Project Management Plan	30 days after initial award
Annual Renewal Application	1	Annual report with technical progress, key findings, and request for continued funding	30 days before end of Budget Period 1 and Budget Period 2
Project Fact Sheet	1	Updated fact sheet for project	30 days after initial award
Basin Scale Paleo-Stress/strain Analysis	2	Basin scale paleo-stress strain setting analysis (Topical report)	September 2015
EDX Upload of Data	3-4	Submit relevant geophysical and core test geomechanical data (upload to EDX, summarize in annual report)	June 2017
Methodology for Geomechanical Site Characterization	5	Summary Methodology for Geomechanical Site Characterization (summary technical report)	March 2017
Reservoir Simulations	6-7	Analysis of Simulation Results (Topical report)	June 2017
CO_2 Storage/Shale Gas Risk Factor Analysis	8	Summary of CO_2 Storage/Shale gas risk factors (summary technical report)	June 2017
Final Technical Report	9+	Technical report detailing all methods, simulations, analyses, and findings	90 days after end of the project

Bibliography