Optimizing accuracy of determinations of CO_2 storage capacity and permanence, and designing more efficient CO_2 storage operations: An example from the Rock Springs Uplift, Wyoming

DOE Project DE-FE0009202

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University of Wyoming Carbon Management Institute

U.S. Department of Energy

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

August 12-14, 2014

Presentation Outline

- Benefits of this program to DOE's CCUS goals.
- Objectives and goals of our study.
- Technical overview: integrated approach to characterizing and assessing uncertainty relative to geologic heterogeneity.
- Results, state of the project, and future plans.

Benefit to the Program

Reducing storage site assessment uncertainties by defining geologic heterogeneities

- The development of a new seismic workflow analysis using volumetric attributes.
- Characterizing the relationship of large-scale geologic processes and their effect on geologic heterogeneity and the overall confining potential of sealing strata.
- Develop calculations based on CO_2-water-rock systems, high-pressure mercury injection, interfacial tension, and wettability data that are realistic for the study site.
- Identify the impact of well completion techniques and in-situ testing on initial formation brine chemistries and introduced unquantified anthropogenic uncertainty.
- Develop a well design scenario that minimizes scaling risks based on site criteria through optimized engineering applications.
- Extrapolate geologic heterogeneity to other potential storage sites.

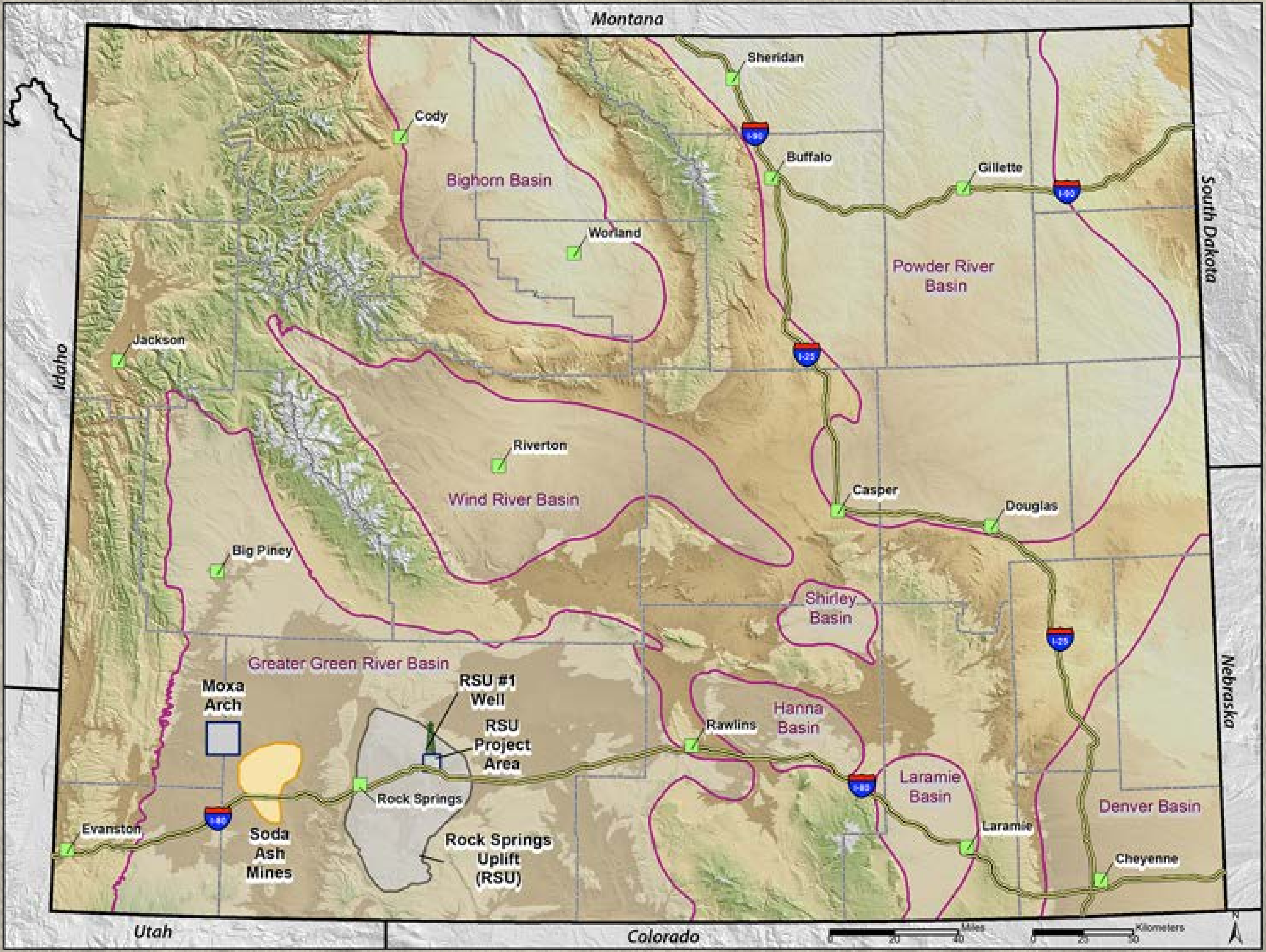
Project Overview:
Goals and Objectives

The objectives for the proposed work are as follows:

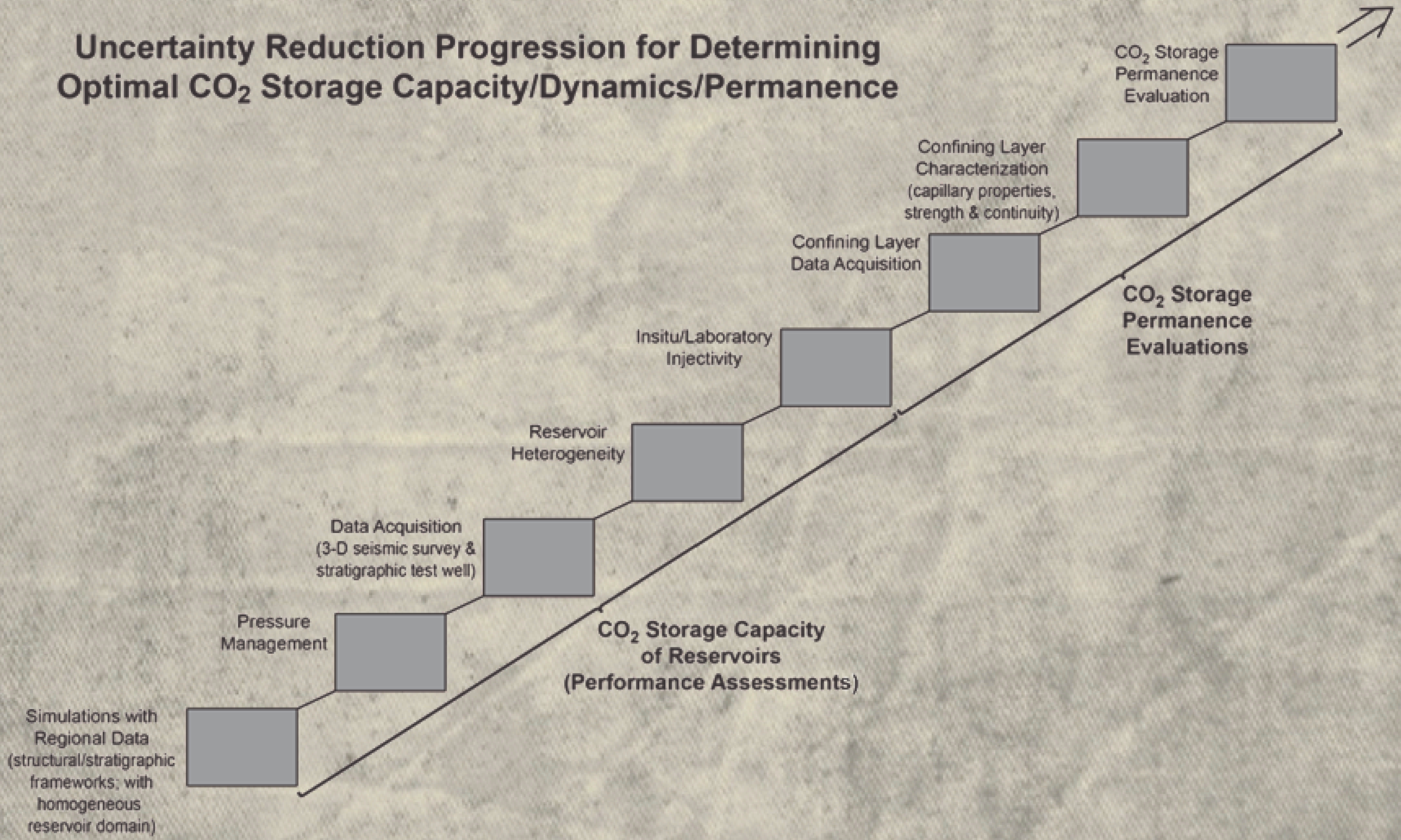
1) Reduce uncertainty in estimates of CO_2 storage capacity at the Rock Springs Uplift;
2) Evaluate and ensure CO_2 storage permanence at the study site by defining sealing potential and character, specifically with regards to geological heterogeneity; and
3) Improve the efficiency of potential storage operations by designing an optimal CO_2 injection/brine production strategy.

Working towards overall goal of reducing uncertainty to the lowest possible levels.

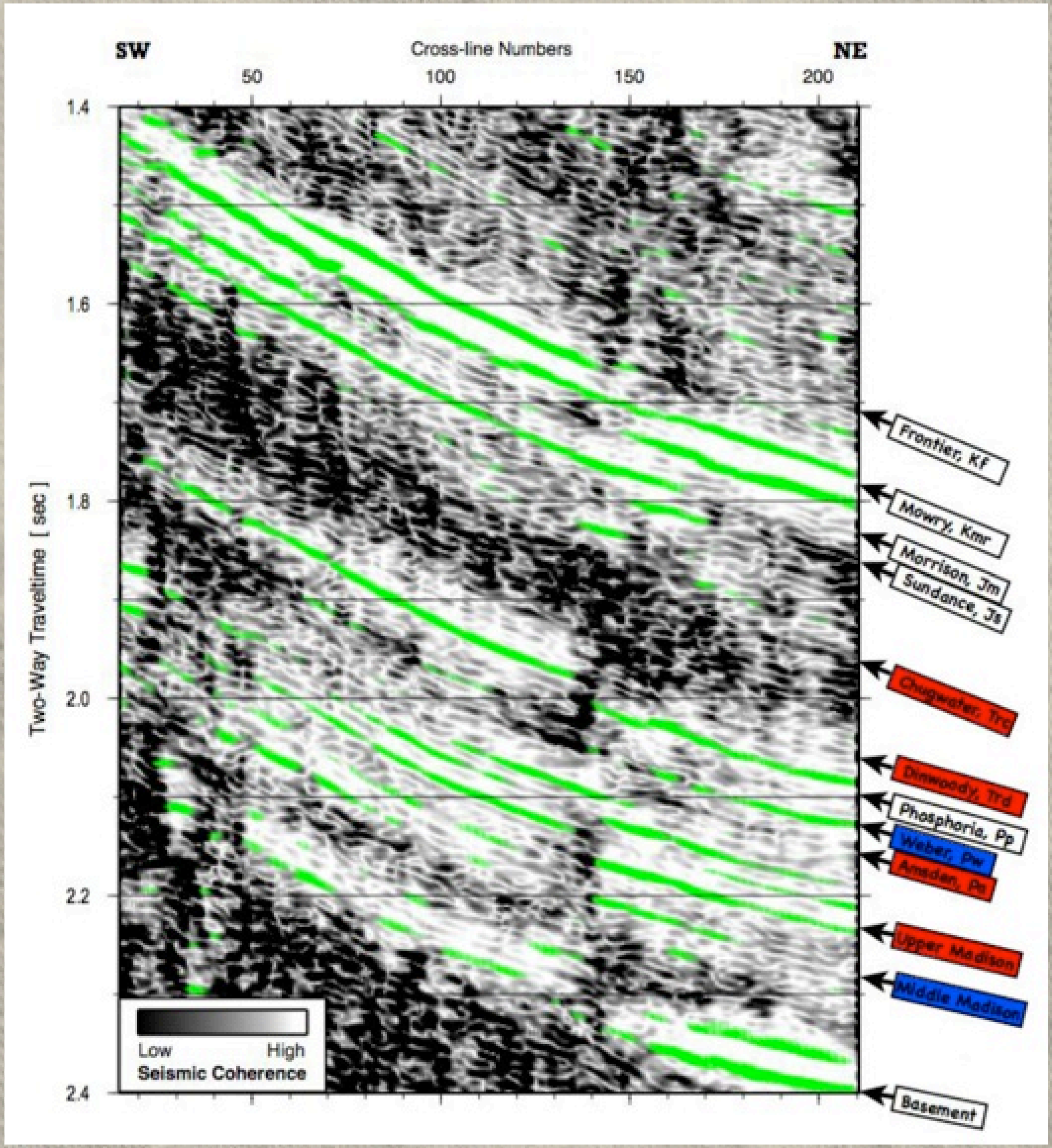
Field Site


Montana
Idaho
South Dakota
Nebraska
Utah
Colorado
Sheridan
Cody
Buffalo
Gillette
Bighorn Basin
Worland
Powder River Basin
Jackson
Riverton
Wind River Basin
Casper
Douglas
Big Piney
Shirley Basin
Greater Green River Basin
Moxa Arch
RSU #1 Well
RSU Project Area
Rawlins
Hanna Basin
Laramie Basin
Rock Springs
Evanston
Soda Ash Mines
Rock Springs Uplift (RSU)
Laramie
Denver Basin
Cheyenne
I-90
I-25
I-80
Miles
0
20
40
Kilometers
0
25
50
N

Integrated Work Flow

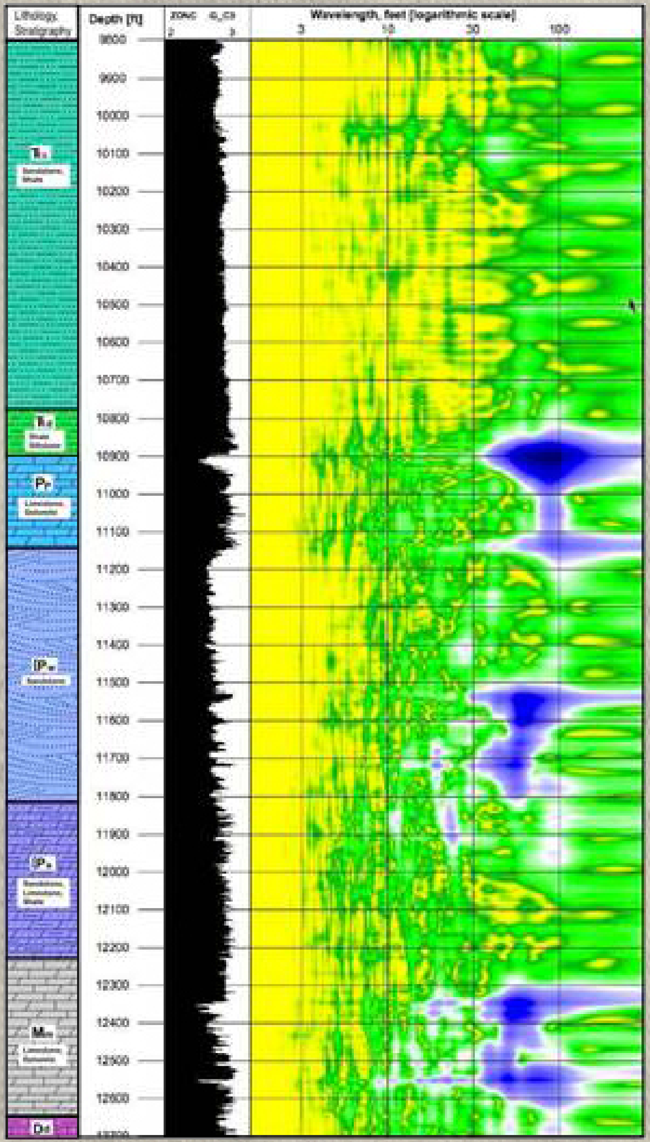


Task 2.0 – Seismic Interpretation and Characterization



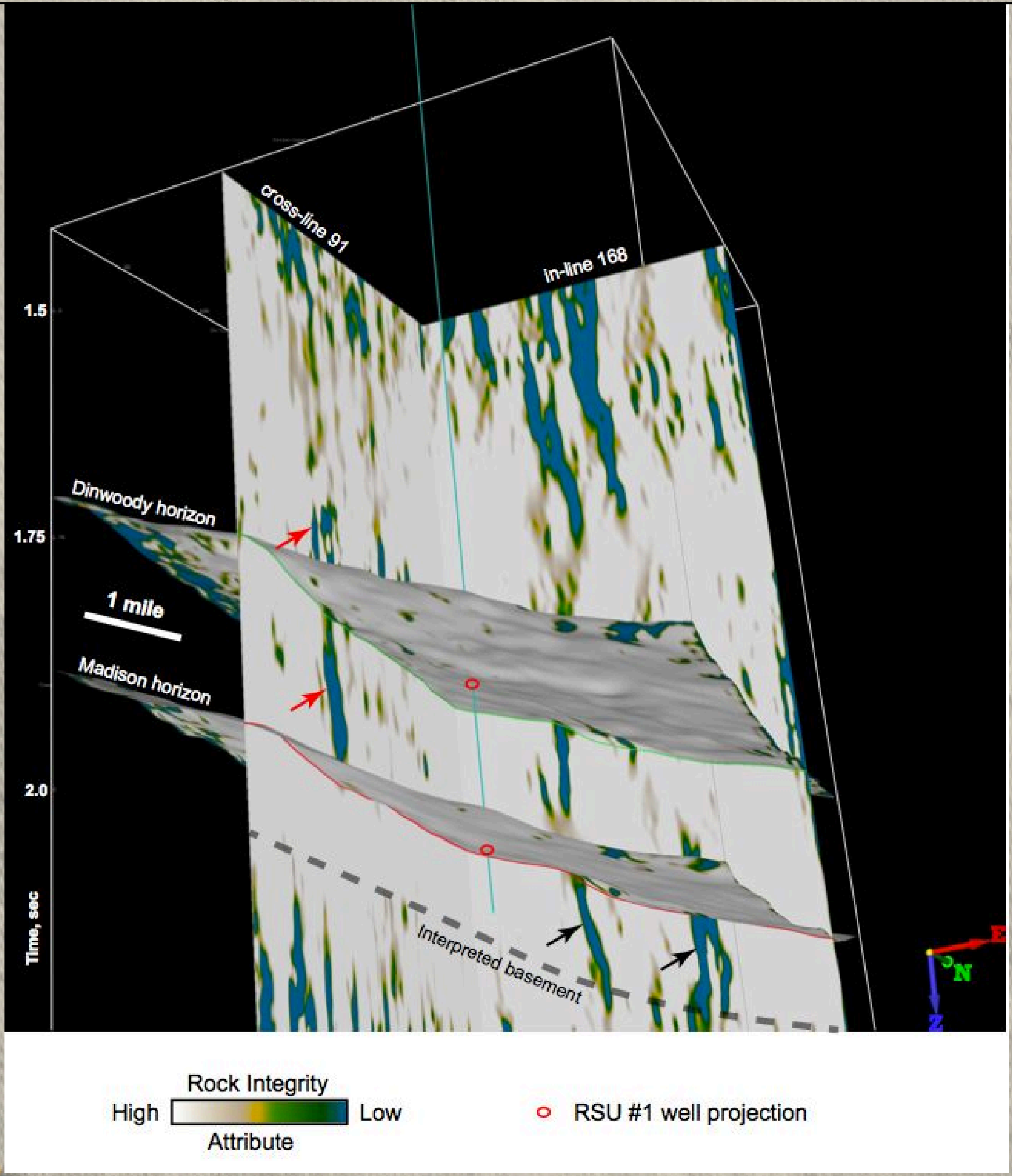
- SW-NE section
- Targeted seals (red), targeted reservoirs (blue)
- Coherency volume (energy-normalized amplitude gradients)
- Interpreted seismic reflections (green)
- Note discontinuities (dark colored)

Task 2.0 – Seismic Interpretation and Characterization



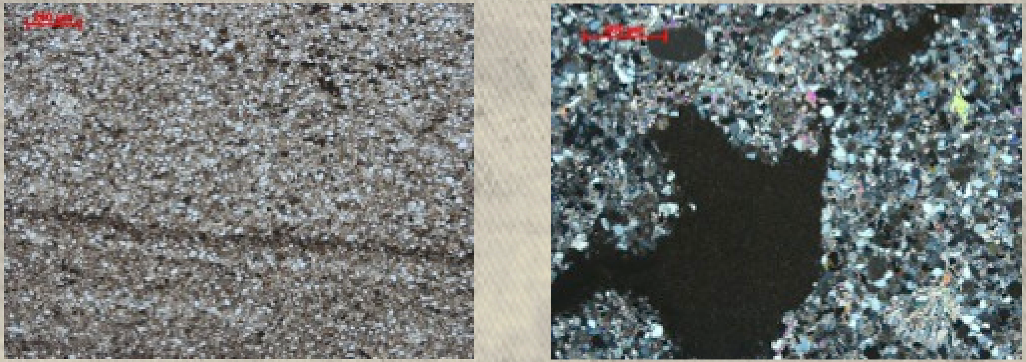
- New Rock Integrity Seismic Volume Analysis.
- Integrates petrophysical, geological, and seismic date.
- Note heterogeneous behavior (multiple amplitude bursts at different scales) below confining layers (10,900+ feet depth) and relatively homogeneous and low-amplitude spectra within sealing sequence.

Task 2.0 – Seismic Interpretation and Characterization



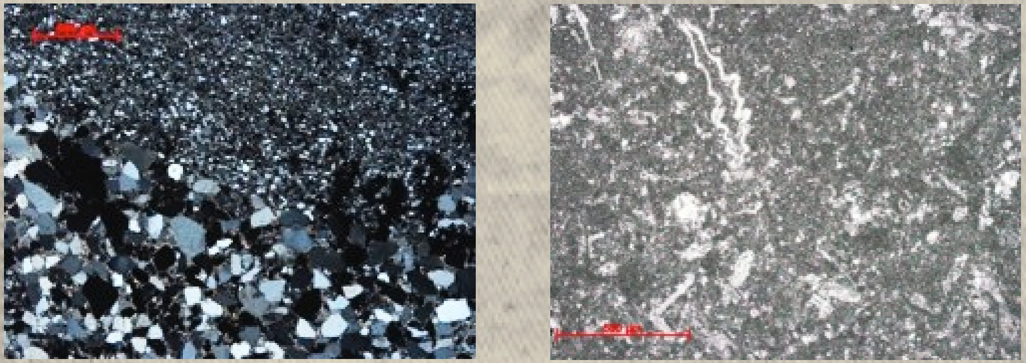
- Two orthogonal vertical sections and two horizon slices of the Madison and Dinwoody formations using Rock Integrity attribute (view from the southeast).
- Red arrowheads indicate a vertical feature that originates at top of the Madison reservoir and into the Dinwoody horizon.
- Basement-rooted faults are marked with black arrowheads.
- *New integrated seismic techniques have identified previously unknown geologic features.*

Task 3.0 – Geological Characterization



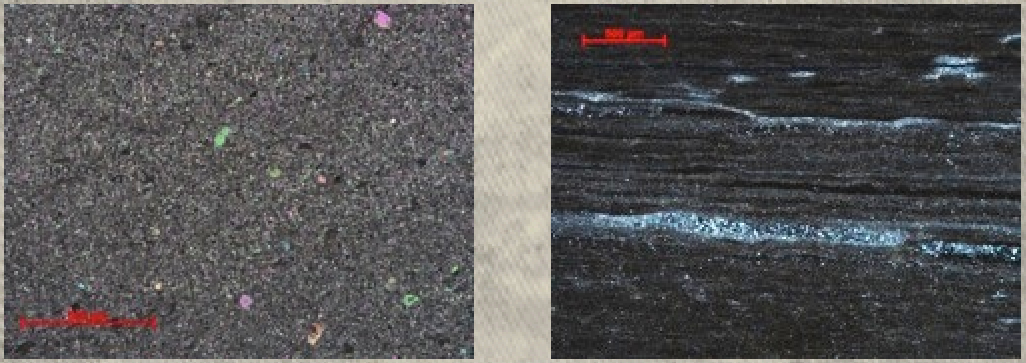
Lower Triassic Units

- Near-shore, laminated siltstones
- Heavily cemented (anhydrite, K-clays, silica)



Amsden Formation

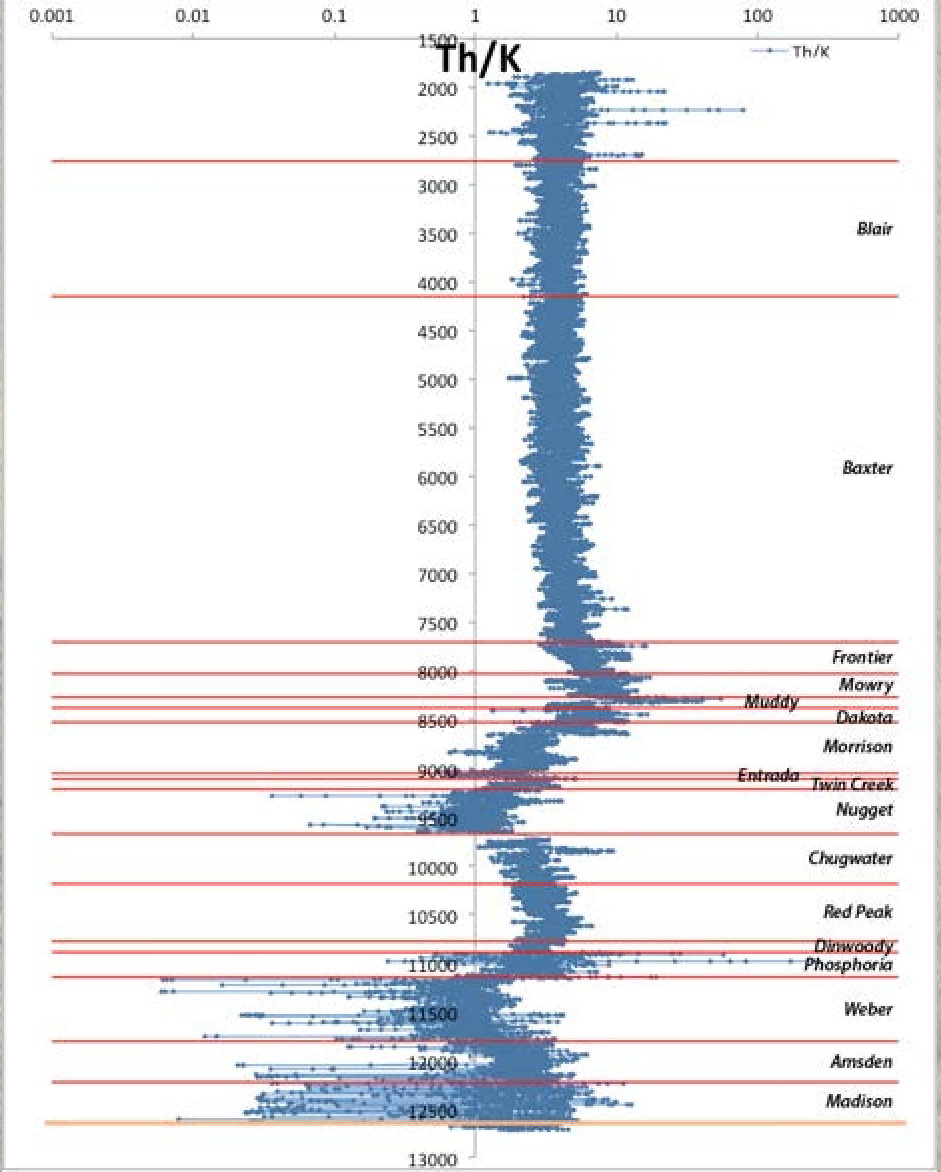
- Heterogenic
- Highly altered post-burial



Madison Limestone

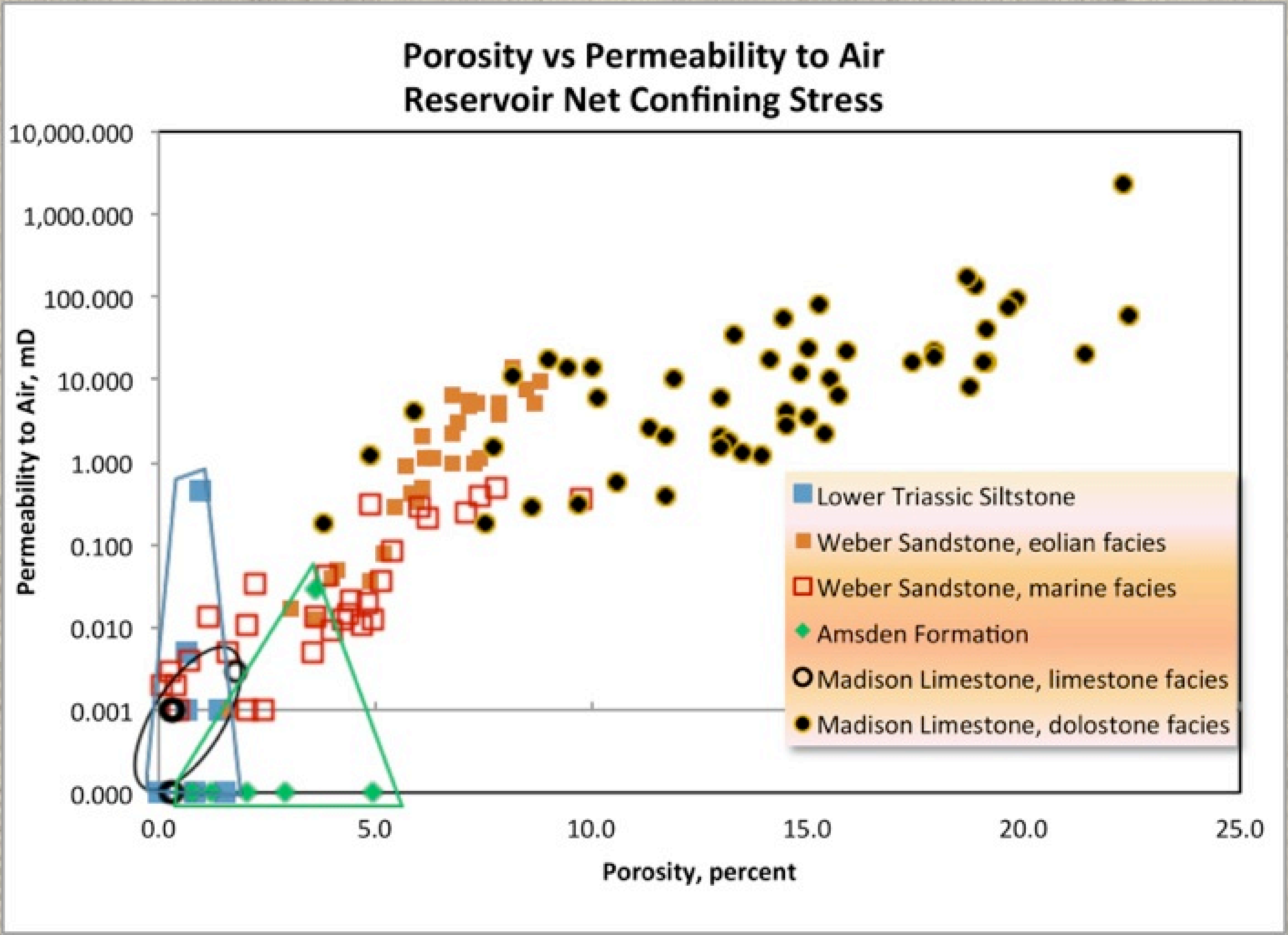
- Mostly primary textures
- Post-burial dissolution

Task 3.0 – Geological Characterization



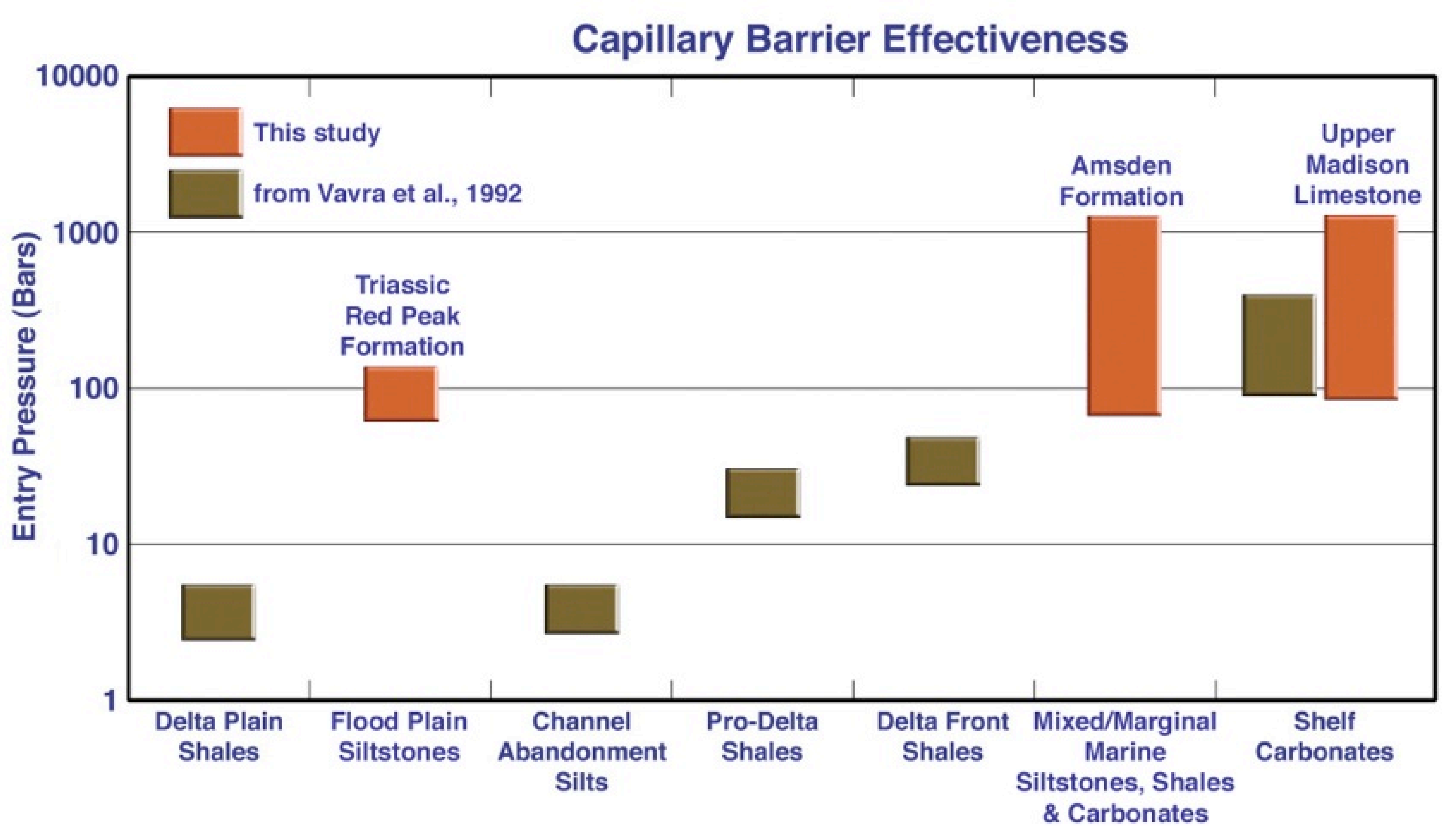
- Thorium/potassium spectral log data by depth and formation.
- Cretaceous shales are uniformly consistent.
- Decreased Th/K ratio consistent with clay diagenesis (> illite, etc. at depth).
- Amsden Formation is relatively heterogenous.

Task 3.0 – Geological Characterization

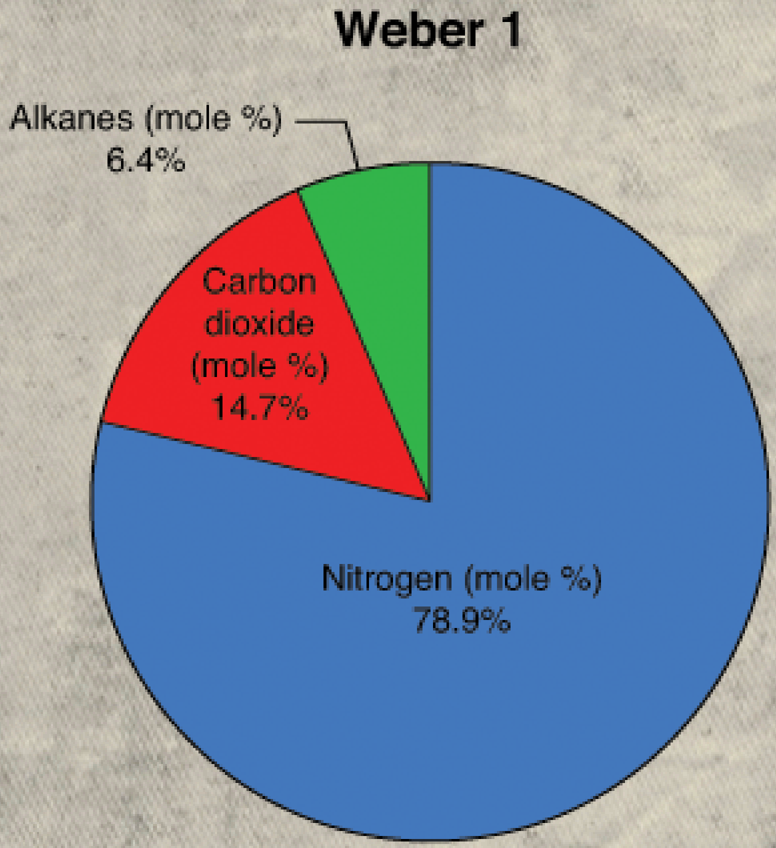


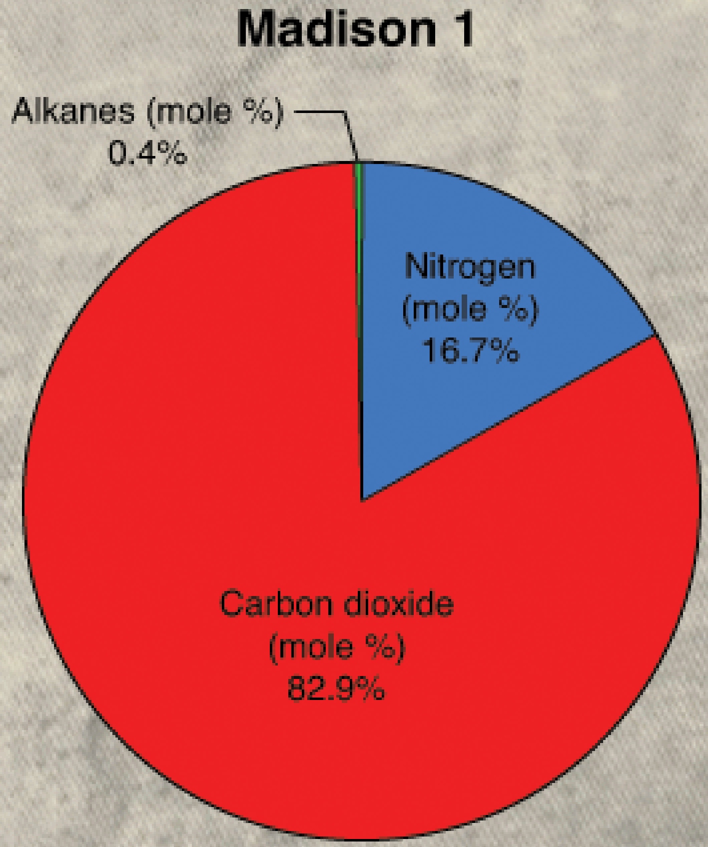
Task 3.0 – Geological Characterization

Depositional and diagenetic history has increased sealing potential for Triassic units (regional processes)



Task 4.0 – Geochemical Models and brine chemistry interactions

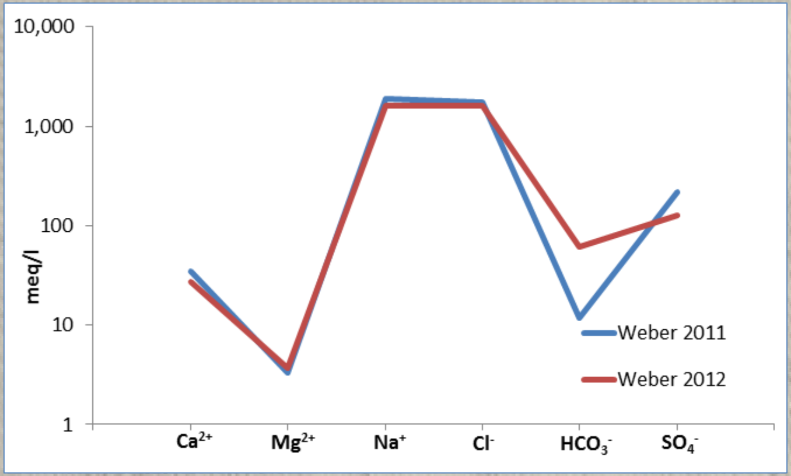


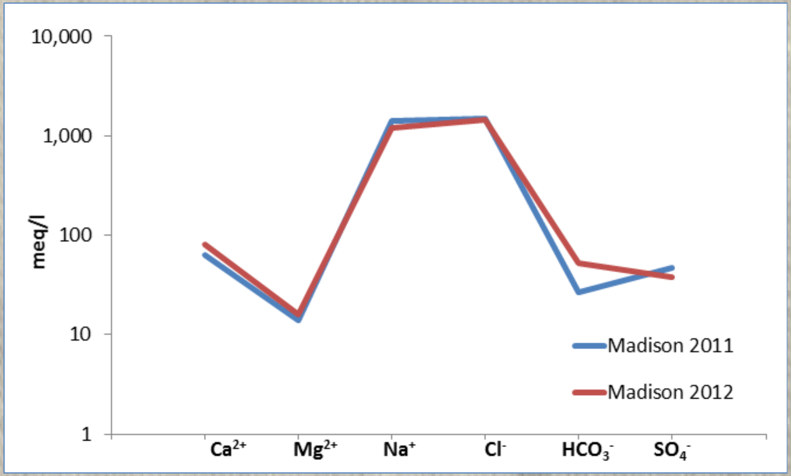


Gas composition of reservoir brines.

Task 6.0 – Optimized water production engineering

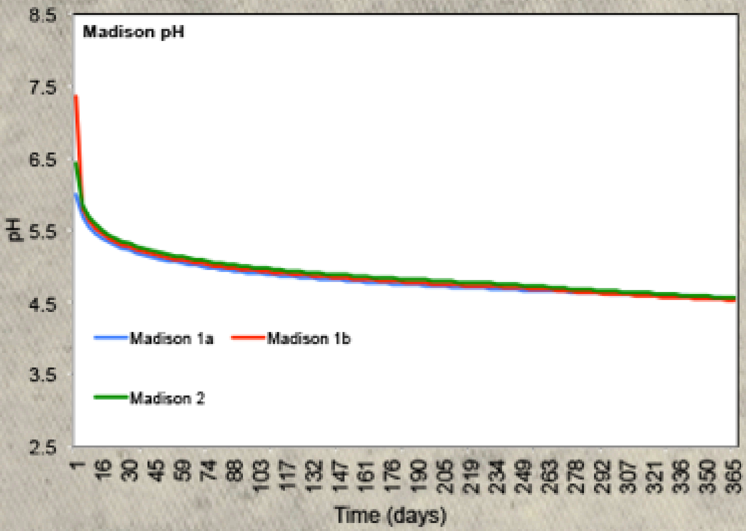
Water chemistry analysis from Task 4.0 identified souring of fluids adjacent to the well bore.

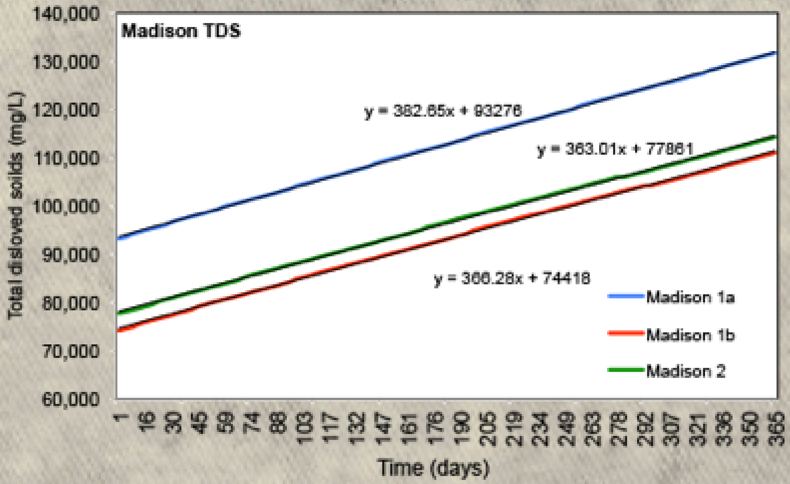




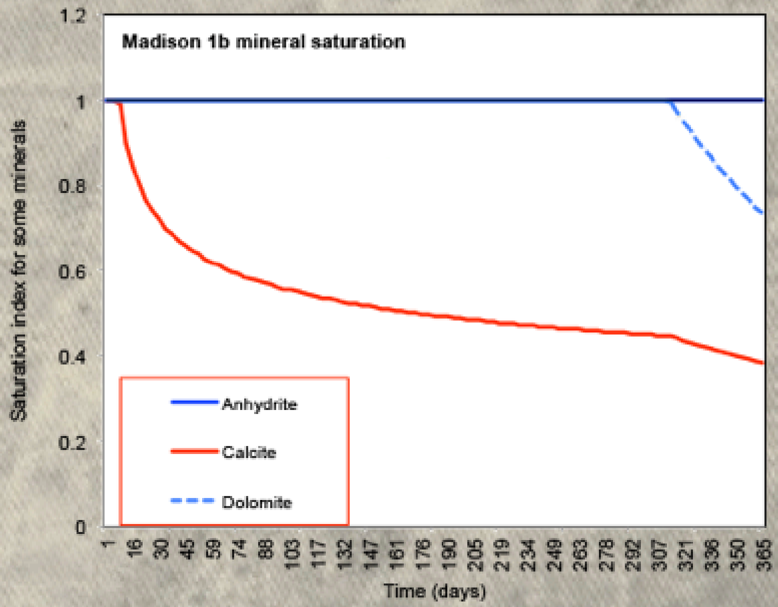
- This suggests that in-situ well site operations can alter fluid chemistry, and possibly “corrupt” geochemical fluid reaction models and well design schematics.
Careful analysis must be made of all retrieved fluids.

Task 4.0 – Geochemical Models and brine chemistry interactions

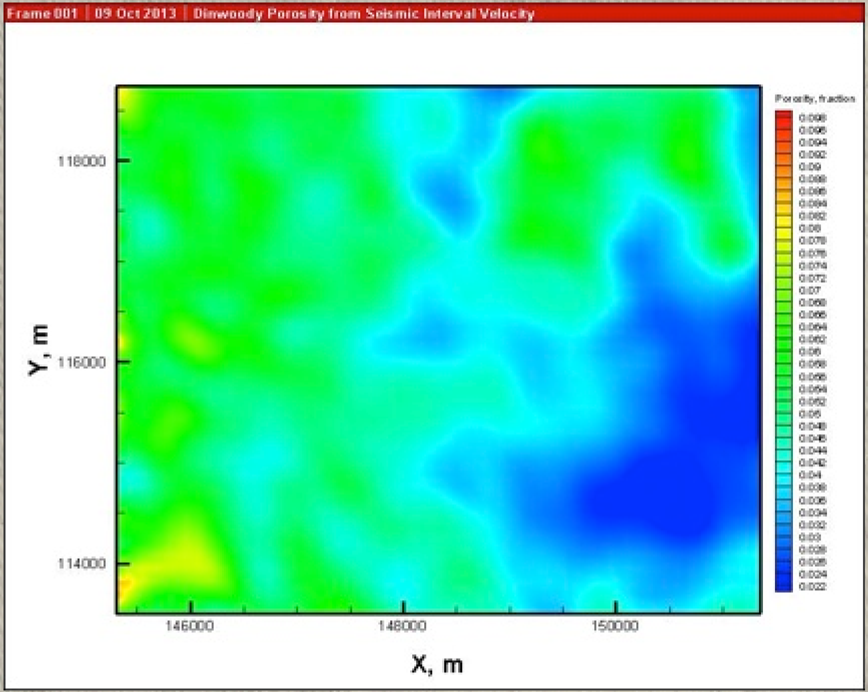




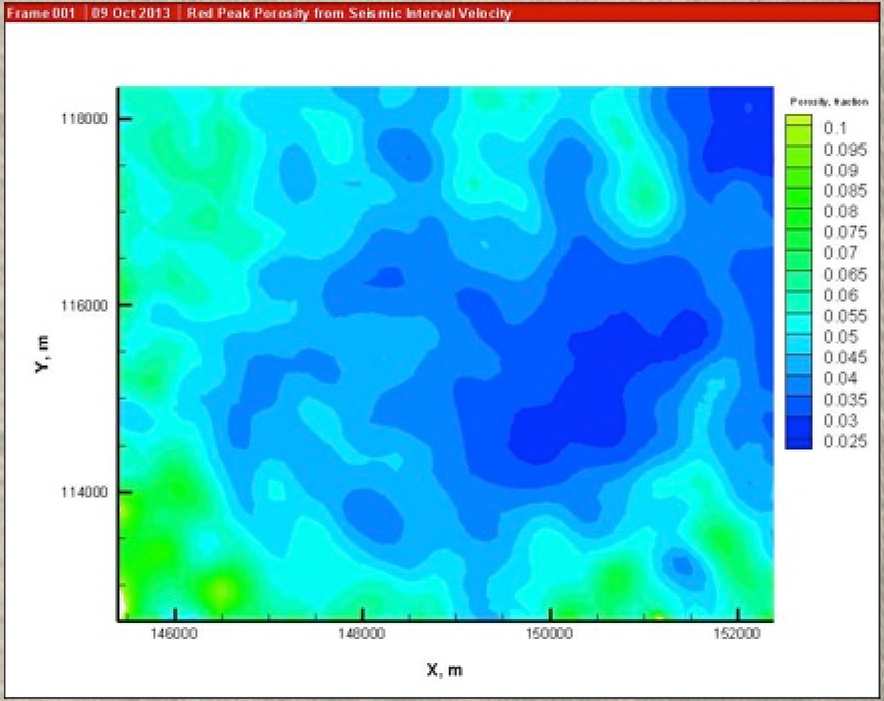
Modeled response of reservoir fluids during simulated CO_2 injection.



Task 5.0 – Modeling and injection simulations

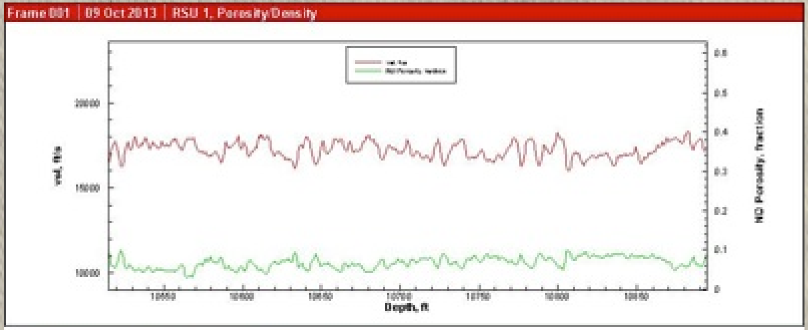


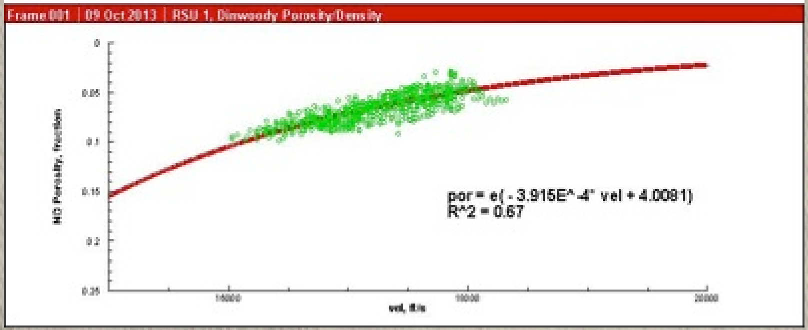
- Contour map of the porosity distribution of the Dinwoody Formation.
- Porosity ranges from 1% to 10%, with a mean of 4.5%.



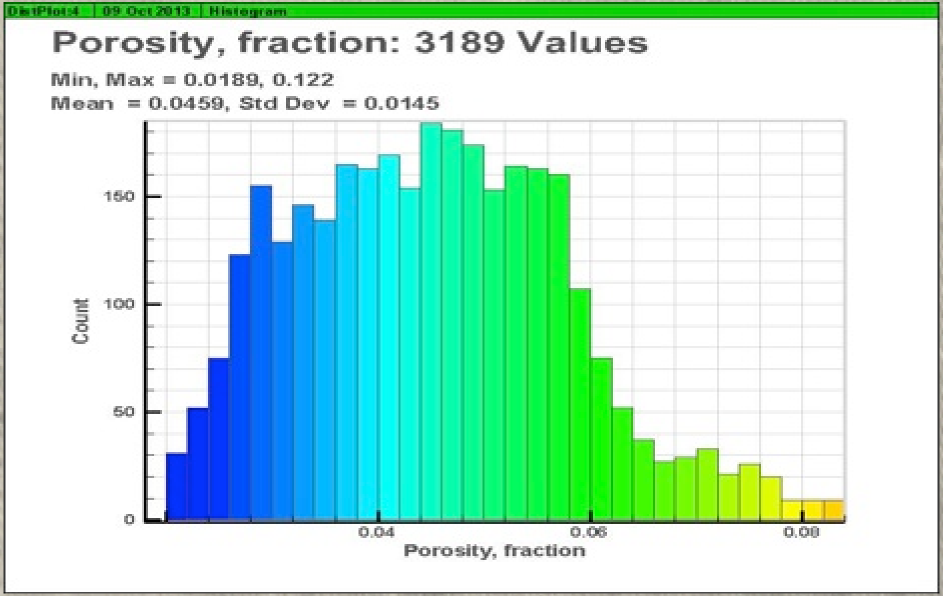
- Contour map of the porosity distribution of the Red Peak Formation.
- Porosity ranges from 1% to 10%, with a mean of 5%.

Task 5.0 – Modeling and injection simulations





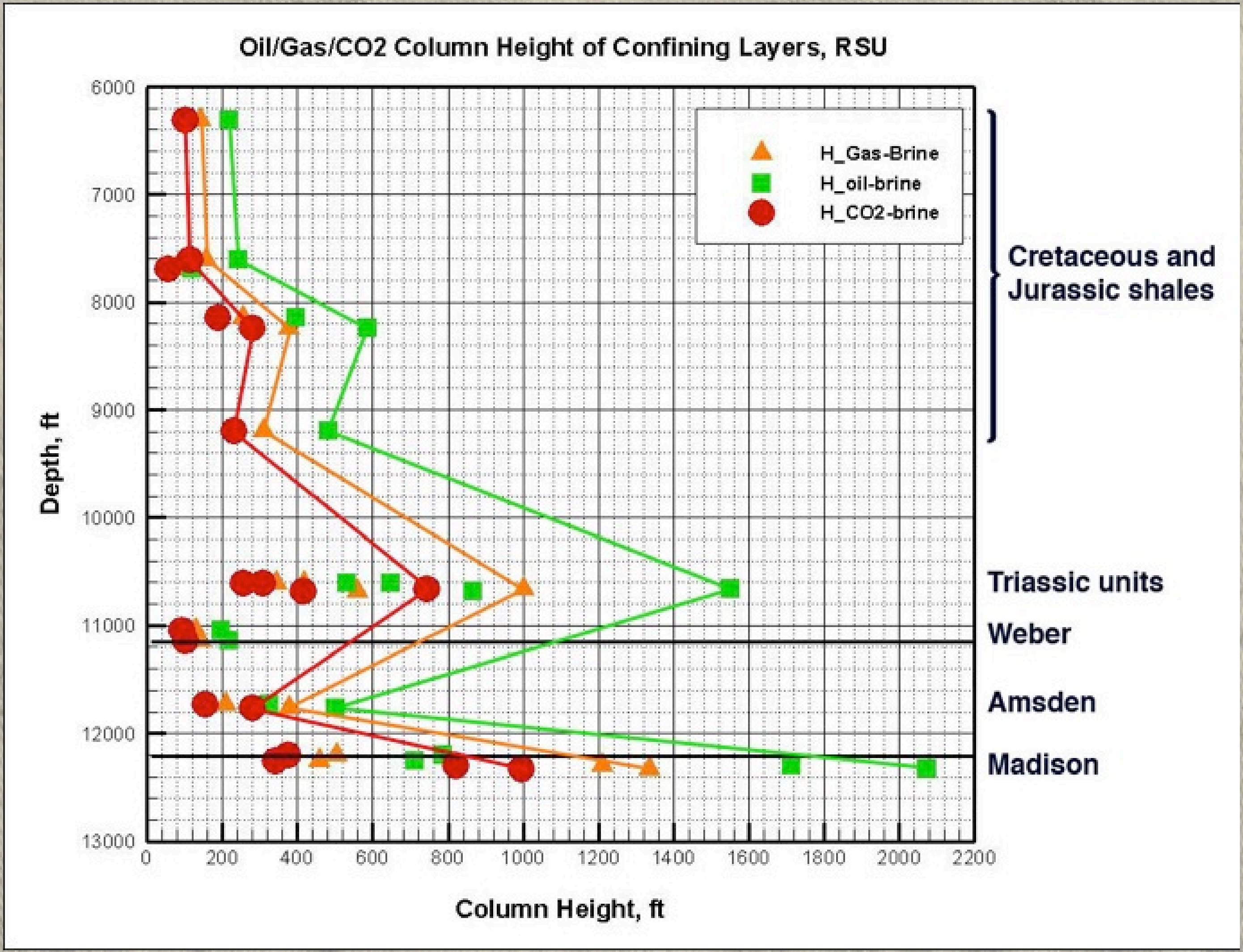
- Smoothed sonic velocity and neutron-density porosity of the Dinwoody Formation
- Cross-plot of velocity and neutron-density logs.



Porosity histogram of the Dinwoody Formation based on functions derived from neutron-density and sonic logs.

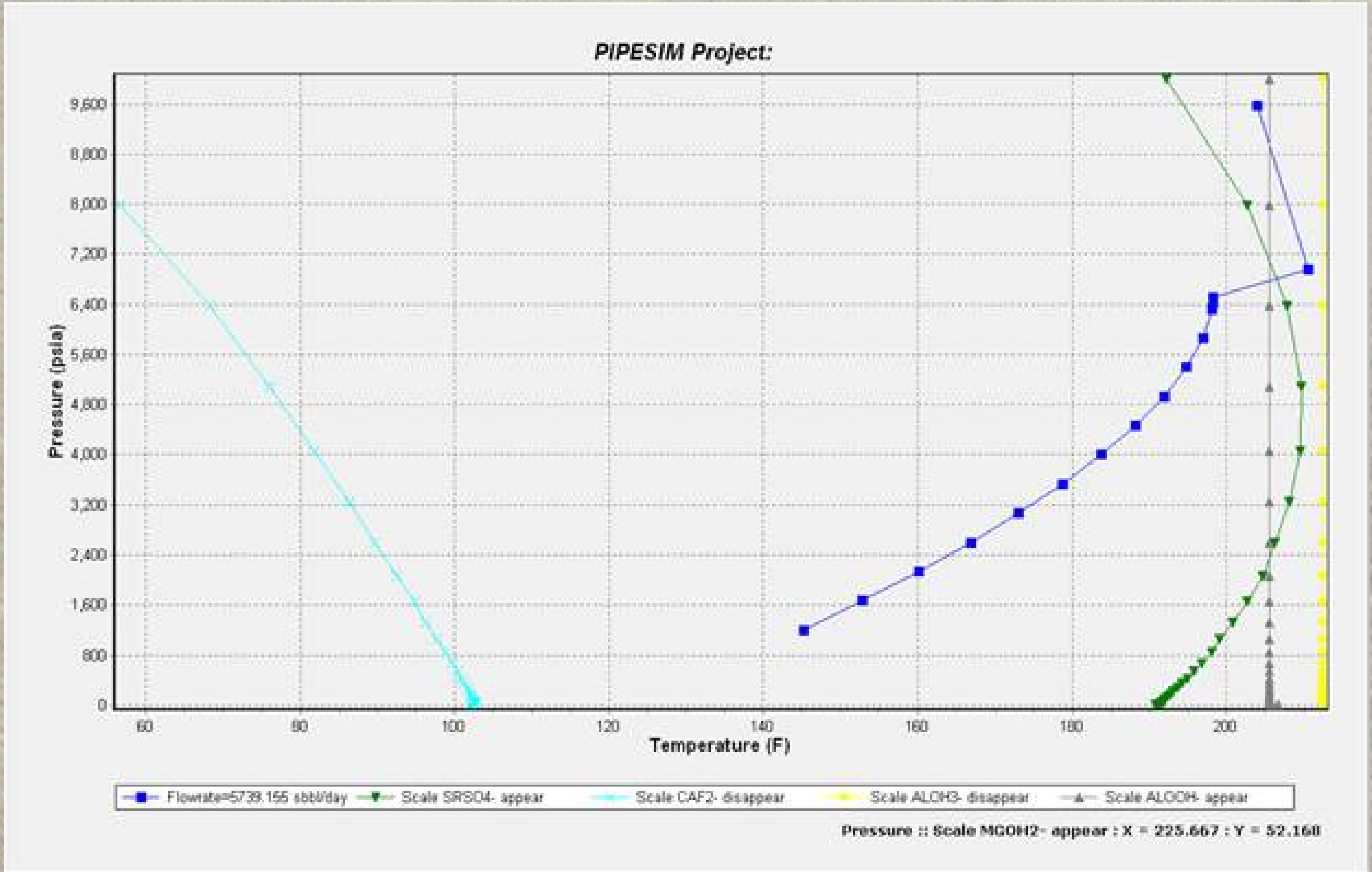
Task 5.0 – Modeling and injection simulations

Column height calculations; reassessing the CO_2-H_2O-Brine system



Task 6.0 – Optimized water production engineering

Potential for scaling at all depths



Accomplishments to Date

Several noteworthy advances include:

- *The development of a new seismic workflow analysis directly identified several previously unknown geologic features within the field area. Many of these features are smaller-scale and vertical and could not be identified using conventional analysis.*
- *Characterizing depositional and diagenetic history has identified the processes responsible for the enhancement of sealing potential of a targeted seal (initially assumed to be of lesser importance).*
- *Brine fluid-CO_2 interactions will dissolve mineral cements.*
- *Calculations based on high-pressure mercury injection, interfacial tension, and wettability data suggest that sealing capacity of a CO_2-water-rock system is significantly lower than previously predicted.*
- *Simulations completed suggest that producing reservoir brines for the purpose of pressure management during injection create a high likelihood of multi-mineral precipitation (i.e. scale formation) within the wellbore.*
- *In-situ testing and well completion has altered initial formation brine chemistries and introduced unquantified anthropogenic uncertainty.*

Future Plans

1) Define potential for reservoir brine mixing based on detailed isotopic brine compositions.
2) Design optimized production/injection well scenarios.
3) Integrate all data/conclusions into a complex geologic model for injection simulations.
4) Assess risk uncertainty relative to geologic heterogeneity, which can be used as an analog for other potential CCUS sites.
5) Integration and compilation of conclusions for a Best Practice Manual.

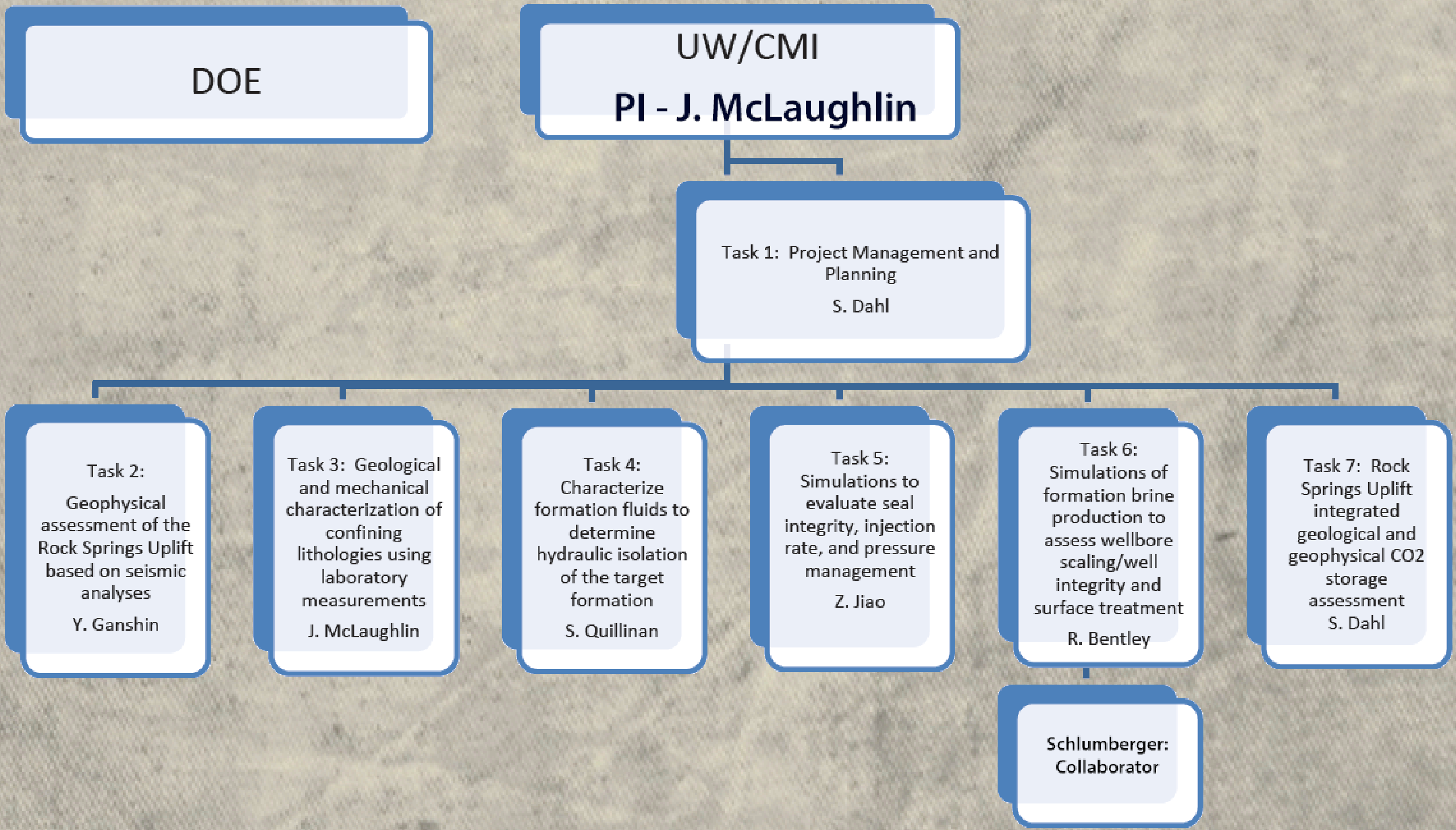
Acknowledgements

This project is funded in part by the U.S. Department of Energy’s National Energy Technology Laboratory (Project DE-FE0009202), and the authors would like to thank Project Manager Karen Kluger for her guidance and support.

Appendix

- Organization chart
- Gantt chart
- Bibliography

Organization Chart



DOE

UW/CMI

PI - J. McLaughlin

Task 1: Project Management and Planning

S. Dahl

Task 2:

Geophysical assessment of the Rock Springs Uplift based on seismic analyses

Y. Ganshin

Task 3: Geological and mechanical characterization of confining lithologies using laboratory measurements

J. McLaughlin

Task 4: Characterize formation fluids to determine hydraulic isolation of the target formation

S. Quillinan

Task 5: Simulations to evaluate seal integrity, injection rate, and pressure management

Z. Jiao

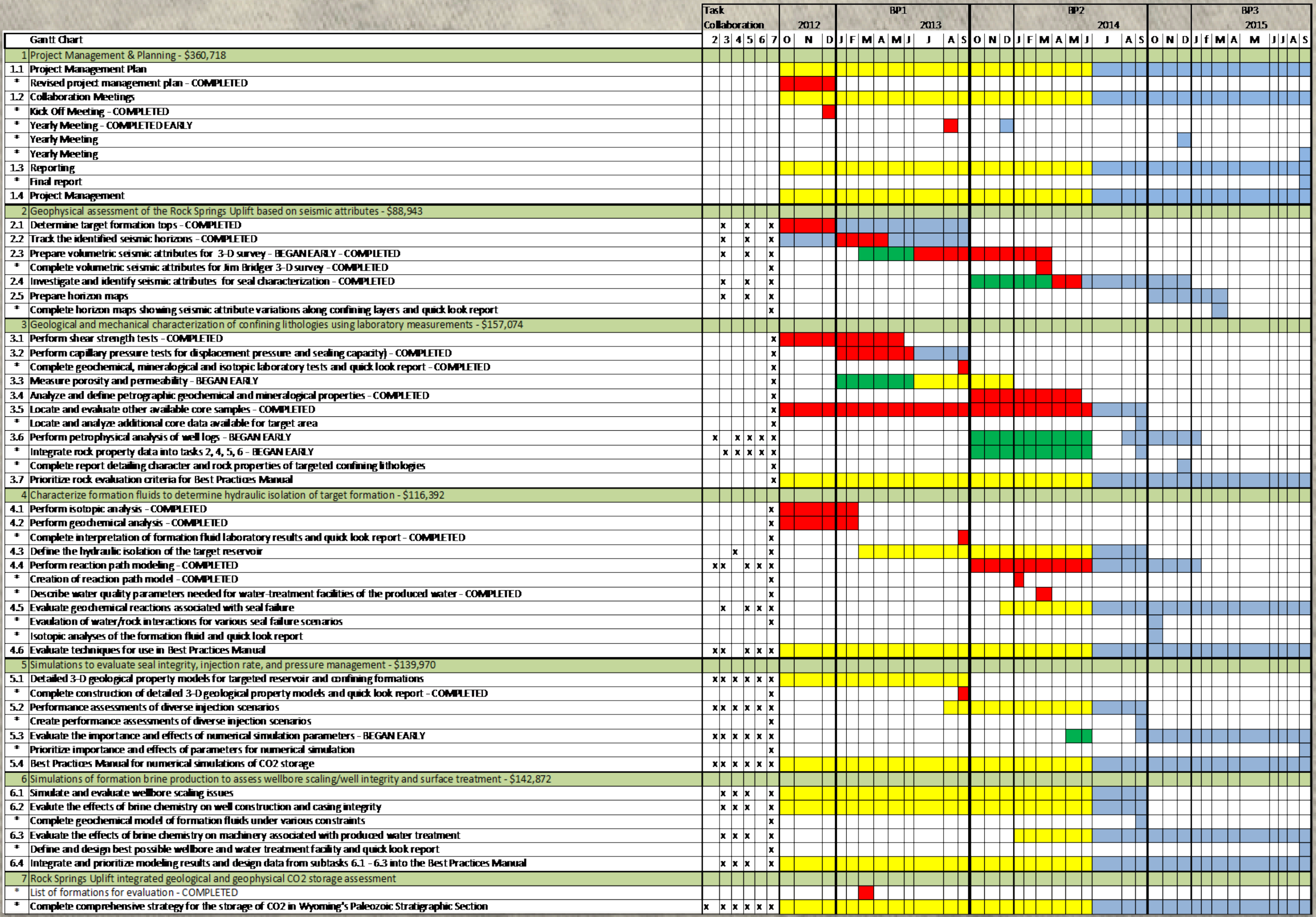
Task 6: Simulations of formation brine production to assess wellbore scaling/well integrity and surface treatment

R. Bentley

Schlumberger: Collaborator

Task 7: Rock Springs Uplift integrated geological and geophysical CO2 storage assessment

S. Dahl



	Gantt Chart	2	3	4	5	6	7
1	Project Management & Planning - $360,718						
1.1	Project Management Plan						
*	Revised project management plan - COMPLETED						
1.2	Collaboration Meetings						
*	Kick Off Meeting - COMPLETED						
*	Yearly Meeting - COMPLETED EARLY						
*	Yearly Meeting						
*	Yearly Meeting						
1.3	Reporting						
*	Final report						
1.4	Project Management						
2	Geophysical assessment of the Rock Springs Uplift based on seismic attributes - $88,943						
2.1	Determine target formation tops - COMPLETED		x		x		x
2.2	Track the identified seismic horizons - COMPLETED		x		x		x
2.3	Prepare volumetric seismic attributes for 3-D survey - BEGAN EARLY - COMPLETED		x		x		x
*	Complete volumetric seismic attributes for Jim Bridger 3-D survey - COMPLETED						x
2.4	Investigate and identify seismic attributes for seal characterization - COMPLETED		x		x		x
2.5	Prepare horizon maps		x		x		x
*	Complete horizon maps showing seismic attribute variations along confining layers and quick look report						x
3	Geological and mechanical characterization of confining lithologies using laboratory measurements - $157,074						
3.1	Perform shear strength tests - COMPLETED						x
3.2	Perform capillary pressure tests for displacement pressure and sealing capacity) - COMPLETED						x
*	Complete geochemical, mineralogical and isotopic laboratory tests and quick look report - COMPLETED						x
3.3	Measure porosity and permeability - BEGAN EARLY						x
3.4	Analyze and define petrographic geochemical and mineralogical properties - COMPLETED						x
3.5	Locate and evaluate other available core samples - COMPLETED						x
*	Locate and analyze additional core data available for target area						x
3.6	Perform petrophysical analysis of well logs - BEGAN EARLY	x		x	x	x	x
*	Integrate rock property data into tasks 2, 4, 5, 6 - BEGAN EARLY		x	x	x	x	x
*	Complete report detailing character and rock properties of targeted confining lithologies						x
3.7	Prioritize rock evaluation criteria for Best Practices Manual						x
4	Characterize formation fluids to determine hydraulic isolation of target formation - $116,392						
4.1	Perform isotopic analysis - COMPLETED						x
4.2	Perform geochemical analysis - COMPLETED						x
*	Complete interpretation of formation fluid laboratory results and quick look report - COMPLETED						x
4.3	Define the hydraulic isolation of the target reservoir			x			x
4.4	Perform reaction path modeling - COMPLETED	x	x		x	x	x
*	Creation of reaction path model - COMPLETED						x
*	Describe water quality parameters needed for water-treatment facilities of the produced water - COMPLETED						x
4.5	Evaluate geochemical reactions associated with seal failure		x		x	x	x
*	Evaulation of water/rock interactions for various seal failure scenarios						x
*	Isotopic analyses of the formation fluid and quick look report						
4.6	Evaluate techniques for use in Best Practices Manual	x	x		x	x	x
5	Simulations to evaluate seal integrity, injection rate, and pressure management - $139,970						
5.1	Detailed 3-D geological property models for targeted reservoir and confining formations	x	x	x	x	x	x
*	Complete construction of detailed 3-D geological property models and quick look report - COMPLETED						x
5.2	Performance assessments of diverse injection scenarios	x	x	x	x	x	x
*	Create performance assessments of diverse injection scenarios						x
5.3	Evaluate the importance and effects of numerical simulation parameters - BEGAN EARLY	x	x	x	x	x	x
*	Prioritize importance and effects of parameters for numerical simulation						x
5.4	Best Practices Manual for numerical simulations of CO2 storage	x	x	x	x	x	x
6	Simulations of formation brine production to assess wellbore scaling/well integrity and surface treatment - $142,872						
6.1	Simulate and evaluate wellbore scaling issues		x	x	x		x
6.2	Evalute the effects of brine chemistry on well construction and casing integrity		x	x	x		x
*	Complete geochemical model of formation fluids under various constraints						x
6.3	Evaluate the effects of brine chemistry on machinery associated with produced water treatment		x	x	x		x
*	Define and design best possible wellbore and water treatment facility and quick look report						x
6.4	Integrate and prioritize modeling results and design data from subtasks 6.1 - 6.3 into the Best Practices Manual		x	x	x		x
7	Rock Springs Uplift integrated geological and geophysical CO2 storage assessment						
*	List of formations for evaluation - COMPLETED						
*	Complete comprehensive strategy for the storage of CO2 in Wyoming's Paleozoic Stratigraphic Section	x	x	x	x	x	x

* Denotes milestone
Red bar denotes completed tasks/subtasks
Yellow bar denotes continuing progress through December 31, 2013
Green bar denotes tasks/subtasks began earlier than scheduled and continuing progress of those tasks.

Bibliography

21st Annual Geological Society of America – Denver, CO – October 2013

Abstracts presented:

An Integrative Strategy to Increase the Economic Feasibility of CO2 sequestration: Mining Brines from Saline Storage Reservoirs

Geochemical evolution of deep saline brines from Paleozoic reservoirs in southwest Wyoming; implications for potential CO2 sequestration

Thirteenth Annual Carbon Capture, Utilization and Storage Conference – Pittsburgh, PA – April 2014

Abstracts presented:

Geologic Controls on Sealing Capacity; Defining Heterogeneity Relative to Long-Term CO_2 *Storage Potential in Wyoming*

The Geochemical Characterization of Reservoir Fluids: Defining the Fluid and Rock System and Identifying Changes to Baseline Conditions Due to Well Completion

Geologic and Stratigraphic Characteristics of Multiple Stacked Sealing Formations at the Rock Springs Uplift, Wyoming