

Optimizing accuracy of determinations of CO₂
storage capacity and permanence, and designing
more efficient CO₂ storage operations:
An example from the Rock Springs Uplift, Wyoming

DOE Project DE-FE0009202

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Developing the Technologies and
Infrastructure for CCS
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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 CO₂-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.

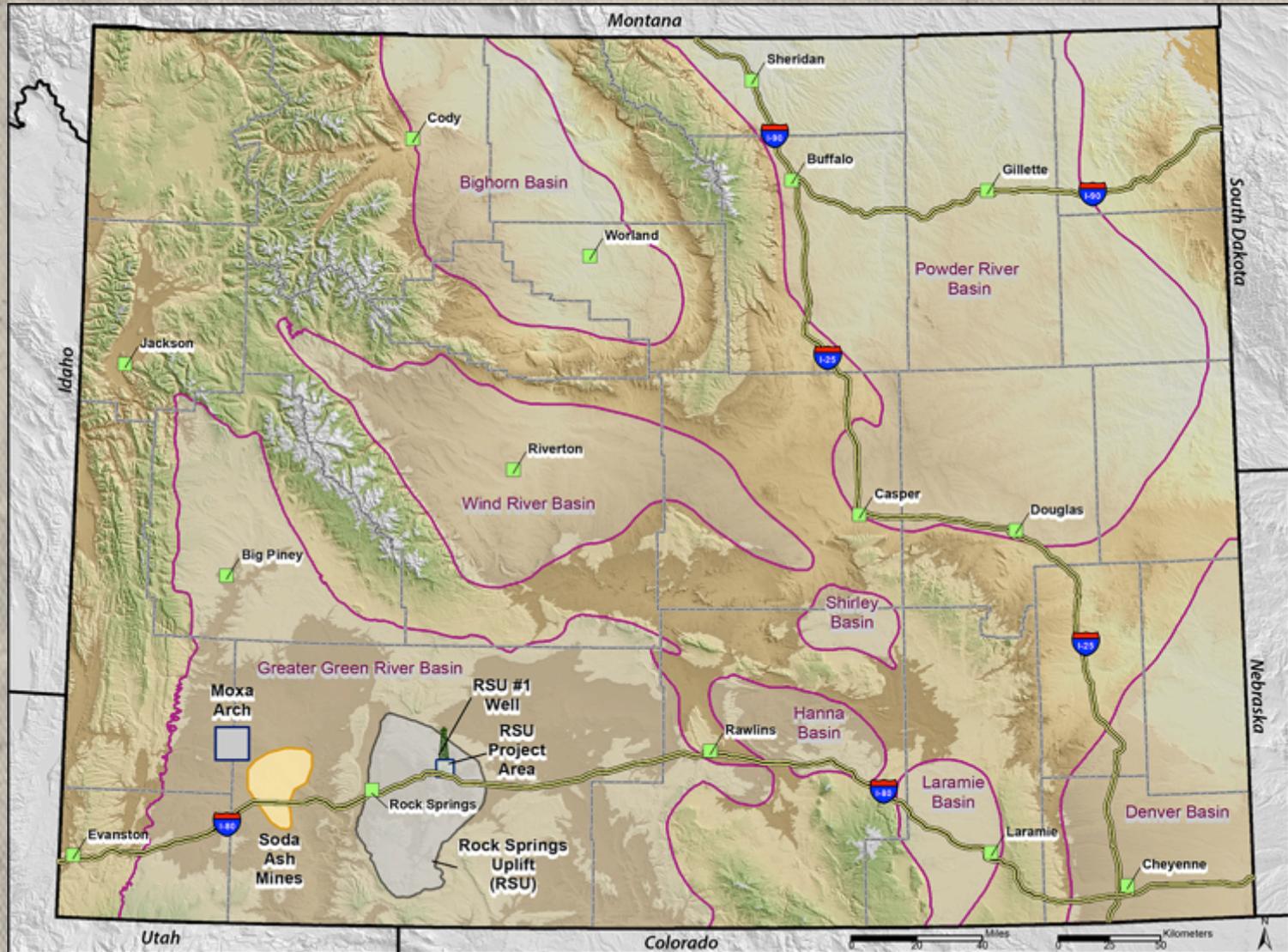
Project Overview: Goals and Objectives

The objectives for the proposed work are as follows:

- 1) Reduce uncertainty in estimates of CO₂ storage capacity at the Rock Springs Uplift;
- 2) Evaluate and ensure CO₂ 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 CO₂ injection/brine production strategy.

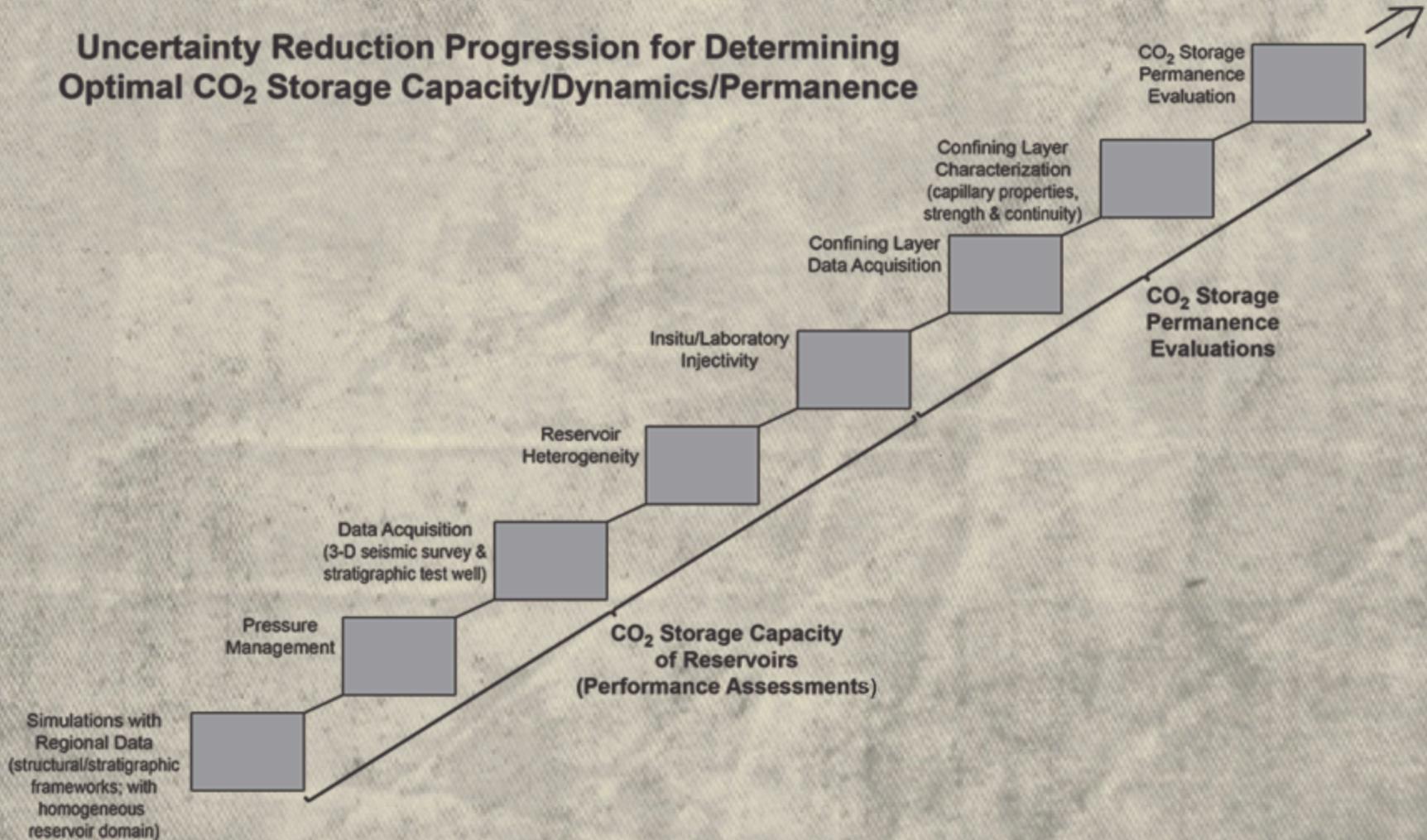
Working towards overall goal of reducing uncertainty to the lowest possible levels.

Field Site

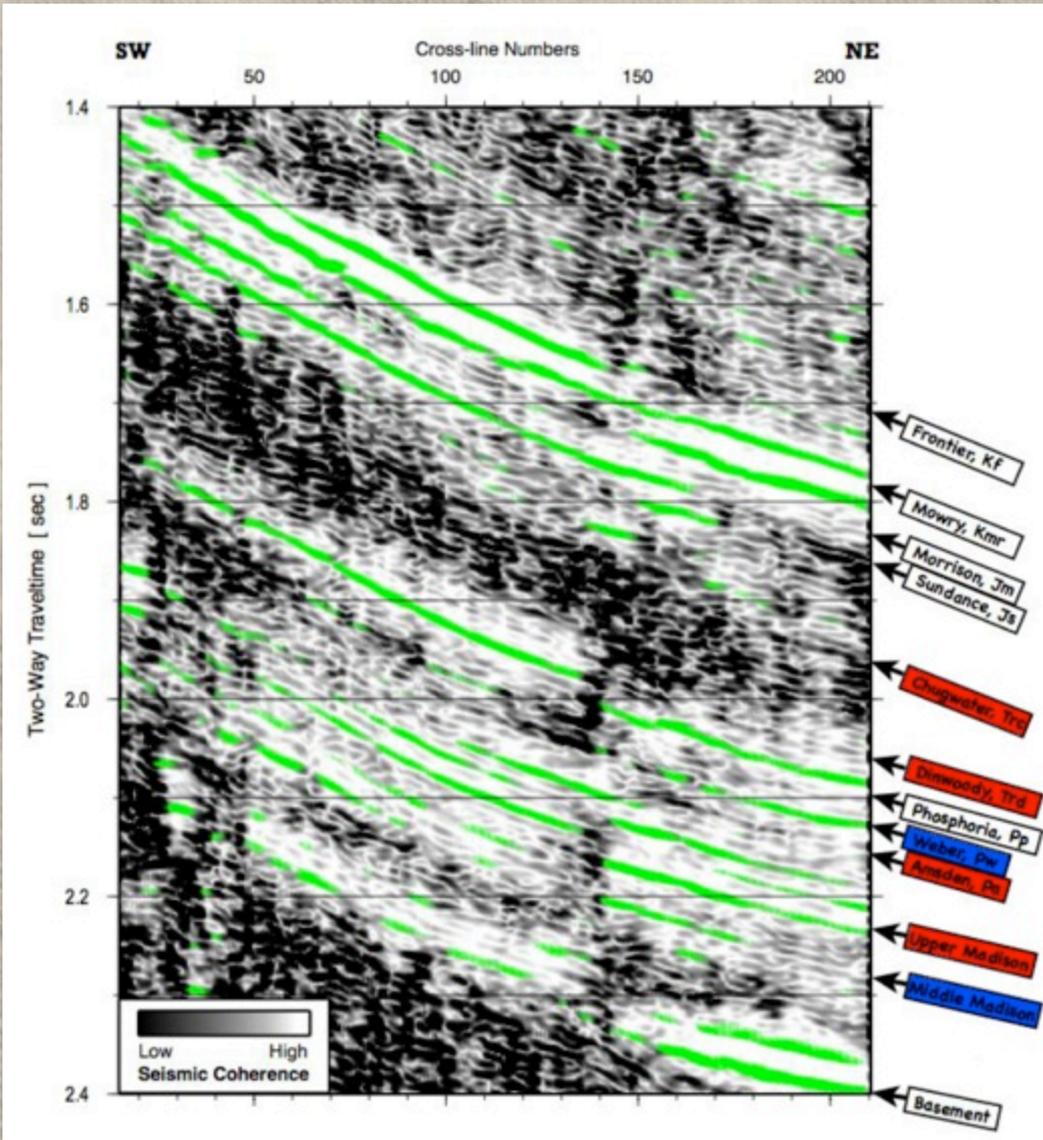


Integrated Work Flow

Uncertainty Reduction Progression for Determining Optimal CO₂ Storage Capacity/Dynamics/Permanence

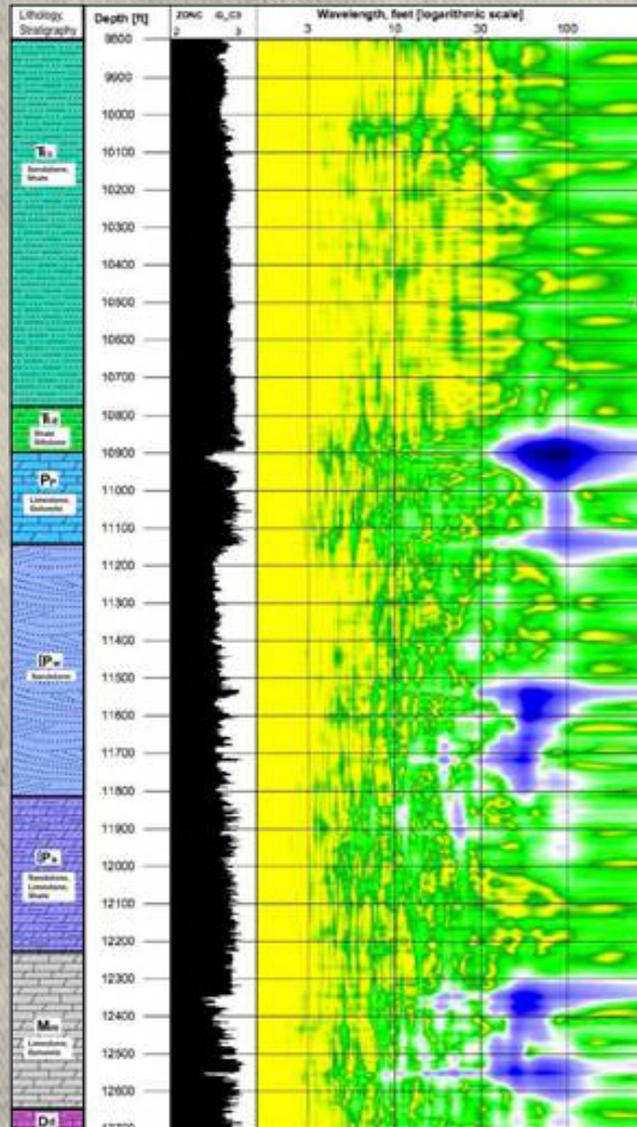


Task 2.0 – Seismic Interpretation and Characterization



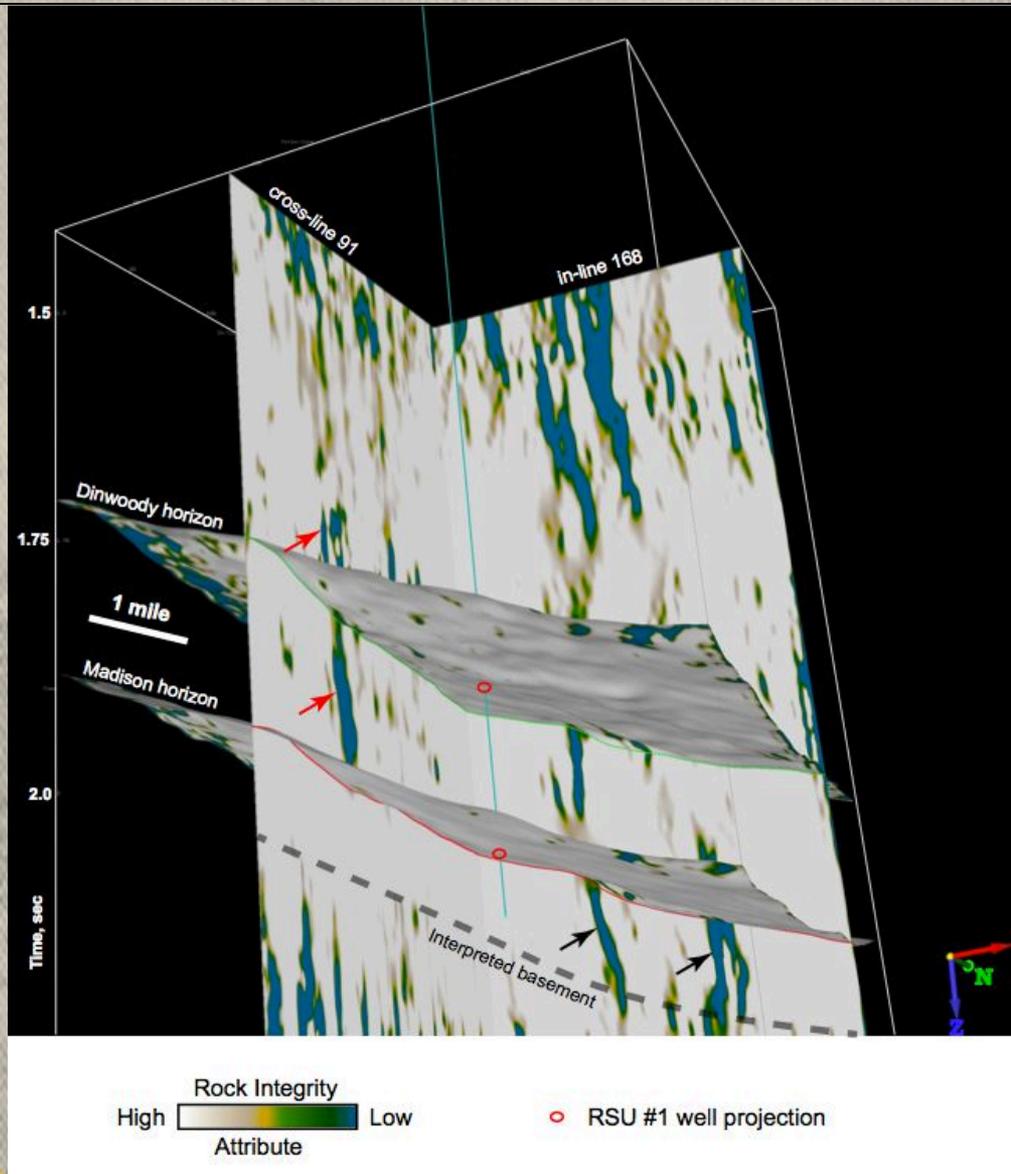
- SW-NE section
- Targeted seals (red), targeted reservoirs (blue)
- Coherency volume (energy-normalized amplitude gradients)
- Interpreted seismic reflections (green)
- Note discontinuities (dark colored)

Task 2.0 – Seismic Interpretation and Characterization



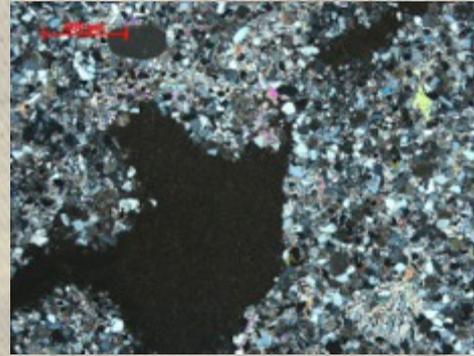
- New Rock Integrity Seismic Volume Analysis.
- Integrates petrophysical, geological, and seismic data.
- Note heterogeneous behavior (multiple amplitude bursts at different scales) below confining layers (10,900+ feet depth) and relatively homogeneous and low-amplitude spectra within sealing sequence.

Task 2.0 – Seismic Interpretation and Characterization



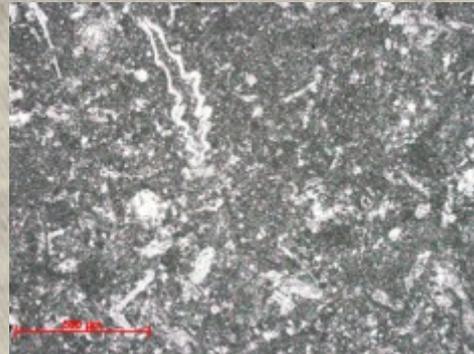
- Two orthogonal vertical sections and two horizon slices of the Madison and Dinwoody formations using Rock Integrity attribute (view from the southeast).
- Red arrowheads indicate a vertical feature that originates at top of the Madison reservoir and into the Dinwoody horizon.
- Basement-rooted faults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

Task 3.0 – Geological Characterization



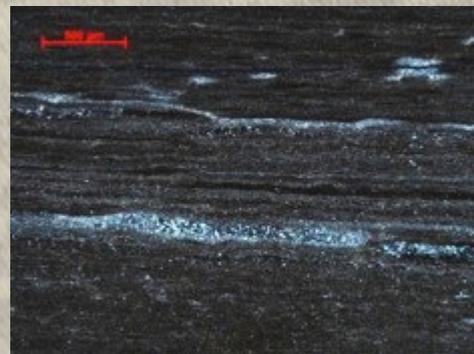
Lower Triassic Units

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



Amsden Formation

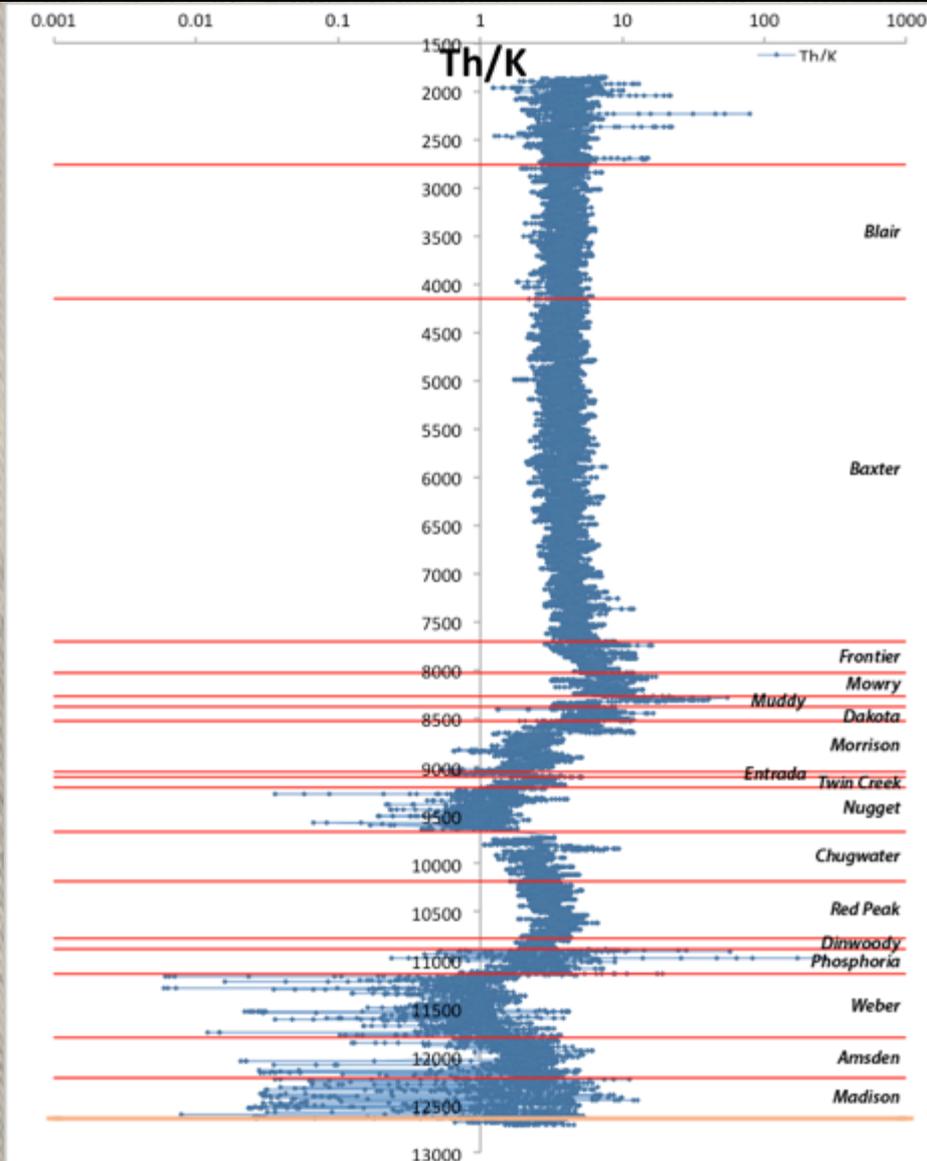
- Heterogenic
- Highly altered post-burial



Madison Limestone

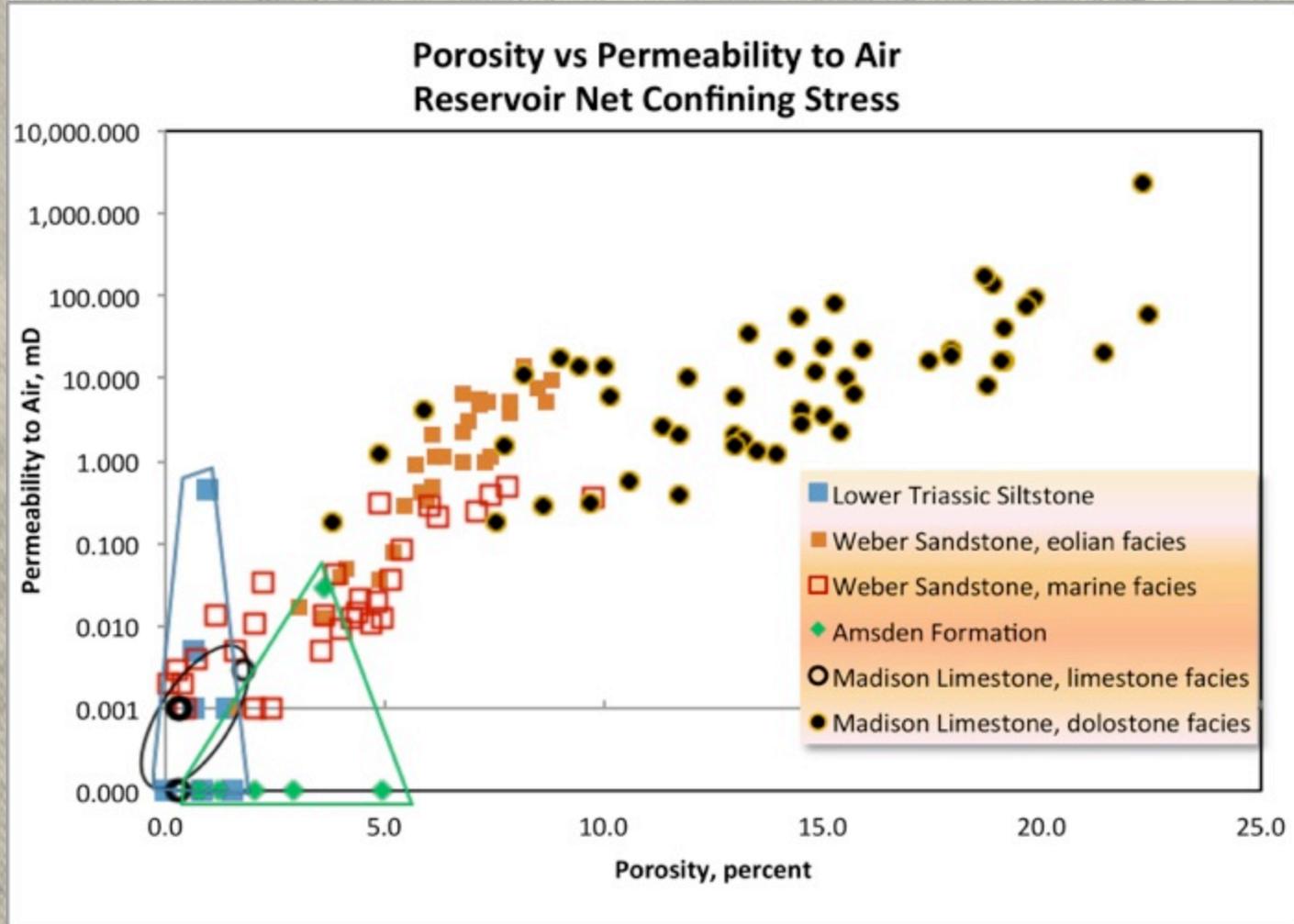
- Mostly primary textures
- Post-burial dissolution

Task 3.0 – Geological Characterization



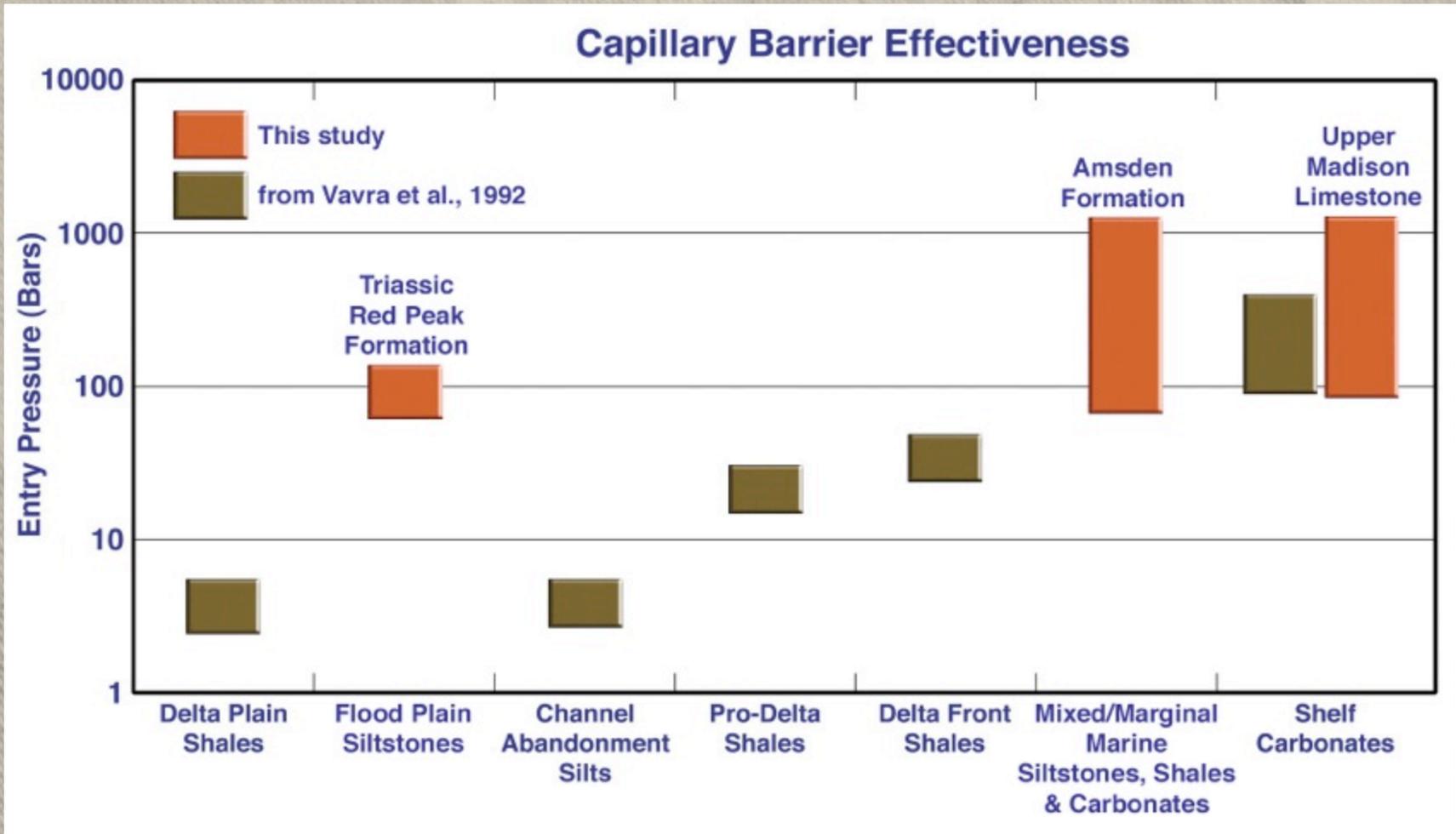
- Thorium/potassium spectral log data by depth and formation.
- Cretaceous shales are uniformly consistent.
- Decreased Th/K ratio consistent with clay diagenesis (> illite, etc. at depth).
- Amsden Formation is relatively heterogenous.

Task 3.0 – Geological Characterization

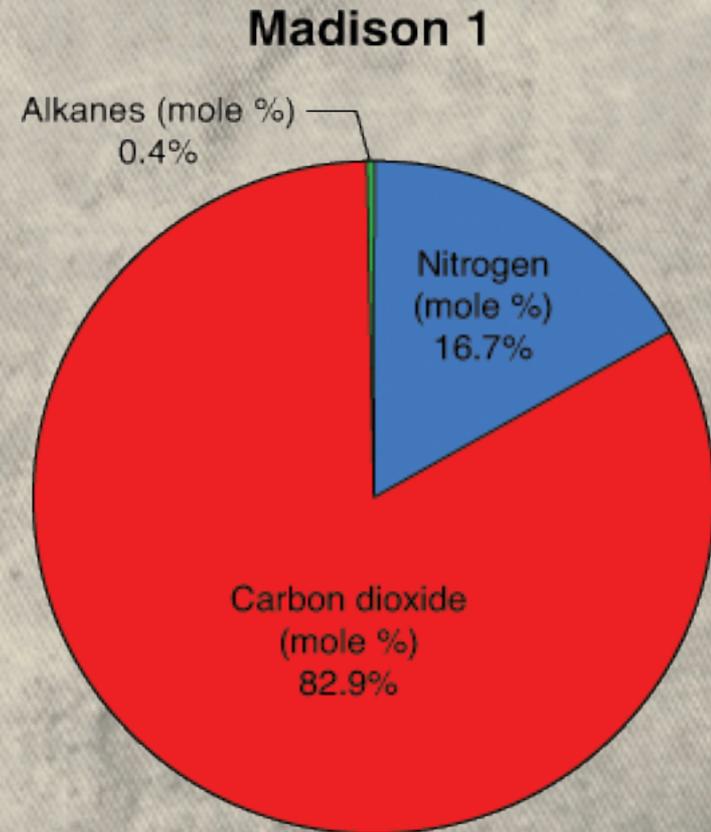
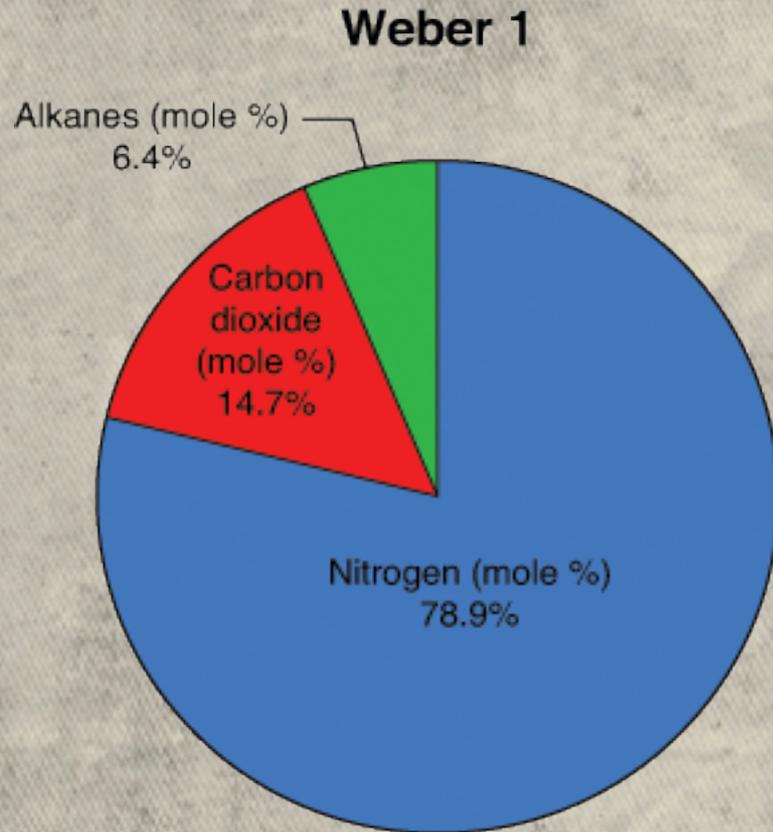


Task 3.0 – Geological Characterization

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



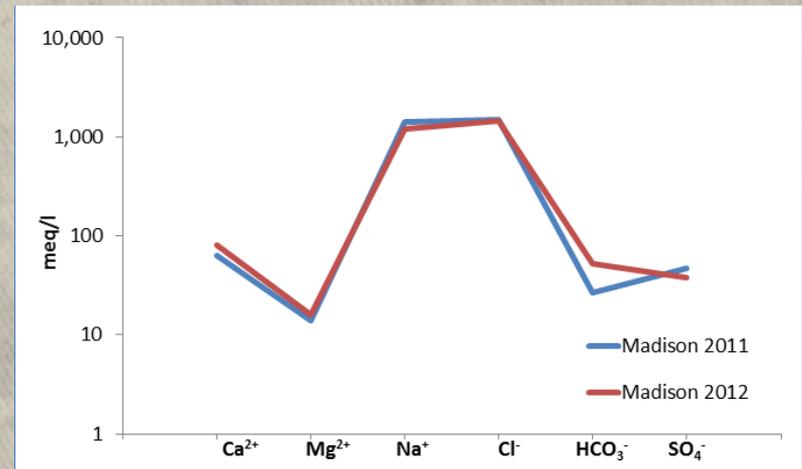
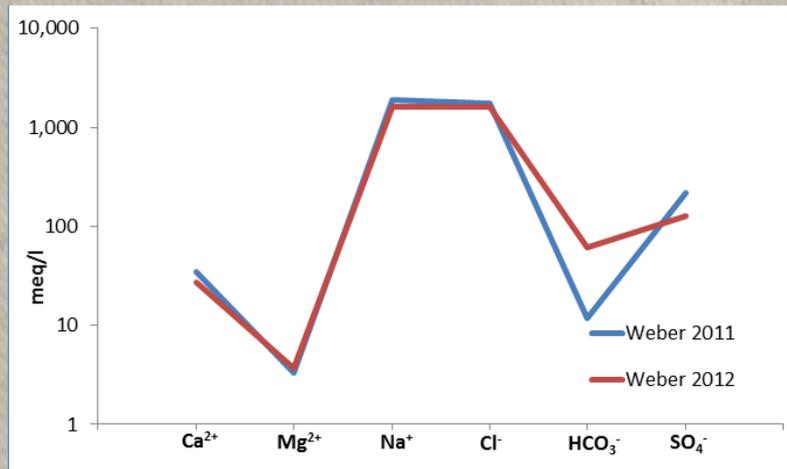
Task 4.0 – Geochemical Models and brine chemistry interactions



Gas composition of reservoir brines.

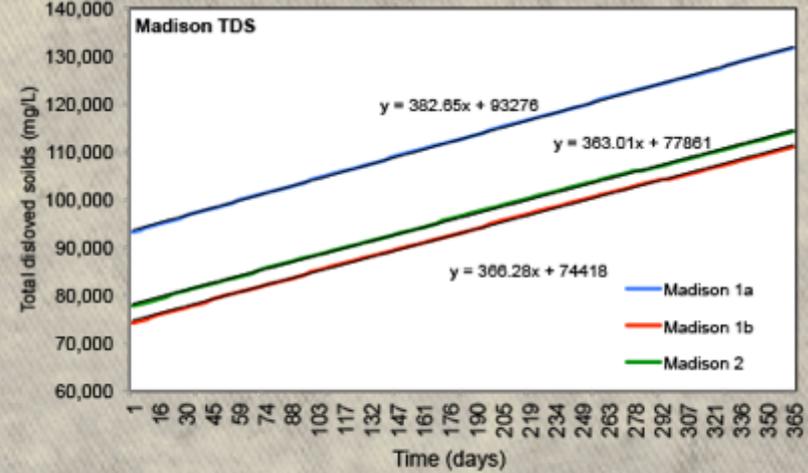
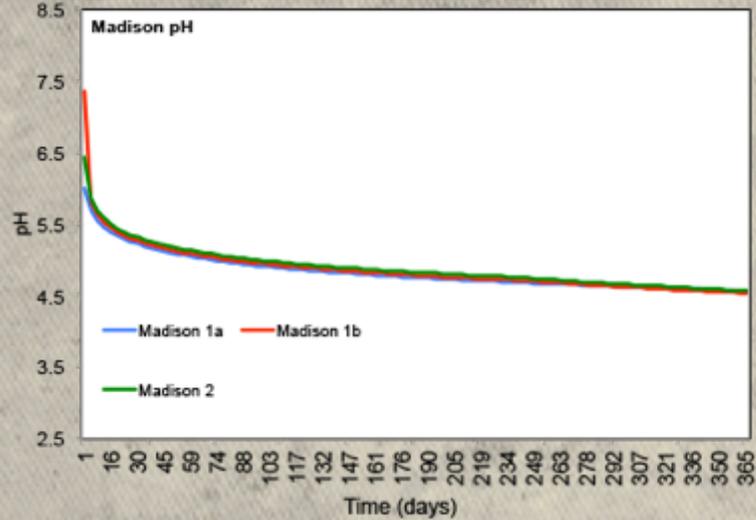
Task 6.0 – Optimized water production engineering

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

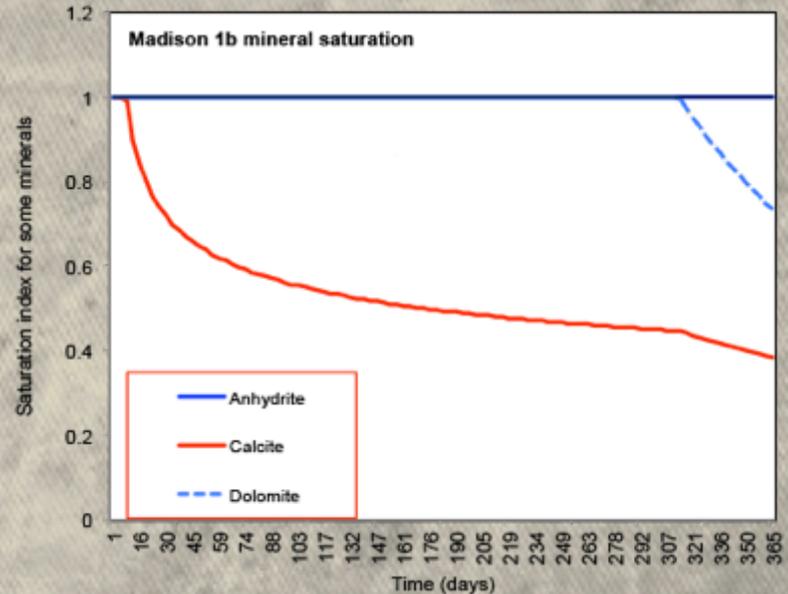


- This suggests that in-situ well site operations can alter fluid chemistry, and possibly “corrupt” geochemical fluid reaction models and well design schematics. *Careful analysis must be made of all retrieved fluids.*

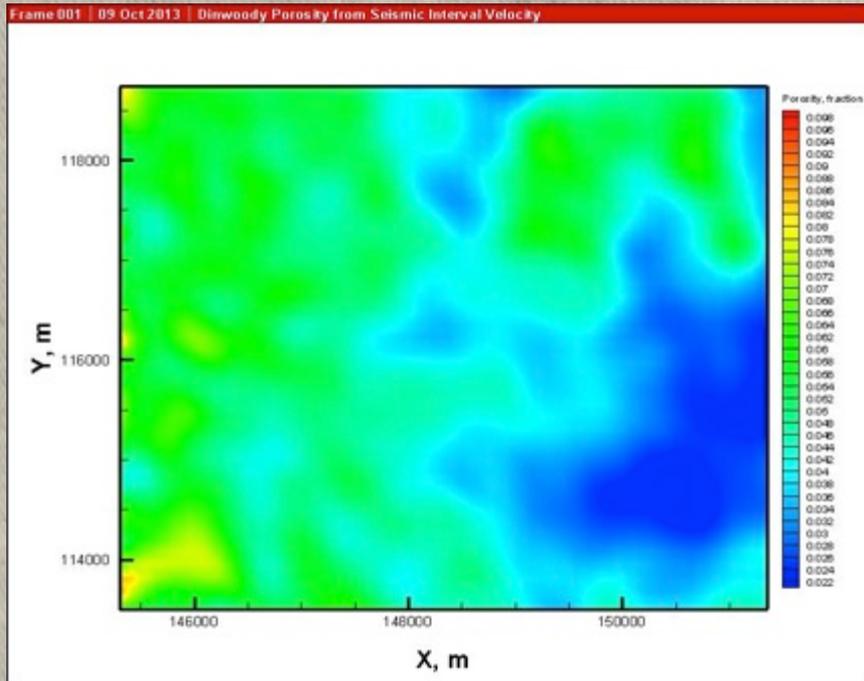
Task 4.0 – Geochemical Models and brine chemistry interactions



Modeled response of reservoir fluids during simulated CO₂ injection.

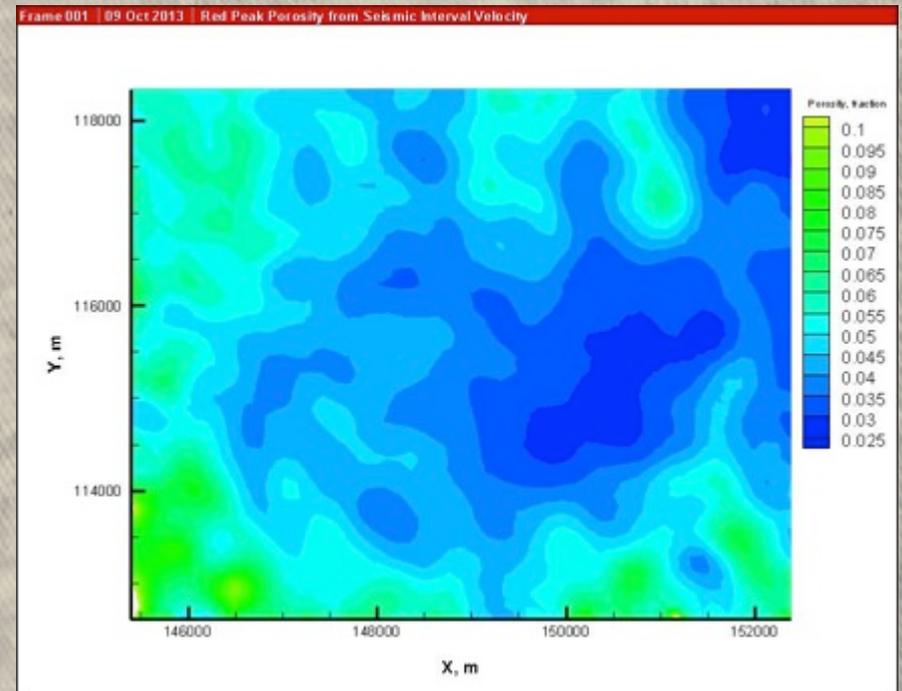


Task 5.0 – Modeling and injection simulations



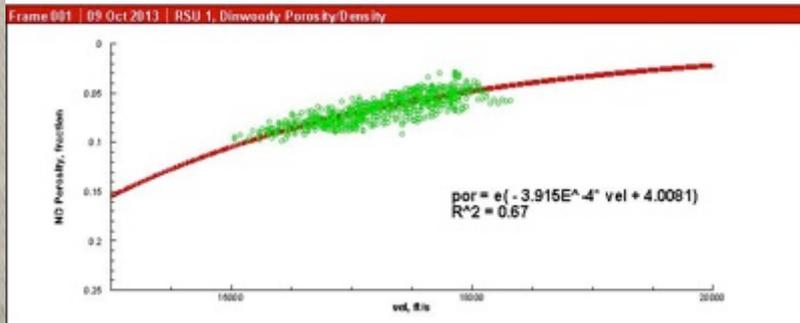
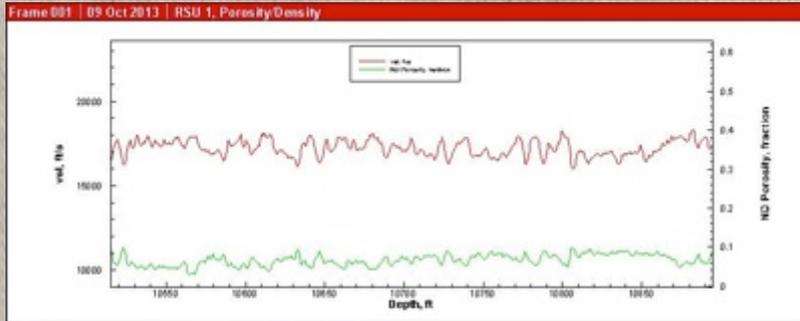
- Contour map of the porosity distribution of the Dinwoody Formation.
- Porosity ranges from 1% to 10%, with a mean of 4.5%.

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

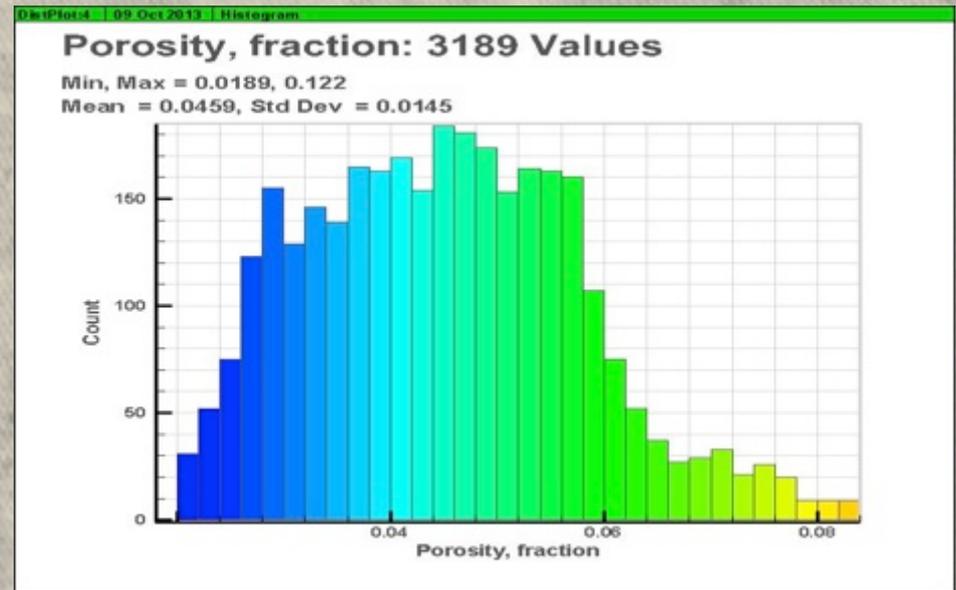


Task 5.0 – Modeling and injection simulations

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

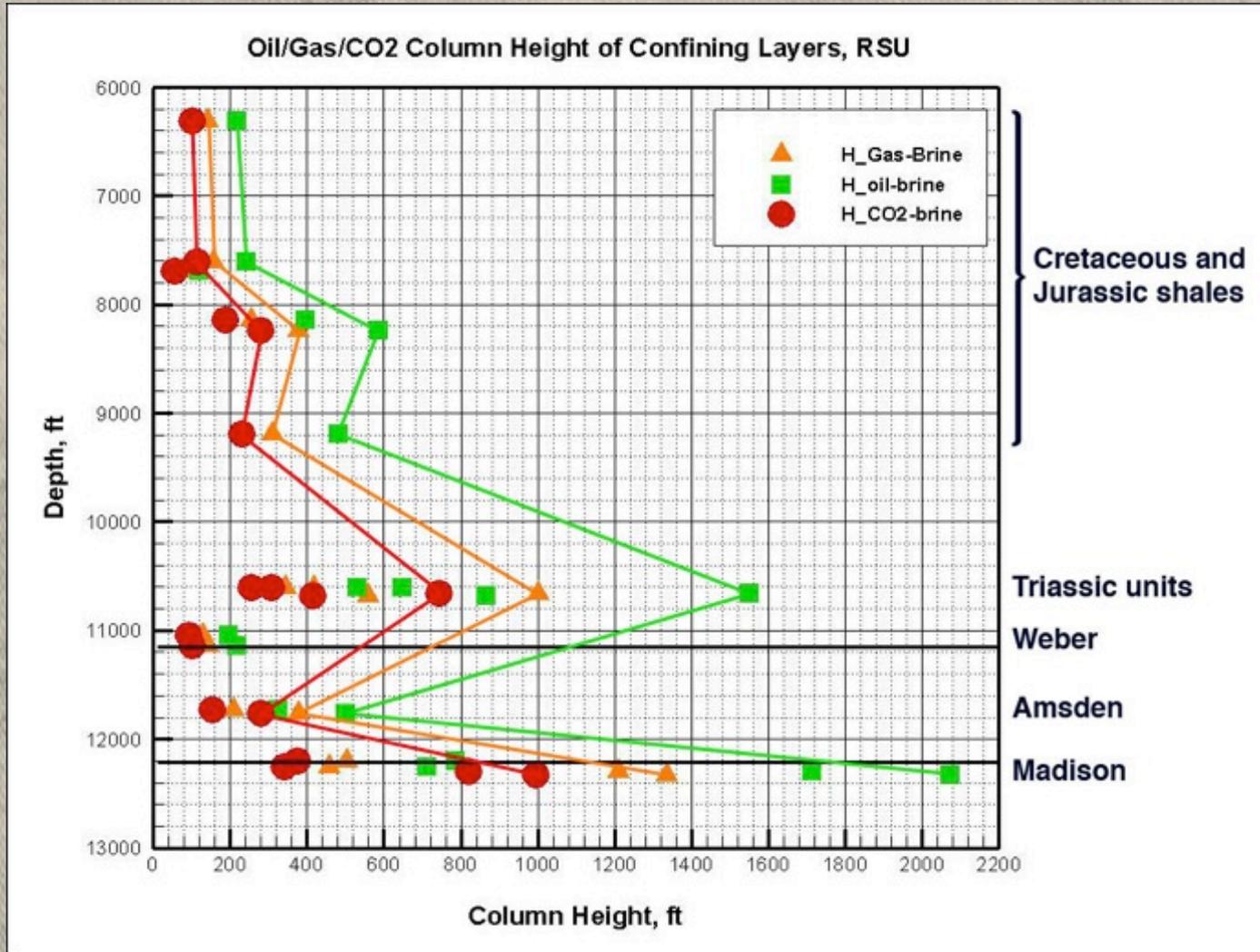


Porosity histogram of the Dinwoody Formation based on functions derived from neutron-density and sonic logs.



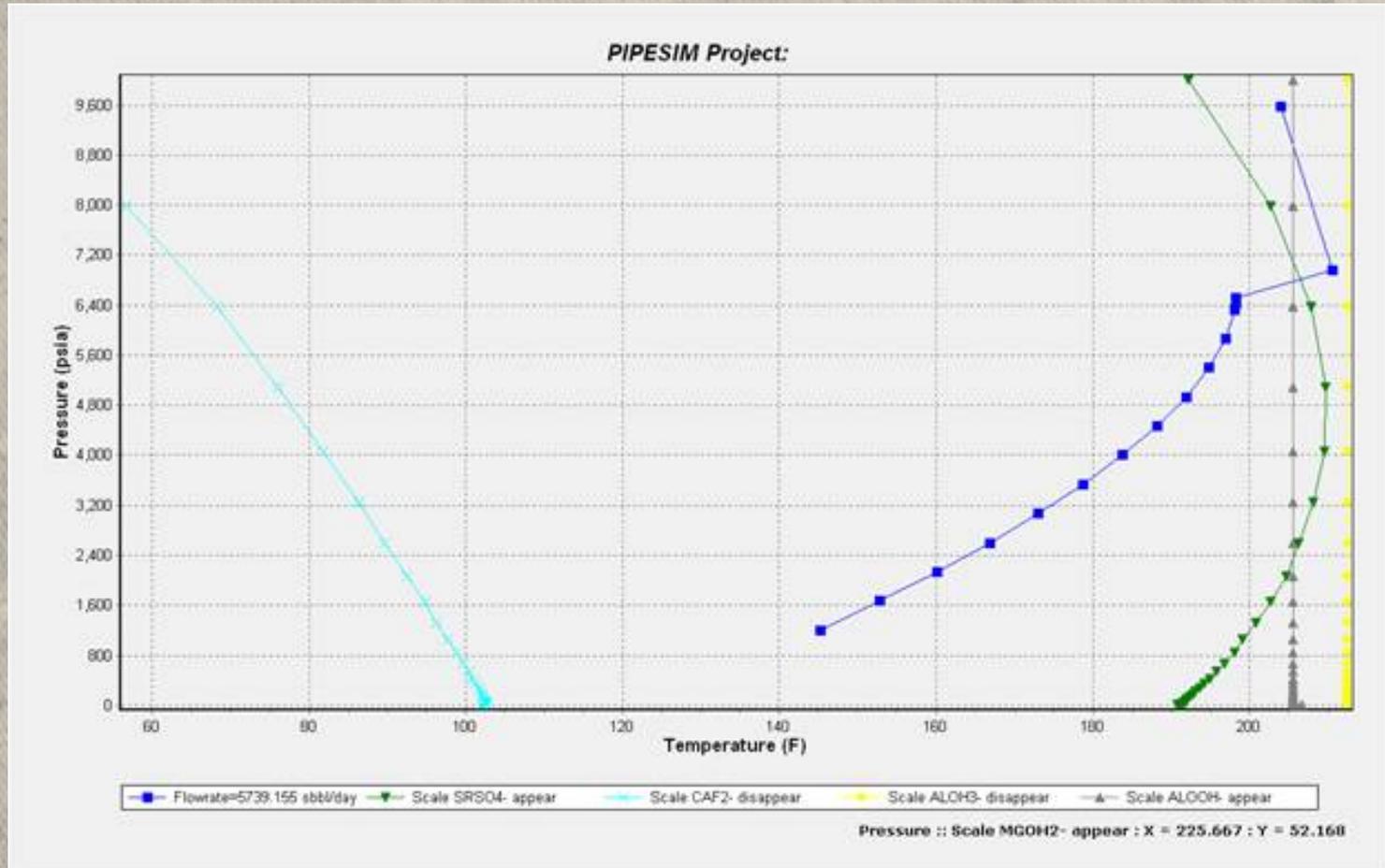
Task 5.0 – Modeling and injection simulations

Column height calculations; reassessing the CO₂-H₂O-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-CO₂ interactions will dissolve mineral cements.*
- *Calculations based on high-pressure mercury injection, interfacial tension, and wettability data suggest that sealing capacity of a CO₂-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.

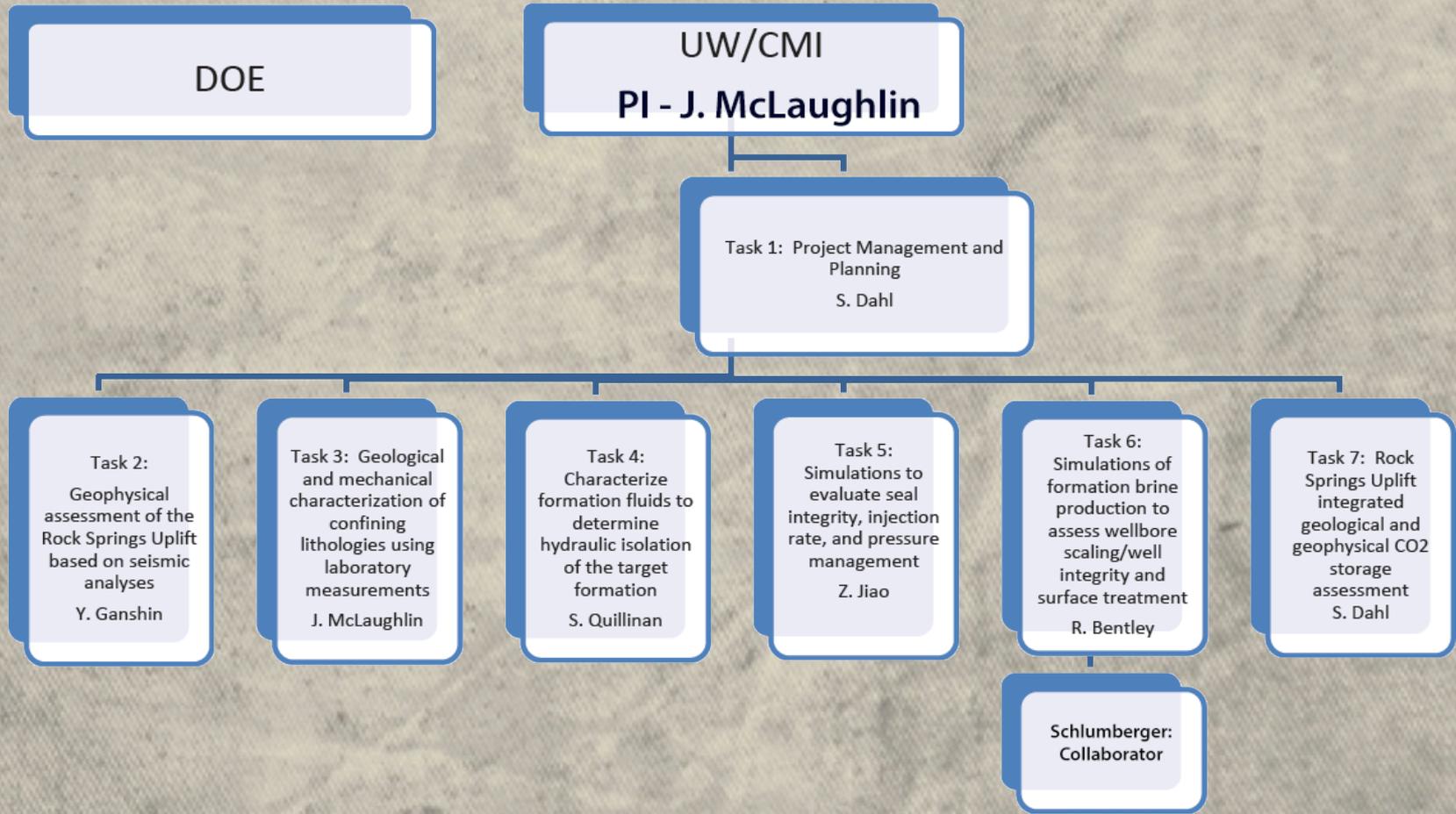
Acknowledgements

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Appendix

- Organization chart
- Gantt chart
- Bibliography

Organization Chart



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 CO₂ 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