The WY-CUSP Program

WORKING TO DELIVER A CERTIFIED COMMERCIAL CO_2 STORAGE SITE TO WYOMING

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University of Wyoming School of Energy Resources

Partners and contributors

- Thank you to the crew from Baker Hughes, Inc., including Paul Williams, Sam Zettle, Dana Dale, and Danny Dorsey.
- TRUE Drilling Co. of Casper, WY provided the large rig and an excellent drilling crew.
- The WY-CUSP characterization project is funded in part by DOE NETL (Project DE-FE0002142). CMI would like to thank DOE Project Manager Bill Aljoe.
- Other contributors include Los Alamos National Laboratory, Lawrence Livermore National Laboratory, PetroArc International, Geokinetics, EMTek, and the Wyoming State Geological Survey.

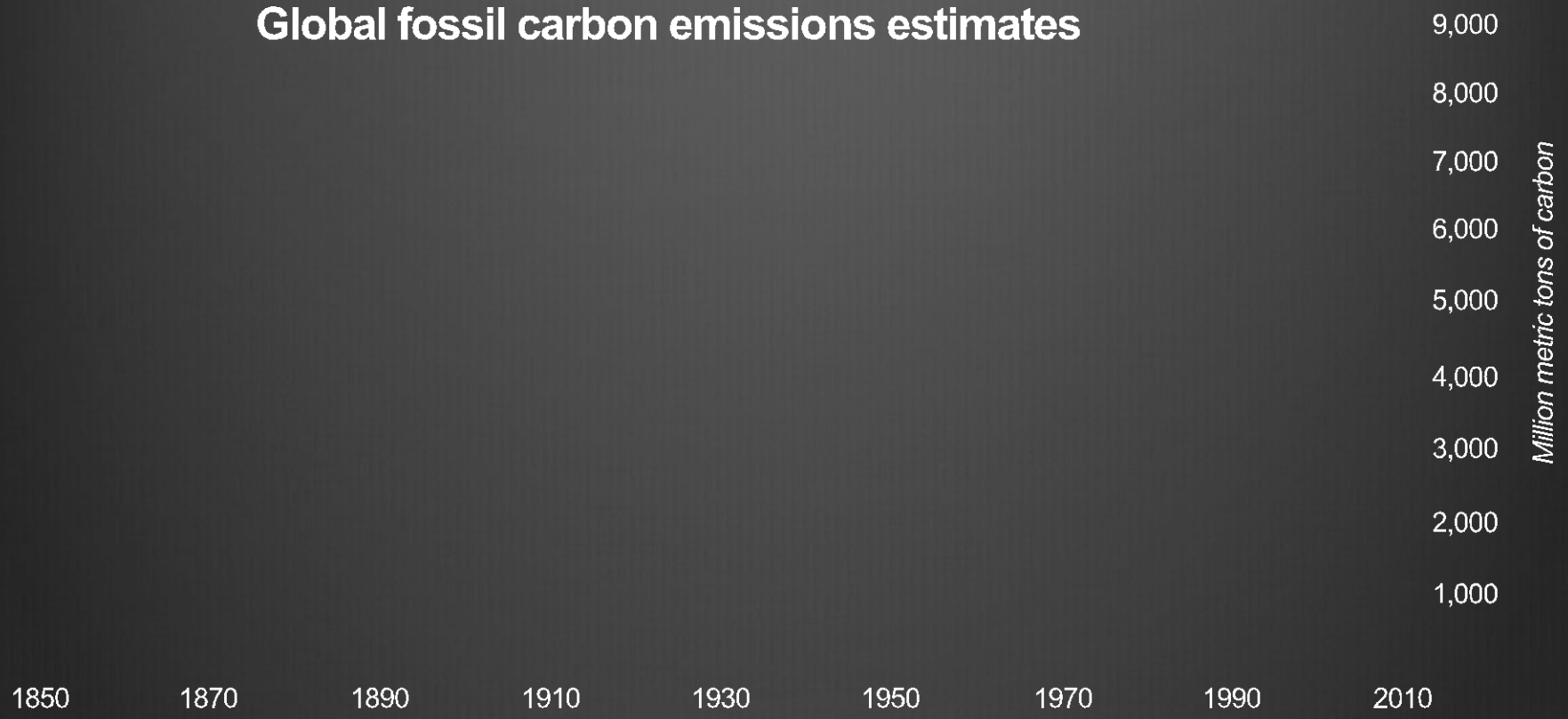
U.S. Energy Imports
2006

Rank	Country or State of Origin	Crude Oil Production Million Bbl/year	Crude Oil Quadrillion Btu	Natural Gas Production Trillion Cubic ft/year	Natural Gas Quadrillion Btu	Coal Production million tons/year	Coal Quadrillion Btu	Total Quadrillion Btu
1	Wyoming	52.93	0.28	1.75	1.77	446.74	7.96	10.01
2	Canada	648.97	3.41	3.59	3.63	1.49	0.04	7.08
3	West Virginia	1.83	0.01	0.22	0.22	152.37	3.91	4.14
4	Mexico	575.61	3.02	0.01	0.01	0.00	0.00	3.04
5	Saudi Arabia	519.40	2.73	0.00	0.00	0.00	0.00	2.73
6	Venezuela	416.83	2.19	0.00	0.00	3.07	0.08	2.27
7	Nigeria	378.51	1.99	0.06	0.06	0.00	0.00	2.05
8	Alaska	270.47	1.42	0.42	0.43	0.00	0.00	1.85
9	Iraq	201.85	1.06	0.00	0.00	0.00	0.00	1.06
10	Angola	187.25	0.98	0.00	0.00	0.00	0.00	0.98
	Total	3,253.61	17.08	6.05	6.12	603.67	11.99	35.19

Note: Total may not equal sum of components because of independent rounding.
Coal imports include coal to Puerto Rico and the Virgin Islands.

Source: Bureau of the Census, U.S. Department of Commerce, *Monthly Report IM 145.*
EIA, U.S. Natural Gas Imports by Country
EIA, U.S. Crude oil Net Imports by Country
EIA, Gross Heat Content of Coal Production, Most Recent Annual Estimates, 1980-2006

Global fossil carbon emissions estimates



Global carbon emissions over time. In 2010, carbon emissions increased by 6% to 9,139 million metric tons, the largest annual net increase to date. Note the sharp increase beginning in 2000 – this is the year emerging economies in China, India, and Brazil began contributing significantly to global carbon emissions. Modified from Oak Ridge National Laboratory Carbon Dioxide Information Analysis Center, 2011.

WY-CUSP Program Rationale

1. Protect Wyoming's coal extraction and future coal-to-chemical industries (provide storage capacity for anthropogenic CO_2)

2. Provide a source of anthropogenic CO_2 for enhanced oil recovery projects (at present rates of CO_2 production from gas processing plants, it will take 150 to 200 years to recover Wyoming's stranded oil)

3. Retrieve reservoir information essential for expansion of natural gas storage in Wyoming

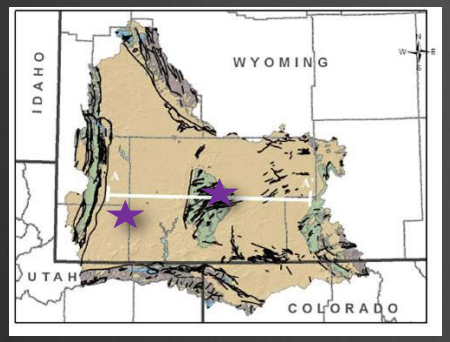
4. Establish a more robust database for two important hydrocarbon reservoirs in Wyoming (substantially reduce uncertainty for all dynamic models of Tensleep-Weber/Madison fluid-flow and rock/fluid systems)

WY-CUSP program design

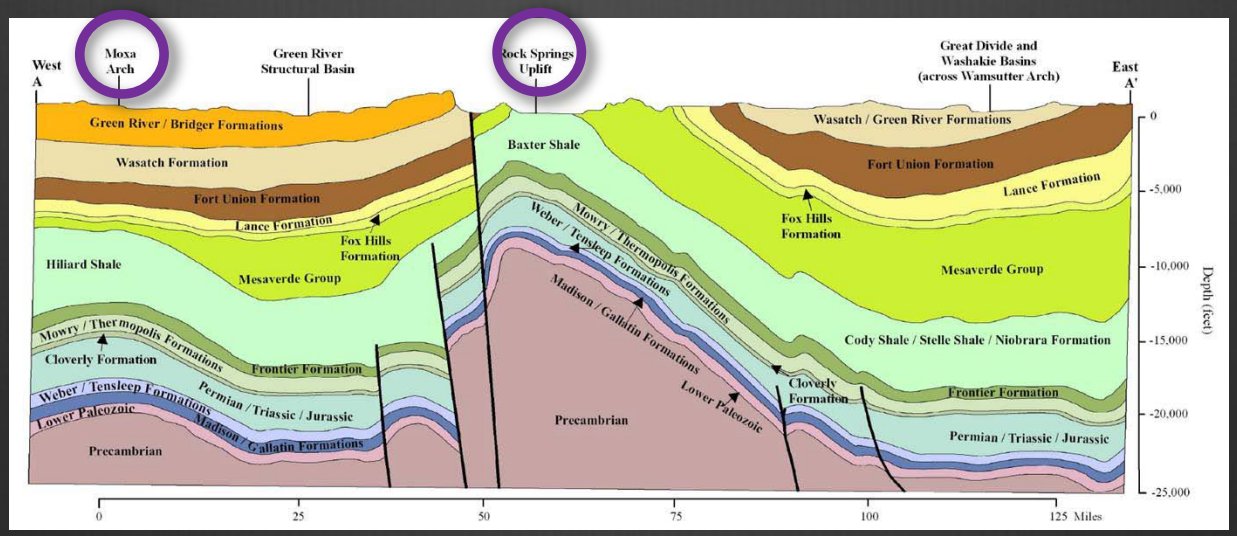
Phase I: Site characterization (i.e., data acquisition – generating a robust and complete database for the Rock Springs Uplift)

Phase II: Design, implement, and test a demonstration of commercial-scale CO_2 storage on the Rock Springs Uplift.

Carbon storage potential in southwest Wyoming



WSGS, UW, State, and DOE- funded research identified two high-capacity sites in southwest Wyoming: *Rock Springs Uplift* and *Moxa Arch*



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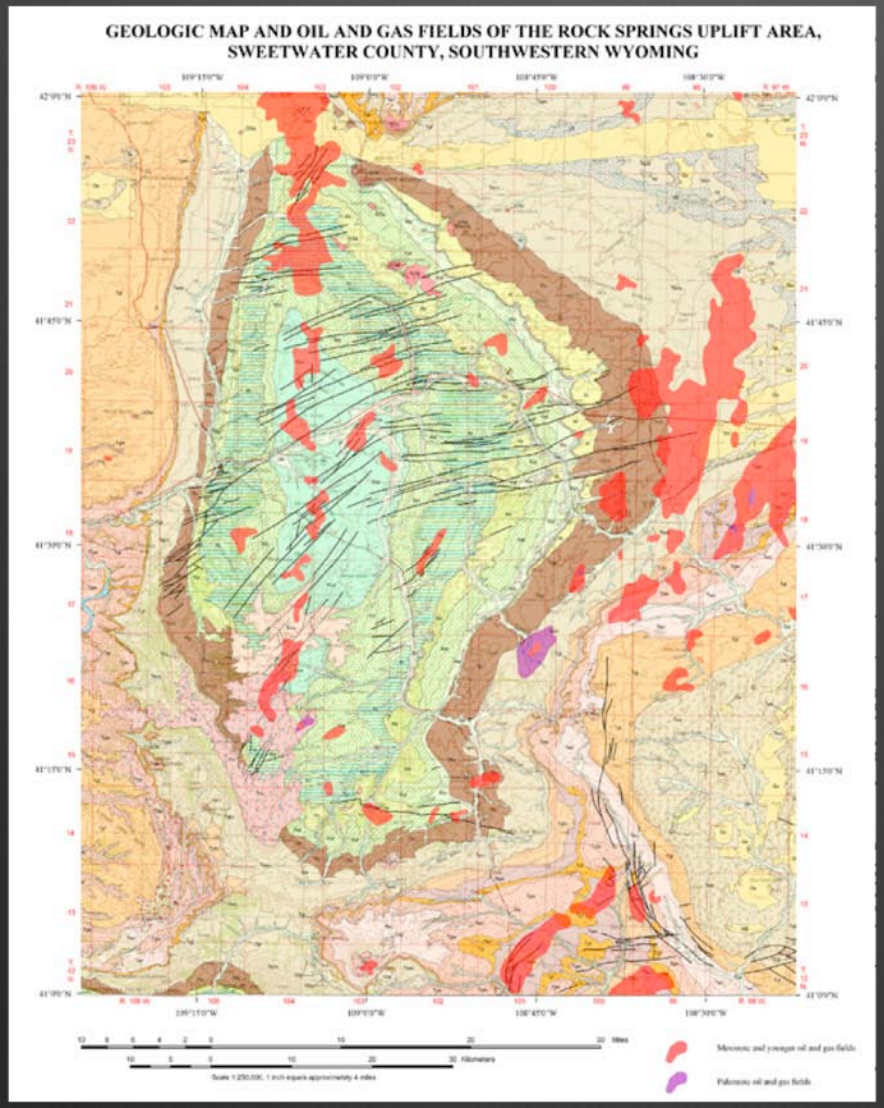
Paleozoic section



Surdam, R.C. & Jiao, Z., 2007, *The Rock Springs Uplift: An outstanding geological CO_2 sequestration site in southwest Wyoming*: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 2, 31 p.

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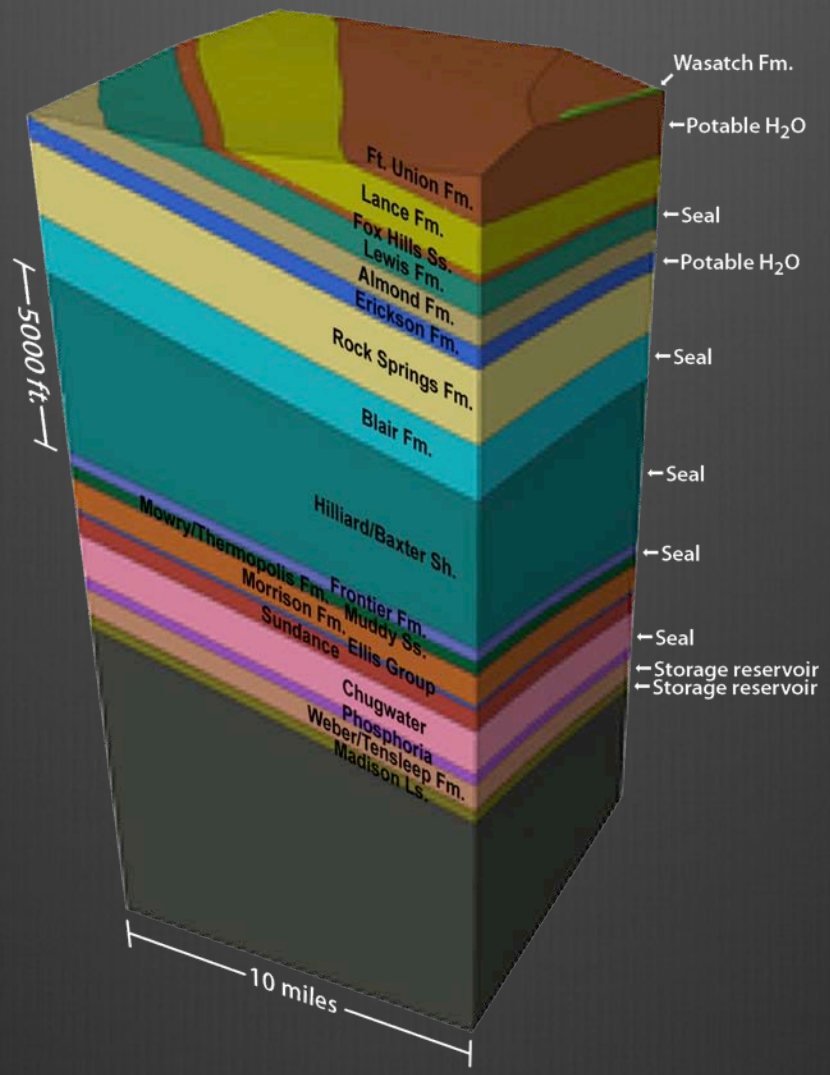
Rock Springs Uplift hydrostratigraphic system



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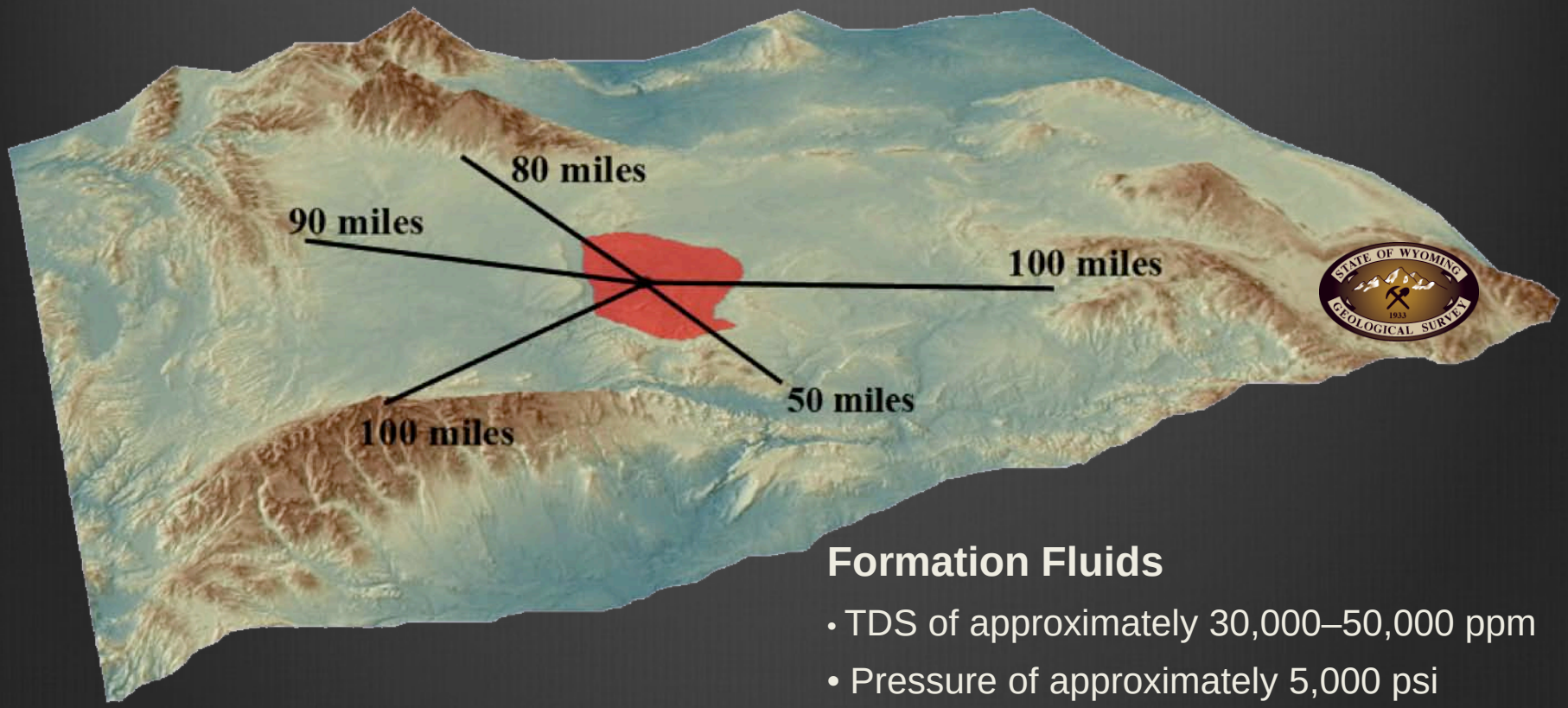
Nearest points of Weber/Madison groundwater recharge



Formation Fluids

- TDS of approximately 30,000–50,000 ppm
- Pressure of approximately 5,000 psi
- Temperature of approximately 100°C

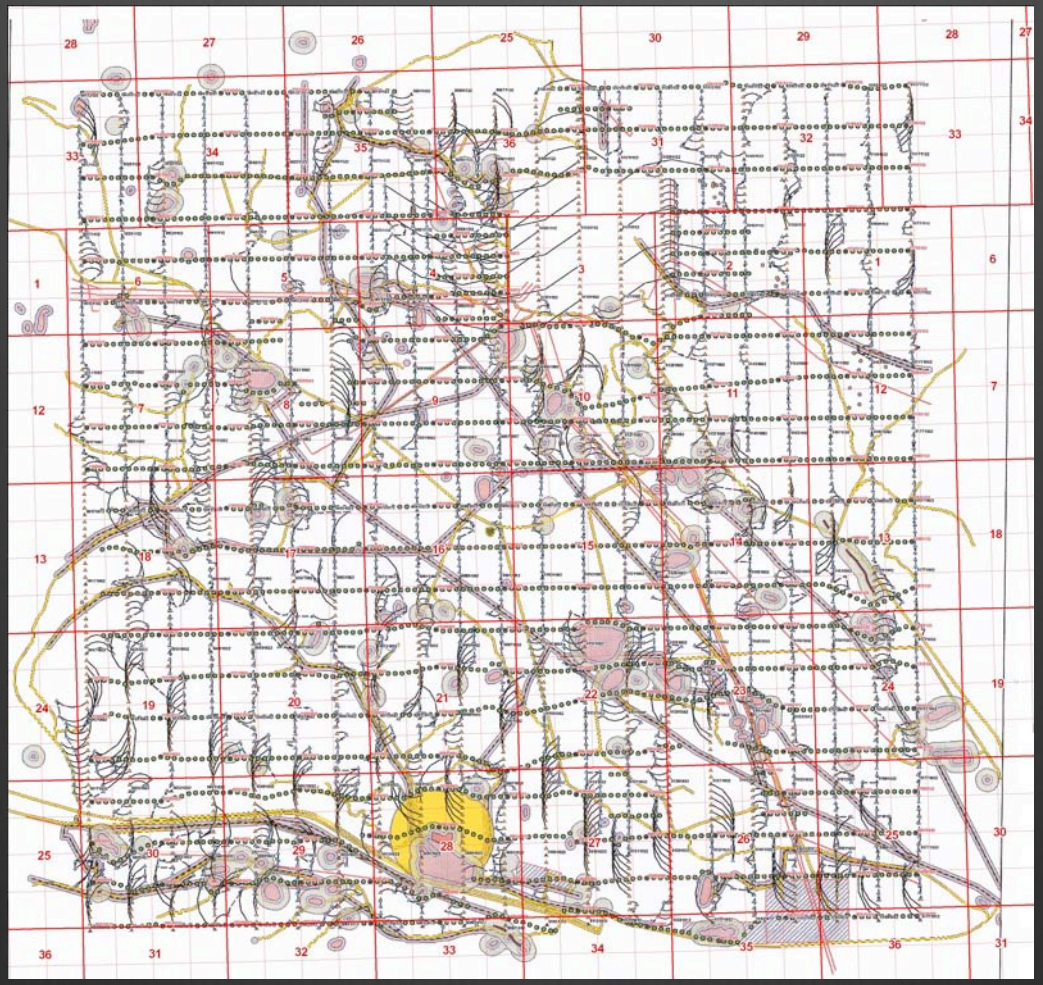
The Rock Springs Uplift: an outstanding geological CO_2 sequestration site in southwestern Wyoming

- Thick saline aquifer sequence overlain by multiple thick sealing lithologies
- Doubly-plunging anticline characterized by more than 10,000 feet of closed structural relief
- Huge area (50 x 35 miles)
- Required reservoir conditions, including, but not limited to fluid chemistry, porosity (pore space), fluid-flow characteristics, temperature and pressure (i.e., regional burial history)

Risk Reduction

The greatest uncertainty in numerically simulating CO_2 sequestration processes is characterizing geological heterogeneity in three dimensions. This uncertainty is being substantially reduced by integrating 3-D seismic techniques with stratigraphic test well observations.

Jim Bridger 3-D seismic survey, Rock Springs Uplift



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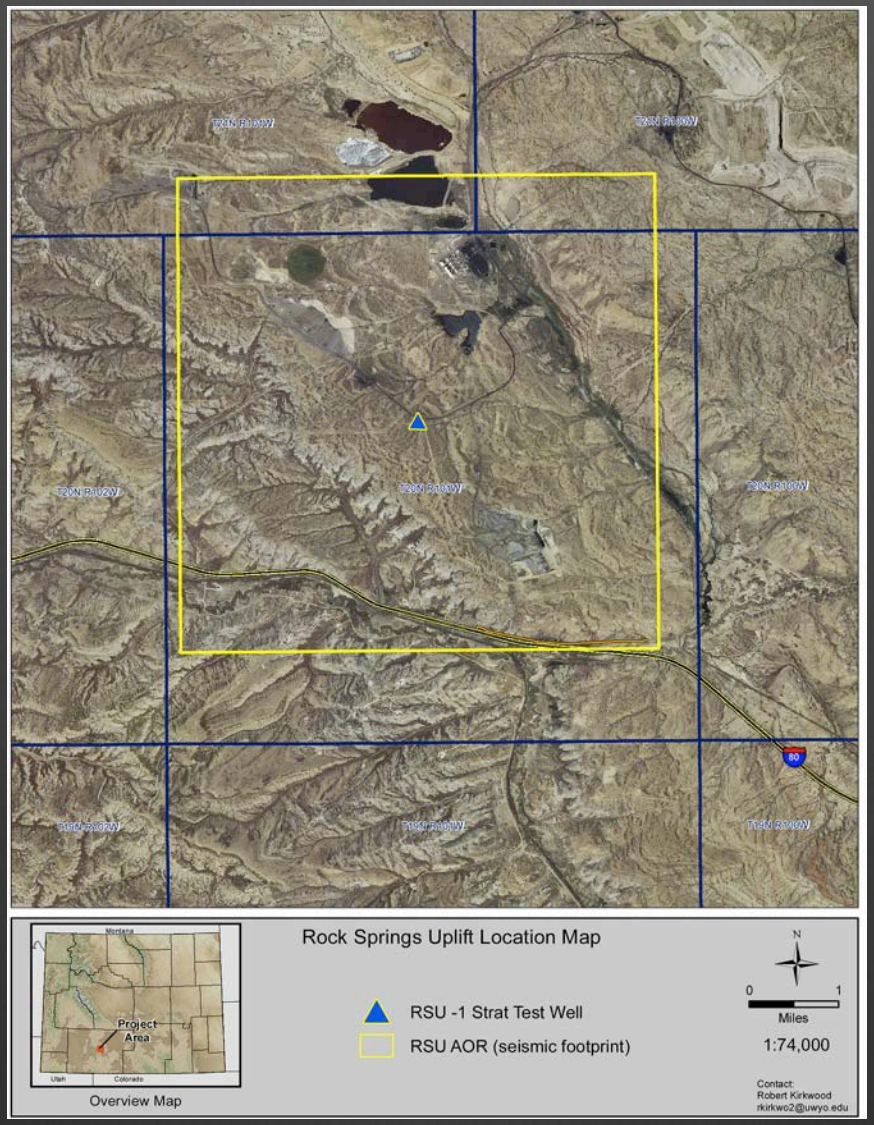

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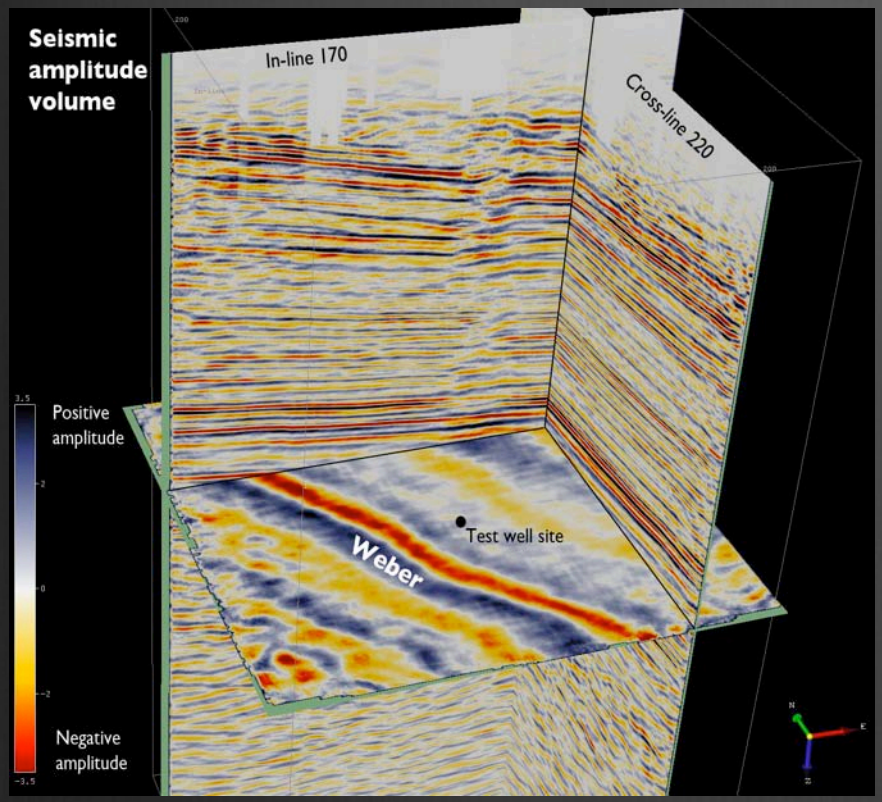
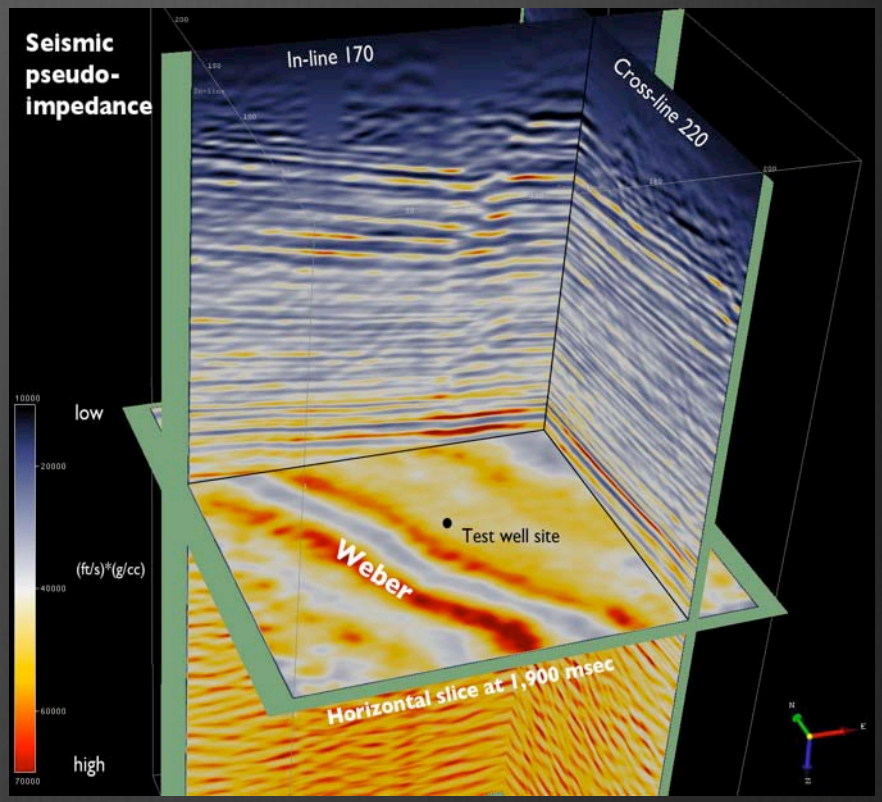
Amplitude and impedance, Weber





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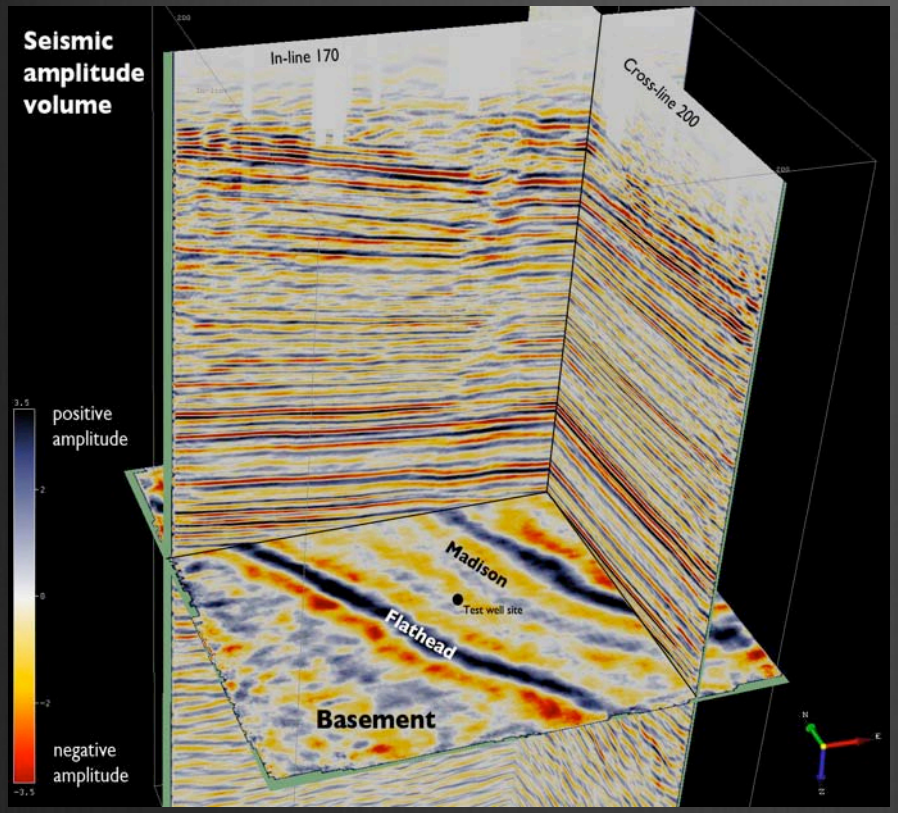
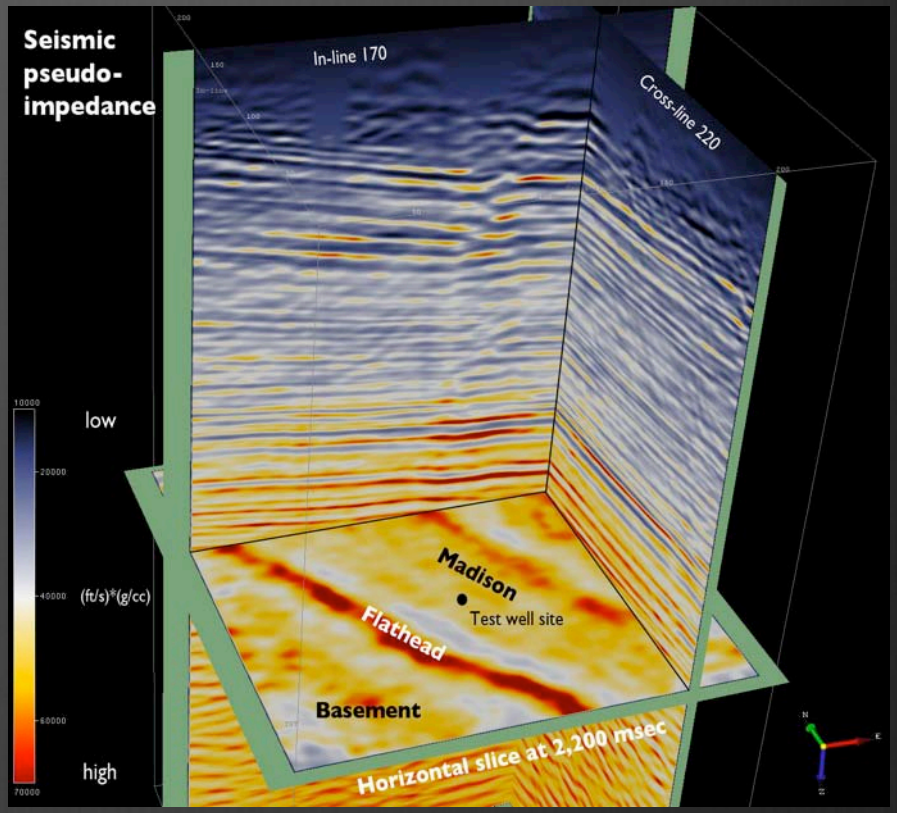
Amplitude and impedance, Madison





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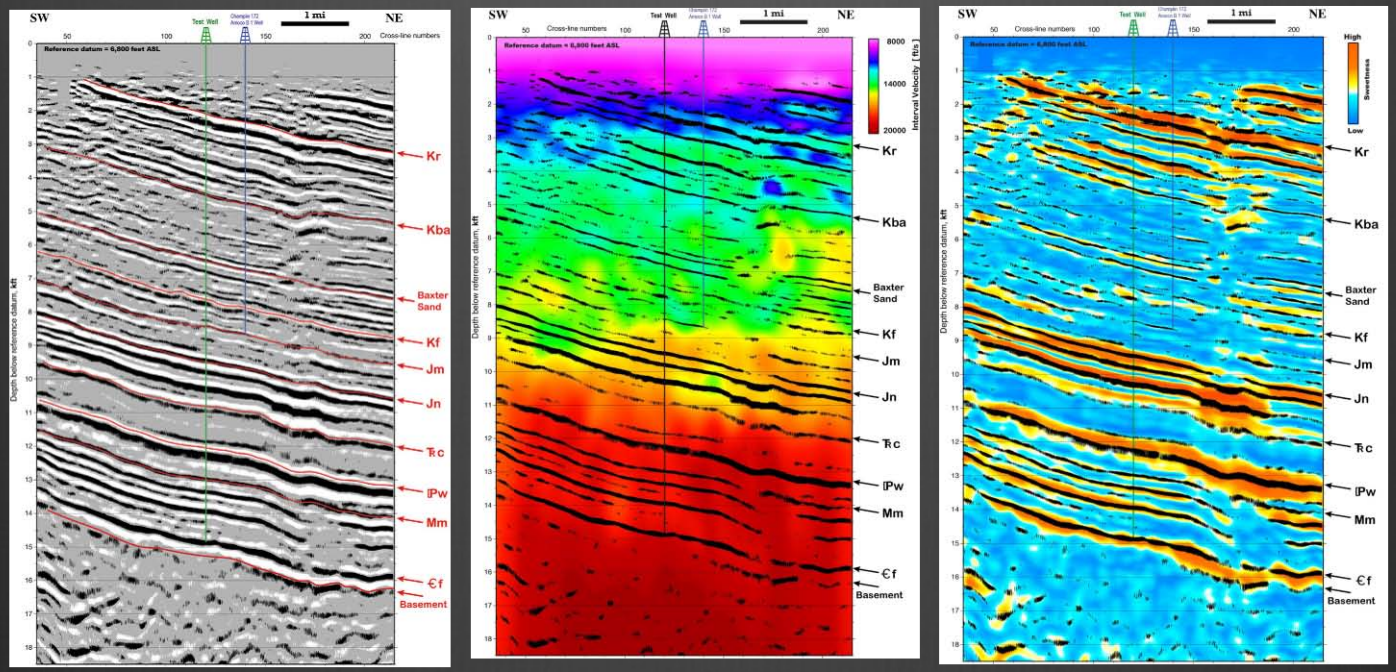
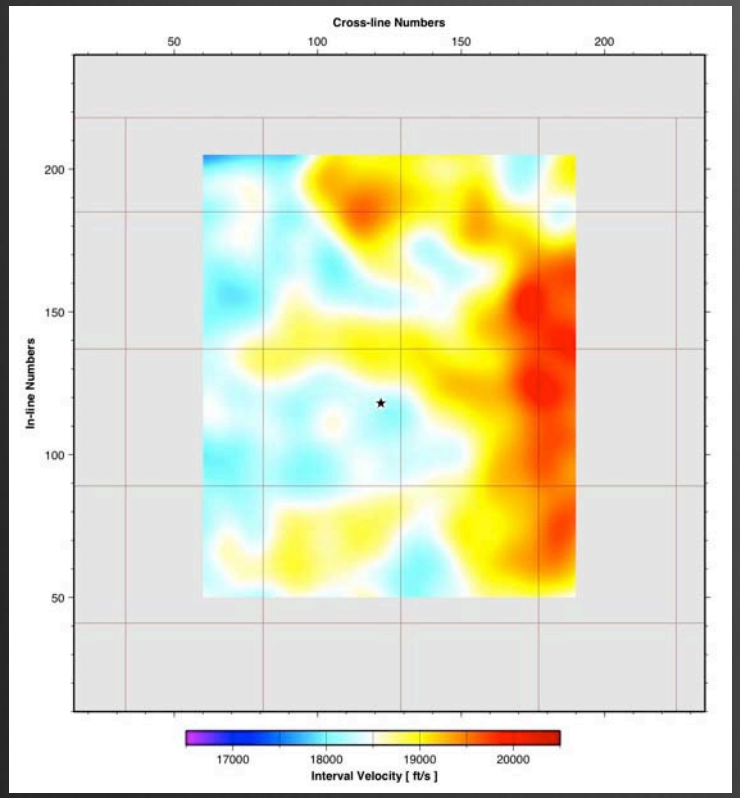
Amplitude, velocity, and lithologic delineation profiles through the test well

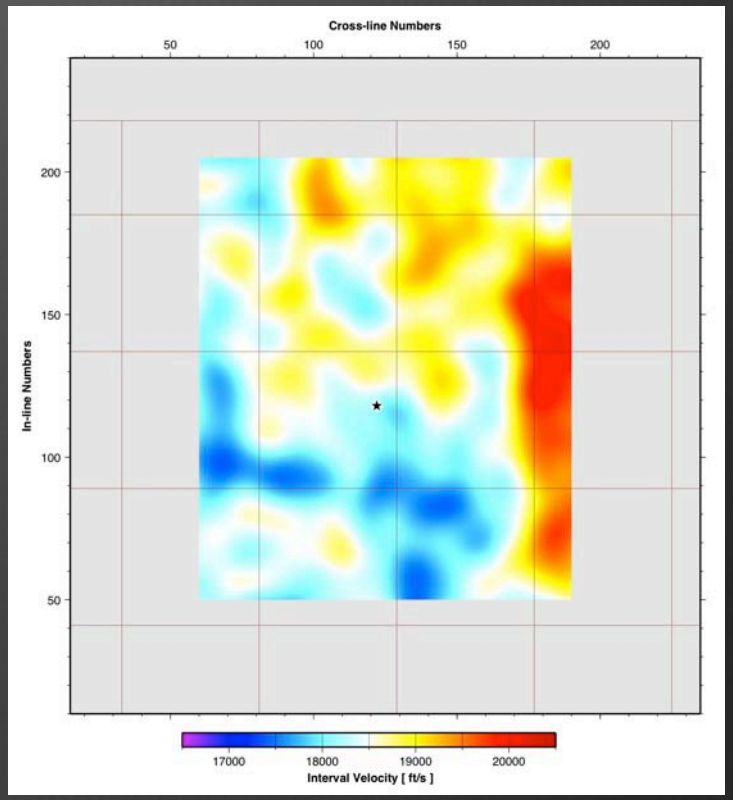


Amplitude profil (left): time-to-depth conversion was performed using interval velocity volume calculated from detailed velocity analysis of reflection common-depth-point data. Stratigraphic interpretation was based on seismic data calibration with well logs from neighboring wells. Positive seismic deflections are shown in black, negative in white. Velocity profil (center) selected from the interval velocity volume. This velocity volume was used for the time-to-depth conversion. Lithology delineation or sweetness attribute (right): parts of a seismic volume characterized by both high amplitudes and low frequency will have high sweetness (Hart, B. AAPG Bulletin, June 2008).

Interval velocity variation along the target horizons



Weber Sandstone



Madison Limestone

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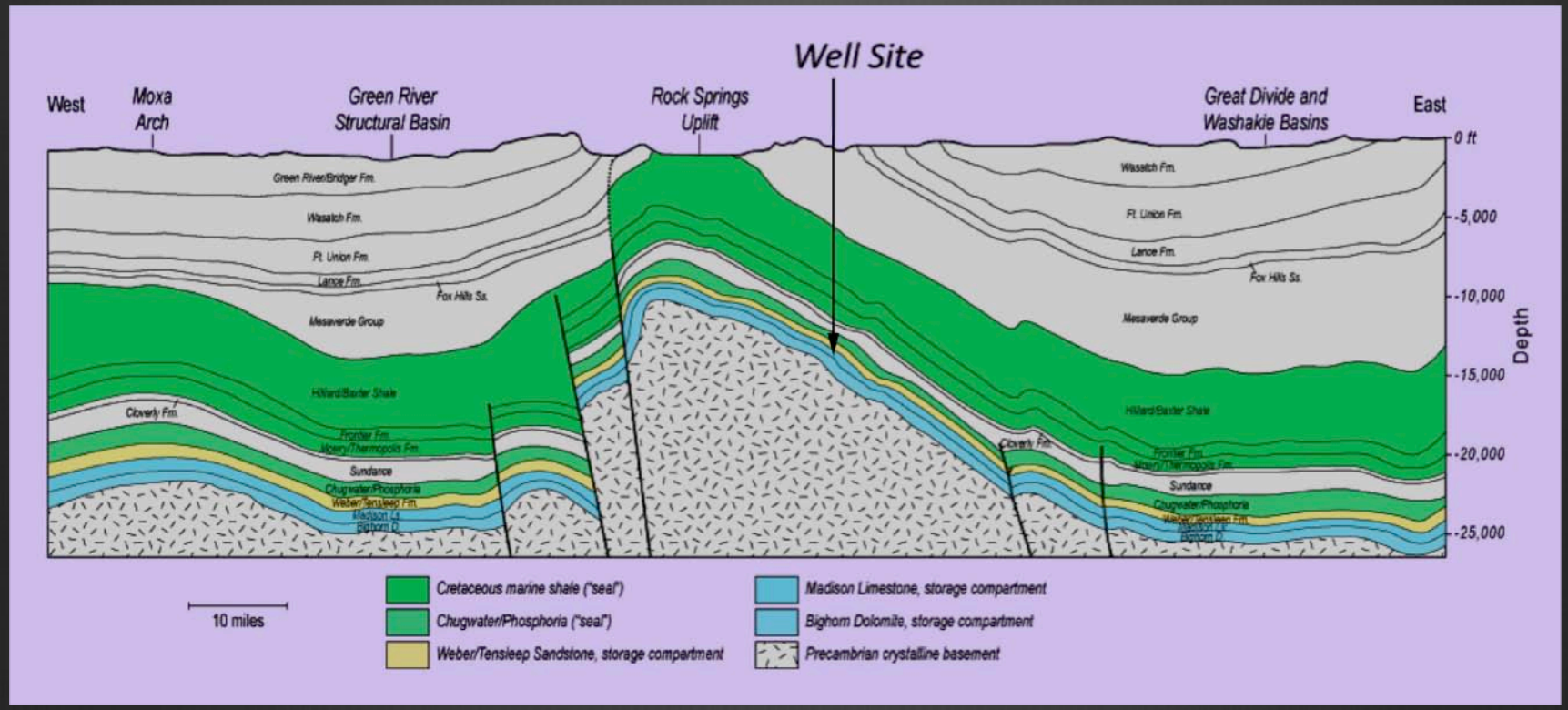

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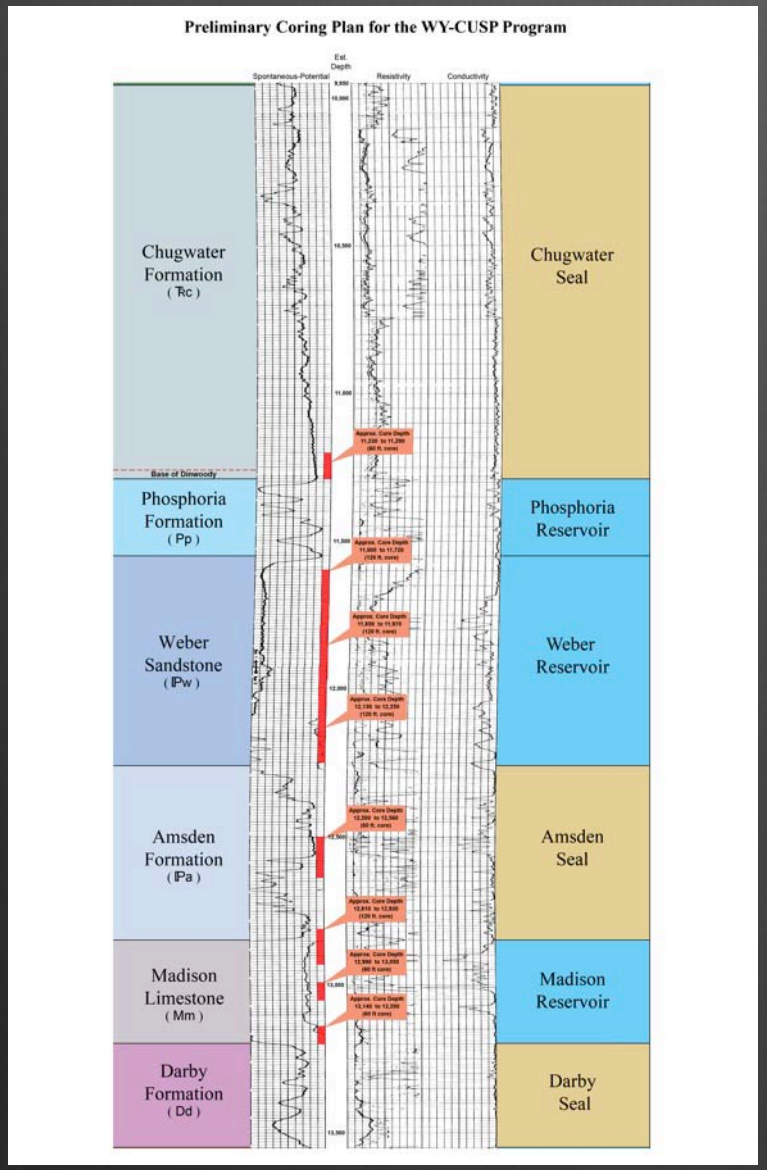

Coring results for the WY-CUSP stratigraphic test well on the Rock Springs Uplift

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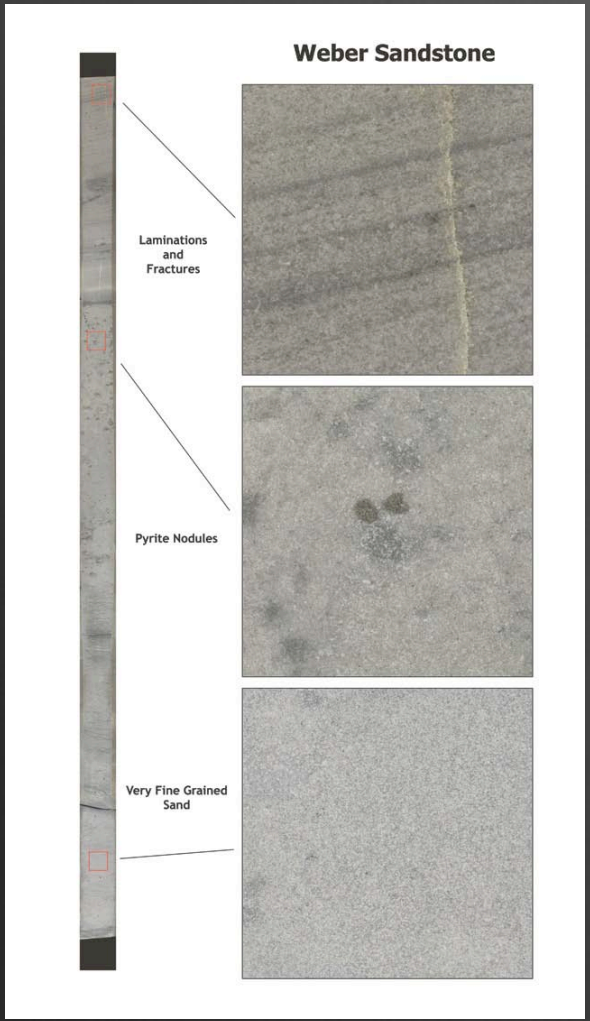
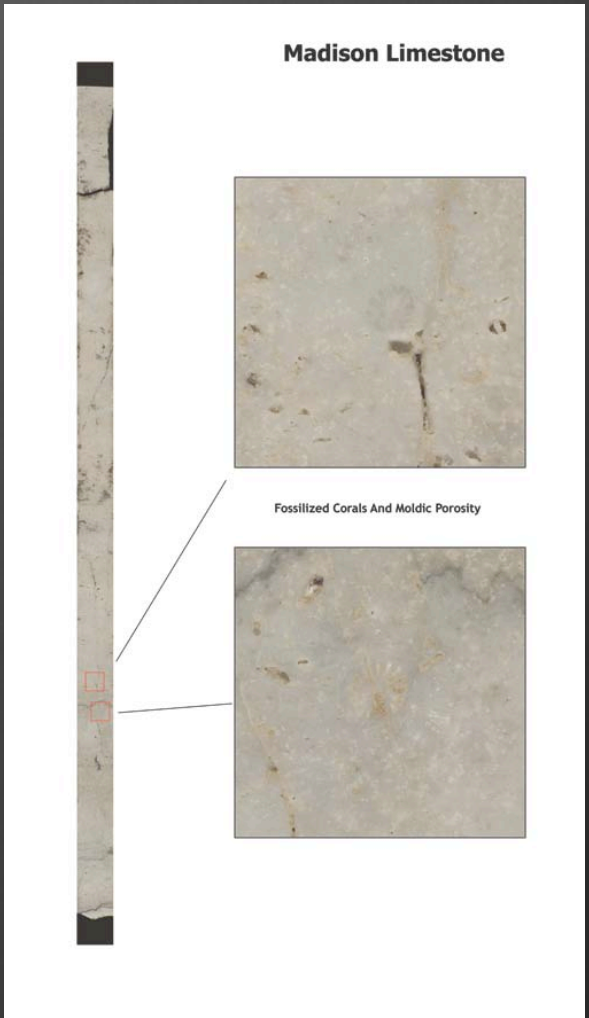
Core from Rock Springs Uplift #1



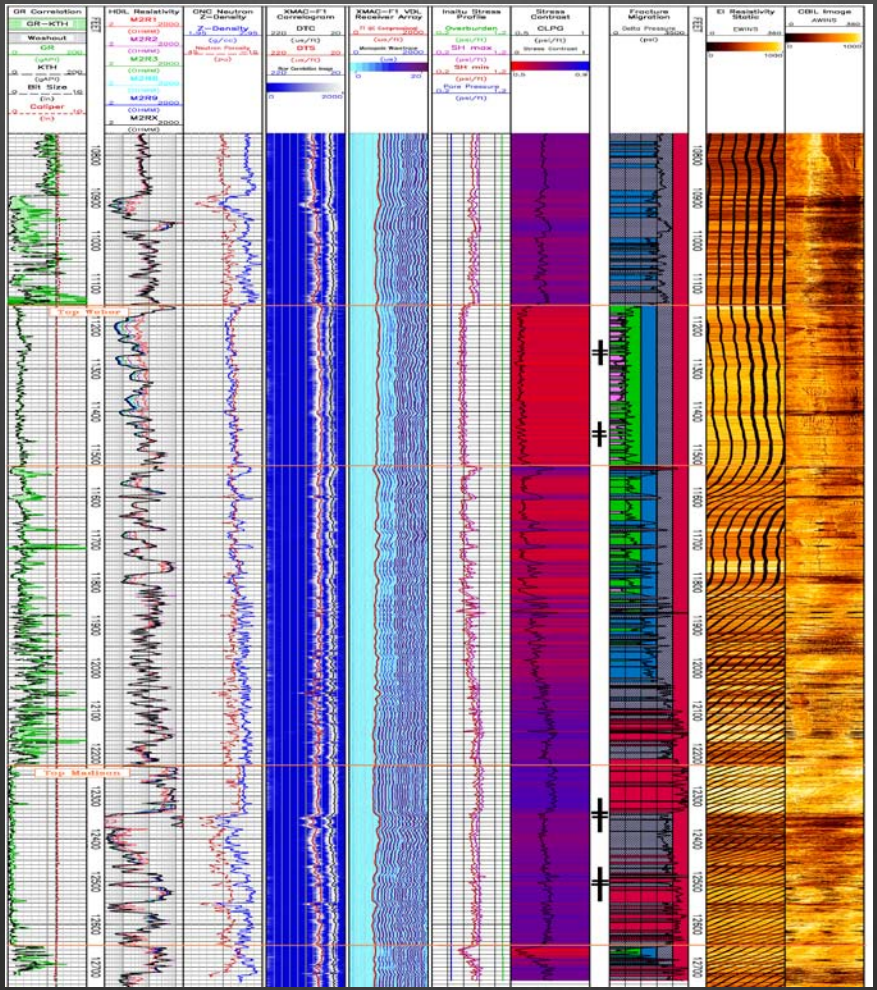


Capturing the right data*

XMAC FI™	Locates and maps formation features such as fractures and bedding planes more than 50 feet (15 m)away from the wellbore.
High-Definition Induction Log™	Provides formation resistivities and water saturation at multiple depths to provide a detailed analysis of formation resistivity.
Compensated Z-Densilog™	Provides formation bulk density and photo-electric absorption data, which are useful in the evaluation of complex formations to determine lithology and porosity.
Compensated Neutron™ (CN™)	Identifies porous formations and provides data for porosity analysis.
FOCUS™ Compensated Z-Densilog™	Gathers density porosity data in a wider range of borehole conditions, even at high logging speeds.
FOCUS™ Gamma ray	Measures the natural radioactivity of the formation being surveyed to identify the type of rock along the wellbore.
EARTH Imager™	Acquires simulataneous high-resolution resistivity and acoustic borehole image data.
Circumferential Borehole Imaging Log™	Provides 360° high-resolution borehole images in difficult wellbore conditions, including highly porous, unconsolidated formations.
Zero-offset Vertical Seismic Profile	Integrates with surface seismic data to identify and describe reservoir compartments not visible with surface seismic alone.
Reservoir Characterization Instrument™	Obtains precise formation pressures and high-quality fluid samples to determine reservoir volume.
WellLink™ LiveWire™	Securely connects the rig site to any location in the world, enabling immediate geoscience interpretation of wireline data to assist critical decision making.

**From* Connexus, the Baker Hughes Magazine, *2011, Vol. 2, No. 2*

Log suite from RSU #1



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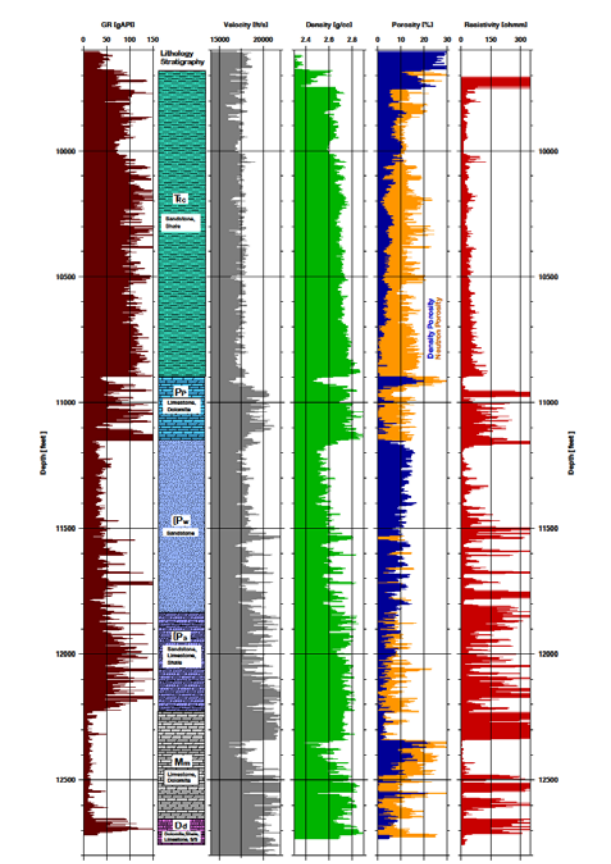
Preliminary interpretation of log suite



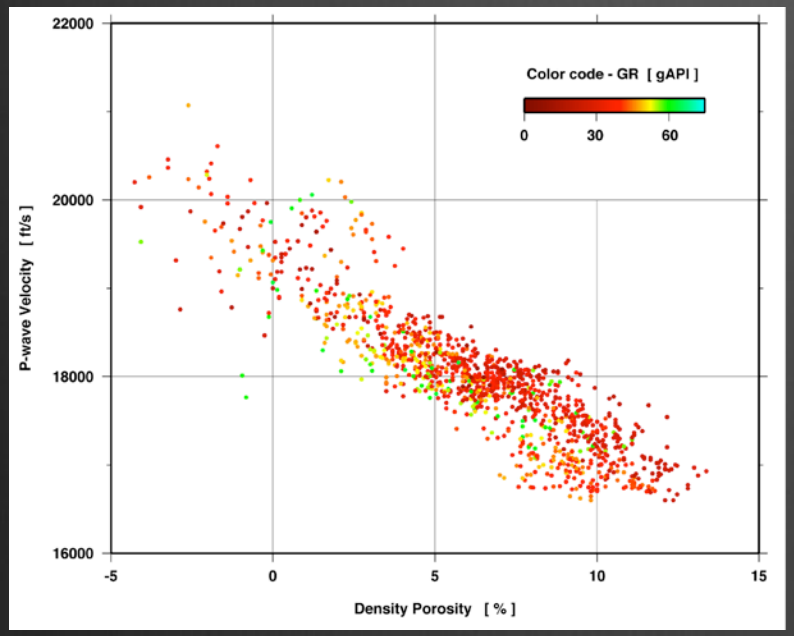
Interpreted composite wireline logs from the RSU-1 well. Well lithology and stratigraphy was interpreted based on formation records and wireline logs characteristics. Porosities were derived from neutron log (orange bar-graph) and density log (blue bar-graph) assuming limestone rock matrix (ρ = 2.75 g/cc) and fluid density = 1.0 g/cc.

Calibrate seismic attributes with core observations

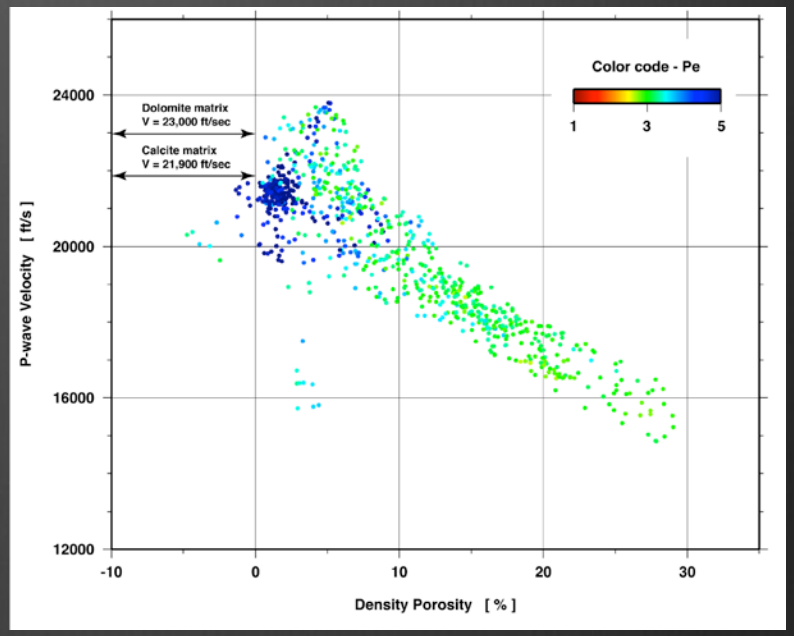
- Electric log suite
- Borehole imaging
- Cores/sidewall cores
- Fluid samples
- VSP survey
- Analysis of reservoir/ seal properties

Time-Depth Transform ⟷ Seismic data = Significant reduction in uncertainty/risk in future CO_2 storage activities on the Rock Springs Uplift

Sonic p-wave velocity vs. density porosity

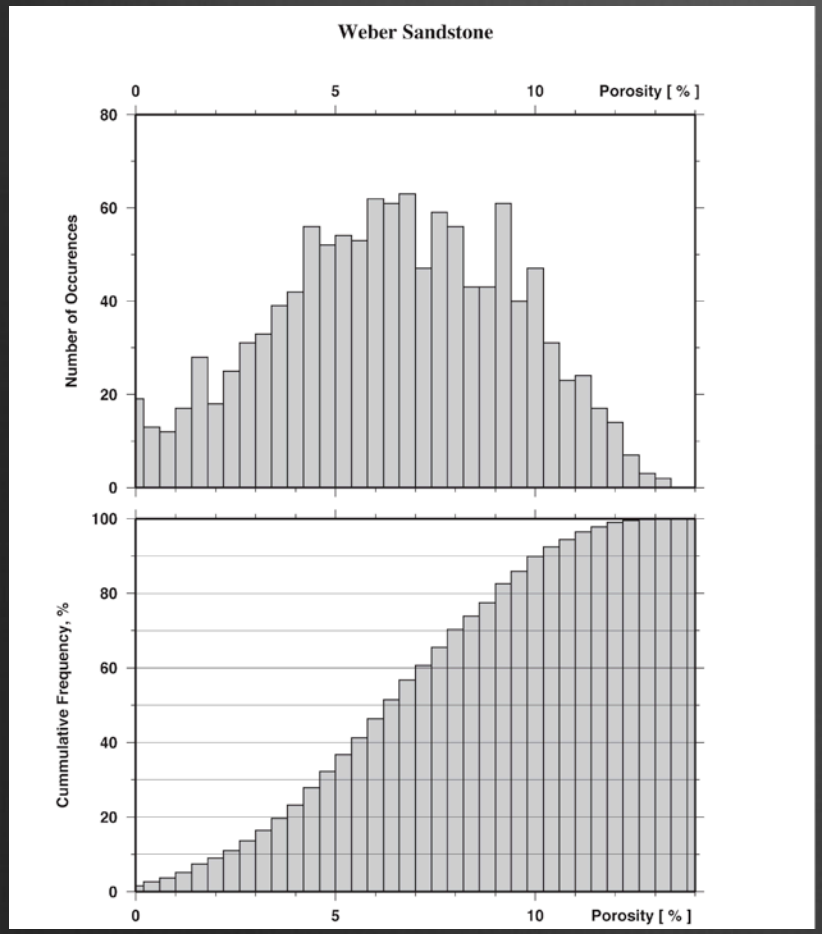


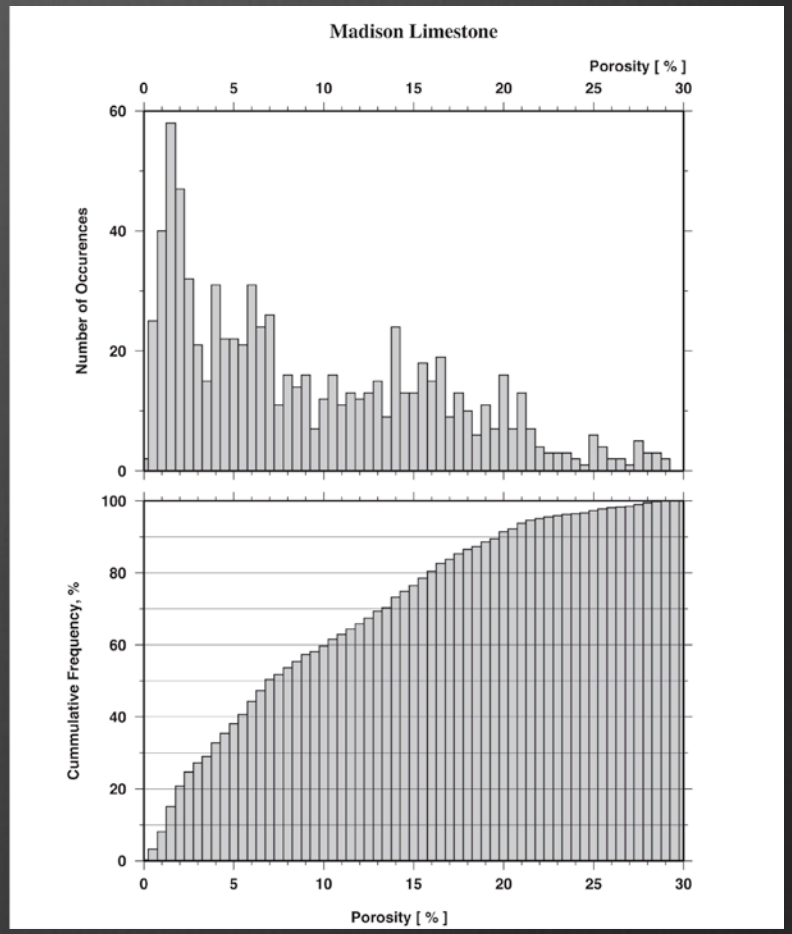
Weber Sandstone



Madison Limestone

Histograms of porosity distribution





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Porosity distribution of Weber Sandstone *(top)* and Madison Limestone *(bottom)*, inverted from Jim Bridger 3-D seismic data

New data from well observations will allow the conversion from relative to real reservoir properties in three dimensions. Vertical bars indicate location of stratigraphic test well. Seismic survey area is 5 miles by 5 miles. Note scale bars.

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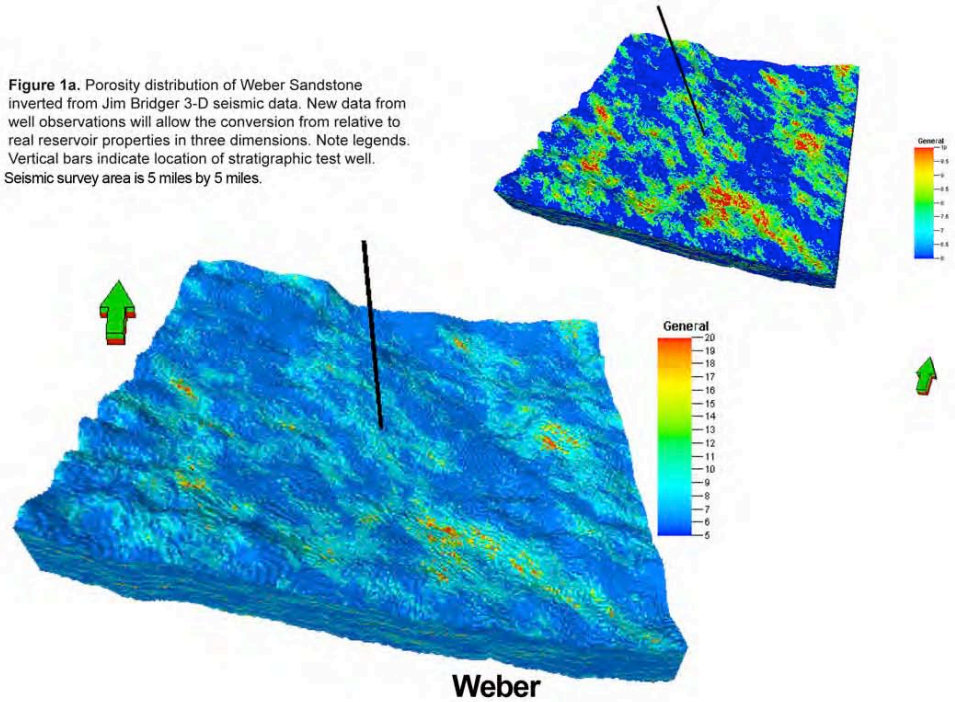


Figure 1a. Porosity distribution of Weber Sandstone inverted from Jim Bridger 3-D seismic data. New data from well observations will allow the conversion from relative to real reservoir properties in three dimensions. Note legends. Vertical bars indicate location of stratigraphic test well. Seismic survey area is 5 miles by 5 miles.

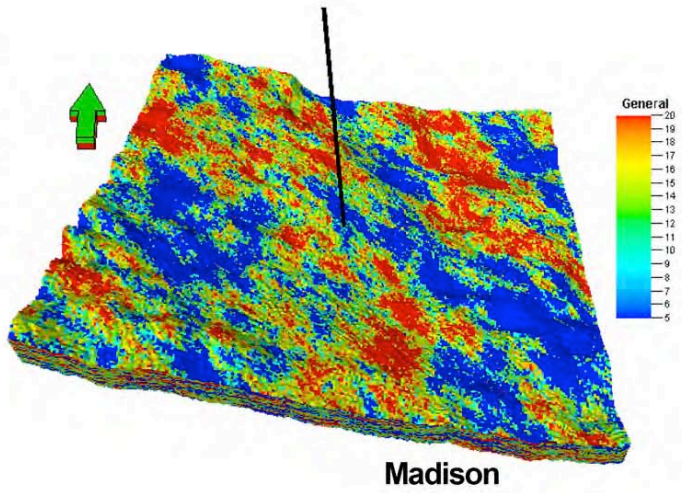


Figure 1b. Porosity distribution of Madison Limestone inverted from Jim Bridger 3-D seismic data. New data from well observations will allow the conversion from relative to real reservoir properties in three dimensions. Note legend. Vertical bar indicates location of stratigraphic test well. Seismic survey area is 5 miles by 5 miles.

Modified from Carbon Management Institute progress report to DOE for project DE-FE0002142, third quarter 2011.

Relative porosity horizon in Madison, which will be converted to real porosity

[redacted]

WY-CUSP Phase II

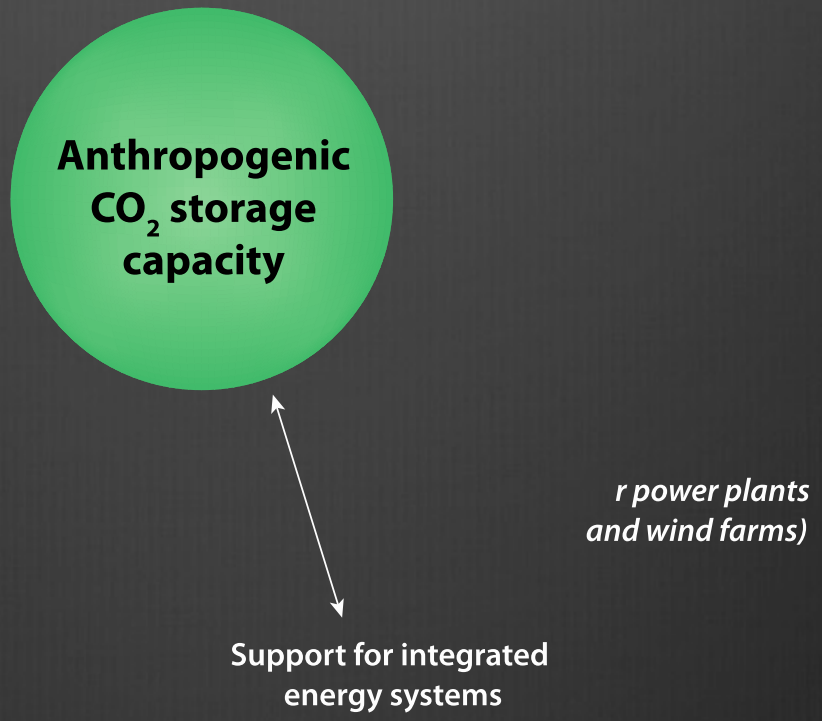
The most critical question remaining is:

Can the storage reservoirs (with a cumulative thickness of more than 1,000 feet) accept large volumes of fluid using a reasonable number of injection wells at a specific site (25 square miles in area) on the Rock Springs Uplift?

The WY-CUSP Program

The ultimate goal of the WY-CUSP program is to deliver a certified commercial CO_2 storage site to the state of Wyoming.

Potential value of WY-CUSP to Wyoming (2010–2030)



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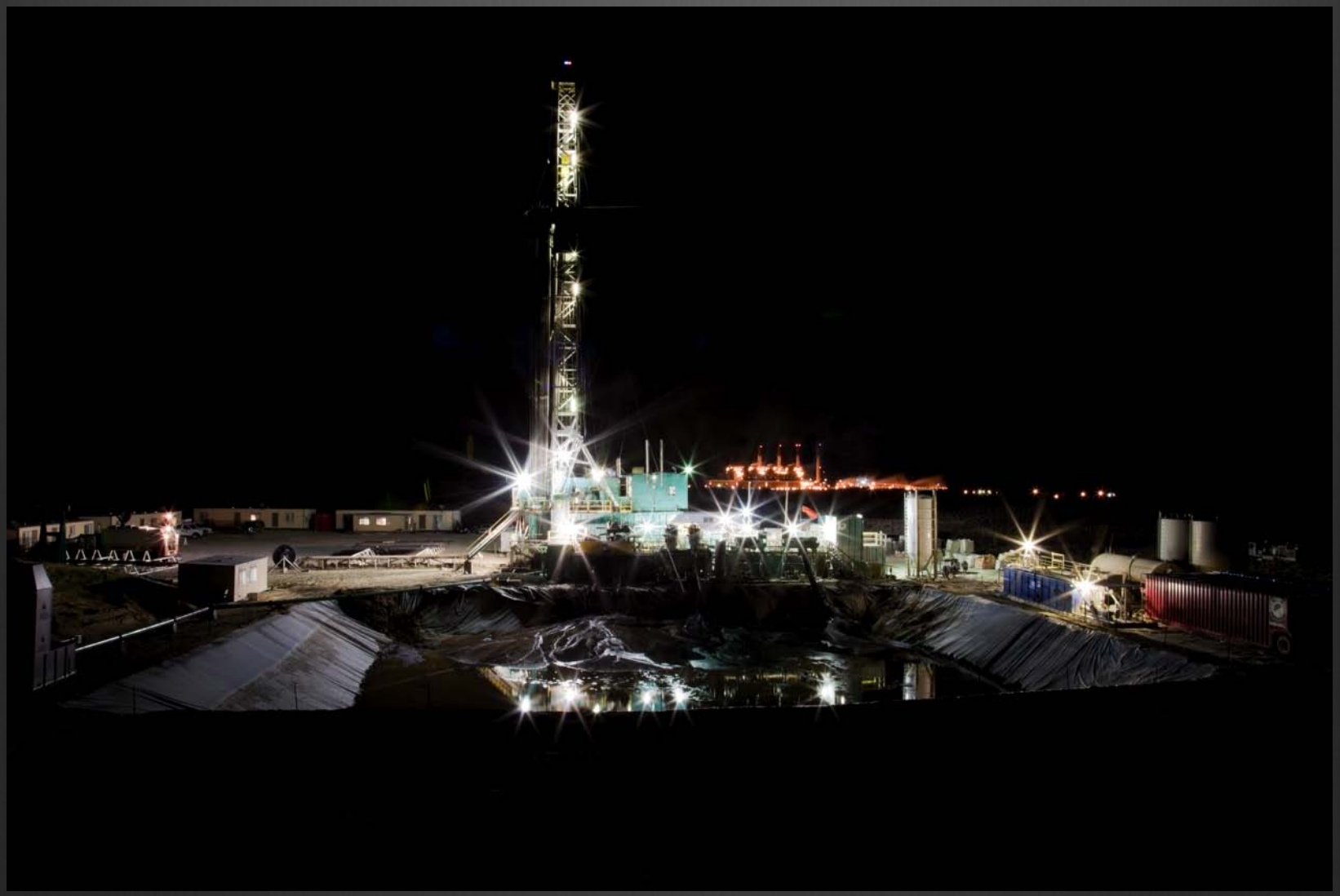

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