

A Geologic Site Characterization Database for Aiding Class VI Permitting in the Greater Green River Basin of Wyoming

Dr. Lily J. Jackson, Abdeldjalil Latrach*, James Amato, Matthew Johnson, Christian Martinez*, Rachel Toner

**Student*



UNIVERSITY
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School of
Energy Resources

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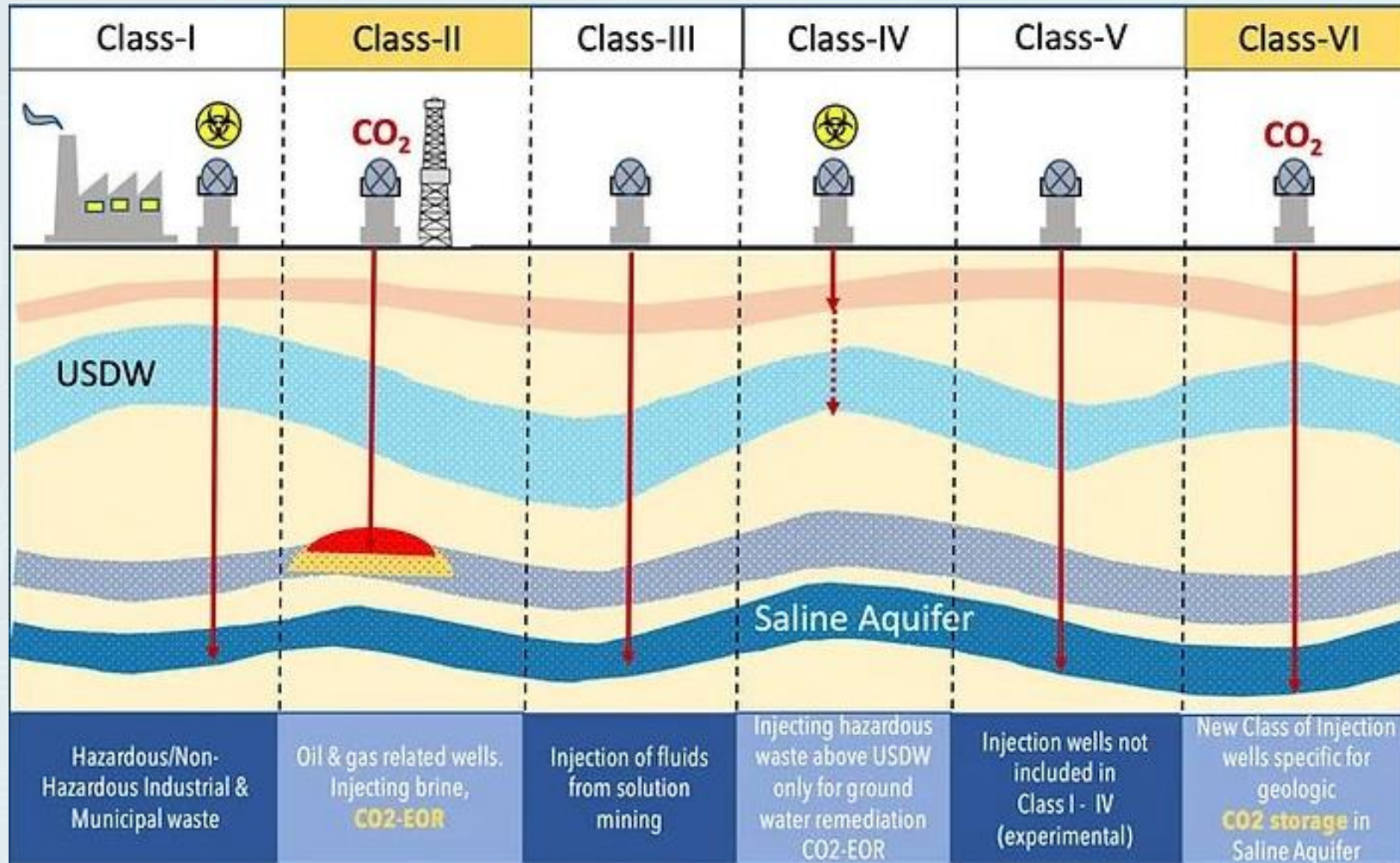
Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-FE0032372

Dr. Lily J. Jackson, Abdeldjalil Latrach*, James Amato, Matthew Johnson, Christian Martinez*, Rachel Toner

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Underground Injection Control (UIC) Program

Well classes



By: Tariq Siddiqui; MAR 2022 ©

CHALLENGES

Permit application review

- Many applications submitted to WY-DEQ

Permit compilation

- Permit compilation is intensive
- No centralized repository for data required in permit applications

Lead Institutions

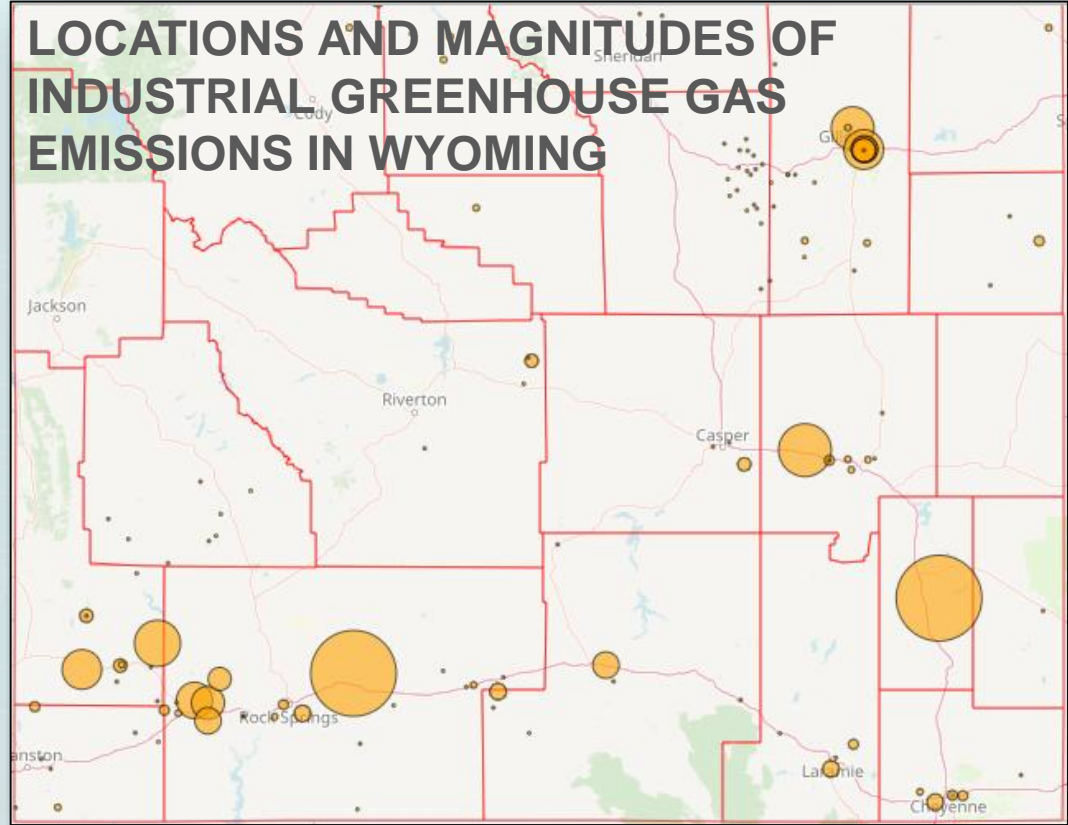
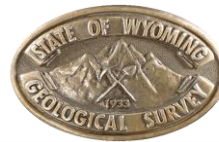
- Center for Economic Geology Research
 University of Wyoming



- Wyoming Department of Environmental Quality

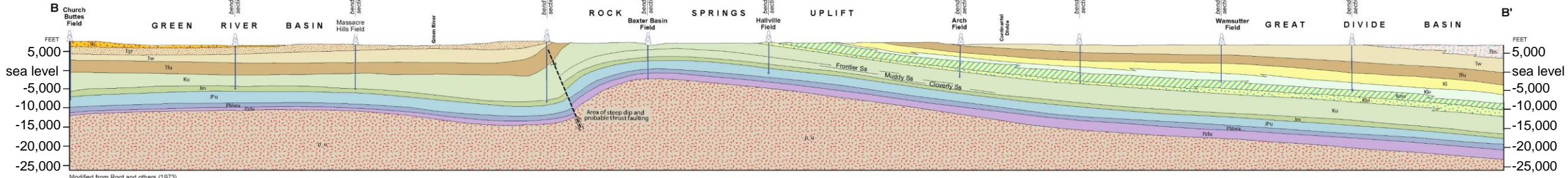


- Wyoming State Geological Survey



2022 GHG Emissions (Million Metric Tons CO₂e)

Power Plants	Petroleum and Natural Gas Systems	Refineries	Chemicals	Other	Minerals	Waste	Metals	Pulp and Paper	Total Reported Emissions <i>What's this?</i>
38	5.8	1.3	1.4	0.1	6.4	0.1	0	0	53
13	30	4	4	3	10	3	0	0	66



Modified from Root and others (1973)

Lynds, 2013

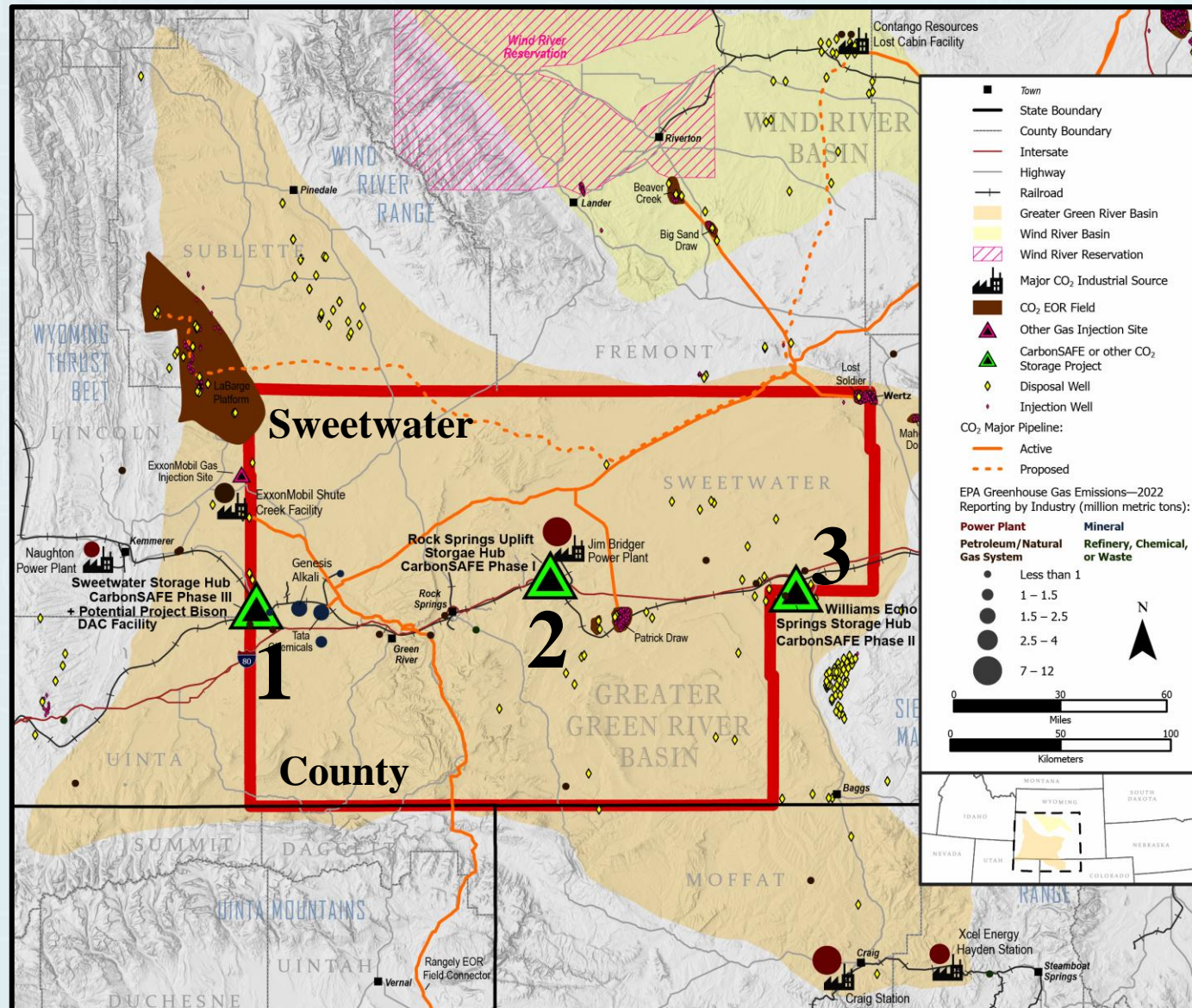


Buursink et al., 2014



Lynds, 2013

- Template for other counties and basins
- Accelerate CCUS in Sweetwater County




Carbon storage hubs

1 Sweetwater
 (CarbonSAFE Phase III)

2 Rock Springs Uplift
 (CarbonSAFE Phase I)

3 Williams Echo Springs
 (CarbonSAFE Phase II)

Site characterization requirements for class VI permit



WATER QUALITY DIVISION

GEOLOGIC SEQUESTRATION

CLASS VI PERMIT APPLICATION - SITE CHARACTERIZATION

Water Quality Rules, Chapter 24 Sections 10 and 12

UIC Class VI Permit Application
 Site Characterization Form A-1
 March 28, 2024

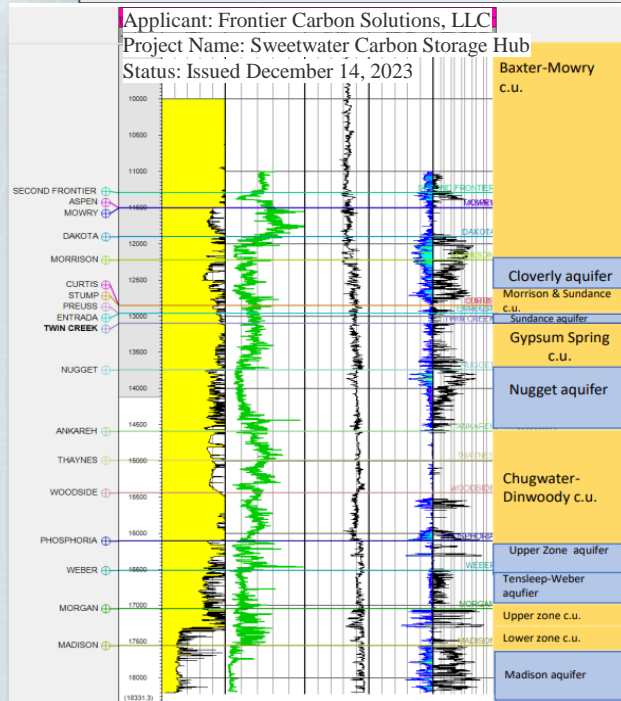
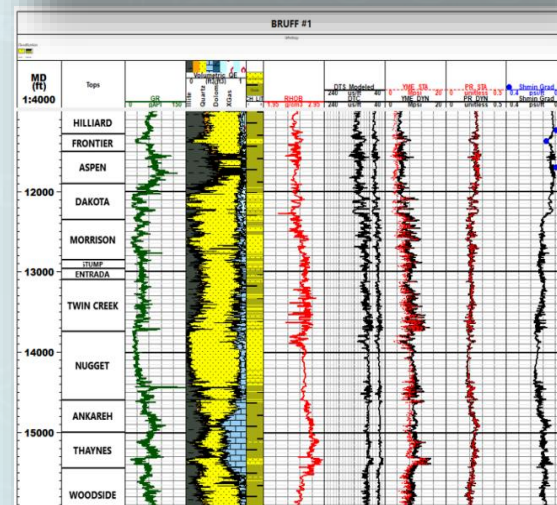


Table 8. Formations Comprising the CO2 Storage System

Formation	Purpose	Average Thickness at Project Site, feet	Average Depth at Project Site, feet	Mineralogy
Twin Creek	Upper confining zone	650	13,000 – 13,750	10-40% Clay; 40- 60% Quartz; 0-10% Calcite
Nugget	Injection zone	850	13,750 – 14,600	0-10% Clay; 70-90% Quartz; 0-10% Calcite
Ankareh	Lower confining zone	400	14,600 – 15,000	20-40% Clay; 0- 50% Quartz; 0-40% Calcite



Example images from an issued permit by applicant Frontier Carbon Solutions, LLC

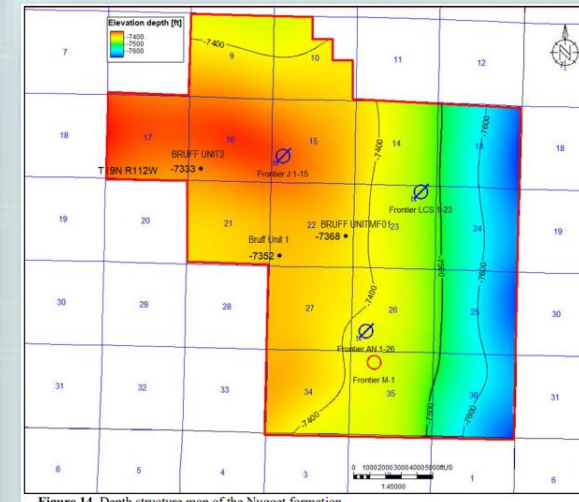


Figure 14. Depth structure map of the Nugget formation.

Data categories

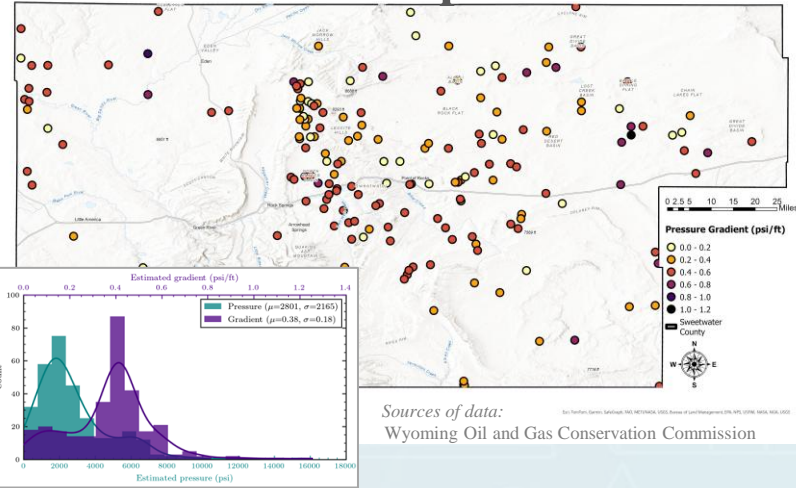
Category	Data
(1) Geologic and Topographic Maps and Cross Sections	Formation tops
	Aquifers characteristics
	Well Logs
	Core data
	2D/3D Seismic surveys (maps only)
(2) Regional Hydrostratigraphy	Formation tops
	Aquifers characteristics
	Water analysis
	Well Logs
	Core data
	2D/3D Seismic surveys (maps only)
(3) Regional Groundwater Flow	Aquifers characteristics
	Baseflow/Recharge map
	Literature*
(4) Surface Air and/or Soil Gas Monitoring Data	
(5) Data on the Injection Zone(s)	Core data
	2D/3D Seismic surveys (maps only)
	Formation tops
	Water analysis
	Aquifers characteristics
	Bottomhole temperature
	Well Logs
	Faults
	Geology / Lithologic description (literature)
	Mineralogy (X-Ray Diffraction)
Pore Pressure (Drill-Stem Test)	

Category	Data
(6) Demonstration of Site Suitability	Faults
	2D/3D Seismic surveys (maps only)
	Formation tops
	Bottomhole temperature
	Water analysis
	Aquifers characteristics
	Well Logs
	Faults
(7) Geomechanical and Petrophysical Information about the Confining Zone(s)	Geology / Lithologic description (literature)
	Pore Pressure (Drill-Stem Test)
	Geomechanical data
	Core data
(8) Data on the Confining Zone(s)	Mineralogy (X-Ray Diffraction)
	Pore Pressure (Drill-Stem Test)
	Core data
	2D/3D Seismic surveys (maps only)
	Formation tops
	Aquifers characteristics
	Well Logs
(9) Information on Faults and Fractures	Faults
	Geology / Lithologic description (literature)
	Mineralogy (X-Ray Diffraction)
(10) Information on Seismic History	2D/3D Seismic surveys (maps only)
	Faults
	Seismic events map

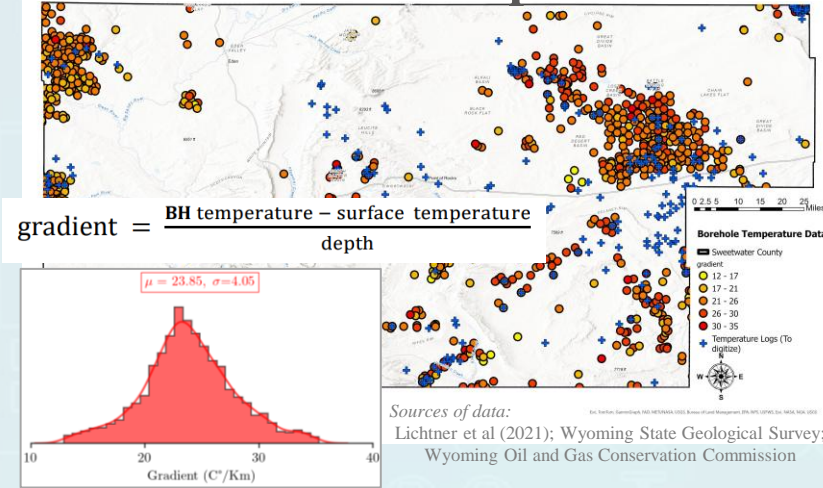
* Categories are not finalized

Data compilation

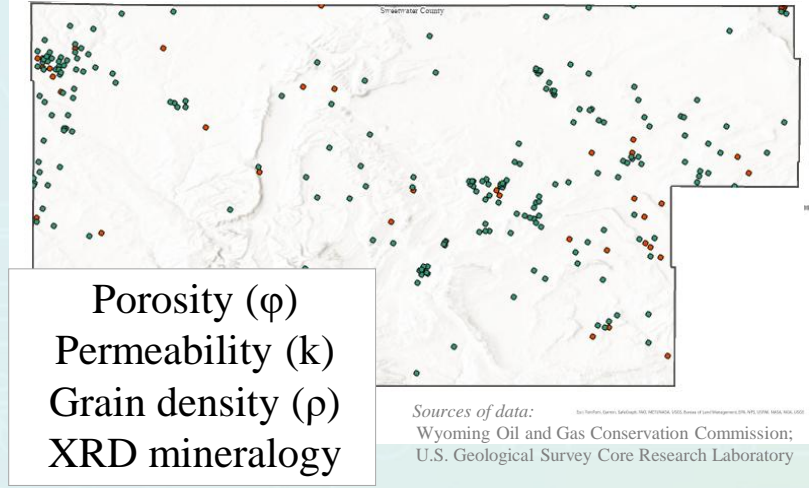
Subsurface pressure



Subsurface temperature

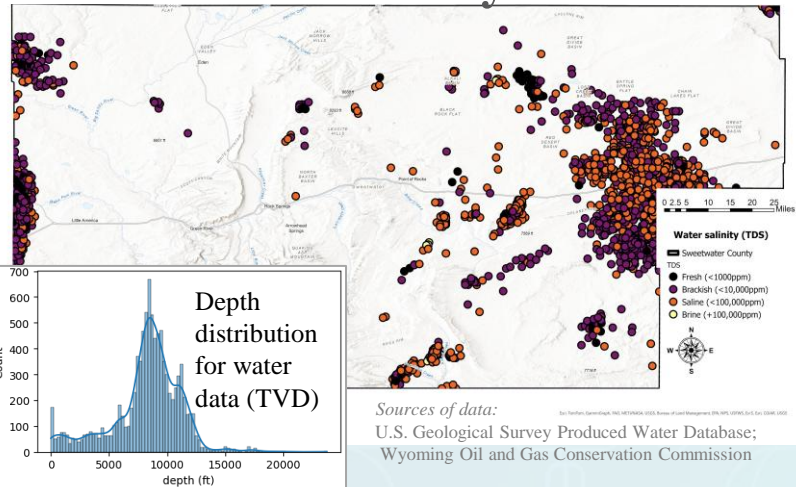


Core data

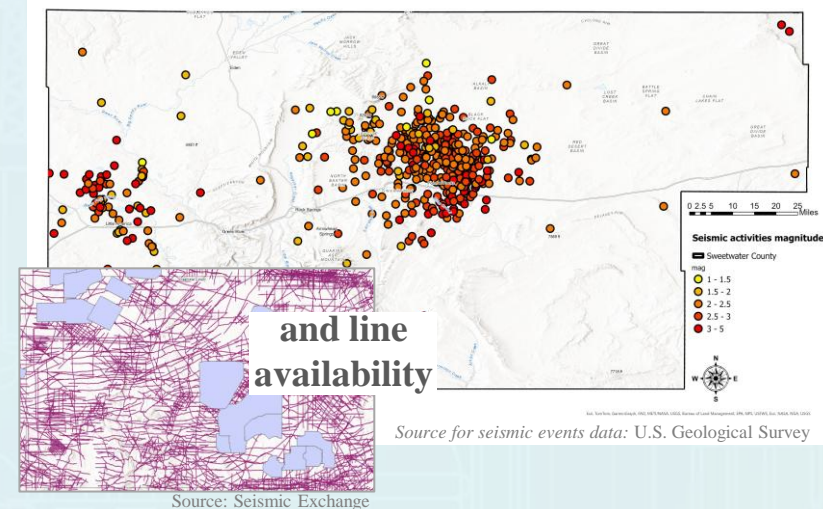


Porosity (ϕ)
 Permeability (k)
 Grain density (ρ)
 XRD mineralogy

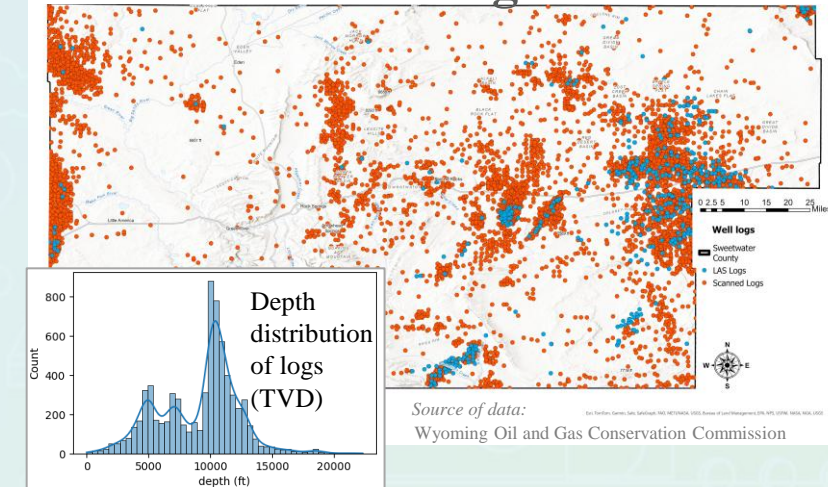
Water analyses



Seismic events



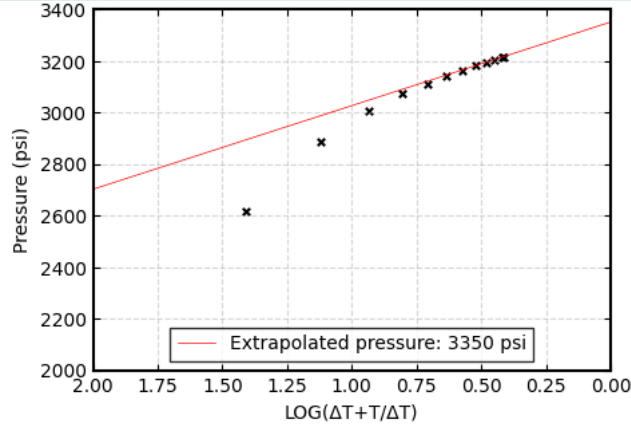
Well logs



Data compilation – drill stem tests

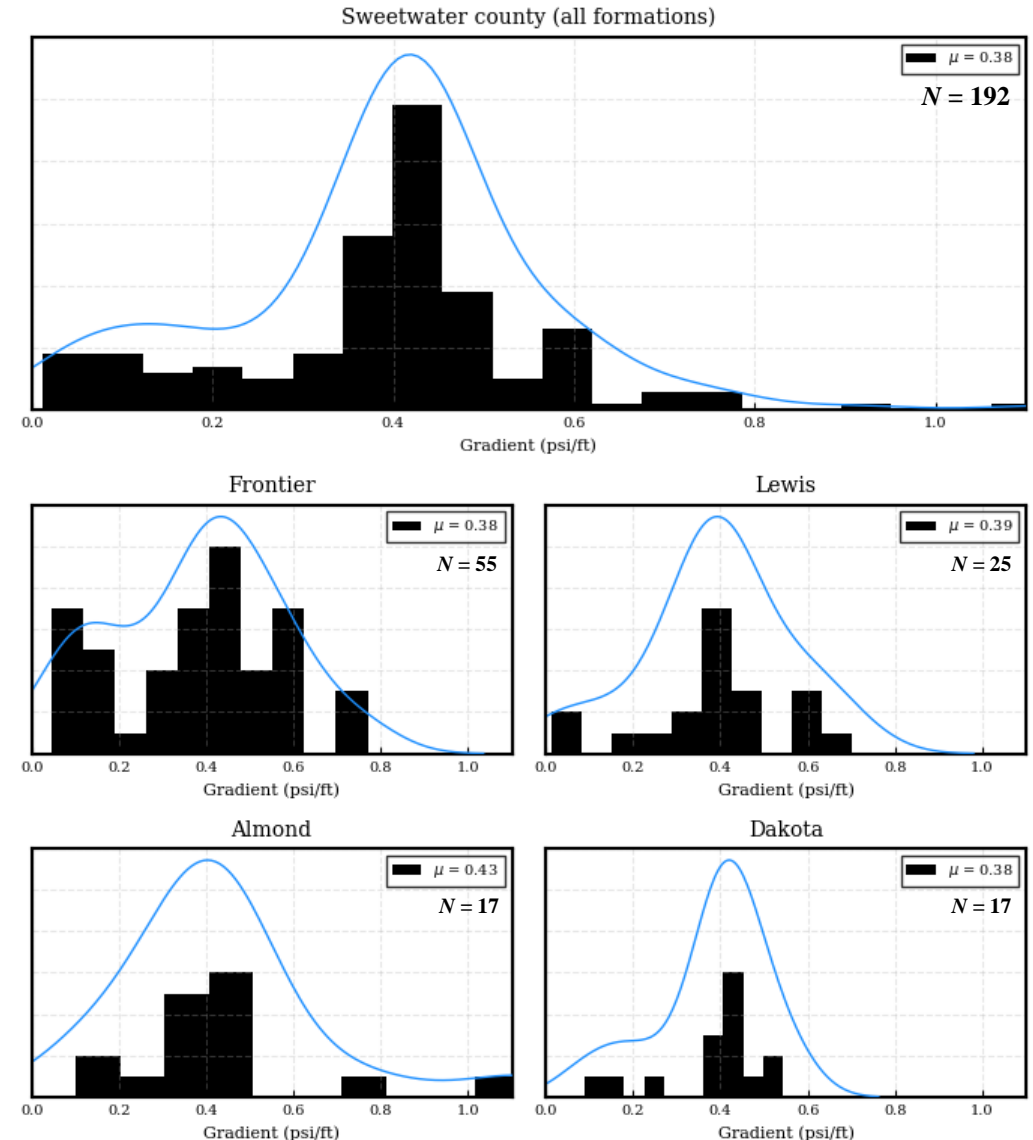
Drill stem test (DST) data digitized for **>200 wells**

Created Python code for running batch Horner analyses



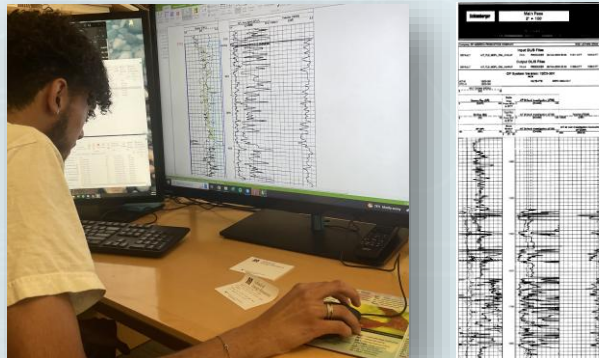
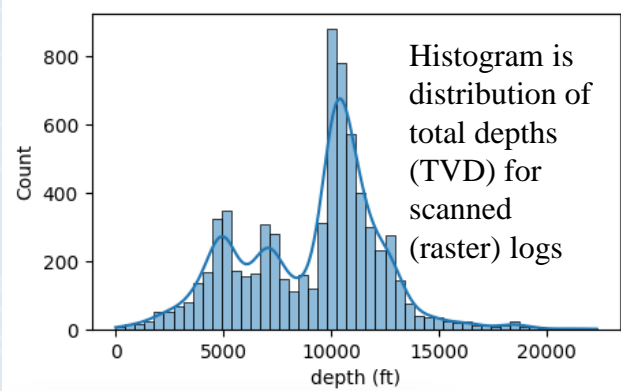
A collage of documents related to drill stem tests. It includes forms for 'SURFACE INFORMATION', 'EQUIPMENT & HOLE DATA', and 'MID DATA'. A 'GUIDE TO IDENTIFICATION OF DRILL STEM TEST PRESSURE CHARTS' shows various pressure curves labeled A through F. Below the forms is a digitized data table with columns for DT, PSI, LOG, and TIME.

DT	PSI	LOG	DT	PSI	LOG
0	594.0	0.909	93	1749.9	0.301
3	1794.0	0.466	96	1777.4	0.316
6	2114.8	0.374	99	1803.3	0.3375
9	2498.3	0.297	102	1831.1	0.3568
12	2779.9	0.258	105	1855.9	0.362
15	4544.6	0.393	108	1884.8	0.3756
18	5264.5	0.320	111	1911.6	0.382
21	5764.4	0.274	114	1935.6	0.388
24	6694.6	0.220	117	1955.6	0.395
27	7294.7	0.181	120	1984.6	0.399
30	7934.9	0.146	123	2005.7	0.399
33	8524.9	0.116	126	2029.7	0.398
36	9154.5	0.090	129	2045.8	0.398
39	9774.0	0.067	132	2064.0	0.398
42	10374.5	0.049	135	2079.2	0.398
45	10994.1	0.036	138	2111.4	0.398
48	11414.9	0.028	141	2115.7	0.399
51	11914.7	0.020	144	2135.0	0.398
54	12314.7	0.016	147	2151.3	0.398
57	12714.7	0.013	150	2166.6	0.398
60	13114.7	0.010	153	2183.8	0.398
63	13754.8	0.007	156	2195.4	0.397
66	14174.9	0.006	159	2209.8	0.396
69	14594.9	0.004	162	2229.2	0.395
72	14994.5	0.003	165	2245.4	0.396
75	15754.9	0.002	168	2268.1	0.392
78	15784.7	0.002	171	2294.8	0.396
81	16794.7	0.002	174	2322.1	0.391
84	16454.2	0.001	177	2342.4	0.388
87	16784.7	0.000	180	2393.3	0.366
90	17114.3	0.000	183	2393.9	0.361



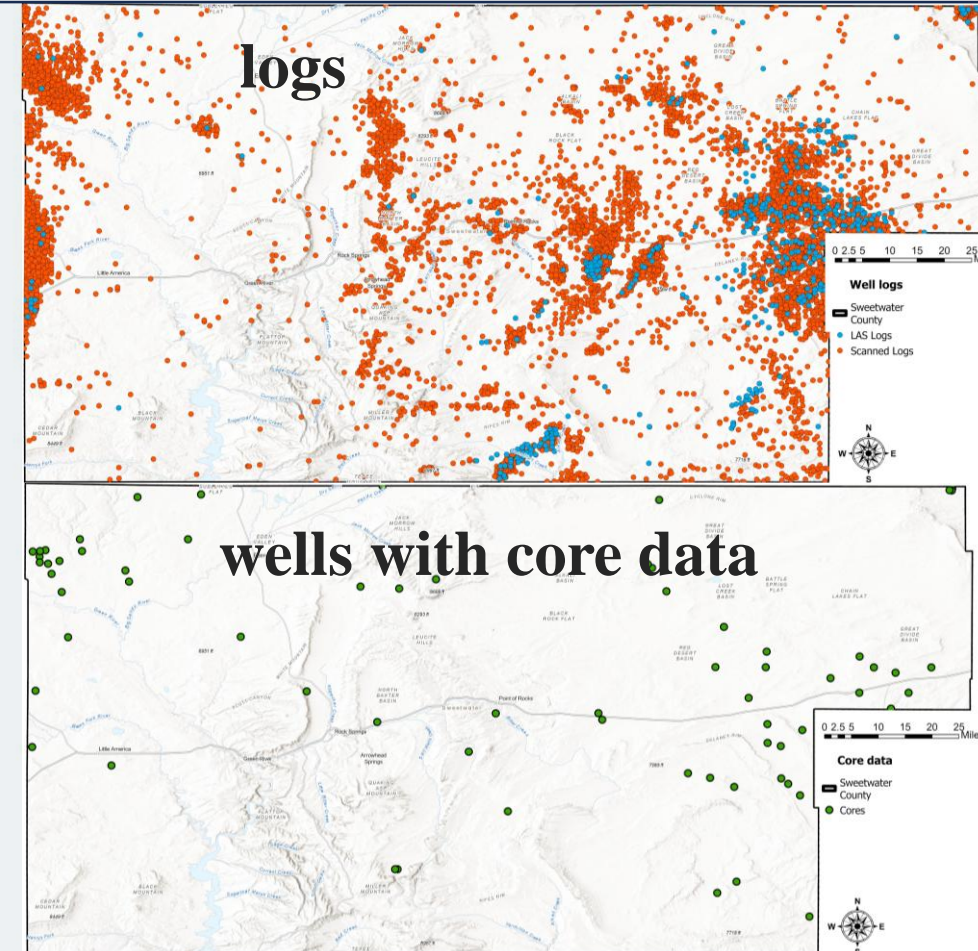
Data compilation – well logs

$N = 1,070$ LAS files
 for **$n = 770$** wells
 $N = 20,800$ scanned
 logs for **$n = 7,200$** wells



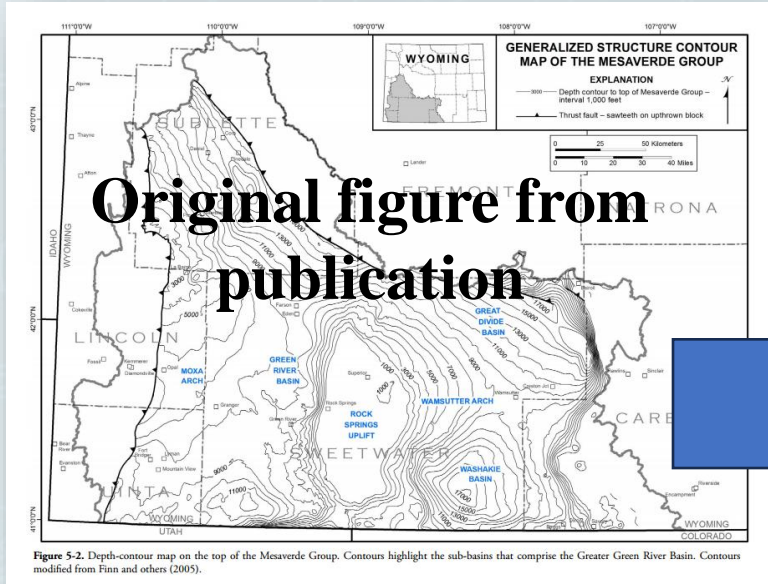
Prioritization

- **Spatial prioritization**
 - maximize coverage
- **Depth prioritization**
 - maximize formations per log
- **Wells with other data**
 - e.g. core data
- **Log types**
 - critical vs nice to have
- **Quality of individual logs**
 - “easy” logs digitized first (for high density areas where multiple are available)

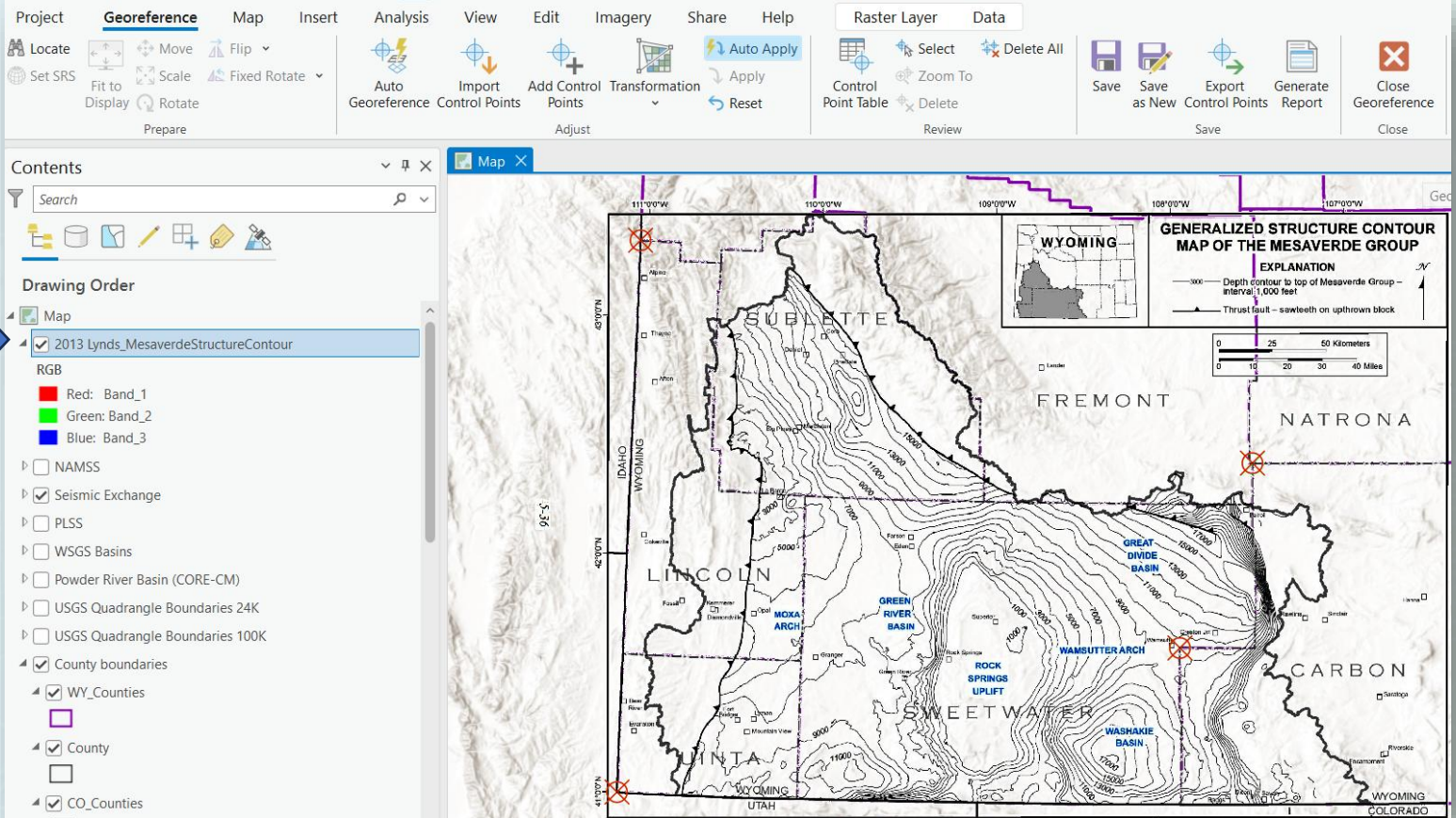


Data: Wyoming Oil and Gas Conservation Commission

Data compilation – maps and cross sections



Lynds, 2013



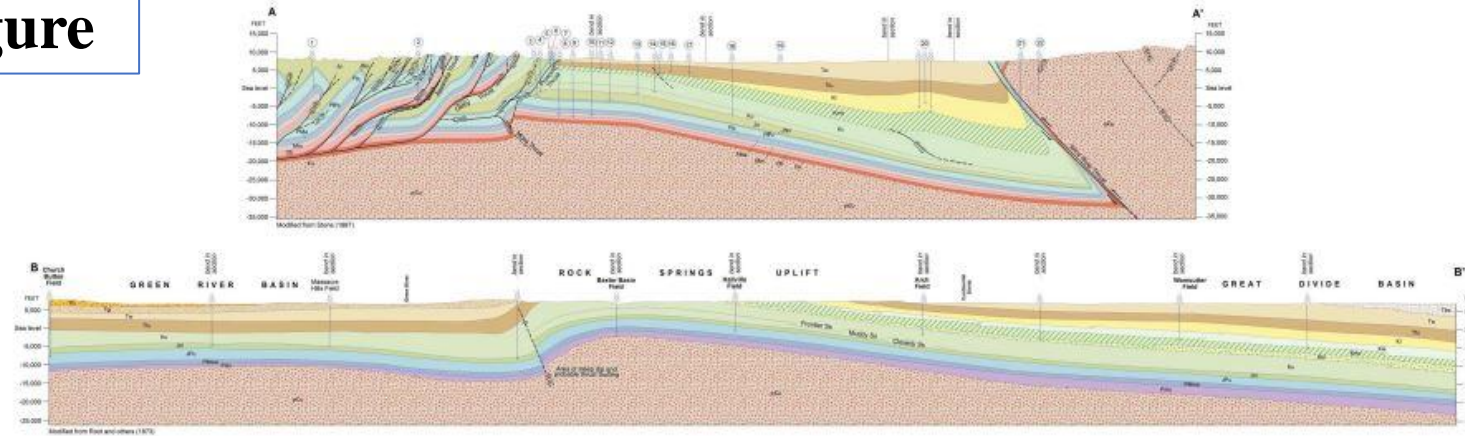
Original figure

cross section lines

WYOMING STATE GEOLOGICAL SURVEY
 Thomas A. Dixon
 Director and State Geologist
 Laramie, Wyoming

**GEOLOGIC STORAGE ASSESSMENT OF CARBON DIOXIDE (CO₂)
 IN THE LARAMIDE BASINS OF WYOMING**

TECHNICAL MEMORANDUM 3
 Plate 5
 Cross Sections
 Greater Green River Basin



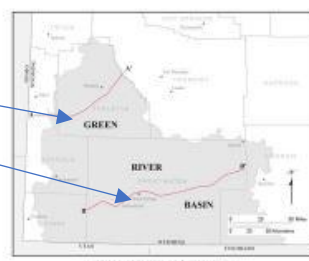
EXPLANATION

CROSS SECTION SYMBOLS

- Formation contact
- Fault - Dashed where inferred, arrow indicates relative movement
- Dip hole - Well log tracks contain cross sections

GEOLOGIC UNITS

CENOZOIC	Jurassic	Mississippi
Tertiary	<ul style="list-style-type: none"> Member Transition Jurassic rocks, undifferentiated Jurassic and Triassic Triassic and Triassic Triassic Sandstone 	<ul style="list-style-type: none"> Mississippi Limestone Devonian and Ordovician Ordovician Sandstone Cambrian Cambrian rocks, undifferentiated
<ul style="list-style-type: none"> Badger Formation Green River Formation Bank Springs Formation Wasatch Formation Fool Creek Formation 	<ul style="list-style-type: none"> Permian, Pennsylvanian, and Mississippian Phosphatic, Wills, and Anadarko Formations 	<ul style="list-style-type: none"> Precambrian Precambrian rocks, undifferentiated
MESOZOIC	Permian, Pennsylvanian, and Mississippian	PRECAMBRIAN
Cretaceous	<ul style="list-style-type: none"> Lower Formation Lewis Shale Mesa Verde Formation Clay Shale Rice Formation Chickadee rocks, undifferentiated 	<ul style="list-style-type: none"> Devonian and Ordovician Ordovician Sandstone Cambrian Cambrian rocks, undifferentiated



WELL CONTROL ALONG CROSS SECTIONS

Well no.	API no.	Operator	Well name	Stratigraphic horizon	Surface location	County	Well type
1	49025-00175	Champion Natural Gas	Sublet 100-A1	Henry Hook	4 20' 129' W	Laramie	1981
2	49025-00180	Alcoa Fertilizer Company	D-33 Polar Duffin 10	Box 8	4 20' 129' W	Laramie	1982
3	49025-00181	Pacific International Energy Corp.	Sublet 20-10	Henry	11 20' 129' W	Sublette	1979
4	49025-00081	Chesapeake USA Inc.	Henry 1	Frank-Duck	11 20' 129' W	Sublette	1987
5	49025-00081	Chesapeake USA Inc.	Sublet 1	Frank	11 20' 129' W	Sublette	1977
6	49025-00081	Chesapeake USA Inc.	Sublet 2	Frank	11 20' 129' W	Sublette	1978
7	49025-00081	Chesapeake USA Inc.	Sublet 3	Frank	11 20' 129' W	Sublette	1978
8	49025-00081	Chesapeake USA Inc.	Sublet 4	Frank	11 20' 129' W	Sublette	1978
9	49025-00081	Chesapeake USA Inc.	Sublet 5	Frank	11 20' 129' W	Sublette	1978
10	49025-00081	Chesapeake USA Inc.	Sublet 6	Frank	11 20' 129' W	Sublette	1978
11	49025-00081	Chesapeake USA Inc.	Sublet 7	Frank	11 20' 129' W	Sublette	1978
12	49025-00081	Chesapeake USA Inc.	Sublet 8	Frank	11 20' 129' W	Sublette	1978
13	49025-00081	Chesapeake USA Inc.	Sublet 9	Frank	11 20' 129' W	Sublette	1978
14	49025-00081	Chesapeake USA Inc.	Sublet 10	Frank	11 20' 129' W	Sublette	1978
15	49025-00081	Chesapeake USA Inc.	Sublet 11	Frank	11 20' 129' W	Sublette	1978
16	49025-00081	Chesapeake USA Inc.	Sublet 12	Frank	11 20' 129' W	Sublette	1978
17	49025-00081	Chesapeake USA Inc.	Sublet 13	Frank	11 20' 129' W	Sublette	1978
18	49025-00081	Chesapeake USA Inc.	Sublet 14	Frank	11 20' 129' W	Sublette	1978
19	49025-00081	Chesapeake USA Inc.	Sublet 15	Frank	11 20' 129' W	Sublette	1978
20	49025-00081	Chesapeake USA Inc.	Sublet 16	Frank	11 20' 129' W	Sublette	1978
21	49025-00081	Chesapeake USA Inc.	Sublet 17	Frank	11 20' 129' W	Sublette	1978
22	49025-00081	Chesapeake USA Inc.	Sublet 18	Frank	11 20' 129' W	Sublette	1978
23	49025-00081	Chesapeake USA Inc.	Sublet 19	Frank	11 20' 129' W	Sublette	1978
24	49025-00081	Chesapeake USA Inc.	Sublet 20	Frank	11 20' 129' W	Sublette	1978
25	49025-00081	Chesapeake USA Inc.	Sublet 21	Frank	11 20' 129' W	Sublette	1978
26	49025-00081	Chesapeake USA Inc.	Sublet 22	Frank	11 20' 129' W	Sublette	1978
27	49025-00081	Chesapeake USA Inc.	Sublet 23	Frank	11 20' 129' W	Sublette	1978
28	49025-00081	Chesapeake USA Inc.	Sublet 24	Frank	11 20' 129' W	Sublette	1978
29	49025-00081	Chesapeake USA Inc.	Sublet 25	Frank	11 20' 129' W	Sublette	1978
30	49025-00081	Chesapeake USA Inc.	Sublet 26	Frank	11 20' 129' W	Sublette	1978
31	49025-00081	Chesapeake USA Inc.	Sublet 27	Frank	11 20' 129' W	Sublette	1978
32	49025-00081	Chesapeake USA Inc.	Sublet 28	Frank	11 20' 129' W	Sublette	1978
33	49025-00081	Chesapeake USA Inc.	Sublet 29	Frank	11 20' 129' W	Sublette	1978
34	49025-00081	Chesapeake USA Inc.	Sublet 30	Frank	11 20' 129' W	Sublette	1978

REFERENCES

Russ, F.K., Edens, D.R., and Lane, D.W., 1973, *Stratigraphic Correlation of the Permian System of Wyoming* (Wyoming State Geological Survey), County, Ransome Series, no. 2.

Stout, D.S., 1957, *Rocky Mountain-Texas*—Wyoming, Unconformity sequence SW 7, SW 6, SW 5, SW 4, Laramie, Co., DWT, version 2.0.

ACKNOWLEDGMENT

The Wyoming State Geological Survey thanks Dick Steer for his permission to modify portions of the Rocky Mountain Transect, as shown in cross sections A-A'.

Layout and design by Rakia W. Lyons and Phyllis A. Ross.
 Edited by Suzanne C. Lohr

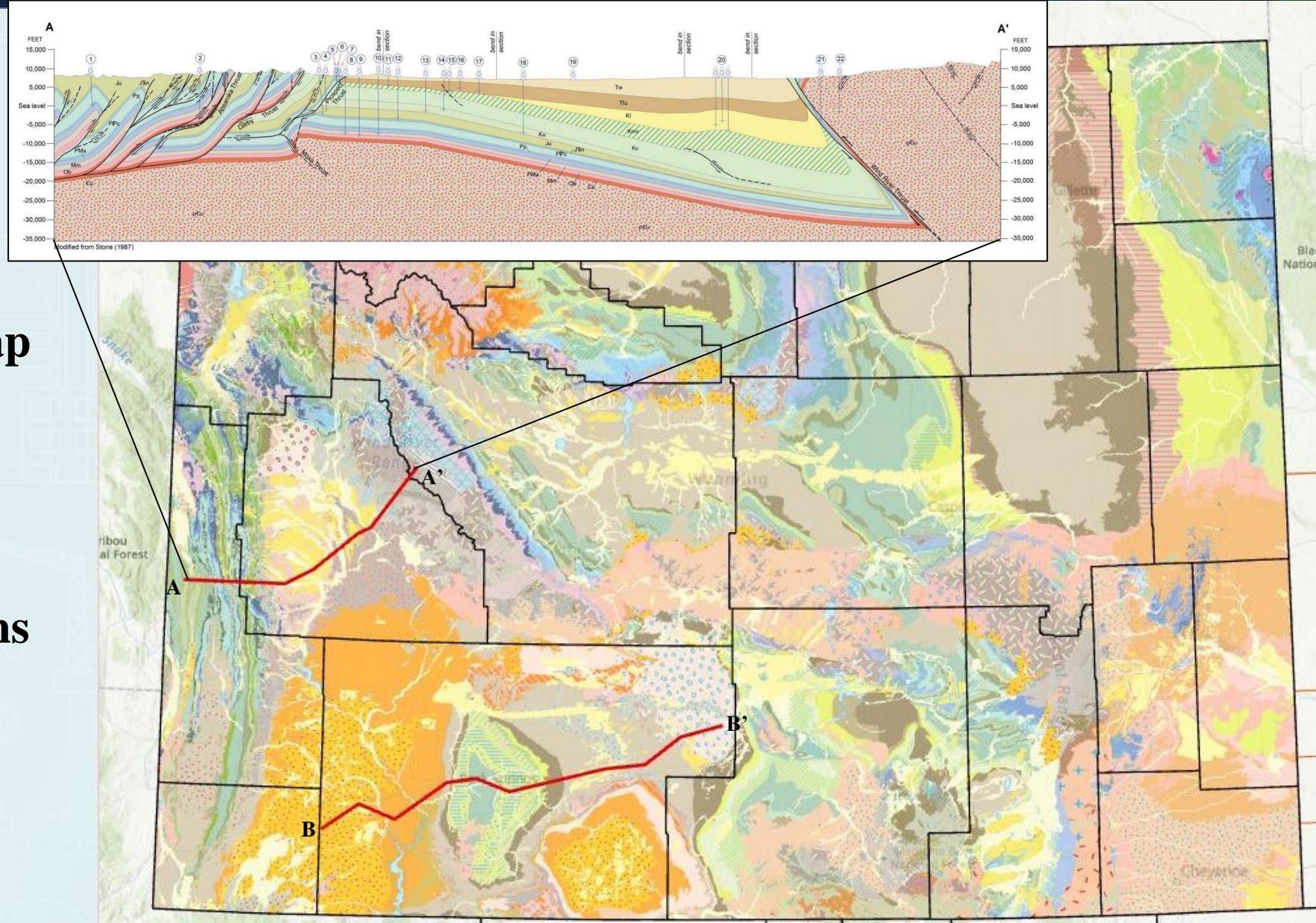
GEOLOGIC CROSS SECTIONS, GREATER GREEN RIVER BASIN, WYOMING
 Vertical exaggeration - 2x

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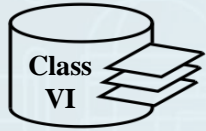


- georeferenced inset map
- digitized cross section lines
- associated cross sections images in pop-up

WEB SERVER

ser-web.arcc.uwyo.edu

File share for non-GIS public downloads



DATABASE SERVER

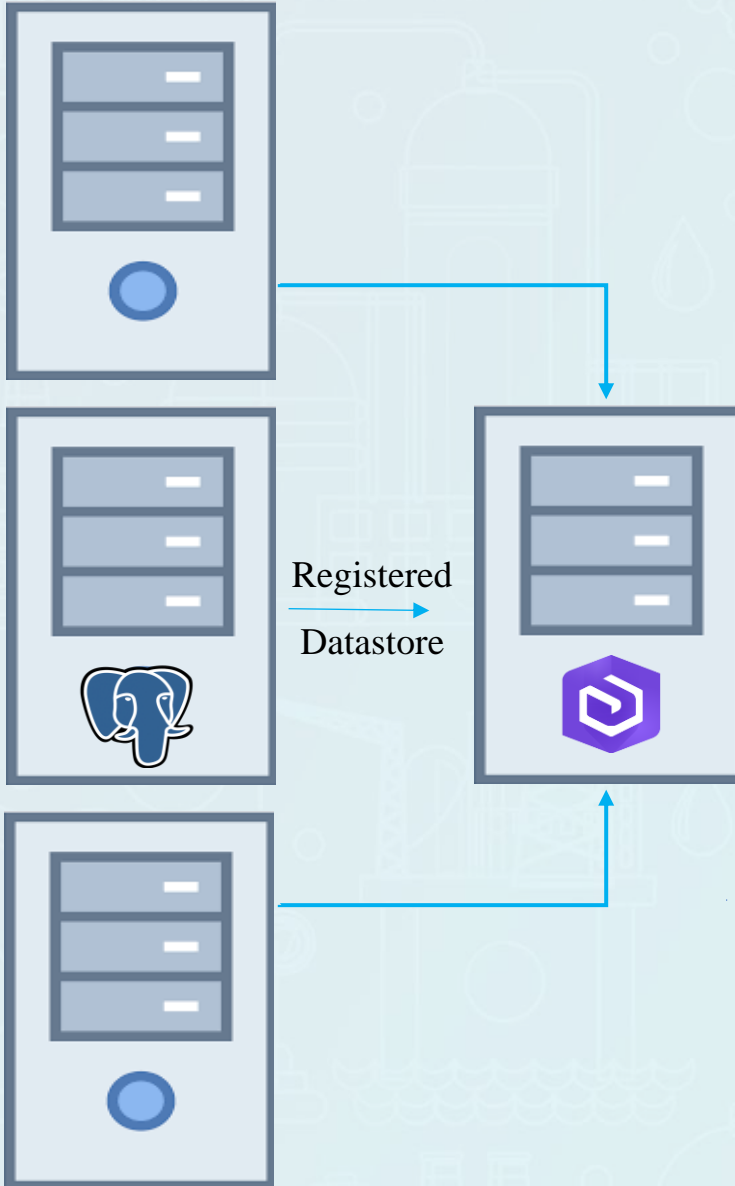
ser-gis-db.arcc.uwyo.edu

Enterprise geodatabase (SDE) running PostgreSQL

IMAGE SERVER

ser-image.arcc.uwyo.edu

GIS Server for raster data



ARCGIS ENTERPRISE

ser-gis.arcc.uwyo.edu

ArcServer & Portal for ArcGIS

DOWNLOAD



End users will be able to download the database as an ESRI file geodatabase or shapefiles.

VIEW



End users will be able to view contents of database in a web mapping application developed using ArcGIS Experience Builder.

STREAM



End users will be able to stream layers from the database using web services from an open-ended ArcGIS REST service directory.

Other tools in development: Carbonex and CCUS-LLM

Carbonex

An open web-based platform for high accuracy simulation of CO₂ solubility in complex brines at a wide range of pressures, temperatures, and salinities

CCUS-LLM

Leveraging AI and Large Language Models for navigating the CCUS regulatory landscape

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