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

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

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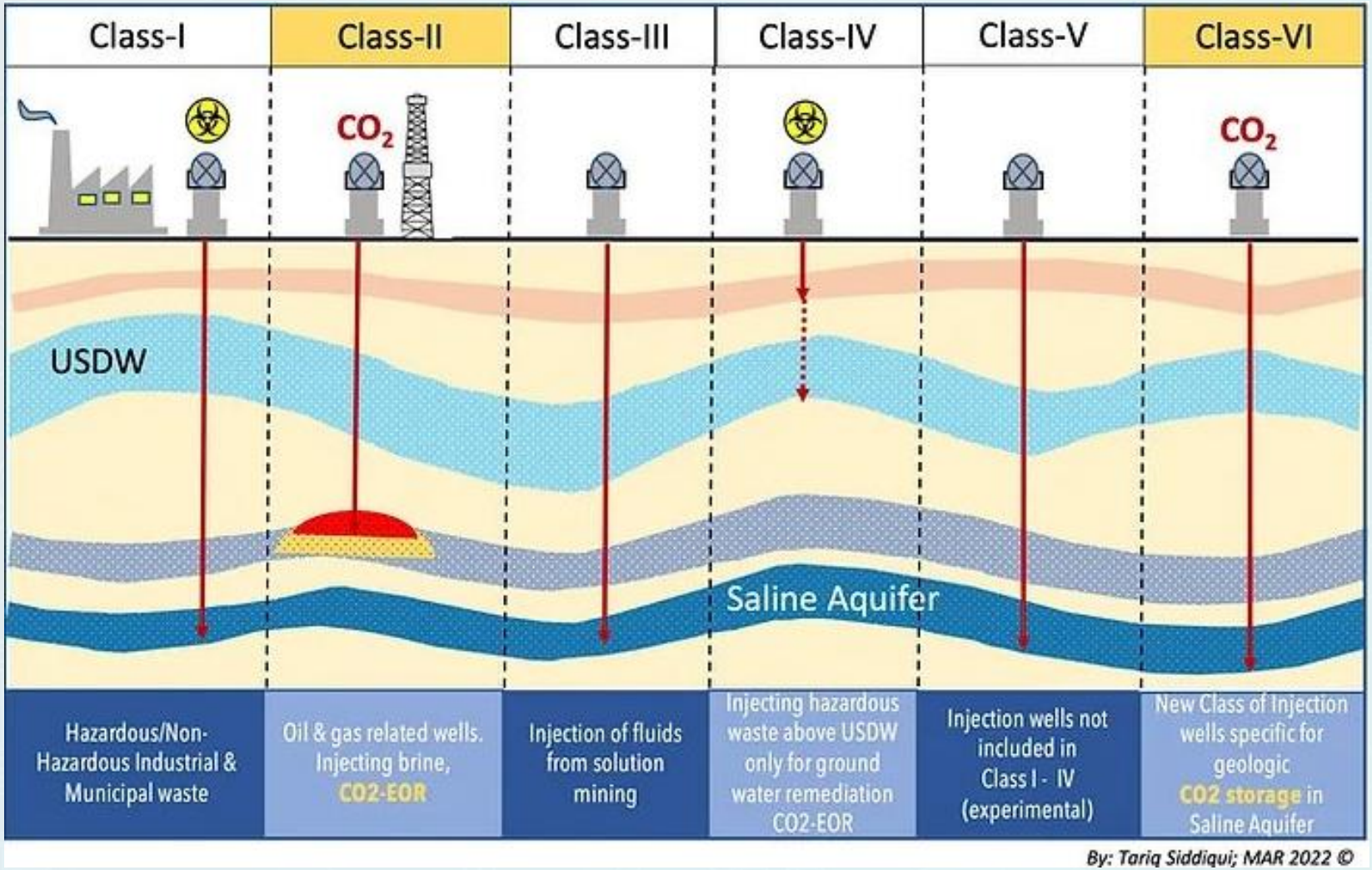
Underground Injection Control (UIC) Program

Well classes



CHALLENGES

<u>Permit application review</u>

- **Many applications submitted to WY-DEQ**

<u>Permit compilation</u>

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

Lead Institutions

- Center for Economic Geology Research
  University of Wyoming

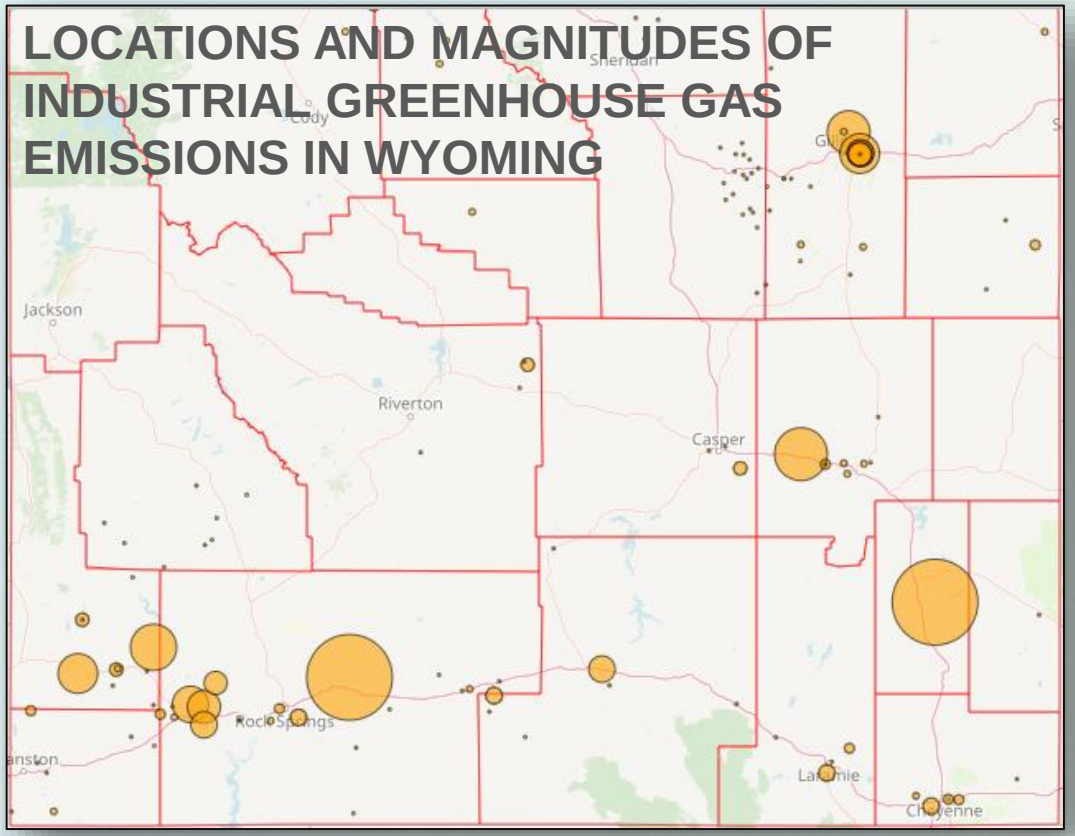
UNIVERSITY OF WYOMING | School of Energy Resources

- Wyoming Department of Environmental Quality

DEQ WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY

- Wyoming State Geological Survey

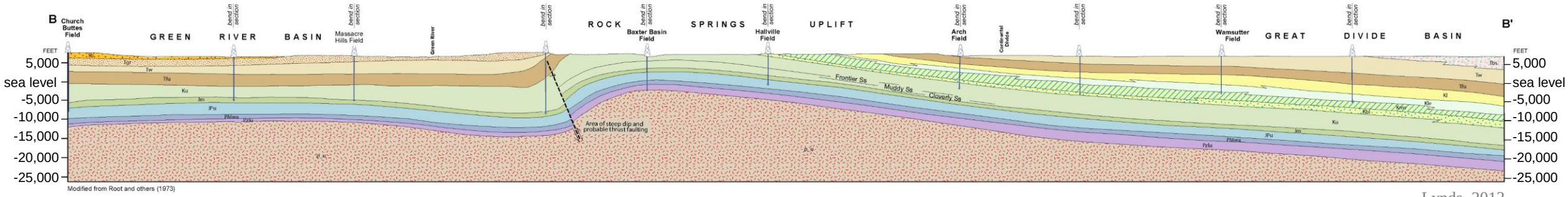
STATE OF WYOMING GEOLOGICAL SURVEY 1933



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 What's this?
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

Data and map from Facility Level Information on GreenHouse gases Tool (FLIGHT) https://ghgdata.epa.gov/ghgp/main.do

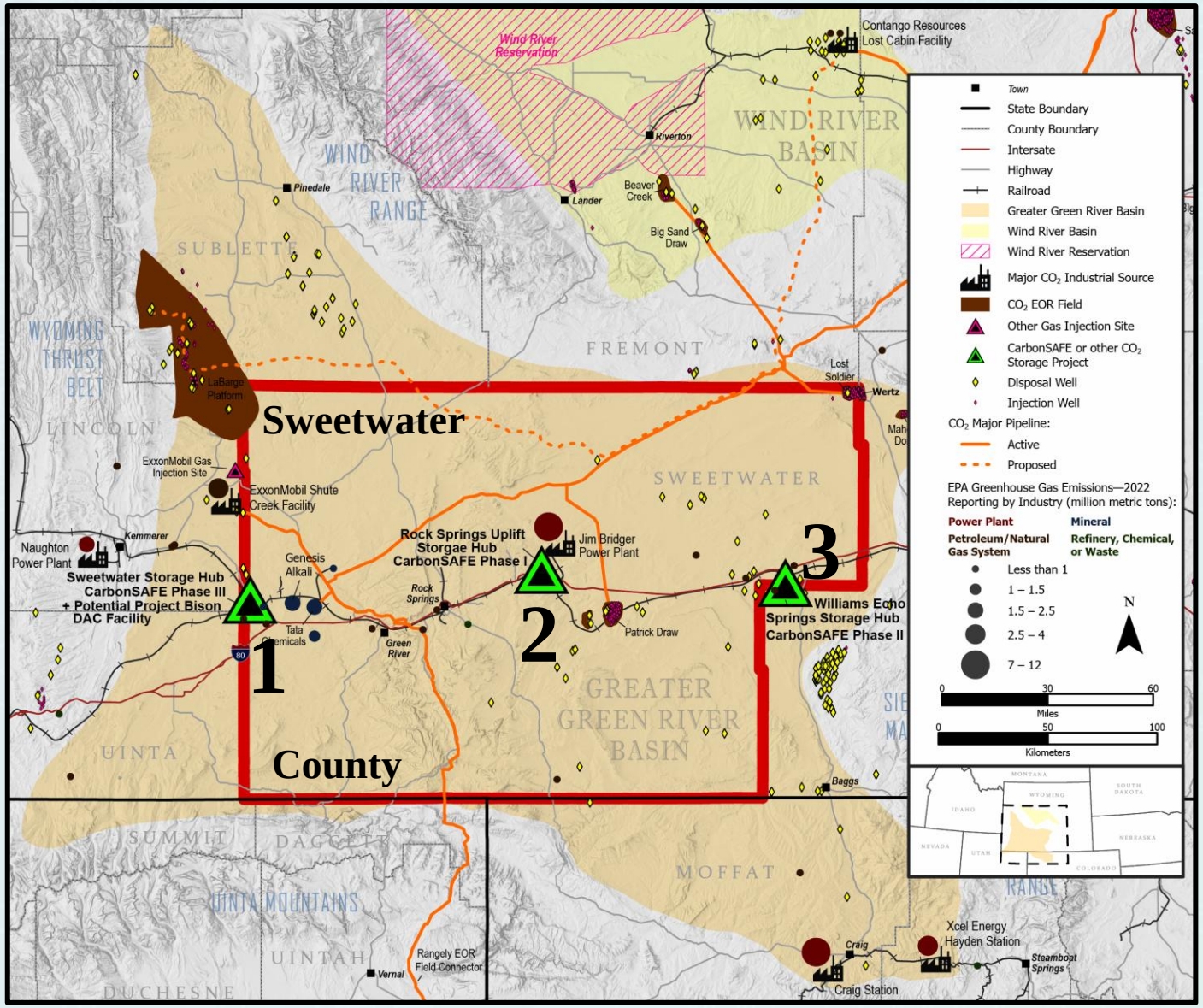


Lynds, 2013

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

DEQ 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

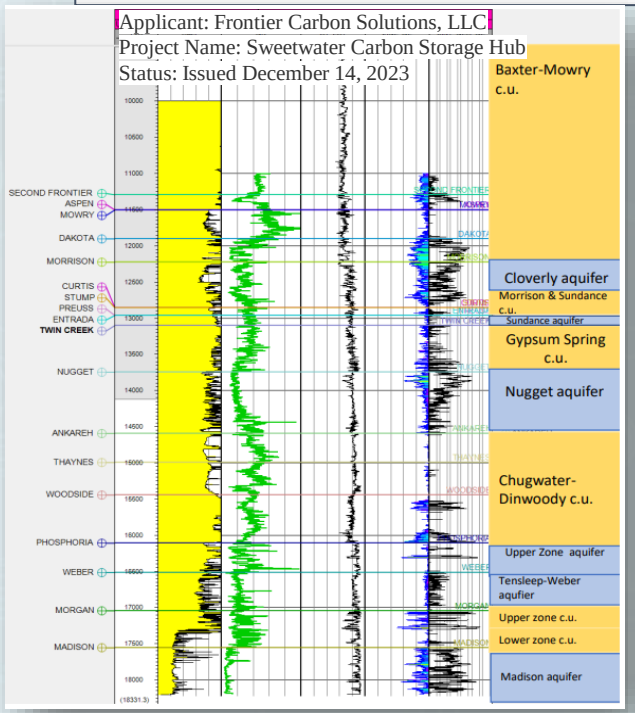
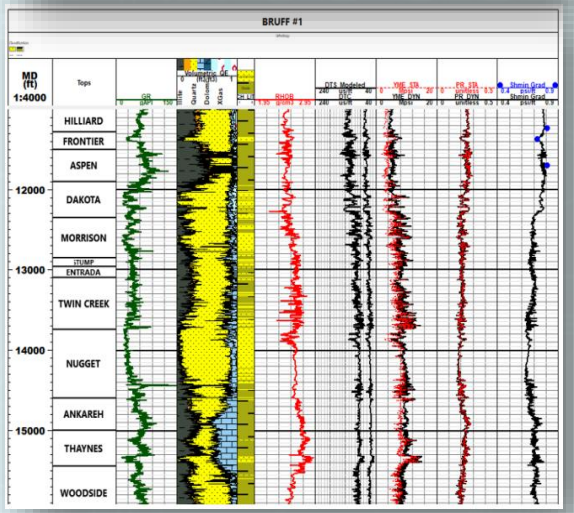


Table 8. Formations Comprising the CO2 Storage System

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

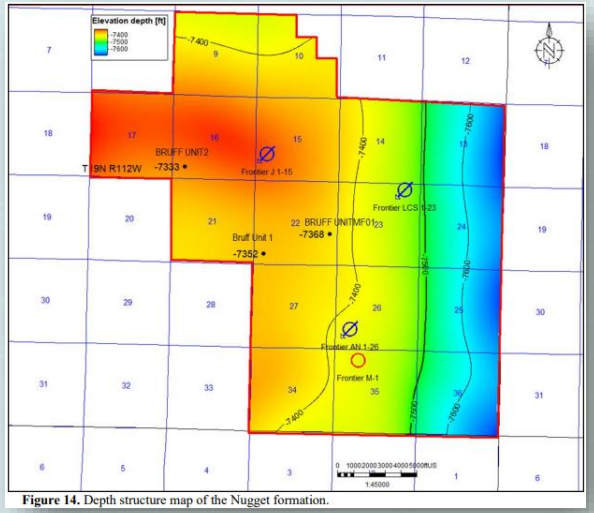


Figure 14. Depth structure map of the Nugget formation.

Sources: Wyoming Department of Environmental Quality https://deq.wyoming.gov/water-quality/groundwater/uic/class-vi/

Data categories

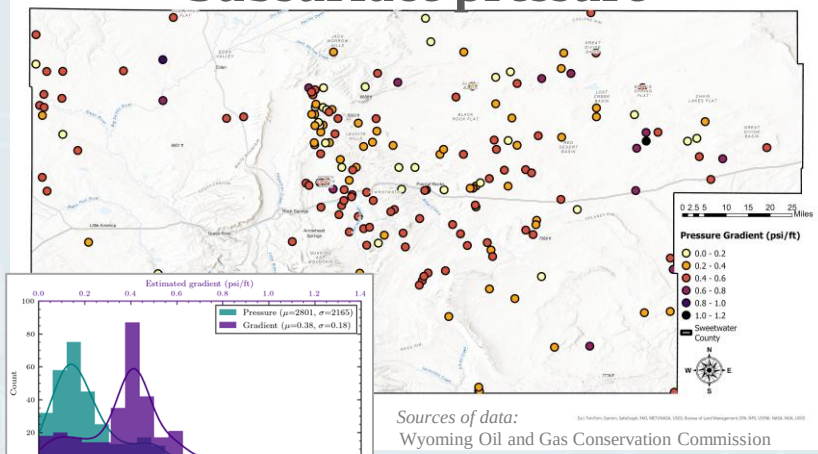
Category	Data
(1) Geologic and Topographic Maps and Cross Sections	Formation tops
	Aquifers characteristics
	Well Logs
	Core data
	2D/3D Seismic surveys (maps only)
(2) Regional Hydrostratigraphy	Formation tops
	Aquifers characteristics
	Water analysis
	Well Logs
	Core data
	2D/3D Seismic surveys (maps 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
	Geology / Lithologic description (literature)
	Pore Pressure (Drill-Stem Test)
(7) Geomechanical and Petrophysical Information about the Confining Zone(s)	Geomechanical data
	Core data
	Mineralogy (X-Ray Diffraction)
	Pore Pressure (Drill-Stem Test)
(8) Data on the Confining Zone(s)	Core data
	2D/3D Seismic surveys (maps only)
	Formation tops
	Aquifers characteristics
	Well Logs
	Faults
	Geology / Lithologic description (literature)
	Mineralogy (X-Ray Diffraction)
(9) Information on Faults and Fractures	2D/3D Seismic surveys (maps only)
	Faults
	Seismic events map
(10) Information on Seismic History	Seismic events map

* Categories are not finalized

Data compilation

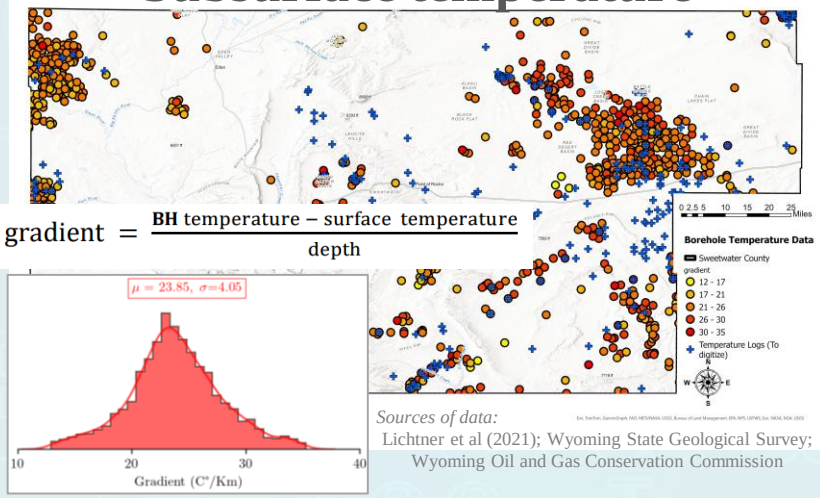
Subsurface pressure



Sources of data: Wyoming Oil and Gas Conservation Commission

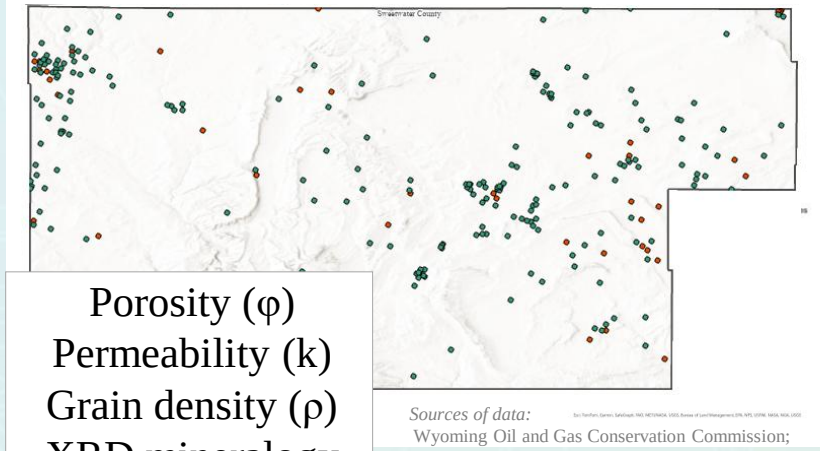
Subsurface temperature

$$\text{gradient} = \frac{\text{BH temperature} - \text{surface temperature}}{\text{depth}}$$



Sources of data: Lichtner et al (2021); Wyoming State Geological Survey; Wyoming Oil and Gas Conservation Commission

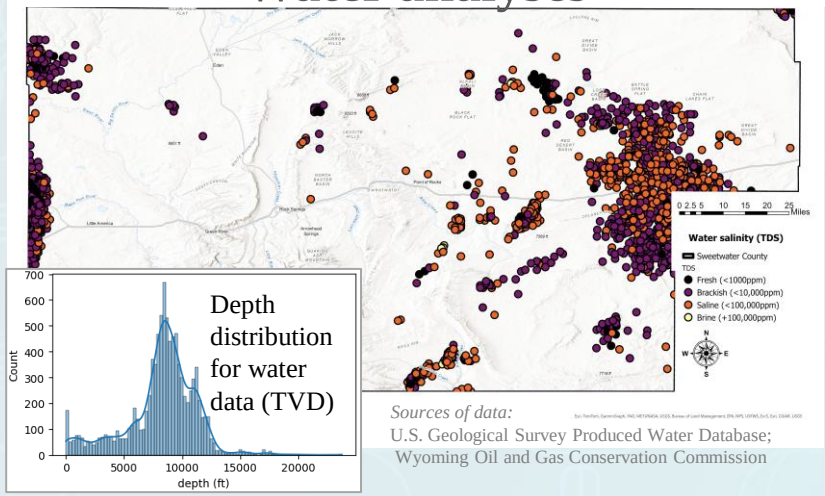
Core data



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

Sources of data: Wyoming Oil and Gas Conservation Commission; U.S. Geological Survey Core Research Laboratory

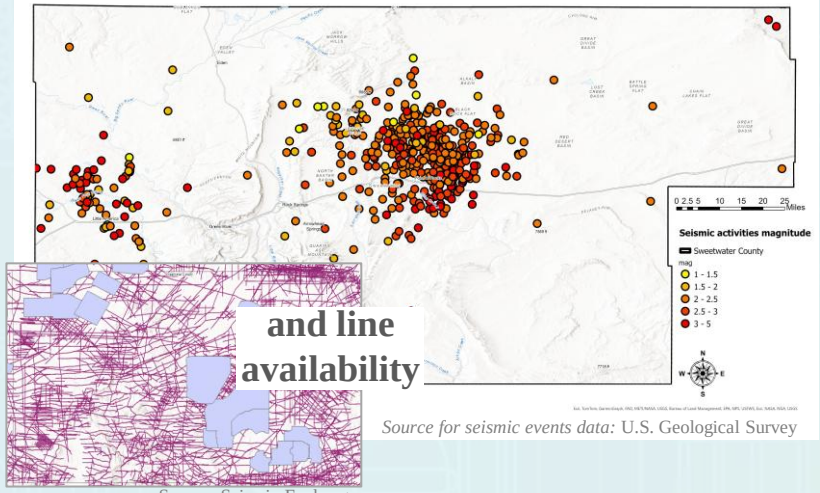
Water analyses



Depth distribution for water data (TVD)

Sources of data: U.S. Geological Survey Produced Water Database; Wyoming Oil and Gas Conservation Commission

Seismic events

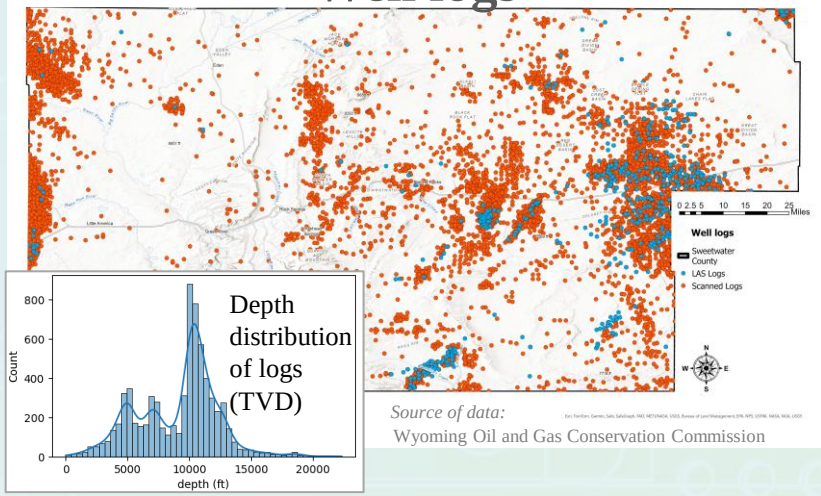


and line availability

Source for seismic events data: U.S. Geological Survey

Source: Seismic Exchange

Well logs



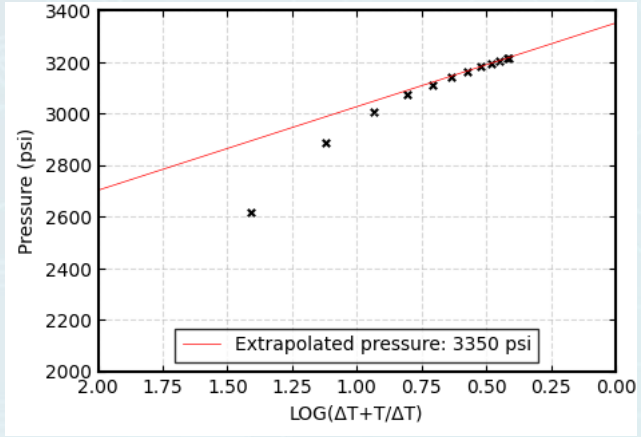
Depth distribution of logs (TVD)

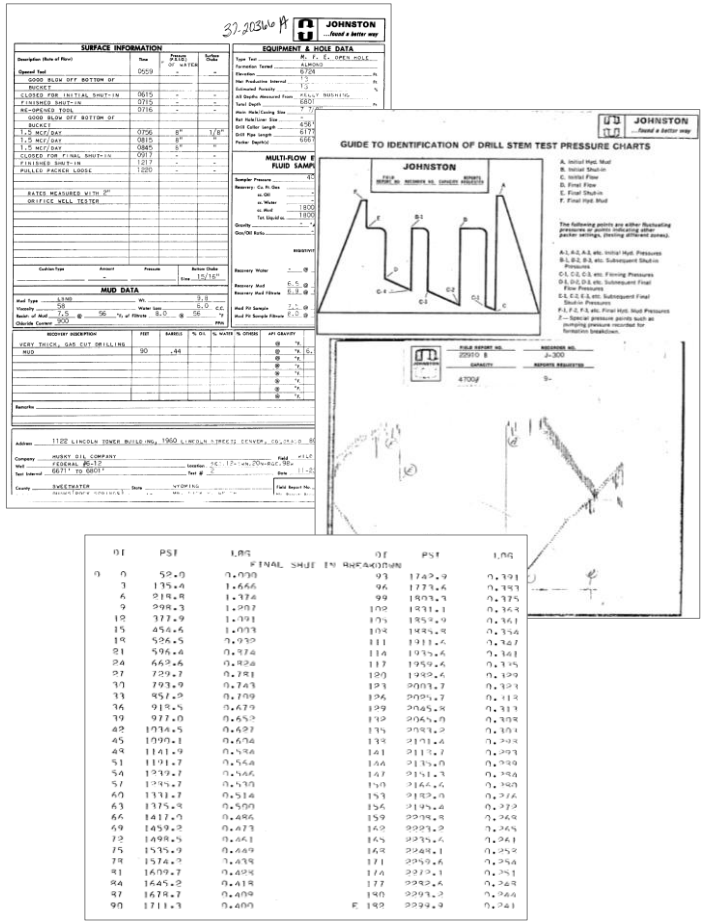
Source of data: Wyoming Oil and Gas Conservation Commission

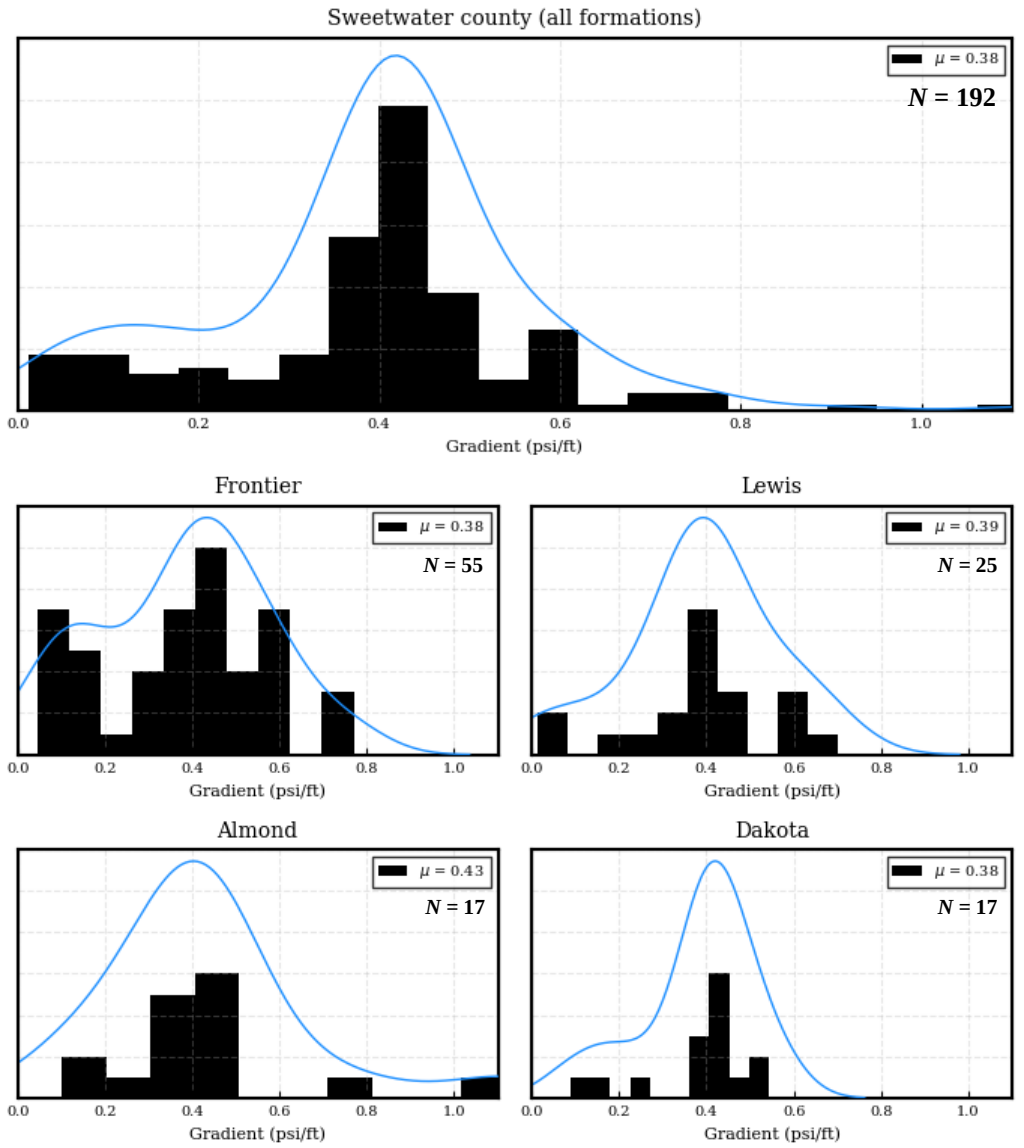
Data compilation – drill stem tests

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

Created Python code for running batch Horner analyses







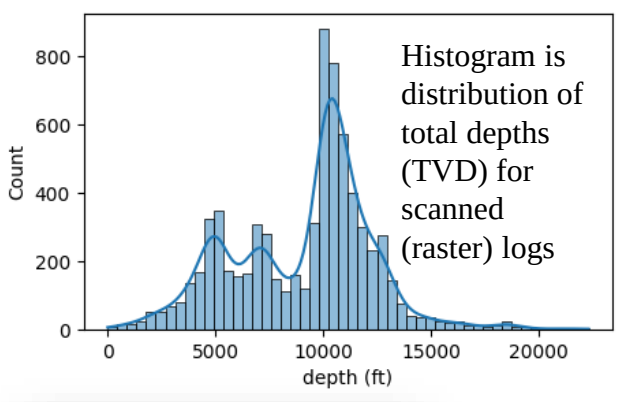
Latrach et al., *in review*

Data: Wyoming Oil and Gas Conservation Commission

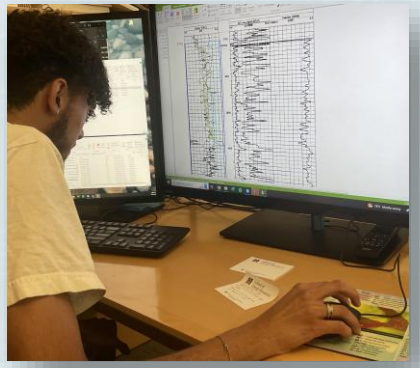
Data compilation – well logs

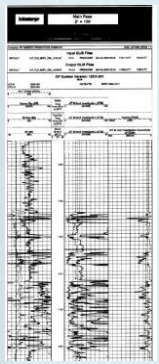
***N* = 1,070** LAS files for ***n* = 770** wells

***N* = 20,800** scanned logs for ***n* = 7,200** wells



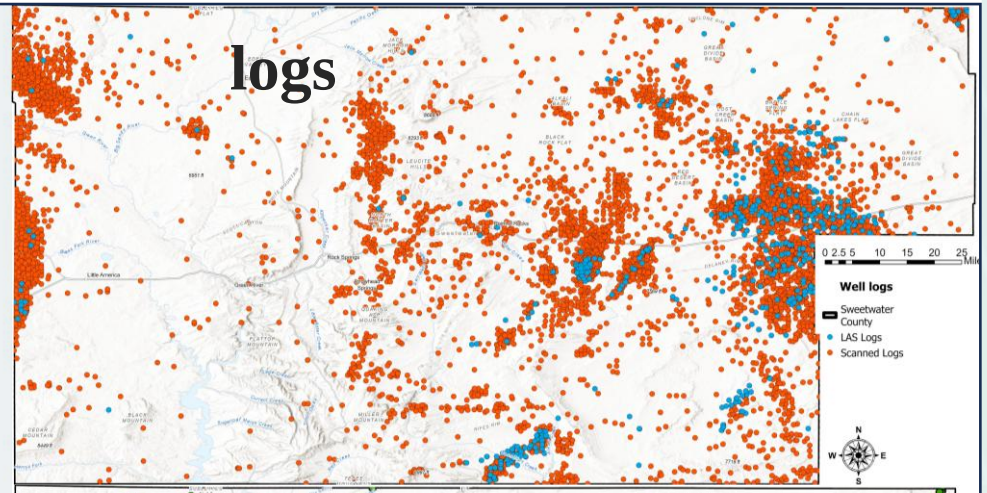
Histogram is distribution of total depths (TVD) for scanned (raster) logs

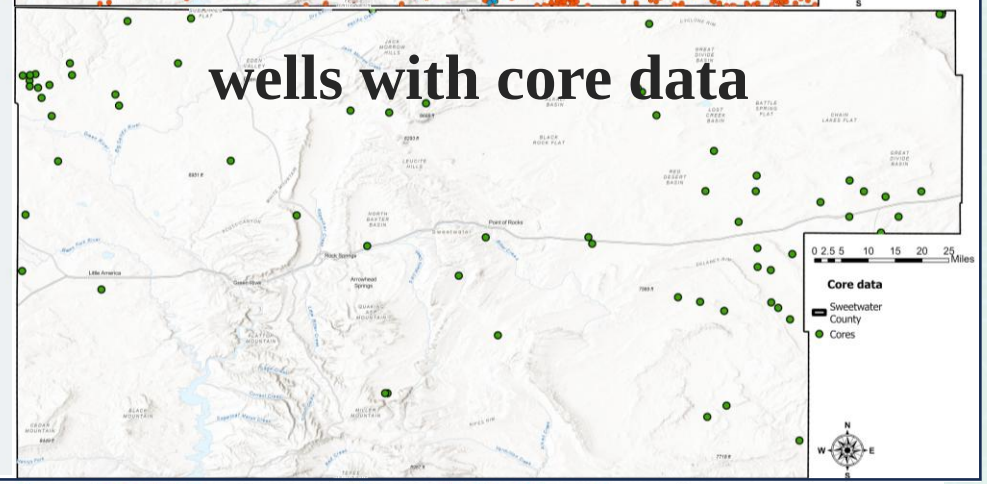




Prioritization

- **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

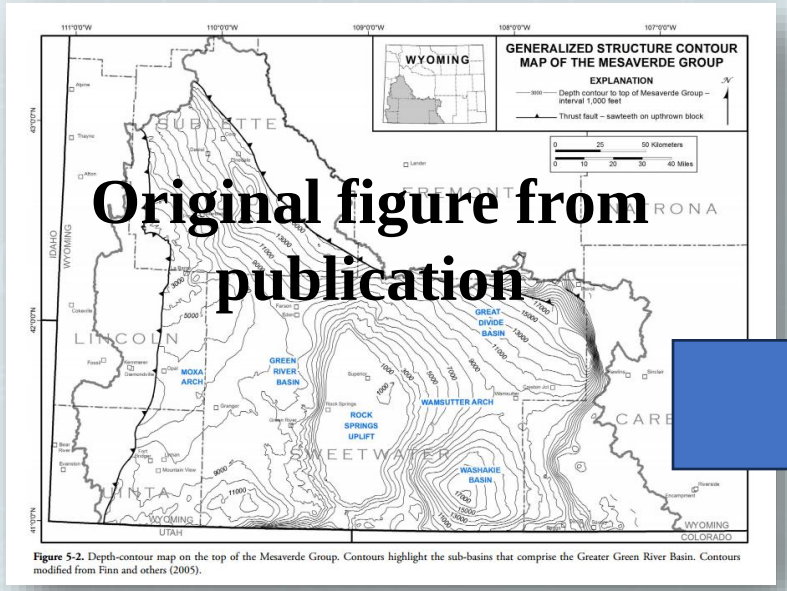
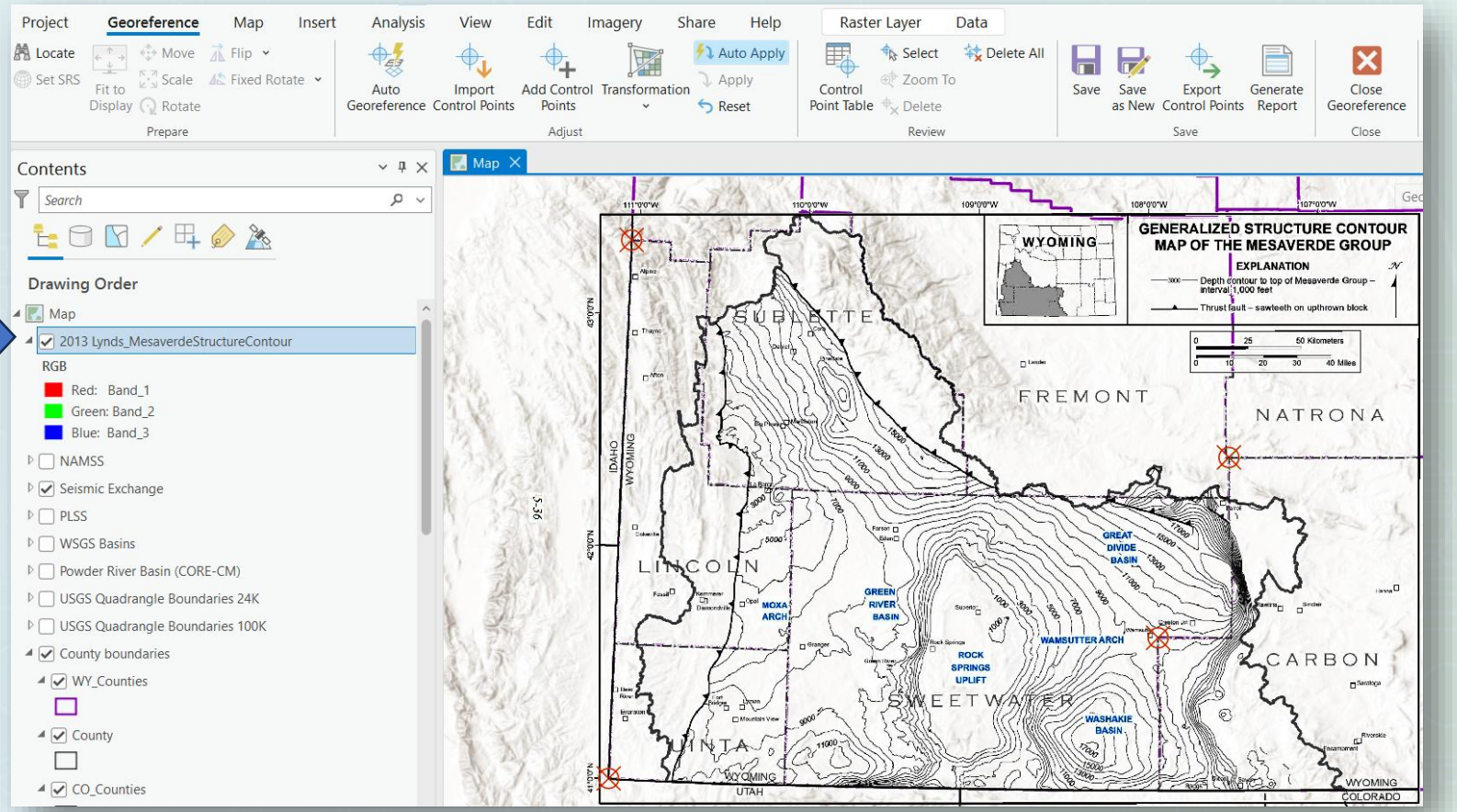


Figure 5-2. Depth-contour map on the top of the Mesaverde Group. Contours highlight the sub-basins that comprise the Greater Green River Basin. Contours modified from Finn and others (2005).

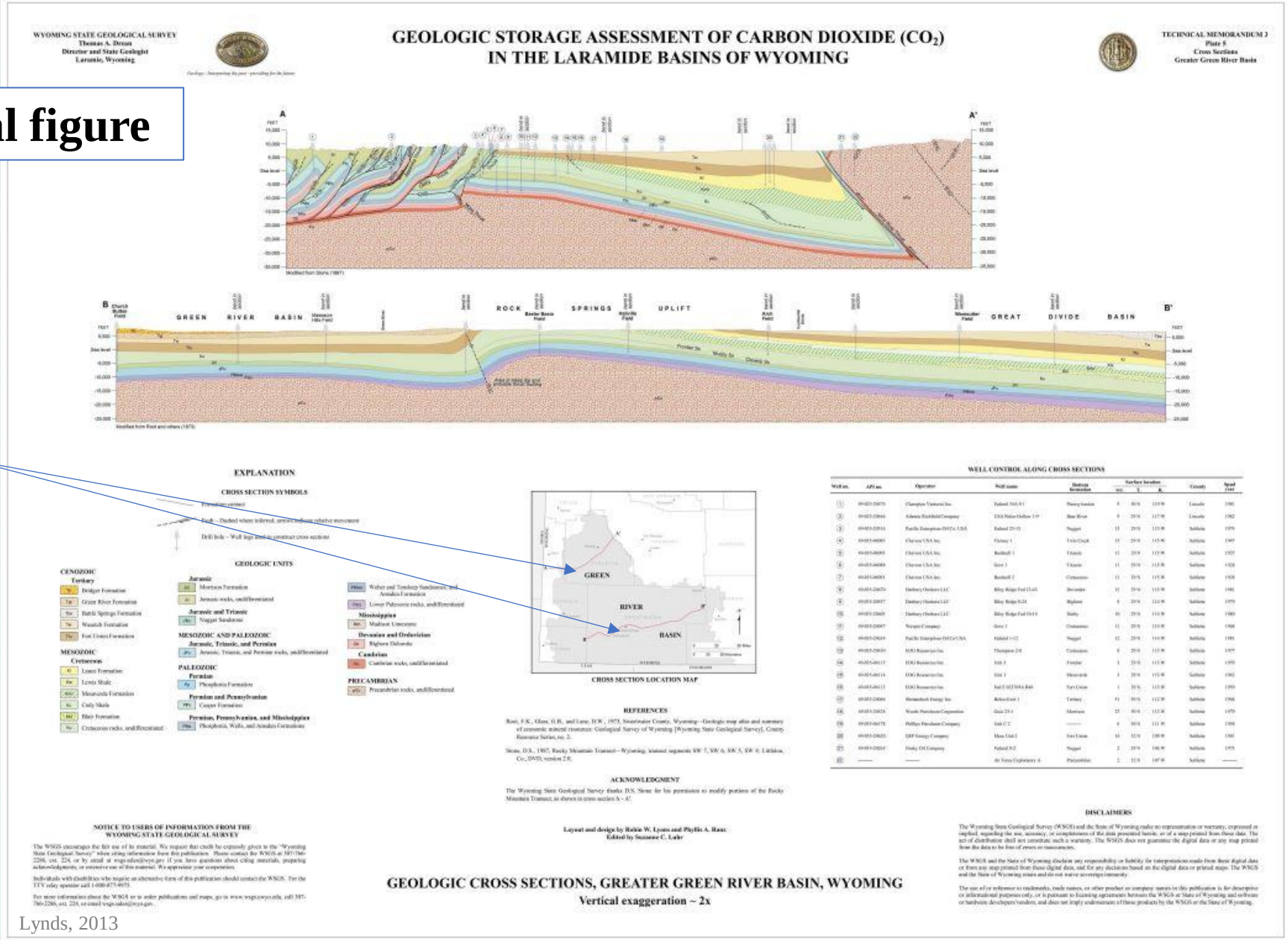
Original figure from publication

Lynds, 2013



Original figure

cross section lines



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

GEOLOGIC STORAGE ASSESSMENT OF CARBON DIOXIDE (CO_2) IN THE LARAMIDE BASINS OF WYOMING

TECHNICAL MEMORANDUM 3
Plate 5
Cross Sections
Greater Green River Basin

A A'

B GREEN RIVER BASIN ROCK SPRINGS UPLIFT GREAT DIVIDE BASIN B'

EXPLANATION

CROSS SECTION SYMBOLS

GEOLOGIC UNITS

CENOZOIC
Tertiary
Bridger Formation
Green River Formation
Battle Springs Formation
Wasatch Formation
Fort Union Formation
MESOZOIC
Cretaceous
Lance Formation
Lewis Shale
Meeteetse Formation
Cody Shale
Mesaverde Formation
Frontier Formation
Cretaceous rocks, undifferentiated
Jurassic
Morrison Formation
Jurassic rocks, undifferentiated
Jurassic and Triassic
Nugget Sandstone
MESOZOIC AND PALEOZOIC
Jurassic, Triassic, and Permian
Jurassic, Triassic, and Permian rocks, undifferentiated
PALEOZOIC
Permian
Phosphoria Formation
Permian and Pennsylvanian
Casper Formation
Permian, Pennsylvanian, and Mississippian
Phosphoria, Wells, and Amsden Formations
Weber and Tensleep Sandstones, and Amsden Formation
Lower Paleozoic rocks, undifferentiated
Mississippian
Madison Limestone
Devonian and Ordovician
Bighorn Dolomite
Cambrian
Cambrian rocks, undifferentiated
PRECAMBRIAN
Precambrian rocks, undifferentiated

CROSS SECTION LOCATION MAP

WELL CONTROL ALONG CROSS SECTIONS

REFERENCES

ACKNOWLEDGMENT

NOTICE TO USERS OF INFORMATION FROM THE WYOMING STATE GEOLOGICAL SURVEY

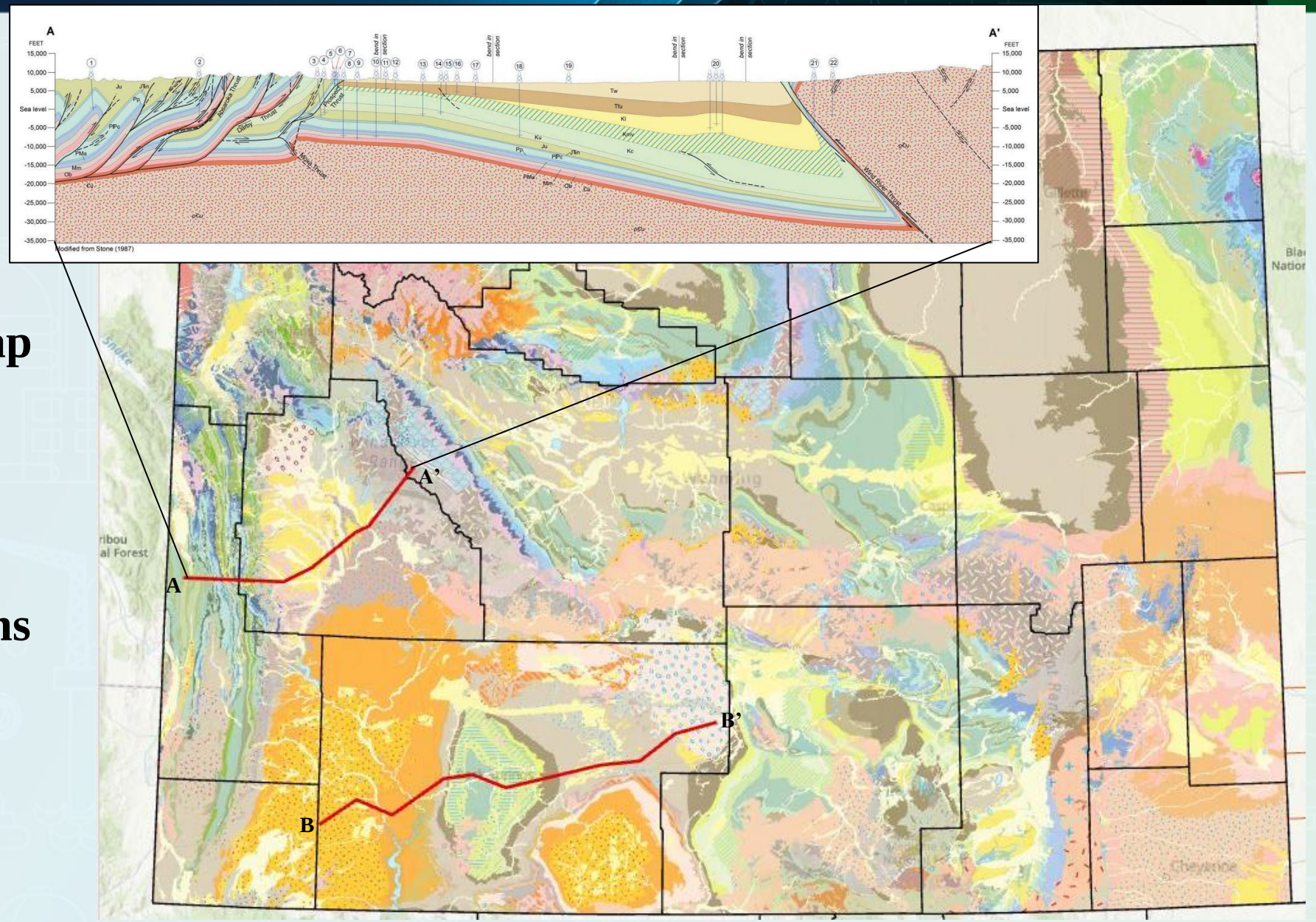
DISCLAIMERS

Layout and design by Robin W. Lyons and Phyllis A. Ranz
Edited by Suzanne C. Luhr

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

Lynds, 2013

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



Map and cross section: Wyoming State Geological Survey; Lynds, 2013

WEB SERVER

***ser-web**.arcc.uwyo.edu*

File share for non-GIS public downloads

Class VI

DATABASE SERVER

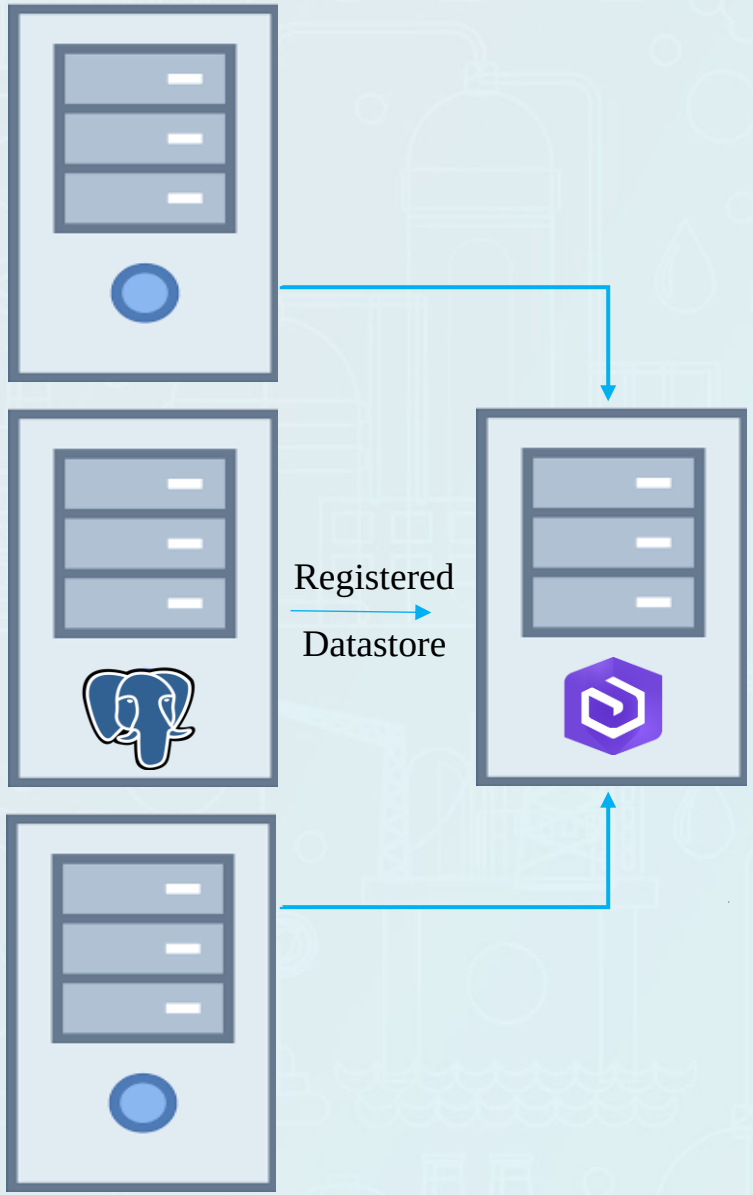
***ser-gis-db**.arcc.uwyo.edu*

Enterprise geodatabase (SDE) running PostgreSQL

IMAGE SERVER

***ser-image**.arcc.uwyo.edu*

GIS Server for raster data



Registered Datastore

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 CO_2 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

Carbonex and CCUS-LLM developer: Abdeldjalil Latrach, University of Wyoming

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