San Juan Basin CarbonSAFE Phase III: Ensuring Safe Subsurface Storage of CO_2 in Saline Reservoirs

DE-FE0031890

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U.S. Department of Energy

National Energy Technology Laboratory

Carbon Management Project Review Meeting

August 5-9, 2024

Presentation Outline

- Project overview
- Project Objectives
- Accomplishments
- Geology of San Juan Basin
- Technical Approach
- Summary
- Next Steps

Program Overview

- Funding Profile
- Overall Project Performance Dates

October 2020 – March 2025

Project Objectives/ Technical Approach

The overall objective of this proposed project is to perform a comprehensive commercial-scale site characterization of a storage complex located within San Juan County, New Mexico to accelerate the deployment of integrated carbon capture and storage (CCS) technology

- Task 1.0 – Project Management and Planning
- Task 2.0 – National Environmental Protection Act (NEPA)
- Task 3.0 – Site Characterization
- Task 4.0 – Reservoir and Caprock Characterization
- Task 5.0 – Geologic Modeling and Simulation
- Task 6.0 – Underground Injection Control (UIC) Class VI Permit Application
- Task 7.0 – Integrated Assessment Modeling
- Task 8.0 – Stakeholder/Policymaker Outreach/Education and Engagement
- Task 9.0 – Coordination with other DOE Projects

SJB CarbonSAFE Project Facts

Key Project Facts

- Perform Site Characterization of storage complex within San Juan Basin
- Source CO_2 from Escalante H_2 plant, located in Prewitt, NM, USA.
- Initial UIC Class VI permit submitted in 2023
- Community and stakeholder outreach on CCS technology and its benefits

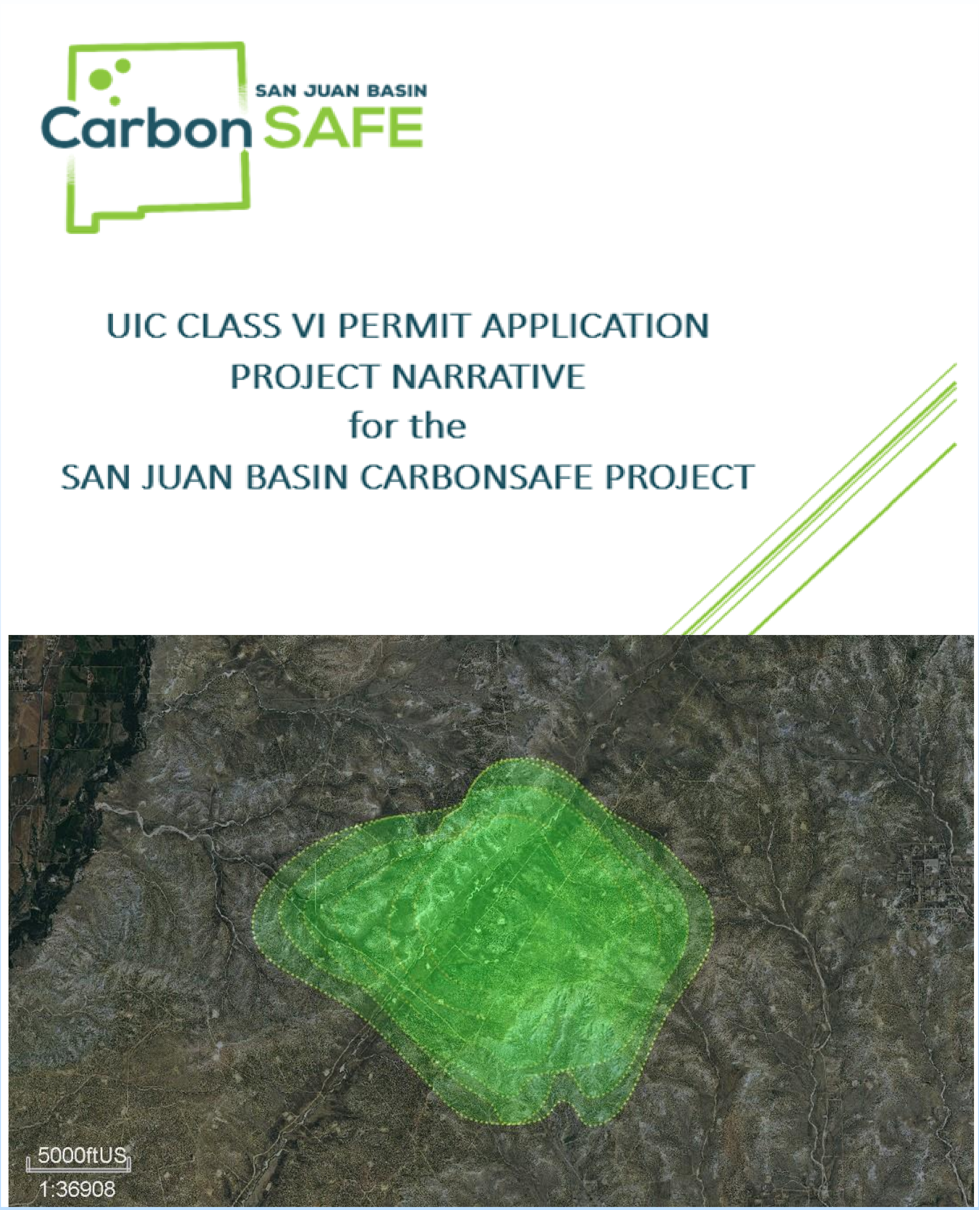
Characterization Plan

- Drilled characterization well, perform injectivity tests
- Recovered ~ 450 ft of Core, sampled drilling cuttings, advanced log suites measurements
- Perform suites of laboratory experiments and numerical models
- Purchased 100 sq.miles 3D seismic, acquire 3D VSP,
- Installed DAS/DTS/DSS Optical fiber behind casing

Technical Approach/Project Scope

Task/ Subtask	Milestone Title & Description	Status
1.0	Project Kick-off meeting	
2.3	NEPA documentation progress	Ongoing
3.1	Evaluation of available data such as seismic	Completed
3.3	Acquisition and processing of Seismic data	Completed
3.4.5	Stratigraphic well drilled	Completed
4	Complete needed Caprock and reservoir analysis for Modeling	Completed
5.2	Complete initial simulations for UIC permit application	Completed
5.2.8	Complete AOR modeling	Completed
5.3	Complete initial Risk assessment for UIC permit application	Completed
6	Complete documentation to submit UIC class VI application	Completed
6.10	Progress report on submitted UIC class VI application	Completed
6.10	Progress and/or receiving approval for UIC class VI application	Ongoing

Update on Submitted UIC Class VI Permit

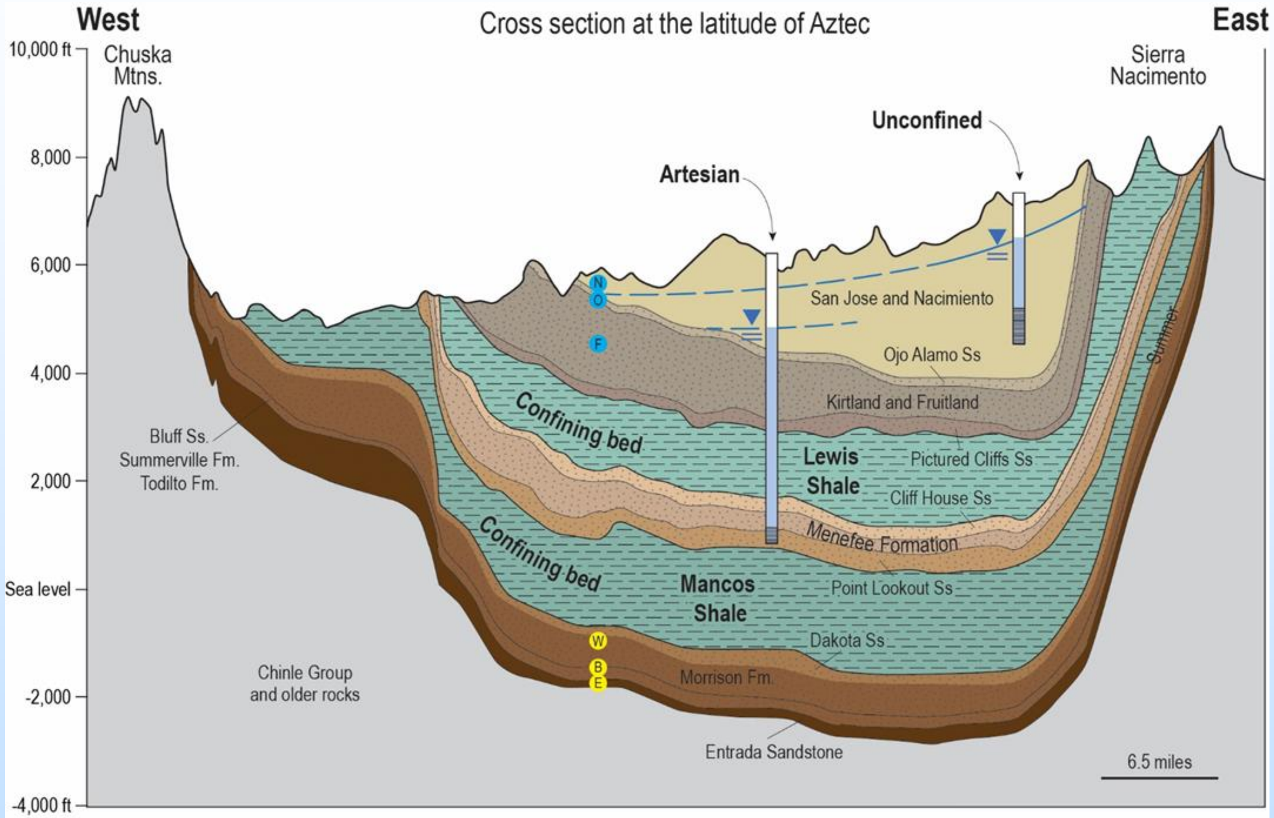


- Permit Application submission date: June 2023
- Completeness Review: July 2023
- Technical Review: January 2025
- Draft Permit: March 2025
- Public Comment: April 2025
- Final Permit Decision: July 2025

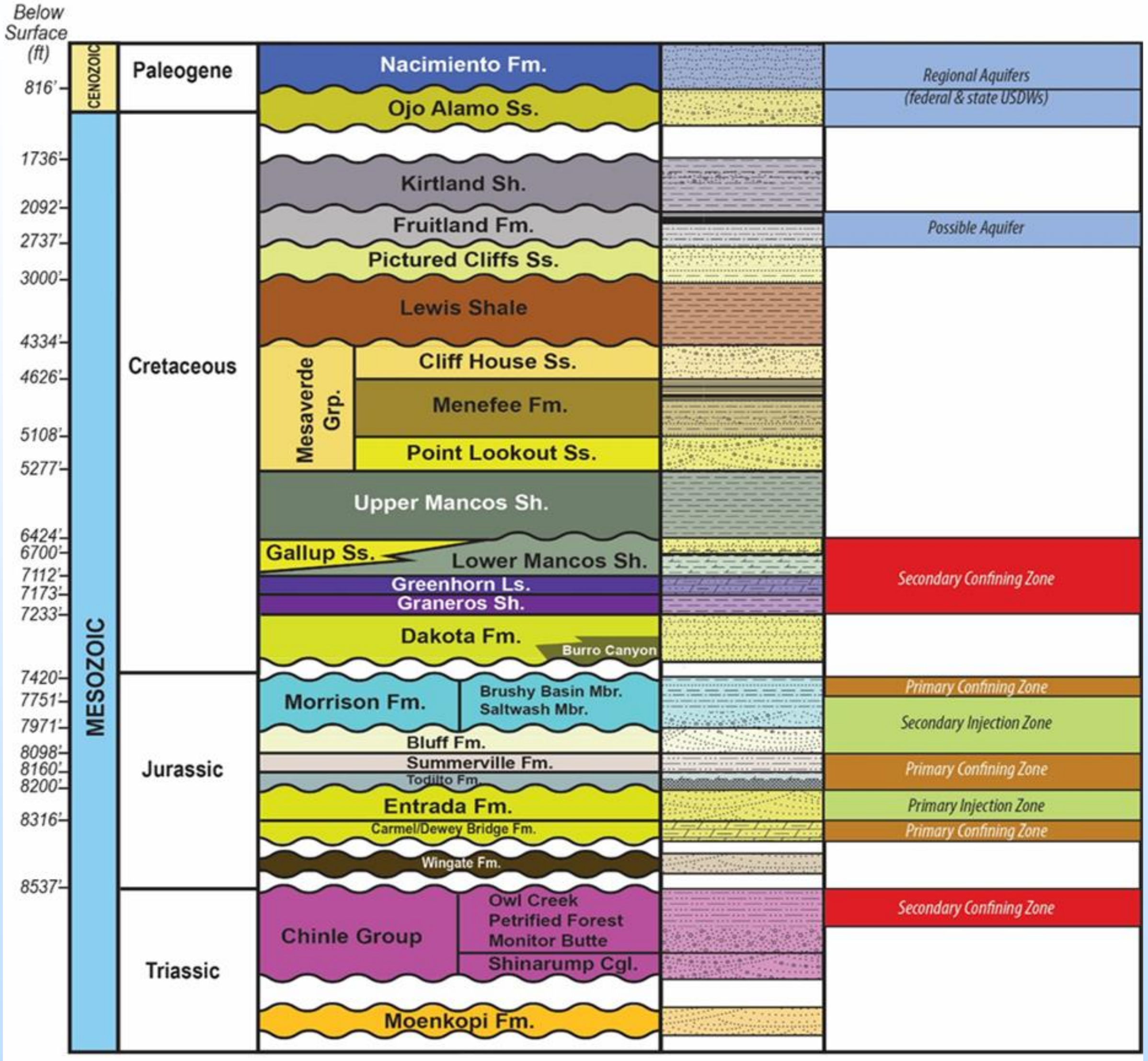
Additional UIC Class VI Plans

- Site Characterization
- Area of Review (AoR) Delineation
- Corrective Action
- Injection Well Construction
- Testing and Monitoring during Operation
- Plugging, Post-Injection Site Care (PISC), and Site Closure
- Financial Responsibility

San Juan Basin Geology



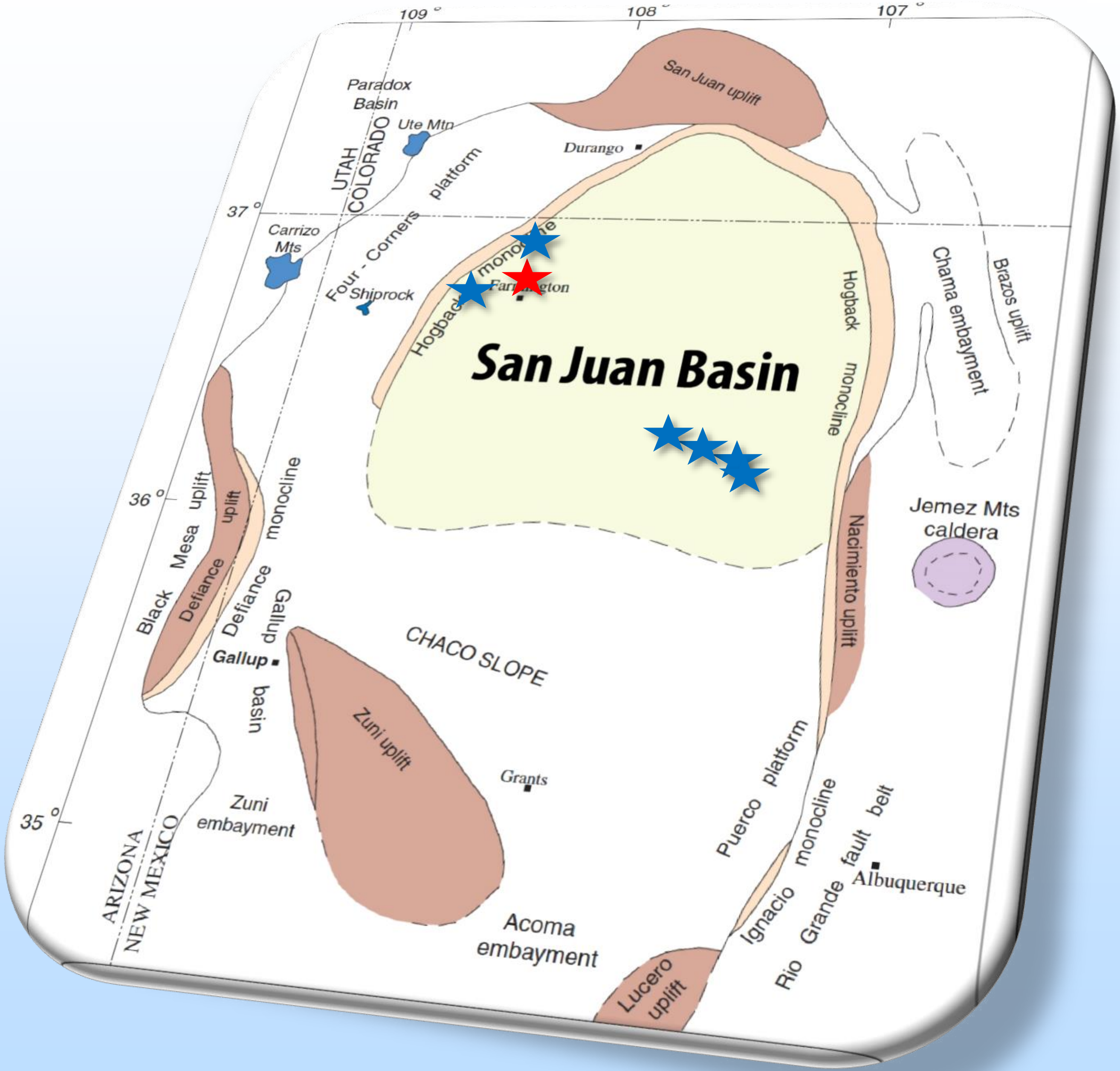
Schematic cross section of the San Juan Basin illustrating confining beds (blue units) and sandstone strata (brown, tan, and gray units).



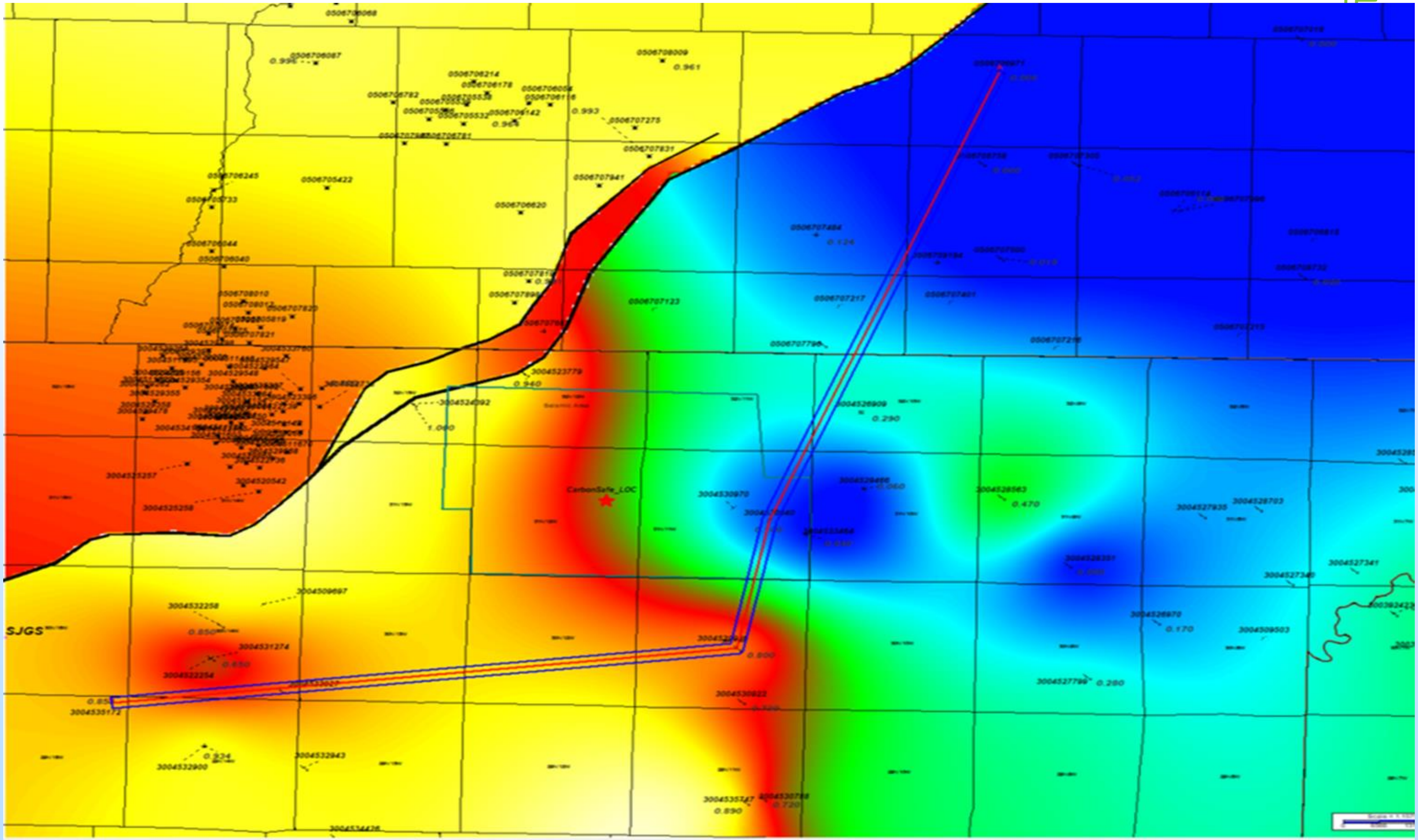
Stratigraphic column for San Juan Basin

SJB Basin Structural Elements

- Key Wells in the SJB:
  - SJB CARBON SAFE STRAT TEST #001 (30-045-38272)
  - State Strat 600 #001
  - Pathfinder AGI #001
  - Santa Fe H 20 #001
  - Federal 21 #002
  - EMU #001
  - San Luis Fed #001



Site Selection

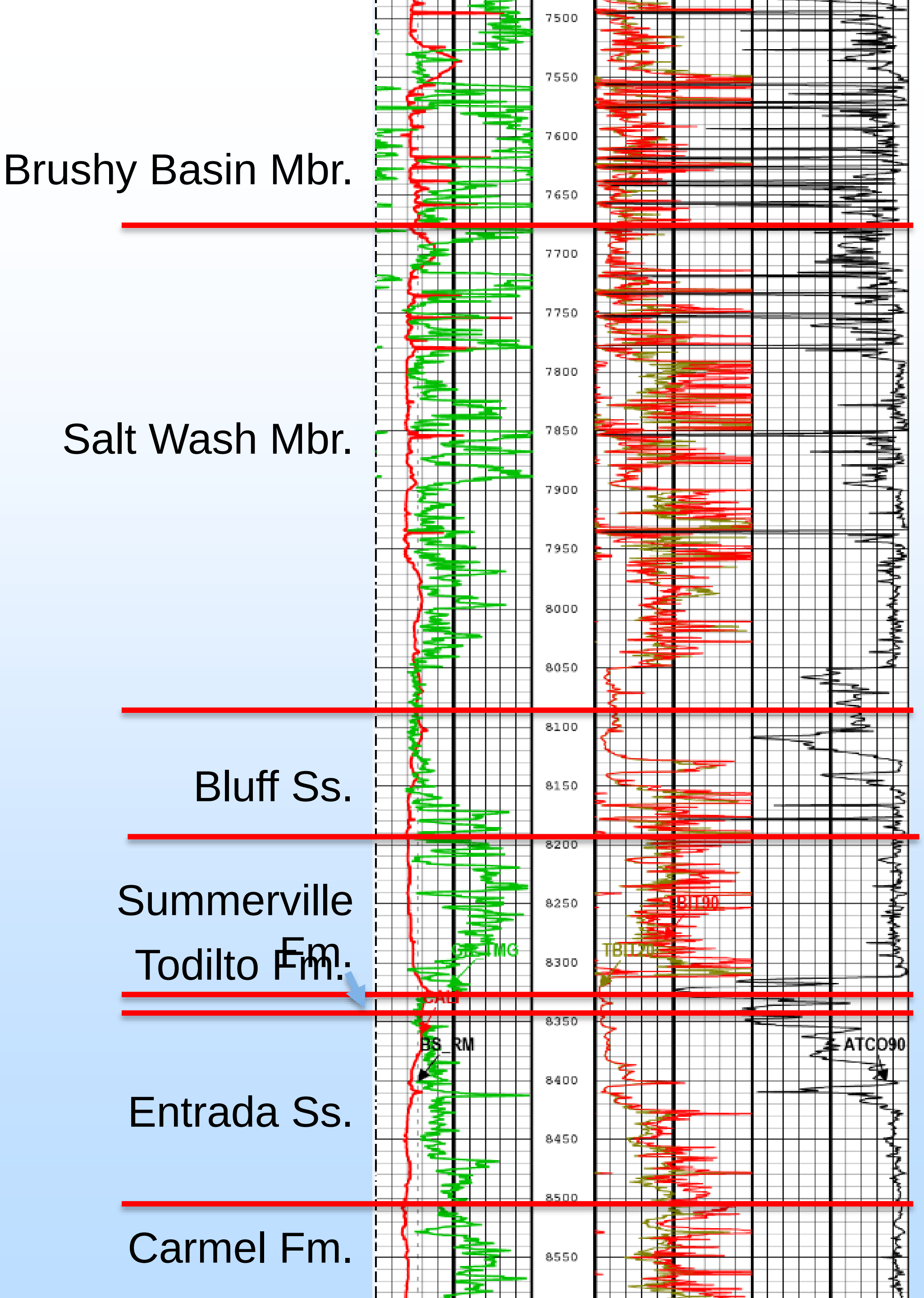


SJB CarbonSAFE Strat Test #001 Core

- Core description
  - Facies descriptions (bedding, grain size, sorting, color, bioturbation, etc.)
  - Fractures and other compactional features
  - Identify locations for sub-sampling
- Petrographic analyses
  - Original mineralogy
  - Fabrics
  - Diagenesis vs. injection
- Core analyses
  - ~~XRD analysis~~
  - Porosity & permeability analyses

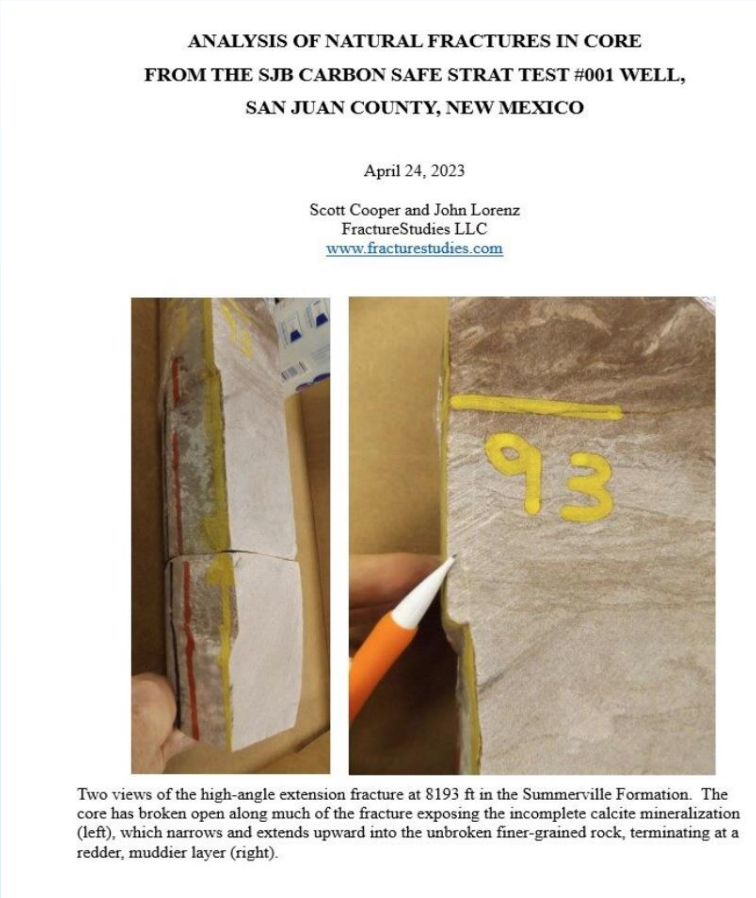
SJB CarbonSAFE Strat Test #001

- 450 ft of core
- CT scans of the entire core
- 120 standard petrographic thin sections (Carmel to Brushy Basin)
- Routine core analysis for ~170 samples
- XRD data for 49 depths



Fracture Distribution in SJB CS Strat Test #001

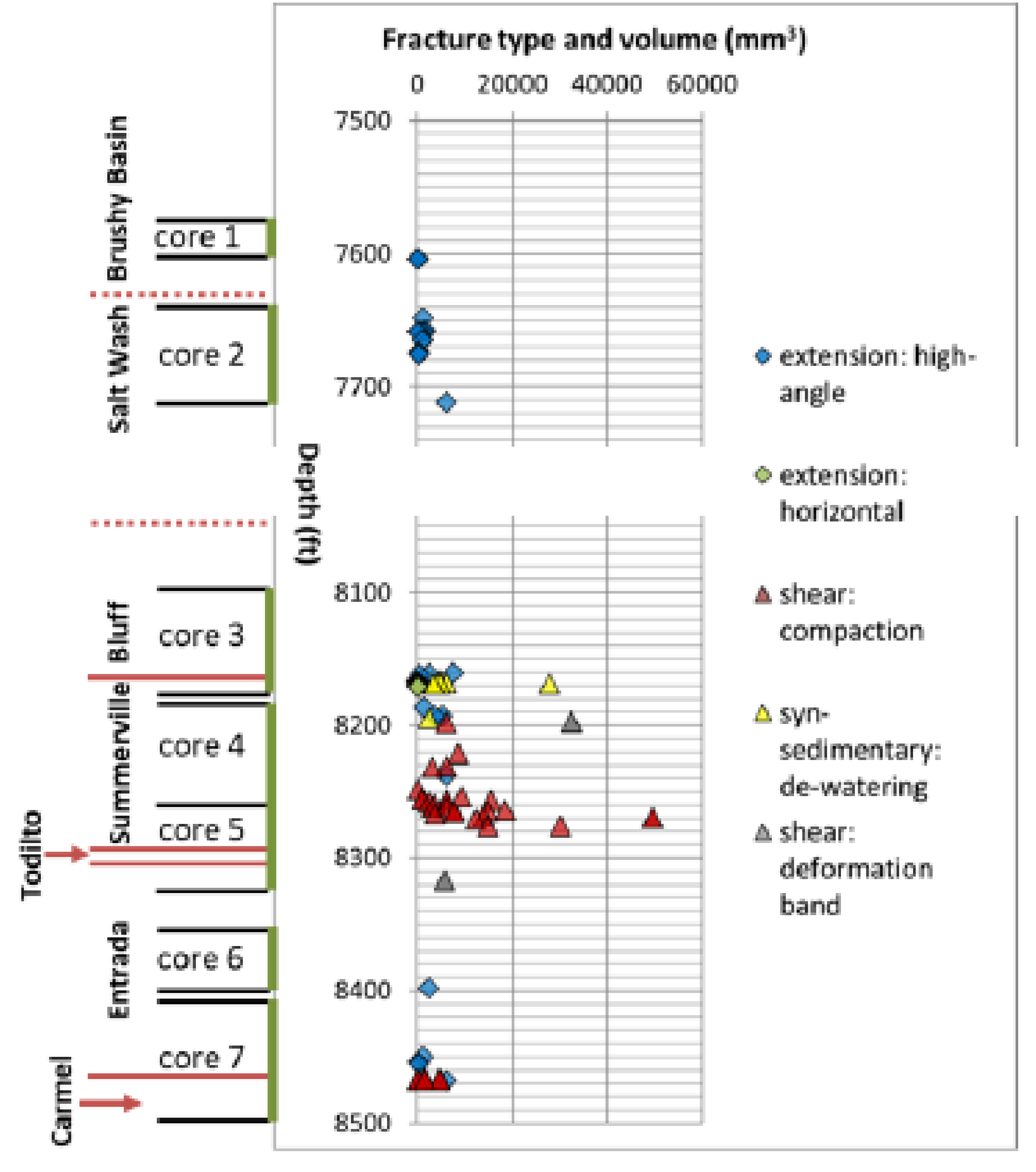
- Out of ~450 ft of core, only 95 fractures were identified
- Fracture types and density vary by formation


ANALYSIS OF NATURAL FRACTURES IN CORE
FROM THE SJB CARBON SAFE STRAT TEST #001 WELL,
SAN JUAN COUNTY, NEW MEXICO

April 24, 2023

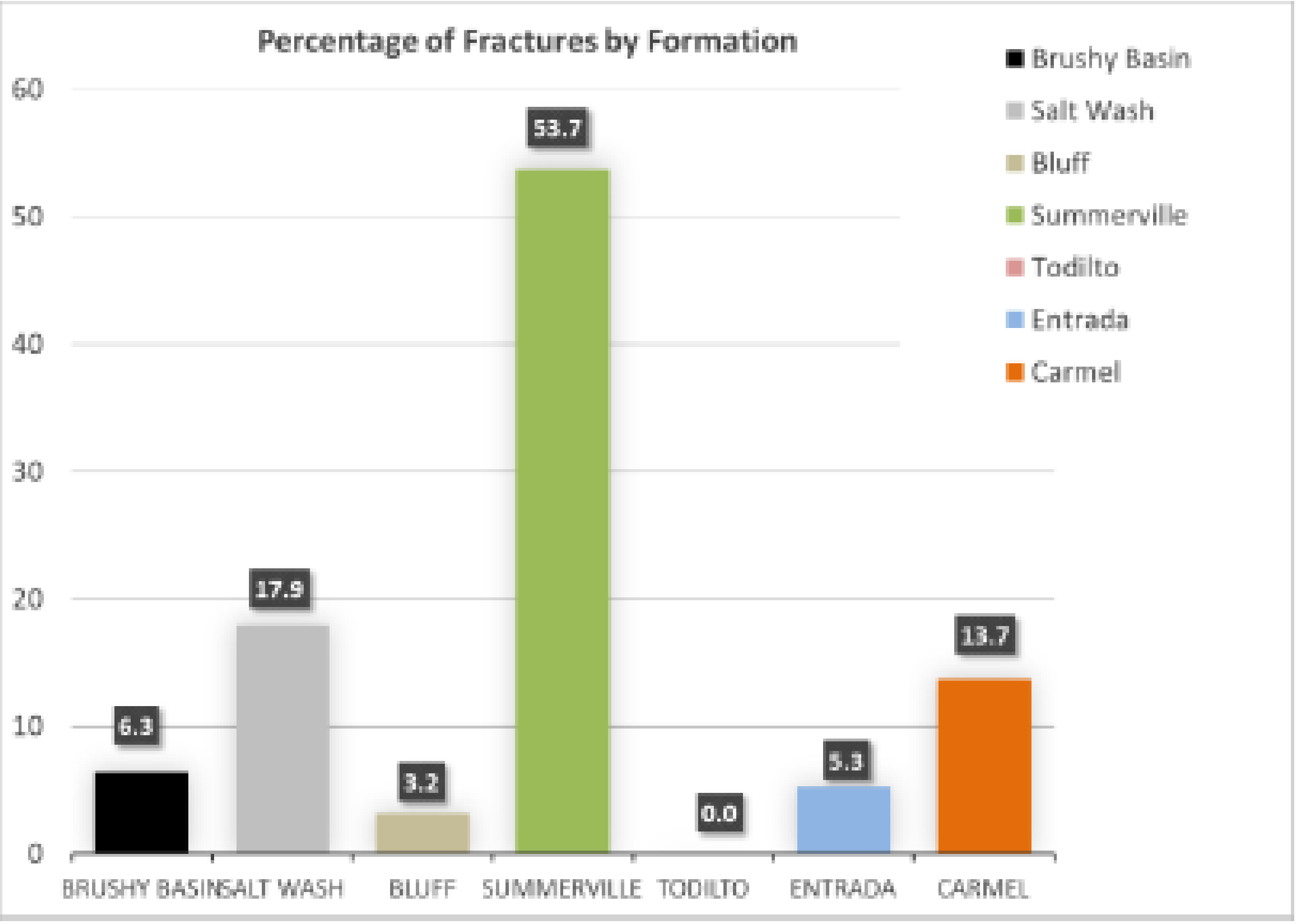
Scott Cooper and John Lorenz
FractureStudies LLC
www.fracturestudies.com

Two views of the high-angle extension fracture at 8193 ft in the Summerville Formation. The core has broken open along much of the fracture exposing the incomplete calcite mineralization (left), which narrows and extends upward into the unbroken finer-grained rock, terminating at a redder, muddier layer (right).



Cooper & Lorenz, 2023

Fracture Distribution in SJB CS Strat Test #001

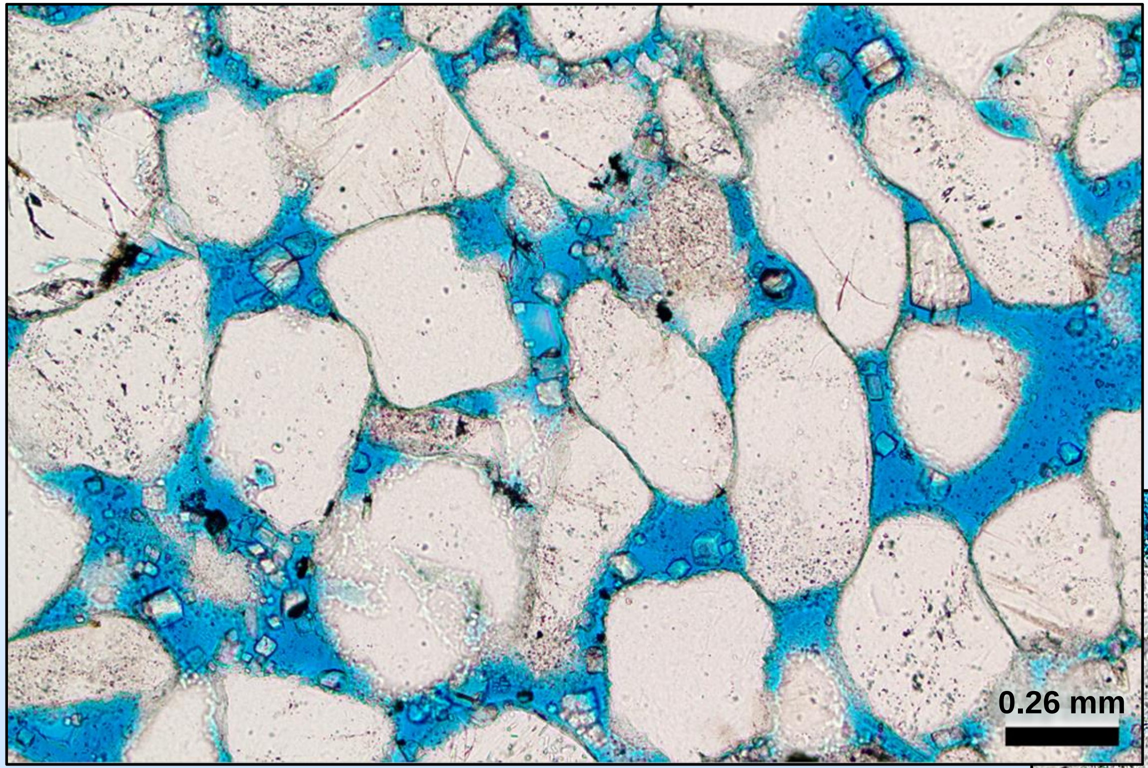


Fracture distribution by formation (n = 95), by percentage of the total fracture population (all fracture types) in the Carbon Safe core

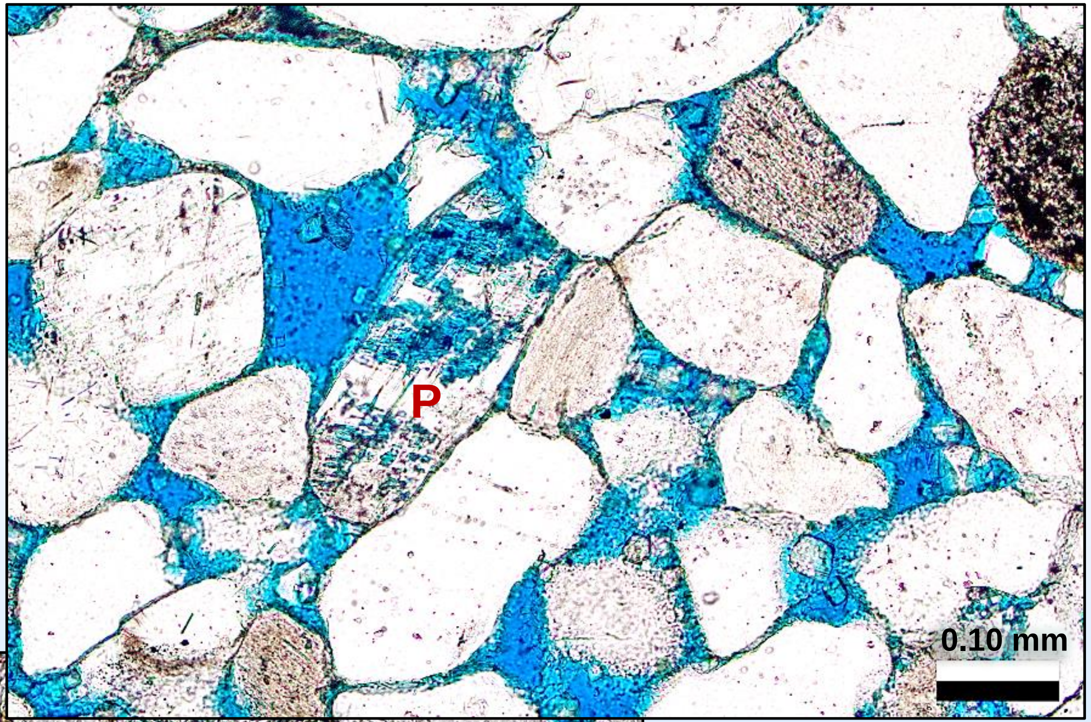
	Formation (#)	Formation (%)
Brushy Basin	6	6.3
Salt Wash	17	17.9
Bluff	3	3.2
Summerville	51	53.7
Todilto	0	0.0
Entrada	5	5.3
Carmel	13	13.7

Cooper & Lorenz, 2023

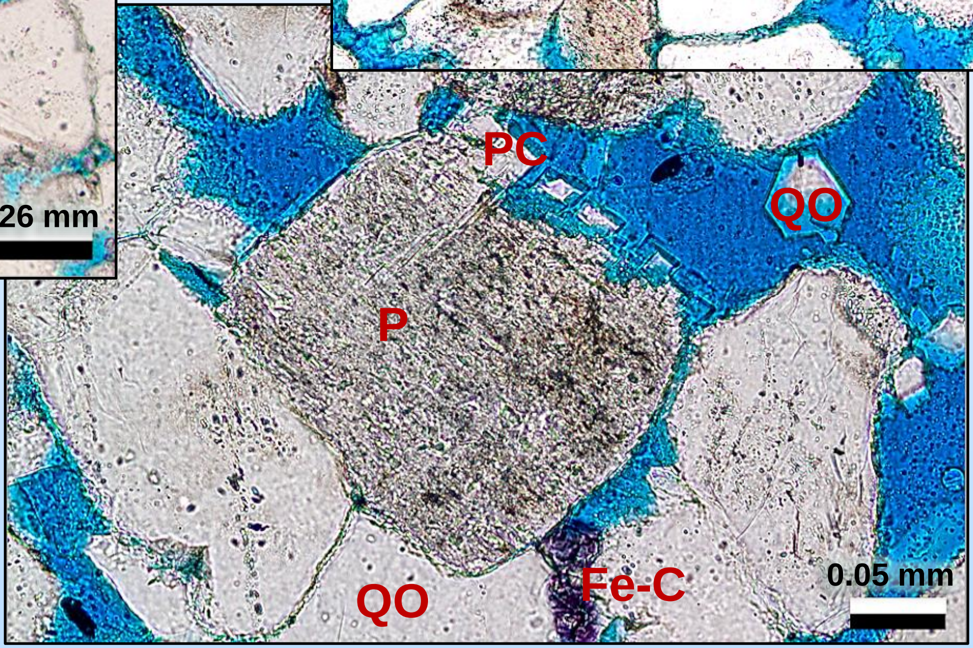
Entrada Ss.



8312.4’ Plain-polarized light Blue = 13.4 % Porosity



8312.4’ Plain-polarized light
Blue = 16 % Porosity



8322.9’ Plain-polarized light Blue = 21.3 % Porosity

Importance of Diagenesis in the Entrada Ss.

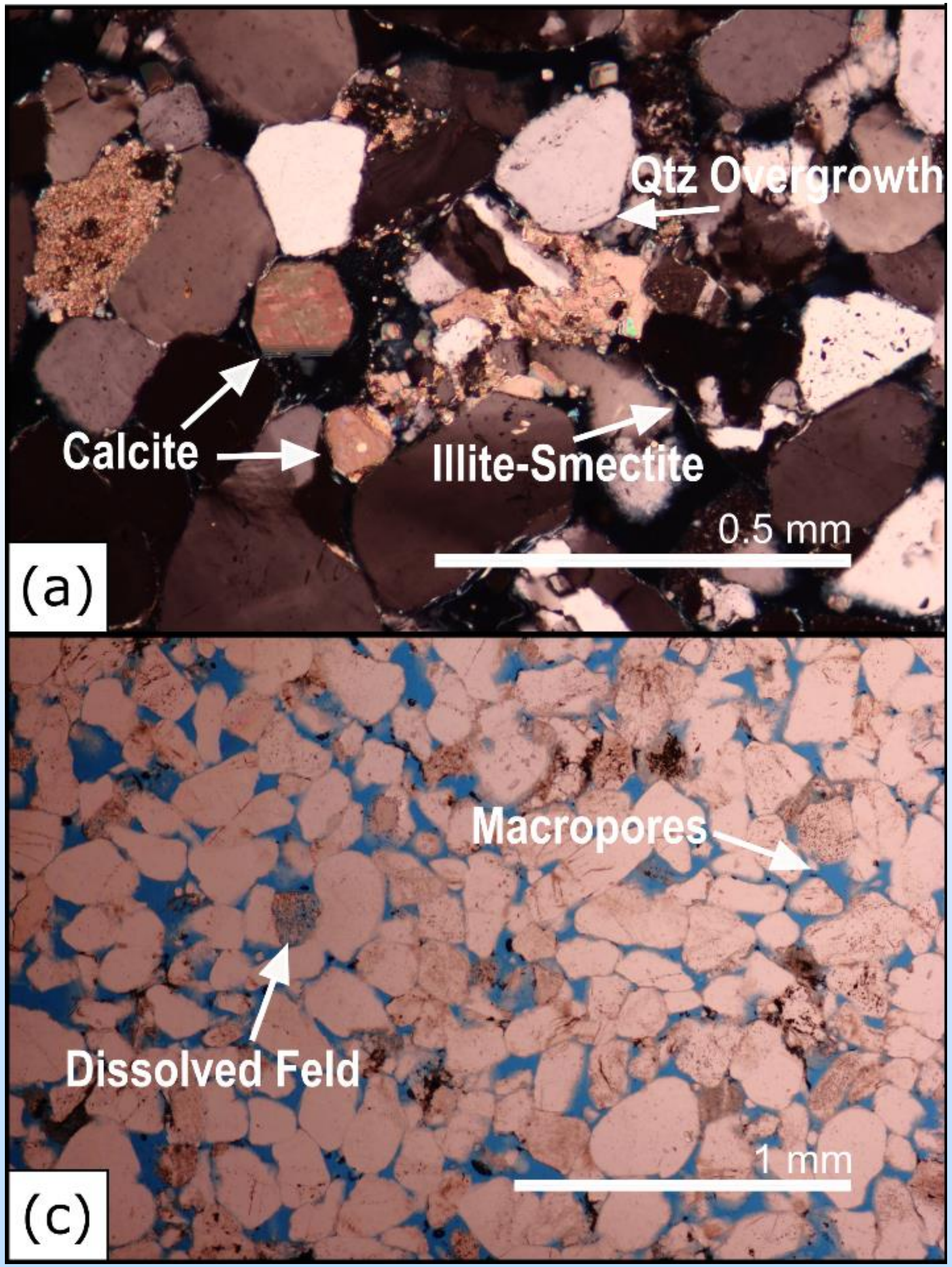
- Quartz overgrowths stabilized pore structure and preserve porosity
- Anhydrite was an early cement and filled some primary porosity, but later dissolution created secondary porosity
- Calcite and minor dolomite has partially replaced evaporites, feldspars, and rock fragments
- Clay cements (chlorite, illite, smectite) appear to have had minimal impacts on P & P within the dune facies due to relatively low abundance
- Fracturing was minimal
- Bitumen partially fills the porosity in the uppermost Entrada Ss.
- **Compaction, grain size, grain angularity and sorting are the major destroyers of porosity in the lower interdune-dominated Entrada**

Flow-through testing for the Entrada Sandstone is completed for primary reservoir strata (Ent1, 8317 ft bgs; pictured) and is ongoing for tighter strata above and below that strata (8310 ft bgs and 8375 ft bgs).

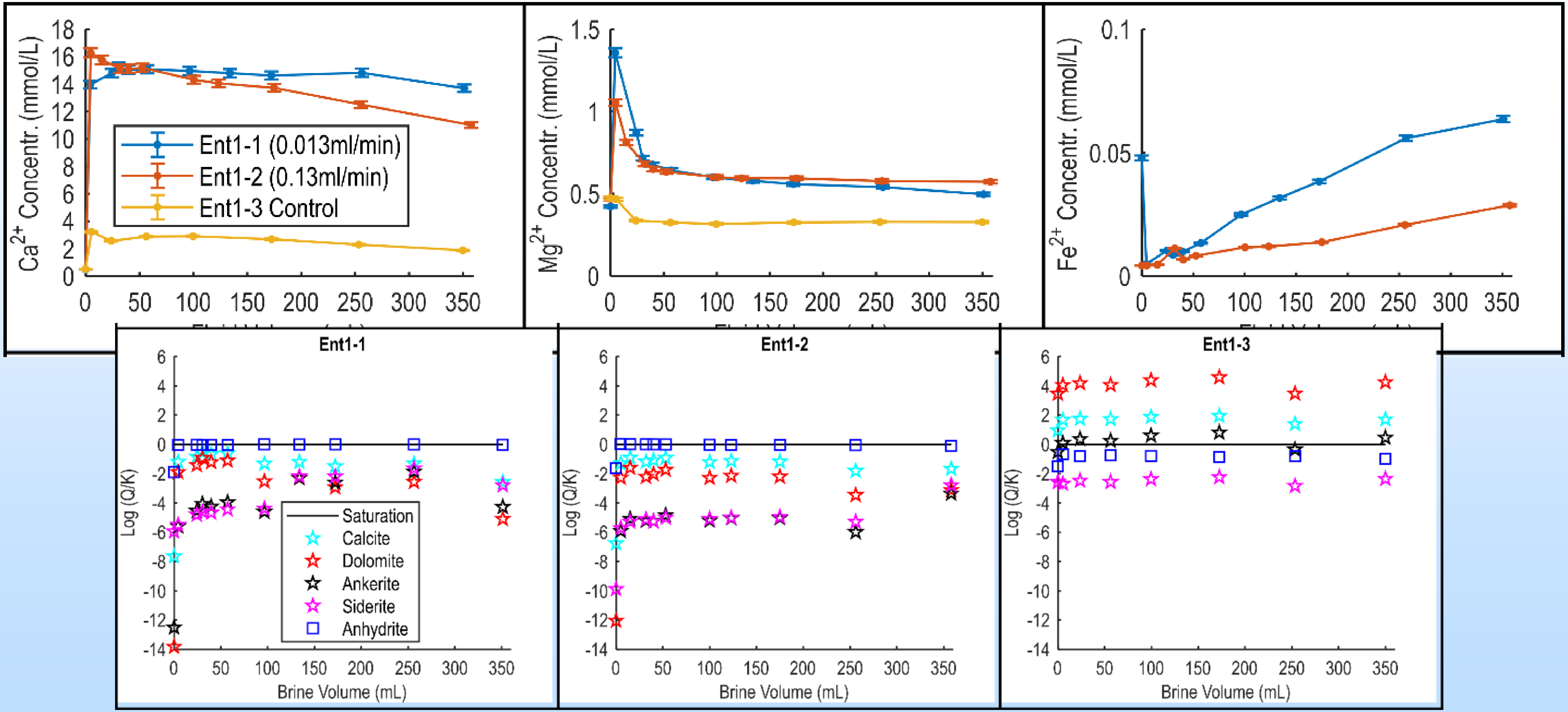
Using same synthetic brine as in relative permeability testing, with two tests with ~77% CO2 saturation and one control test with brine only.

94˚C, 3500 psi pore pressure and 7130 confining pressure.

Ent 1 is macroporous with long grain contacts and quartz overgrowths – low susceptibility to loss of strength. Uncommon reactive minerals that are not load-bearing.



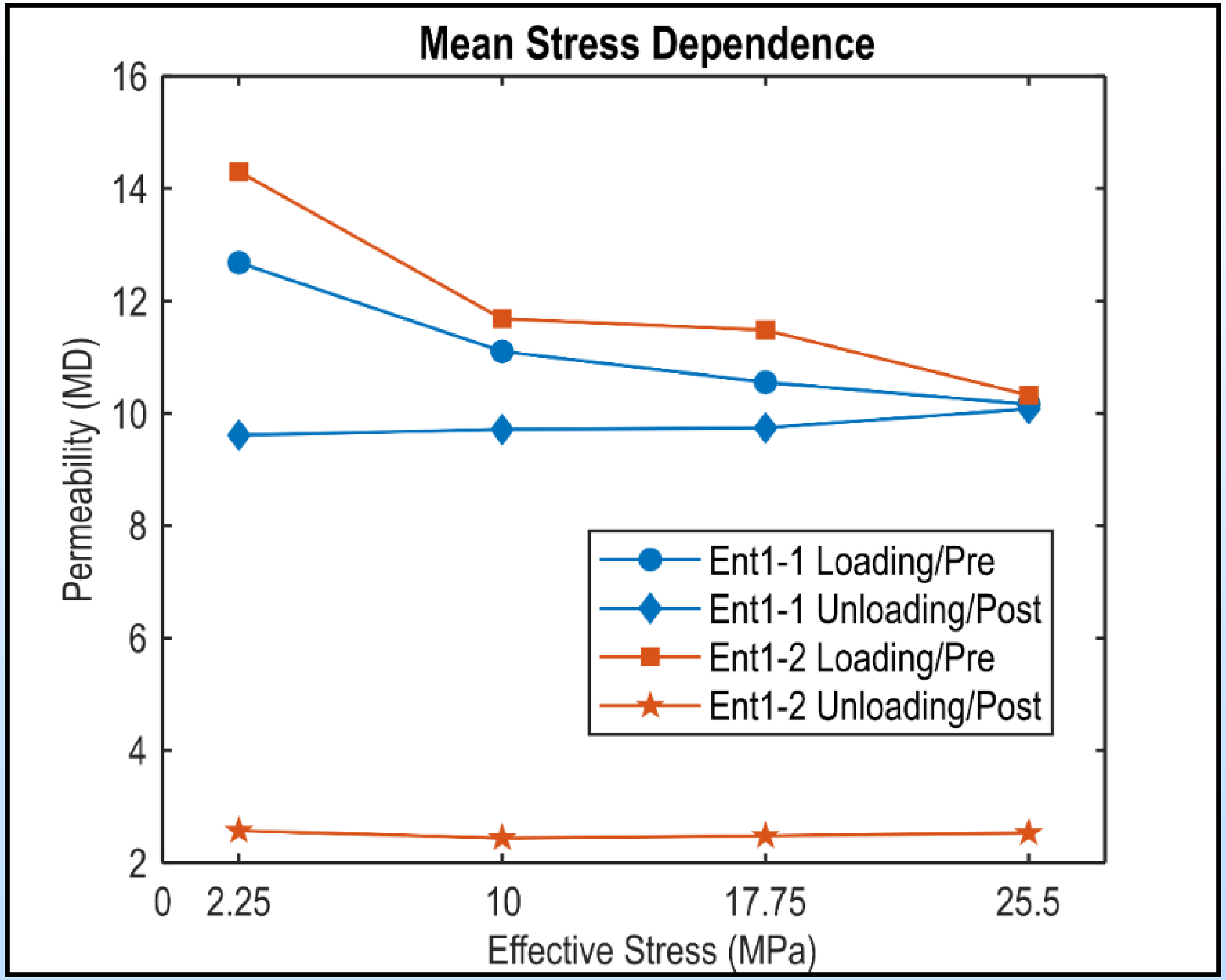
Dissolution of calcite and Fe-rich minerals are rapid and ongoing during tests, but these cements are not dominant or load-bearing. CO2-enriched tests remained undersaturated with respect to carbonate minerals.



Permeability **decreased and became mean stress independent** after flow-through experiments. This is evidence of pore clogging from fines migration or precipitation of Fe-oxides.

Relatively uncommon reactive phases indicate that solution and capillary trapping may be long-term storage mechanisms, over carbonation.

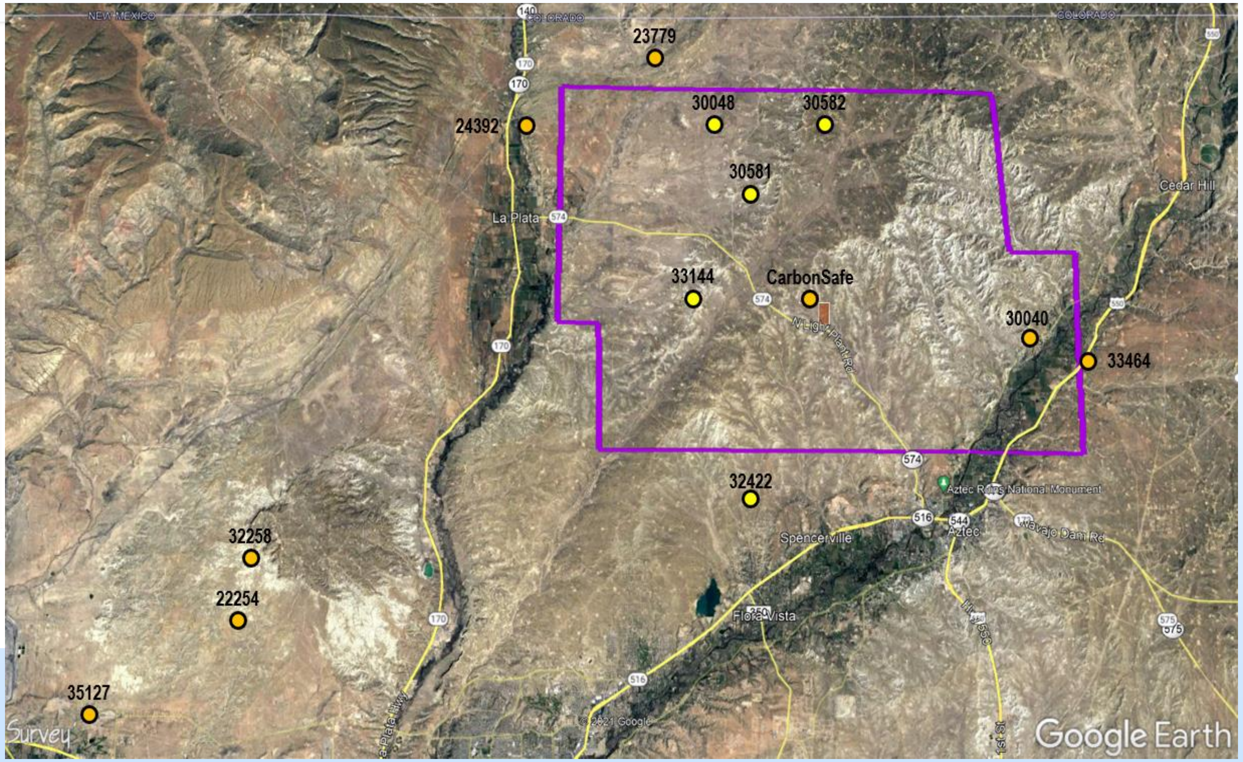
Mechanical parameters (consolidation strain and Young's modulus) are being analyzed.



Our Approach to Earth Modeling

	Seismic, Wellbore images	Triple-combo, Sonic, Core	Wellbore images, Sonic, Core	Petrophysics, Sonic, Core
Intrinsic properties	**Framework** Structure Faults Horizons	**Petrophysics** Lithology, Vcl Porosity, Sw Matrix Perm Elastic Moduli	**Mechanical** Strat Column Facies Support Fracture Attributes	**Rock Strength** Compressive & Tensile Strength Friction Angle
Extrinsic properties	**Vertical Stress** Overburden	**Pore Pressure** Pore Pressure	**Stress Direction** Maximum Horizontal Stress Direction	**Stress Magnitude** Minimum & Maximum Horizontal Stress
	Density log, Petrophysics	Formation testing, Petrophysics, Mud logs	Wellbore images, Sonic, 4-Arm calipers	In-situ stress tests, Sonic

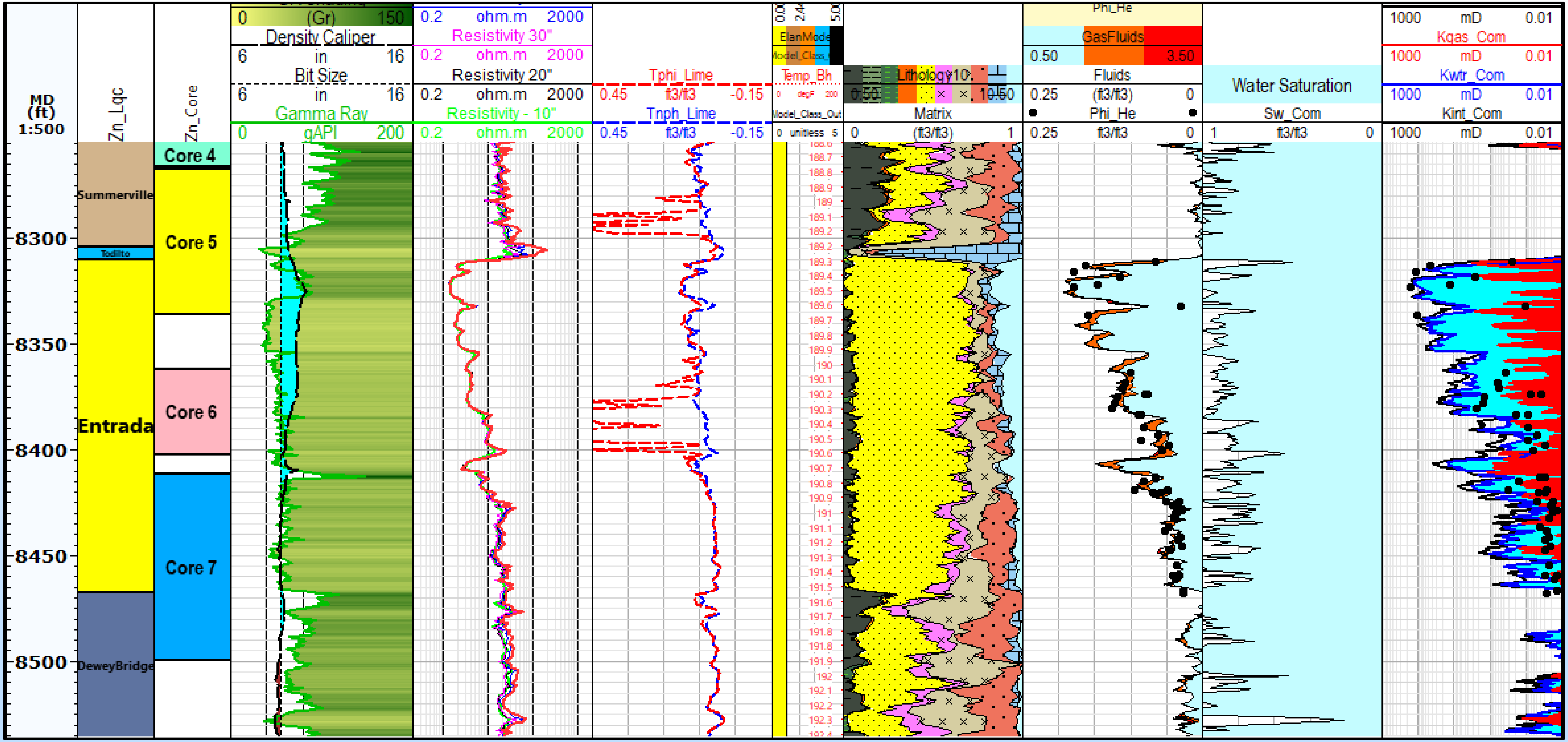
Brie and Bratton, 1994



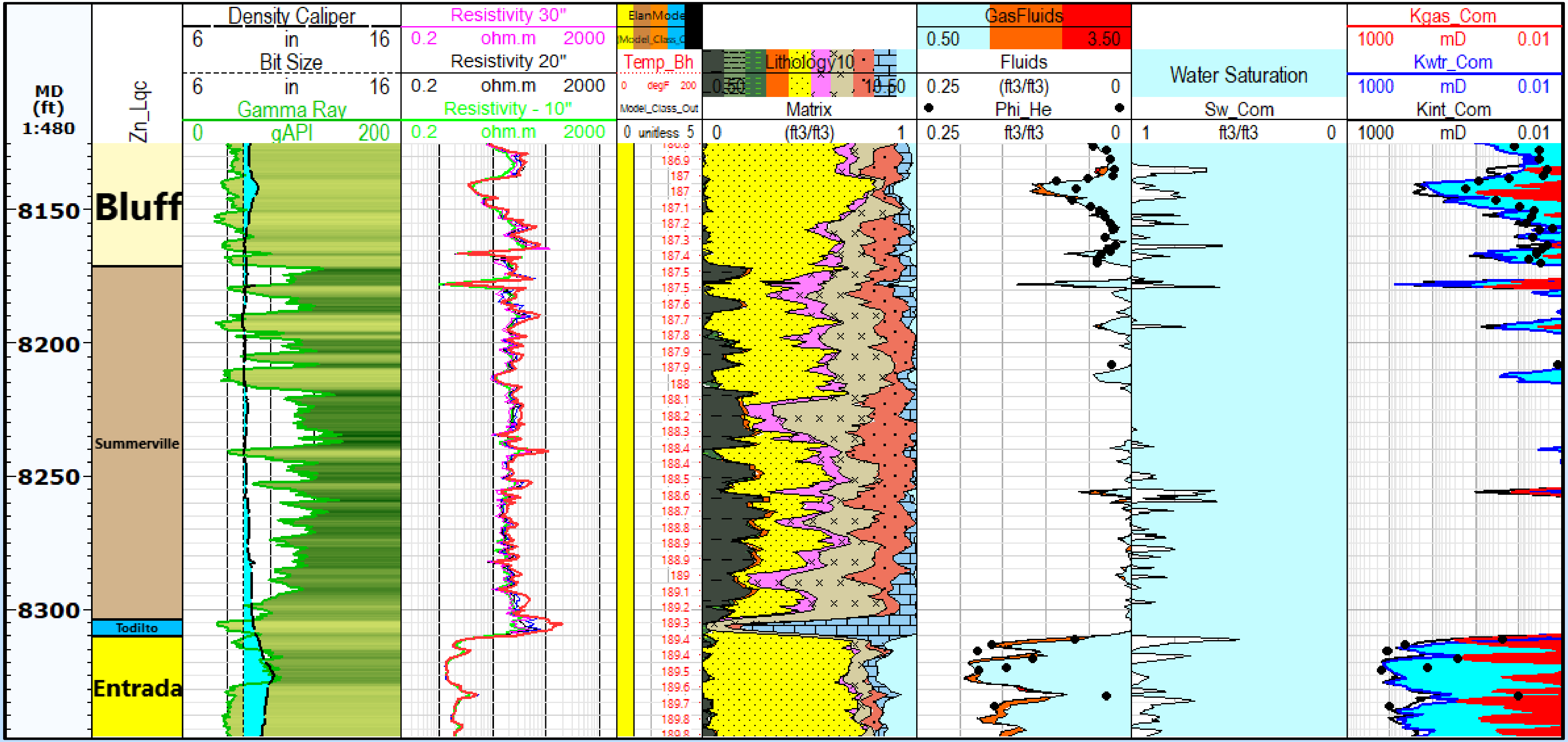
Wells used for Petrophysical analysis

A petrophysical analysis has been completed on 14 wells and a geomechanical analysis has been completed on a single well.

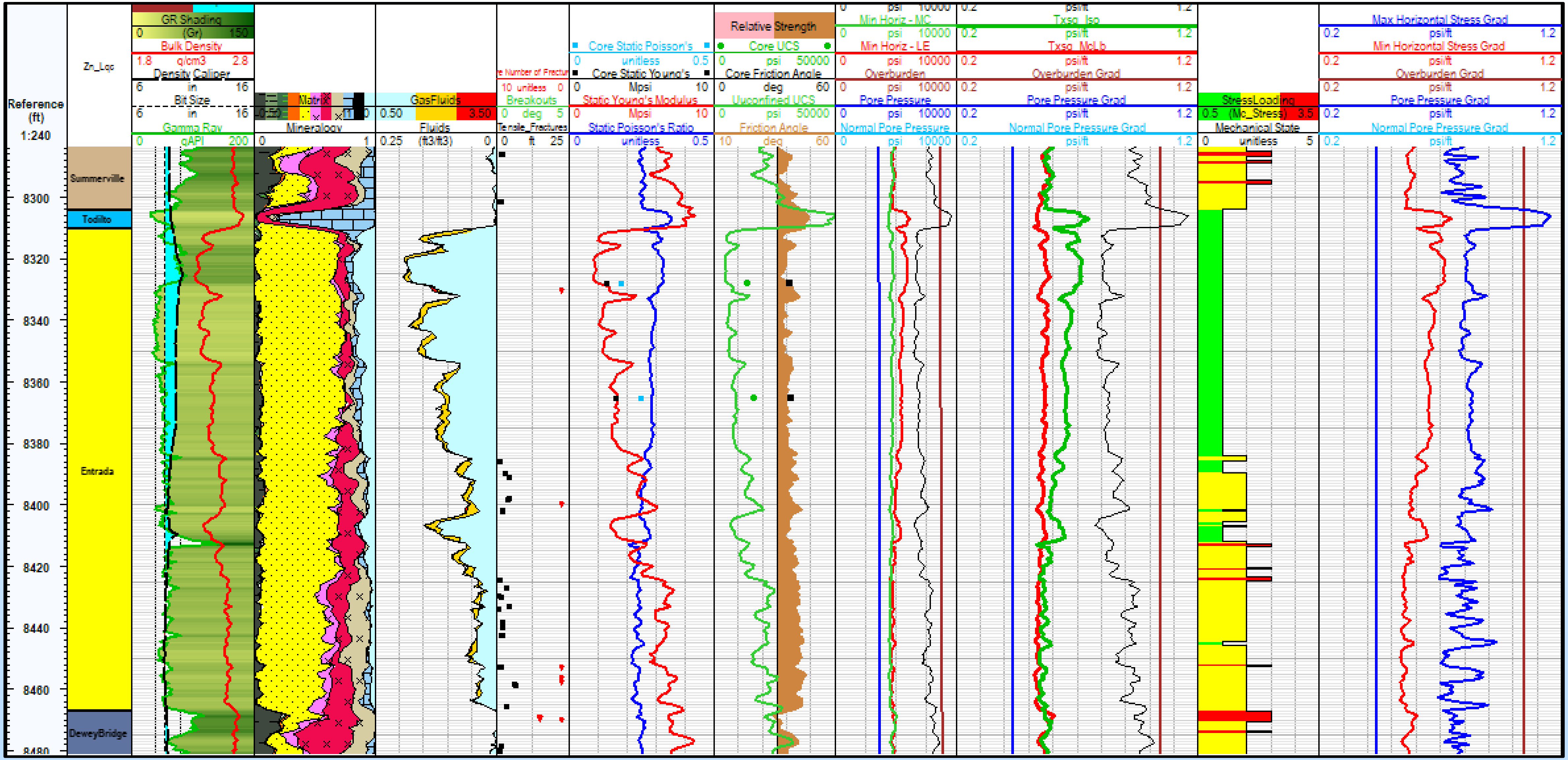
Entrada petrophysics



Summerville petrophysics



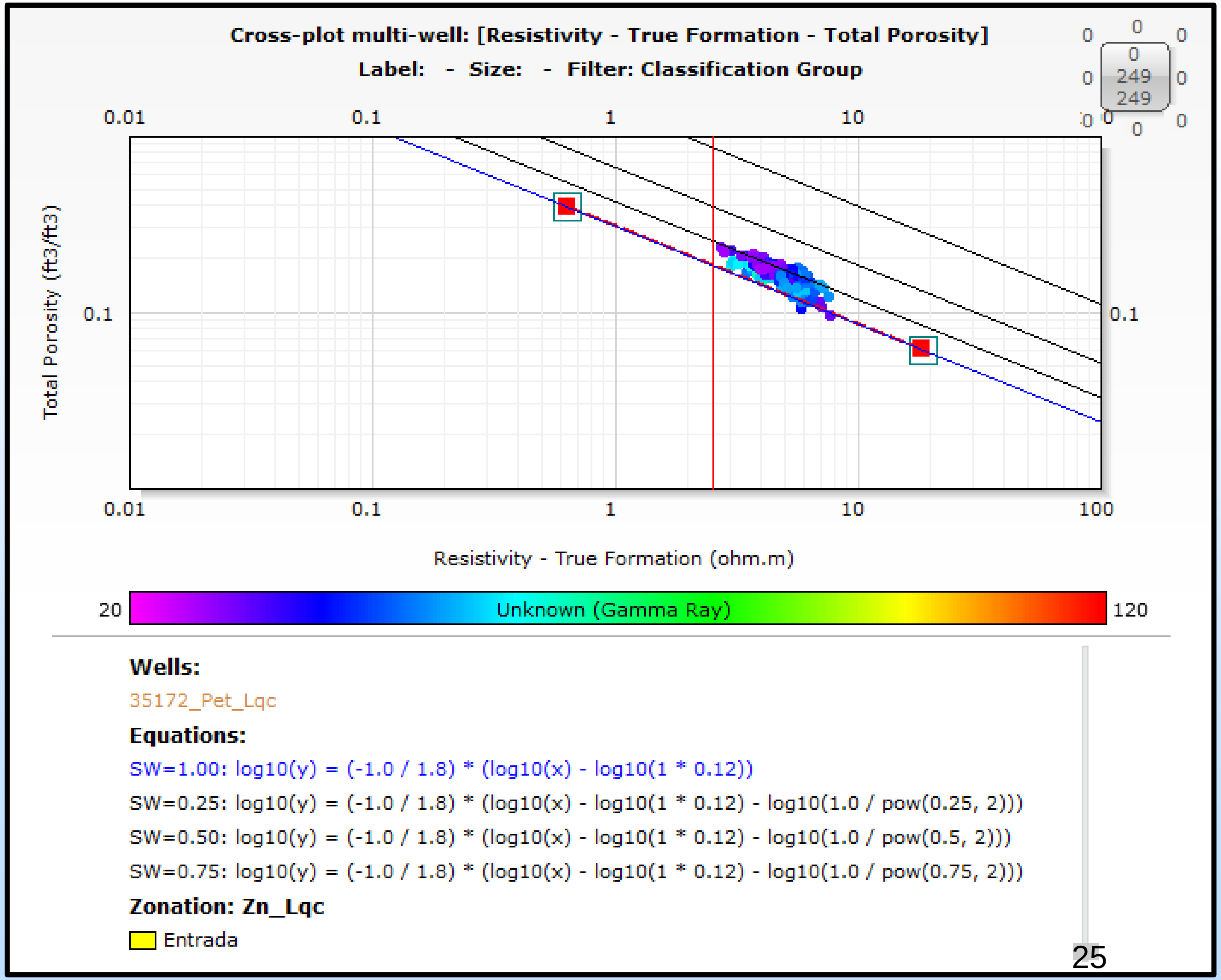
Mechanical model – Entrada formation



Entrada Salinity Estimation

- Pickett plot

- A=1
- M=1.8
- N=2.0
- Rw = 0.12
- Temp = 164 degF
- **Salinity = 24,102 ppm**



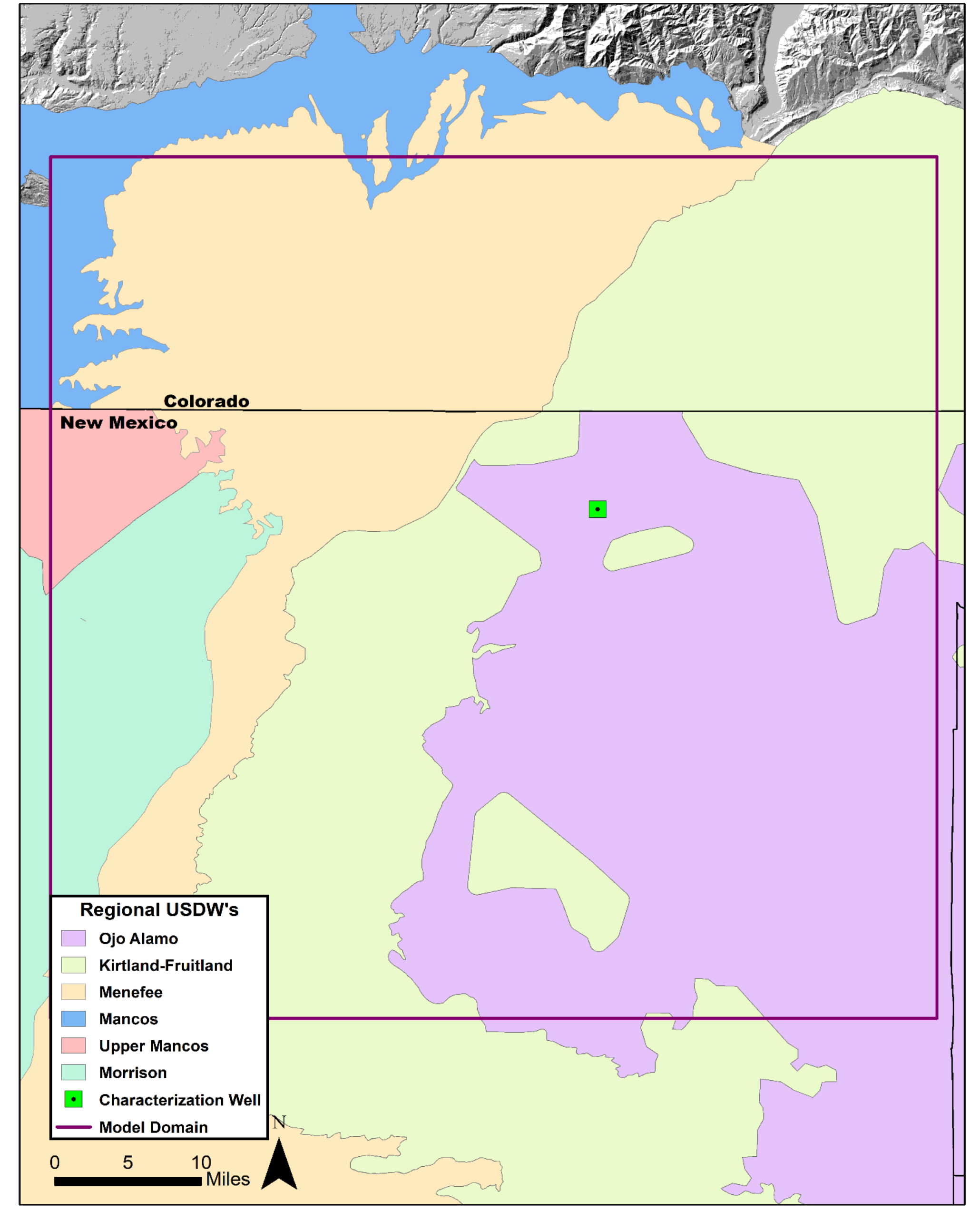
Lowest Most USDW's

- 6 unique lowest most USDWs exist in various regions of the model domain

  1. Ojo Alamo Sandstone - NM
  2. Kirtland/Fruitland - NM/CO
  3. Menefee Formation - NM/CO
  4. Mancos Shale - CO
  5. Upper Manco Shale - NM
  6. Morrison Formation - NM

- The Ojo Alamo, Menefee, Mancos, and Morrison
  - Determined by existing water wells in each

- The Kirtland-Fruitland and Upper Mancos (Gallup)
  - Determined by produced water data

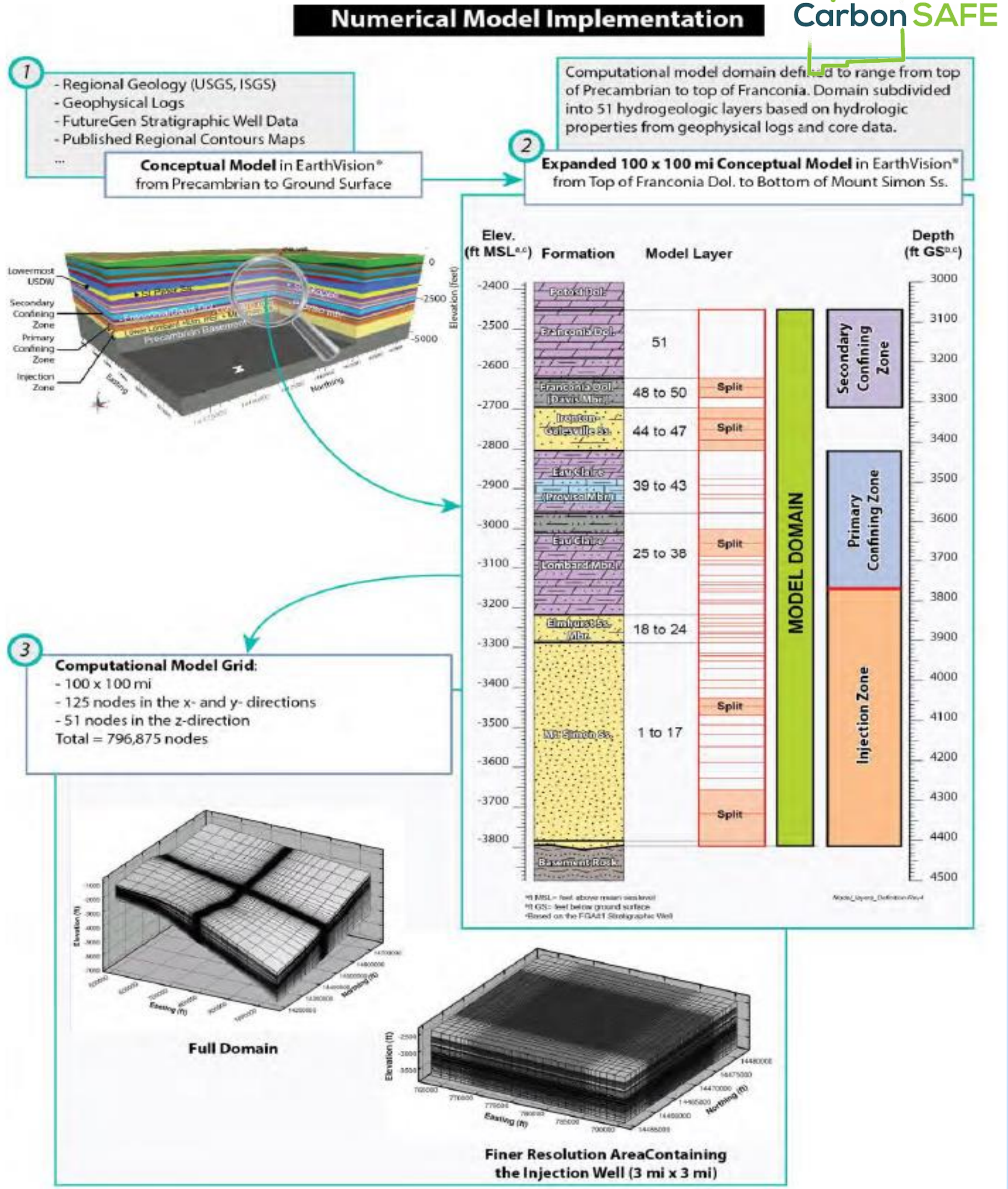


Areal extent of all USDW's within the project model domain from well data

Performing AoR modeling and delineation

- 146.82(a)(2)“A map showing the injection well for which a permit is sought and the applicable area of review consistent with § 146.84.”

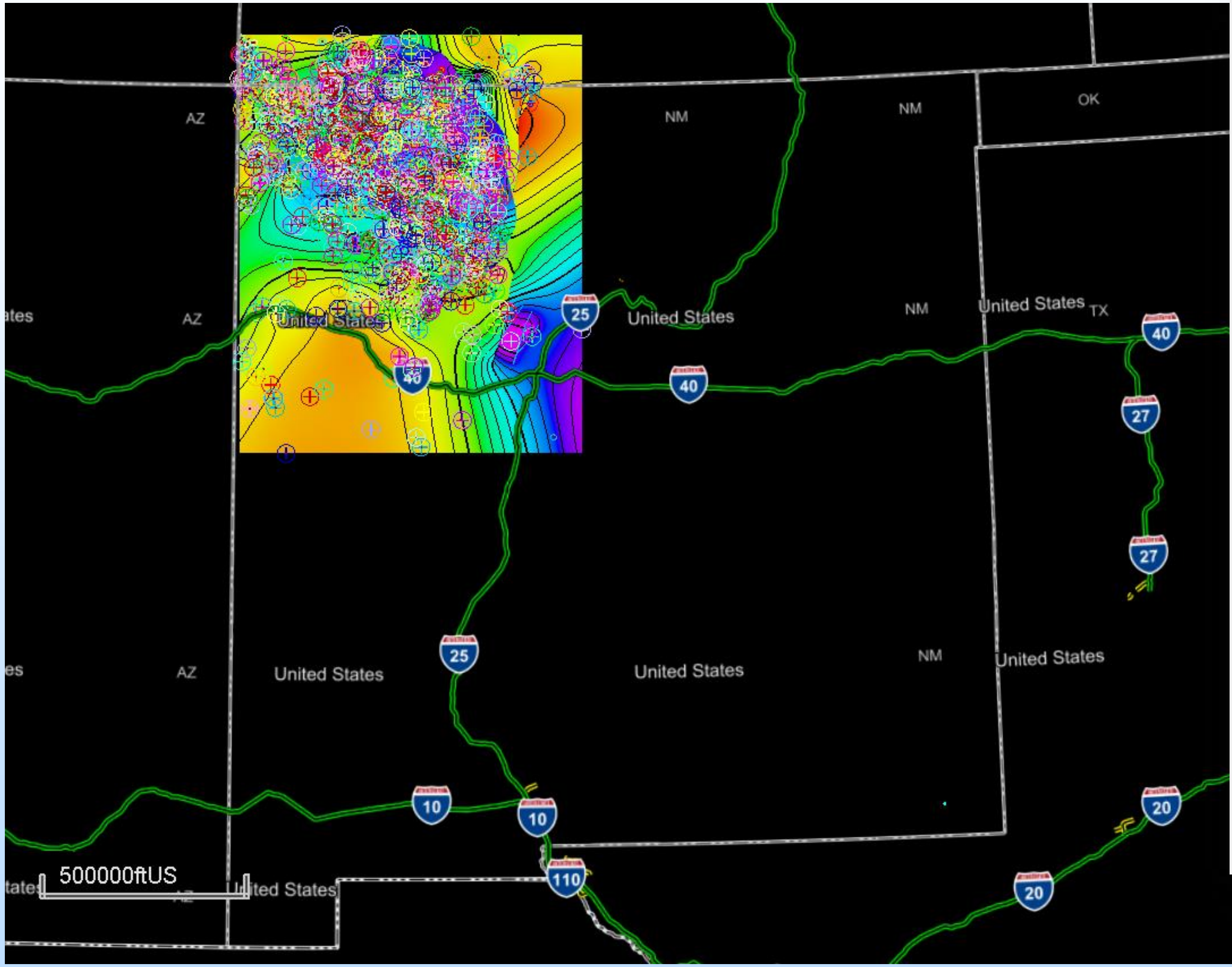
1. Model Development
   - Area encompasses proposed injection site
   - Determination of physical processes
   - Model design
     - Computational Code Determination
     - Model Spatial Extent, Discretization, and Boundary Conditions
     - Model Timeframe
     - Parameterization, etc …
2. Multiphase Numerical modeling
   - CO_2 saturation and pressure plume size thru time
3. Identify Area of Review
   - Area around injection zone where pressures are high enough to force fluid through open conduits into the overlying USDWs
   - Identify potential leaky well-bores
   - Identify potential open/high permeable faults
4. NRAP Tools to characterize endangerment of USDW due to well leakage

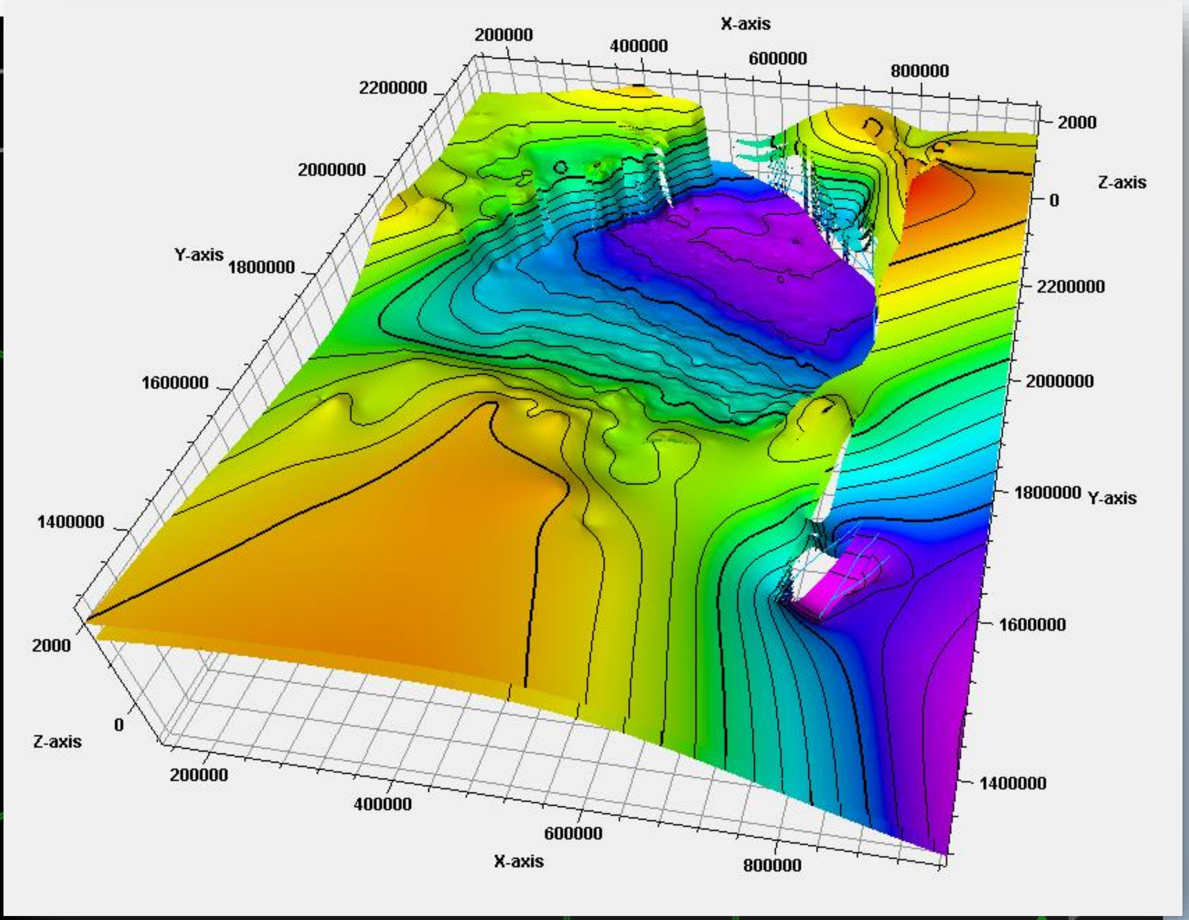


Implementation of the Numerical Model: From the Geological Conceptual Model to the Numerical Model

San Juan Basin Geological Modeling

- More than 2200 well tops so far





CO_2 Storage Estimation

$$S = Ah\phi\rho E_A E_h E_\phi E_V E_d \,,$$

where A is the area of the storage formation, h is the thickness of the storage formation, ϕ is the porosity of the storage formation, ρ is the density of the CO_2 (which depends on the pressure and temperature), E_A is the Net-to-total-area efficiency factor, E_h is the net-to-gross-thickness efficiency factor, E_ϕ is the effective-to-total porosity efficiency factor, E_V is the volumetric displacement efficiency factor, and E_d is the microscopic displacement efficiency factor.

Storage Formation	Entrada		Bluff		Saltwash	
Area (km^2)	9,571	0	9,571	0	9,571	0
Thickness (m)	47.4	4.74	55.7	5.57	103.5	10.35
Porosity (%)	10.9	0.4	9.7	0.3	7.9	0.2
Pressure (MPa)	17.2	1.72	15.0	1.50	15.3	1.53
Temperature (°C)	71.5	7.15	64.1	6.41	62.1	6.21

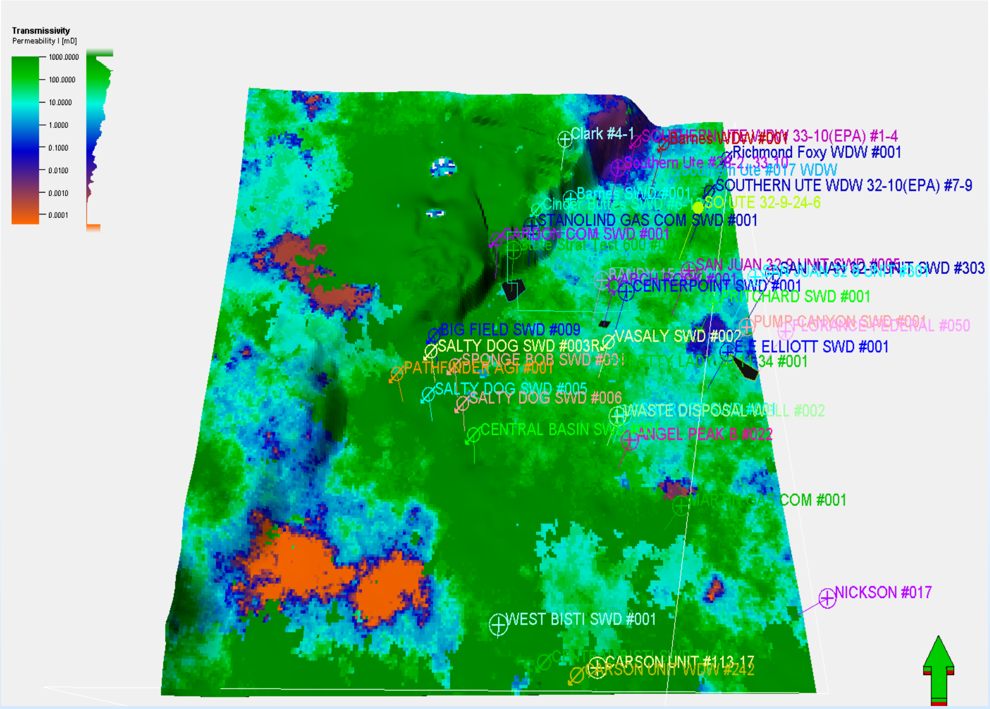
Input Parameters

Storage Formation	P_{10}	P_{50}	P_{90}	Mean
Entrada	**1,690**	**2,441**	**3,434**	**2,542**
Bluff	1,688	2,492	3,547	2,592
Satlwash	2,708	3,969	5,547	4,125
Total	6,086	8,901	12,527	9,259

Storage Estimation millions of metric tons of CO_2

Model Description

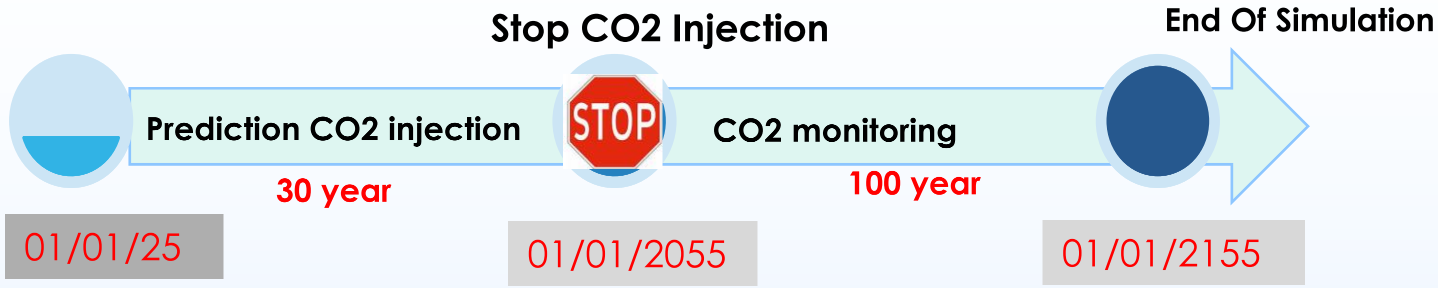
Layer No.	Formation
1	Dakota
2	
3	Brushy Basin
4	
5	
6	Salt Wash
7	
8	
9	
10	
11	
12	Bluff
13	
14	
15	
16	
17	Summerville
18	
19	
20	
21	Todilto
22	
23	Entrada
24	
25	
26	
27	
28	Camel
29	
30	
31	Wingate



- ❑ An advanced multi-phase compositional simulator : CMG
- ❑ Using well logs, well injection data, and 3D seismic data.

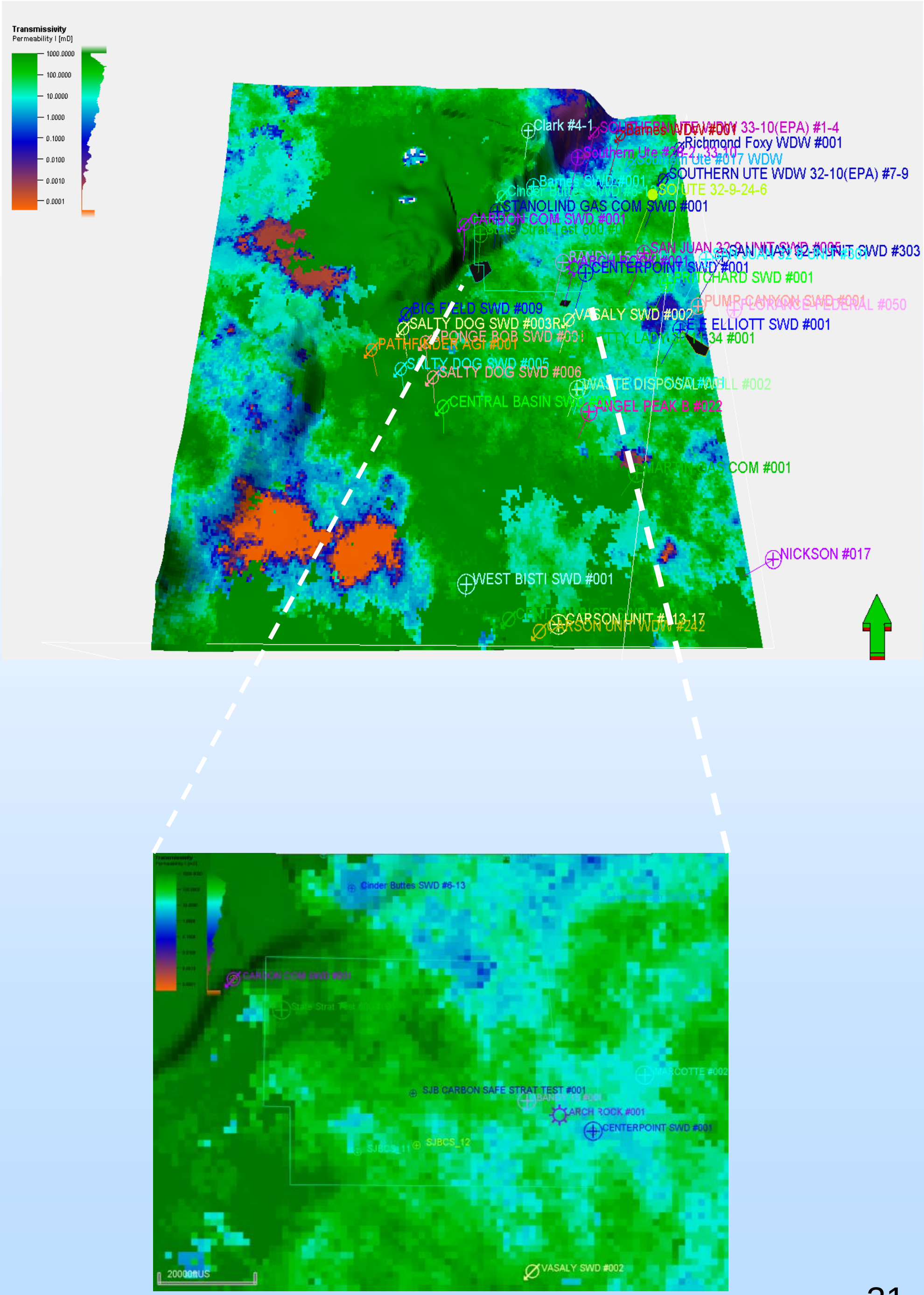
Reservoir Parameter	Value	Remarks
Dimension Dynamic model	241 × 242 × 29	60 miles by 60 miles, 1000x1000 ft, 1,691,338 grid block
Net-to-Gross ratio (NTG)	1	Full basin scale grid model
Initial water saturation (Swi)	100%	Saline-Aquifer with 50,000 ppm salinity assumption
Relative permeability	2 RT	2 rock type
Injection wells	34 Injection Water and 1 Injection Gas	Three wells dominated 50% Cumulative volume injection
Initial Pressure at Entrada	3500 psia	
Geological zones	5	Summerville, Todilto, Entrada, Camel, and Wingate
Fluid compositions	3	CO_2, H_2O, CH_4 (tracing component)
Boundary Model	500 PV	Edge reservoir pore Volume multiplier

Forecasting CO2 Sequestration Case



Injection strategy in the full-scale field after HM period:

1. Maintaining the history water injection rate in the prediction stage
2. Primary Group Control: Group constraint of 1 to 3 wells with a maximum of 2 MMton/y CO_2
3. Primary Well Control: BHP as the fracture pressure gradient of each well (0.9 X 0.63 psi/ft X TVD)

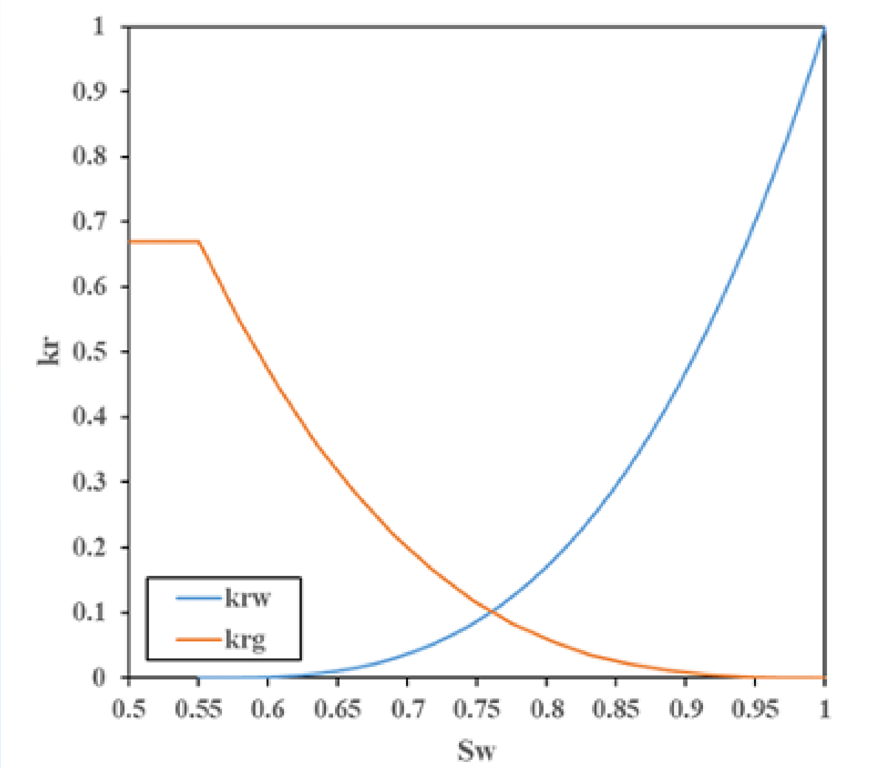


Scenario Injections

Parameters	Minimum	Maximum
Gas Inj Group Target , MMscfd	103	120
BHP, psia	4100	4500
Well Placement Sinj1, CM1, SJB: I, J, K	Seismic Line Boundary	
Perforation on Entrada		

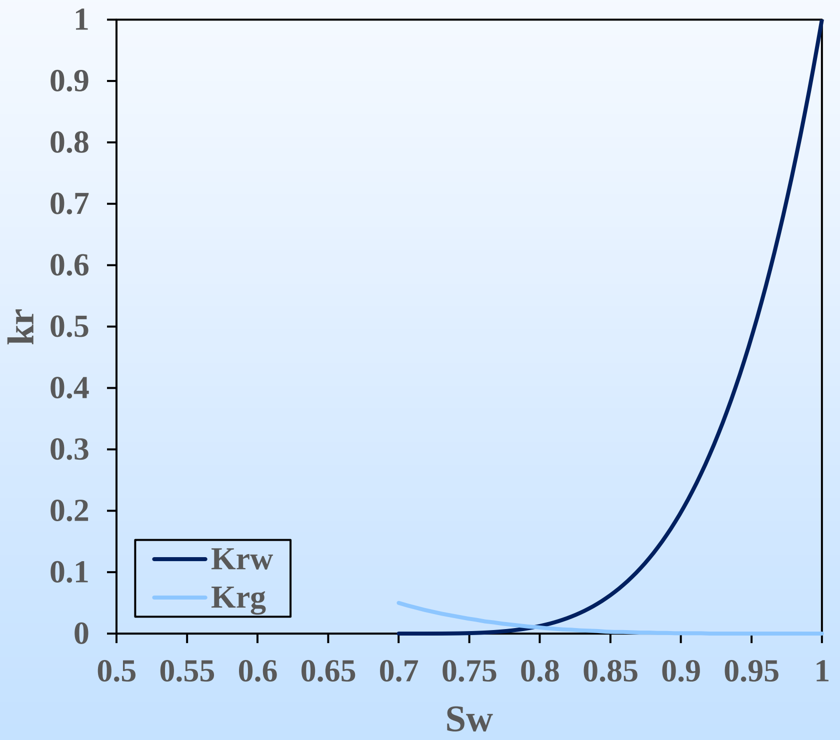
Rock Type at San Juan Basin

RT-1 Entrada Fm

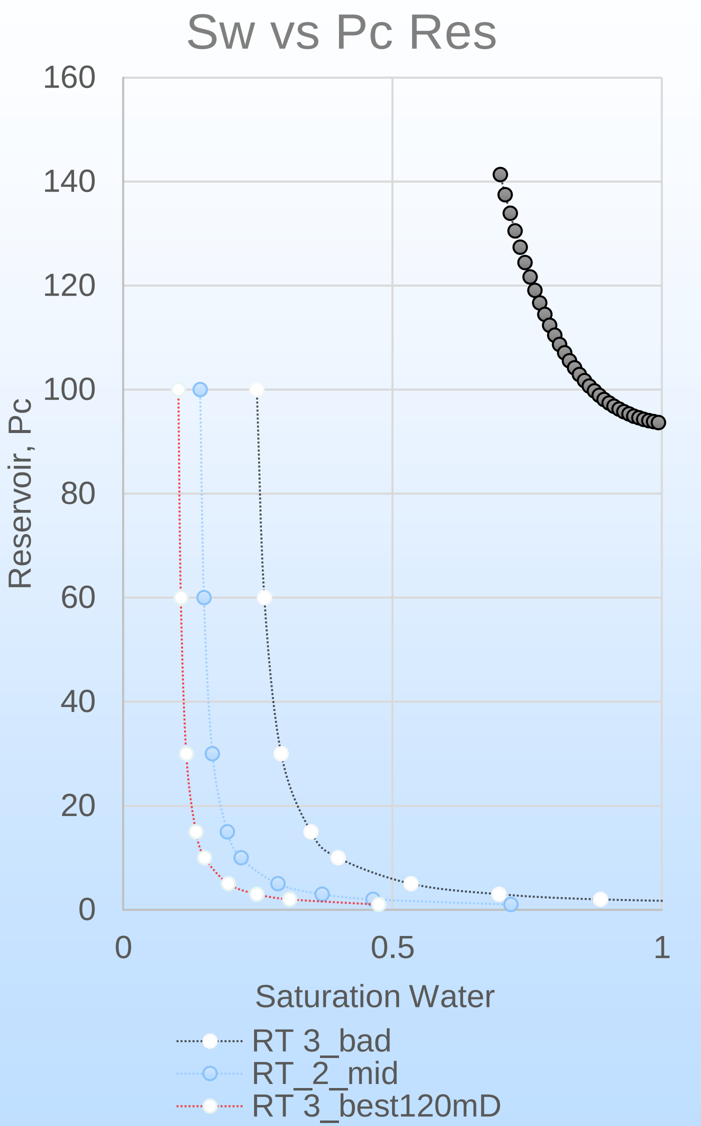


Relative permeability curves krg-krw

RT-2 Todilto-Summerville Fm (Caprock)



Relative permeability curves krg-krw



MICP Test lab

Cappilary Pressure

- Injection Target:
- Entrada have avg 21 mD and max 982 mD and avg porosity of 13%,

Well Placement Optimization Workflow

Optimization the Parameters using PSO from Well placement (WP) 1, WP2, WP3, BHP, Cum Gas Inj

Design Multi Layer Network add sampling number to optimize NN

Optimization NN with GA, Derivative flow method

Uncertainty Analysis for selected case

Objective Function:

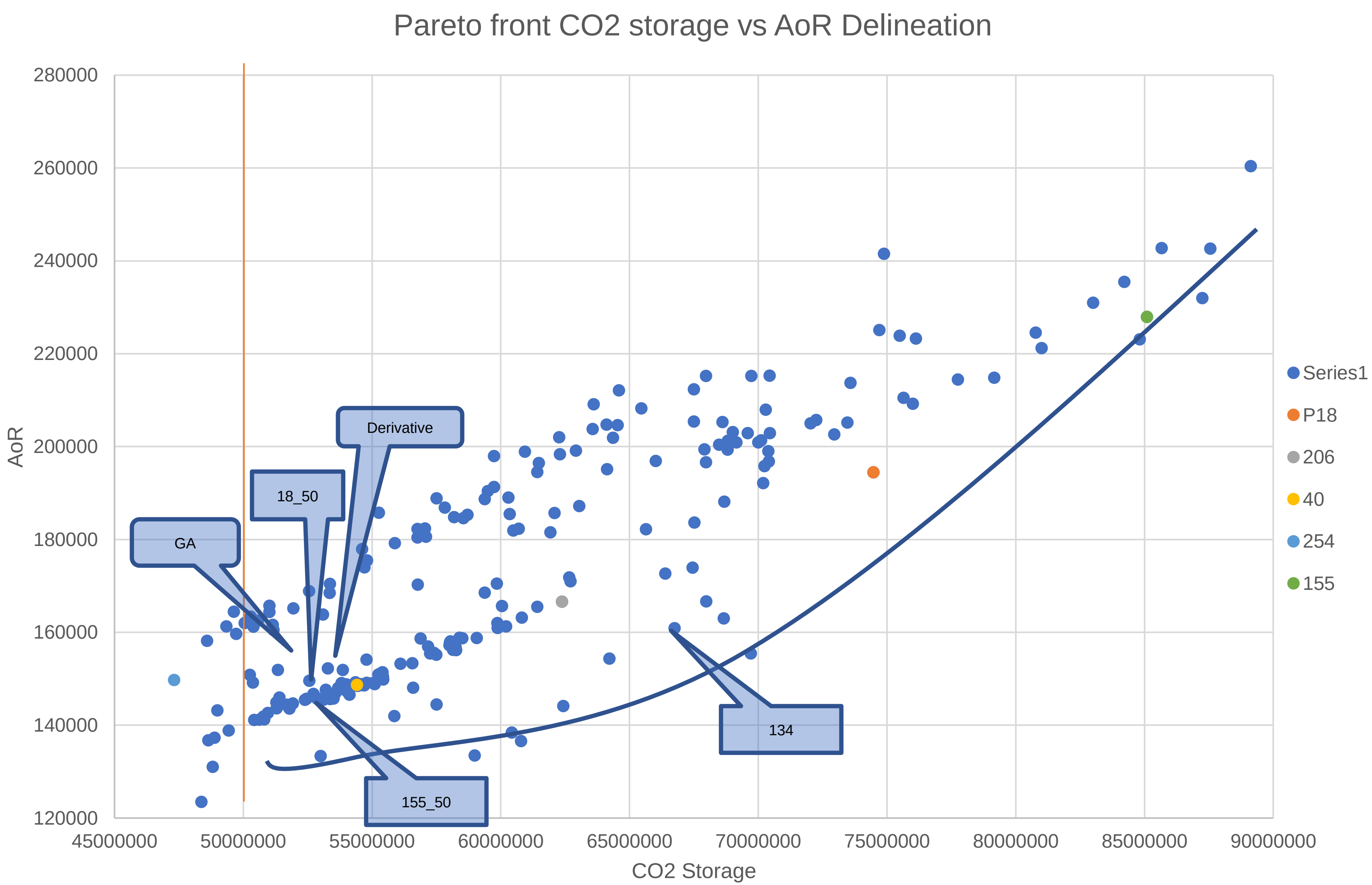
1. AoR delineation minimum
2. Gas Injection 50 Mton

Risk Map

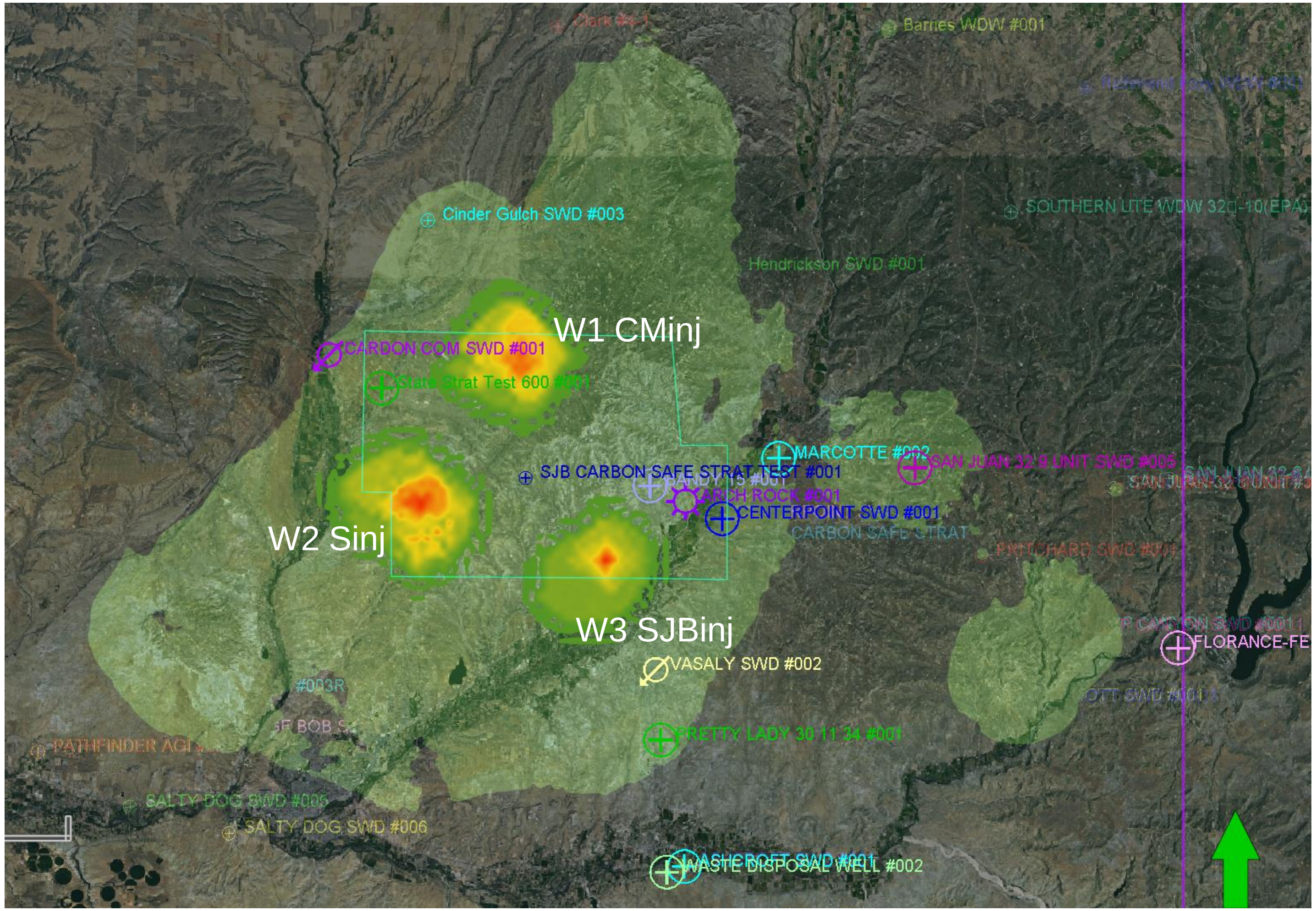
Pareto Front – Multi Objective Function

- 300 sampling number from PSO
- 50% validation number & 50% test
- Match to Risk map
- Select & Uncertainty the potential candidate

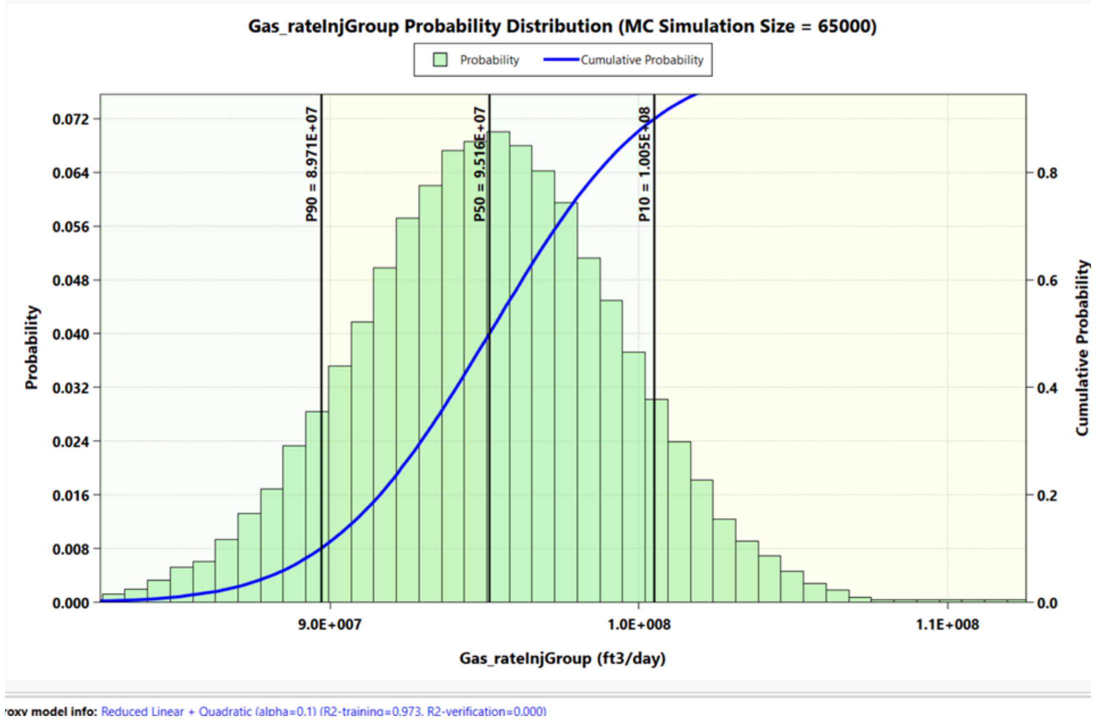
Probabilistic :
18, 155, 134, 132, 254,



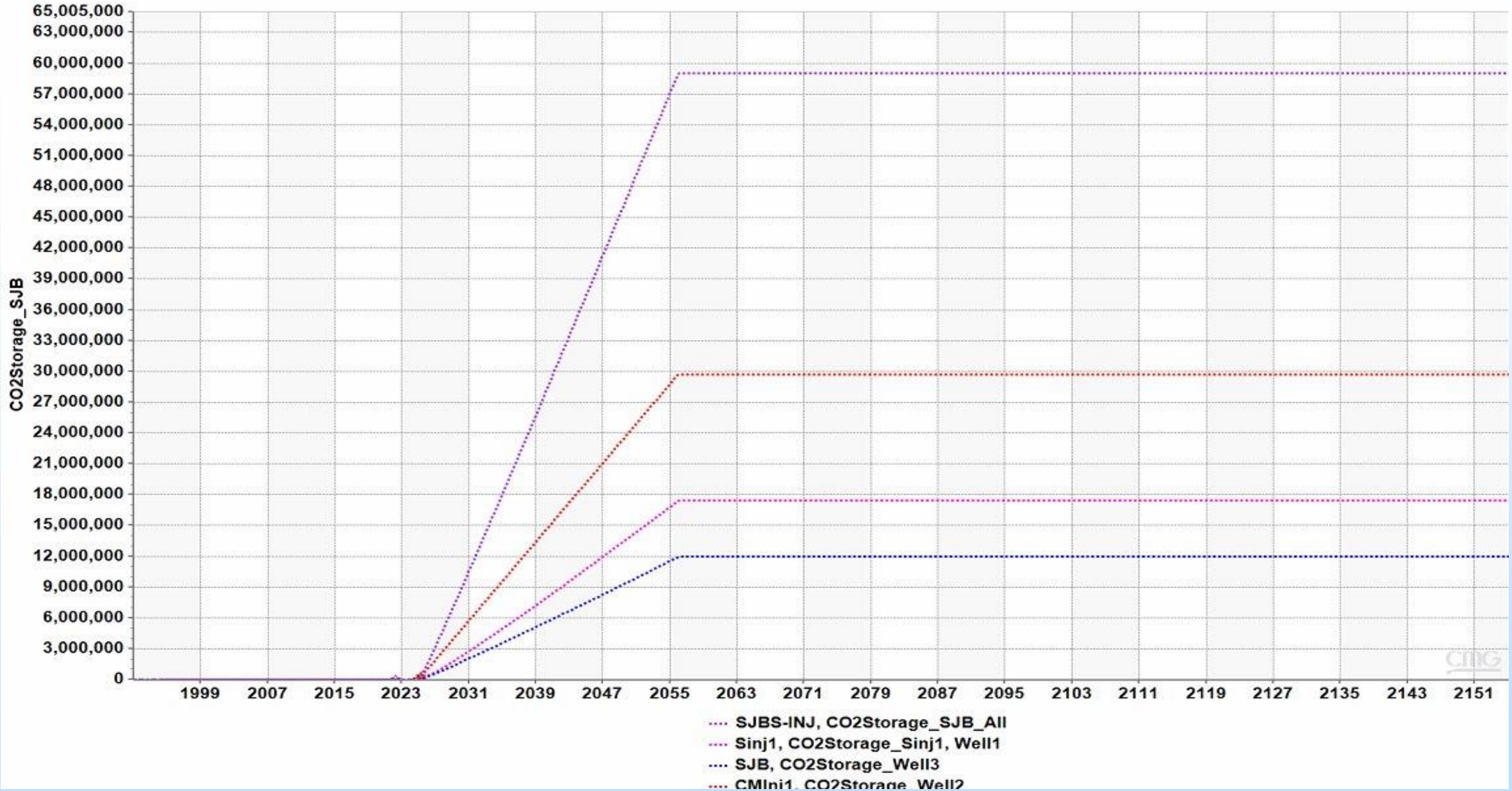
A sample of Optimized Case (Case 18)



- Storage CO_2 volume of 52 MMton
- the green circle line indicates AoR within a 17-mile diameter encircling the gas plume saturation.



Well Injection Profile- Sample case



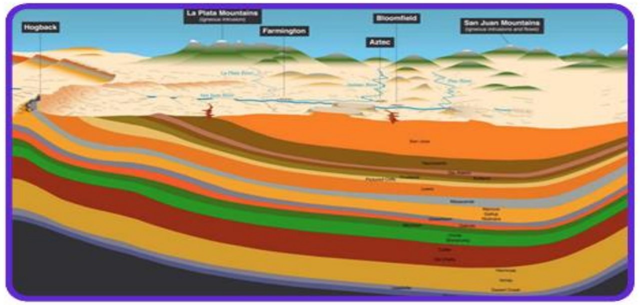
Project Facts Sheet

San Juan CarbonSAFE III
Site Characterization and Permitting

NEW MEXICO TECH

ABOUT THE PROJECT

The San Juan Basin CarbonSAFE Phase III project, led by the New Mexico Institute of Mining and Technology, aims to facilitate the safe subsurface storage of CO2 in saline reservoirs as part of carbon capture and storage (CCS) efforts. By conducting comprehensive commercial-scale site characterization in northwest New Mexico, the project seeks to accelerate the deployment of integrated CCS technology at the San Juan Generating Station, a significant coal-fired electricity generation plant in the region.



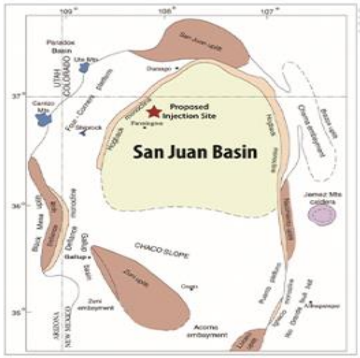
Project Objectives

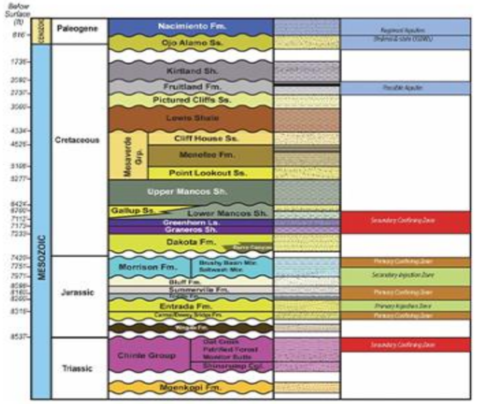
Site Characterization
Conducting thorough investigations to understand the geological conditions of the storage complex in northwest New Mexico. This involves assessing the suitability of saline reservoirs for CO2 storage and identifying potential risks and challenges associated with the process.

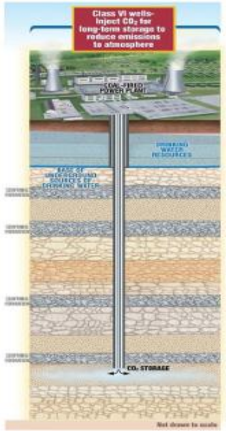
Regulatory Compliance
Preparing, submitting, and attaining a Class VI permit from the Environmental Protection Agency (EPA) for the construction of CO2 injection wells. This regulatory approval is crucial for ensuring compliance with environmental standards and guidelines for geologic sequestration.

Carbon Capture and Storage
Capturing approximately 6 to 7 million metric tons of CO2 per year from the San Juan Generating Station, with a portion of it (2 million metric tons per year) being stored at a site located around 20 miles away. The remainder will be sent to the Cortez pipeline for enhanced oil recovery (EOR) usage in the Permian Basin.

Technology Evaluation
Studying CO2 capture technologies, particularly Mitsubishi Heavy Industry's KM CDR Process, to assess their feasibility and effectiveness in the context of the project. This involves evaluating the efficiency of these technologies in capturing CO2 emissions from the power plant.







Overall, the project represents a significant step towards addressing climate change by reducing greenhouse gas emissions from coal-fired power plants through the implementation of CCS technology. It underscores the importance of interdisciplinary collaboration, regulatory compliance, and technological innovation in achieving carbon neutrality and mitigating the impacts of climate change.

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Community Engagement

LOCAL

Commissioners approve carbon management agreement

New Mexico Tech will move ahead with carbon capture projects in the region

BY DAVID EDWARD ALBRIGHT
TRI-CITY RECORD

The San Juan County Commission on Tuesday unanimously approved a memorandum of agreement between New Mexico Tech and the San Juan County.

The agreement states that the county will provide support and engagement with the communities in the county.

William Ampomah, a research engineer from New Mexico Tech, gave a detailed slide presentation seeking cooperation from the county for its carbon capture and storage efforts.

According to the county staff summary report, the funding from the U.S. Department of Energy will be used to "accelerate the deployment of carbon capture and storage projects in the San Juan Basin in an equitable and environmentally responsible manner."

It also states that New Mexico Tech will "engage a "multidisciplinary team with expertise in education, community engagement, carbon storage resource assessment, project management, monitoring, reporting and verification for CCS projects, CO_2 pressure management and optimization, legal, regulatory, CO_2 transportation and safety."

Ampomah, describing the geological features in the San Juan Basin, said there is a "salt-water invested formation" that will serve as the storage complex. He said there is a cap rock that will "seal that will more or less maintain the CO_2 that has been injected" so that will prevent CO_2 from leaking into the underground source of drinking water.

"The photic zone, euphotic zone, epipelagic zone, or sunlight zone is the uppermost layer of a body of water that receives sunlight, allowing phytoplankton to perform photosynthesis. It undergoes a series of physical, chemical, and biological processes that supply nutrients into the upper water column," according to Wikipedia.

Ampomah, emphasizing the safety considerations, said, "and that is a big deal for the EPA," he said, adding that "for us as scientists to make sure that we can store it successfully and safely."

Ampomah said they drilled an 8,800-foot-deep well in the San Juan Basin to collect more than 450 core samples and done a lot of experimental work to "support the analysis" that this area is a "strong basin to be able to store CO_2."

Though not specific with amounts of funding from the U.S. Department of Energy, Ampomah said, it would allow "them to put in fiber in the well that will "record potential microseismic events that can happen as a result of injection."

It will measure temperature that will reveal movement of the CO_2 and if it's coming up, he said.

New Mexico Tech plans to work on three sites to prove they can store CO_2 in the San Juan Basin. They plan to store 50 million metric tons of CO_2 within 10 or 15 years, he said.

Ampomah said they cannot do the project without support and must engage the community and are "mandated" to look at quality jobs and how many jobs will be created. He was unclear on how many jobs would be created when asked by the commissioners.

He said they are looking for support, including technical, from San Juan County as they plan to hire people from the area, based on "diversity, inclusion and accessibility." "Even though the budget hasn't started, I'm hiring people from the area," Amporah said. "We really want you to be engaged in this particular process."

He asked the commissioners to participate in their outreach programs and conferences and to hold them accountable.

Beckstead asked for clarification on the scale – the storage of 50 million tons of CO_2 – of the project and the number of jobs that will be provided and what it would be worth to the community.

Ampomah said the first well they drilled was a $12 million project and the next two are estimated to be about $9 million each.

He said that all three projects, including a carbon transport pipeline, will create jobs in the community.

Commissioner Teri Fortner also asked about jobs, and Ampomah replied that he would have to look up the numbers, but there were 20 entities involved in the first well and that the majority of jobs are of a three-month duration during the drilling phase. He said that a number of other long-term maintenance and process control jobs are also created.

The question of water consumption was posed by commissioner Commissioner Steve Lanier. Ampomah said they work very hard to use "reused water," but he would have to cross check to get the actual number of gallons that was used on the first well project.

The San Juan County agreement

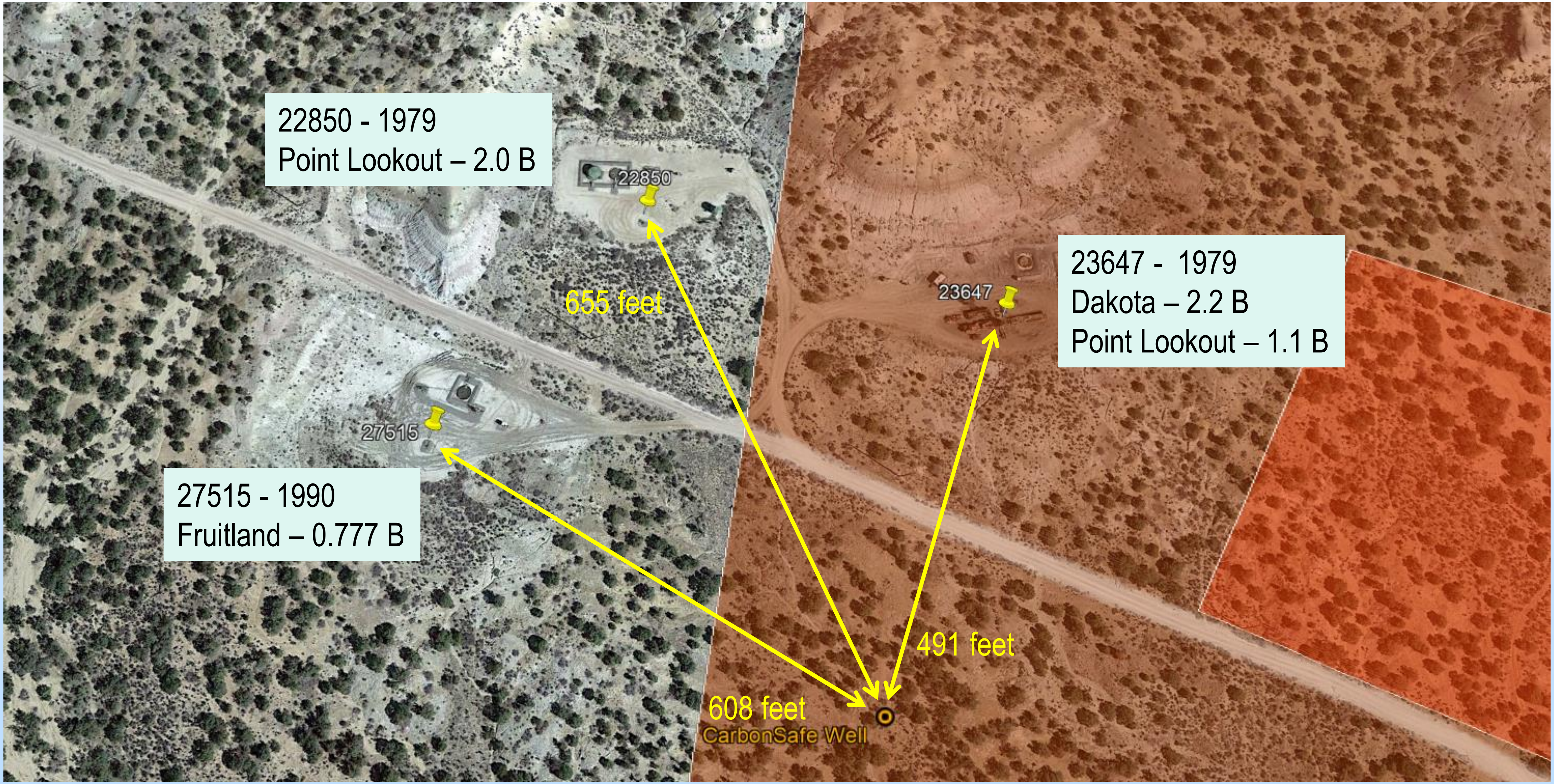
The county acknowledges the expertise and capabilities of New Mexico Tech's multidisciplinary team.

a. Support engagement with communities to implement the community benefit plan.
b. Provide training for various organizations, including universities, community colleges, and trade professionals.
c. Reevaluate and share CO_2 storage resource and hazard assessment for the San Juan community.
d. Identify crosscutting opportunities for supporting the development of CO_2 storage projects.
e. Offer technical assistance to both project developers and the community to ensure equitable deployment of multiple carbon storage projects in the San Juan Basin.

DAVID EDWARD ALBRIGHT/Tri-City Record

William Ampomah, a New Mexico Tech research engineer, presents a carbon management report.

Lessons Learned from Strat Well Drilling



Summary- Next Steps

- Drilled stratigraphic well and completed to UIC Class VI standard.
- Successfully installed Silixa fiber optic behind casing
- Submitted first part of UIC Class VI Permit documentation to EPA.
- Commence NEPA documentation after DOE-NEPA determination
- Performed seismic inversion for reservoir properties to enhance property distribution into our geological model
- Completed core analysis and advancing petrophysical and mechanical modeling
- Continue environmental justice analysis unto completion and ensure inputs are appropriately aligned with economic assessment inputs and analysis
- Complete injectivity test
- Submit additional permits to meet program goals
- Obtaining UIC Class VI permit for submitted permit

Acknowledgements

The project would like to thank DOE for the award opportunity through DE-FE0031890 and our partners.

Project Objectives

- Perform a comprehensive site characterization of a storage complex located in northwest New Mexico to accelerate the deployment of CCS technology in the San Juan Basin

- The data and analysis performed will be used to prepare, submit and obtain UIC Class VI permit from the Environmental Protection Agency (EPA).

- Public awareness of CCS technology and its benefits

- Collaborate with regional partnerships and regional initiative projects to accelerate CCS technology deployment in the region