

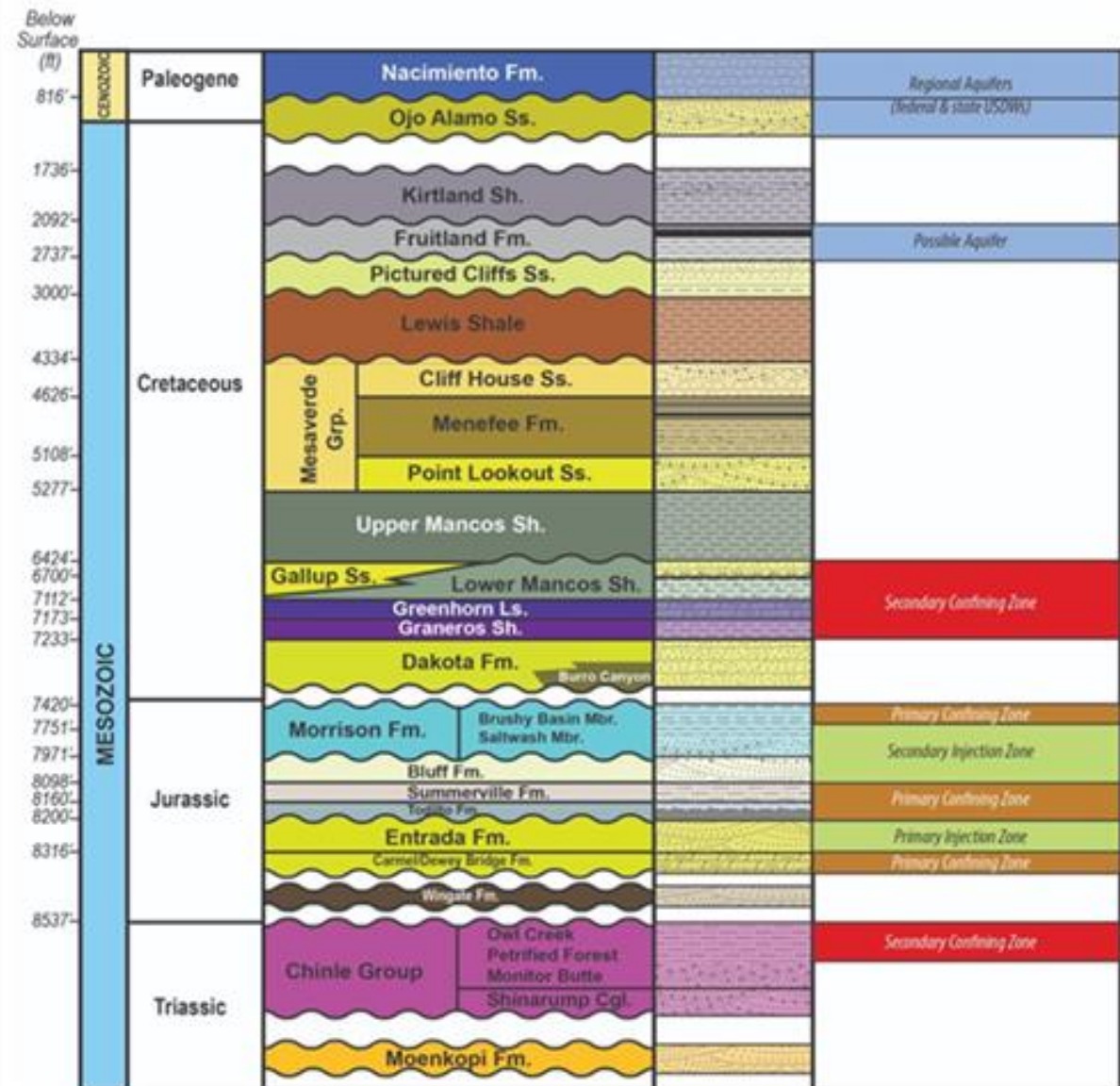
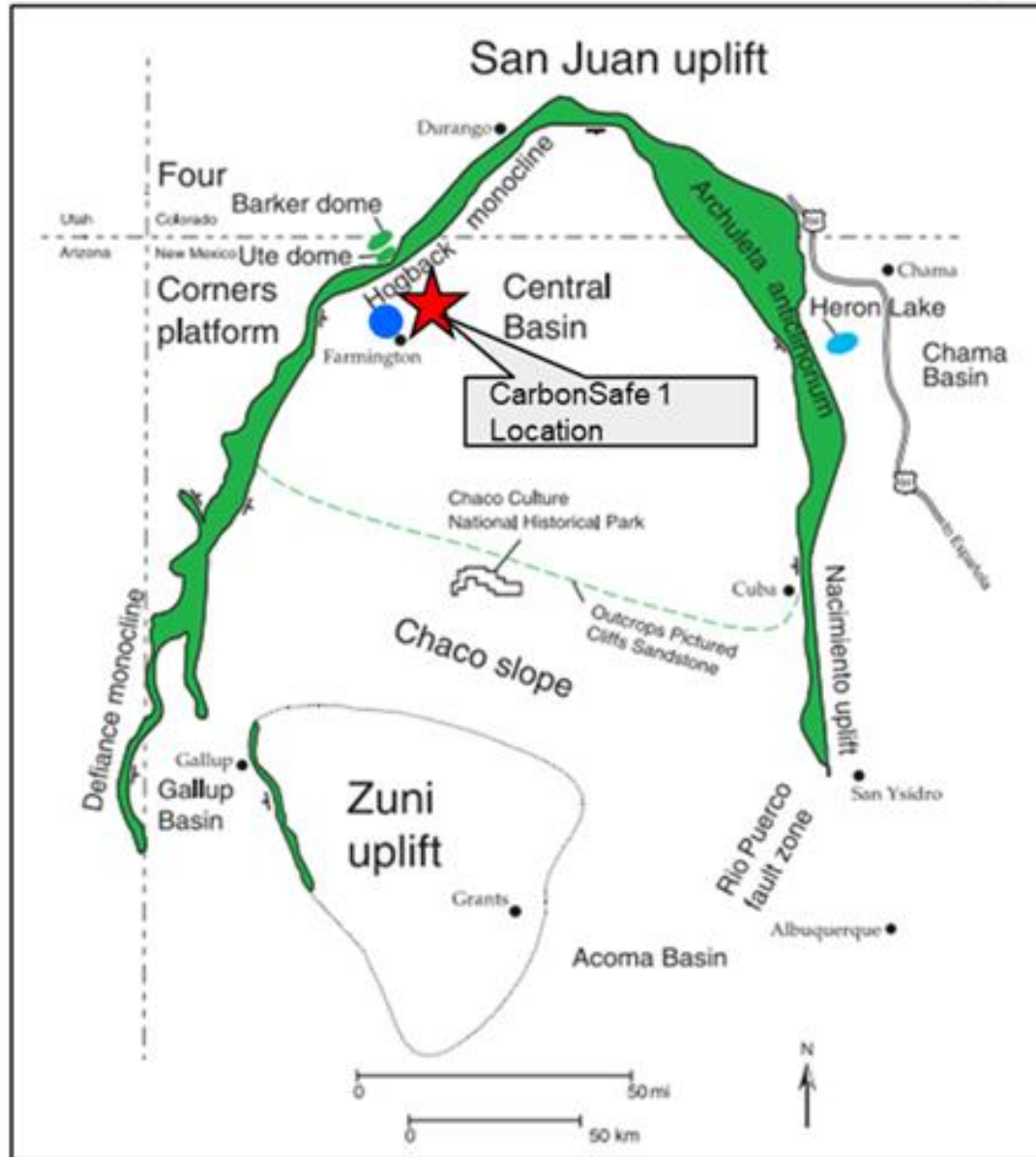
Evaluating Faults, Fractures, Migration Pathways, Reservoirs and Seals for CCS Risk Assessments in the San Juan Basin Using Rock Volatiles Stratigraphy of Cuttings and Cores from Legacy Oil Wells and a New CCS Monitoring Well.

Michael P. Smith¹, William Ampomah², Luke Martin²,
Timothy Smith¹, Patrick Gordan¹, and Christopher Smith¹

1. Advanced Hydrocarbon Stratigraphy, Tulsa, Oklahoma, USA

2. New Mexico Institute of Mining and Technology, Socorro New Mexico, USA

San Juan Basin - Structure and Stratigraphy



From Lorenz and Cooper, 2003; Modified from Fasset, 1989

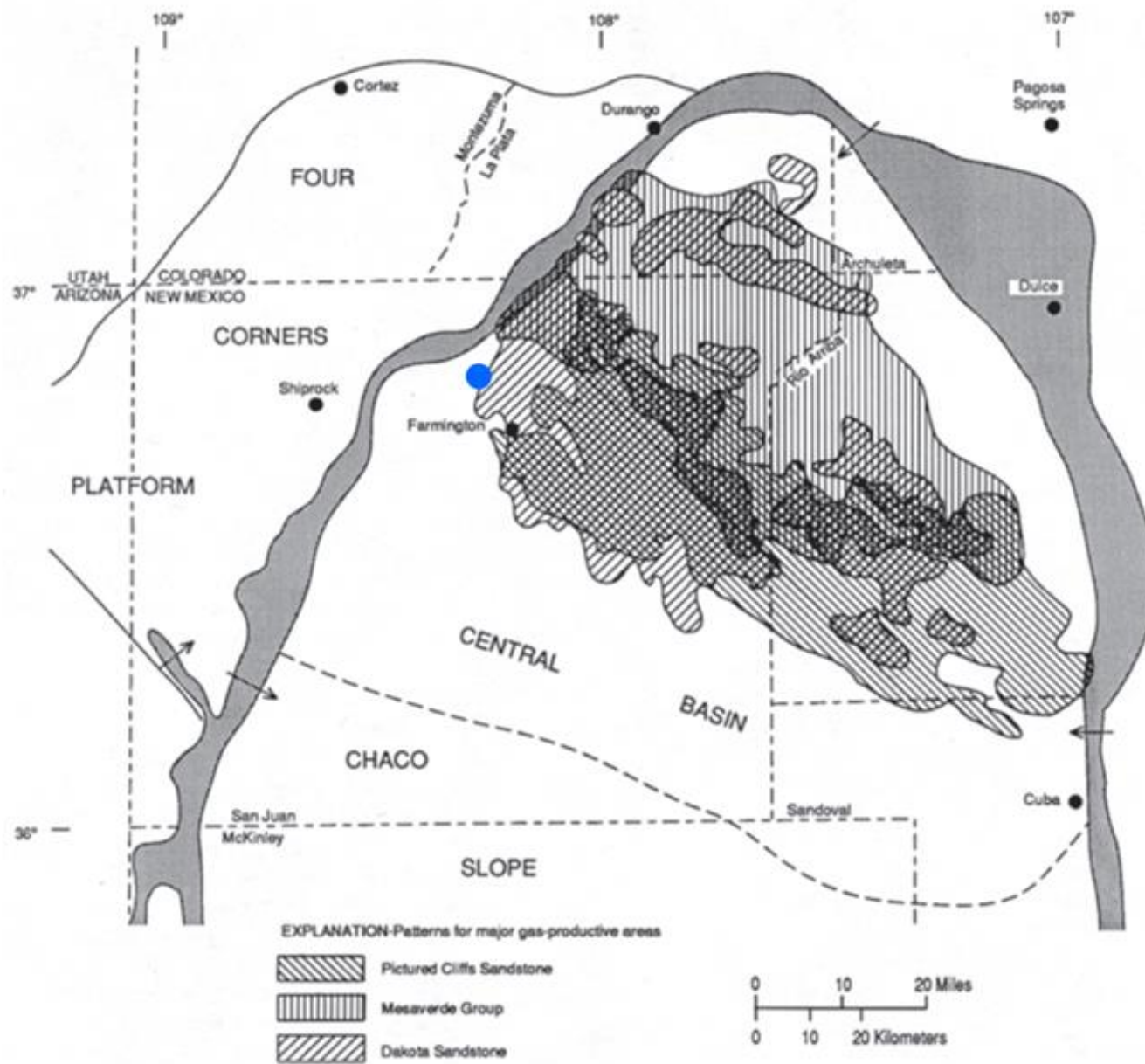


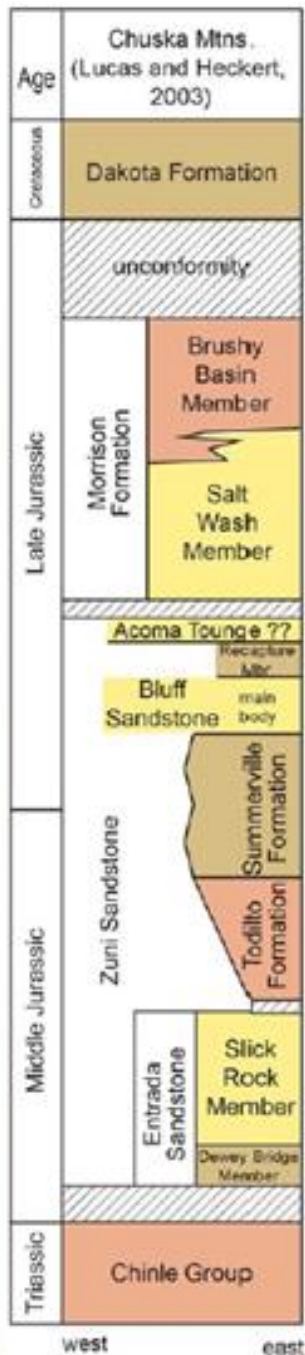
FIGURE 6. Map showing major gas-producing areas for the Upper Cretaceous Dakota Sandstone, Mesaverde Group, and Pictured Cliffs Sandstone in the San Juan Basin. Maps showing productive gas-wells for each of these formations are on Plate 16.

OIL AND GAS RESOURCES OF THE SAN JUAN BASIN



FIGURE 4. Map showing Paleozoic oil and gas fields on the Four Corners platform in the San Juan Basin. New Mexico and Colorado recognize 28 Paleozoic fields. Only 22 named fields are shown because some fields contain more than one named reservoir or pool within a named field. Oil fields are shown crosshatched, gas fields are white, and oil and gas fields are black. Producing systems are abbreviated: Dev. = Devonian, Miss. = Mississippian, and Penn. = Pennsylvanian.

Storage Complex @ SJ Basin



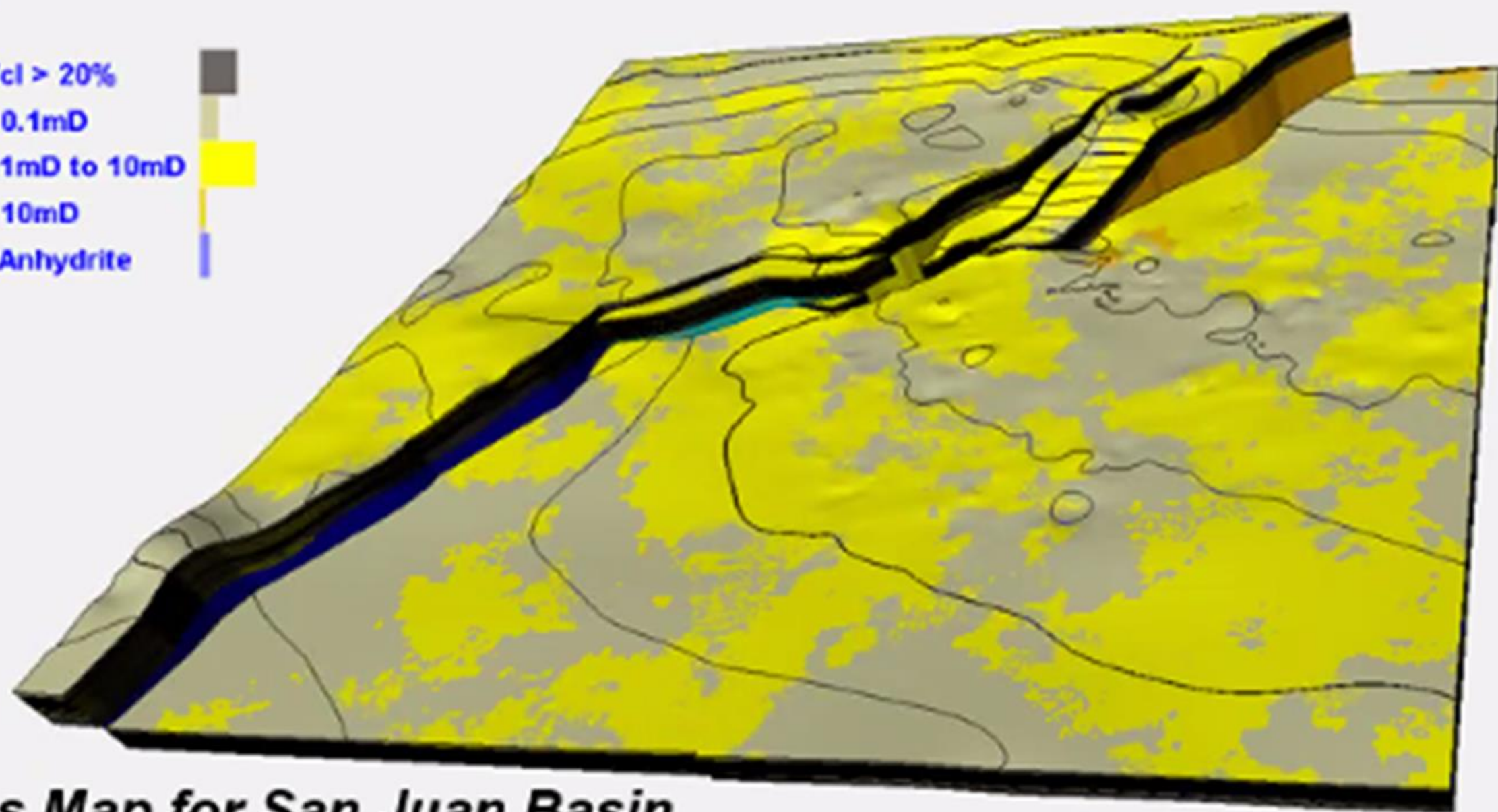
← **Seals**

← **Reservoirs**

- Multiple sandstone zones with good porosity and permeability
- No production in the area within the lower units
- Jurassic era formation within the storage complex
- Sandstones are interbedded with siltstones and shales as well as overlying shales and carbonates that can act as seals
- Morrison Formation has numerous high porosity zones encased in siltstones and shale

Facies2 [U]
Facies

- Shale Vcl > 20%
- Sand < 0.1mD
- Sand 0.1mD to 10mD
- Sand > 10mD
- Calcite Anhydrite



Facies Map for San Juan Basin

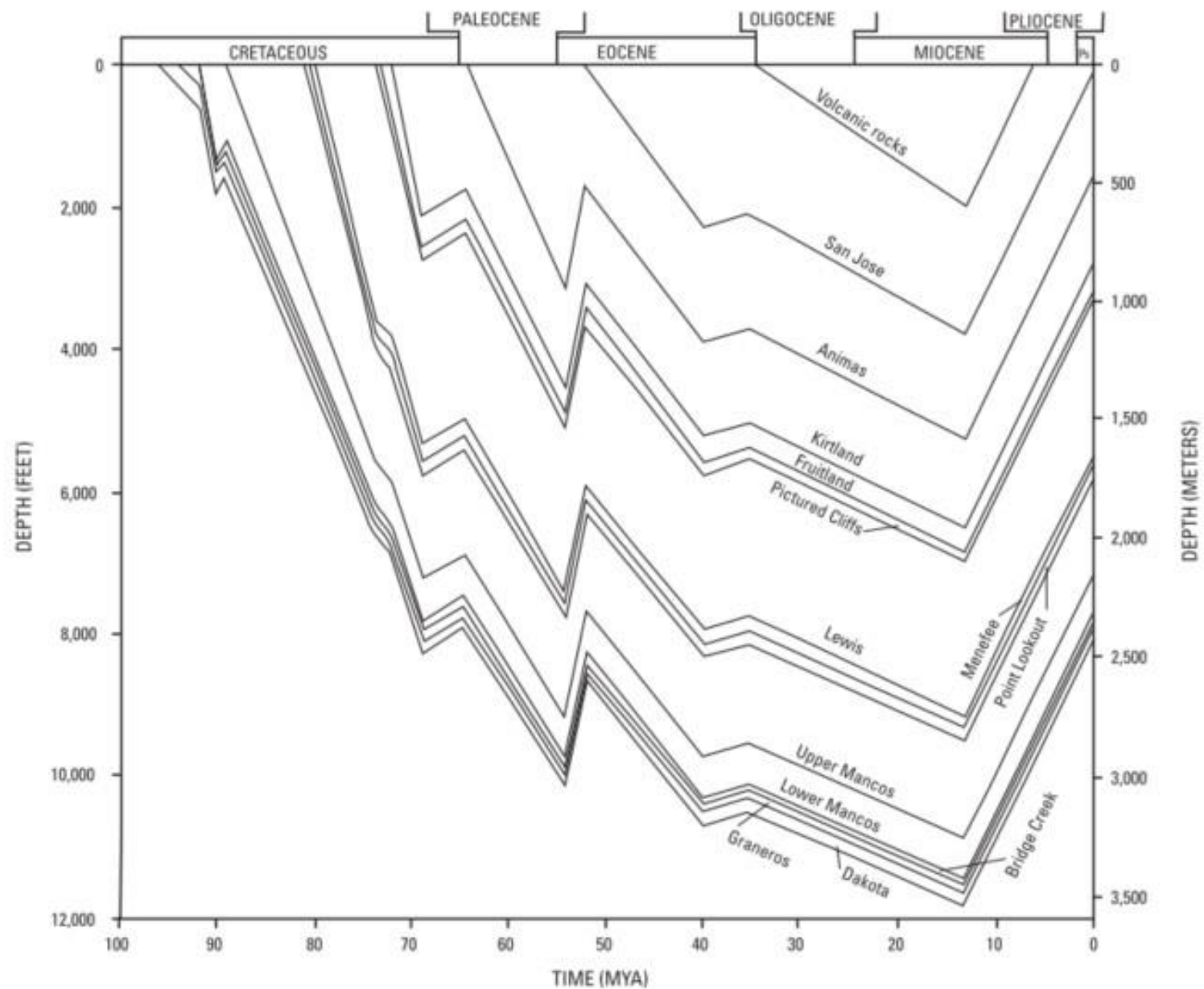
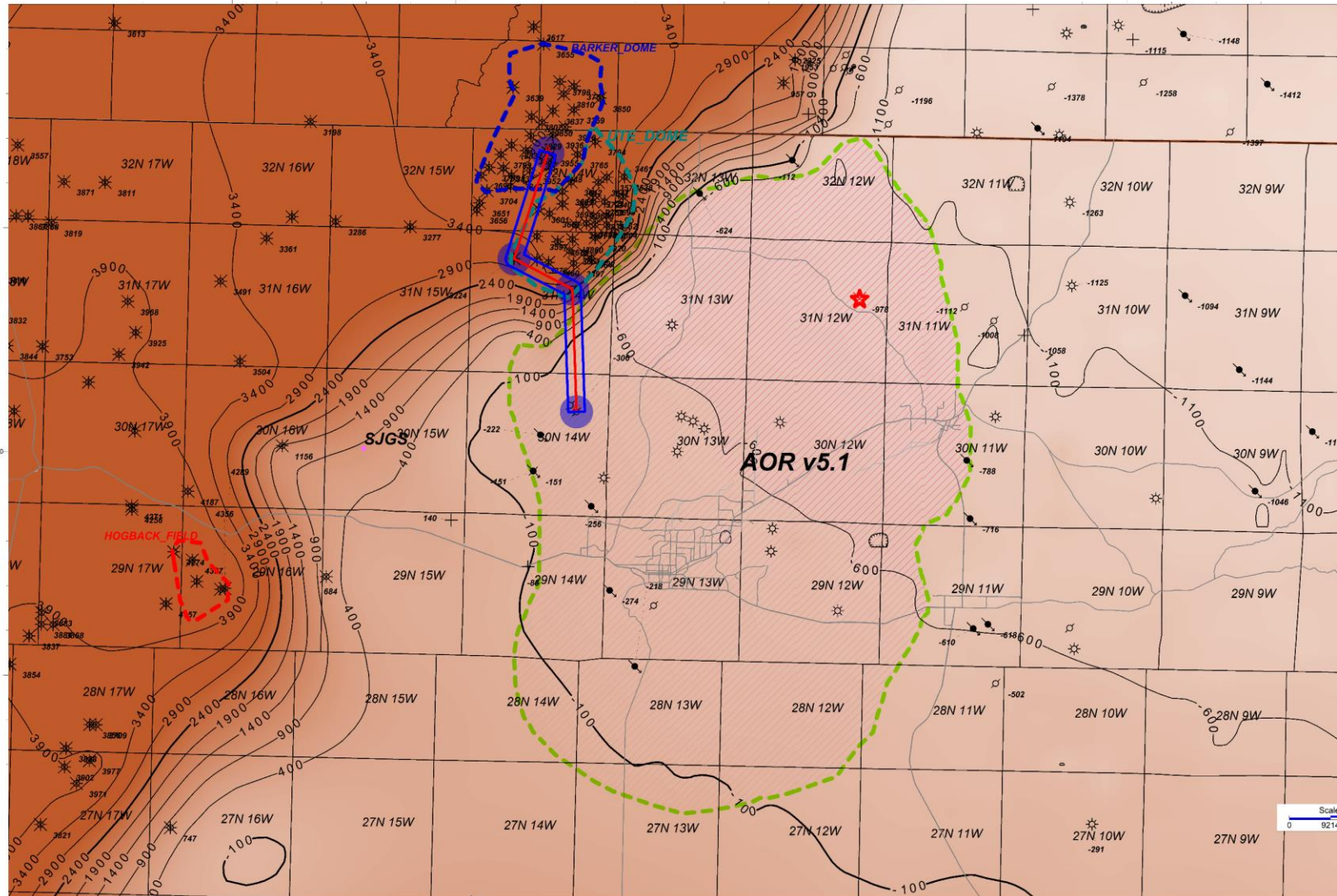


Figure 8B. Composite burial history curve for the Bakke Southern Ute 2 and Sohio Southern Ute 15-16 wells in the northern part of the central San Juan Basin (modified from Law, 1992). MYA, million years ago; Ps, Pleistocene.

N.T. Feet

1020400

1120400



Highlight Wells

★ CarbonSafe_LOC (Public)

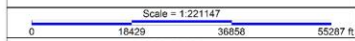
Data Posted Along Borehole

(Tops: Dakota) Time, Depth

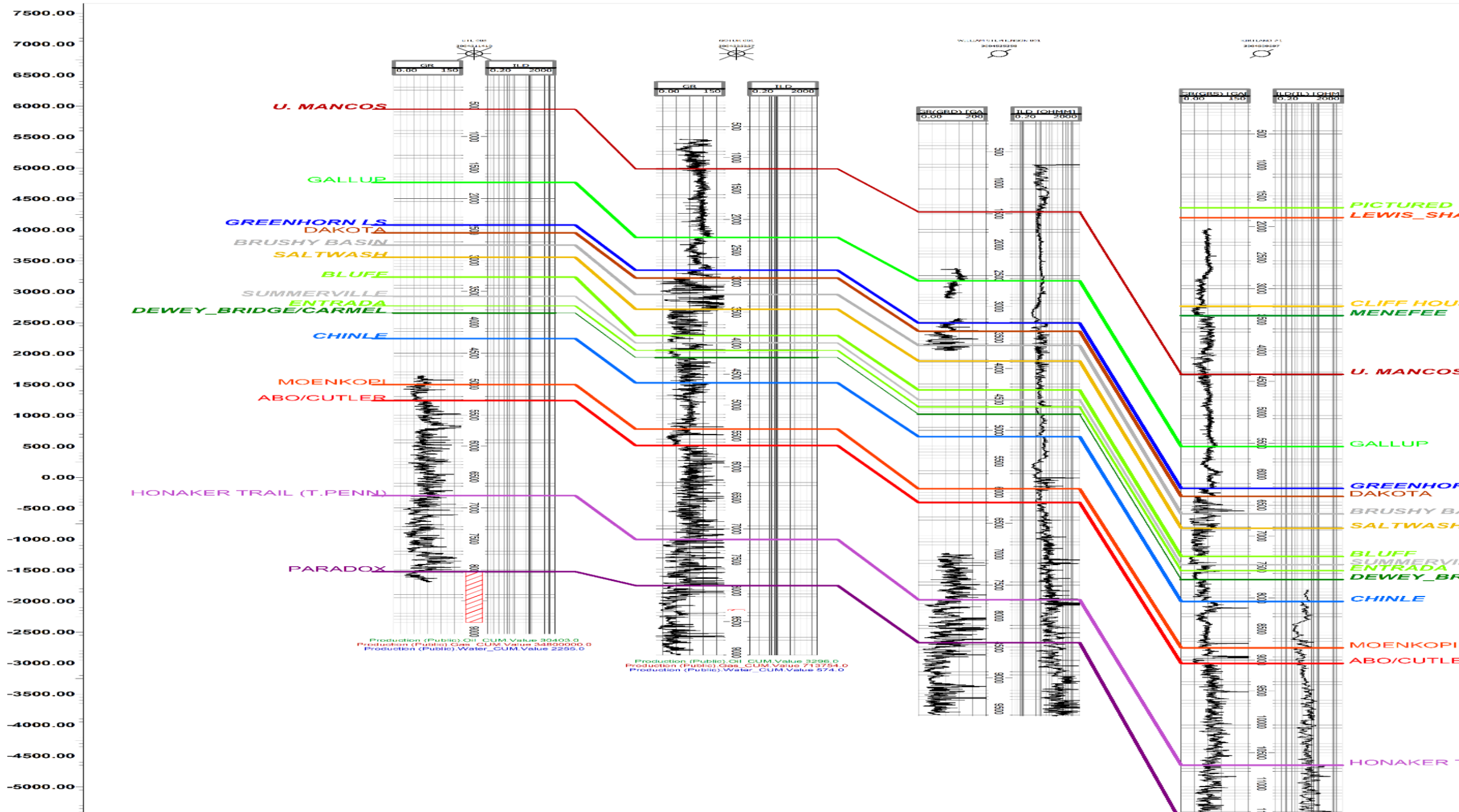
CarbonSafe

Project: San Juan Basin CarbonSafe

Project Location:



Grid: Dakota
Deep wells with Entrada tops plotted



Realized Benefits

1. Operations

- Intelligent, enhanced completion design
- Actual production forecasting before completion
- Land horizontals in best zones

Bottom-line impacts: Detailed knowledge of pay identification, rock type and properties prediction, and report development with expert consultation

2. Exploration

- Identify new opportunities and plays
- Basin petroleum system evaluation

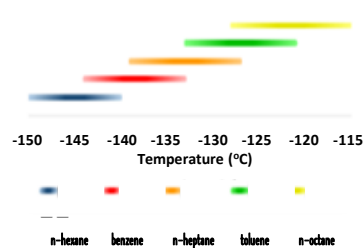
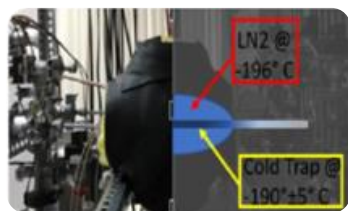
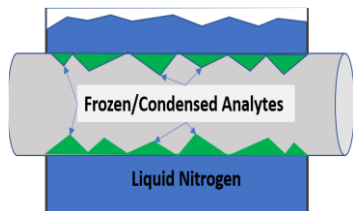
Bottom-line impacts: Optimized exploration and successful production



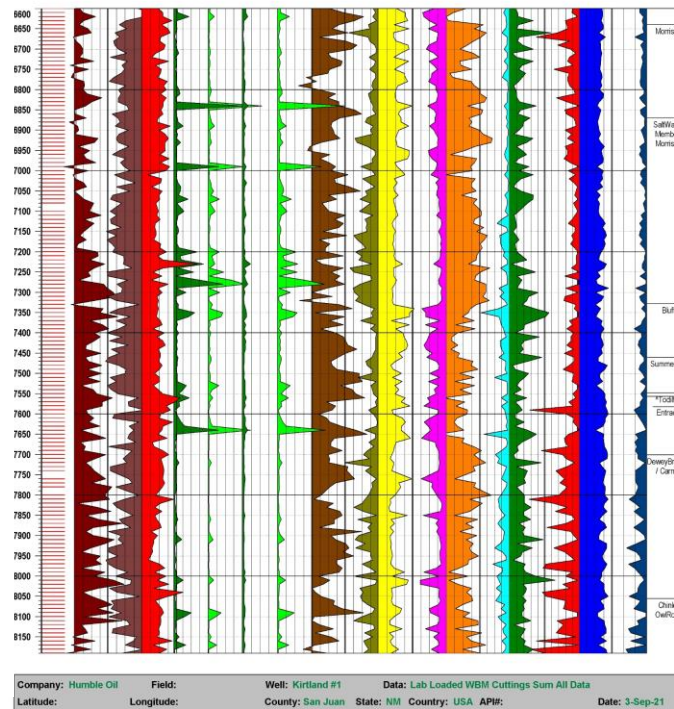
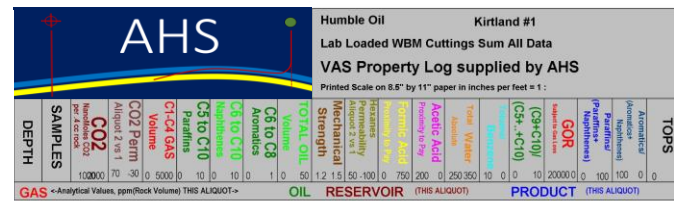
AHS Rock Volatiles CCS Well Site Evaluation: DOE-New Mexico Tech SJB Fault Risk Assessment

ADVANCED
HYDROCARBON
STRATIGRAPHY

Analyze Rock Volatiles



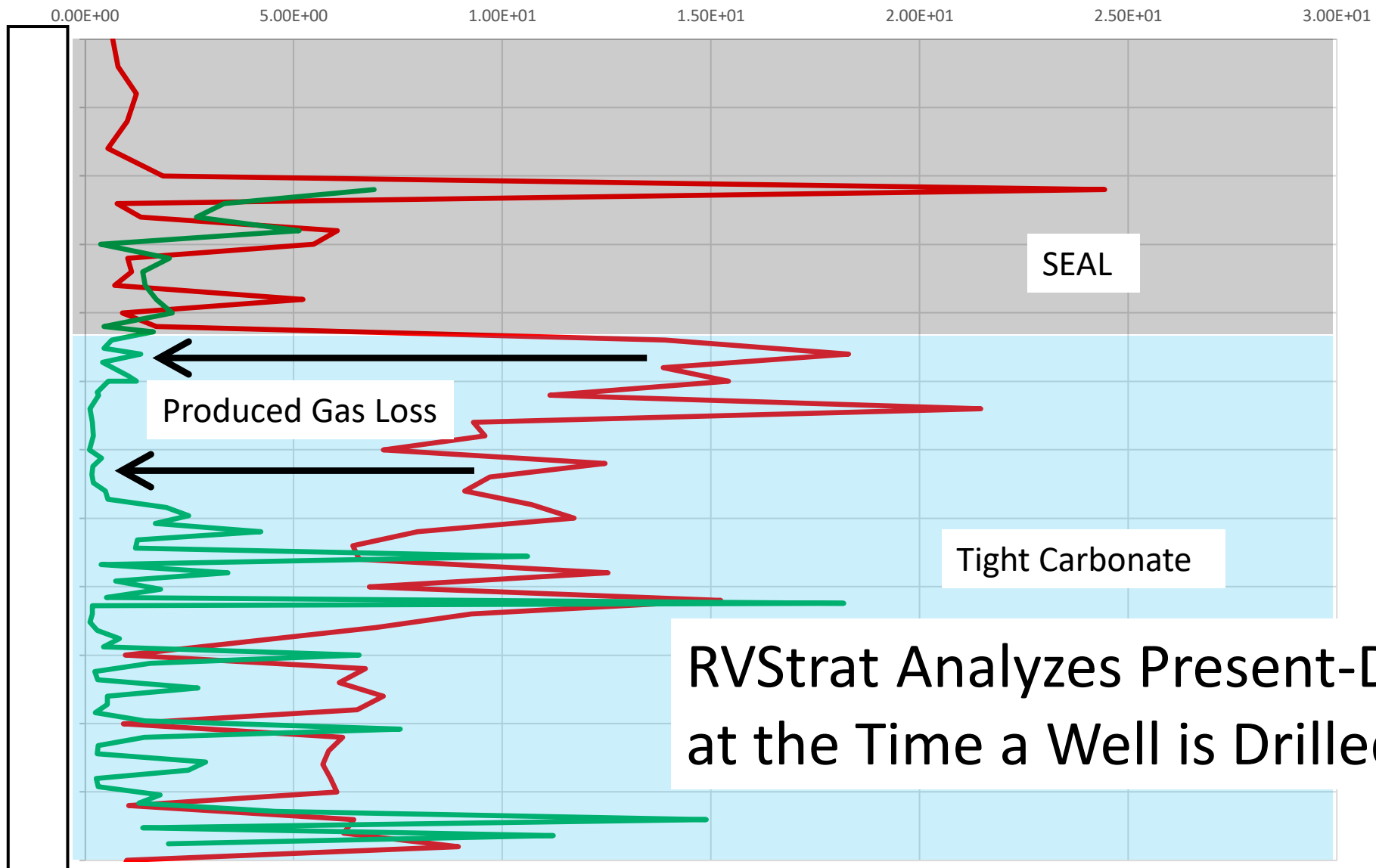
Evaluate Data



Assess Risks

- Faults/Fractures
- Fault Activating Fluid Conduits
- CO₂ Seals
- CO₂ Permeability
- Past CO₂ Loss
- Future CO₂ Loss

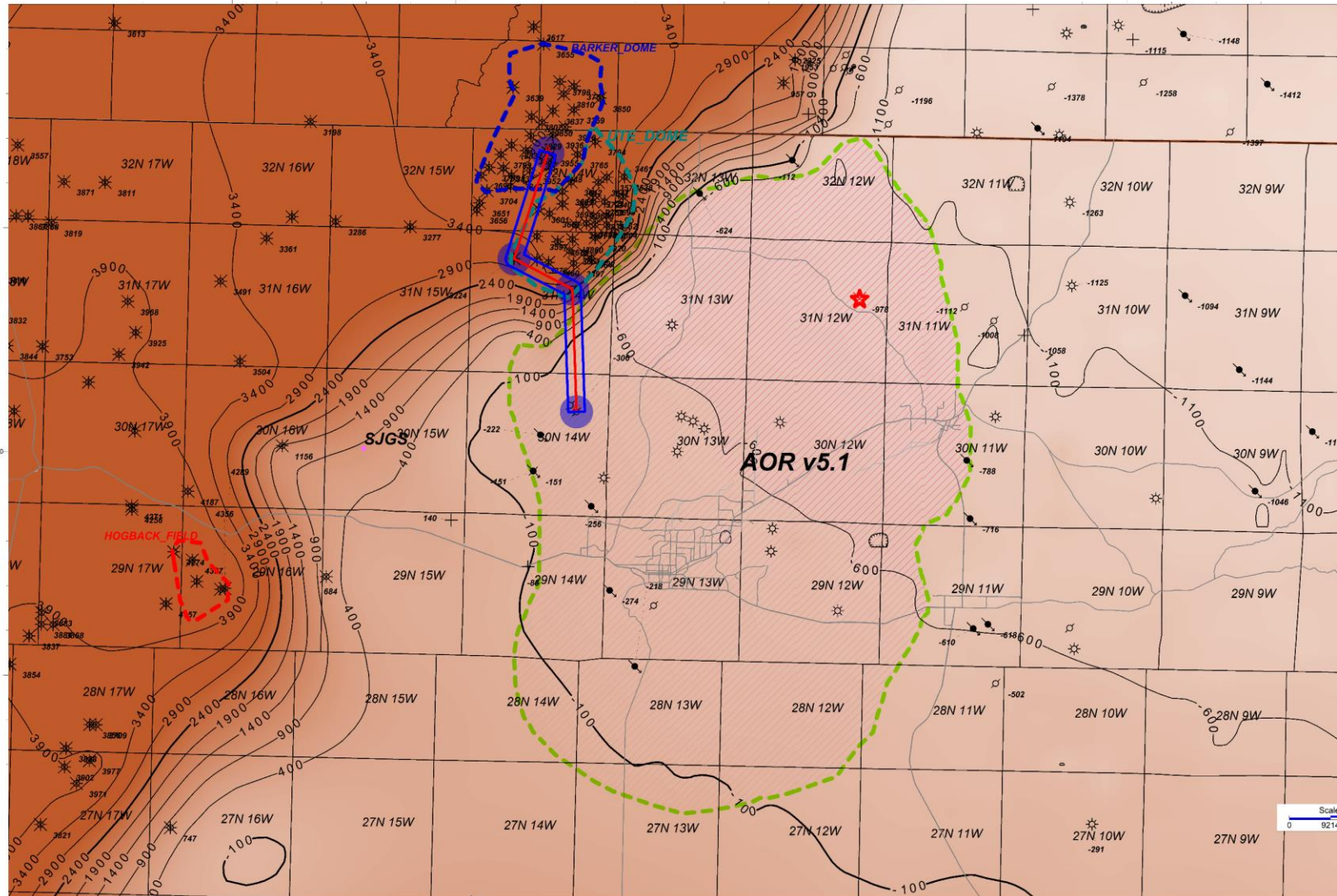
First Documentation of Cuttings Oil/Gas Loss From Production:
RVStrat Cuttings Pentanes Before vs After Production: 1985 vs 2021



N.T. Feet

1020400

1120400



Highlight Wells

★ CarbonSafe_LOC (Public)

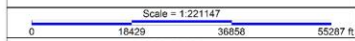
Data Posted Along Borehole

(Tops: Dakota) Time, Depth

CarbonSafe

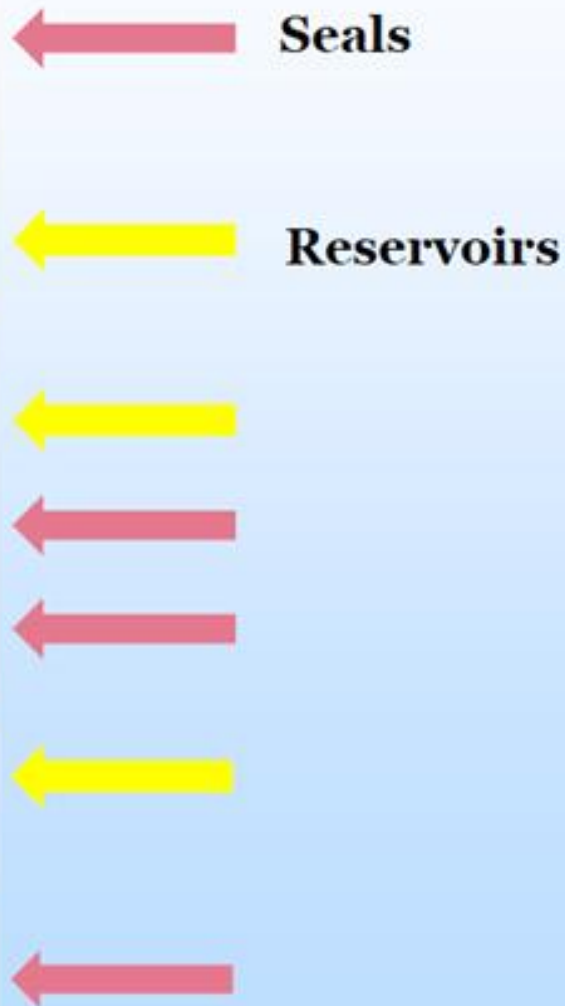
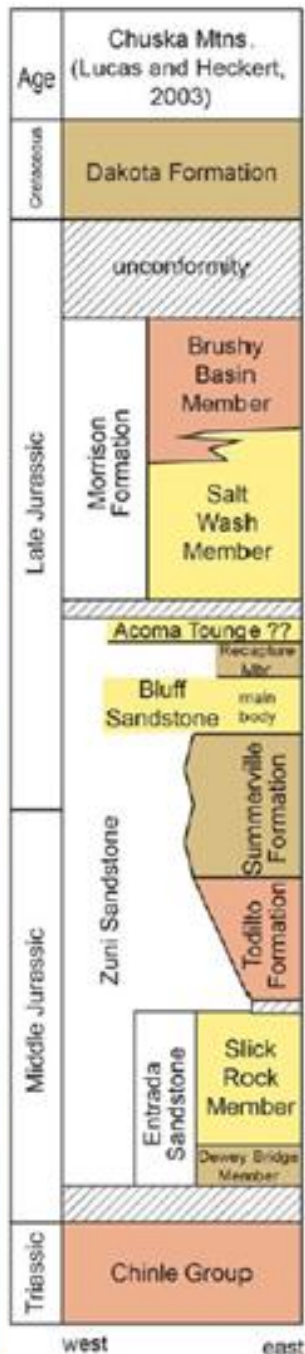
Project: San Juan Basin CarbonSafe

Project Location:



Grid: Dakota
Deep wells with Entrada tops plotted

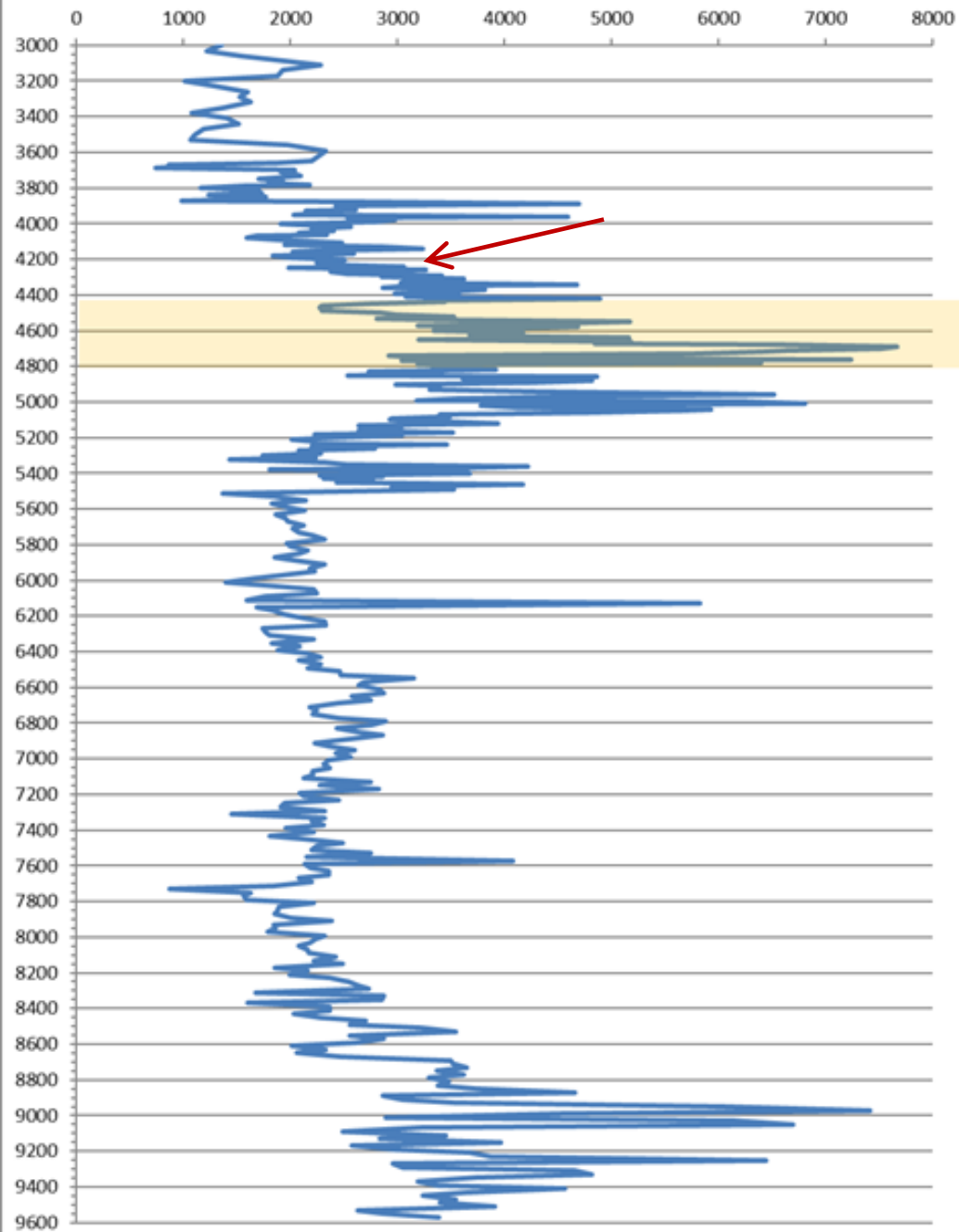
Storage Complex @ SJ Basin



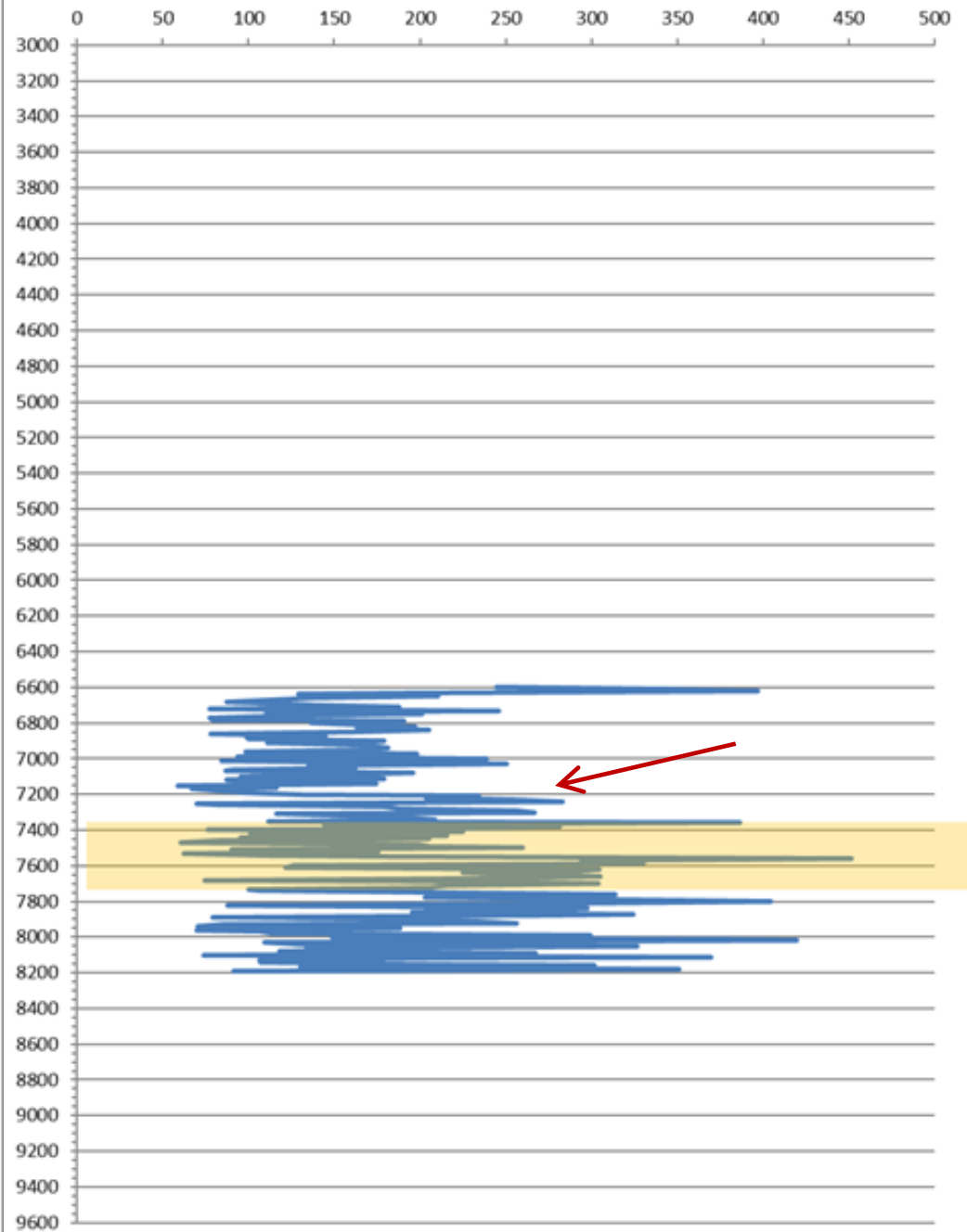
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Good Vertical CO2 Seals

Stephenson Q1CO2

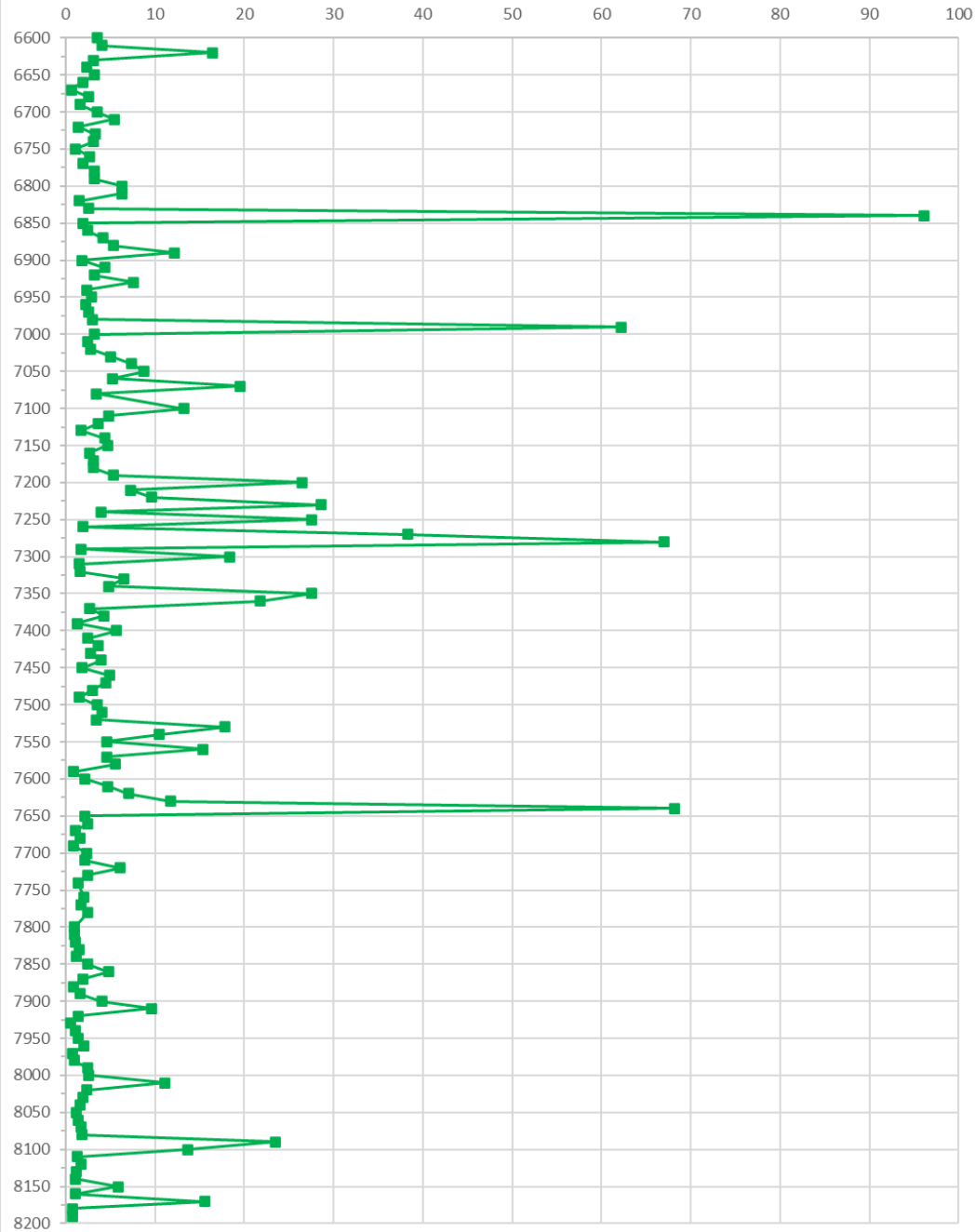


Kirtland-1 Q1CO2

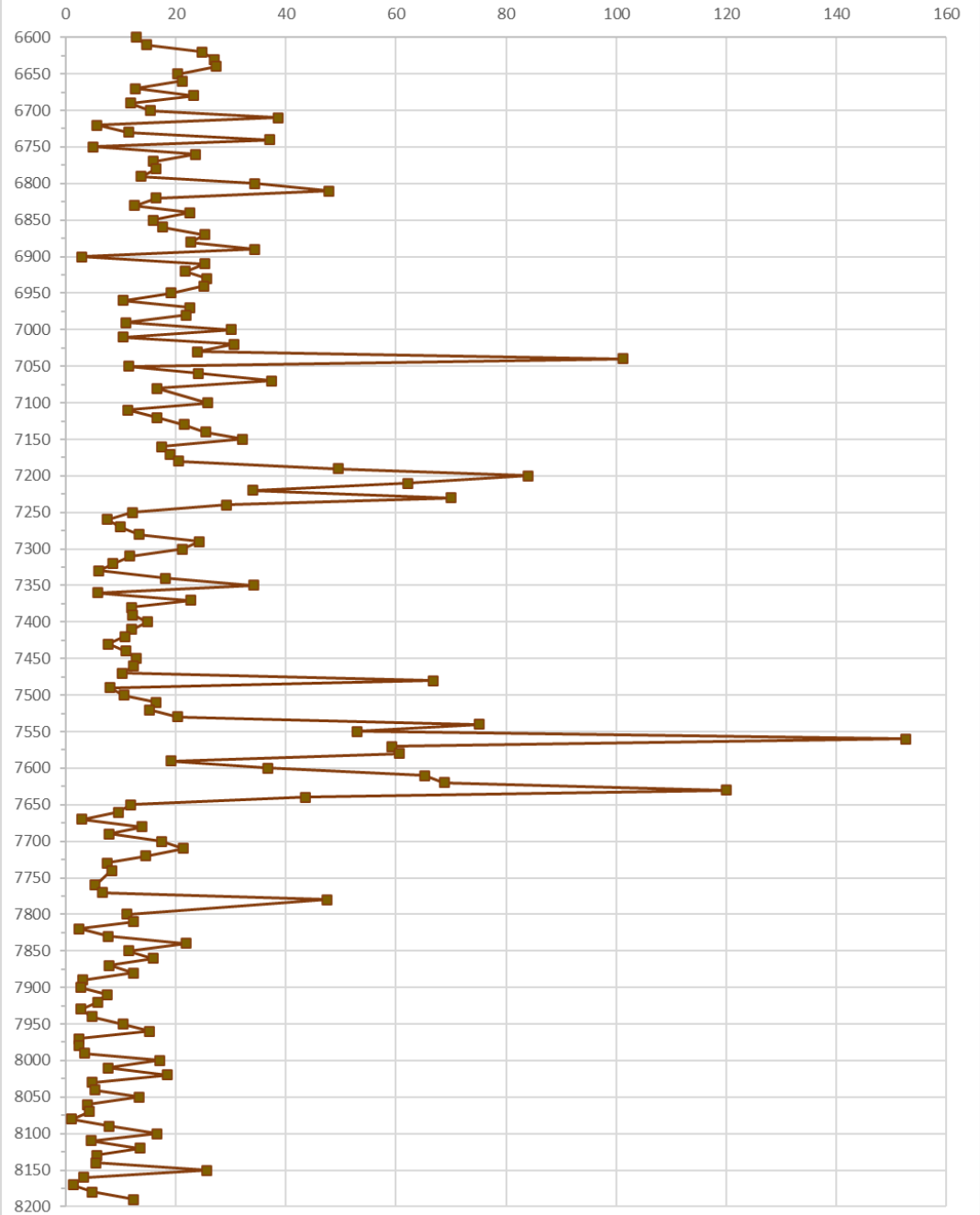


Fluids Migrate Both Aways Across The Hogback Fault

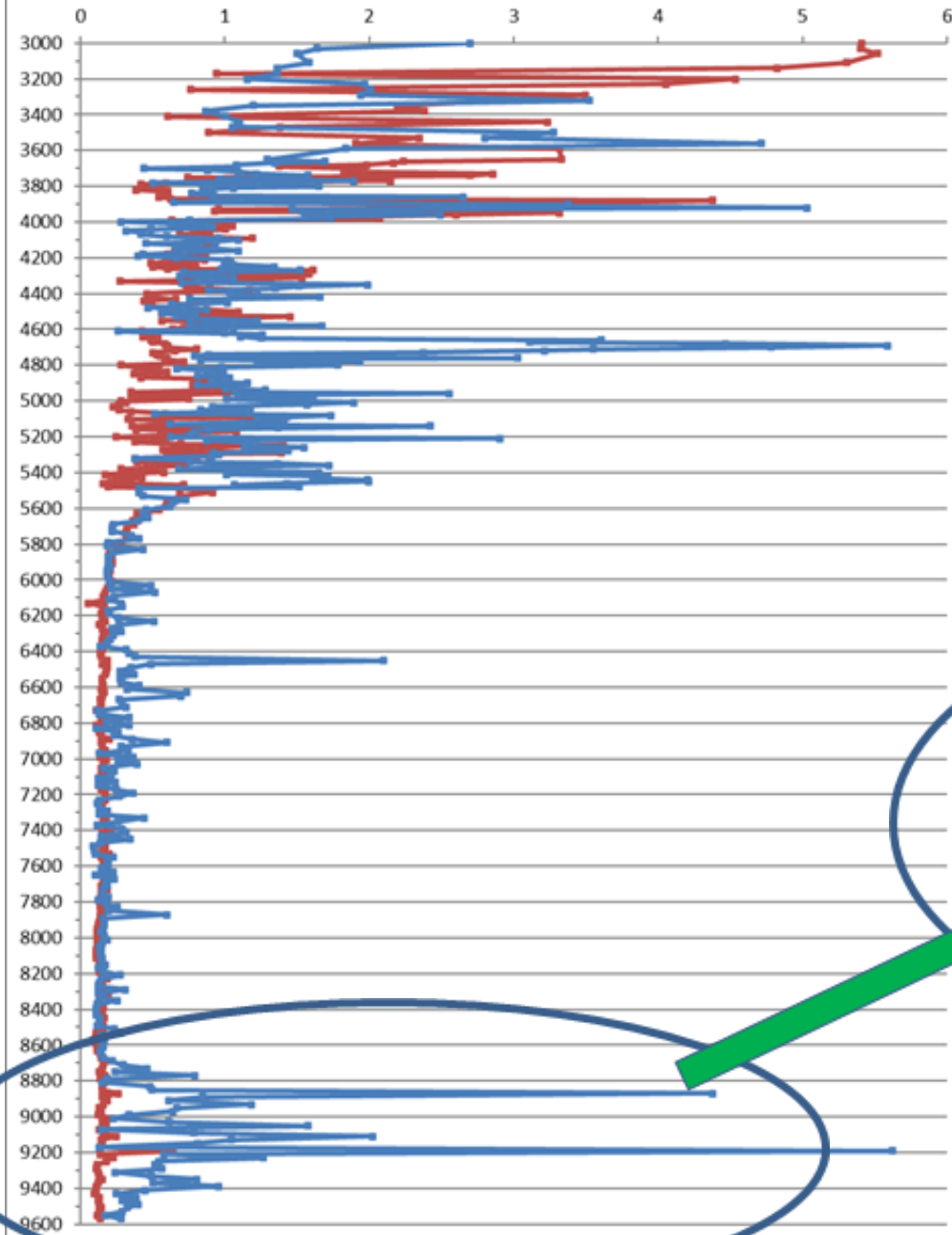
Kirtland-1 Cuttings Total Oil



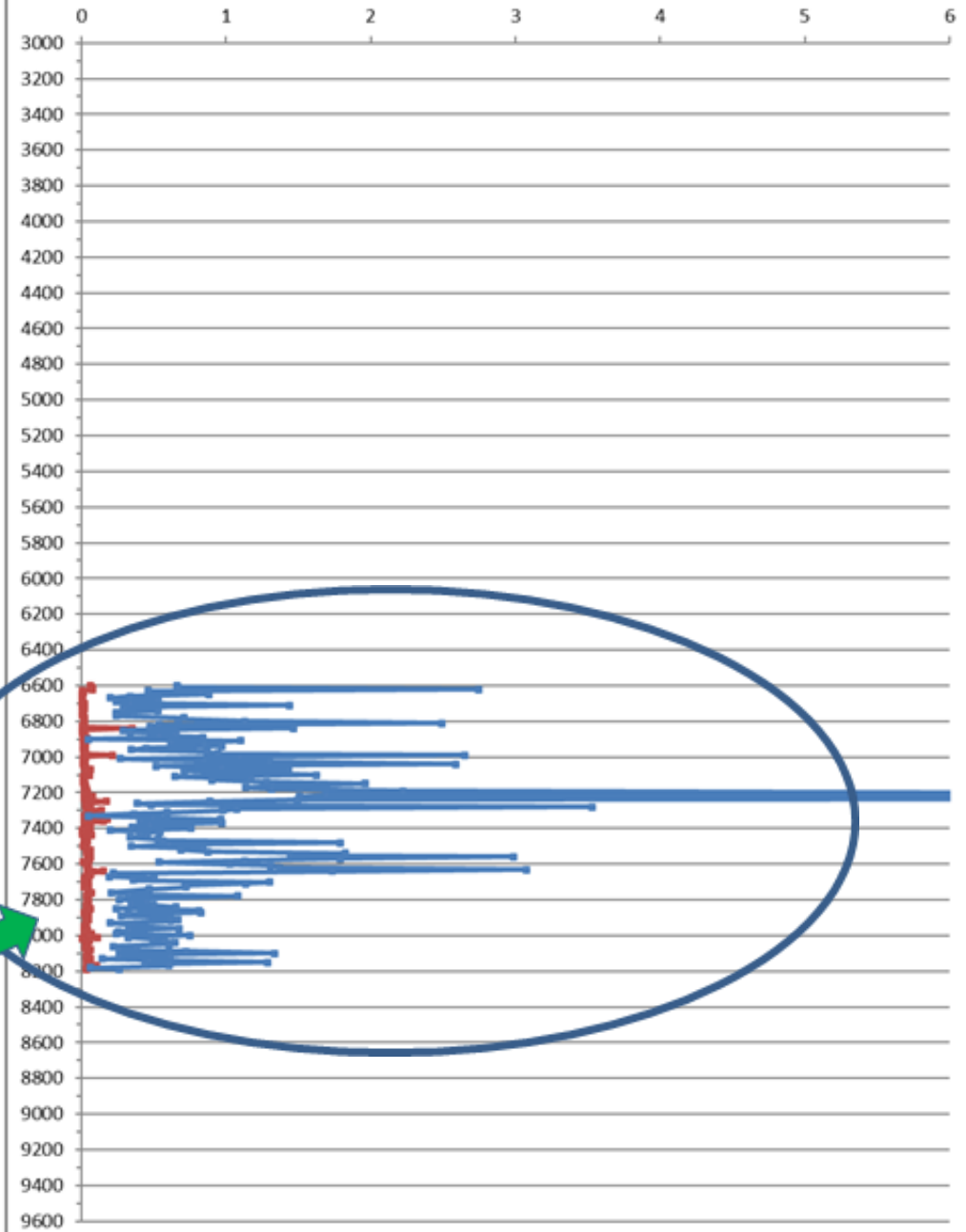
Kirtland-1 Mud Log Propane

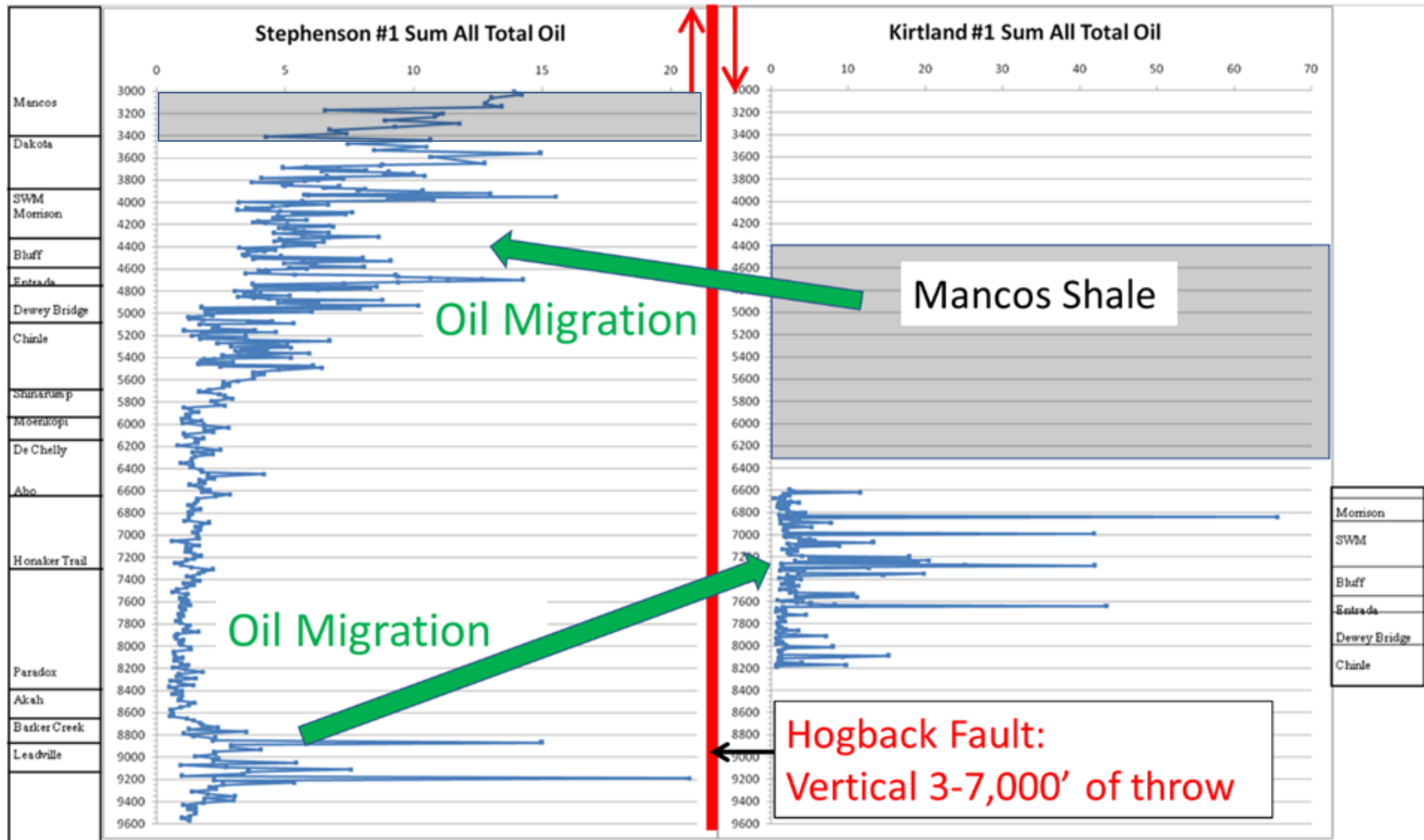


Stephenson #1 SumAll Pentanes vs Decanes



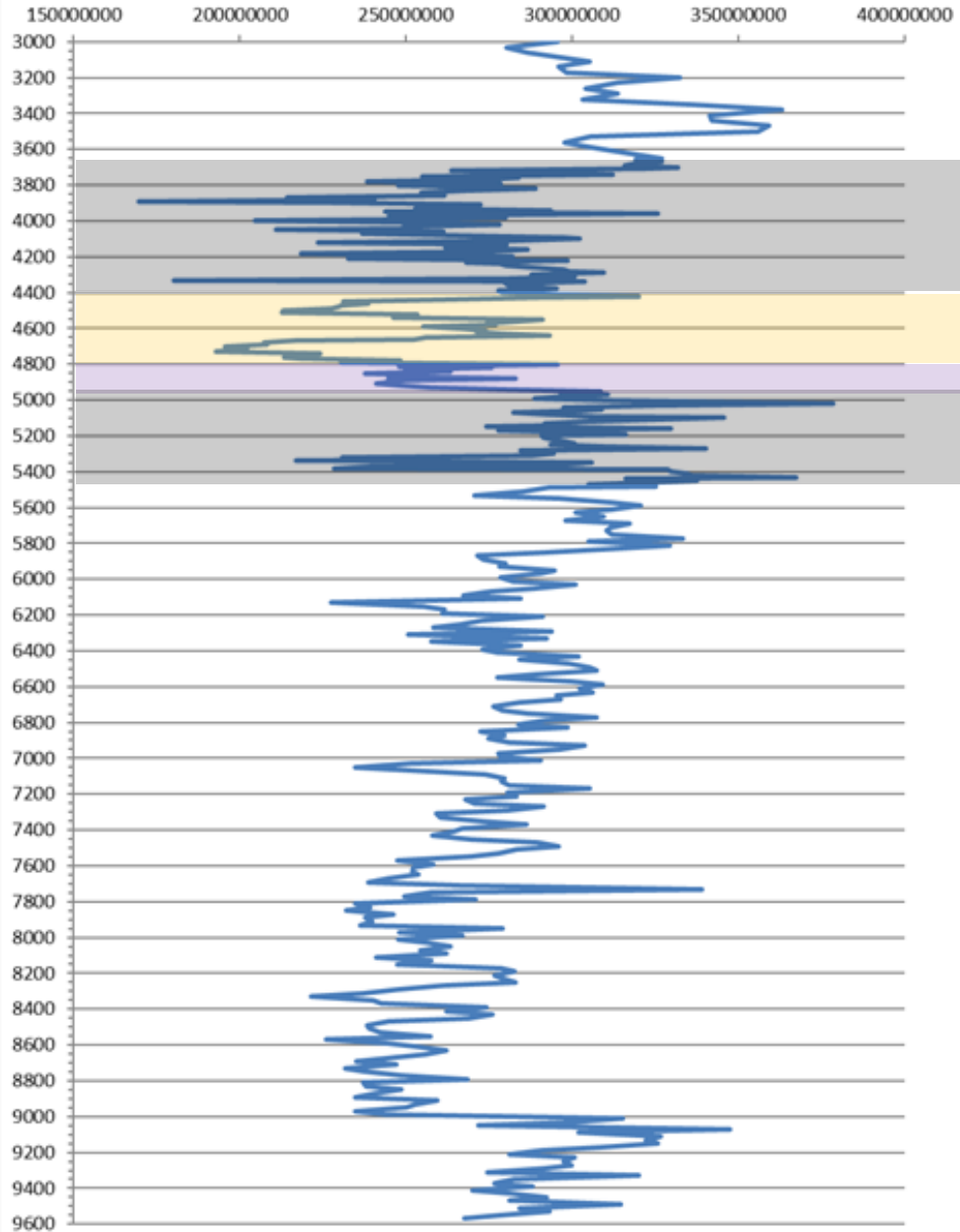
Kirtland 1 Sum All Pentanes vs Decanes



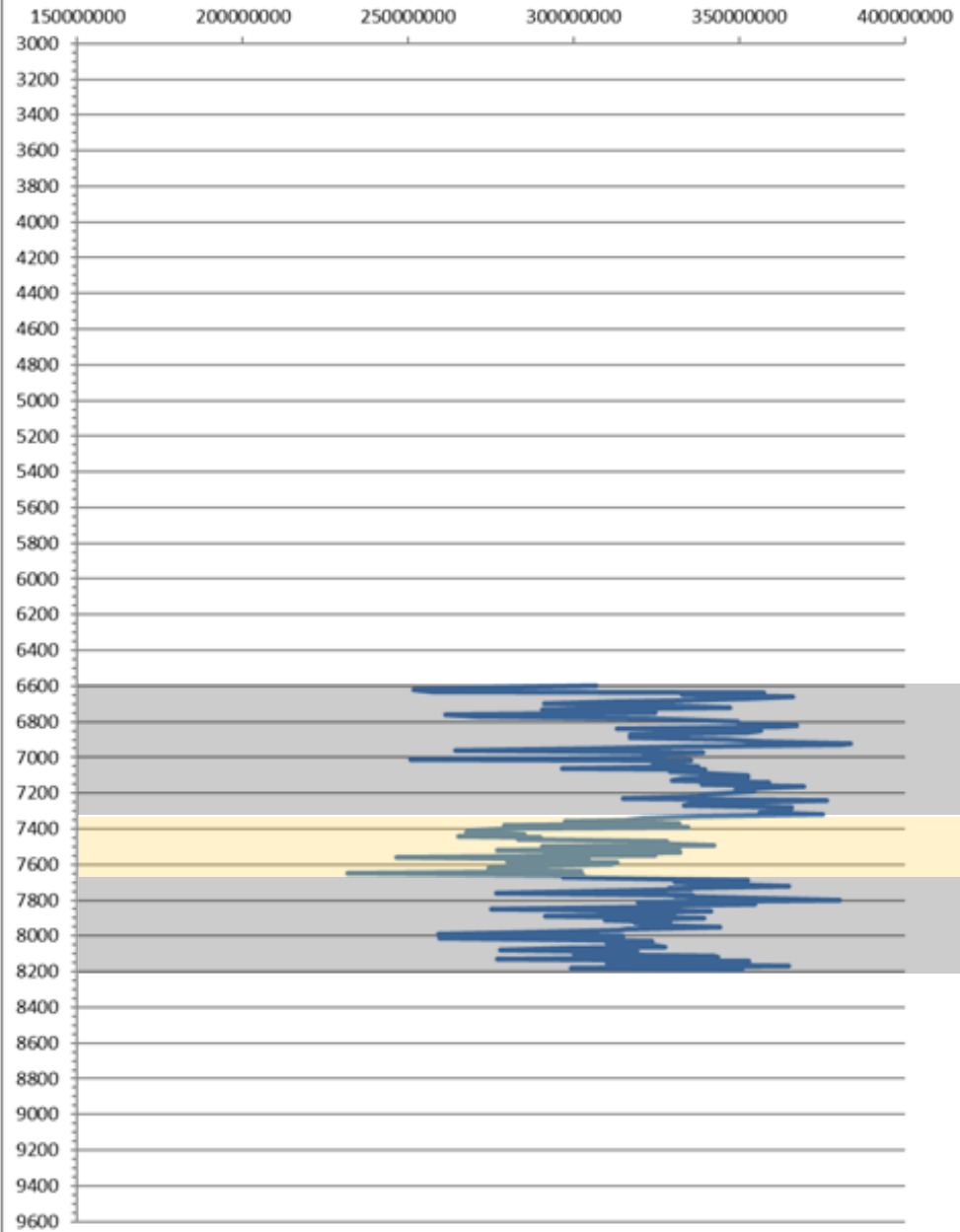


Cuttings Water Data Suggests Fault Base of Entrada in Kirtland-1

Stephenson SumAll H2O

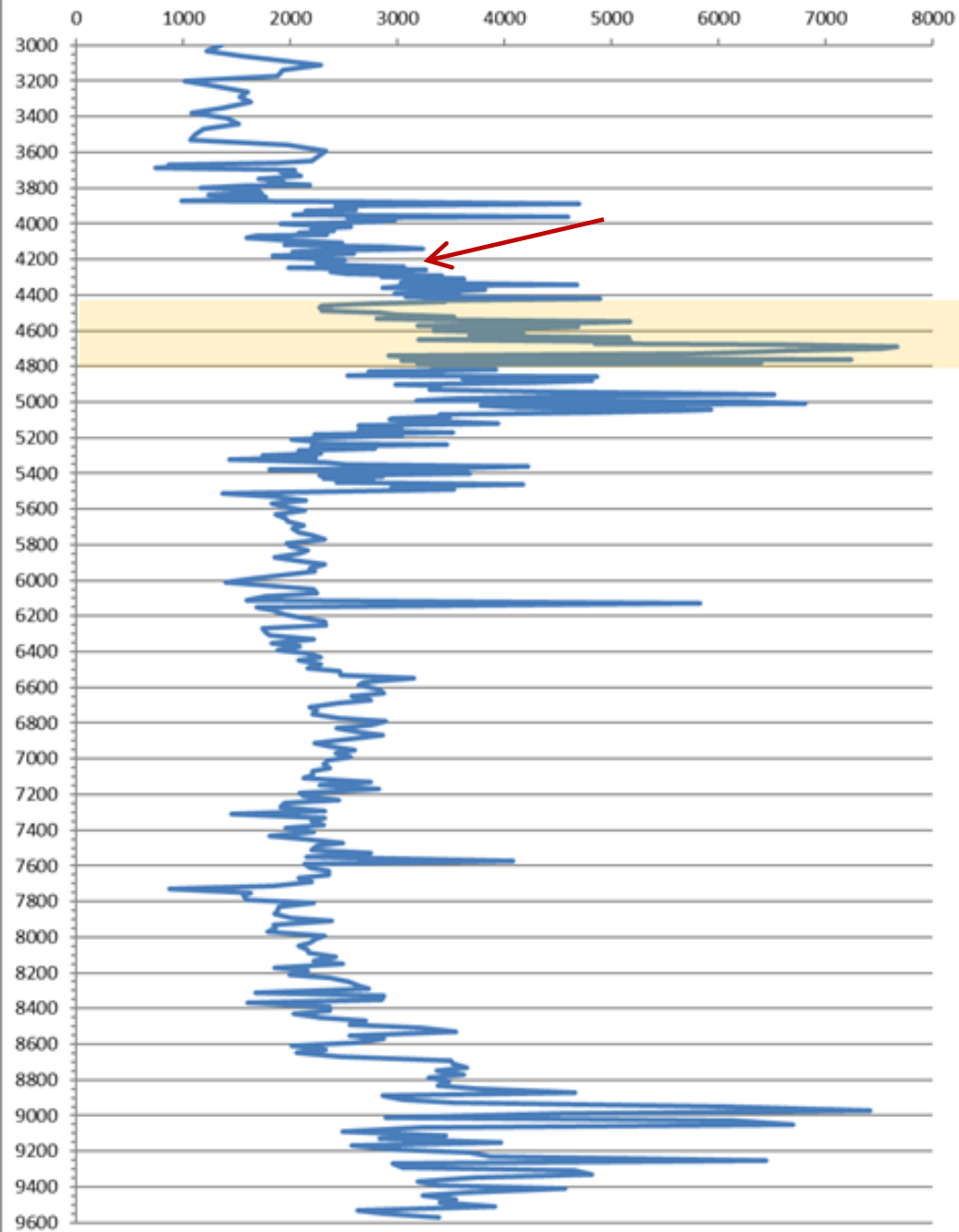


Kirtland SumAll H2O

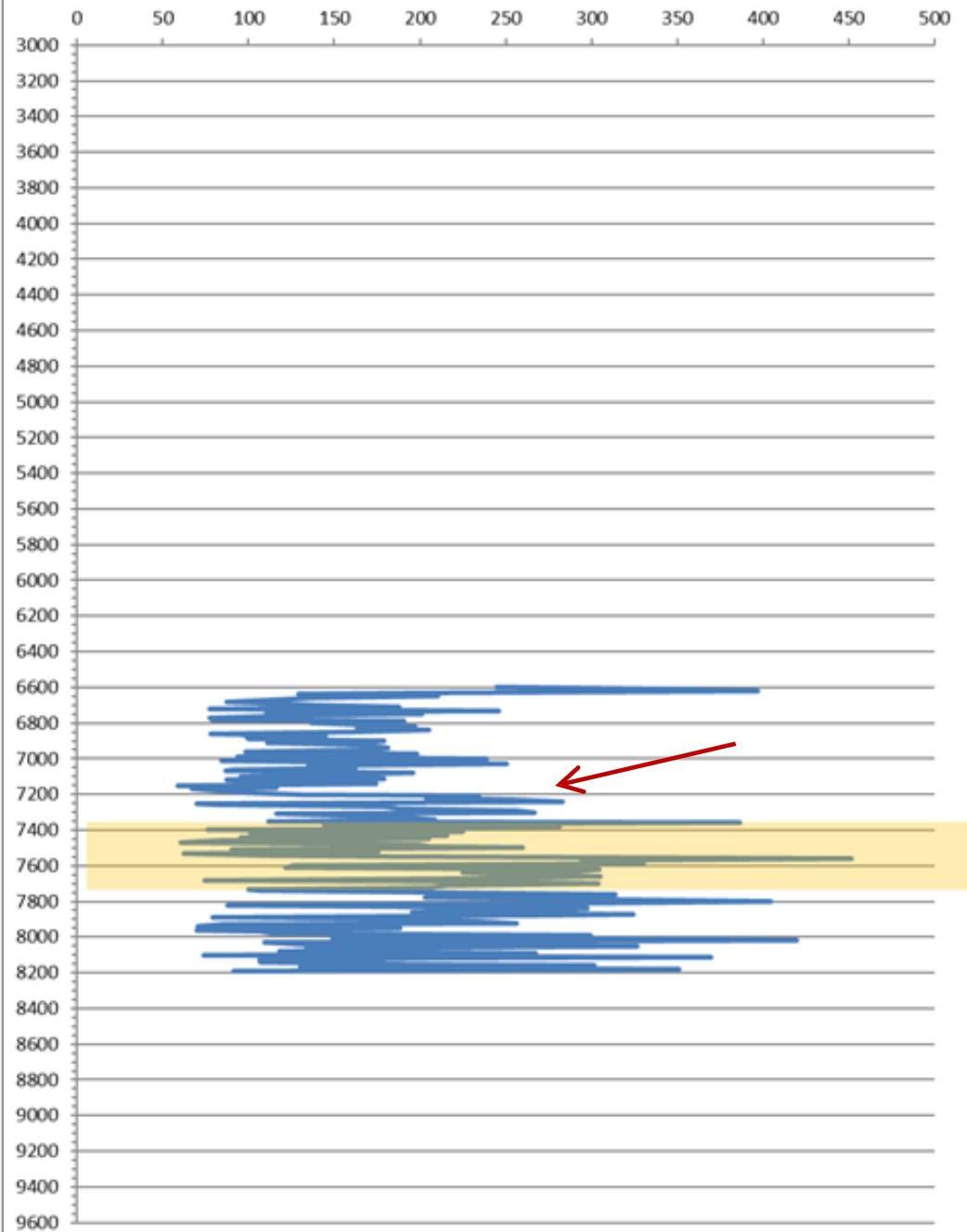


CO2 Systematics:
1) Good Vertical Seal

Stephenson Q1CO2



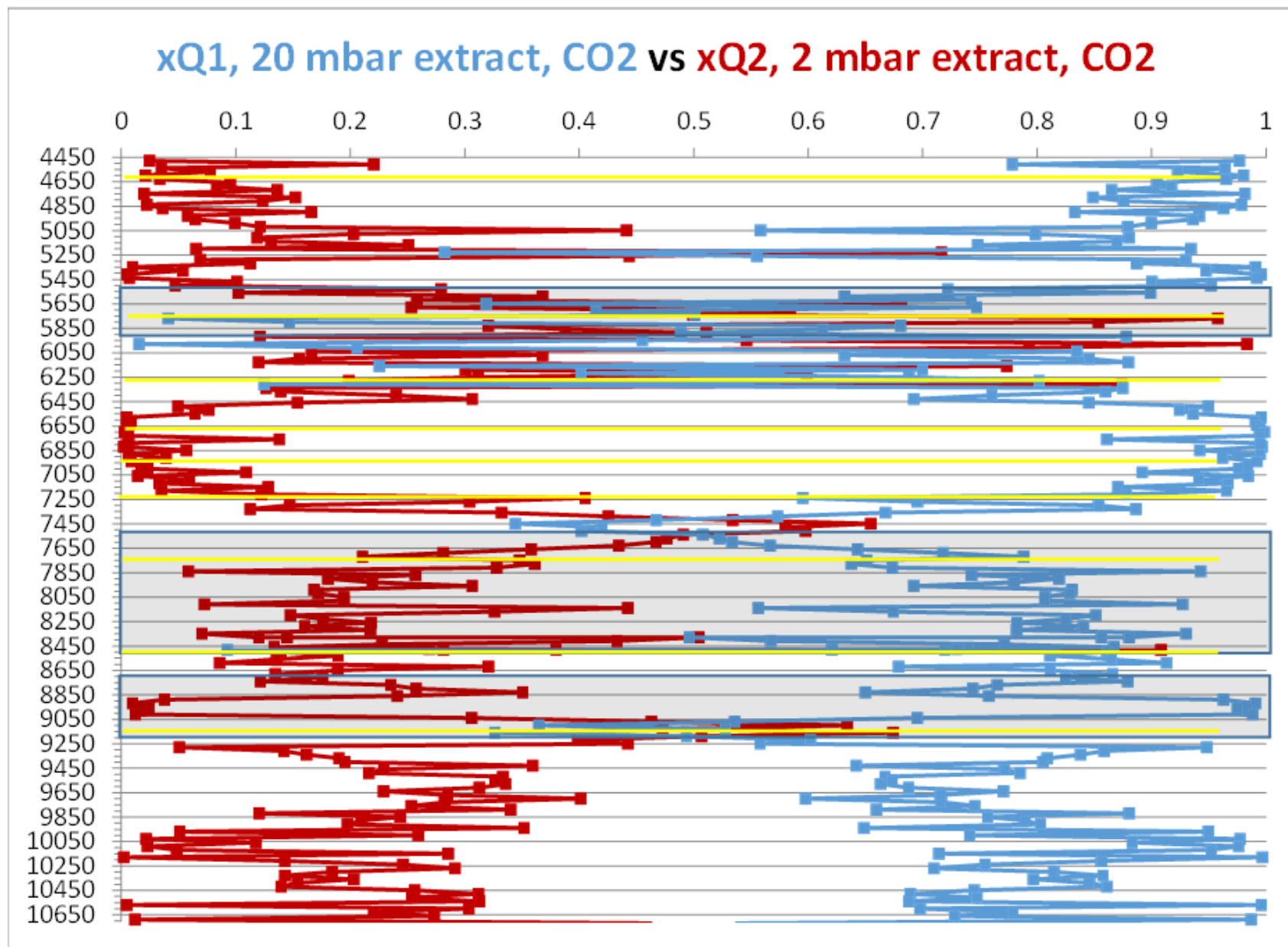
Kirtland-1 Q1CO2



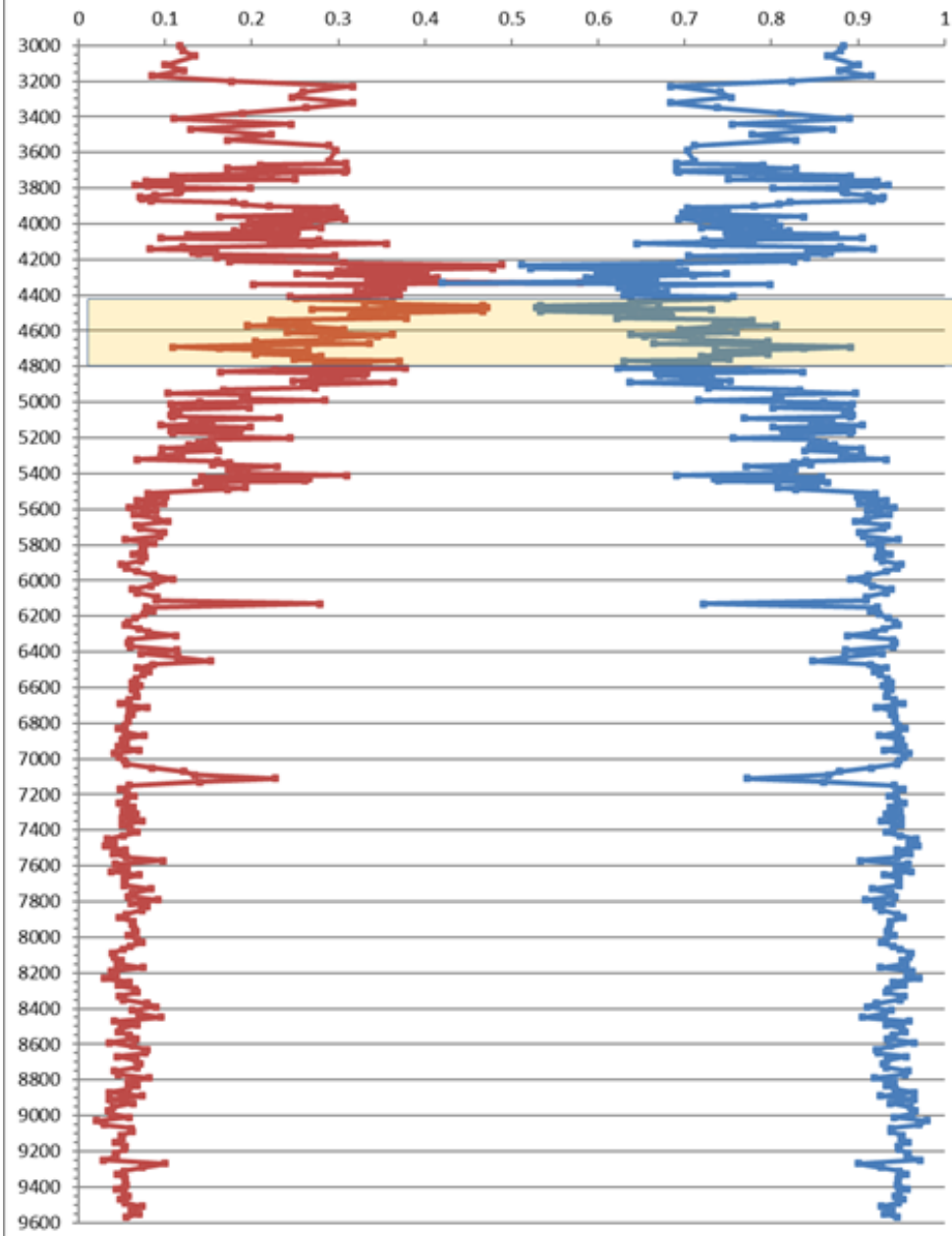
CO2 Systematics:

2) Large Changes in CO2 Phobicity Between the 2 Wells

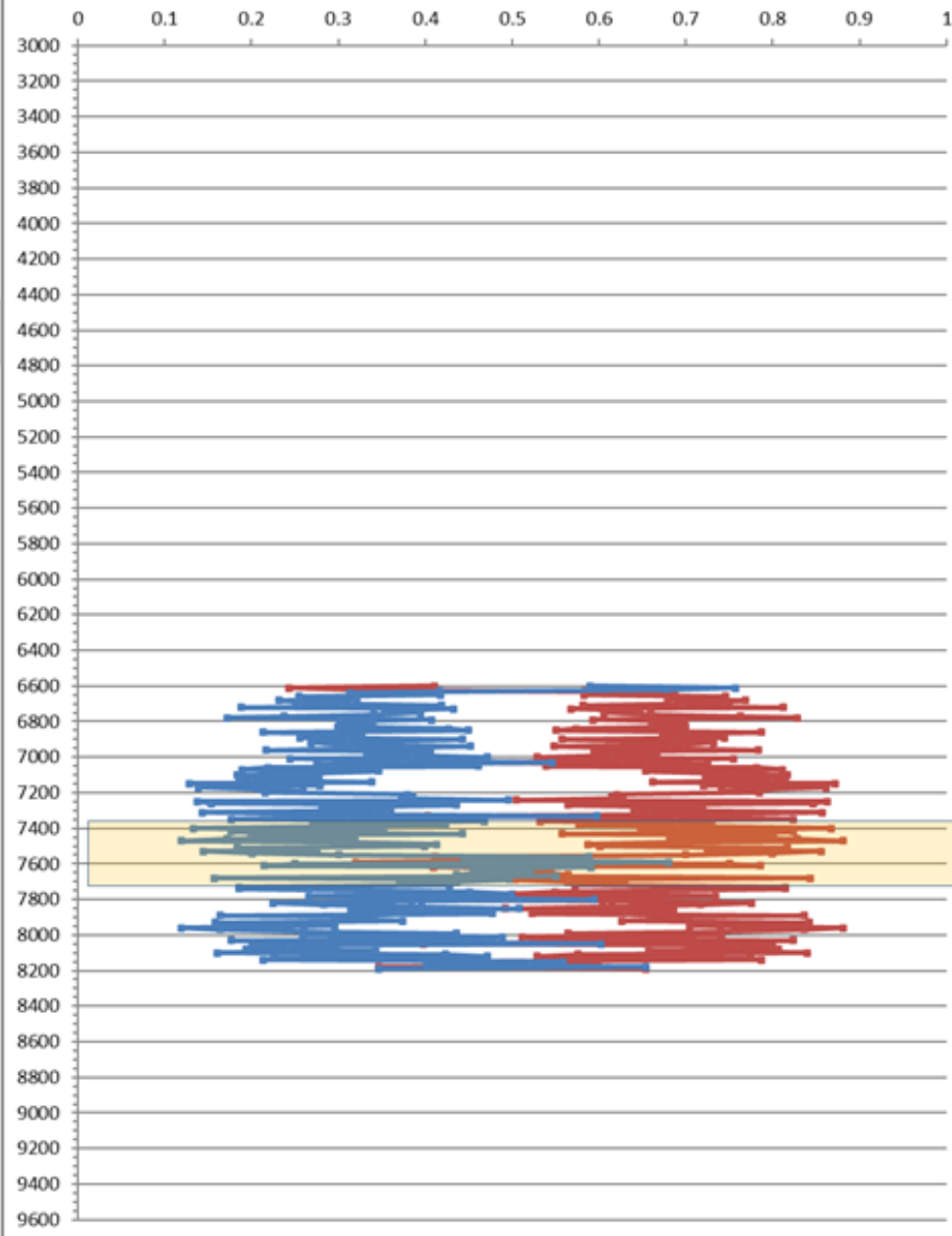
Figure: RVStrat Cuttings Volatiles High Island 24 L Well No. 9:
CO₂-Phobicity



Stephenson #1 xQ1CO2 vs xQ2CO2



Kirtland #1 xQ1CO2 vs xQ2CO2



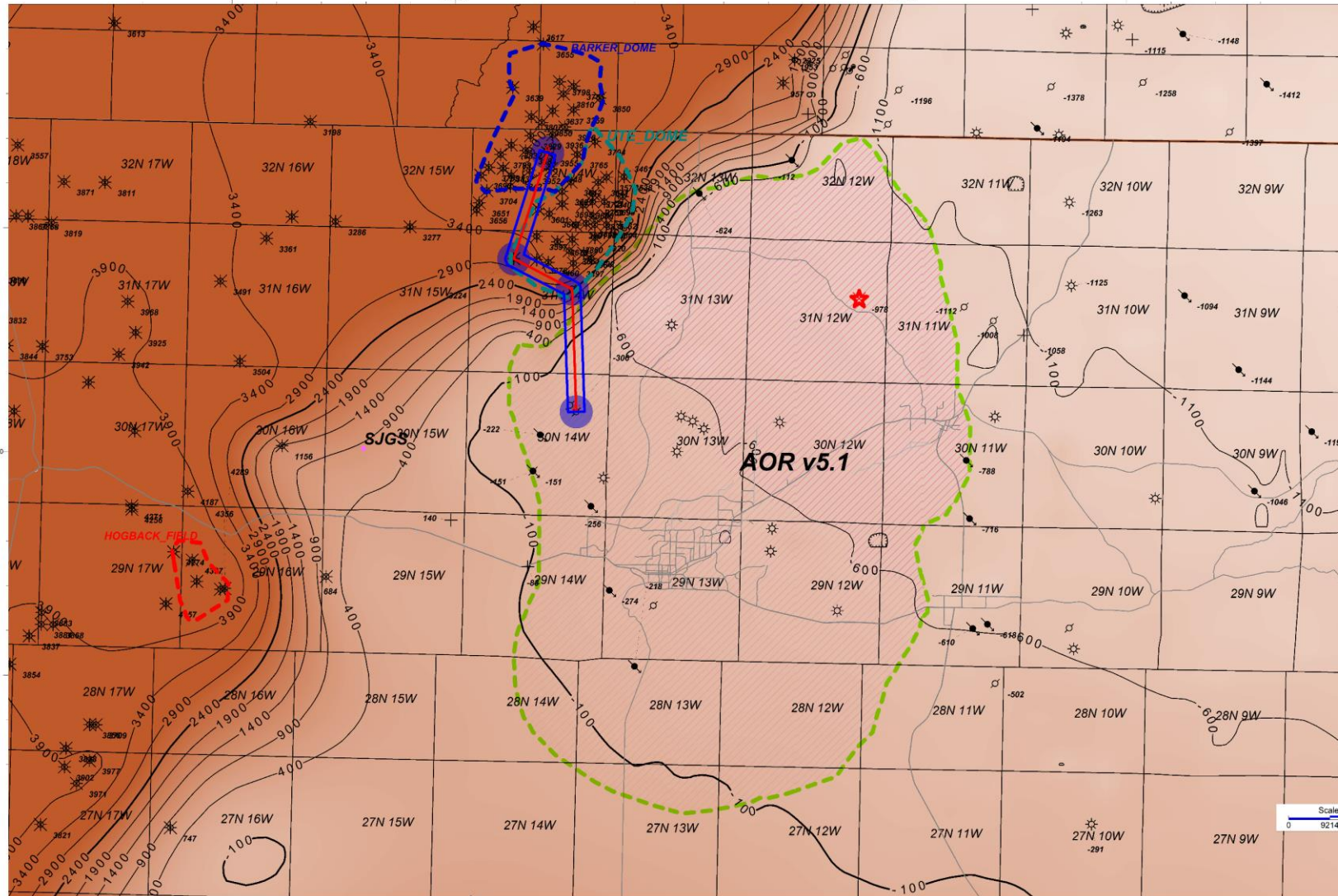
CO2 Systematics:

- 2) Large Changes in CO2 Phobicity Between the 2 Wells
Possibly Related to Proximity to Hogback Fault

NXT Feet

1020400

1120400

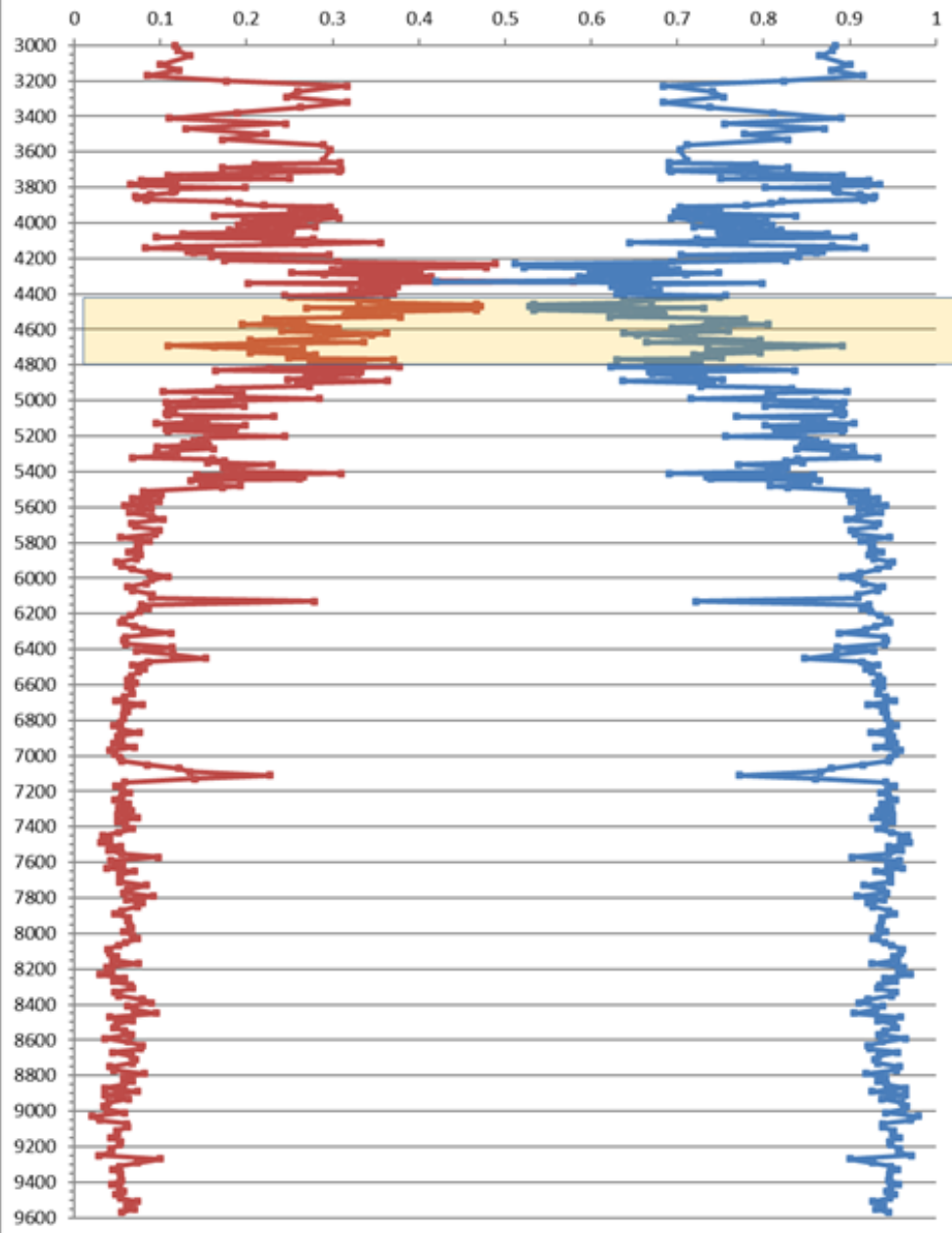


Highlight Wells
 ★ CarbonSafe_LOC (Public)

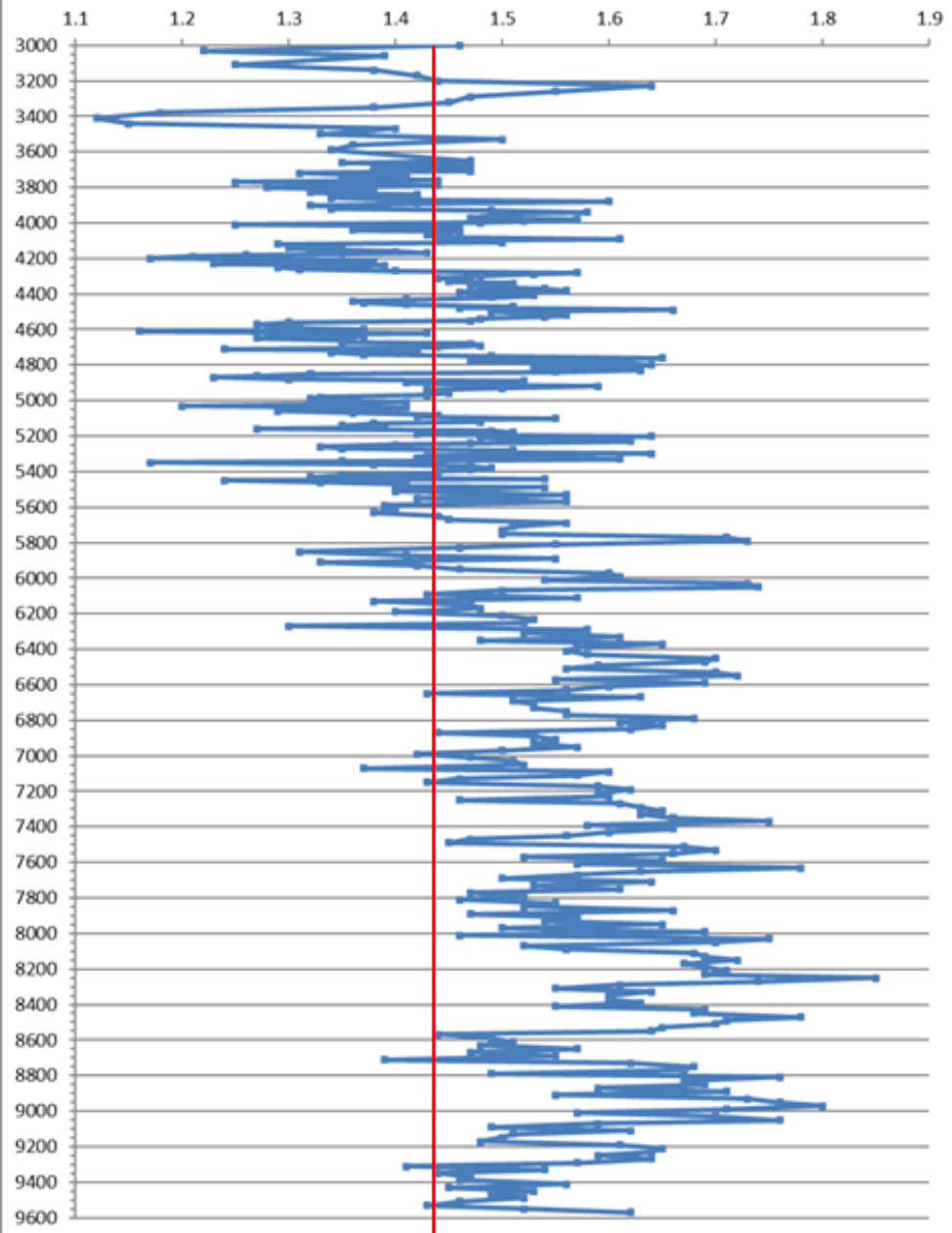
Data Posted Along Borehole
 (Tops: Dakota) Time, Depth

CarbonSafe
 Project: San Juan Basin CarbonSafe
 Project Location:
 Scale = 1:221147
 0 16429 36858 55287 ft
 Grid: Dakota
 Deep wells with Entrada tops plotted

Stephenson #1 xQ1CO2 vs xQ2CO2



Stephenson #1 Mechanical Strength



Conclusions

- 1) Good Vertical CO₂ Seals
- 2) Hogback Fault is a Migration Superhighway
- 3) Fluids Migrate Into and Out Of the Hogback Fault
- 4) Jurassic SJB Reservoirs in Fluid Communication with Hogback Fault,
In Near Proximity to the Fault
Through Lateral Fractures and Possible Minor Faults
- 5) Fluids from Hogback Fault Maybe Altering Nearby
CO₂ Phobicity
Mechanical Strength
- 6) CCS Wells Should be Located a Safe Distance from The Hogback Fault

Acknowledgements:

This material is based upon work conducted as part of the San Juan Basin Fault Characterization project, supported by the Department of Energy under Award Number DE-F0032064. Additional support was received from the San Juan Basin CarbonSAFE Phase III project, supported by the Department of Energy under Award Number DE-FE0031890.