

CCS Site Evaluation in the San Juan Basin Using the Analysis of Volatiles from Legacy and Fresh Cuttings - Implications for CO2 Injection and Storage

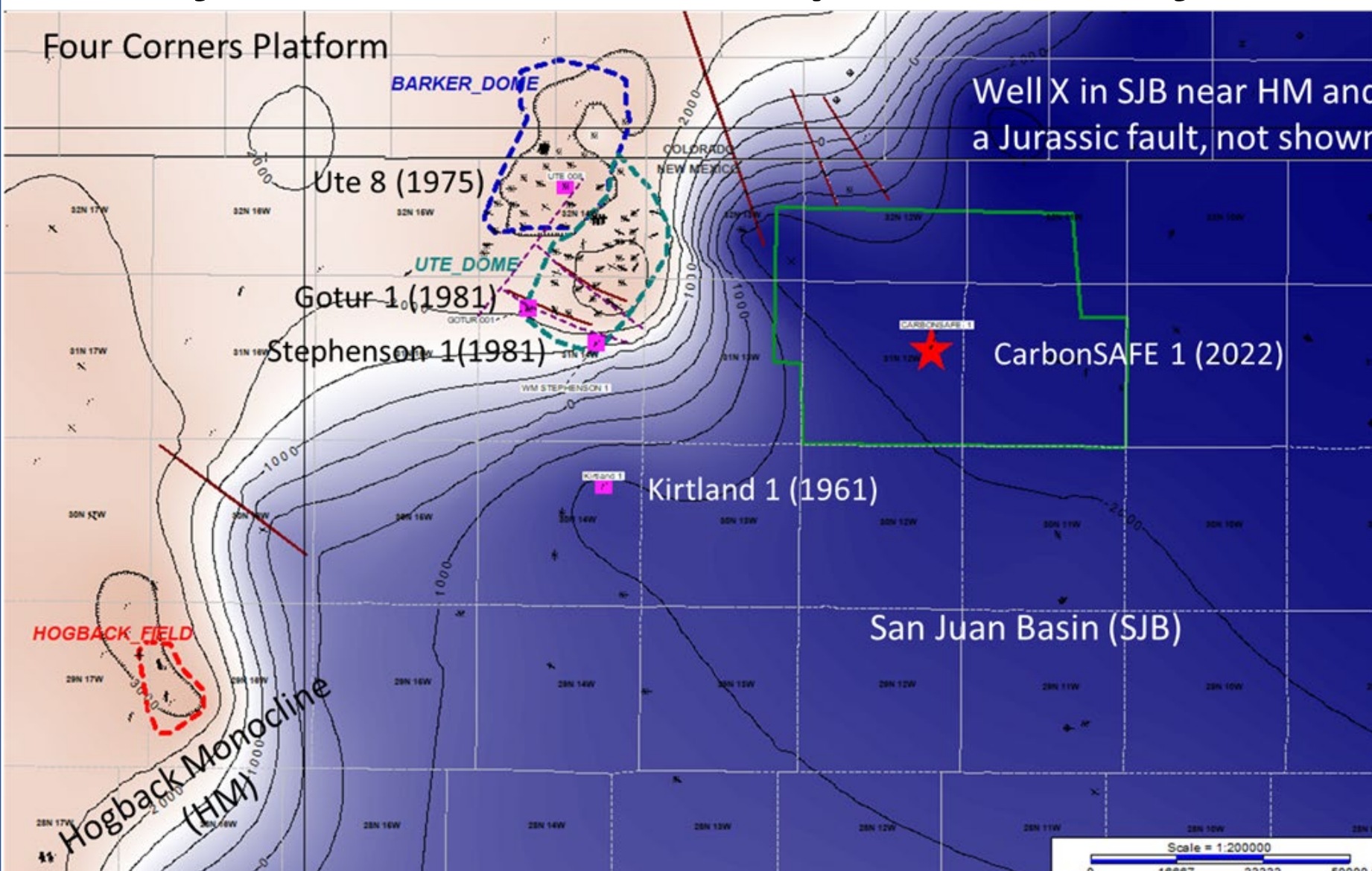
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1. Advanced Hydrocarbon Stratigraphy 2. New Mexico Institute of Mining and Technology

Abstract To evaluate the area around New Mexico Tech's CarbonSAFE Phase II Farmington site, specifically examining for potential faults/communication pathways that may represent a risk to migration out of zone of the injected CO₂, rock volatiles stratigraphy (RVS) was used on legacy and fresh drill cuttings from wells in the immediate area and the CarbonSAFE 1 well drilled in late 2022/early 2023. RVS, developed and built by Advanced Hydrocarbon Stratigraphy (AHS), and utilizes a novel cryo-trap mass spectroscopy system to gently extract, separate, identify, and quantify 40+ different subsurface volatiles from fresh and legacy rock samples, in some cases several decades old, under different vacuum extraction conditions – these data provide a wide view of the fluids present in the subsurface and associated rock properties related to how readily they are extracted. Legacy unpreserved cuttings from 5 wells, 2 in the San Juan basin (SJB) and 3 on the Four Corners Platform, were analyzed covering the targeted Jurassic injection zone and typically a 1000+ ft above and below. Additionally, both sealed at the well site (containing representative populations of fluids) and some unsealed cuttings (comparable to the legacy samples) from CarbonSAFE 1 have been analyzed. The examination of the legacy cuttings revealed important aspects of subsurface migration history for HC gases which may be an analog for possible migration pathways of injected CO₂; vertical migration along the deep faults associated with the Hogback Monocline (HM), typically on the platform, and lateral migration via fracture networks likely due in part to the HM – these were unknown aspects of the petroleum system prior to the RVS study. At the same time no significant evidence of vertical migration in the basin was observed and RVS data reveal positive insights into the sealing quality of the confining features including direct evidence of impeding and trapping naturally migrating CO₂. The establishment of a regional CO₂ baseline from the legacy cuttings samples and provides a straightforward way to assess if there is evidence of past CO₂ migration at the CarbonSAFE Farmington site – while the insights into how CO₂ interacts with the rocks provides important insights into the relevant rock properties that may impact the rate of plume expansion of the injected CO₂ - these learnings identified several features of interest for the CarbonSAFE site which are being evaluated using RVS on CarbonSAFE 1 samples.

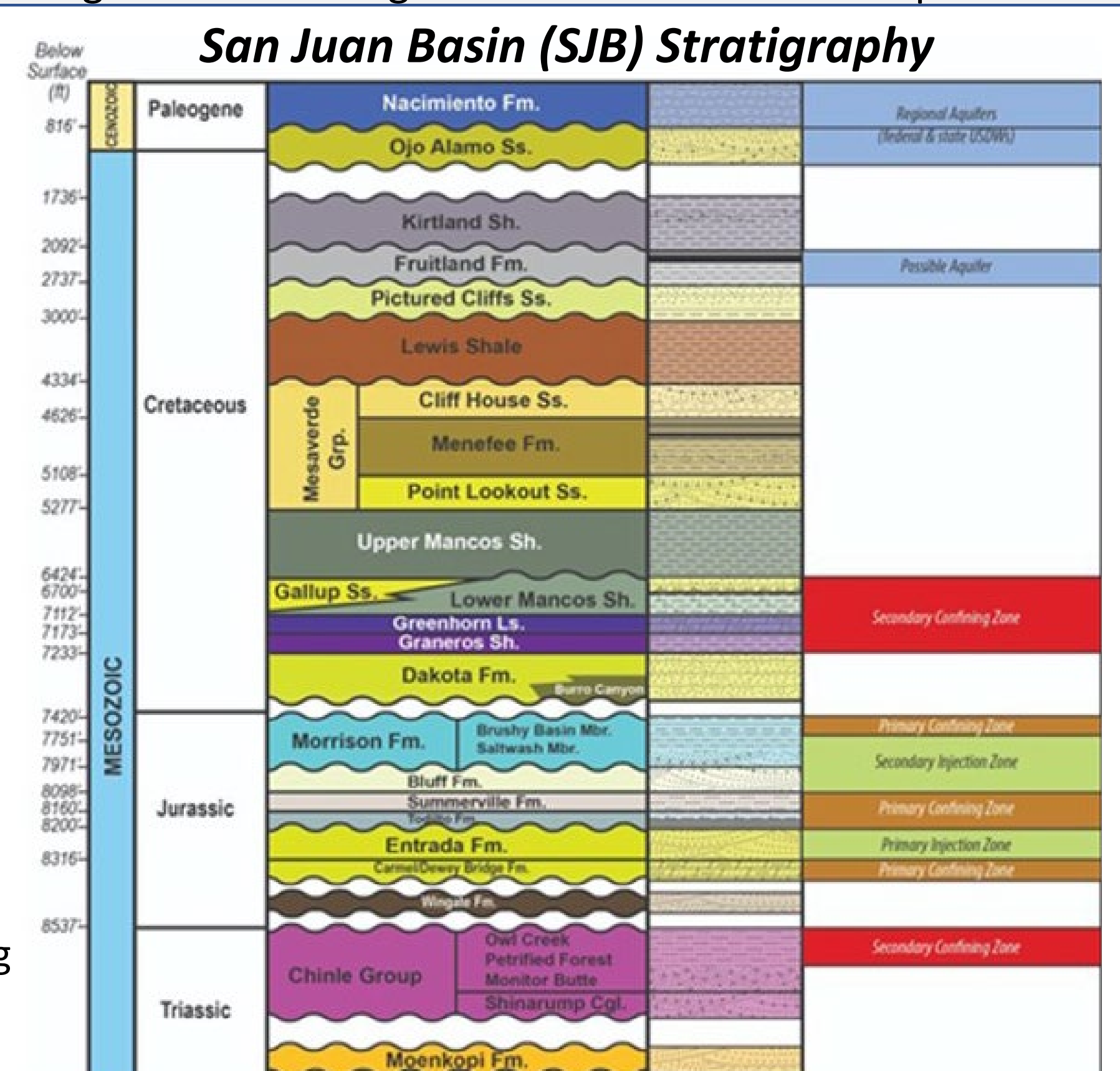
Setting/Geology and Analytical Work

Area of Interest and Wells Map, Jurassic Surface



Study Area, Well Selection, and Analytical Work

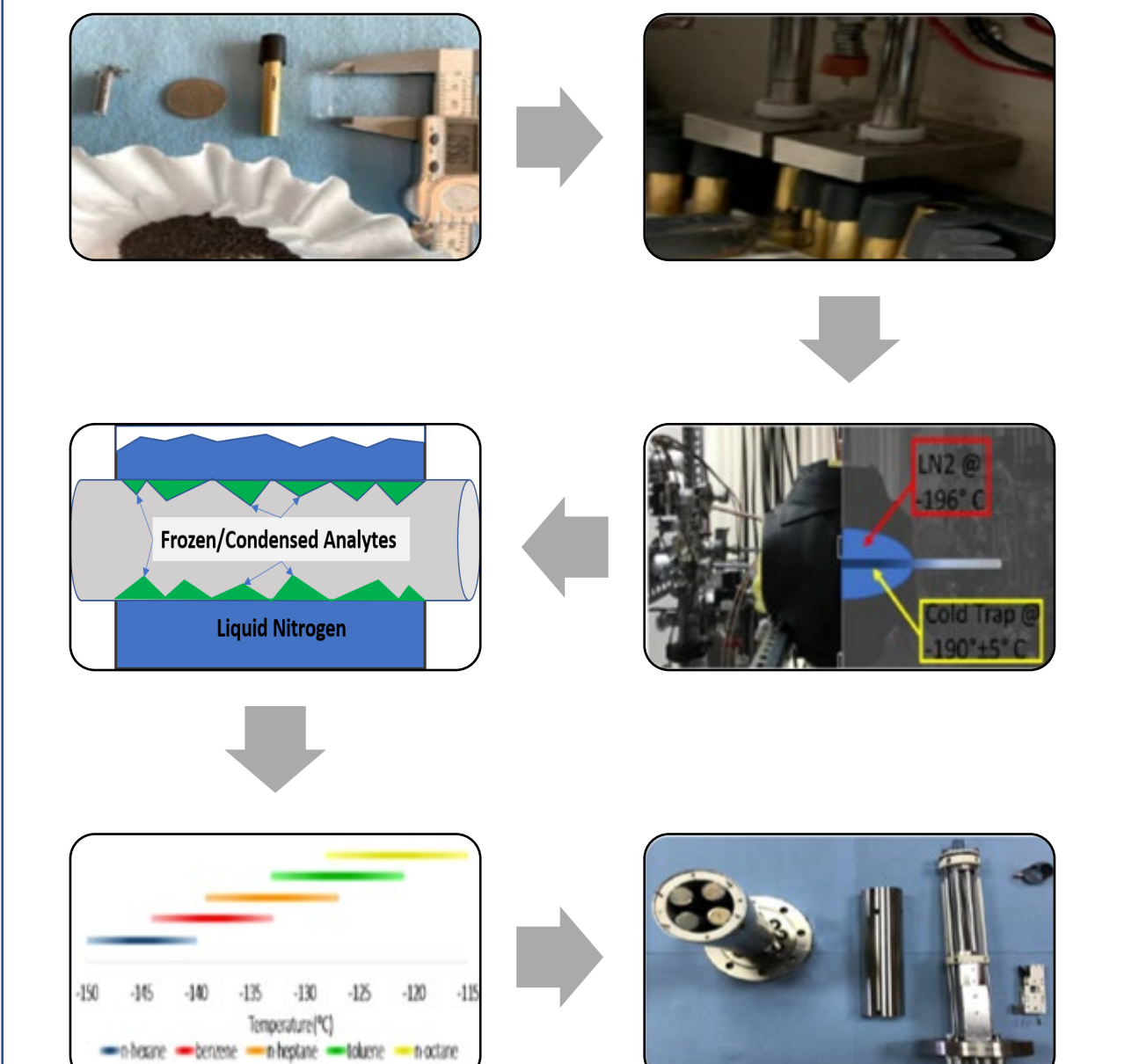
- Five wells in the study area with available legacy cuttings covering the Cretaceous to the Paleozoic were analyzed before the CarbonSAFE well to identify features of interest in the subsurface
- Sealed at well cuttings samples from CarbonSAFE 1 well were collected in 2022/2023 and analyzed in 2023
- Initial analysis of subset of unsealed cuttings from CarbonSAFE 1 carried out in 2024 – complete set of unsealed cuttings to be analyzed later this year
- Core samples being collected and will be analyzed in 2024



CCS Model in SJB From Lorenz and Cooper, 2003; Modified from Fassett, 1989

- High porosity Entrada is the primary injection target
- Bluff and Salt Wash Morrison are secondary injection targets
- Brushy Basin Morrison, Summerville, Todilto, and Dewey Bridge are primary seals
- Mancos/ Greenhorn and the Chinle are secondary seals

Rock Volatiles Stratigraphy



Rock Volatiles Stratigraphy (RVS) is an advanced geochemical analysis technique developed by AHS that provides and detailed geochemical and rock properties description of the subsurface by gently vacuum extracting, identifying, and quantifying 40+ volatile compounds from fresh and legacy rock samples under multiple vacuum pressures; utilizing vacuum conditions on the same rock sample rock properties information like affinity and permeability can be evaluated.

Hydrocarbons	Small Molecules	Sulfur Species
C1-4 Gases	Water	Hydrogen Sulfide
C5-10 Paraffins	Carbon Dioxide	Carbonyl Sulfide
C6-10 Naphthenes	Hydrogen	Carbon Disulfide
C6-9 Aromatics	Nitrogen	SO ₂ (Sulfate Proxy)
Noble Gases	Oxygen	Sulfur Dioxide
Helium	Ammonia	
Argon	Carbon Monoxide	Biological Compounds
Xenon	Stimulation Chemicals	Formic Acid
Bit Burn	Trichloroethylene	Acetic Acid
Ethene	Methanol	Methyl Ethyl Ketone
2-Transbutene	Ethanol	

Isomers, isotopes, and additional signatures are also possible.

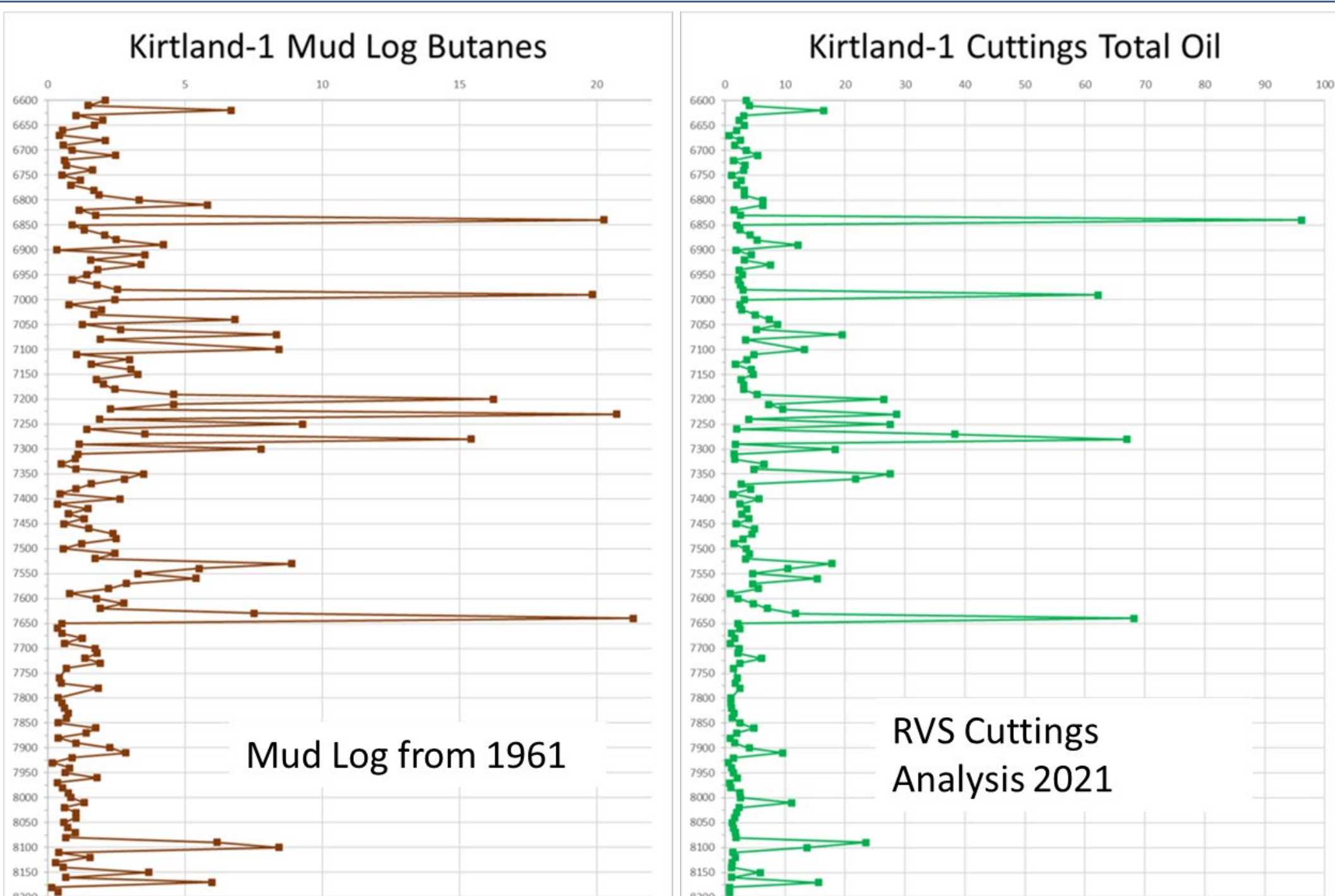
Acknowledgements

This poster represents a portion of the work being done by AHS with NMT's Petroleum Recovery Research Center as part of a US Department of Energy (DOE) grant under DOE Agreement DE-FE0032064 in support of identifying faults and communication pathways that may serve as conduits for CO₂ migration in the SJB. We would like to acknowledge and thank both DOE and NMT for the opportunity to work on this important project.

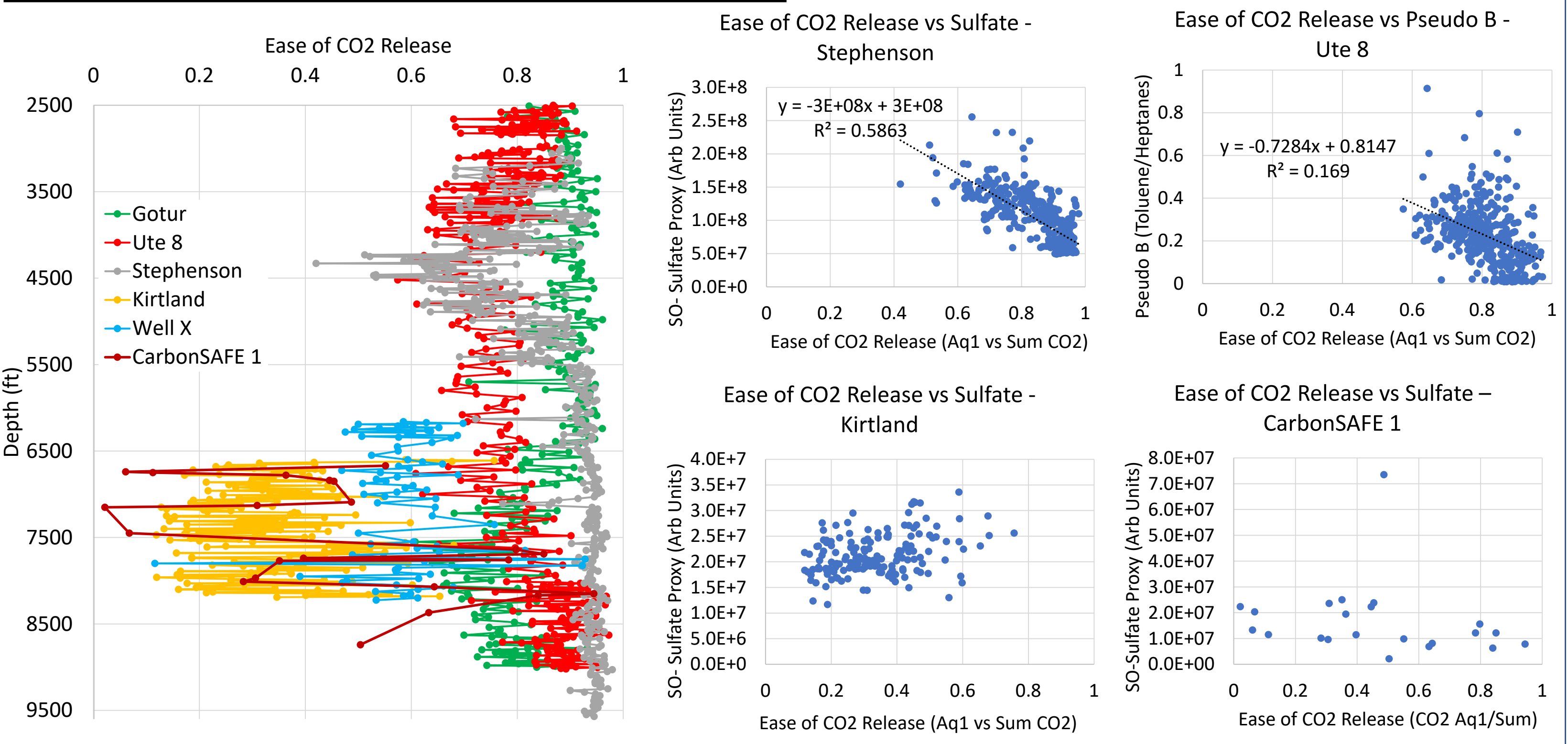
Comparing Legacy and Present-Day Data

- When working with legacy materials it is important to evaluate if present-day RVS responses relate to the subsurface at the time of drill
- Throughout the Jurassic section of Kirtland-1 the detected HC liquids in the legacy cuttings strongly mirror the distribution of butanes detected in the 1961 mud log

Correlation between the historical mud log and the RVS data strongly demonstrate that the volatiles retained in these 60-year-old cuttings samples is still meaningfully relate to the subsurface at the time of drilling



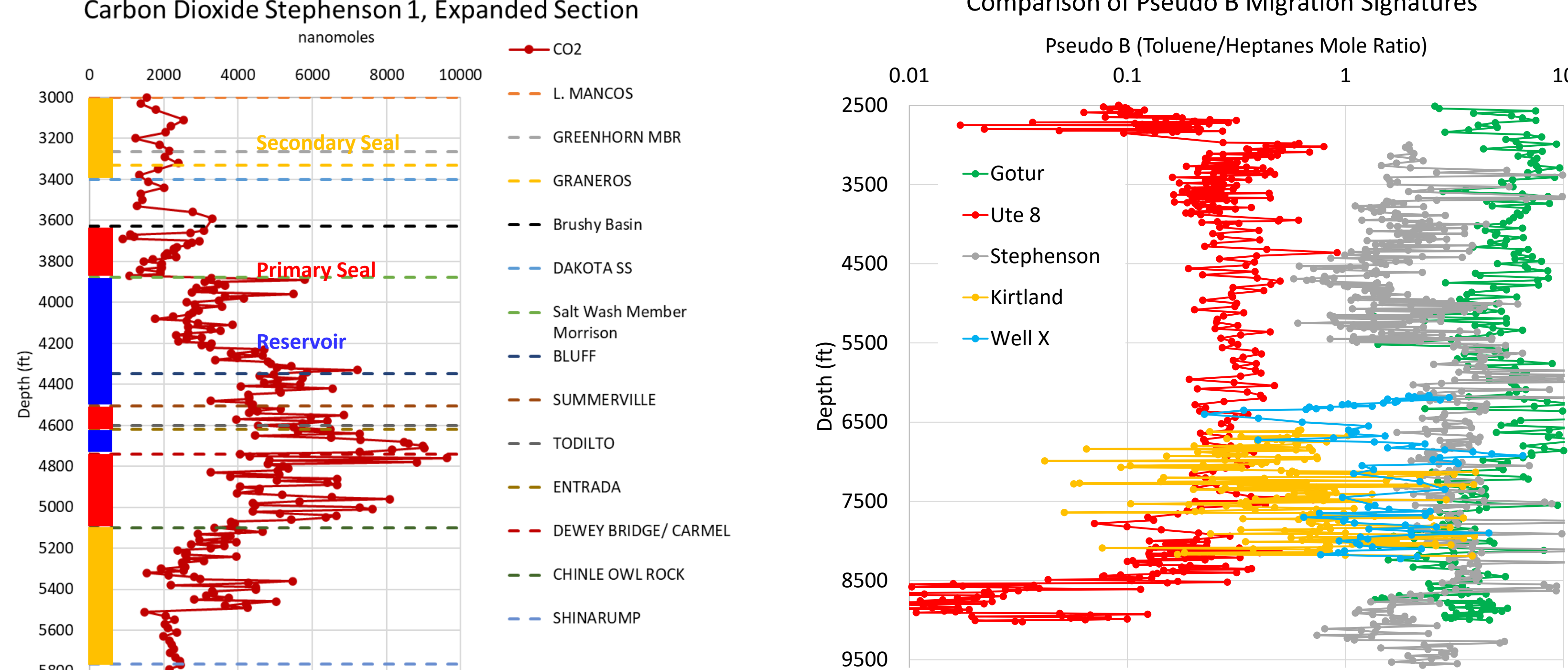
Nature of Carbon Dioxide Release



- A unique difference in the rock properties of the SJB vs Platform wells is how readily they release the entrained CO₂ suggesting a significant post depositional alteration of the rock – Platform wells are CO₂ phobic
- Platform wells show relationships between gas migration signatures/sulfur species and the ease of CO₂ release suggesting that the migration of sour gas from deep Paleozoic gas zones played a role in altering the rocks

These CO₂ phobic rocks can have significant impacts on CO₂ migration in the subsurface, such rock properties are not significantly observed in legacy basin wells; the current CarbonSAFE 1 unsealed cuttings data it too incomplete to fully evaluate, but no relationships with sulfur species are observed

Seals, Migration Signatures, and Fractures



- While Stephenson has undergone significant vertical CO₂ migration from Paleozoic CO₂ rich zone up fault there has been significant trapping of CO₂ in relation to target reservoirs and seals – these and other data suggest high quality seals
- Vertical migration signatures in Stephenson, Gotur, and Well X – discrete lateral signatures in Kirtland likely due to faults

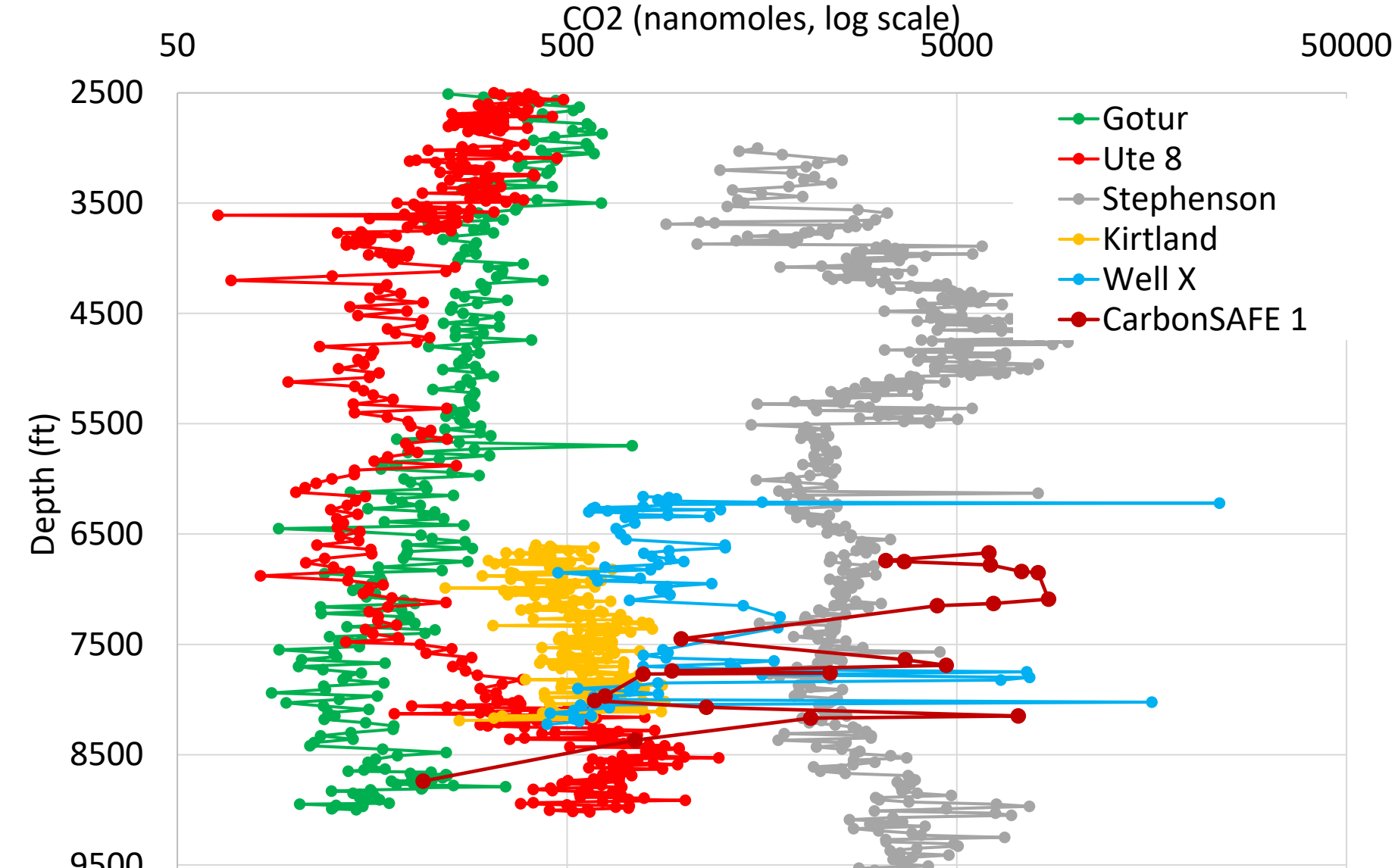
While the HC filled fractures in CarbonSAFE needs to be better understood, evidence of good seals (CO₂ and Helium), no significant vertical migration in the Jurassic/few lateral migration signatures in relation to fractures (Tol/Benz ≥ 3)

Conclusions

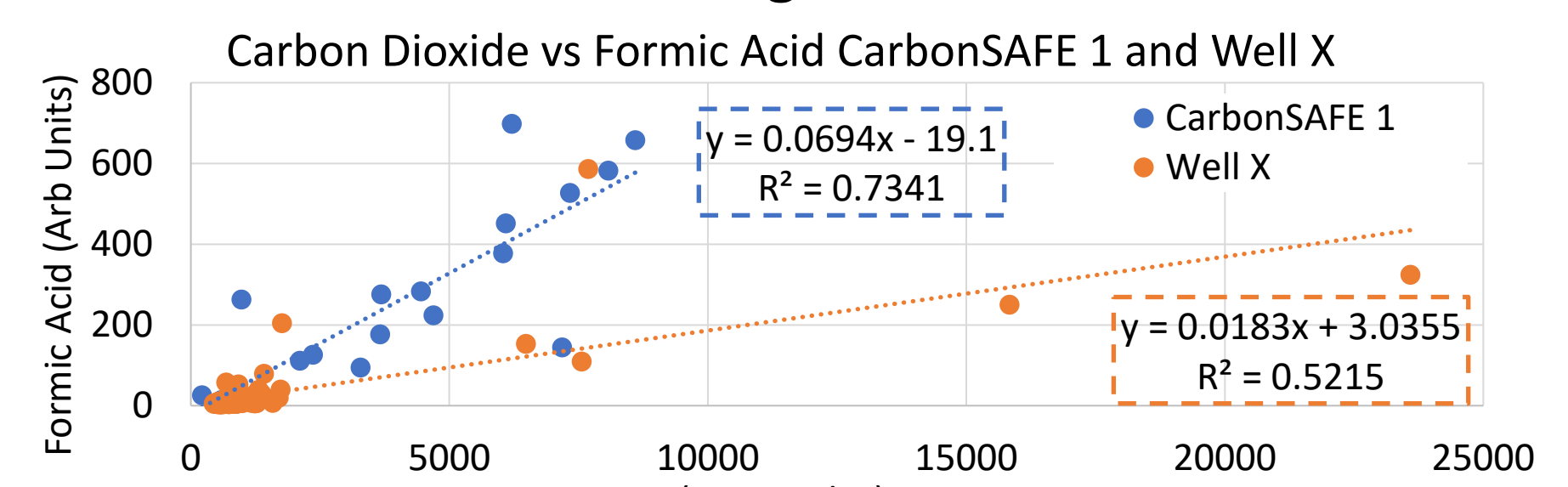
Feature of Interest	Status in CarbonSAFE 1 Well
Petroleum System - Lateral Migration	Needs Evaluation
Petroleum System - Vertical Migration	Encouraging
Carbon Dioxide Regional Baseline	Encouraging
Nature of Carbon Dioxide Release	?
Vertical Seals	Positive

Based on the goals of the SJB CarbonSAFE program and analysis of legacy cuttings features of interest in the were identified and evaluated by RVS with CarbonSAFE 1 cuttings, work is ongoing, but the results are broadly encouraging

Carbon Dioxide Regional Baseline



Initial unsealed CarbonSAFE 1 CO₂ RVS data are roughly in line with Kirtland and Well X CO₂ values – **suggests CarbonSAFE 1 matches the regional baseline**



Discrete highs in CO₂ in CarbonSAFE 1 and Well X likely due to local subsurface biological activity

Selected RVS and Image Logs Results from CarbonSAFE 1

