Multidisciplinary Approach to Niobrara Gas Development in an Overlooked High Temp, High Pressure Reservoir: A Southeast Piceance Case Study

Session: Innovative Workflows

Barrett A. Lavergne[1], Keith Jagiello[2], Steve Sturm[3], and Salar Nabavian[4]

Search and Discovery Article #42573 (2022)**
Posted August 13, 2022

*Adapted from extended abstract based on oral presentation given at 2022 AAPG Rocky Mountain Section Meeting, Denver Colorado, July 24-27, 2022
 DOI:10.1306/42573Lavergne2022

[1]Trifecta Geo Solutions Geoscience Manager (barrettlavergne@outlook.com)
[2]Petro Data Integration (kjagiello@petro-int.com)
[3]Principal Technical Advisor 303PetroImages LLC (303petro.images@gmail.com)
[4]GELLC President (Salar.Nabavian@OXBOW.COM)

Abstract

Early Piceance Basin test wells were completed in the Niobrara, a formation at the base of the Mancos group, beginning in 2009. These first wells were completed on projects which had assets primarily focused on the Williams Fork and Illes Formation. With the last widely known horizontal Niobrara activity circa 2015, the opportunity to incorporate recent technology became possible. To the southeast, little focus had been made on the underlying Mancos, where an overlooked high-pressure reservoir exists. In the early 2010's a few groups drilled test wells in the Niobrara in this area, beginning the uncharted development of the Niobrara in the Southeast Piceance.

This paper discusses the multidisciplinary approach needed to define a prospective resource, from concept to completion, using recent technology. Several evaluation steps were taken to achieve a reliable subsurface model. Along the way, challenges of limited data and model constraints were encountered, which the development team was able to successfully manage.

Available well data was processed and normalized with an appropriate model for petrophysical properties. An early development in the analysis suggested lithologic changes from the "main trend" differentiating the southern development area. Another determining factor used to define the project area was the learnings of the deep and high pressure mapped intervals from offset well data. Other log data including image logs and acoustic information was also a critical part of the subsurface geo model.

A vertical test well near the proposed project area revealed important gas production by zone using a normalized proppant per foot metric. This metric tied to the subsurface geologic model and gave the management team confidence to propose a plan in a focused target window.

3D Seismic information was acquired in the ideal project area identified from the subsurface model and used to identify localized faulting and geohazards. Also, the seismic was a critical component of zone placement and geosteering of the planned well. The seismic quality allowed for the advanced processing of seismic volumes, which proved useful when drilling.

Outside of the subsurface evaluation, there was a wide scale logistics and surface infrastructure need, a challenging endeavor in a remote mountain setting. The installed infrastructure was critical to executing one of the largest completions in the basin to date, allowing implementation of recent technology in a geologic derived target window, for the first time in the area. Initial results suggest this well is expected to be one of the best performing wells in the Piceance, with a 6 hr IP test of 30+ MMCFD. It is hoped that the development roadmap for this overlooked resource can be replicated, as the horizontal Niobrara play in the Southeast Piceance has a great deal of future potential.

References

Steve Cumella, Geology of the Piceance Basin MesaverdeGas Accumulation, Search and Discovery Article, 2009

Jason Eleson, Chip Oakes, Graham McClave, 2020. Insights into productivity drivers for the Niobrara-equivalent horizontal play in the Piceance Basin, Colorado

Jason Eleson, 2020. The Past, Present and Future of Niobrara/Mancos B Horizontal Development in the Piceance Basin

Warren C. Day and Dana J. Bove, USGS, Resource Potential & Geology of GMUG USGS Bull 2213R, 2004.

J.L. Ridgley, S.M. Condon, and J.R. Hatch, USGS. Geology and Oil and Gas Assessment of the Mancos-Menefee Composite Total Petroleum System https://pubs.usgs.gov/dds/dds-069/dds-069-f/REPORTS/Chapter4_508.pdf

The Parable of the 6 Blind Men. https://blog.arkieva.com/data-to-decisions-faster/

Gunnison Energy LLC An Oxbow Company

Multidisciplinary Approach to Niobrara Gas Development in an Overlooked High Temp, High Pressure Reservoir: A Southeast Piceance Case Study

Barrett Lavergne

Steve Sturm (303PetroImages LLC)

Keith Jagiello (Petro Data Integration)

Salar Nabavian (VP, GELLC)

TRIFECTA GEO SOLUTIONS

July 2022

Assessment Workflow

Fully Integrated Assessment

Regional Perspective and Initial Opportunity

- Strat Column Understanding, Relate to "Basin Center Gas" Development, Understand Prior Niobrara Activity, and Key in on Initial Geologic Variability from "main trend" not widely Known

Subsurface Model Viability and Plan

- Multidisciplinary Venn Diagram

Assess Available Data

- Understand Data Limitations
- Incorporating Historic Data (Shallow Intervals)

Seismic Integration

- Planning & Short Acquisition Window
- Structural understanding and geohazard mitigation
- Advanced attributes incorporated Into Operations

Regional Mapping/Framework

- Normalized and Consistent Tops
- Regional Structure/Isopach's
- Pressure/Depth Trends

Petrophysics

- OGIP Estimates
  - Clay adjustments
  - XRD tie to Multi Mineral Model

Geomechanics

- Understand Regional Stress
  - Localized variability (fracture, and stress)

Multidisciplinary Model

- Tie Geologic Earth Model to Performance Metrics & Other Engineering Data (Spotfire)

Execution Phase

- Target Deeper, Thicker, Higher Pressured Intervals
- Focused Target; 95% + in primary zone for first time in area (Rangely)
- Advanced Drilling and Completions Technology
  - Utilize Optimized logistics and communication

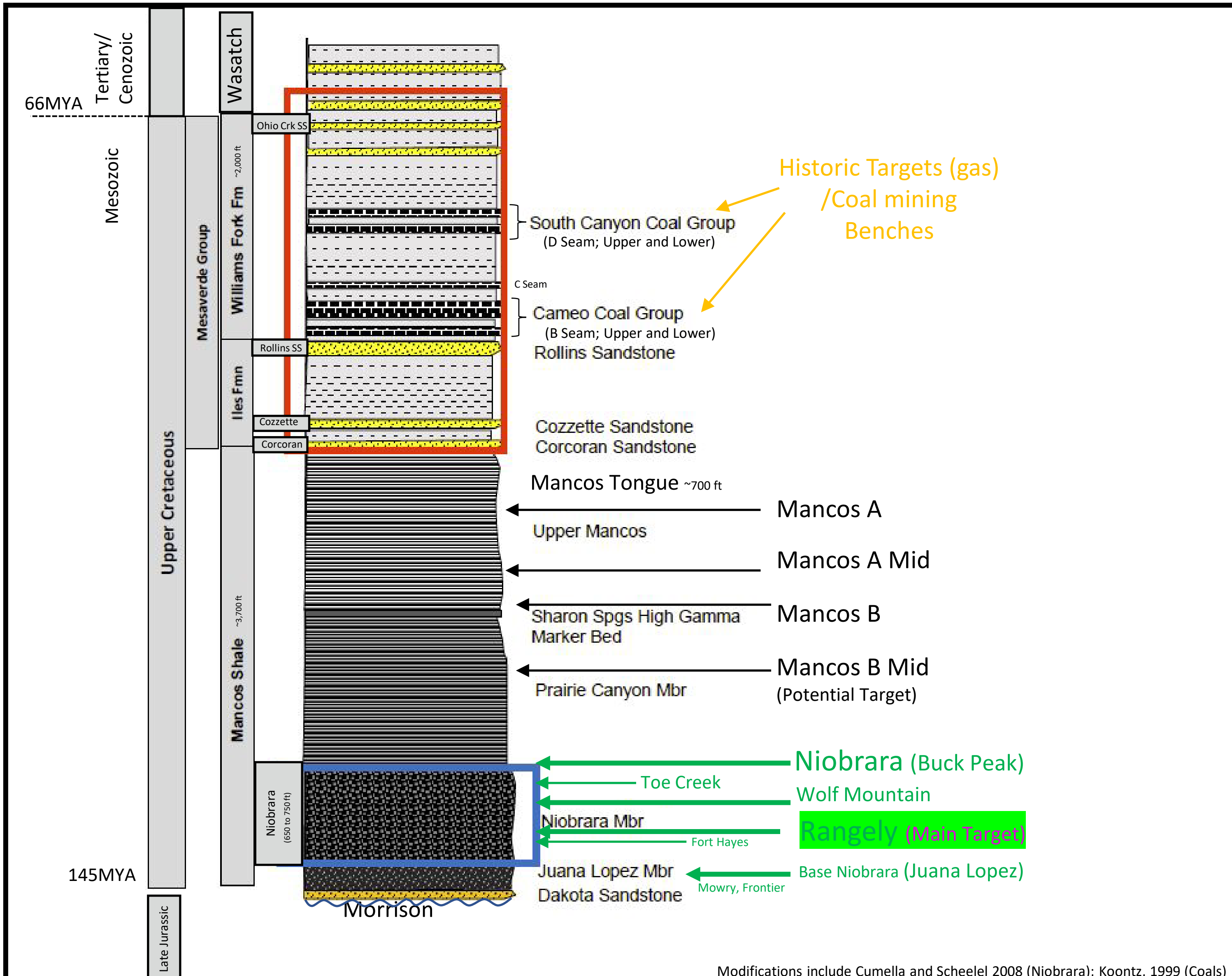
Initial Performance

- 6 hr. IP test of 30+ MMCF
- Currently highest Horizontal Daily Gas Production Rate

Strat Column and Regional Geology

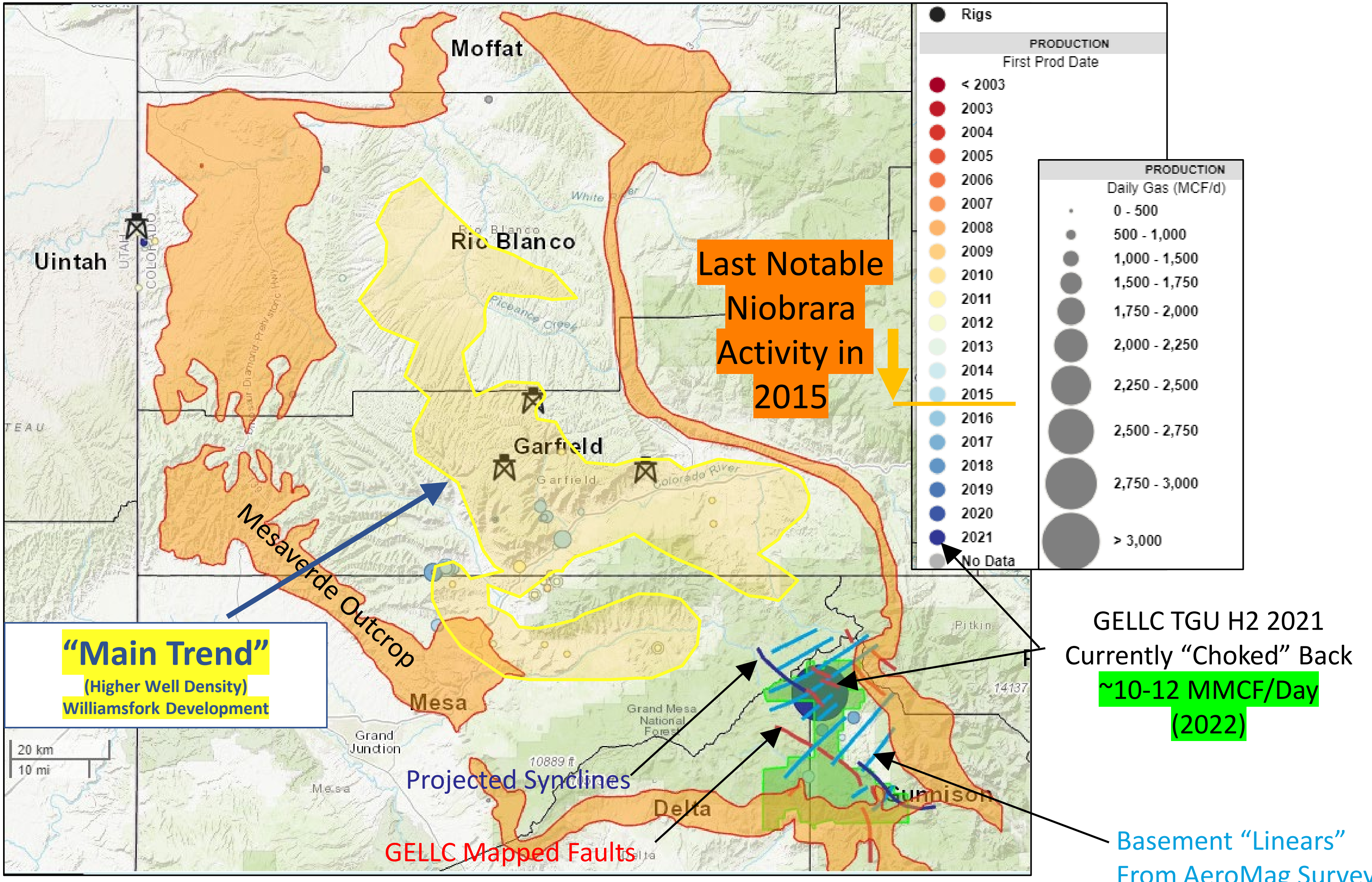
Stratigraphic Column and Nomenclature

Stratigraphic Column and Historic Targets



Piceance Basin Niobrara/Mancos History

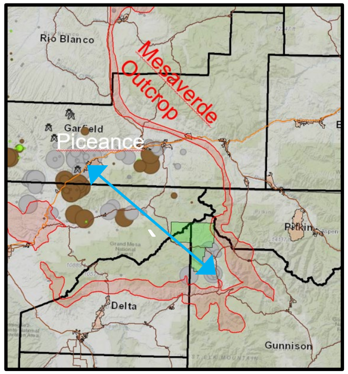
Current Daily Production Bubbles Colored by Spud Date (Niobrara/Mancos Horizontals)



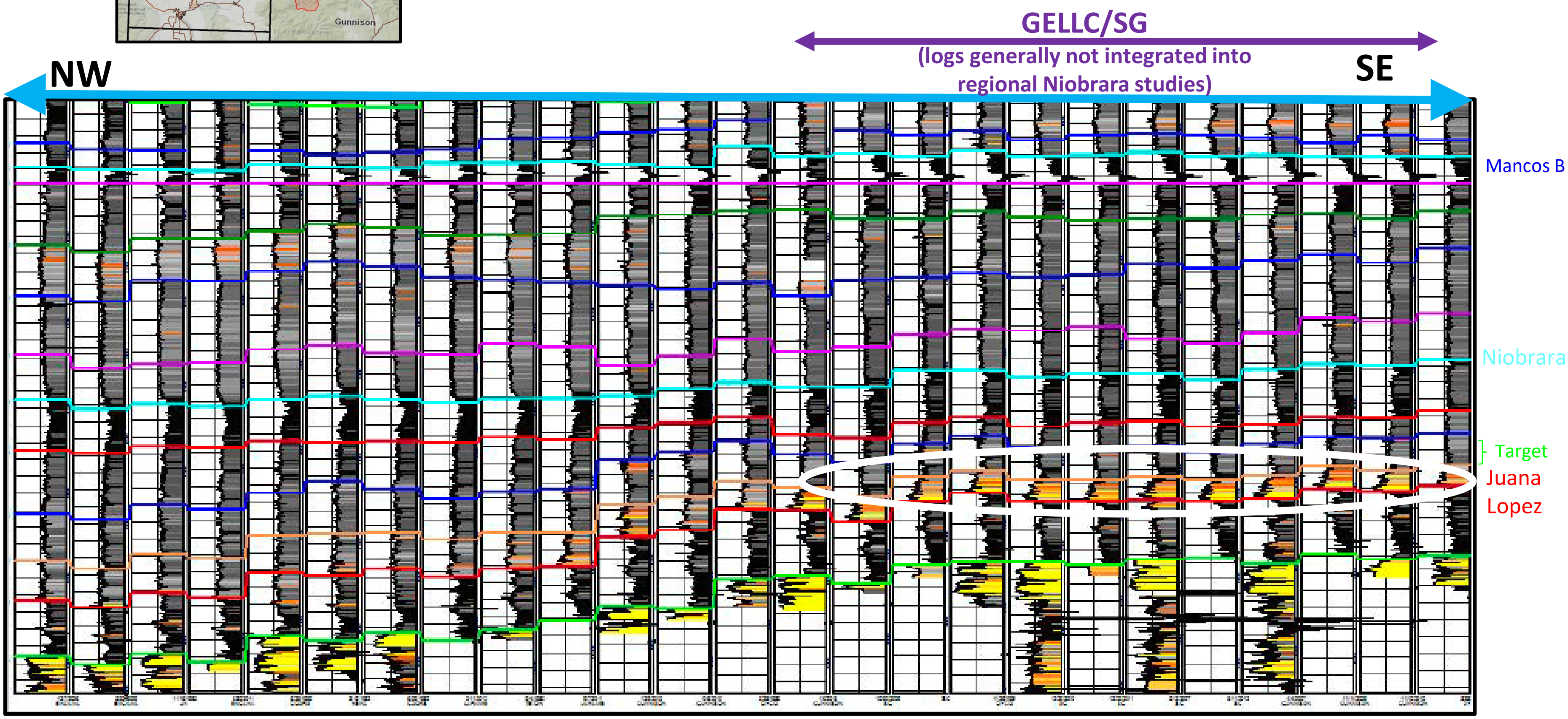
*Modified from Drilling Info (Enverus)

Depositional Differences from "Main" Trend

Lower Niobrara on GELLC acreage shows distinct reservoir rock quality

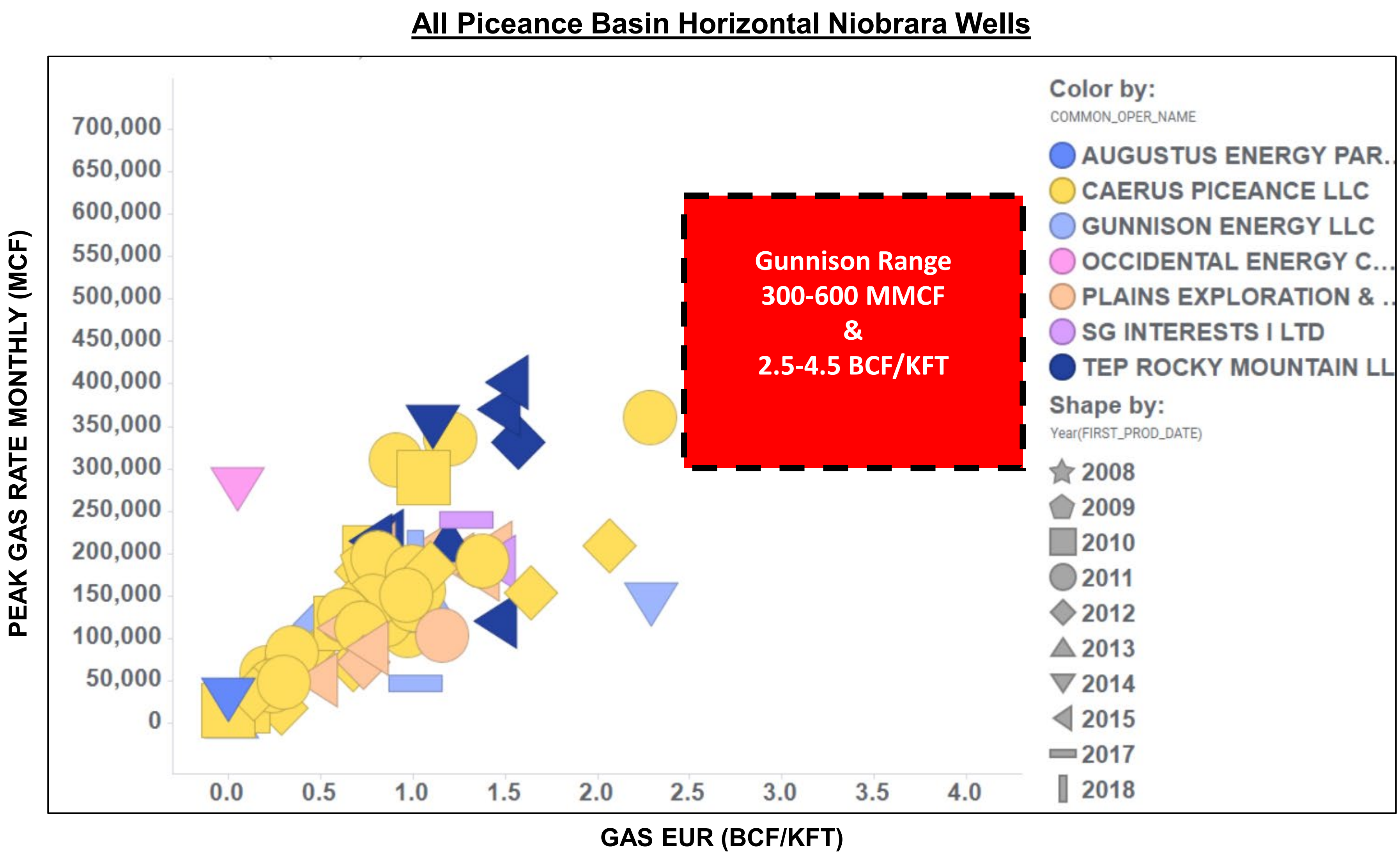


- Lower Niobrara mineralogy change
  - Higher Calcite and Silica to SE
  - Viable porosity and brittleness
- Southern Basin mapping not available in many available studies



Initial Performance Prediction

Initial Modelling Using Regional Performance



How Did we Get There

Target Zone Available Niobrara Data Map

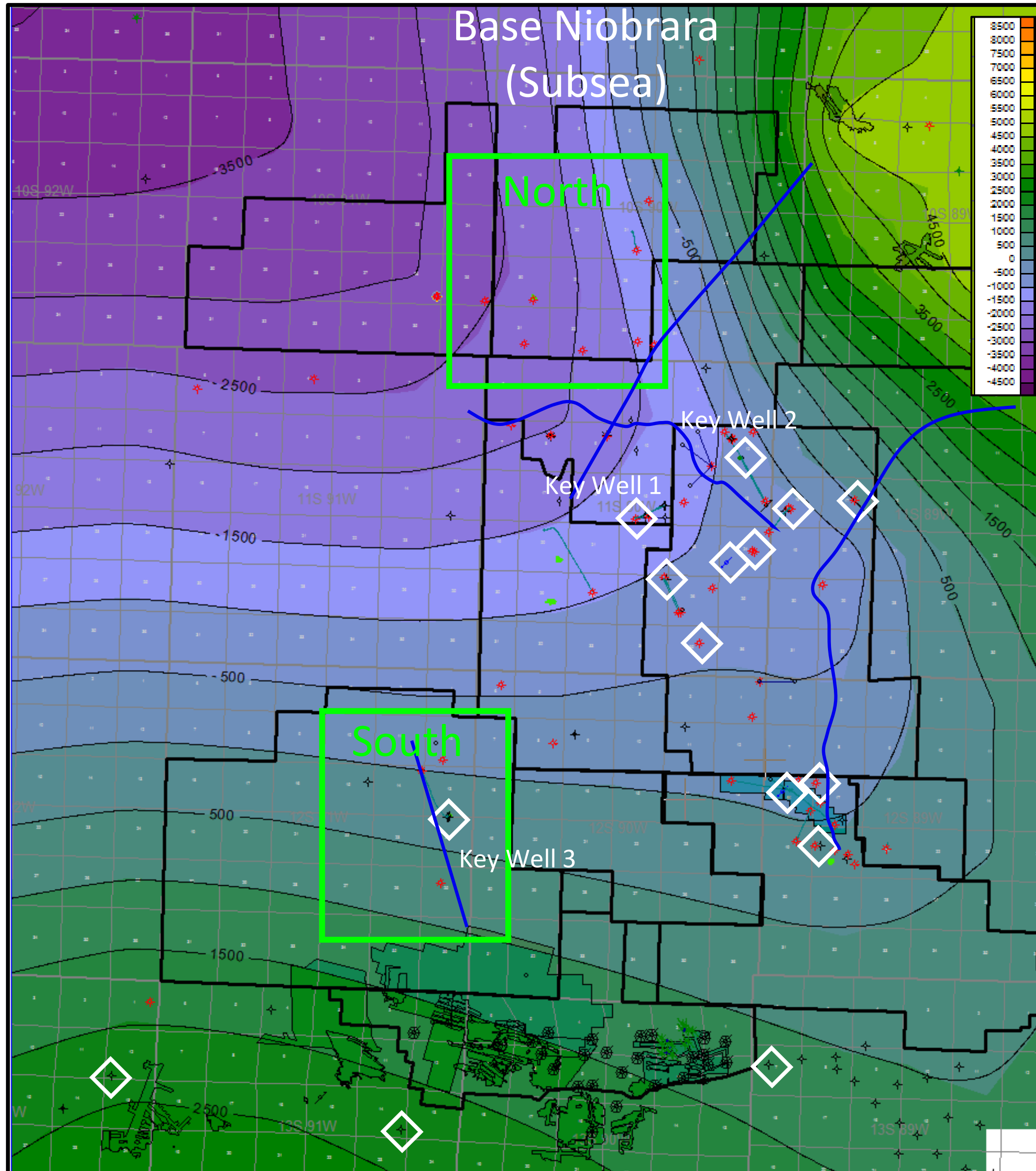
TRIFECTA GEO SOLUTIONS

GELLC Niobrara Dataset

- 15 log suite for Petrophysical Analysis
  - Major challenges include correcting for clay, salinity, and lower Niobrara grain density issue
  - Uranium increase in spectral gamma ray relates to high TOC/organic zones near preferred target zone
- Deeper portion of project area seismic tie used pseudo log
  - Deeper project area targeted for increased pressure trend and accretive thickness trend to NW
- Additional shallow data (red dots) from historic targets (Coals, Cozzette, Corcoran, etc.) assisted filling in data holes.
  - Shallow triple combo, RSWC, Image logs, Geochemistry, Cuttings, TOC, XRD, etc.

Legend:

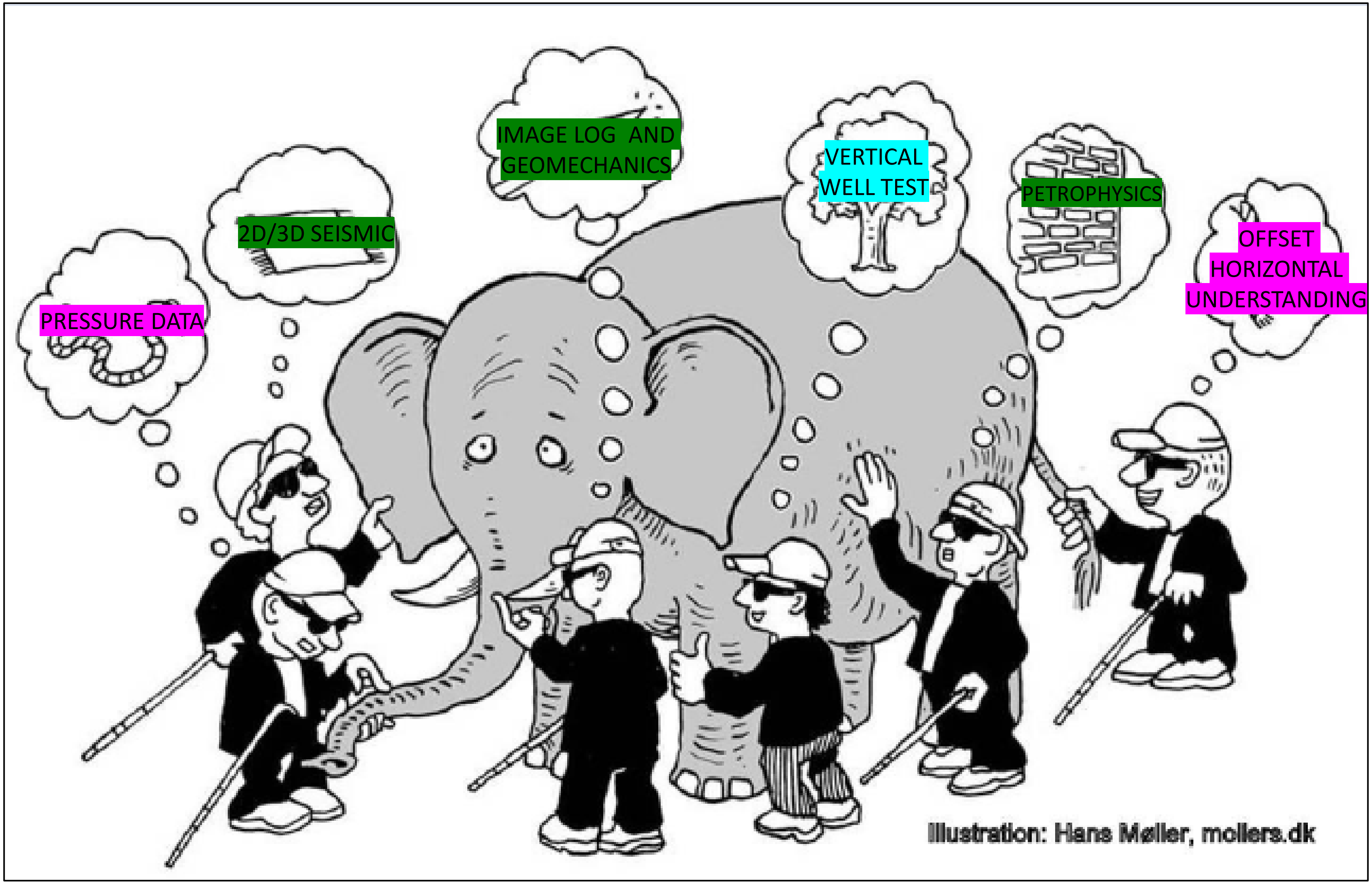
- ◇ Wells Available for Mancos Petrophysics
- ▢ 3D Seismic Extents
- ╲ 2D Seismic
- * Shallow Vintage Wells



Multivariate Data Analytics Approach

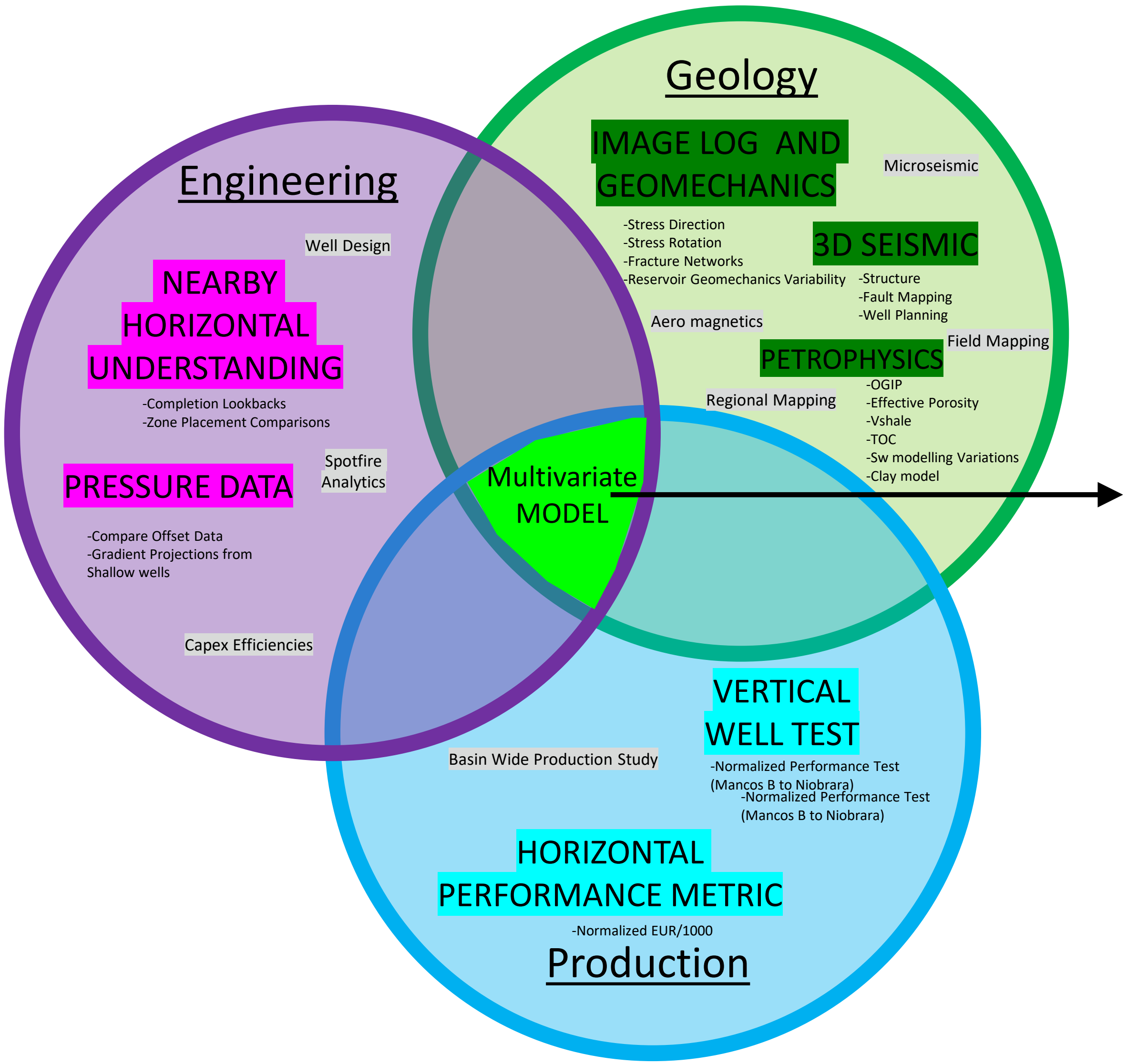
Prior Analytic Approach and Industry Struggle

Parable of the 6 Blind Men



GELLC Approach and Strategy

GELLC Multidisciplinary Integration



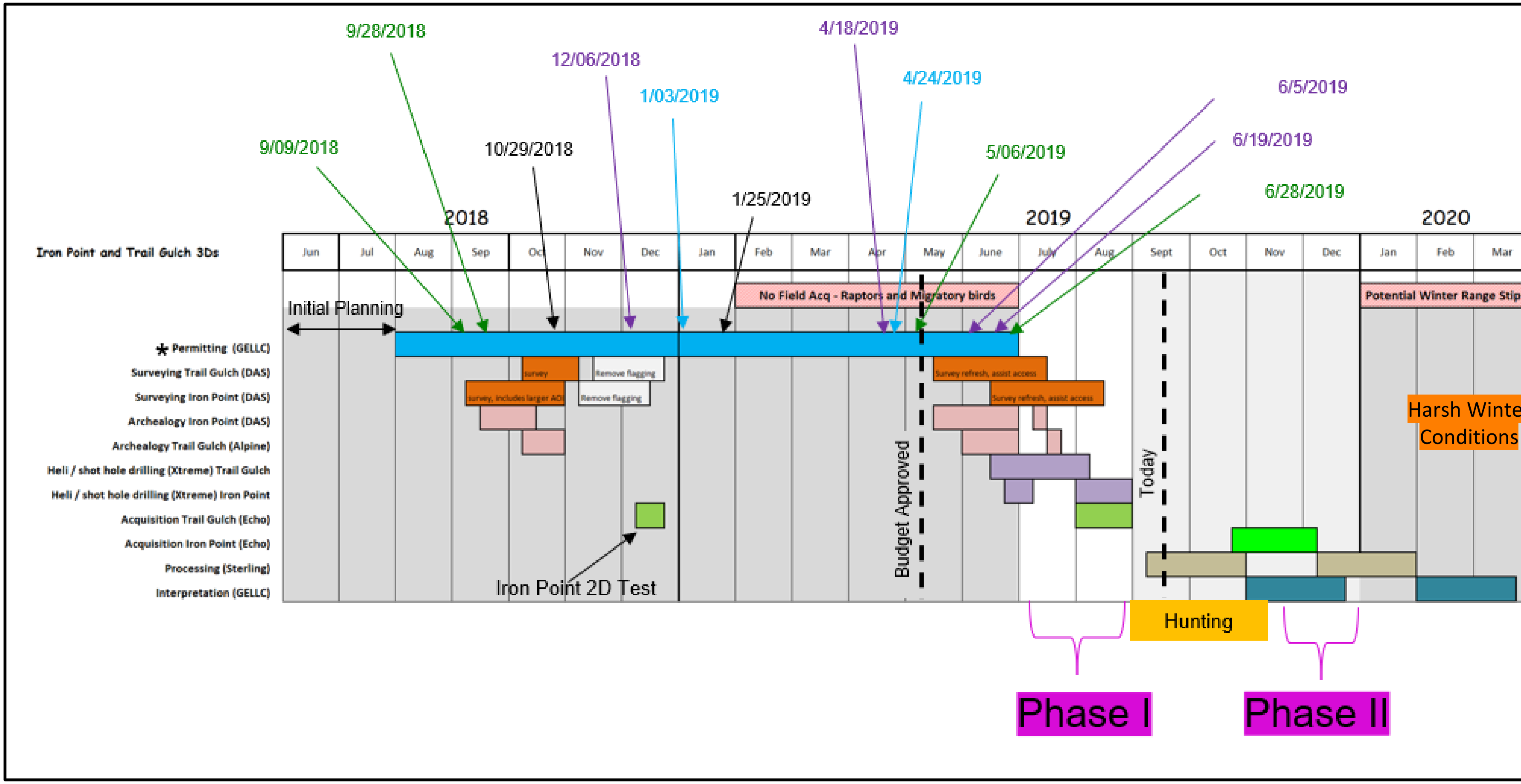
Execution:

- -Fundraise ✓
- -Financial Model ✓
- -Permitting ✓
- -Logistics (Water/Sand) in remote setting ✓
- -Construction ✓
- -Drilling/Completion Design ✓
- -Rig Contracts ✓
- -Geosteering (Focused ✓ Target Zone)

Begin Planning and Additional Data Acquisition

GELLC Planning and Lead Time

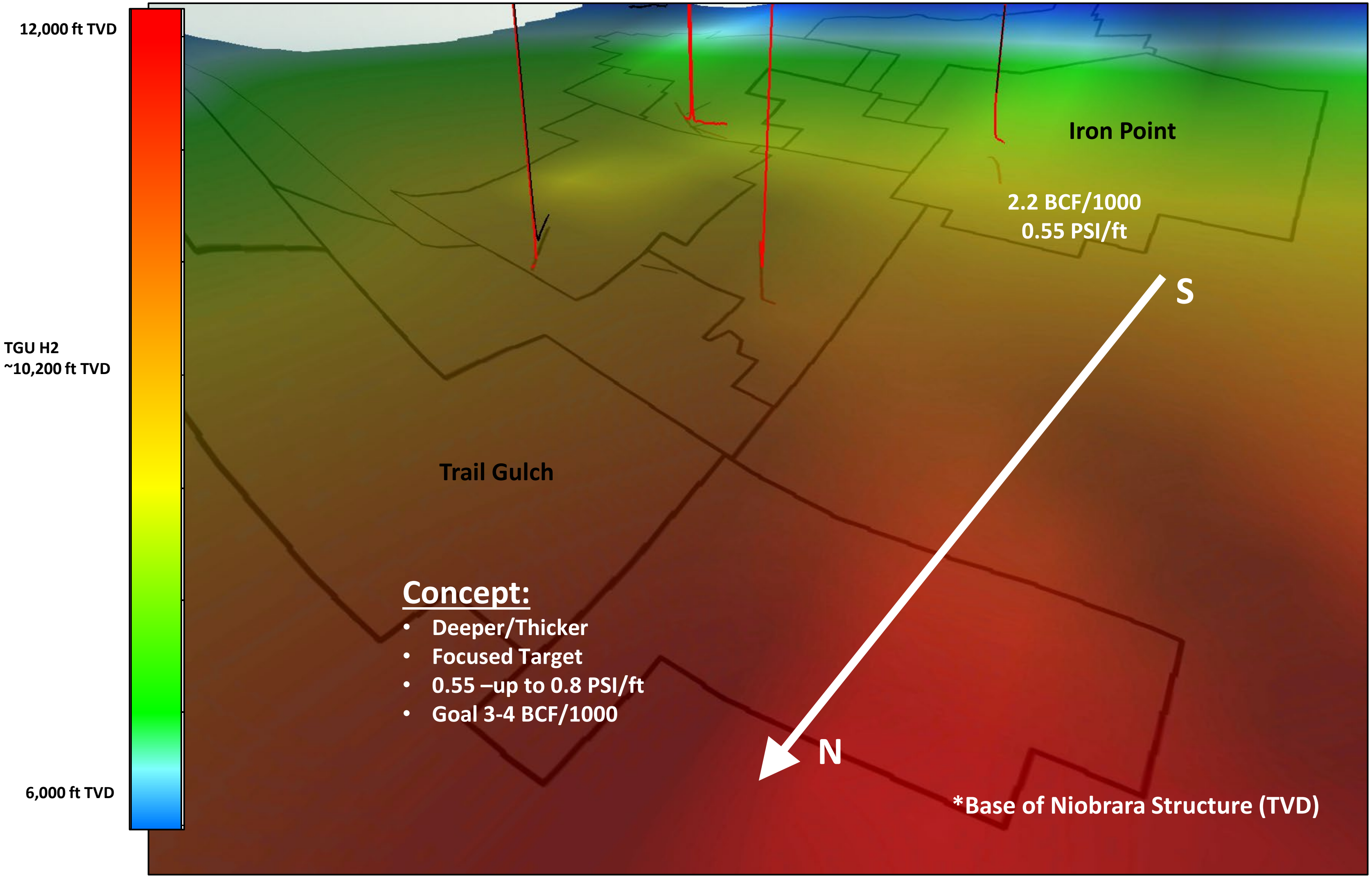
Time Sensitive Project Planning (3D Seismic Example)



*In Person Stakeholder Meetings/Agency Meetings/Deadlines/Applications etc.

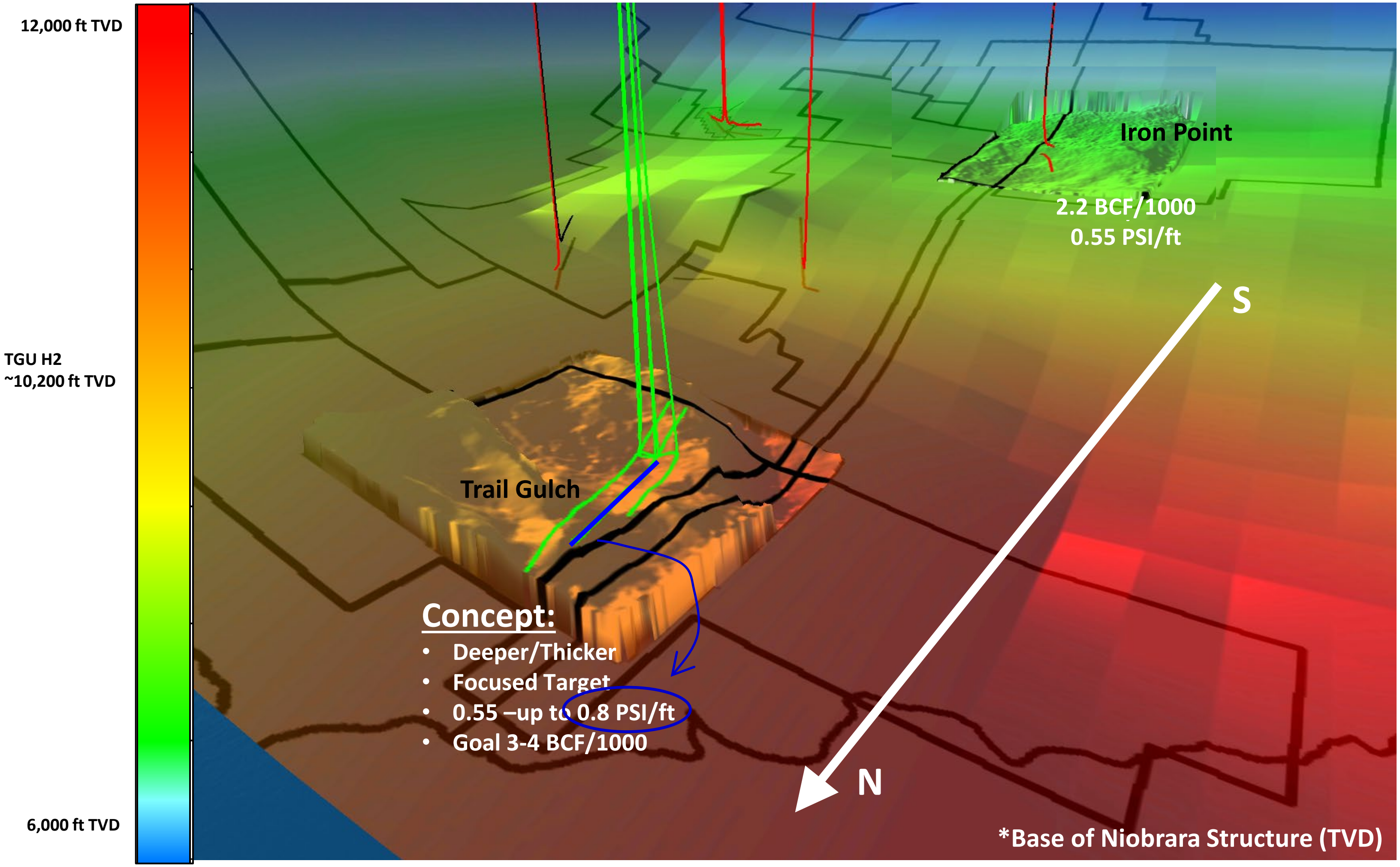
Initial Concept

Initial Concept: Target Deeper, Thicker, Higher Pressure in a focused Target



Seismic Acquired; Now What?

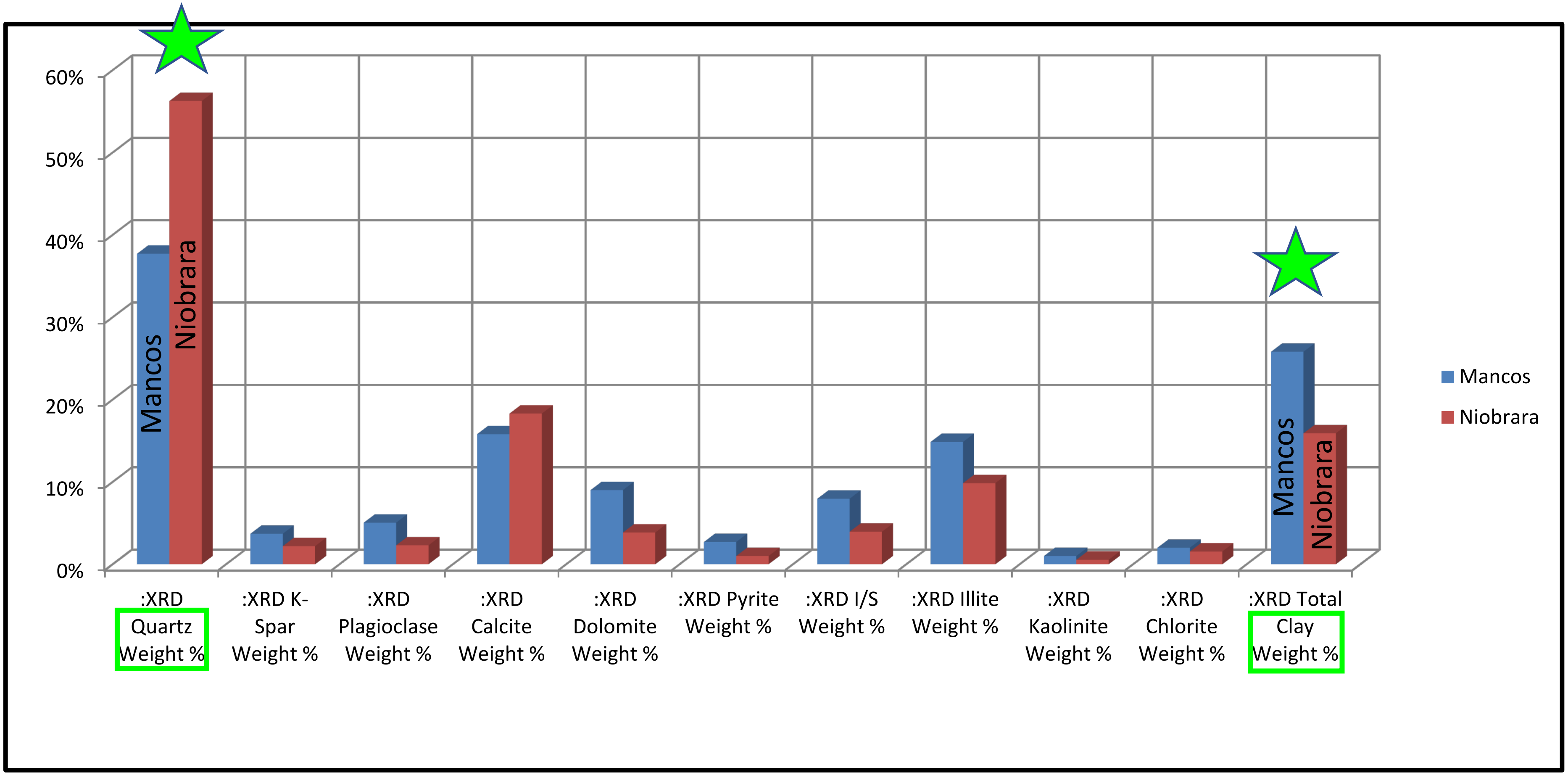
Seismic Acquired: Development Plan and Geohazards De-Risked



Petrophysical Modelling

Petrophysics: Lithology Understanding

Multi Mineral Model Inputs; Mancos vs Niobrara: Key Well 11

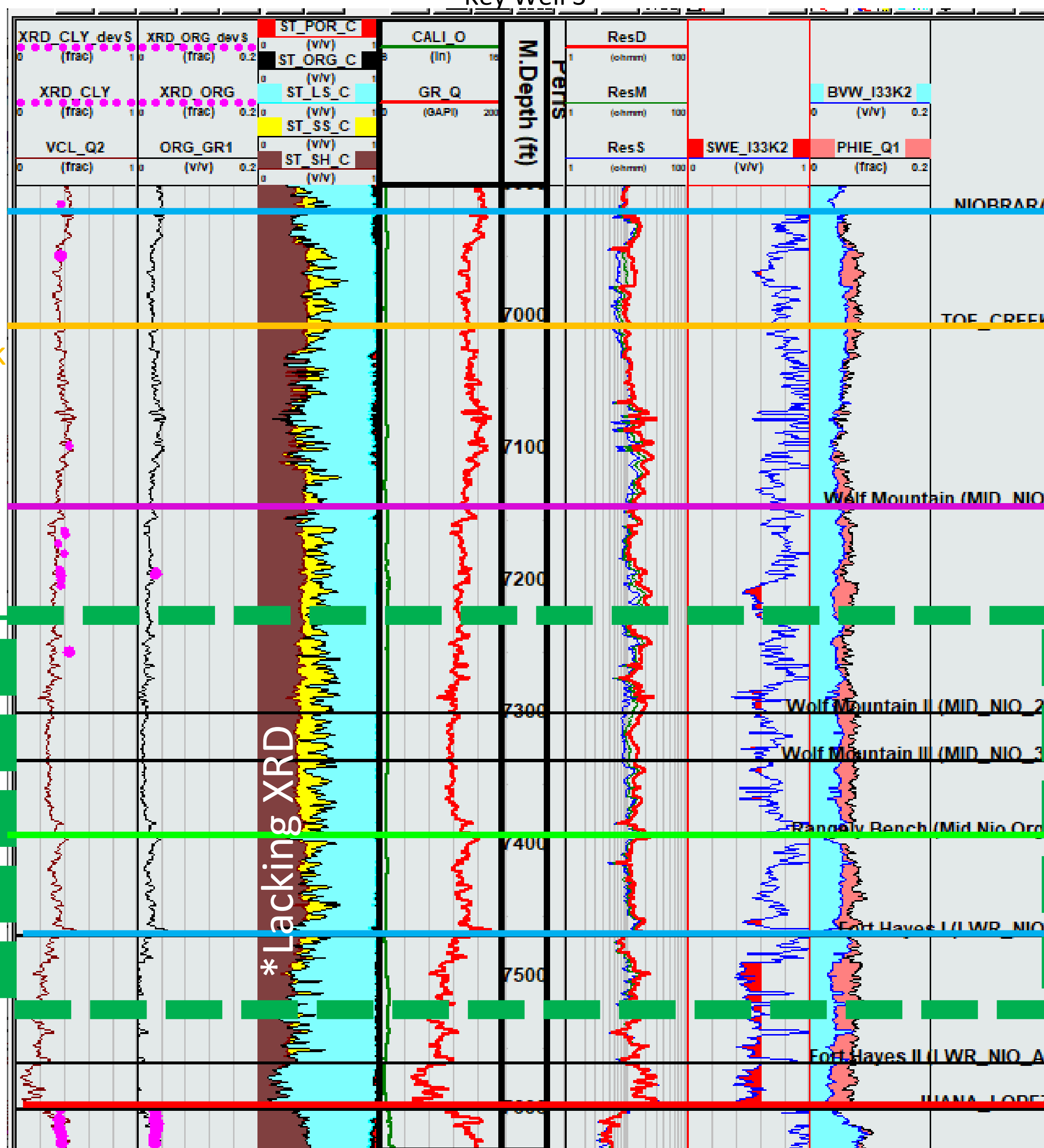


- Mancos has a higher clay content relative to Niobrara
  - Implications for Niobrara being a more preferred reservoir
- Quartz content increases in Niobrara with porosity and brittleness implications

Petrophysical Model-South

Stratigraphic Column Key Well 3 Type Log near 2.2 BCF/1000 Southern Well

Key Well 3



Niobrara

Niobrara Top (Buck Peak)

Toe Creek

Wolf Mountain

686 ft Total; 750 ft to North

Fort Hayes

Juana Lopez

*Secondary Target

Target Box

- 300 ft thickness
- Avg Phi ~7%
- Avg SW ~42%
- 65 BCF/Section
- Nearby Well 2.2 BCF/1000 drilled in 2010

Rangely ***Main Target**

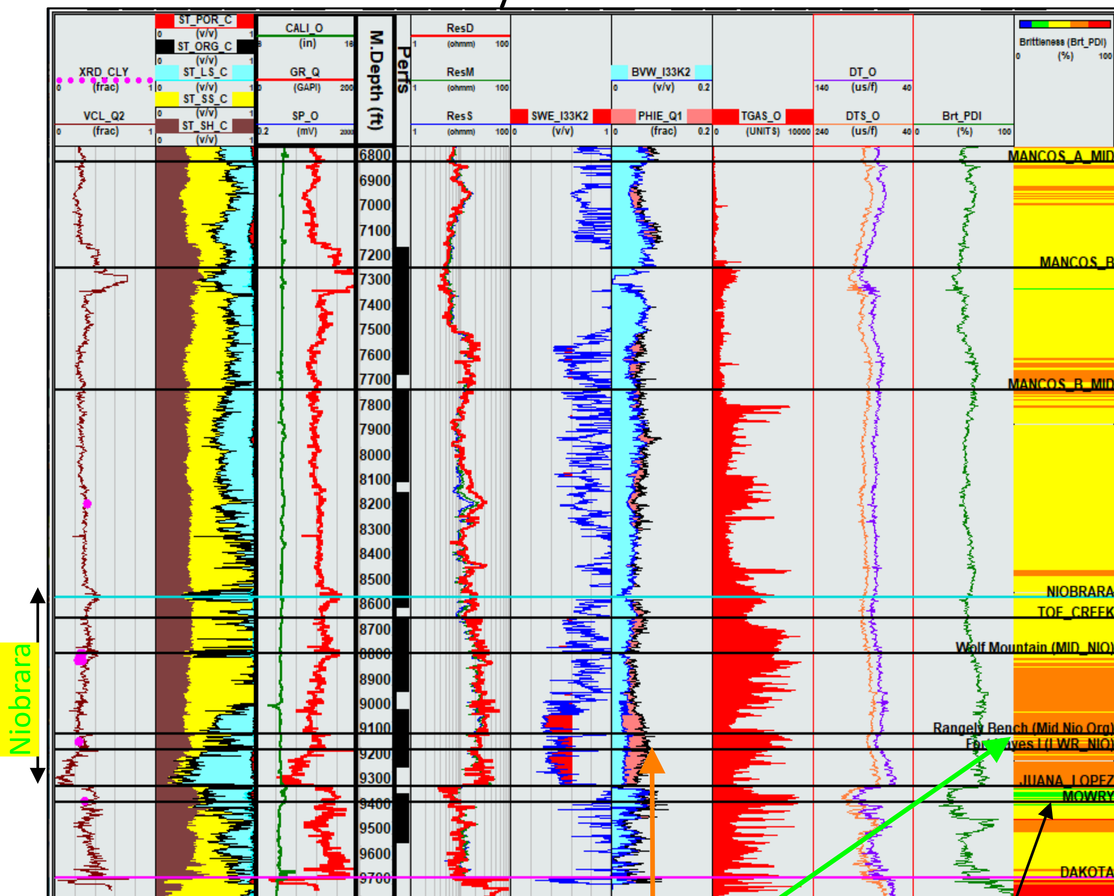
Target Zone Key Characteristics:

- Organic Rich Zone
- Highest Mud Gas Kicks
- Above Ductile frac barrier
- Target zone, ~60 ft thick

Petrophysical Model Geomechanics-North

Petrophysics and Key Properties Key Well 1 (and nearby Key Well 13 XRD)

Key Well 1

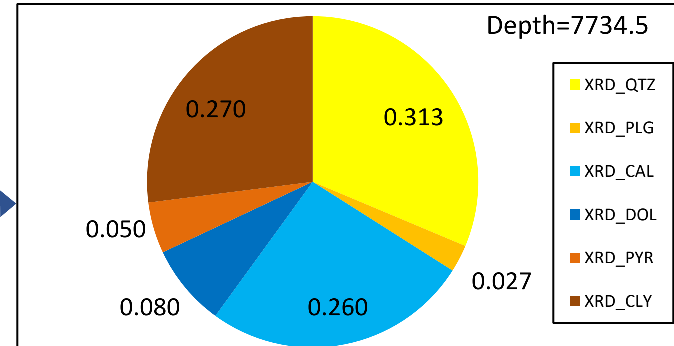


XRD Supports Multimineral Lithology Model

Landing Point in Rangely with best Effective Porosity

Potential Lower Frac Barrier in Juana Lopez (green/ductile/high stress)

Wolf Mountain (**Upper Niobrara**)

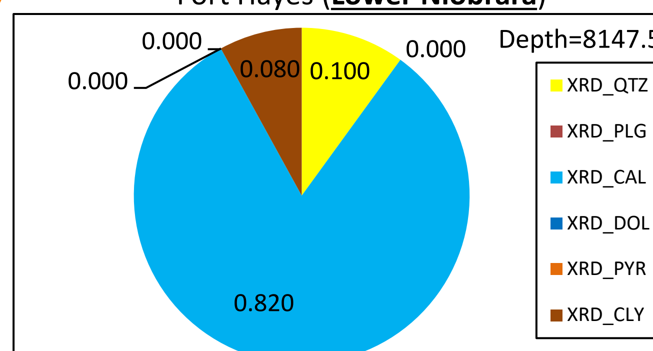


XRD Upper Niobrara data Key Well #13

- The **Upper Niobrara is dominated by quartz, calcite and Illite clay**

Lower Stress or "Brittle" Rock in Lower Niobrara (orange)

Fort Hayes (**Lower Niobrara**)



XRD Lower Niobrara data Key Well #13

- One of the only existing data point to characterize the **Lower Niobrara (Fort Hayes) shows a high concentration of calcite**.

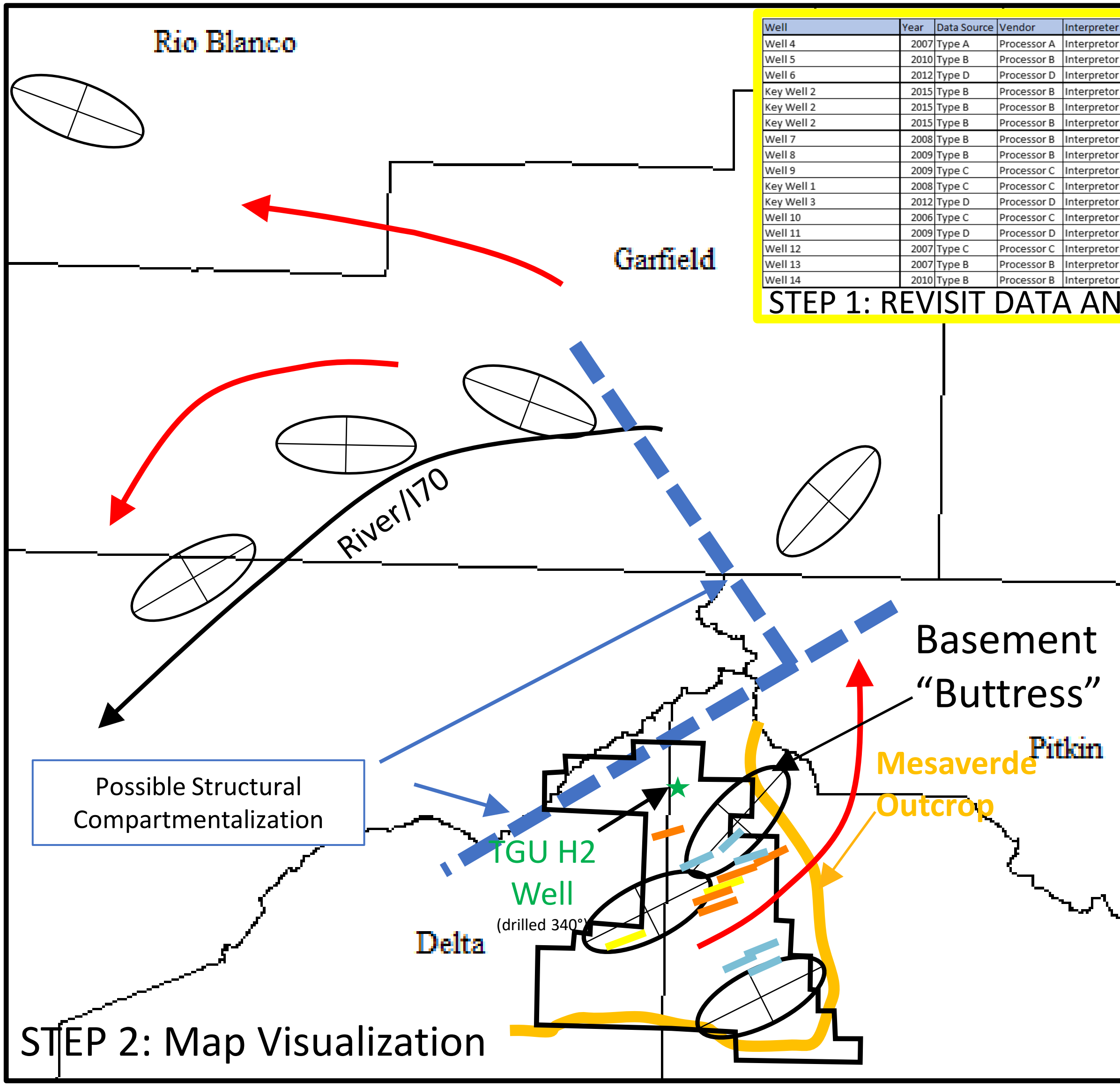
Geomechanics and Image Logs

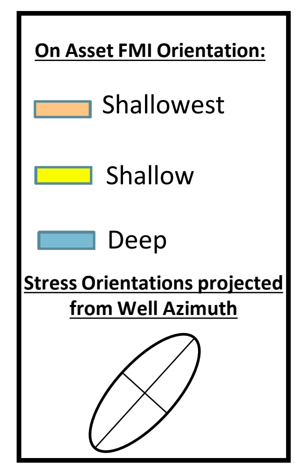
Fracture and Stress

Regional Stress Summary

Well	Year	Data Source	Vendor	Interpreter	Fm	Shmax Strike	N_Frac1	N_Frac2
Well 4	2007	Type A	Processor A	Interpretor B	Shallow	ENE-WSW	ND	ND
Well 5	2010	Type B	Processor B	Interpretor E	Deep	ENE-WSW	75	285
Well 6	2012	Type D	Processor D	Interpretor D	Deep	ENE-WSW	70	****
Key Well 2	2015	Type B	Processor B	Interpretor B	Shallowest	NE-SW		281
Key Well 2	2015	Type B	Processor B	Interpretor B	Shallow	NNE-SSW		300
Key Well 2	2015	Type B	Processor B	Interpretor B	Deep	ENE-WSW	75	300
Well 7	2008	Type B	Processor B	Interpretor E	Shallowest	ENE-WSW	ND	ND
Well 8	2009	Type B	Processor B	Interpretor E	Shallowest	ENE-WSW	75	***
Well 9	2009	Type C	Processor C	Interpretor E	Shallowest	ENE-WSW	65	295
Key Well 1	2008	Type C	Processor C	Interpretor E	Deep	ENE-WSW	70	***
Key Well 3	2012	Type D	Processor D	Interpretor D	?	ENE-WSW	ND	ND
Well 10	2006	Type C	Processor C	Interpretor C	Deep	NE-SW	***	***
Well 11	2009	Type D	Processor D	Interpretor D	Deep	ENE-WSW	72	280
Well 12	2007	Type C	Processor C	Interpretor E	Shallow	ENE-WSW	***	***
Well 13	2007	Type B	Processor B	Interpretor E	Shallowest	ENE-WSW	80	280
Well 14	2010	Type B	Processor B	Interpretor E	Shallowest	ENE-WSW	75	***

STEP 1: REVISIT DATA AND NORMALIZE *Modified from 303PetroImages Llc



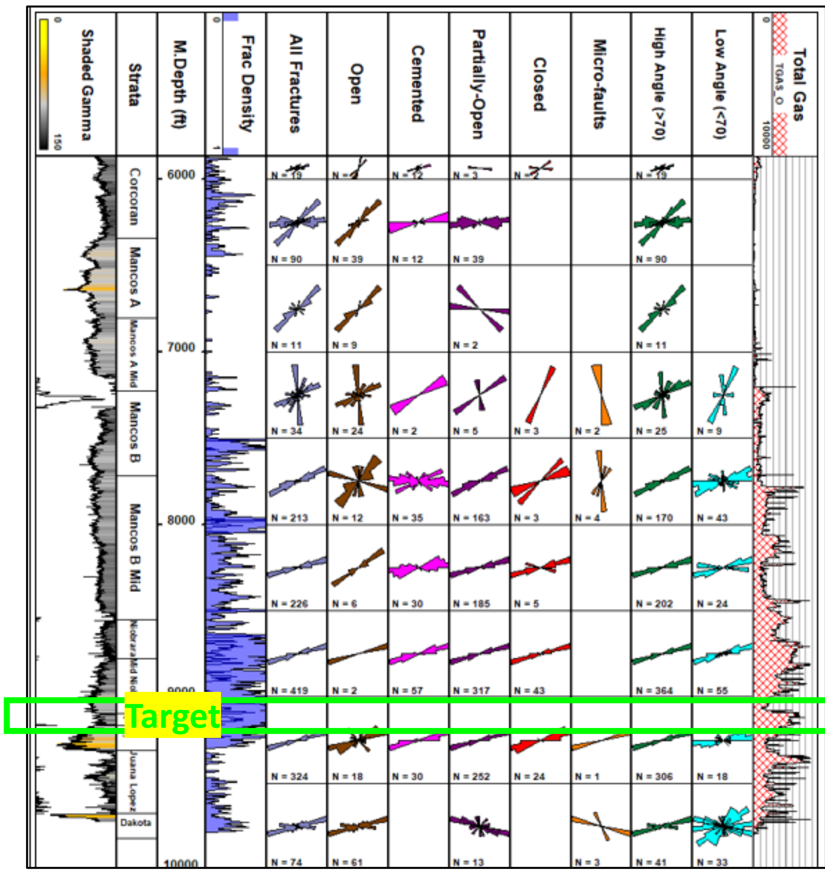


*Modified from 303PetroImages Llc

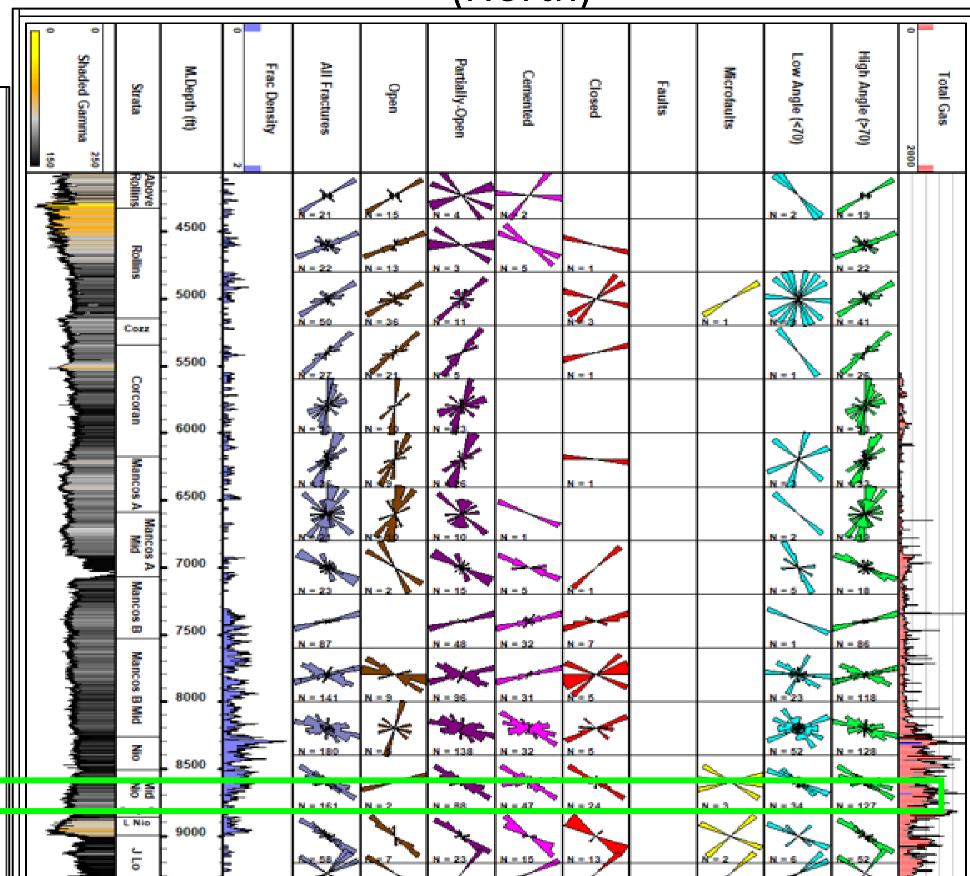
Fracture and Stress Understanding

Image Log Classification Near Proposed Development

Key Well 1
(North)



Key Well 2
(North)



*Modified from Borehole Image Specialist

*Not to scale

Target Zone Image Log Analysis

Target Zone Evolution Key Well 2 (North)

*Modified from 303PetroImages Llc

TGU H2 Landing

Refined Target Window:
Window 8818 to 8838 bottom (20 ft window)…11 ft buffer on top 22 ft buffer on bottom

Recovery Estimates

GELLC Spacing and Recovery (South)

Performance Sensitivities: Spacing, Height, and RF sensitivities from Key Well 3 (South)

Northern Project OGIP Model "Higher"

IPU Empirical Performance
2.2 BCF/1000
@65 BCF/Section
7% Avg Phi (effective)
42% Avg Sw

GELLC Assett Spacing Scenarios	Result	Variable	1320 ft spacing			Variable	
Scenario (@1320 ft spacing)	BCF/1000 ft	BCF/Sec	Wells/Sec	OGIP/Well	BCF EUR/1-Mile Well	RF%	
Lower Niobrara (300 ft)-Average Model (Downside)	1.39	42	4	10.50	7.35	UP to 70%	
Lower Niobrara (300 ft)-Updated Model (Base)	2.18	65.85	4	16.46	11.52		
Upper Niobrara (300 ft)-Average Model (Downside)	1.44	43.5	4	10.88	7.61		
Upper Niobrara (300 ft)-Updated Model (Base)	1.88	56.7	4	14.18	9.92		
Lower Niobrara (350 ft)-Updated Model (Upside)	2.89	76.35	4	19.09	15.27	80	"Bigger Frac" and Taller H

Realistic Base Case

	Result	Variable	1500 ft spacing			Variable	
Scenario (@1,500 ft spacing)	BCF/1000 ft	BCF/Sec	Wells/Sec	OGIP/Well	BCF EUR/1-Mile Well	RF%	
Lower Niobrara (300 ft)-Average Model (Downside)	1.59	42	3.5	12.00	8.40	UP to 70%	
Lower Niobrara (300 ft)-Updated Model (Base)	2.49	65.85	3.5	18.81	13.17		
Upper Niobrara (300 ft)-Average Model (Downside)	1.65	43.5	3.5	12.43	8.70		
Upper Niobrara (300 ft)-Updated Model (Base)	2.15	56.7	3.5	16.20	11.34		
Lower Niobrara (350 ft)-Updated Model (Upside)	3.31	76.35	3.5	21.81	17.45	80	"Bigger Frac" and Taller H

Upside 4+ BCF/1000

	Result	Variable	2400 ft spacing			Variable	
Scenario (@2,400 ft spacing)	BCF/1000 ft	BCF/Sec	Wells/Sec	OGIP/Well	BCF EUR/1-Mile Well	RF%	
Lower Niobrara (300 ft)-Average Model (Downside)	2.53	42	2.2	19.09	13.36	UP to 70%	
Lower Niobrara (300 ft)-Updated Model (Base)	3.97	65.85	2.2	29.93	20.95		
Upper Niobrara (300 ft)-Average Model (Downside)	2.62	43.5	2.2	19.77	13.84		
Upper Niobrara (300 ft)-Updated Model (Base)	3.42	56.7	2.2	25.77	18.04		
Lower Niobrara (350 ft)-Updated Model (Upside)	5.26	76.35	2.2	34.70	27.76	80	"Bigger Frac" and Taller H

- Recovery factor uncertainty due to limited data in the area, but empirical results suggest Recovery as high as 70%

Vertical Production Test

Vertical Production Test

Normalized Proppant and Initial Rates: Key Well 1 (North)

Mancos B

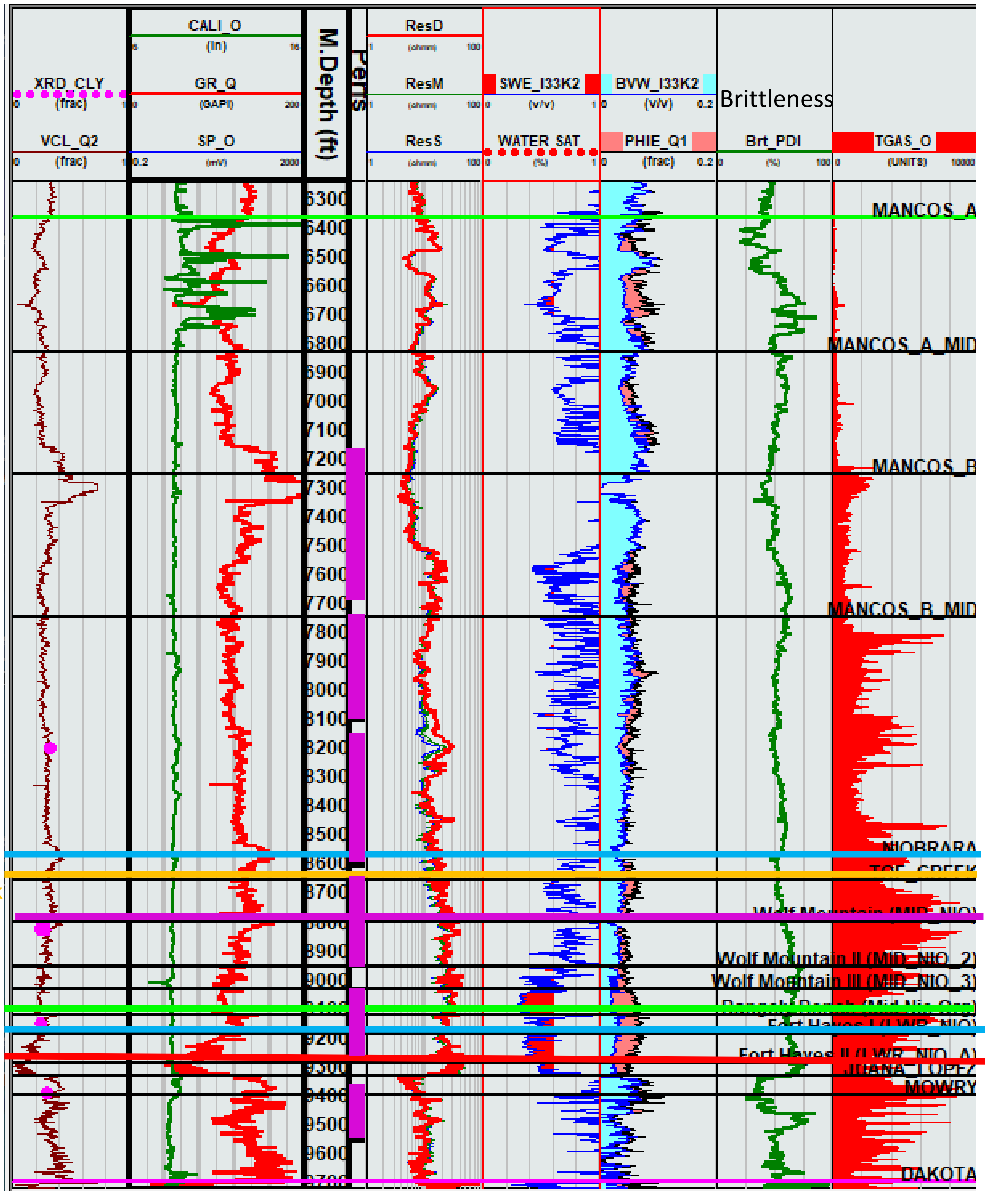
Niobrara Top (Buck Peak)

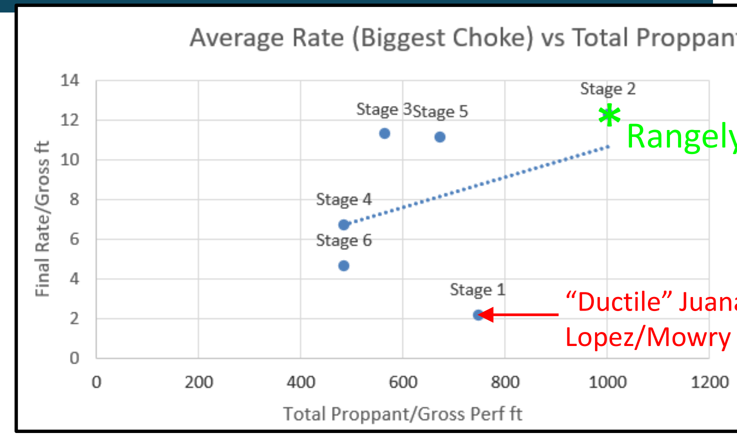
Toe Creek

Wolf Mountain

Fort Hayes

Juana Lopez





Stage 6 (27 hrs.)

Stage 5 (27 hrs.)

Stage 4 (116 hrs.)

Stage 3 (169 hrs.)

Stage 2 (158 hrs.) - TARGET

Stage 1 (169 hrs.)

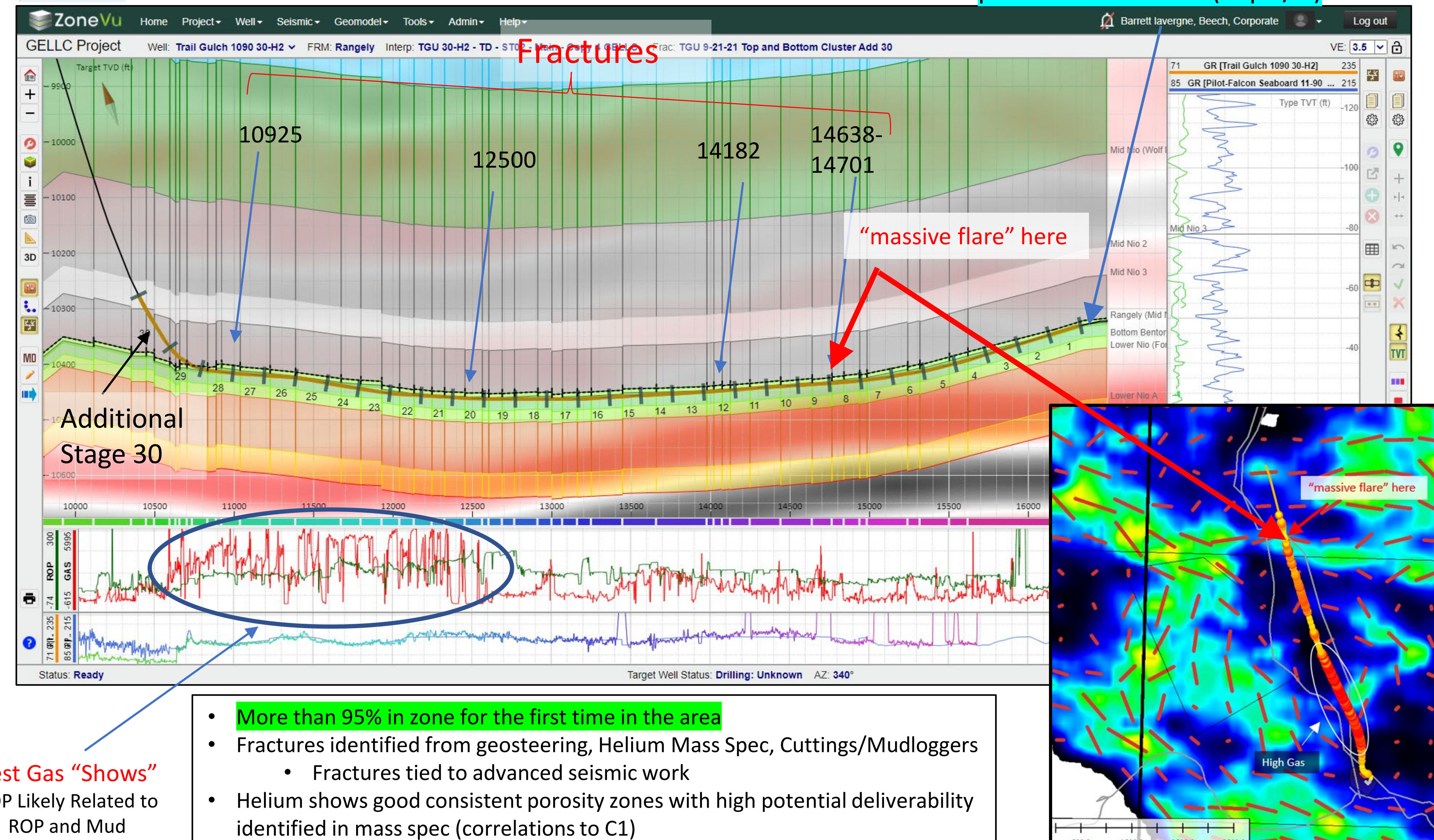
Project Execution

Project Execution

TGU H2: Final Geosteering Plot Using ZoneVu in Focused Target Window

- TD MW at 14.8 w/ High Temps (+300° F)
  - 0.77 PSI/FT similar to high end pressure estimates (.8 psi/ft)

TOTAL DEPTH
PREMIER REMOTE GEOSTEERING



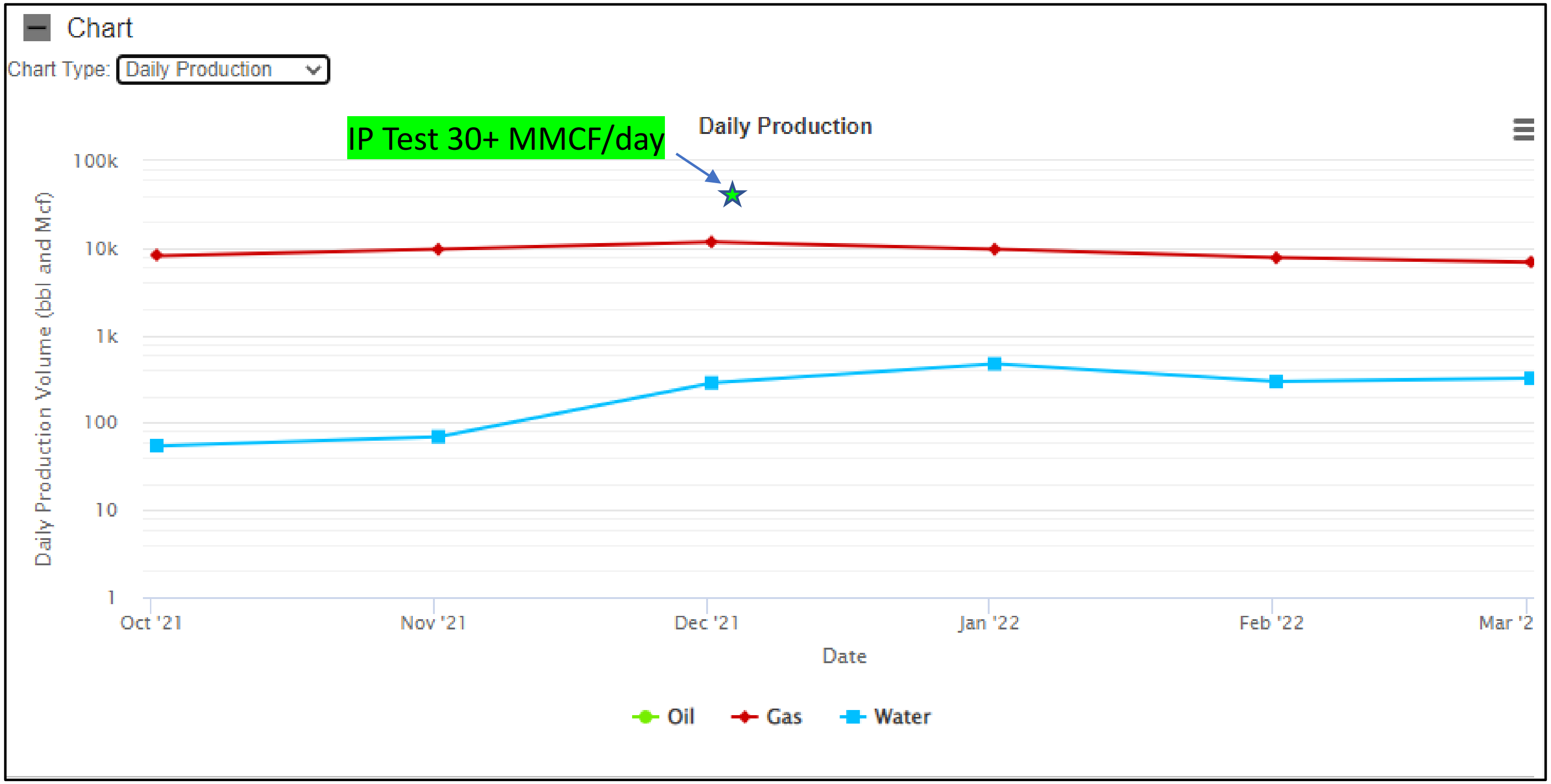
- More than 95% in zone for the first time in the area
- Fractures identified from geosteering, Helium Mass Spec, Cuttings/Mudloggers
  - Fractures tied to advanced seismic work
- Helium shows good consistent porosity zones with high potential deliverability identified in mass spec (correlations to C1)

Best Gas "Shows"
ROP Likely Related to ROP and Mud Weight

Performance

Current Production

Daily Production on Choked Back Well (DI)



Completions:

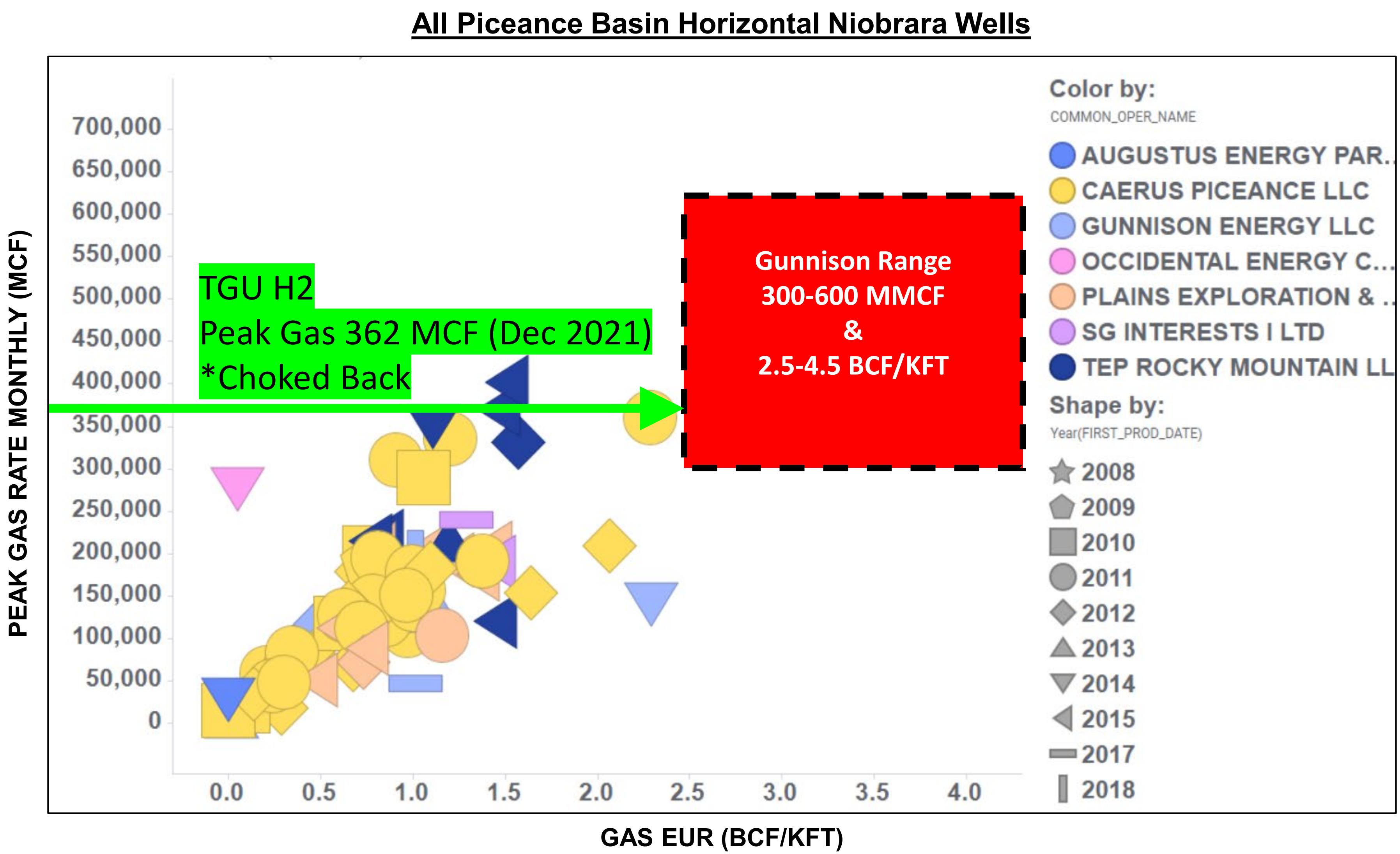
- DI 11,808 LL …GELLC 5,831 ft Perf'd Interval
- 3,580 lb/ft (DI)..GELLC 3,930 lb/ft
- 74 bbl/ft (DI)…GELLC 90 bbl/ft

Production:

- Choked back daily production near 10MMCFD
- EURs very subjective to date (Choked back)
  - DI Gas EUR 5,884,145 on 5/24/22
  - DI Gas EUR 7,562,691 on /6/29/22

Initial Prediction vs Current Rate

Initial Performance Expectations aligns with Current Production Rates (On a Choked Back Well)



Next…

We Hope to See More "Working" Signs Soon…

Thanks

Acknowledgements

- **AAPG Presentation Contributors and Technical Resources**
  - Petro Data Integration-Keith Jagiello
  - 303PetroImages Llc-Steve Sturm
  - GELLC-Salar Nabavian
- **Data Contributors!**
  - SG Interests- Al Haertlein (Exploration Manager)
- **Project Contribution/Technical Resources/Feedback**
  - Reservoir Insight Geosolutions- Chad Baillie
  - Borehole Image Specialists-Roger Reinmiller and Ron Parker
  - Tricon-Scott Cook (Advanced Seismic Processing, Anisotropy)
  - Sterling-Tim Michel (Geophysicist; Data Processor)
  - ZoneVu –Rachel Stocking (Geosteering Software)
  - Total Depth-Jason harms (Onsite/Remote Geosteering)
  - Jason Eleson (Principal Geologic Advisor at Enverus)

References

References

[1] Steve Cumella, Geology of the Piceance Basin Mesaverde Gas Accumulation, Search and Discovery Article, 2009

[2] Jason Eleson, Chip Oakes, Graham McClave, 2020. Insights into productivity drivers for the Niobrara-equivalent horizontal play in the Piceance Basin, Colorado

[3] Jason Eleson, 2020. The Past, Present and Future of Niobrara/Mancos B Horizontal Development in the Piceance Basin

[4] Warren C. Day and Dana J. Bove, USGS, Resource Potential & Geology of GMUG USGS Bull 2213R, 2004.

[5] J.L. Ridgley, S.M. Condon, and J.R. Hatch, USGS. Geology and Oil and Gas Assessment of the Mancos-Menefee Composite Total Petroleum System https://pubs.usgs.gov/dds/dds-069/dds-069-f/REPORTS/Chapter4_508.pdf

[6] The Parable of the 6 Blind Men. https://blog.arkieva.com/data-to-decisions-faster/