The Past, Present and Future of Niobrara/Mancos B Horizontal Development in the Piceance Basin*

Jason Eleson[1]

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[1]GeoIntegra Consulting, LLC, Denver, CO (jasoneleson3@gmail.com)

Abstract

The Mancos Shale Formation within the Piceance Basin is one of the richest hydrocarbon-bearing formations in the world but remains a relatively unexplored play. Numerous wells have tested the liquid-rich, transitional and dry gas window, with variable results. The main drilling targets are typically the Niobrara Formation, comprised mainly of marls, siltstones and shales, and the overlying Mancos B Formation, comprised mainly of silty shales with relatively low carbonate content.

Beginning in 2008, several horizontal wells have targeted these formations, mostly in gas-prone deposits on the southern side of the Piceance Basin. Results to date have been mixed, but the highest initial production comes from the more overpressured, carbonate-prone benches, such as the Tow Creek and Rangely Bench. The wells drilled before 2014 were typically shorter with lower frac intensity, resulting lower production rates. Beginning in 2014, longer laterals with higher frac intensity resulted in higher production rates. The increased yields are due to a combination of improved frac design and drilling strategies. Importantly, the Niobrara Formation is well suited to test the impact of more modern frac designs, including higher proppant and 63 Wyoming Geological Association – September 15-18, 2019 water volumes, shorter stage lengths, and plug-and-perf completion techniques.

The Niobrara Formation has been drilled in the liquids window along the western and northern margins of the Piceance Basin from 2014 to 2018, with longer lateral lengths and higher proppant volumes, but the results have proven somewhat disappointing. Due to the lower number of wells, it is difficult to determine the exact cause of lower production rates. However, available data indicate that it is likely due to a combination of lower formation pressures, higher hydrocarbon viscosities, reservoir properties, and ill-suited completion techniques.

The Piceance Basin has substantial gas processing and transport infrastructure in place and can be competitive against existing US gas markets. If Piceance Basin operators can merge newer completion styles with access to international LNG markets, there is unlimited potential for future natural gas production.

Selected References

Bruginoni, D., 2017, Fault, Fracture, and Porosity Analysis and Their Effects on Reservoir Heterogeneity in the Niobrara Formation, Wattenberg Field, Colorado: MS Thesis, Colorado School of Mines, Golden, Colorado.

Cicero, A.D., I. Steinhoff, T. McClain, K.A. Koepke, and J.D. Dezelle, 2010, Sequence Stratigraphy of the Upper Jurassic Mixed Carbonate/Siliclastic Haynesville and Bossier Shale Depositional Systems in East Texas and Northern Louisiana: Gulf Coast Geological Association of Geological Societies Transactions, v. 60, p. 133-148.

Cumella, S.P., and M.A. Duhailan, 2014, Niobrara Maturity Goes Up, Resistivity Goes Down; What's Going On?: Unconventional Resources Technology Conference, Denver, Colorado USA, August 25-27, 2014, 21 p.

Yurewicz, D.A., K.M. Bohacs, J.D. Yeakel, and K. Kronmueller, 2003, Source Rock Analysis and Hydrocarbon Generation, Mesaverde Group and Mancos Shale, Northern Piceance Basin, Colorado, *in* K.M. Peterson, T.M. Olson, and D.S. Anderson (eds.), Piceance Basin 2003 Guidebook: Rocky Mountain Association of Geologists, p. 130-153.

Website Cited

https://www.macrotrends.net/2478/natural-gas-prices-historical-chart Website accessed February 2020.

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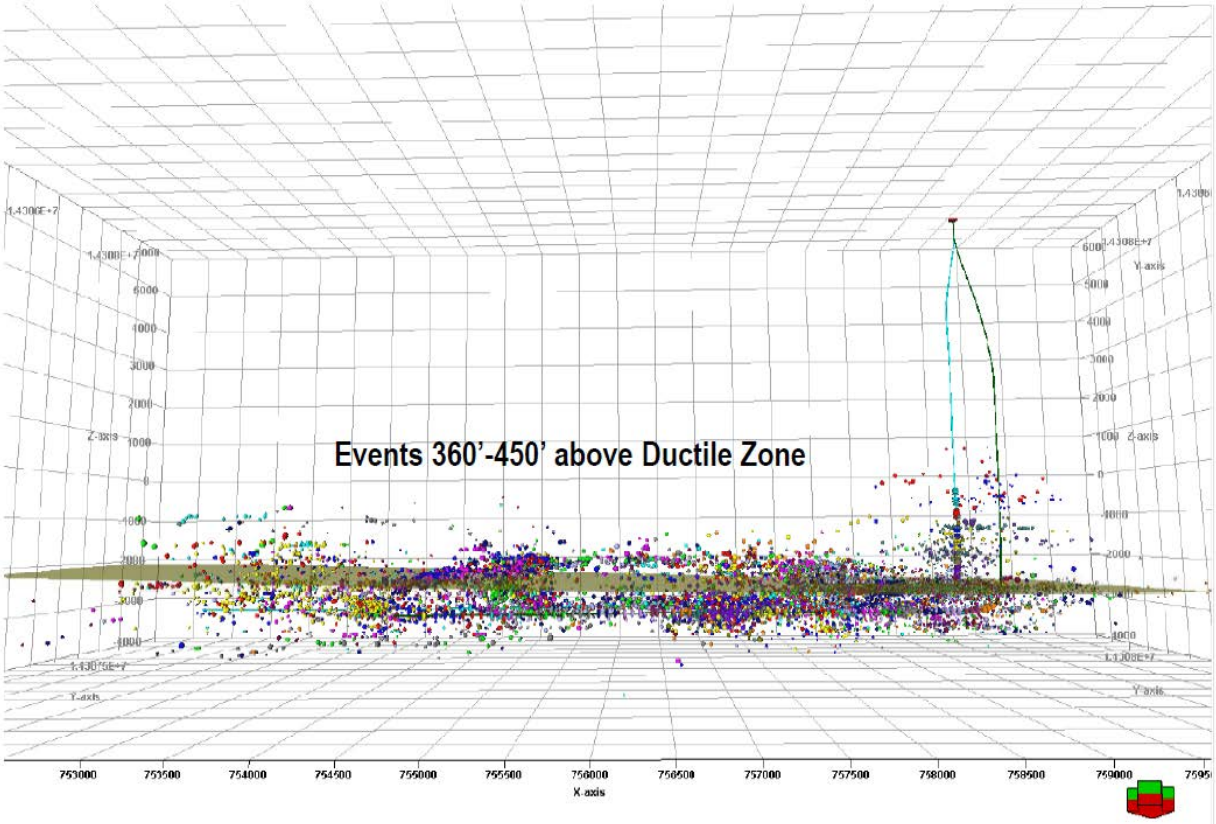
Jason Eleson, Manager of Technical Sales @ Enverus (Drillinginfo)
& Owner of GeoIntegra Consulting, LLC

RMS-AAPG Sectional Meeting, September 18, 2019



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- **Caerus Piceance LLC**– Mike Leibovitz, Nate Cumella, Nick Barber, Maurice Dukes, Mike Mengers, John Benton, Cole Spurgeon, Mike Strabala, Kristine Mize-Spansky, Allison Woolston
- **Augustus Energy Partners II**– Graham McClave
- Gus Gustason
- Steve Cumella
- Retamco Operating – Chip Oakes
- Terra Energy Partners – Steve Sunnenberg
- Ursa Resources – Duke Cooley
- Gunnison Energy – Barrett Lavergne, Karl Umland, Salar Nabavian
- Chris Martin
- Encana – For acquiring so much good data!

The Piceance Niobrara Play: A Suitable Metaphor…

Own your own Han Solo Frozen In Carbonite replica, Available on Ebay for $6000!

"Description: This life size prop/replica of Star Wars Han Solo in Carbonite is cast in fiberglass and hand-finished in metallic paint to create the carbon-freeze prop used in the landmark films The Empire Strikes Back and Return of the Jedi. This item, produced in 1997, is unique as it is signed by the artist, Mario Chiodo, in the bottom right front corner and dated on Halloween, 10/31/96. This authentic piece with authentic signature is the size of a normal door and features four vents on each side. It is still in the original box. Makes a great addition to your collection!"

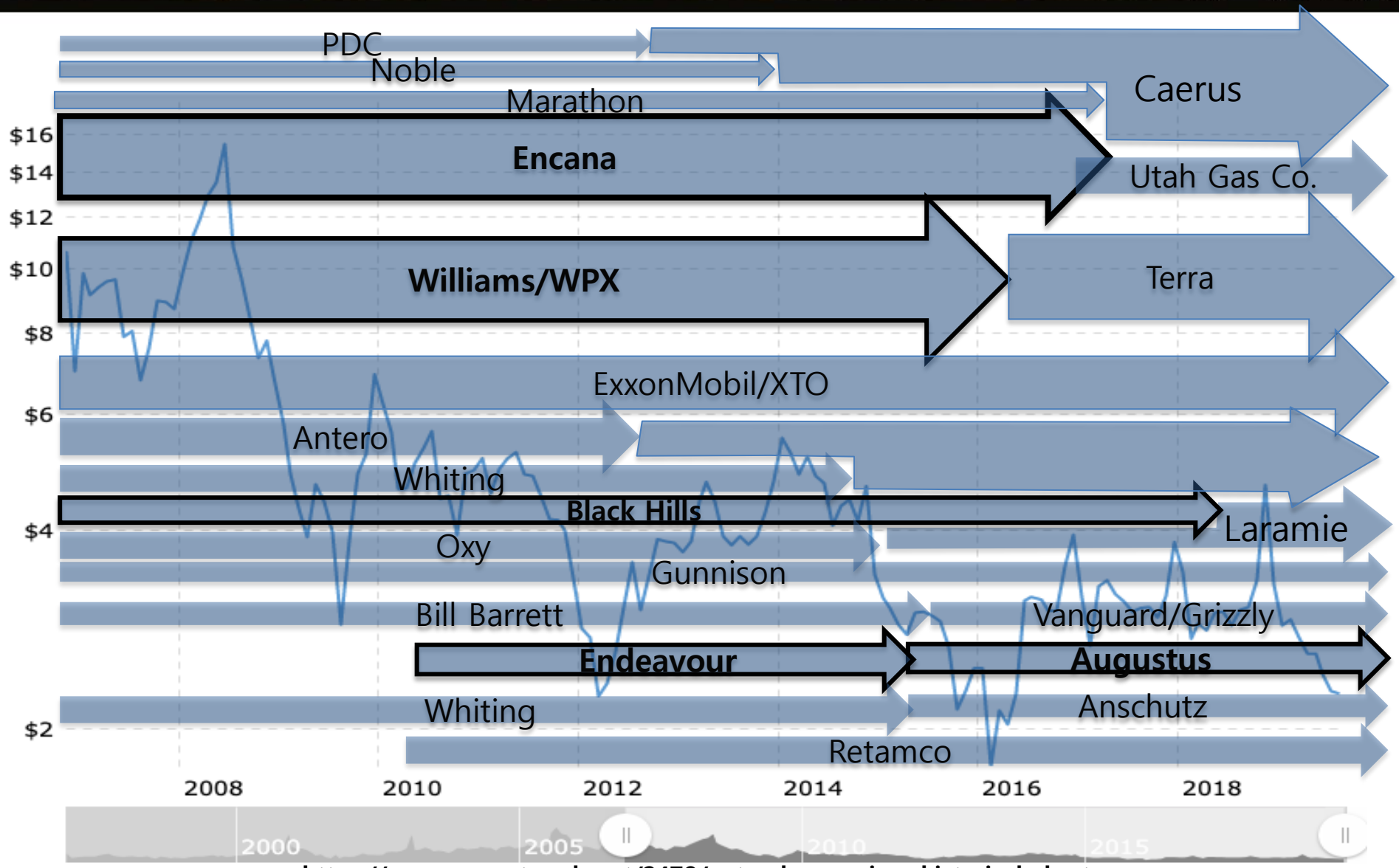
10 Year US Natural Gas Prices

Nowhere to go but down since 2008!

https://www.macrotrends.net/2478/natural-gas-prices-historical-chart

Key Piceance Niobrara Players

Lots of P.E.-backed Asset Transitions From 2012-2017



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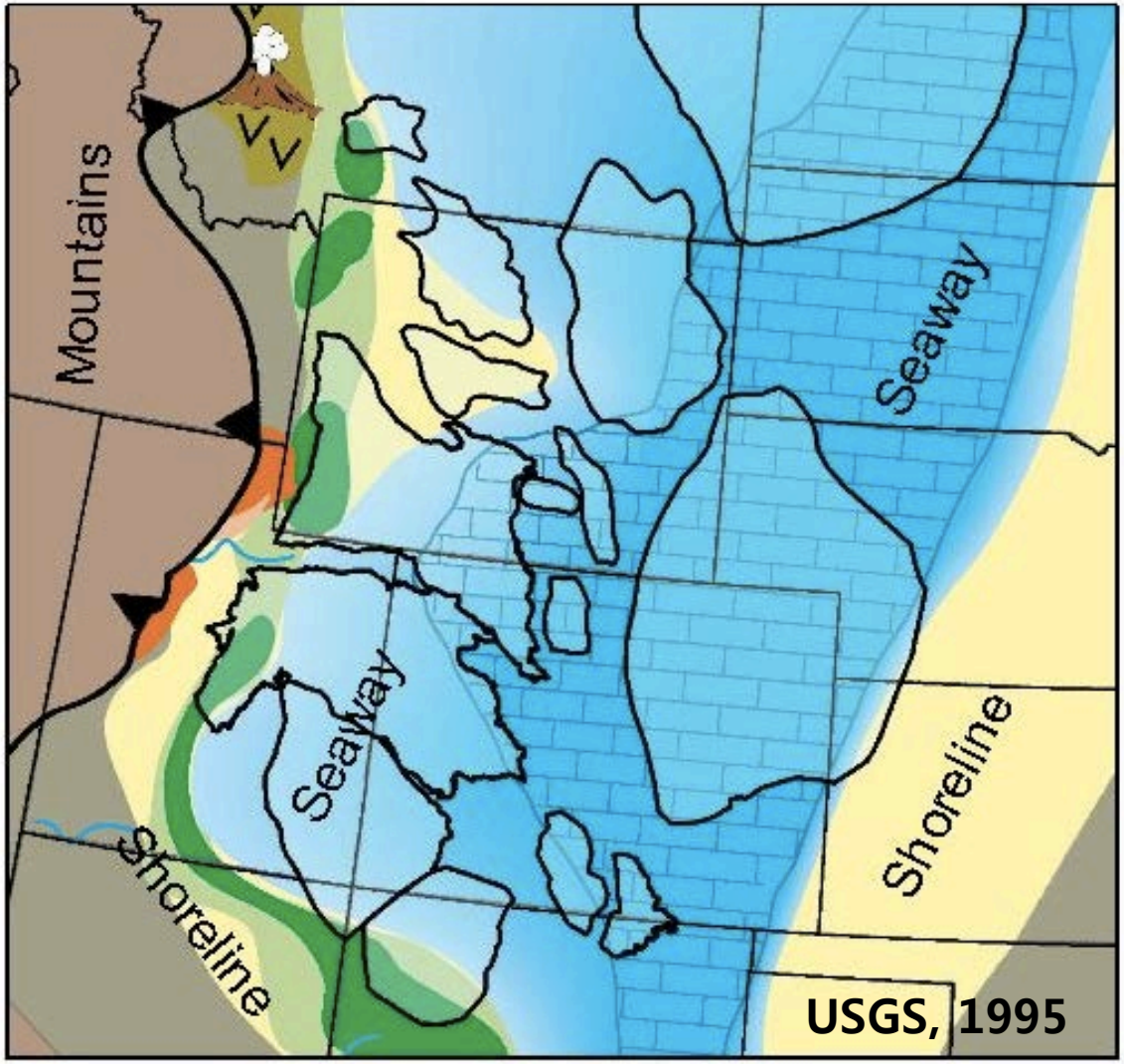
Western Interior Seaway During Niobrara Deposition

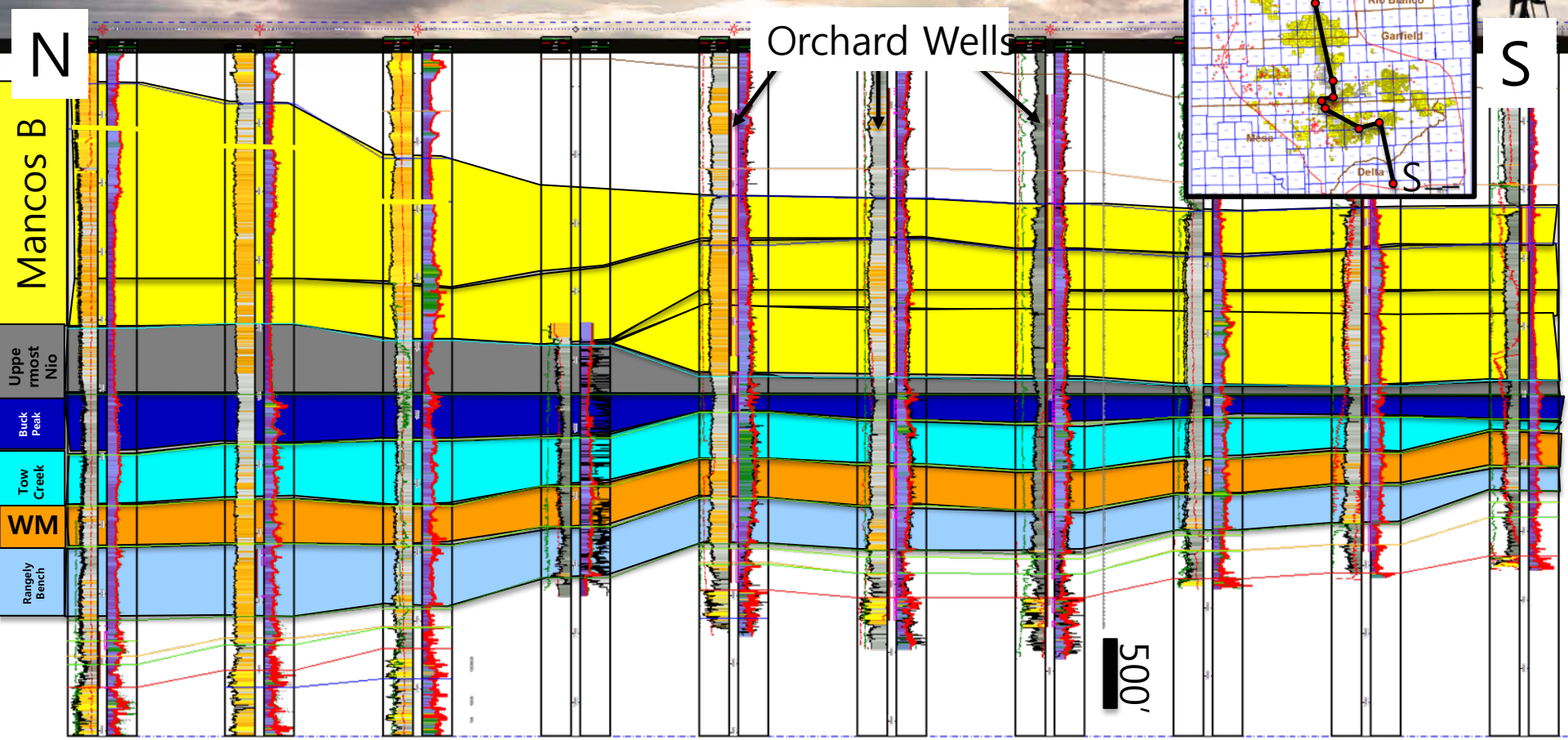
Carbonates Prominent To The East, Clastic Prominent to the West



Don’t forget: 40-50 miles of crustal shortening during Laramide!

Mancos: Big Changes from NW/SE

Thinning to SE, Increase in TOC/Calcite, Slight Change in Organic Matter Type



Northwest Piceance:

- Higher clastic content
- Lower calcite & TOC content
- Mixed Type III/II Source Rock (gas-prone at lower thermal maturity, slightly lower quality)

Southeastern Piceance:

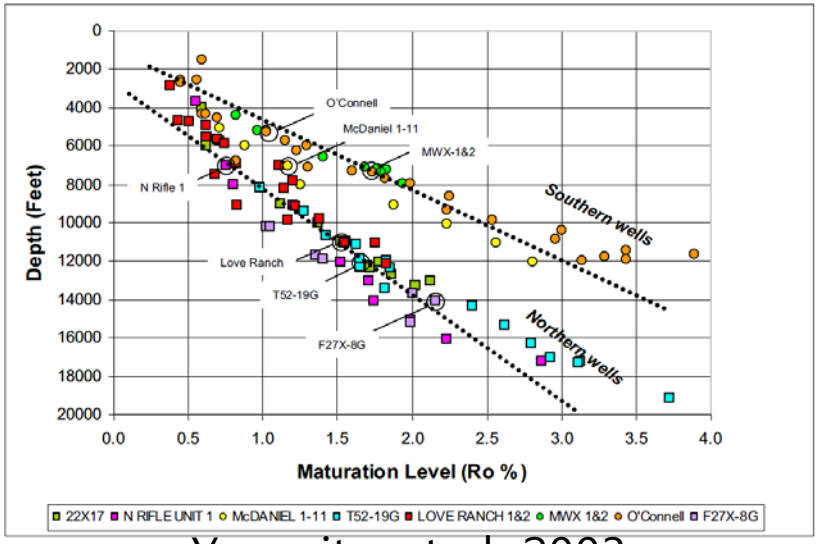
- Lower clastic content
- Higher calcite & TOC content
- Mixed Type II/III Source Rock (less gas-prone at lower thermal maturity, slightly higher quality)

Images & Content Courtesy of Caerus Piceance LLC

High Volcanic Heat Flow in Southern Piceance

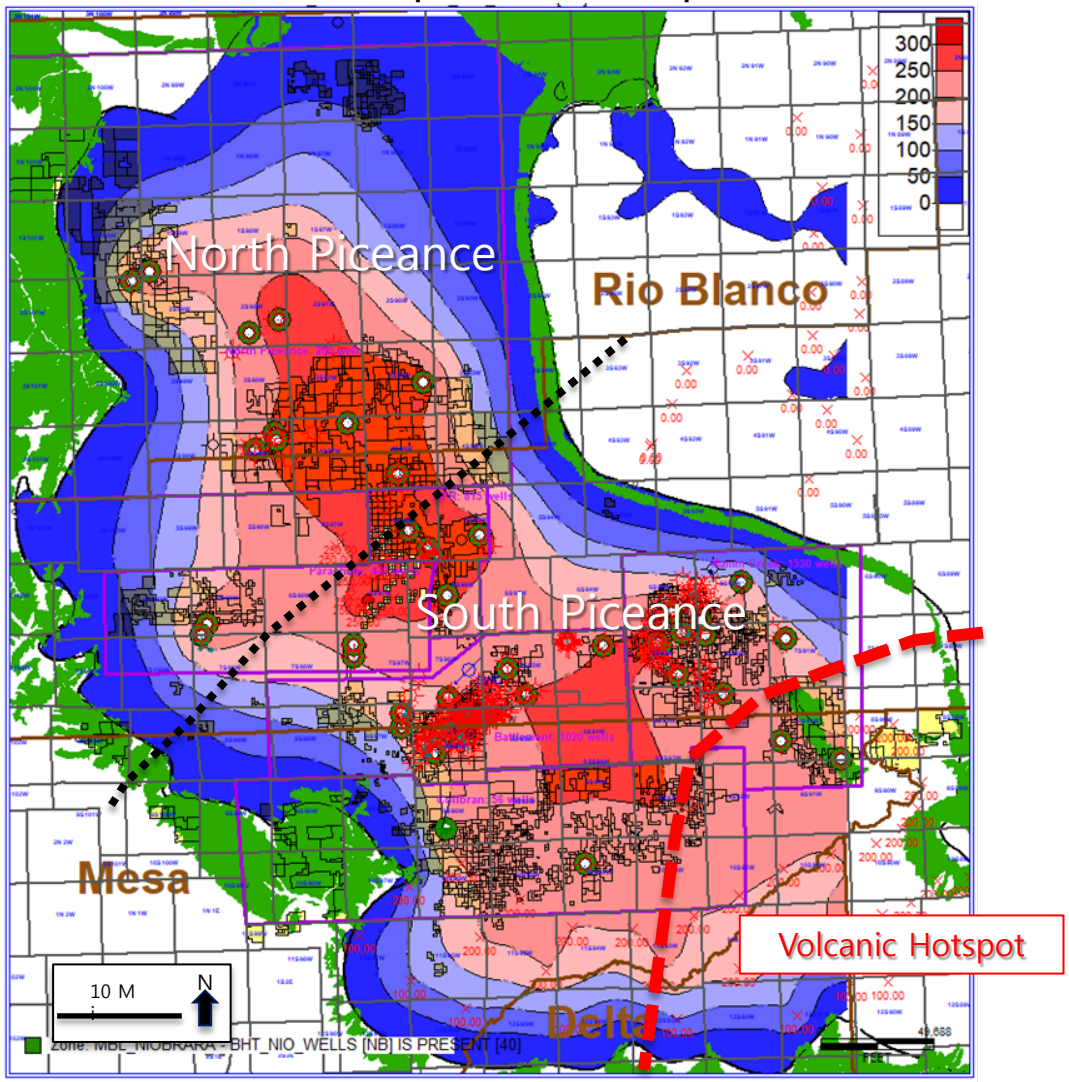
Results in high thermal maturities at shallower depths

- Modern day BHL temperature maps indicate notably hotter temps in southern Piceance
- Volcanic intrusives along SE Piceance margin results in high thermal maturities at shallower depths
- Low chance of encountering significant liquid accumulations in SE Piceance basin
- Higher chance of encountering liquid accumulations in north/northeastern Piceance basin

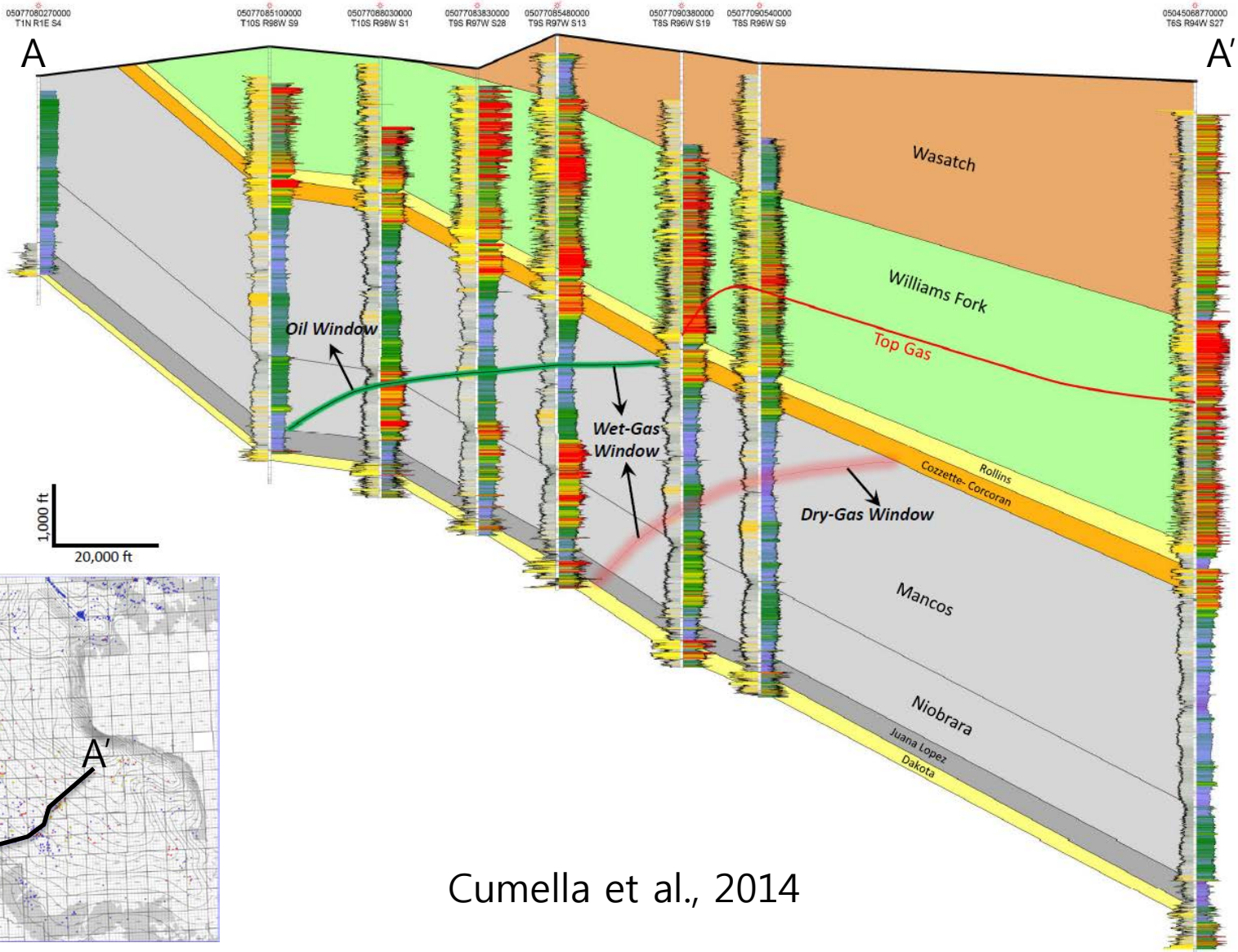


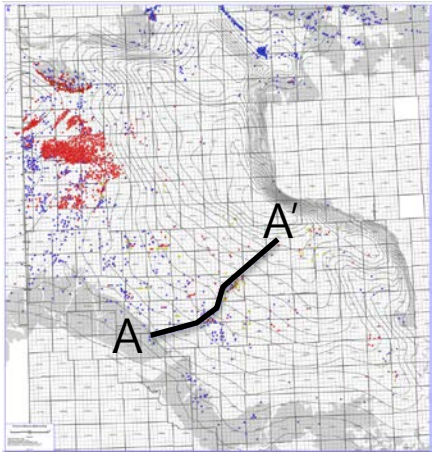
Yurewitz, et al. 2003

Bottom Hole Temperature Map @Niobrara



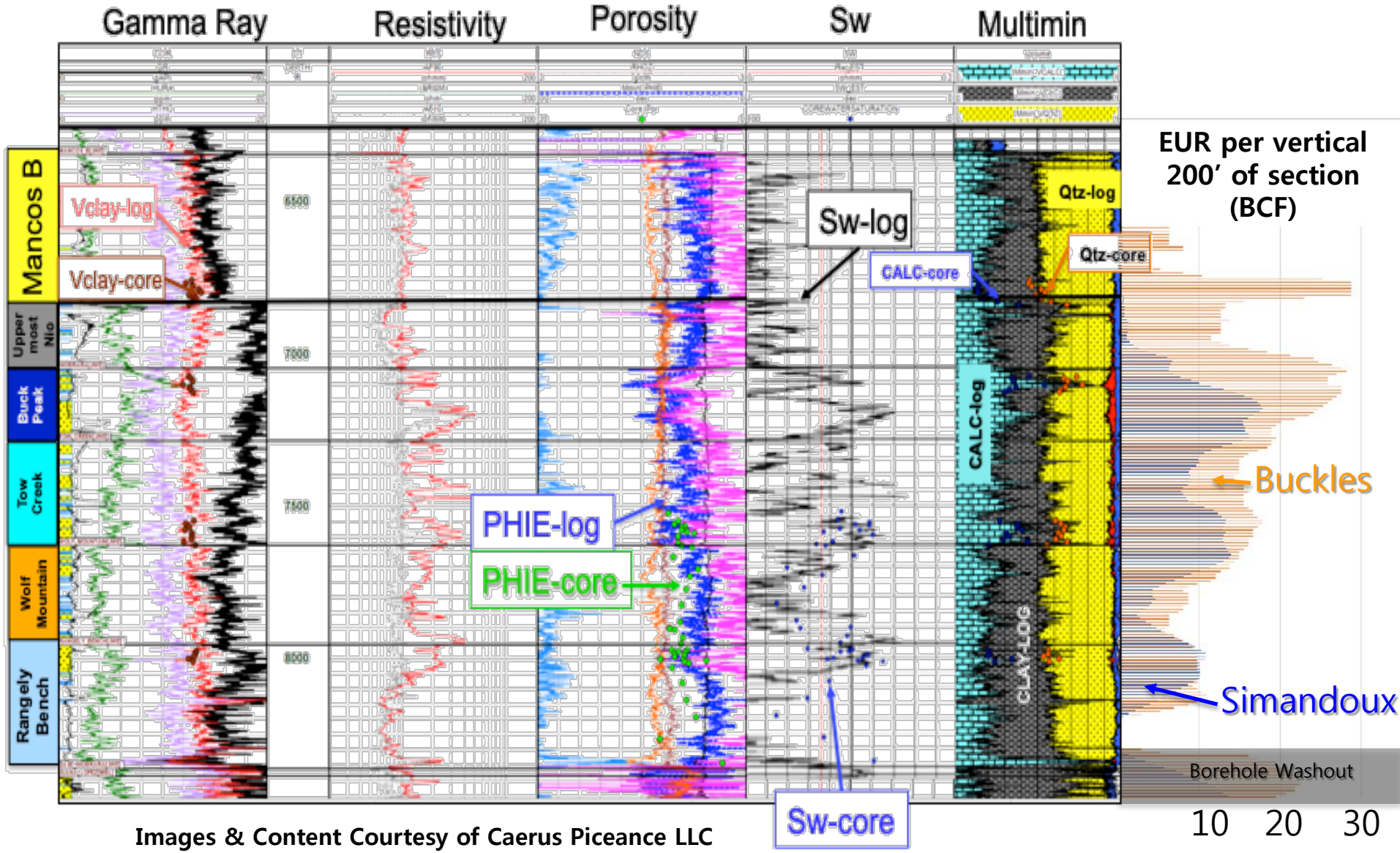
Issue: Resistivity Not Always Tied To Sw in Shale Gas Plays





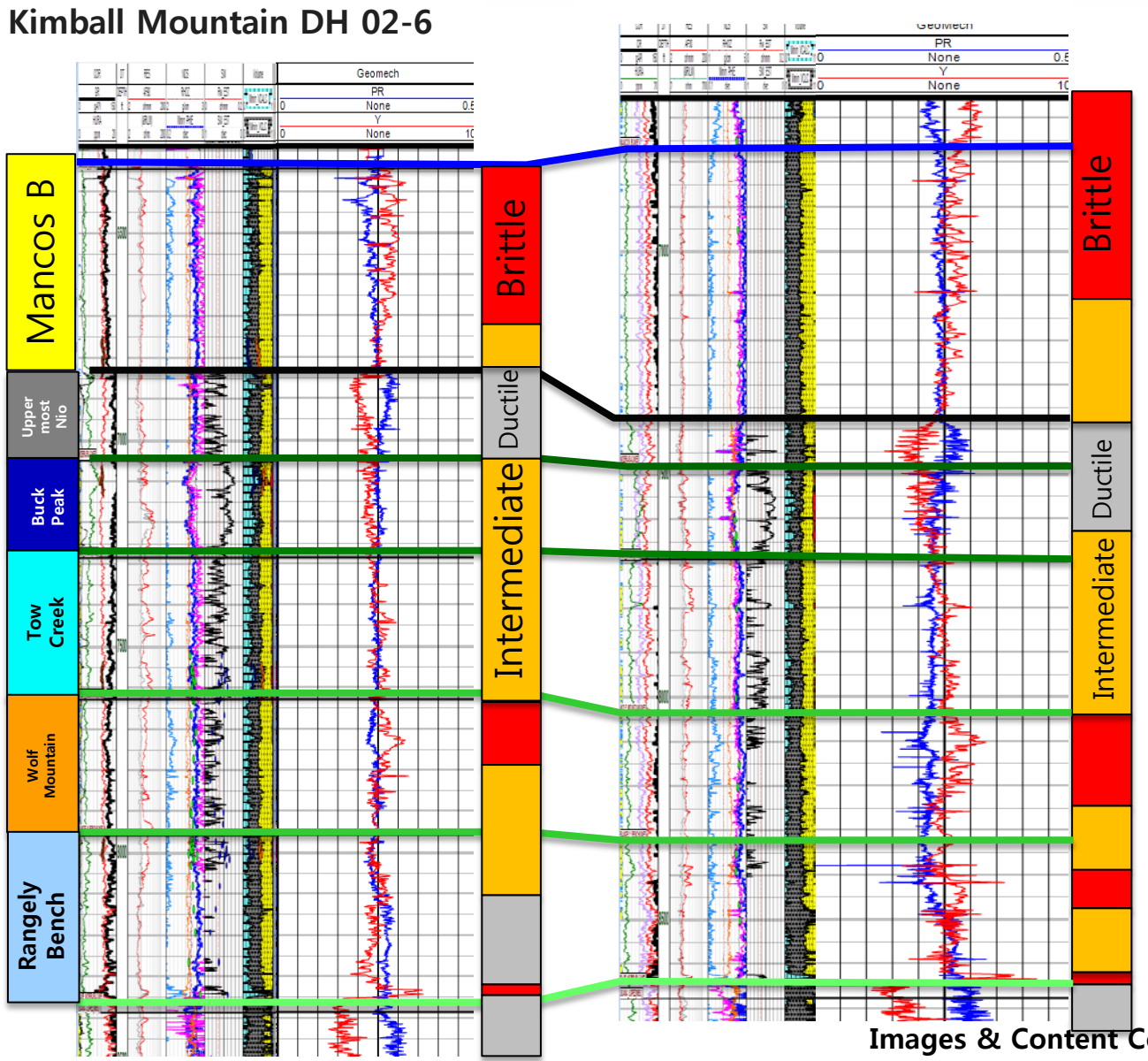
Cumella et al., 2014

Petrophysical Model Indicates Multi-bench Potential



Images & Content Courtesy of Caerus Piceance LLC

Favorable Geomechanical Properties in Calcite & Silica Prone Benches



- Most brittle intervals are Mancos B & Wolf Mountain, likely due to higher quartz content
- Least brittle intervals are "Uppermost Nio" and lower portion of Rangely Bench, likely due to higher clay content
- Lower Tow Creek target has similar intermediate brittleness in both wells, but Buck Peak target is less brittle in the Fed 24-16 well (closest proximity to Orchard)

Conclusions

- Mancos B is the most brittle and would likely frac well, but concerns remain about elevated water saturation and quality of pore networks
- Lower Tow Creek bench would likely respond better to a frac treatment than the Buck Peak in the Orchard Unit, potentially due to variations in organic matter
- Rangely Bench may also be a relatively brittle target, but lower hydrocarbon pore volume is a concern

Images & Content Courtesy of Caerus Piceance LLC

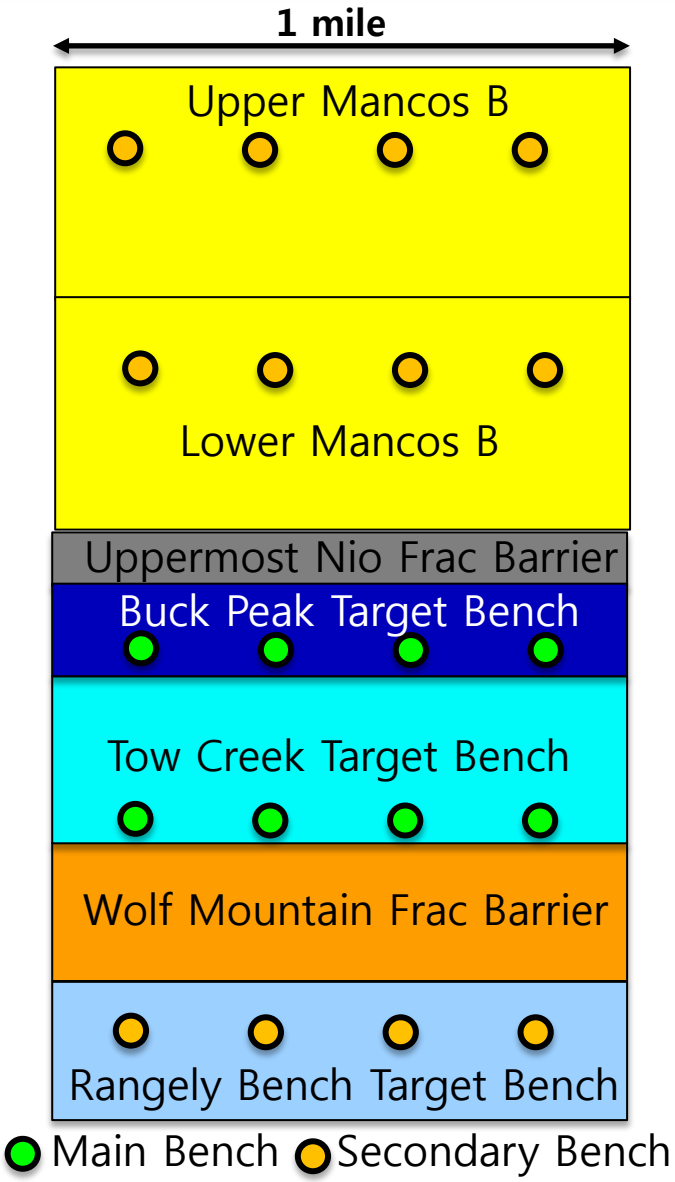
Orchard Niobrara & Mancos B Bench Summary

Poor to Fair RQ, Overpressured, Thick Stacked Pay, No Aquifers

Potential for a "Permian Basin of Gas"

Bench	Lithology	Thickness	Average Porosity	EUR (2 mile well, 200' Frac height)	Pressure (psi/ft)	Brittleness
Mancos B	Sandstones, siltstones & interbedded grey shales	1000'	6-8%*	5-35 BCF*	0.55	High
Uppermost Nio	Grey shales, siltstones & lenticular pelleted carbonates	125'	3-6%	2-10 BCF	0.55	Low
Buck Peak	Black shales, pelleted carbonates and siltstones	200'	6-8%	15-25 BCF	0.60	Moderate
Tow Creek	Grey shales, pelleted carbonates and siltstones	325'	5-7%	8-18 BCF	0.65	Moderate
Wolf Mountain	Siltstones, grey shales	290'	4-6%*	2-10 BCF*	0.65-0.68	High
Rangely Bench	Grey shales, pelleted carbonates and siltstones	300'	3-5%*	2-12 BCF*	0.65-0.68	Moderate

*More detailed petrophysical model needed to refine estimate



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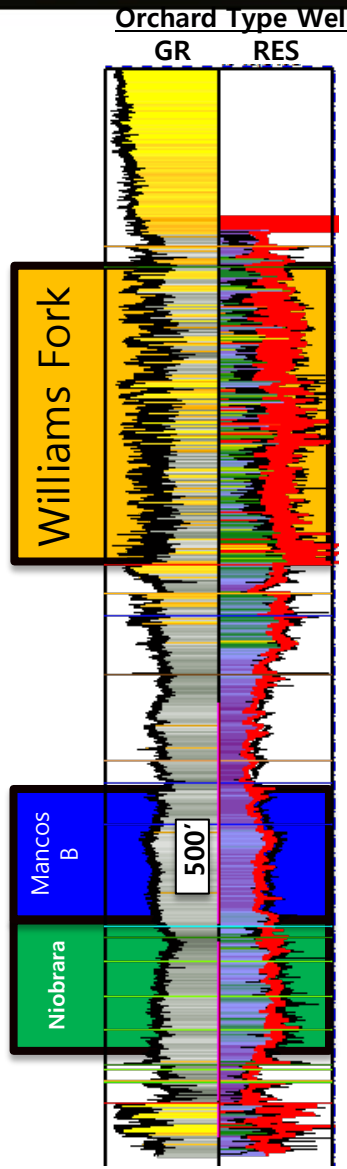
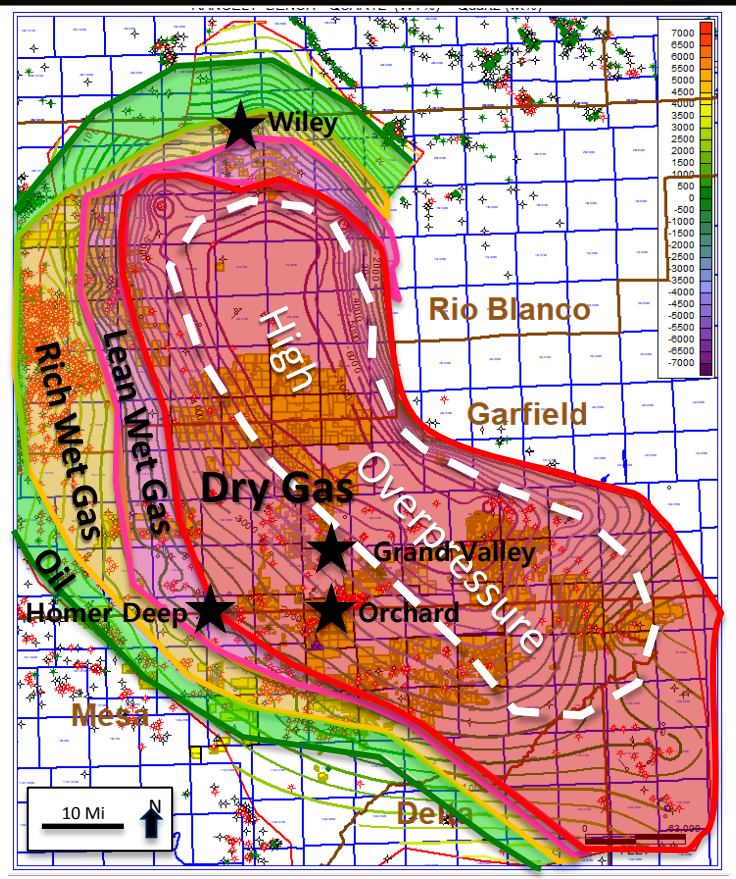
Niobrara/Mancos B Geologic Domains





Domain	BTU Content	CO2 Content	Pressure Profile (psi/ft)	Summary
Oil	1300 +	<1.0 %	0.43 -0.5	Favorable commodity price, but low production rates
Rich Wet Gas	1200 - 1300	1.0-1.5%	0.50 -0.5	Favorable commodity price, but low production rates
Lean Wet Gas	1100 - 1200	1.5-2.5%	0.55 -0.6	Neutral commodity price, but low to moderate production rates
Dry Gas	980-1100	2.5-3.5%	0.65 -0.8	Lower commodity price & higher CO2 content, but higher production rates
Dry Gas High Overpressure	<980	3.5% +	0.8+	Lower commodity price, higher CO2 content, challenging drilling, but highest production rates

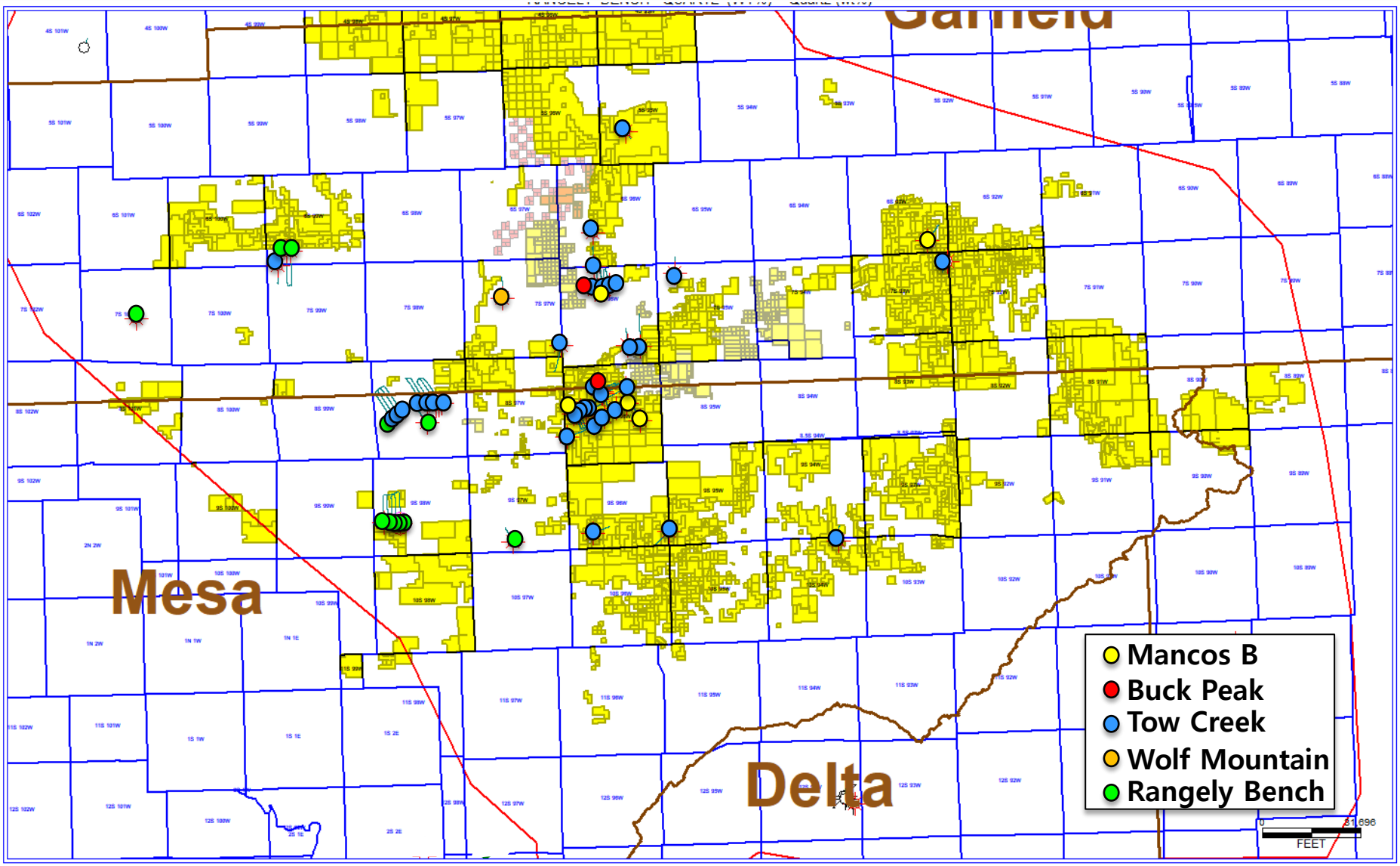
Images & Content Courtesy of Caerus Piceance LLC

Bottom line: The Niobrara dry gas play has lowest exploration risk, and best chance for high production rates & positive economics*

* Not everyone agrees with me on this; stay tuned…

Tow Creek = Main Horizontal Target

Mancos B, Rangely Bench = Second Target. Buck Peak = ~Untested Opportunity?

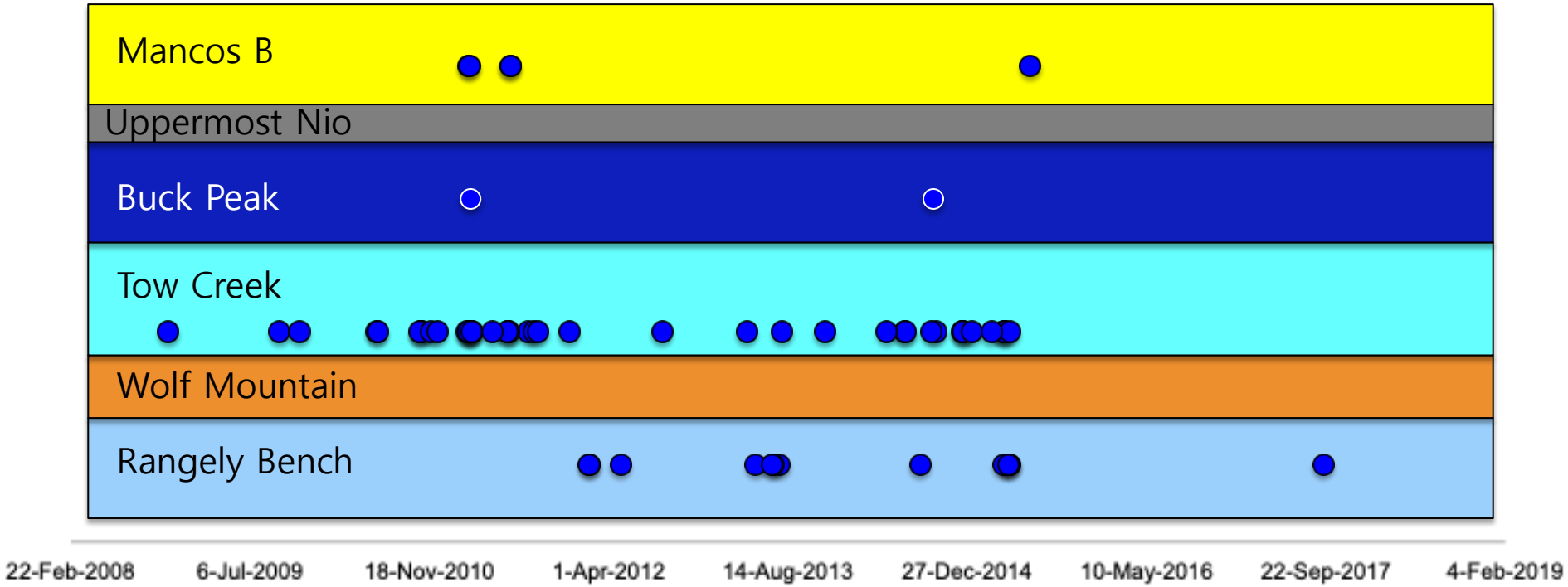


Images & Content Courtesy of Caerus Piceance LLC

Lower Tow Creek = Main Horizontal Target

Mancos B, Rangely Bench = Second Target. Buck Peak = ~Untested Opportunity?

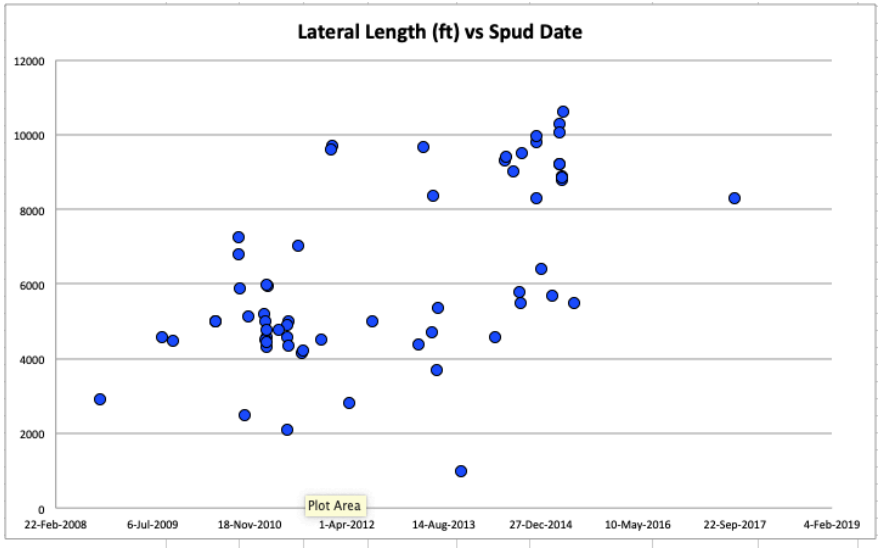
Target Bench vs Spud Date

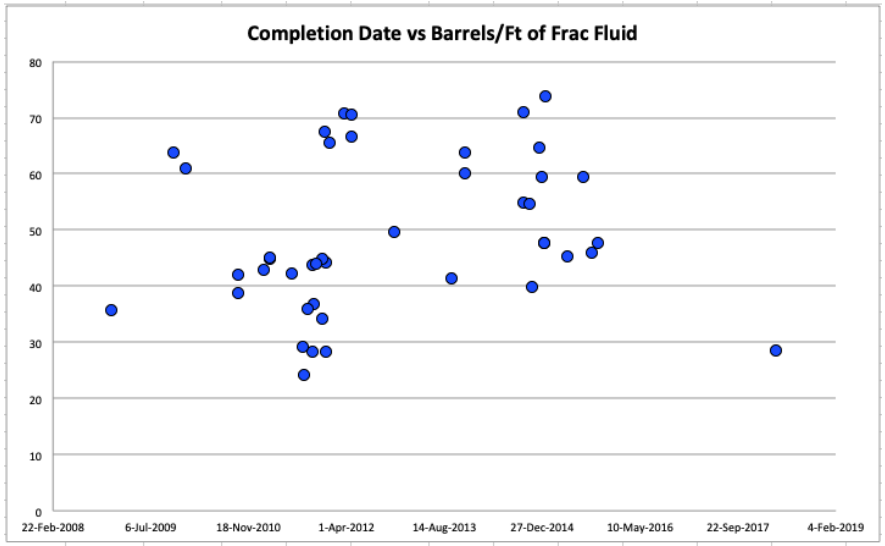


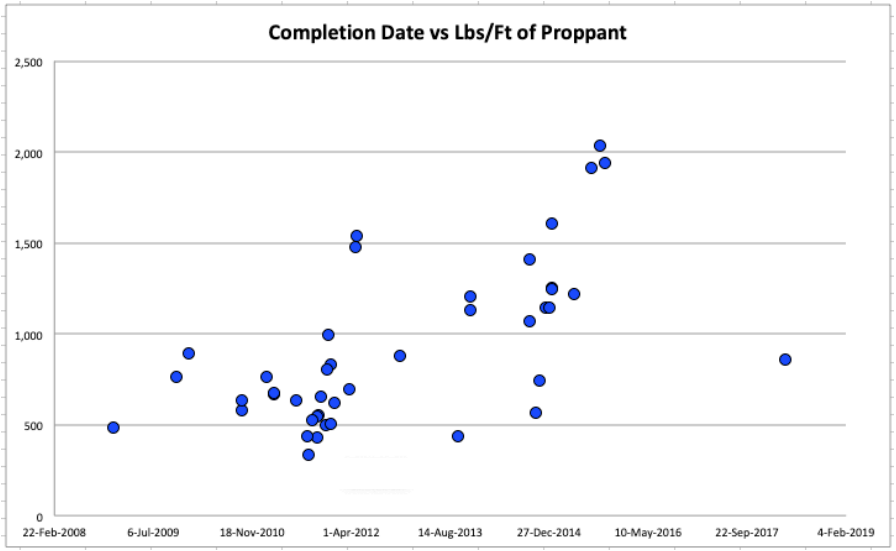
Content Courtesy of Caerus Piceance LLC

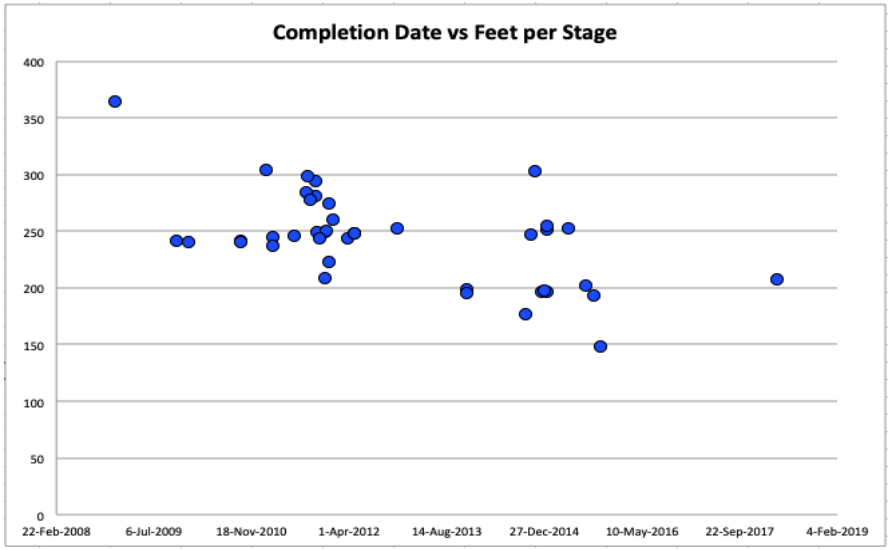
Nio Drilling & Completions Through Time

Longer laterals, higher frac intensity, tighter stage spacing







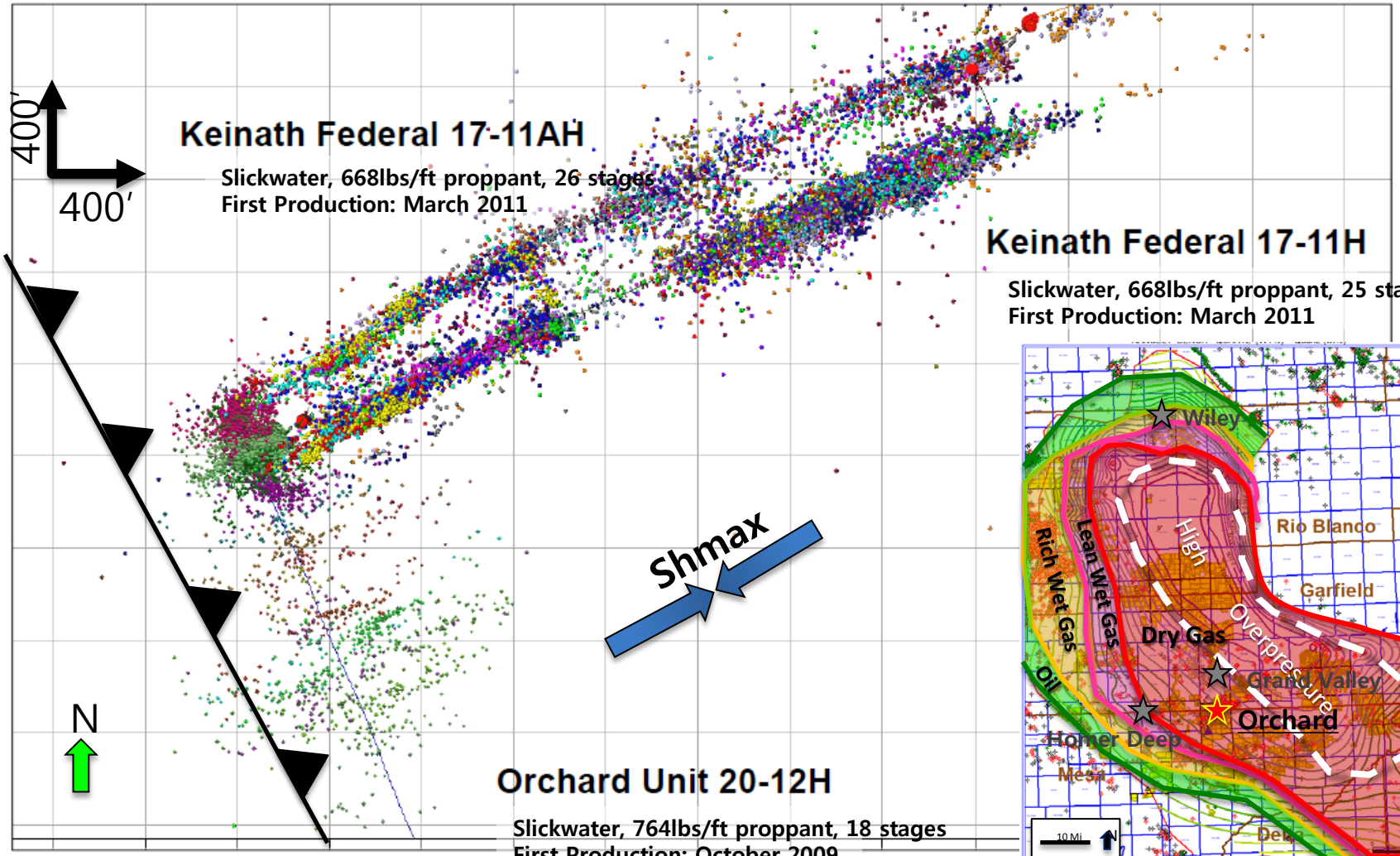


Images & Content Courtesy of Caerus Piceance LLC

Nio Case Study: Encana's Orchard Experiment

Longitudinal wells: interesting idea, poor result

Concept: Tightly spaced wells parallel to Shmax in folded/fractured area to maximize vertical growth and minimize interference with other laterals

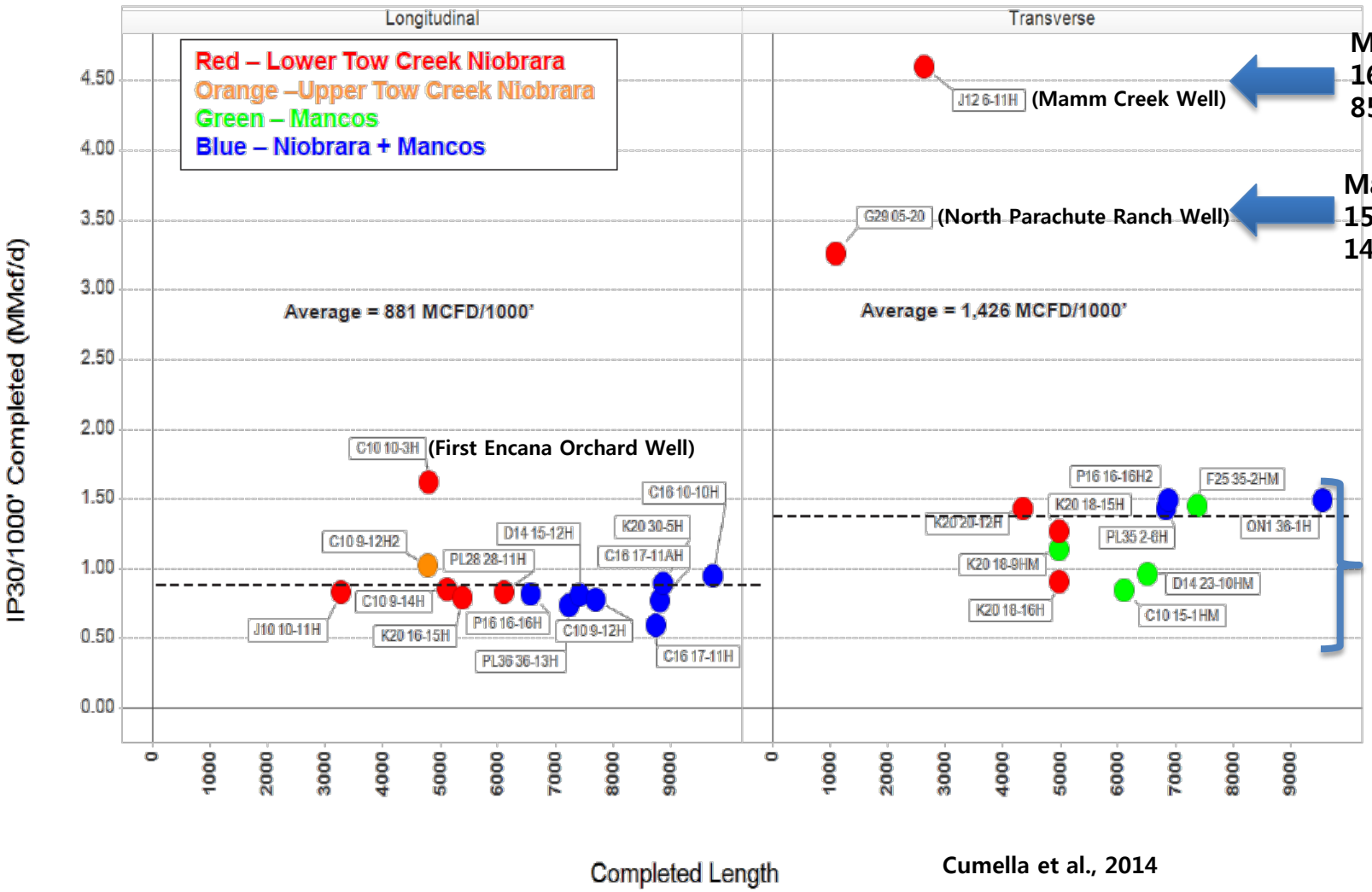


Images & Content Courtesy of Caerus Piceance LLC

Nio Case Study: Encana's Orchard Experiment

Longitudinal Wells: Interesting idea, poor result

Reality: Tranverse Wells Perform Better Than Longitudinal Wells



Max Mudweight: 16ppg
85 days to drill!

Max Mudweight: 15ppg
145 days to drill!

Max Mudweight: 12-14ppg
30-60 days to drill

Cumella et al., 2014

Nio Case Study: Black Hills Homer Deep Liquids Rim

Longer laterals & bigger fracs, with poor to moderate results

Well Name	Max MW (PPG)	Completed Lateral	Stages	Feet per Stage	Fluid (BBLS)	Total Proppant (LBS)	BBLS/FT	LBS/FT	Avg Daily Gas Production - 90 days (MMCFD)	Avg Daily Oil Production - 90 days (BOPD)
Homer Deep 9-41AH	12	8242	42	196	532360	9418933	65	1143	5.5	0
Homer Deep 9-41BH	12	9842	50	197	726783	15776109	74	1603	5.9	0
Homer Deep 9-41CH	12	9118	46	198	542987	10452798	60	1146	6.2	0

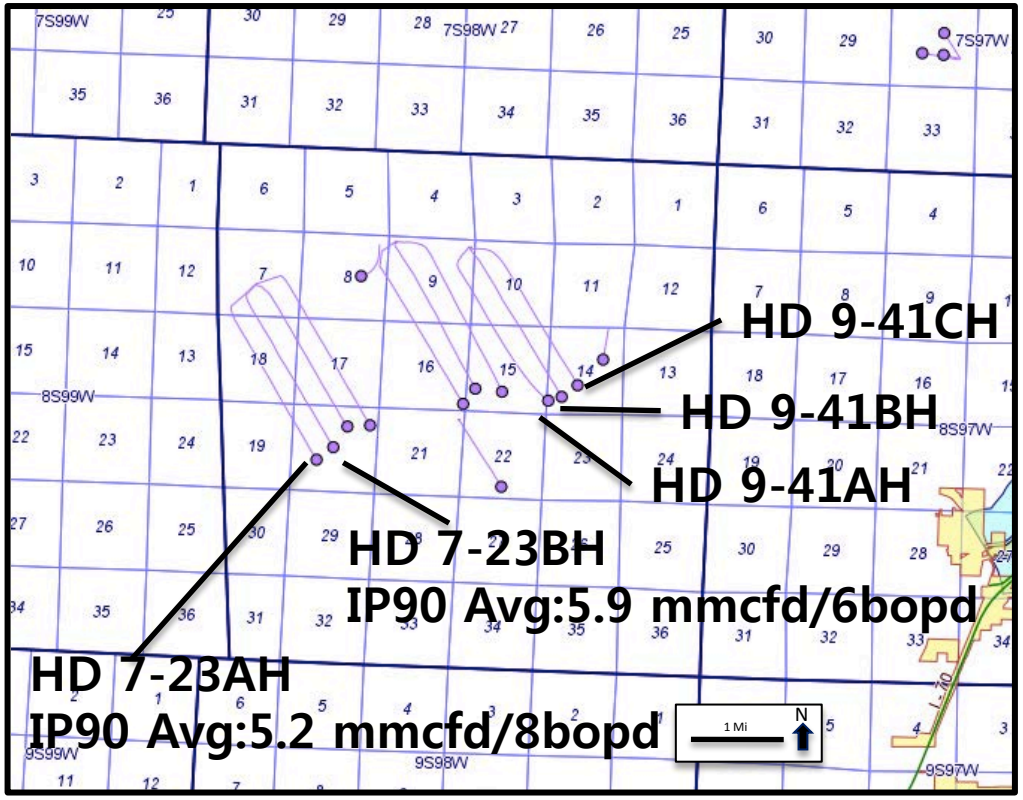


Image Courtesy of COGCC

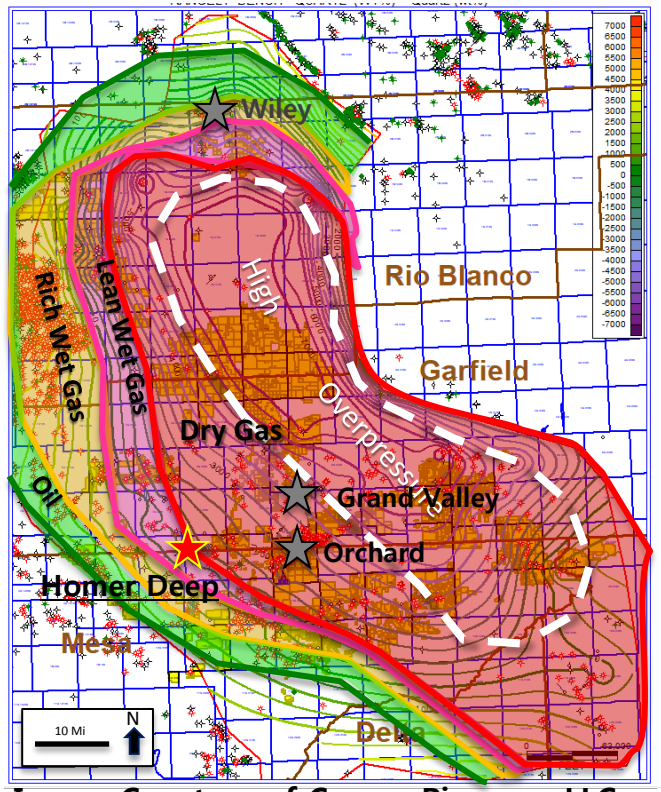
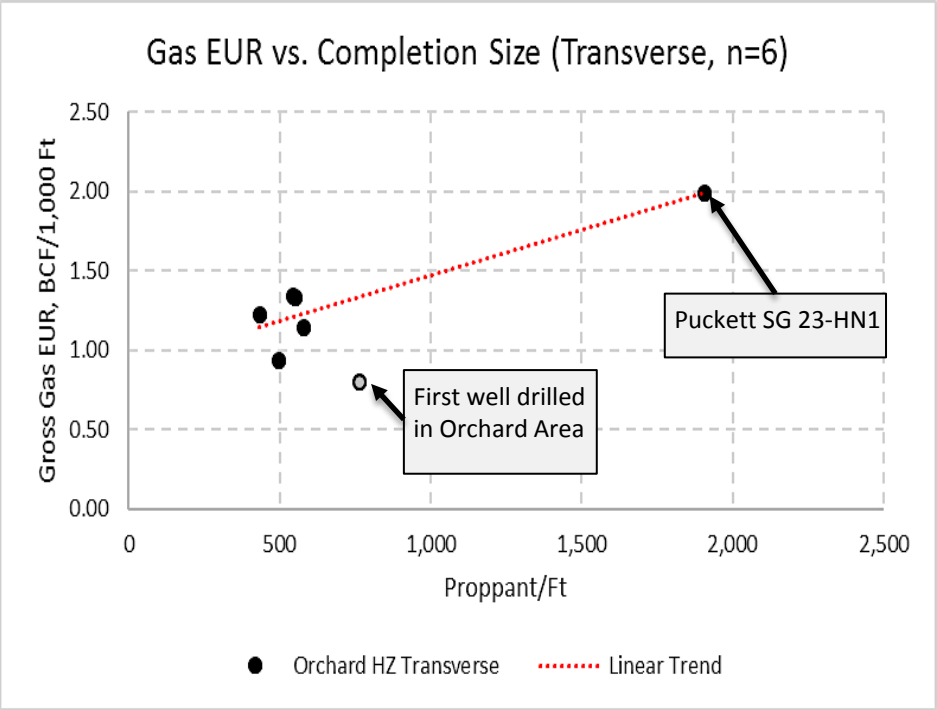


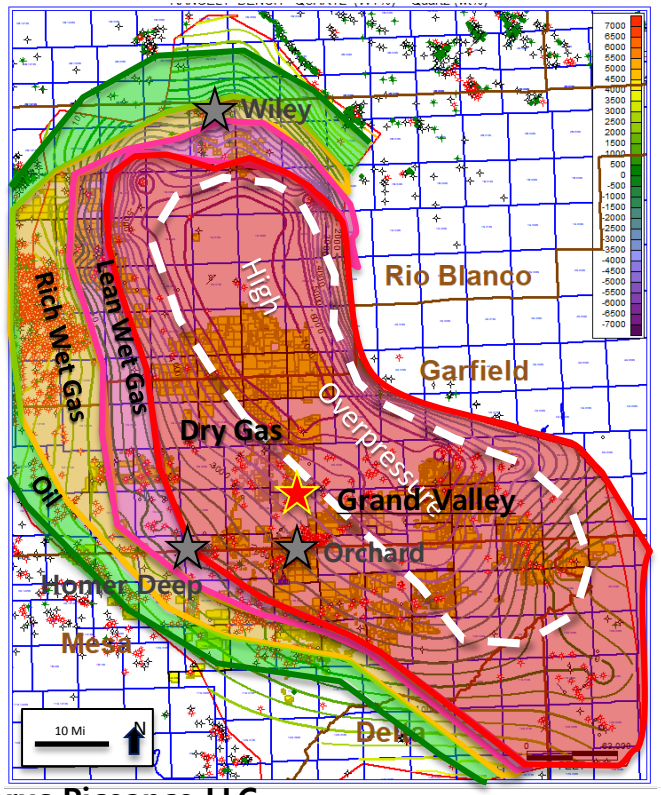
Image Courtesy of Caerus Piceance LLC

Nio Case Study: WPX High Pressure Puckett Gas Well

Encouraging results from one of the biggest fracs to date

Well Name	Max MW (PPG)	Completed Lateral (FT)	Stages	Fluid (BBLS)	Total Proppant (LBS)	FT/Stage	BBLS/FT	LBS/FT	Avg Daily Gas Production - 90 days (MMCFD)	Avg Daily Oil Production - 90 days (BOPD)
Puckett SG 714-44-23-HN1	15.2	8906	44	529173	17003411	202	59	1909	12.8	1.2





Images & Content Courtesy of Caerus Piceance LLC

Nio Case Study: Endeavour/Augustus Liquids Play

Higher pressure liquids window, moderate production rates; understimulated(?)

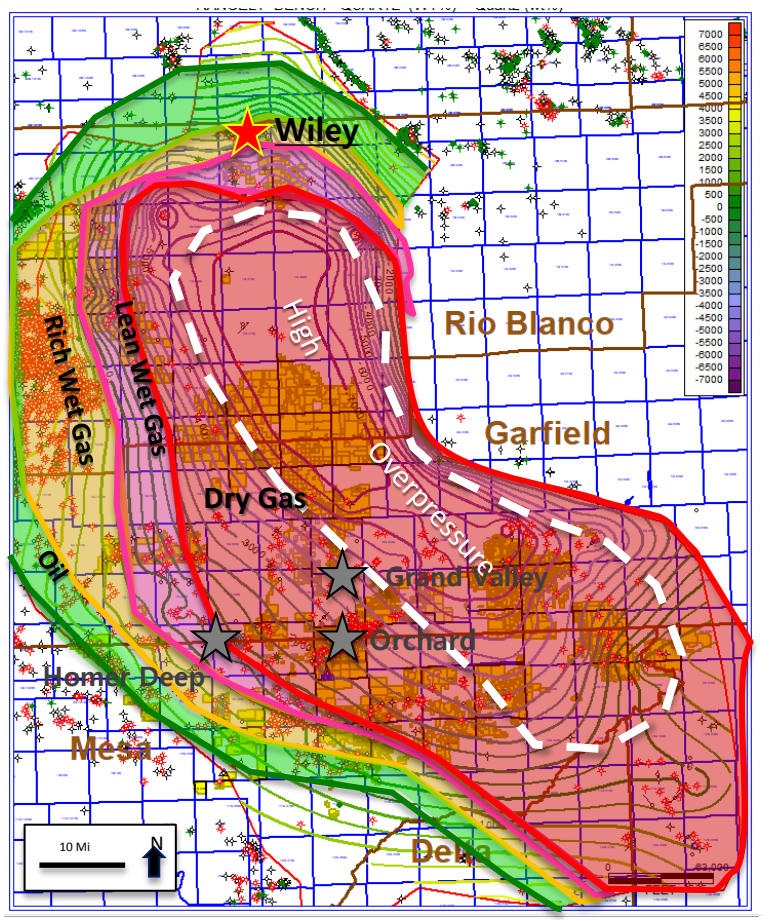
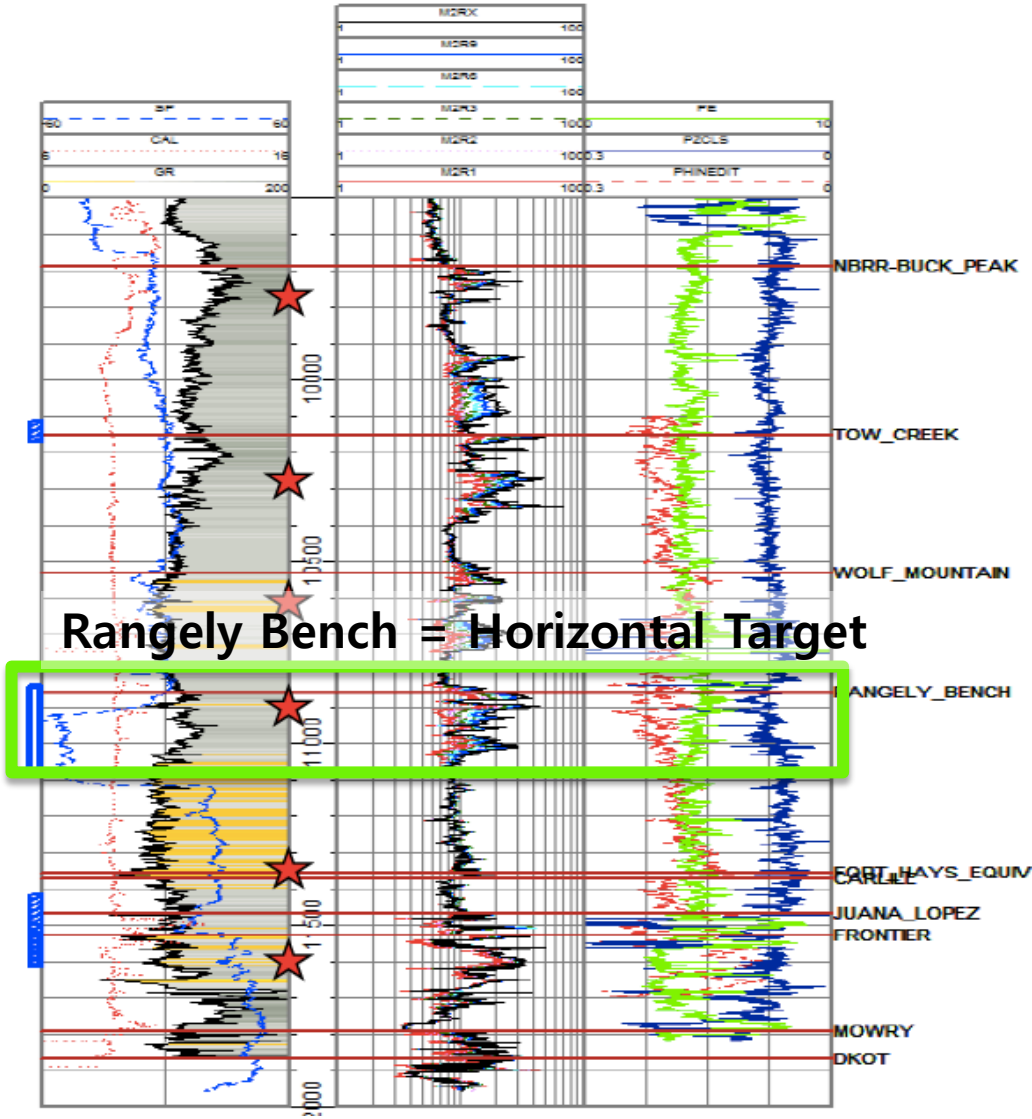


Image Courtesy of Caerus Piceance LLC



Type Log Courtesy of Augustus Energy Partners II, LLC

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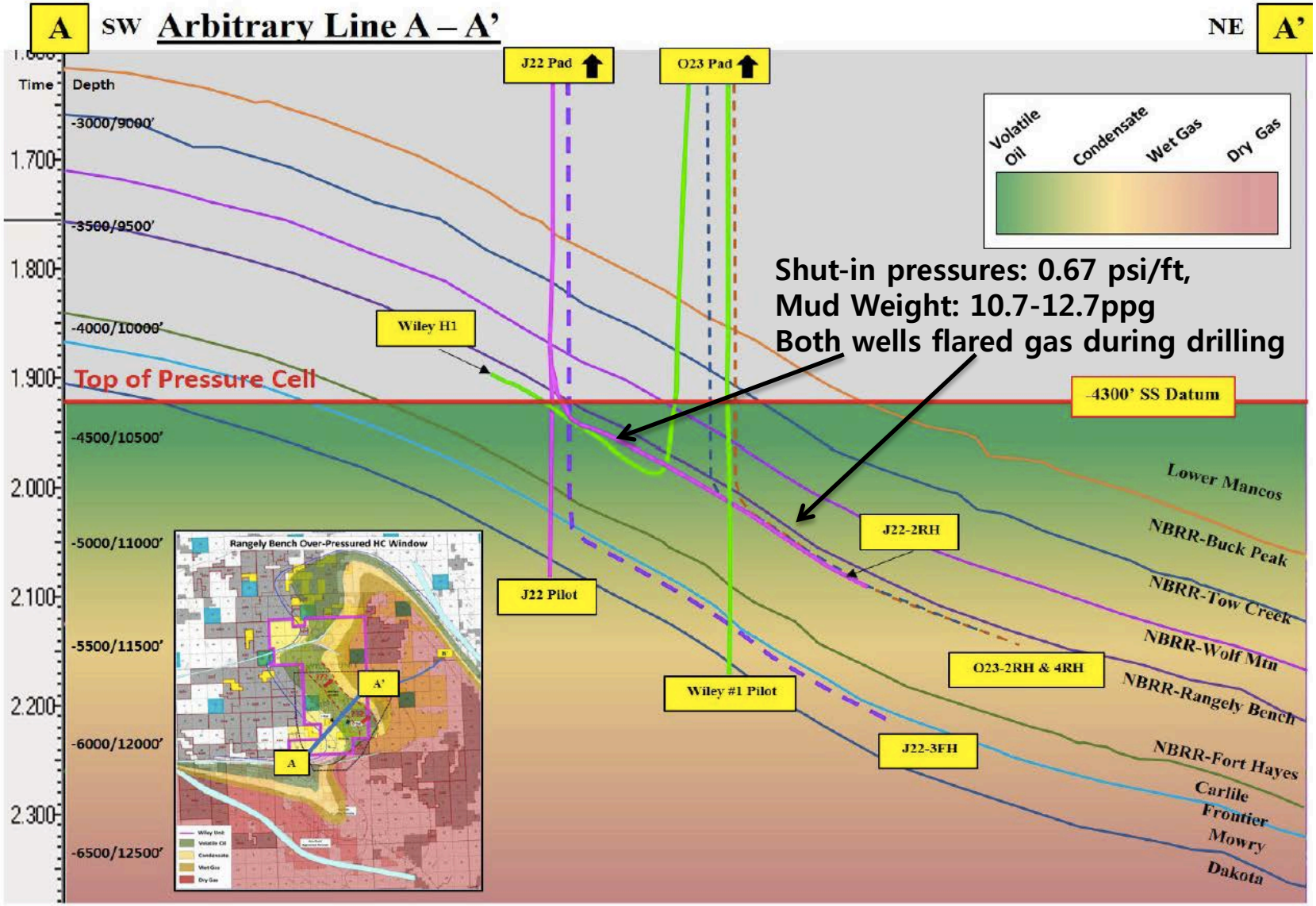

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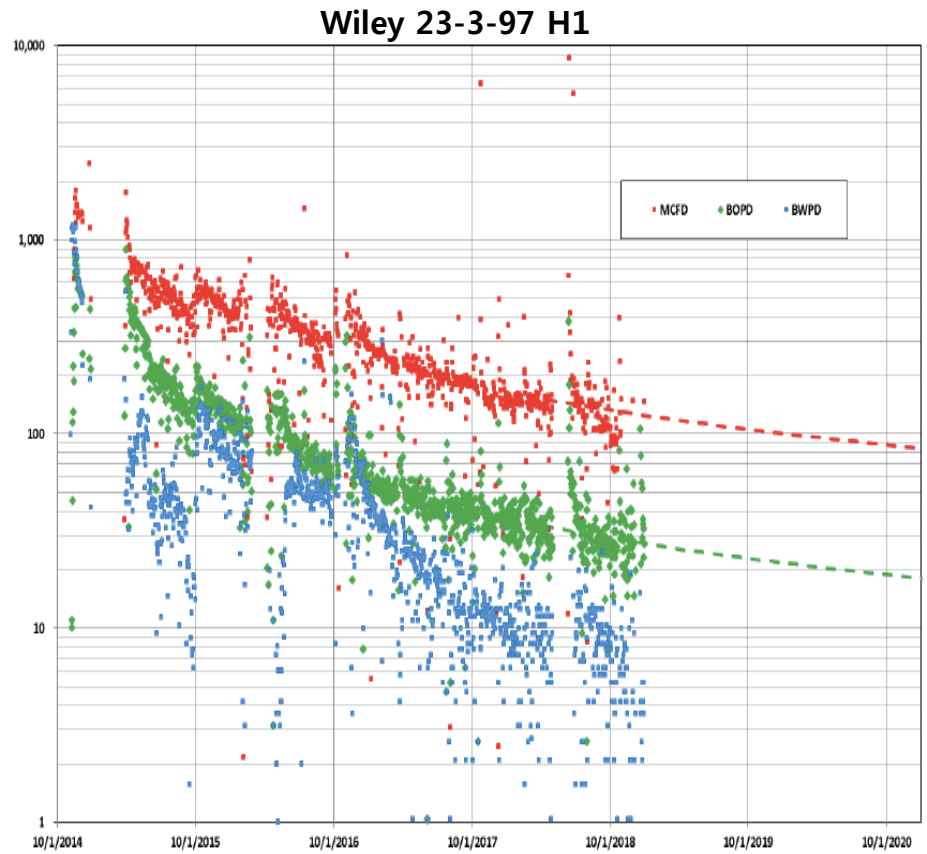
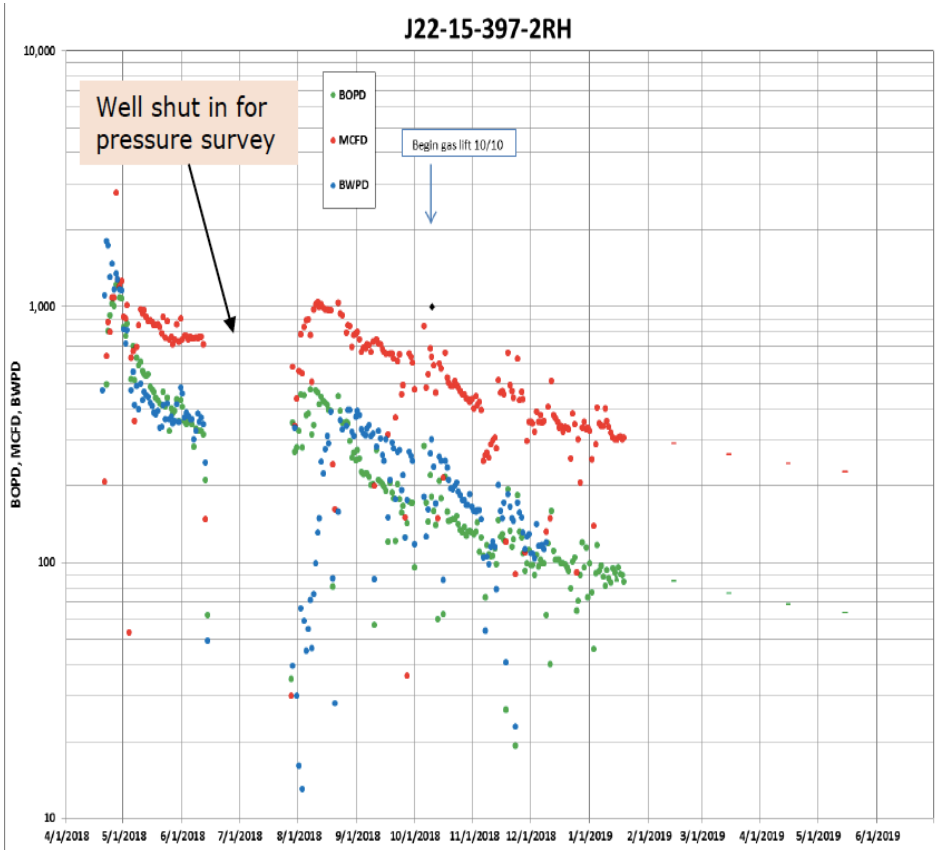
Wiley 23-3-97 H1	11.8	4,940	20	247	269,551	Slickwater	2,809,770	247	55	569	0.82	366
J22-15-397-2RH	12.8	8,300	40	207.5	237000	Hybrid	7,140,000	207.5	29	860	0.84	516





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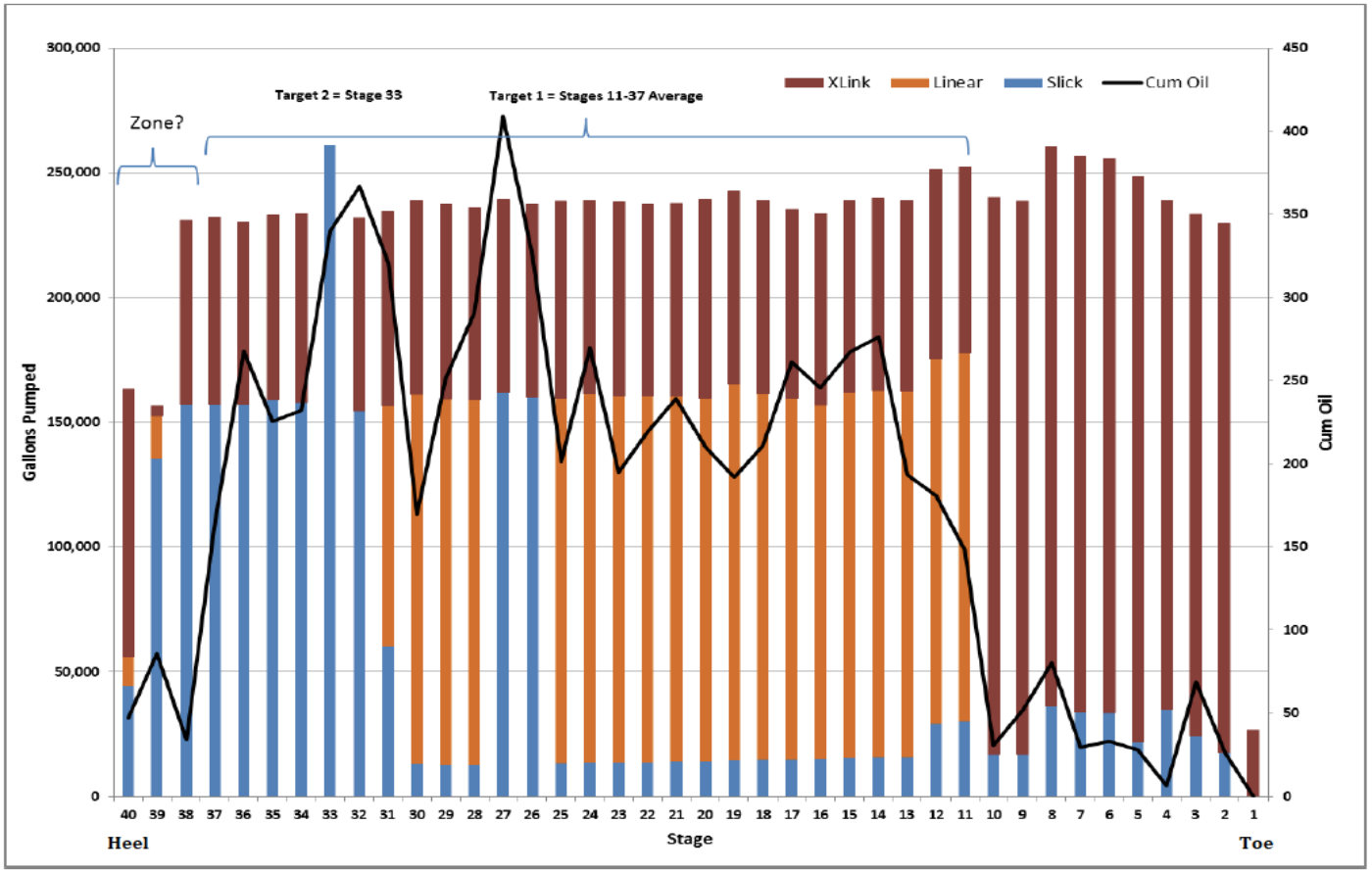


Images & Content Courtesy of Augustus Energy Partners II, LLC

- J22 well: Hybrid frac with mix of Xlink Gel, Linear Gel and Slickwater
- Injected tracers indicate clear trend of higher production in slickwater stages
- Augustus uses slickwater fracs in PRB as analog for predicted uplifting in future slickwater completions
- Augustus believes 2 mile HZ with 2000#/Ft will yield 1500 bopd in Rangely Bench in their future well(s)

Future Piceance Nio Activity

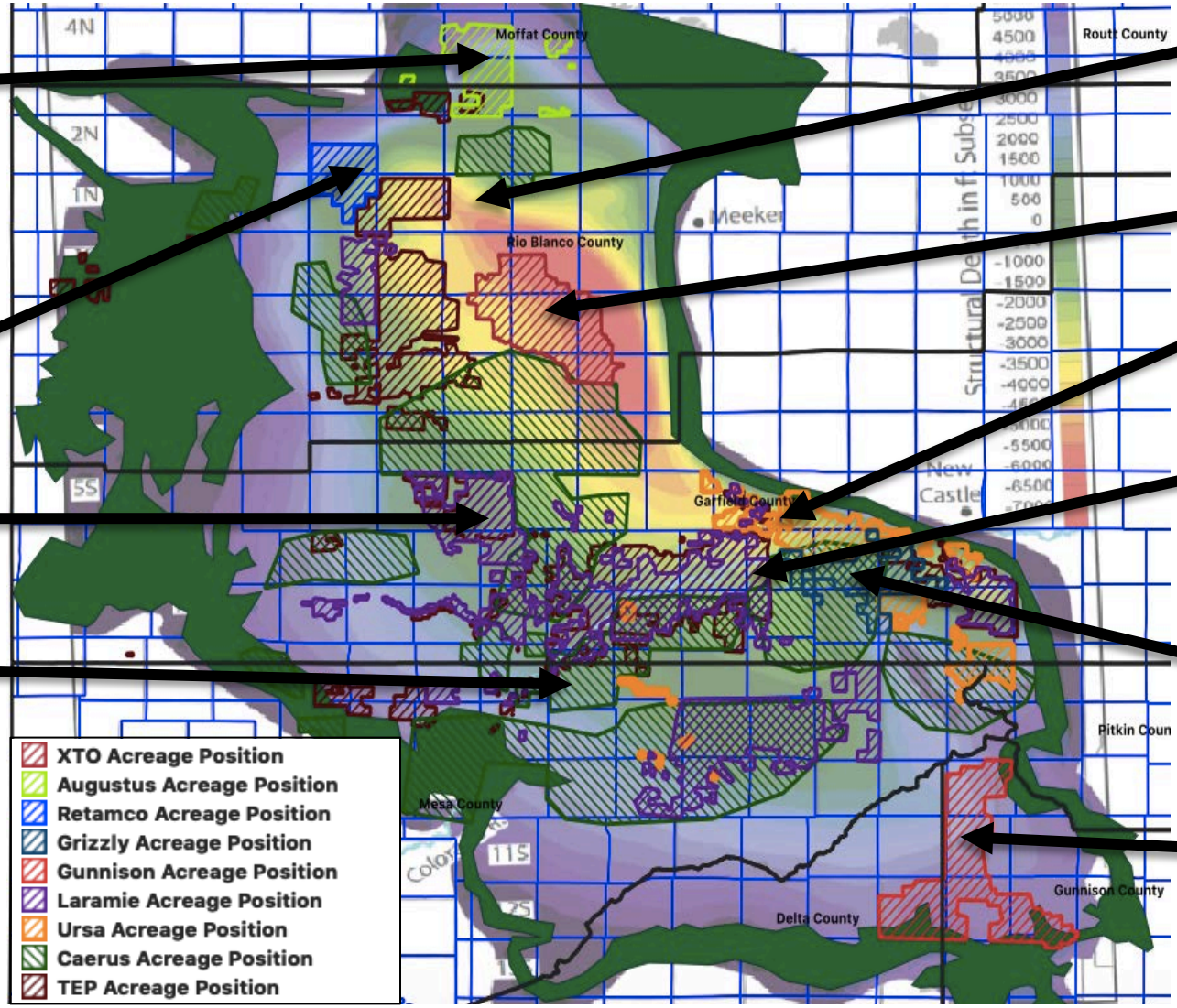
Piceance Operators + Leibovitz Rollins Structure Map (2012)

Augustus Energy
- Actively seeking partner
- Wants to drill 3 HZs in next year
- 2 HZs in Rangely Bench, 1 HZ in Frontier
- 3 wells permitted, 1 pending

Retamco Operating
- Actively seeking partner
- Plans to drill vertical pilot hole in 2020
- Wants to drill HZ target (Rangely Bench?) in 2021
- No wells permitted at this time

Laramie Energy
- No Nio plans at this time

Caerus Operating
- Actively seeking partner
- Wants to shoot 3D seismic at Orchard, then drill 4 pilot development of horizontal wells (Tow Creek or Buck Peak)



Anschutz Exploration
- No known Nio plans at this time
- 6 approved HZs, 2 pending HZs

XTO Energy
- No known Nio plans at this time

Ursa Energy
- No Nio plans at this time

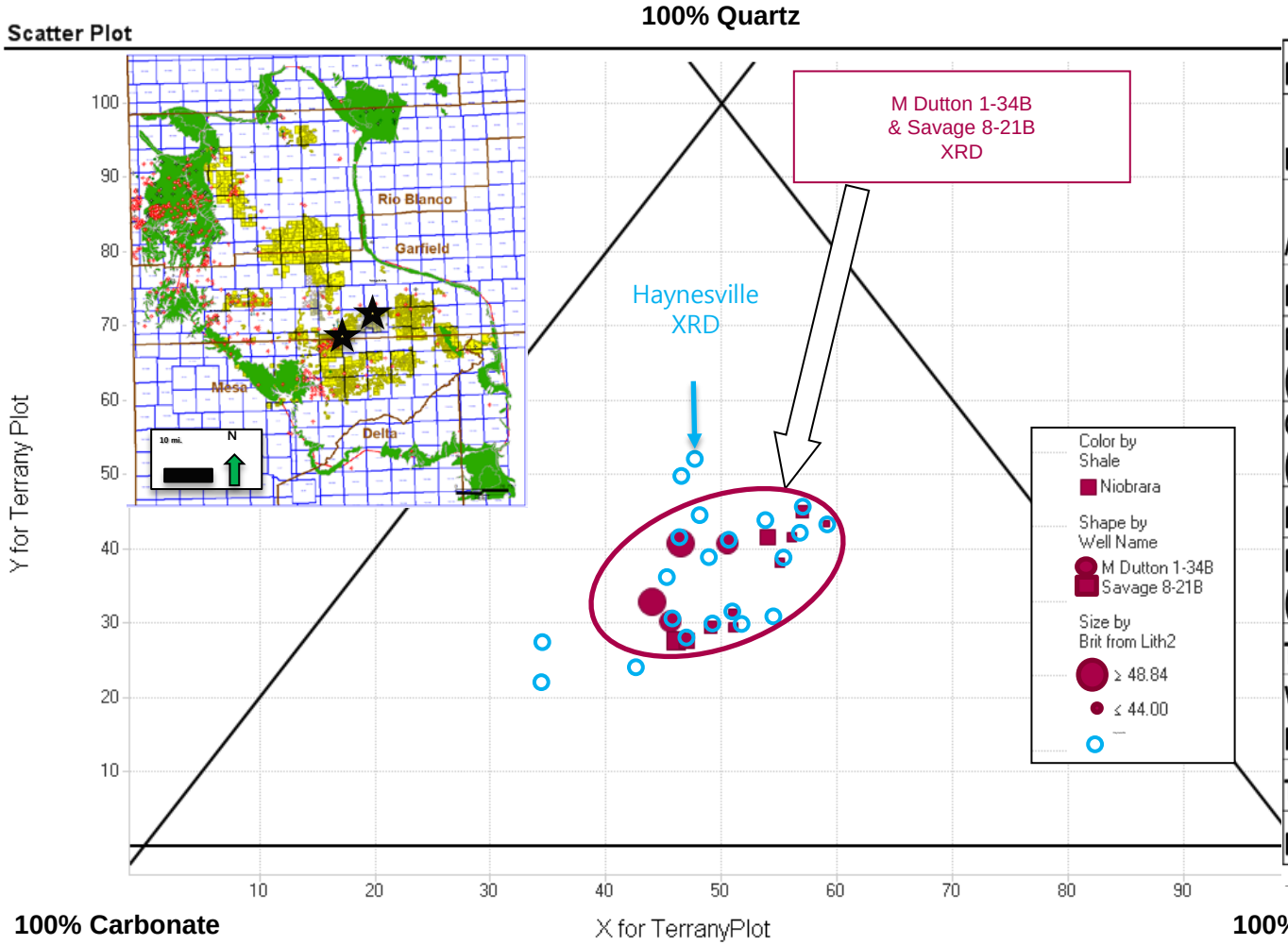
Terra Energy Partners
- No Nio plans at this time

Grizzly Energy
- Formerly Vanguard, just emerged from Chapter 11 bankruptcy
- No known Nio plans at this time

Gunnison Energy
- Wants to drill 5 horizontals by EOY 2020
- Main target is Rangely Bench, +/- Wolf Mountain

Haynesville = Useful Niobrara Gas Reservoir Analog

S. Piceance XRD Indicates Similar Clay/Quartz/Calcite Content + Dry Gas + Overpressure



Property	Haynesville
Location	E. Texas/W. Louisiana
Age	Upper Jurassic
Depth (feet)	10000-14000
Net Thickness (feet)	200
Gross Thickness (feet)	200
Pressure (PSI)	8500
Pressure gradient (PSI/ft)	0.8-0.95
TOC (%)	3
Vitrinite Reflectance (%Ro)	2.2
Total Porosity (%)	8.5-10
BHT (Degrees F)	340

Haynesville = Useful Niobrara Gas Reservoir Analog

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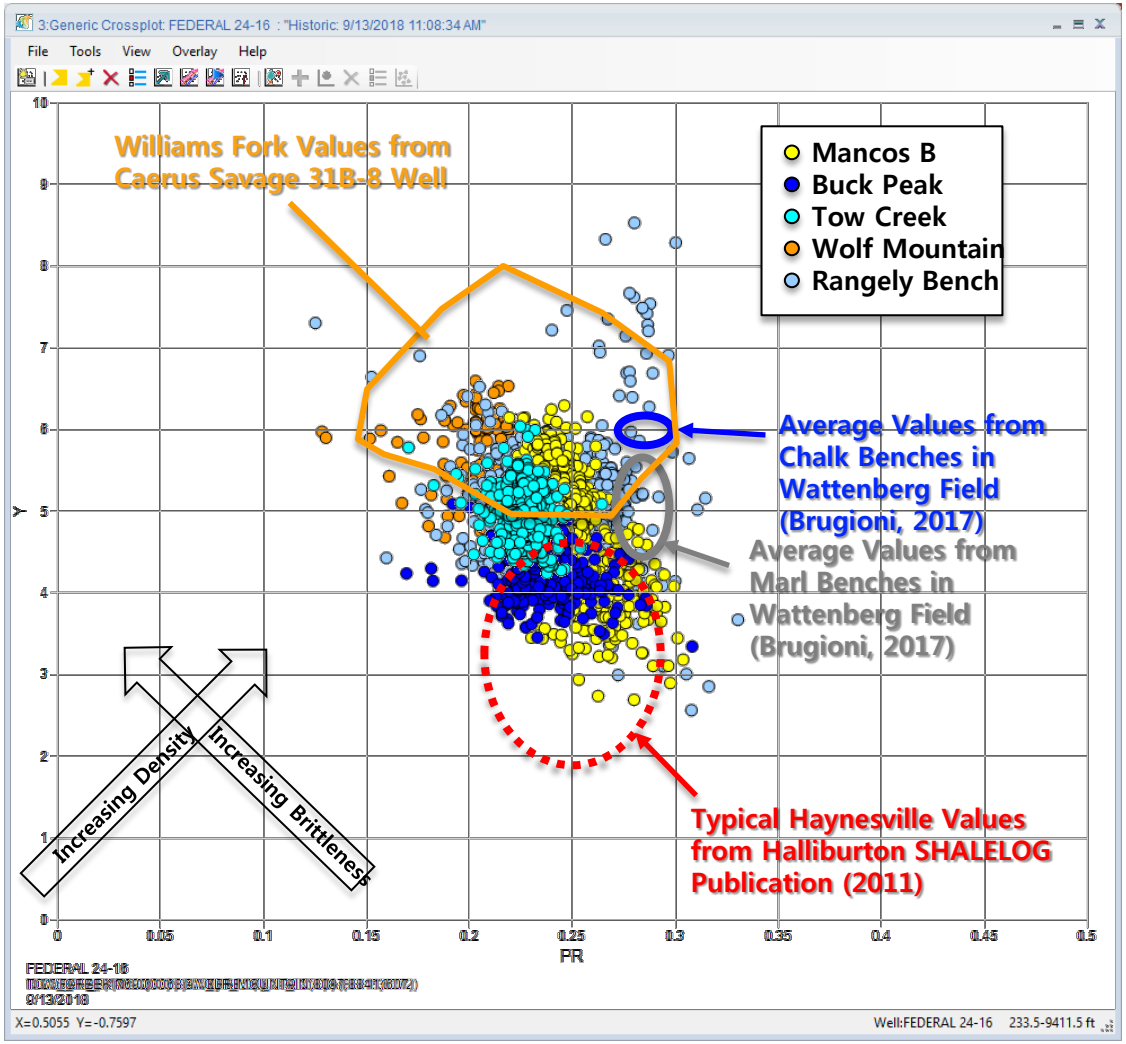
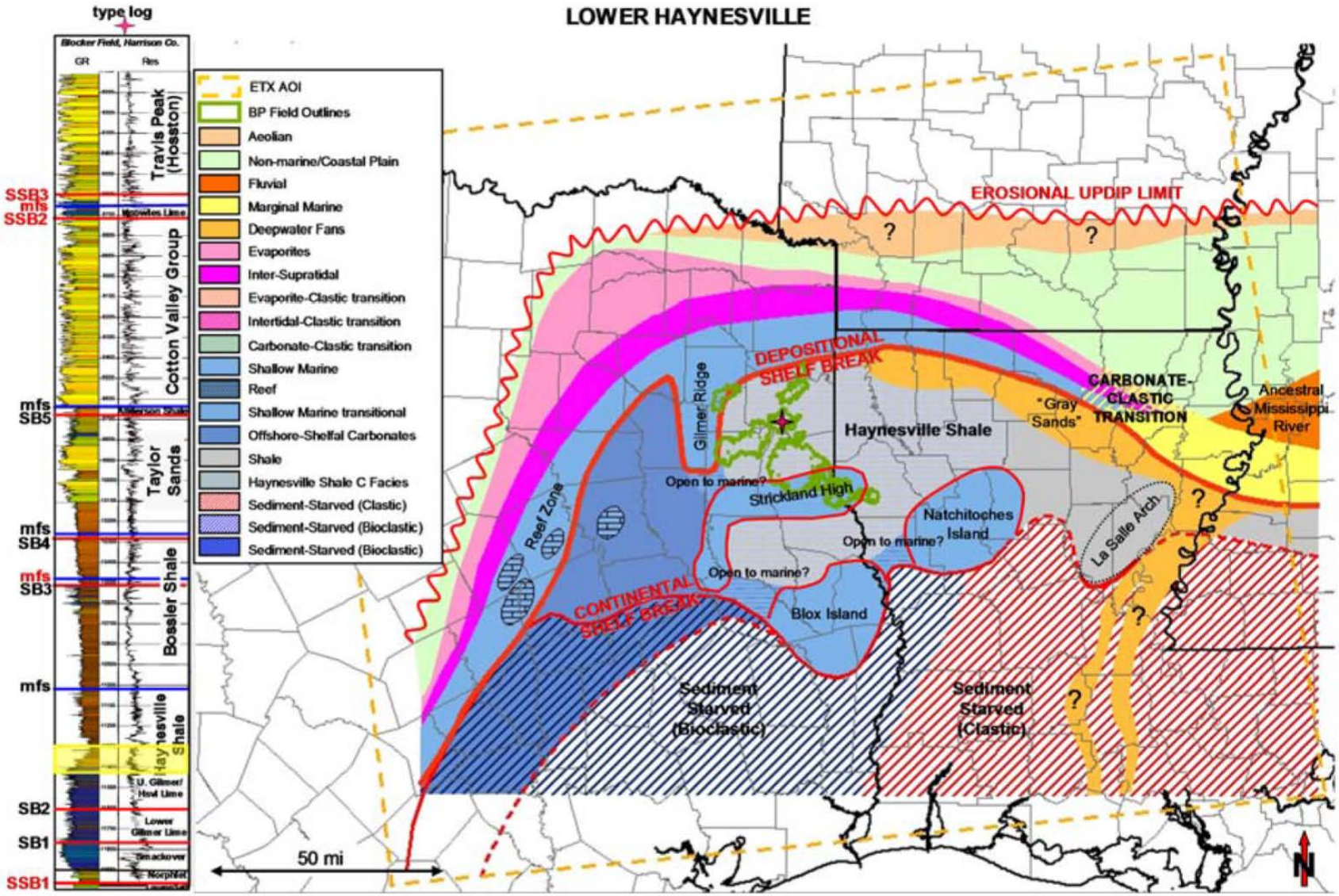


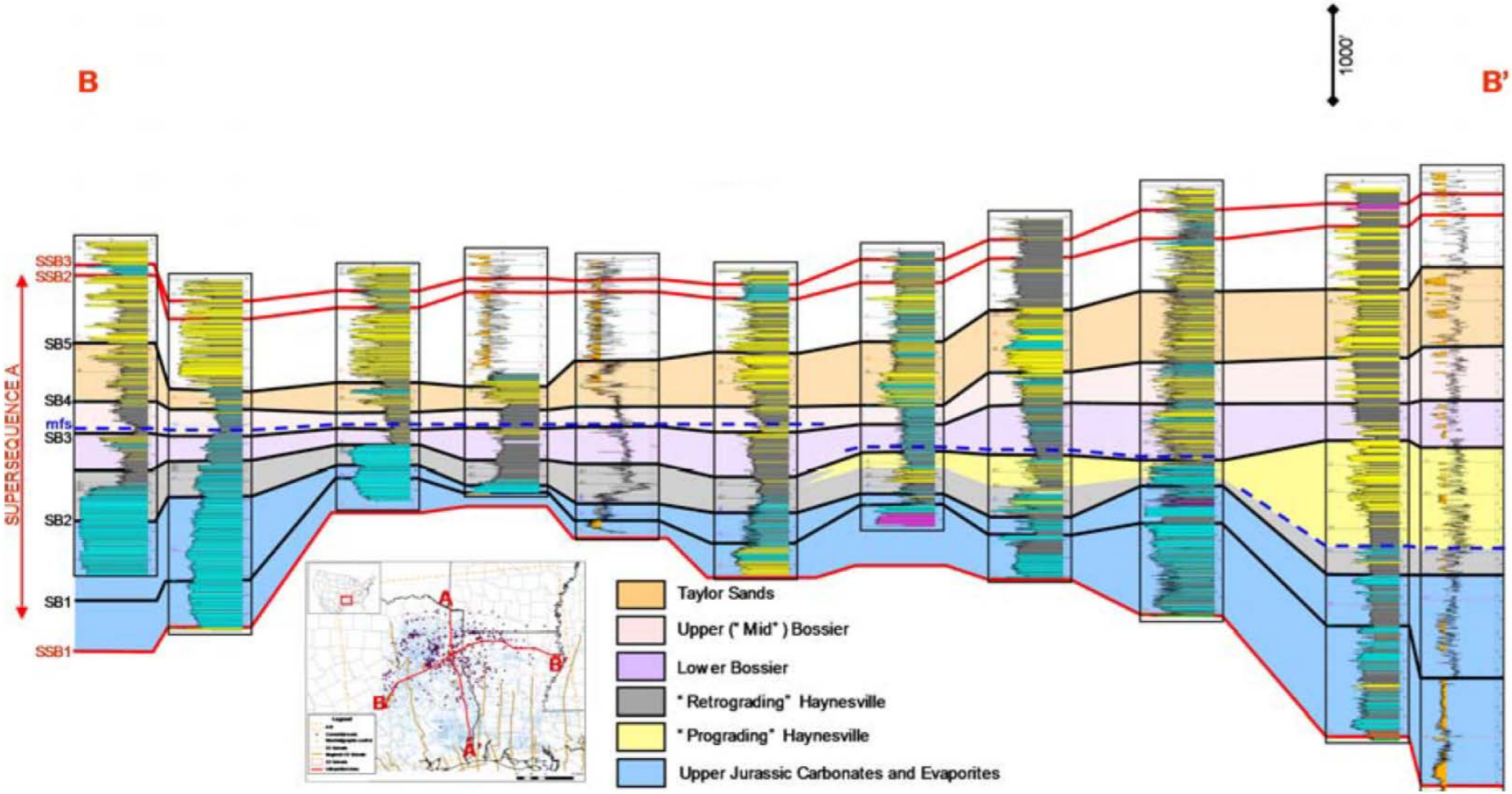
- Intervals with highest degree of brittleness are Wolf Mountain, Tow Creek, Rangely Bench & Mancos B
- Intervals with lowest degree of brittleness are Buck Peak & Uppermost Nio
- Overall, the Niobrara section in this well appears to be more brittle than Haynesville, comparable to the DJ Niobrara, but less brittle than the Williams Fork formation
- Williams Fork is far more brittle than the key Niobrara benches, indicating that proppant less fracs would not work in Niobrara horizontals

Haynesville Paleogeography: Varying Carbonate/Clastic Content



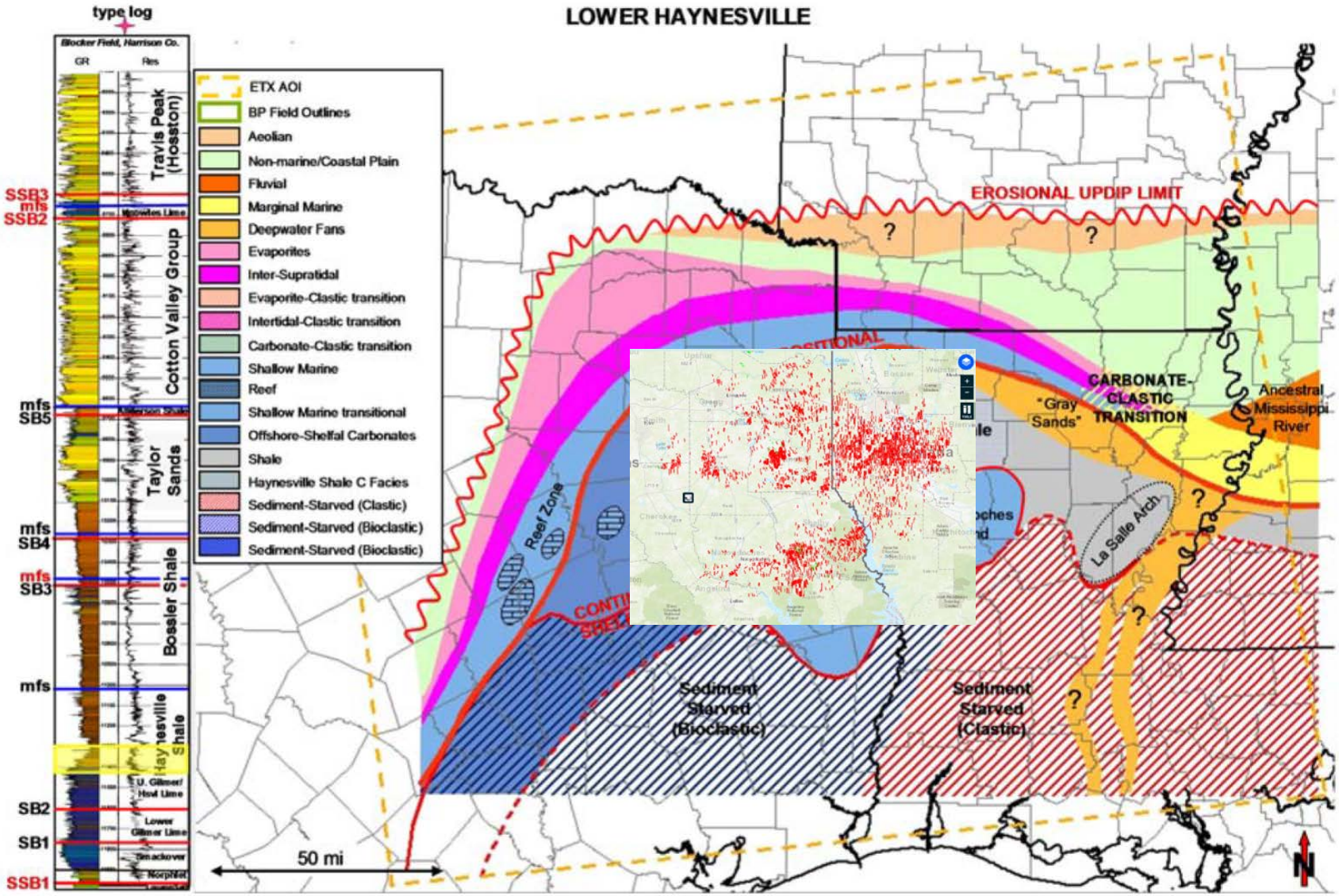
Cicero et al., 2010

West to East Lithologic Transition



Cicero et al., 2010

Haynesville Paleogeography: Varying Carbonate/Clastic Content



Cicero et al., 2010

Next Steps: Use DI Data for “Res-Frac” Analog

- Piceance Niobrara play has been “frozen in time”, and modern well completions in dry gas intervals are non-existent since 2015
- Haynesville shale has similar lithologies, temperatures, pressures and drilling depth, and represents a useful frac analog
- Using Haynesville data, we could be able to quantify:
    - Predicted improvements from newer reservoir stimulation with longer laterals, higher frac intensity, frac fluid types, narrower stage spacing, etc.
    - Differences in reservoir performance in marly vs. silty Haynesville lithologies
- Bossier shale may also be a useful analog for the silty Mancos B reservoirs of the Piceance basin
- Powder River Basin Niobrara depositional environment appears analogous to Piceance Nio play; fewer wells, but may yield insight into best frac techniques for overpressured liquids window on northern margin of Piceance basin

Conclusions

Tremendous potential exists within the Piceance Basin Niobrara play, but updated completion design & improved commodities prices are crucial to "un-freezing" this basin

- Most horizontal development targeted the lower Tow Creek and Rangely Bench in the dry to wet gas window
- Majority of existing horizontal well bores produce from ~1 mile laterals with <700#/ft of proppant; newer completion design should provide significant uplift to initial and long term production rates
- Commercial rates have been demonstrated in some of the overpressured gas HZ wells, but the liquids-rich HZ wells have not yet been proven (remedied by overpressure + slickwater + more proppant?)
- If suitable completion strategy can be identified, there are 3-5 target benches within the Niobrara/Mancos B succession, and perhaps even more below

So, When Will The Piceance Nio Play Be Unfrozen?

Not sure, but improved drilling & completions improvements and commodities price support,
This can be avoided…

Piceance Basin Basin During Niobrara Times:

Deepwater setting at crossroads of clastic/carbonate sedimentary systems