Targeting Mechanical Facies in the Green River Basin to Improve Completions Strategies*

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Search and Discovery Article #42295 (2018)**
Posted October 15, 2018

*Adapted from oral presentation given at 2018 AAPG Annual Convention & Exhibition, Salt Lake City, Utah, May 20-23, 2018
 DOI:10.1306/42295Havens2018

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Abstract

Drilling vibration monitoring has been used in the Green River Basin to estimate the elastic properties along a series of vertical wells to improve targeting of pay sands and increase perforation efficiency. The mechanical properties provide an assessment of pay sands independent of the traditional Gamma Ray pay determination for each individual well. In many cases hotter Gamma Ray zones have shown low Poisson's ratios in line with the expected response of reservoir sands, and when produced, demonstrate high reservoir quality.

The standard operating procedure field-wide is to use Gamma Ray and mud gas to pick producible multi-stage completion units within each formation and target these areas with hydraulic fracturing. However, due to radioactive minerals and clays in some of the formations, Gamma Ray and even other log curves, are not always a reliable indicator of reservoir sands. Without the independent mechanical information, pay zones would have been bypassed during completions. Sidewall core measurements confirm the higher Gamma Ray readings with favorable mechanical properties are target worthy facies.

Determining vertical, multi-stage hydraulic fracture boundaries is difficult in fluvial dominated systems. Traditionally stage boundaries are picked geometrically based on a gross stage height of 200-250' with minimal effort placed on identifying fracture barriers between stages in the relatively homogenous looking log character of the overbank mudstones. Using the down-hole, drilling-derived mechanical properties, we are able to identify barriers to fracture height growth and more properly determine appropriate stage placement and distribution within the vertical well.

By isolating zones based on mechanical facies rather than the Gamma Ray response, the perforation efficiency has been increased when compared to standard well performance in the area. Production is still in the early stages, but initial readings indicate the wells completed based on mechanical facies are within the upper quartile of the field. With more initiated perforation clusters the well should have better contact with the reservoir, and produce higher yields over time. With the industry focused on completions strategies in unconventionals, this study may serve as an endmember showing the uplift that is possible when hydraulic fracture stages are adjusted to target mechanical facies rather than applying geometric completions or using radioactivity as a proxy for mechanical variability.

References Cited

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Meyer, Thomas, Stephen R. Kneller, Robert McDermott, and Mark Longman, 2014, Geology of the Lance Pool, Pinedale field, *in* M. Longman, S. Kneller, T. Meyer, and M. Chapin, eds., Pinedale field: Case study of a giant tight gas sandstone reservoir: AAPG Memoir 107, p. 61-116.

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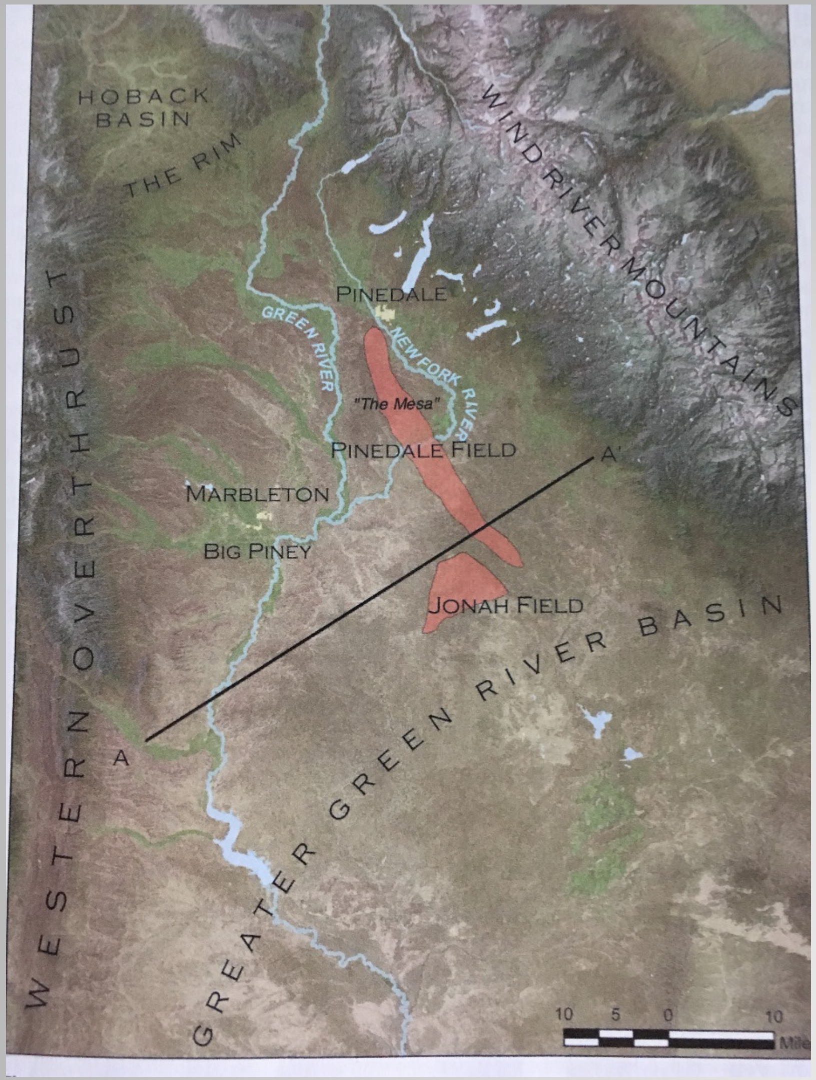
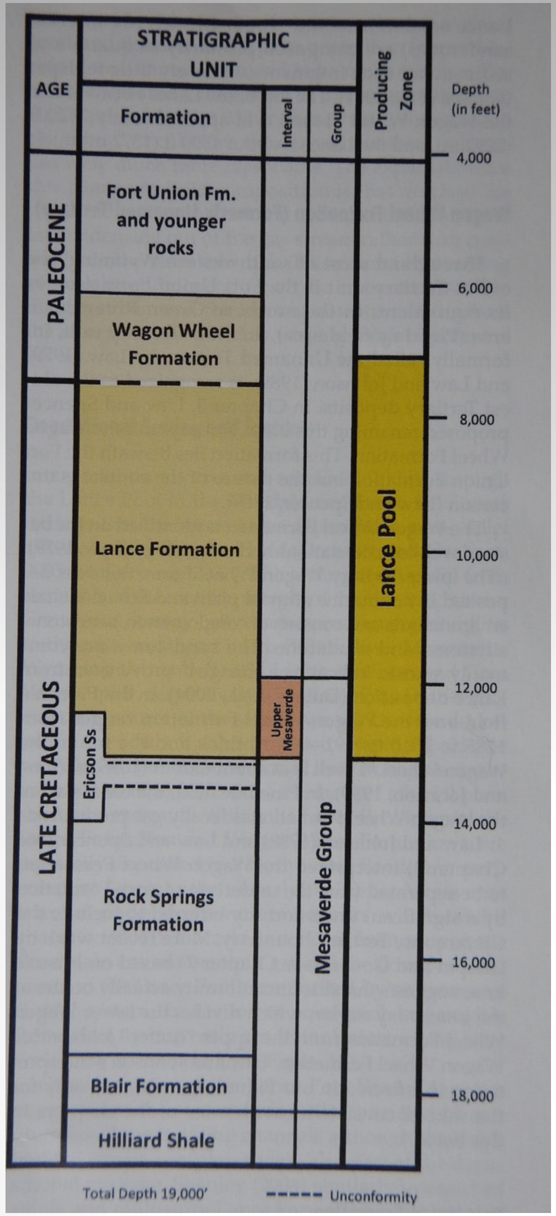
Outline

- **Introduction to the Lower Lance Pool**
- **Vertical program completions strategy and uplift**
- **Facies mapping for lateral program**

Lance Pool in the Greater Green River Basin

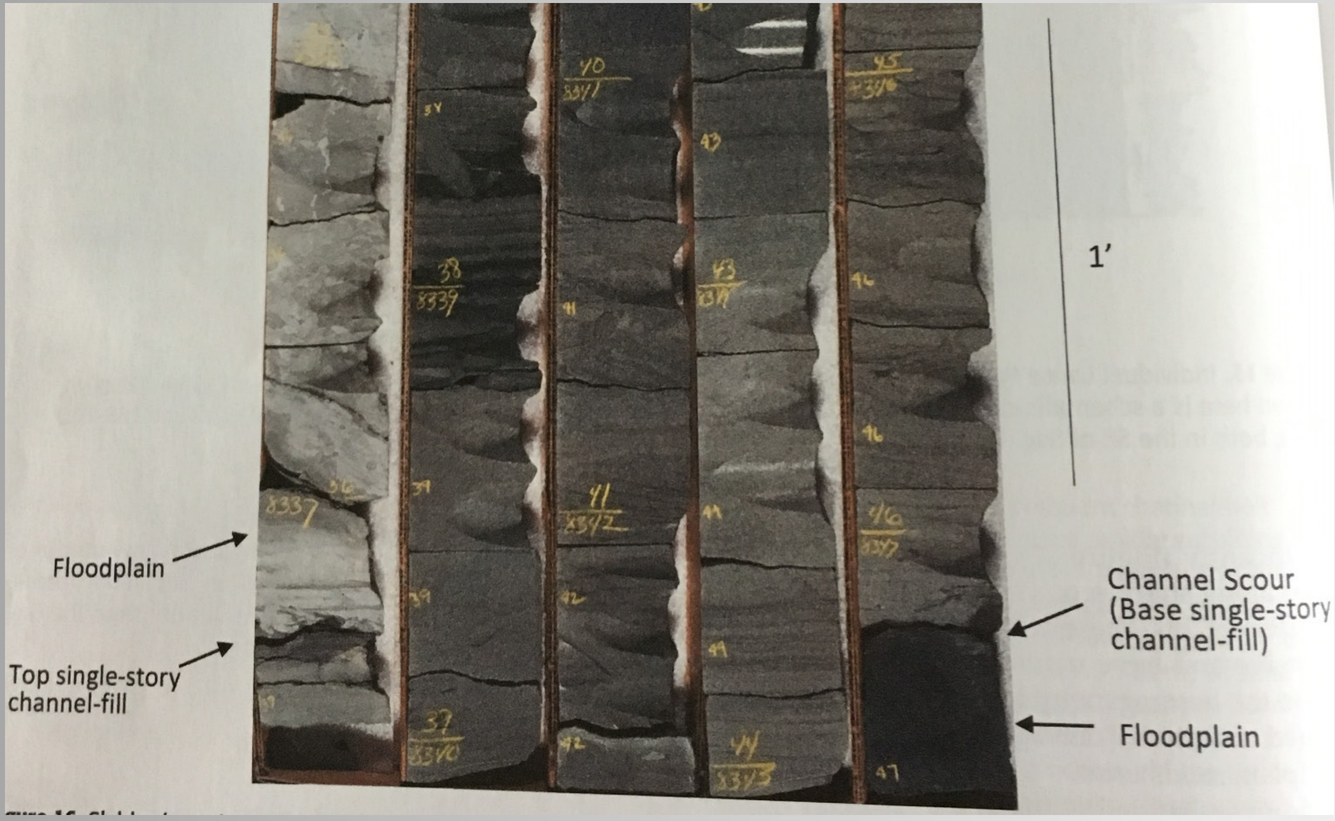


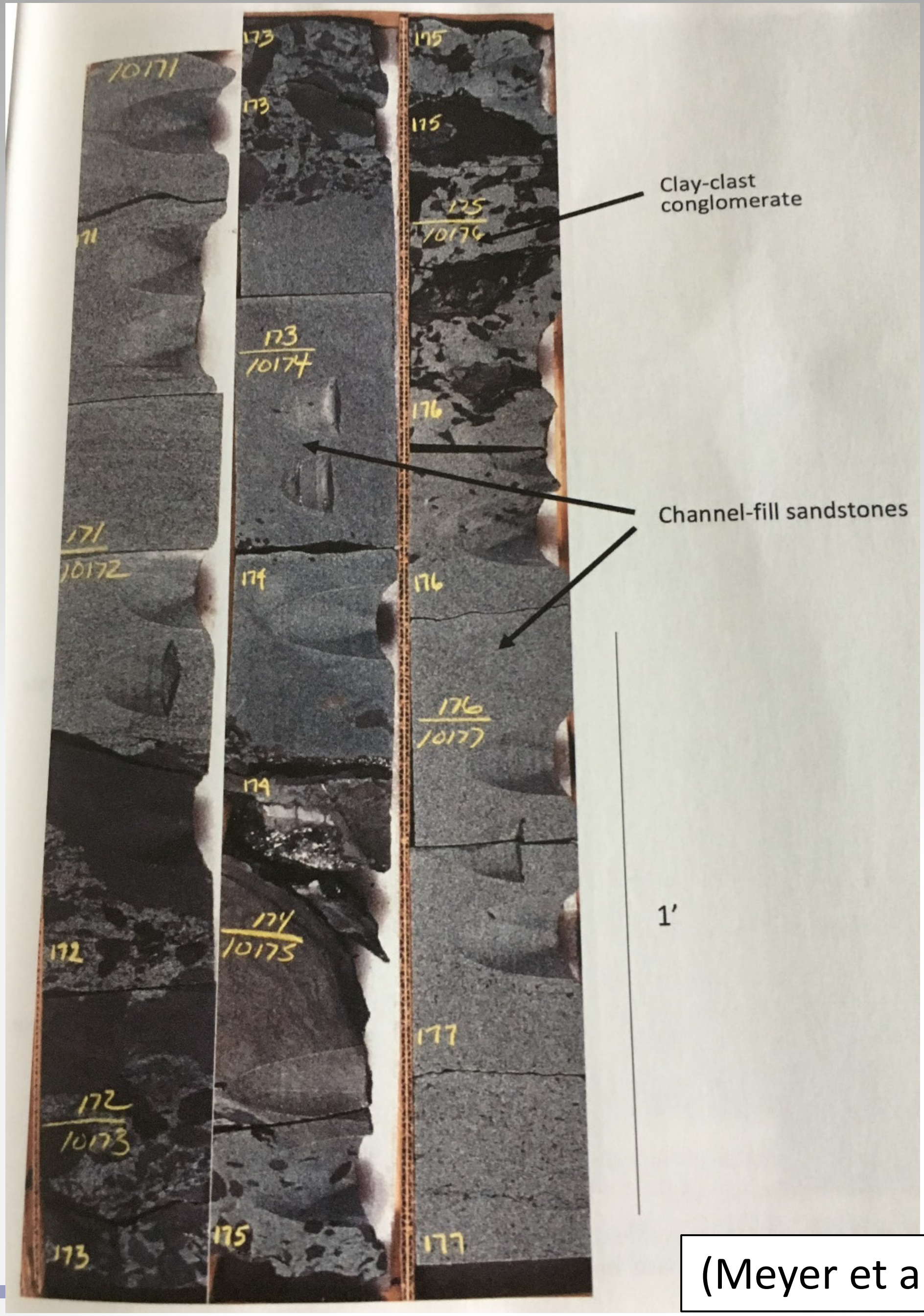


(Meyer et al, 2014)

Channel-fill and Floodplain Deposits

- ❑ Channel fill and floodplain deposits
- ❑ Highly variable, fine scale features



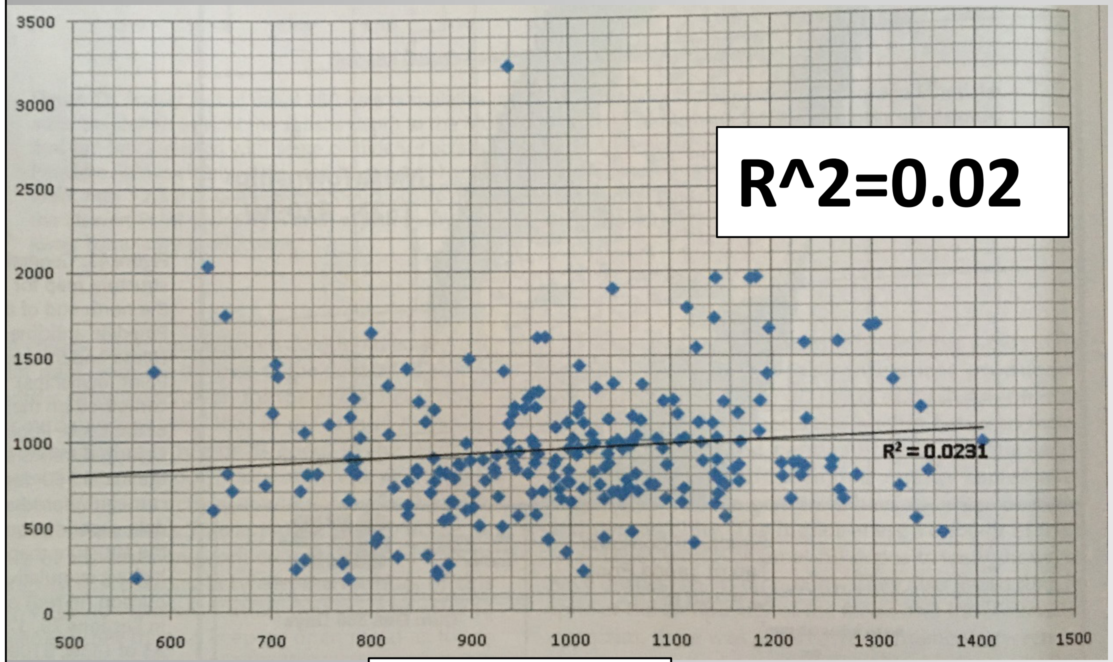


(Meyer et al, 2014)

Net Pay Relation to Production

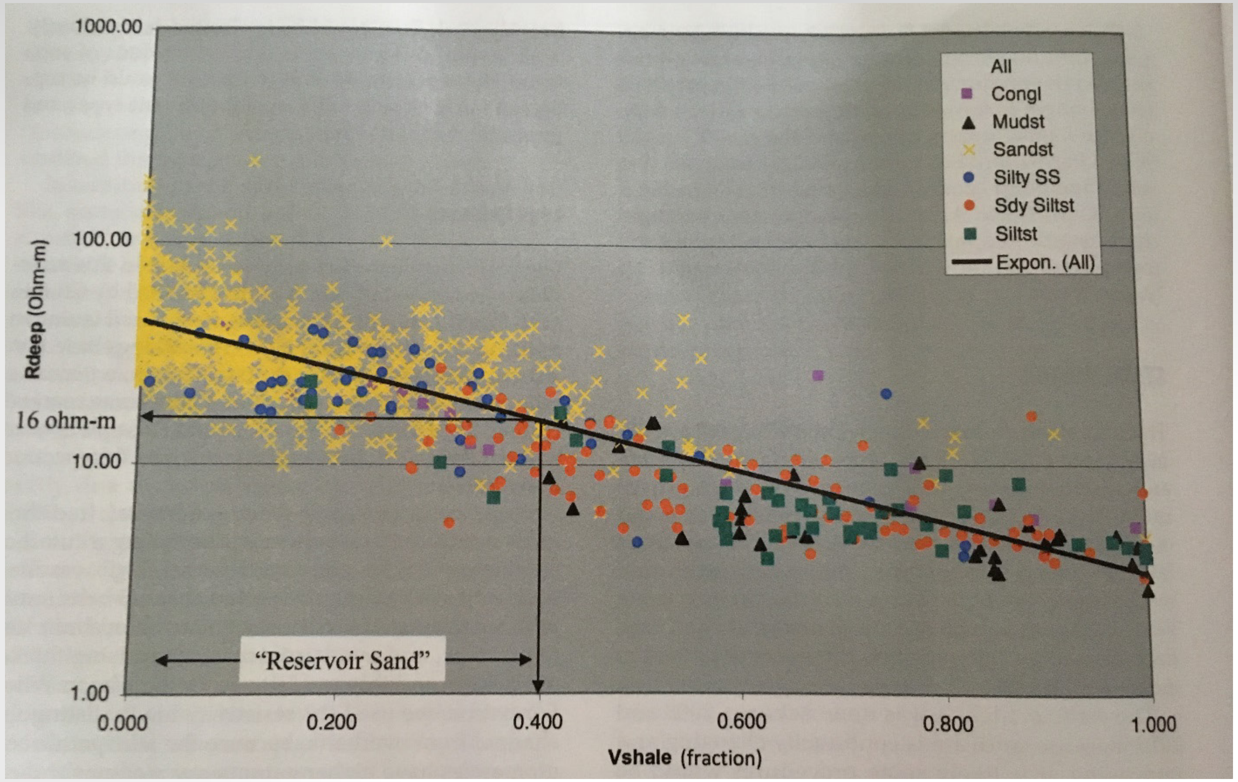
- Standard petrophysical evaluations lead to low net pay estimates in lower section of Lance Pool
- Net pay estimates show no relationship with production
- Siltstones must contribute larger than expected volumes

1st YEAR PRODUCTION



$R^2=0.02$

NET PAY



(Chapin et al, 2014)

Chapin et al (2014) on Production in Pinedale

"… we speculated productivity and recovery were primarily functions of sandbody connectivity and permeability… **static properties** alone are **not** necessarily **a good predictor of stage contribution**"

"**History matches were obtained** mainly **by tuning the frac half-length** to match the stage contributions measured by production logs."

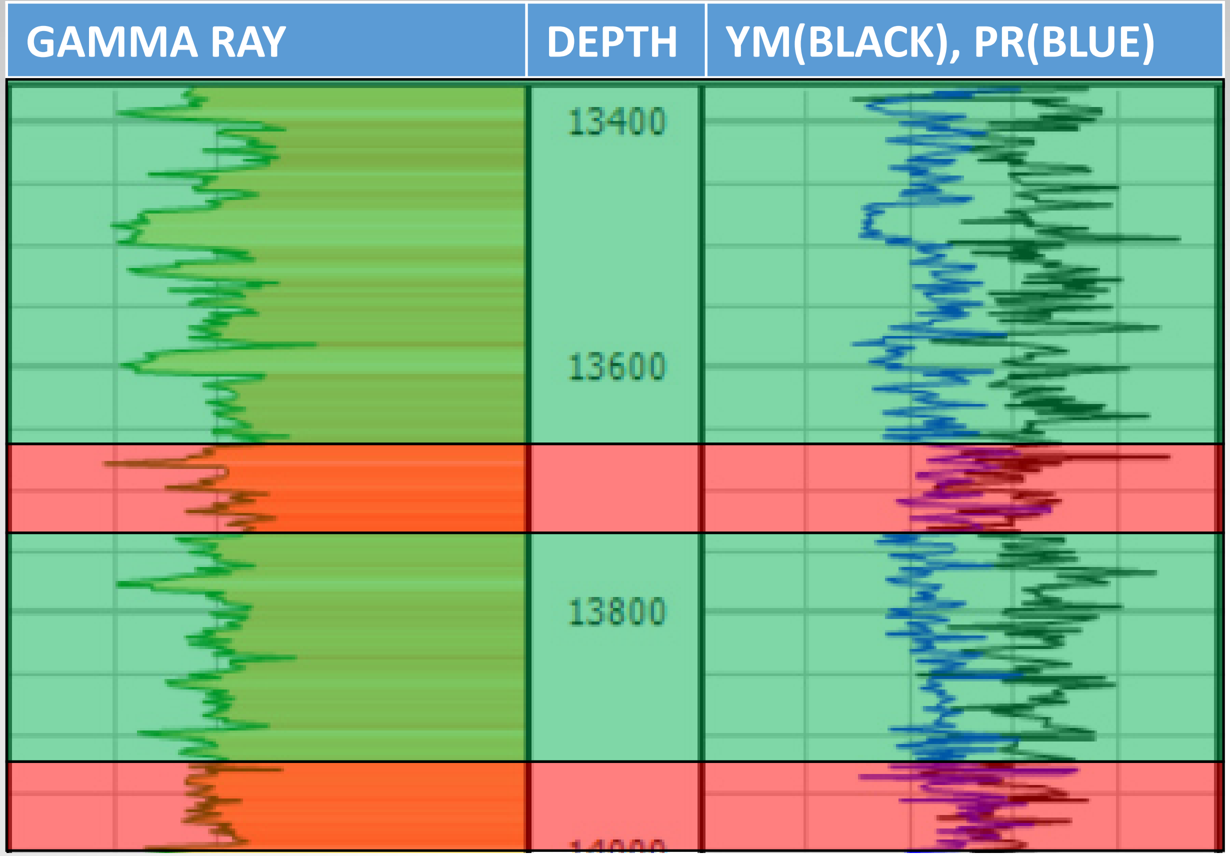
"An especially important lesson is to not overlook seemingly poor or "ratty" intervals such as the Upper Mesaverde at Pinedale… **complete everything** at first, and **use production logging to sort out which intervals are better or worse**."

(Chapin et al, 2014)

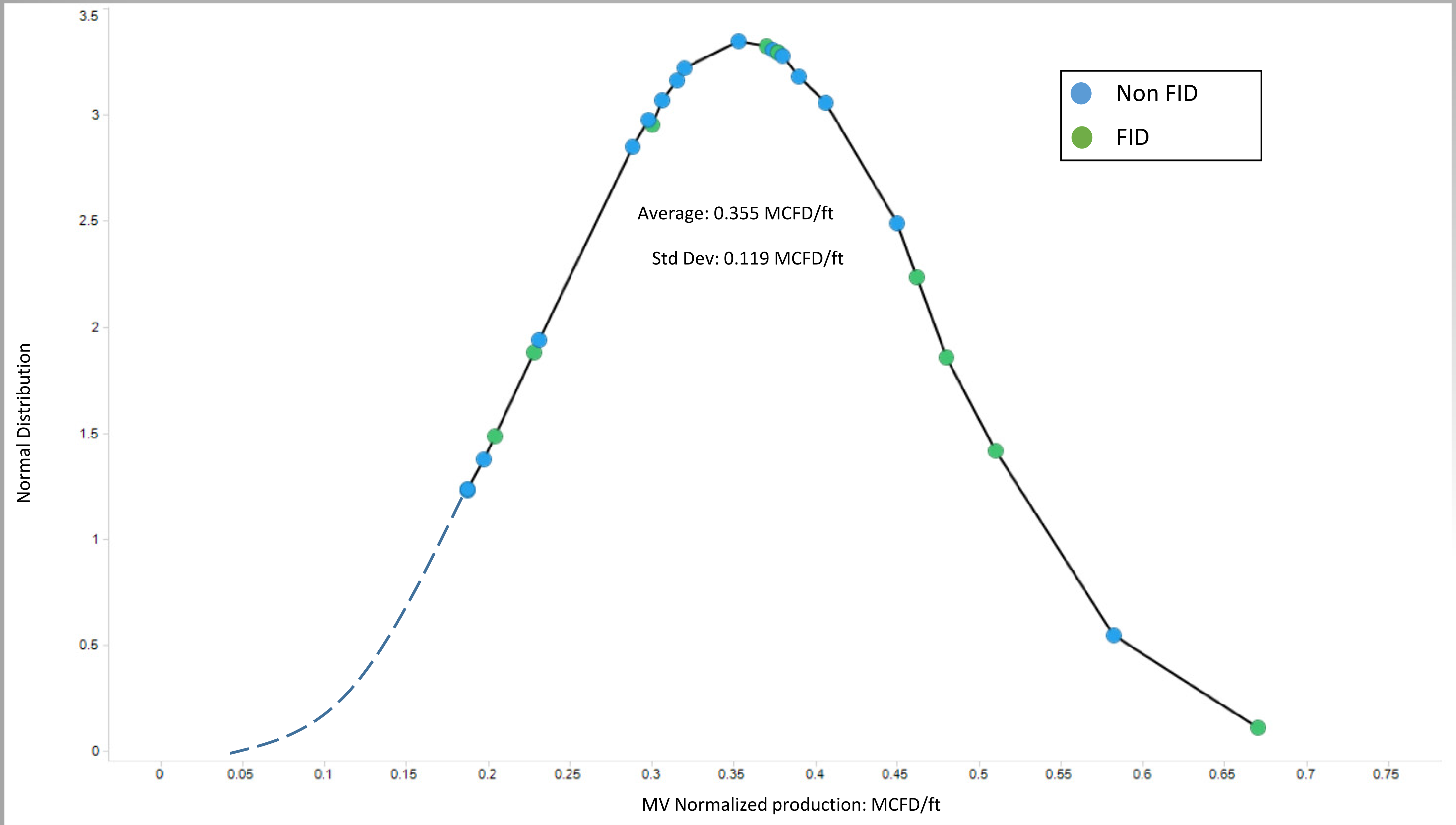
Phase 1: Completions Based on Mechanical Properties

- Monitored drilling vibrations on 10 vertical wells to obtain mechanical properties
- Stages and perfs located around brittle (easy to complete) rock
  - Low Young's modulus
  - High Poisson's Ratio
- Compared with nearby wells completed with Gamma Ray

Mechanical "Butterfly" plot



Phase 1 – Vertical program, completions review



Phase 1 – Vertical program, completions review

FID?	Average of Date of Survey	Average of MCFD/Ft LLP PLT	Average of Days Produced	LLP Avg Holes Open	Average of LLP Perf Efficiency	Average of Total Stages	Average LLP FG	Average of LLP Stages	Average of Gross LLP Pay
N	**3/19/2017**	**0.332**	**41**	**18**	**0.46**	**12.8**	**0.96**	**2.6**	**839**
Well B	1/11/2018	0.353	33	18	0.45	15	0.969	4	935
Well C	1/11/2018	0.394	33	21	0.48	14	0.964	3.5	899
Well D	12/22/2017	0.380	51	No Stepdown	No Stepdown	12	0.957	3	1145
Well E	1/21/2018	0.298	18	21	0.78	13	No Stepdown	3	1098
Well F	6/6/2017	0.288	21	14	0.30	12	0.942	2.5	862
Well G	11/10/2017	0.322	2	No Stepdown	No Stepdown	11	No Stepdown	2	1067
Well H	5/17/2016	0.315	29	No Stepdown	No Stepdown	15	No Stepdown	2.5	800
Well I	5/18/2016	0.306	31	No Stepdown	No Stepdown	14	No Stepdown	2	576
Well J	10/12/2017	0.197	80	14	0.27	12	0.95	2.5	823
Well K	12/19/2017	0.406	17	No Stepdown	No Stepdown	13	No Stepdown	3	1016
Well L	12/23/2017	0.377	51	No Stepdown	No Stepdown	11	No Stepdown	2.5	770
Well M	12/23/2017	0.374	51	No Stepdown	No Stepdown	11	No Stepdown	2.5	835
Well O	1/6/2017	0.187	26	No Stepdown	No Stepdown	13	No Stepdown	1.5	460
Well P	12/15/2016	0.582	54	No Stepdown	No Stepdown	13	No Stepdown	2.5	584
Well R	5/25/2016	0.231	40	No Stepdown	No Stepdown	15	No Stepdown	2.5	697
Well S	6/13/2015	0.447	121	No Stepdown	No Stepdown	11	No Stepdown	2	680
Well T	1/7/2015	0.187	44	No Stepdown	No Stepdown	12	No Stepdown	2	1020
Y	**11/28/2017**	**0.400**	**21**	**20**	**0.51**	**13.3**	**0.96**	**3.7**	**968**
Well V	1/7/2018	0.485	29	19	0.41	15	0.961	4.5	1054
Well W	6/24/2017	0.370	17	18	0.47	14	0.929	4	1073
Well X	8/5/2017	0.462	22	19	0.39	14	0.973	4	1079
Well Y	12/21/2017	0.666	19	18	0.39	13	0.955	3.5	941
Well Z	12/21/2017	0.512	20	19	0.41	13	0.968	3	852
Well AA	1/23/2018	0.228	20	20	0.67	12	0.965	3.5	905
Well AB	1/23/2018	0.204	20	23	0.82	13	0.97	4	1006
Well AC	12/21/2017	0.377	20	No Stepdown	No Stepdown	13	No Stepdown	3.5	1061
Well AD	1/20/2018	0.296	22	No Stepdown	No Stepdown	13	No Stepdown	3	744

- **20% uplift in production**, slight uplift in perforation efficiency and holes open
- 1 extra stage/well in the LLP, 130 ft extra gross pay completed

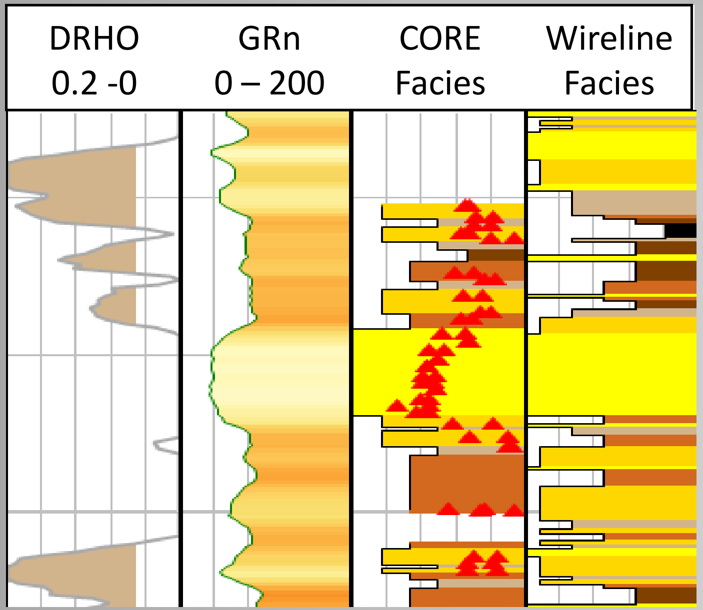
Completions Study Conclusions

- Wells completed with mechanical properties
  - ~20% production uplift per well
  - 130 ft additional pay completed per well
- Gamma Ray not a good predictor of production
  - Need additional ways to high grade reservoir

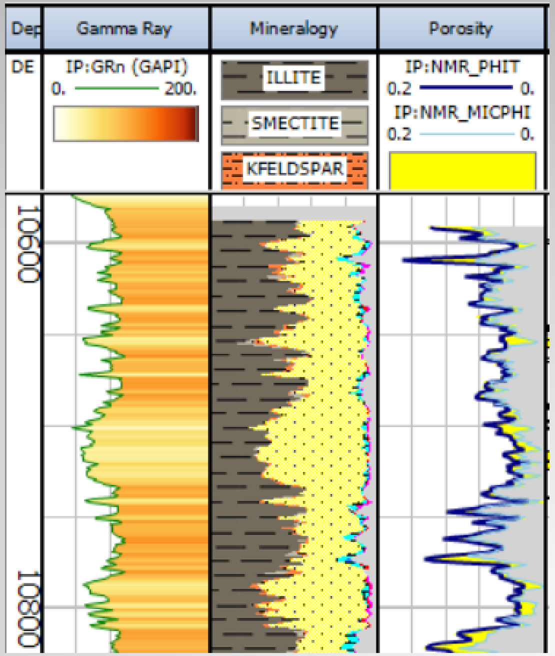
Phase 2 - Mechanical Facies

Development of Facies Model

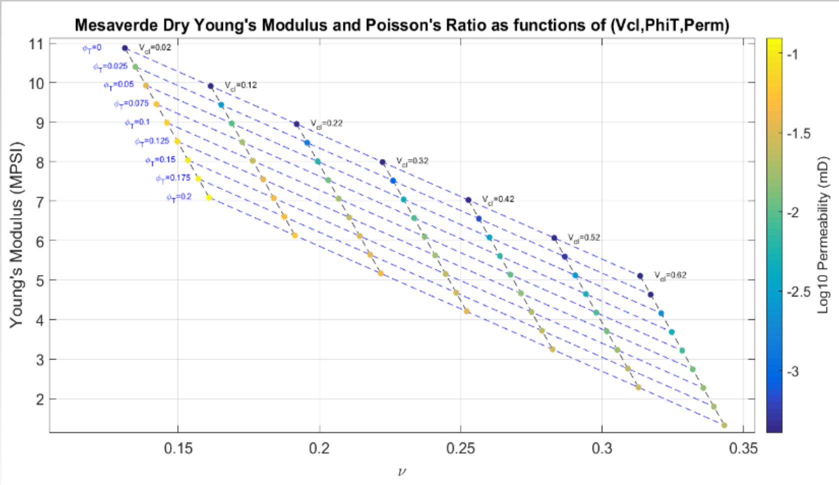
CORE ANALYSIS



PHYSICAL MODELING



MECHANICAL MAPPING



<u>WELL A:</u>

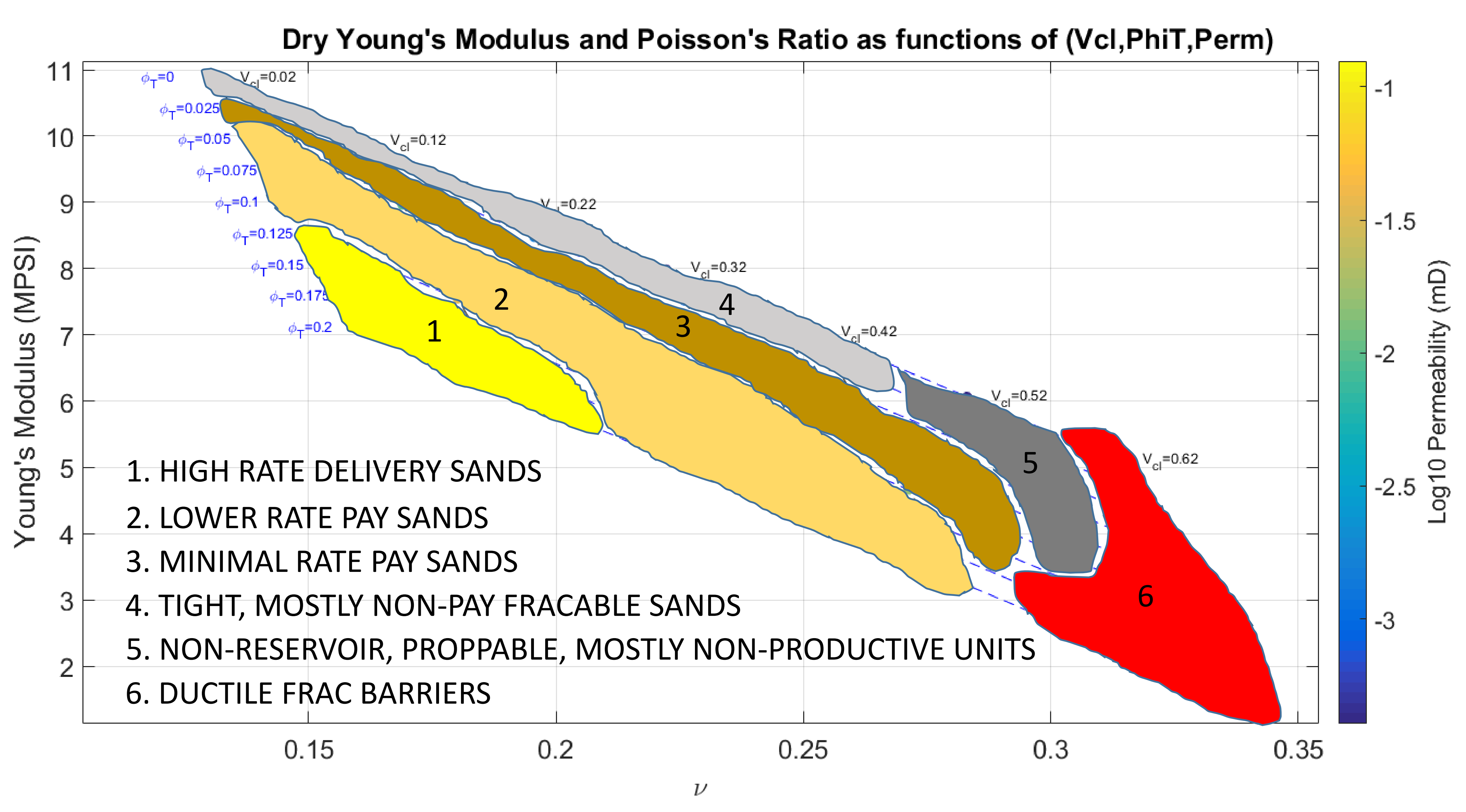
- ❑ Lithology
- ❑ Porosity
- ❑ Permeability

<u>WELL B:</u>

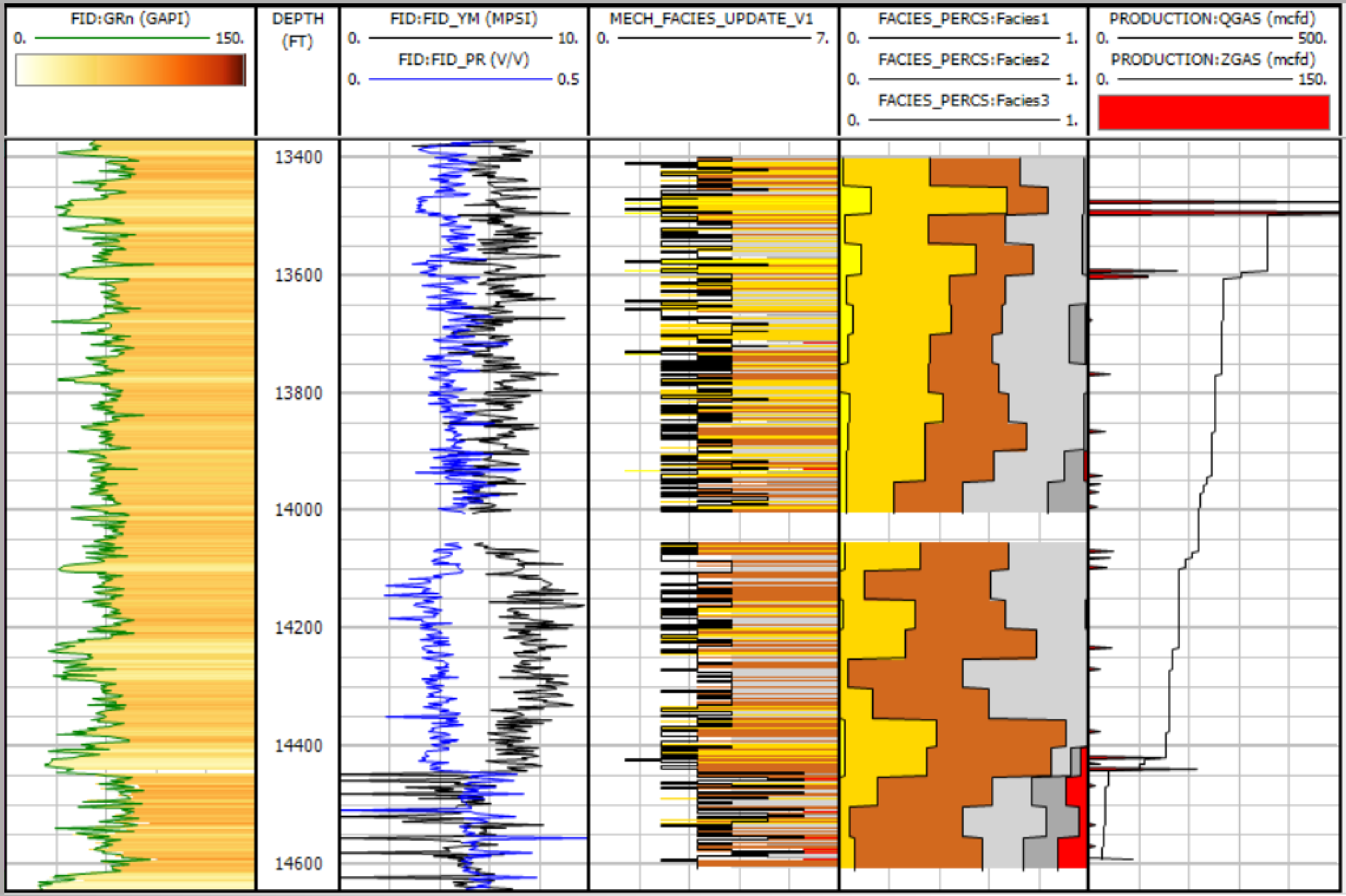
- ❑ Lithology
- ❑ Porosity
- ❑ Mechanicals

- ❑ Calibrated Rock Physics Models
- ❑ Flow Units

Facies Selection - LLP

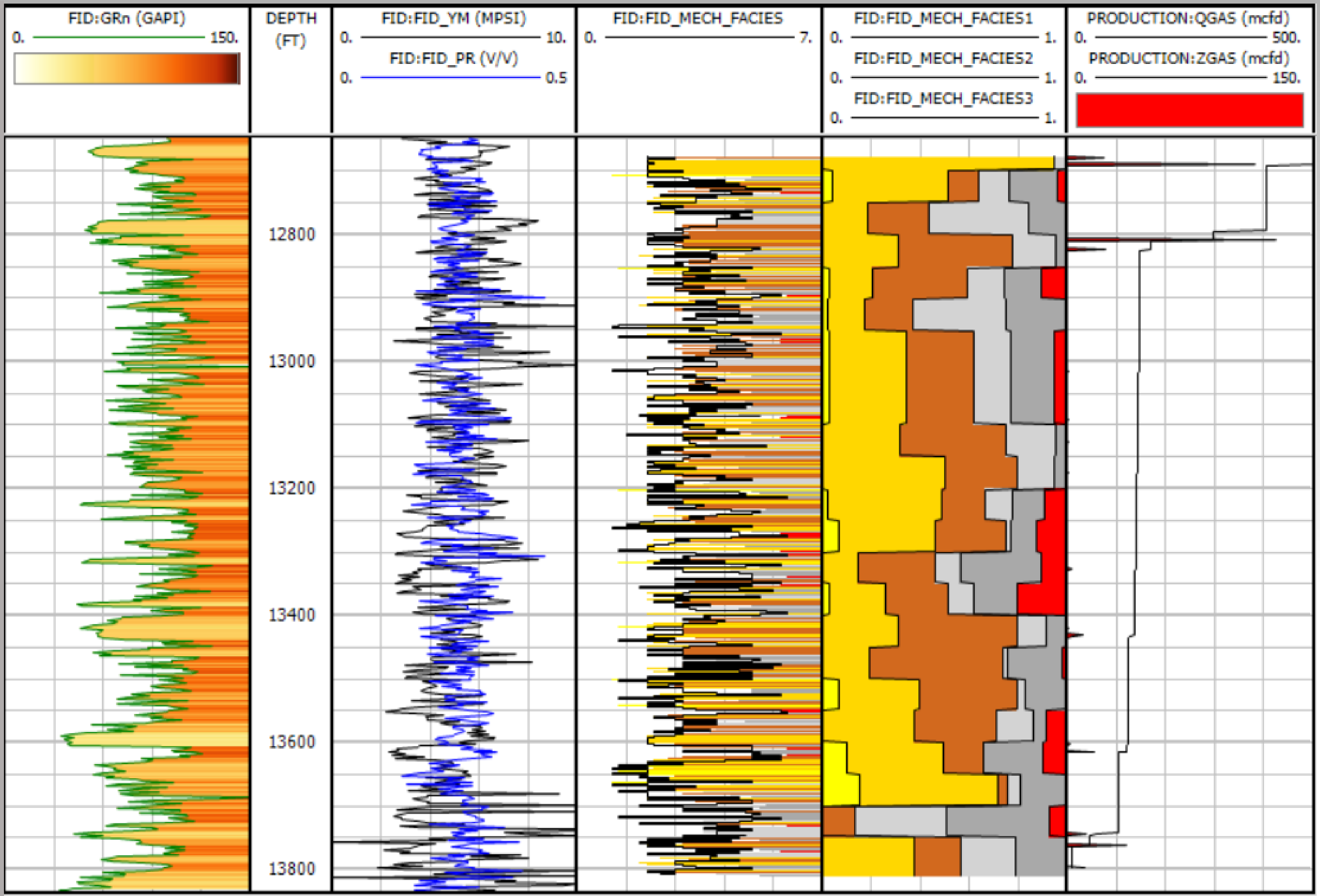


Well U



FID:GRn (GAPI)
0. 150.
DEPTH (FT)
FID:FID_YM (MPSI)
0. 10.
FID:FID_PR (V/V)
0. 0.5
MECH_FACIES_UPDATE_V1
0. 7.
FACIES_PERCS:Facies1
0. 1.
FACIES_PERCS:Facies2
0. 1.
FACIES_PERCS:Facies3
0. 1.
PRODUCTION:QGAS (mcfd)
0. 500.
PRODUCTION:ZGAS (mcfd)
0. 150.
13400
13600
13800
14000
14200
14400
14600

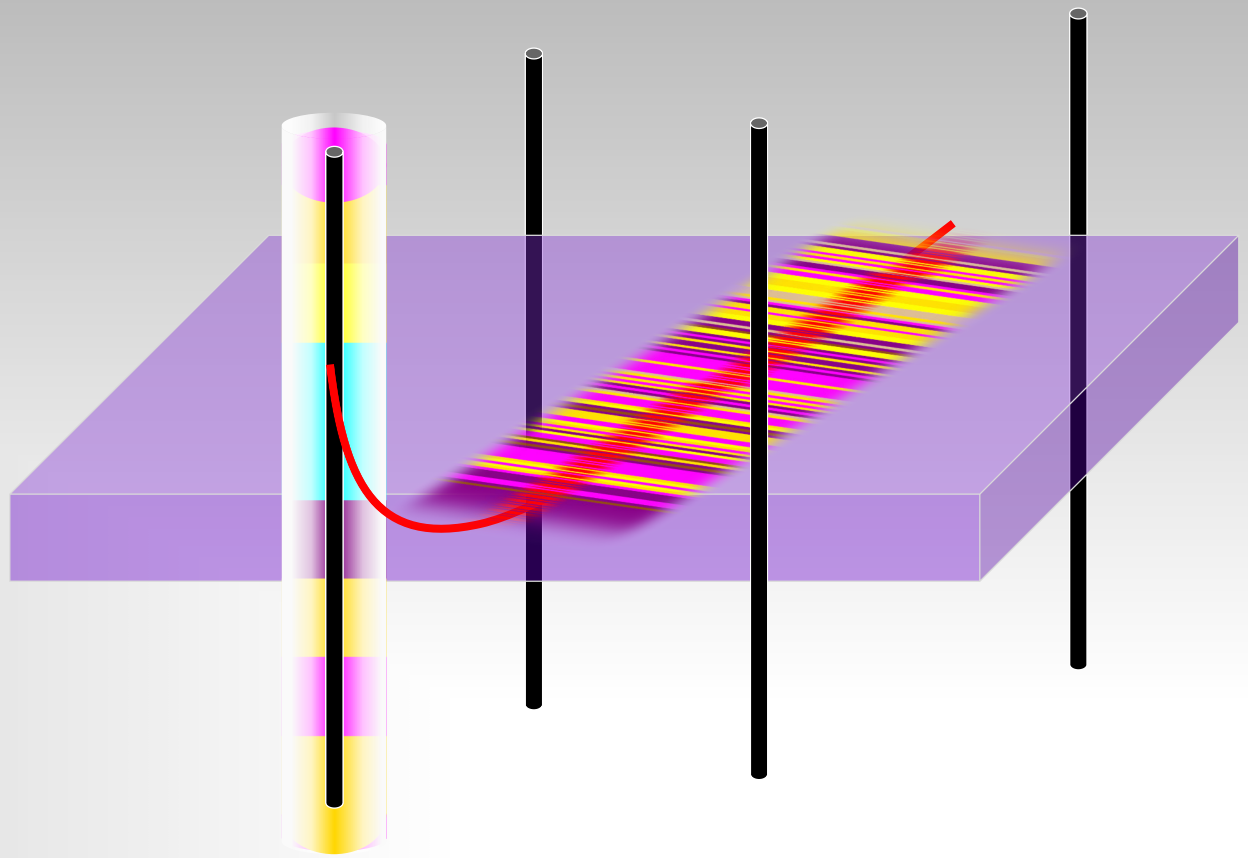
Well Y



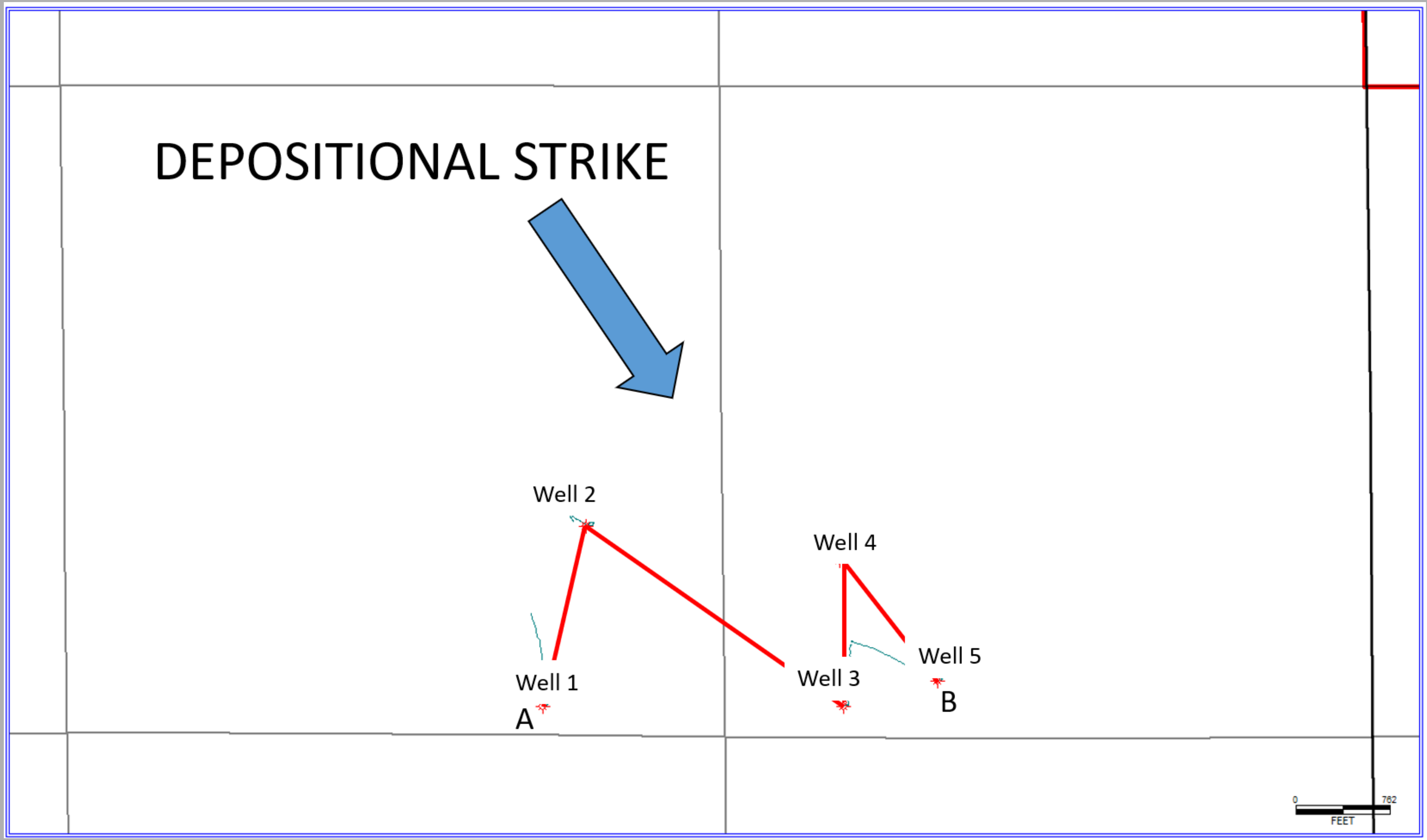
FID:GRn (GAPI)
0. 150.
DEPTH
(FT)
FID:FID_YM (MPSI)
0. 10.
FID:FID_PR (V/V)
0. 0.5
FID:FID_MECH_FACIES
0. 7.
FID:FID_MECH_FACIES1
0. 1.
FID:FID_MECH_FACIES2
0. 1.
FID:FID_MECH_FACIES3
0. 1.
PRODUCTION:QGAS (mcfd)
0. 500.
PRODUCTION:ZGAS (mcfd)
0. 150.
12800
13000
13200
13400
13600
13800

Plan Landing Zones and High Grade Sections

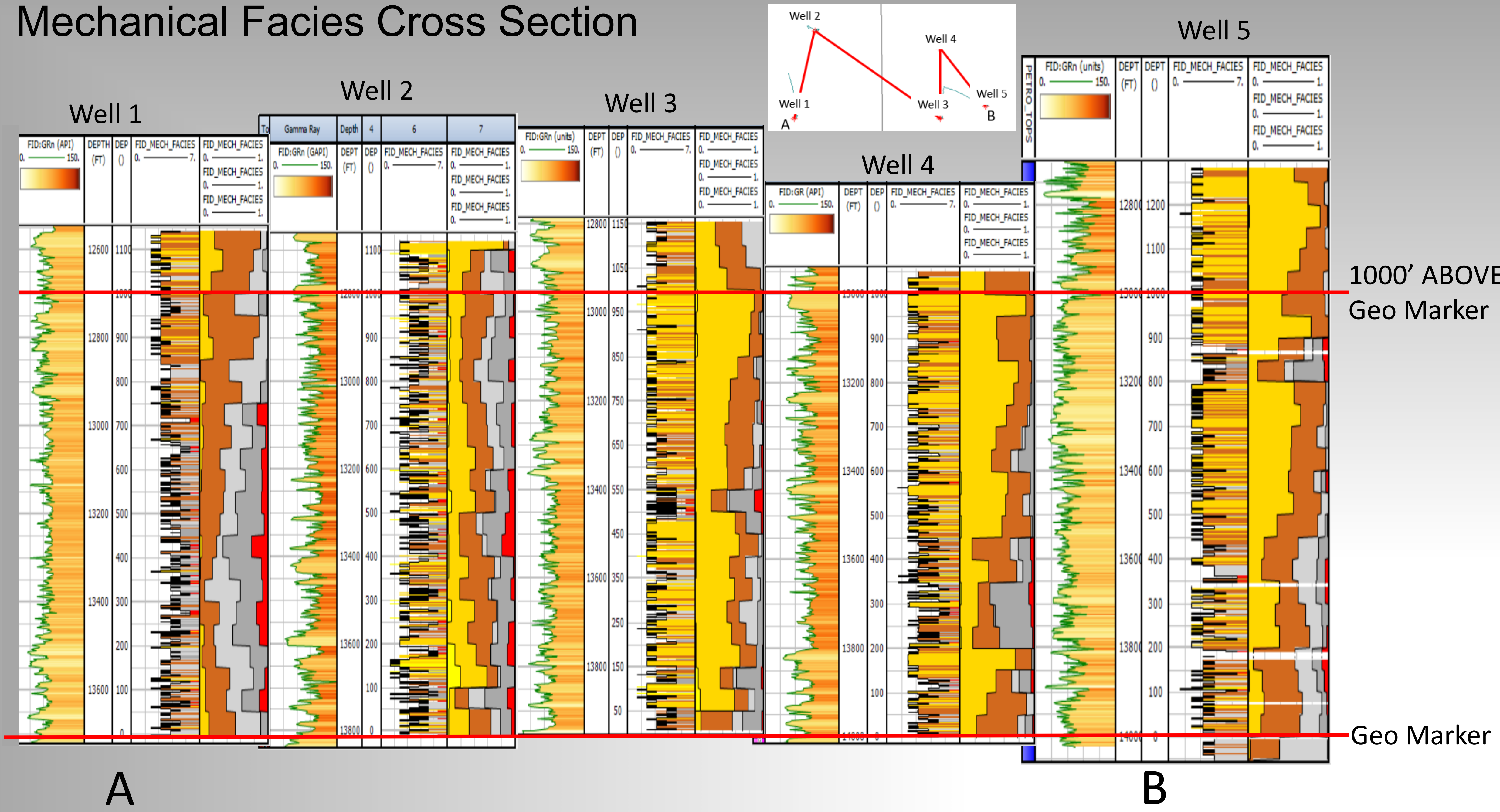
- ❑ Four wells added (five total) in neighboring sections to test continuity of units
- ❑ Lateral completions have shown mechanicals predict completions performance
- ❑ Facies mapping will allow us to optimize lateral well placement



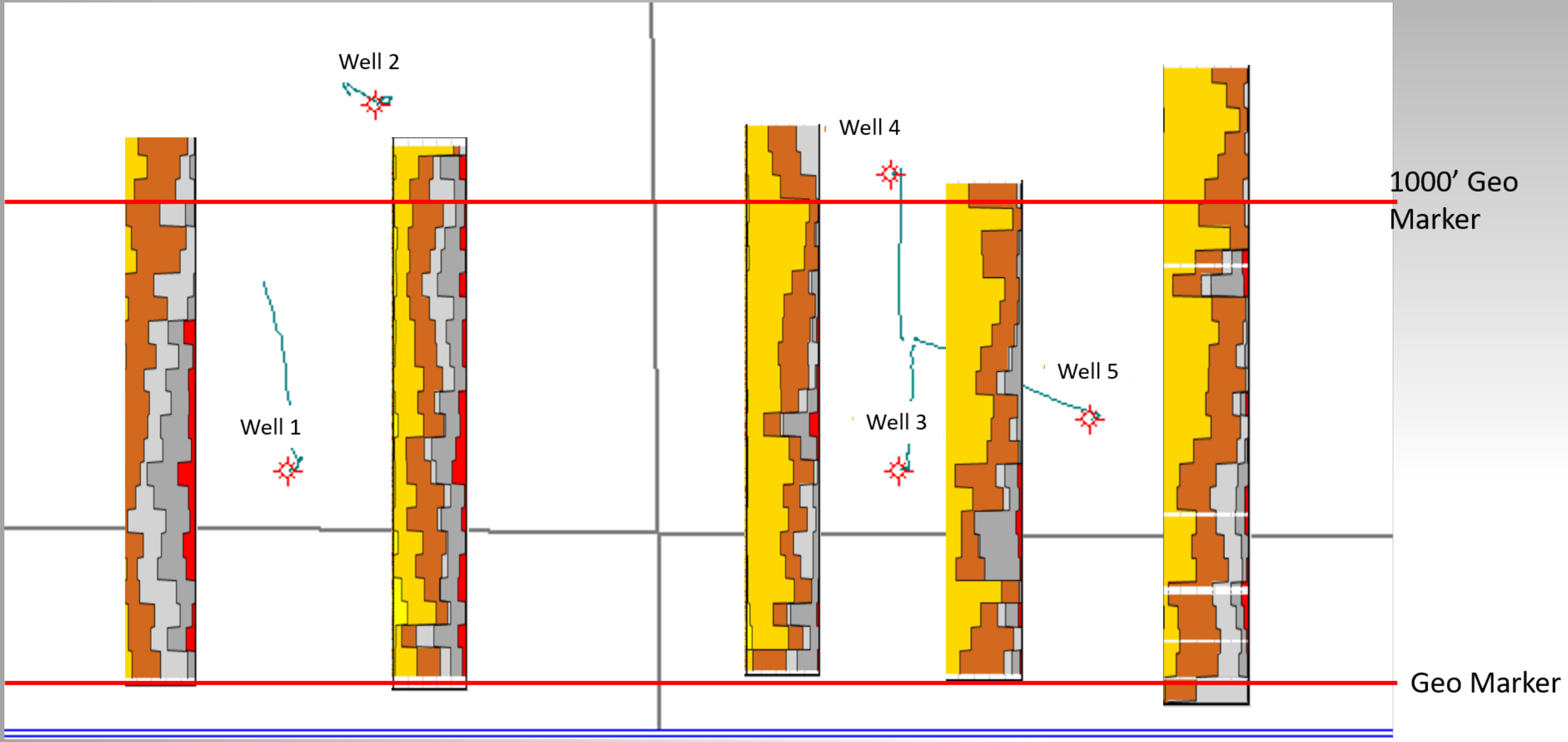
Cross Section Map View



Mechanical Facies Cross Section

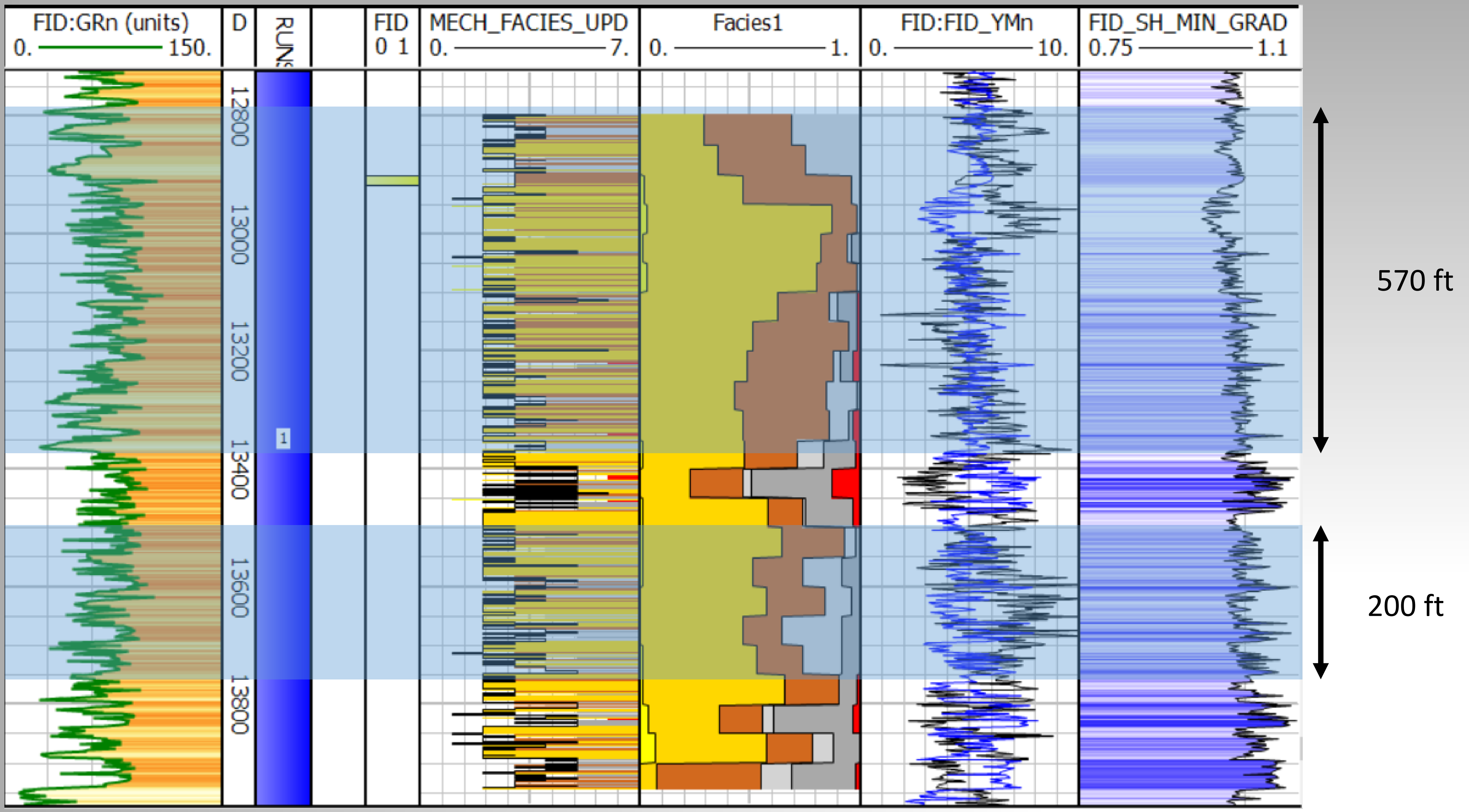


Mechanical Facies Map View

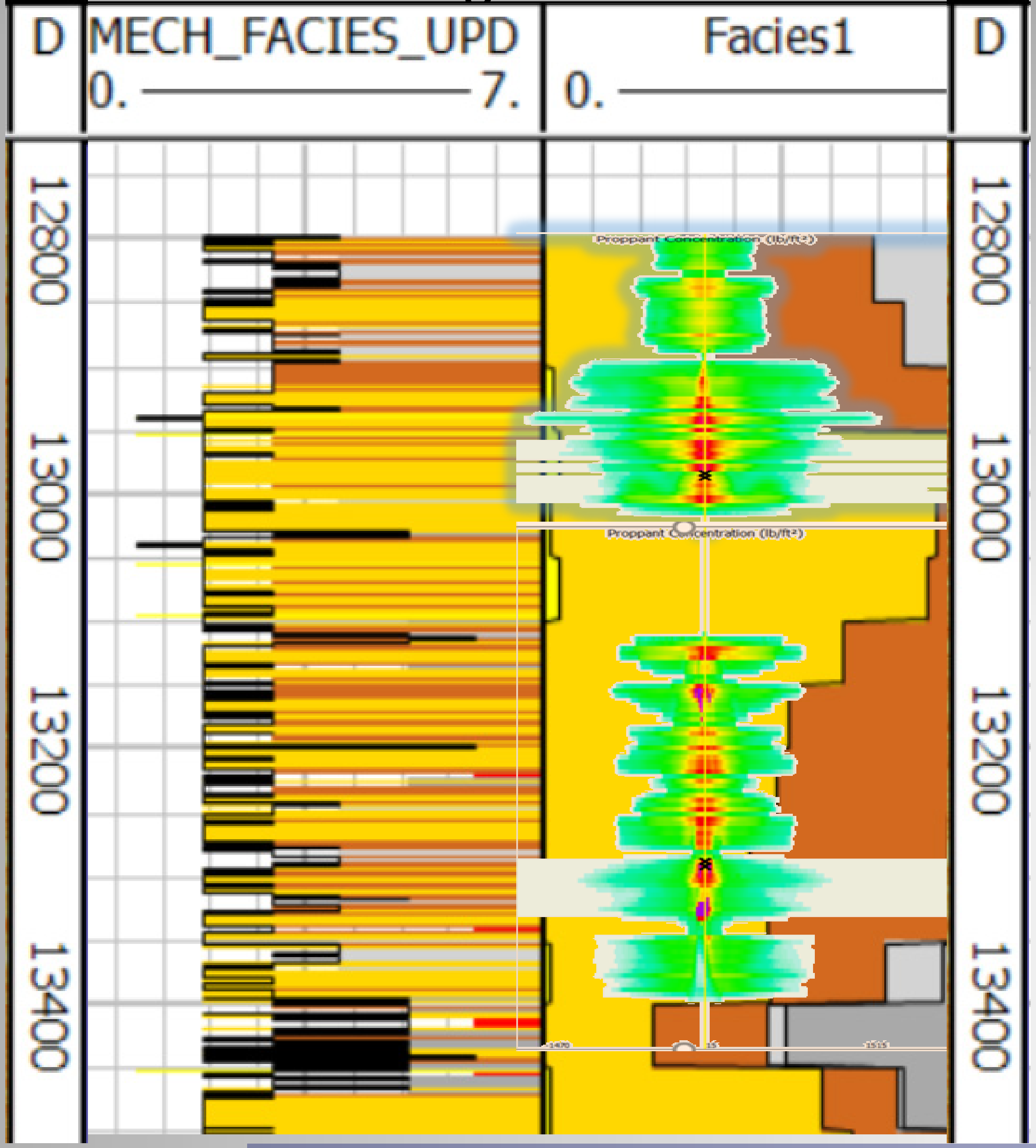


GOHFER Modeling

Well 3 Potential Landing Zones



Well 3 Potential Landing Zones – GOHFER Model Example



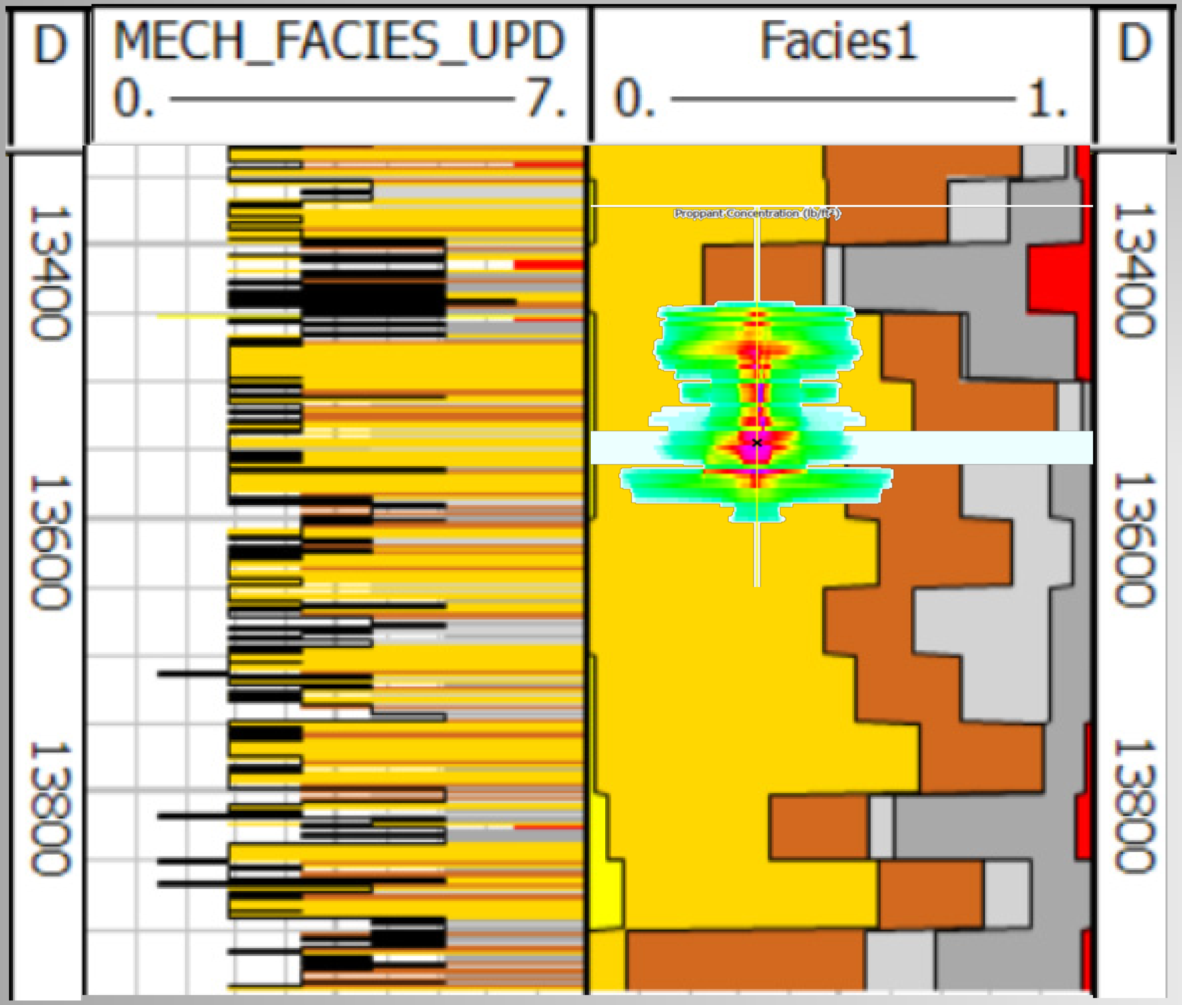
Generic design

- 40/70 with borate XL
- 100k lbs/entry point
- PZS: 400 psi
- k: 0.001 md

Hypothetical perforations at 13,000 ft
~200 ft total propped height

Hypothetical perforations at 13,300 ft
~300 ft total propped height

Well 3 Potential Landing Zones – GOHFER Model Example



Generic Design

- 40/70 with borate XL
- 100k lbs/entry point
- PZS: 400 psi
- k: 0.001 md

Hypothetical perforations at 13,550 ft

~150 ft total propped height

Mechanical Facies Conclusions

- Mechanical facies agree well with production logs
- The 50ft. binned facies are mappable within sections but not across sections
- GOHFER modeling suggests the barrier facies can be strong frac barriers and frac height can change dramatically depending on the facies present
- Multiple lateral targets are possible depending on facies present