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City Centre, Houston, Texas  
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# SHALETECH™



# Tailored Stimulation Designs For Every Horizontal Well

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**SHALETECH™**

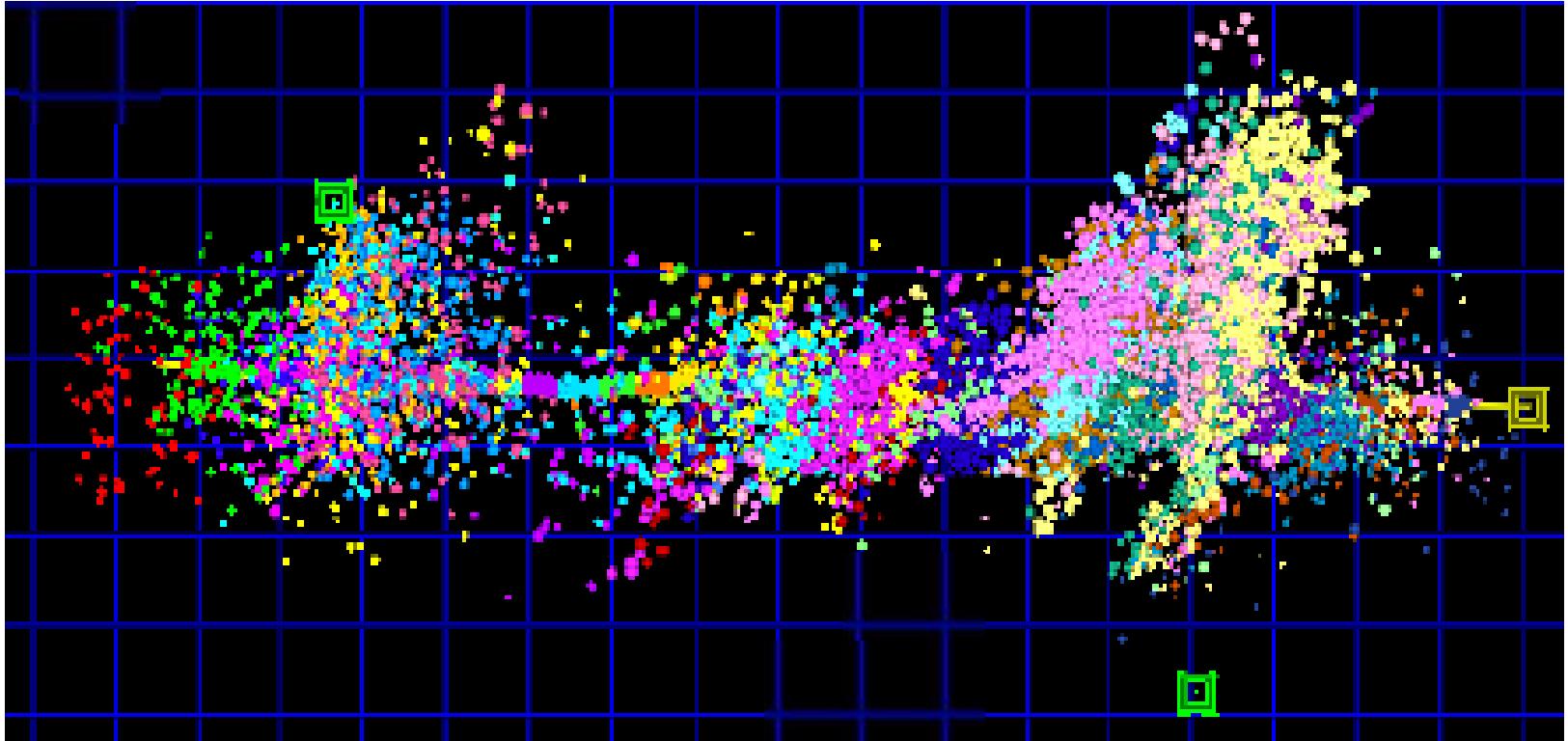
# Well Stimulation Challenges

- Consistent stage/treatment response
- Mitigate offset frac-hits
- Reduce screenout risk
- Tailored pump schedule based on stage characteristics



# Microseismic Map View

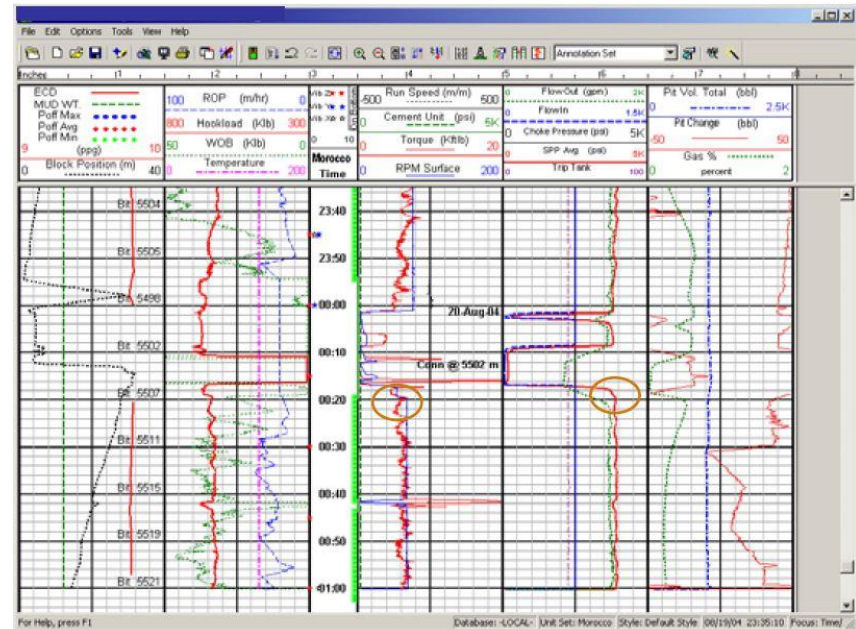
Demonstrated Variability



How do we proactively understand this variation and design the completion to optimize frac and well performance?

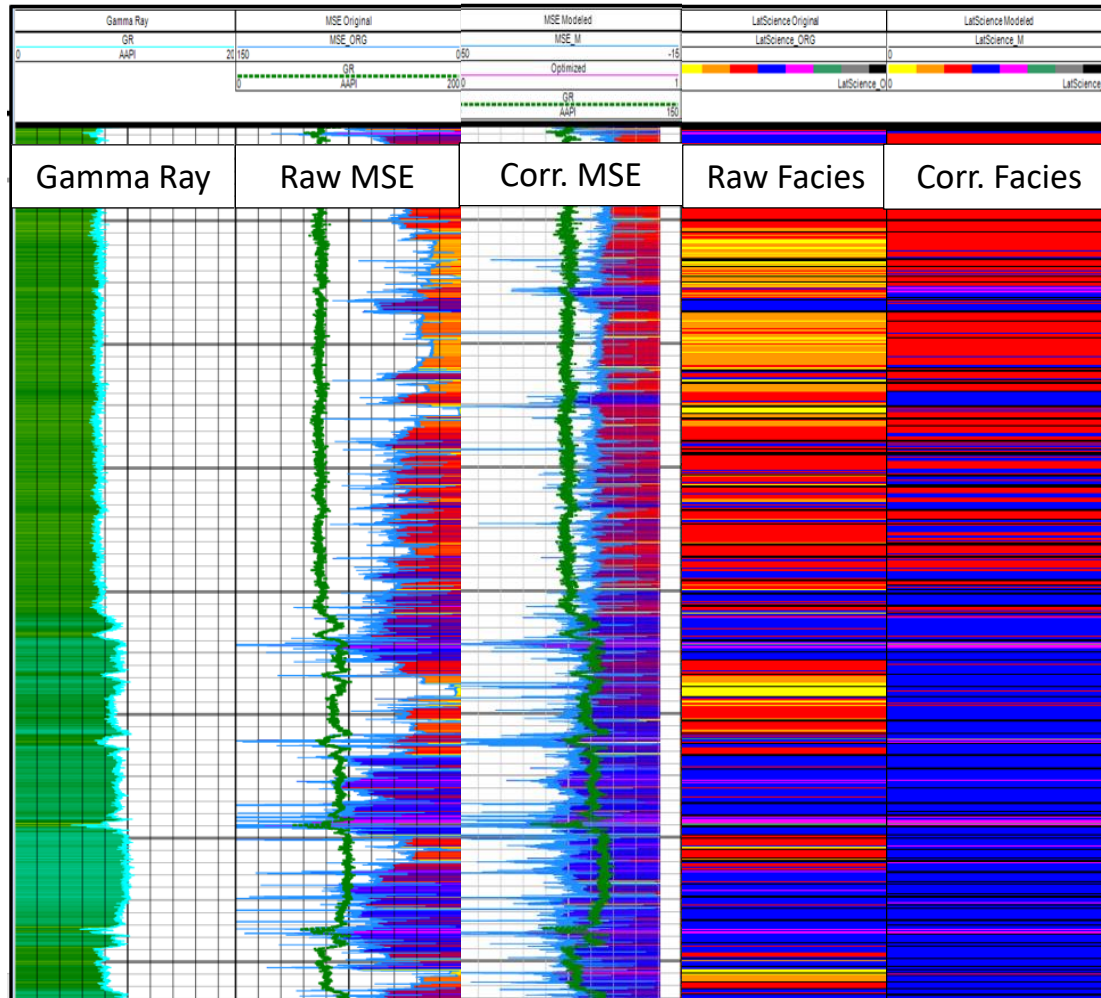
# Drilling Data .... A New Direction

- Weight On Bit (WOB)
- Drilling Speed (RPM)
- Rotary Torque (TOR)
- Rate of Penetration (ROP)
- Differential Pressure (DIFP)
- StandPipe Pressure (SPP)
- Mud Flow Rate (Q)



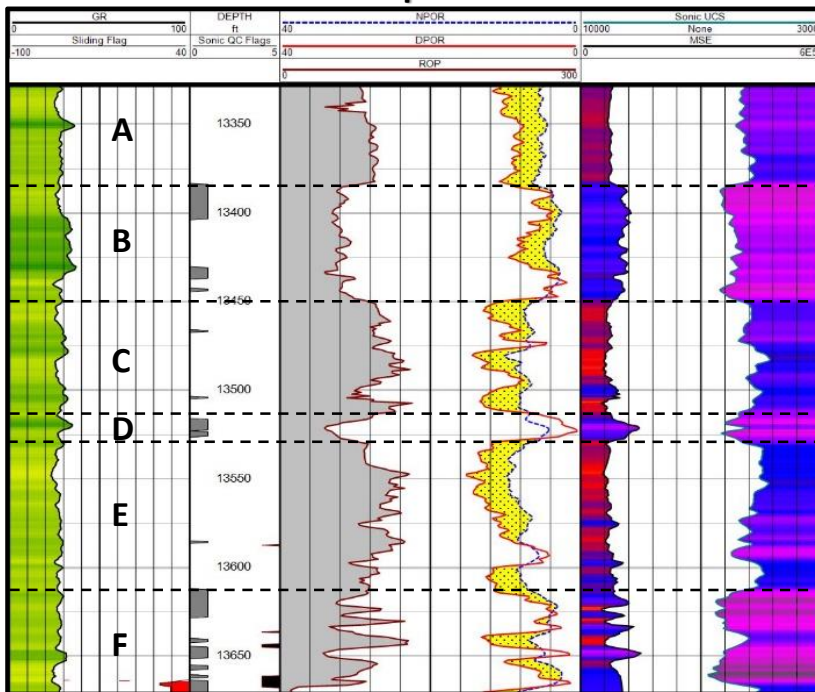
$$MSE \text{ [ksi]} = \frac{4 \cdot WOB}{\pi D^2} + \frac{480}{D^2} \frac{(N+K_N \cdot Q) \cdot ((T_{MAX} / \Delta P_{MAX}) \cdot \Delta P / 1000)}{ROP}$$

# MSE - Original versus Corrected



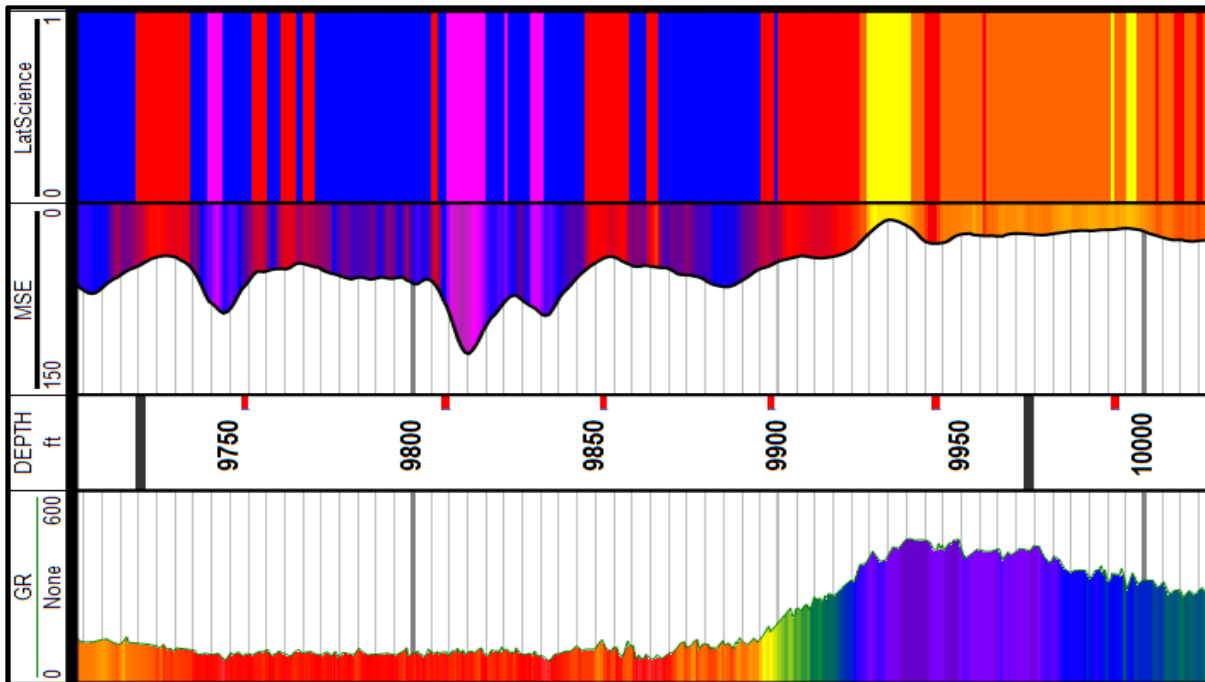
# Openhole Log Data Comparison

Powder River Basin example



- Neutron/Density/GR/Dipole Sonic
- N/D as “ground truth”
- Correlation between N/D and MSE was excellent throughout
- Sonic UCS often had QC issues that made it unreliable
- GR often insensitive

# Facies Log Plot



$$\text{MSE} = \text{UCS} * \text{Deff}$$

Color	Hardness	MSE
Yellow	HD 1	0-20K
Orange	HD 2	20-30K
Red	HD 3	30-50K
Blue	HD 4	50-85K
Magenta	HD 5	85-135K
Green	HD 6	135-200K
Grey	HD 7	200K +

Hardness Increases  
↓



# Standard Engineered Completions

Geometric Perf Design						
Stage	Plug	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
1		15,705	15,665	15,625	15,585	15,545
2	15523	15,505	15,469	15,433	15,397	15,361
3	15341	15,323	15,287	15,251	15,215	15,179
4	15159	15,141	15,105	15,069	15,033	14,997
5	14977	14,959	14,923	14,887	14,851	14,815
6	14795	14,777	14,741	14,705	14,669	14,633
7	14613	14,595	14,559	14,523	14,487	14,451
8	14431	14,413	14,377	14,341	14,305	14,269
9	14249	14,231	14,195	14,159	14,123	14,087
10	14067	14,049	14,013	13,977	13,941	13,905
11	13885	13,867	13,831	13,795	13,759	13,723
12	13703	13,685	13,649	13,613	13,577	13,541
13	13519	13,501	13,465	13,429	13,393	13,357
14	13335	13,317	13,281	13,245	13,209	13,173
15	13151	13,133	13,097	13,061	13,025	12,989
16	12971	12,953	12,917	12,881	12,845	12,809
17	12791	12,773	12,737	12,701	12,665	12,629
18	12611	12,593	12,557	12,521	12,485	12,449
19	12431	12,413	12,377	12,341	12,305	12,269
20	12251	12,233	12,197	12,161	12,125	12,089
21	12071	12,053	12,017	11,981	11,945	11,909
22	11891	11,873	11,837	11,801	11,765	11,729
23	11711	11,693	11,657	11,621	11,585	11,549
24	11531	11,513	11,477	11,441	11,405	11,369
25	11351	11,333	11,297	11,261	11,225	11,189
26	11171	11,152	11,116	11,080	11,044	10,984

LateralScience™ Perf Design						
Stage	Plug	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
1		15705	15665	15629	15587	15545
2	15523	15502	15472	15433	15397	15361
3	15341	15318	15283	15247	15213	15179
4	15159	15139	15110	15078	15037	14994
5	14977	14957	14923	14886	14855	14819
6	14795	14777	14743	14709	14674	14634
7	14613	14595	14559	14527	14495	14458
8	14431	14413	14377	14341	14307	14274
9	14249	14227	14192	14154	14121	14087
10	14067	14047	14013	13980	13938	13901
11	13885	13866	13831	13793	13759	13725
12	13703	13683	13646	13613	13577	13541
13	13519	13500	13463	13424	13388	13361
14	13335	13316	13281	13247	13215	13177
15	13151	13129	13090	13058	13022	12986
16	12971	12953	12918	12881	12846	12811
17	12791	12773	12737	12704	12665	12627
18	12611	12592	12557	12521	12485	12449
19	12431	12413	12383	12346	12309	12270
20	12251	12233	12197	12161	12128	12092
21	12071	12053	12012	11973	11940	11909
22	11891	11873	11836	11792	11761	11729
23	11711	11707	11688	11658	11618	11589
24	11531	11513	11474	11437	11405	11369
25	11351	11333	11297	11261	11225	11189
26	11171	11152	11110	11068	11026	10984

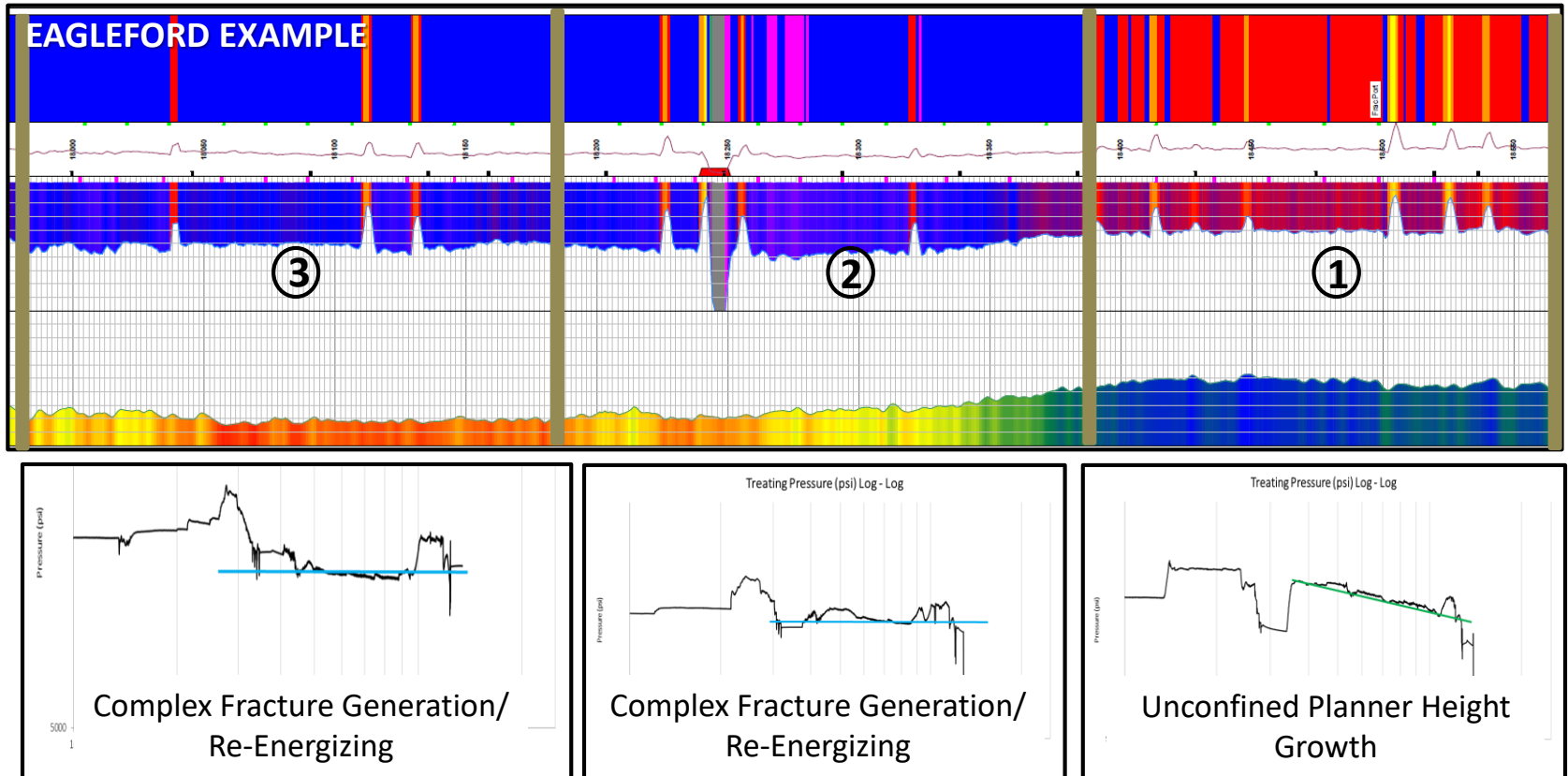
- Shift clusters to “like rock”
- Fact: Not all stages are the same strength
- Despite this, most operators still complete all stages with the same treatment schedule

Design	Est. Cluster Efficiency
Geometric	60%
Optimized	94%

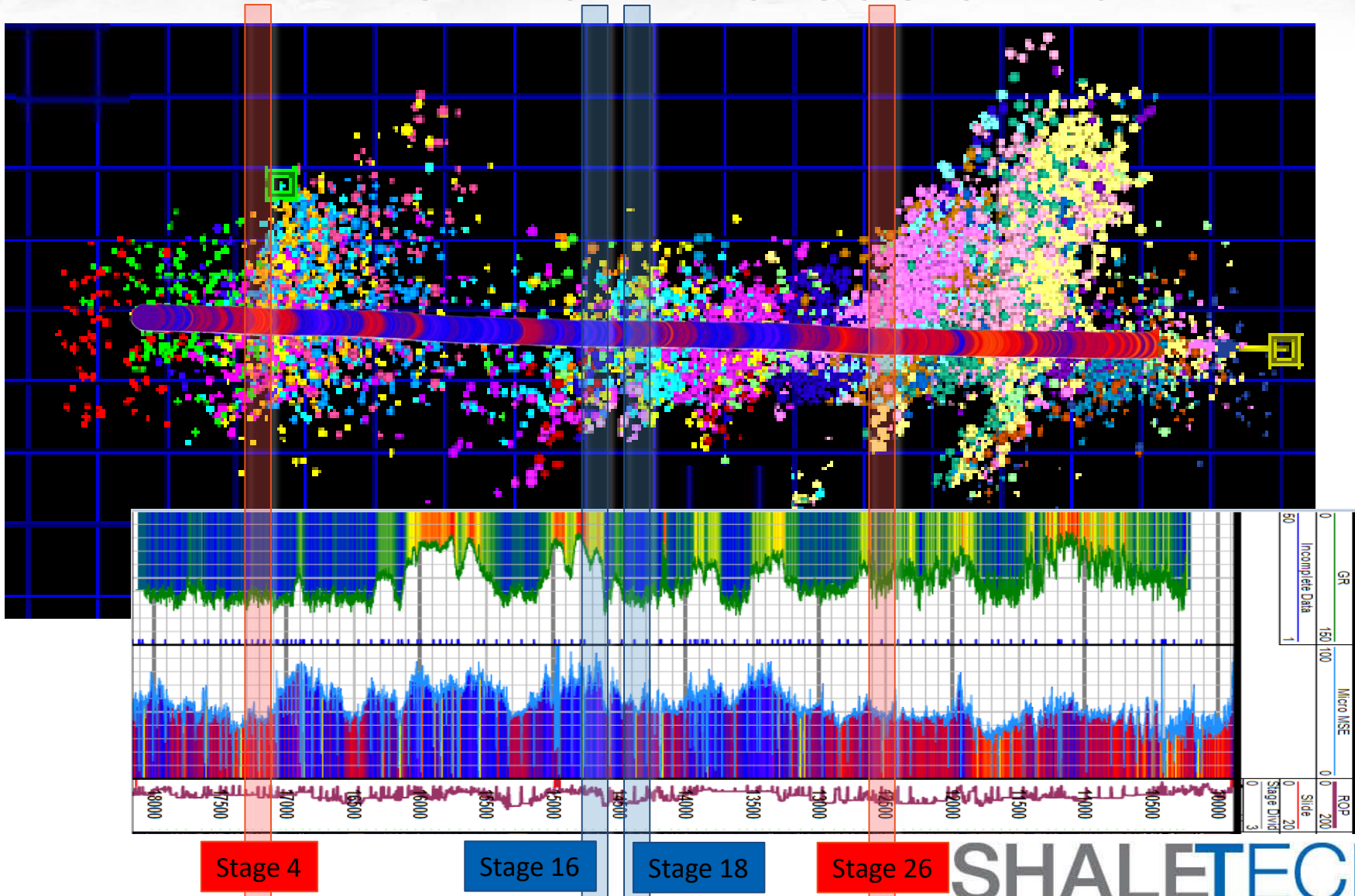
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Grey	HD 7	200K +

↓ Hardness Increases

# MSE vs. Nolte-Smith Plots

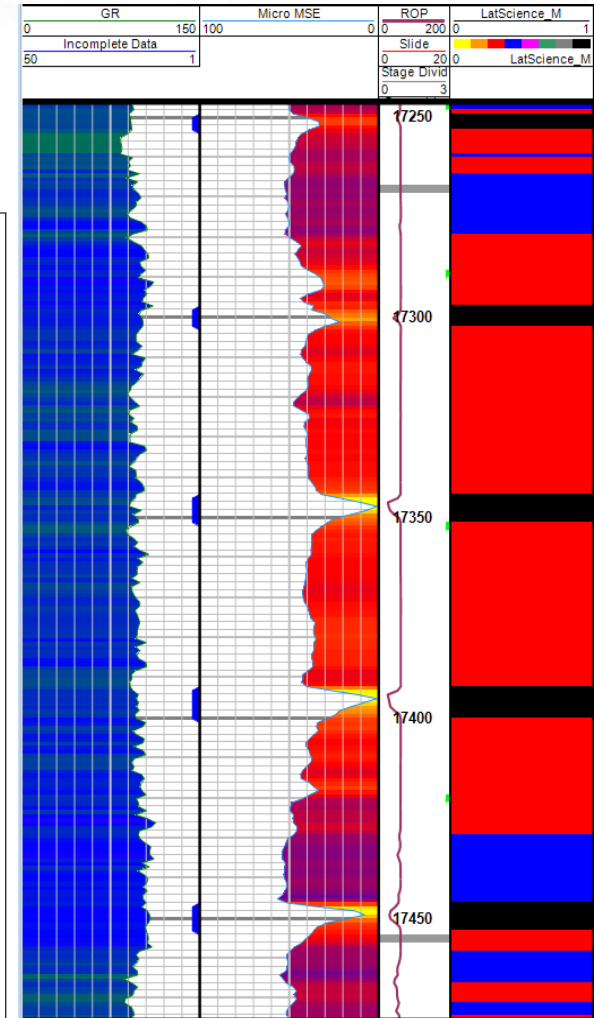
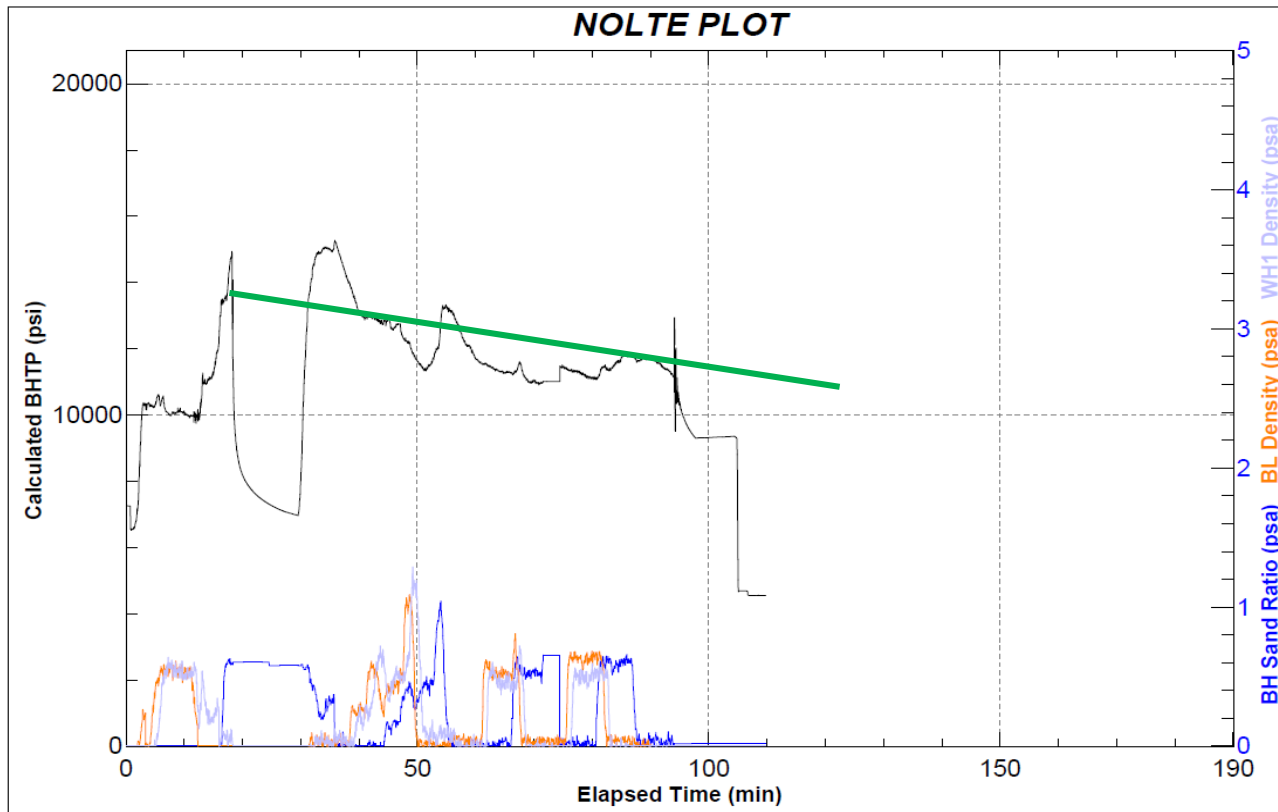


# MSE vs. Microseismic



# Stage 4

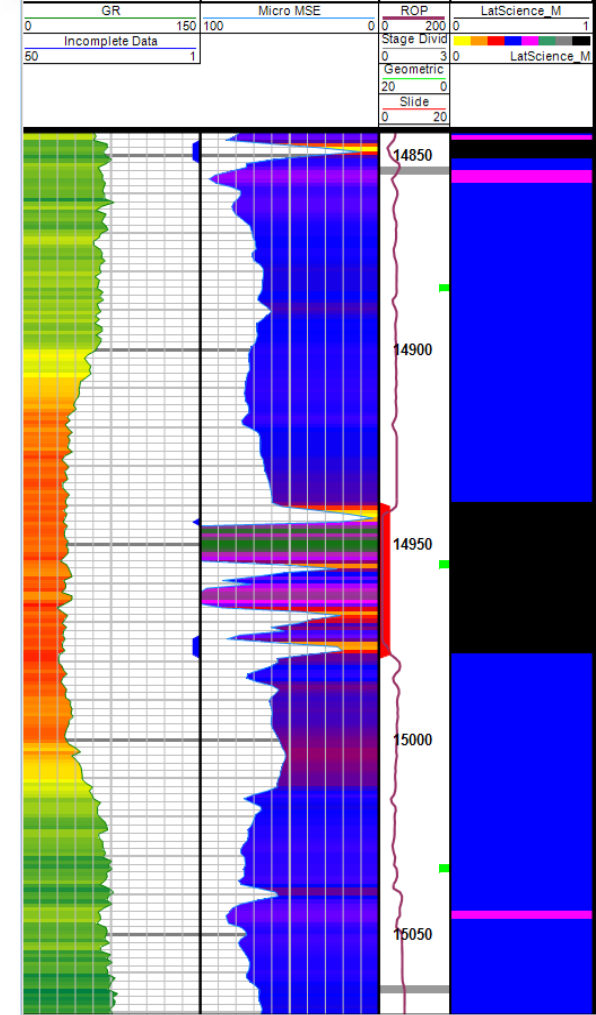
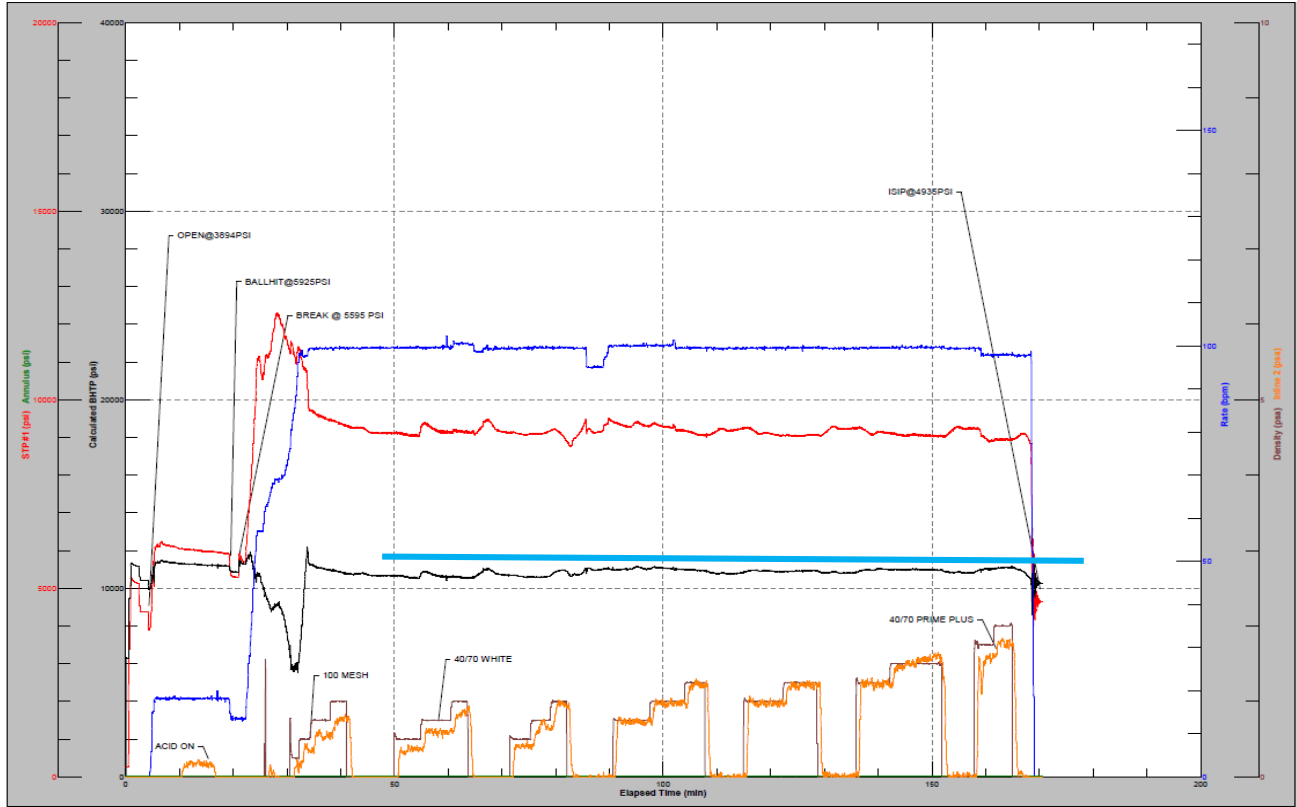
Customer's Completion Design				
Stage	Plug	Cluster 1	Cluster 2	Cluster 3
4	17454	17419	17351	17288





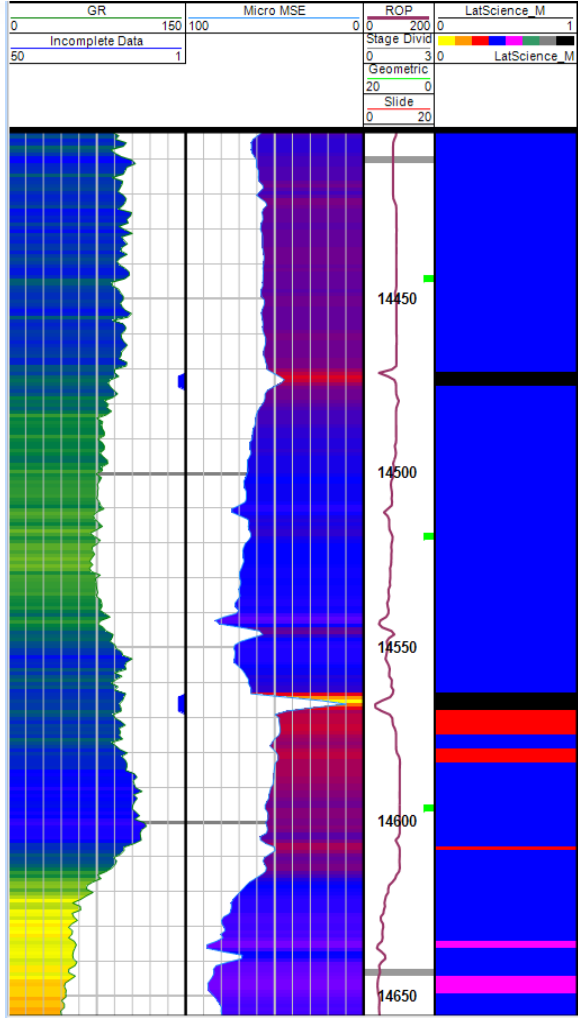
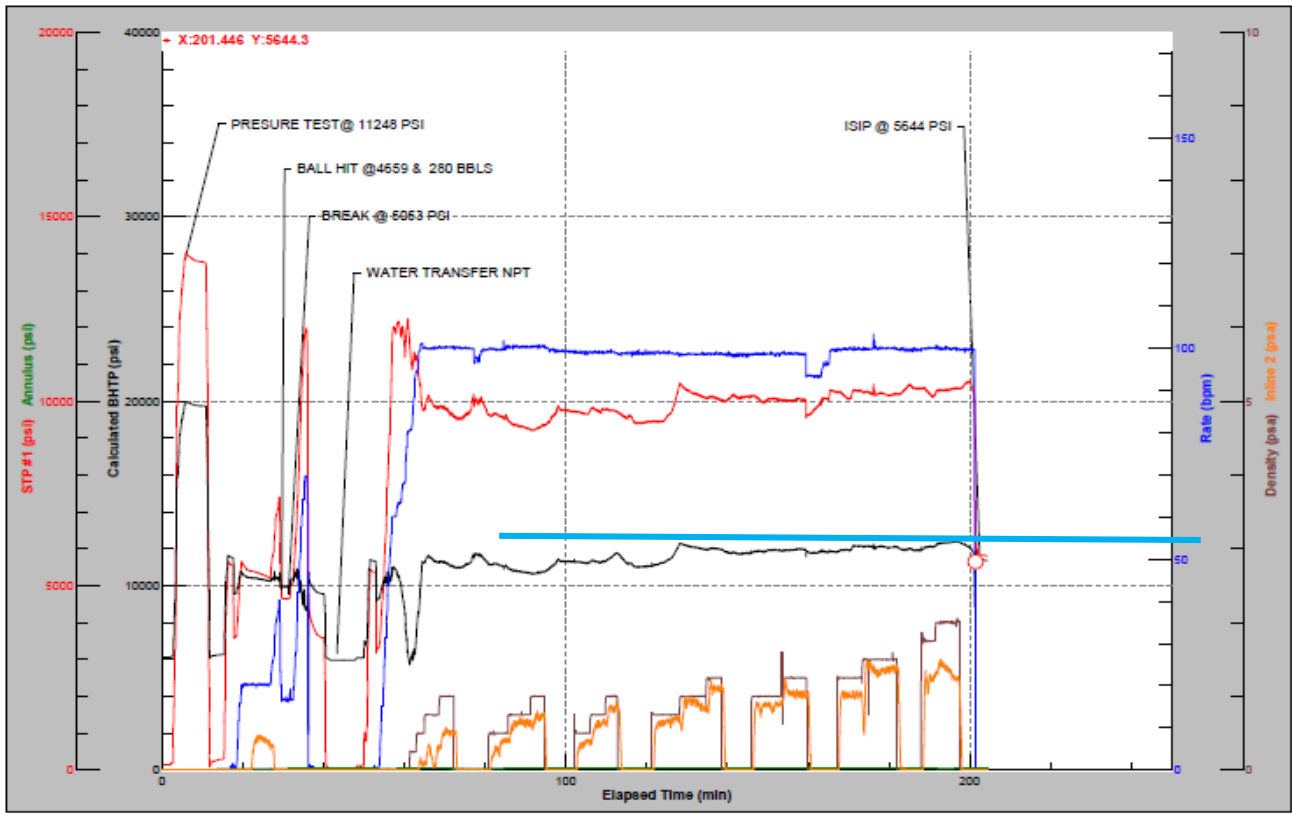
# Stage 16

Customer's Completion Design				
Stage	Plug	Cluster 1	Cluster 2	Cluster 3
16	15063	15032	14954	14883



# Stage 18

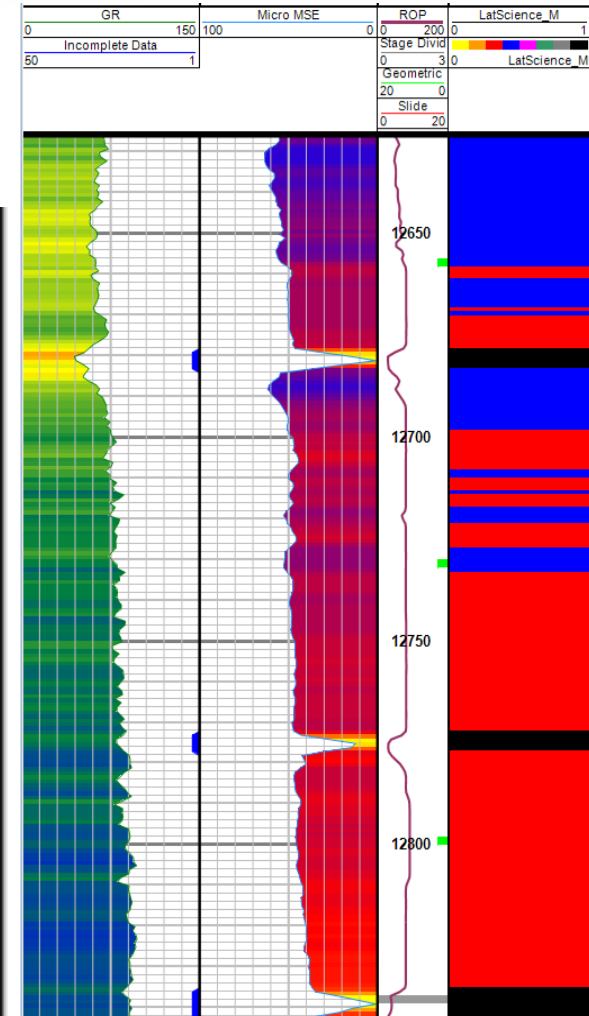
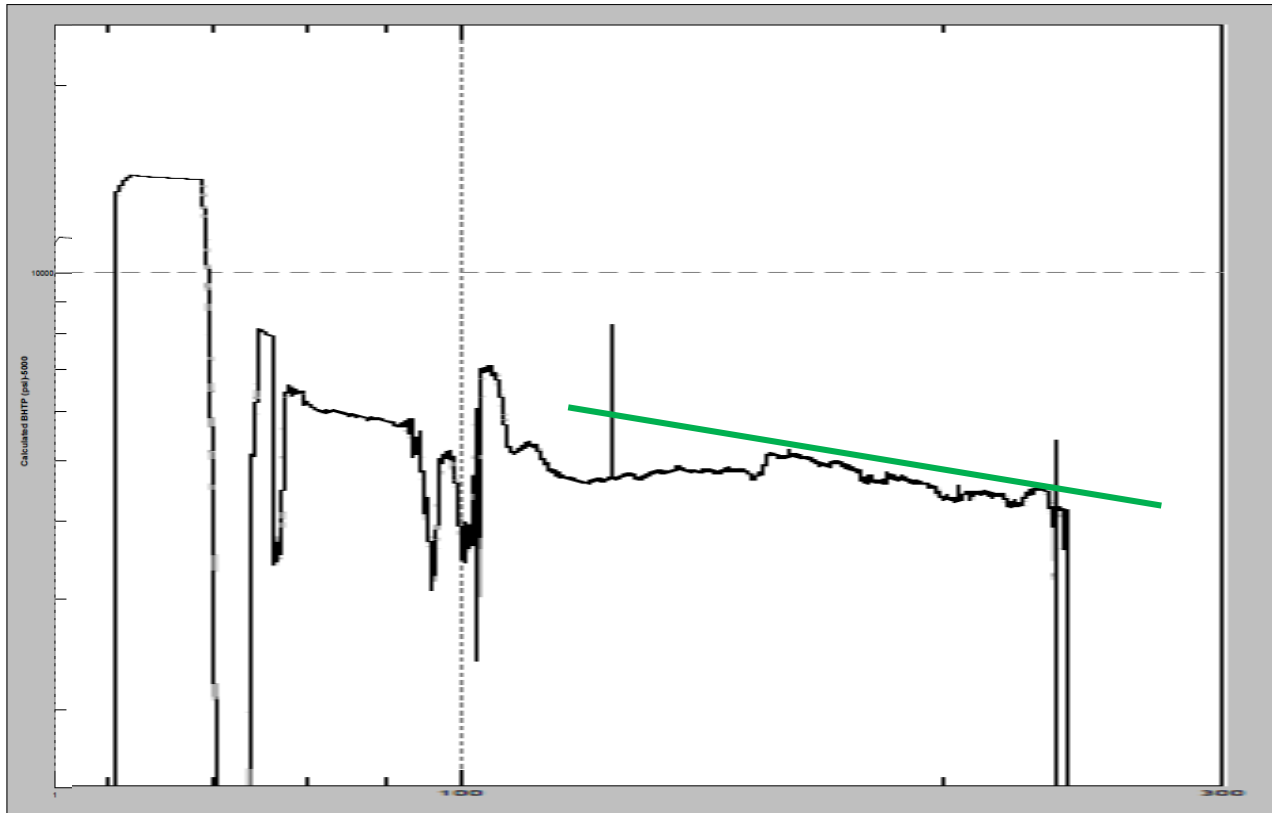
Customer's Completion Design				
Stage	Plug	Cluster 1	Cluster 2	Cluster 3
18	14642	14595	14517	14443



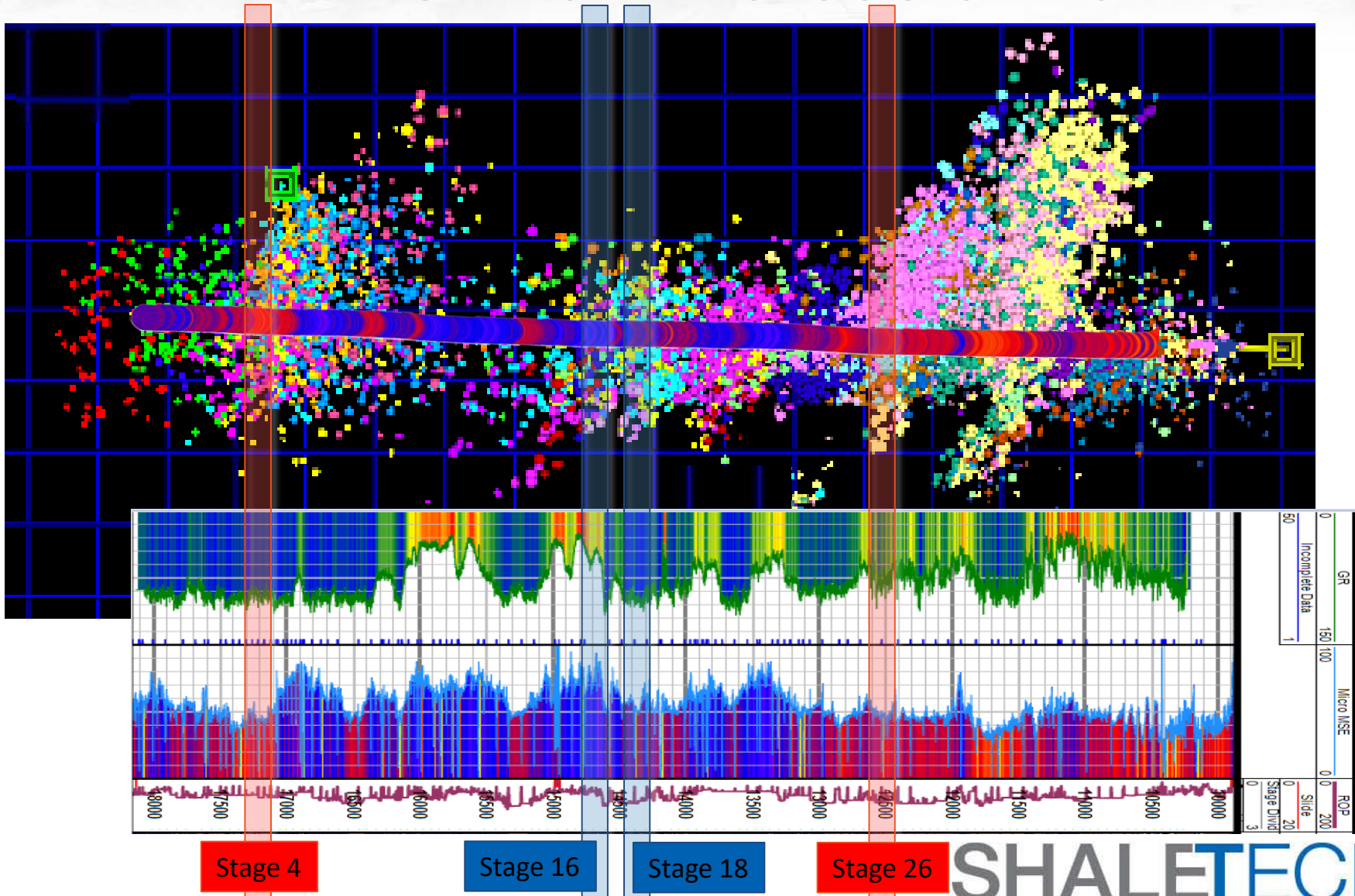
# Stage 26

## Customer's Completion Design

Stage	Plug	Cluster 1	Cluster 2	Cluster 3
26	12837	12798	12730	12656



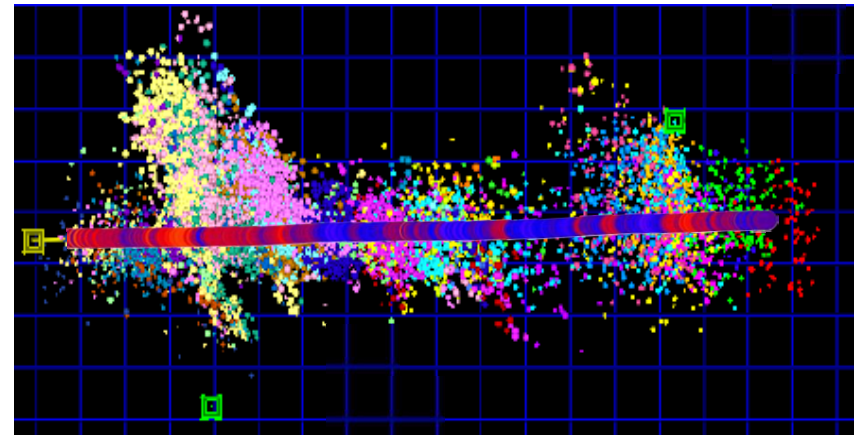
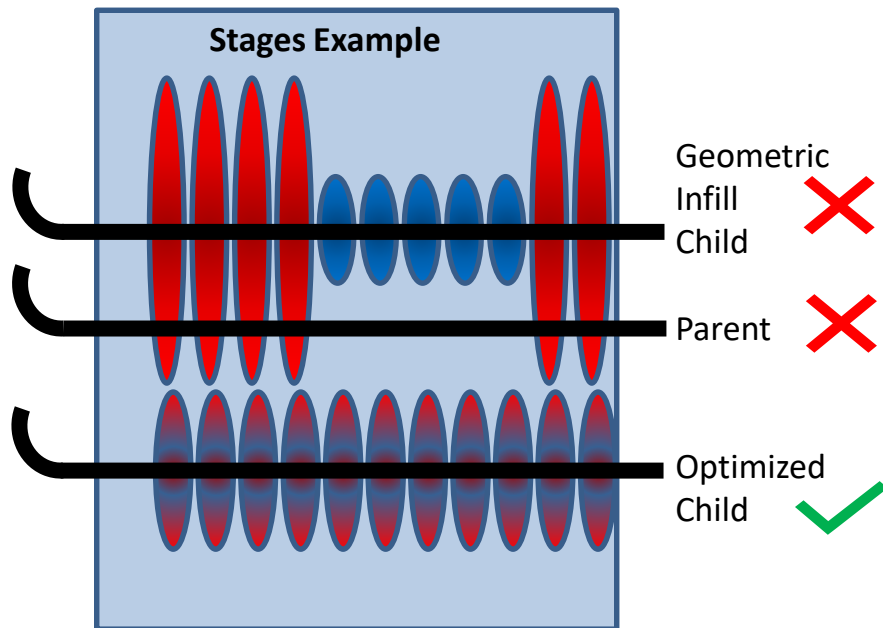
# MSE vs. Microseismic





# Impact of Variation in Fracture Generation Type

- Frac Hits
- Poor rock volume stimulation/exploitation



# Wrap-Up

- Ability to evaluate wells using existing drilling data
  - No Hz logs needed
  - Information is usually undervalued and readily available
  - Corrected MSE is a proxy for rock hardness
- MSE data can provide an opportunity to optimize the treatment design based on prevailing fracture type to achieve:
  - consistent stage/treatment response
  - mitigate offset frac-hits
  - improve stimulated rock volume
  - improve production for the well and field
- Factors that can be adjusted to impact stimulation based on MSE data:
  - Stages/Clusters
    - Number / Spacing / Placement
  - Fracturing treatment
    - Amount of Fluid / Type of Fluid / Proppant Amount / Proppant Size / Slurry Rate / Diverter