Marcellus Shale Energy and Environmental Laboratory (MSEEL)

Project Number (FE-0024297)

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West Virginia University

U.S. Department of Energy

National Energy Technology Laboratory

Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

August 26-30, 2019

Project Objectives

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

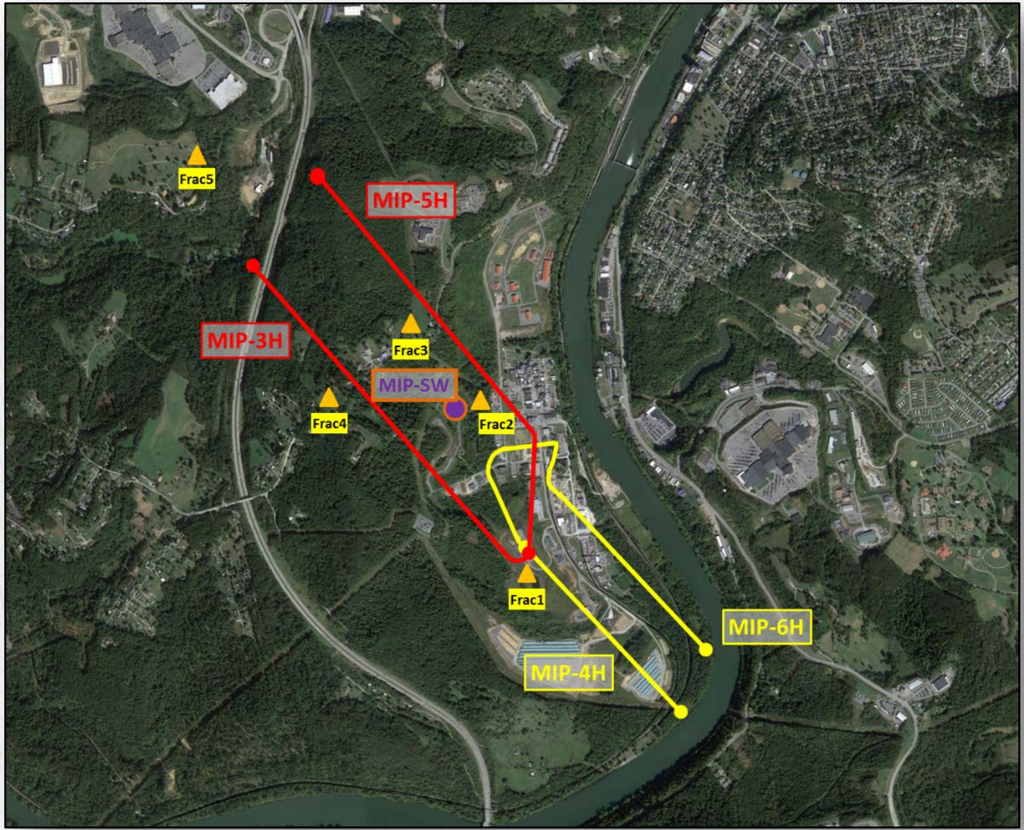
MSEEL

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development

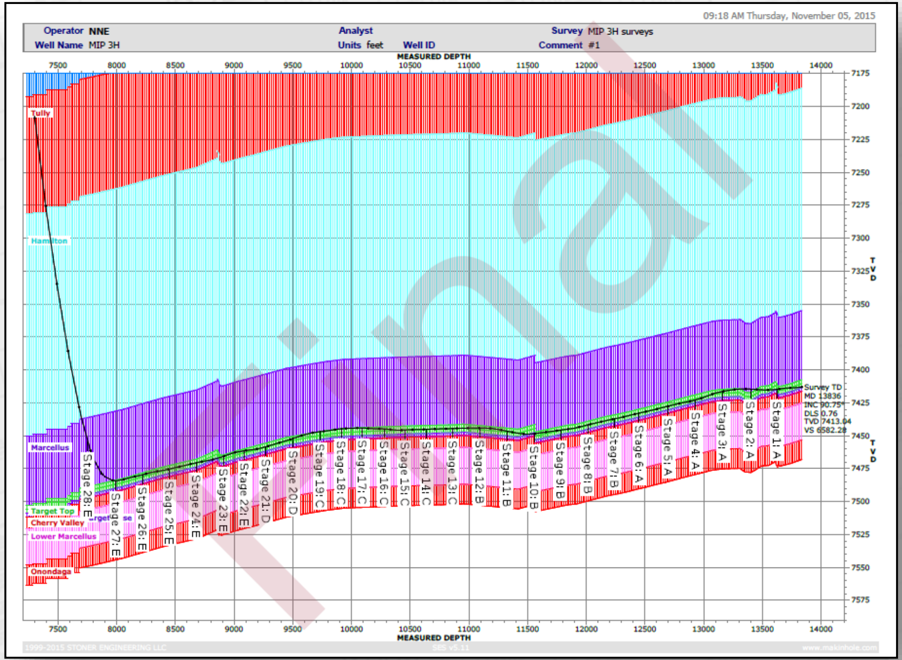
Outline

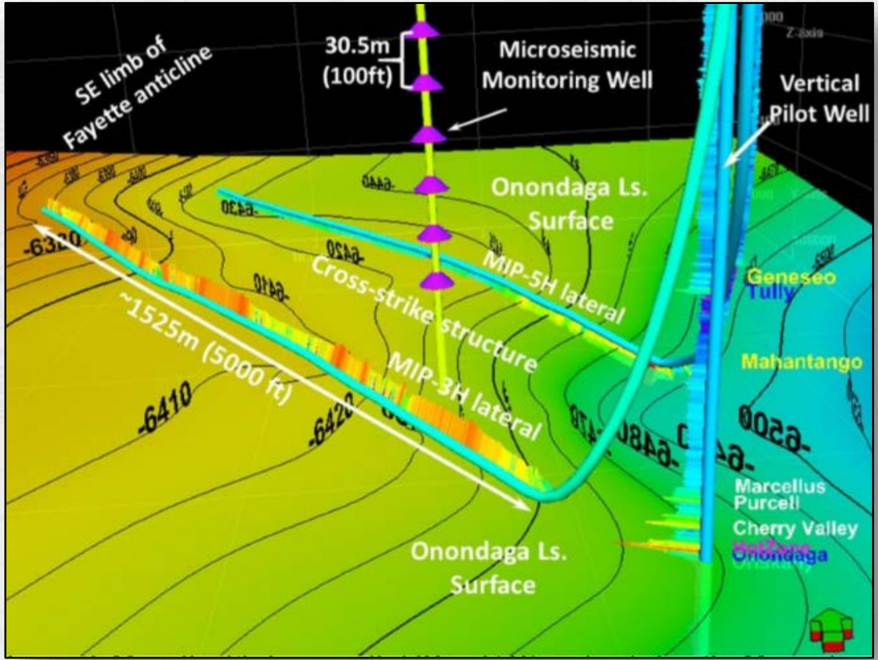
- ❑ **Overview of MSEEL Project**
  - History
  - MIP 3H Well - Completion
- ❑ **The Importance of Logging the Lateral**
  - Fractures
  - Geomechanical Properties
- ❑ **Fiber Optic Data**
  - Distributed Acoustic Data (DAS)
  - Distributed Temperature Data (DTS)
- ❑ **Long-Term Reservoir Monitoring by DTS:**
  - Snap-shot of production at one time
  - Engineered stages improve production efficiency
- ❑ **MSEEL 2**
  - Cost Effective Data
  - Actionable Data (Near Real-Time)
- ❑ **Underway**
  - Plans
  - Initial Results

MSEEL MIP Site

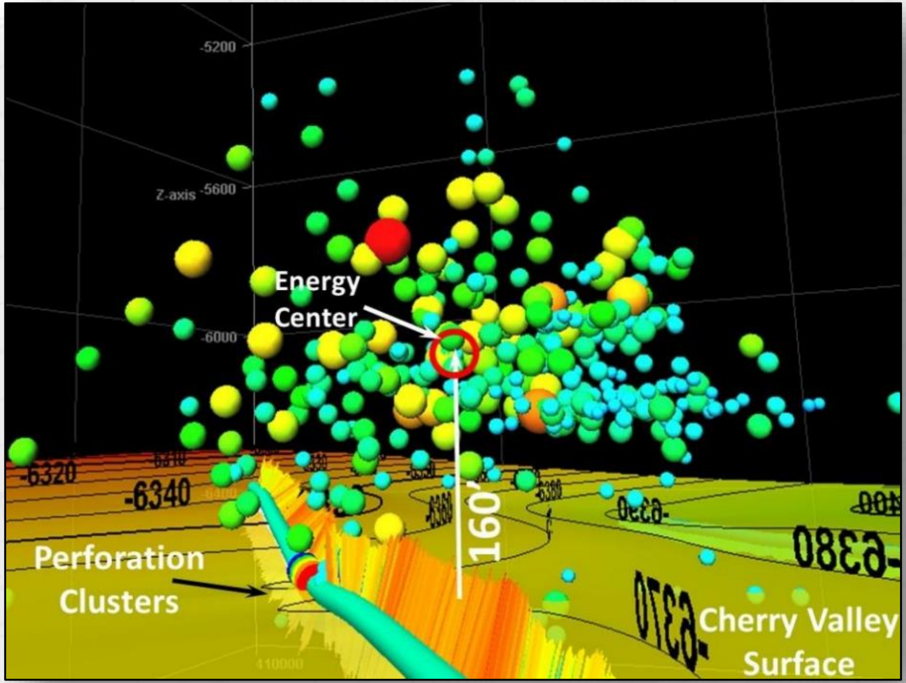


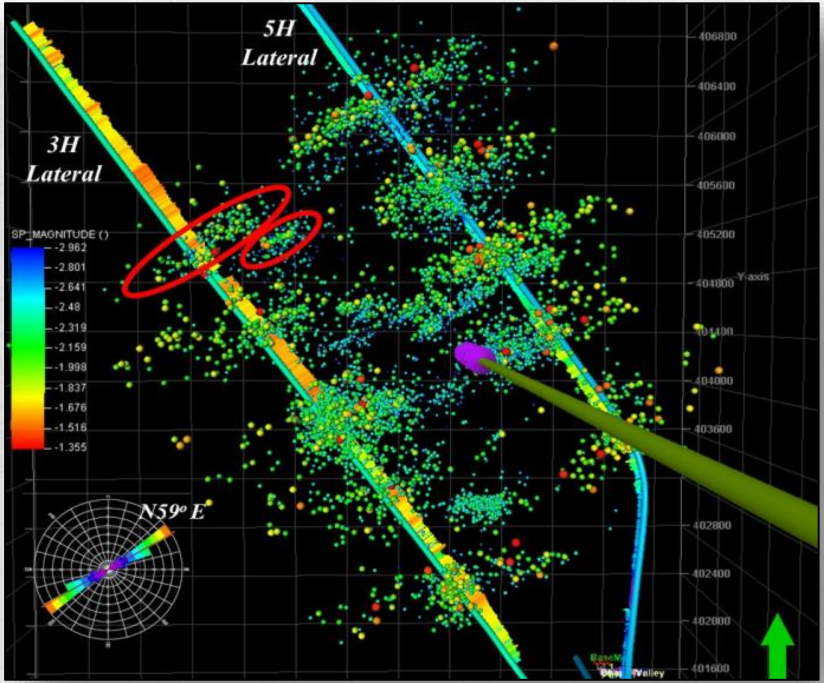
Geologic Background





Microseismic





Logging Lateral MIP-3H

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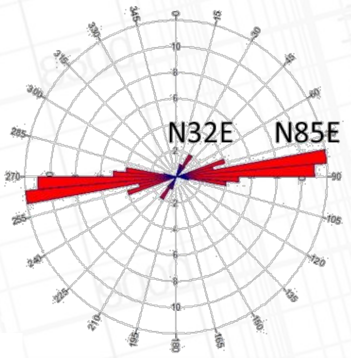
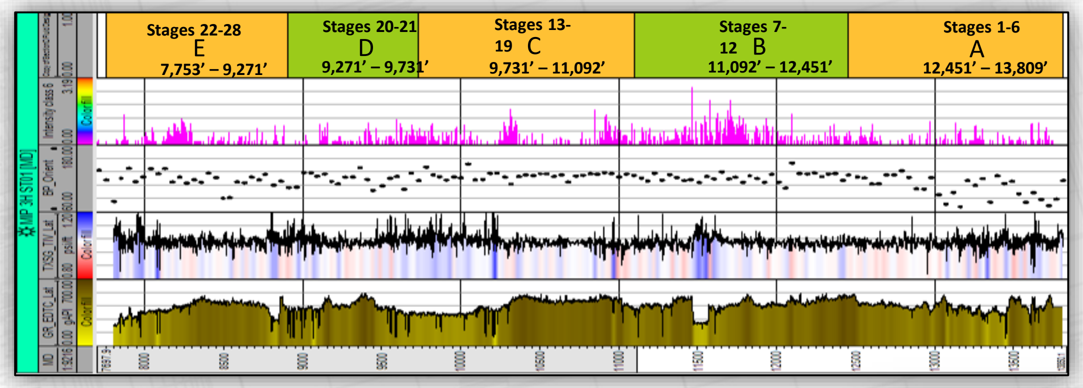
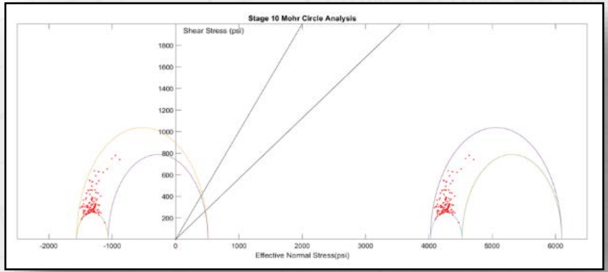
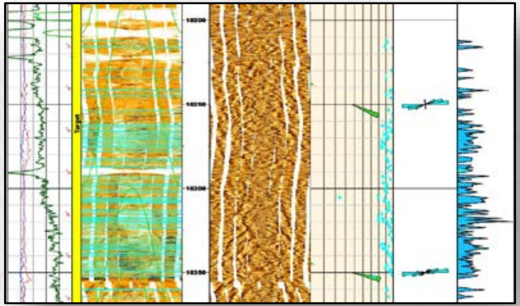
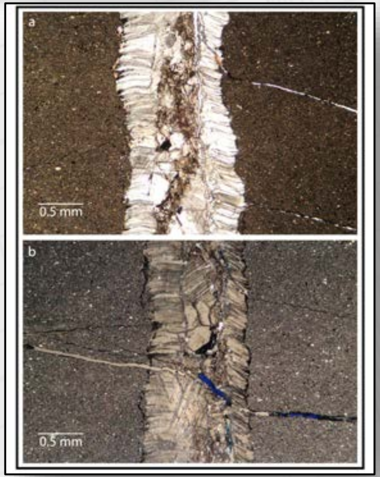
3H Lateral





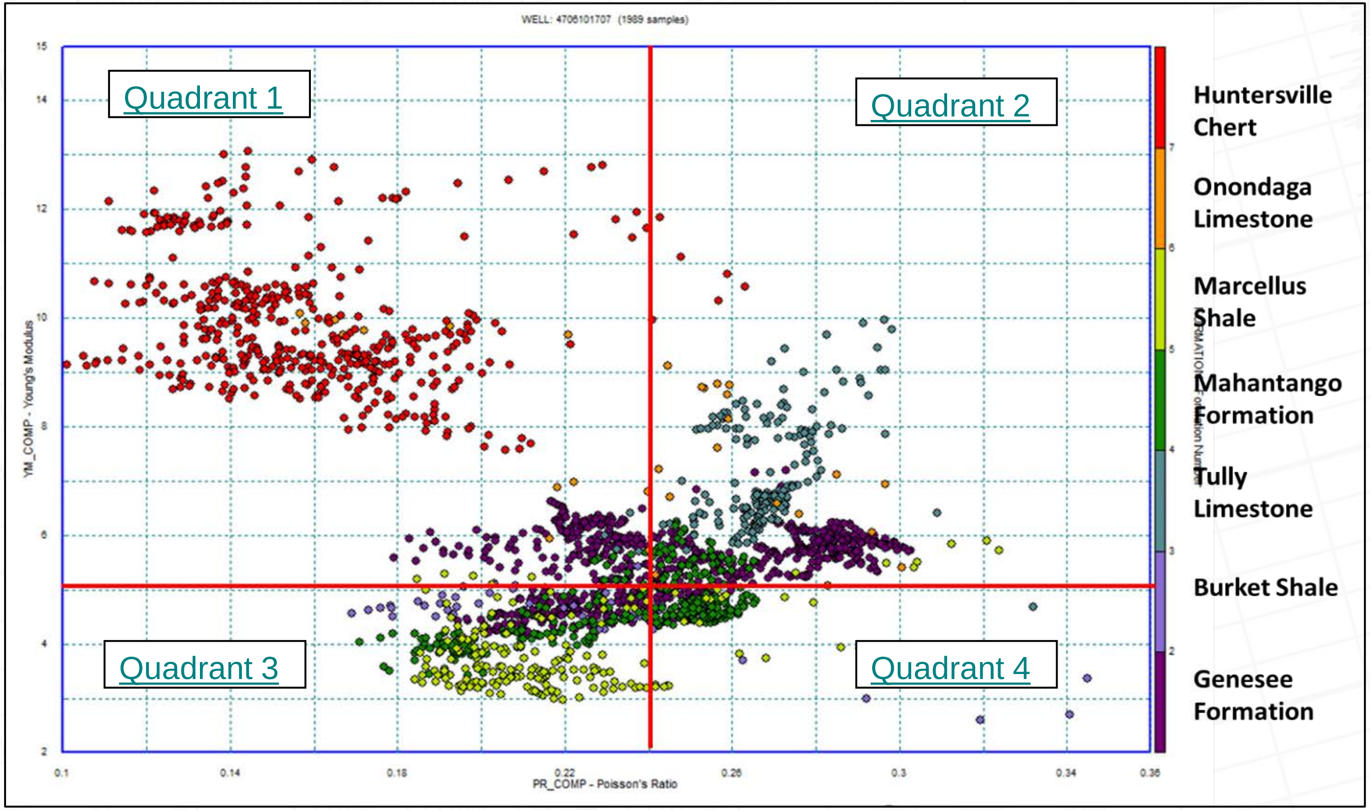






Stage / Fault/Fracture	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
No of Faults	3				2	1				2	1																	
No of Fractures	41	25	48	29	15	69	47	51	97	160	86	65	72	17	14	90	25	56	68	71	37	46	21	41	42	89	66	28

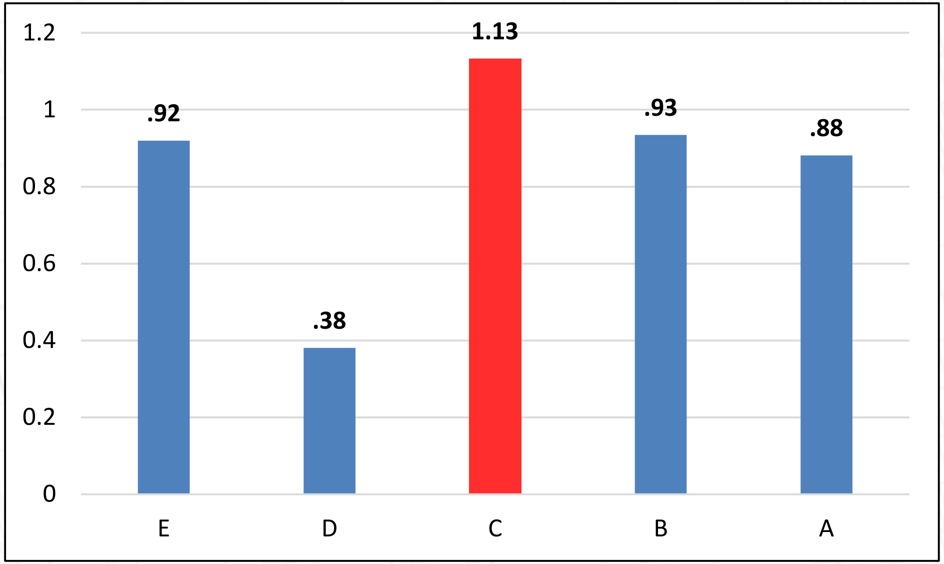
Geomechanical Logs
3H Vertical Pilot



Engineered Stages
Fiber-Optic Data DAS & DTS

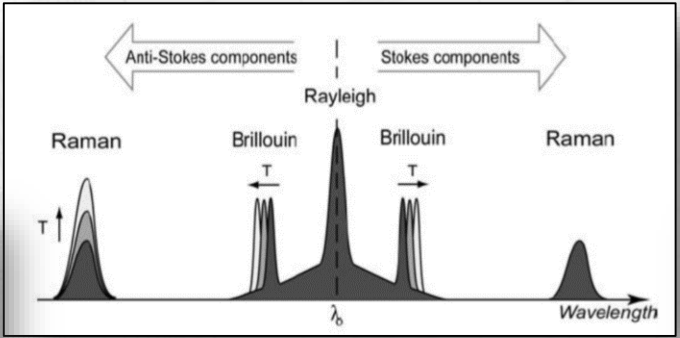
- ❑ **Challenges**
- • Expense
- • Borehole Risk
- • Data Overload (Big Data)
  - Volume, Velocity, Variety, Veracity
- ❑ **Benefits**
- • Improved Stimulation Efficiency
- • Improved Production Efficiency
- ❑ **Don’t have the solution, but progress**
- • Lower Costs
- • Decrease Time
- • Increase Production

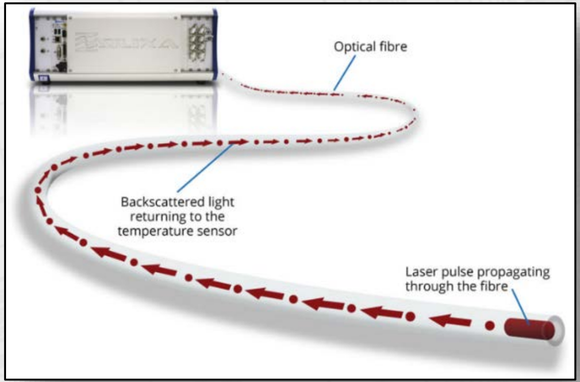
MIP 3H Gas Production – mcf/ft



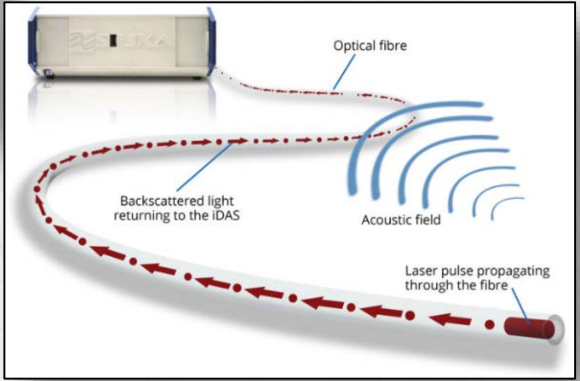
Engineered design using data obtained during MSEEL has ~20% increased production compared to standard NNE completion techniques
EUR for future wells could be ~10-20% greater ***IF*** we can exploit the technologic advantages gained through MSEEL in a more cost-effective fashion

Fiber-Optics Distributed Acoustic Sensing (DAS) & Distributed Temperature Sensing (DTS)





Courtesy of Silixia Ltd., UK



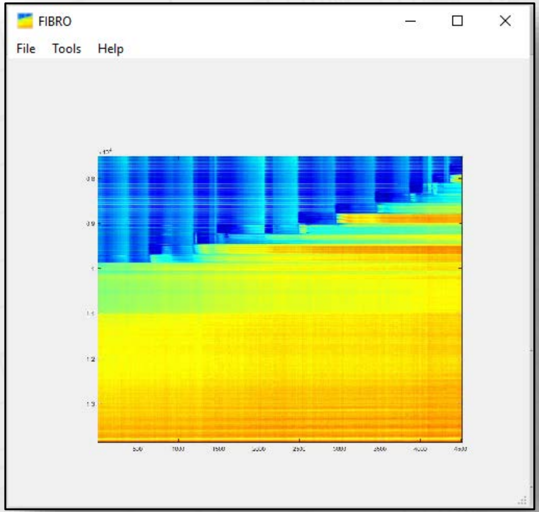
Courtesy of Silixia Ltd., UK

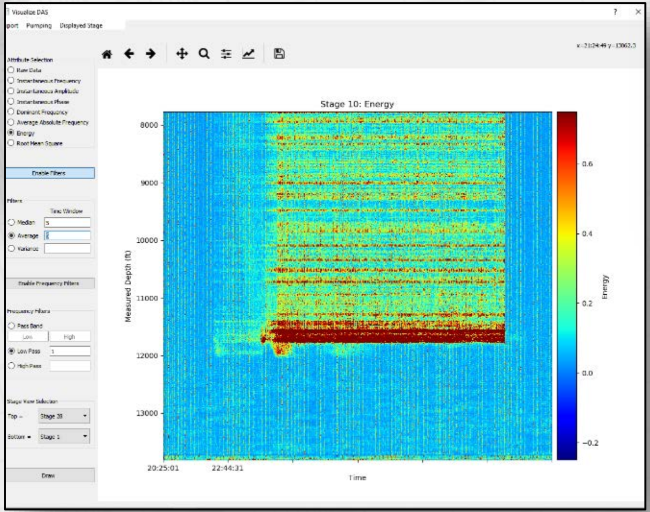
Courtesy of Mishra et al., 2017

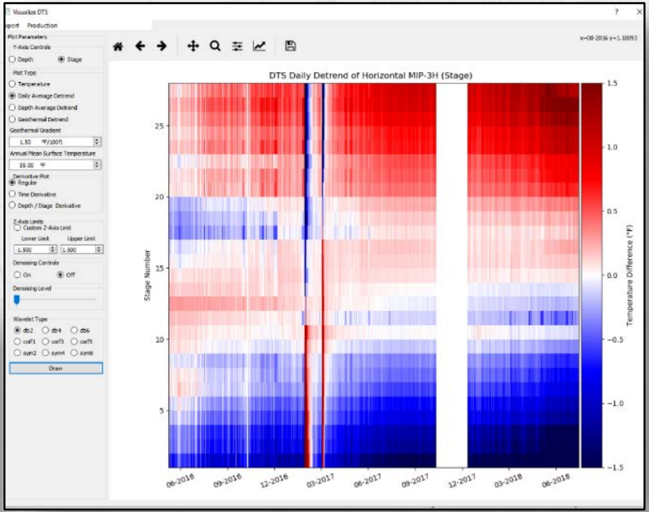
DAS, DTS and Terabytes Oh My

FIBRO

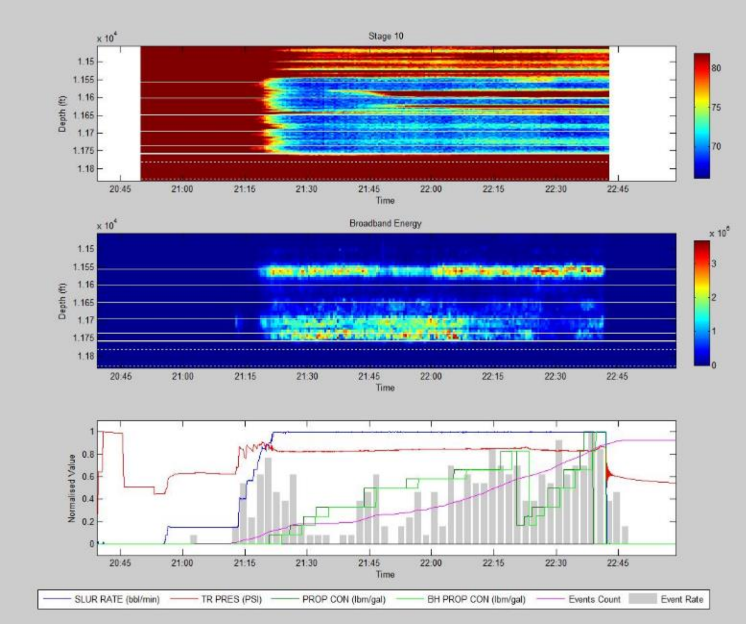
Payam Kavousi Ghahfarokhi

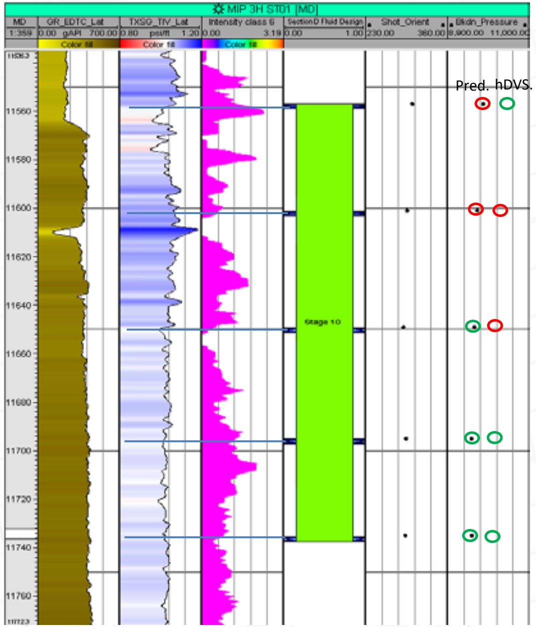






Section B (Stage 10) - Geometric





Design Parameters:

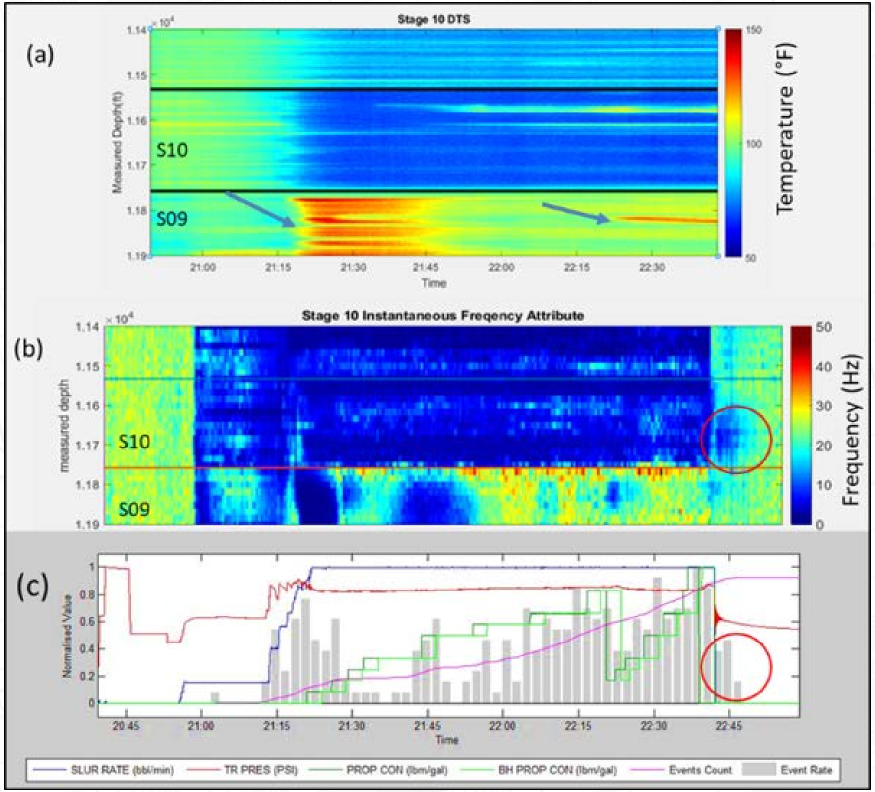
– 5 clusters, 5spf, 50 holes, 0.42”, 100 bpm
– Perforation friction ~ 1120 psi
– In-situ stress contrast ~ 393 psi
– BD pressure contrast ~299 psi

- DTS show cooling effect on all clusters
- hDVS show intermittent energy on all clusters
- Clusters 1,2,5 seem to breakdown initially based on hDVS
- 60% match between predicted and actual breakdown

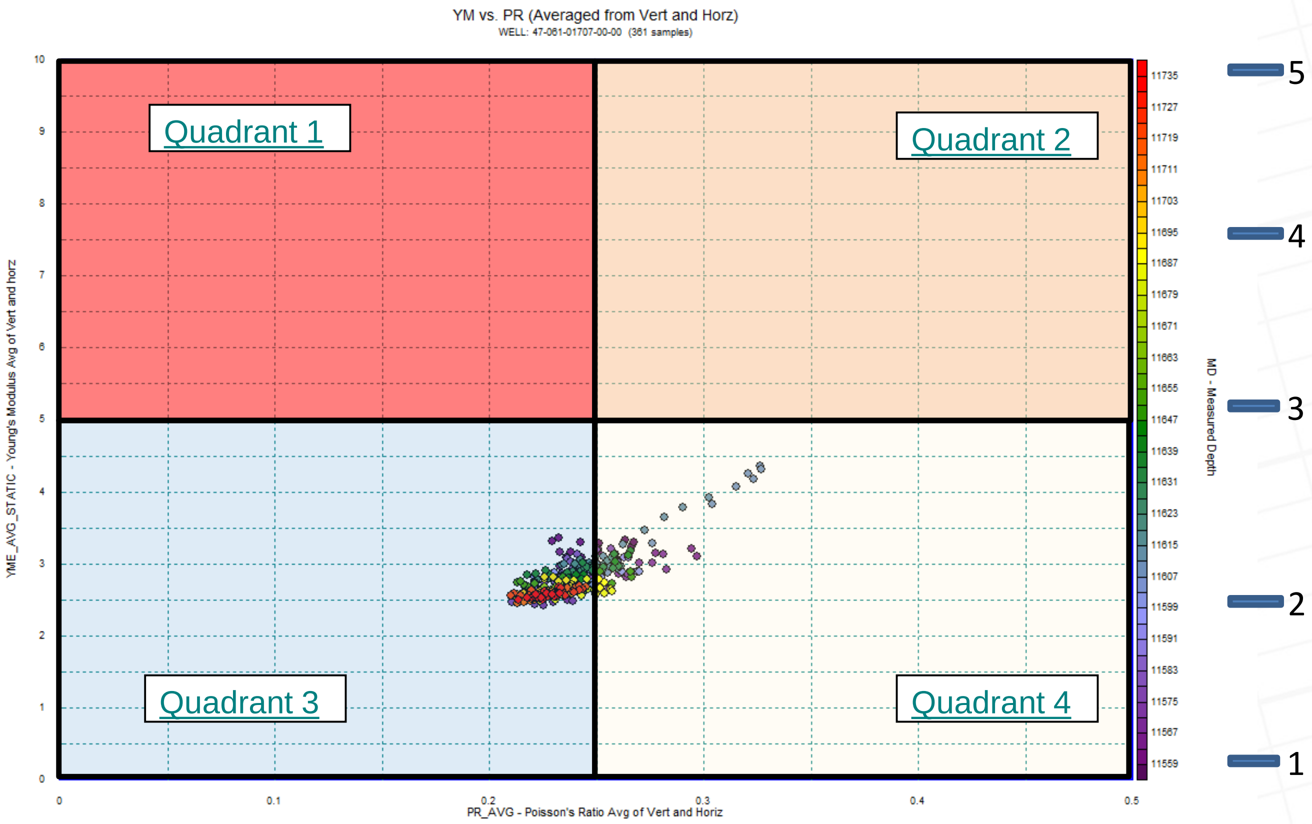
Section B (Stage 10) - *Geometric*

Courtesy of Schlumberger

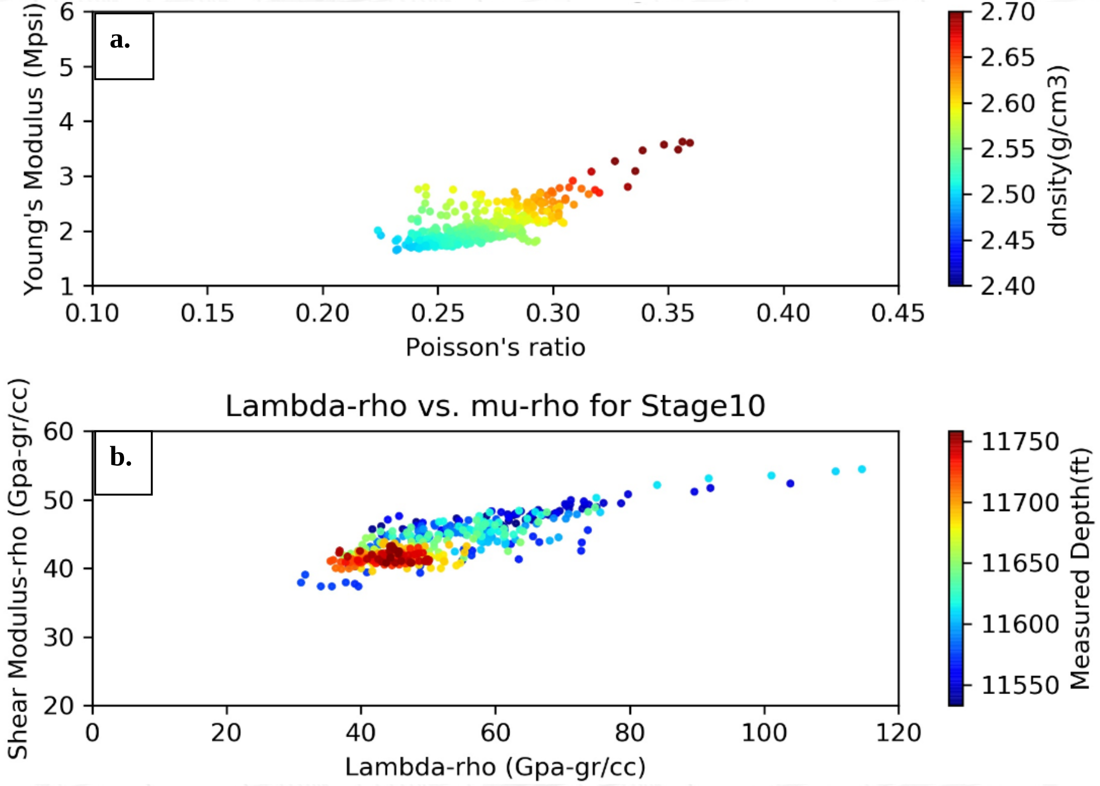
DAS and DTS
Stage 10 Stimulation



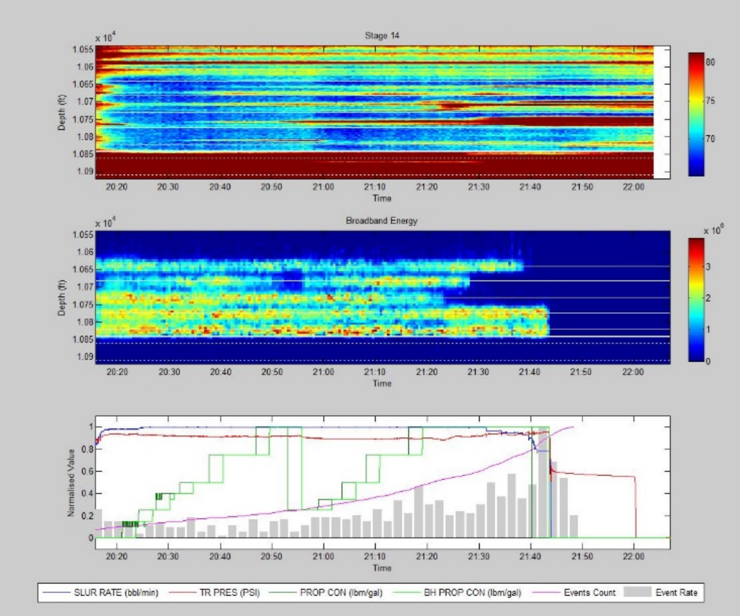
Stage 10 Geometric

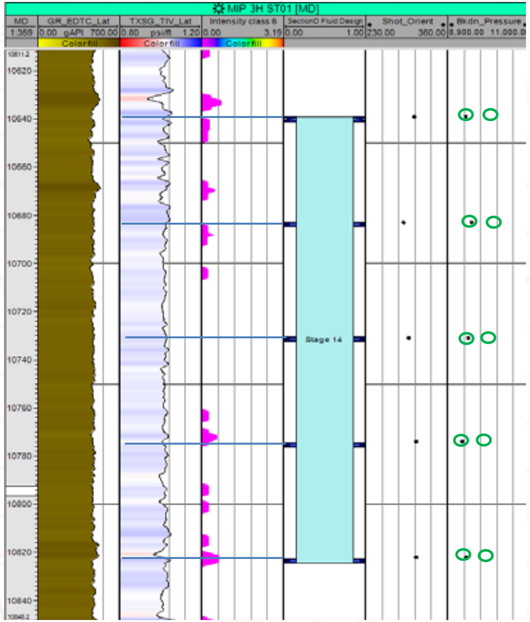


Stage 10 Geometric



Section C (Stage 14) – Engineered





Design Parameters:

– 5 clusters, 3spf, 30 holes, 0.42”, 100bpm

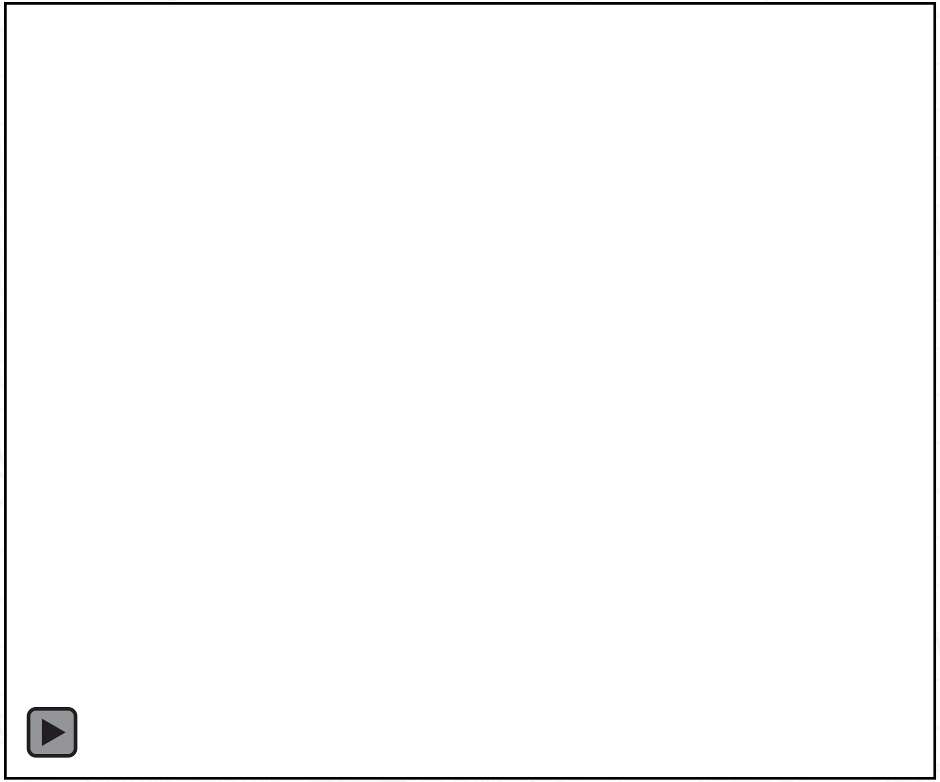
– Perforation friction ~ 3000 psi

– In-situ stress contrast ~ 294 psi

– BD pressure contrast ~ 242 psi

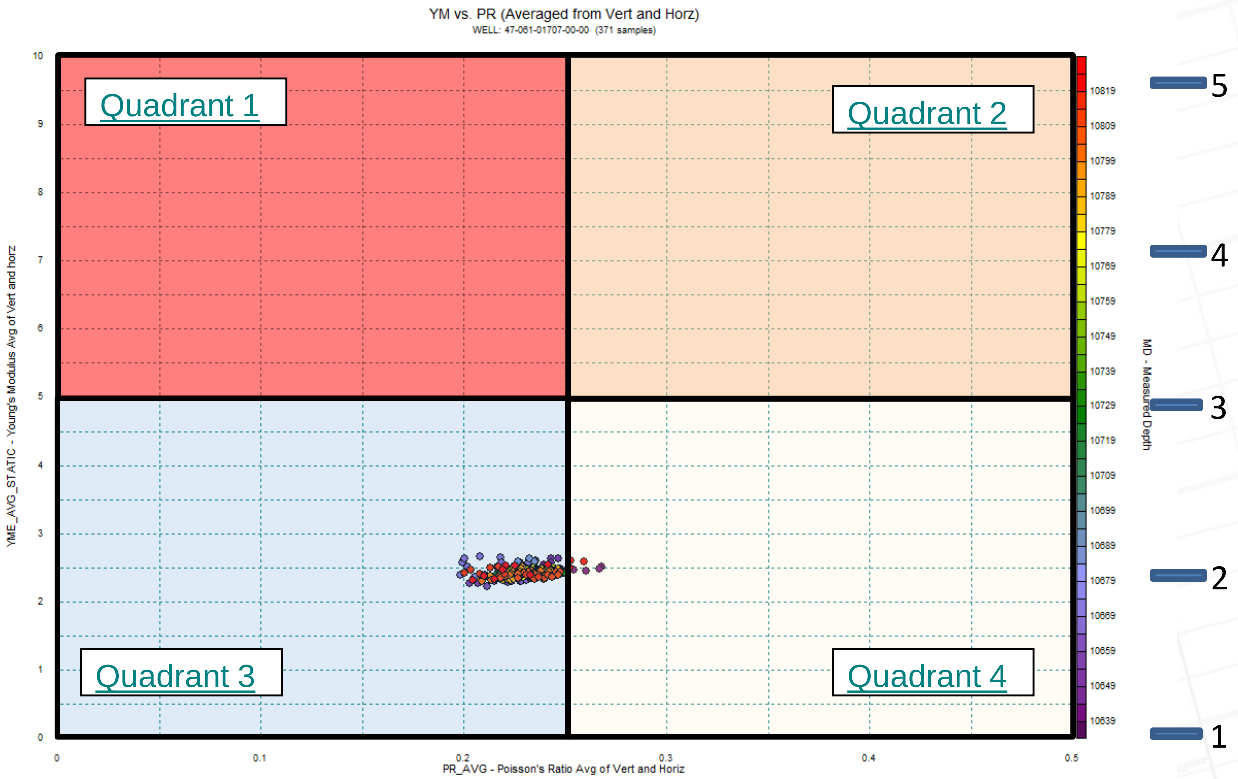
- DTS show cooling effect on all clusters
- hDVS show more uniform energy on all clusters
- All clusters seem to breakdown initially based on hDVS
- 100% match between predicted and actual breakdown

Section C (Stage 14)
Engineered and Limited Entry

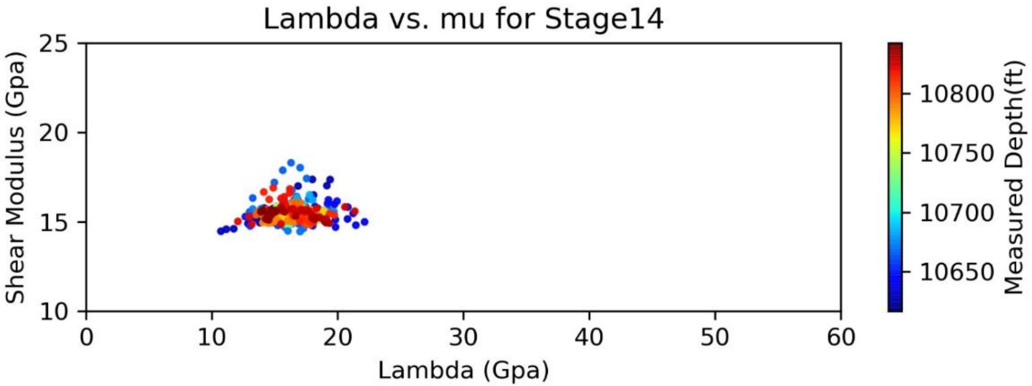


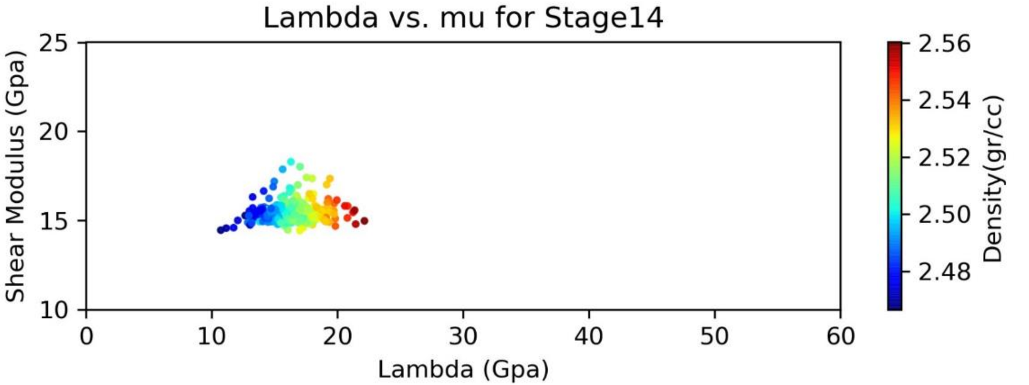
Courtesy of Schlumberger

Section C (Stage 14) Engineered



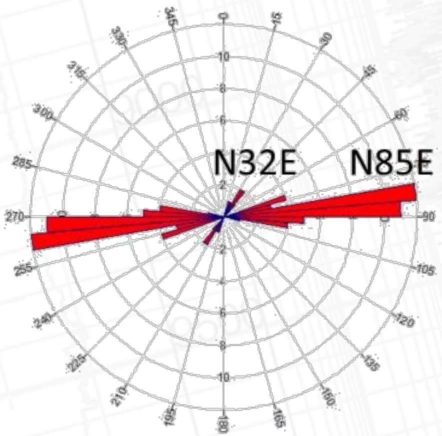
Section C (Stage 14) Engineered

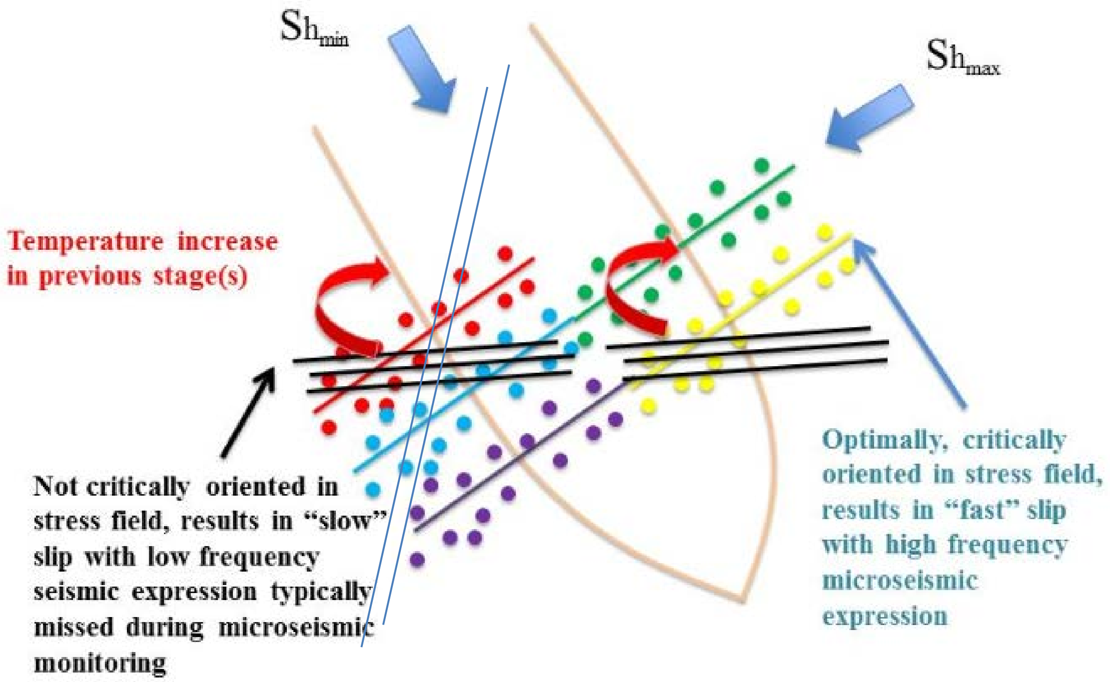


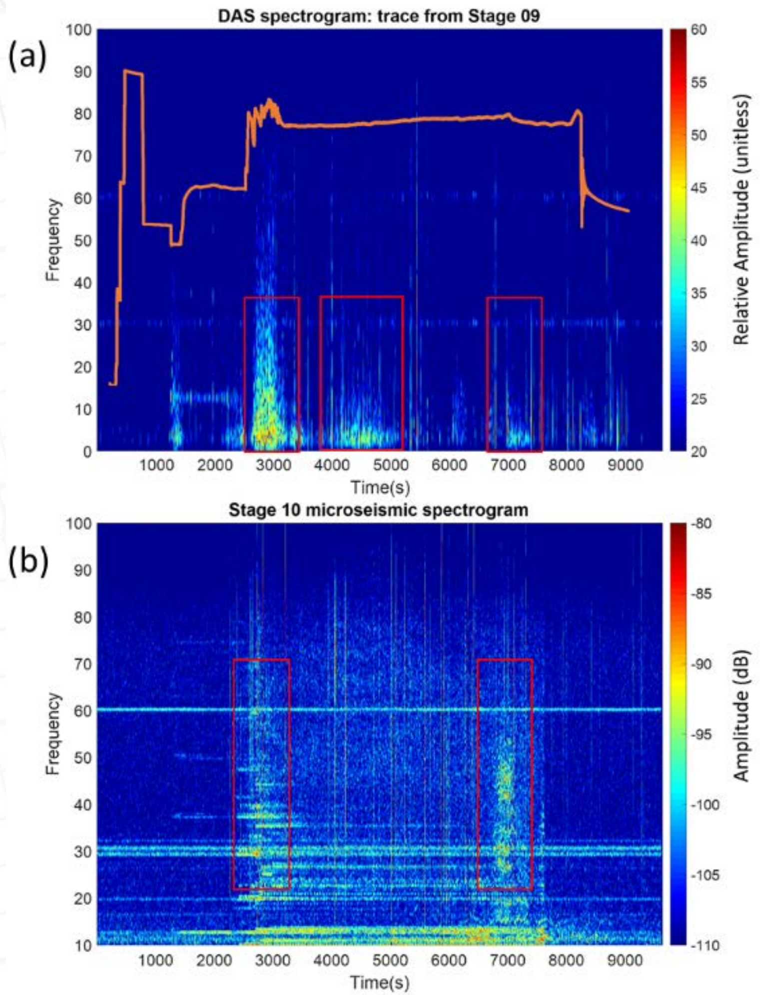


Cross-Stage Flow Communication

3H Lateral

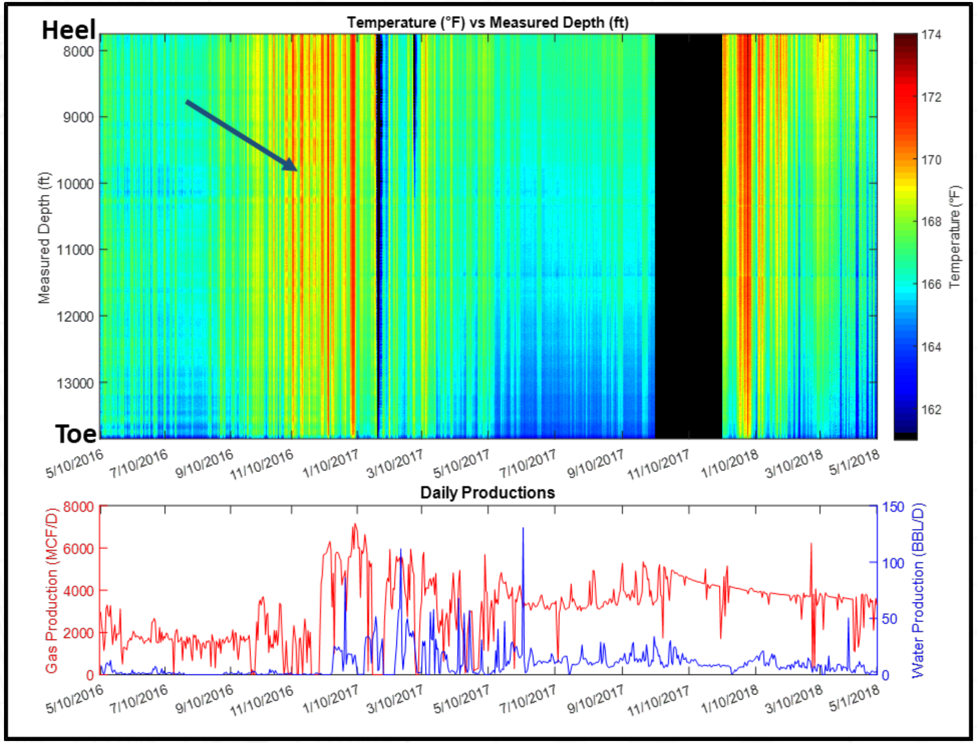




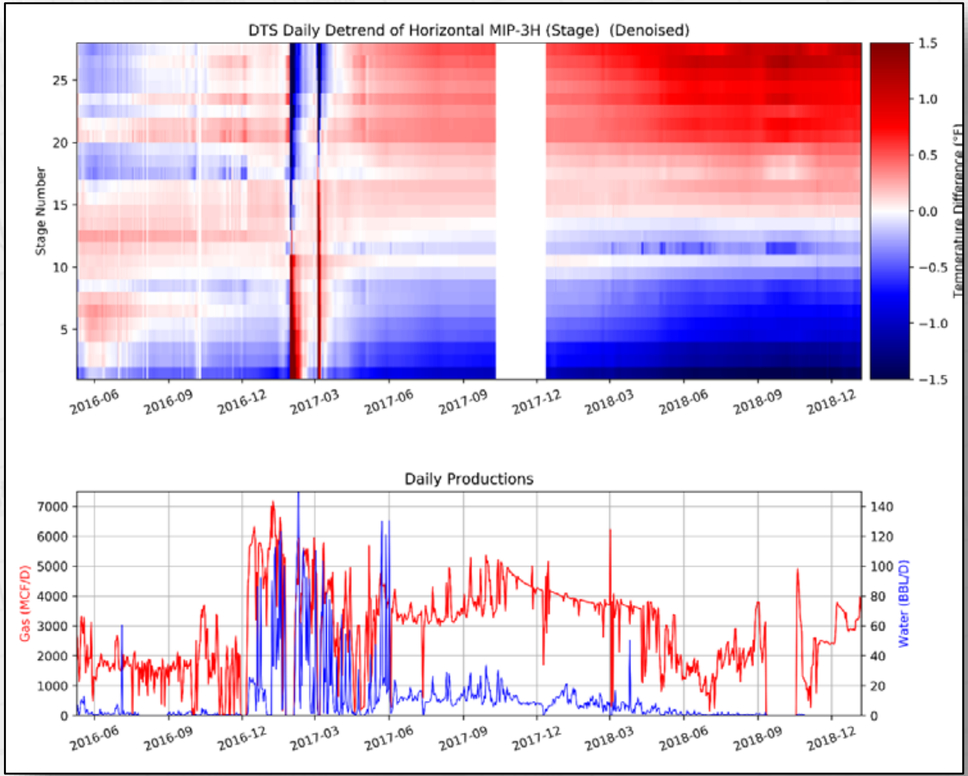


DAS and Geophone Spectrograms

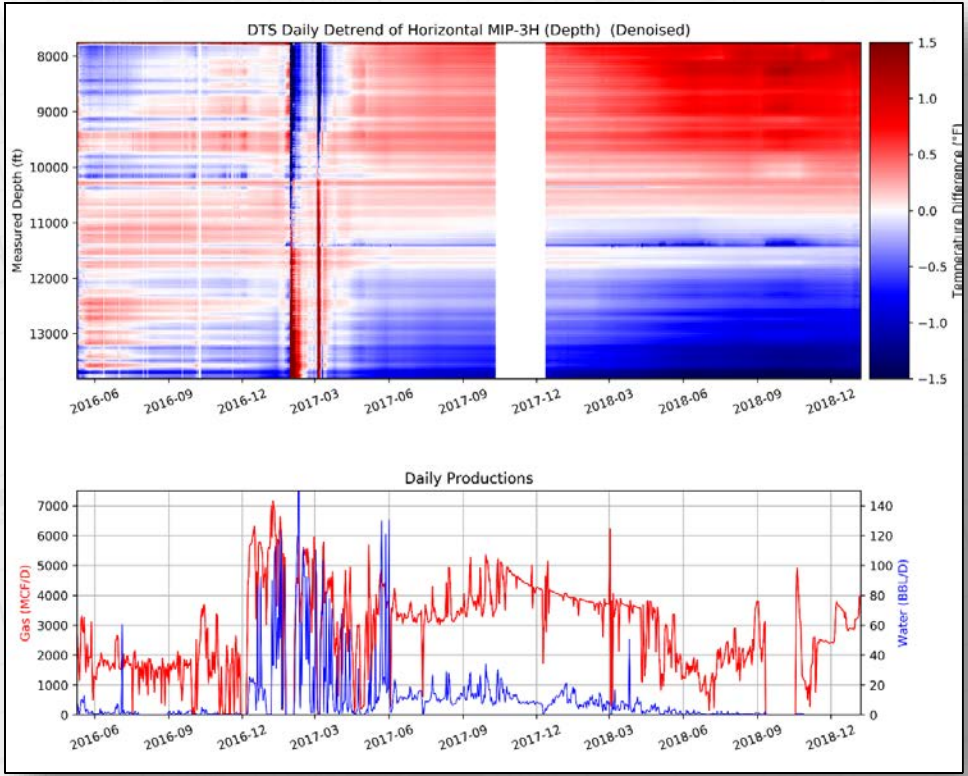
Long-Term DTS Monitoring



De-Trended DTS



De-Trended DTS



Modeling Sequence

DTS Prediction Model (Random Forest)

- **Inputs**: Geomechanical parameters from sonic log completion parameters such as treatment rate, proppant concentration, stage length, etc., along with operational conditions (e.g. Line Pressure and offset well (MIP-5H) Line Pressure)

Gas Production Model (Neural Network)

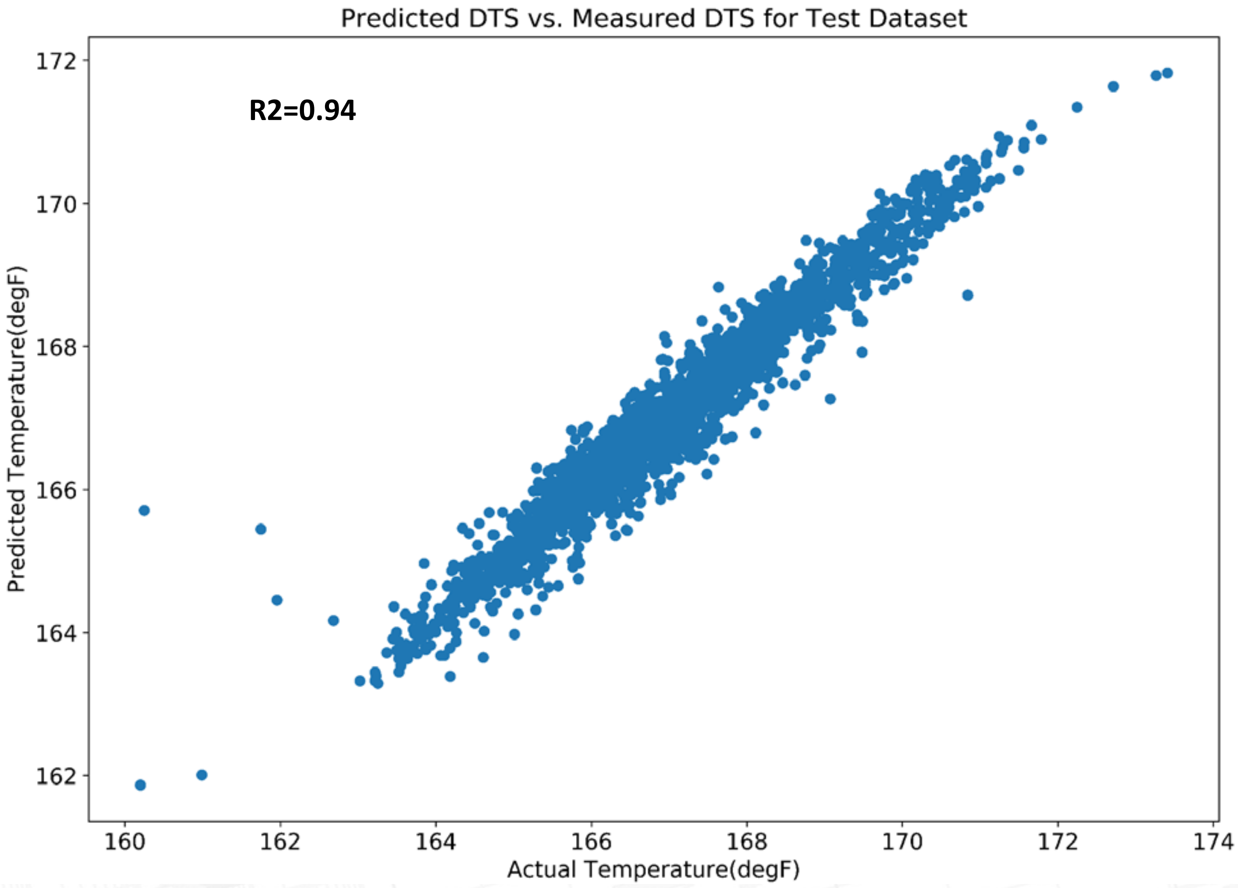
- **Inputs**: DTS data for the 28 stages

Daily Gas Production

This approach provides a composite that connects completion data, operational data, and geomechanical data to surface daily gas production.

DTS Model

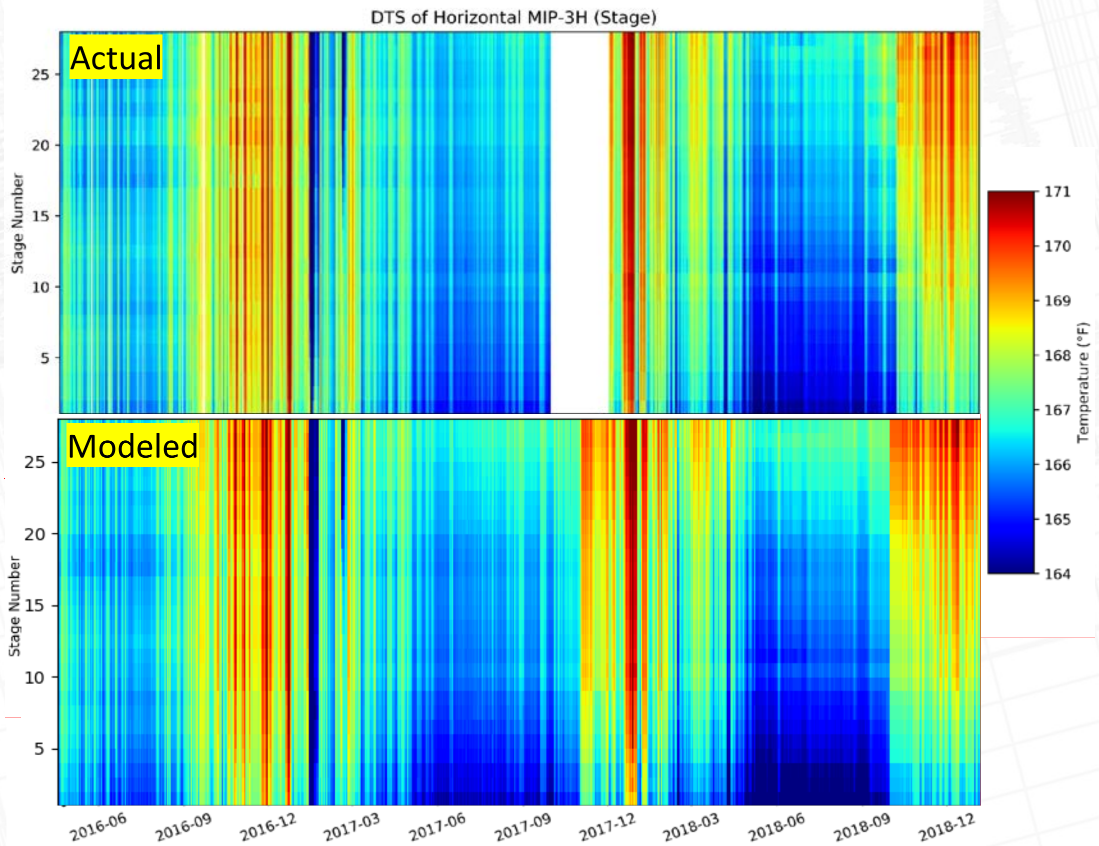
Random Forest Regressor predicted DTS data with a high accuracy



DTS Modeling

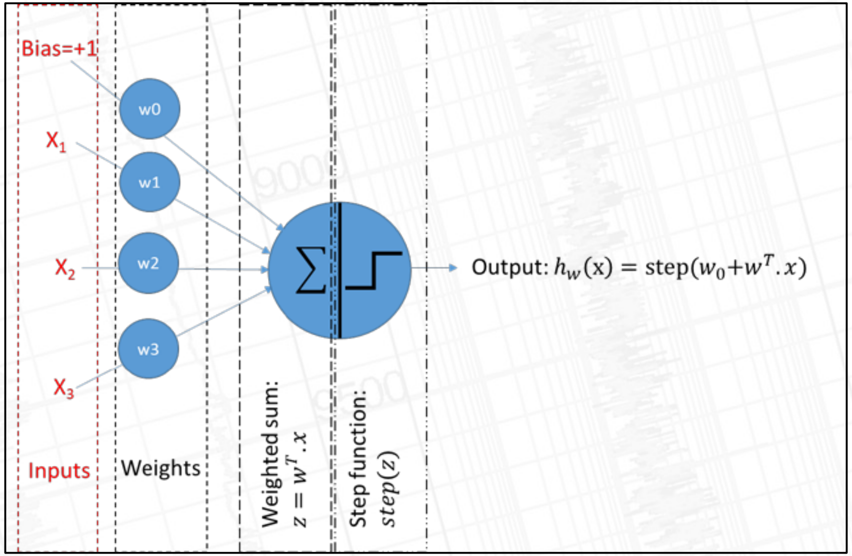
We recovered missing data in late 2017. Modeled DTS is slightly overestimated.

- A model is built to use completion data, geomechanical data, and operational condition to predict daily average temperature for each of the 28 stages.

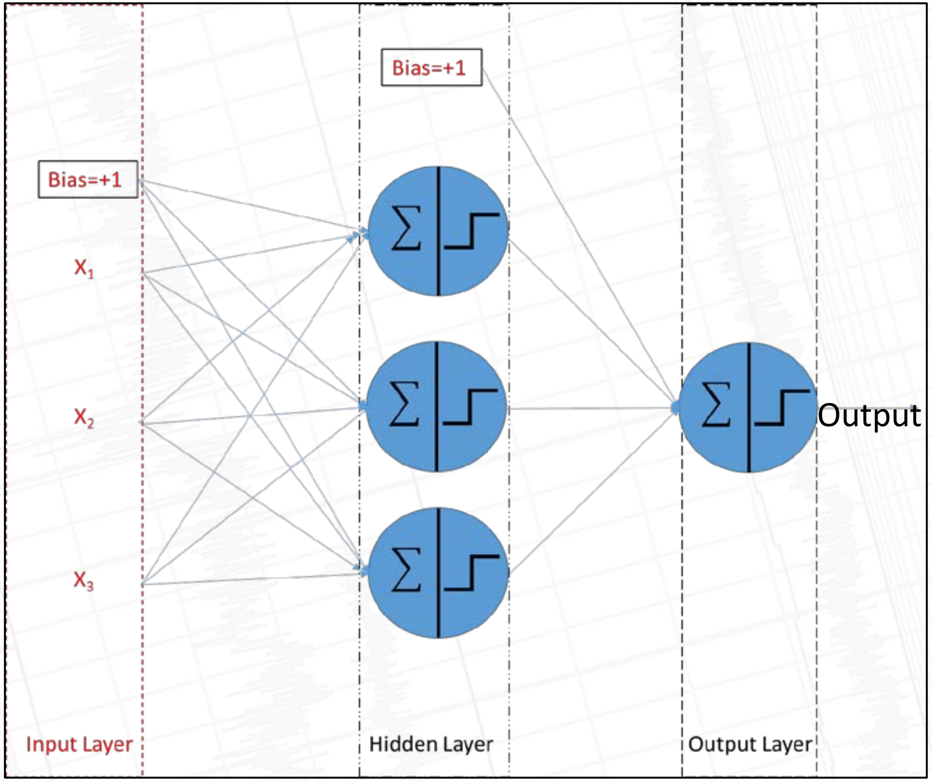


Neural Network

Single Perceptron

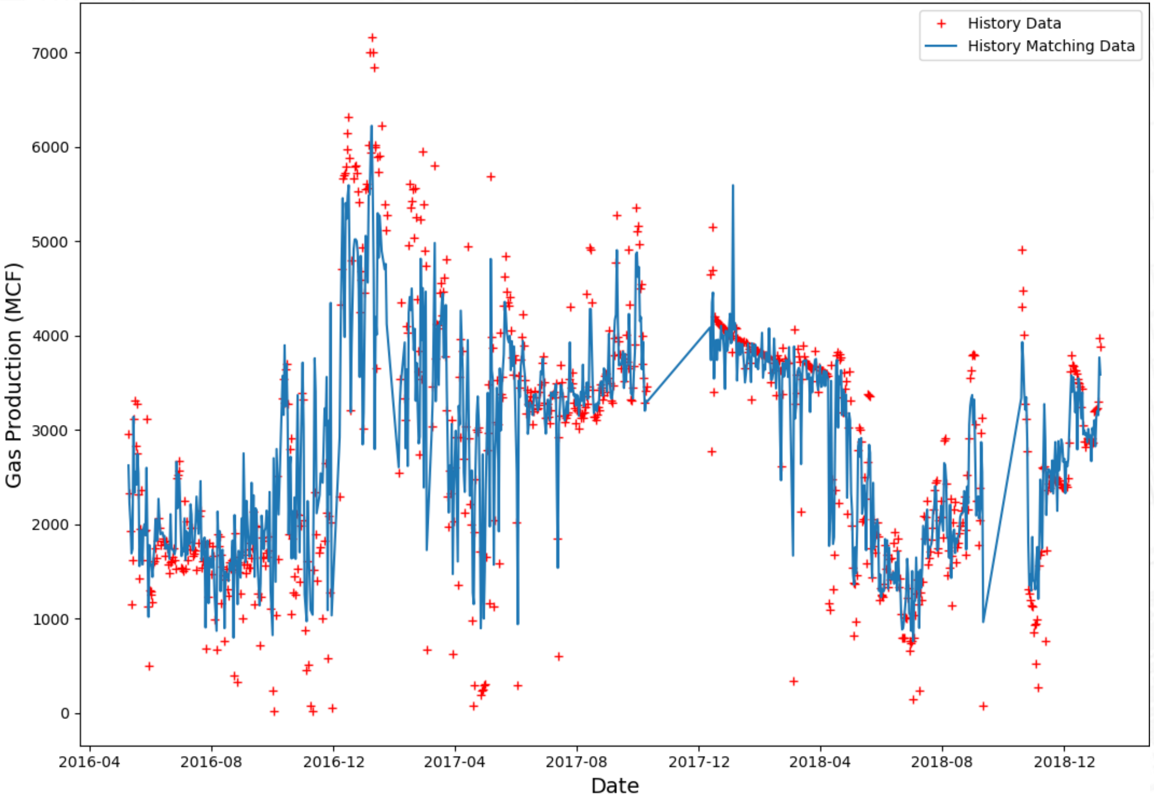


Multi-layer Perceptron



Neural Network Gas Production Model

History matching result of the built neural network model.



Sensitivity Analysis

The effect of each DTS attribute on gas production is evaluated.

DTS attributes:

- Days since completion
- Line pressure of MIP-3H
- Line pressure of the offset well (MIP-3H)
- Distance of each stage center to the toe of the well
- Each stage TVD median
- Each stage TVD mean
- Number of shots per foot for each stage
- ...

DTS Model

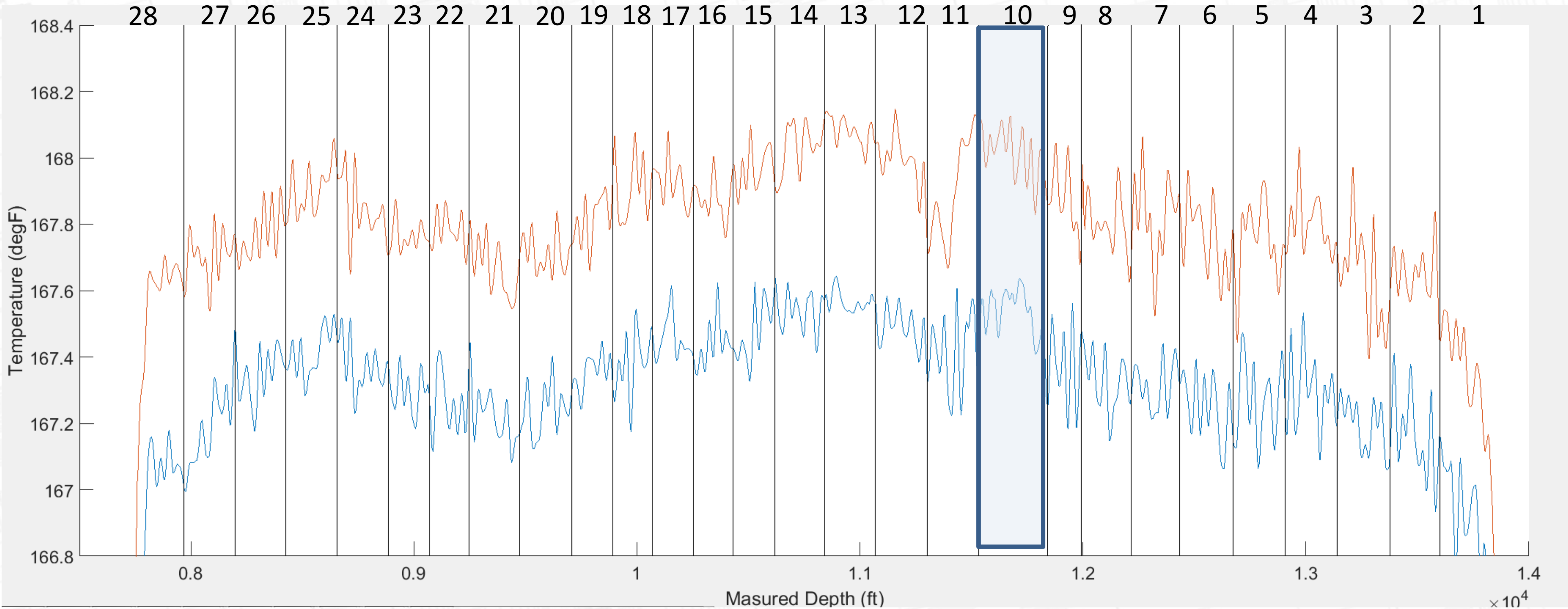
Average daily temperature for each of the 28 stages

Gas Model

Daily Gas Production

Composite Model

DTS Traces at Two Different Rates

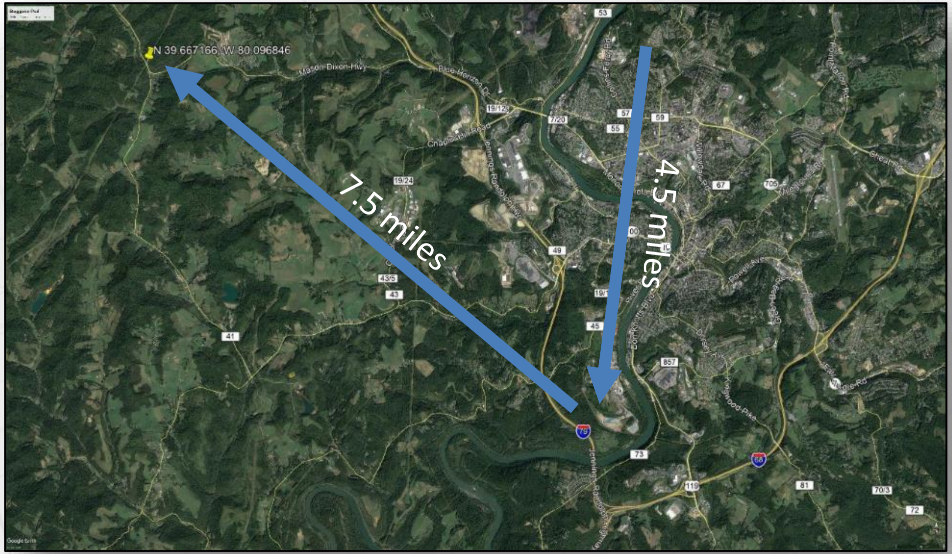


Jan 24,2019 - 165MCF/hr.

December 02,2018 - 100MCF/hr.

MSEEL Phase 3 MSEEL-2 Wells

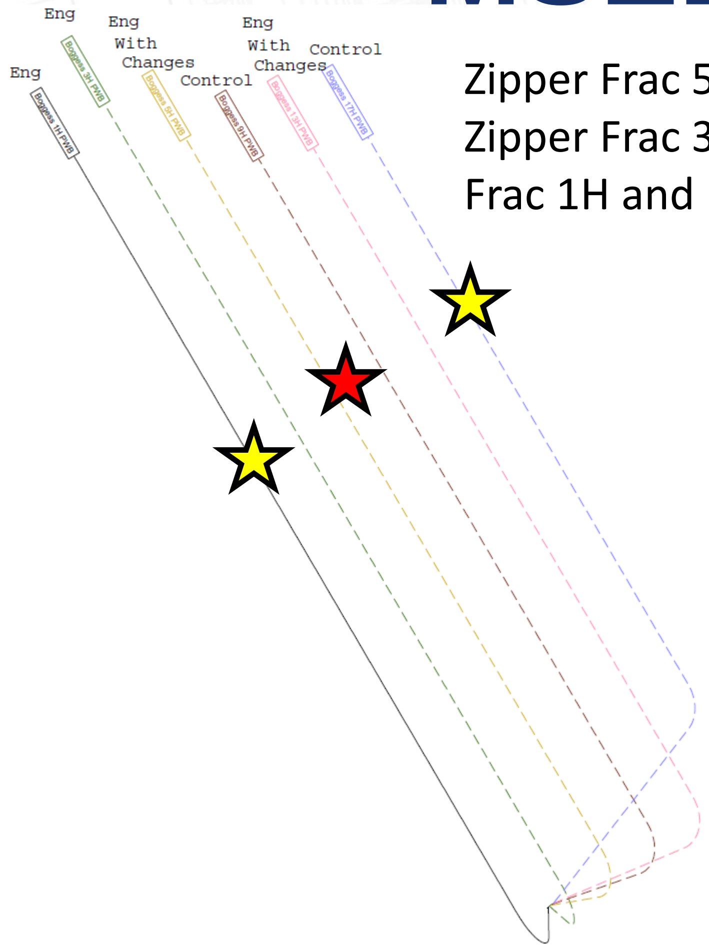
- **Continued Testing on MIP3**
  - Continued DTS Monitoring
  - Temporary DAS Coupled with Pressure Transients to Develop Continuous Production Log
  - Work with LANL
- **MSEEL 2 - Boggess Pad**
  - Vertical Pilot Hole
  - 6 Laterals



MSEEL Phase 3
MSEEL-2 Wells

- “How can one leverage this improved understanding gained through MSEEL to drill better wells?”
  - More gas extracted, minimal risk, similar/lower costs
- Test next generation cost-effective technologies in an area with previous drilling to determine feasibility of applying lessons learned on an “every well” basis to determine if we can get more gas from each well
- Work toward real-time intervention and modification during stimulation
- Improved Fracture Characterization
  - Natural and Induced
  - Unconventional Fracture Modeling

MSEEL-2 Wells



Zipper Frac 5H and 9H
Zipper Frac 3H and 13H
Frac 1H and 17H

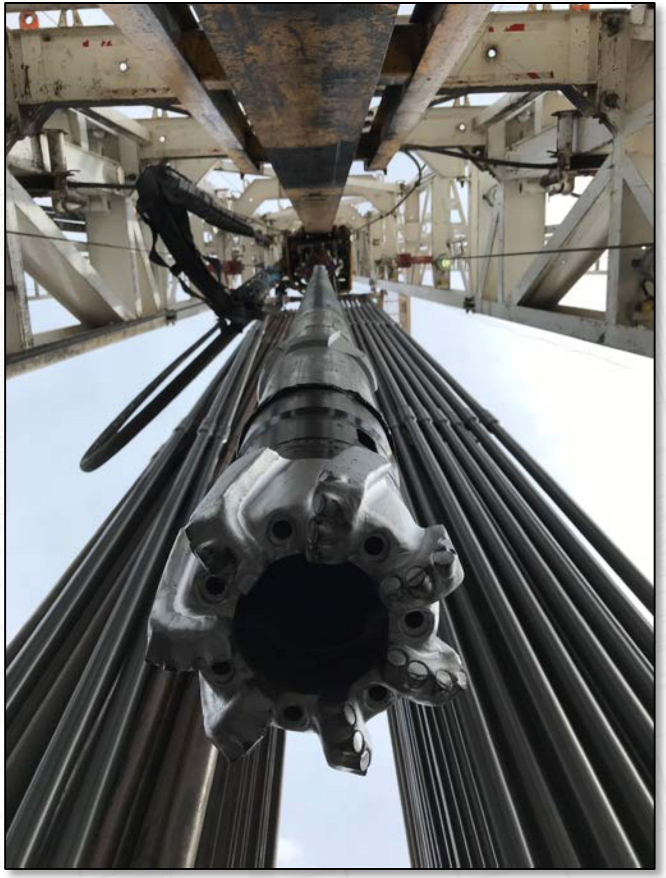
Permanent Fiber

Intervention Fiber

- Advanced Fiber
- Distributed acoustic and distributed temperature sensing data acquisition.
- Actionable Information During Stimulation.
- Microseismic and Active Proppant Monitoring
- Long term Monitoring with Permanent Fiber

MSEEL 2 Pilot

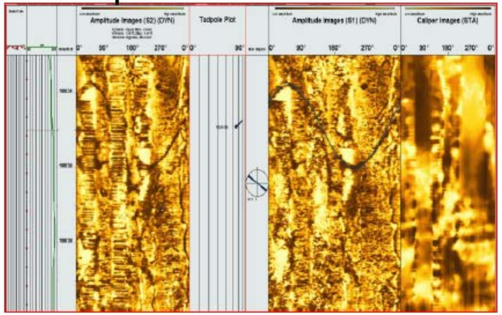
- **Vertical Pilot Hole**
  - Core and Sidewall Cores
  - Core with FractureID
  - Complete Log Suite
- **MSEEL 2 Tie to Vertical**
  - Develop algorithms to efficiently incorporate thin low-cost data during the drilling process (e.g., LWD geomechanics).
- **Engineer Completions**



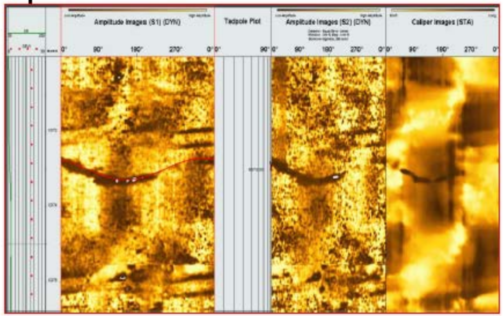
MSEEL-2 Wells

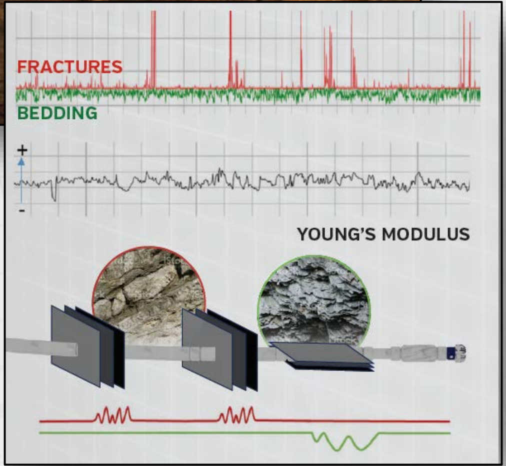
- All Six Laterals
- Tie to Vertical Pilot
- FractureID
- Petromar FracView
- Active Proppant

Low Amplitude Fracture



Open Fracture

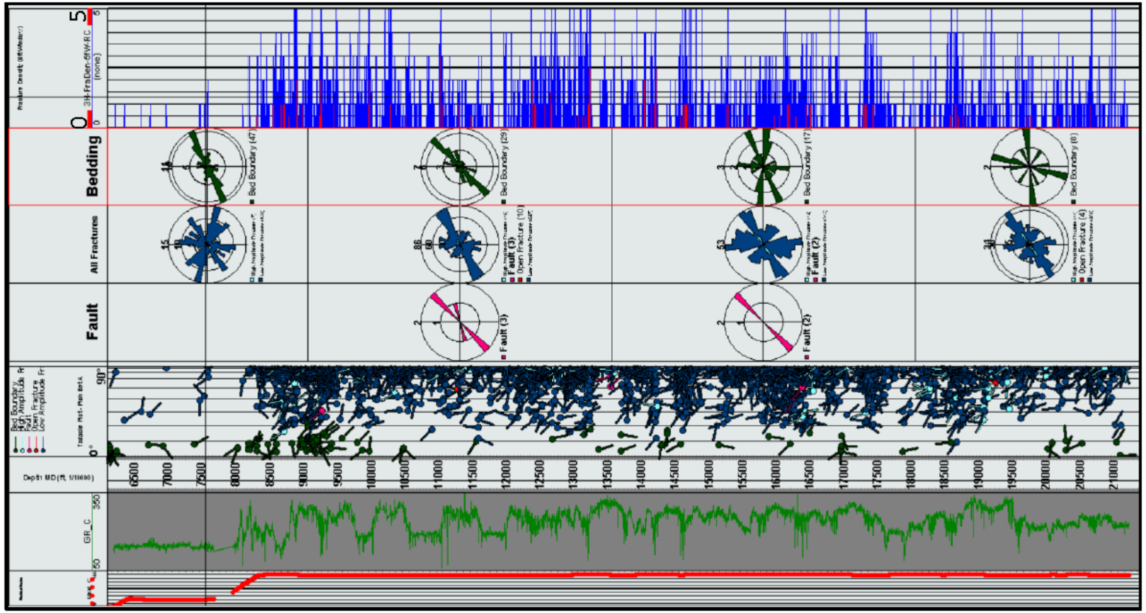




MSEEL-2 Wells Fracture Data

WestVirginiaUniversity

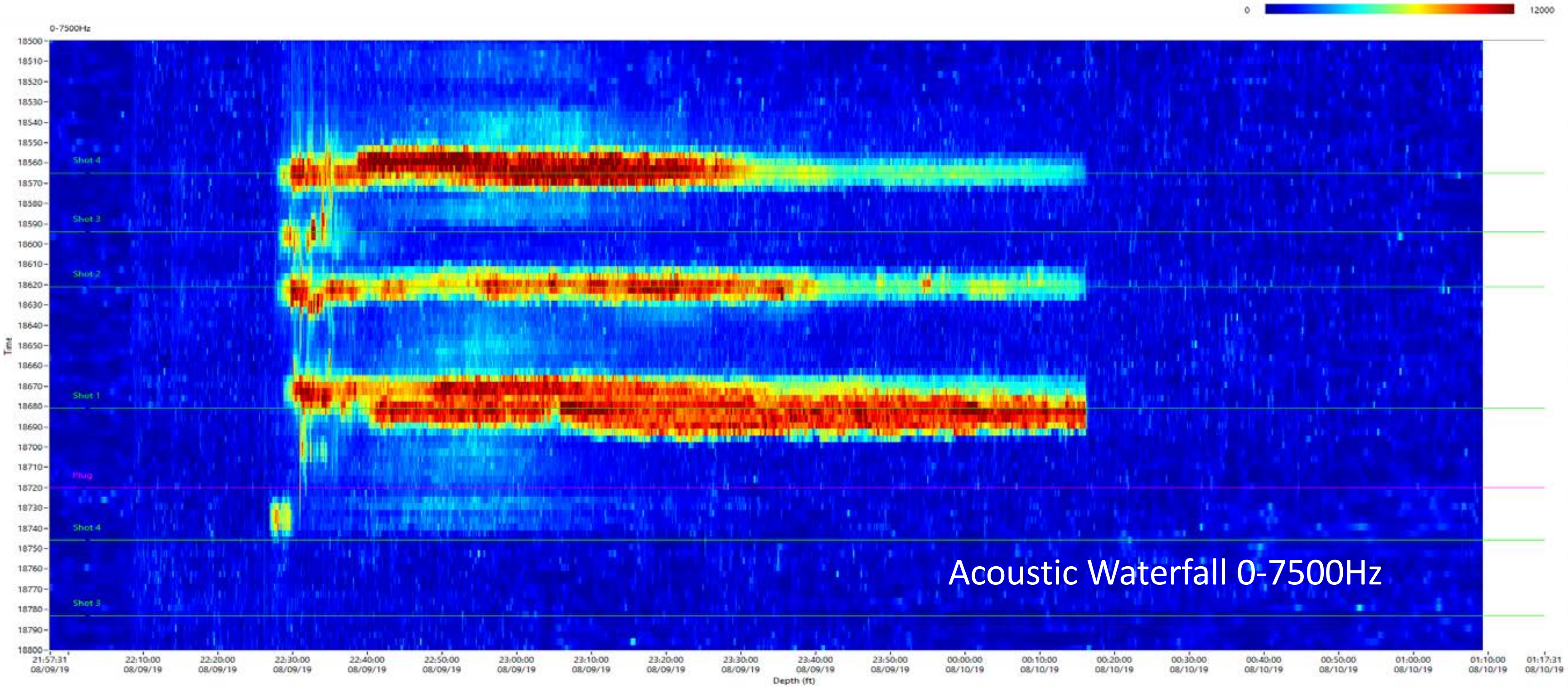
Fracture density along the wellbore – Boggess-3H (Horizontal view)



BLACKRIVER GEOSCIENCE

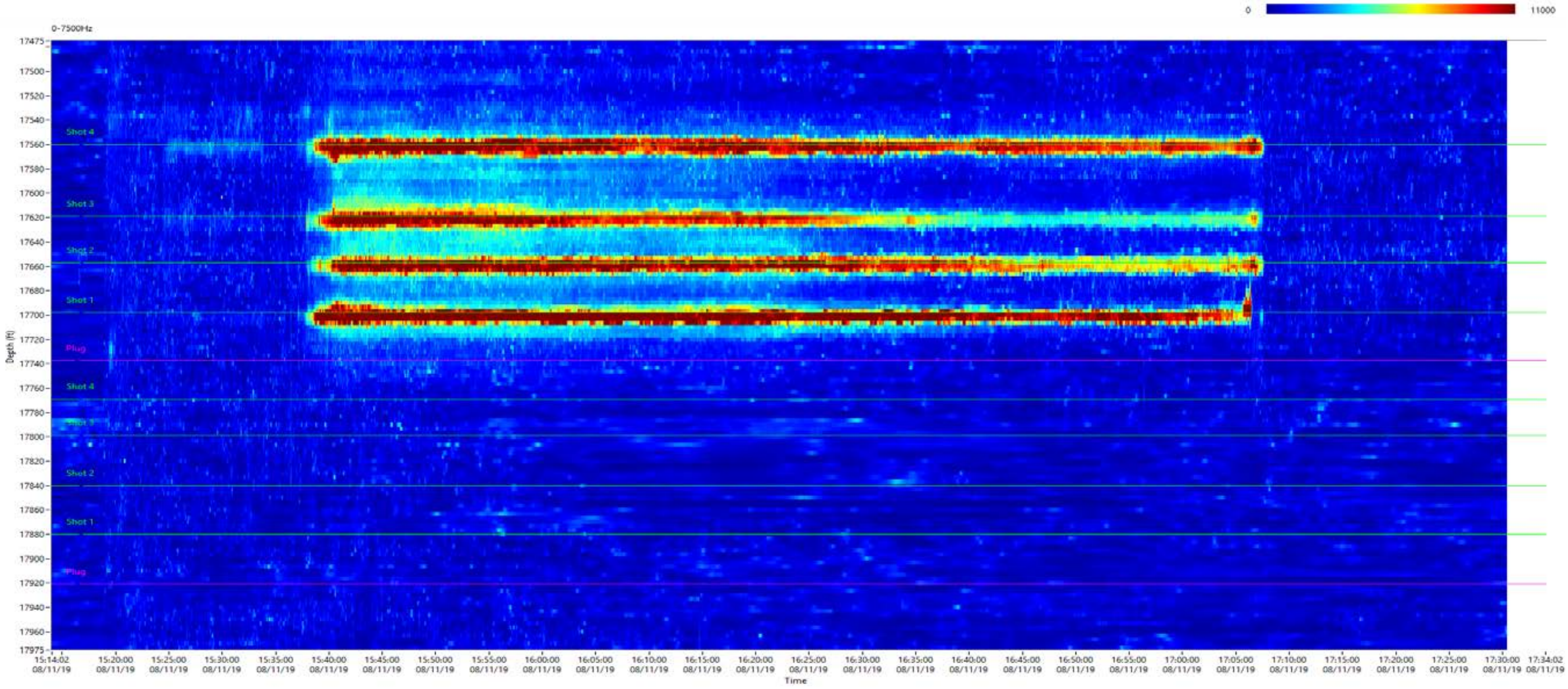
Fracture Type	#
Low amplitude fractures	1580
High amplitude fractures	133
Open fractures	14
Fault	5
Total	**1732**

MSEEL-2 DAS Data



Stage 5

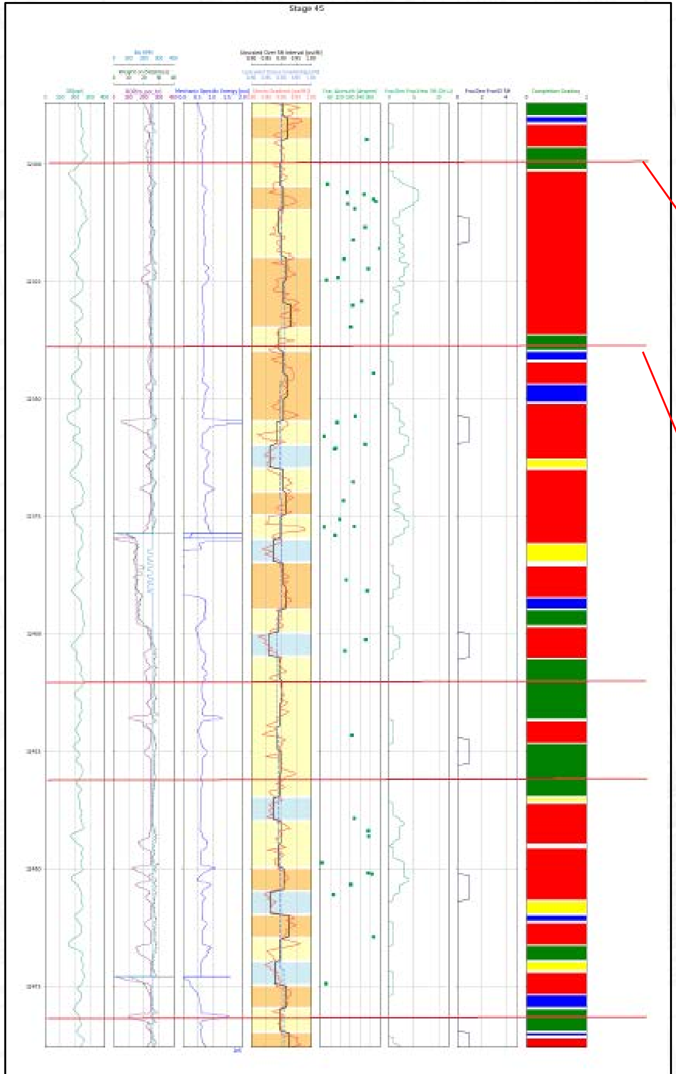
MSEEL-2 DAS Data

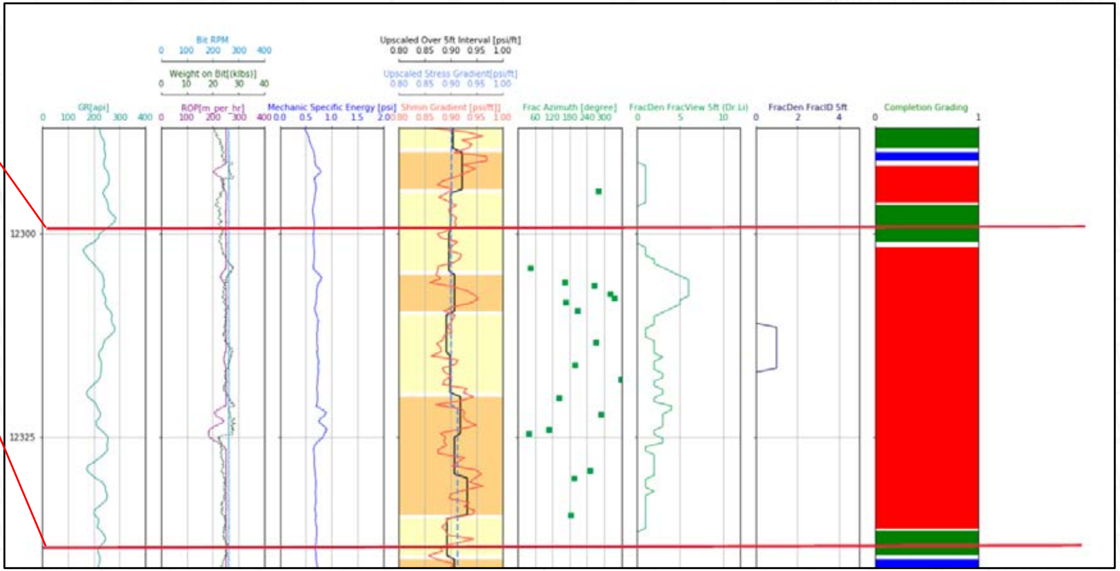


Stage 10

MSEEL-2 Microseismic

sense the difference





Semi-Automated Cluster Spacing Boggess 3H

Building Partnerships for Research, Education, and Outreach

Industry

Community **MSEEL** Academia

Government

This research is funded by a grant from Department of Energy's National Energy Technology Laboratory (DE- FE0024297)