the Energy to Lead

International Gas Union Research Conference
IGRC COPENHAGEN 2014
September 17-19

Expanding Sustainable Shale Gas Supply through Hydraulic Fracturing Efficiency Improvements

RPSEA
Research Partnership to Secure Energy for America

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Gas Technology Institute (GTI)
International Gas Union Research Conference
Copenhagen, Denmark
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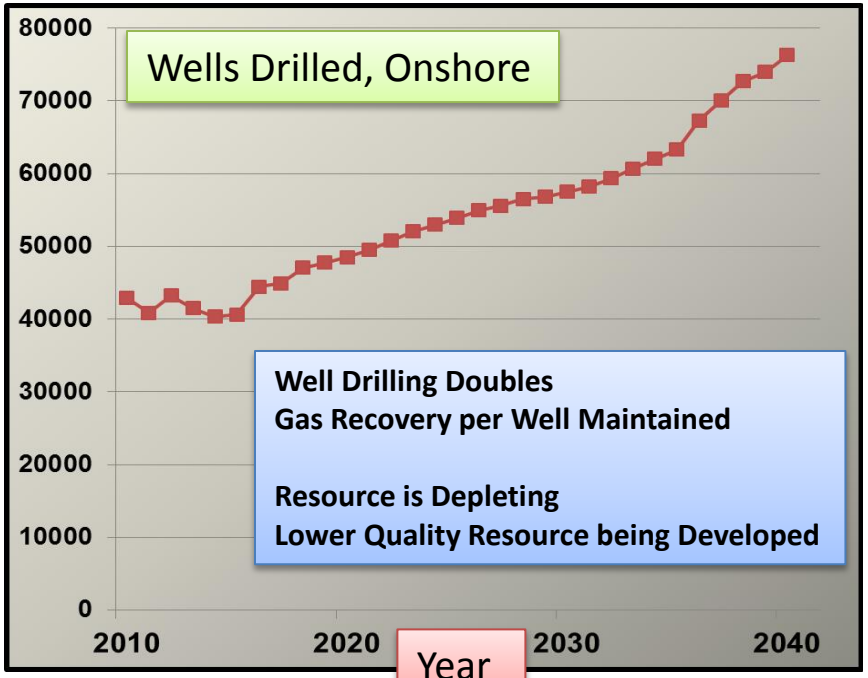
Sustainable Shale Gas Supply

- Maximize recovery of each fracture stage
- Increase well spacing to reduce number of wells drilled



Source: US EIA – Annual Energy Outlook 2013

Building on Prior Success: Field Based Co-operative R&D

Motivation:

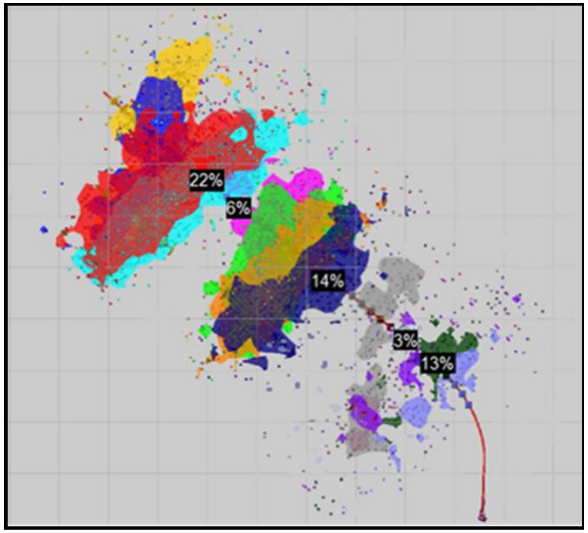
>Current hydraulic fracturing practices are environmentally and economically wasteful and fracture diagnostic techniques inadequate

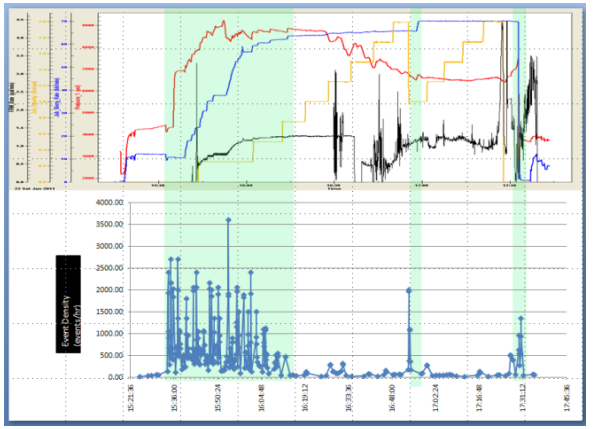
Field Based Experiments:

>Provide greatest amount of insight into what works and what doesn't

>Generate invaluable data for engineering analysis and enables rapid validation with production

>**Enable development of more effective fracture designs leading to increased production per unit of energy and water used**

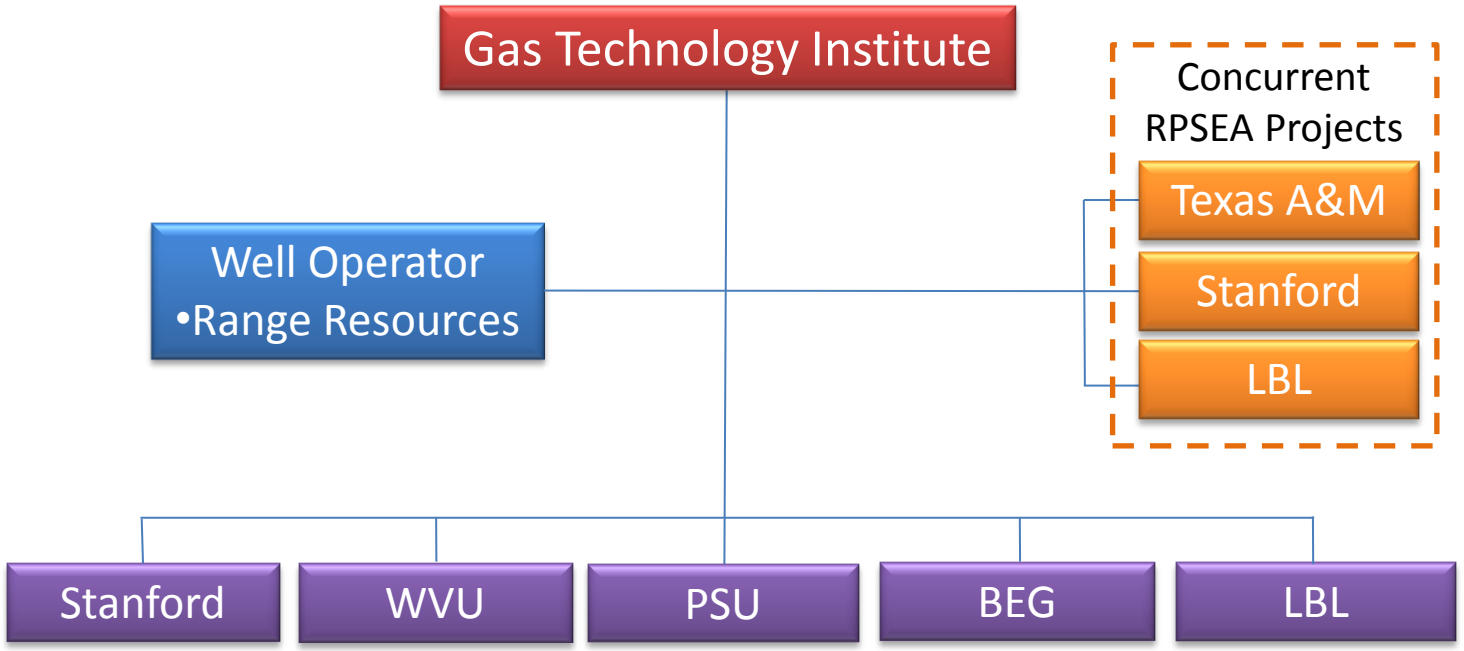




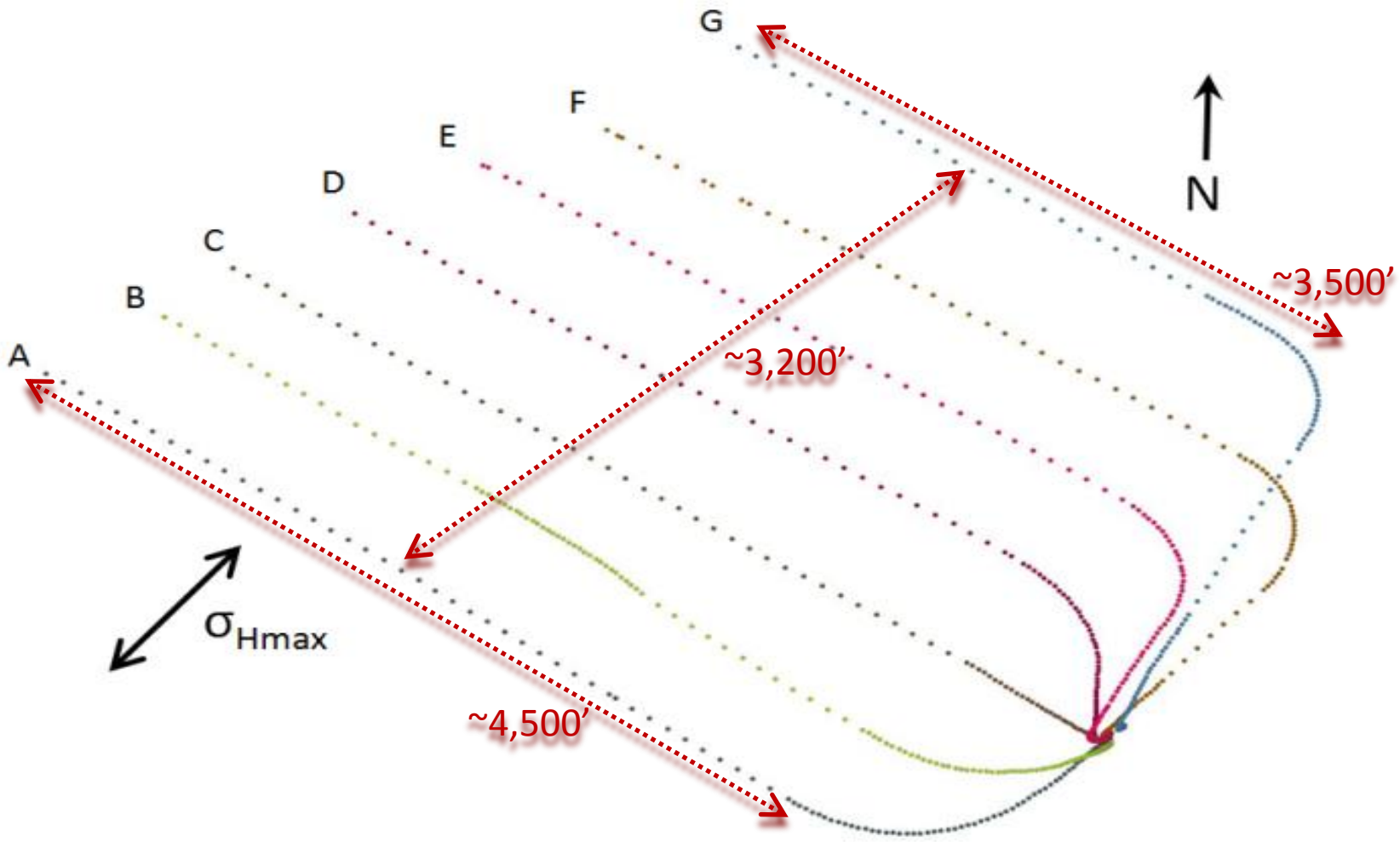
Marcellus R&D Project Structure Collaborative Research

Collaborative Field Based R&D Project – Utilizing Producing Wells for Research

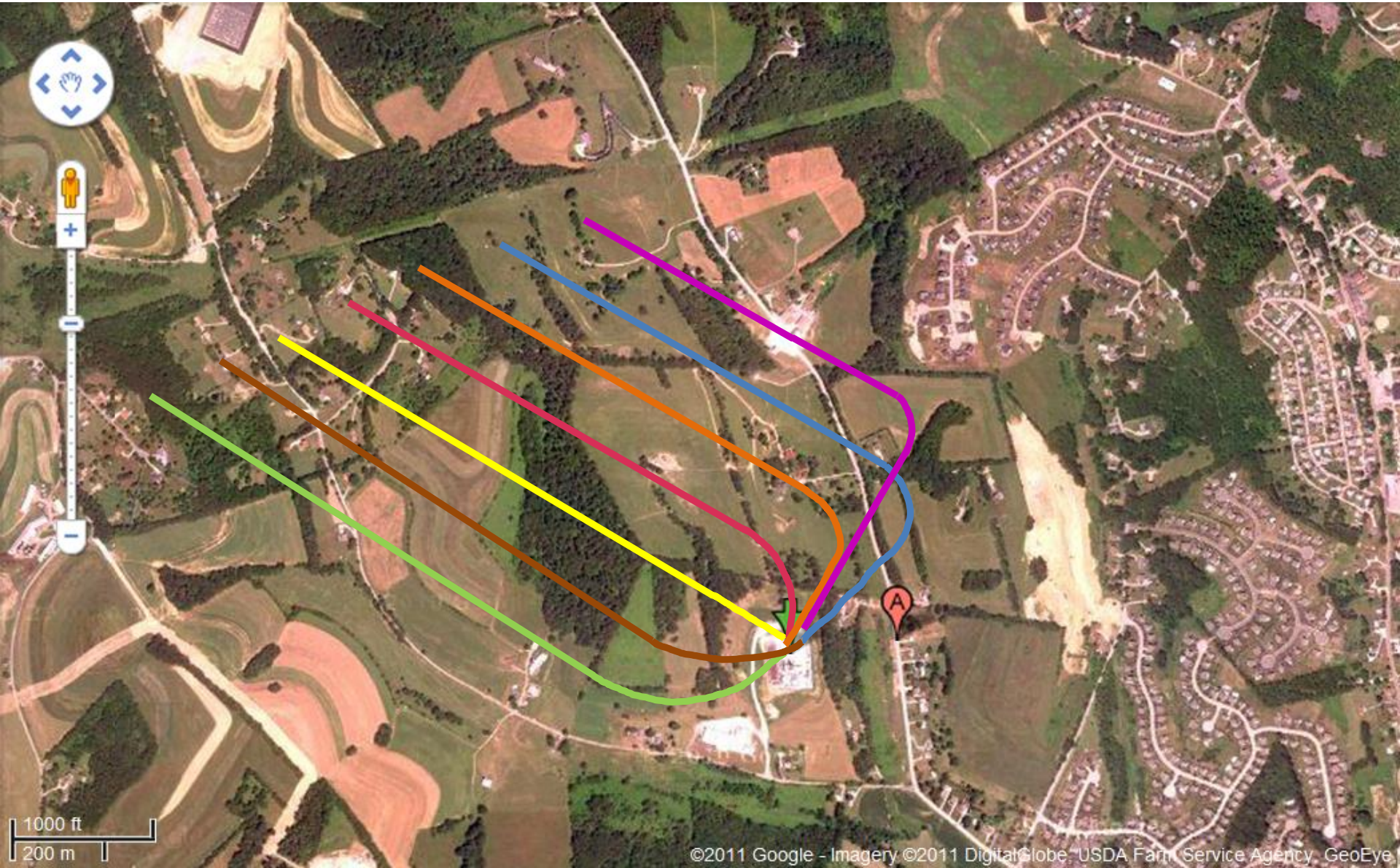
The completed project comprised gathering of data and information from the participating producers, publicly available data, field data acquisition including sampling, coring, logging, hydraulic fracturing, fracture diagnostics, and production logging.



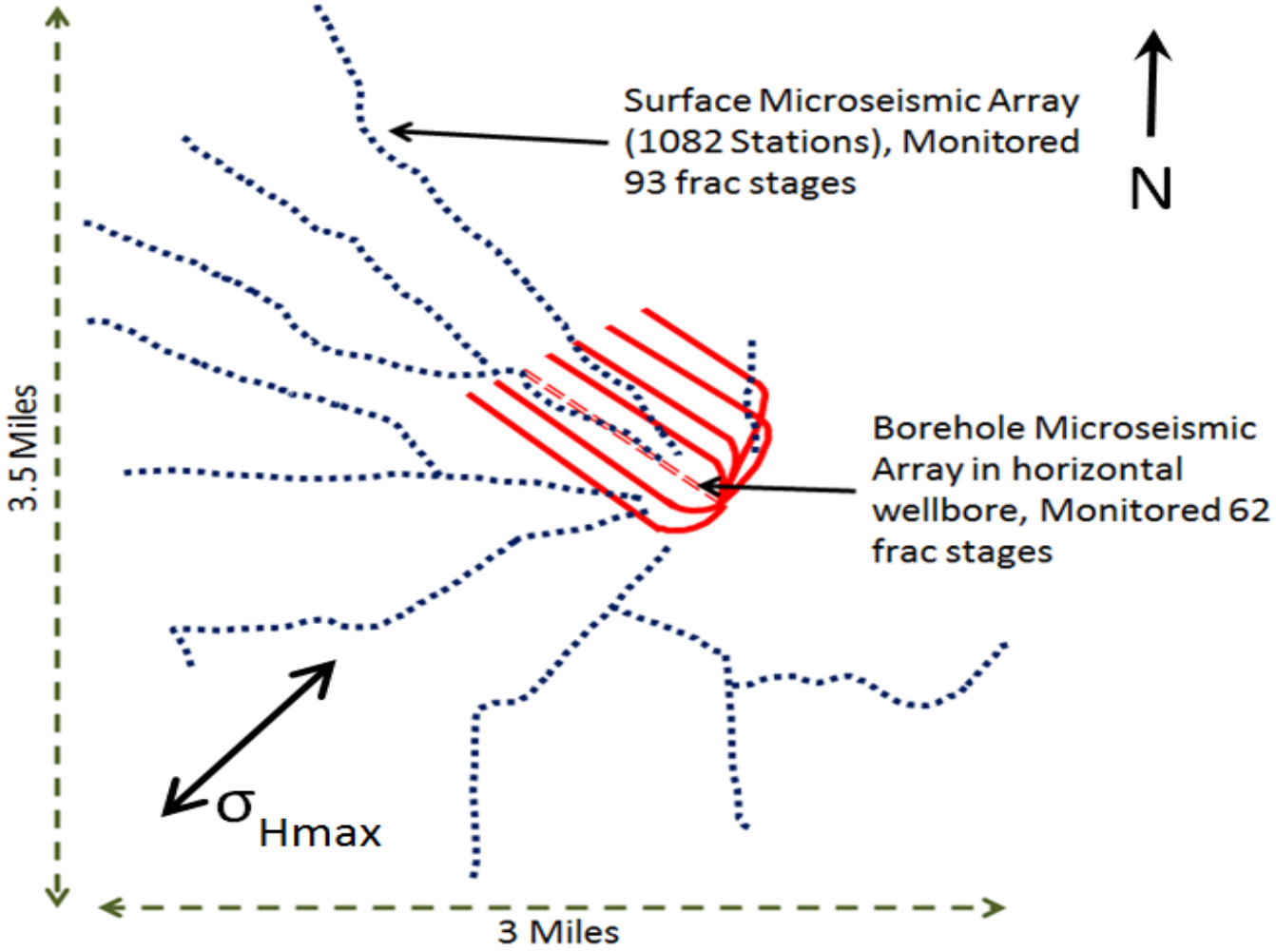
Marcellus Gas Shale Research Site



Local Setting - Pennsylvania



Surface and Borehole Microseismic



Fracture Stages Mapped

- 93 Fracture Stages Mapped with Surface MS
- 62 Fracture Stages Mapped with Borehole MS

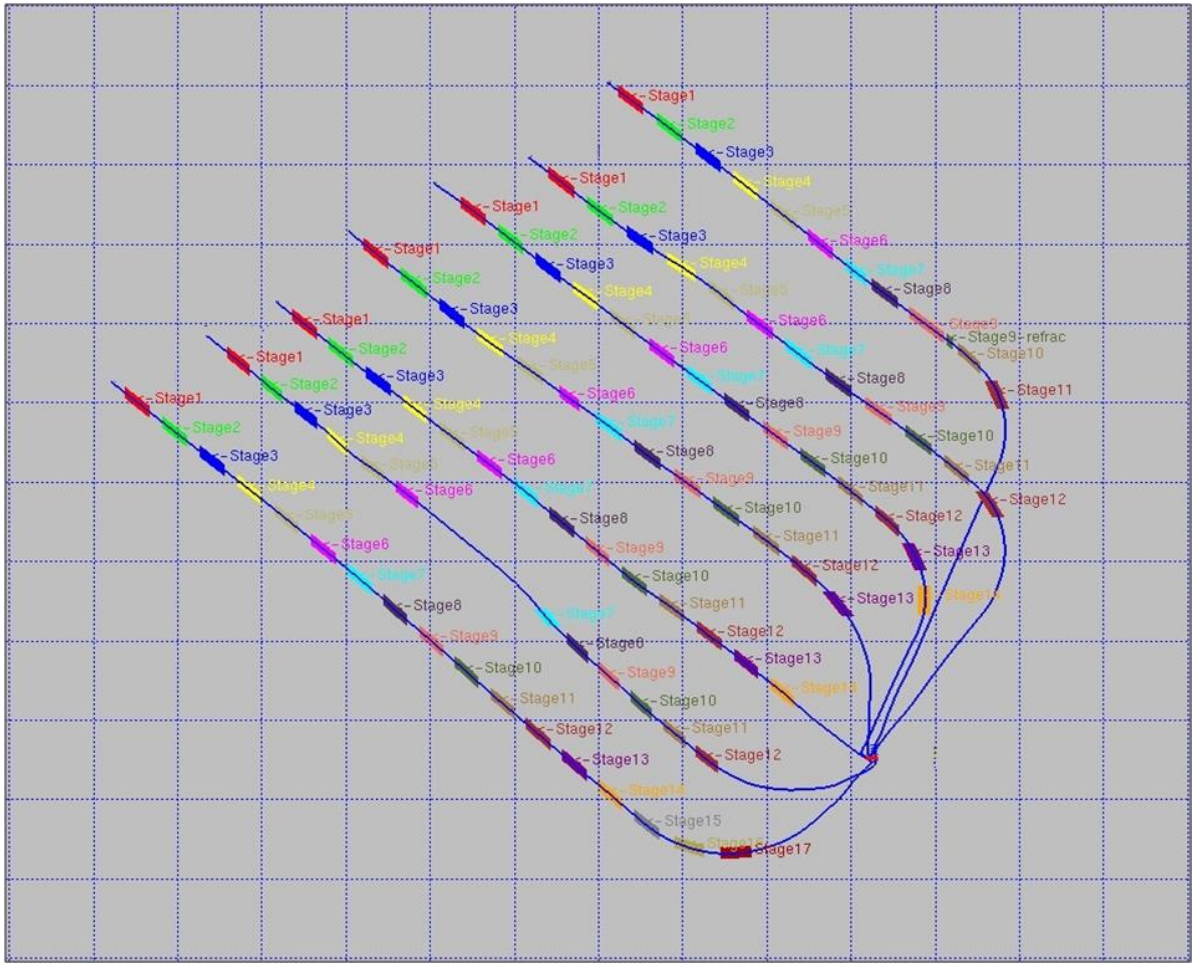
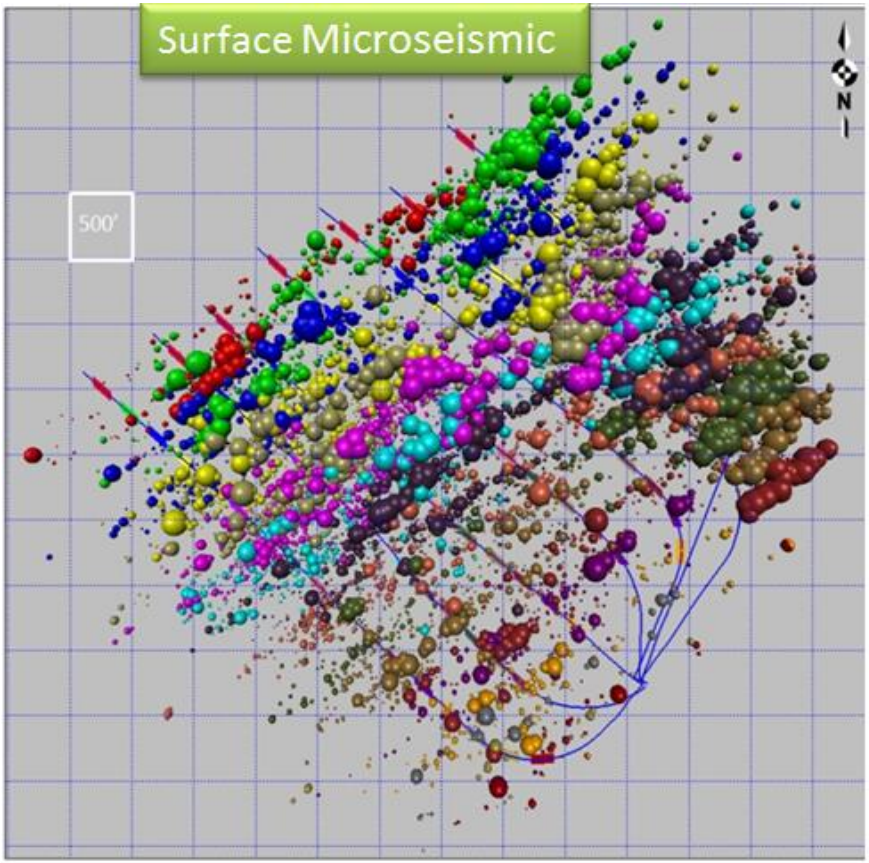
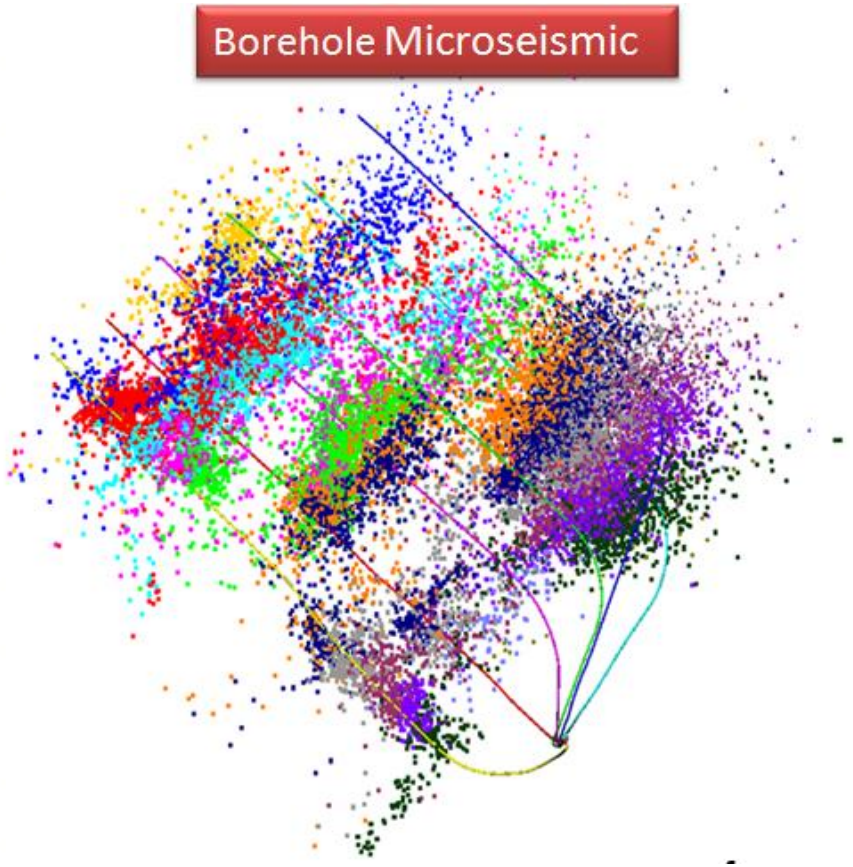


Image Courtesy: Range Resources

Microseismic Results and Validity





Why the discrepancy in event count and concentration?

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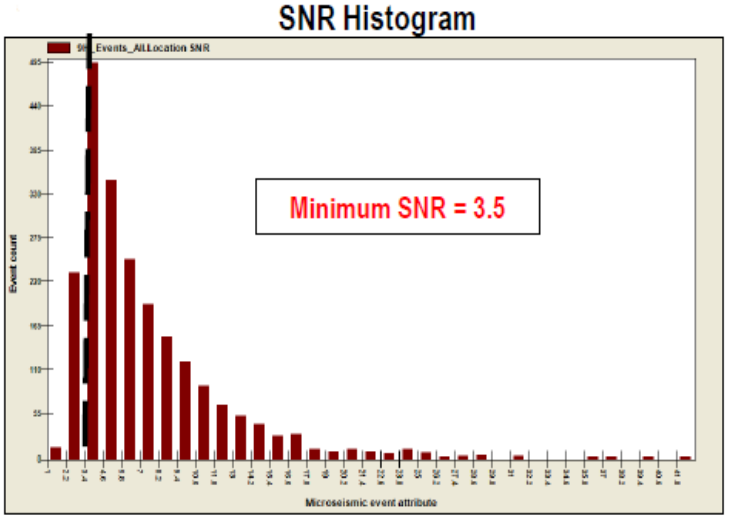
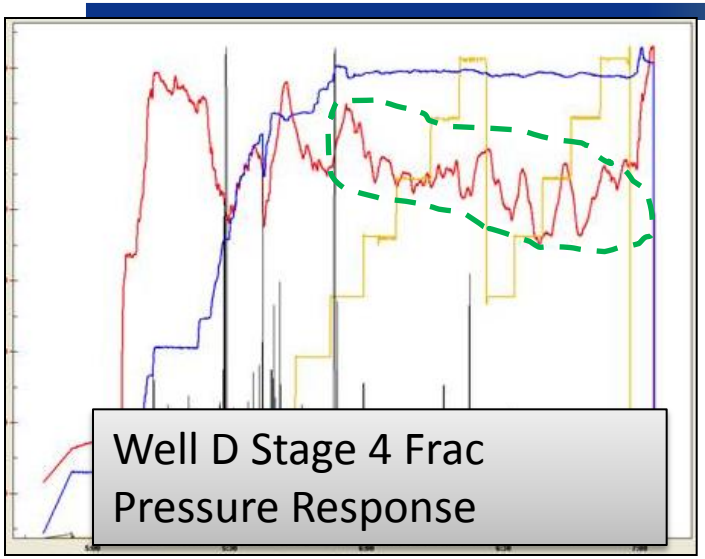
Test Well D: Analysis of Microseismic Event Count

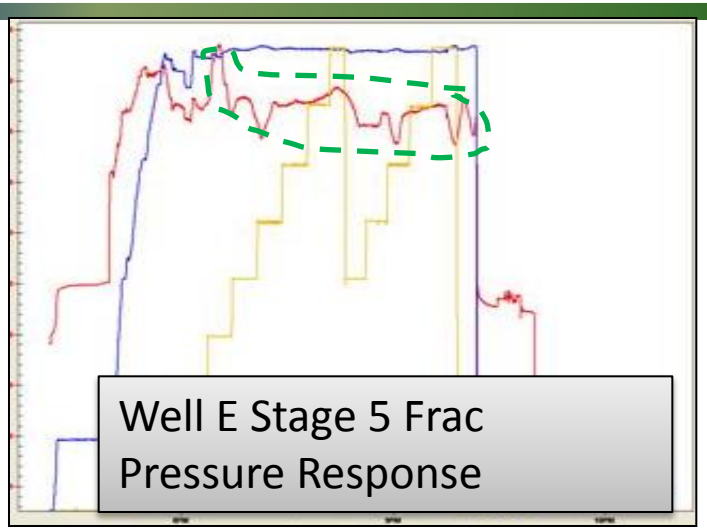
Stage	Event Count	Azimuth (N-deg-E)
1	430	41
2	328	30
3	984	45
4	1,081	54
5	441	5
6	702	27
7	604	45
8	649	54
9	220	20
10	79	33
11	100	47
12	113	42
13	122	43

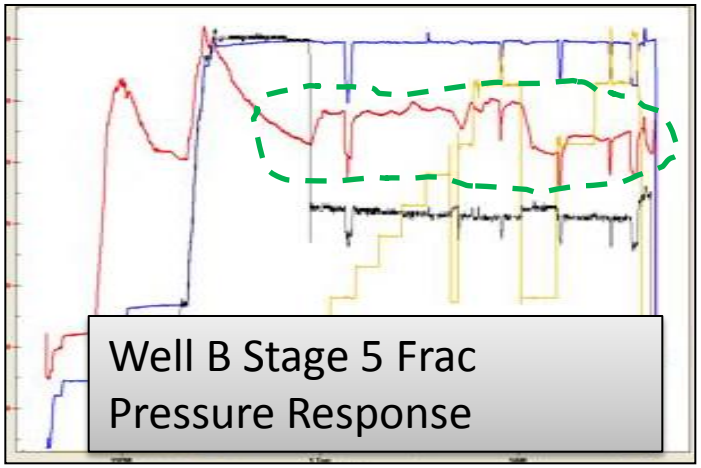


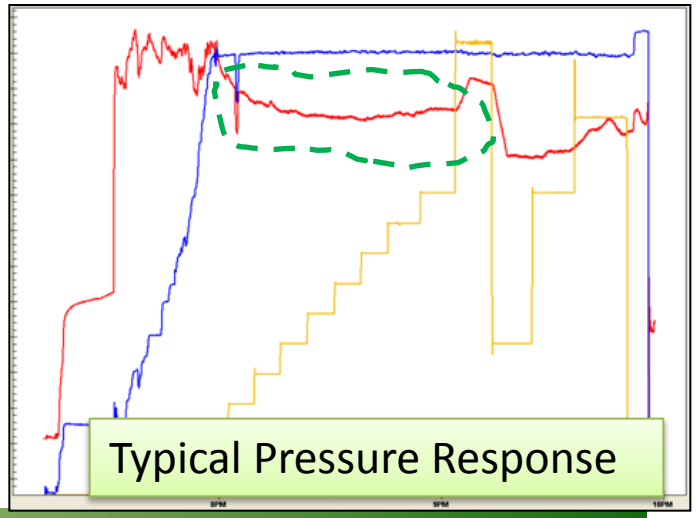
- Borehole geophones repositioned 5 times to increase S/N
- Perforation shots used to recalibrate velocity model

Pumping Diagnostics

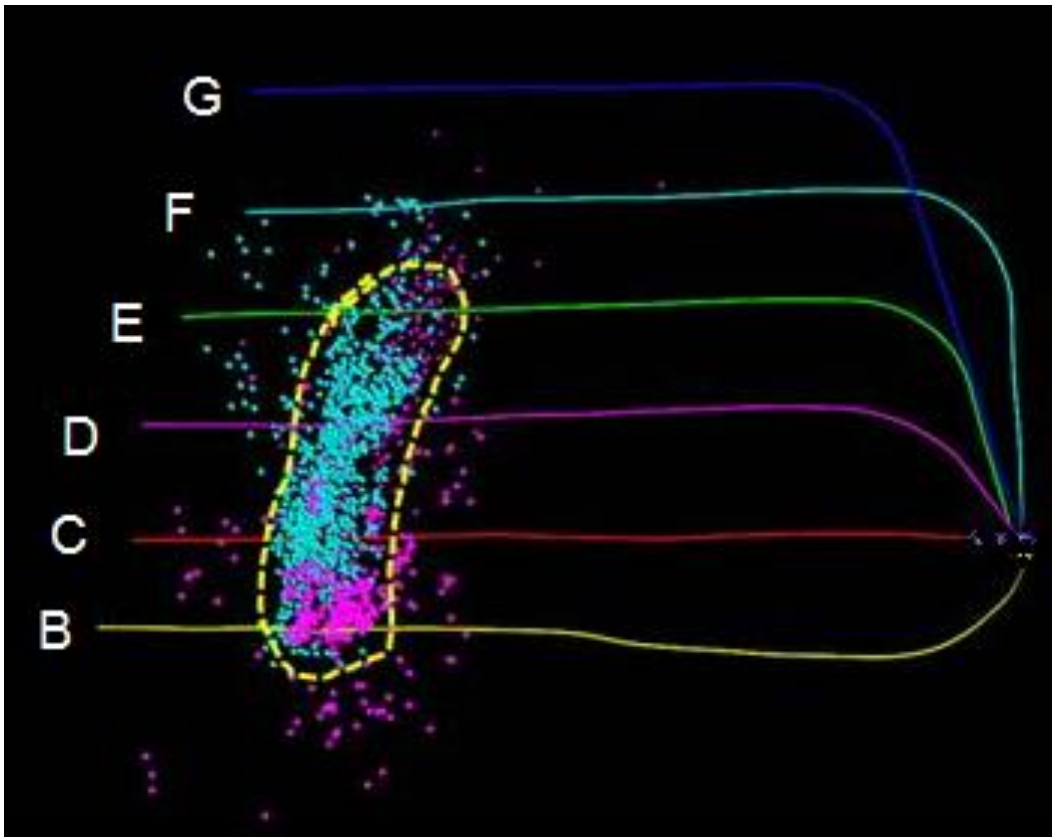






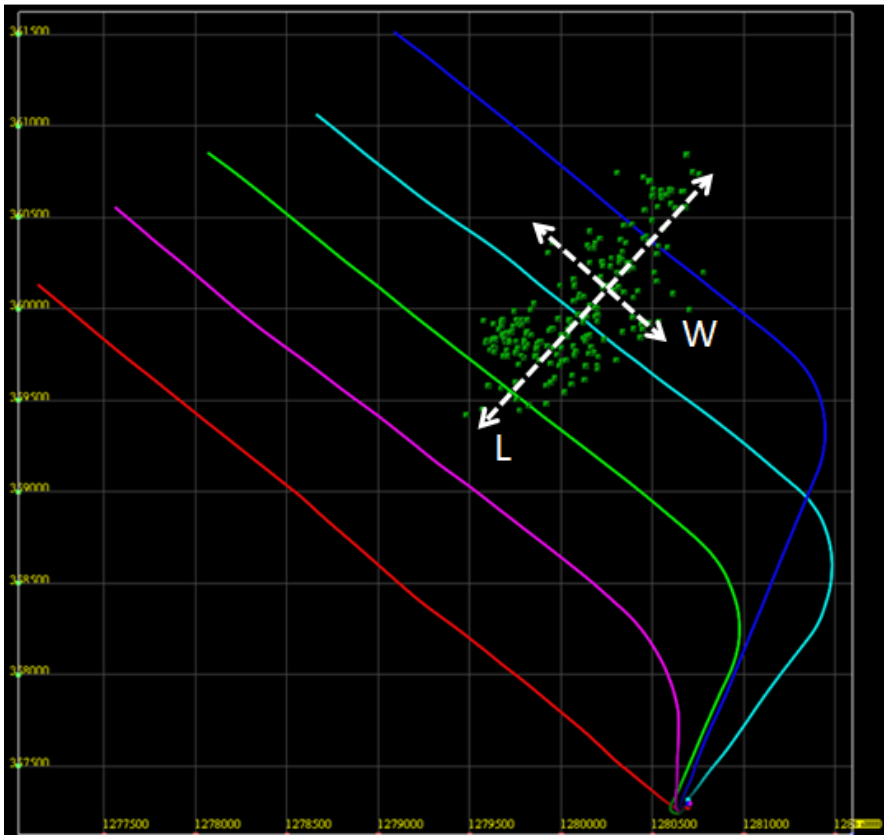


Natural Fracture Swarm?

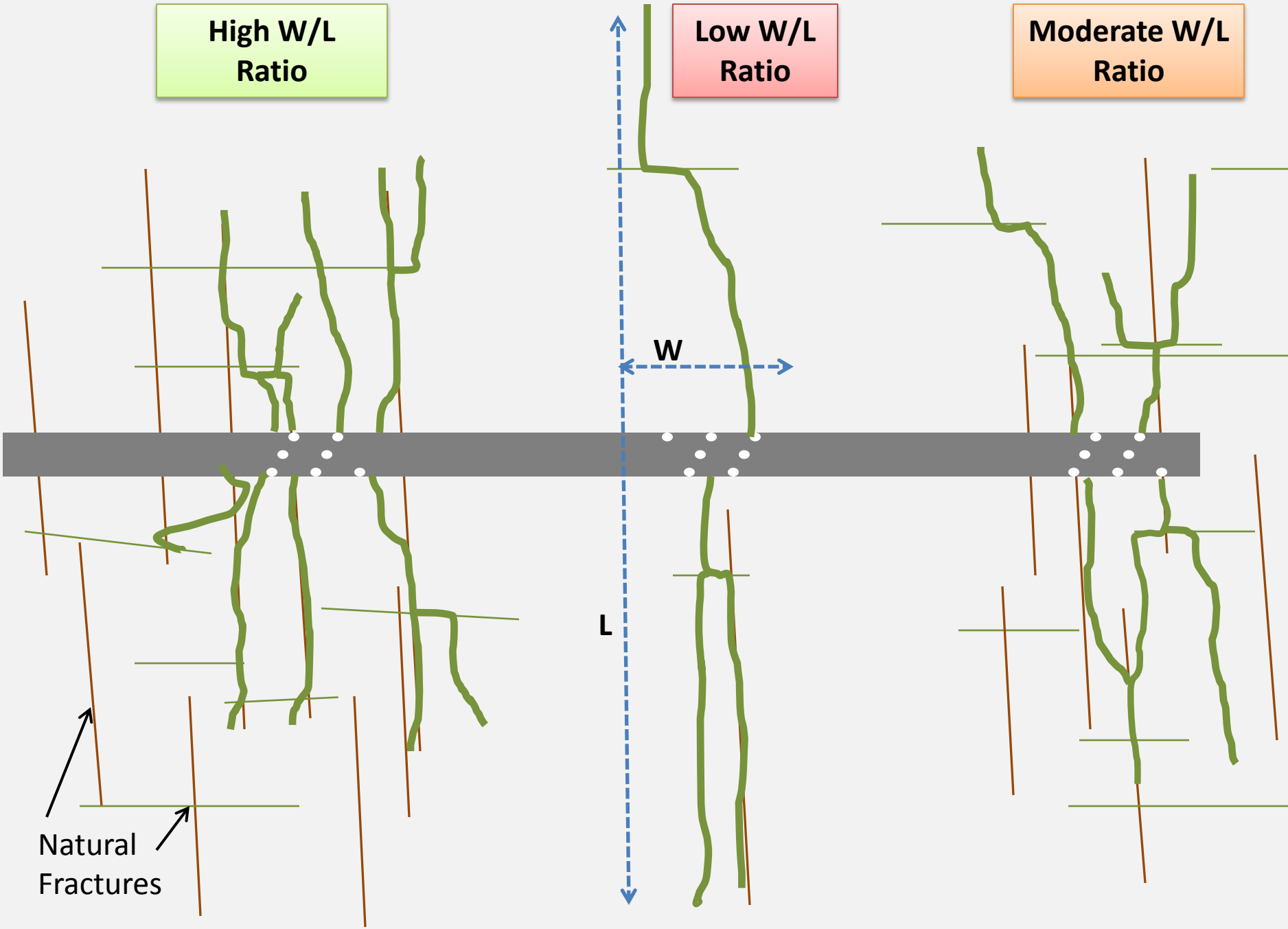


- Three fracture stages in adjacent wells with erratic pressure
- All three stages in same general position along the horizontal
- All exhibit high microseismic event response

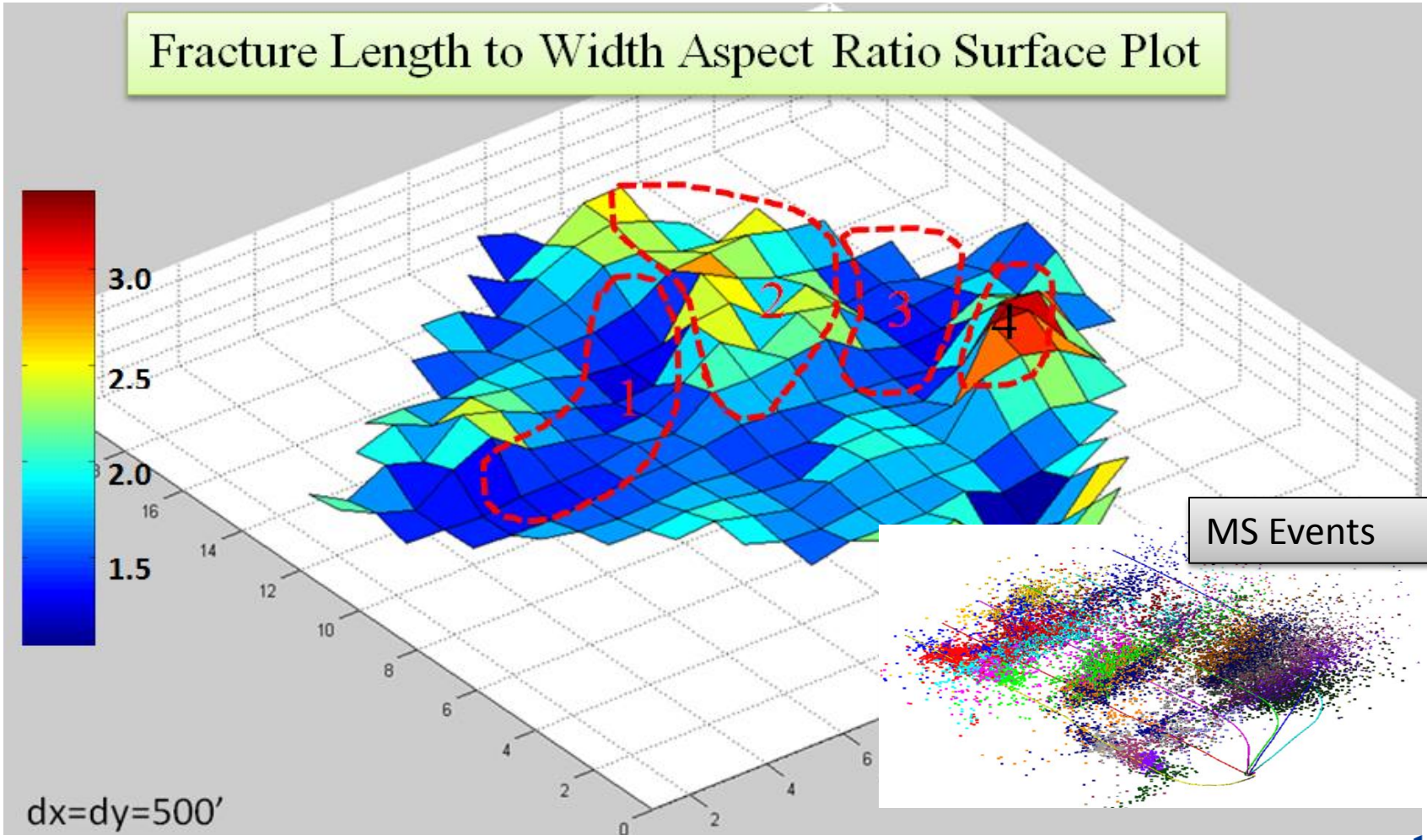
Microseismic Analysis - L/W Aspect Ratio



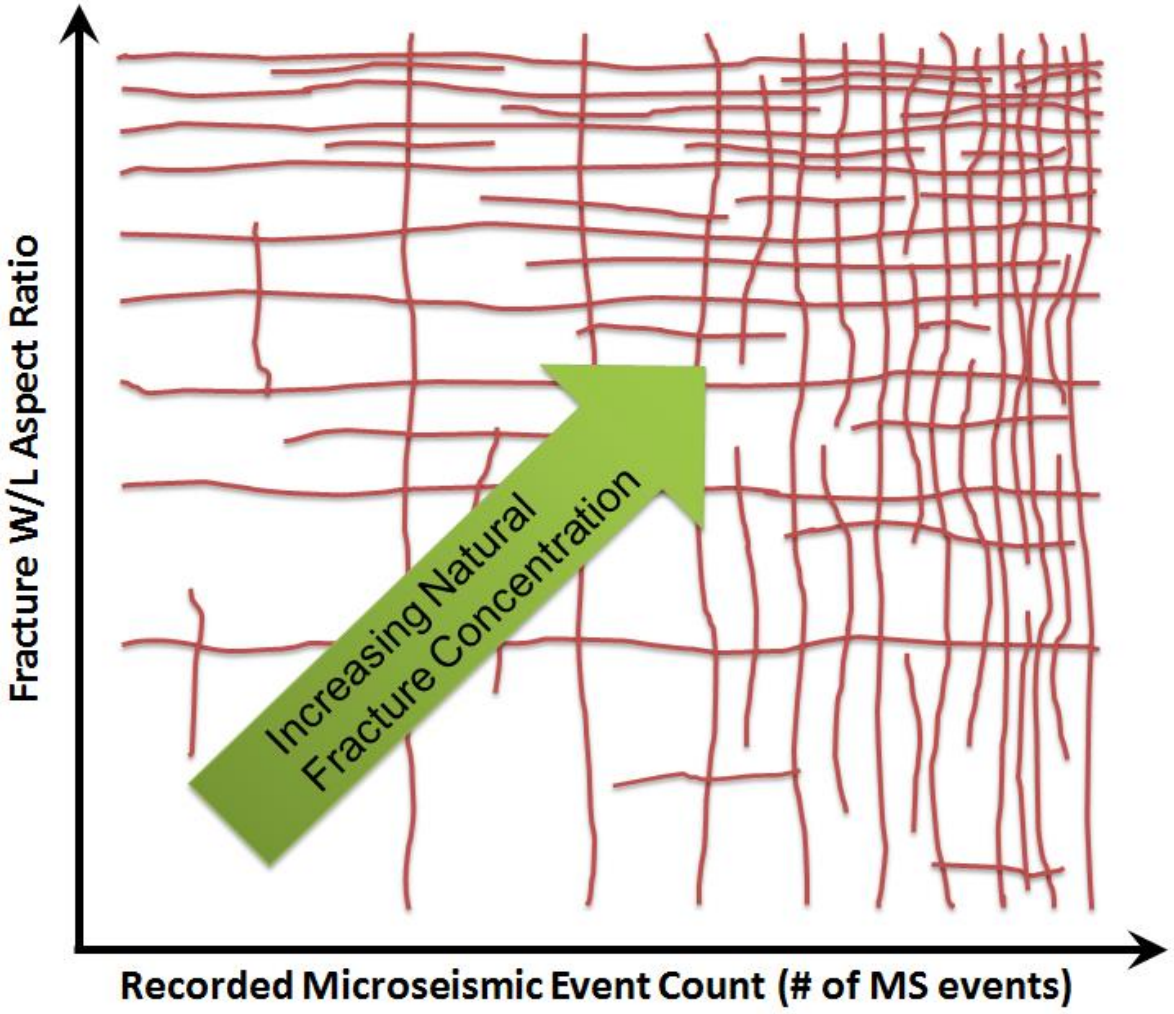
- Plan view of horizontal wells witch microseismic data for a single frac stage showing the fracture geometry in terms of fracture width and length
- The fracture width here is the width of the fracture network and not the fracture aperture


High W/L Ratio
Low W/L Ratio
Moderate W/L Ratio
W
L
Natural Fractures

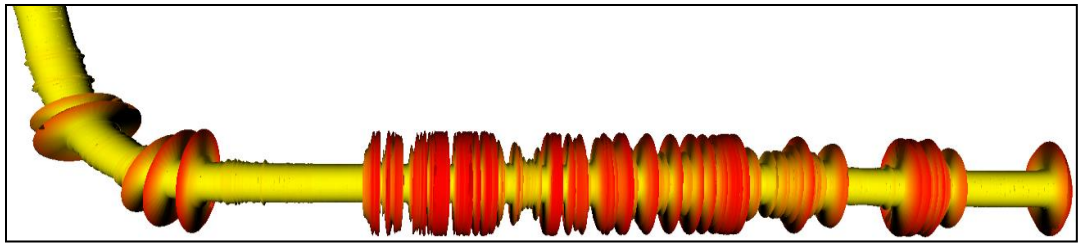
The BIG Picture



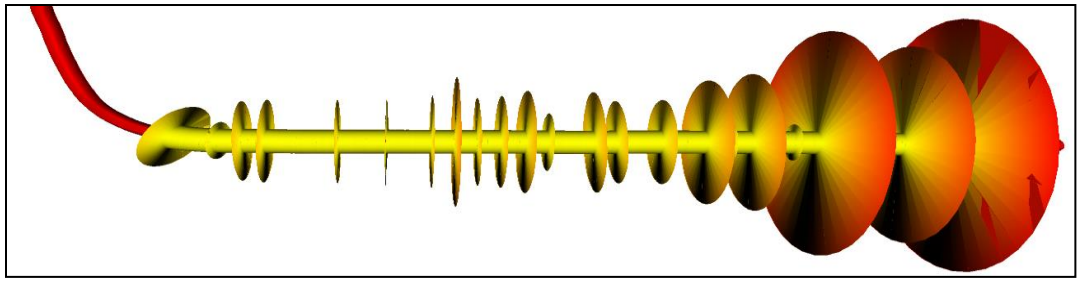
Natural Fracture Concentration from Microseismic data



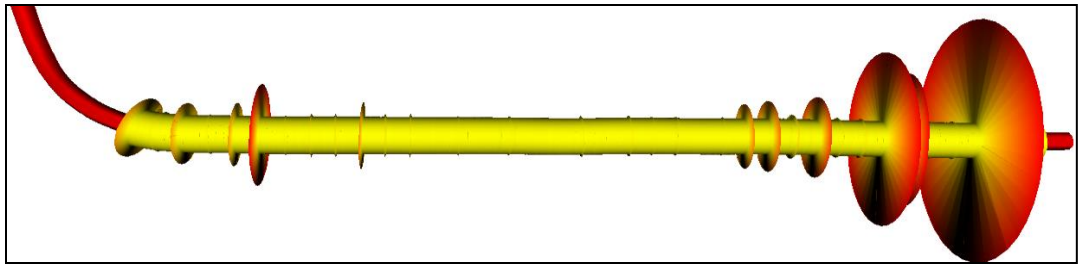
Test Well D: Mud Log Compared to Early and Late Production Logs



Mud Log Gas Shows



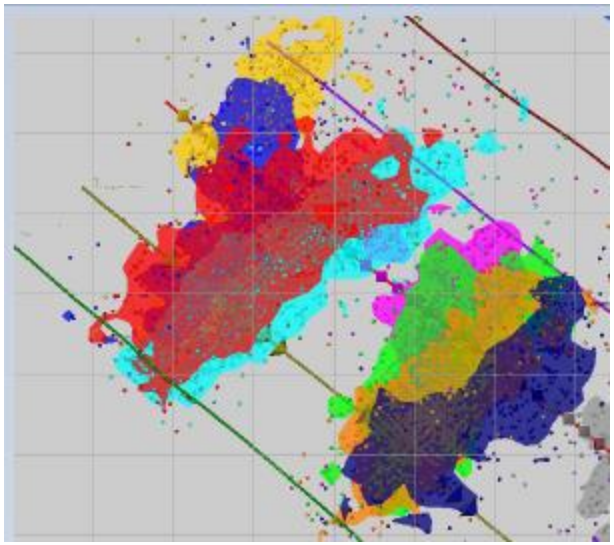
1st Production Log Results – 4 Months



2nd Production Log Results – 13 Months

Results and Next Steps

- **Natural fractures** in Marcellus exist in swarm like patterns
  - Microseismic event count
  - Microseismic event cloud L/W aspect ratio
  - Production log results
- **Stimulation efficiency** is high in areas of fracture swarms
- Stimulation efficiency is low in areas void of natural fractures



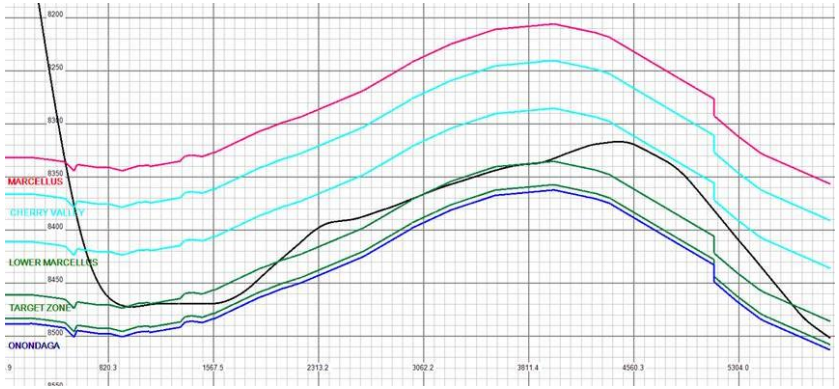
- **Hydraulic fracture spacing could be improved**
  - **Next: Novel Modeling Approach for Fracture Spacing Design**

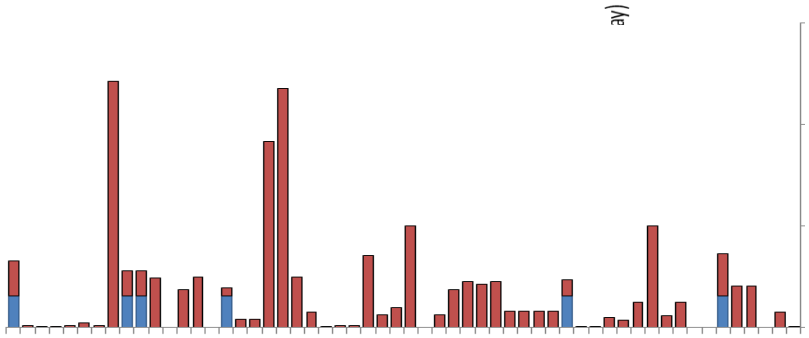
Novel Modeling Approach for Fracture Spacing Design

Motivation for Fracture Spacing Design

> Industry is used to a “one size fits all” fracturing approach.
  - Same frac design (volume, rate, proppant, etc.) for multiple (10’s) stages per lateral.
  - Same spacing for all fractures in varying rock layers along lateral (even though horizontal lateral encounters variable reservoir conditions).

> The results from current approach are typically:





Proposed Solution: Use Conventionally Collected Data

Natural Gamma

- Used for geo-steering
- Indicates shales

Gas Shows from Mud Logs

- Higher or lower shows indicate productive or non-productive zones
- Natural Fractures

Rate of Penetration (ROP) during Drilling

- Influenced by multitude of factors
- Critical in harmonizing gas shows for better analysis

Other potential datasets for use?

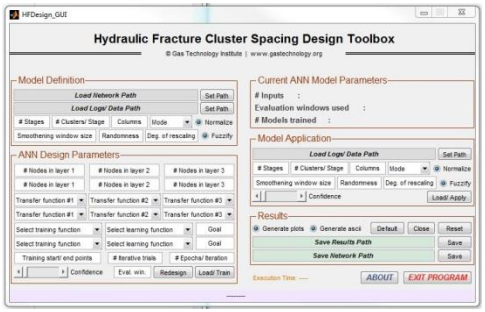
Potential Future Benefits & Application

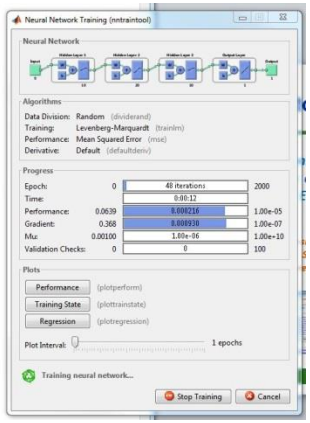
- **Enhanced productivity** per specific input use (water, proppant, chemicals, etc.) leading to reduced environmental footprint per unit of gas produced.
- Optimal completion programs without having to resort to **expensive post drill wireline logs** or LWD tools.

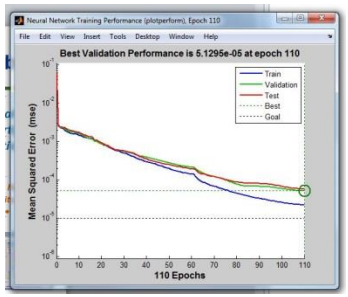
New Fracture Spacing Design Toolbox

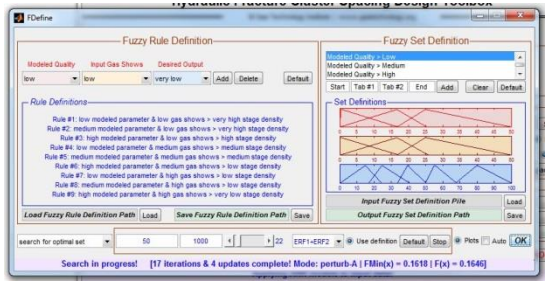
A fracture spacing design toolbox that uses **commonly available data** and **advanced soft computing** (AI) tools such as Artificial Neural Nets (ANN), Fuzzy Classifiers and Evolutionary Algorithms.

- ***Simple to implement***
- ***Ability to map highly non-linear relationships***
- ***Robust with noise***
- ***Easy to understand framework (for humans)***
- ***Simplicity***
- ***Adaptability***



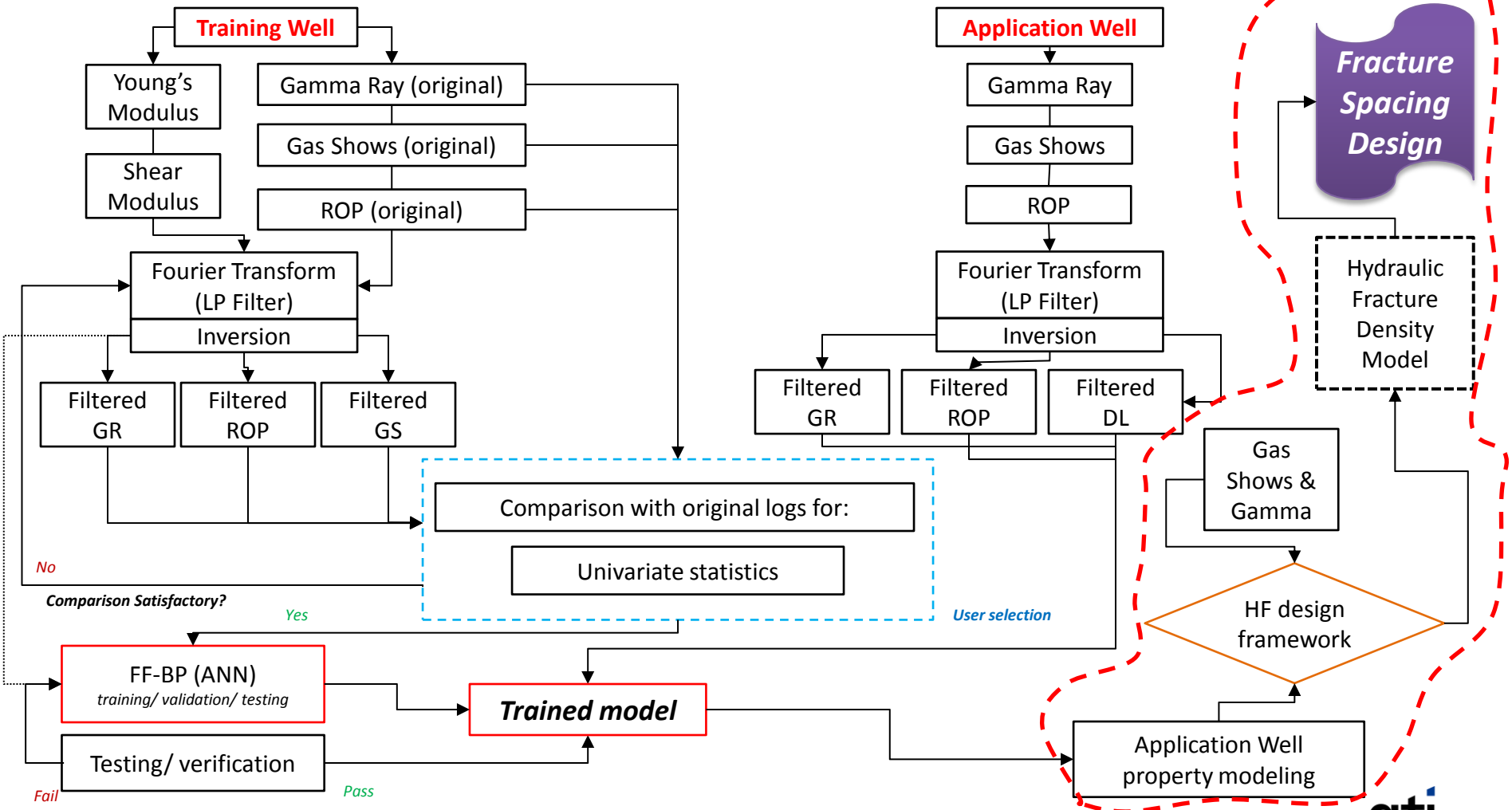




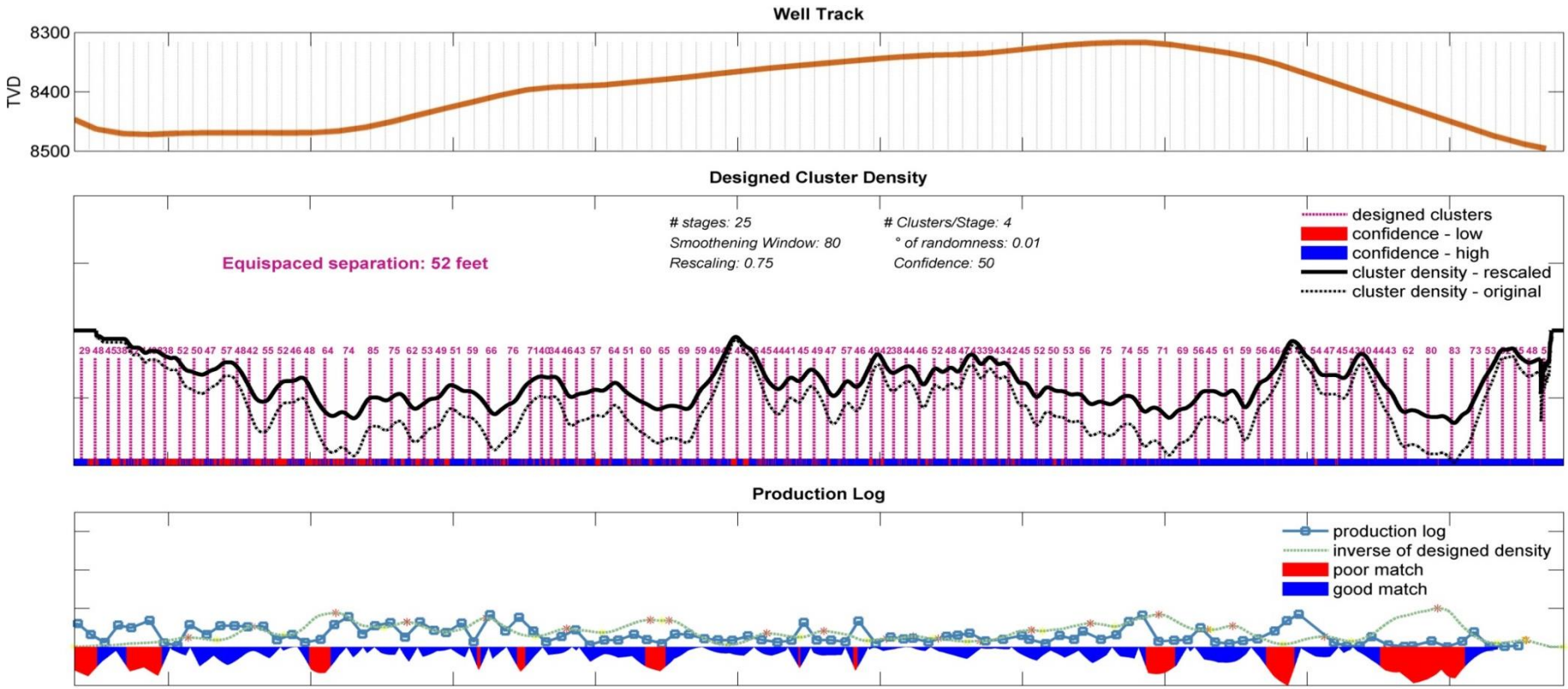


Design workflow

Fuzzy Rule based optimal combinational framework



Sample Design for Well



Inverse of modeled cluster density shows good correlation with observed production

Conclusions & Next Steps

- Production from long horizontal shale wells is variable and often many stages do not contribute to production
- Routinely collected data can be used to predict production performance and optimize fracture spacing
- Developed a workflow to optimize fracture spacing based on commonly collected data and validated with production
- Implemented the workflow into a usable toolbox
- *Implement fracture spacing toolbox on more wells to refine modeling workflow and identify limitations and potential ways to overcome them*

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Thank You!

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