



# **WELLS RANCH SEC. 25: OBSERVATIONS FROM A UNDERGROUND IN-SITU LABORATORY**



Dave Koskella

Bob Parney

David Brock

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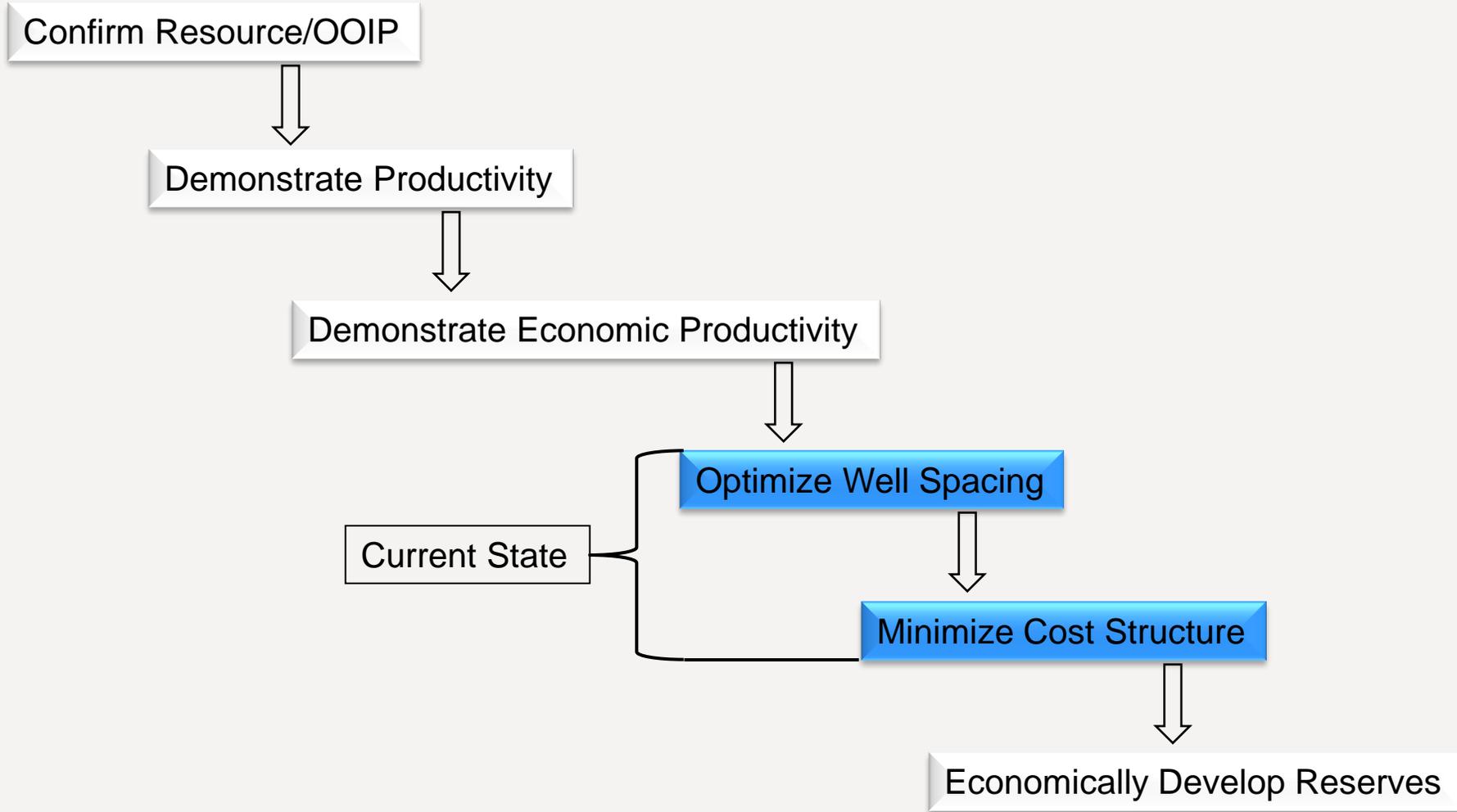
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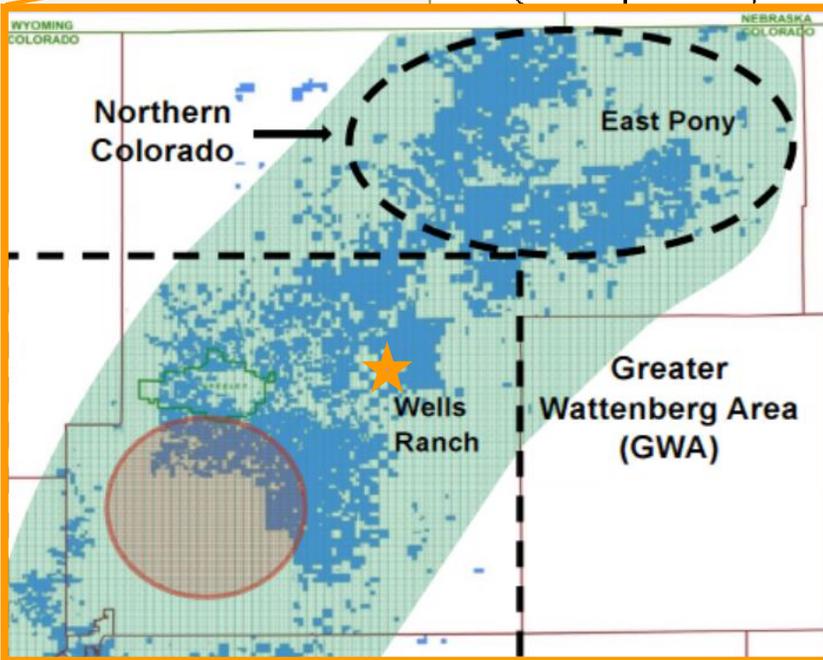
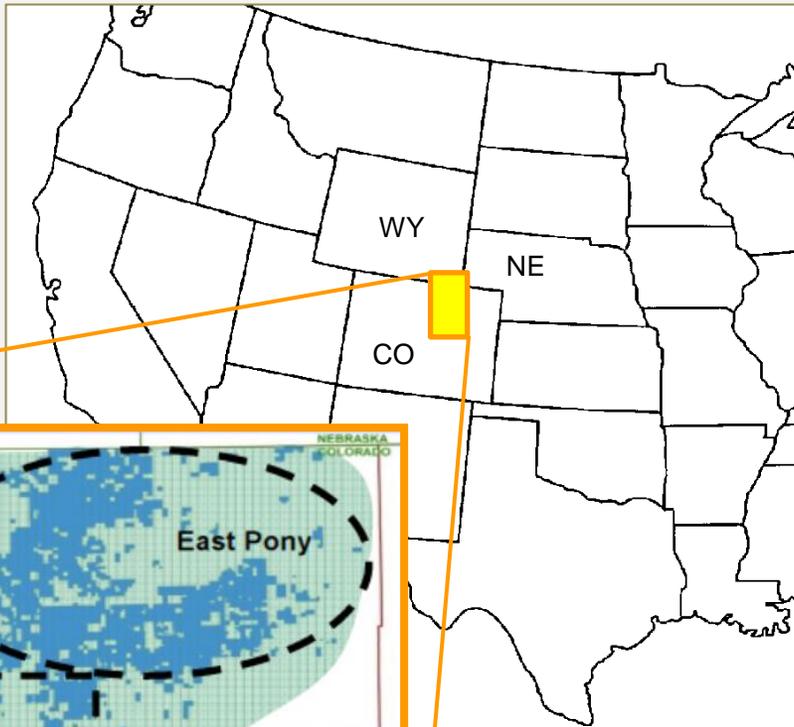
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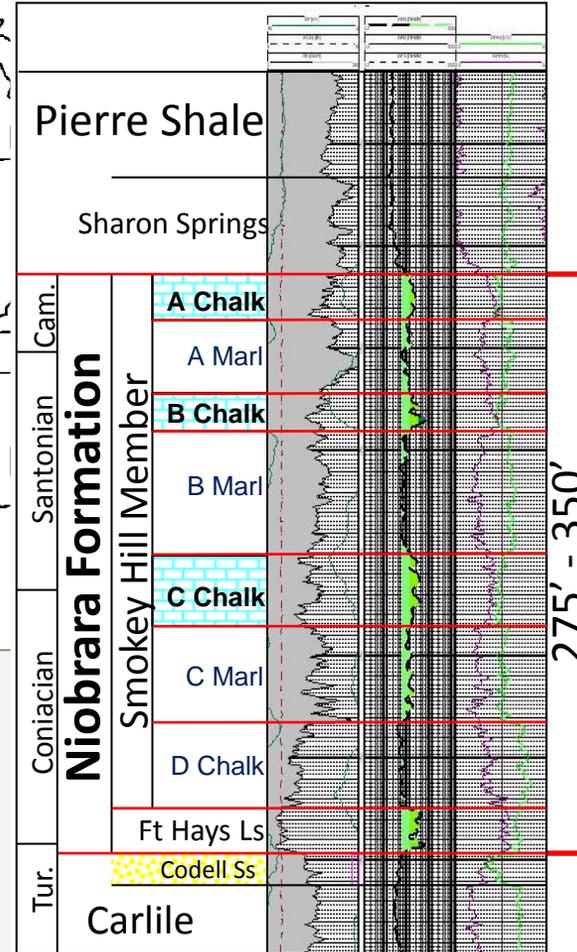
# Life Cycle of a Resource Play



# Greater Wattenberg Area



## Niobrara Stratigraphy

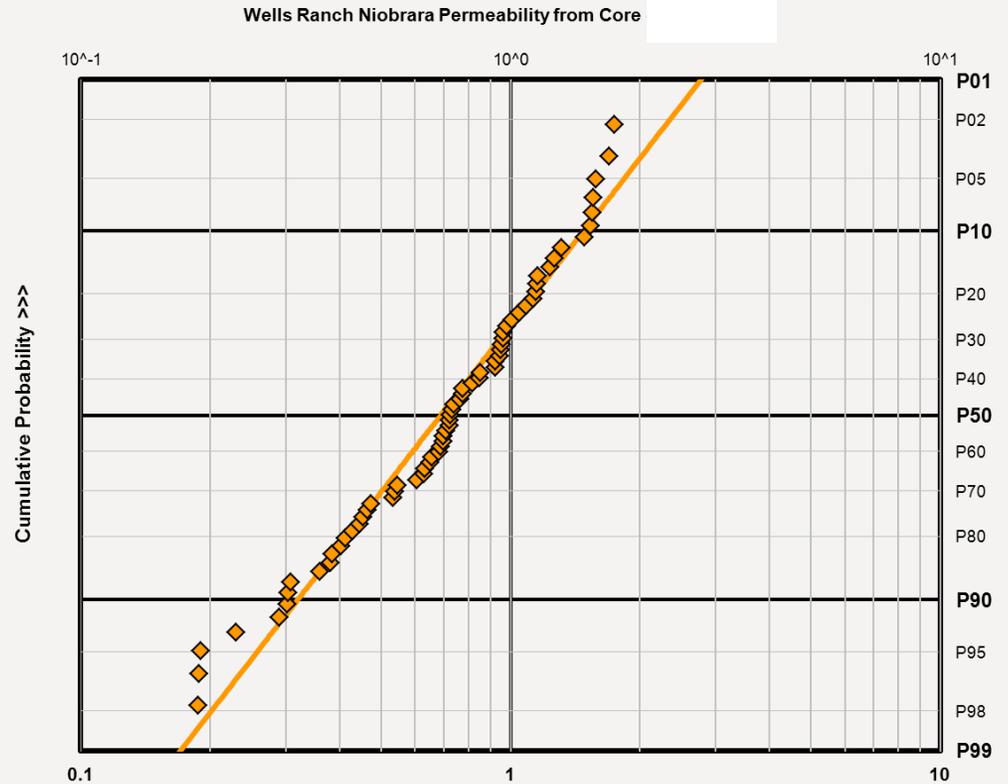
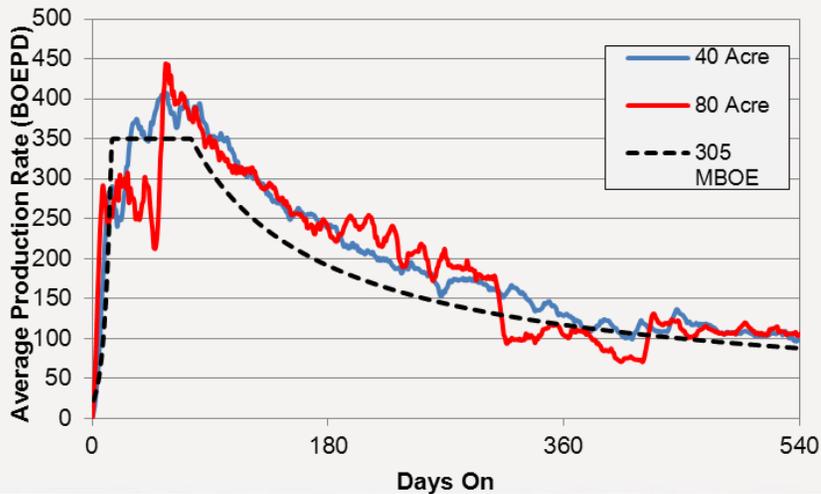




Cemex Limestone Quarry, Lyons, CO

# Niobrara Characteristics

**OOIP** 70 MMBOE/Section  
**TVD** 6,700'  
**H** 300'  
**Phi** 9%  
**K** 0.81 uD  
**P\*** 0.49 psi/ft  
**API** 40  
**GOR** 5,000 scf/bbl  
**Sh min** 0.75 psi/ft  
**Sh max** > 0.75 psi/ft  
**Frac Grad** 0.85 psi/ft  
**Sv** 1.06 psi/ft

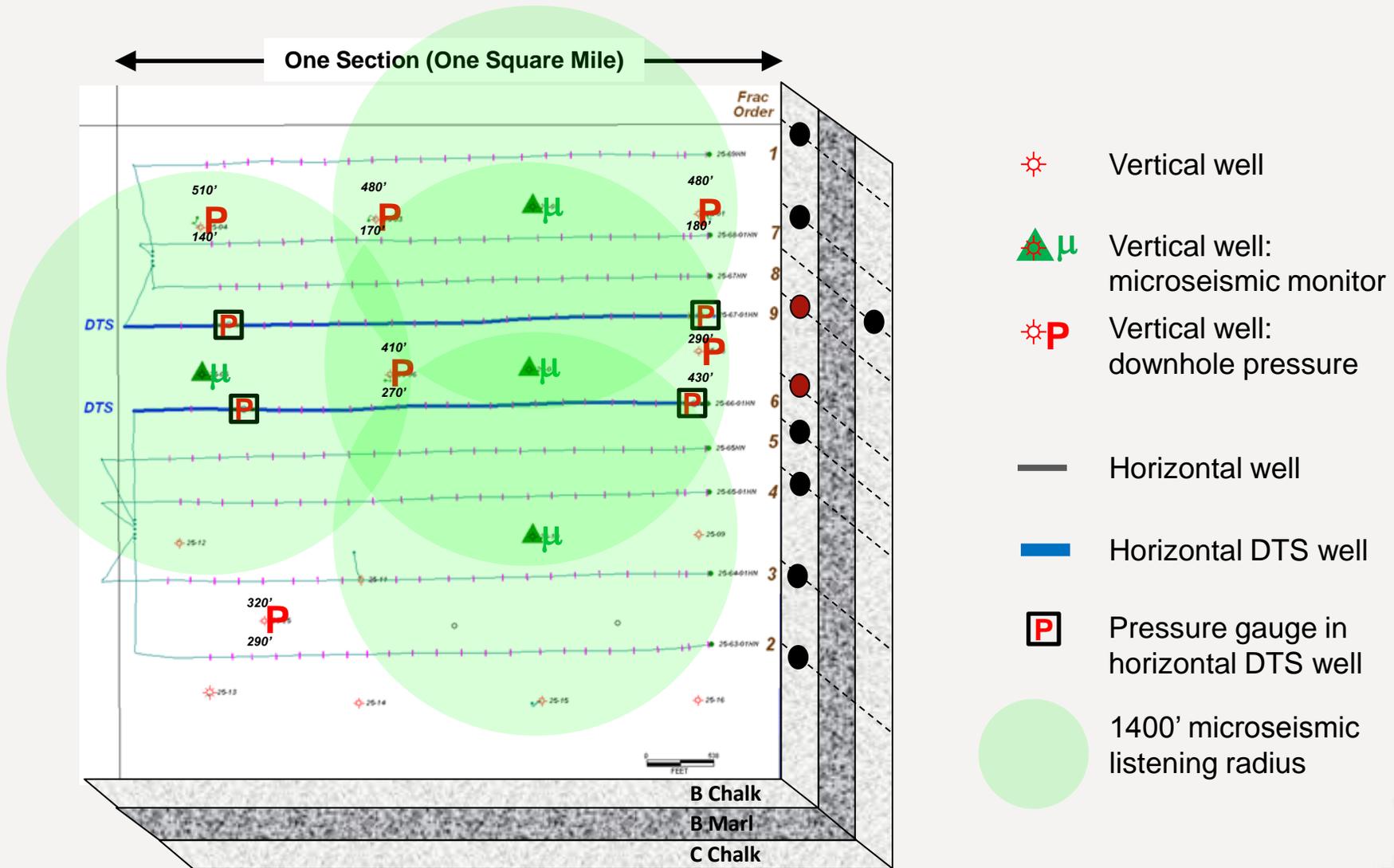


|       | Permeability (Micro Darcy) |
|-------|----------------------------|
| P10   | 1.48                       |
| Pmean | 0.81                       |
| P90   | 0.32                       |

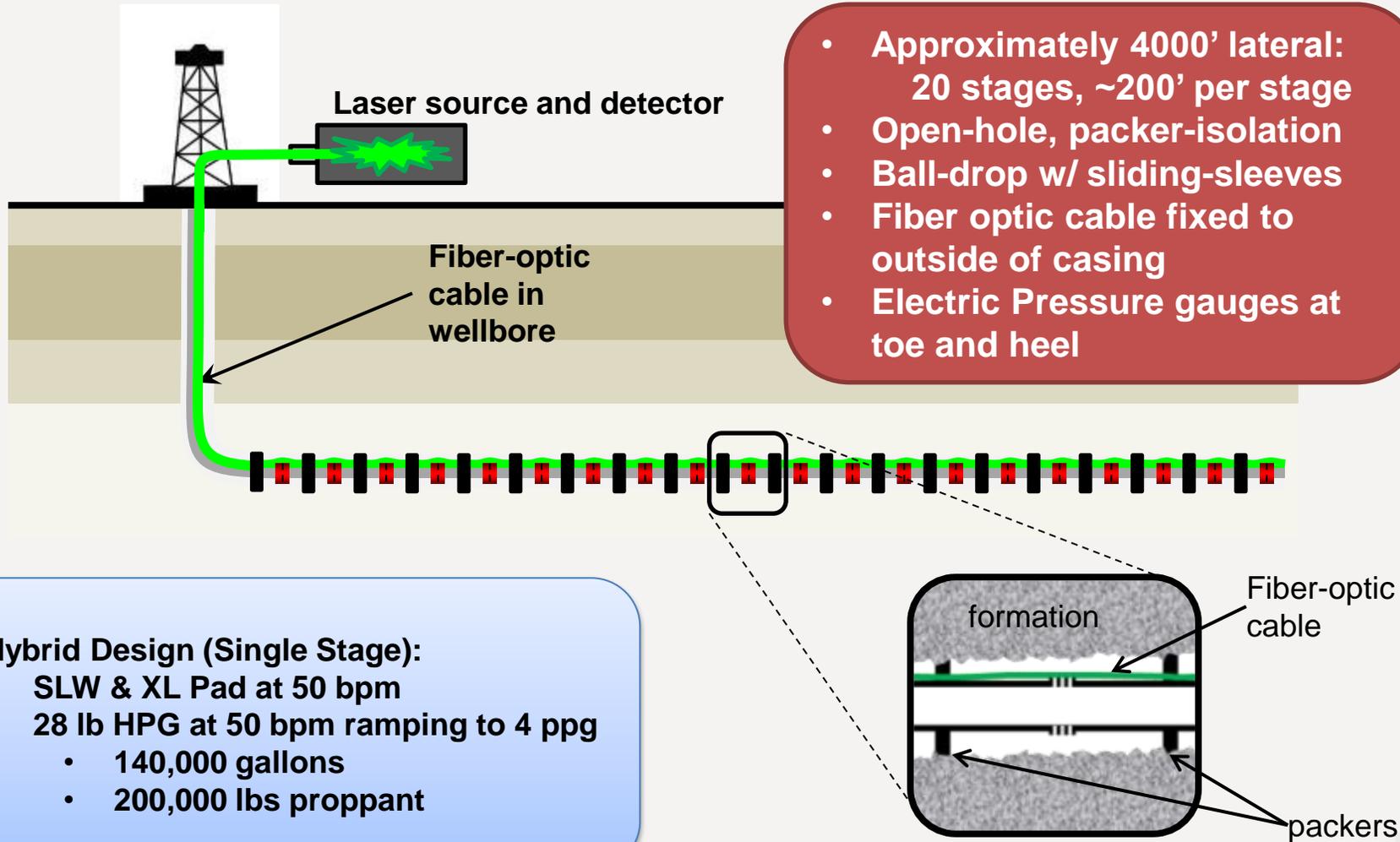
# In-Situ Underground Laboratory Technologies Employed

- **Multi-Array Down Hole Micro Seismic (Six Wells)**
- **Ten Down Hole Pressure Gauges**
- **Ten Down Hole Temperature Gauges**
- **Two wells with Fiber Optic:**
  - ▶ DTS Stimulation
  - ▶ DTS Production Logging
  - ▶ DAS
- **RA Proppant Tracers**
  - ▶ Three Wells Traced
  - ▶ Five Wells Logged
- **Liquid Tracers (Nine Wells):**
  - ▶ Water Based
  - ▶ Oil based
- **FMI's (Nine Wells)**
- **Core (Two Wells)**
- **Core Laboratory Testing**
- **DFITS (Nine Wells)**
- **VSP**
- **Geochemistry**
  - ▶ Core Extracts
  - ▶ Produced Oil
- **3-D Seismic**

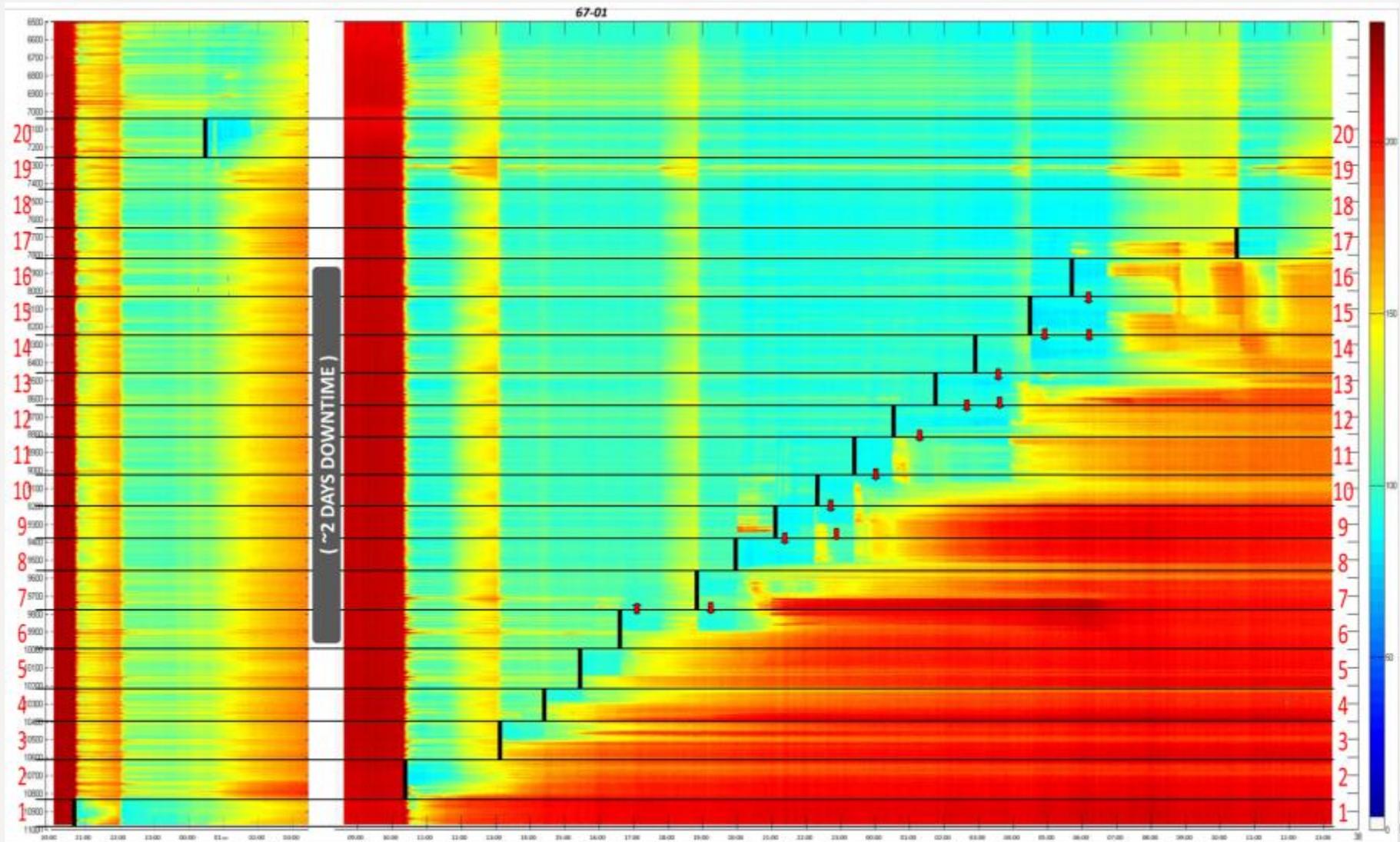
# In-Situ Underground Laboratory



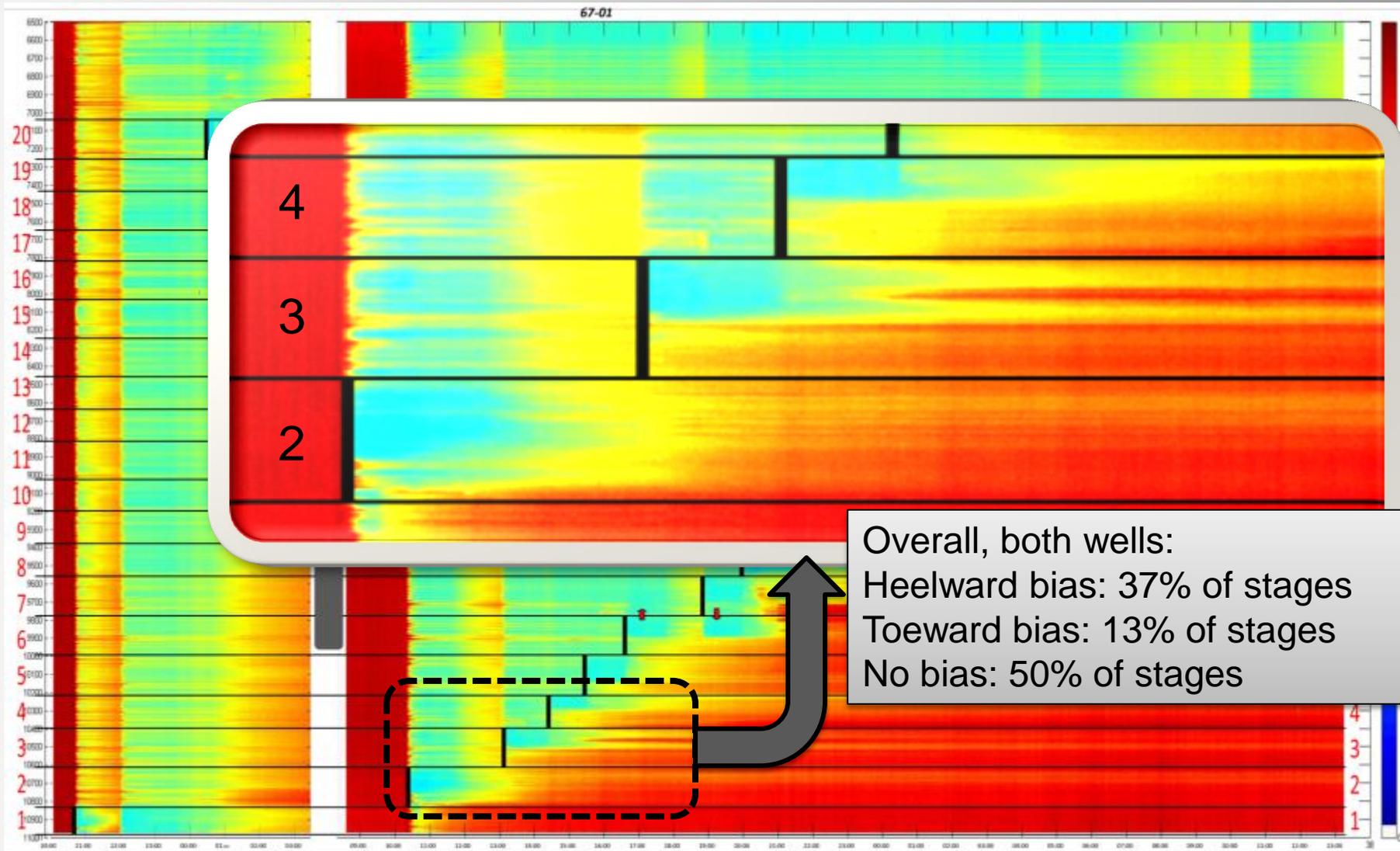
# DTS Well Construction



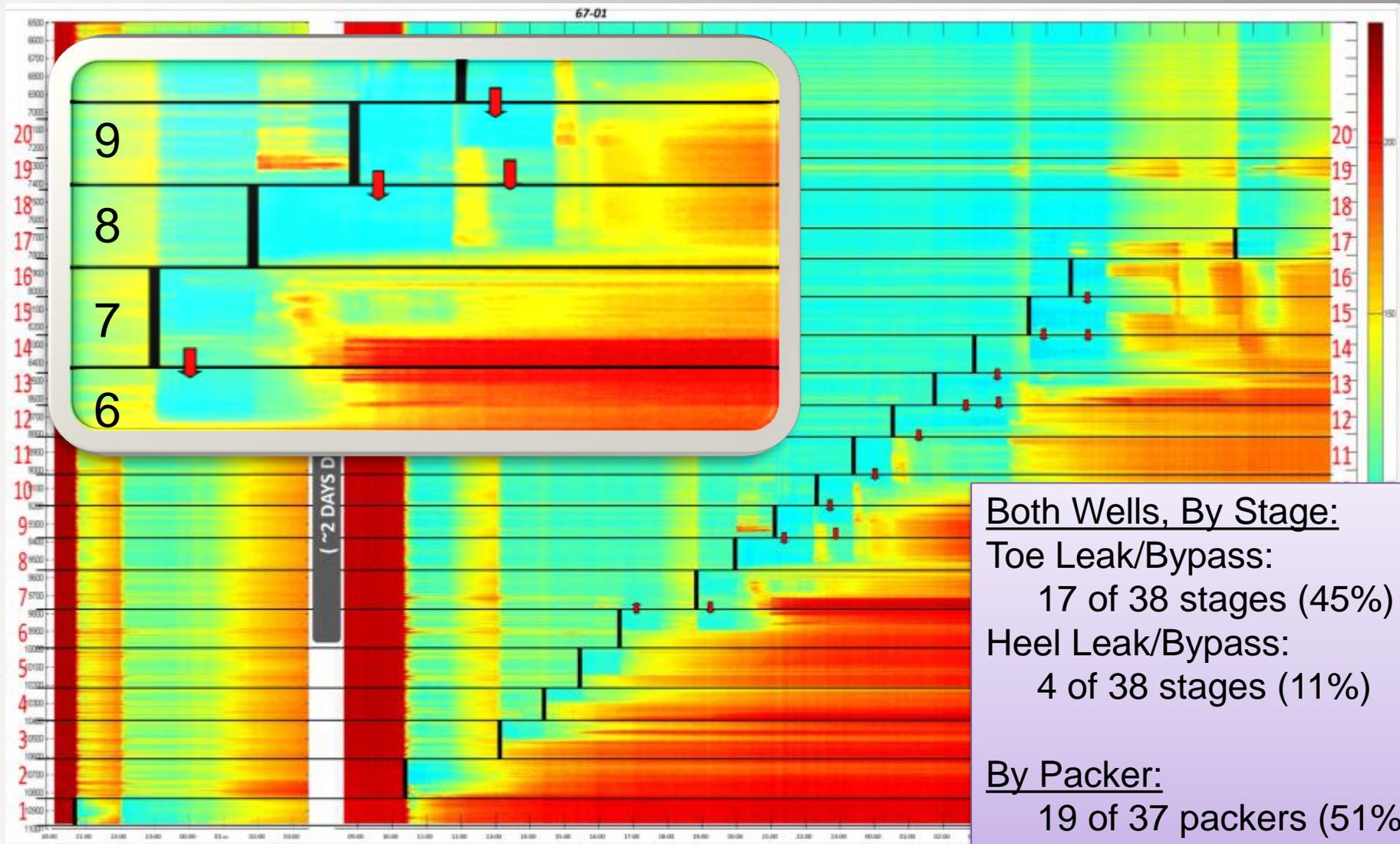
# DTS During Completion



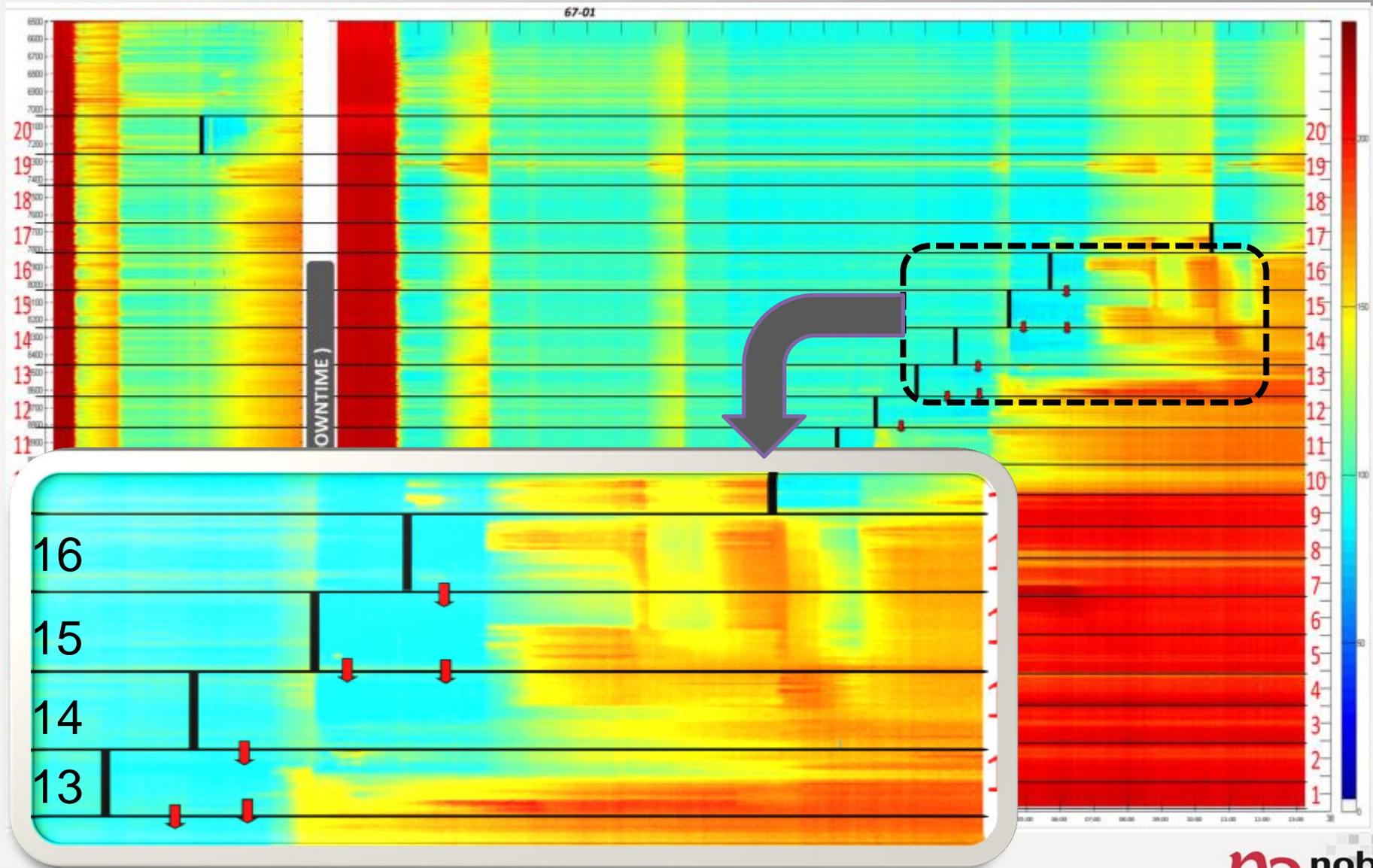
# DTS During Completion: Fluid Movement and Warmback



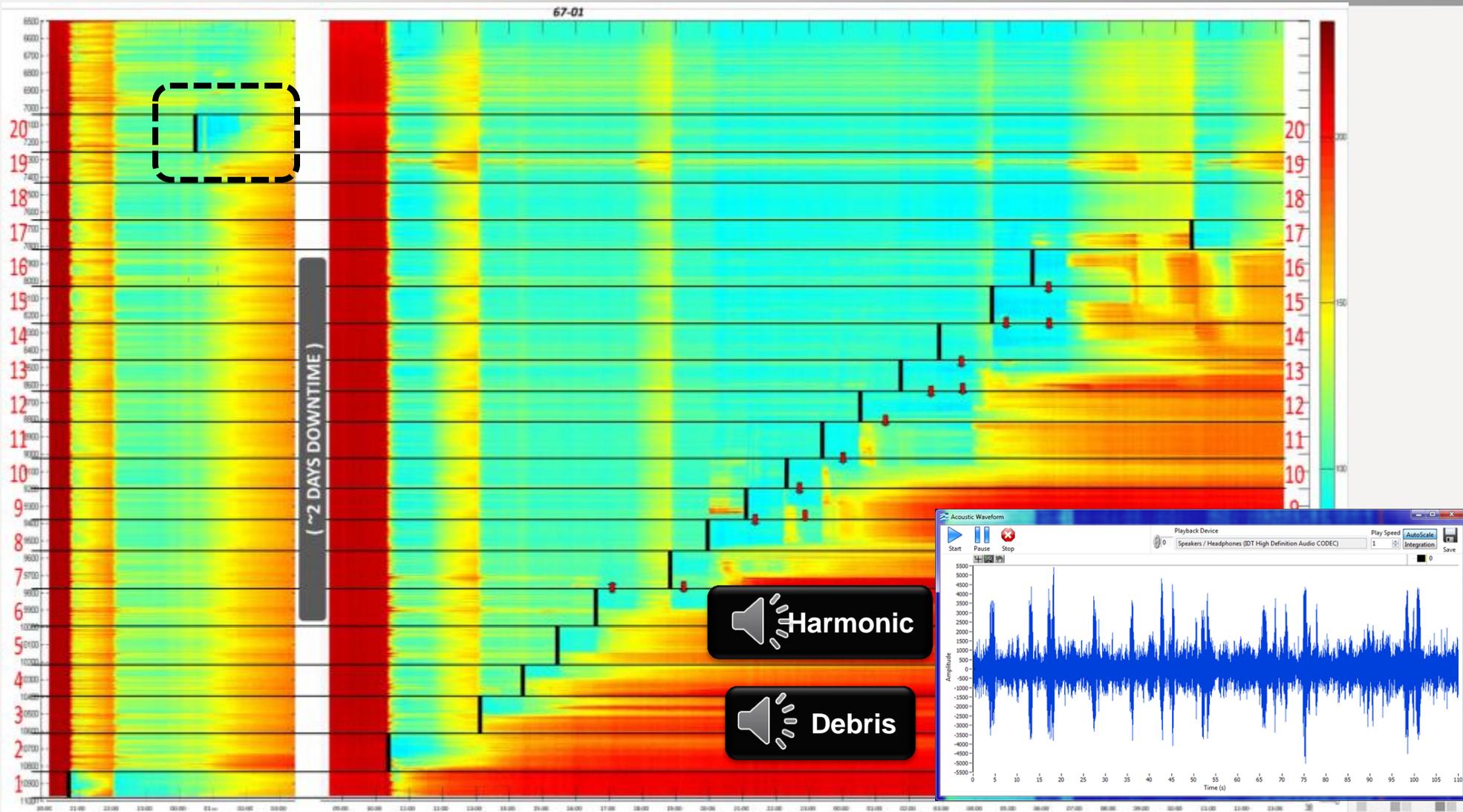
# DTS During Completion: Packer Leak/Bypass



# DTS During Completion: Multiple Packer Leaks/Bypass



# DTS During Completion: Operations Diagnostic Example

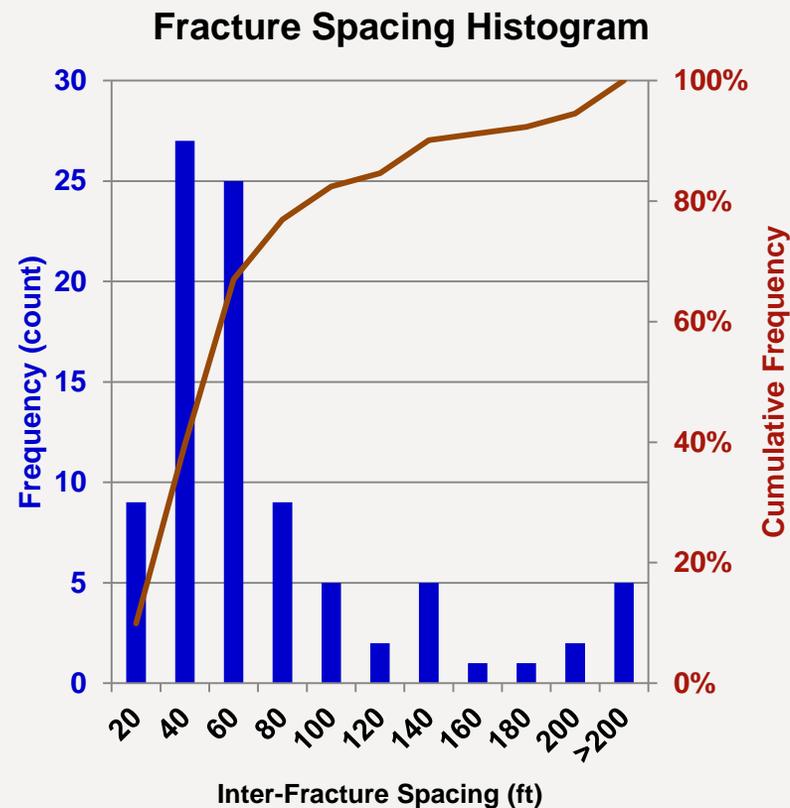


# Fracture Statistics from DTS

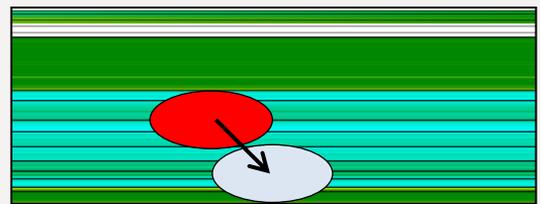
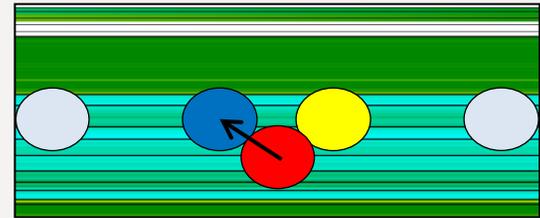
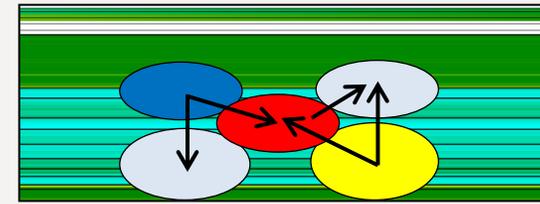
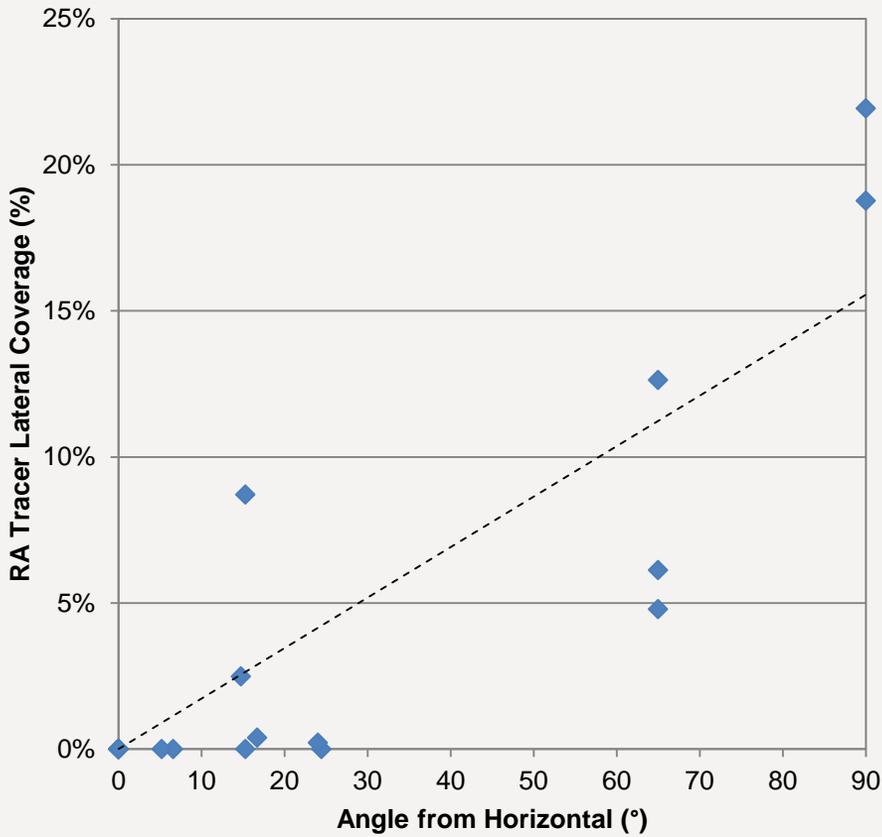
Two wells, 38 stages total

Fractures: 135 (avg 3.5 fracs/stage)

| Feature                                                  | # stages (of 38) | % of stages |
|----------------------------------------------------------|------------------|-------------|
| “Dominant” Frac (one frac >> others)                     | 18               | 47%         |
| “Significant” Frac (long lasting DTS warmback)           | 12               | 32%         |
| Frac <u>at</u> toe packer                                | 6                | 16%         |
| Frac <u>at</u> heel packer                               | 15               | 39%         |
| Fluid bias: toe                                          | 5                | 13%         |
| Fluid bias: heel                                         | 14               | 37%         |
| Packer Leak/Bypass: toe                                  | 17               | 45%         |
| Packer Leak/Bypass: heel                                 | 4                | 11%         |
| <i>Leak/Bypass by Packer:<br/>19 of 37 packers = 51%</i> |                  |             |

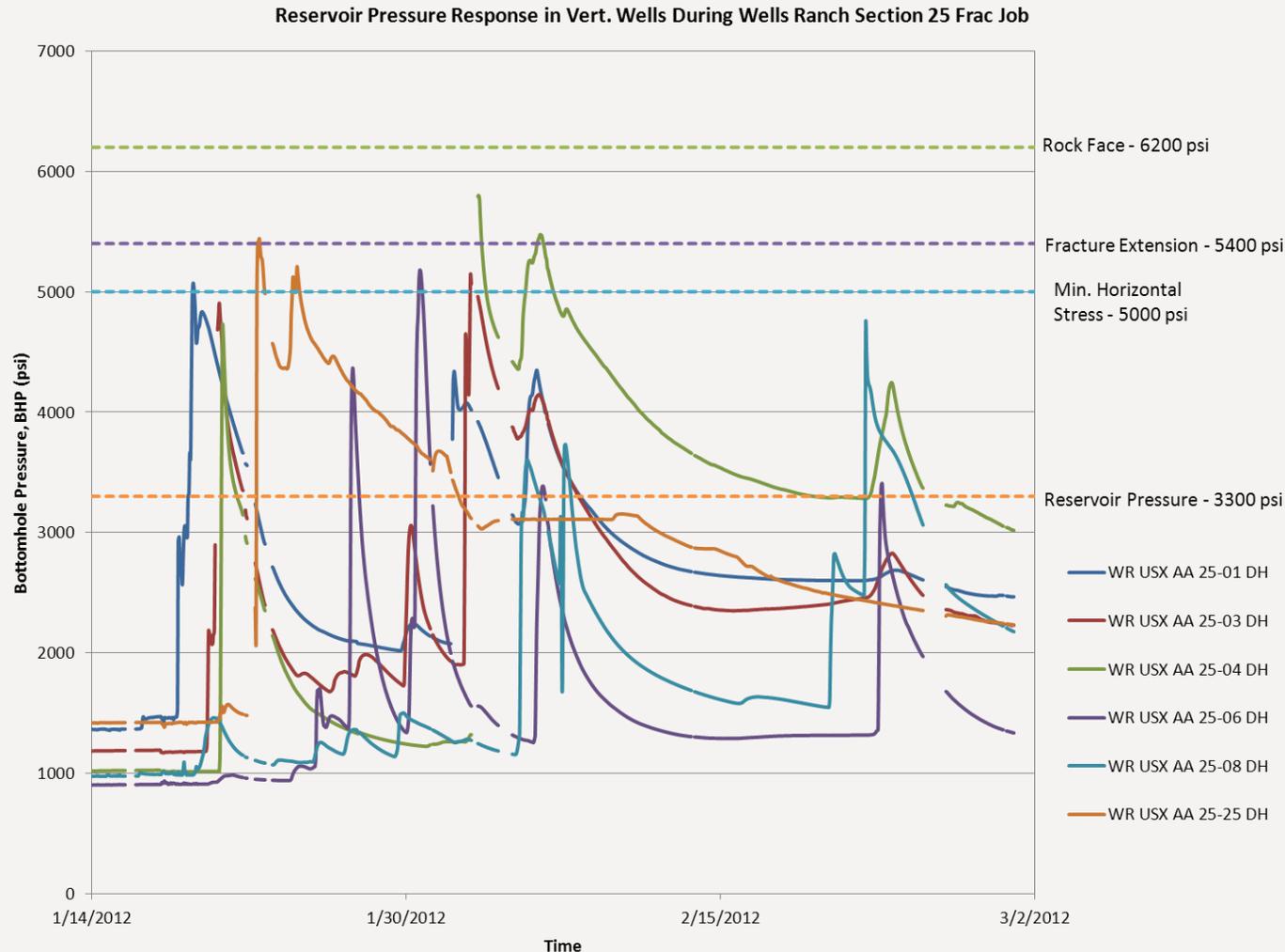


# Proppant Tracer Inter-Well Transport

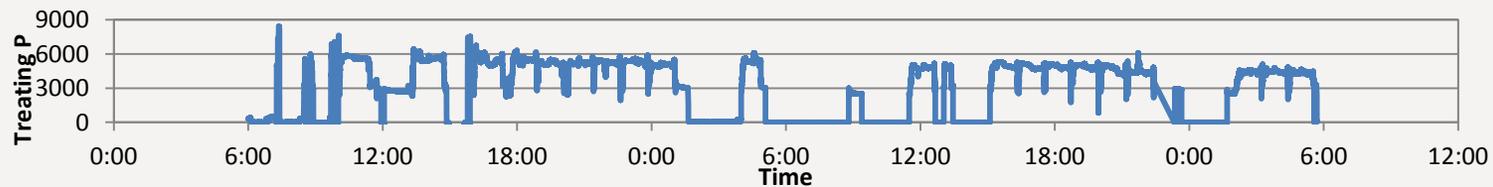
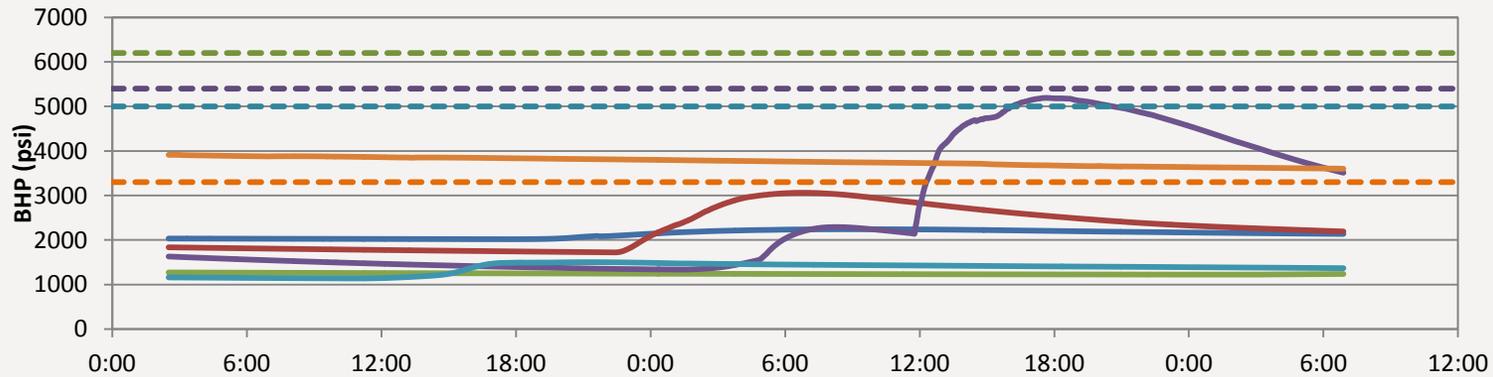
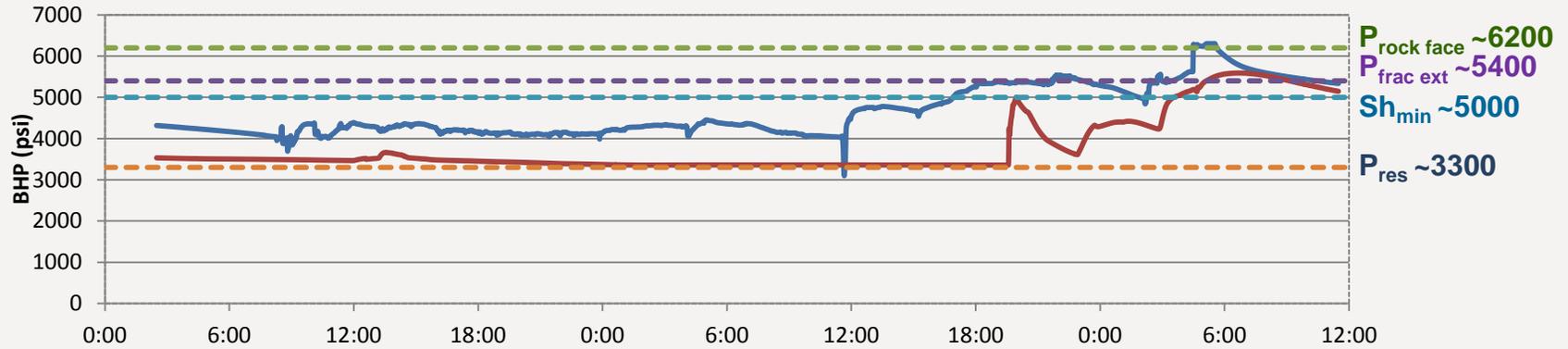


# Down Hole Pressure Monitoring in Vertical Wells During Stimulation (178 Frac Stages)

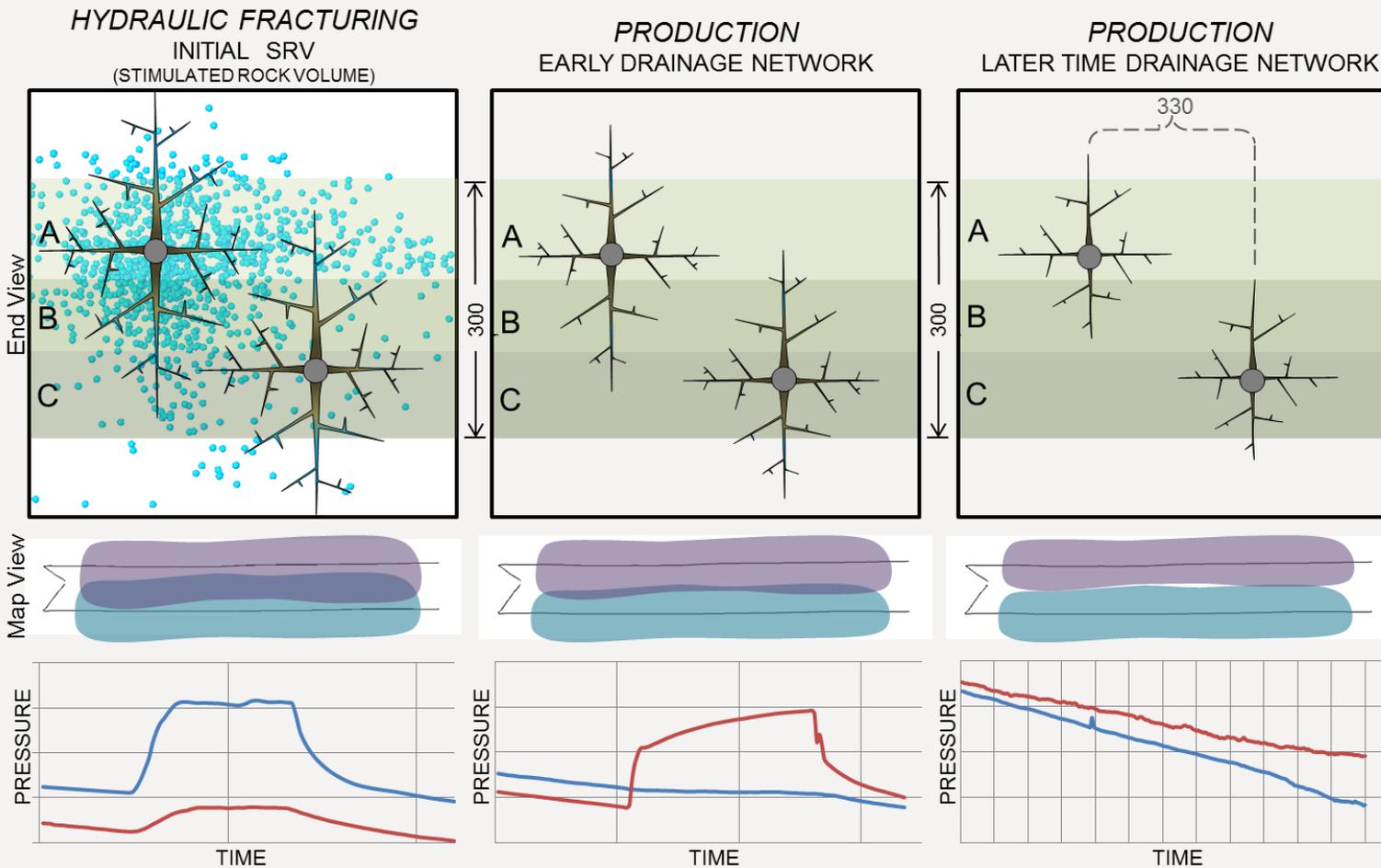
Vertical well monitoring distances: 140-510'



# Pressure Response During Completion of One Well



# Drainage Network Geometry

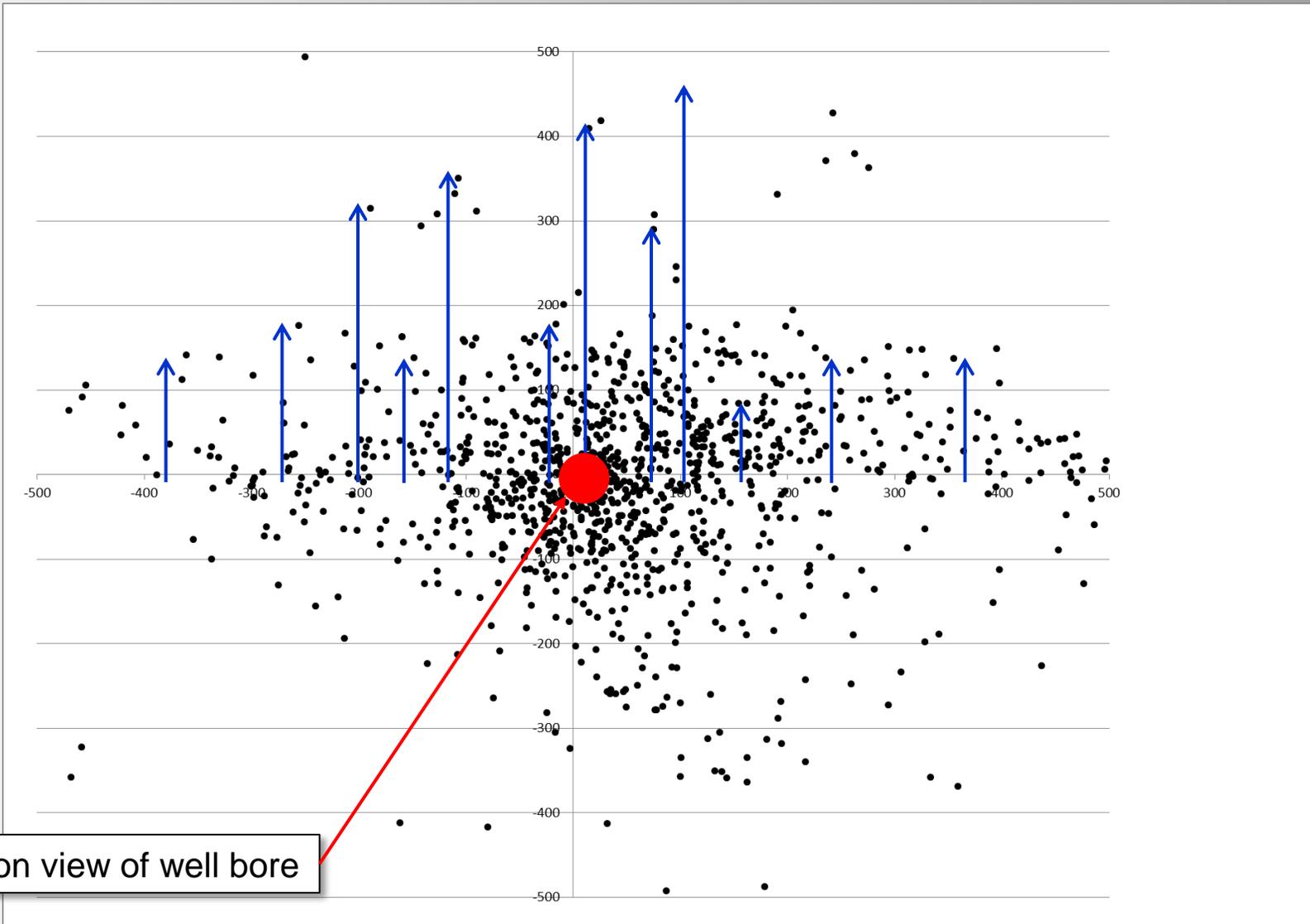


- *Constructive interference*
- Calibrated with: Microseismic, pressure gauges, proppant tracers & DTS

- Reducing interference
- Calibrated with: Pressure gauges & geochemistry

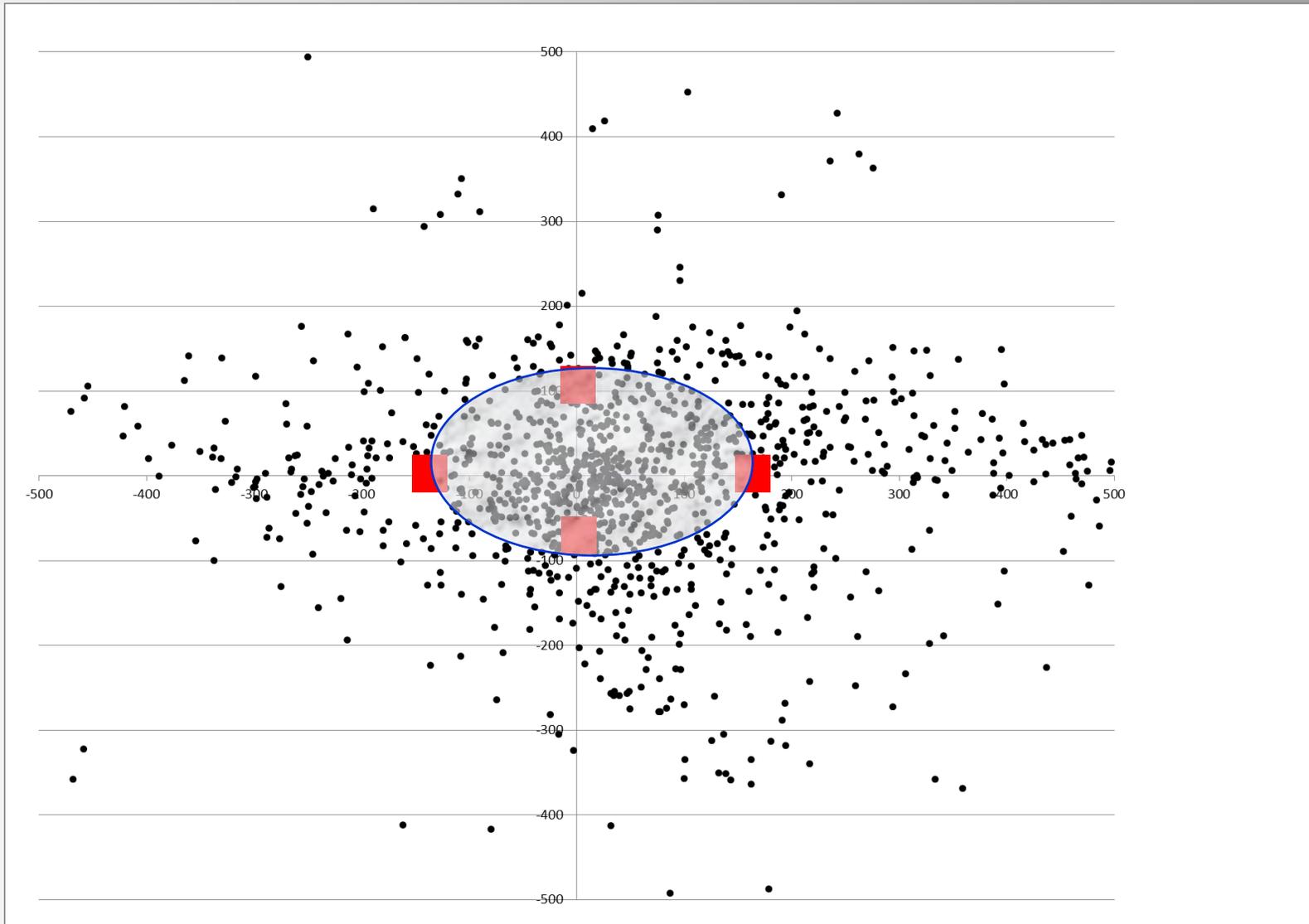
- Low interference
- Calibrated with: Pressure gauges & geochemistry

# Lognormal Elliptical Analysis of Micro-Seismic Events

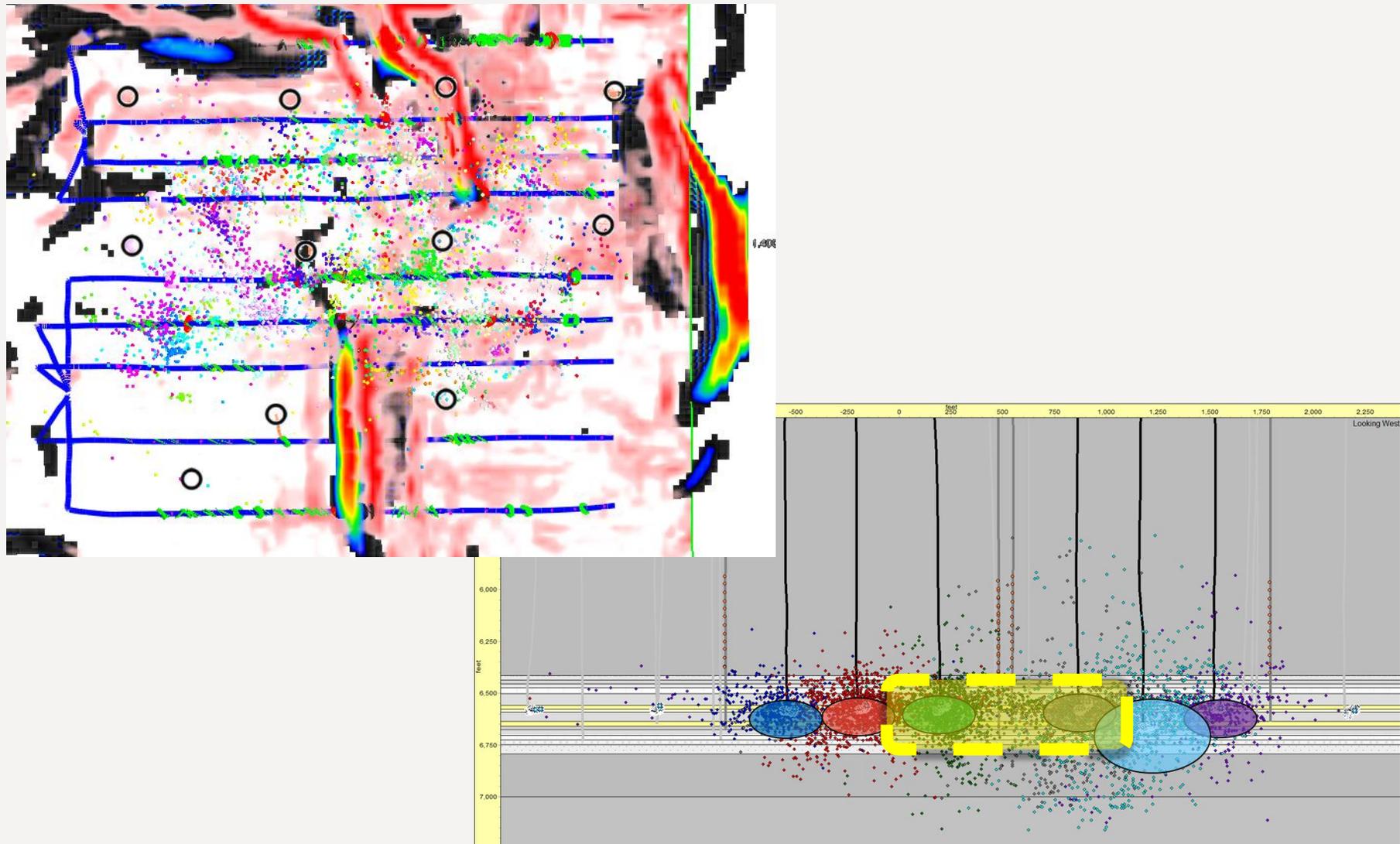


End on view of well bore

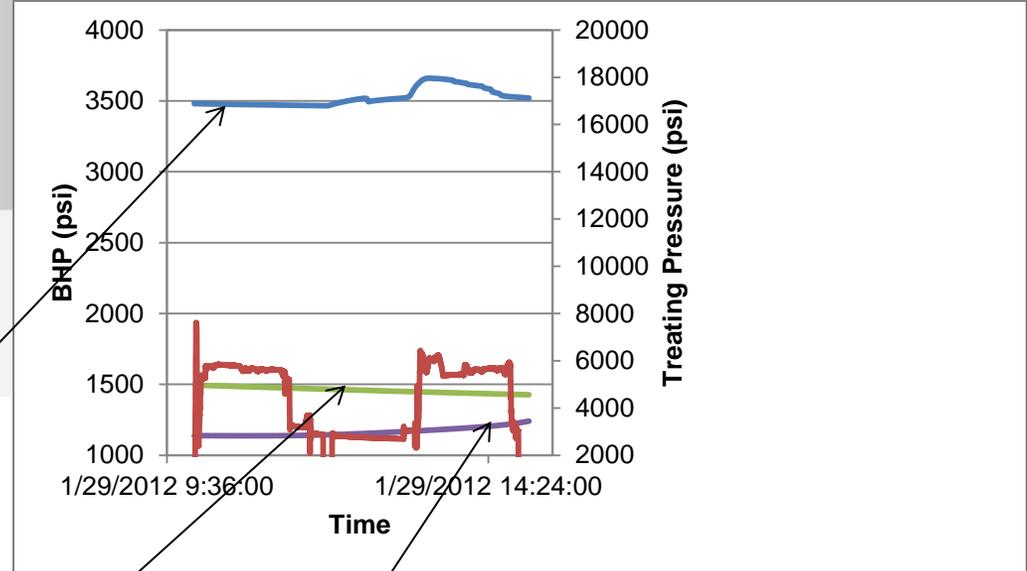
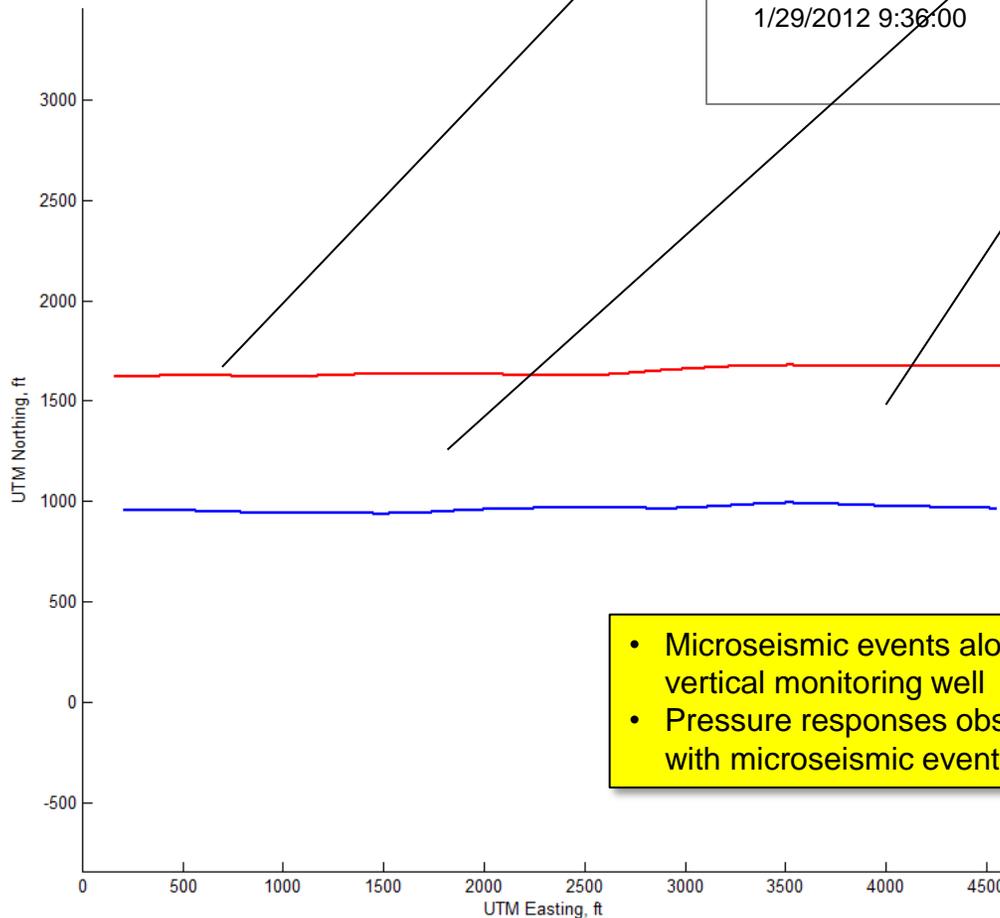
# Lognormal Elliptical Analysis



# Microseismic Overview



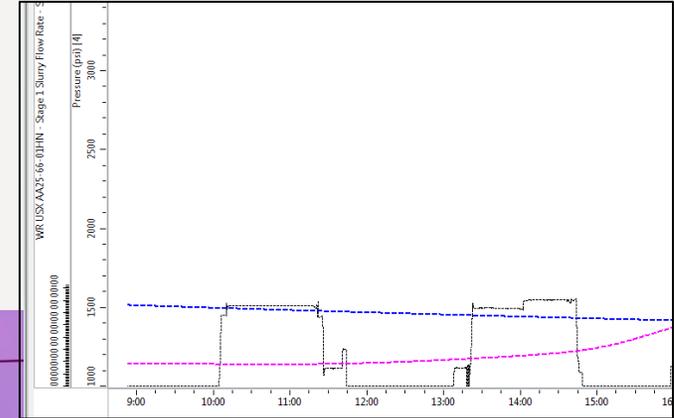
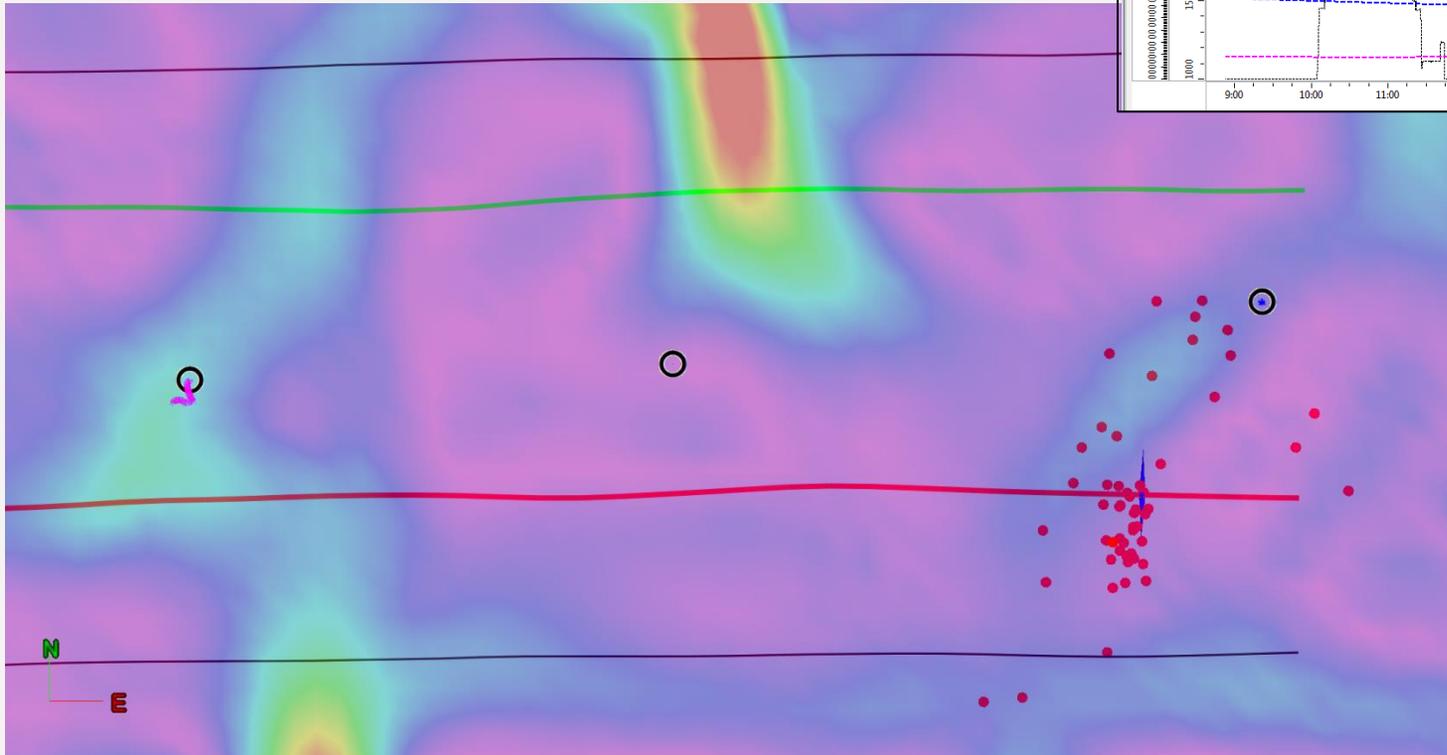
# Microseismic & Pressure Correlation?



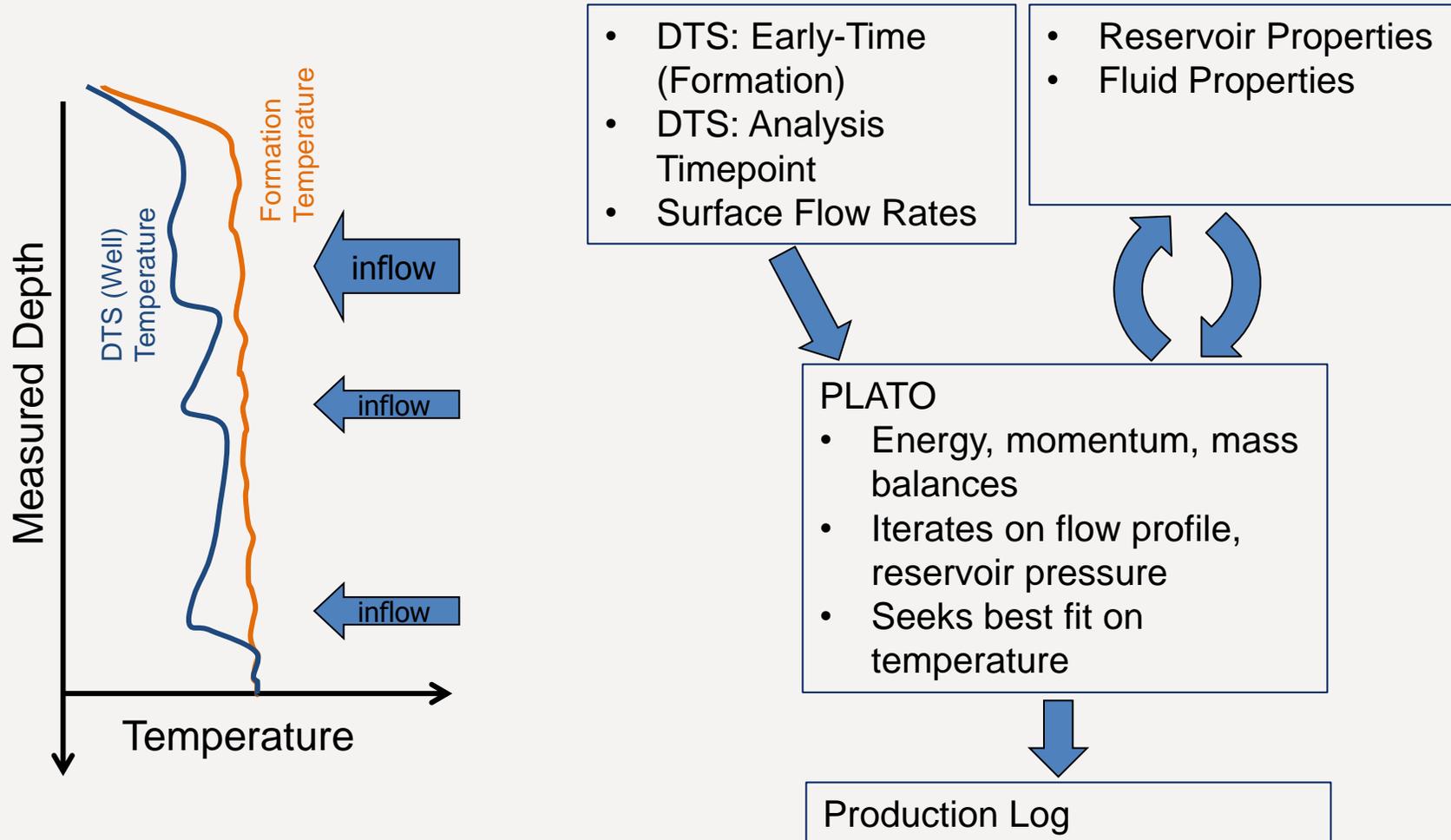
- Microseismic events along path from frac stage #2 toward and around vertical monitoring well
- Pressure responses observed in nearby observation wells not correlated with microseismic events

# Inter Well Behavior: Intergrating Pressure & Microseismic?

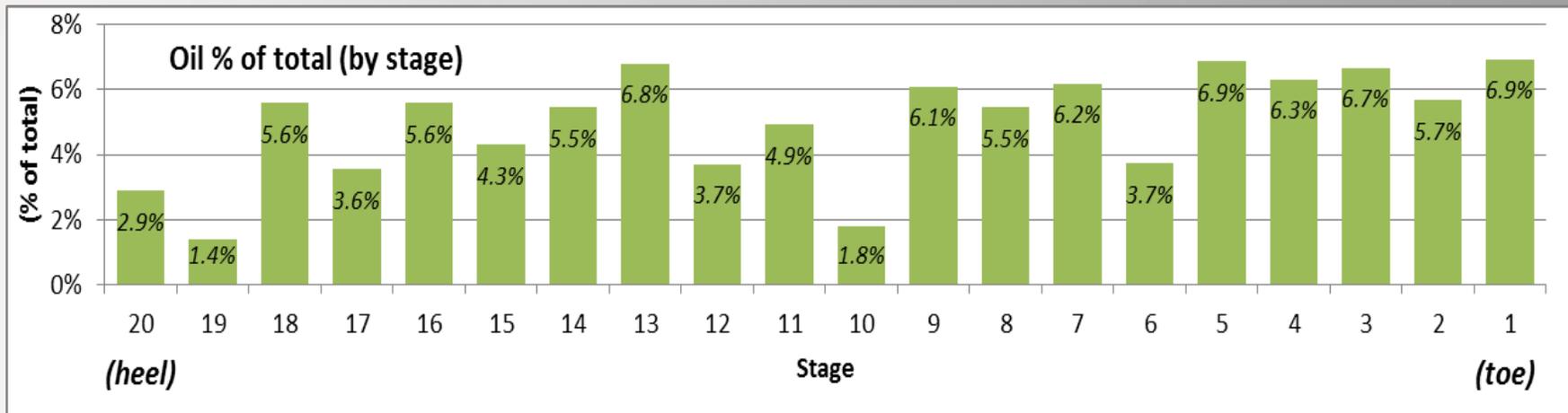
- Micro seismic events along path from frac well toward and around vertical monitoring well
- No pressure response observed in nearby vertical well



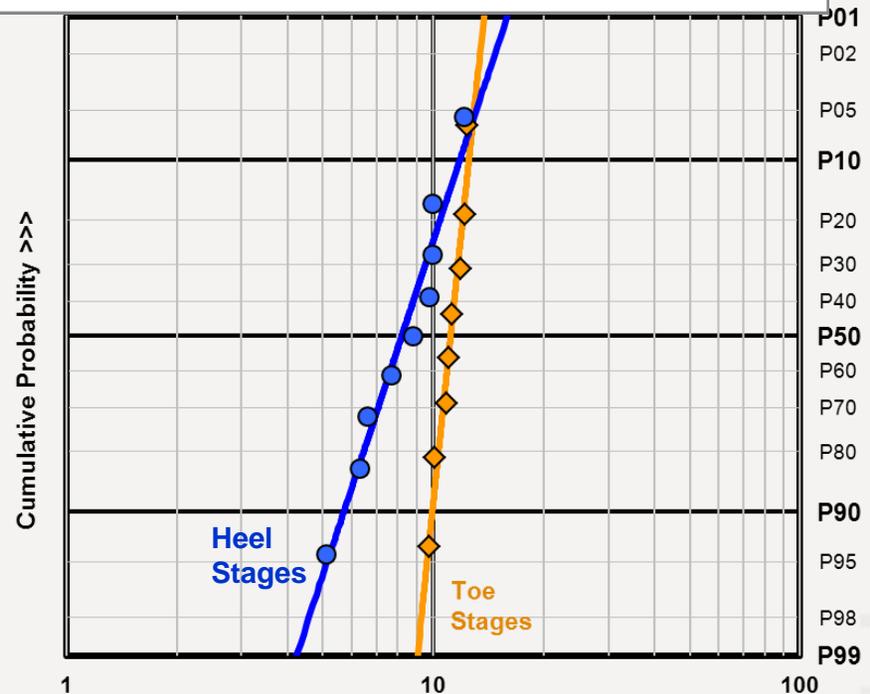
# DTS Analysis for Production Logging: A History-Match Process



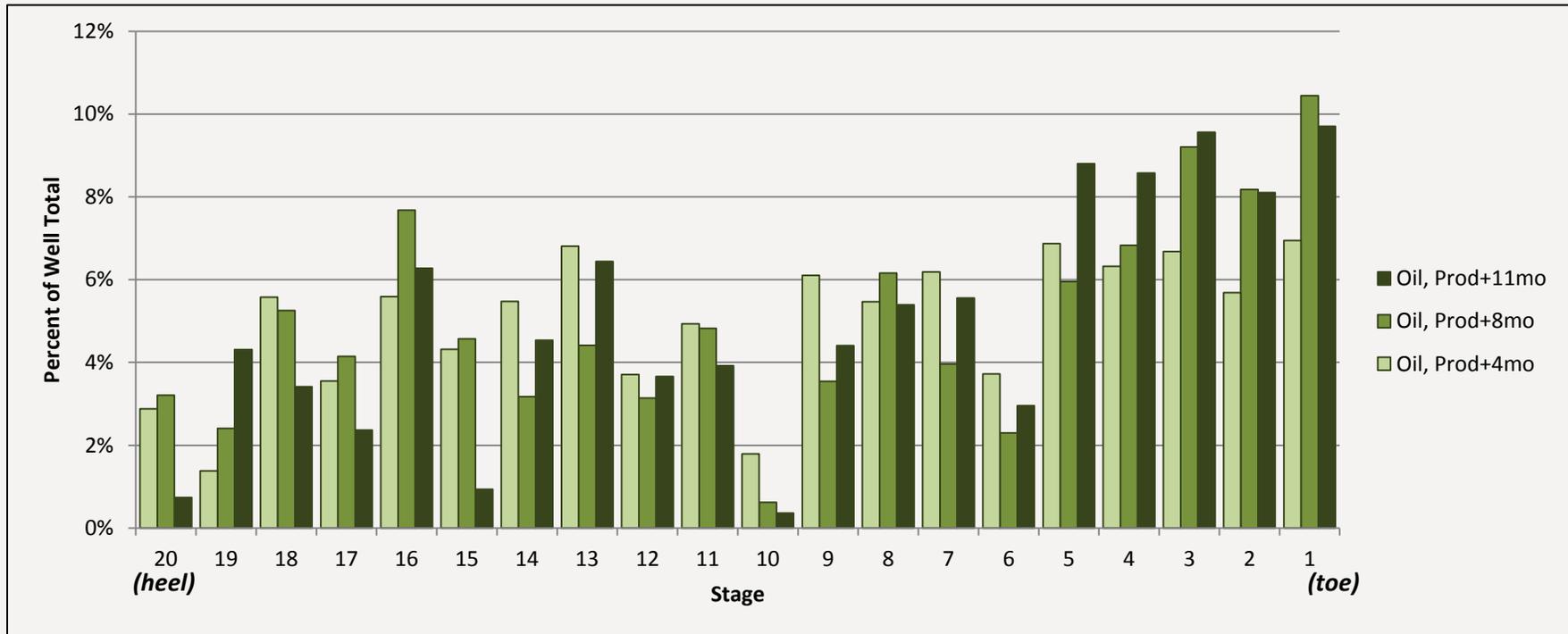
# Oil Production (4 months into production)



- By stage oil production
- (Average stage would have 5% flow)
- Best stage: 6.9%
- Poorest stage: 1.4%
- Production profiles do not correlate to FMI artifacts
- $P_{\text{mean}}$  oil rate 32% better in Toe Stages



# Oil Production through Producing Life



- By-stage oil production results

# Summary

## Stage Perspective:

- Fracture Initiation: Average 3.5 fractures per 200 foot stage
- “Stress Shadowing”? Heelward fluid bias vs. toward bias (37% vs. 13%)

## Well Perspective:

- More instances of packer leaks/bypass in the heelward half of wells (78% heel stages vs. 30% toe stages)
- DTS production logging shows all stages producing with no large redistributions over time. Toward stages 32% more productive than heelward stages.

# Summary (cont.)

## Inter-Well Perspective:

- RA Proppant Tracer:
  - Horizontally not observed, 0-15 degrees, 0% coverage
  - Diagonally observed, 15-50 degrees, 8% coverage
  - Vertically observed, 90 degrees, 20% coverage
- Pressure responses  $\ll Sh_{\min}$  observed up to 1,520'
- Pressure responses  $> Sh_{\min}$  rarely seen at distances of 140-510 feet, 7 events out of 178 frac stages
- Dynamic inter-well hydraulic connectivity, shrinking drainage radius
- Microseismic responses seen 1,400' away
- *Inferred drainage ellipse orientation:*
  - *Microseismic (horizontal) vs. other data sets (vertical)?*
- *Pressure and microseismic event correlation is not obvious*
- No consistent temperature response seen in offset DTS wells
- *Much still to learn....*

# Acknowledgements

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**Barree & Associates**

**Silixia**