Fracturing and Refracturing Insights from Microseismic Geomechanics

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IMaGE™

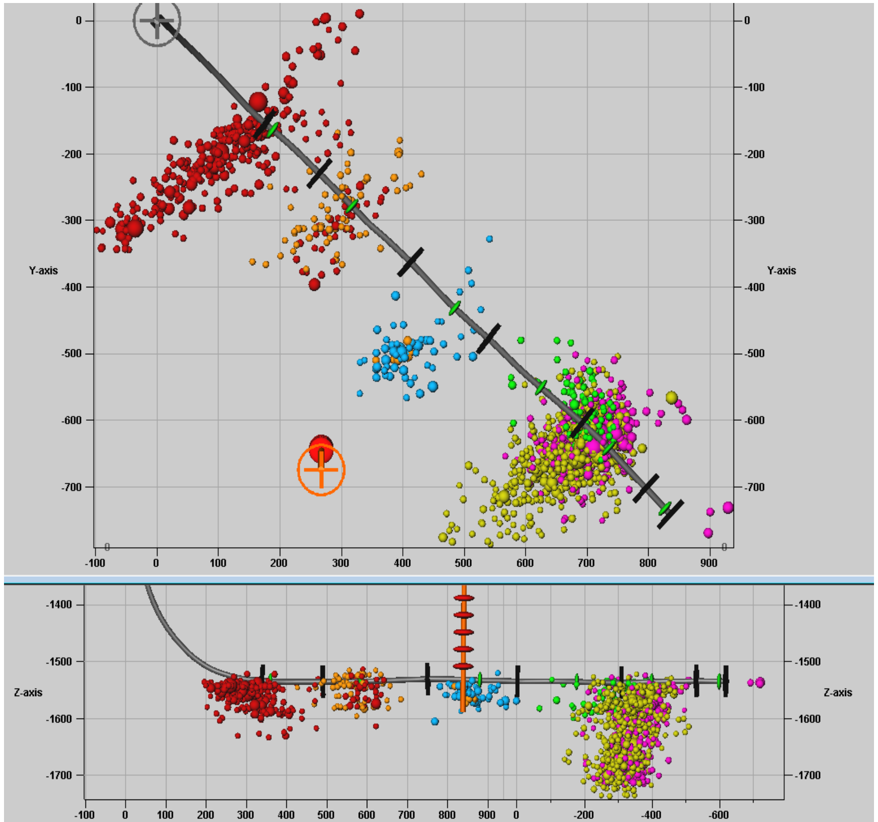
ITASCA Microseismic and Geomechanical Evaluation

Microseismic Geomechanics: Increased understanding; reduced risk

Outline

- Quick overview of applications of microseismic in hydraulic fracturing
- Introduction to Microseismic Geomechanics
- Horn River Basin case study to illustrate the workflow
  - Basic inputs
  - Calibration
  - Sensitivity
  - Completion Optimization
  - Reservoir Modeling
- Upper Montney case study to address a specific question
  - Does microseismic asymmetry indicate fracture asymmetry or microseismic ”blindspots”?
- Eagle Ford refracturing example
  - Diagnosing Success of Diversion
- Wrap-up

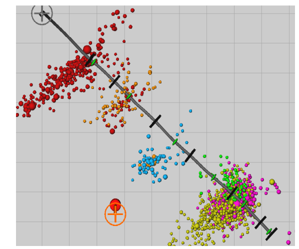
Microseismic Hydraulic Fracture Applications



✓ Fracture direction
✓ Height
✓ Length
✓ Complexity

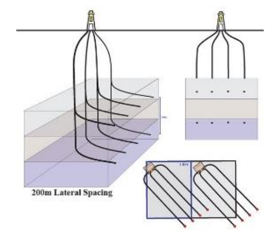
Optimize Stimulation Design

- height growth
- injection rate and volume
- fluid type, additives, and diverters
- proppant placement



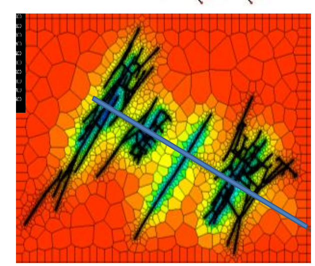
Validate Completion Design

- completion types and designs
- stage isolation
- stage sequencing
- refracturing



Refine Well Plan

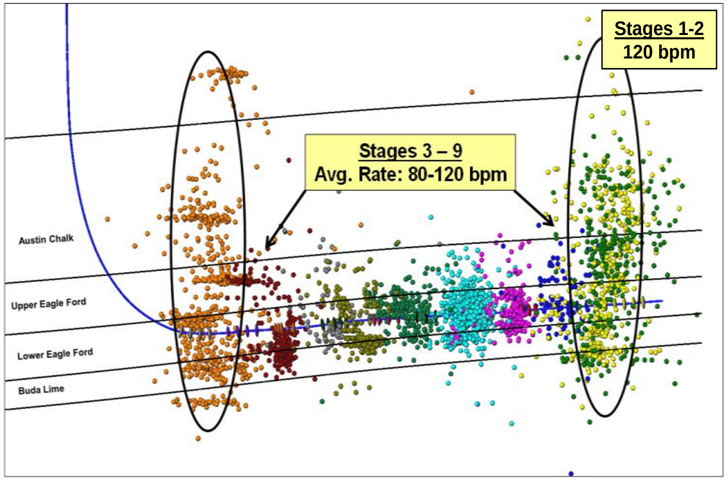
- well orientation
- landing point
- well integrity



Improve Reservoir Management

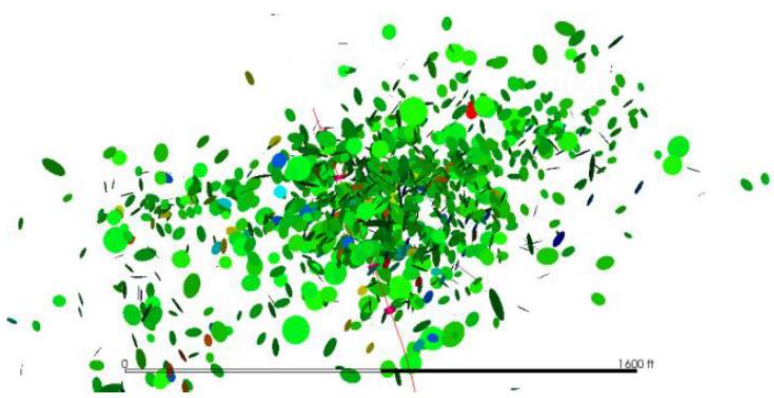
- well spacing
- well placement
- induced seismicity and fault activation
- reservoir characterization
- production optimization

Qualitative/Geometry

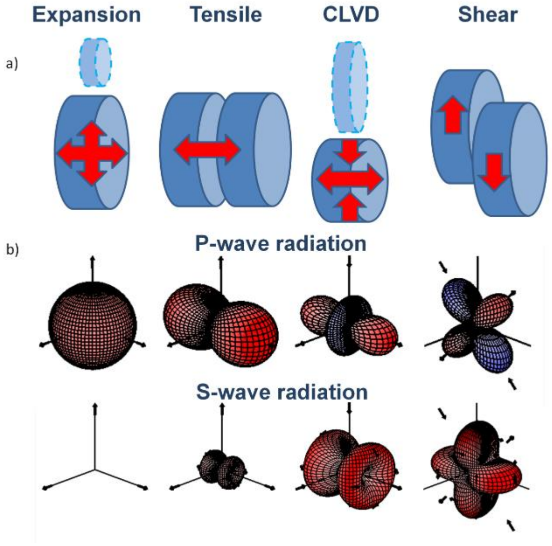


True quantitative interpretation can *only* be achieved with a geomechanical context of both microseismic and aseismic deformation

Quantitative/Deformation

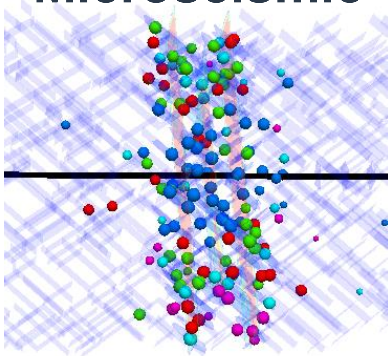


Baig et al, 2012



Microseismic Geomechanics Definition

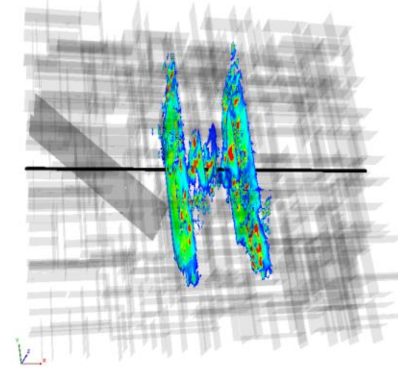
Microseismic



Inelastic shear fracture strain

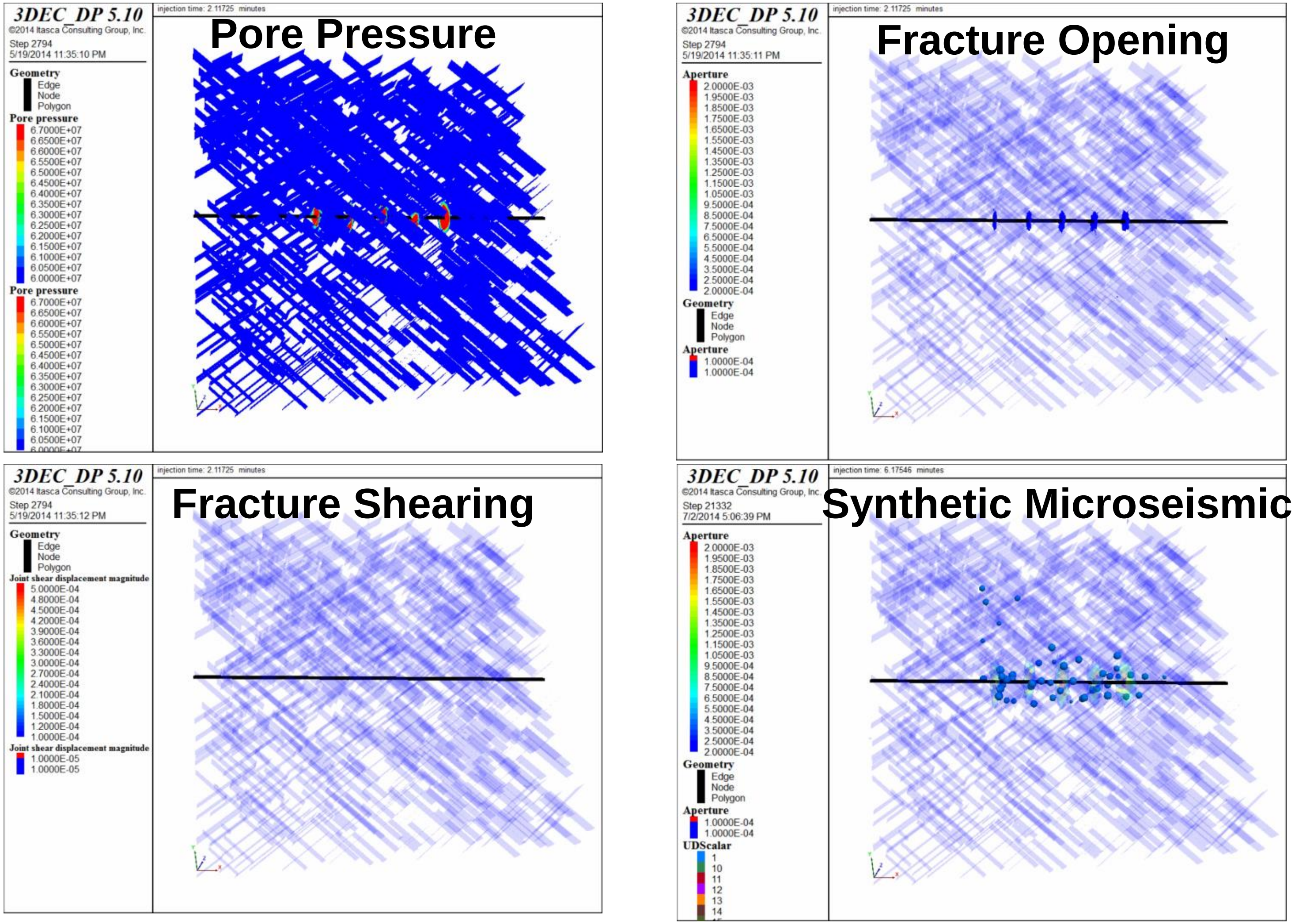
"microseismic geomechanics"

Geomechanics

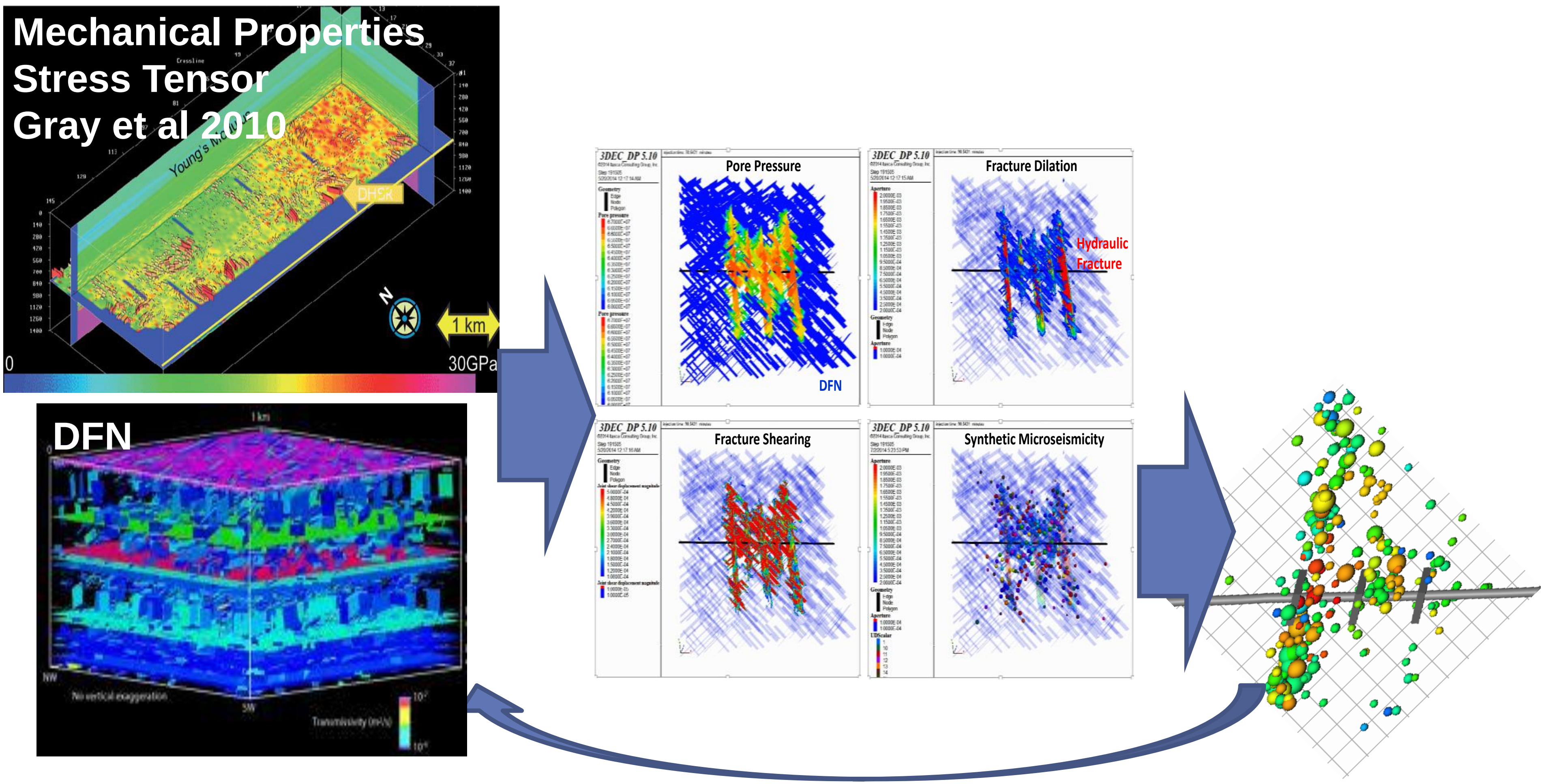


Entire stress and strains

Complex Hydraulic Fracture Growth



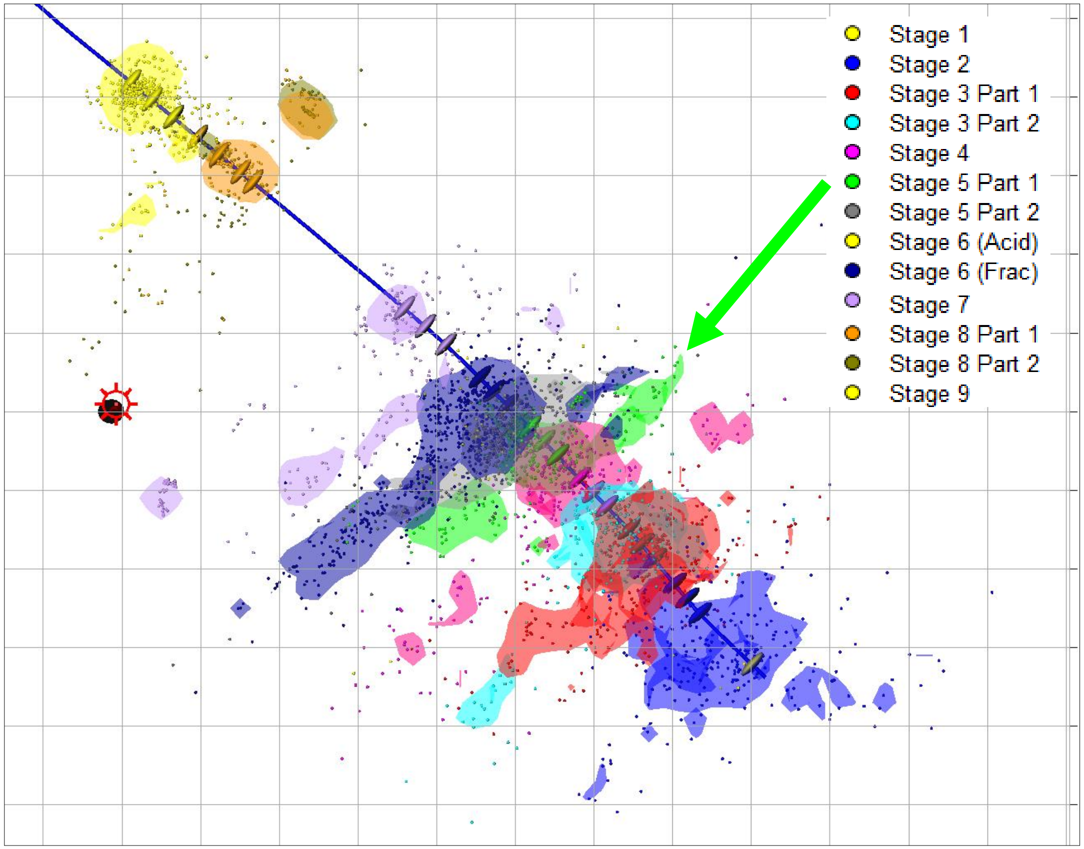
Predictive Workflow

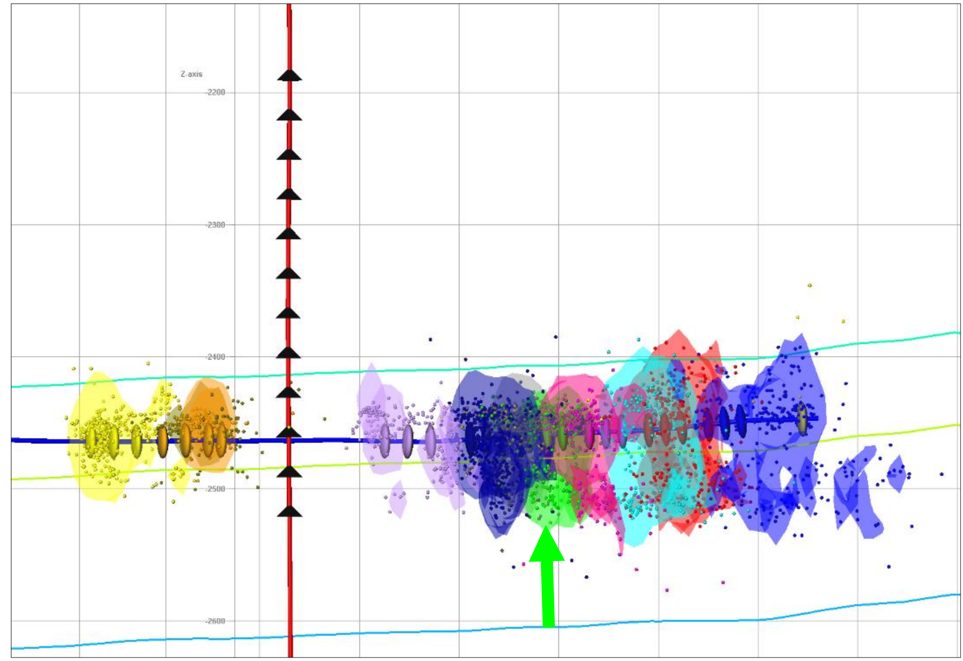


Horn River Basin Case Study

- Workflow
  - Basic inputs
  - Calibration
  - Sensitivity Study
  - Completion Optimization

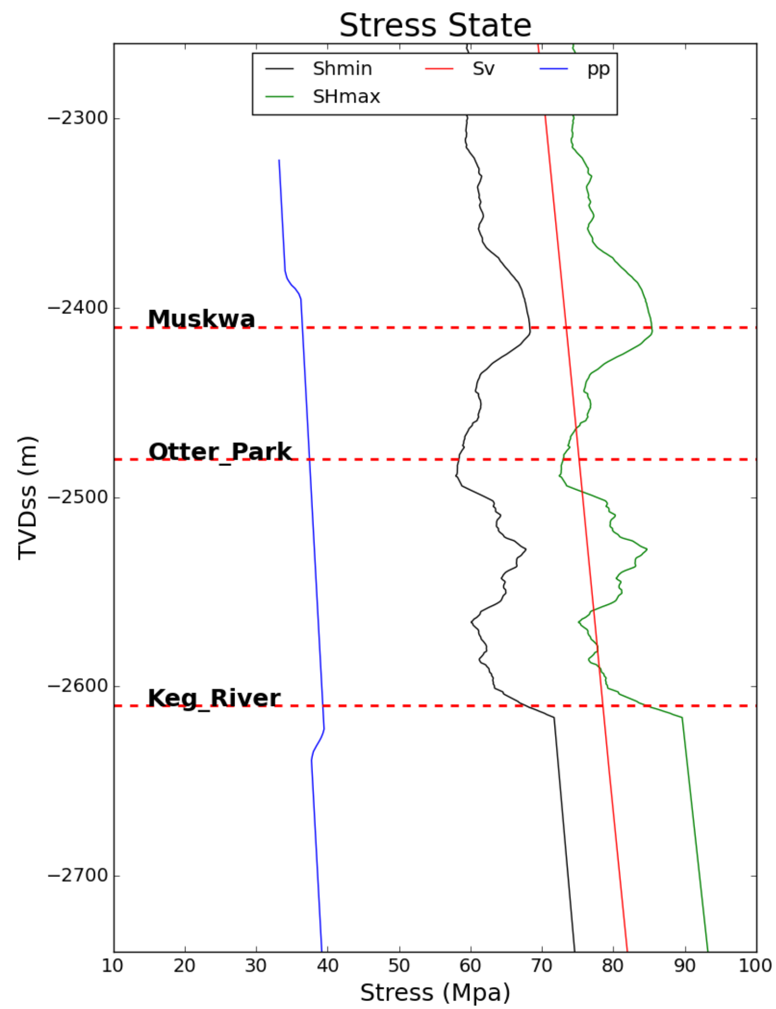
Representative Stage: St5 Part 1



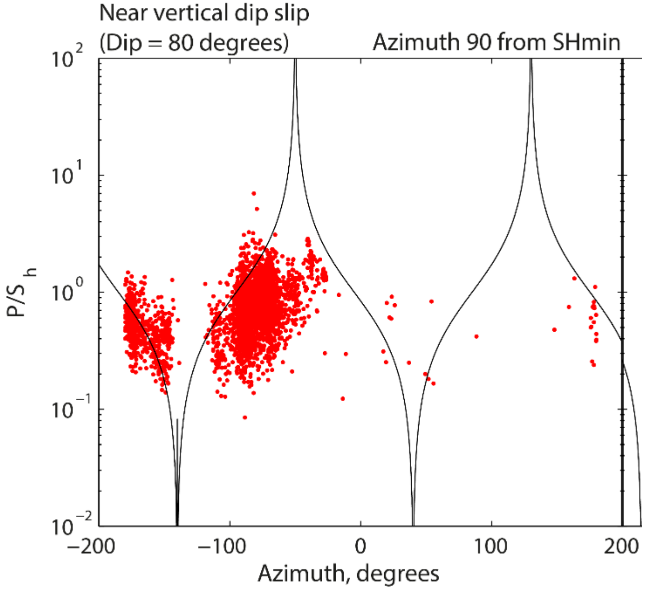


Stage 5 - Part 1 - Model Inputs

- Injection Depth: 2460 m (approx. 8000 ft)
- Cluster Spacing: 25 m (80 ft)
- Injection Rate: 60 bpm for 95 min
- Fluid viscosity: 100 cP
- Leakoff Coefficient: 5×10^{-5} ft/min$^{1/2}$

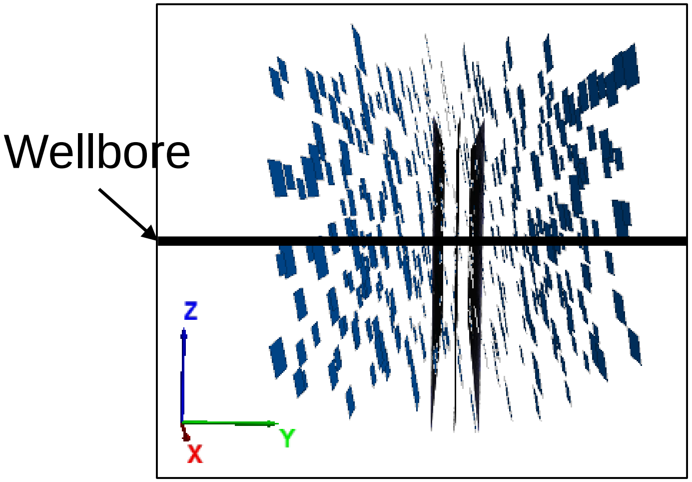


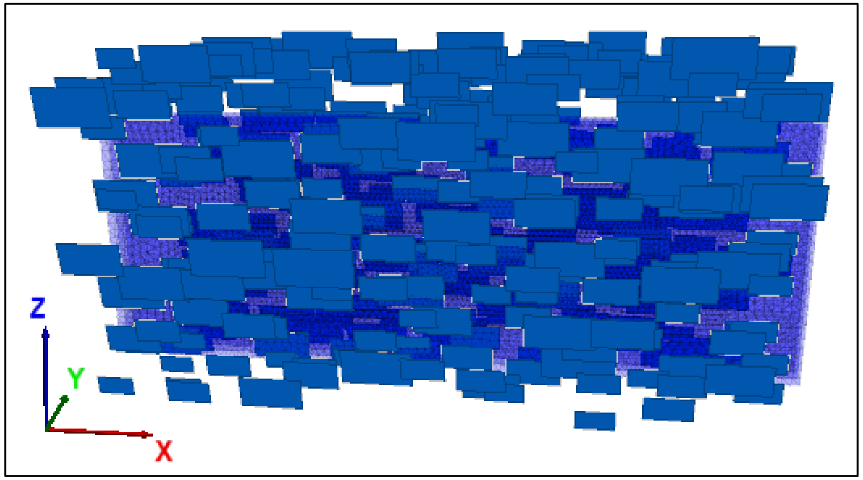
Stage 5 - Part 1 – Defining the DFN



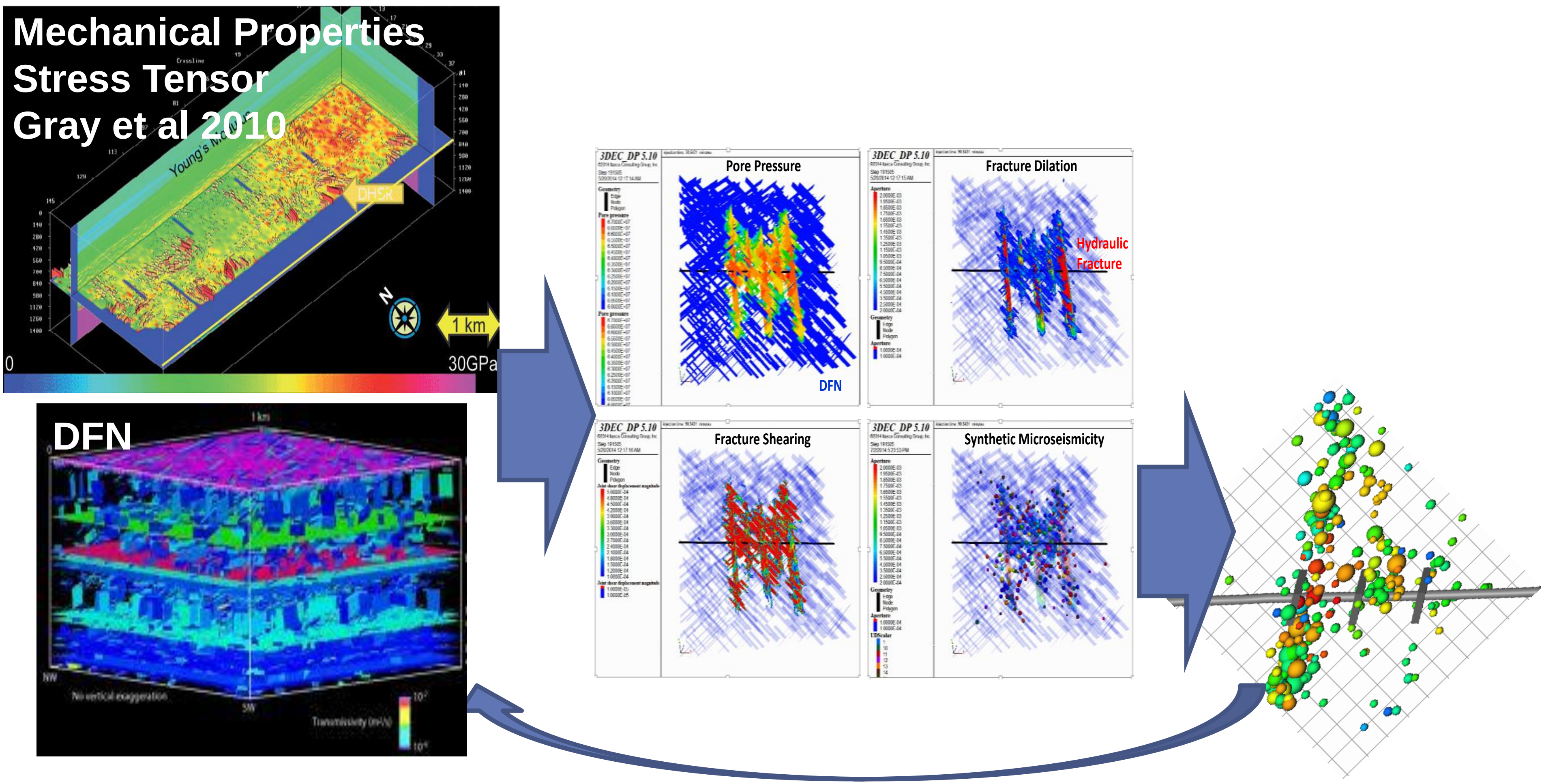
- Field MS data consistent with 90° strike (parallel to SHmax) and 80° dip

  => DFN
- Fracture Density: 6.9×10^{-6} num/m^3
- Fracture element size derived from magnitude distribution

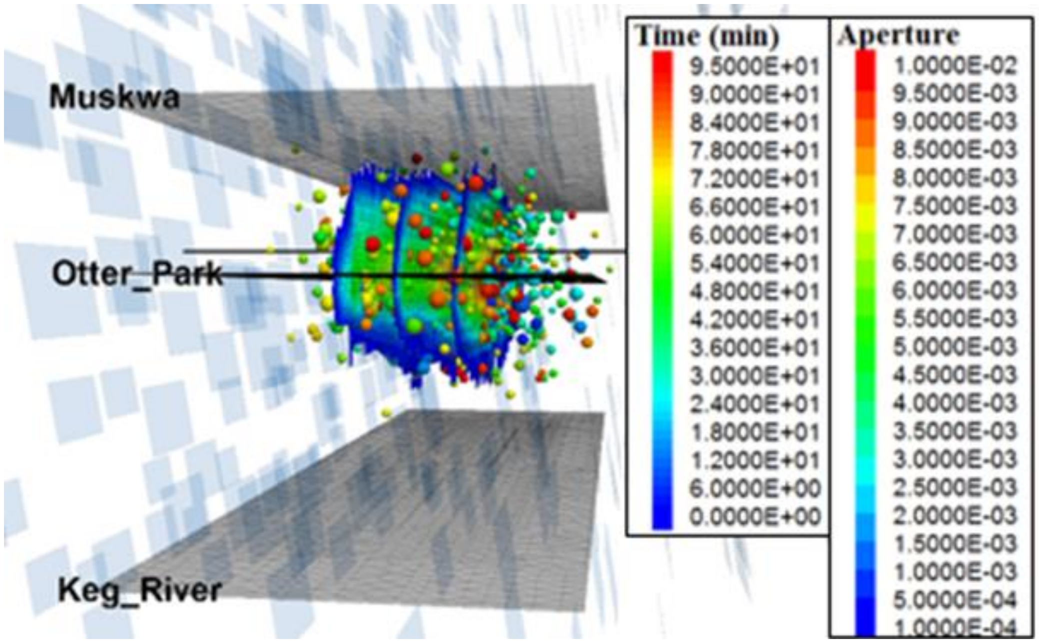


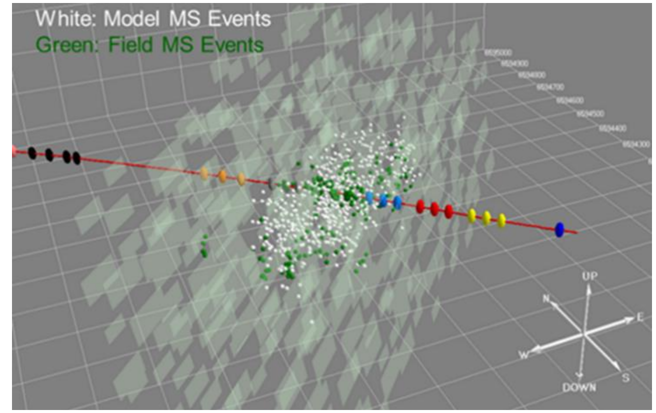


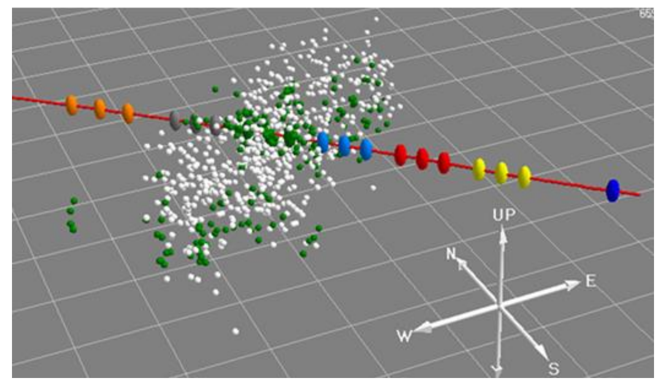
Model Calibration



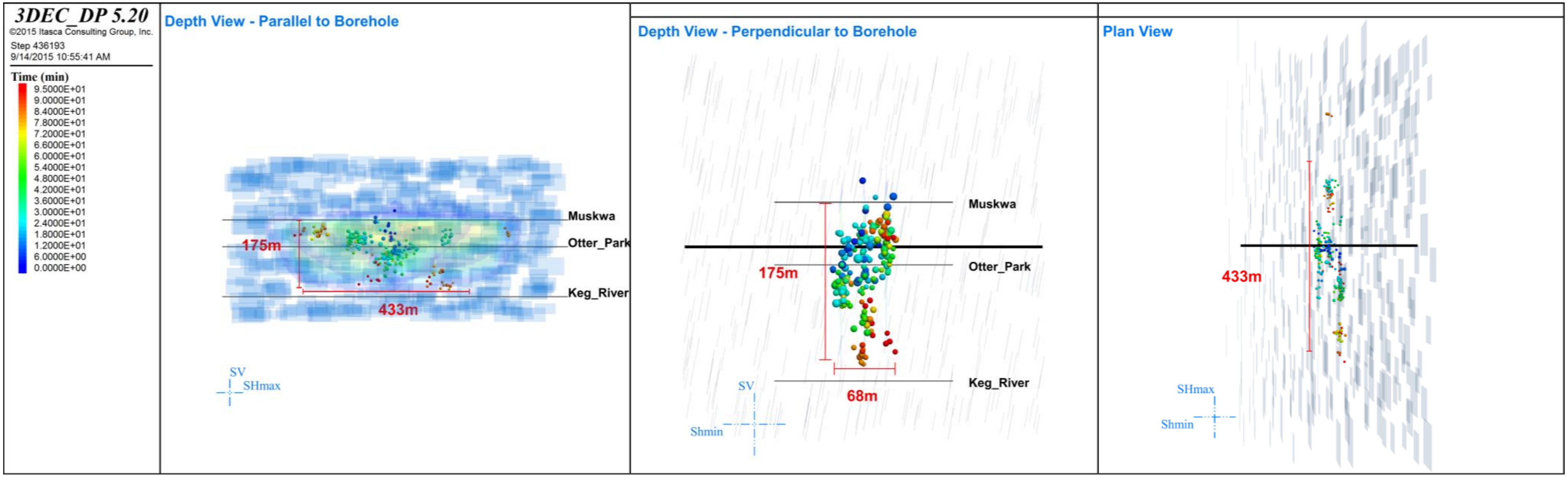
Microseismically Calibrated Model

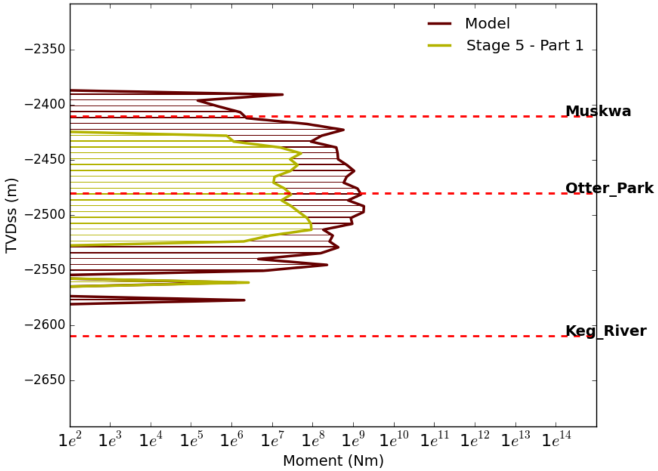


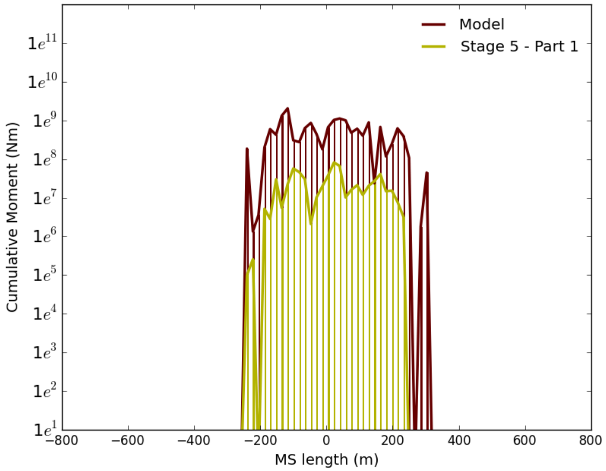




Calibrated Model – Microseismic Moment

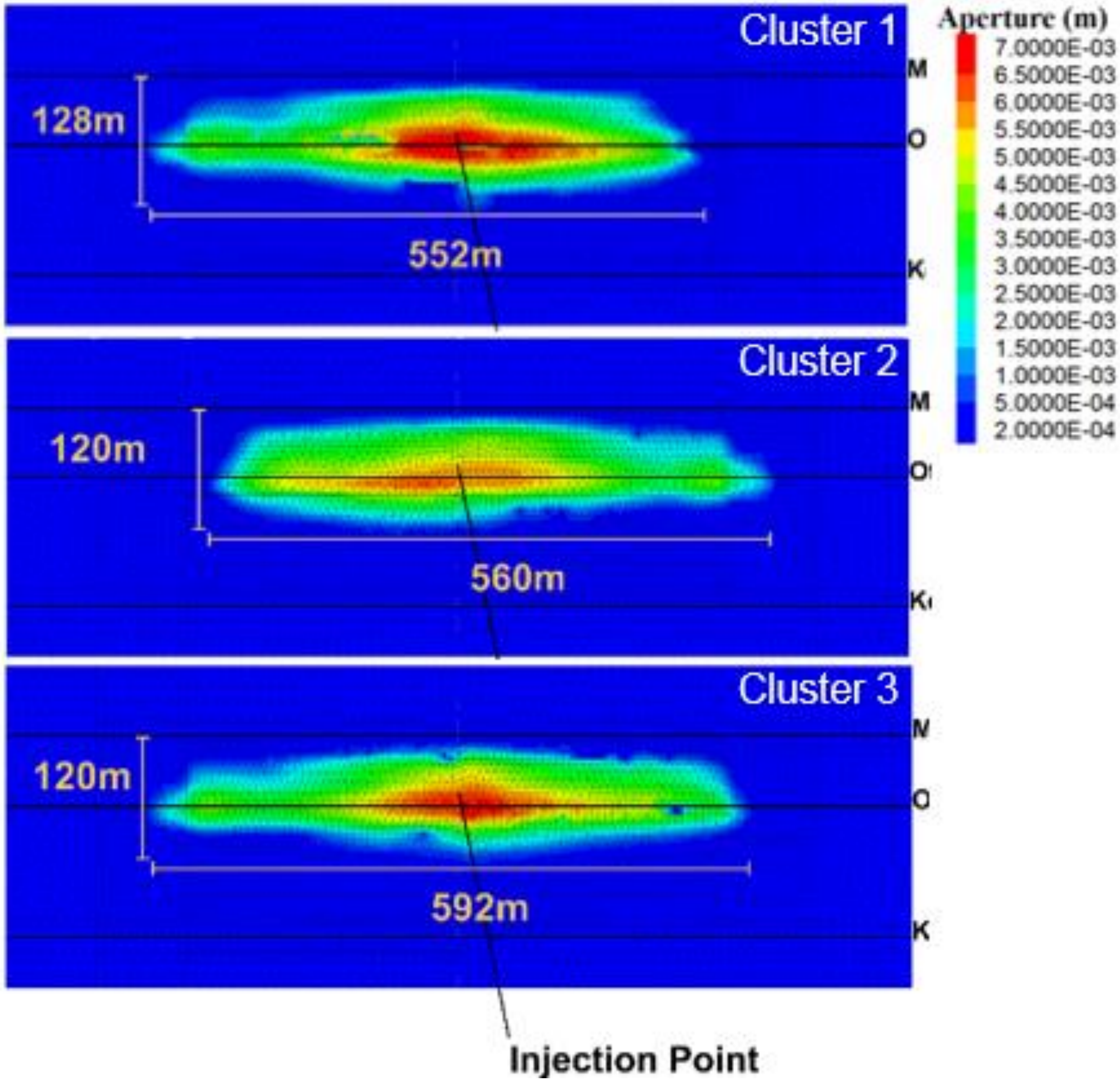




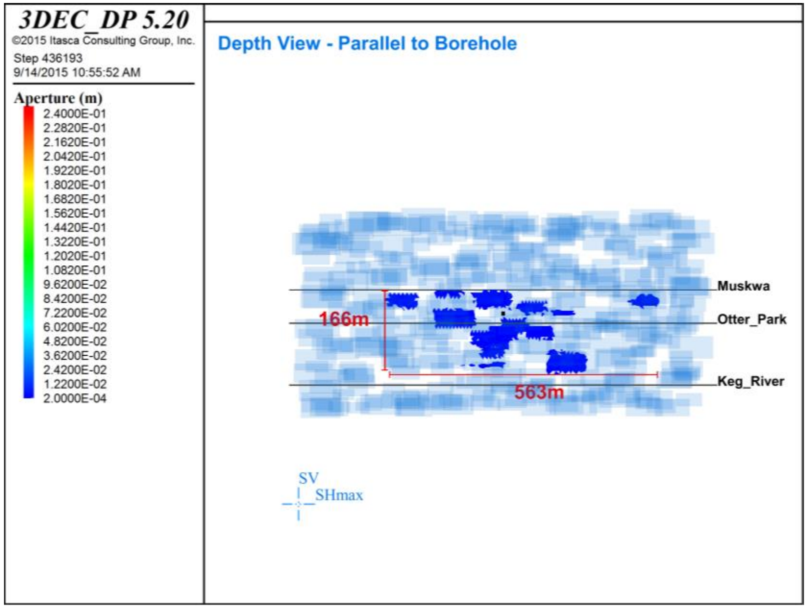


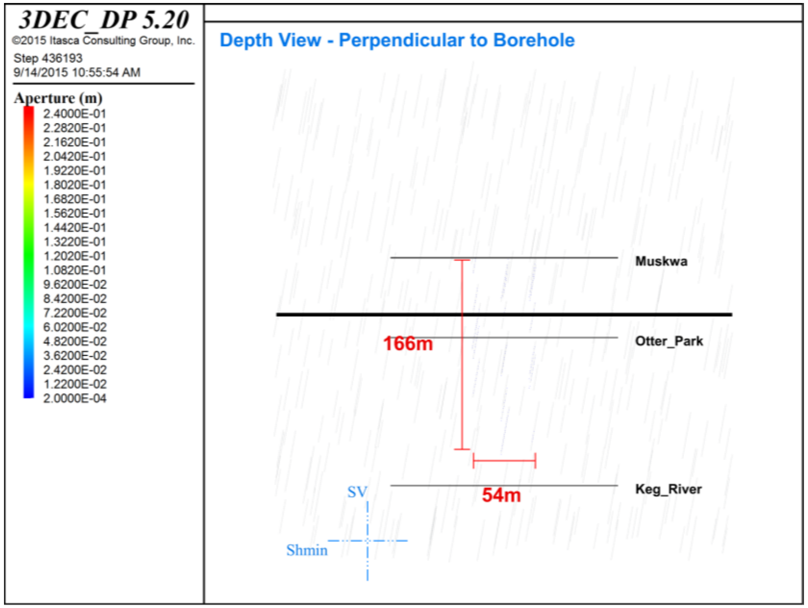
Calibrated Model Results

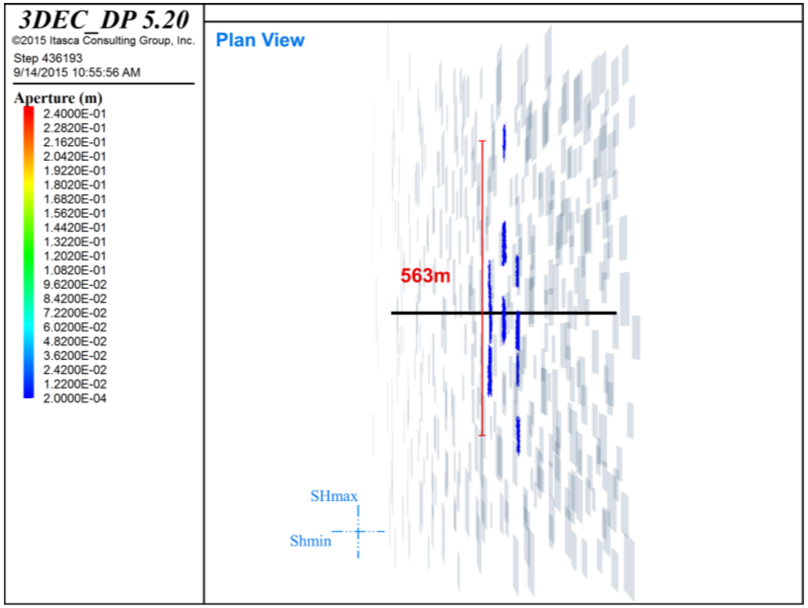
Aperture in Primary Fractures



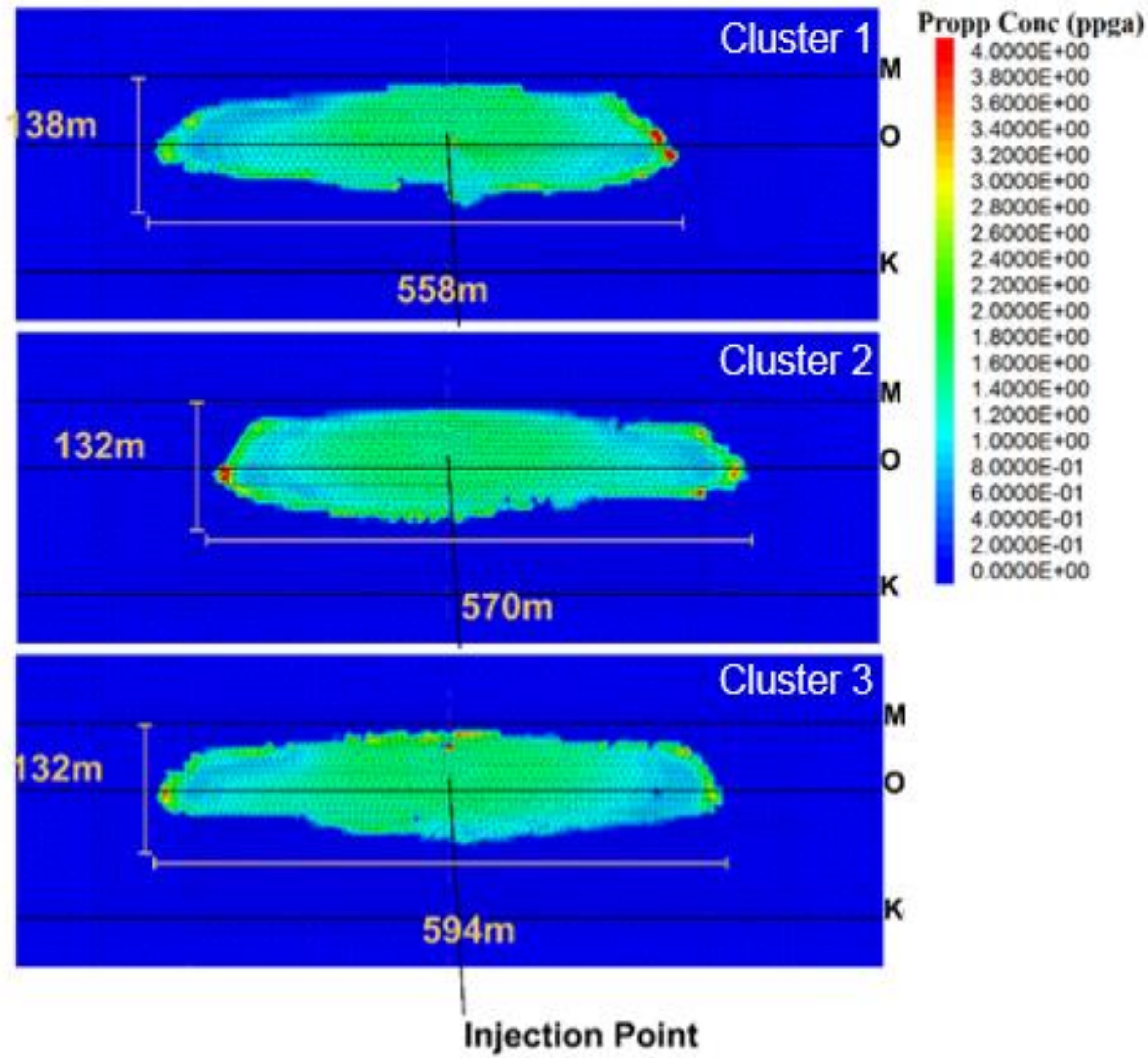
Stimulated DFN



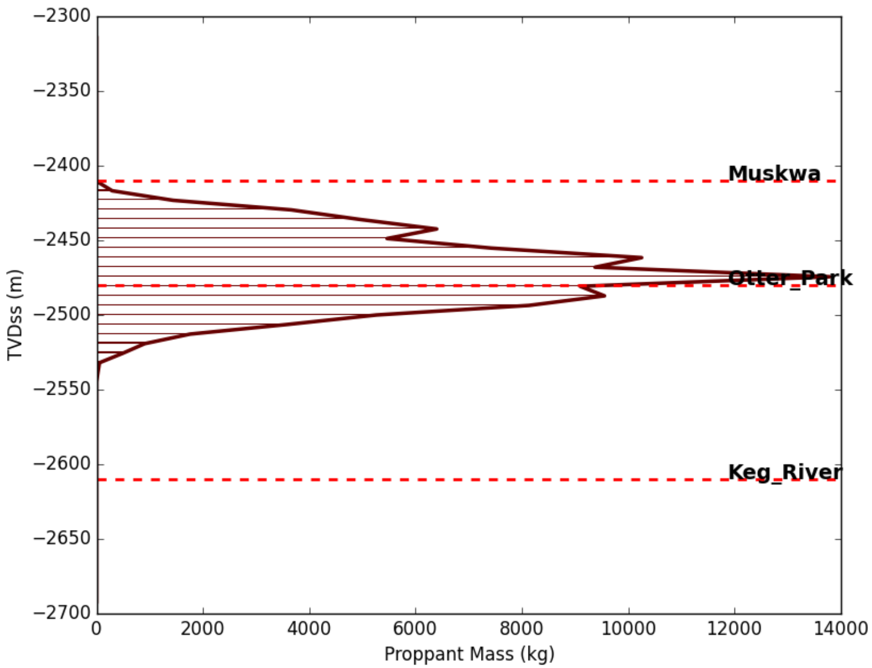


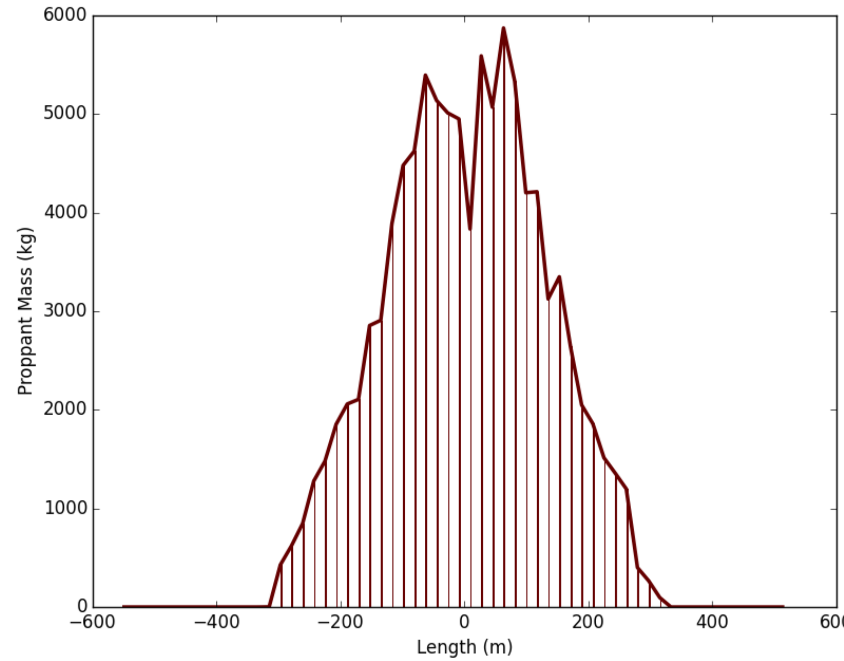


Proppant Concentration

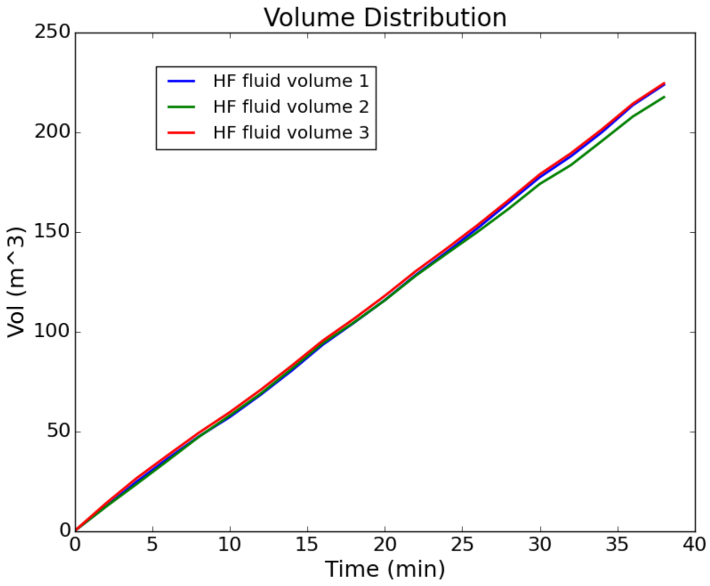


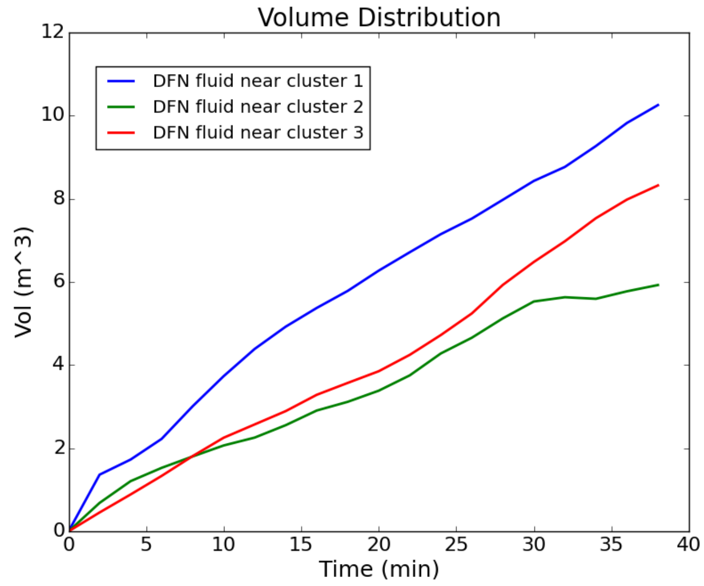
Proppant Distribution

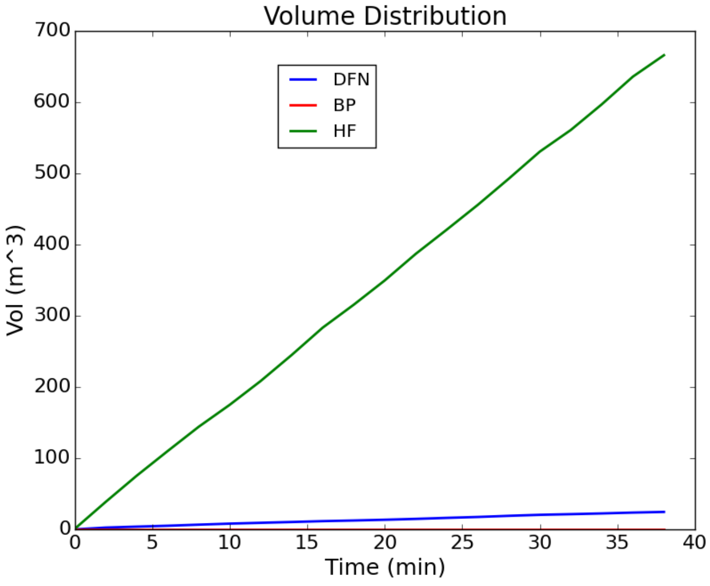


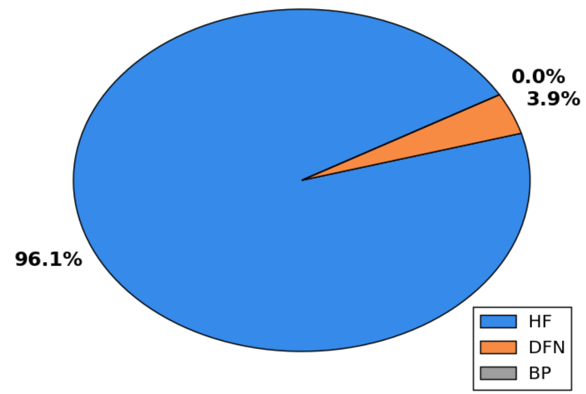


Fluid Distributions









Sensitivity Testing

- How much do fracture geometry and microseismic response change if inputs change?

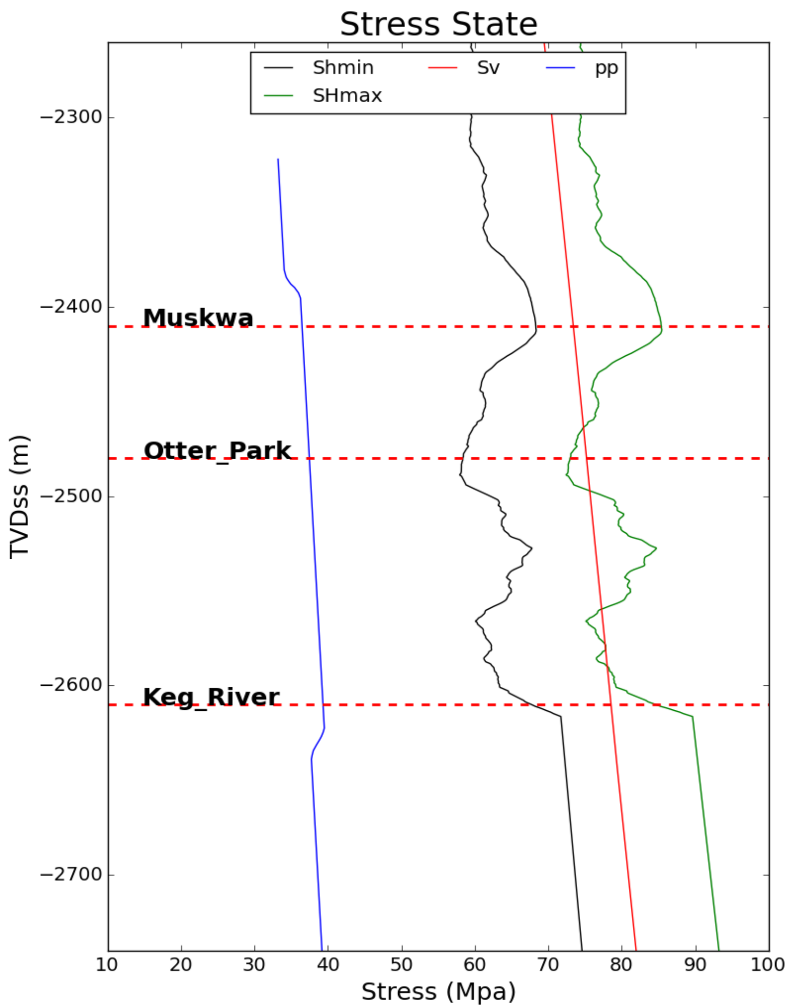
- Are fracture geometry AND microseismic similar to original model?
  - Model results insensitive to parameter change. Not important to future results.

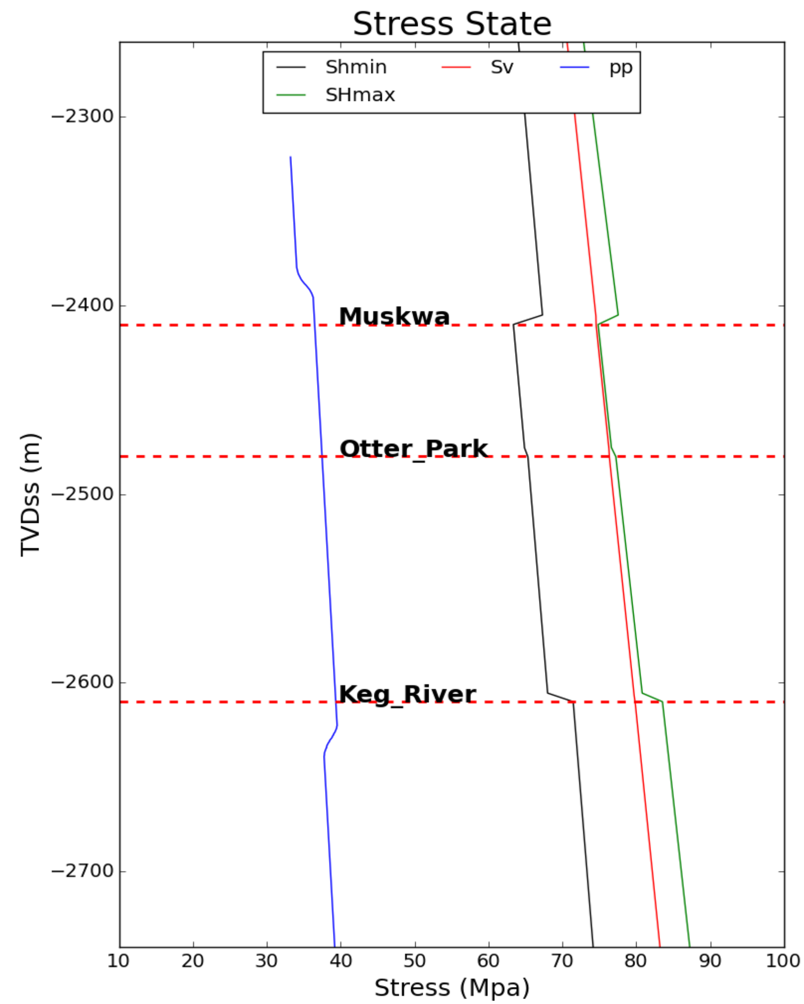
- Is the geometry the same but the microseismic response changes?
  - Microseismic depends on reservoir parameters and completion.
  - Microseismic can be used to define reservoir parameters (e.g. DFN)

- Does fracture geometry AND microseismic change?
  - Microseismic can be used as a diagnostic in future wells.

- Does the geometry change but the microseismic response stay the same?
  - NON-UNIQUE CALIBRATION. Need other data to calibrate the model better.

Example – Changed Stress Profile





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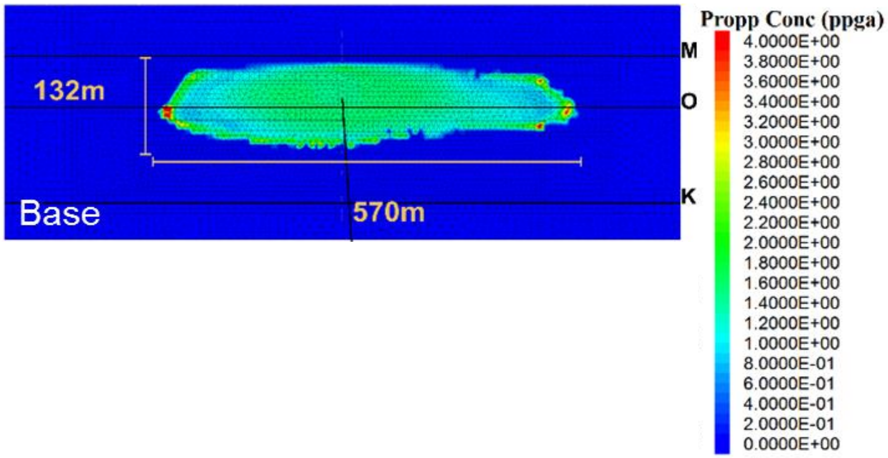

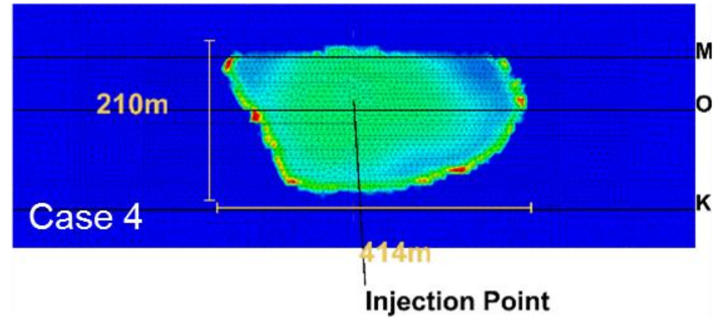

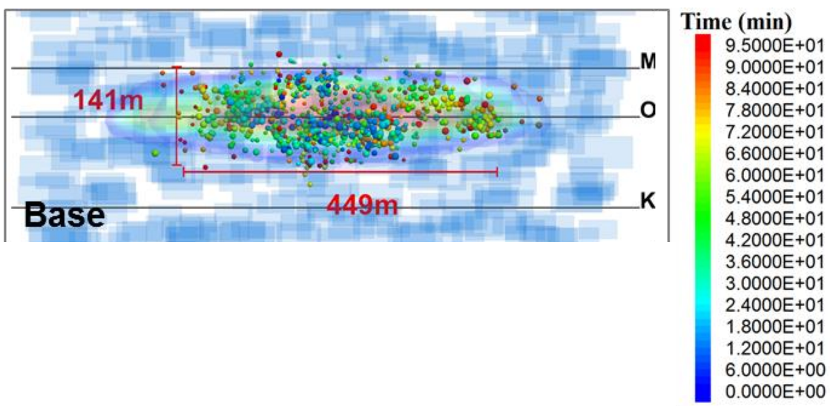

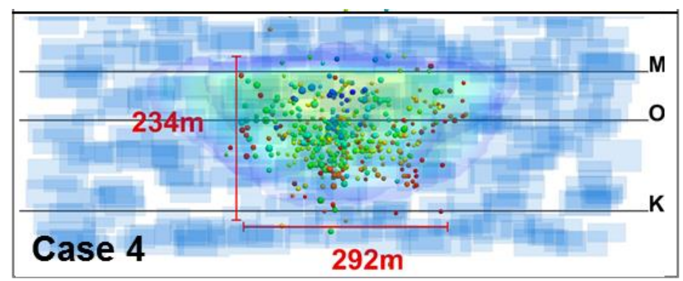

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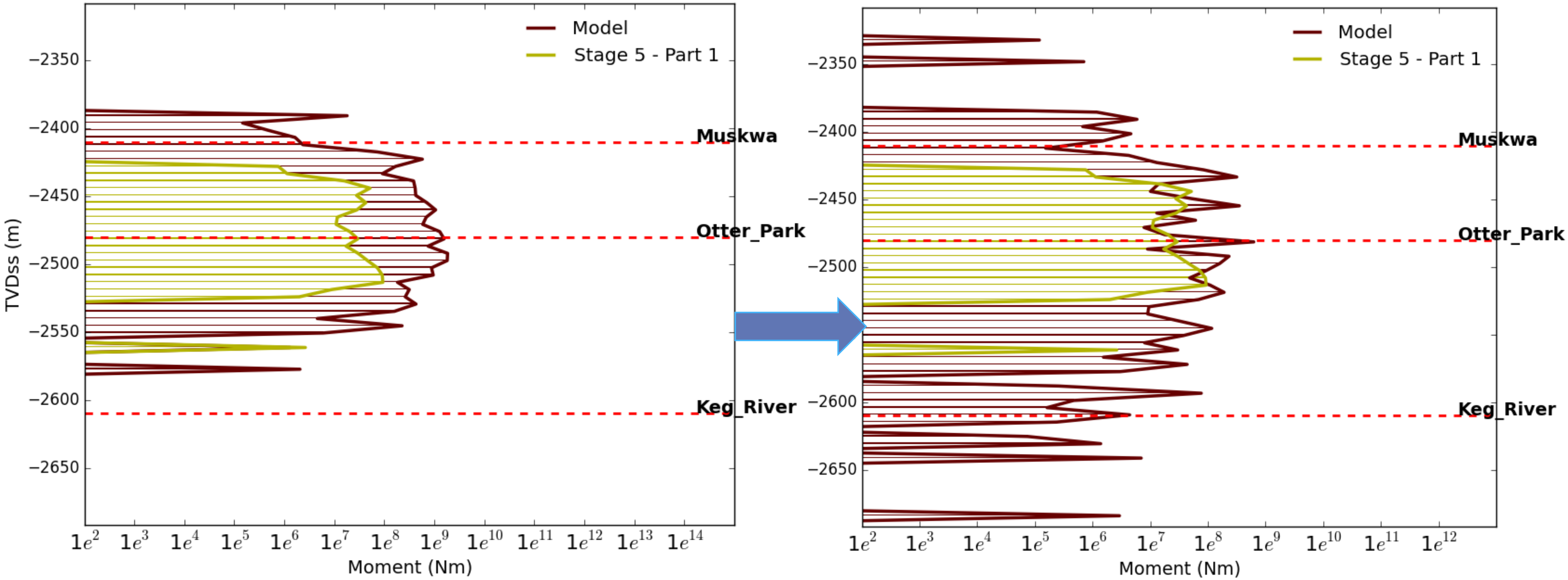
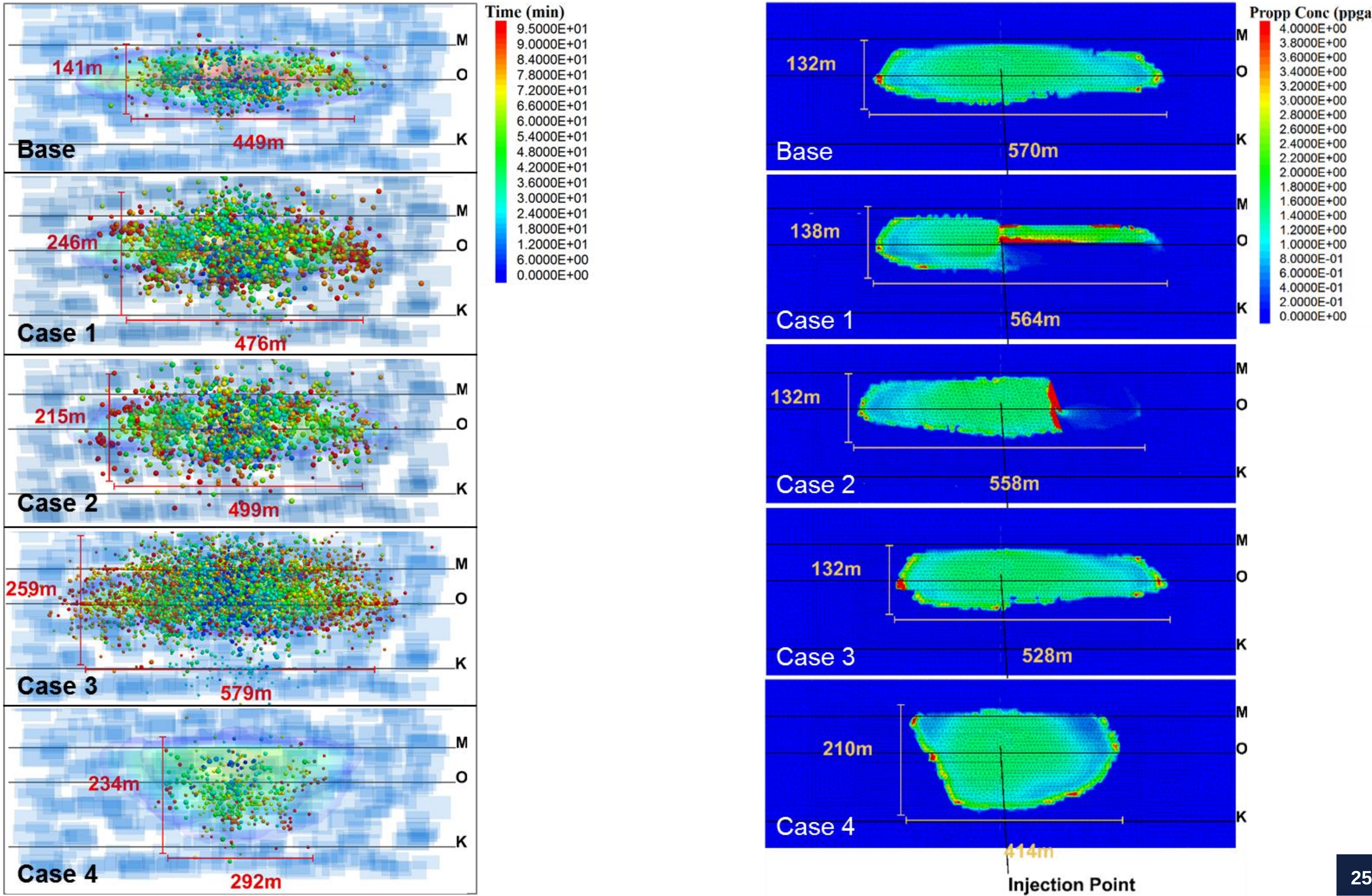


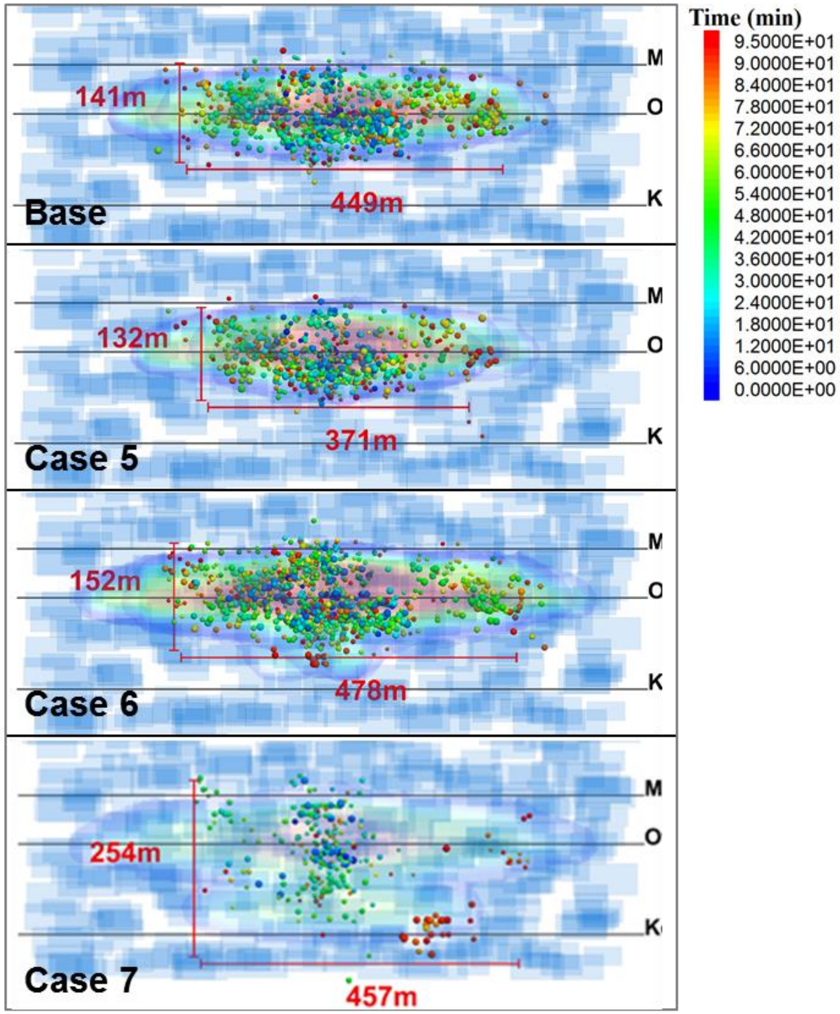
Sensitivity to DFN geometry

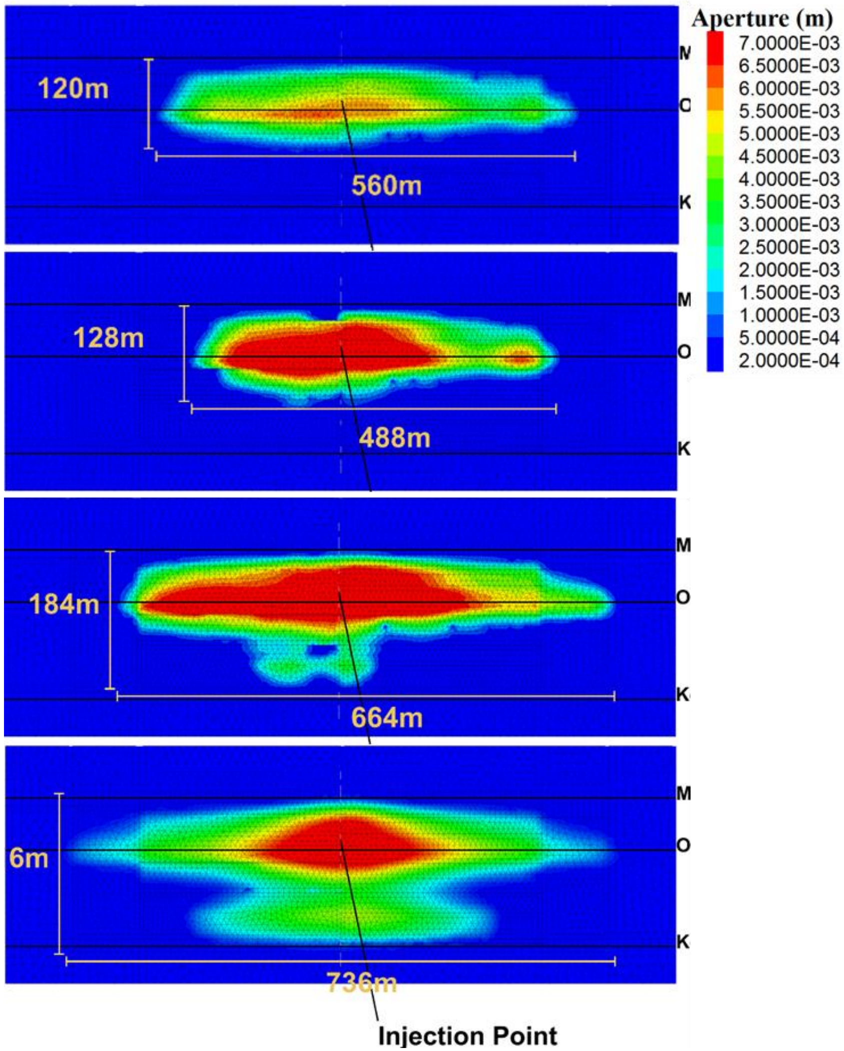


Completion Optimization

- A calibrated model can be used to drive field test program or other changes.

Alternate Design – Viscosity, Injection Rate, Clusters





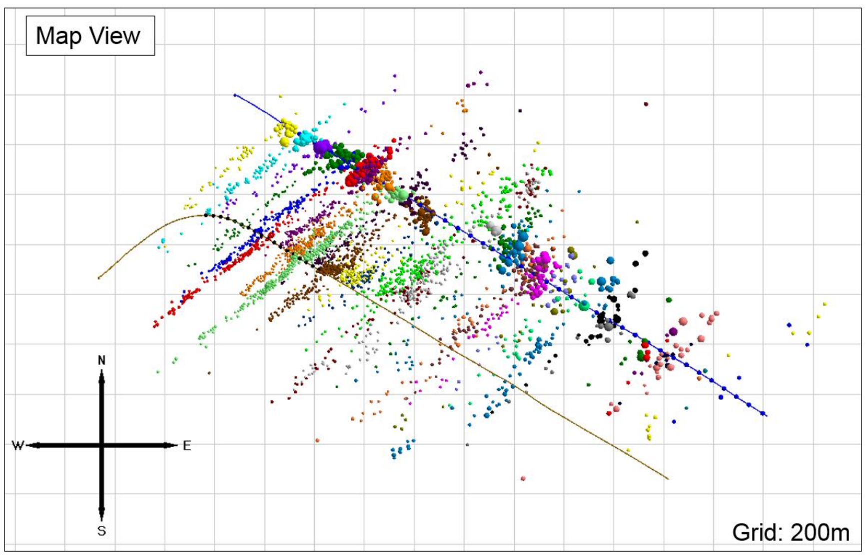
Upper Montney Case Study

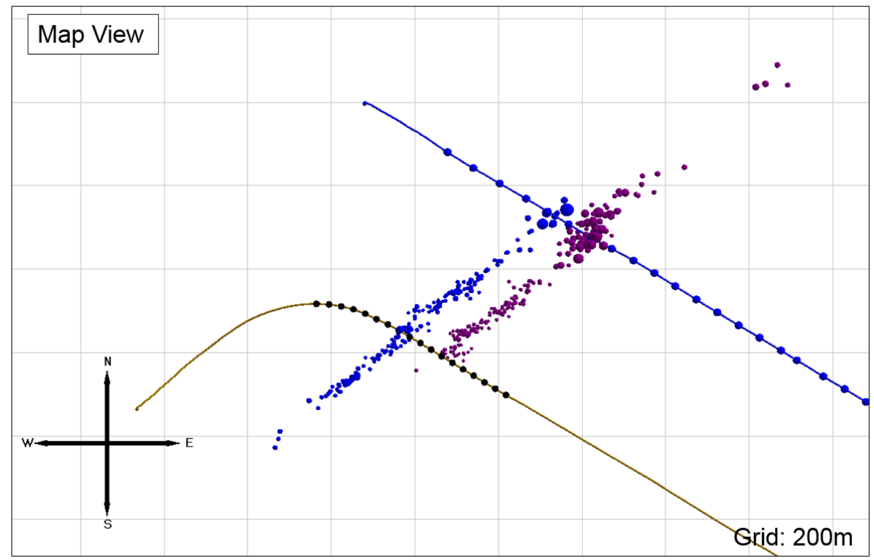
- The microseismic data cloud is asymmetric.
  - Is the fracture asymmetric?
  - What could cause this asymmetry?

- Build a 3D hydraulic-geomechanical model using available geologic data, and simulate the injection sequence.
  - Relate hydraulic fracture dimensions (length, height) to microseismic dimensions
  - Do the volumetrics make sense?

Overview

- Open-hole, sliding-sleeve hydraulic stimulation in the Upper Montney
- Microseismic data recorded during stimulation
  - Asymmetric microseismic data about injection point
  - Is the asymmetry real?
  - What causes asymmetry ?

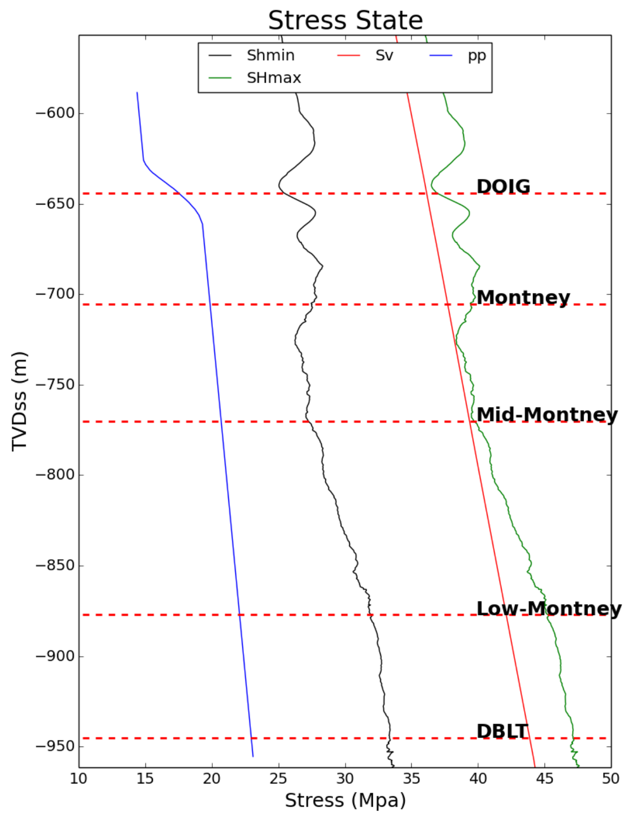




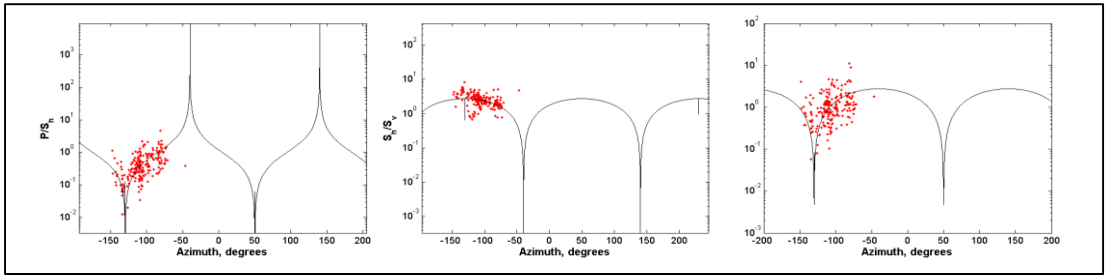
Model Inputs

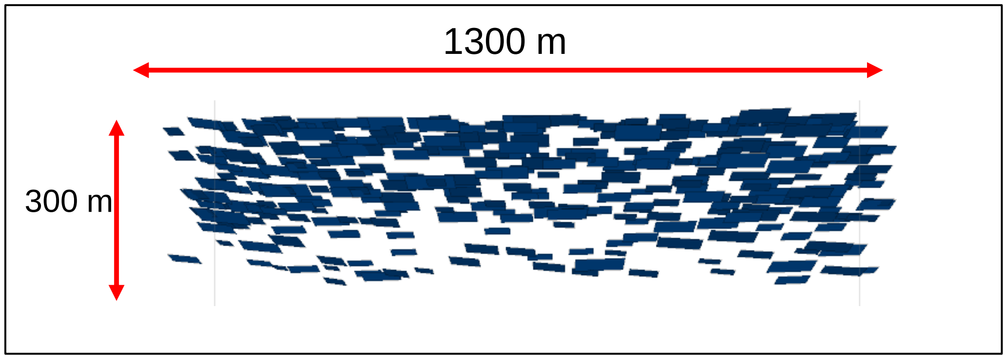
Geologic inputs for the geomechanical model:

- Elasticity parameters
- Stress field
  - Shmin from DFIT analysis
  - Corrections due to tectonic effects
- DFN density and fracture characteristics
- Pore pressure
- Injection Schedule
  - Slickwater @ 11 m^3/min for 33 min
  - 30/50 proppant ramp



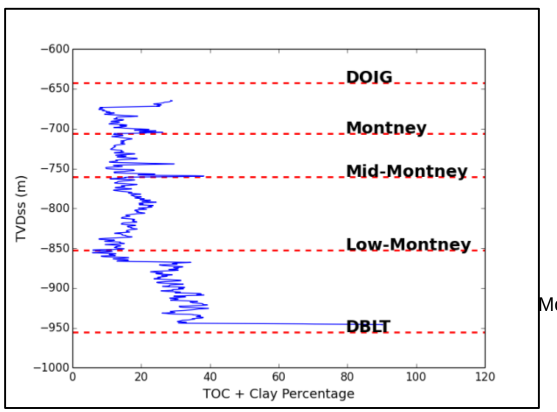
Discrete Fracture Network





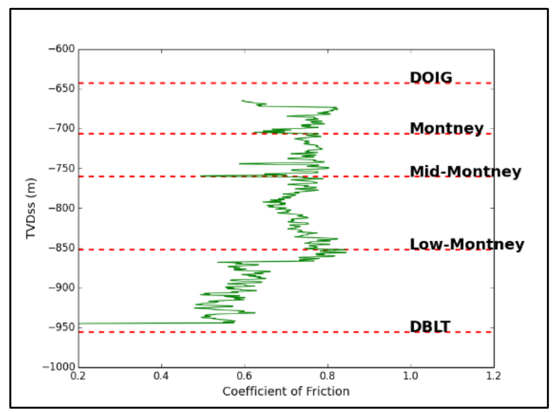
Primary fracture set with strike 40^0, dip 35^0

Secondary fracture set with strike 87^0, dip 35^0



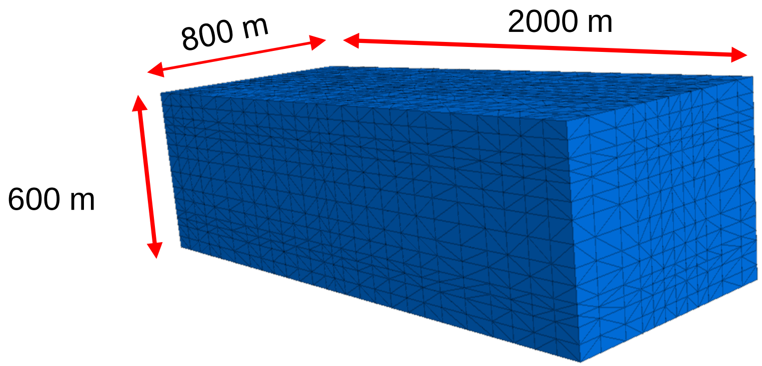
Clay+TOC

Modeled via Kohli & Zoback, 2013

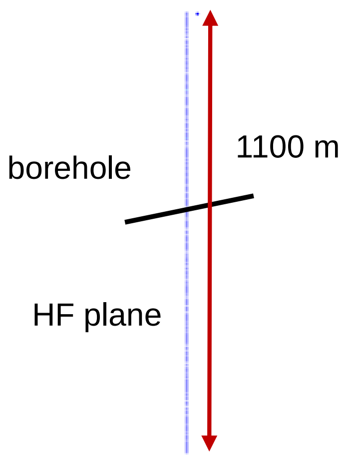


Friction

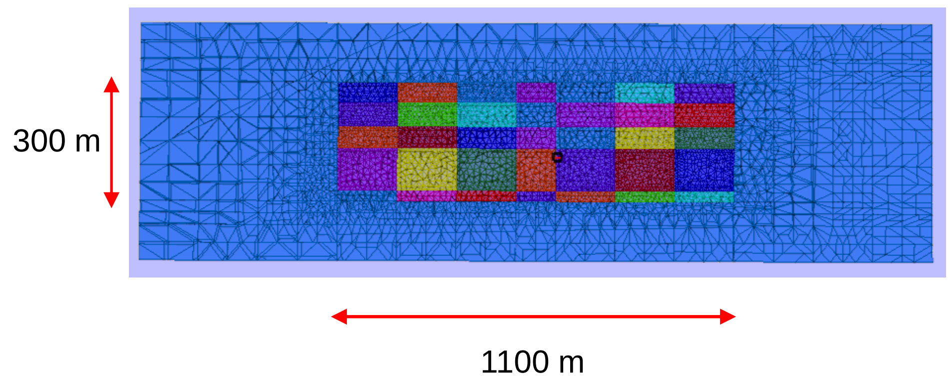
Model geometry



Single HF - Plan View



Depth View

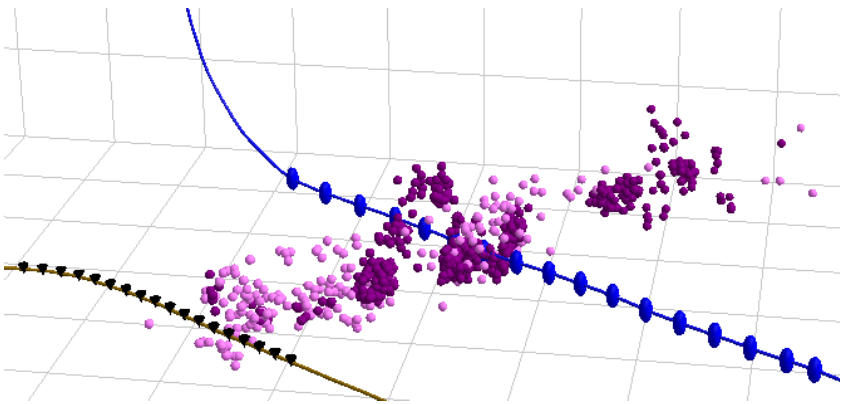


Calibrated Synthetic vs Field Microseismicity

- Good match for both stages 32 and 34 for MS lengths and heights

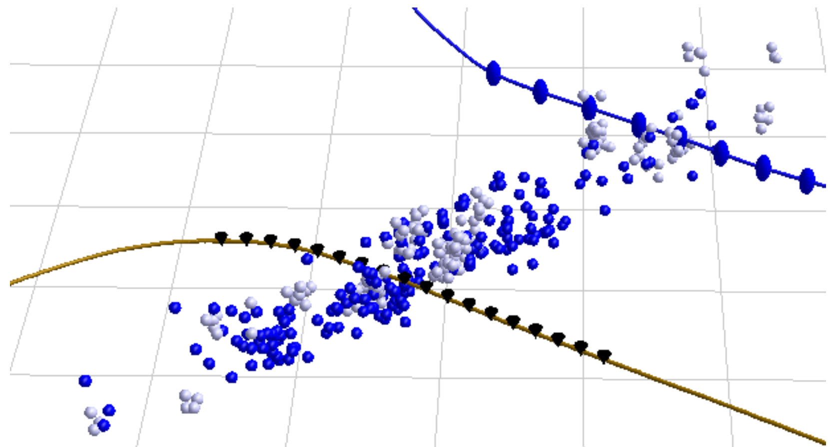
  => fracture lengths and asymmetry in MS data could be real

Stage 32



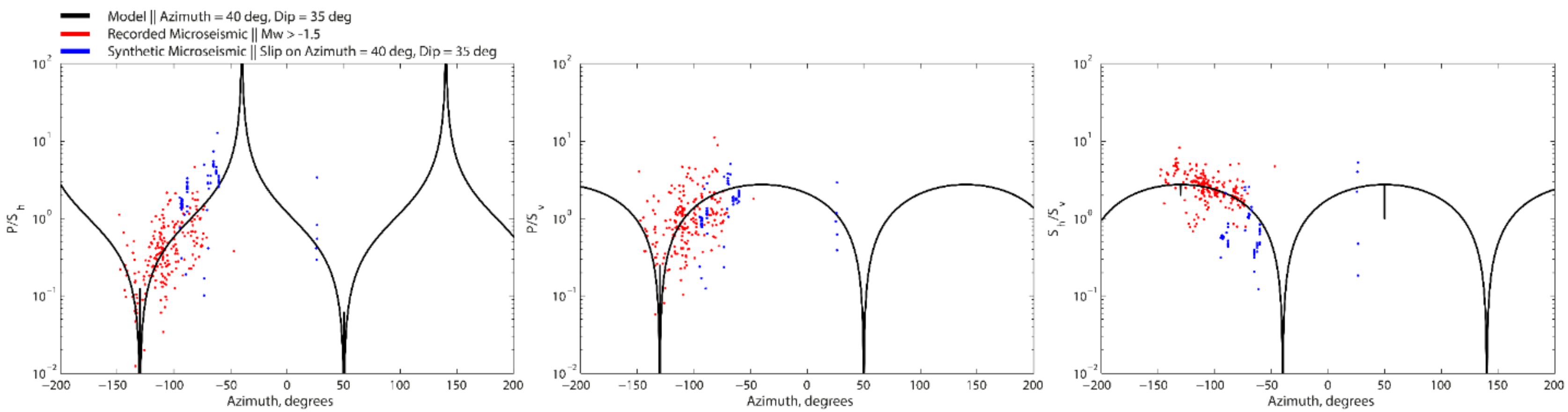
Field MS
Modeled MS

Stage 34

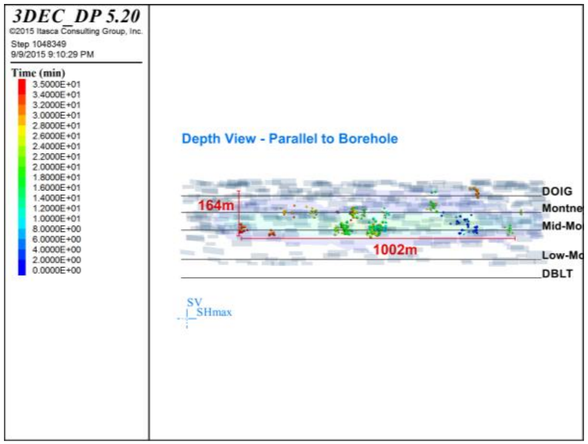


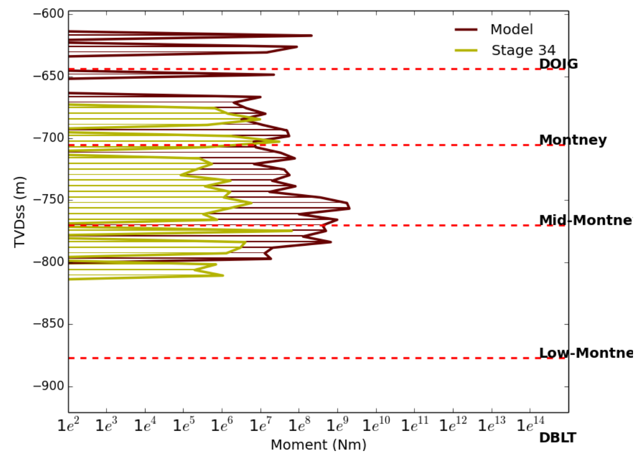
Field MS
Modeled MS

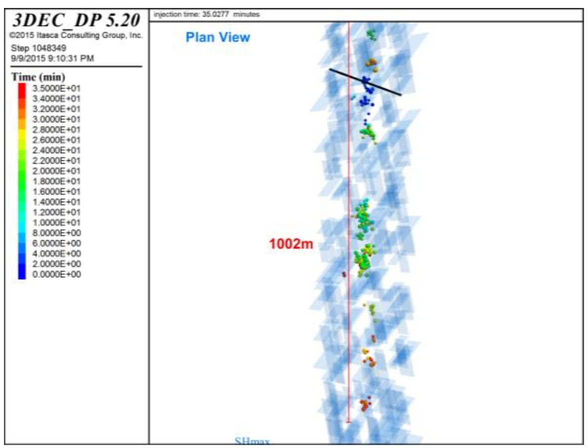
Synthetic microseismic mechanisms

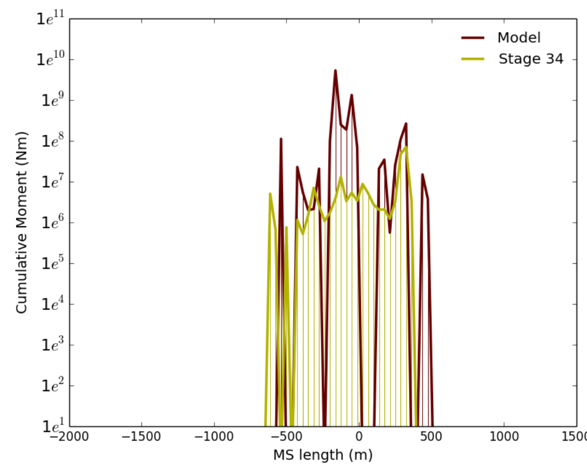


Calibrated Model

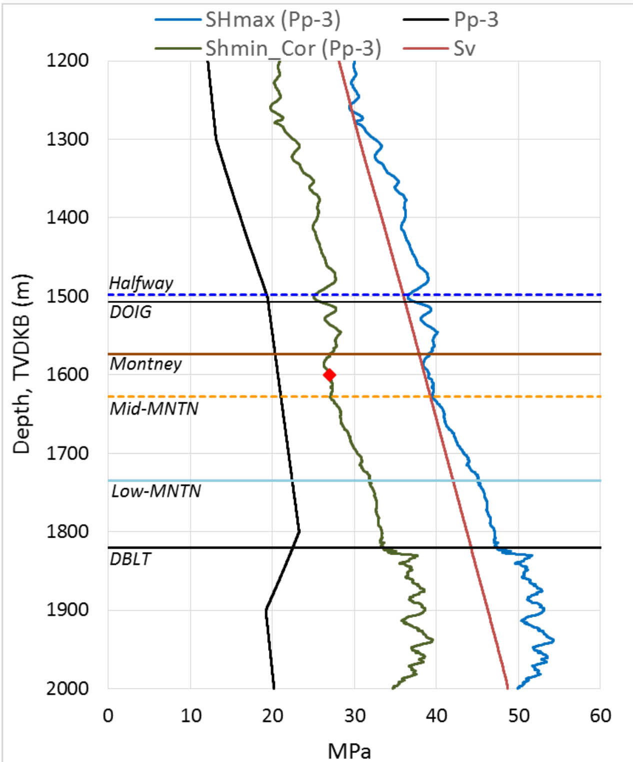


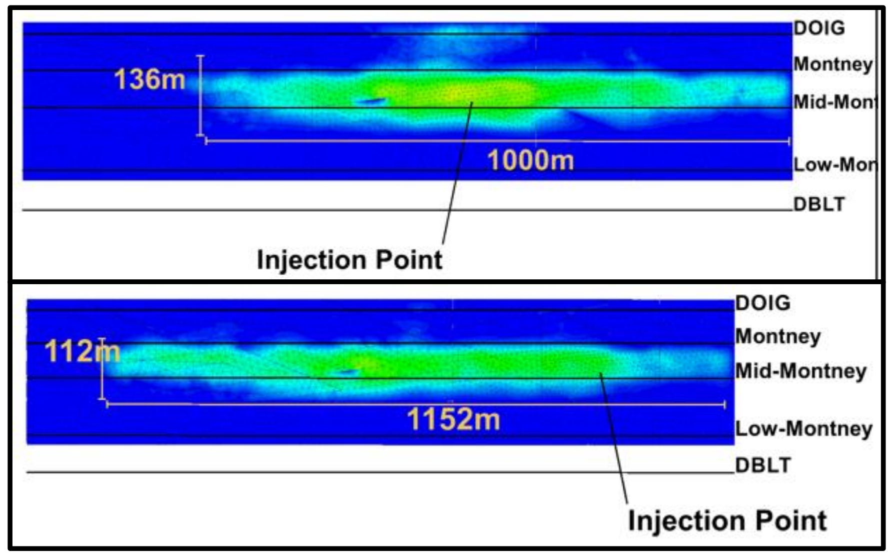






Height Growth

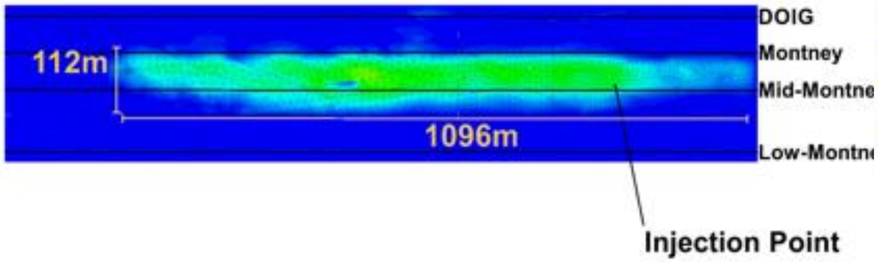


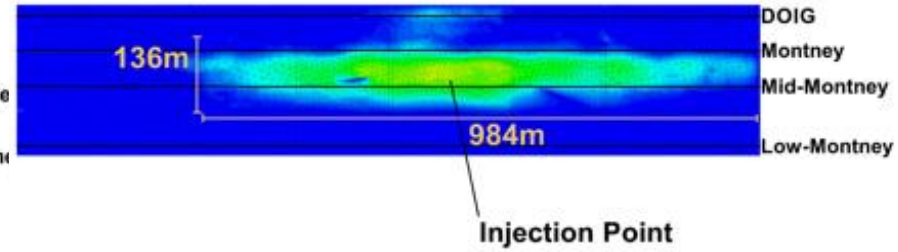


Fracture and Proppant Extents

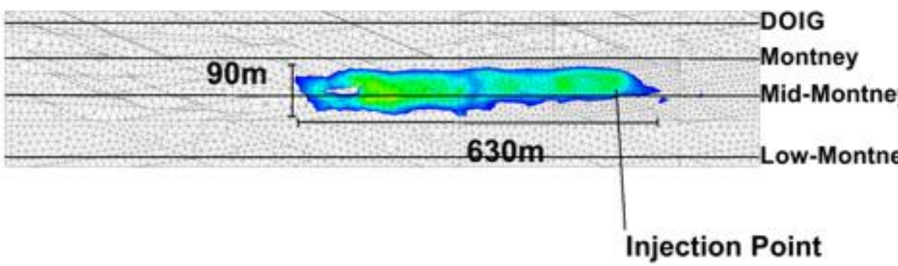
Stage 34 | **Stage 32**

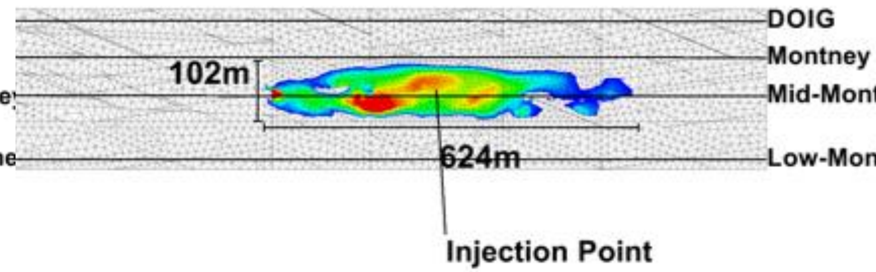
Fracture Extent





Proppant concentration



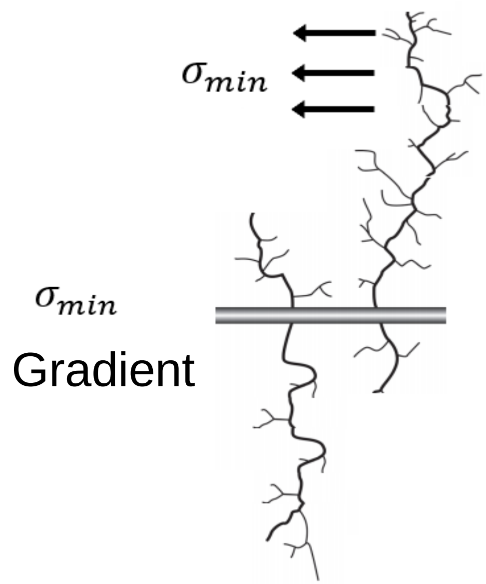


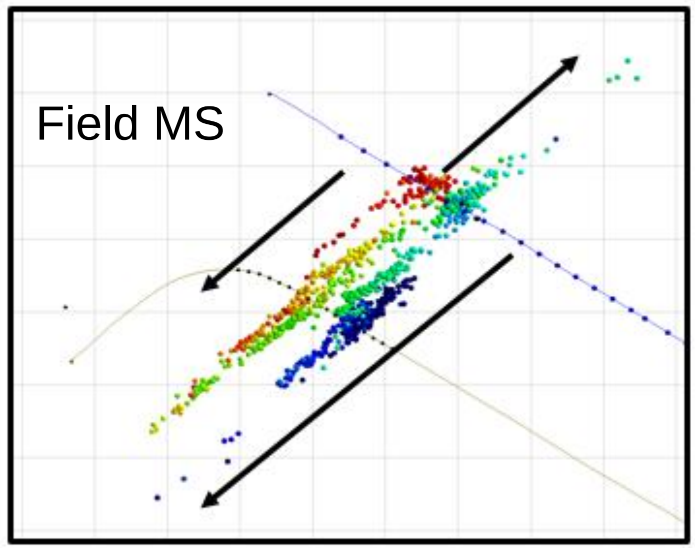
Fracture Asymmetry – a Stress Shadow Effect?

Stage 34 calibration requires a horizontal stress gradient

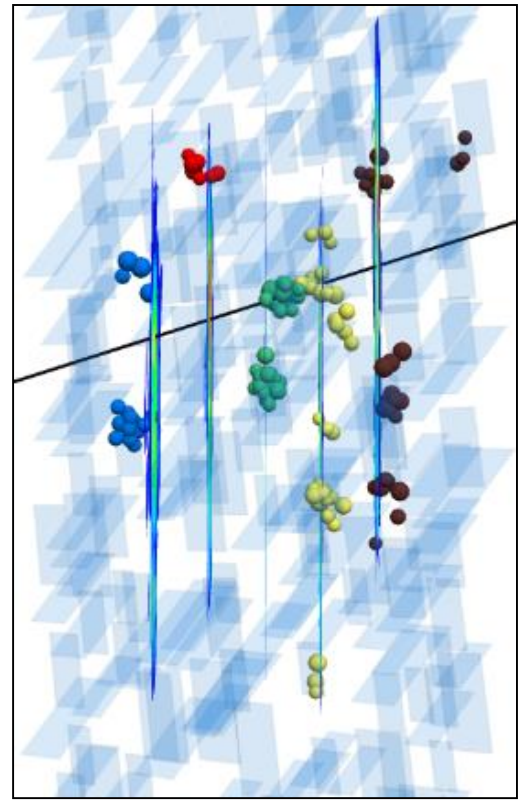
5 Perforation clusters

- Model indicates a stress shadow effect between clusters
- Local effects could be responsible



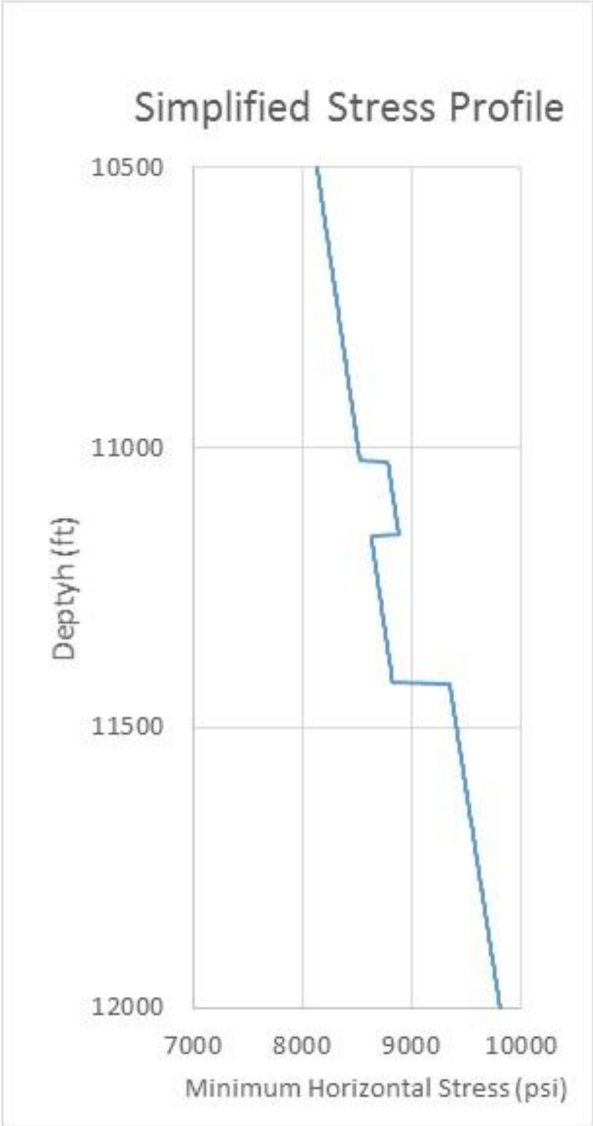


Synthetic MS

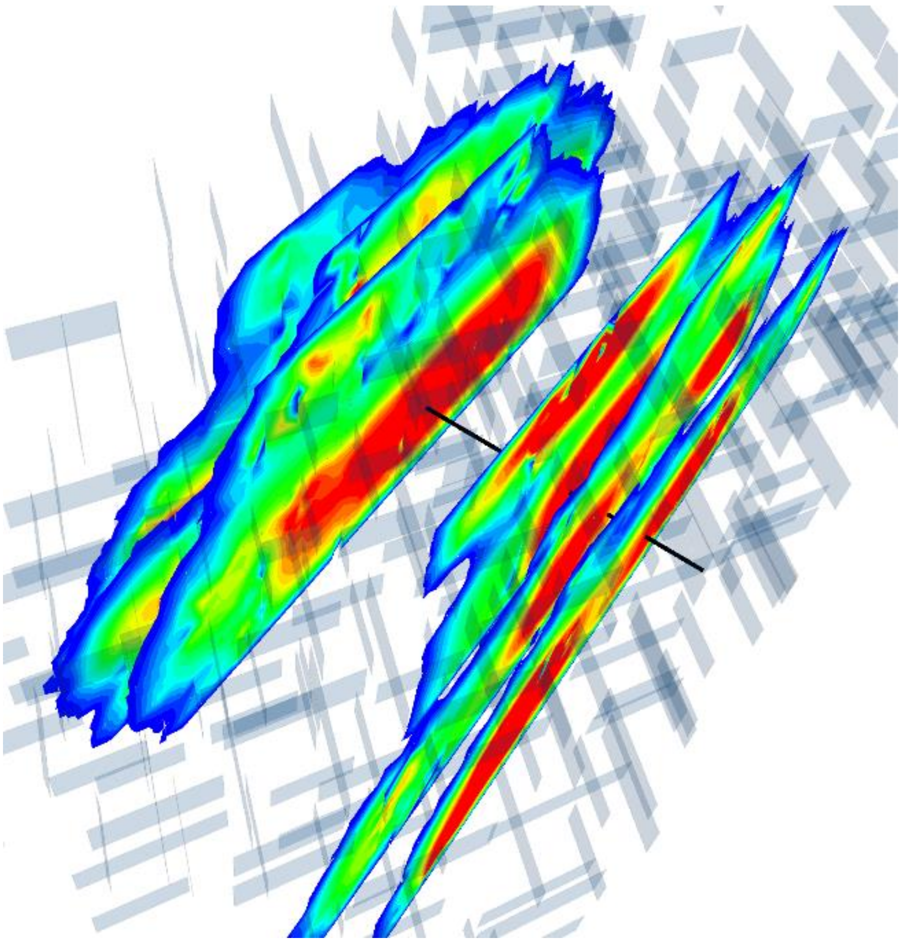


Refracturing in the Eagle Ford

- Typical Eagle Ford well refractured after 3 years on production

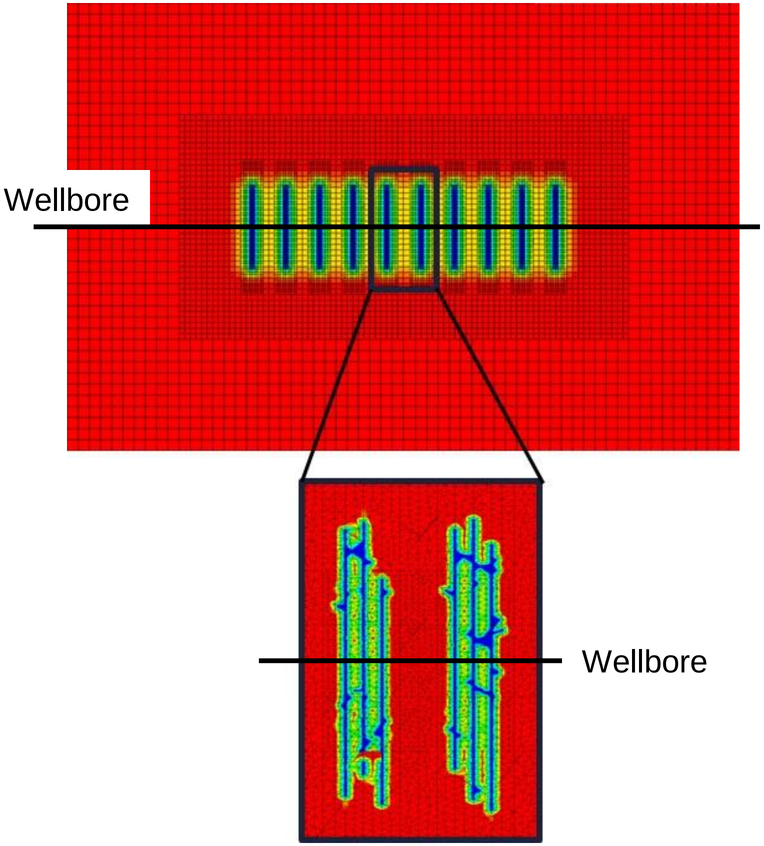


Geometry of initial fractures and DFN

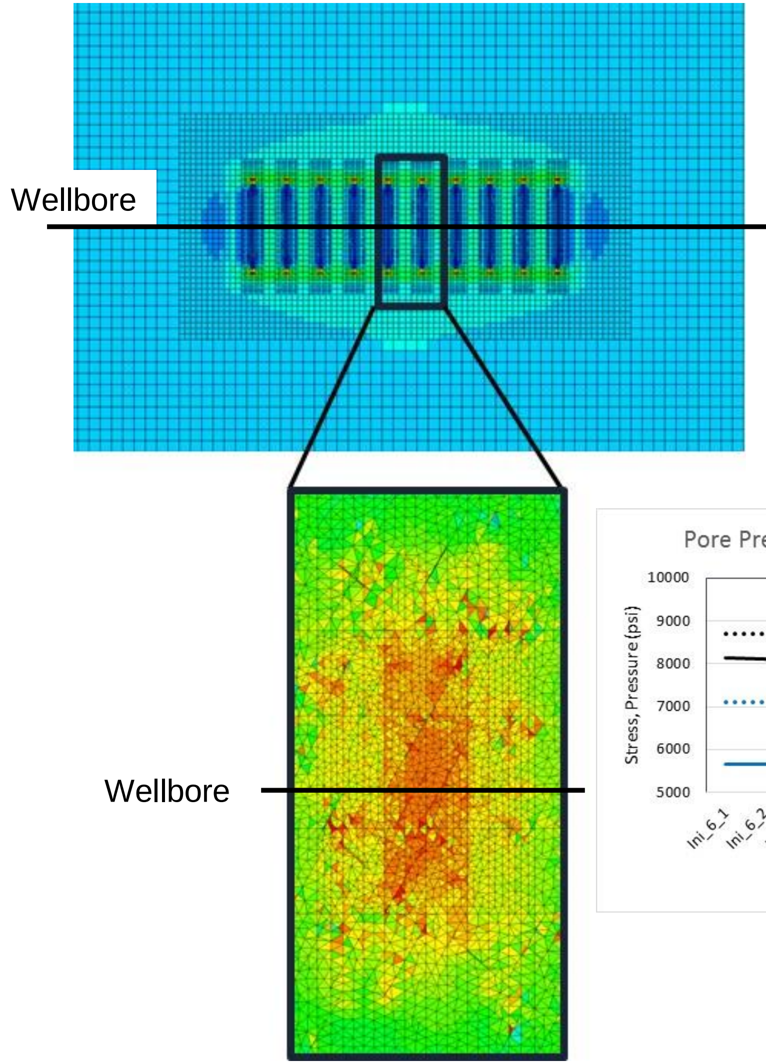


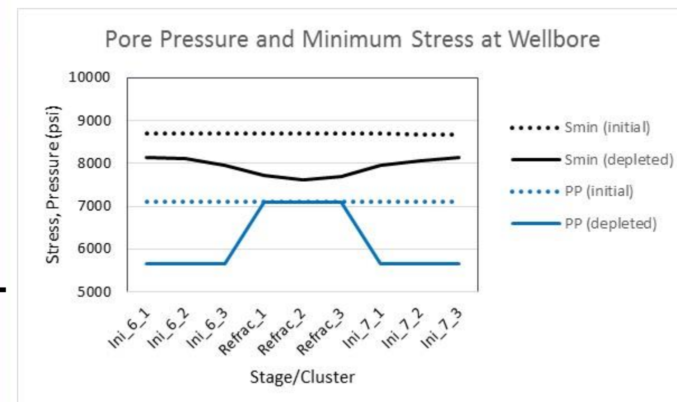
Stress state and pore pressure after depletion

Pore pressure



Minimum horizontal stress

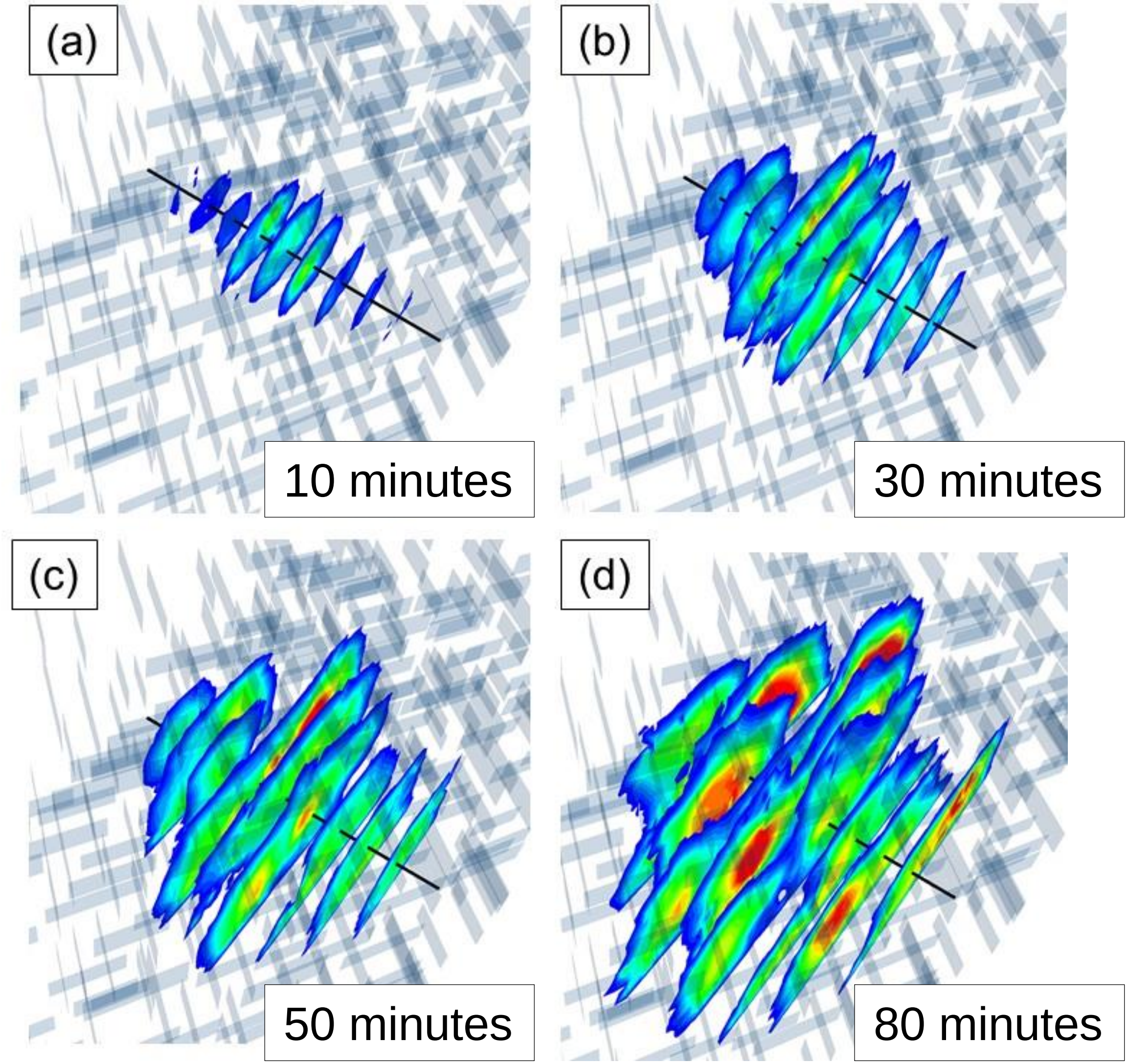




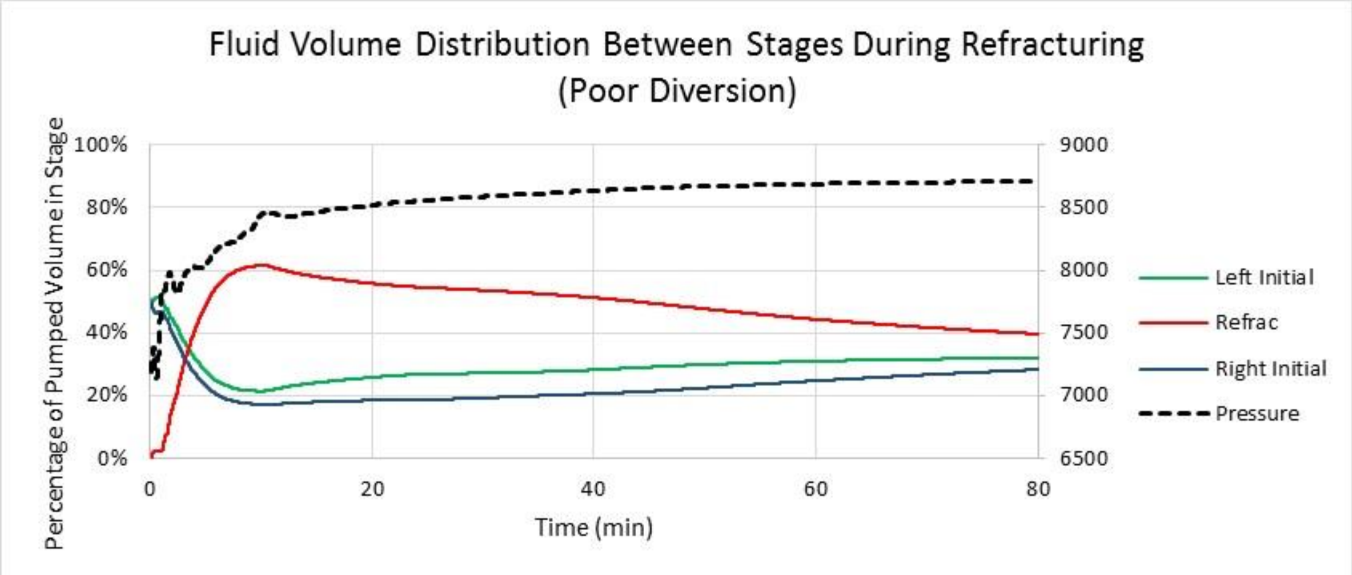
Four Refracture Scenarios

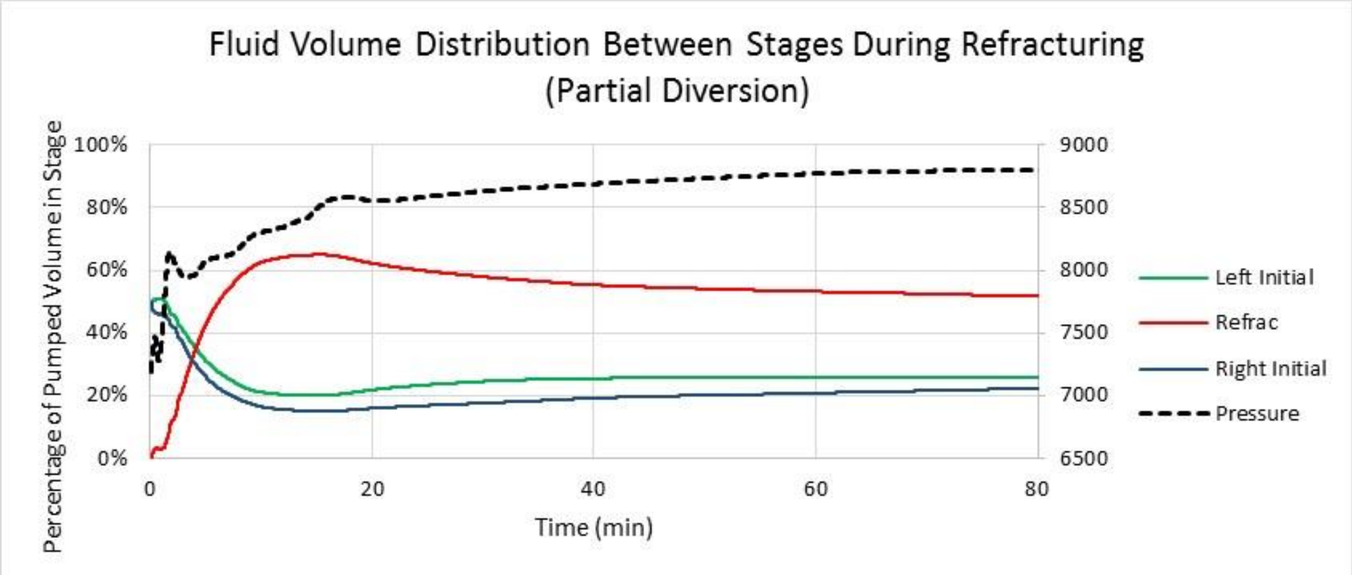
1. Poor diversion with <u>all initial and refracture perforations open</u>
2. Partial diversion, with <u>half the initial perforations closed</u>
3. Perfect diversion with <u>all initial perforations closed</u>
4. Perfect diversion, with a <u>limited number of perforations</u> in the new stage

Geometry of Primary Fractures: Poor Diversion

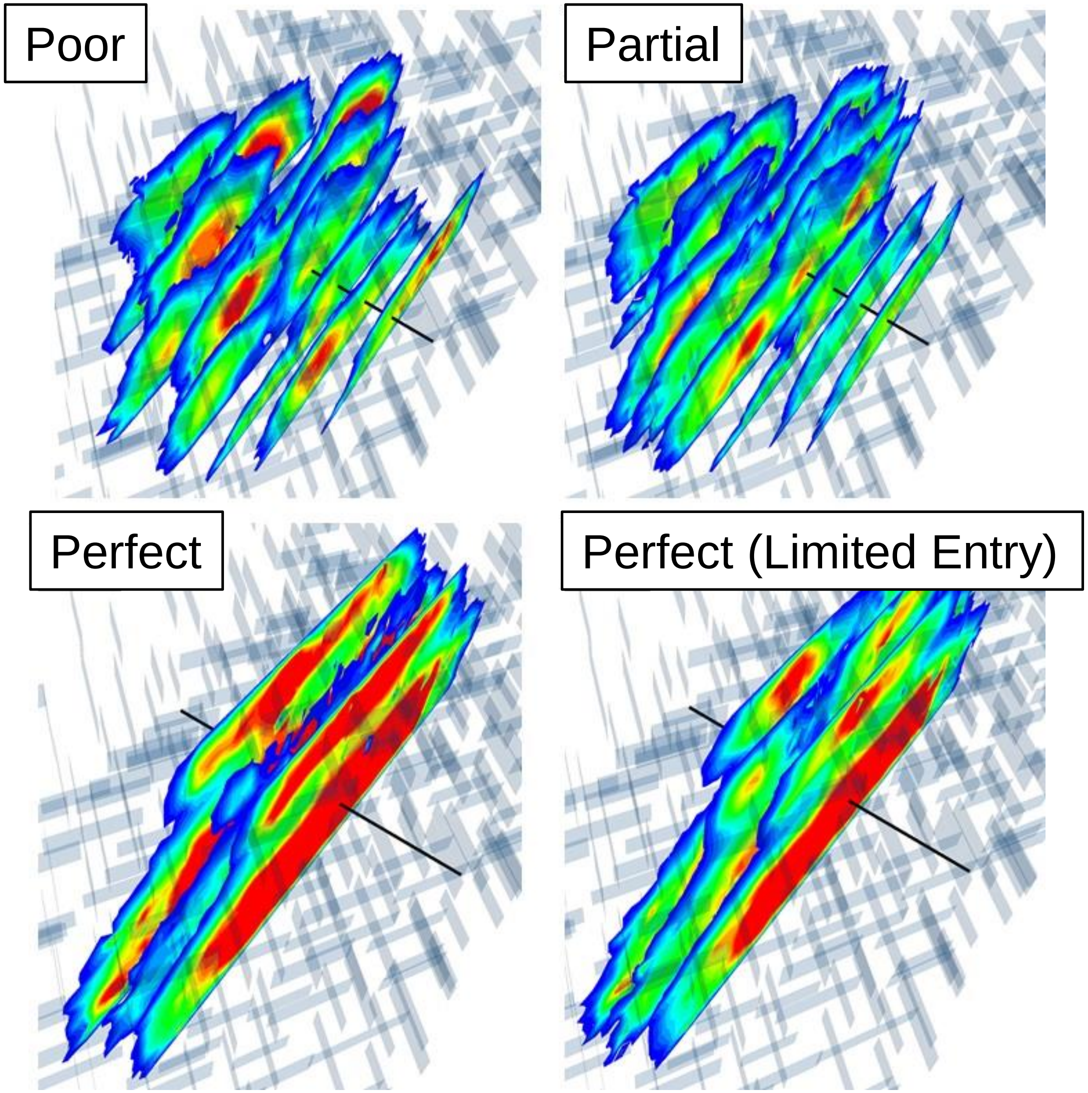


Fluid Distribution: Poor versus Partial Diversion

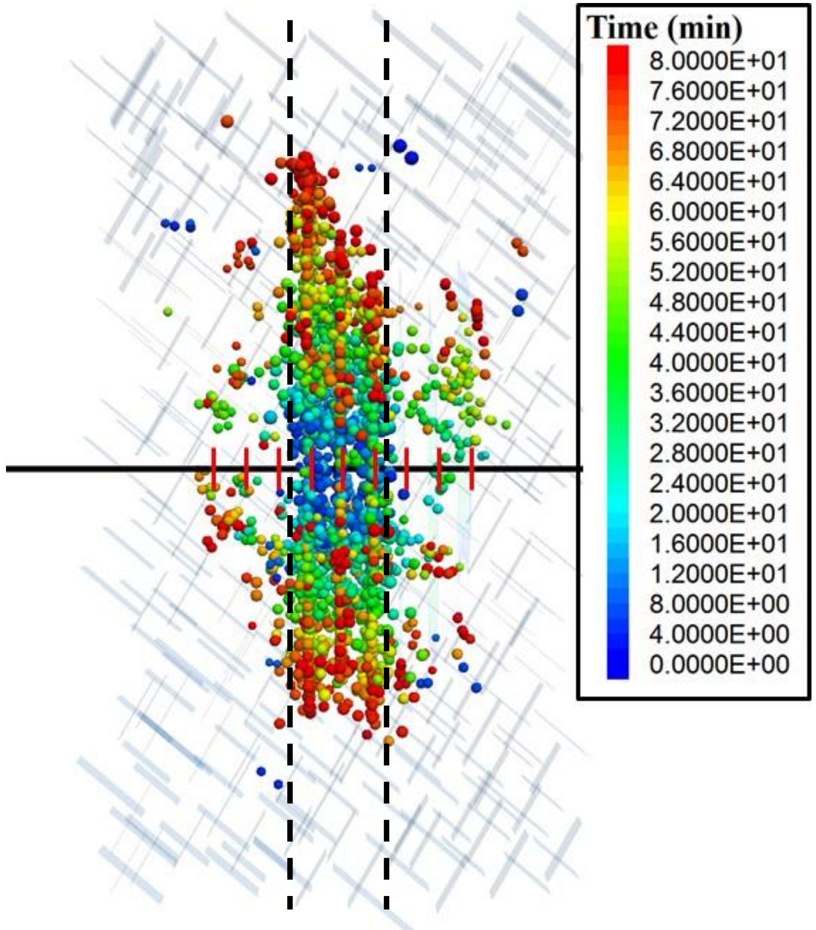


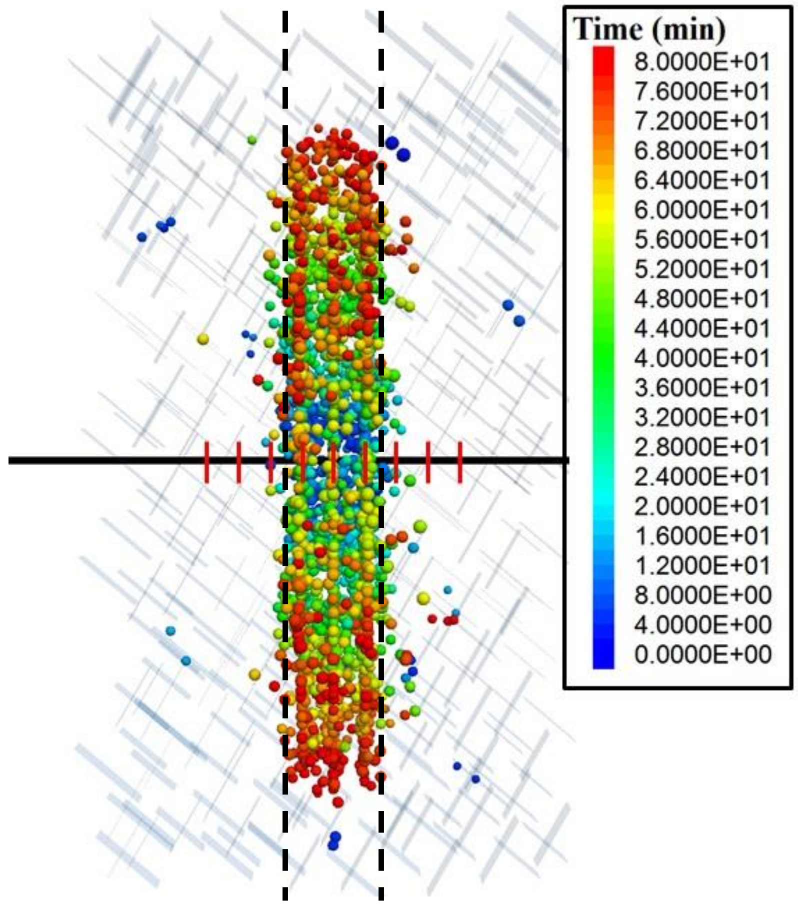


Final Geometry for Four Cases

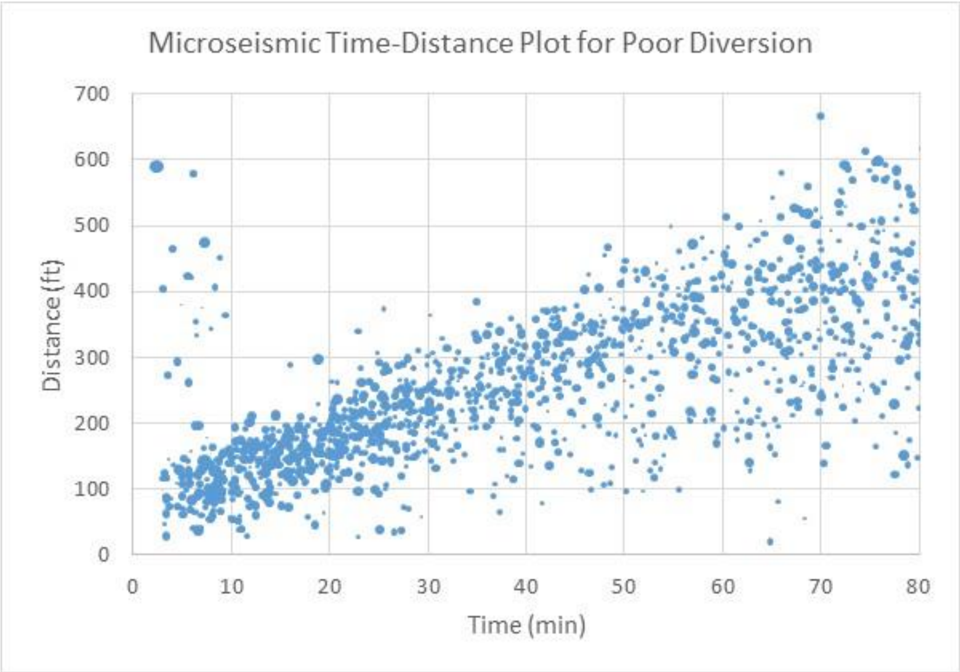


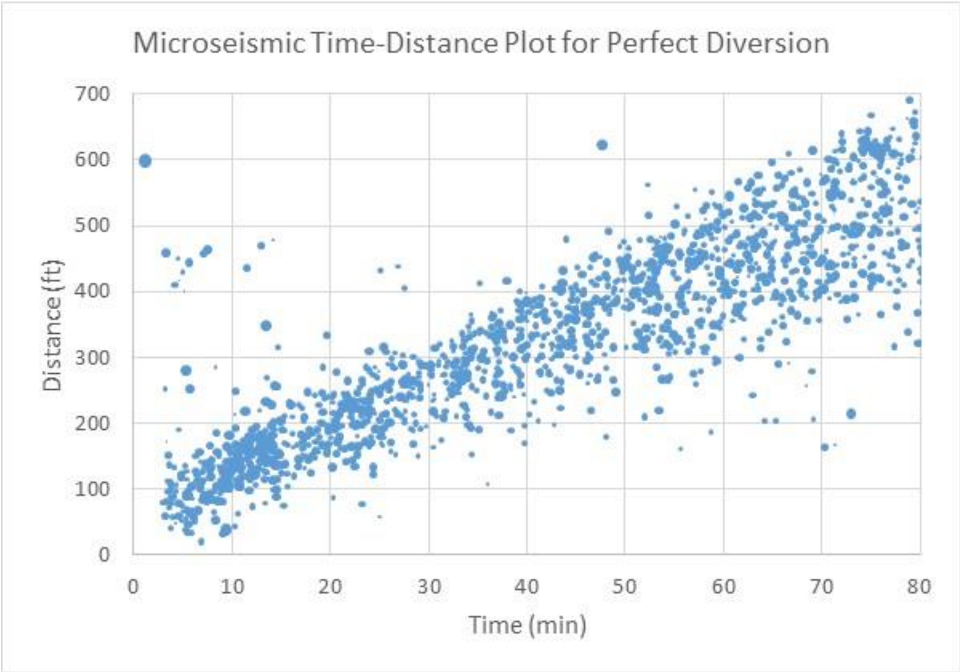
MS Signature: Poor versus Perfect Diversion



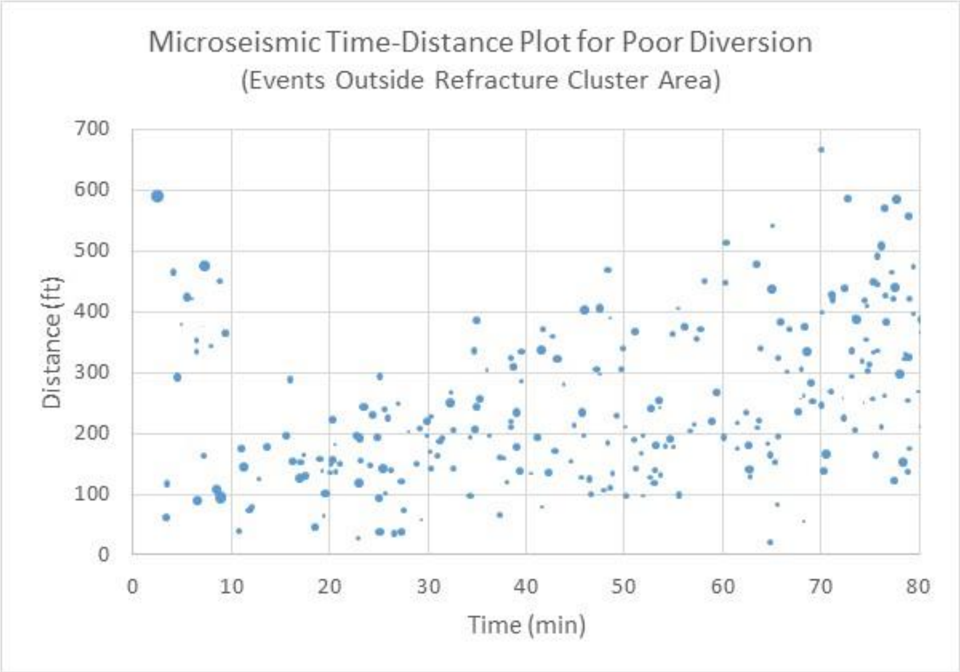


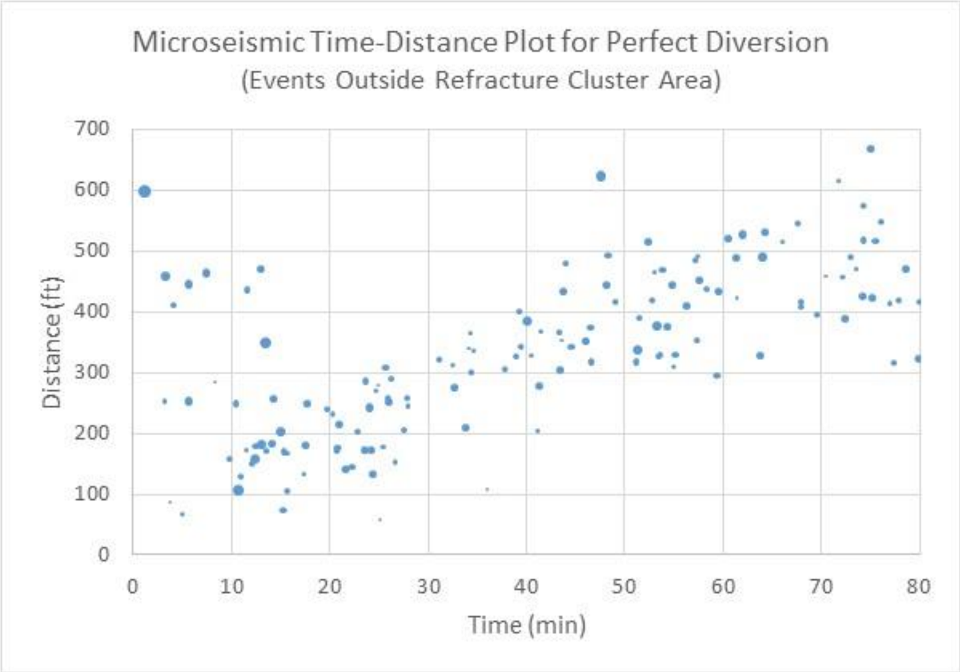
Microseismic Time-Distance Plots



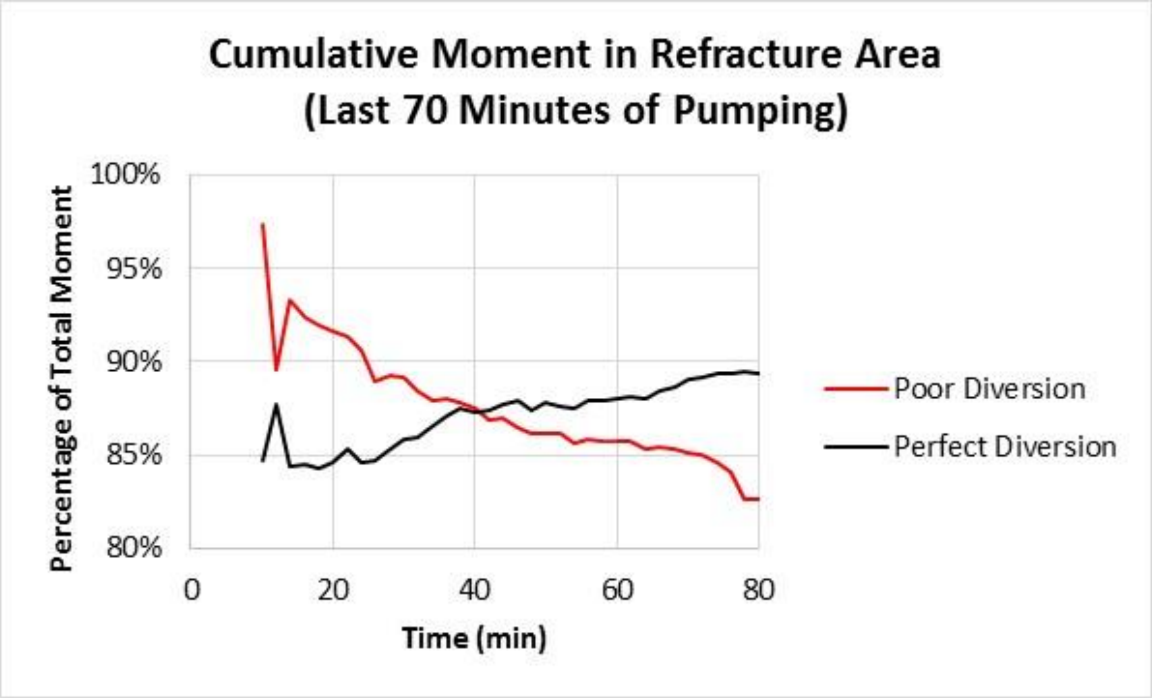


Microseismic Time-Distance Plots - Filtered





Cumulative Moment Diversion Diagnostic



Wrap-up

- Microseismic Geomechanics to understand microseismic data
  - Calibrated fracture model
  - Insights into the complete fracture network including tensile and aseismic parts
- Horn River Basin case study
  - Field data => Calibrated model => Completion optimization
- Upper Montney case study
  - Stress shadowing can cause microseismic asymmetry
- Eagle Ford refracturing example
  - Field diagnostic of diversion success
  - Good example of using model to gain insight and lead to a simple field diagnostic

Questions