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The Impact of Reservoir Heterogeneity on Hydraulic Fracture Geometry: Integration of Microseismic and Seismic Reservoir Characterization*

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Abstract

Economic recovery of shale gas reservoirs requires effective hydraulic fracturing in order to stimulate production. Microseismic imaging has shown that the hydraulic fractures often create complex fracture networks containing multiple fractures in various orientations. These fracture networks are often highly variable from well-to-well and even between frac stages in a single well. In this paper a case study is presented from the Montney Shale in northeastern British Columbia, where microseismic and reservoir characterization data were used to understand some of the constraints on the fracture geometry. The study found that when wells were close to pre-existing faults, the hydraulic fractures were found to interact with these faults and act as a barrier to fracture growth. The microseismicity associated with the fault activation was found to have relatively large magnitudes and anomalous frequency-magnitude characteristics. Regions with the increased level of microseismic deformation and corresponding fault-related source characteristics correlated with the presence of a pre-existing fault identified by edge detection and tracking algorithms applied to seismic reflection data. In cases where the wells were far from pre-existing faults, simple, planar hydraulic fractures were observed. However, there was a tendency to grow towards regions of low Poisson's ratio identified through amplitude versus offset inversion of the seismic reflection data. The tendency for the hydraulic fractures to be asymmetric and grow preferentially towards the low Poisson's ratio region is attributed to material property changes and associated lower stresses in these regions.

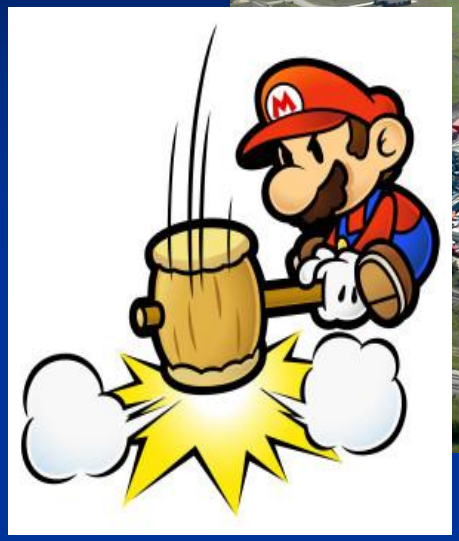
Integrating microseismic interpretations and fracture treatment data with enhanced reservoir characterization has been used to rethink well placement and completion designs, resulting in improved well performance. This article describes the data integration steps that resulted in these conclusions, the impact of reservoir heterogeneity on hydraulic fracture geometry, and the subsequent improvements with future well placements and fracturing designs that resulted from these findings.

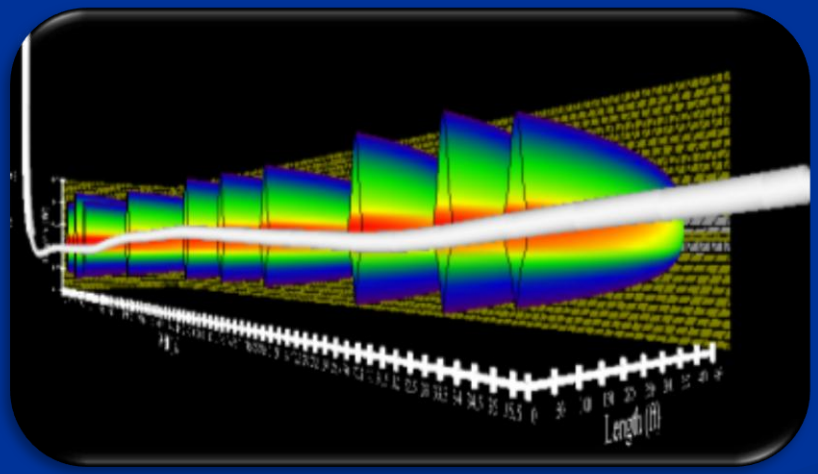
The Impact of Reservoir Heterogeneity on Hydraulic Fracture Geometry: Integration of Microseismic and Seismic Reservoir Characterization

Shawn Maxwell (Schlumberger)
Mark Norton (Progress Energy)

Schlumberger

$20Billion Where Does It All Go?





Fracture Complexity & Natural Fractures

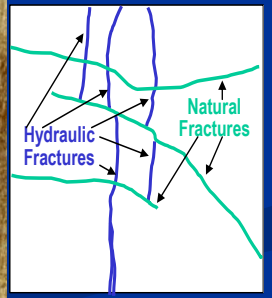
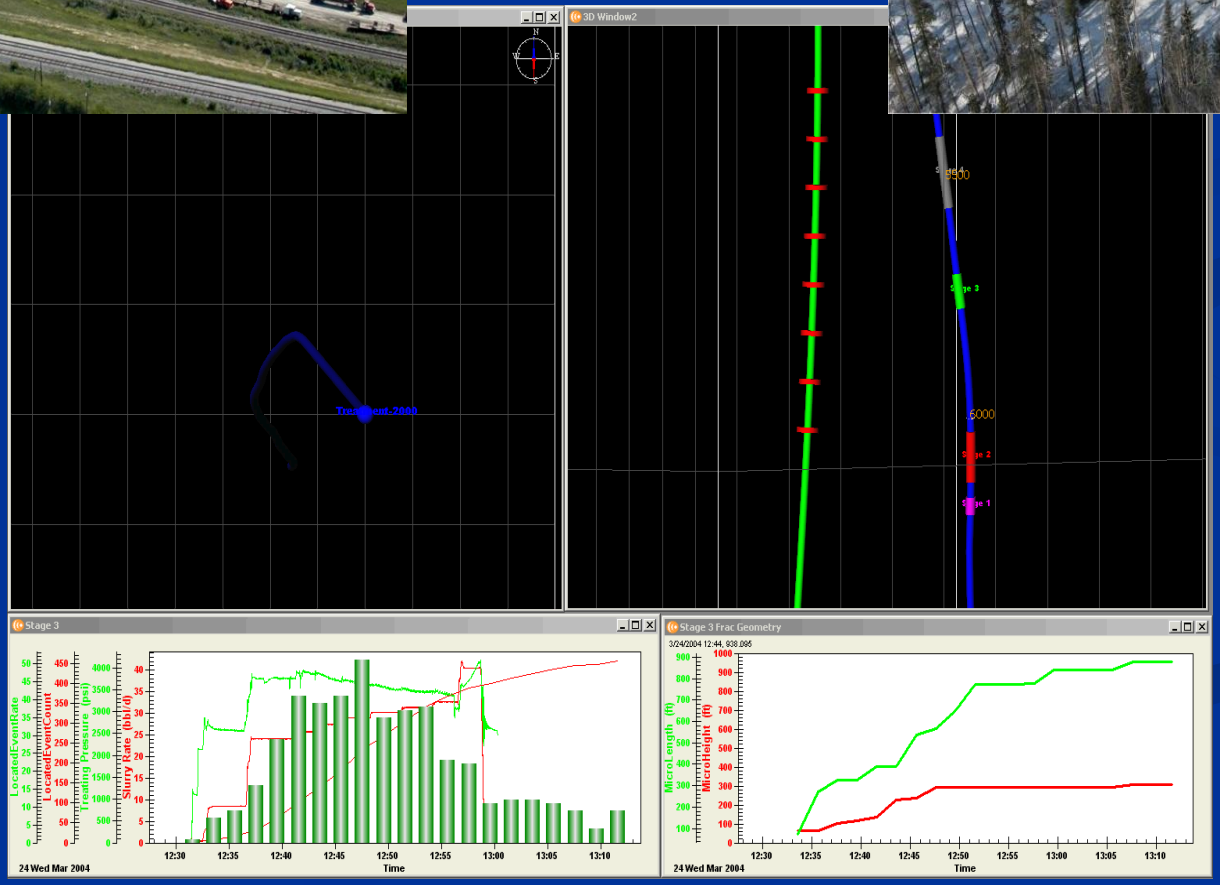
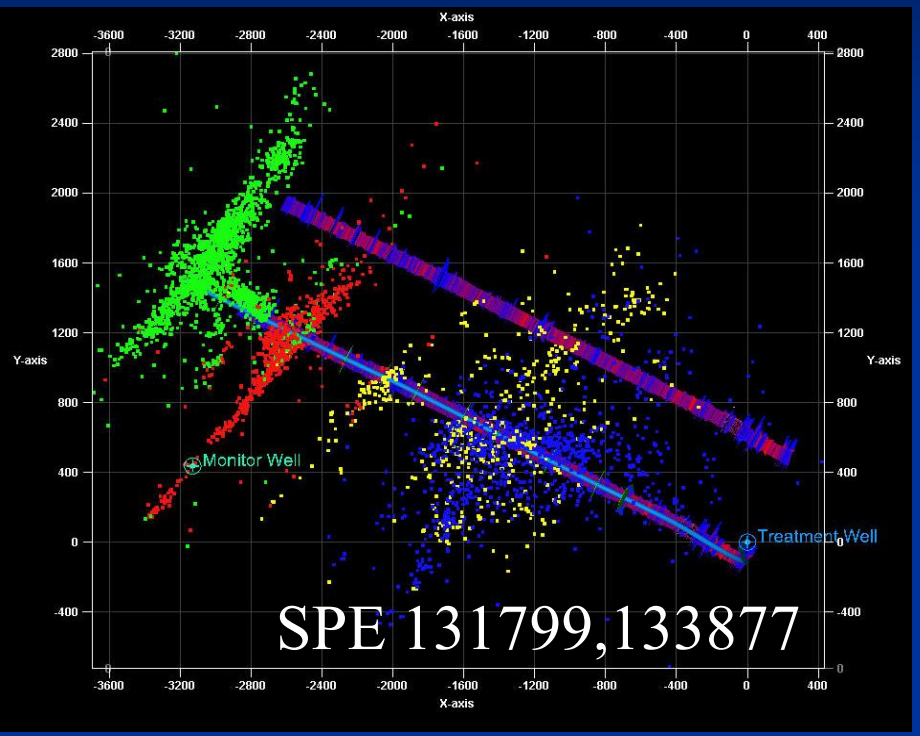


Image of fracture growth



Microseismic Hydraulic Fracture Applications



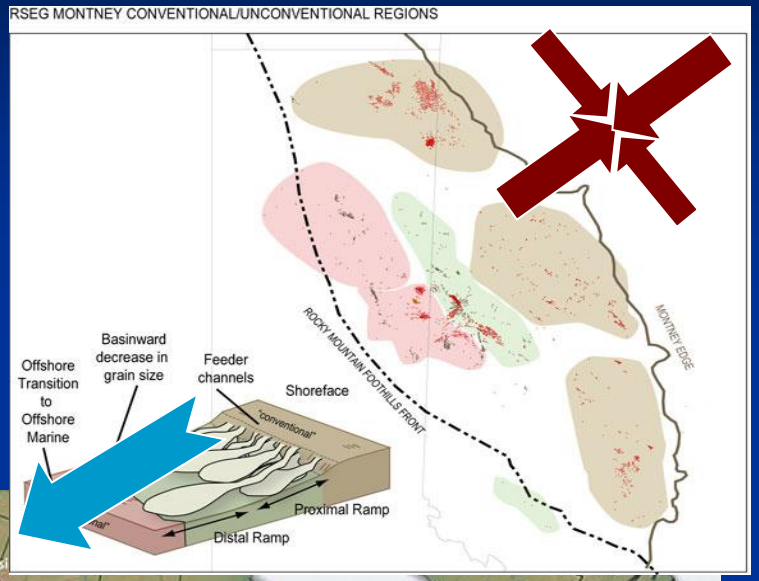
- ✔ Fracture direction
- ✔ Height
- ✔ Length
- ✔ Complexity

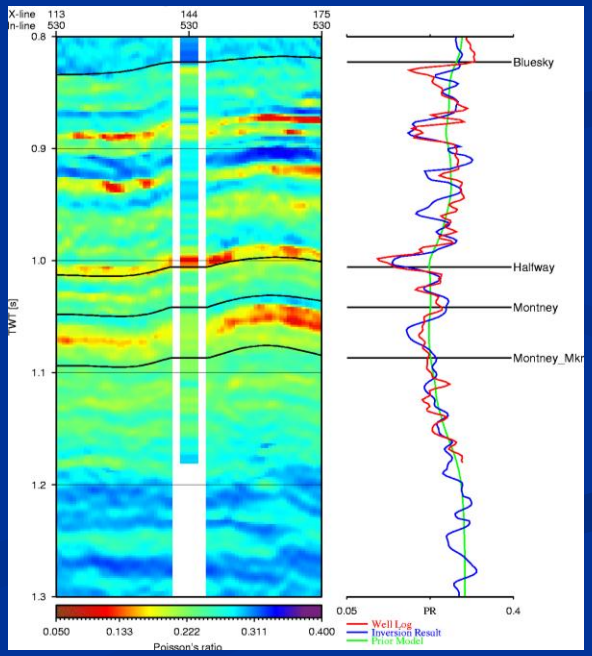
- Real-Time Fracture Control
  - ✓ Geo-Hazards
  - ✓ Re-fracturing
  - ✓ Stage modification
- Completion Strategy
  - ✓ Staging & Isolation
  - ✓ Frac Design
  - ✓ Perforation strategy & frac initiation
- Field Development
  - ✓ Well placement
  - ✓ Well spacing
  - ✓ Drainage patterns

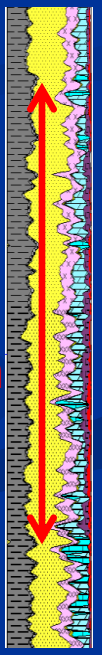
✓ Improved fracs/production

Montney 'Shale'

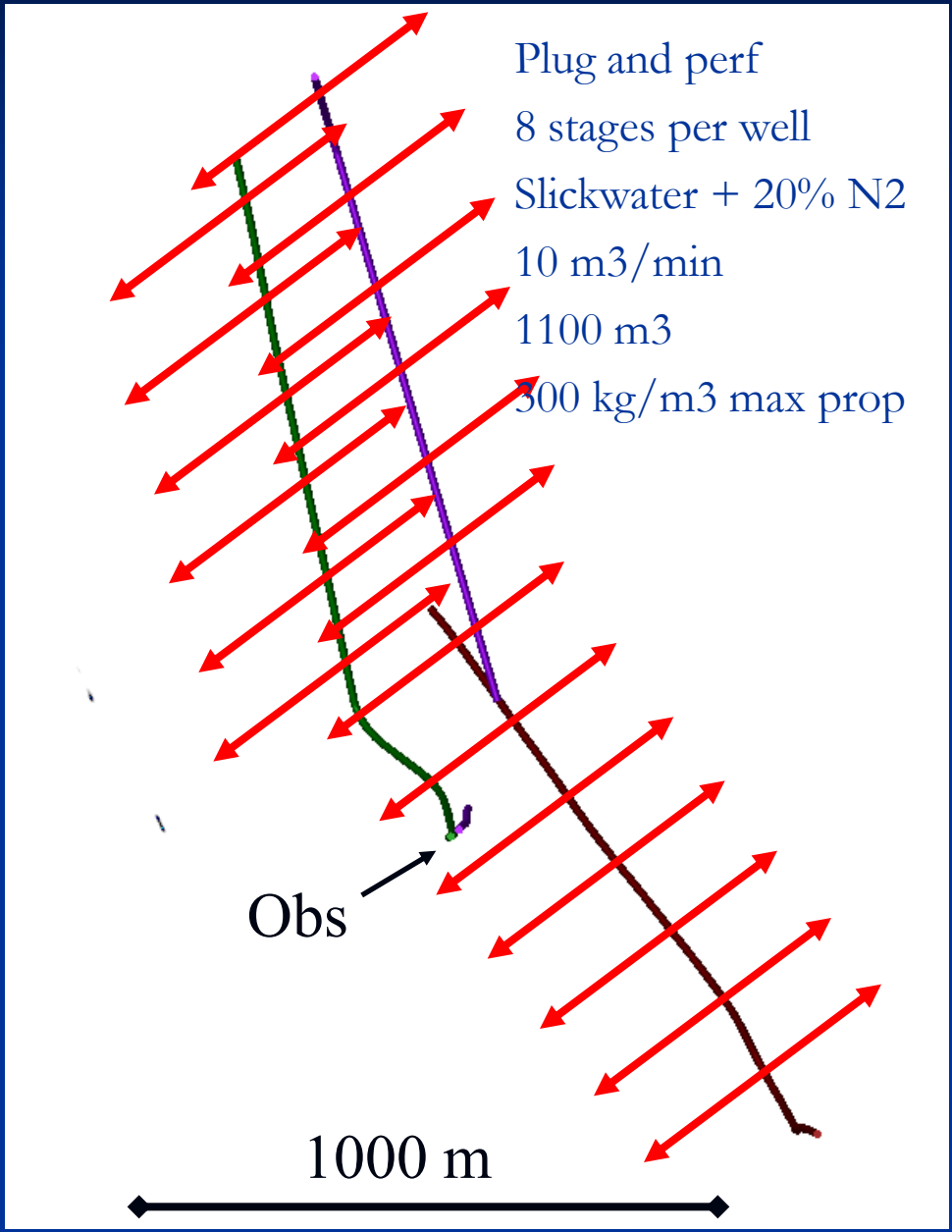
- Lower Triassic siltstone
- Frac for economic gas production





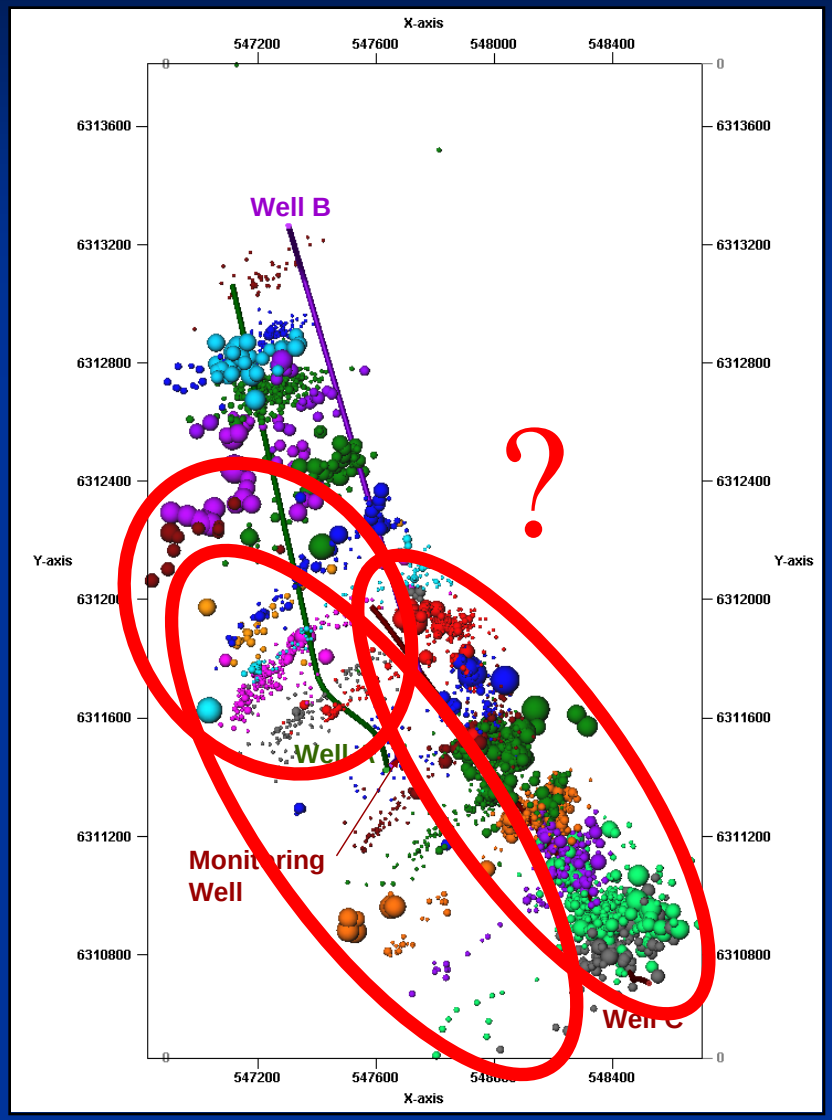


Expected Response



- Known azimuth
- Length vs height?
- Complexity?
- Heterogeneity?
- How many stages?
- Well spacing?

Reservoir Heterogeneity

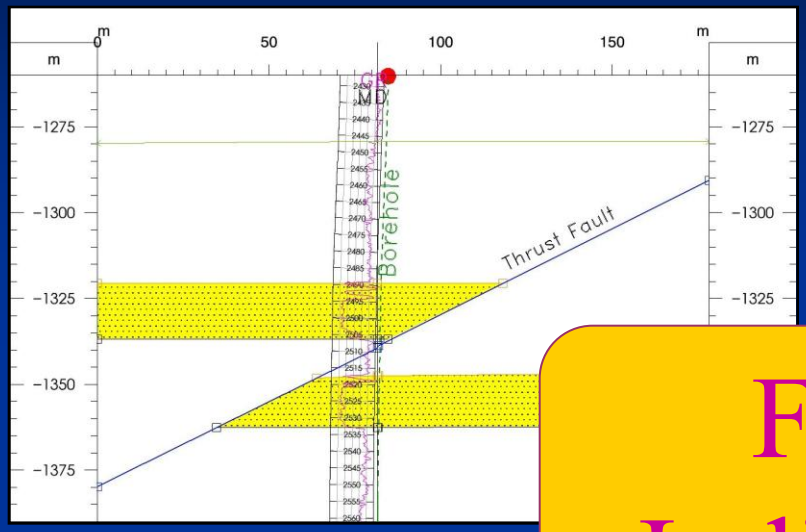


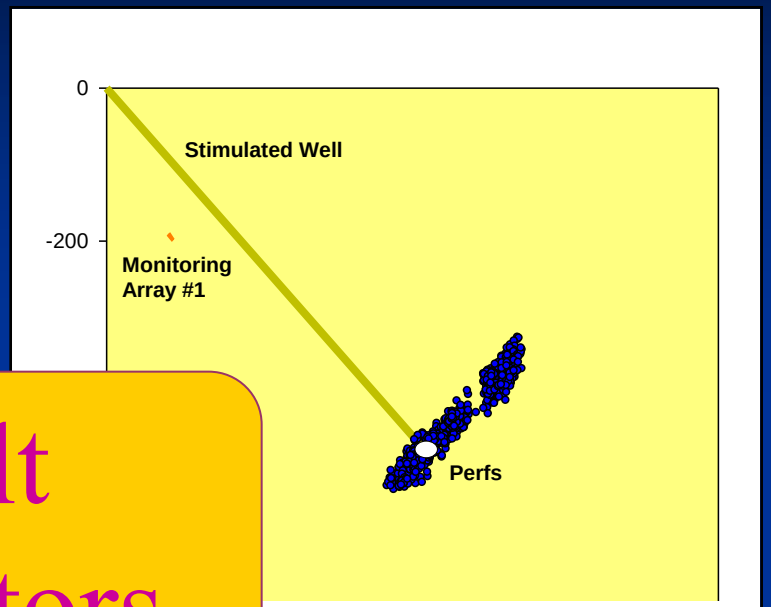
- Why are the events near Well C big?
- Why are there no events to the NE?

  Fault Activation
- Why do the events tend to go to the SW?
- Why is the geometry different near Well A?

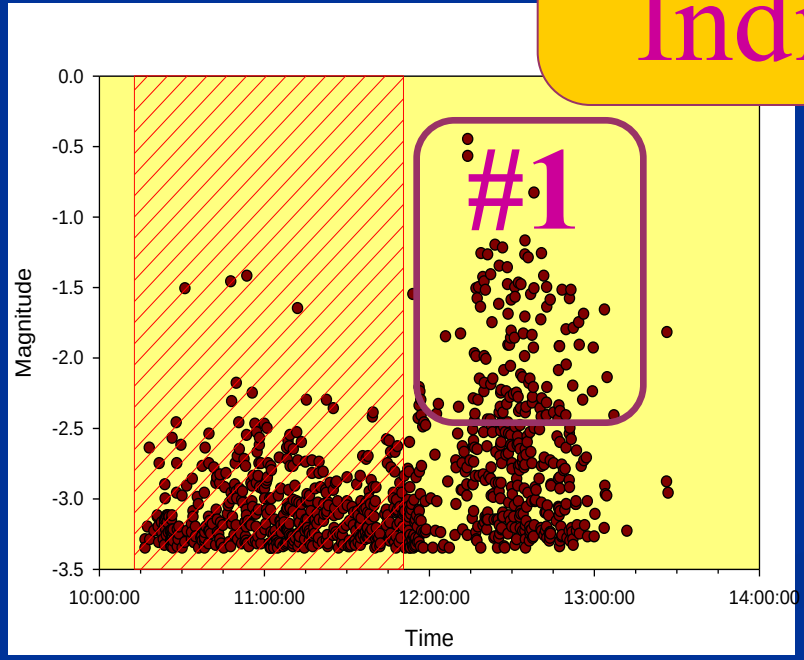
  Stress Heterogeneity

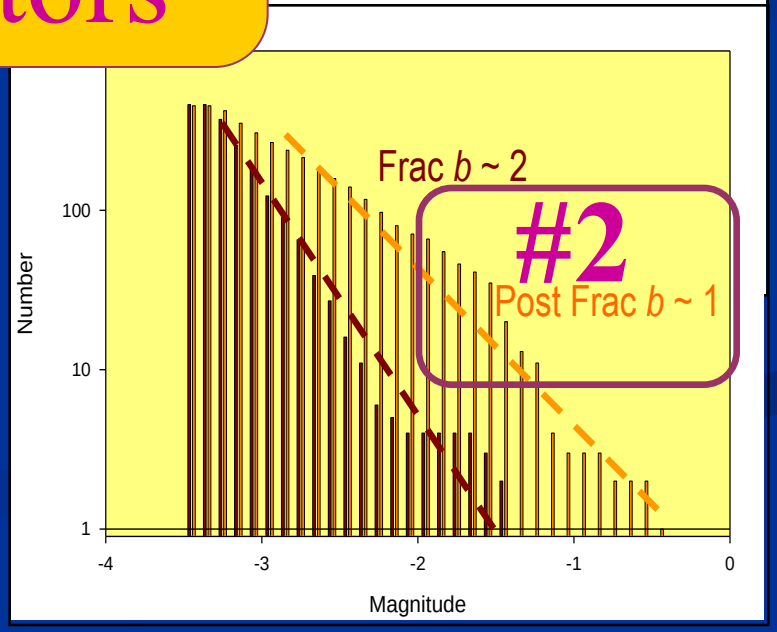
Fault Activation (EAGE 2010)



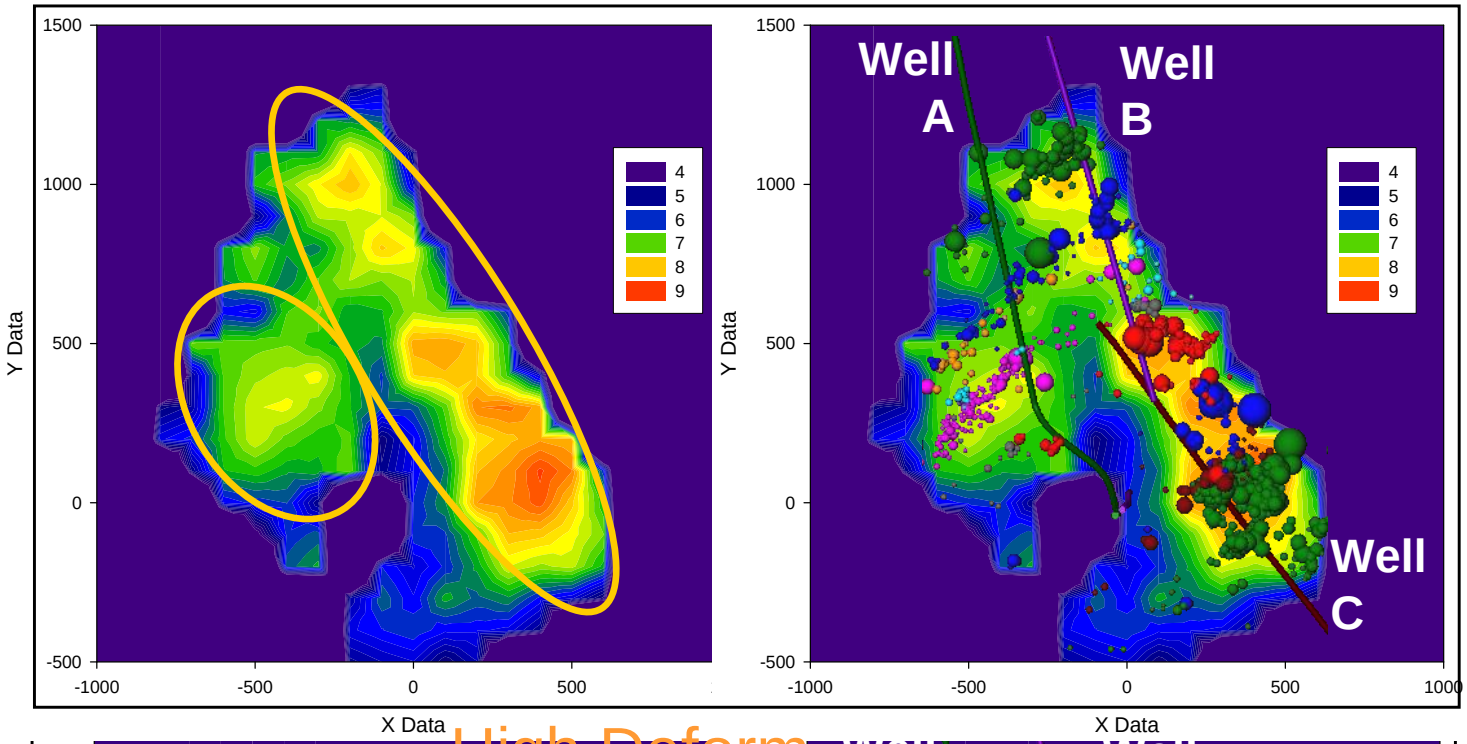


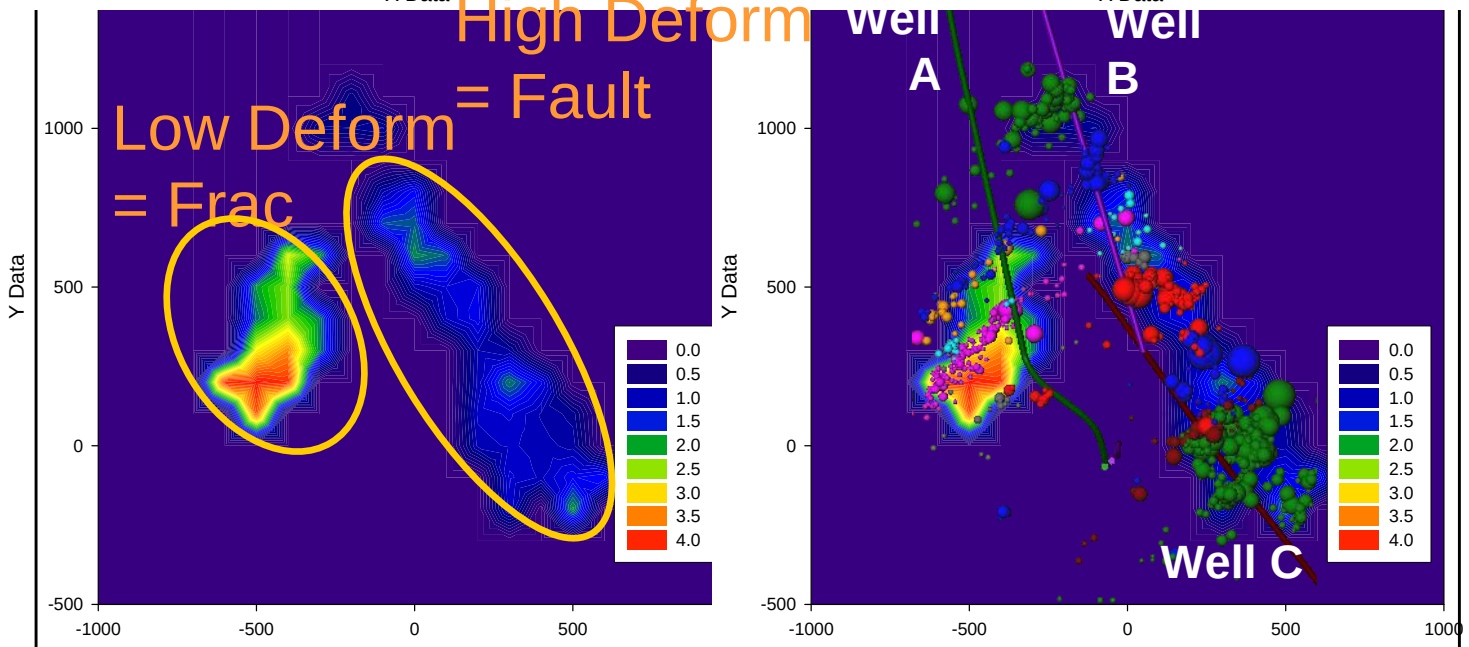
Fault Indicators



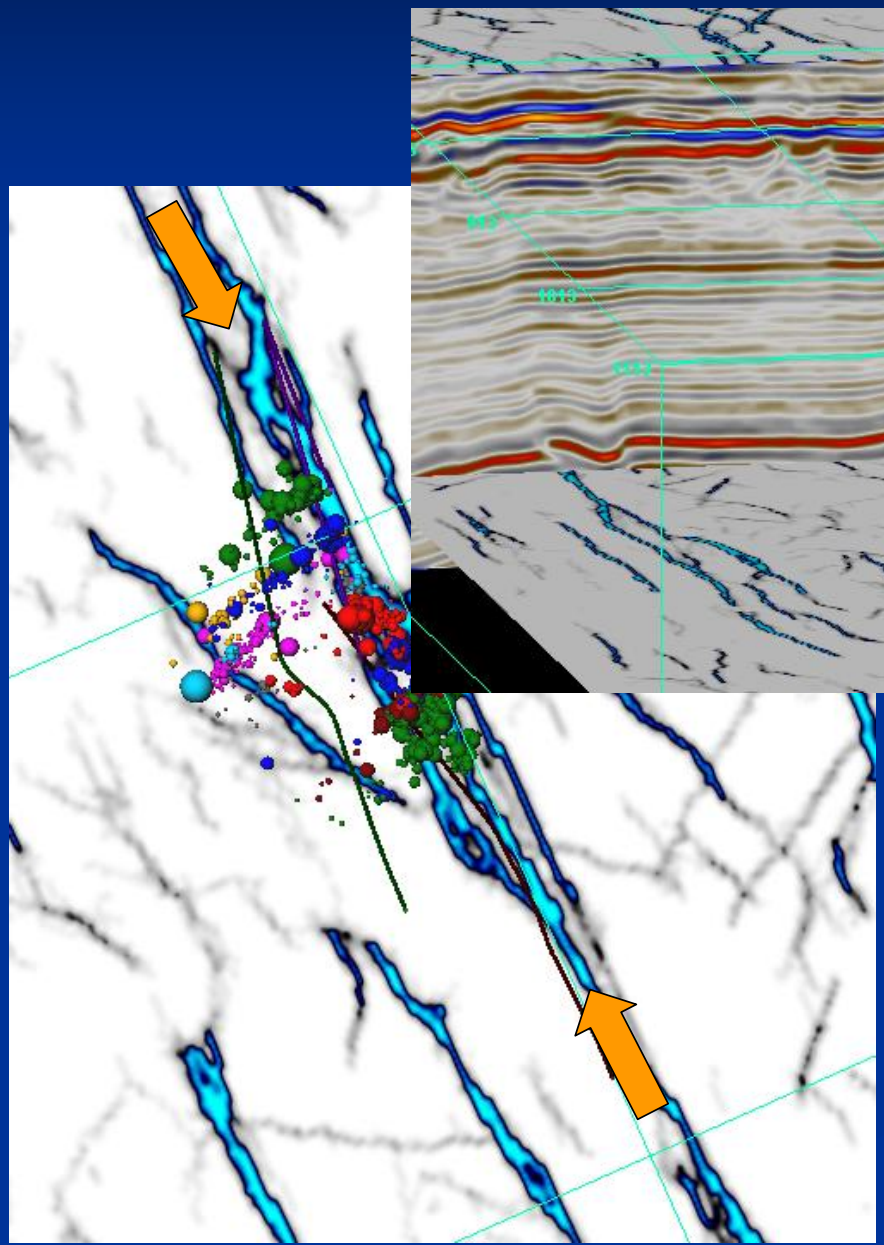


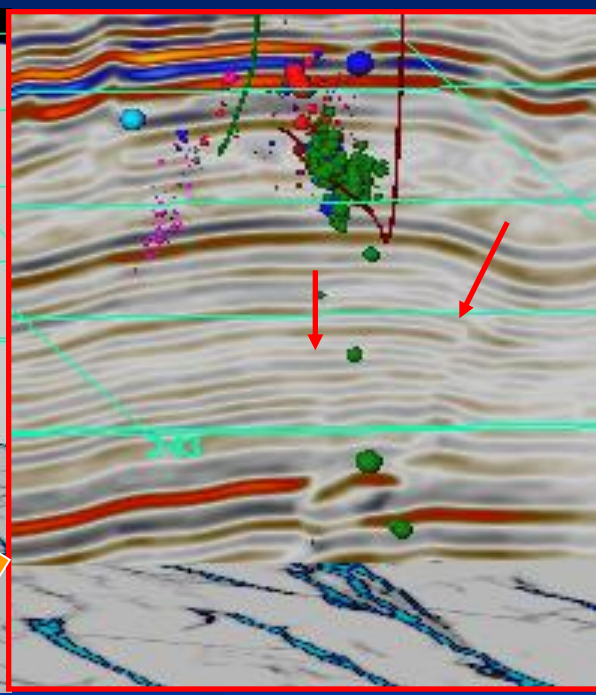
Microseismic Deformation



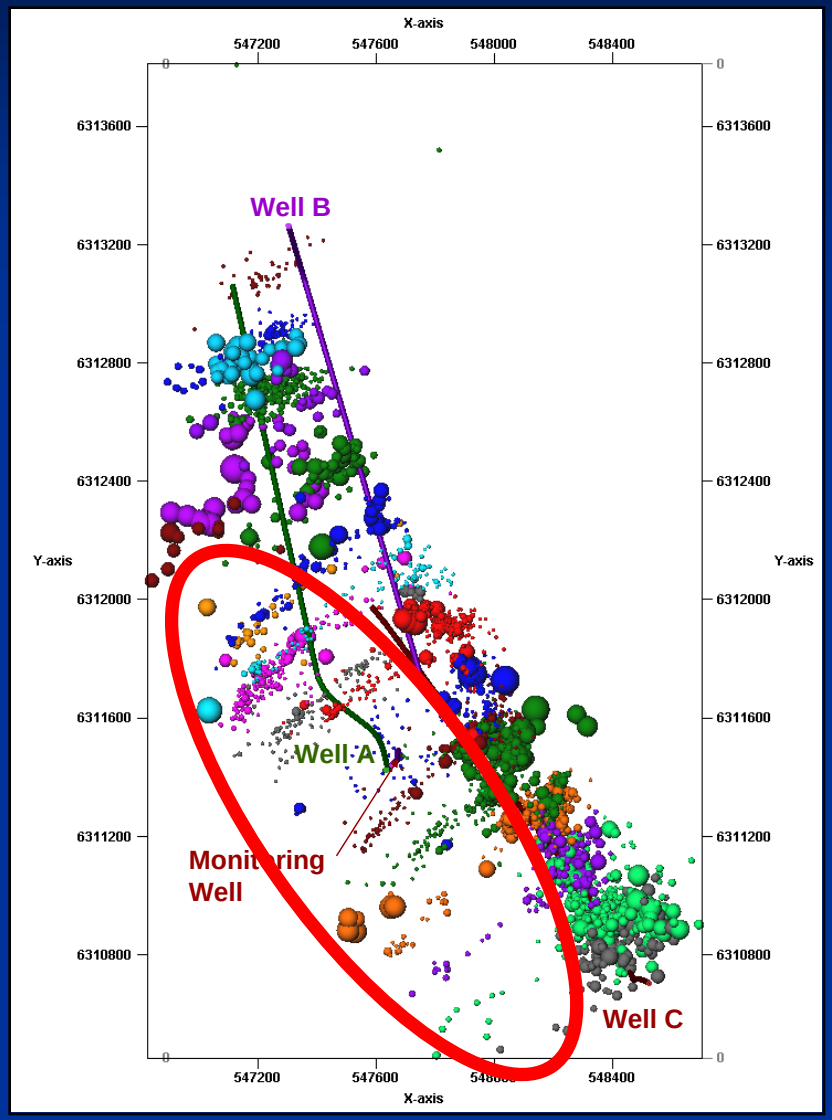


Seismic Evidence of a Fault





Reservoir Heterogeneity



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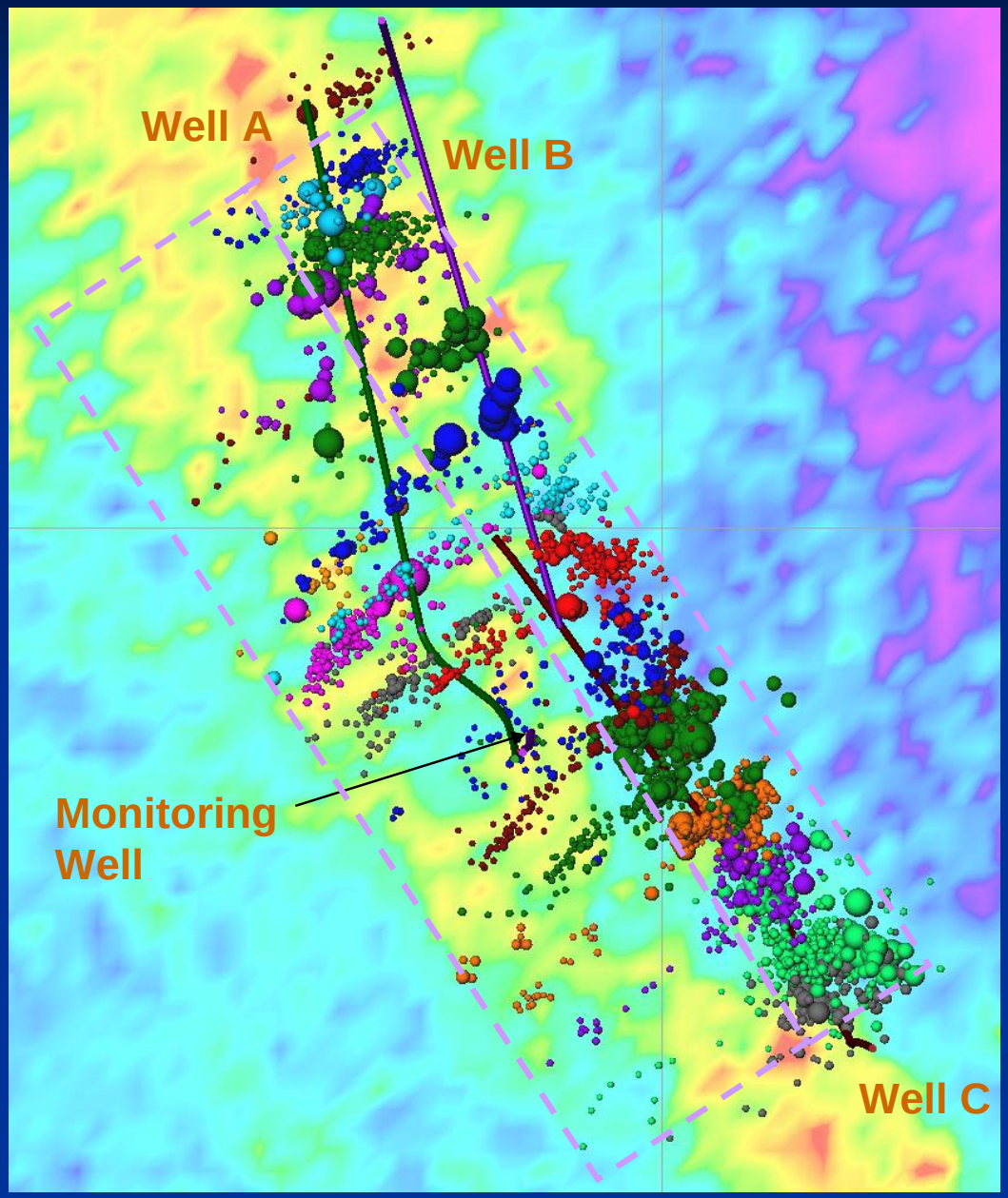
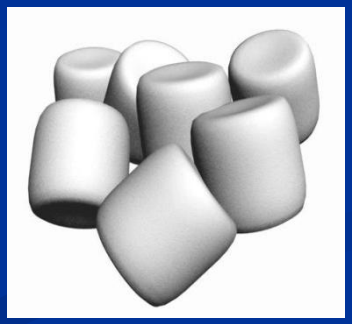
Reservoir Characterization



High PR

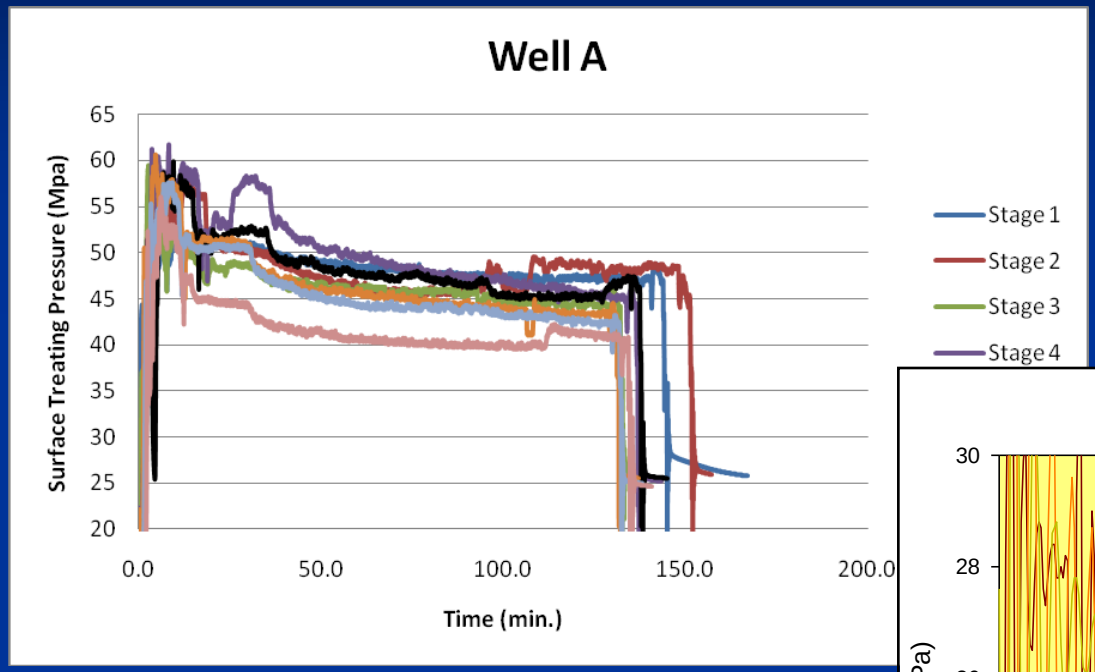
Low PR

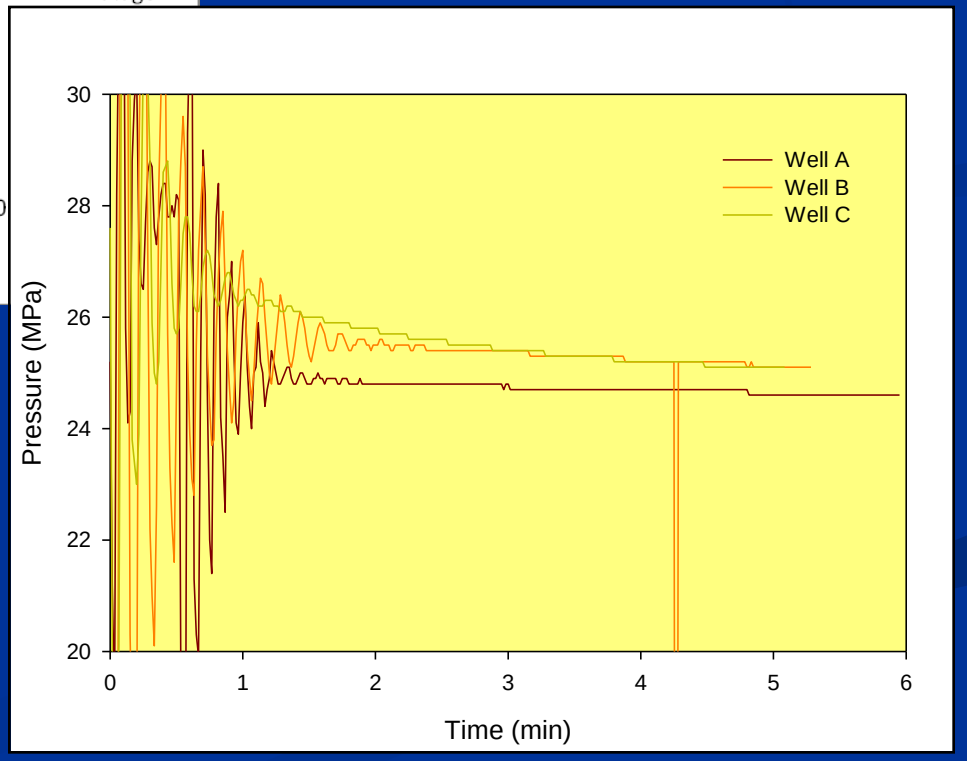


- AVO inversion for Poisson's ratio
- Red PR=0.1
- Purple PR=0.3
- Material property?
- Stress?

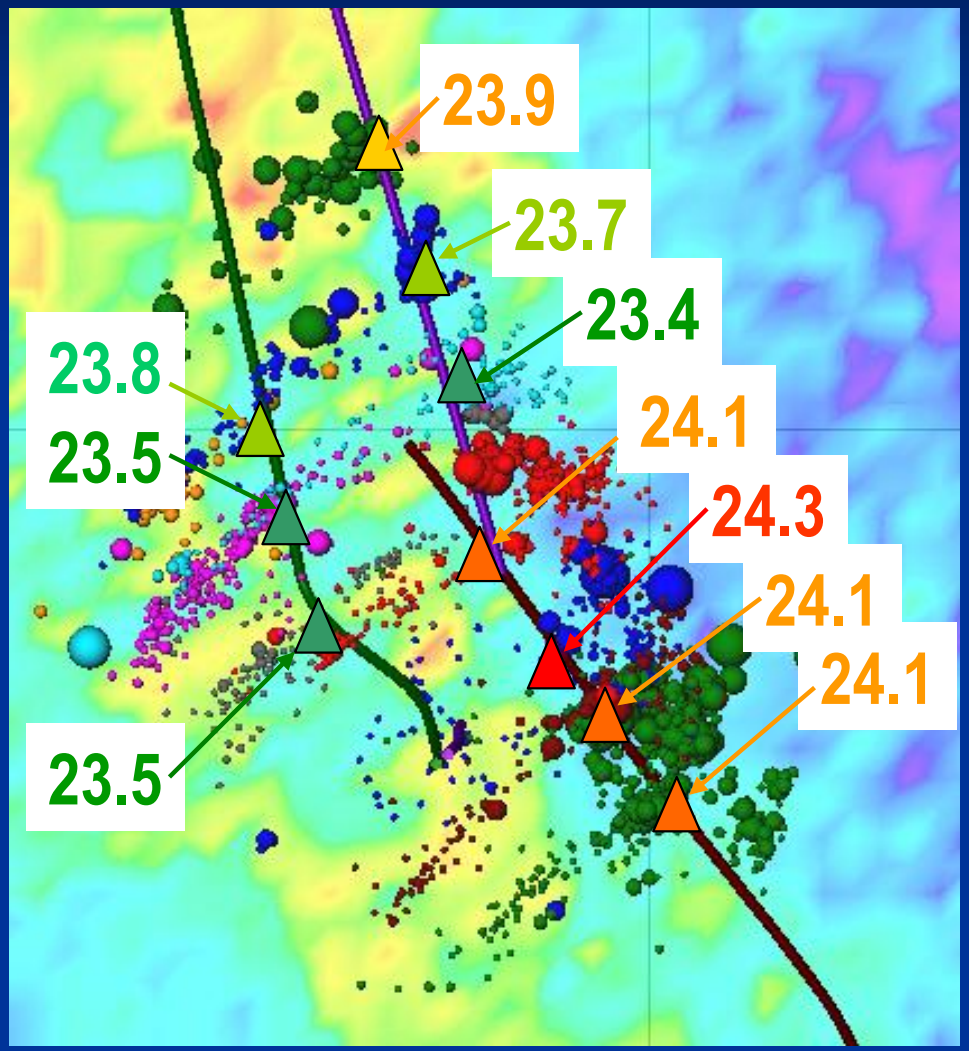
$\sigma_H=\sigma_h= (\nu/(1 - \nu))*\sigma_{zz} + \sigma_{tectonic}$

Treatment Details



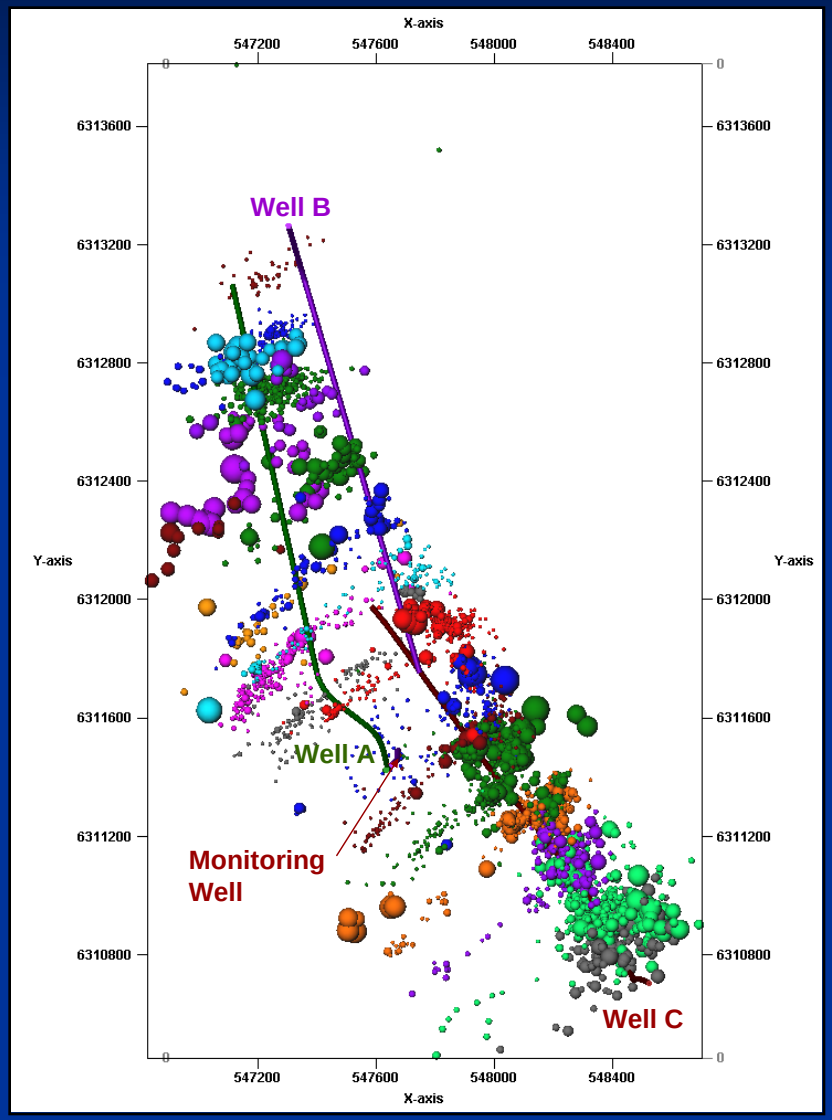


ISIP Variations



- ISIP gradients
- Low ISIP = low PR
- Microseismic tends to grow towards lowest σ

Summary



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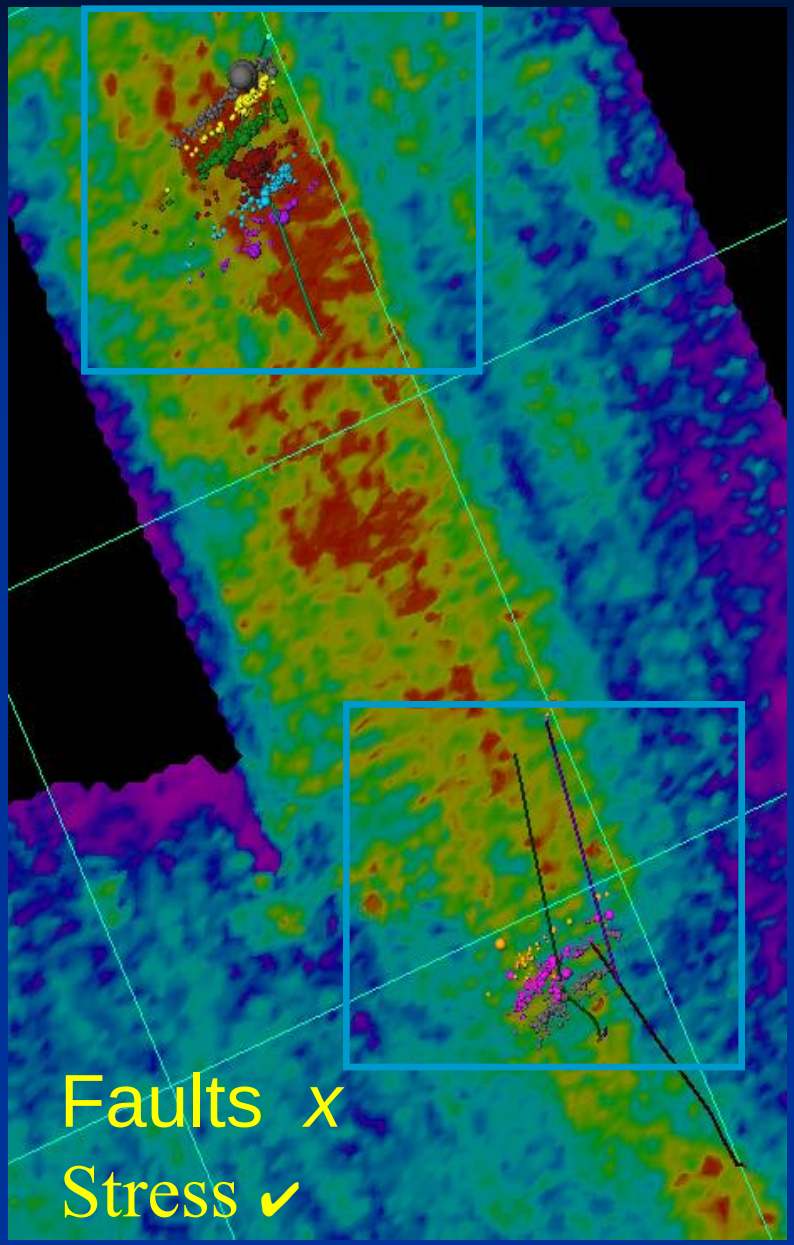
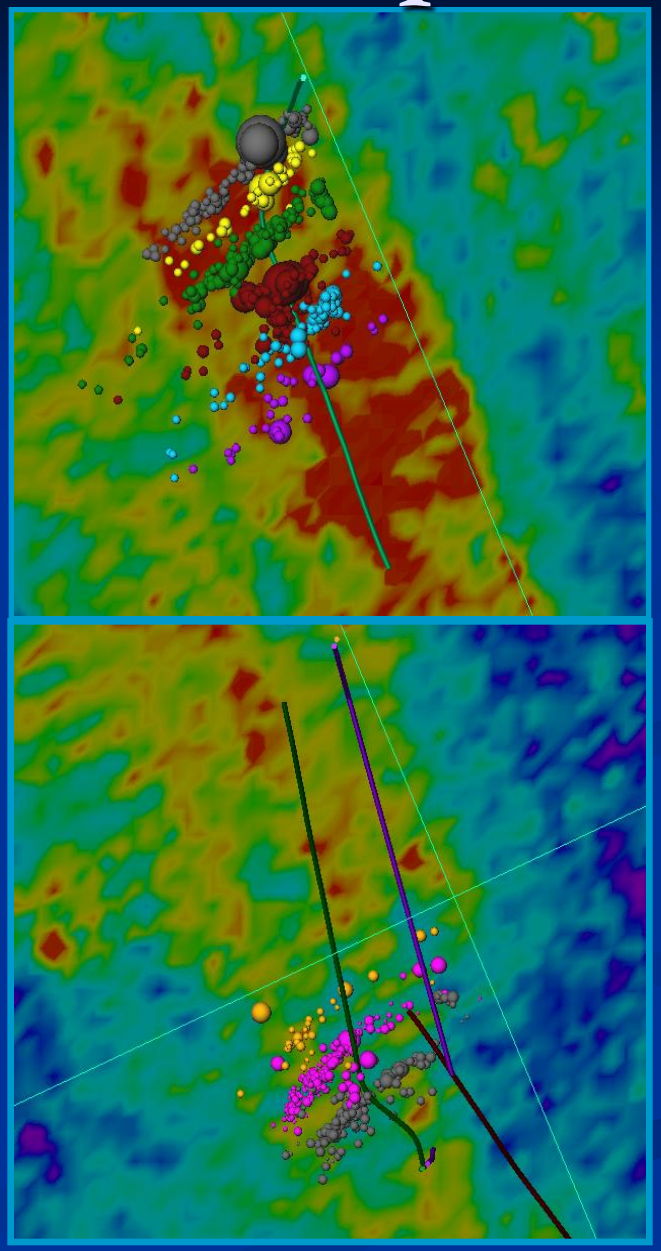
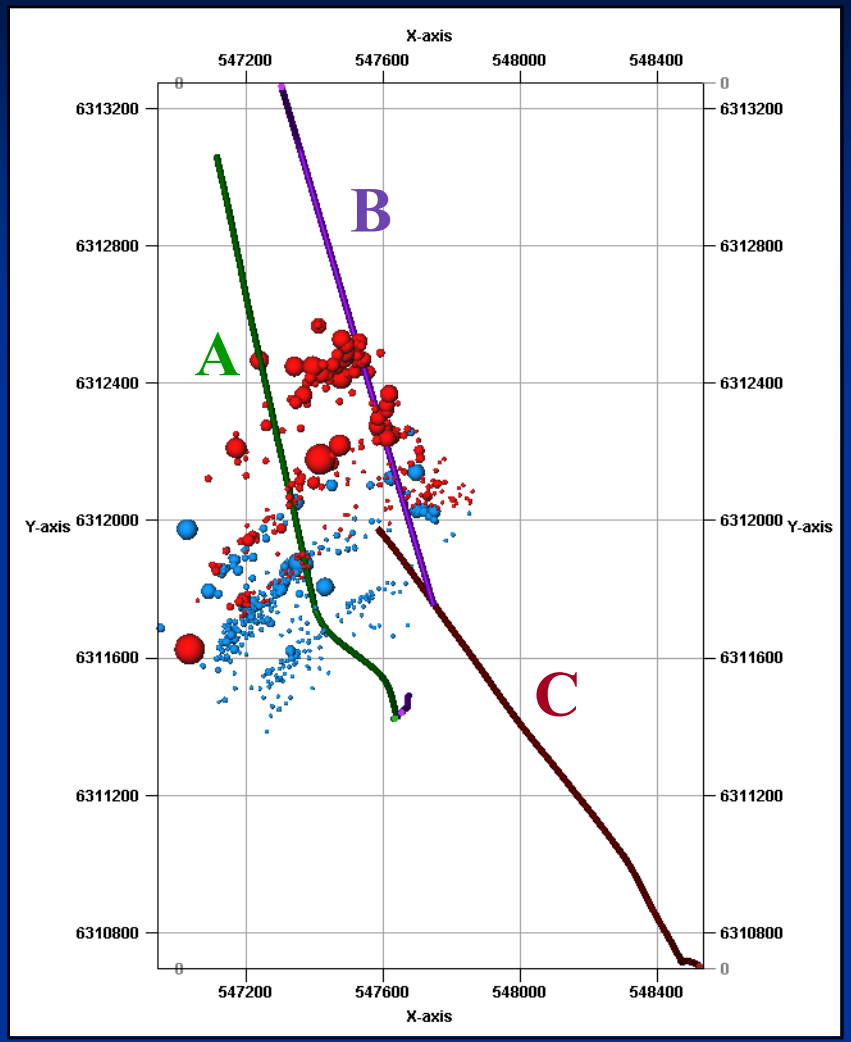
  Stress Heterogeneity

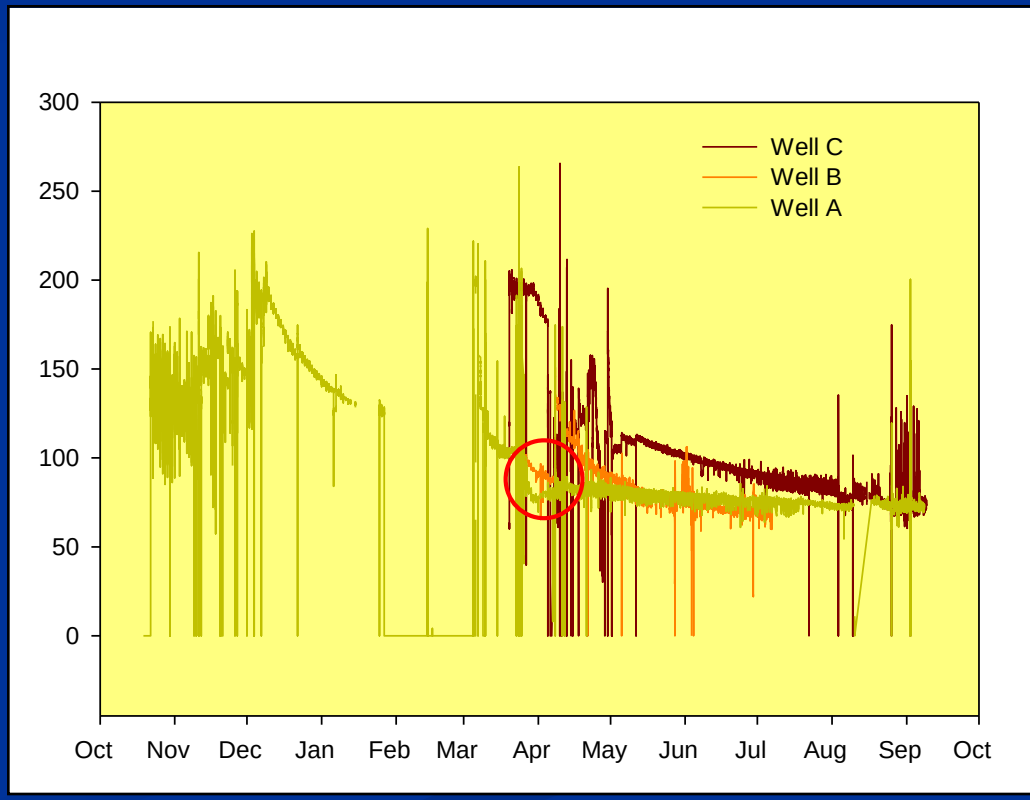
Geomechanical “Sweet spots”





Well Interference





Geomechanical Sweet Spots

- Reservoir heterogeneity impact frac response
- Fault activation can act as frac barrier
- Fracs grow towards lower stress regions
- Sweet spots = low stress & no faults
  - Better place wells
  - Tailor frac to the conditions

"Using these seismic methods we can better plan our well locations and stimulation programs to optimize the result"

Mark Norton (Progress) SEG/CSEG Recorder