

Microseismic Mapping of Hydraulic Fracture Stimulations

(Applications, Observations, and Conclusions for Optimizing Production)

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Presentation Outline

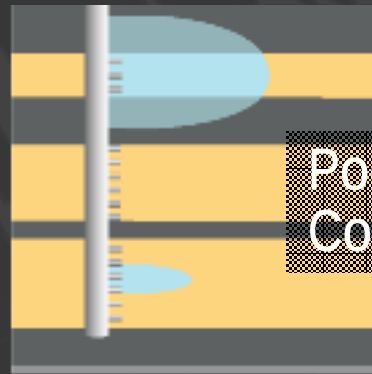
- I. Introduction
- II. Microseismic Technology and Deployment
- III. Application of MS Technology
- IV. Applying MS mapping in Egypt
- V. Conclusions
- VI. Questions

Introduction

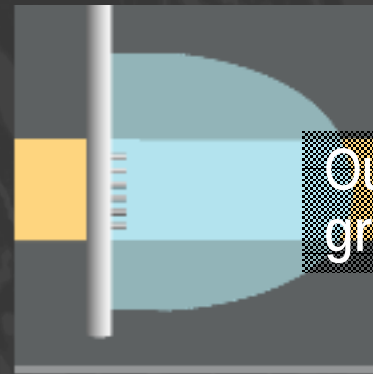
The Evolution of Hydraulic Fracturing

- First Frac was in 1947
- Rapidly proved to be one of the most cost effective production enhancement techniques
- Tremendous advancements made since inception:
 - Equipment
 - Designer Fluids and Proppants
 - Wide Range of Applications
 - Most reservoirs could benefit from placing an optimally designed stimulation
 - Over 70% of wells in North America Frac
 - Stimulation Models
 - Now most of the models are 3D
 - Pressure matching
- What is Missing?

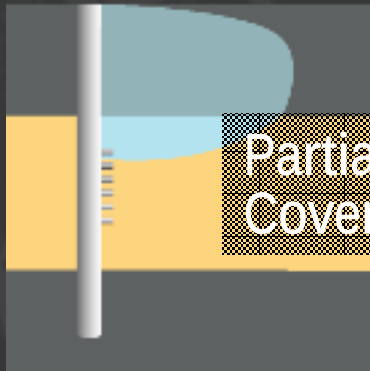
We Know Everything About Fractures Now Except...



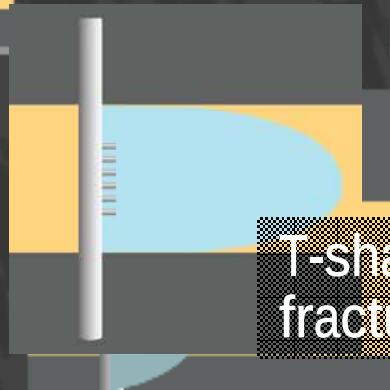
Poor Interval
Coverage



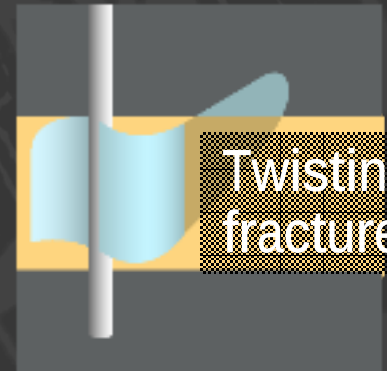
Out-of-zone
growth



Partial Zonal
Coverage

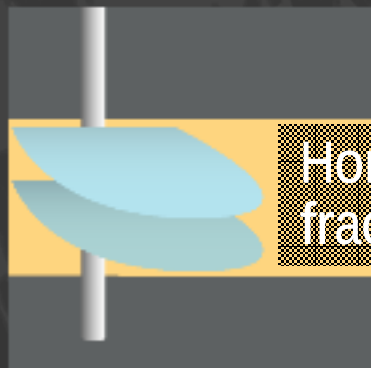


T-shaped
fractures

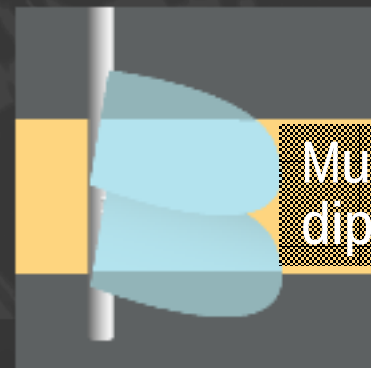


Twisting
fractures

Perfectly confined frac



Horizontal
fractures



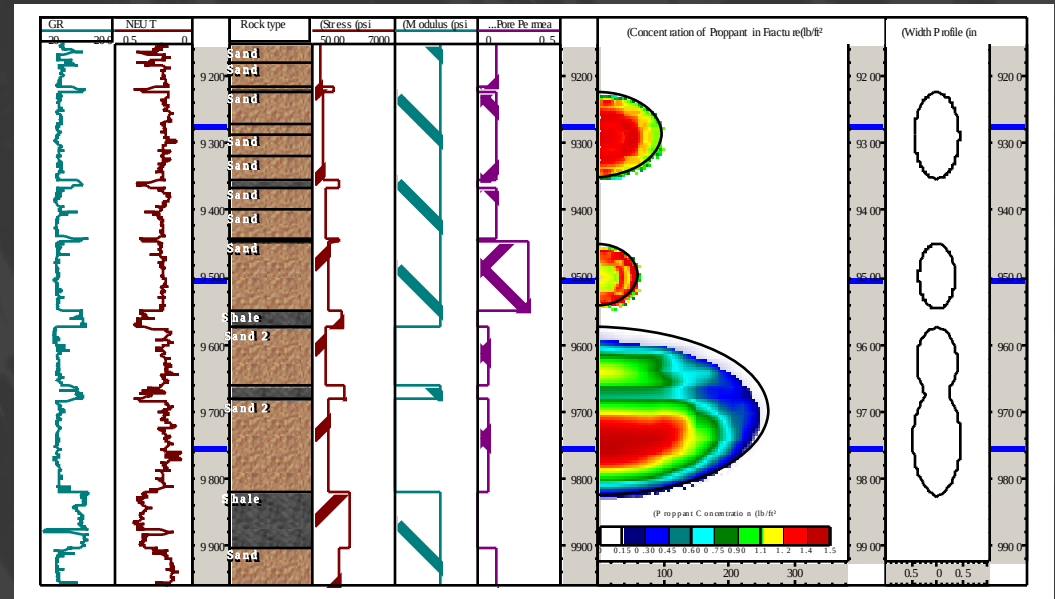
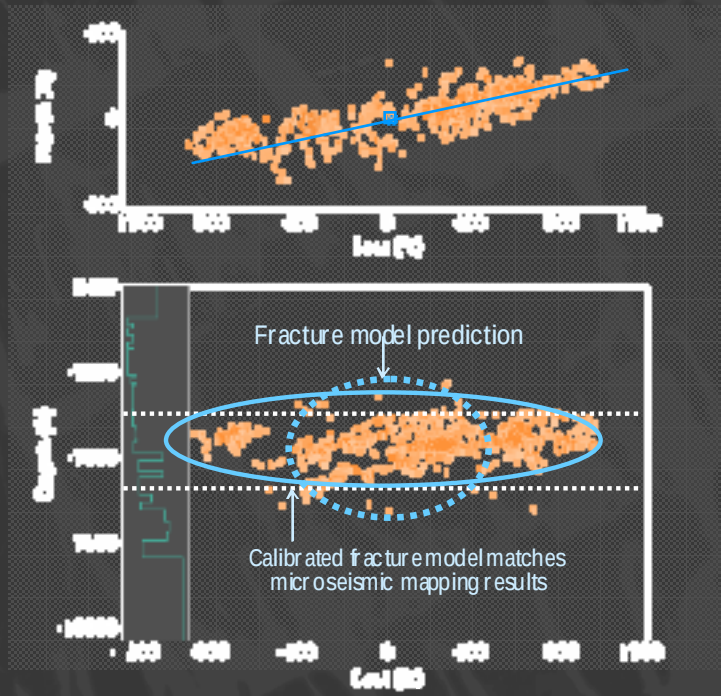
Multiple fractures
dipping from vertical

We Know Everything About Fractures Now Except...

The fracture half-length,
the fracture height,
the fracture orientation,
and
the fracture location once it leaves the
wellbore

Fracture Mapping (Monitoring)

The Current Advancement Frontier Technology for Fracturing



What are the actual dimensions of the fracture and where is it located?

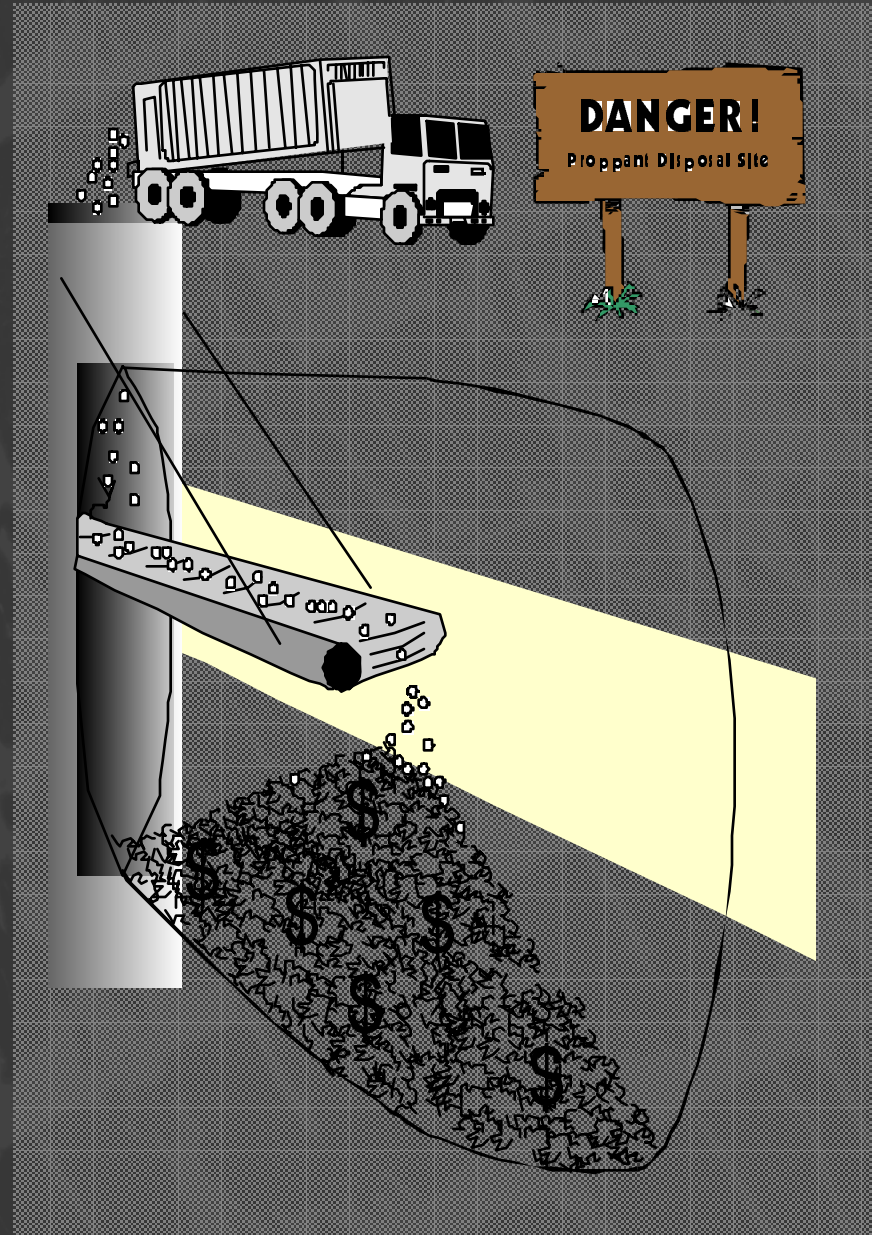
Far-field Fracture mapping technologies for answering this question are now where the most important advancements are being made in hydraulic fracturing.

Motivation for Frac Engineering & Diagnostics

Hydraulic
fracturing is
done for well
stimulation

NOT

for proppant
disposal



Microseismic
Far-Field Fracture
Acoustic, Micro-Earthquake,
Monitoring
Passive Seismic Monitoring

The background image is a composite. The top portion is an aerial photograph of an oil field in a grassy, hilly area. Three wells are visible, each with a tall derrick and a circular pad. A central processing facility with various tanks and equipment is located between the wells. The bottom portion is a geological cross-section showing different rock layers. Several vertical lines represent wellbores. Yellow wavy lines, representing seismic waves, are shown propagating from a point labeled 'Pinnacle' in the lower left towards the right. The text is overlaid on a dark, semi-transparent rectangular area in the center of the cross-section.

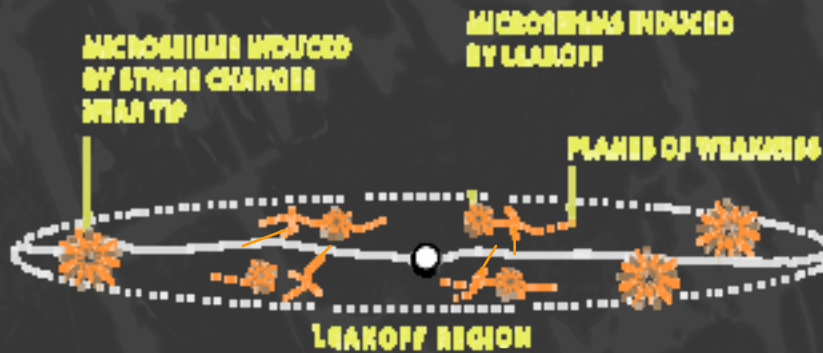
Pinnacle

Microseismic Technology and Deployment

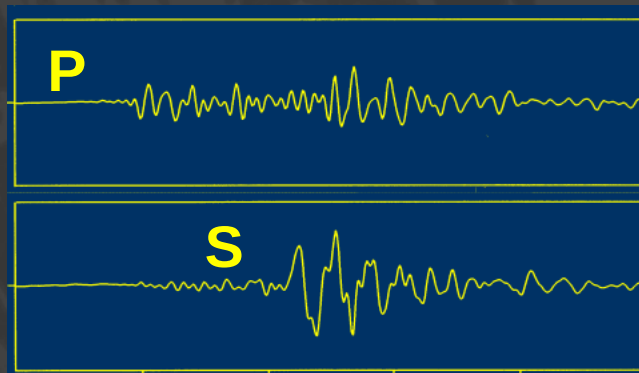
Microseismic Mapping

Concept/Principle

Microseisms Originate in an Envelope Surrounding the Fracture

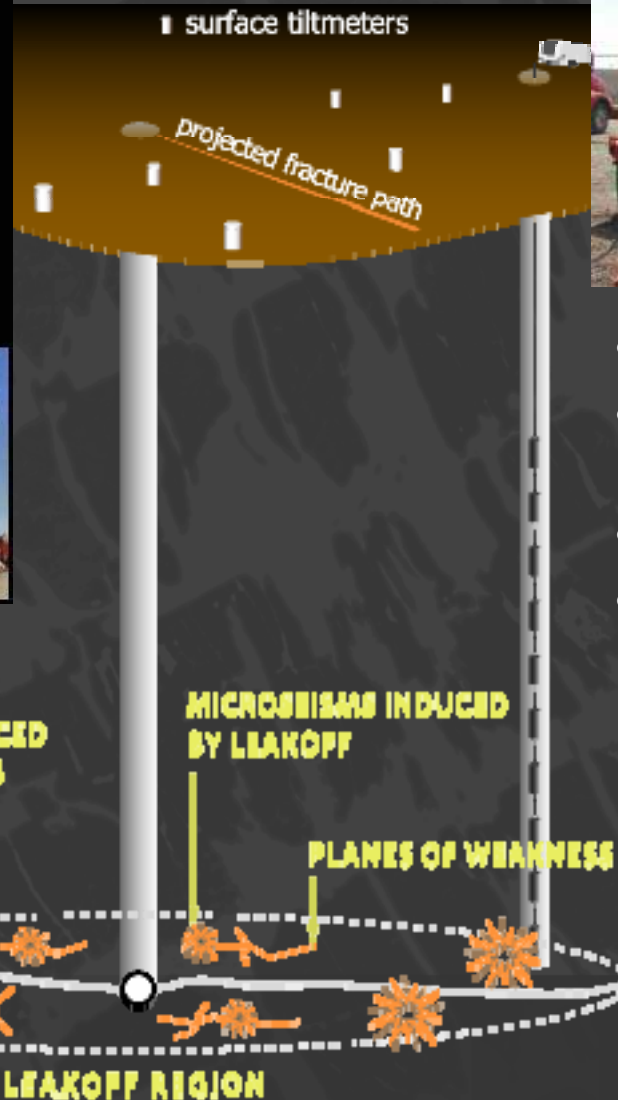


- Slippage Emits Both P & S Waves (Compressional & Shear)
- Velocities Are Different
P Wave > S Wave
- Detected At Tri-Axial Receiver

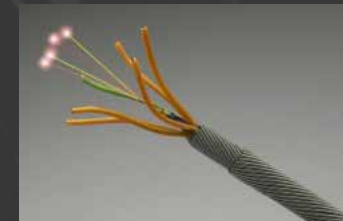


Microseismic Mapping

Obtaining Data From an Offset Observation Well



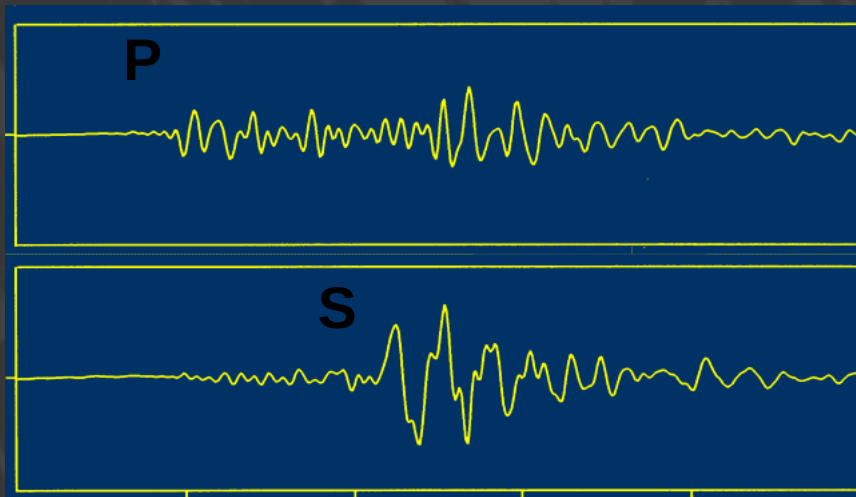
- Fiber optic wireline
- 12-20 Levels, 3 Component Sensors
- Mechanically Coupled
- Can be deployed under pressure



Microseismic Mapping

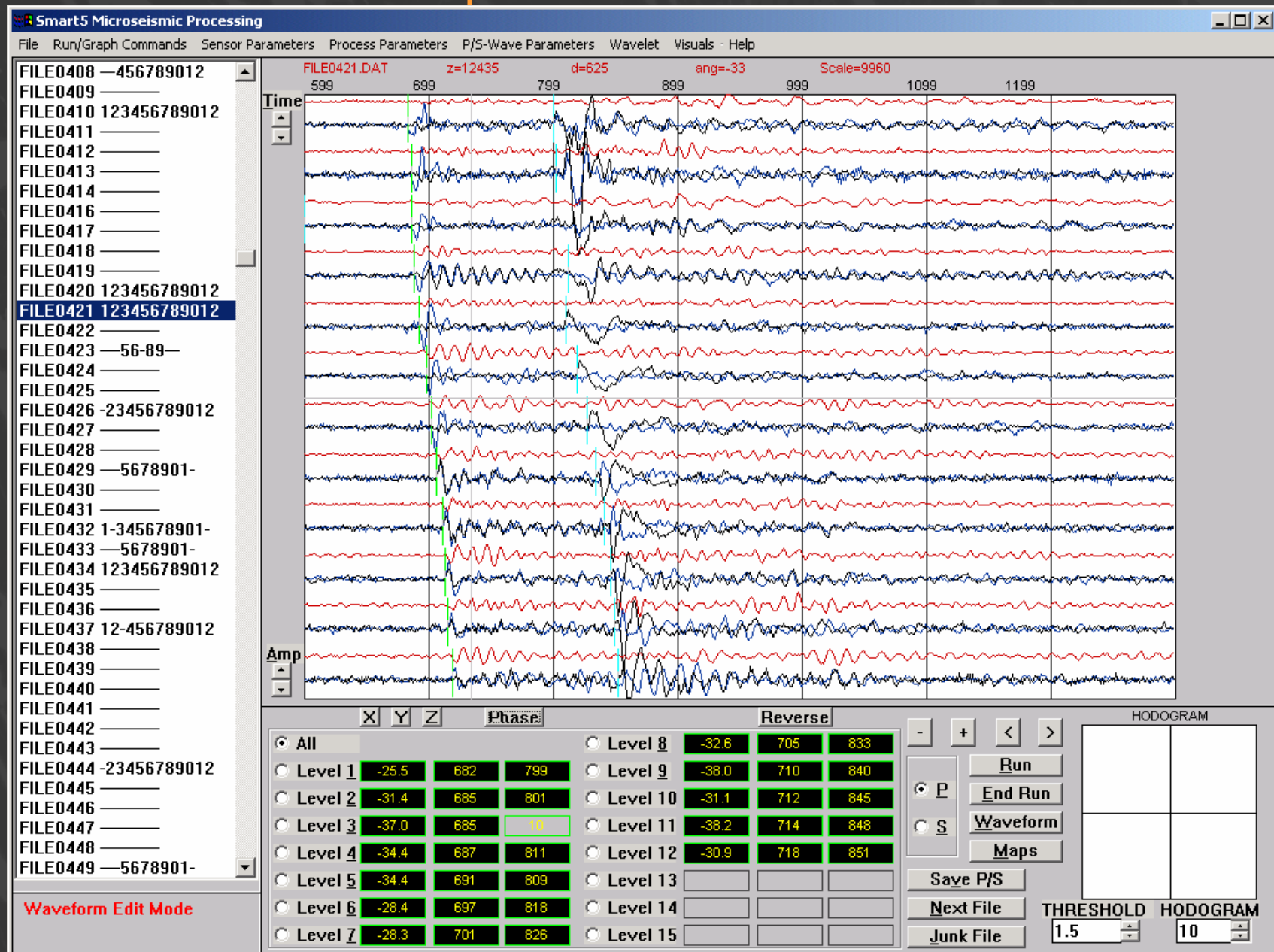
Determining Distance and Elevation

- Slippage Emits Both P & S Waves (Compressional & Shear)
- Velocities Are Different
P Wave > S Wave
- Detected At Tri-Axial Receiver



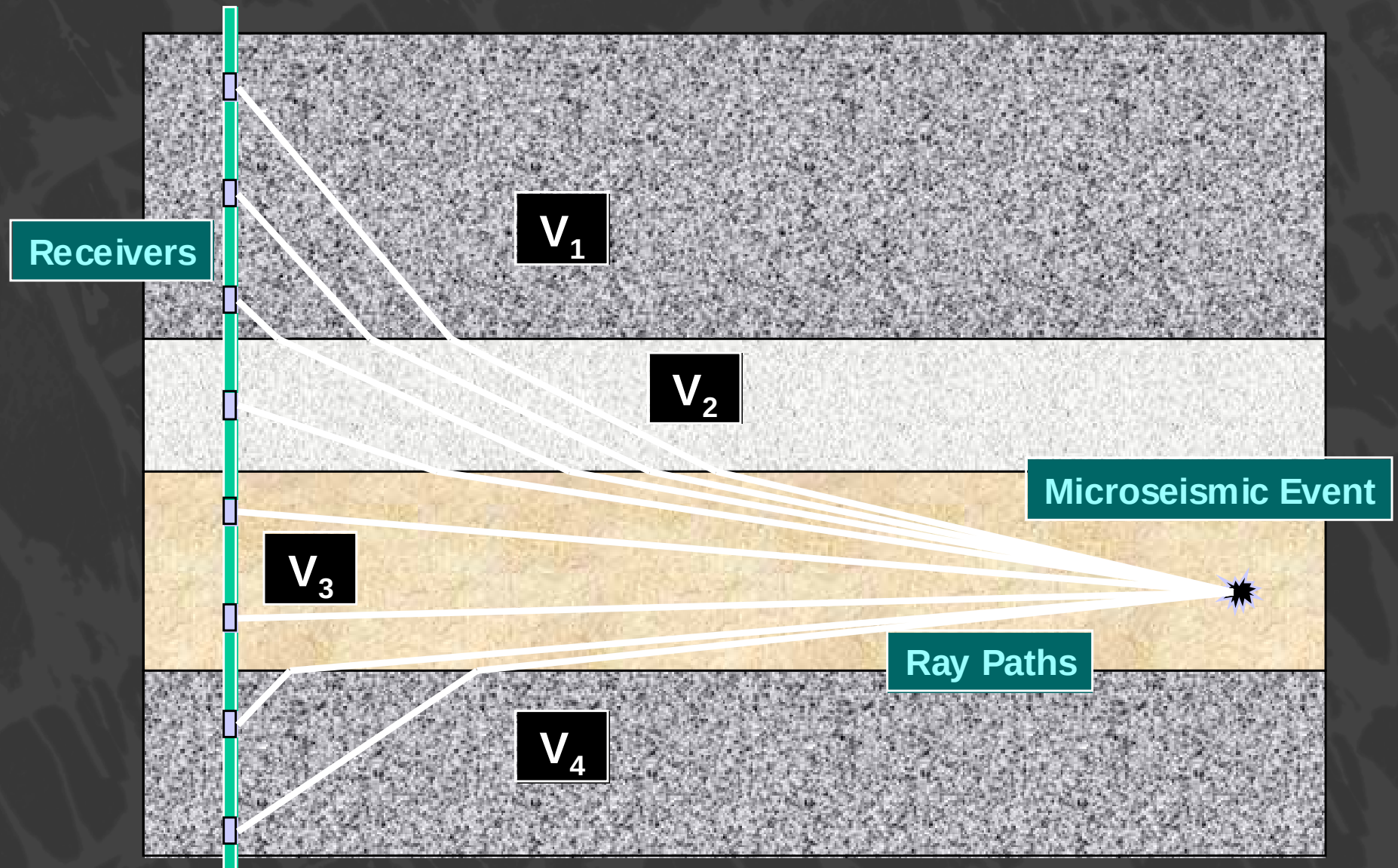
Microseismic Mapping

Example Recorded MS Event



Microseismic Mapping

Velocity Model



Microseismic Mapping

Azimuth Determination

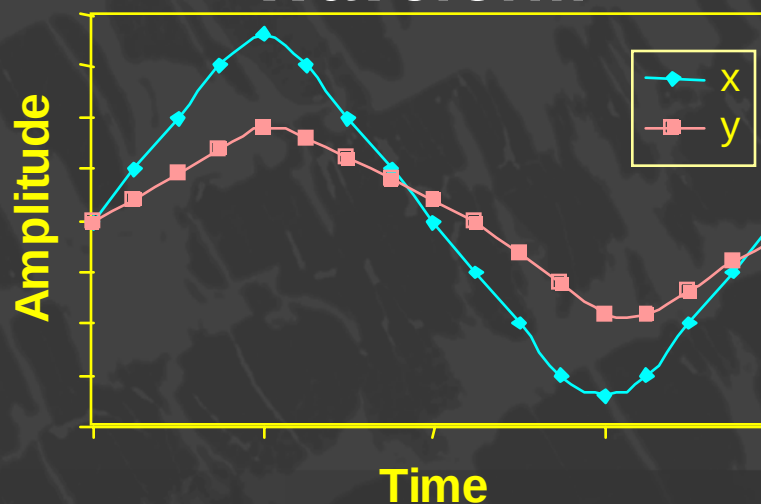
The Direction to a Microseismic Source Is Found by Examining the Particle Motion of the P Wave, Which Is Always Directed Radially Outward from the Source.

While Many Techniques Are Available to Determine the Direction, the Simplest Representation Is a Hodogram, which is a Crossplot of the Amplitudes.

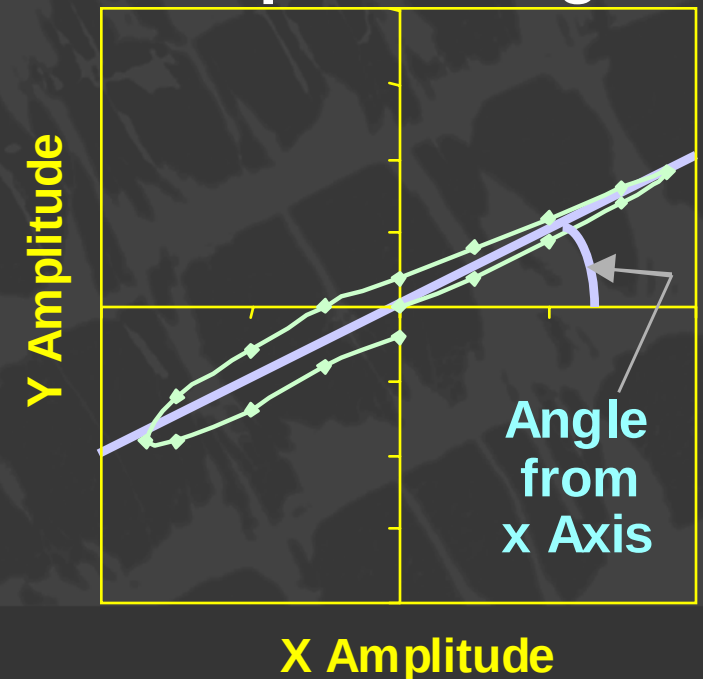
t	x	y
0	0	0
1	10	4
2	20	9
3	30	14
4	36	18
5	30	16
6	20	12
7	10	8
8	0	4
9	-10	0
10	-20	-6
11	-30	-12
12	-34	-18
13	-30	-18
14	-20	-14
15	-10	-8
16	0	-4

← Data

Waveform

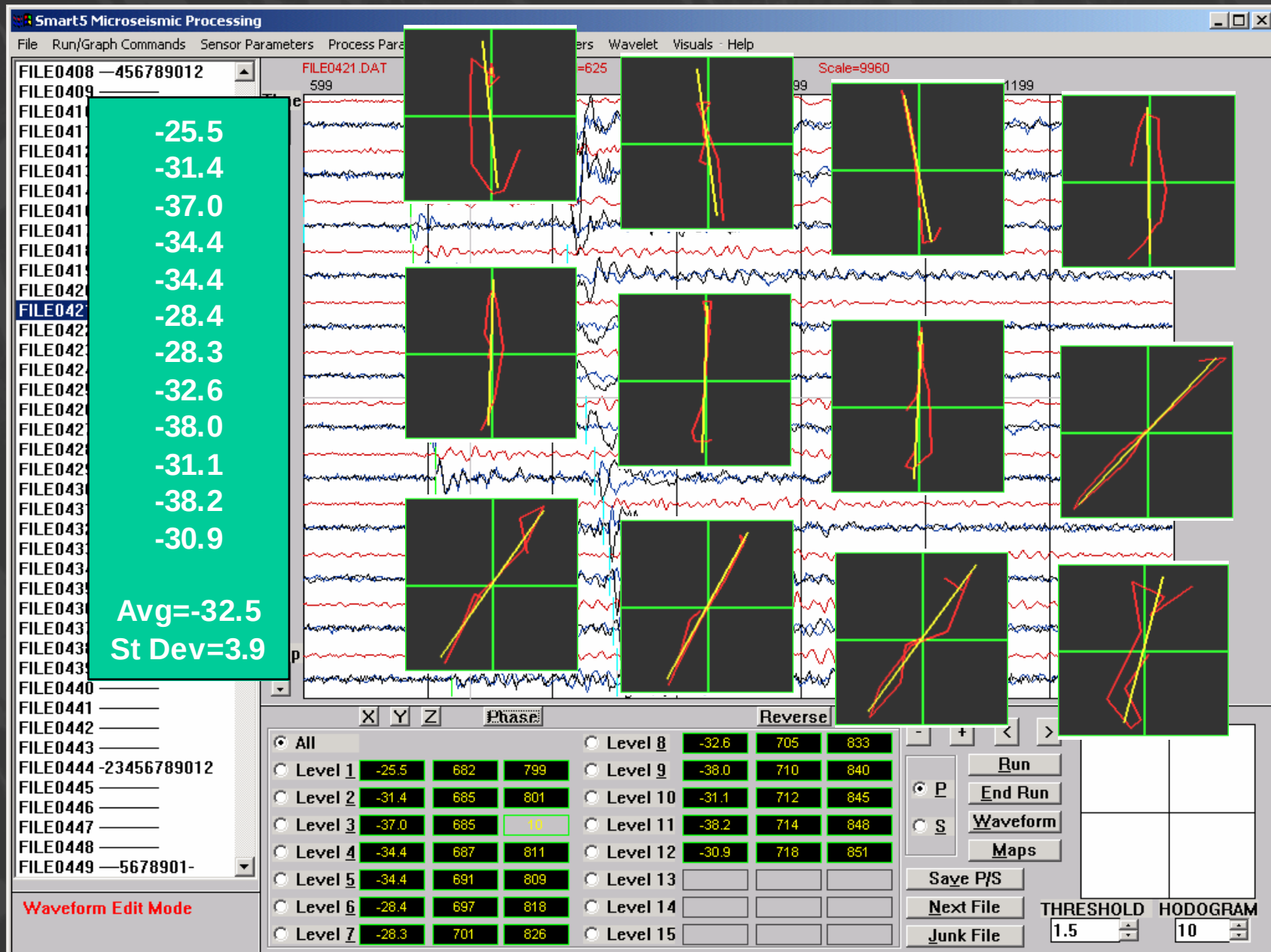


Example Hodogram



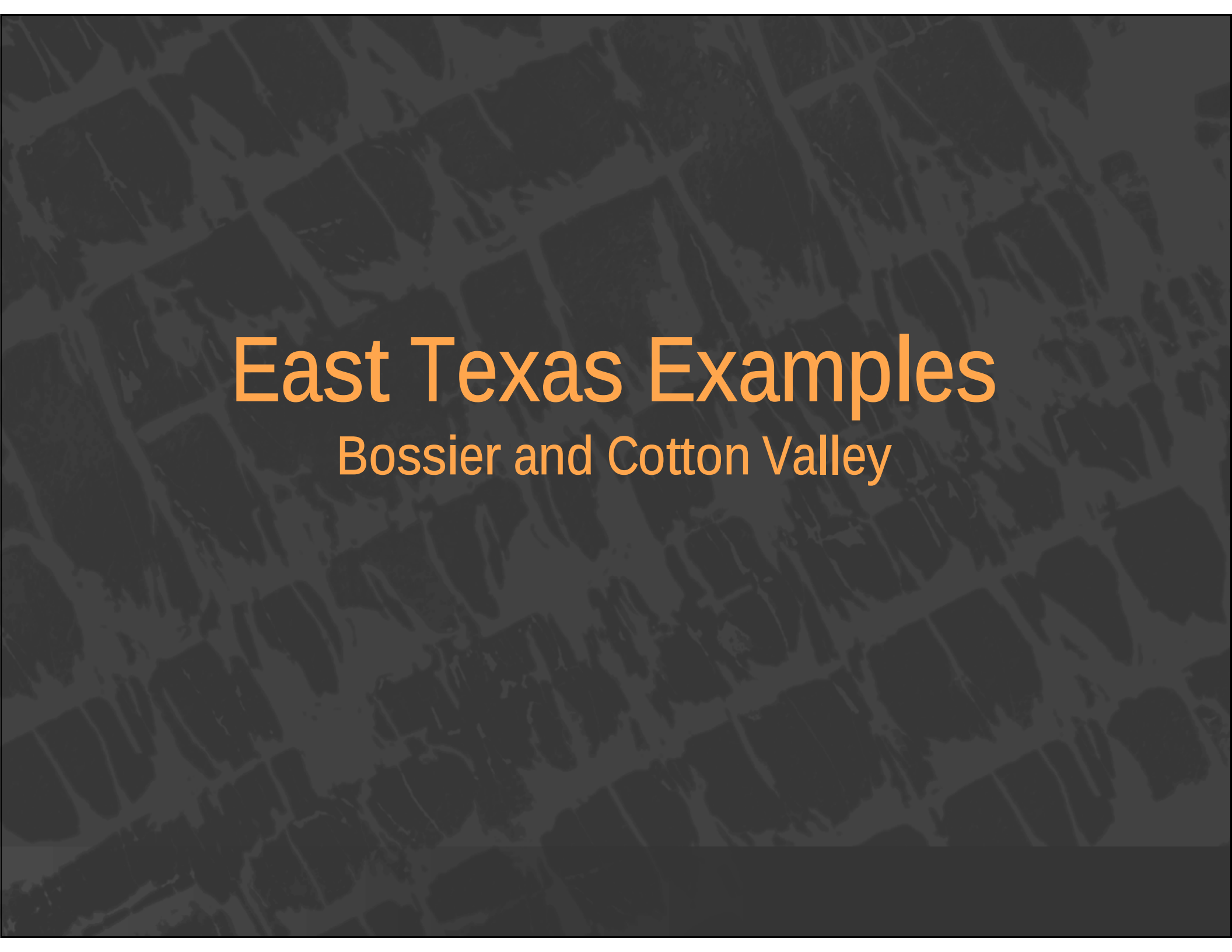
Microseismic Mapping

Hodogram Analysis



Applying Microseismic Mapping

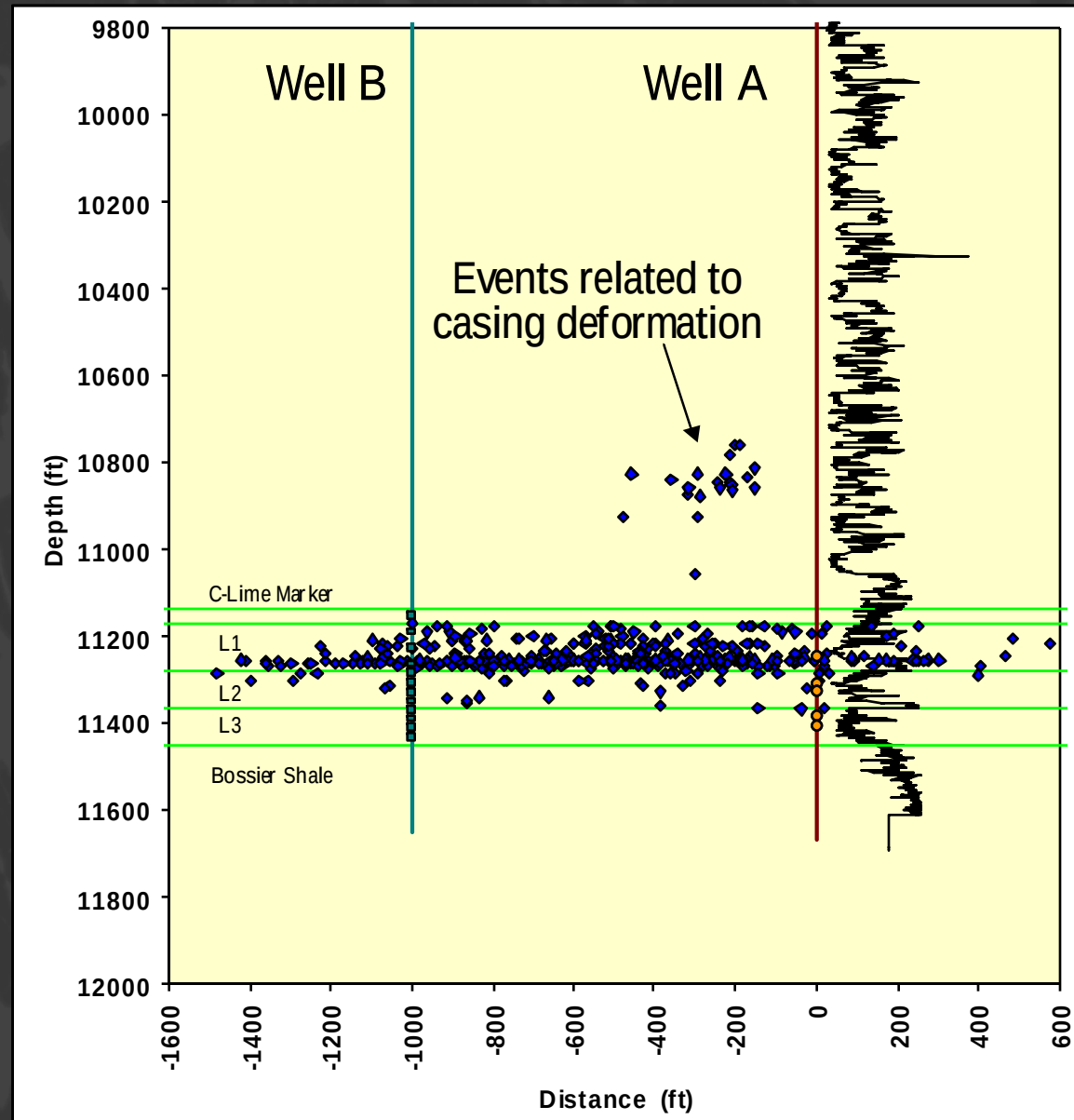
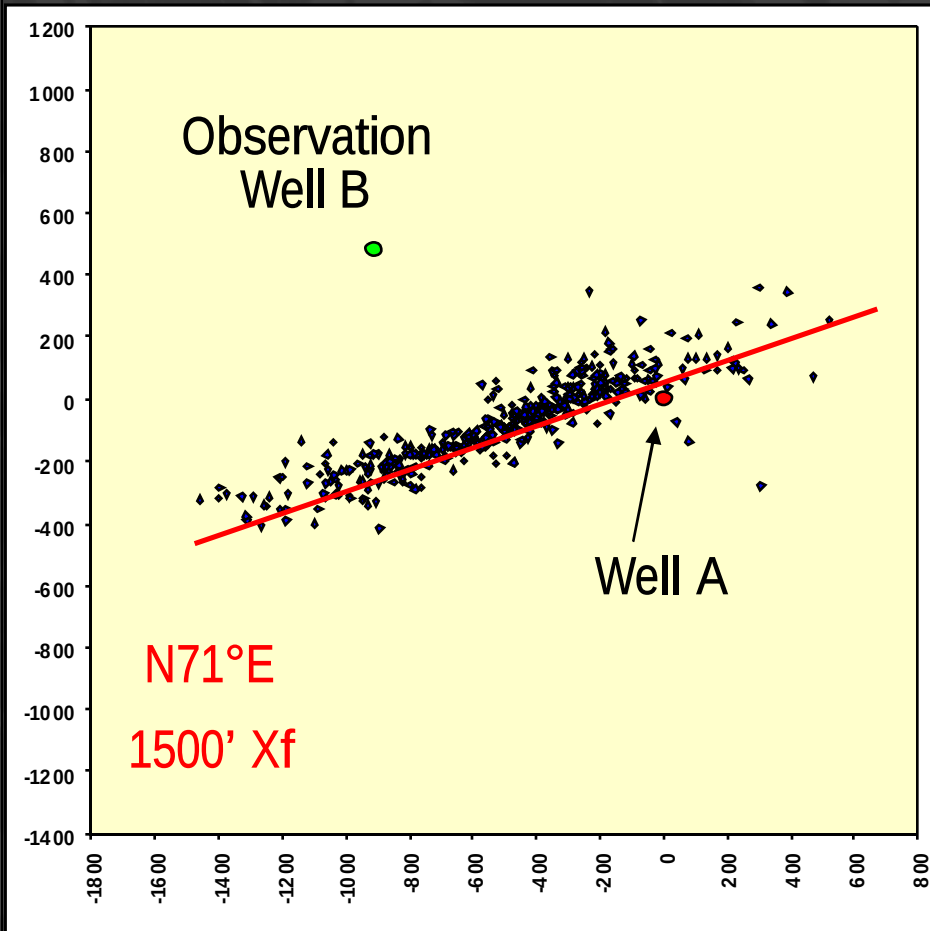
Determining Fracture Growth

An aerial photograph of a cotton field, showing a grid-like pattern of rows of cotton plants. The plants are dark green, and the rows are separated by lighter, bare soil. The perspective is from directly above, looking down at the field.

East Texas Examples

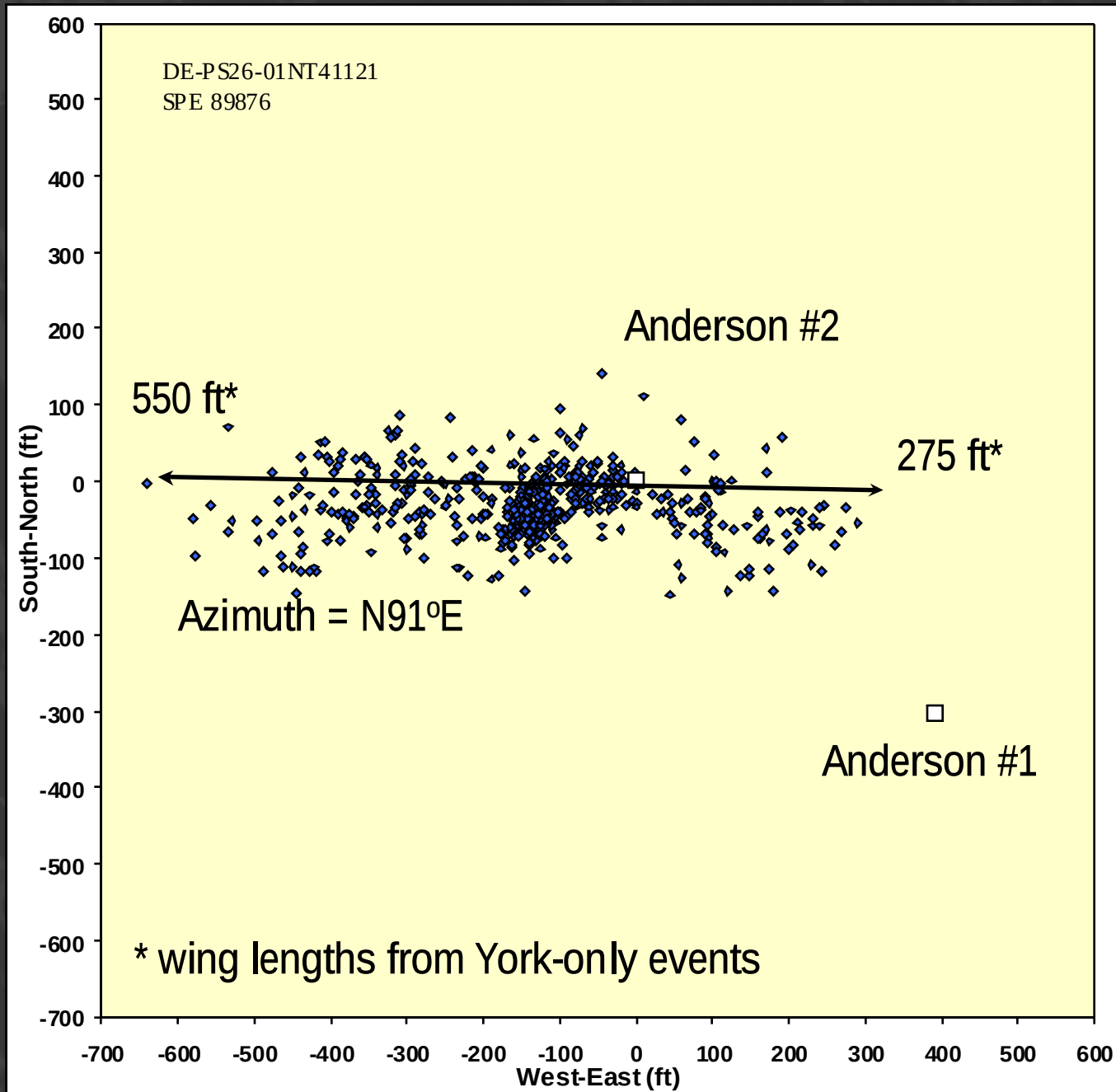
Bossier and Cotton Valley

Microseismic Mapping Results – Taylor Sands



APC Anderson #2

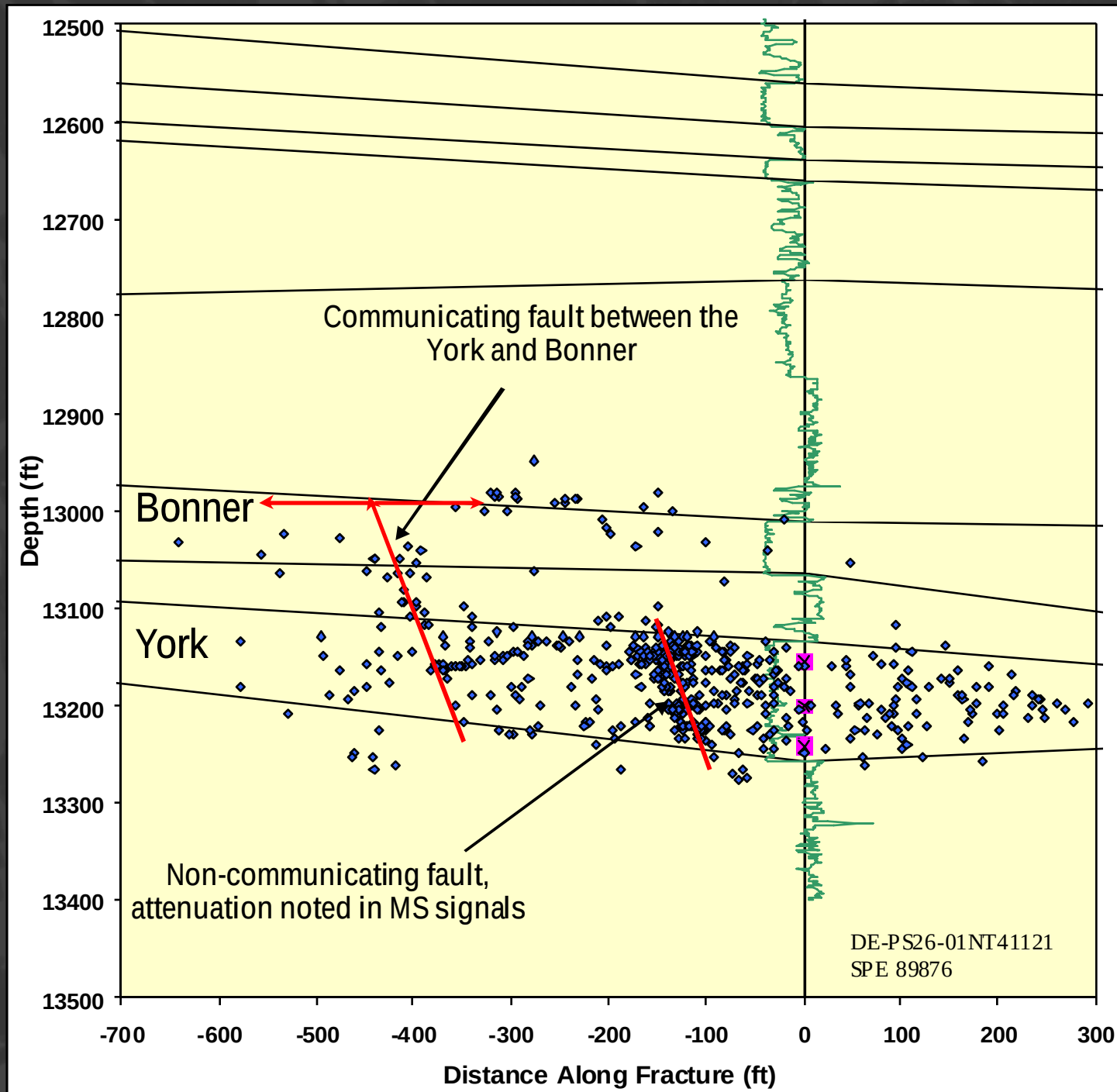
York Frac – Map View



SPE 84876

APC Anderson #2

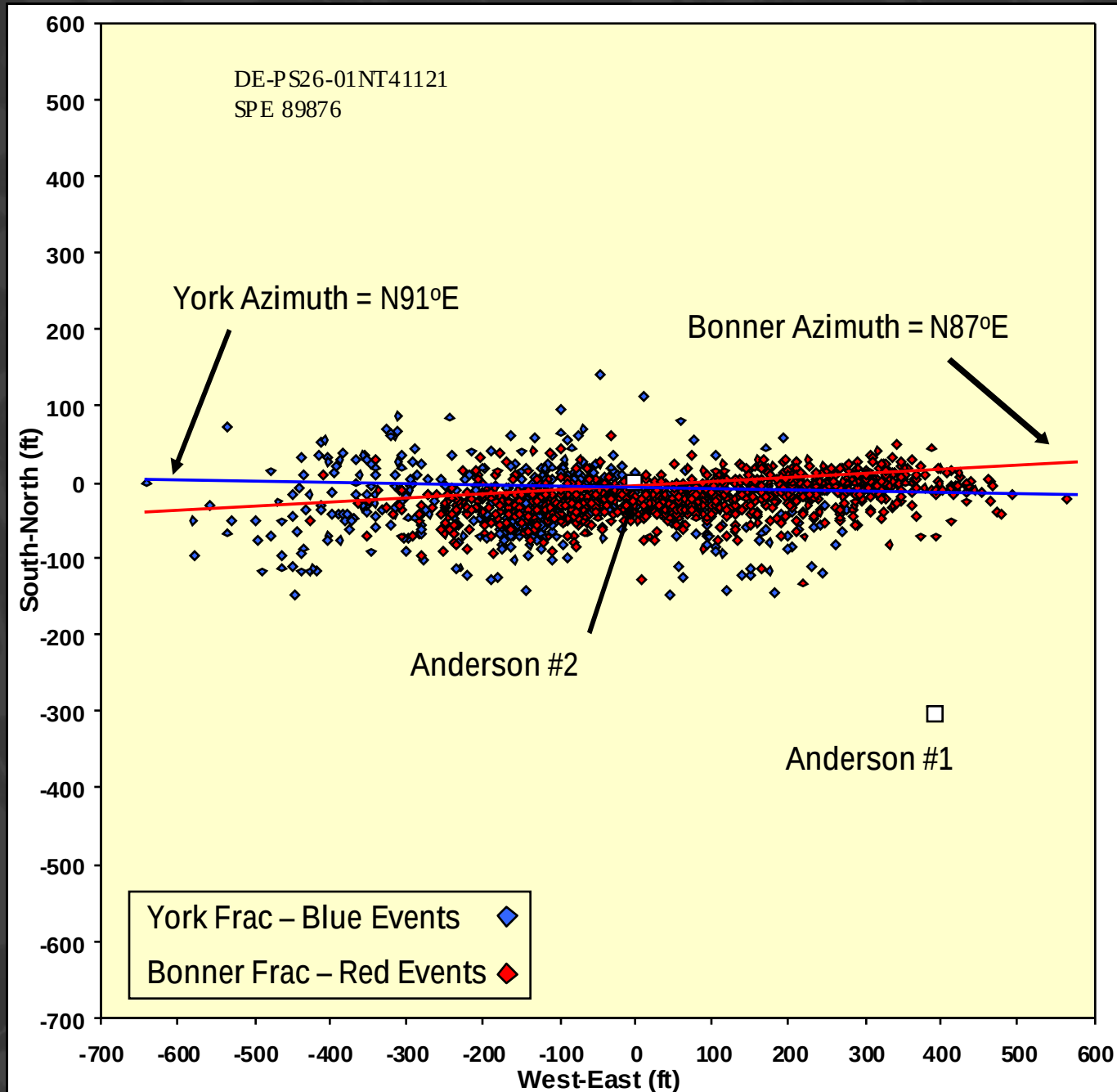
York Frac – Side View



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APC Anderson #2 Map View

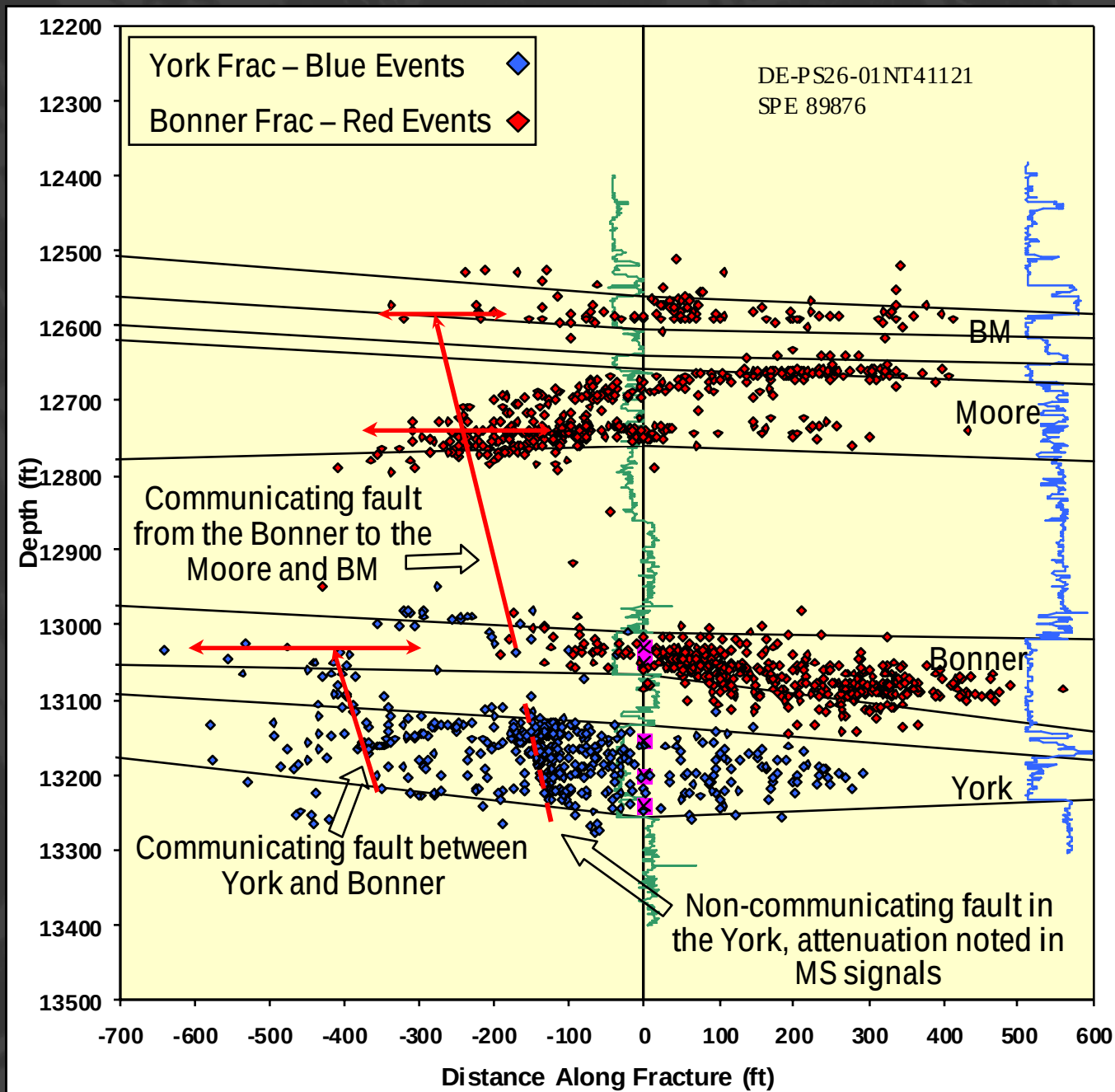
York and Bonner Fracs



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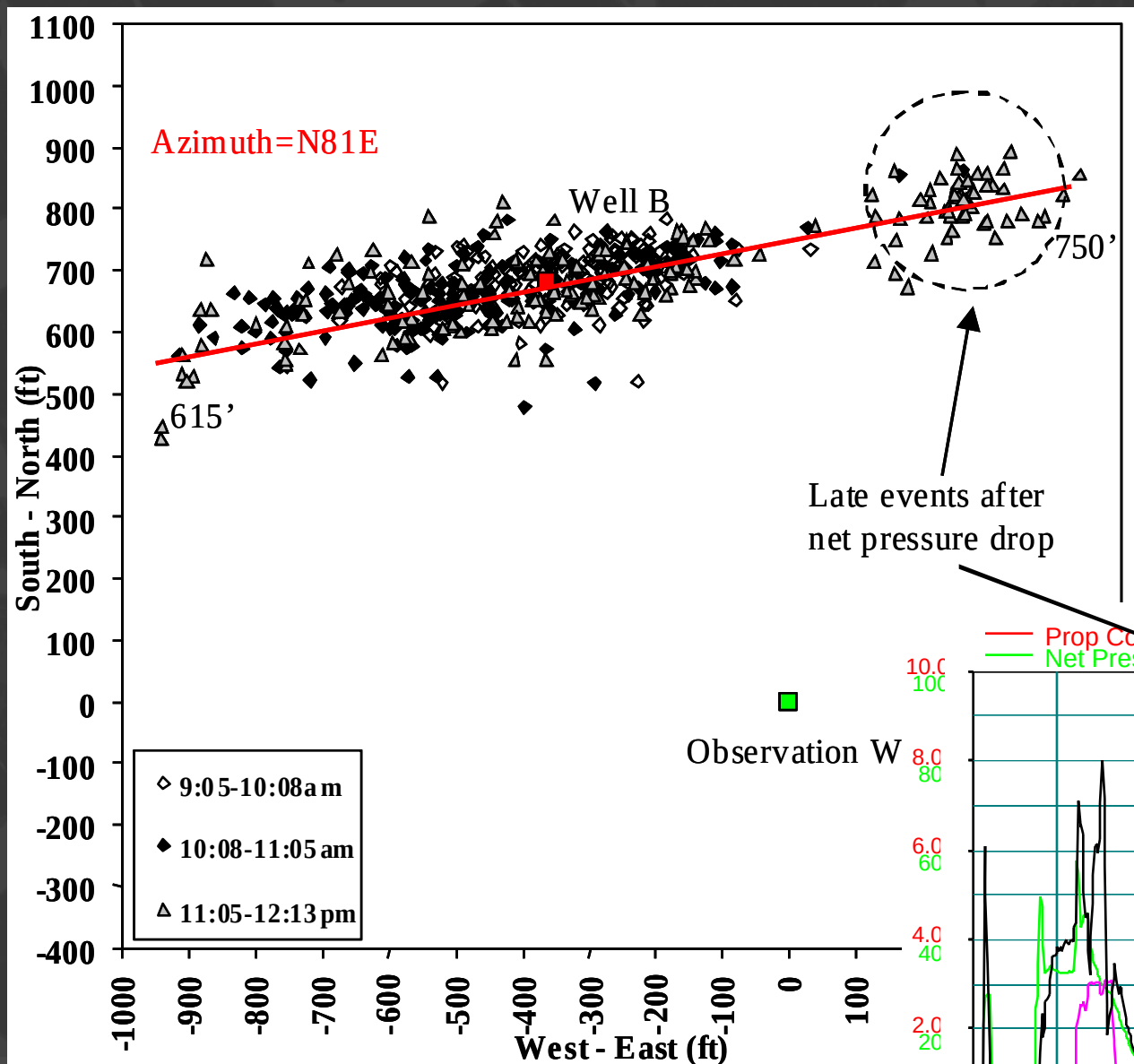
APC Anderson #2 Side View

York and Bonner Fracs

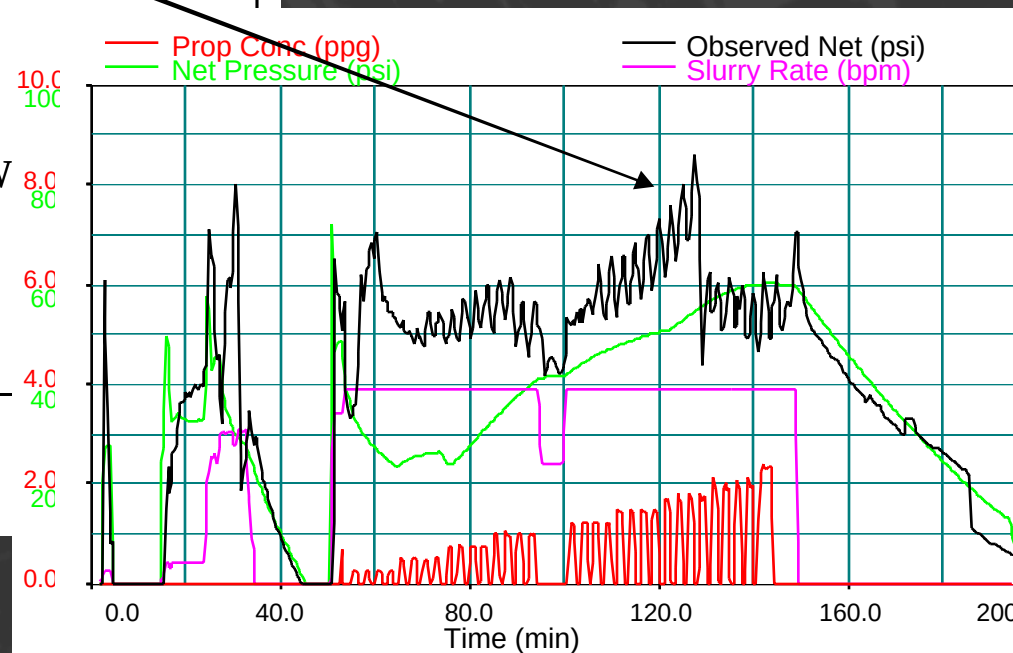


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Plan View Well B Stimulation

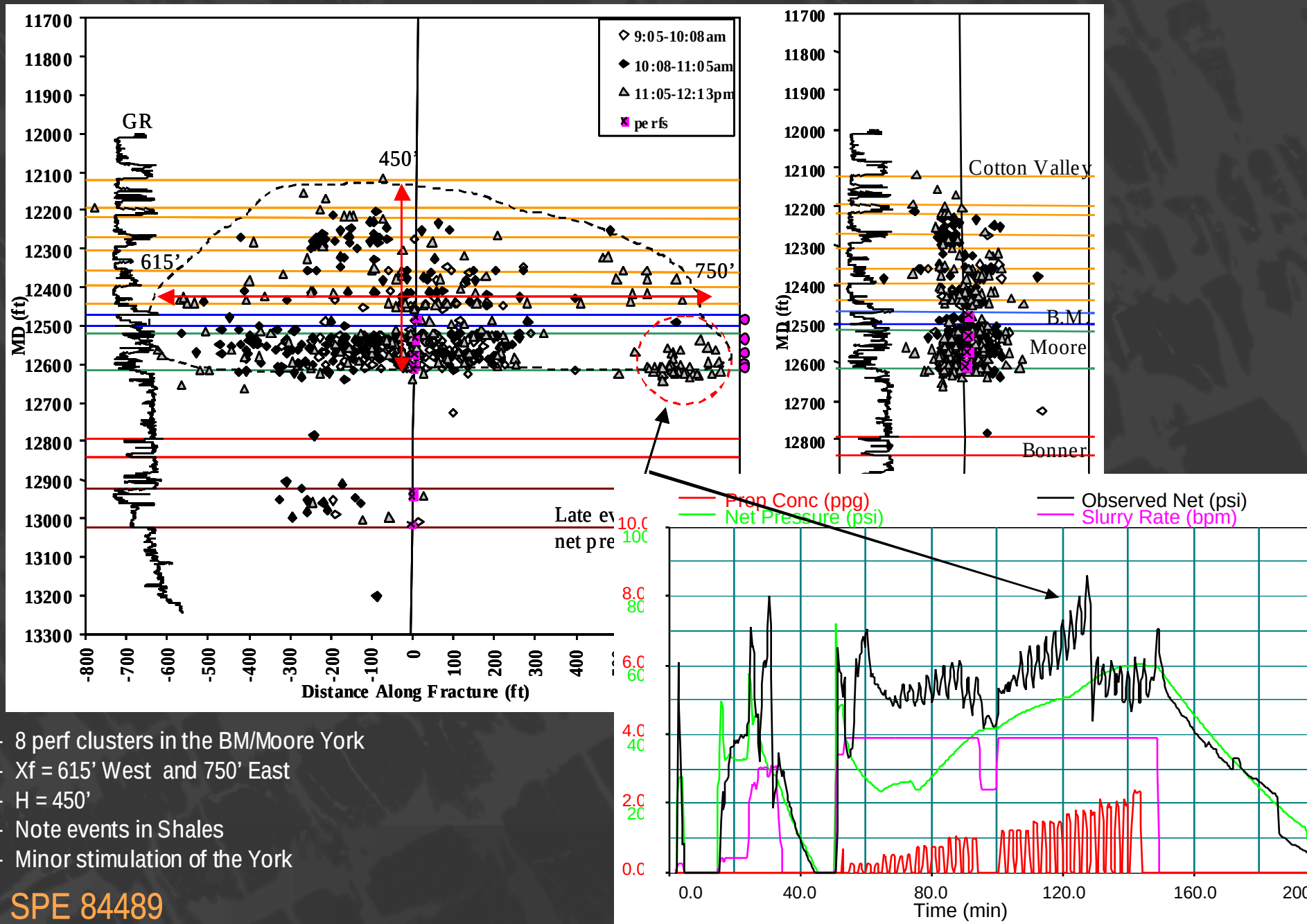


Xf = 615' West and 750' East



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Side/Edge View Well B



Applying Microseismic Mapping

Model Calibration

Fracture Model Calibration?

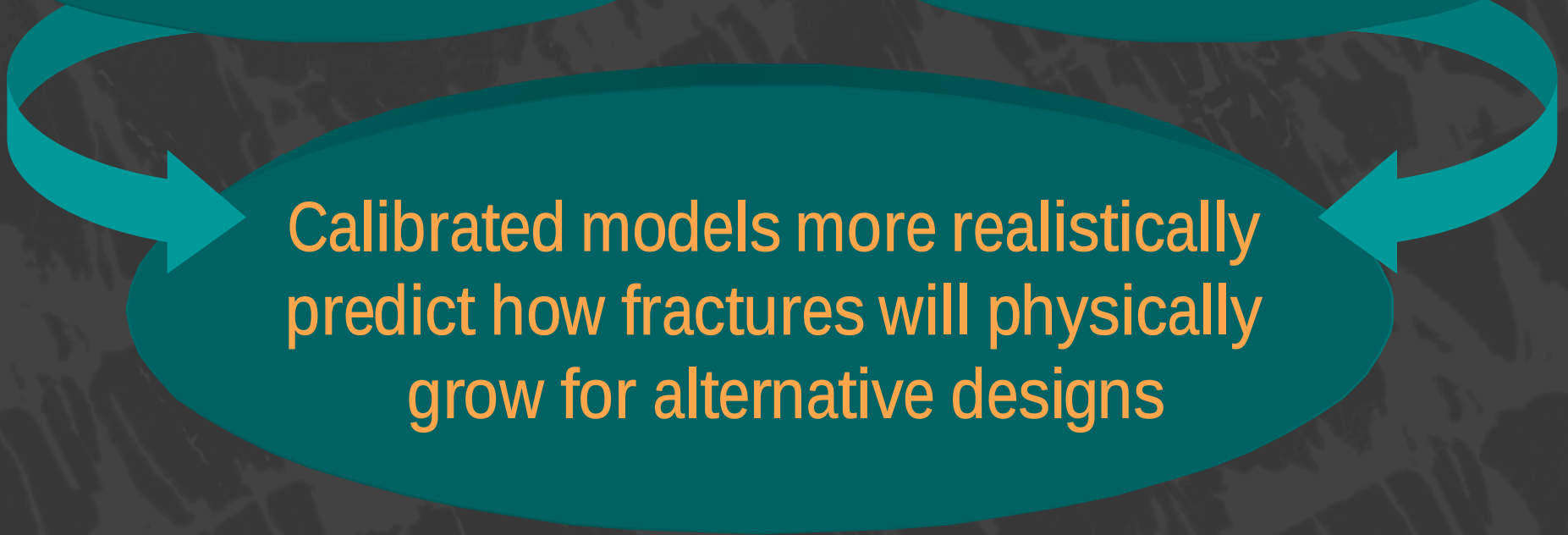
History match the OBSERVED net pressure responses with the DIRECTLY measured fracture dimensions using a 3D fracture simulator to develop a reliable tool for understanding and predicting fracture growth.

Modeling Versus Measuring

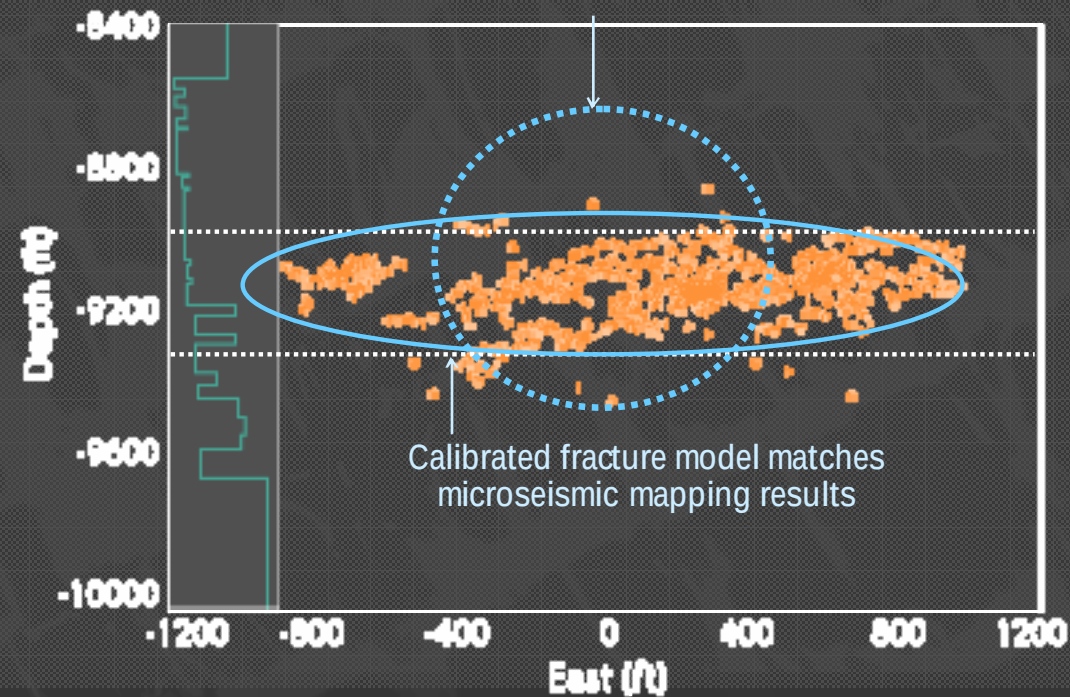
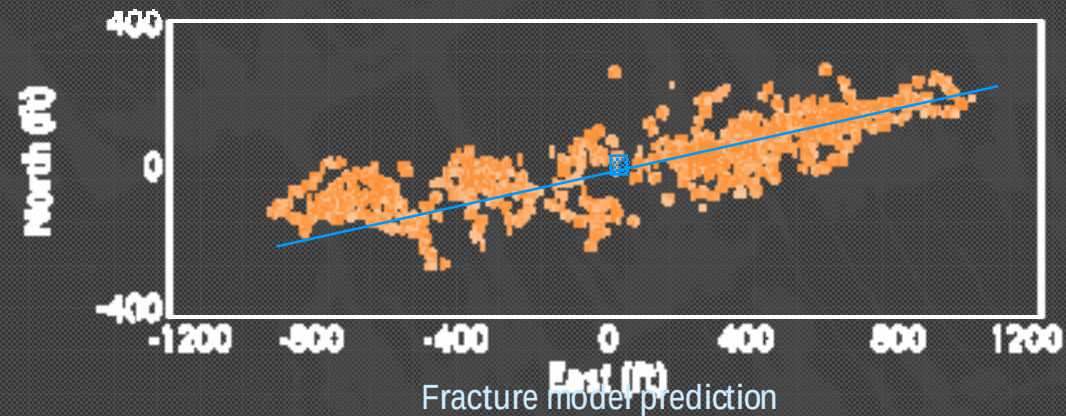
Fracture growth models
incomplete physical
understanding

Direct diagnostics
not predictive

Calibrated models more realistically
predict how fractures will physically
grow for alternative designs

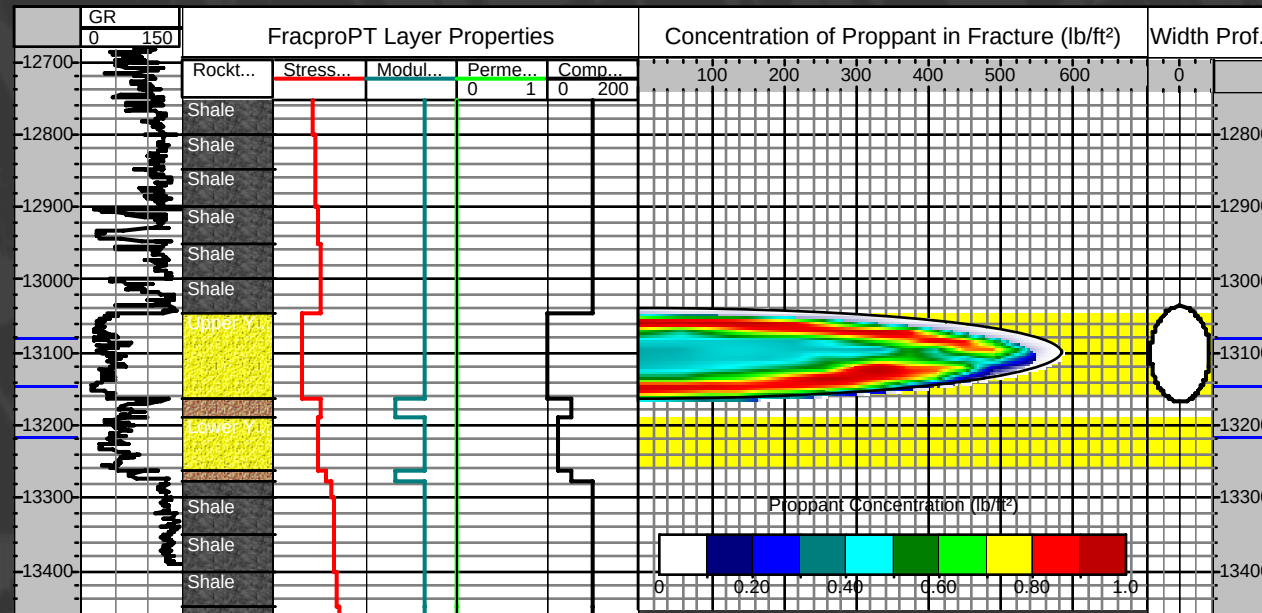
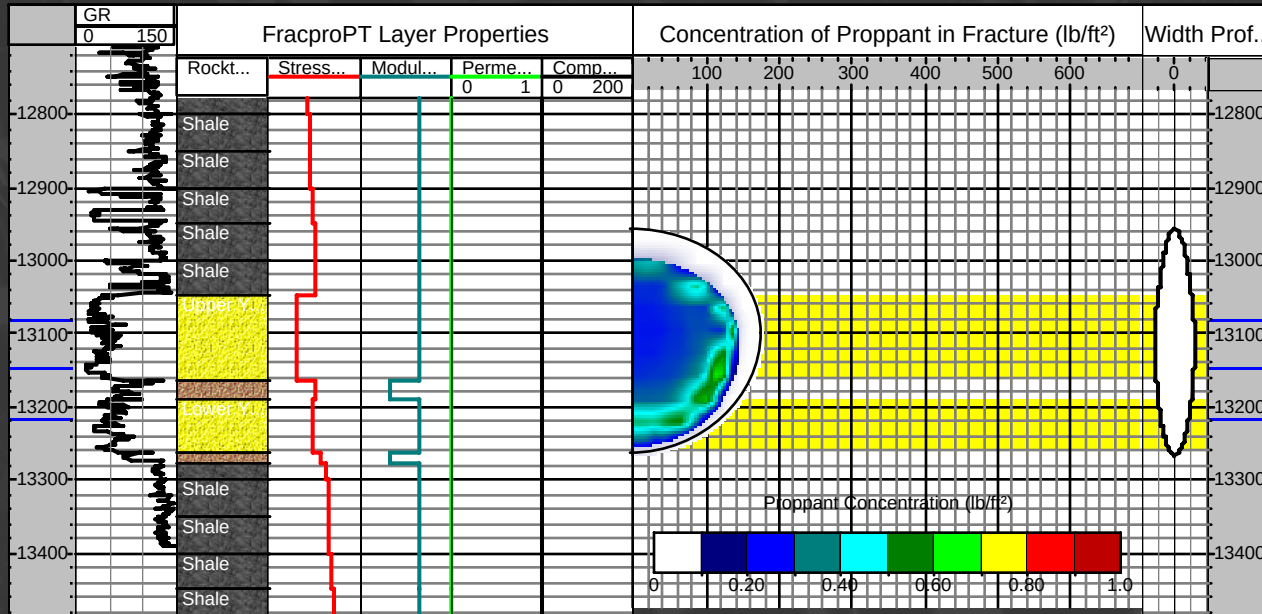


Microseismic Fracture Mapping Cotton Valley Sandstone



Bossier Sand

Calibrated Modeling Results for Well C

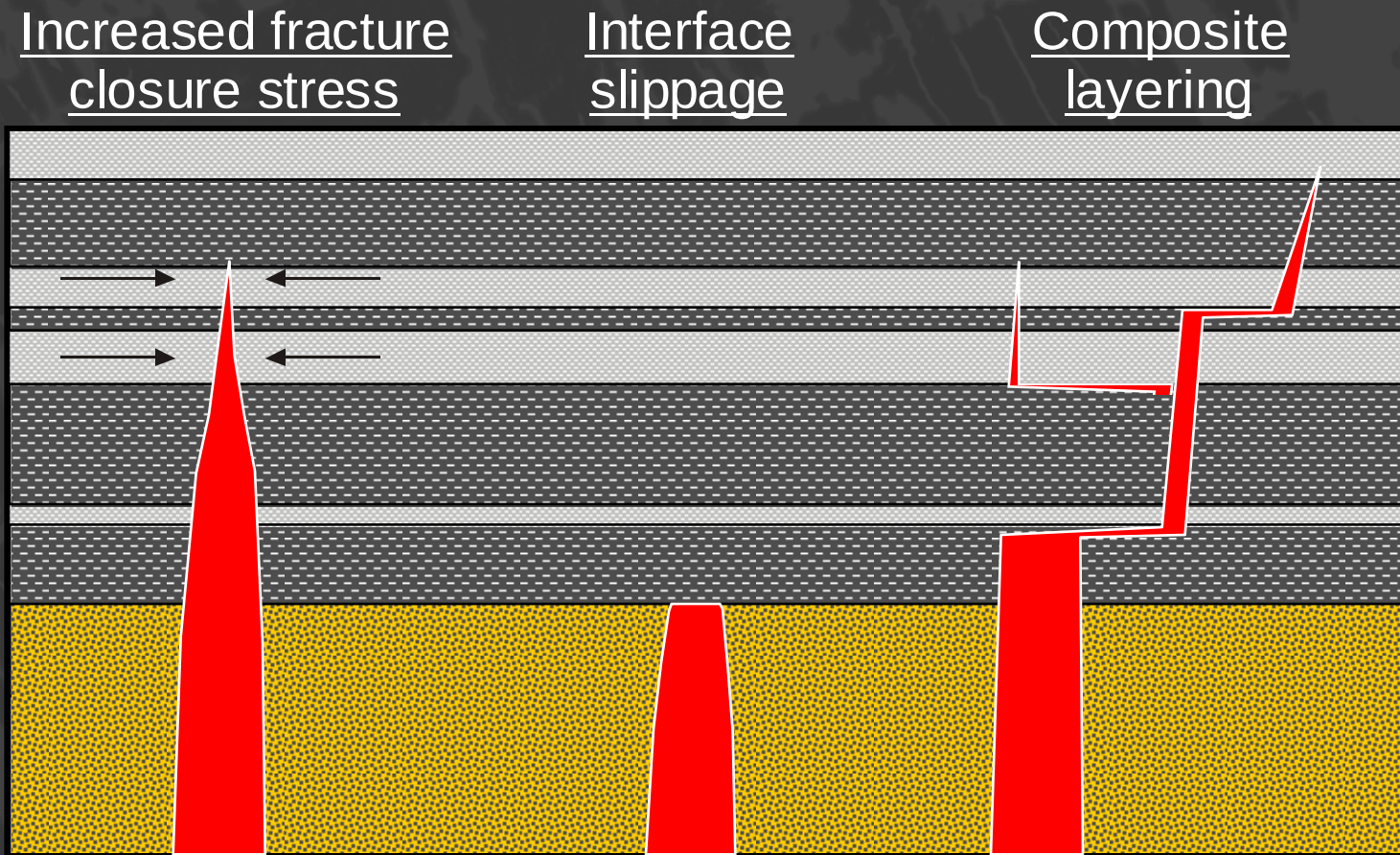


More confinement than can be attributed to stress contrast, permeability or modulus.

- Composite layering
- Width decoupling

Confined Fracture Height Growth

- Hard to explain confinement with current “essential physics” if
 - Net fracturing pressures are higher than measured/estimated closure stress contrasts
 - No known “permeability barriers” exist
- Is there another containment mechanism?



FRACTURE COMPLEXITY

HYDRAULIC FRACTURE
MINEBACK



Applying Microseismic Technology In Egypt

Can it be applied in Egypt?

Reservoirs Where Microseismic Mapping has Been Successfully Applied

Oil/Gas/Geothermal/Disposal

Lithologies

- Granites (Geothermal)
- Shales
- Sandstone/Shale
- Carbonates
- Coal Bed Methane
- Chalk
- Unconsolidated Sands

How Far Can Microseismic See?

Microseismic Observation Distance

- Range from <100m to over >>1,500m
- Observation Distance Depends on:
 1. Size (Amplitude) of the Microseism
 - Formation
 - Treatment size and rate
 2. Attenuation
 - Formation property
 3. Background noise
 - Quiet Wellbore
 - Field Activities
 - Same pad operations

How Far Can Microseismic See?

Actual Observation Distances:

• Granites (Geothermal)	>>1500m
• Shales	900 - 750m
• Sandstone/Shale	350 - 450m
• Carbonates	300m
• Coal Bed Methane	250m
• Chalk	<100m*
• Unconsolidated Sands	<100m*

* Long-term reservoir monitoring has seen significantly large observation distances

Conclusion

Microseismic Mapping Can Be Successfully Applied in Egypt

- Same limitations as found in the North America
- Must find suitably near observation wells
- There is not a technology problem
- Must mobilize specialized FBO equipment to Egypt
- Need technology leader (early adopter) to decide to do this in Egypt

The Egyptian Western Desert Should Work Well

- Typical Sand/Shale sequences
- Reasonably large treatments
- Not same pad operations (low noise levels)
- Would anticipate observation distances of ~450m

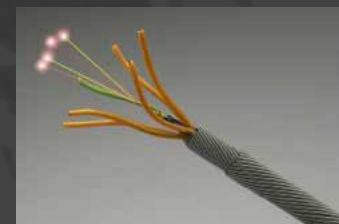


Questions?

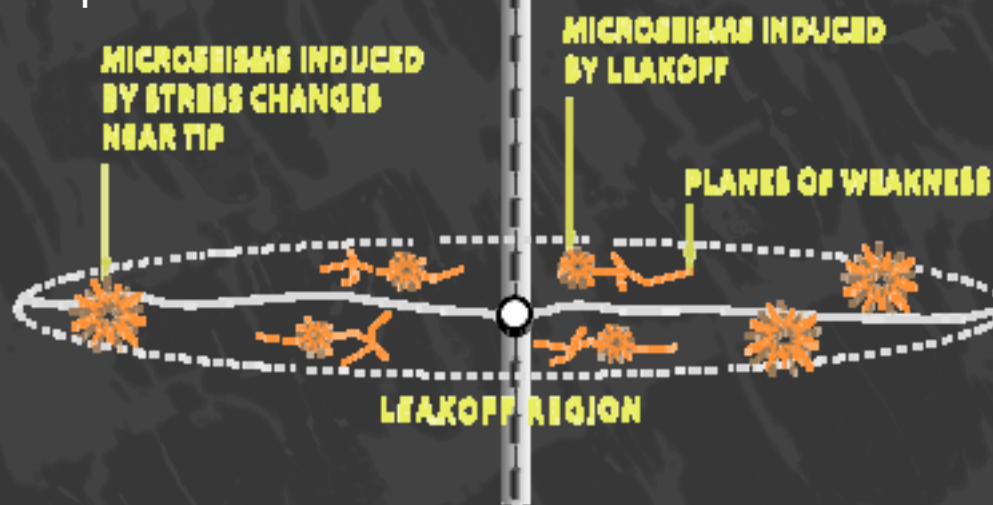
Future Advances

Microseismic Mapping From an Active Treatment Well

Currently only Available in North America



- Fiber optic wireline
- Mechanically Coupled geophones using blocks
- Typically run 10 tools with ~200' aperture
- Only obtain usable data during SI time
- Tools run pulled under pressure



Microseismic Mapping From A Horizontal Well

Currently only Available in North America



Gravity Coupled geophones using blocks

Typically run 5 tools with ~700' aperture



Deployed on tractor

Can also be done on treatment wells

