

Microseismic, 3D, and Log Image Data for Unconventional Targeted Drilling and Treatment*

Mark Houston¹

Search and Discovery Article #41135 (2013)**
Posted June 30, 2013

*Adapted from oral presentation given at Pacific Section AAPG, SEG and SEPM Joint Technical Conference, Monterey, California, April 19-25, 2013

**AAPG©2013 Serial rights given by author. For all other rights contact author directly.

¹VSFusion a Baker Hughes-CGG joint venture company (mark.houston@magnitude-geo.com)

Abstract

The mining of unconventional oil and gas resources has been driven by “cookie-cutter” methods of drilling and completion to deliver thousands of lowest-cost wells. Development goals have focused on change that delivers value: produce more gas/liquids per well NOW, reduce the cost per well and reduce the environmental/operational footprint. In spite of a decade of spectacular success, we have begun to realize that we need to adjust our methods to allow changes and tradeoffs between spending and performance, and between short-term and long-term based decisions. Most shale play capital-intensive investment decisions are made on short-term data but some of these early decisions, which may obviate later efforts to extend the life of the field, can significantly reduce future returns.

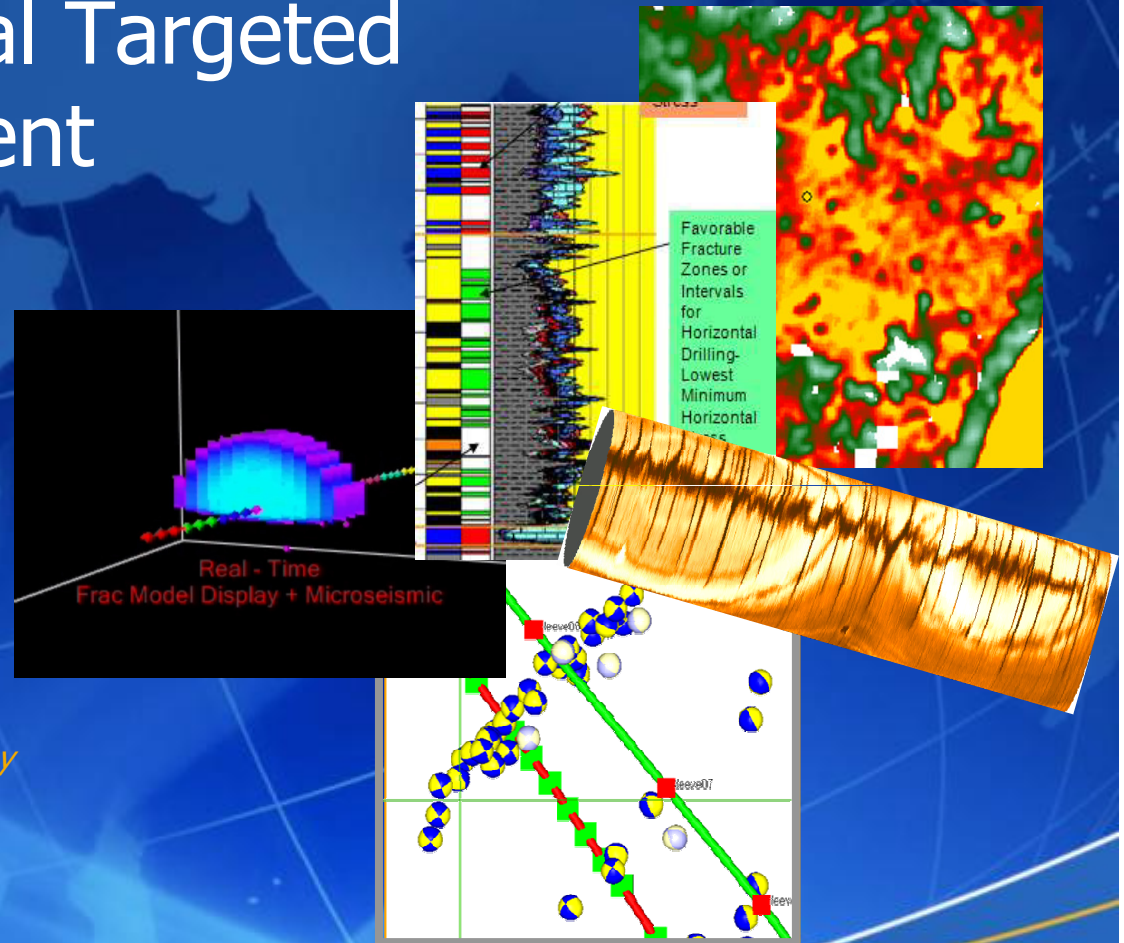
Although standardized, geometric placement of wells and hydraulic-fracturing treatments may cost less than custom designs in the short-term, we argue that an increase in upfront investment in information to better optimize well placement as well as the number, location and size of frac stages will pay off in increased long-term productivity. For example, an understanding of why specific fracturing stages are more effective could lead to frac methods that use less material, cost less, produce more and reduce the treatment footprint. We present a simplified workflow and examples that illustrate the use of multi-disciplinary data: surface seismic inversion, microseismic monitoring and advanced image logging in a geomechanical context to support custom-design drilling and hydraulic fracturing treatments.

3D + Log Image Data + Microseismic for Unconventional Targeted Drilling & Treatment

Mark Houston

VSFusion

a Baker Hughes – CGG joint venture company



Monterey Shale

Motivation

- Covers Substantial Area
 - From San Francisco
 - To Los Angeles
- Highly Fractured and Faulted
- Development & Workflow Unique to Monterey Formation



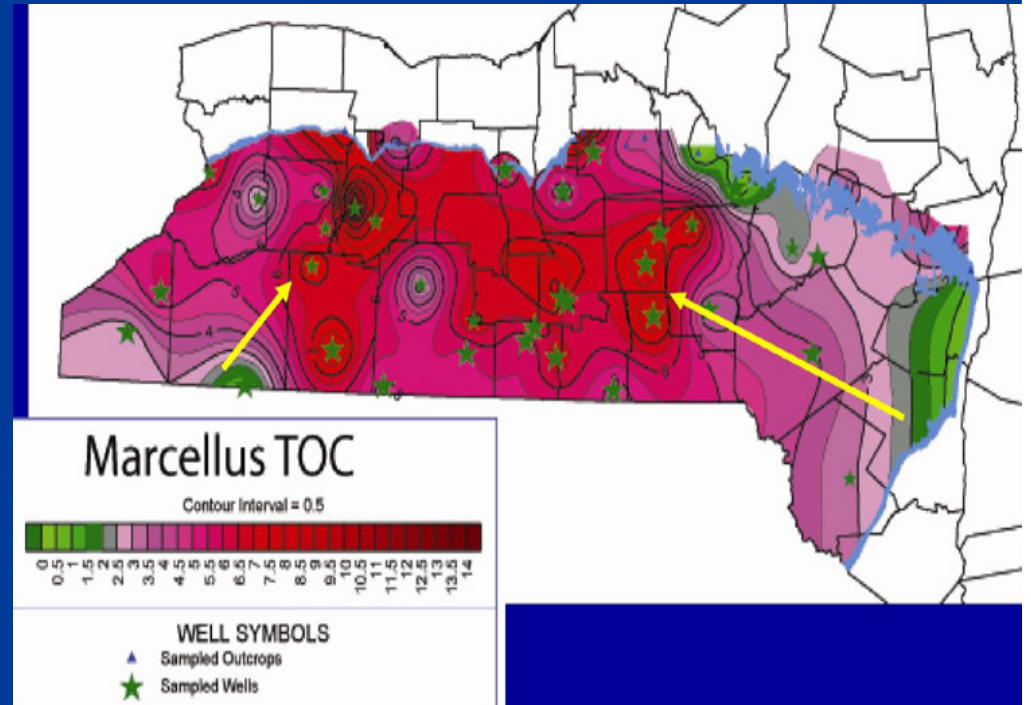
Agenda

- Factory Drilling, Completion & Treatment (DCT)
- Advantages of Targeted DCT
- Workflow for Targeted Drilling
 - Advanced logging for petrophysical properties & TOC
 - Imaging for natural fractures
 - Microseismic monitoring for stimulation control / evaluation
 - Calibration of 3D seismic inversion for rock properties
- Targeted DCT → Increased EUR/\$

Workflow for Factory Drilling

Silo Activities

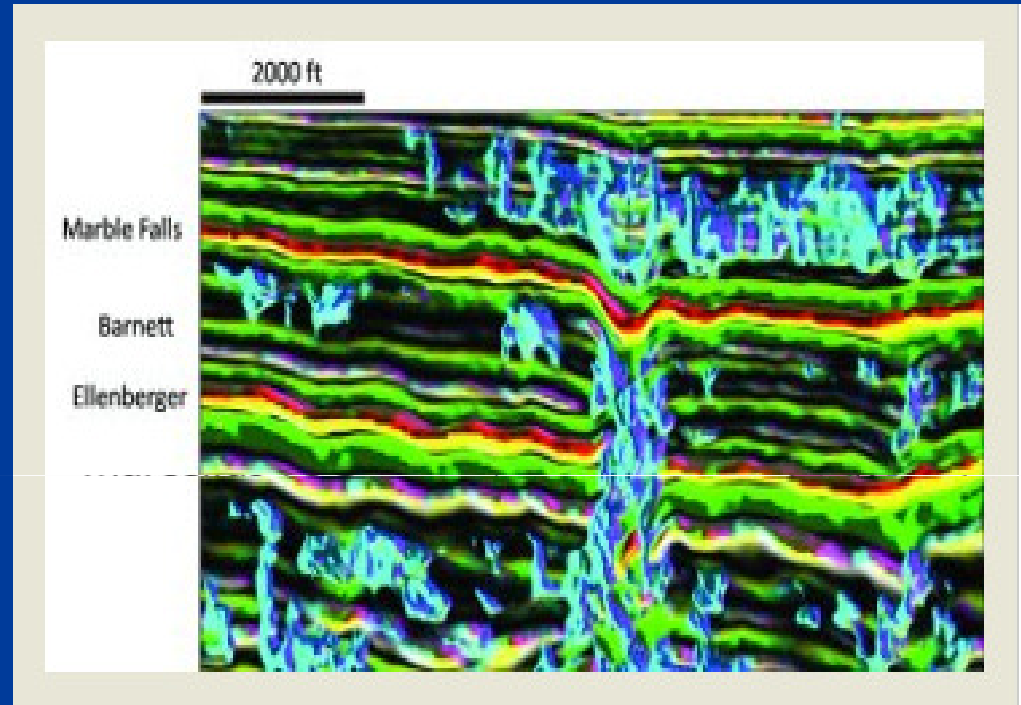
- Geologic Mapping
 - Source Rock
 - TOC
 - Thermal Maturity
- Seismic Mapping
 - Hazard Assessment
- Petrophysics
 - Vertical wells
- Drilling & Completion
- Stimulation
- Production



Workflow for Factory Drilling

Silo Activities

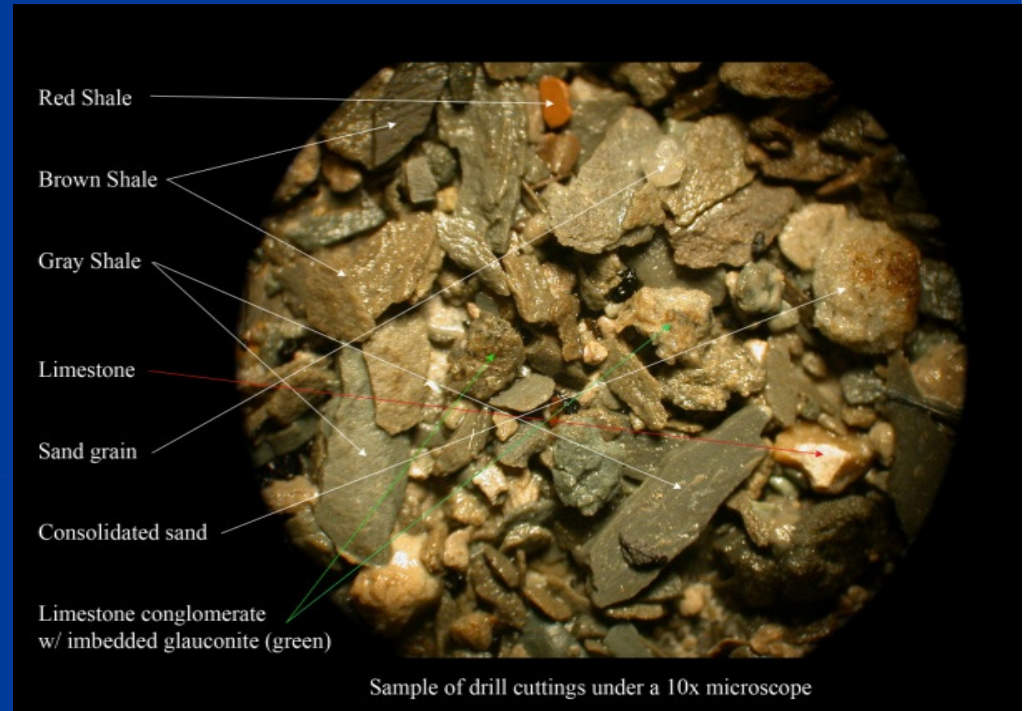
- Geologic Mapping
 - Source Rock
 - TOC
 - Thermal Maturity
- Seismic Mapping
 - Hazard Assessment
- Petrophysics
 - Vertical wells
- Drilling & Completion
- Stimulation
- Production



Workflow for Factory Drilling

Silo Activities

- Geologic Mapping
 - Source Rock
 - TOC
 - Thermal Maturity
- Seismic Mapping
 - Hazard Assessment
- Petrophysics
 - Vertical wells
- Drilling & Completion
- Stimulation
- Production



Sample of drill cuttings under a 10x microscope

Workflow for Factory Drilling

Silo Activities

- Geologic Mapping
 - Source Rock
 - TOC
 - Thermal Maturity
- Seismic Mapping
 - Hazard Assessment
- Petrophysics
 - Vertical wells
- Drilling & Completion
- Stimulation
- Production



Workflow for Factory Drilling

Silo Activities

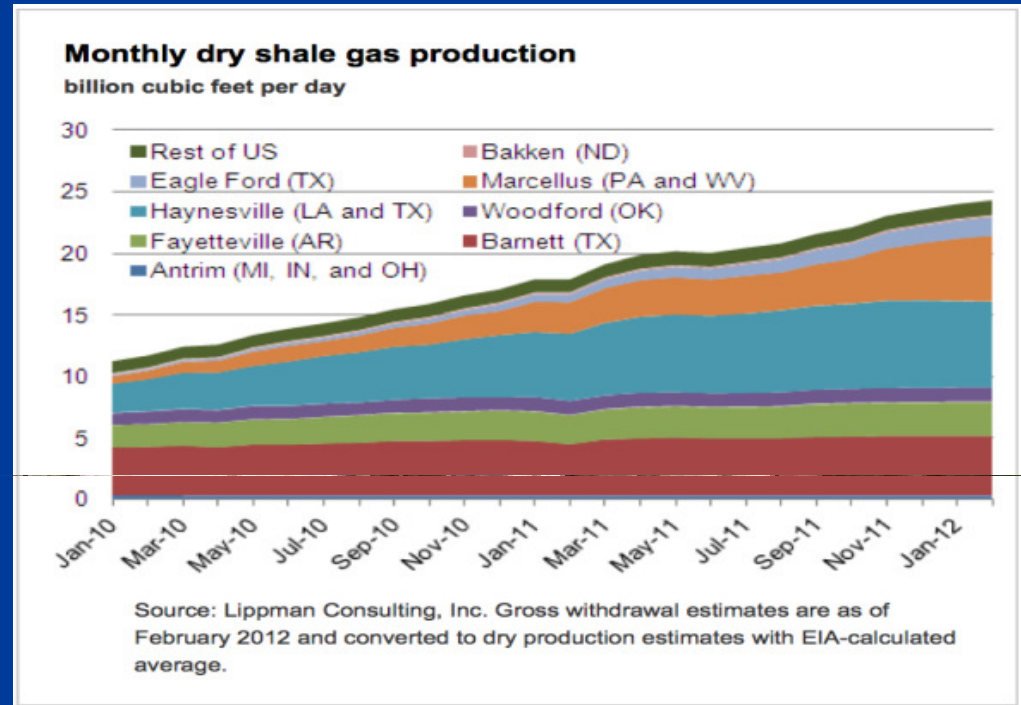
- Geologic Mapping
 - Source Rock
 - TOC
 - Thermal Maturity
- Seismic Mapping
 - Hazard Assessment
- Petrophysics
 - Vertical wells
- Drilling & Completion
- Stimulation
- Production



Workflow for Factory Drilling

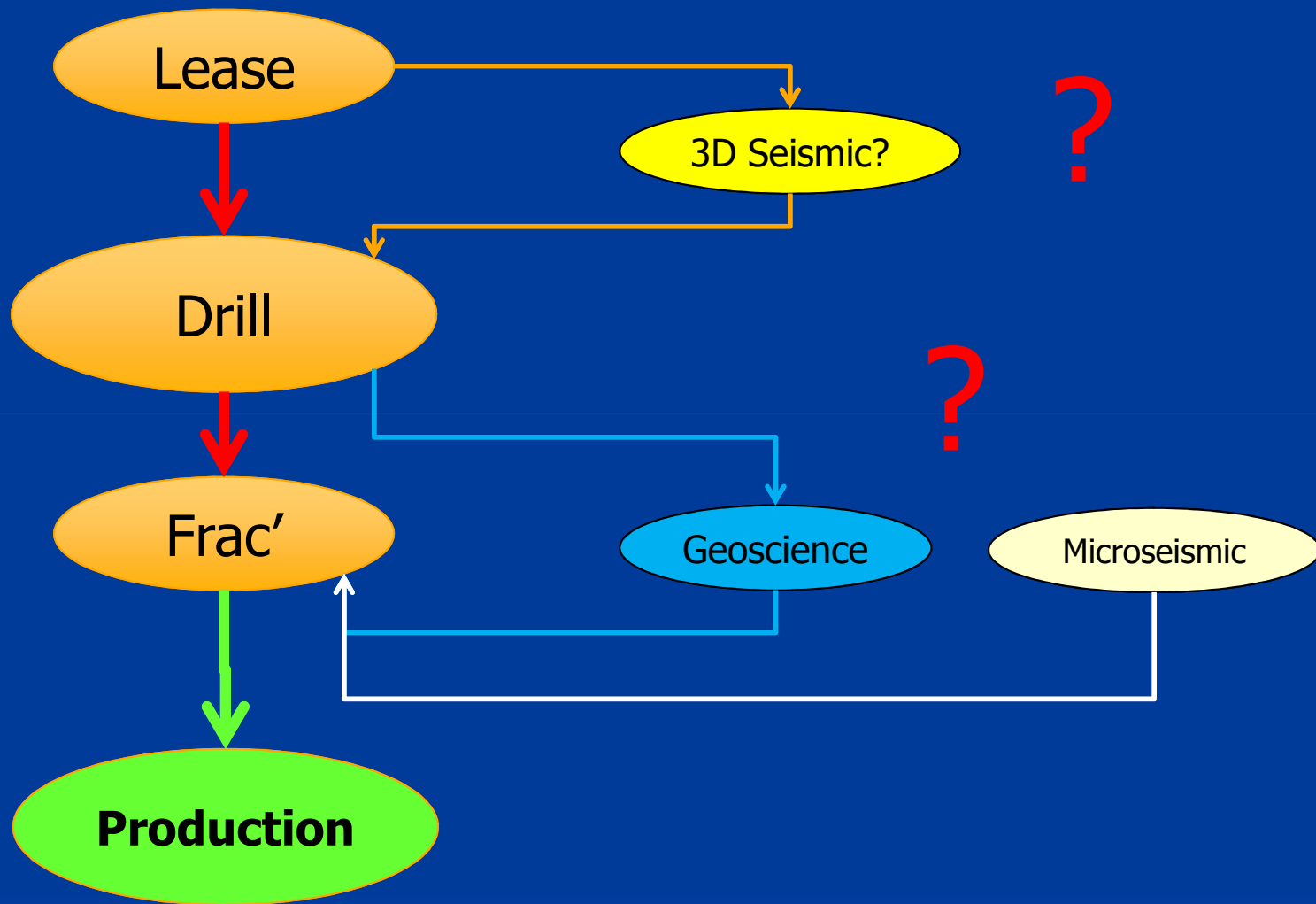
Silo Activities

- Geologic Mapping
 - Source Rock
 - TOC
 - Thermal Maturity
- Seismic Mapping
 - Hazard Assessment
- Petrophysics
 - Vertical wells
- Drilling & Completion
- Stimulation
- Production



Workflow for Factory Drilling

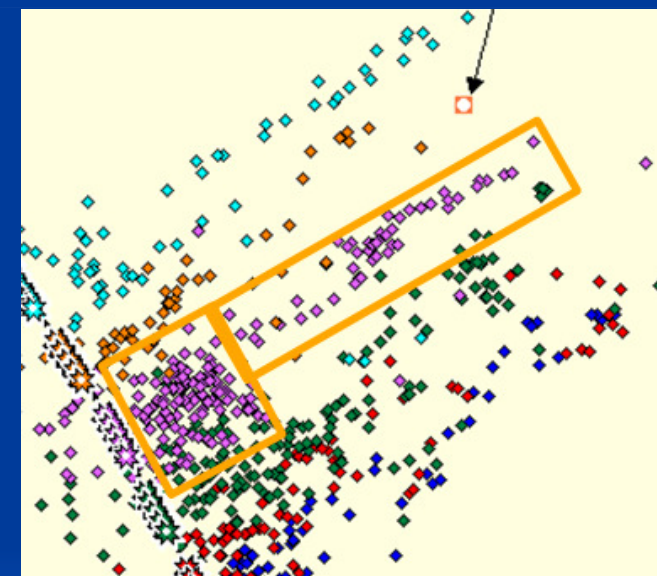
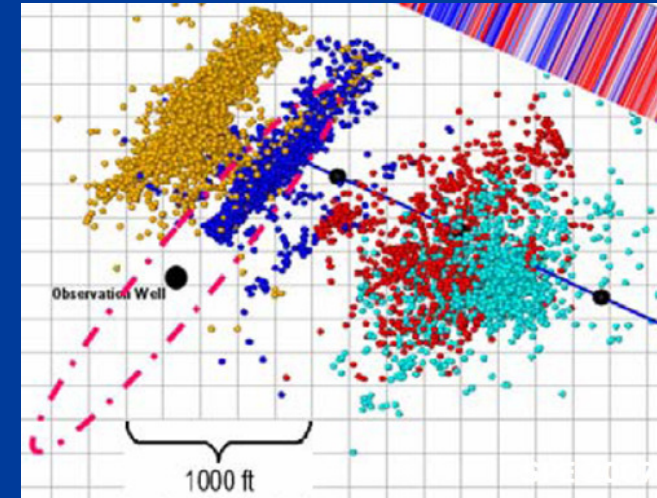
Maximize Short-Term Cash Flow – Drive Cost



Microseismic for Risk & Stimulation Assessment

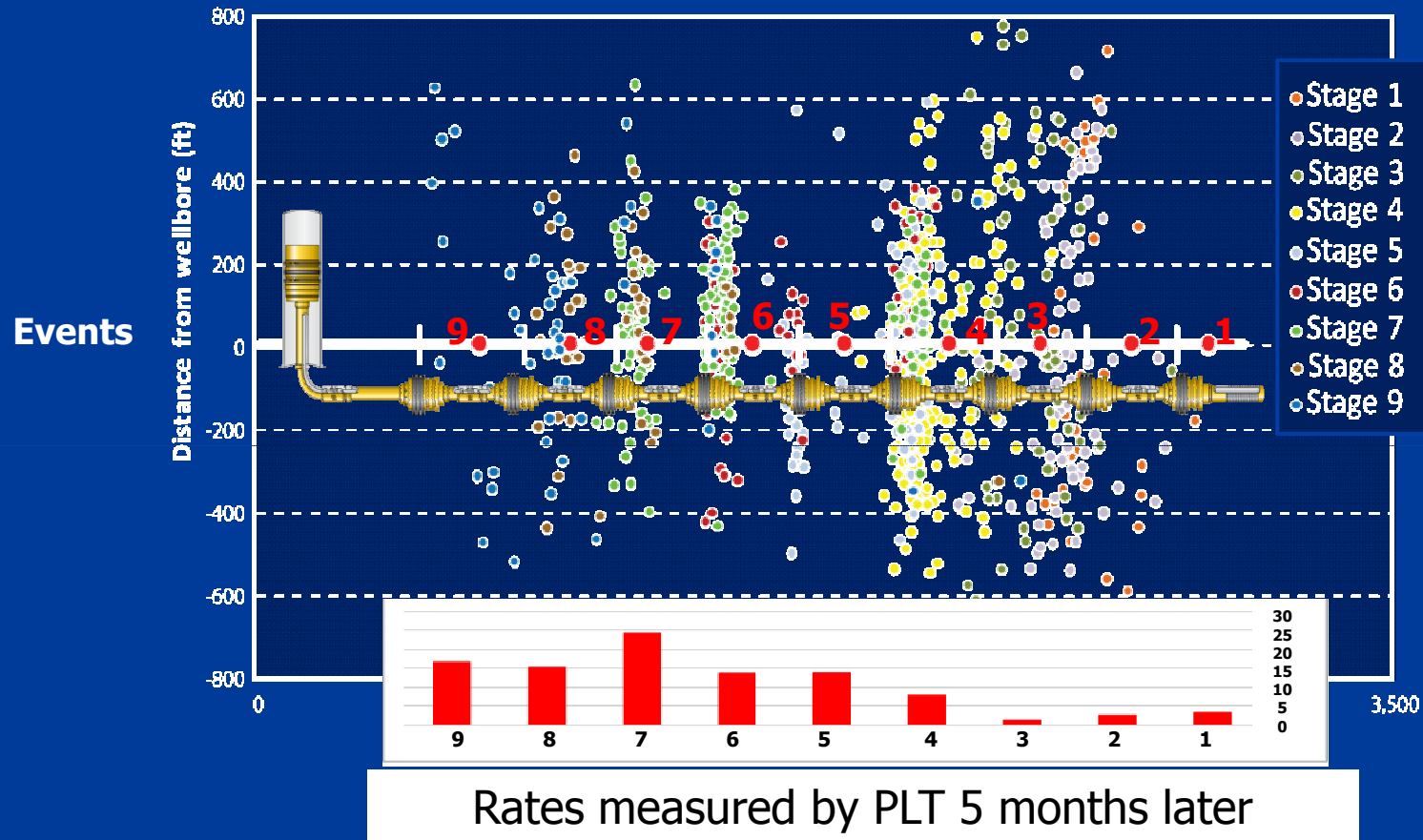
Silo Strategy

- Spatial Maps
 - Induced fractures
 - Faults
- Temporal Maps
 - Stress (fluid) diffusivity
 - Differential rock behavior
 - Validation of stimulation



But ... All Wells and Stages Are NOT the Same

Production Is Variable, Why??

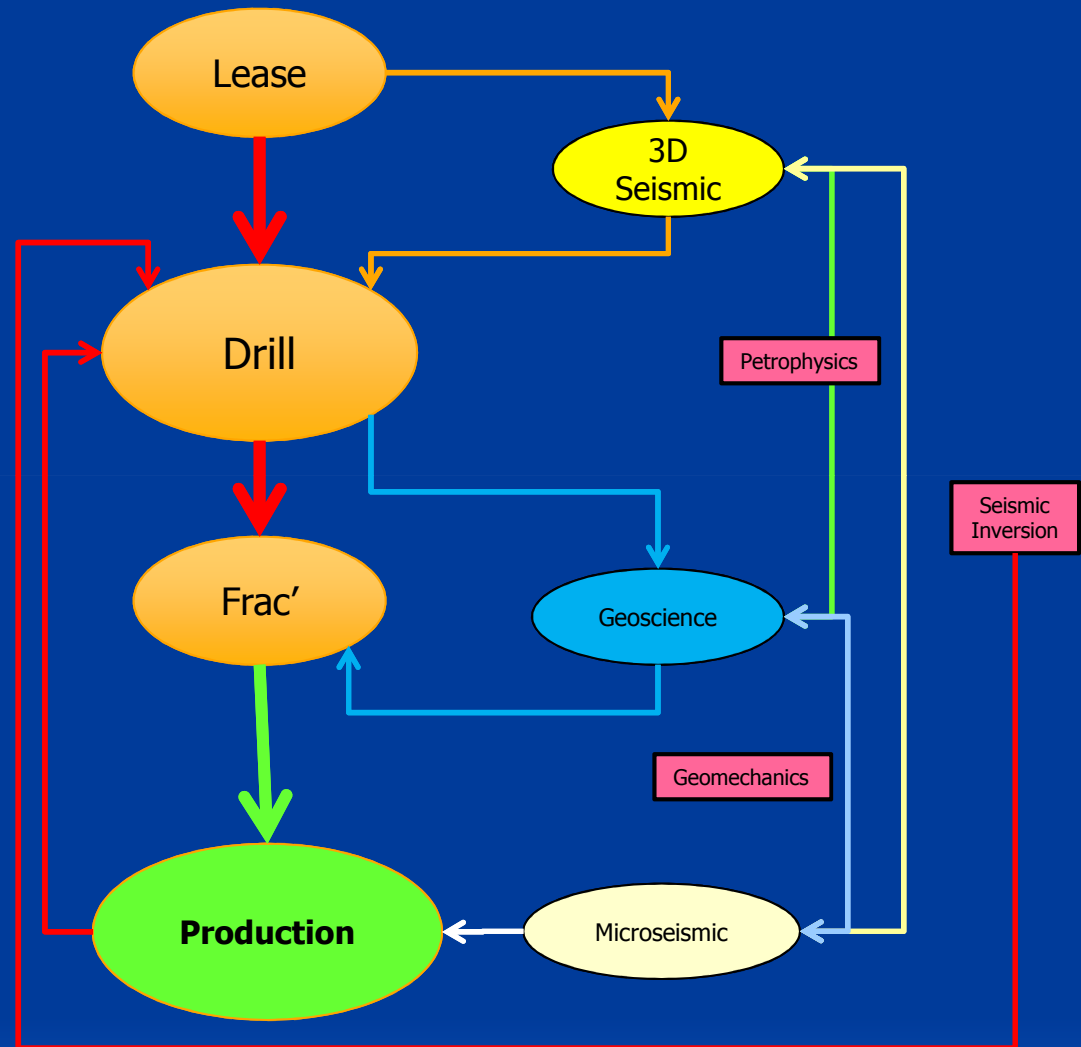


Comparison of microseismicity to stage-by-stage PLT logged rates

Targeted Drilling, Completion & Treatment

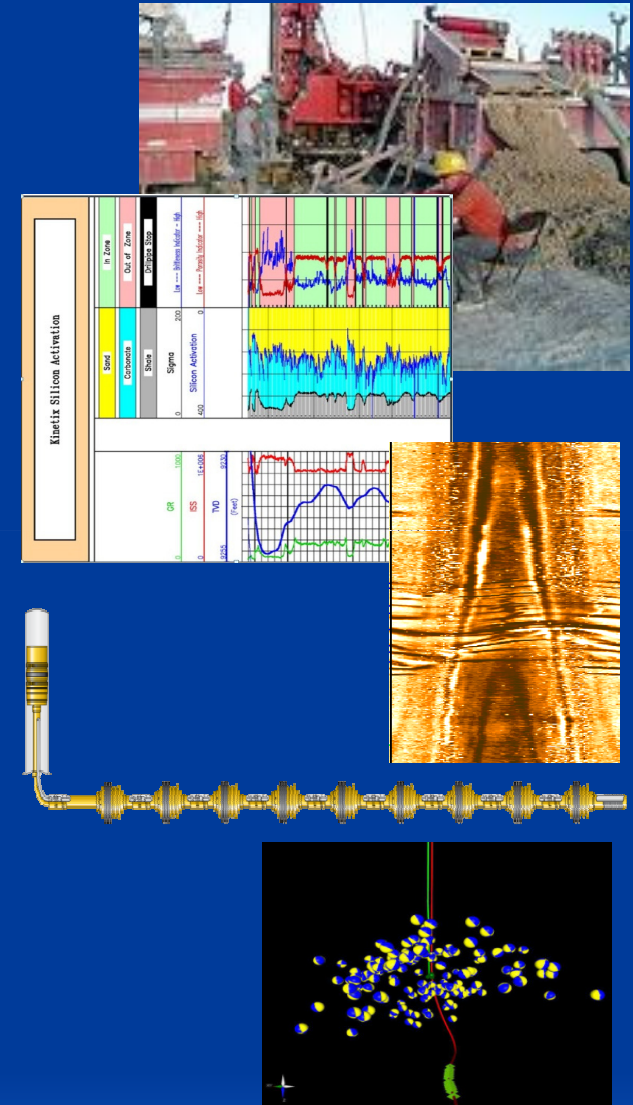
Understand Well Production Variability – Manage to Lifetime Return

- Acquire High-Def 3D
- Run Early Geoscience
 - Adv logs
 - Petrophysics
- Monitor Stimulation Behavior
- Calibrate Seismic Inversion
- Measure Production Performance
- Predictions of Behavior in Next Wells



Geoscience to Optimize Completions & Treatments

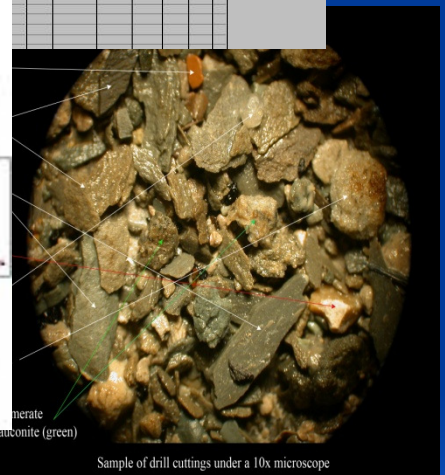
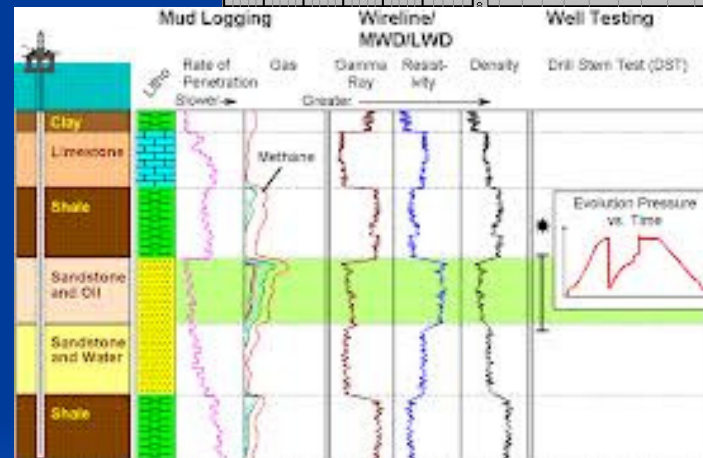
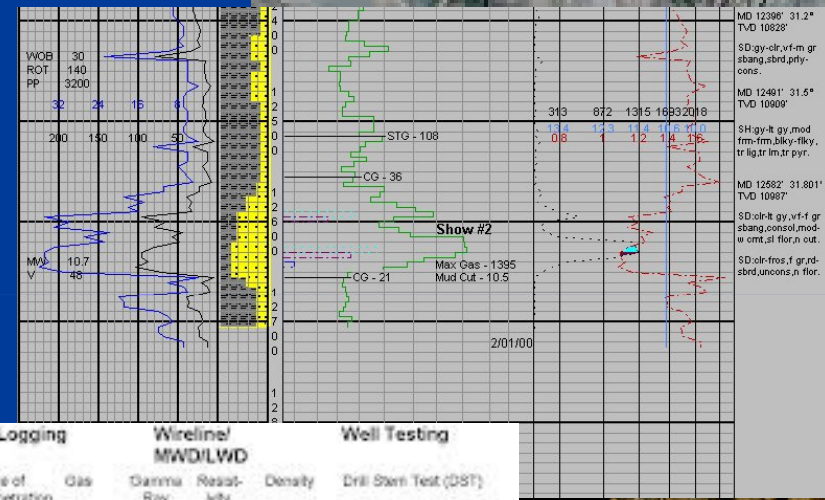
- Measure Petrophysical and Rock Properties along Well
 - Mud Logging
 - Kinetix (Pump-down)
 - Flex, RMD (Wireline / Coiled tubing)
- Image Natural Fractures along Well
 - StarTrack (LWD)
- Design Completions & Stimulations
- Monitor & Assess Frac' Program



Mud Logging

Petrophysical Measurements

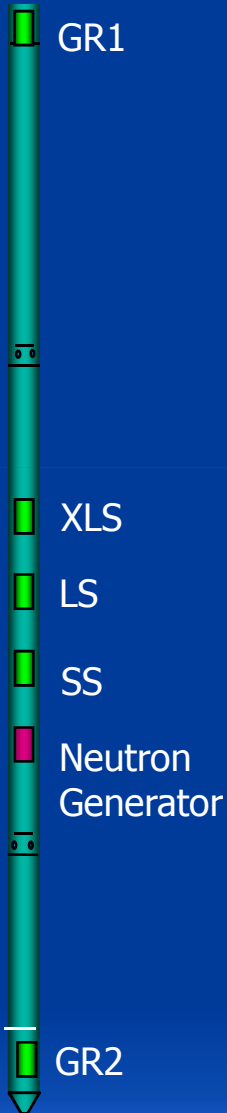
- Recover Samples from Drilling Mud
- Petrophysical Analyses for Rock Properties
- Fluids & TOC Measurements



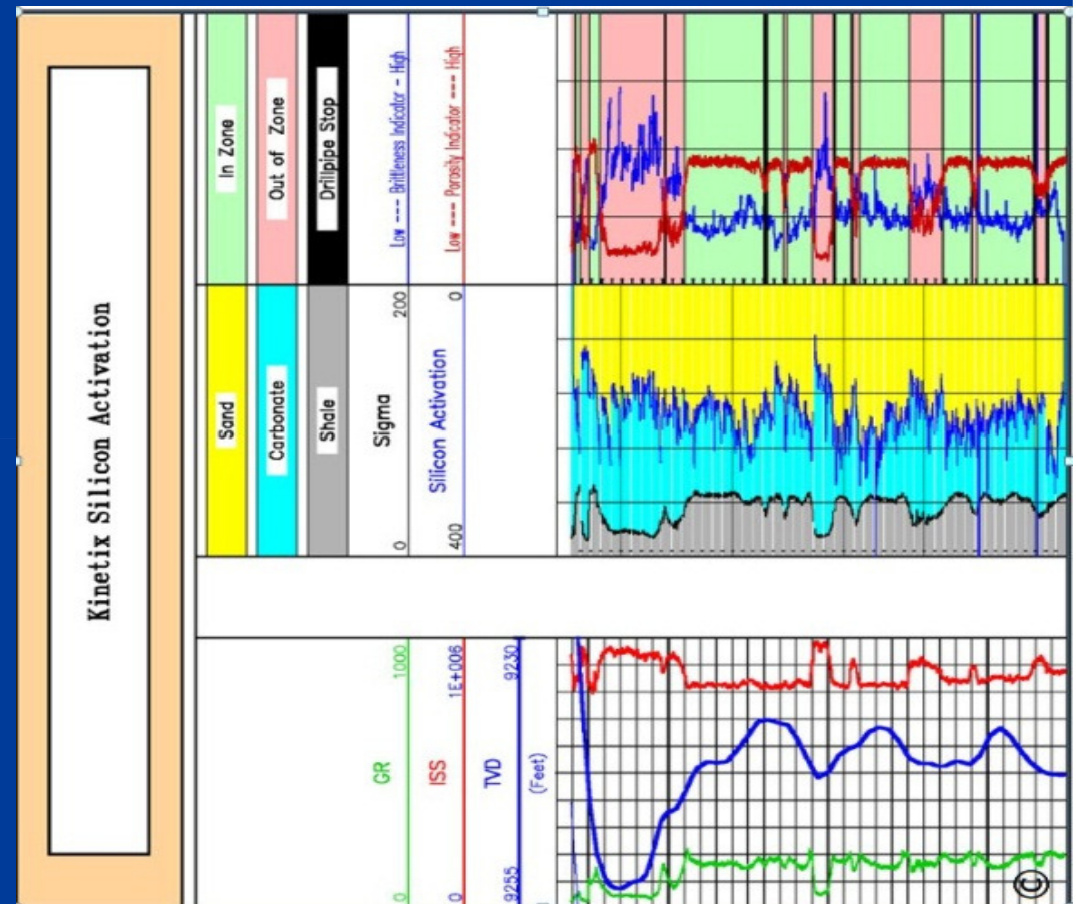
Sample of drill cuttings under a 10x microscope

Kinetix – Fast Tool for Rock Properties

Measure Brittleness, Silica, Sand, Carbonate, Shale while Drilling



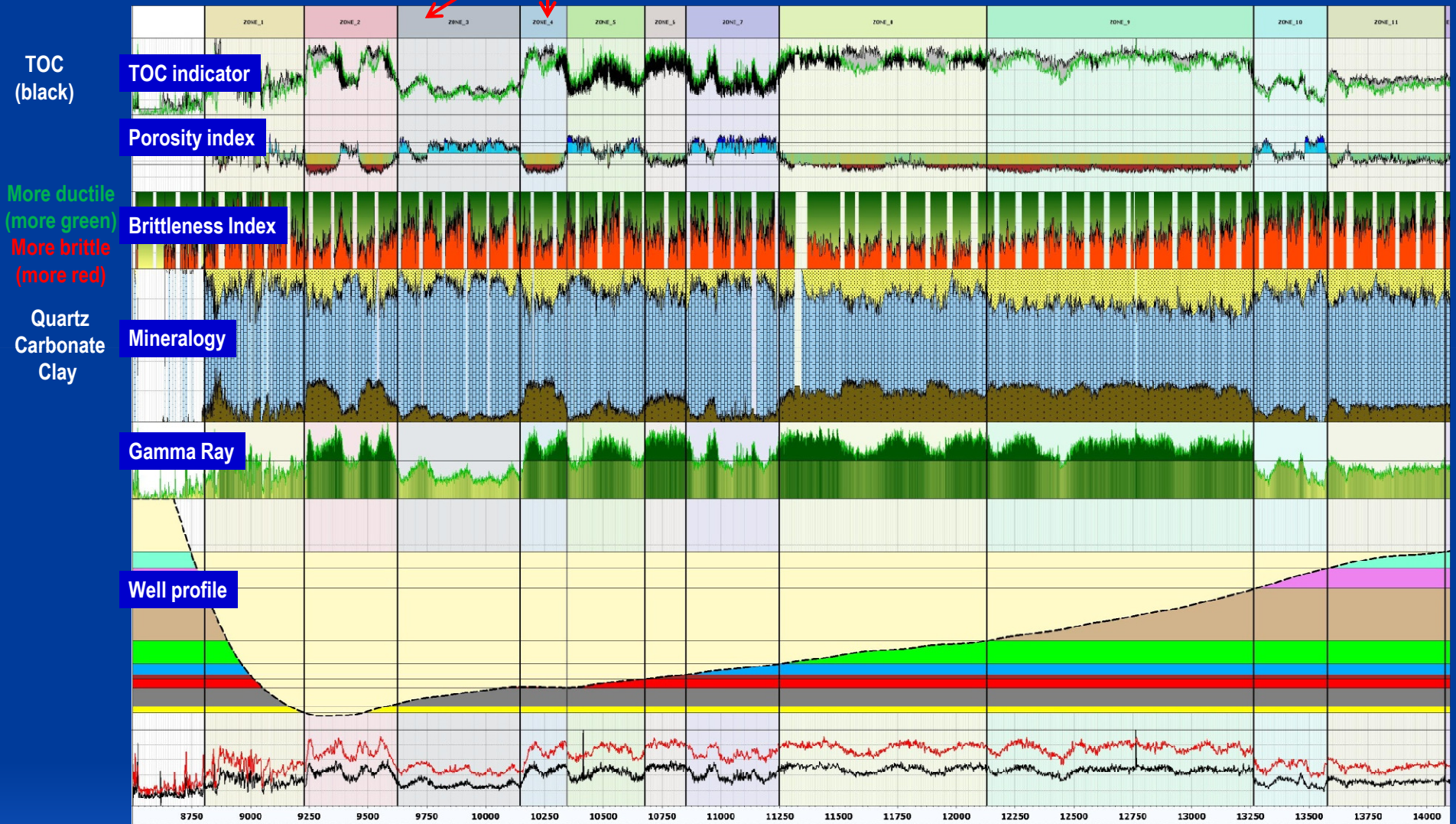
- Fast neutron activation of Silicon emits gamma rays
- Acquired at 10, 15, or 20 ft/min
- Silicon count rate is an indicator of brittleness



Use Logs for Custom Completion Design

Design Completions & Treatments

Recommended divisions for frac stages

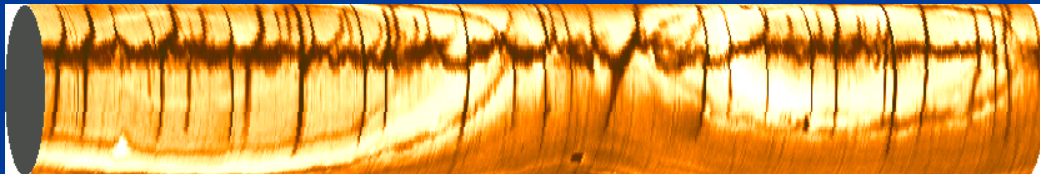


StarTrak LWD Imaging Tool for Wellbore Fractures

Measure Natural Fractures

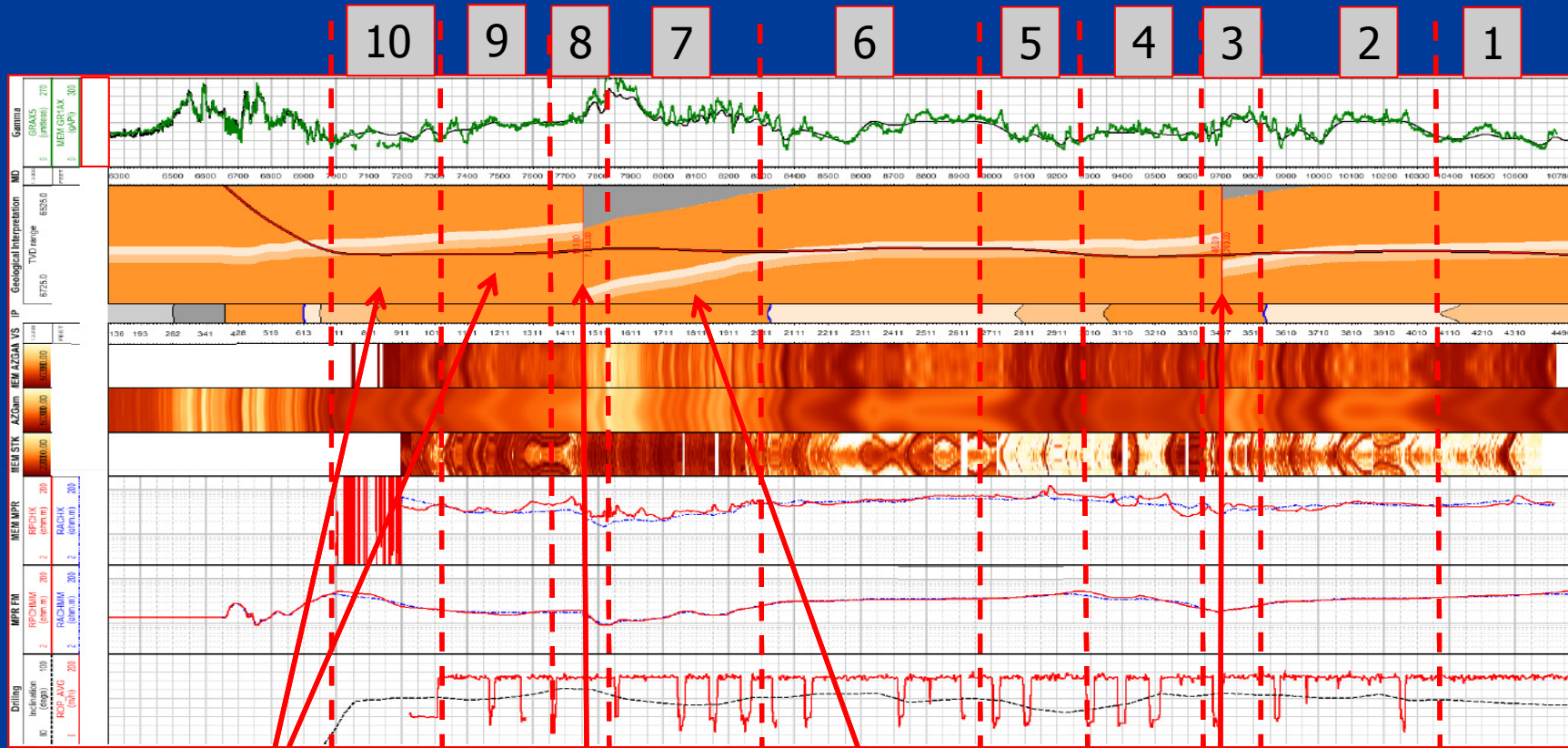
High resolution imaging applications

- *Structural analysis*
- *Sedimentary analysis*
- *Geosteering*
- *Geomechanical analysis*
- *Production information*



Completions Recommendations

Design Completions & Treatments



**Aggressive tie-in
Higher PPG**

Isolate fault

Isolate fault

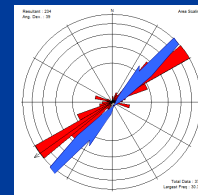
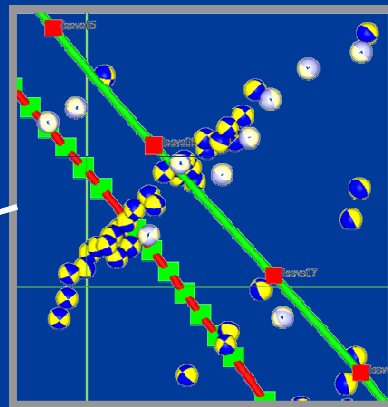
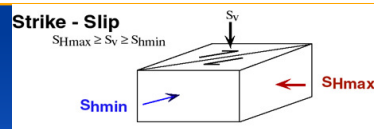
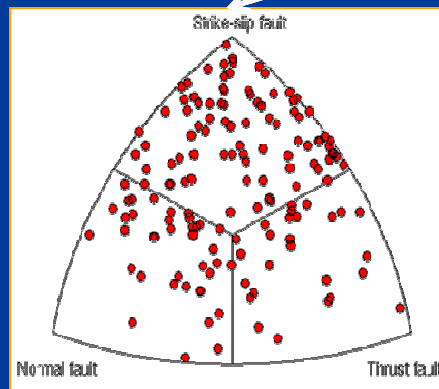
**Move sleeve towards lower packer
Tail in with higher ppg sand
Walk away?**

Microseismic Can Show Rock Failure Modes

*Dots show all located events .
Color code indicates Frac ' Stage.*

*Beach balls show focal mechanism
calculated from seismic waveform.*

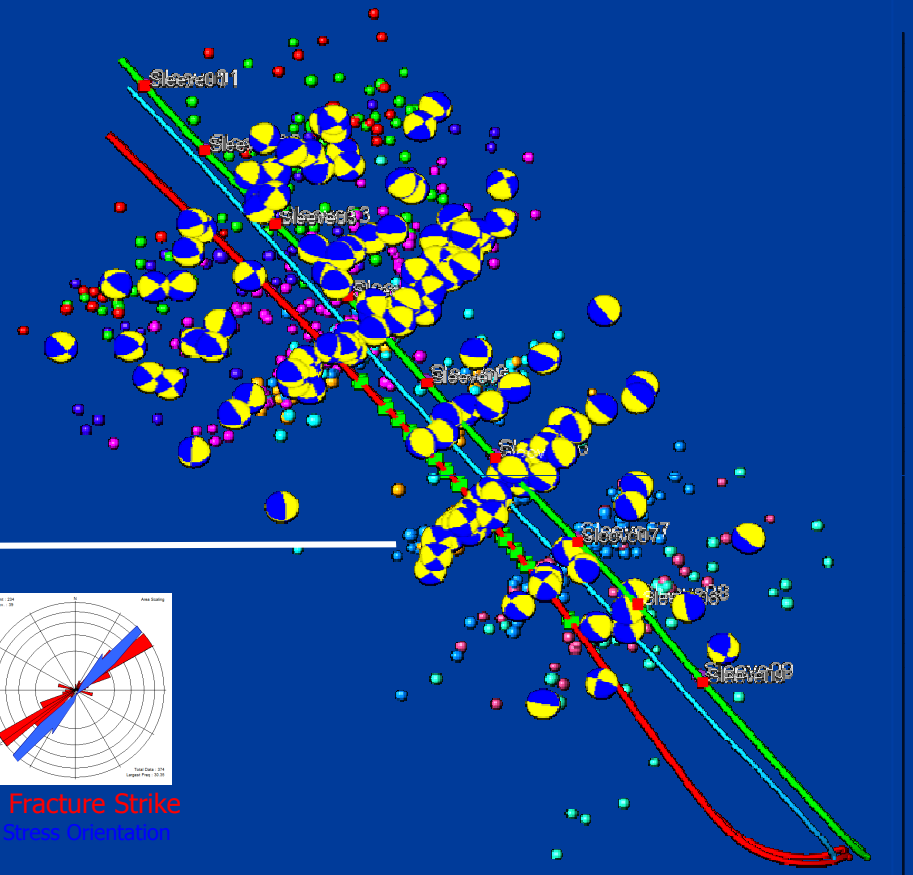
*Focal mechanisms show
style of fracturing.*



Fracture Strike
Stress Orientation

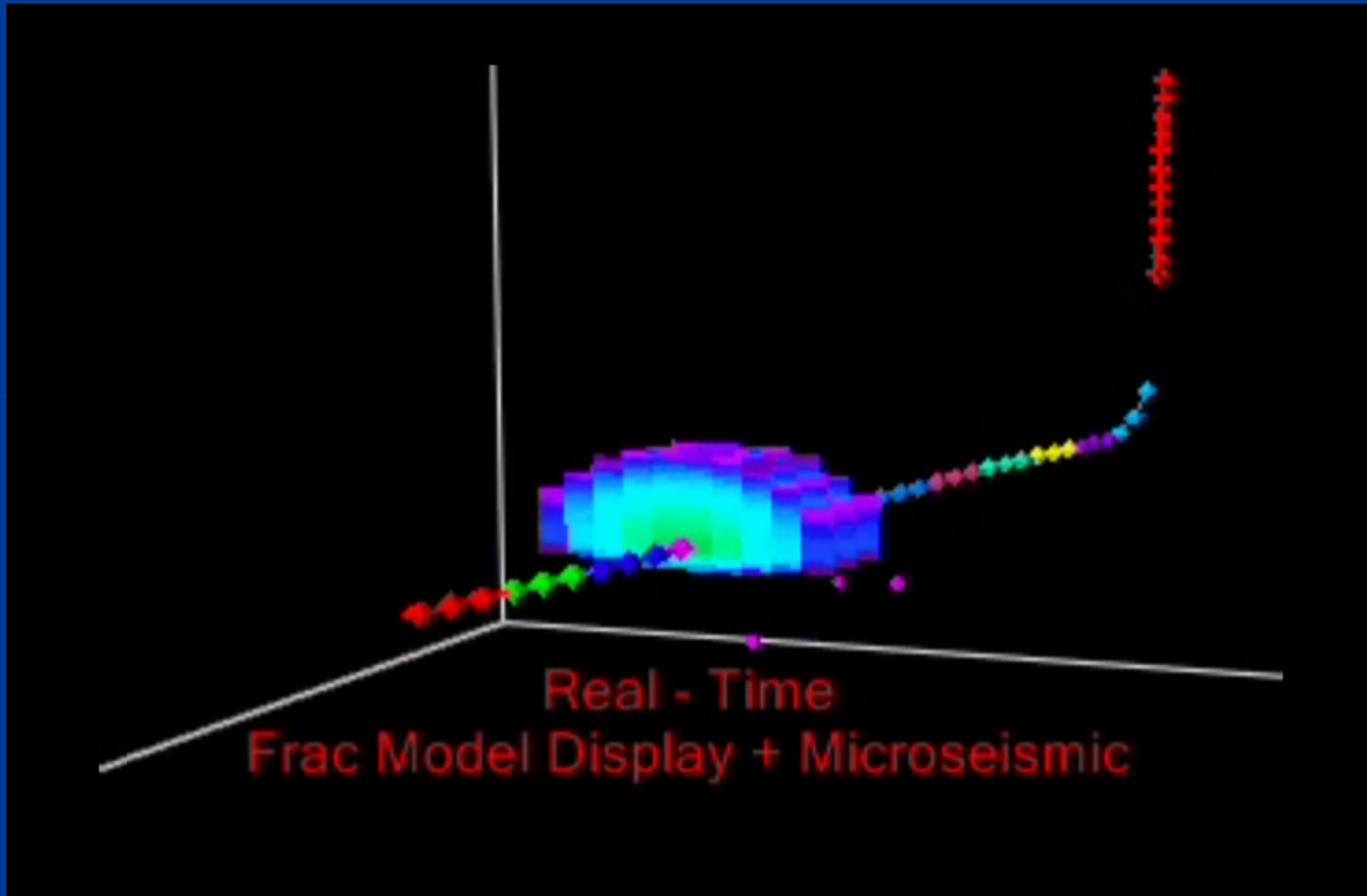
**Narrow microseismic zones - Wider zones
at toe associated with higher net
pressure.**

Frac direction N46°E



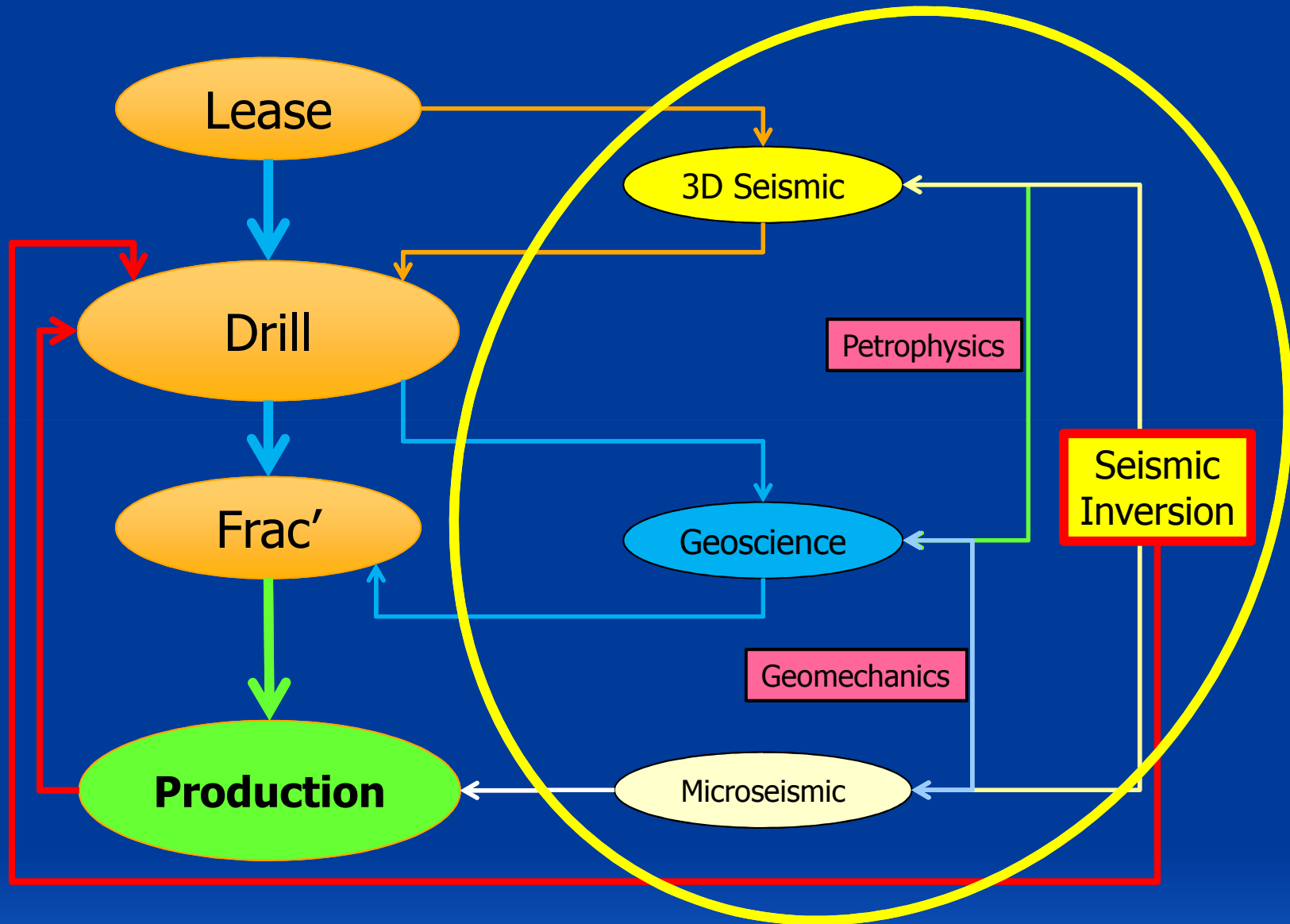
Compare Response with Stimulation Design

RT Microseismic & Frac' Visualization Movie



Workflow for Targeted Drilling

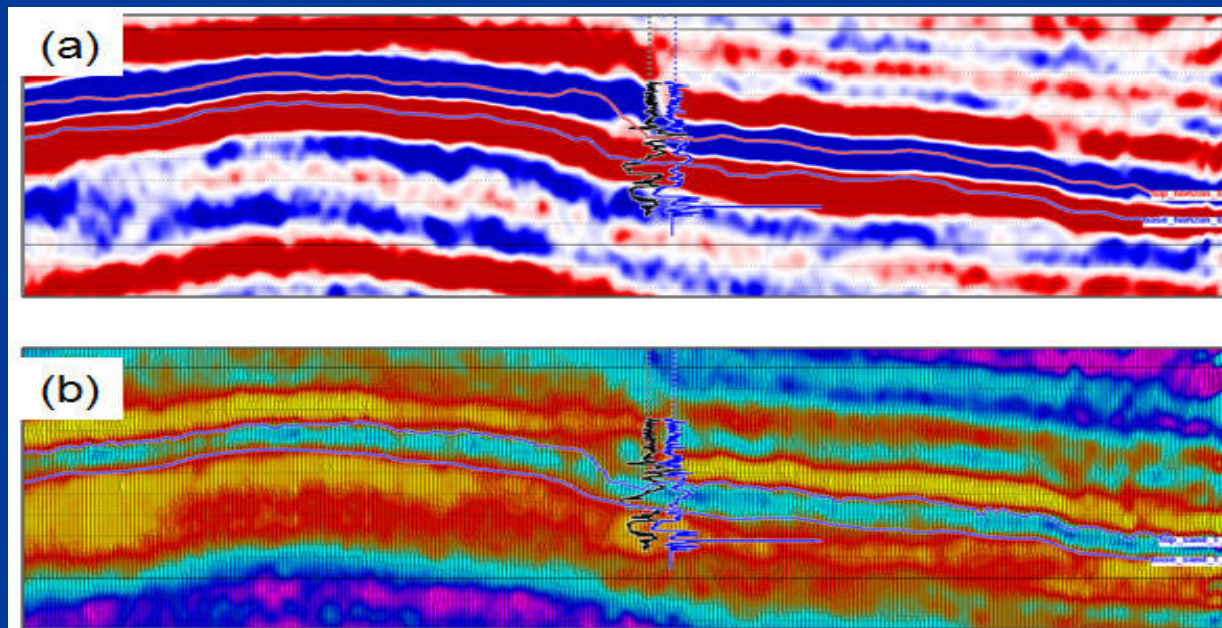
Integrated Strategy – Leverage 3D Seismic



3D Seismic to Extrapolate Rock Properties

Seismic Inversion

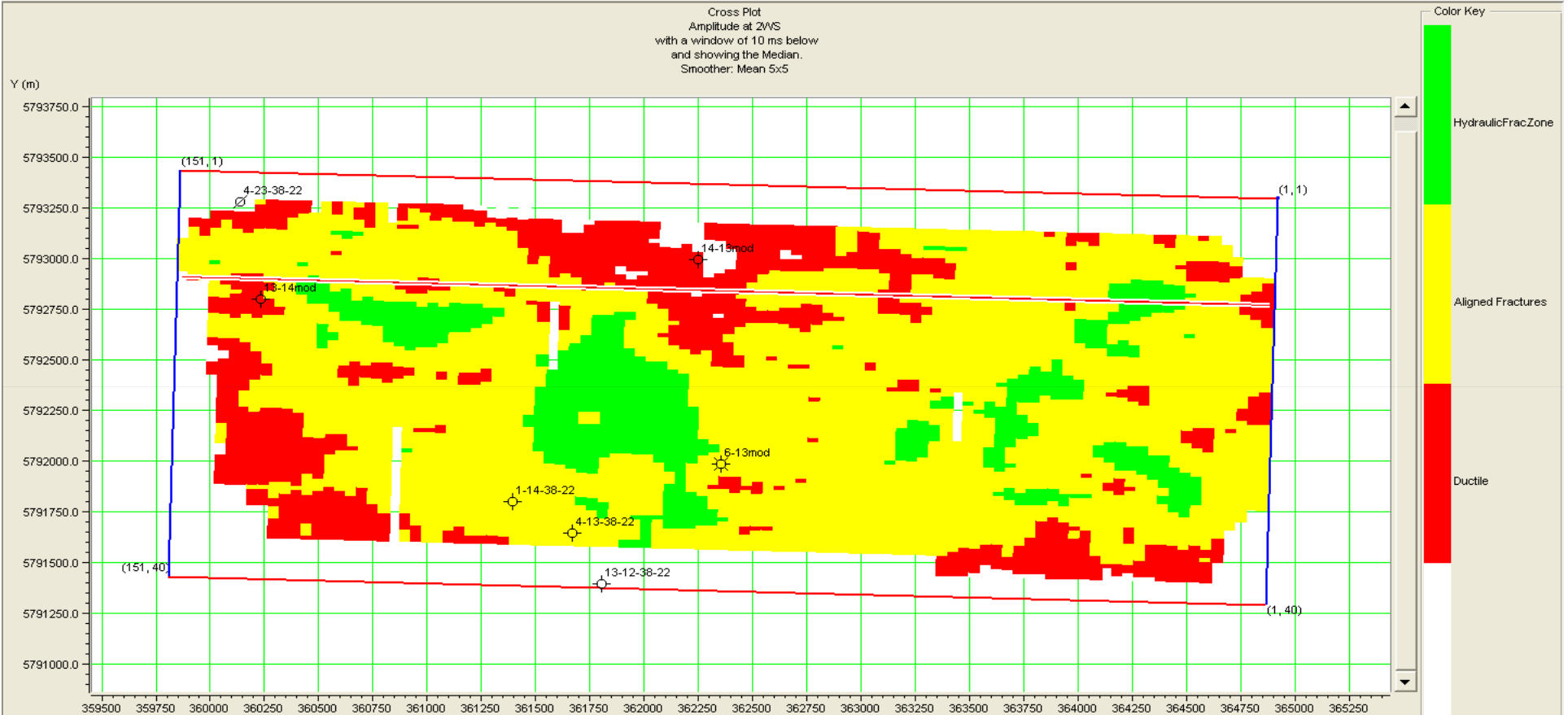
- Prestack inversion for porosity and lithology prediction, Poisson's ratio, V_p/V_s
- Infer and map fractures from thickness and curvature attributes
- Measure horizontal anisotropy from multi-azimuth surveys
- Integrate velocity analysis with well logs for 3D pore pressure model



Courtesy R. Mayer, Hampson-Russell

Probable Zones of Better Hydraulic Fractures

Seismic Inversion

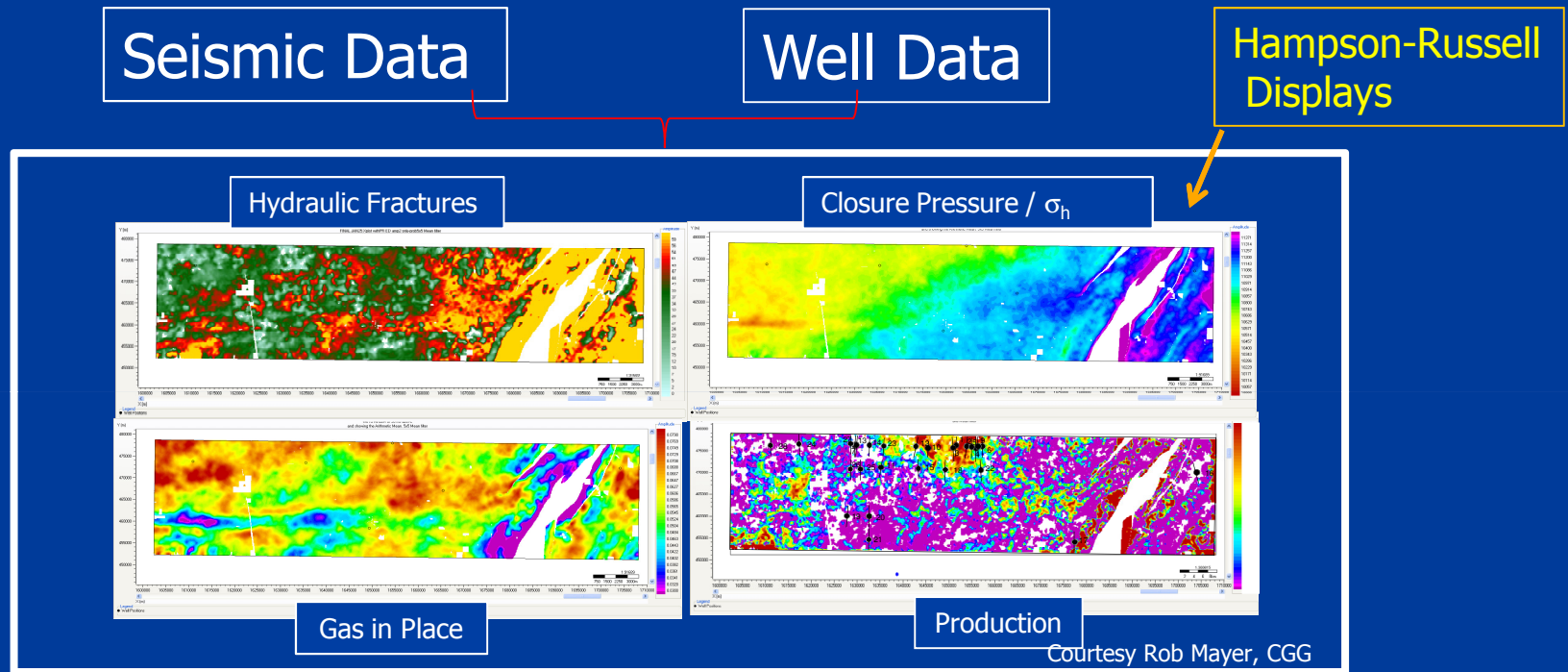


Map showing zones highlighted in seismic attribute crossplot. Green is where fracture swarms will form, red is where the rocks are more ductile and yellow is where aligned fractures will occur. Note that only about $\frac{1}{4}$ of this reservoir is optimal for hydraulic fracturing.

Courtesy R. Mayer, Hampson-Russell

Rock Properties from 3D Seismic Data

Calibrate / Interpret Seismic Inversion

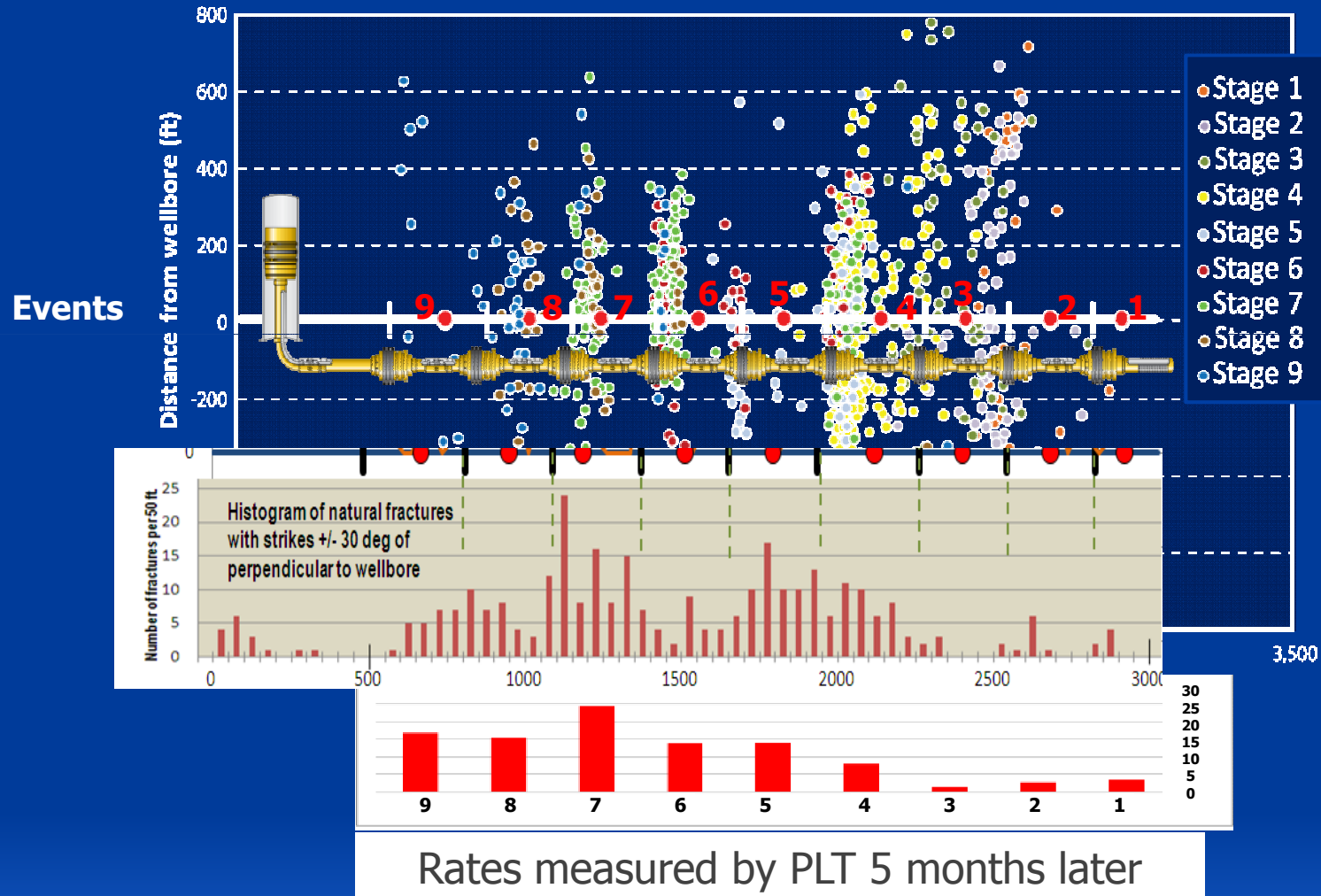


- Resource development requires reservoir volumetric description – 3D rock properties

Tie Production To Seismic?

Validate

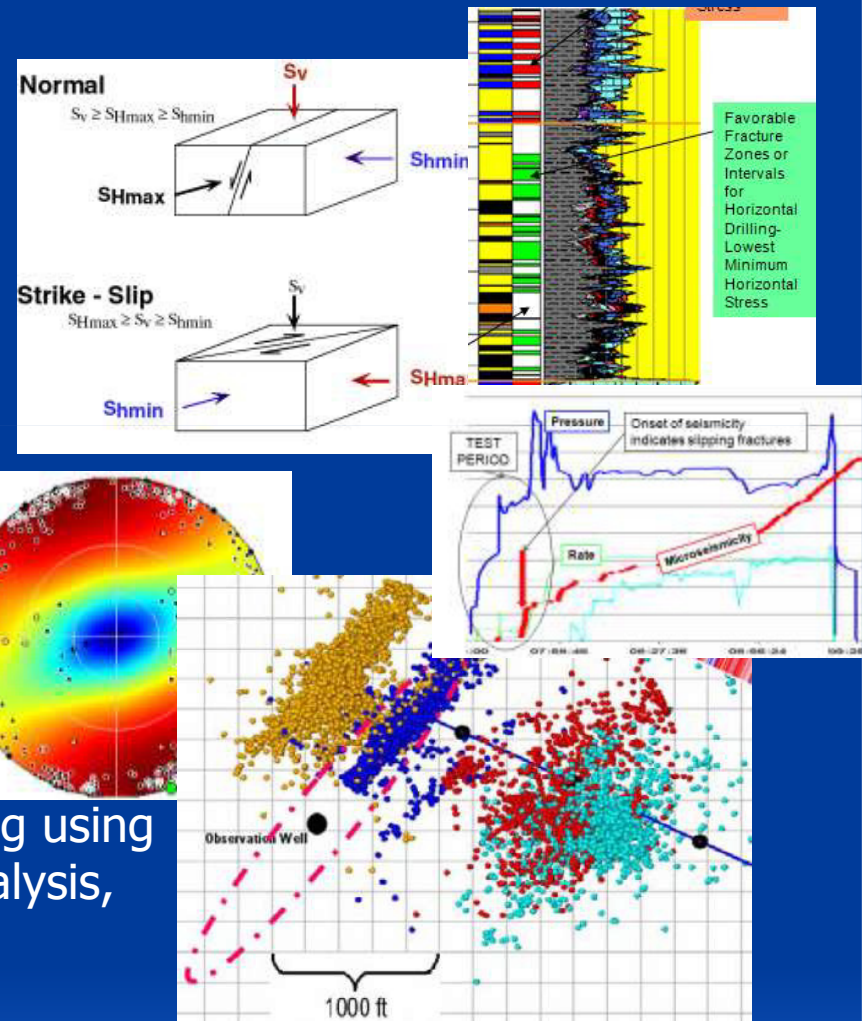
Comparing microseismicity and natural fractures to stage-by-stage PLT logged rates



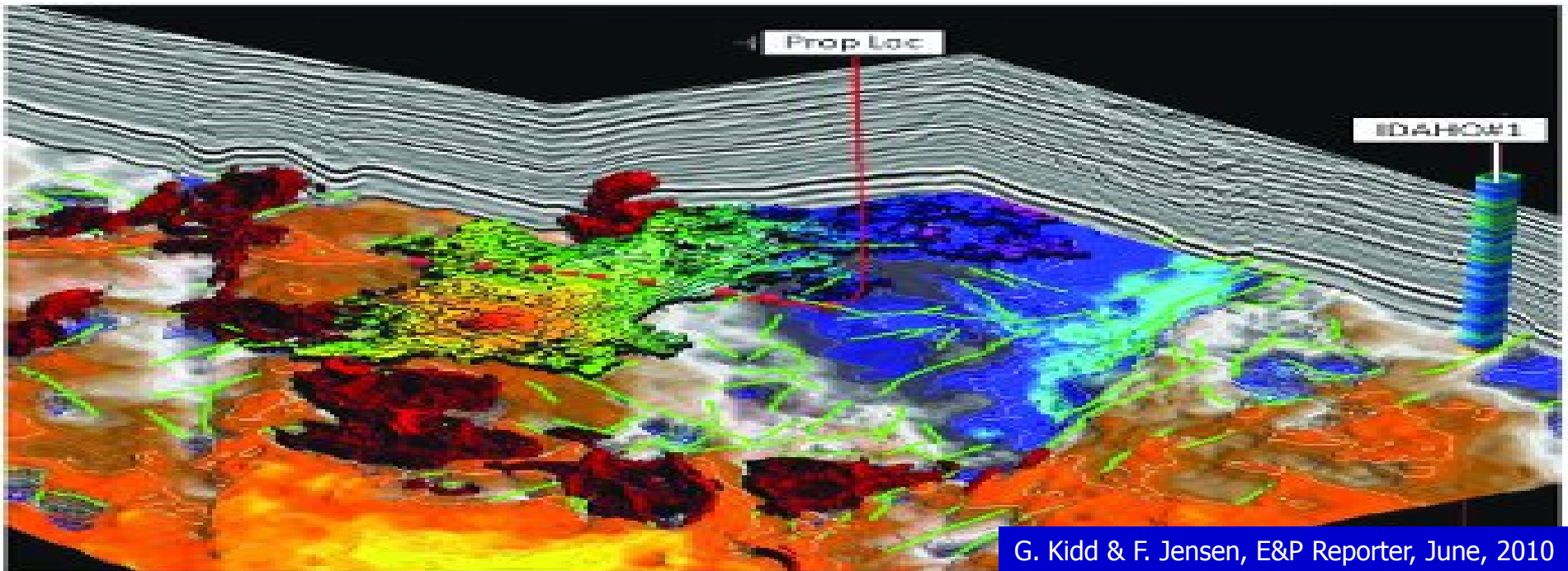
Shale Gas Requires Multi-Disciplinary Approach

Summary

- Successful development requires a multi-disciplinary approach
 - Geomechanics
 - Geochemistry and petrophysics
 - Rock properties
 - Seismology
 - Reservoir, well, and stimulation modeling
- Data required include
 - Image logs
 - Acoustic and geochemical logs
 - Seismic data (perhaps time-lapse)
 - Advanced microseismic data collection
 - Careful pre-test calibration and monitoring using advanced microseismic collection and analysis, tied to flow and pressure data



Targeted Drilling, Completion & Treatment



3D Seismic + Advanced Logging Data + Microseismic Data

→ Increased EUR/\$

PSAAPG/SPE/SEG - Monterey, 2013

Thank You.

*The Earth speaks
We listen*

