SPE Hydraulic Fracturing Technology Conference

24–26 January 2017
THE WOODLANDS, TEXAS, USA
The Woodlands Waterway Marriott Hotel and Convention Center

Sampling a Stimulated Rock Volume: An Eagle Ford Example

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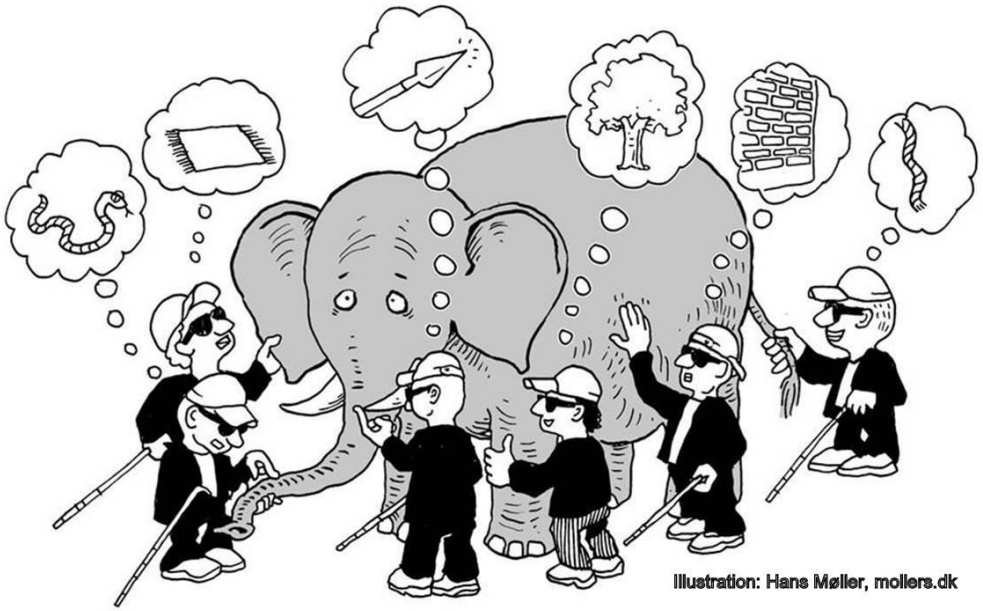
URTec_2670034

ConocoPhillips

Where to begin?



Our Questions

- » **What is Stimulated versus Drained Rock Volume?**
  - – **Are SRV and DRV identical?**
    - **What data are sufficient to describe either?**
  - – **What is the spatial extent and variability of SRV/DRV?**
    - **Well spacing and stacking**
    - **Cluster spacing**
- » **Are outcomes repeatable?**
- » **Can predictions be improved?**
    - **Fracture and proppant propagation modeling**

Pilot Design

- » **Spatial sampling … define what is there**
  - – **2 Pre-completion sample wells**
  - – **4 Post-completion sample wells**
- » **Remote completion monitoring … extend beyond the known**
  - – **Distributed Acoustic/Temperature Sensing (DAS/DTS)**
  - – **Dual well microseismic**
- » **Production monitoring … establish link to performance**
  - – **Production logs**
  - – **Tracers (oil, water, and proppant)**
  - – **Pressure monitoring within the SRV**

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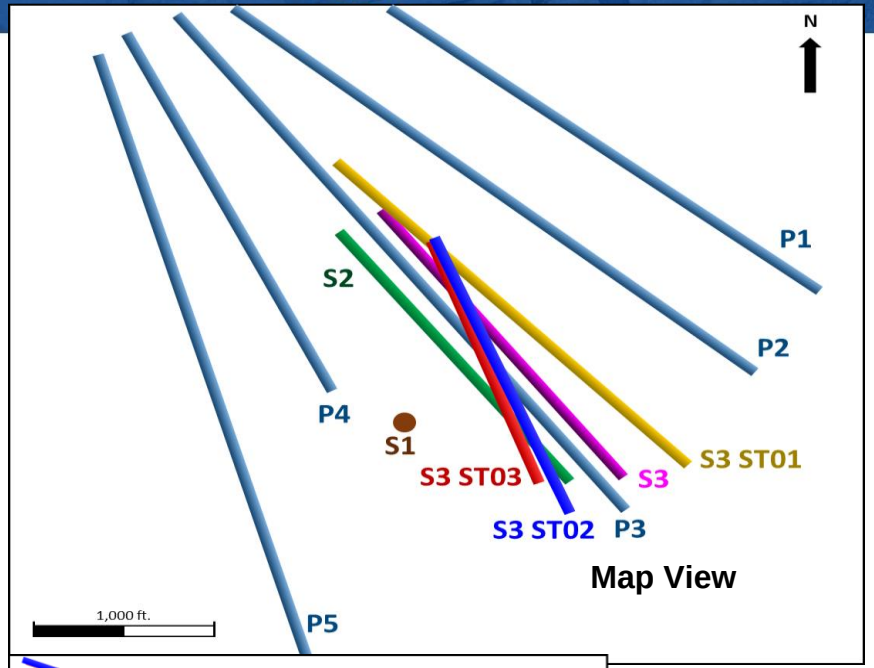
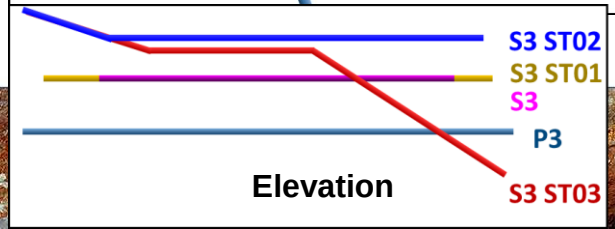




Well	Producer	Cuttings - proppant	Core	Image Logs	RA Tracer	RA Tracer Log	DTS/DAS	Geophones	Pressure Gauges
P1	X								
P2	X				X	X			
P3	X				X	X	X		X
P4	X					X			
P5	X								
S1				X		X	X	X	X
S2			X	X				X	
S3		X	X	X		X			
S3 ST01		X		X		X			
S3 ST02		X		X		X			
S3 ST 03		X	X	X		X			X

Completion Design

Design Type	Limited entry
Clusters /Stage	5
Cluster Spacing	47 ft.
Pre flush	Acid/linear gel
Slurry Carrier Fluid	30# borate gel
Flush	Linear gel/slickwater
Fluid Volume	21 bbl./ft.
Proppant Load	1500 lb./ft.
Proppant type	White sand
Proppant Size	40/70, 30/50

Hydraulic Fracture Characteristics

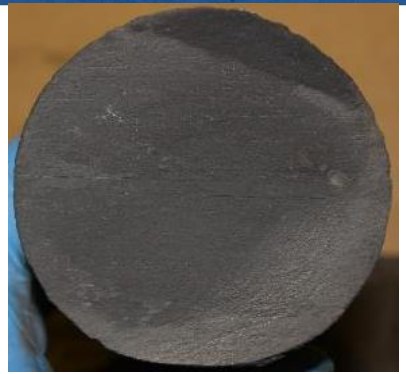
- Frequency
- Spatial distribution
- Length and height
- Simple or complex
- Vertical or dipping
- Orientation vs principal stresses

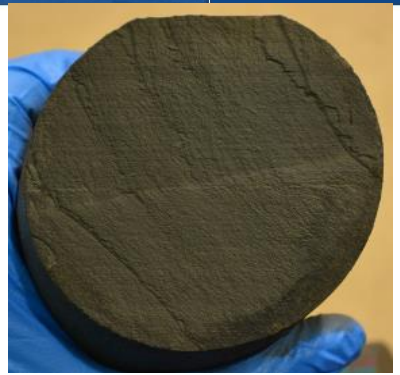
Base State : Natural Fractures

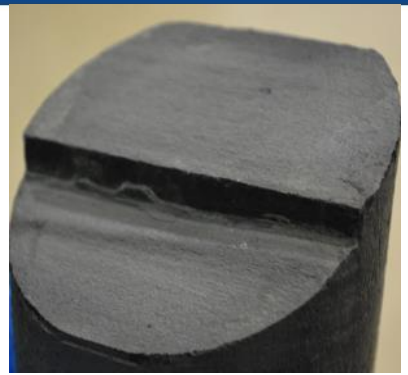
- Pilot located in seismically quiet area
  - No mappable faults
  - Few subseismic features (FEV)
- S1 image log – 1 fracture in 216 ft. of section
- S2 baseline core – 5 fractures in 200 ft. core
- S2 image log – 7 fractures in 1,120 ft. log
- Natural and hydraulic fractures are ~ parallel

Hydraulic Fracture Facts

- » Abundant
- » Not mineralized
- » Extensional
- » Planar and dipping
- » Strike perpendicular to S_{Hmin}
- » Smooth, ridged, and stepped surfaces
- » No matrix damage

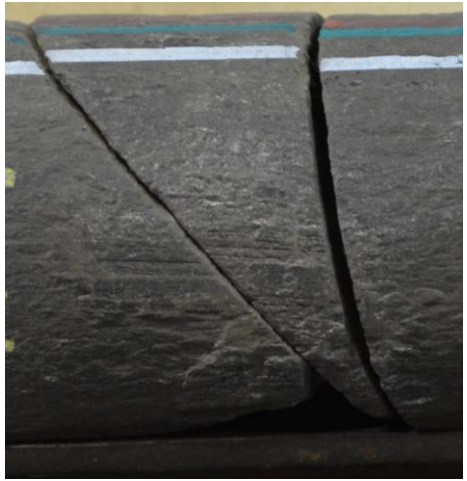


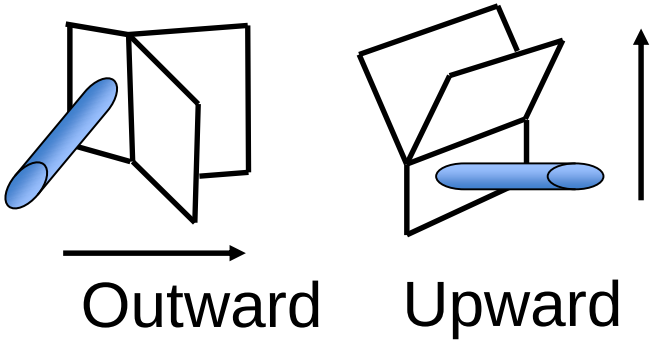




Hydraulic Fracture Branching

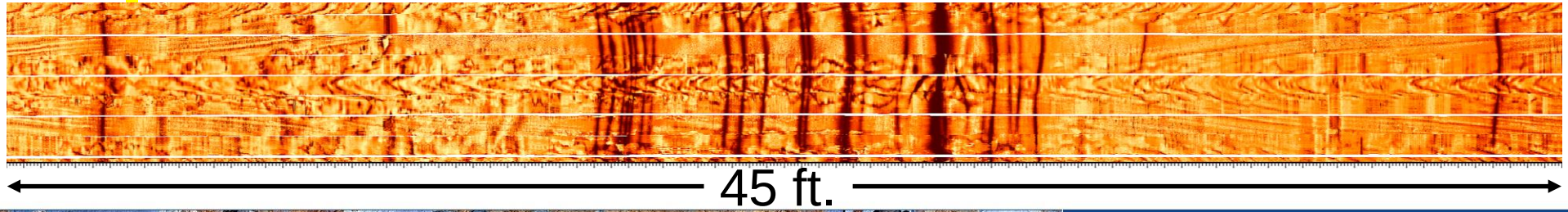
- Branching evident in core and FMI
- Complex 3D fracture pattern
  - More prevalent upwards vs outwards

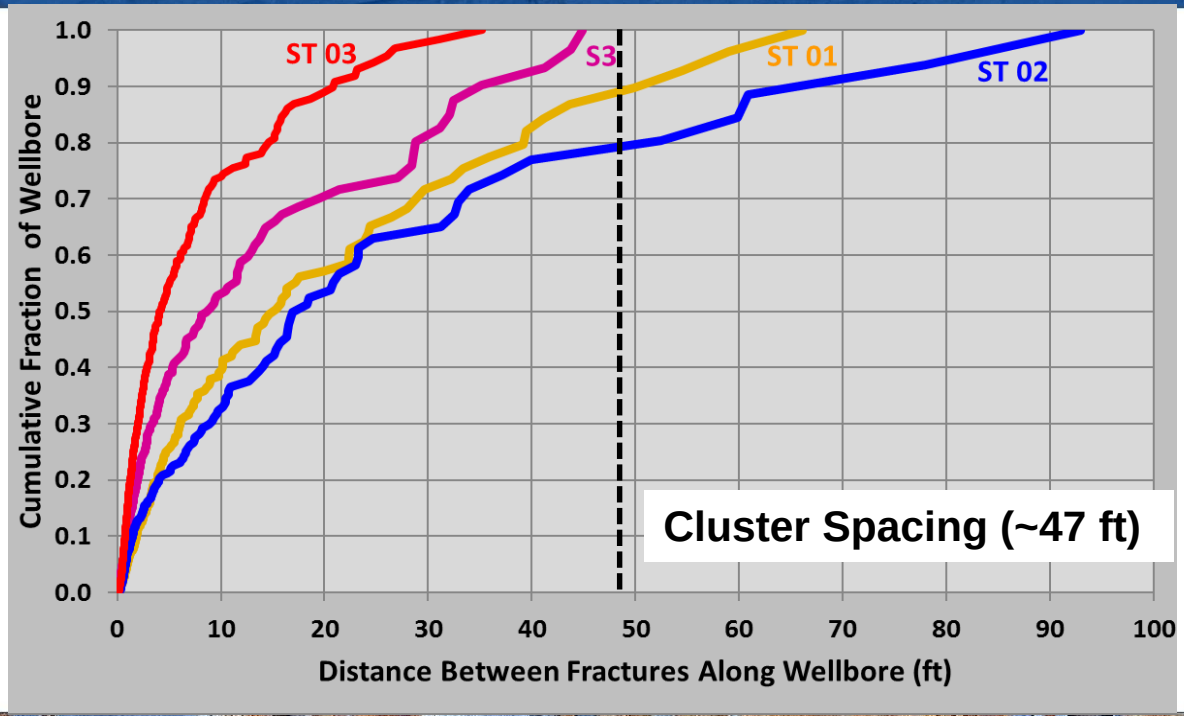




Hydraulic Fracture Swarms

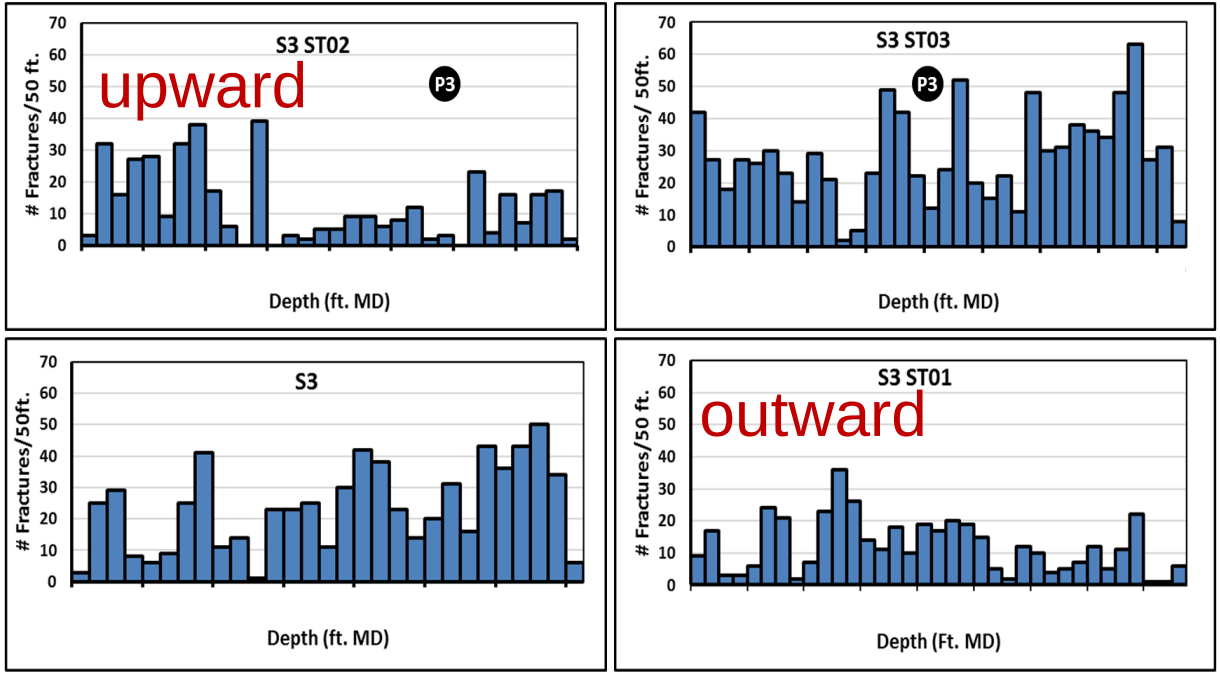
- » **Swarms of closely spaced hydraulic fractures**
- » **Less intensely fractured between swarms**
- » **15 – 25 fractures per swarm**
- » **Weak correlation between swarm frequency and cluster spacing**





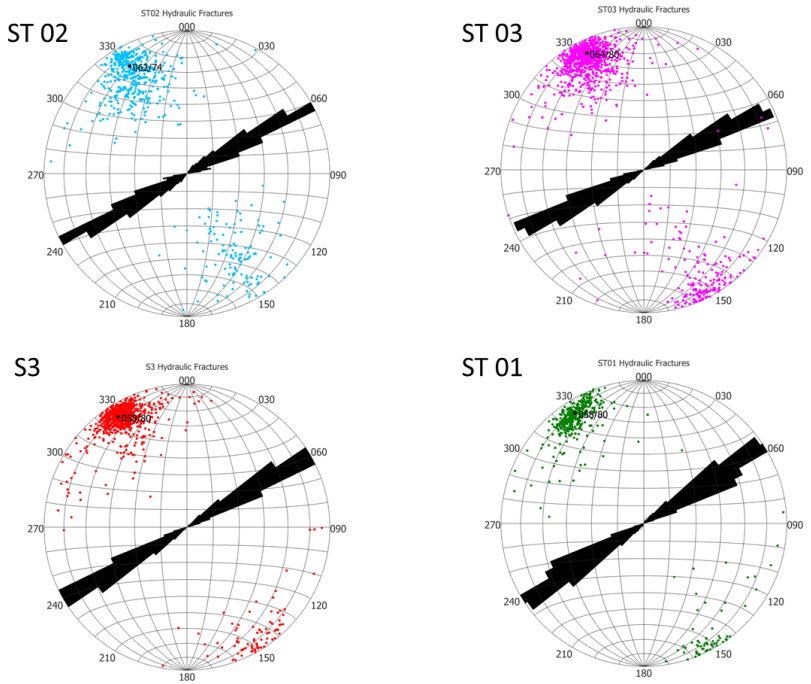
Hydraulic Fracture Spacing

- » Fracture count exceeds cluster count
- » 20 – 60% of wellbore has fractures at < 5ft. spacing (swarm)
- » Larger gaps with distance from producer



Hydraulic Fracture Density

- » **Fracture density and count greatest near producer**
- » **Fracture density declines upward and outward**

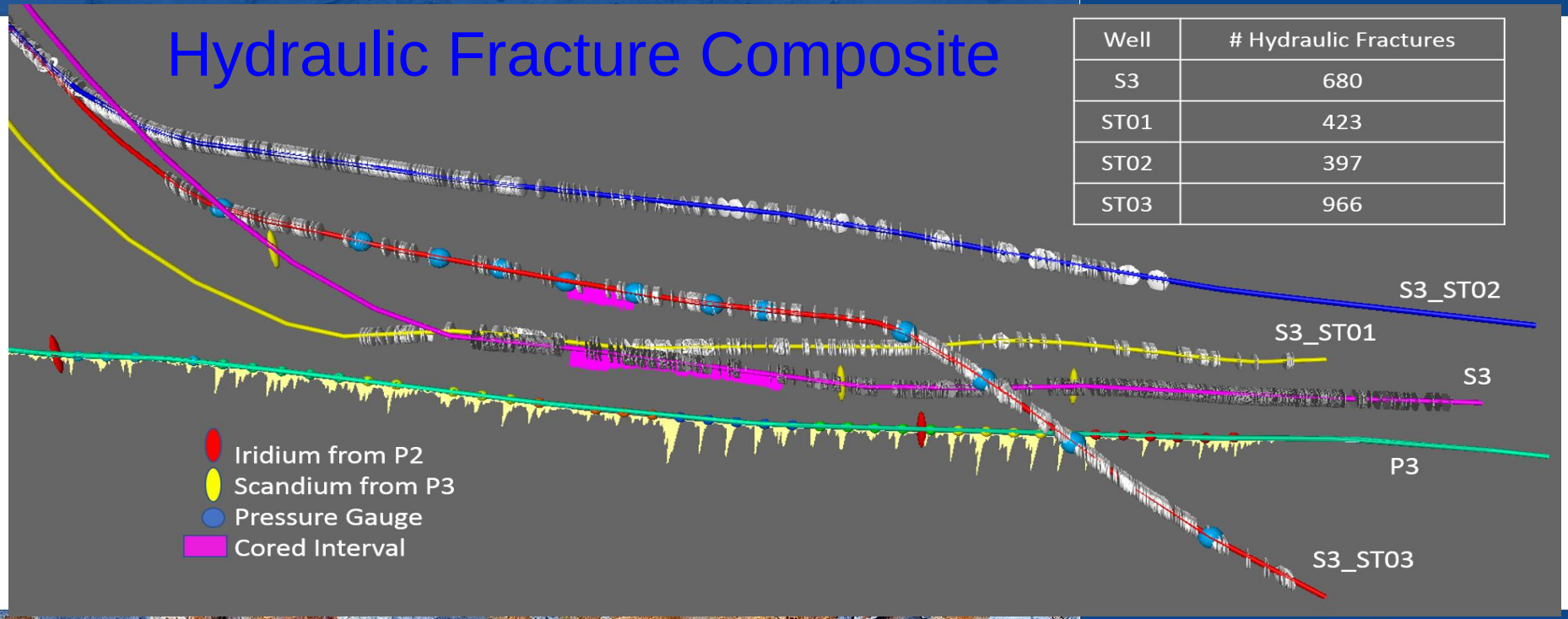


Dip and Orientation

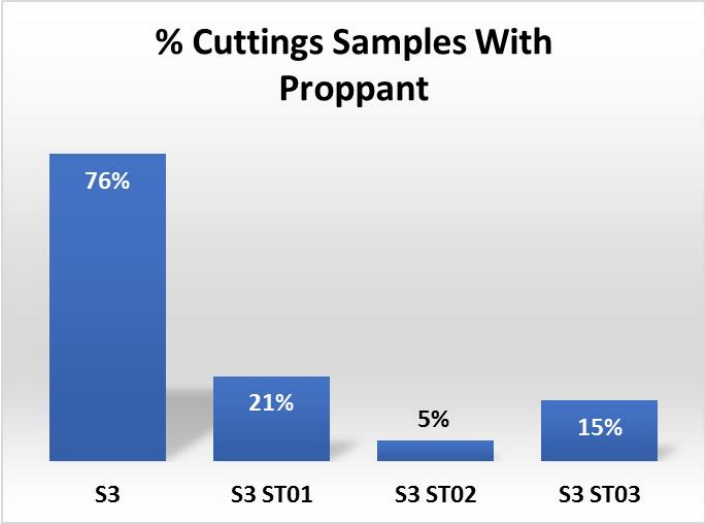
- » Perpendicular to S_{Hmin}
- » Strike: N 60° E / Dip: 75-80°SE
- » Predominantly parallel fractures at all locations
- » More dip variation above the producer

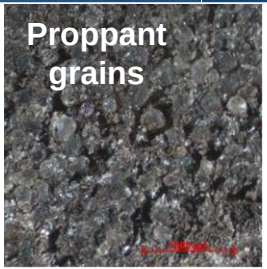
Hydraulic Fracture Composite

Well	# Hydraulic Fractures
S3	680
ST01	423
ST02	397
ST03	966



Proppant Transport

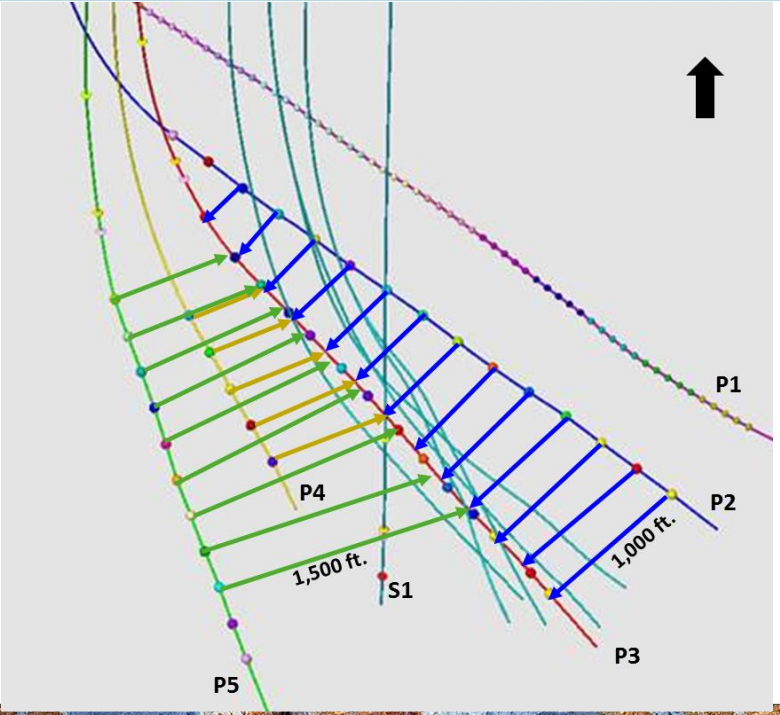




- **3 proppant filled fractures in 480 ft. of core (7 perf clusters)**
- **Little evidence for abundant proppant transport at distances greater than 75 ft.**

Hydraulic Fracture Character

- Hydraulic Fractures are complex not simple
  - multiple, discrete and parallel
  - dip, but align with in-situ stress
  - spatially distributed unevenly
  - often occur in swarms
- Proppant is rarely sampled, especially far from producer
  - RA tracers indicate limited well-to-well proppant transport
- No matrix permeability enhancement
  - core perm measurements



DAS Completion Monitoring

- » **DAS response recorded from all monitored stages at P3**
- » **Multiple hydraulic fractures per stage extend >1,500 ft.**
- » **Pre-existing hydraulic fractures at P3 prior to stimulation**

A Few Key Points

- Hydraulic stimulation creates fracture complexity
  - Simple concepts of one fracture per cluster are unrealistic
  - Fracture area likely exceeds that predicted by models
- Multiple fractures per stage extend long distances
- Sparse evidence for abundant proppant transport beyond 75 ft.