Microseismic Fracture Mapping Results in the Woodford Shale

Oklahoma Gas Shales Conference

Oklahoma Geological Survey

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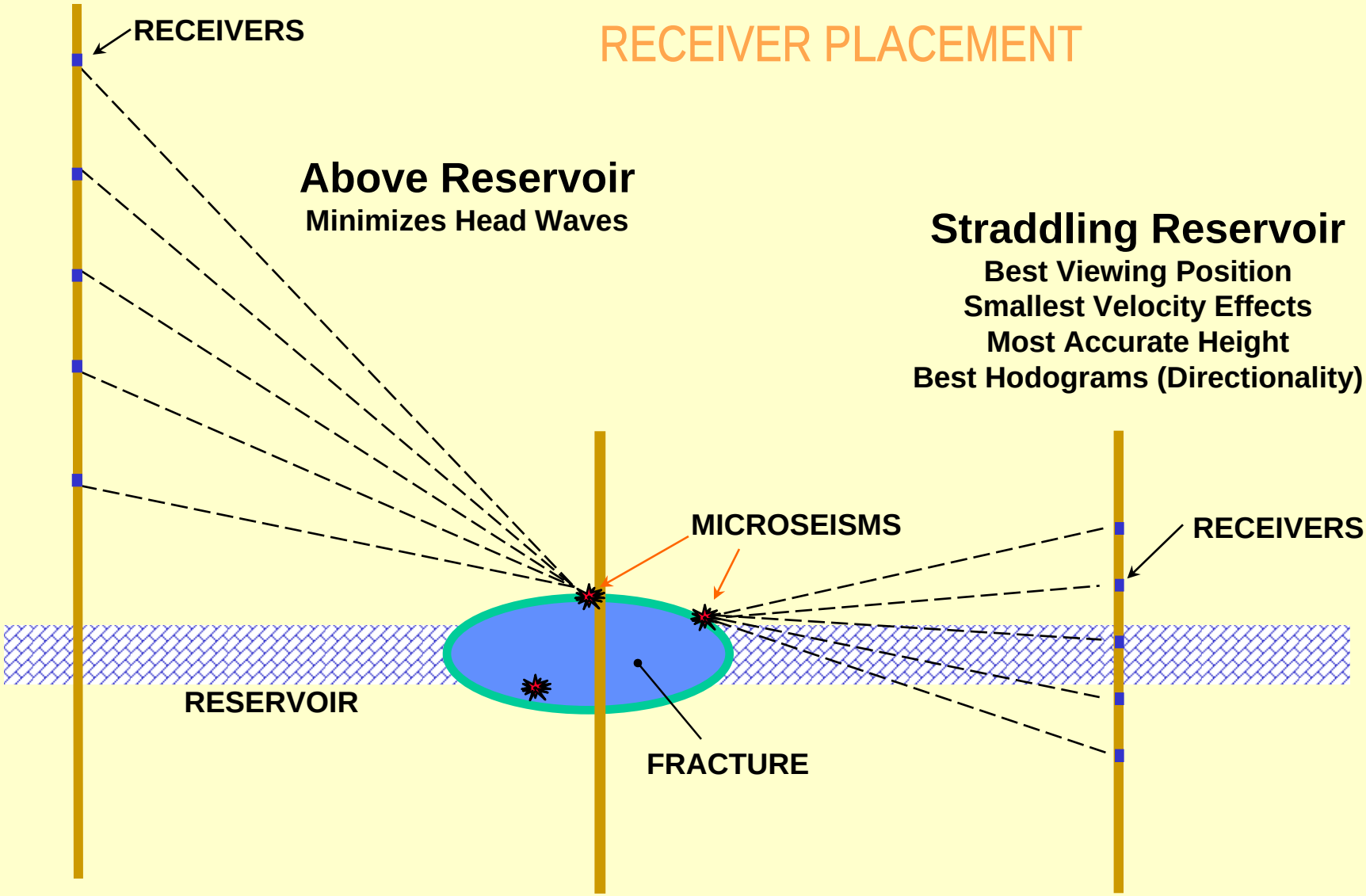
Pinnacle Technologies

Introduction

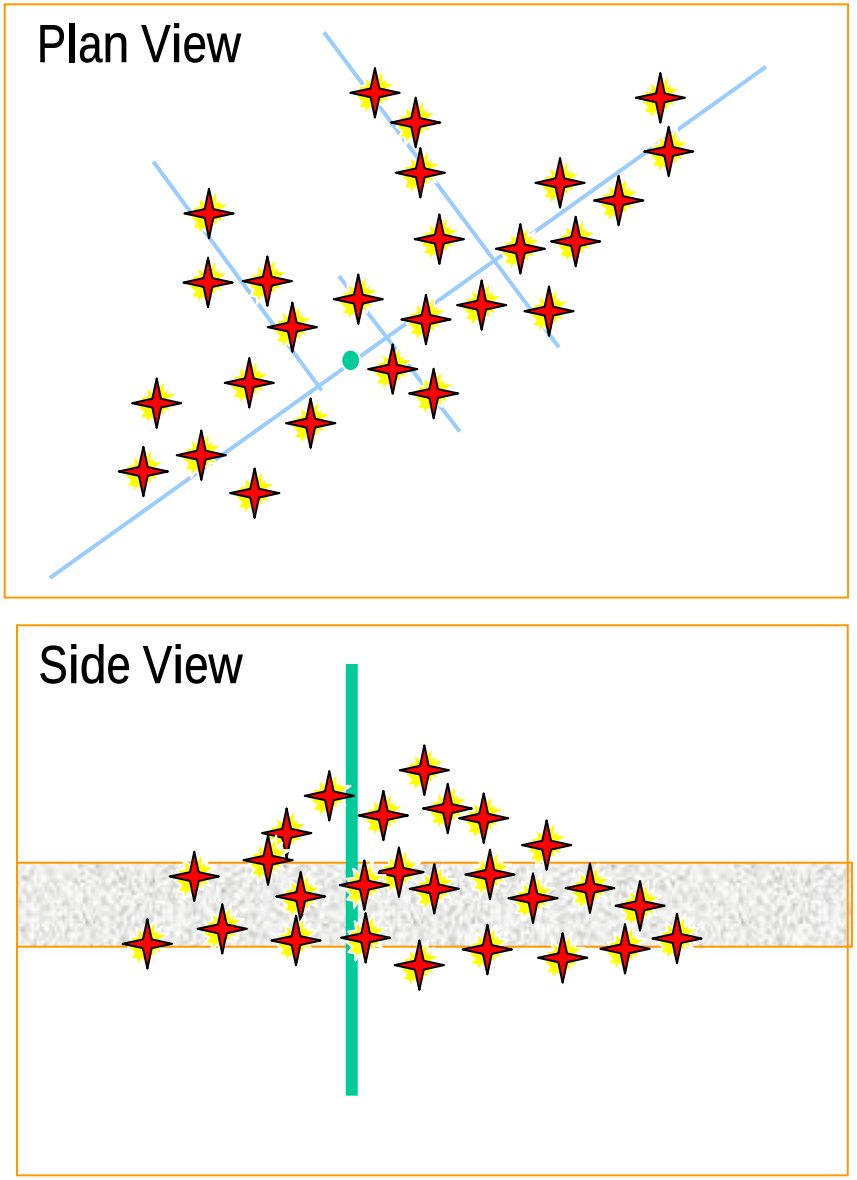
- Microseismic Mapping
- Fracturing Shale Reservoirs

RECEIVER PLACEMENT

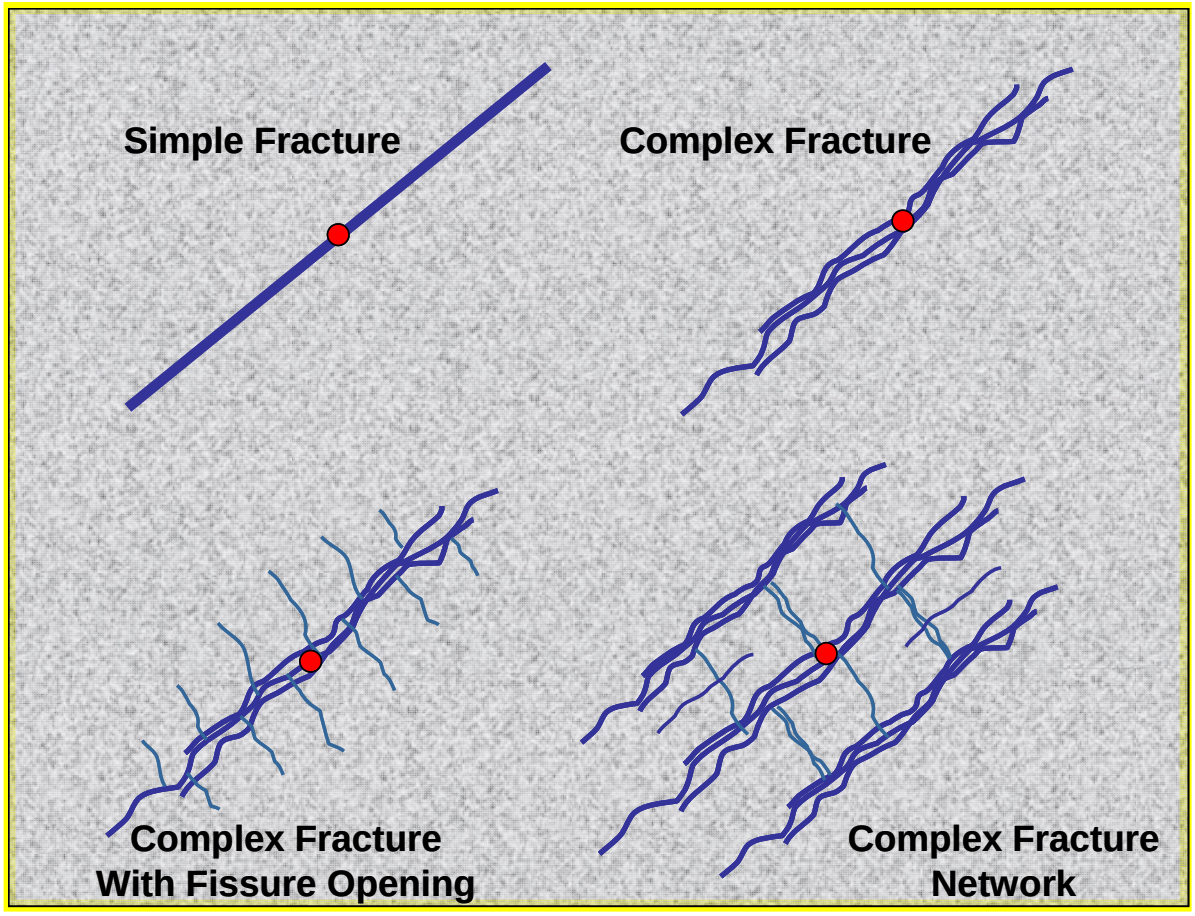


Microseismic Monitoring

- The Detection And Locating Of Micro-Earthquakes Induced By Hydraulic Fractures To Map Out The Geometry & Characteristics Of The Hydraulic Fracture

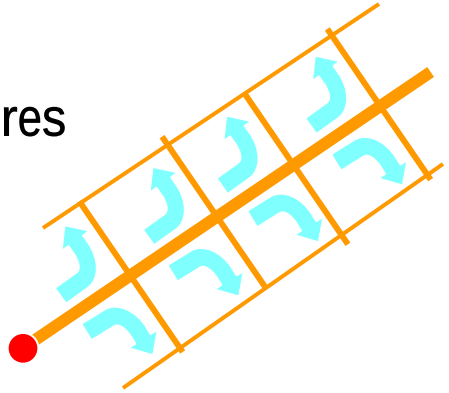


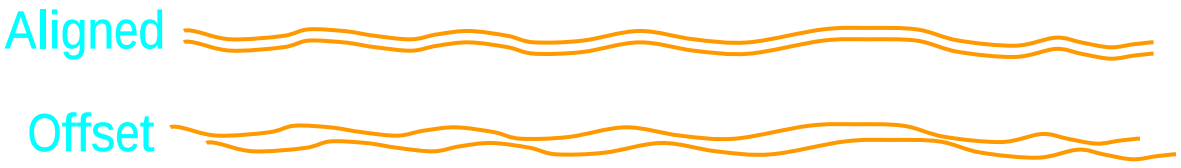
Fracture Complexity & Network Growth



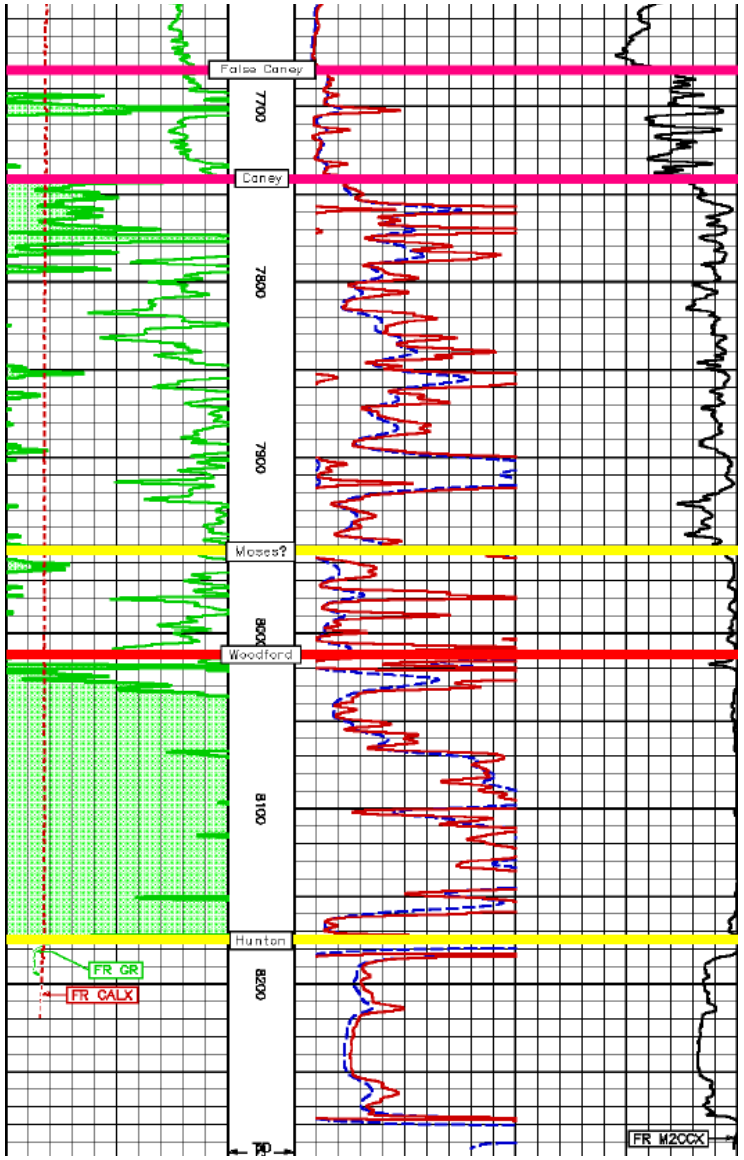
Network Fracture Conductivity

- Primary Hydraulic Fracture
  - Likely Extensive Sand Banking & Transport Distances
- Orthogonal Network Fractures
  - Proppant Behavior
    - Proppant Can Turn Corner
    - Smaller Width, Lower Rate In Orthogonal Fractures
      - Results In Less Efficient Transport
  - Proppant Bridging (May Enhance Fracturing)
    - 100 Mesh
  - Shear Offset
    - Microseismic Events Are Shear Slippages
    - High Shear Environment Due To Massive Fracture Planes With Different Pressures





Woodford Shale Type Log



Thickness ranges from 50 - 300 ft

Main exploitation with long horizontal wells and large slickwater fracs

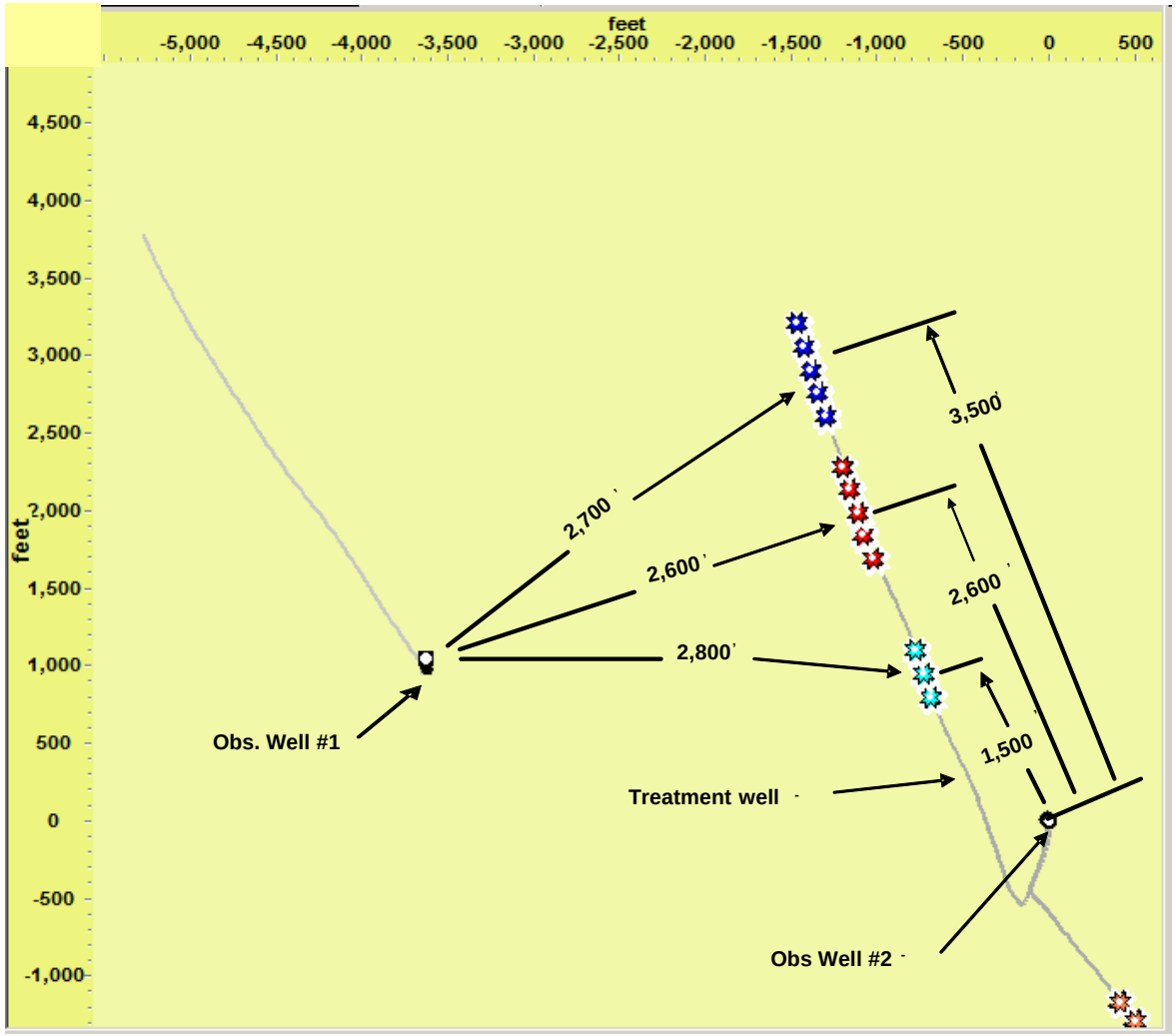
- Lateral lengths 2500 – 4000 ft
- 10,000 – 30,000 bbls/stage
- 200k – 500k lbs proppant/stage

Barnett-style stimulations to maximize stimulated reservoir volume (SRV)

Woodford Mapping Project
SPE 110029

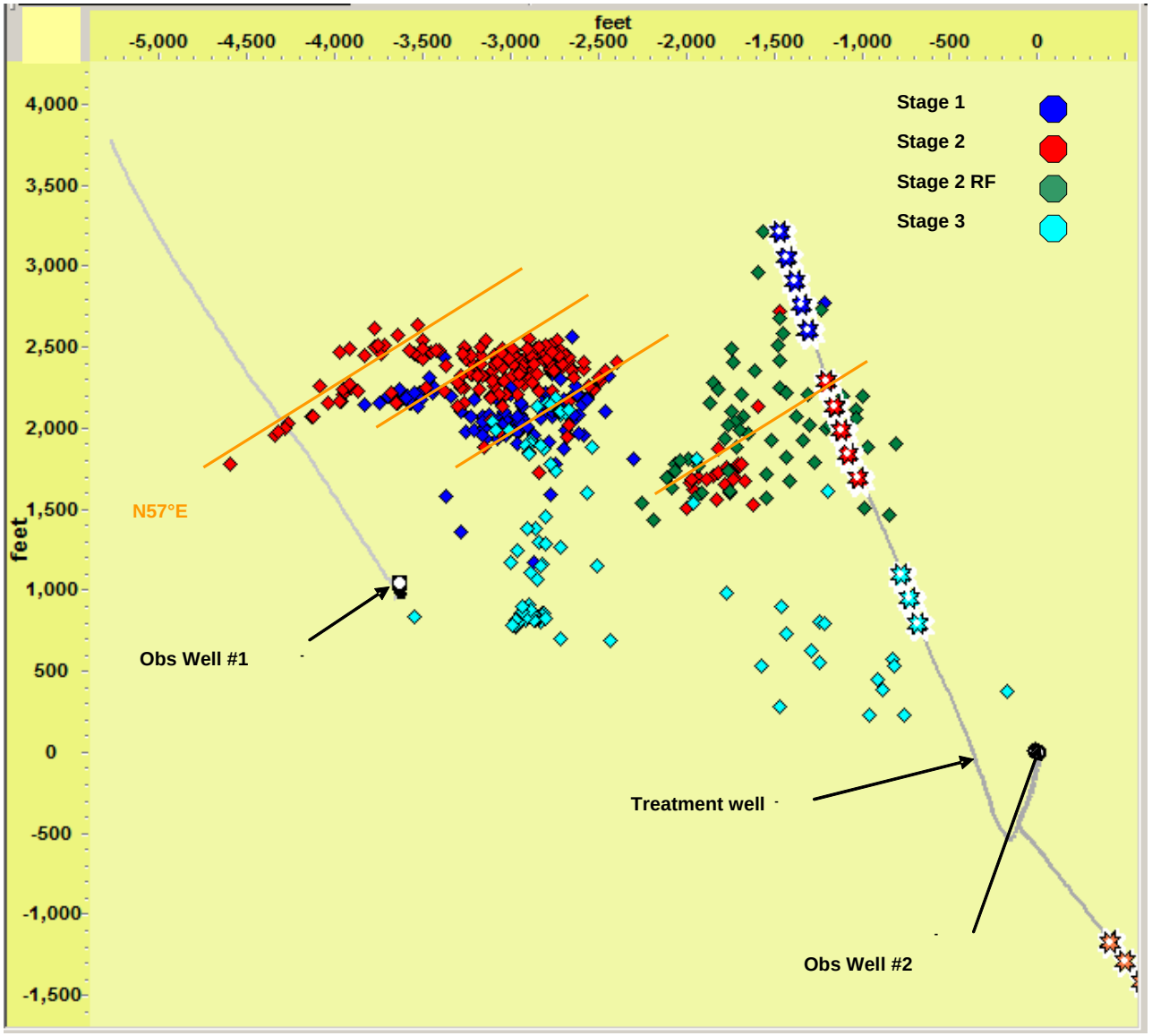
- Early stages of development in the Woodford
- Objective – measure hydraulic fracture geometry in order to optimize future well locations and completion/stimulation design
- Wellbore Trajectory
  - Land the lateral high, low or midway within the Woodford?
  - Transverse or longitudinal fracs being created?
- Payzone coverage (fracture height & lateral depth)
- Wellbore Coverage (along the lateral)
- Diversion & Staging Methods
  - Perf balls, bridge plug, frac staging systems, etc.
- Well Spacing

Project 1 Layout



- Horizontal well mapped
  - 3 stages MSM
  - 1 ReFrac
- Observed Stage 1 and 2 from Obs. Well #1
- Observed Stage 2 ReFrac and 3 from Obs. Well #1 and Obs Well #2
- Stage 2 ReFrac and Stage 3 preformed approx 40 days following initial treatments
- 17-28K bbls Slickwater
- 85-90 BPM
- 70k-550k lbs 30/70-20/40 sand

Project 1 Plan View

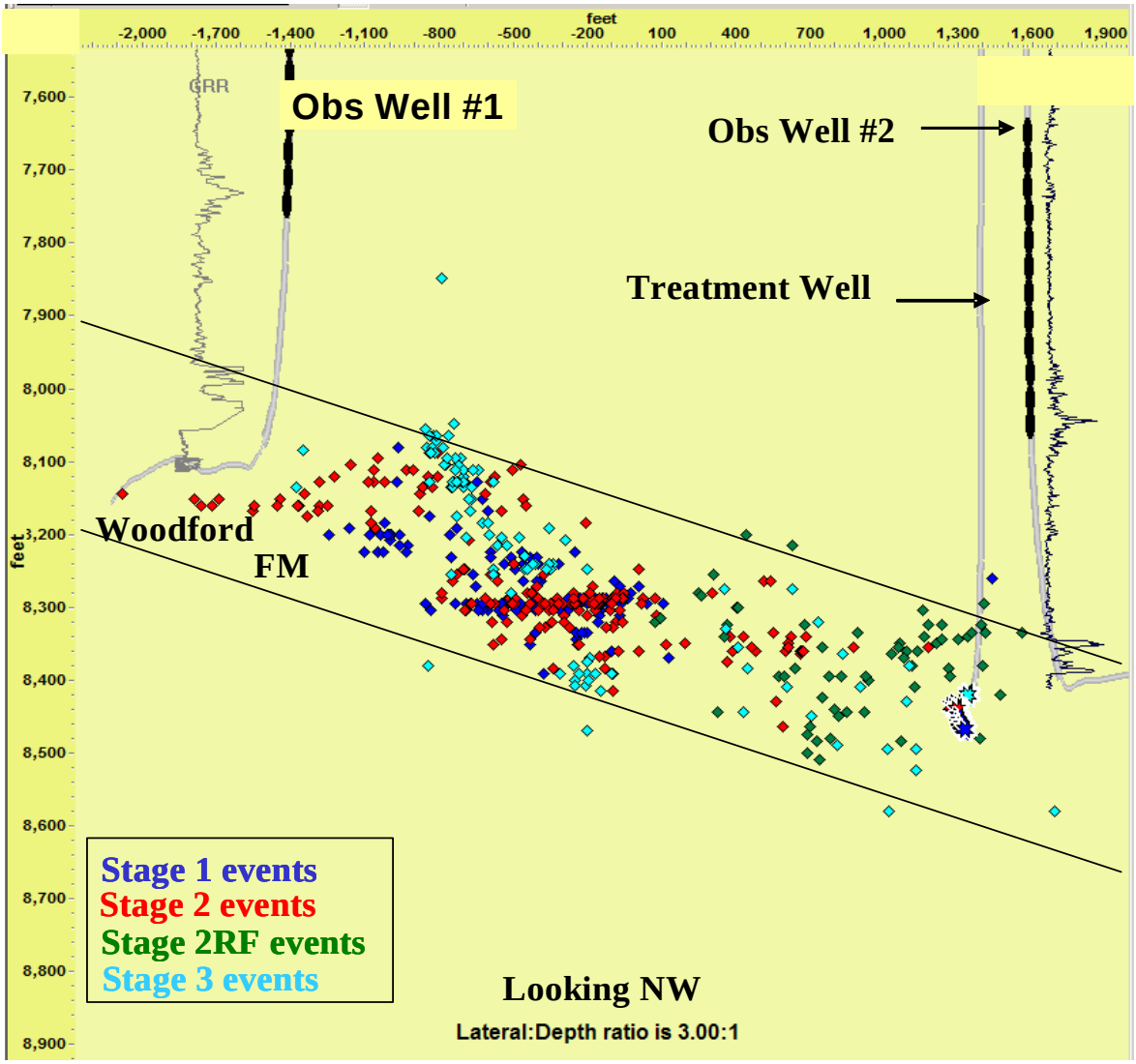


- Three stages
- Complex growth – wide network
- Data affected by Feature (fault or natural fracture system)
- Azimuth N57^{o}E
- Frac lengths 2000-2500 ft
- Asymmetry

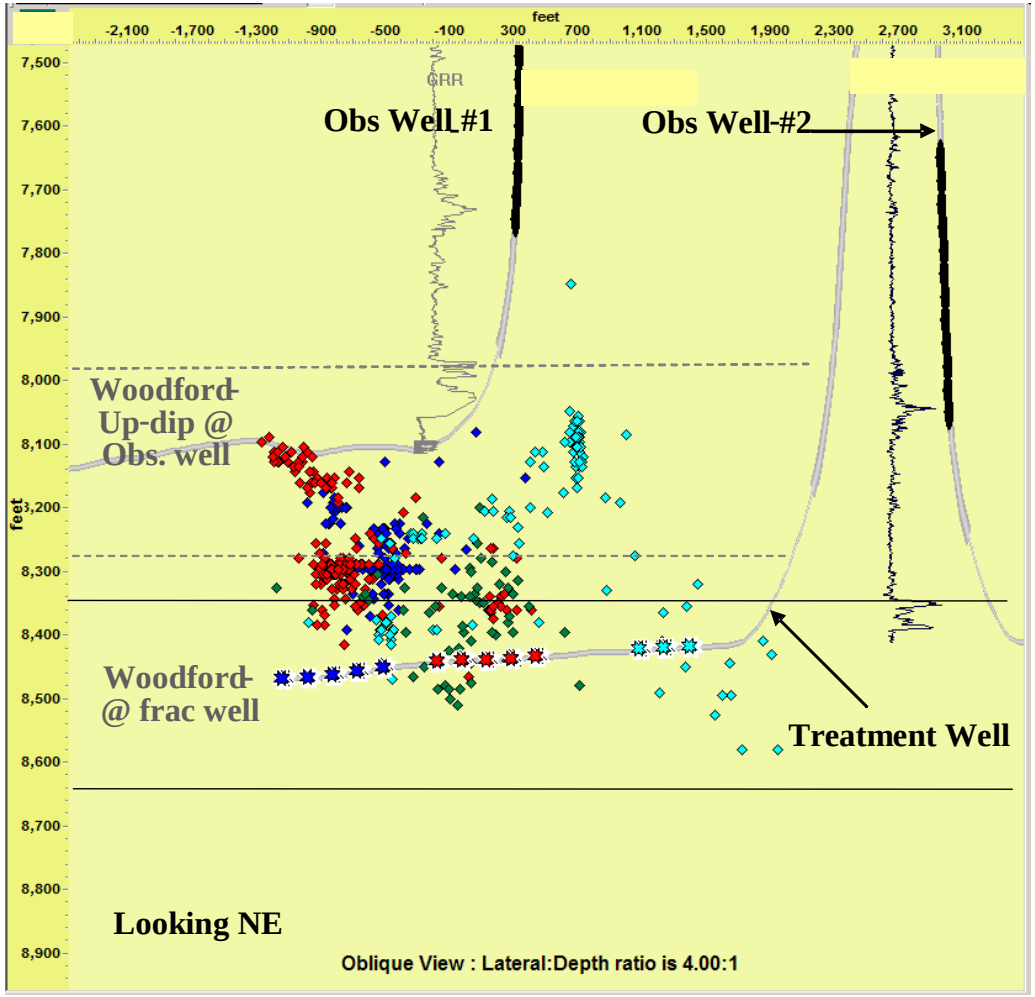
Project 1 Edge View

Fracture Lengths
- Stage 1: 2500’
- Stage 2: 3300’
- Stage 3: 1400’
- Stage 4: 1200’

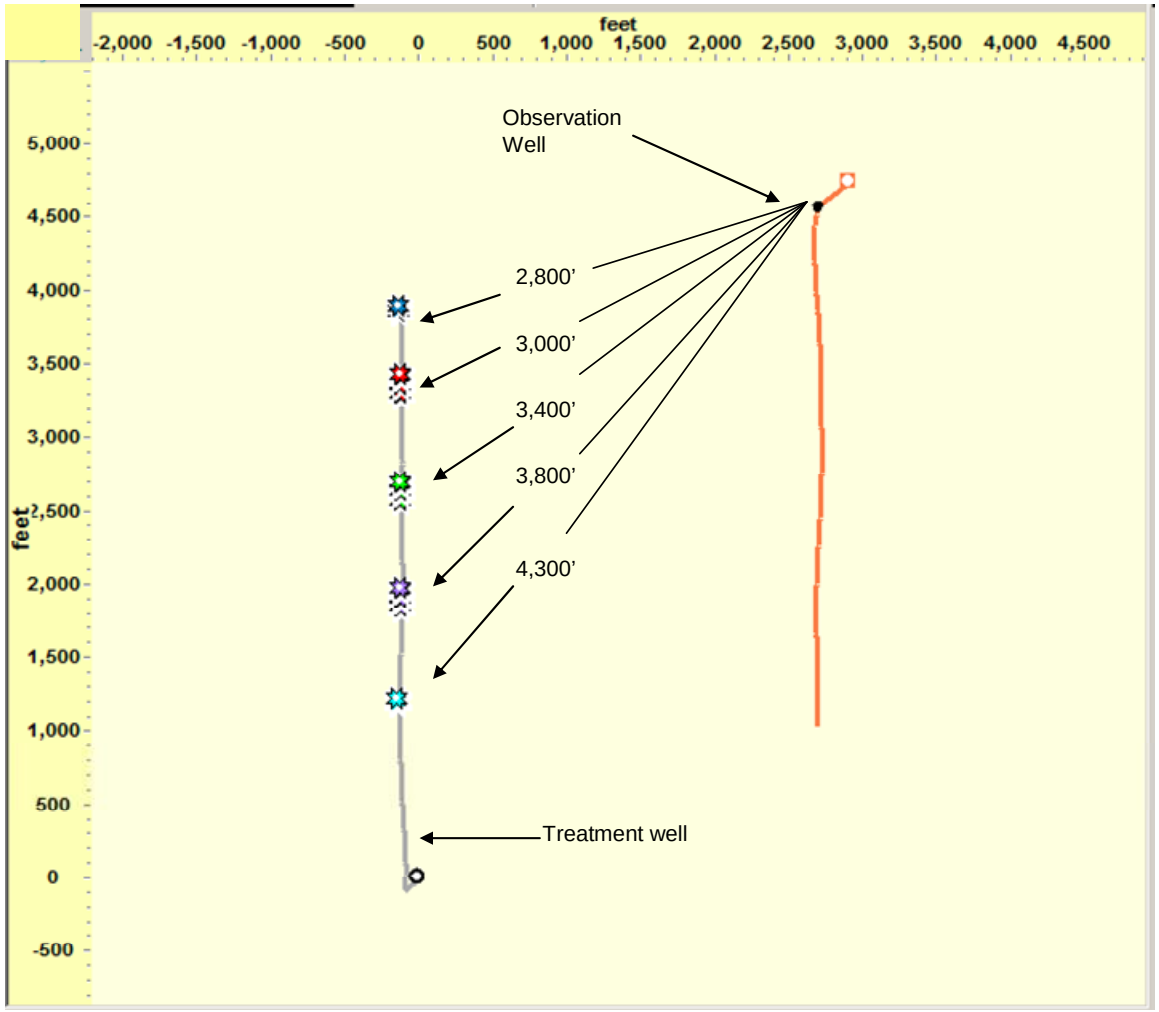
Fracture Heights
- Stage 1: 250’
- Stage 2: 280’
- Stage 3: 280’
- Stage 4: 280’
- Well contained



Project 1 Side View



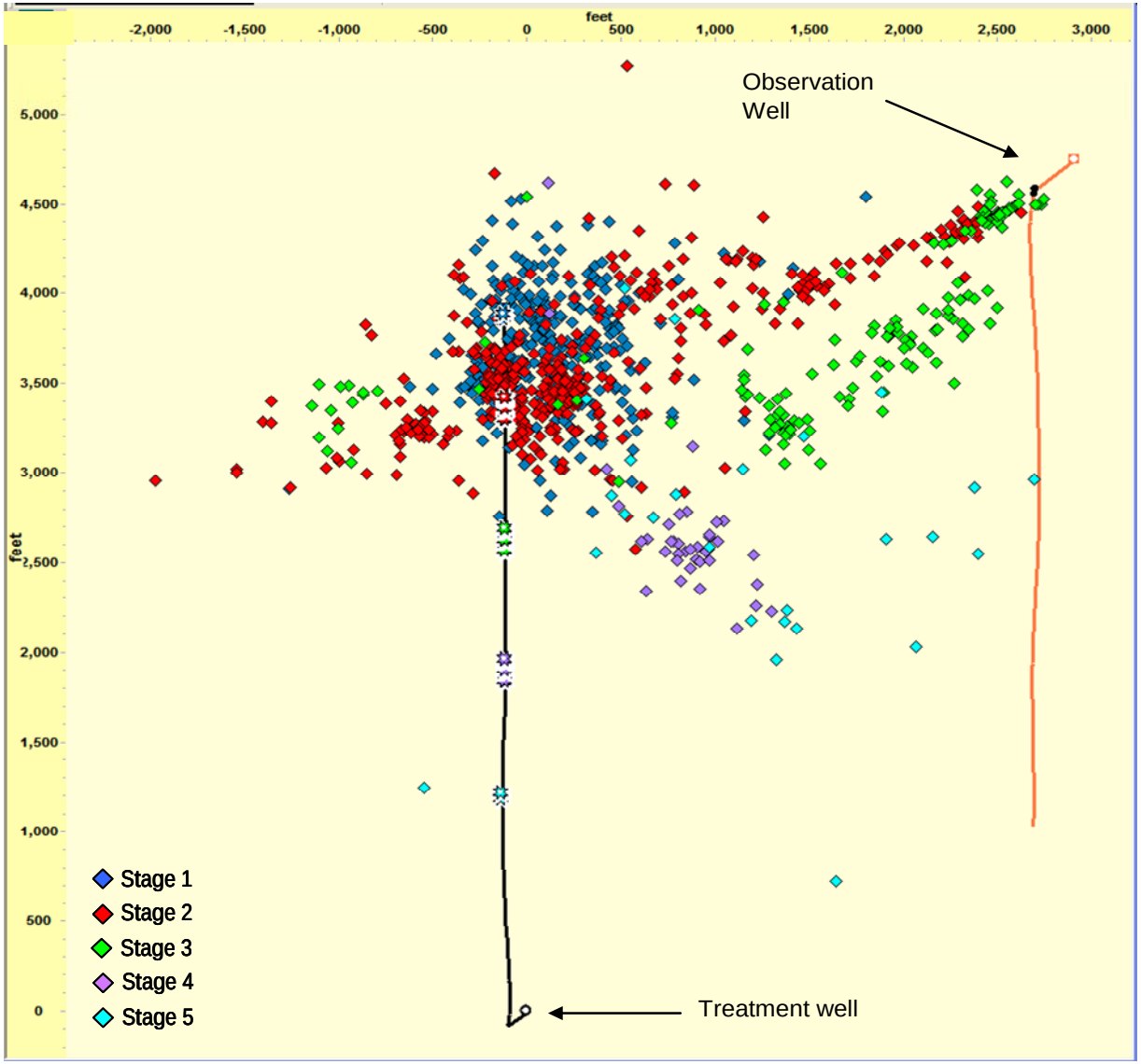
Project 3 Layout



- Horizontal well mapped
  - 5 stages MSM
  - 4300 ft to stage 5
- Observed Stage 1 -5 from Obs. Well #1
- 10-20K bbls Slickwater
- 85-100 BPM
- 100-mesh sand for diversion
- 70k-370k lbs 30/70-20/40 sand

Project 3 Map View

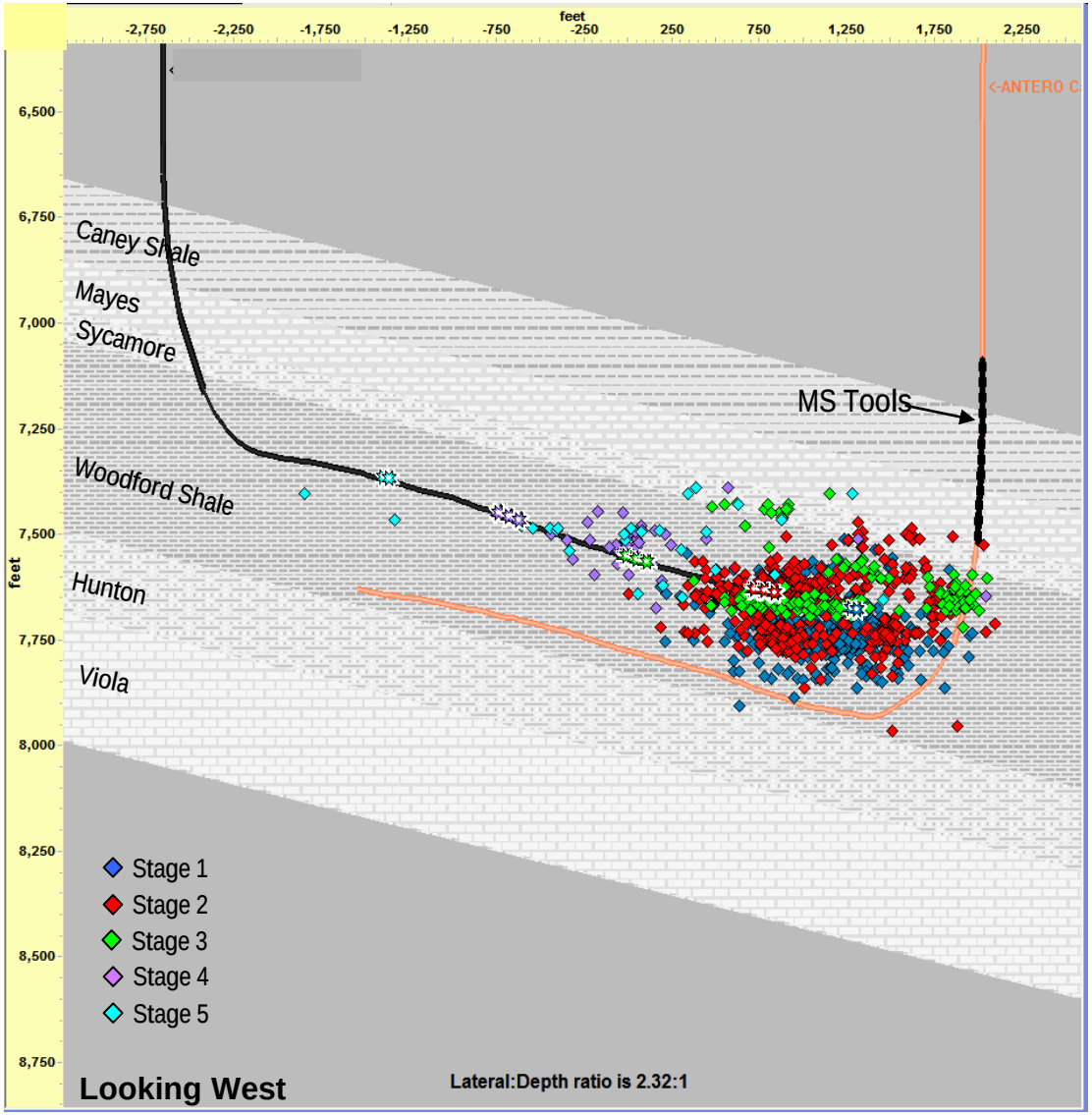
- 5 intervals
- Data affected by Fault
- Azimuth N60^{o}E
- Fracture lengths 1,300 – 4,300 ft
- Asymmetry



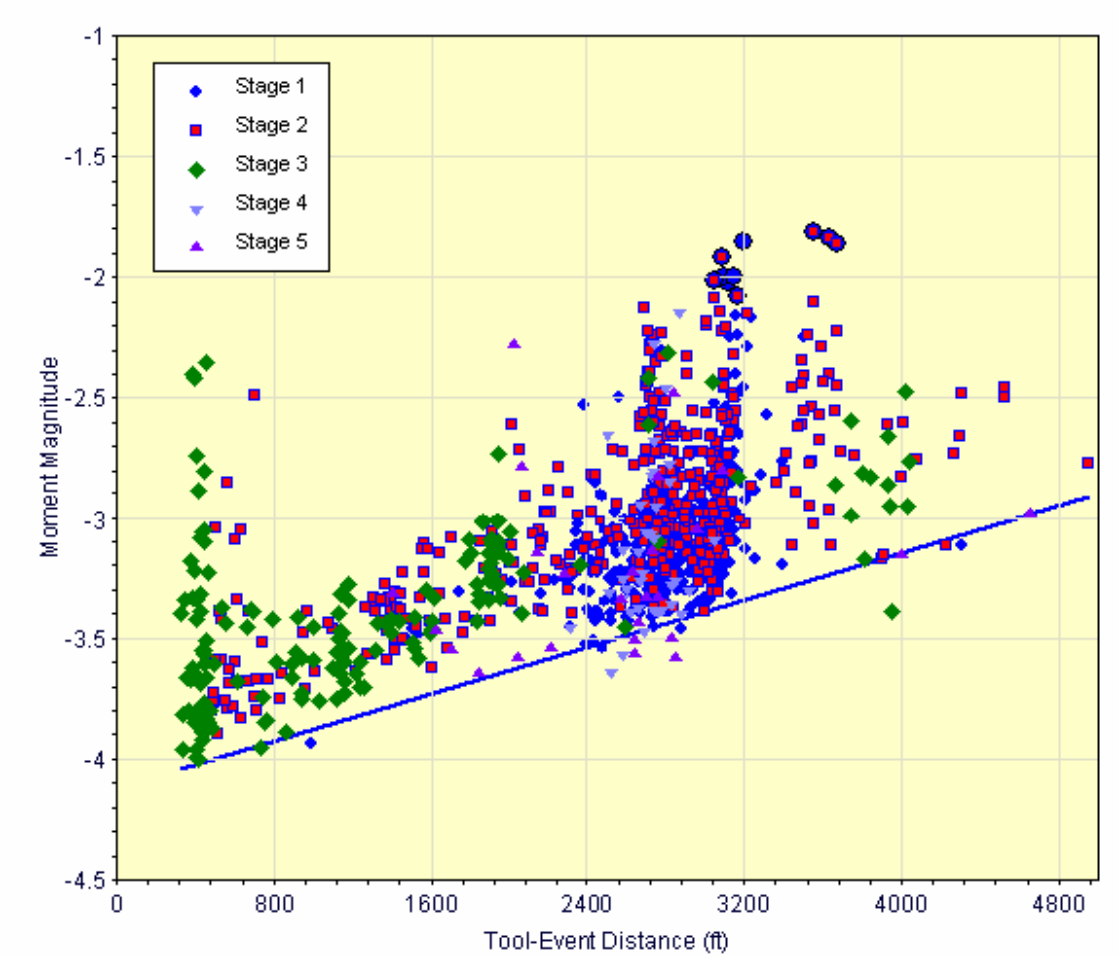
Project 3 Side View

Fracture Lengths
- Stage 1: 2130’
- Stage 2: 4360’
- Stage 3: 3400’
- Stage 4:
- Stage 5:

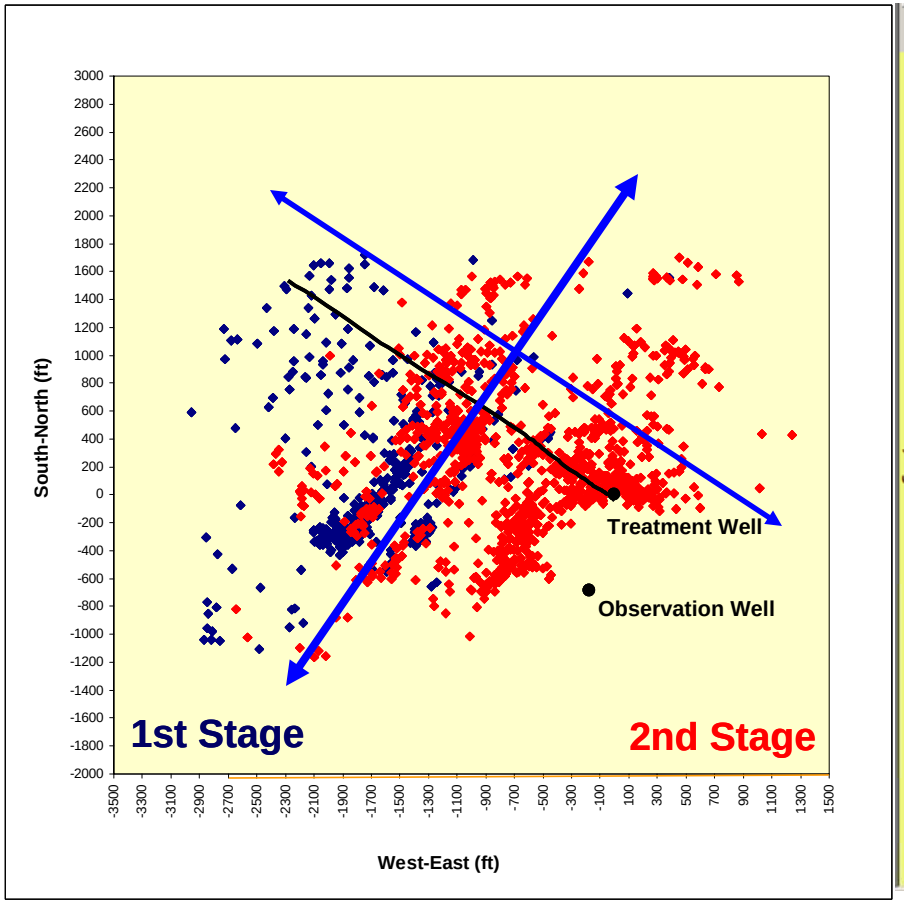
Fracture Heights
- Stage 1: 350’
- Stage 2: 500’
- Stage 3: 250’
- Stage 4:
- Stage 5:

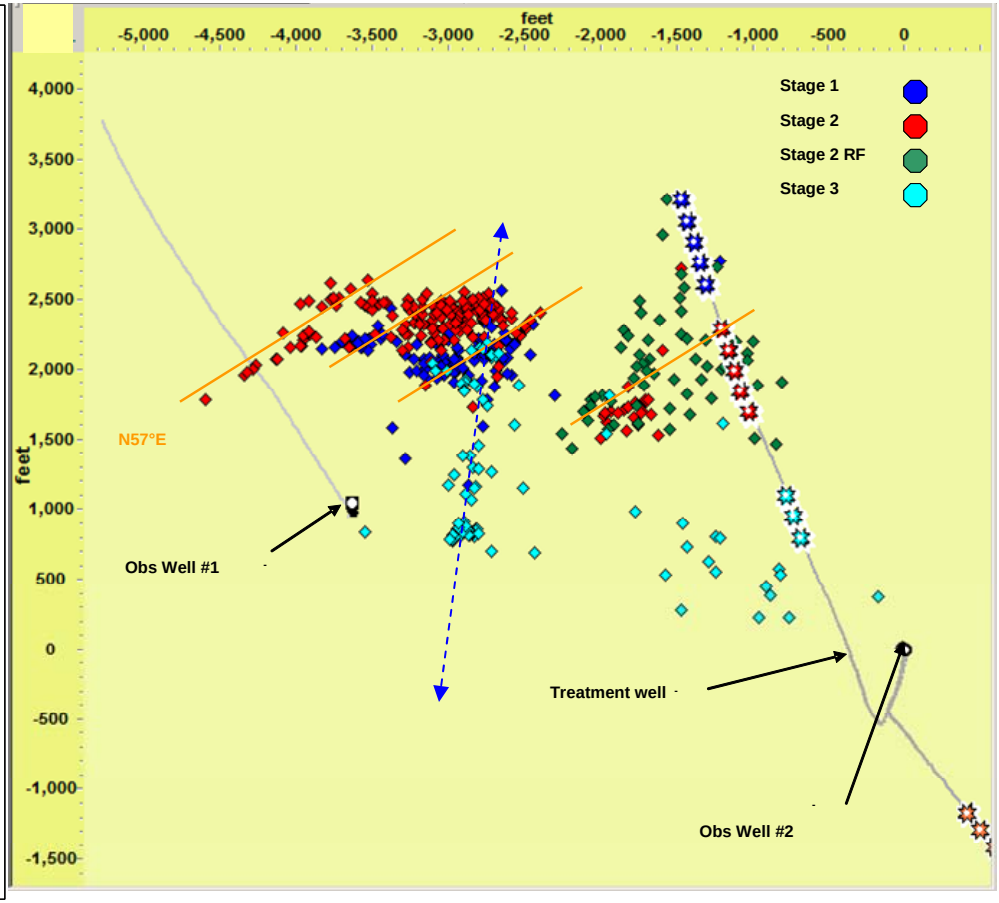


Project 3 Magnitude Vs. Distance Plot

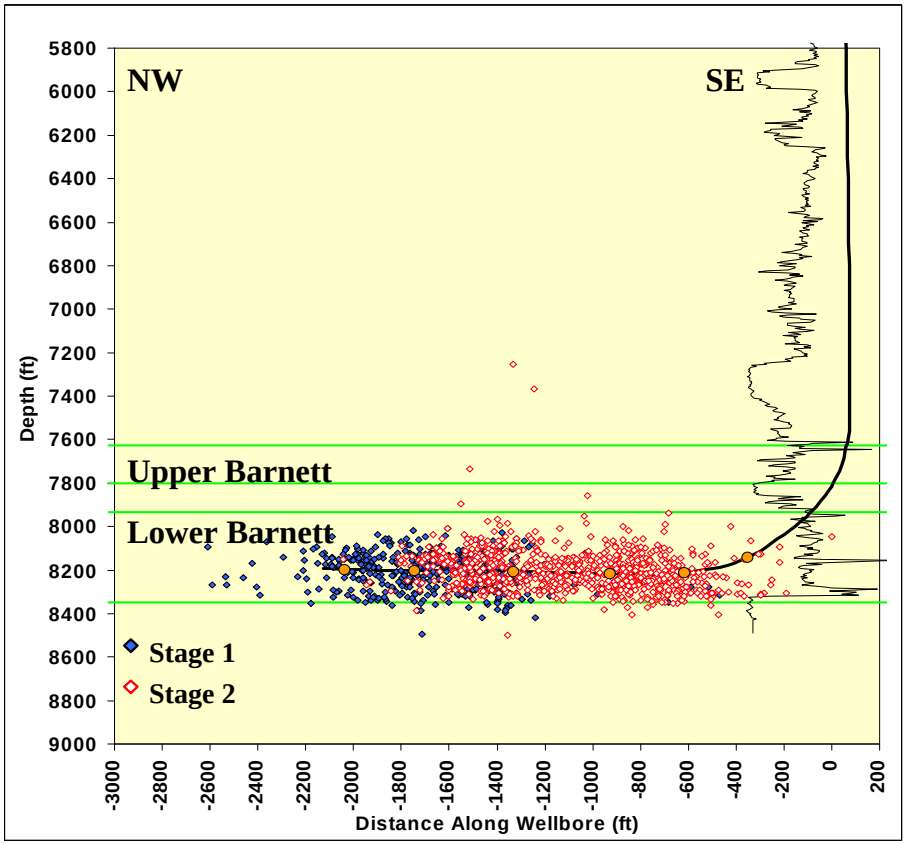


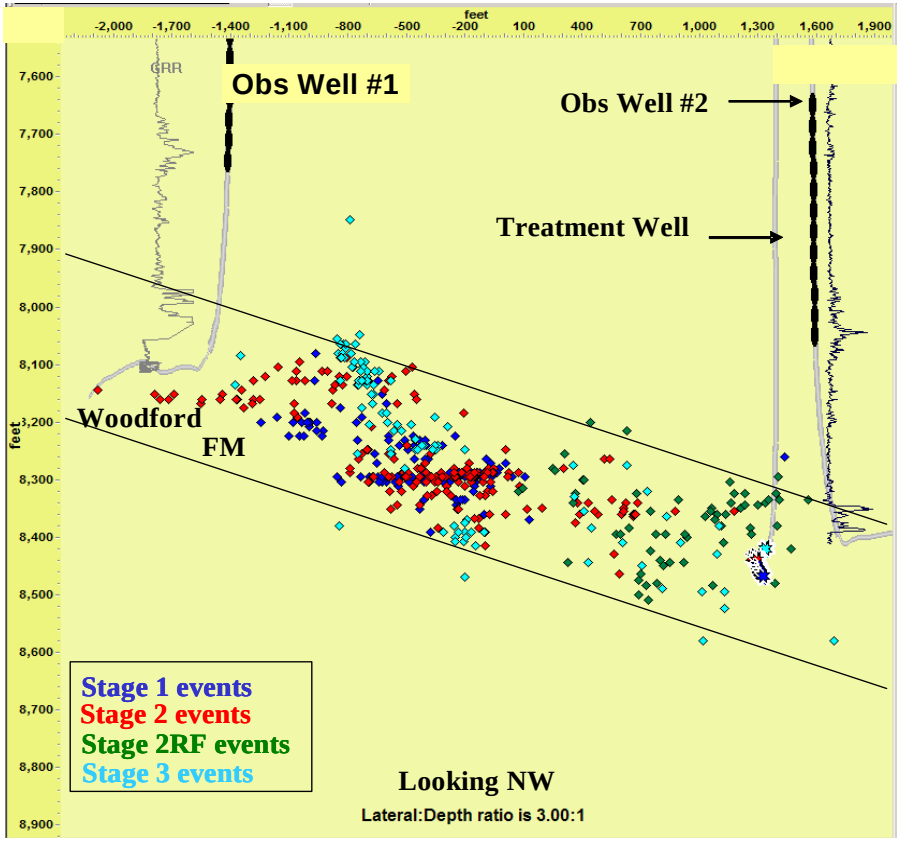
Barnett vs Woodford





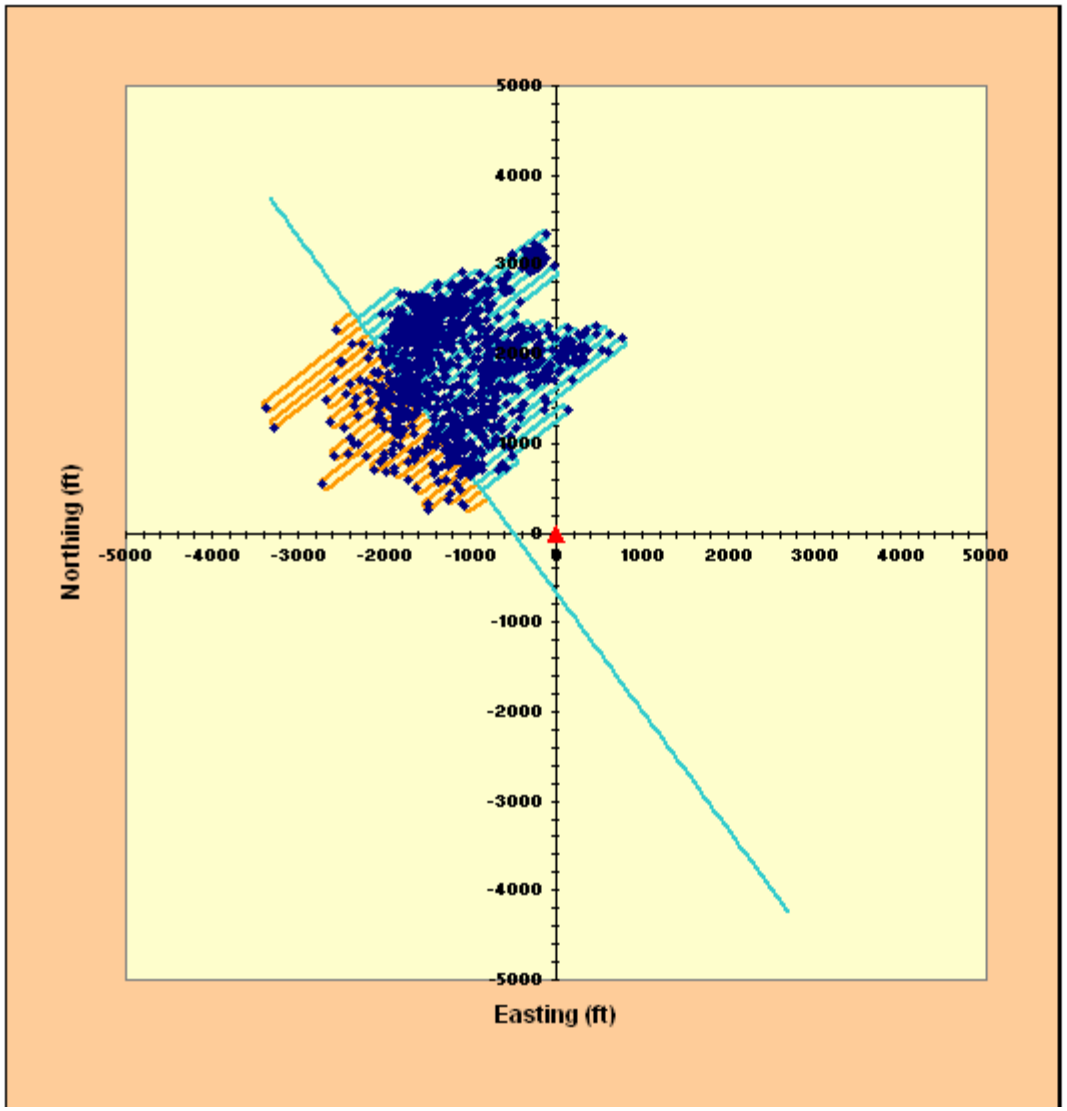
Barnett vs Woodford





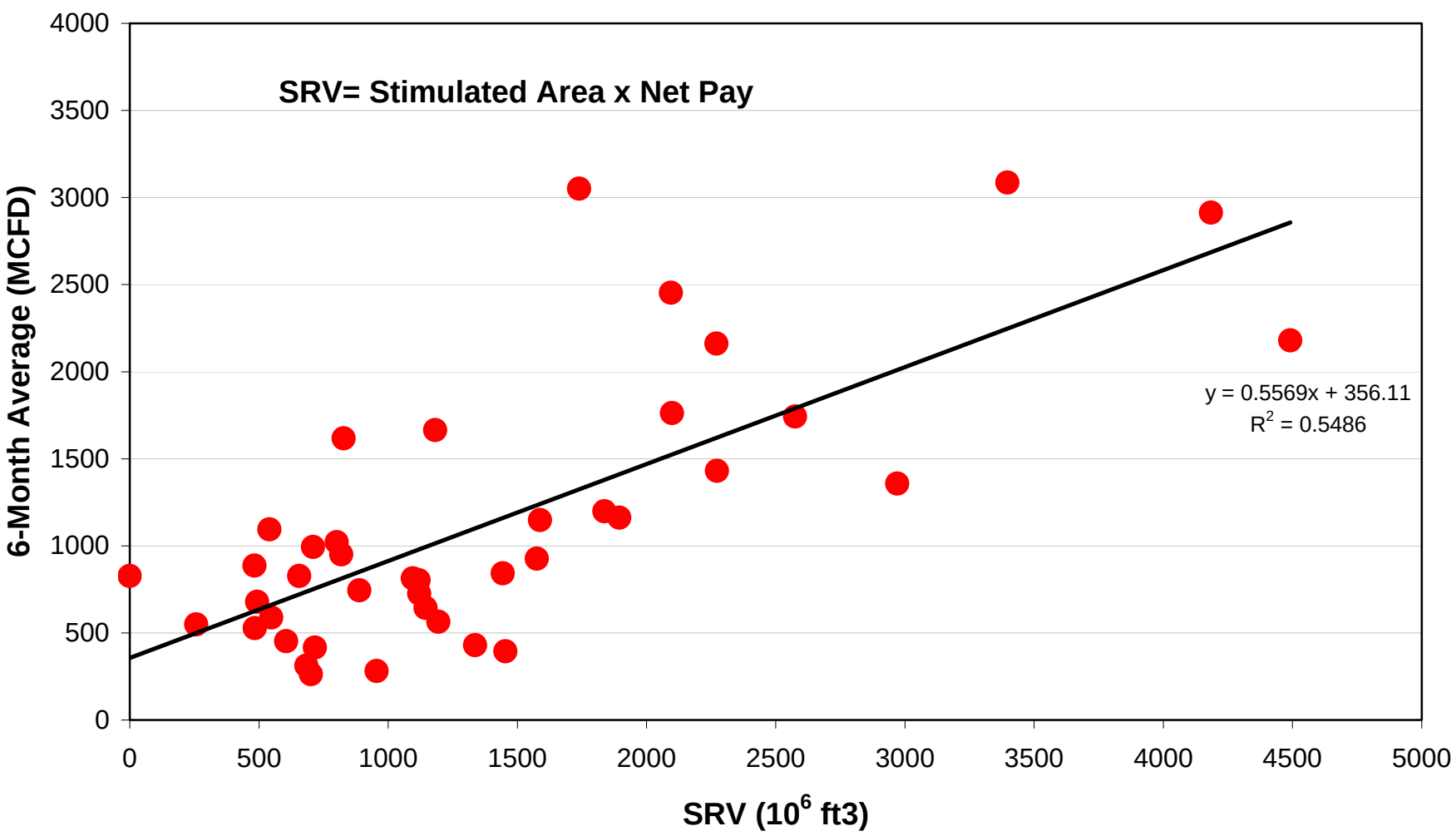
Mapping Data and Production

Stimulated Reservoir Volume (SRV)

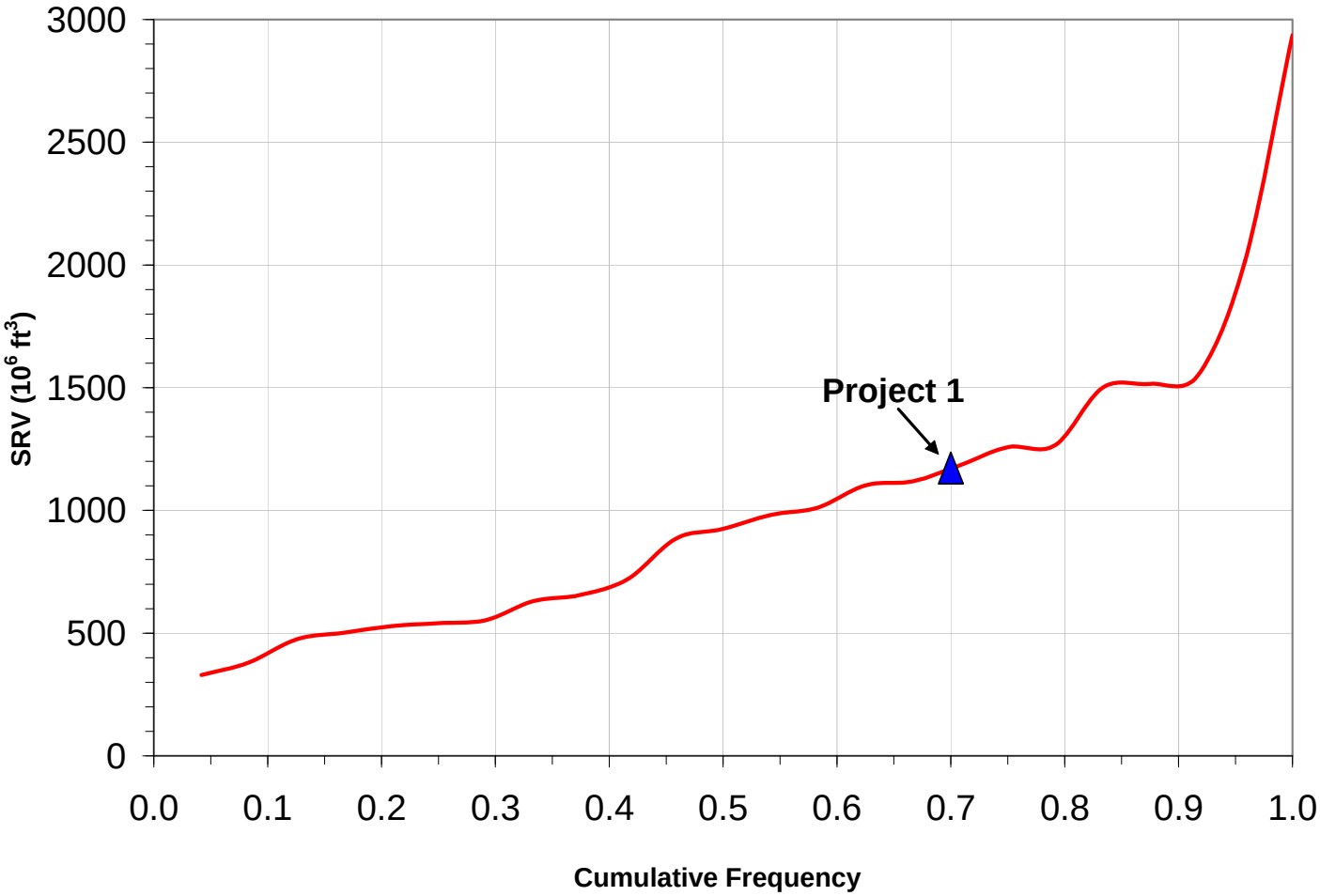


As-mapped SRA [ft²]	5,639,894
Symmetric SRA [ft²]	7,766,826
As-mapped SRV [ft³]	1,353,574,530
Symmetric SRV [ft³]	1,864,038,260

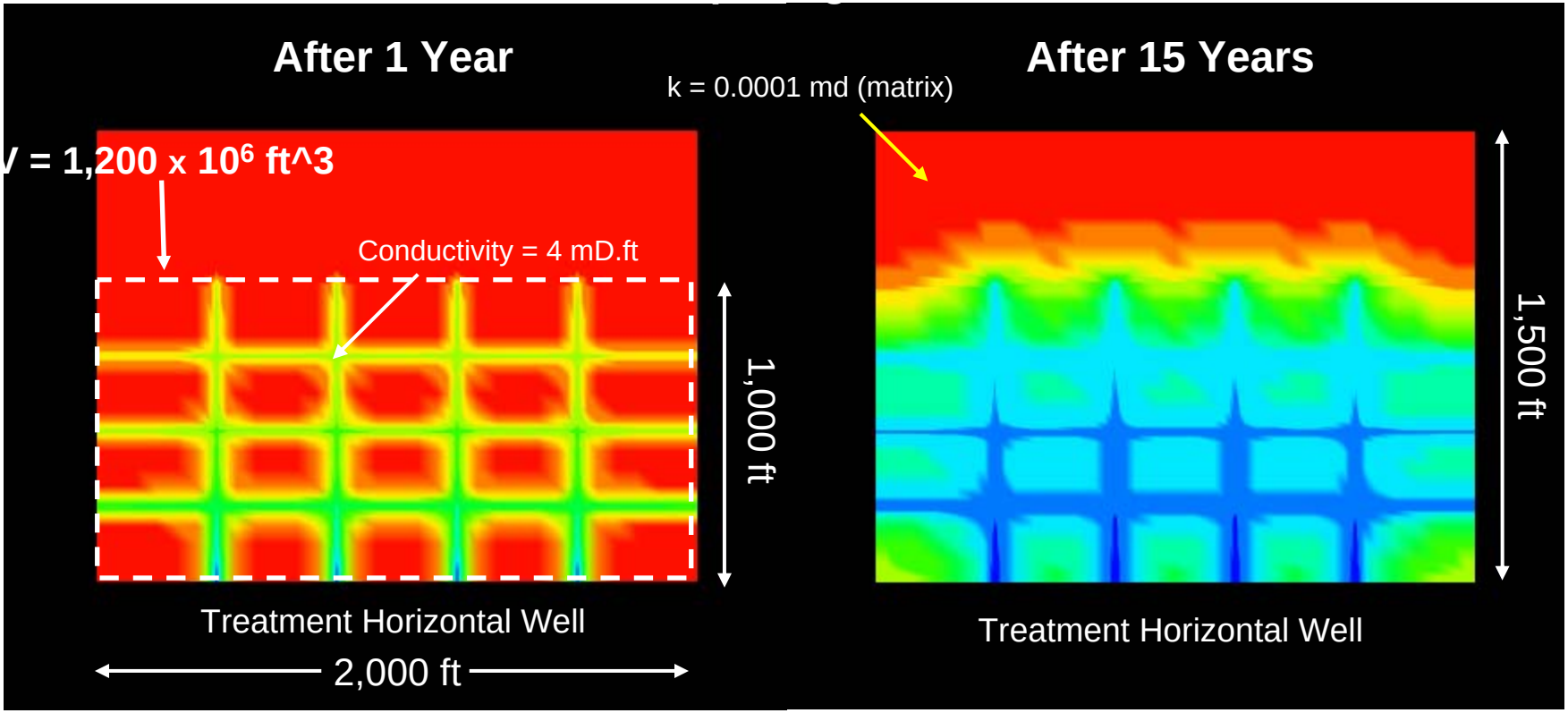
$$\Sigma\ (SRA \times h)$$


SRV vs. 6-month Average
All Wells
SRV= Stimulated Area x Net Pay
y = 0.5569x + 356.11
R2 = 0.5486
6-Month Average (MCFD)
SRV (10^6 ft3)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

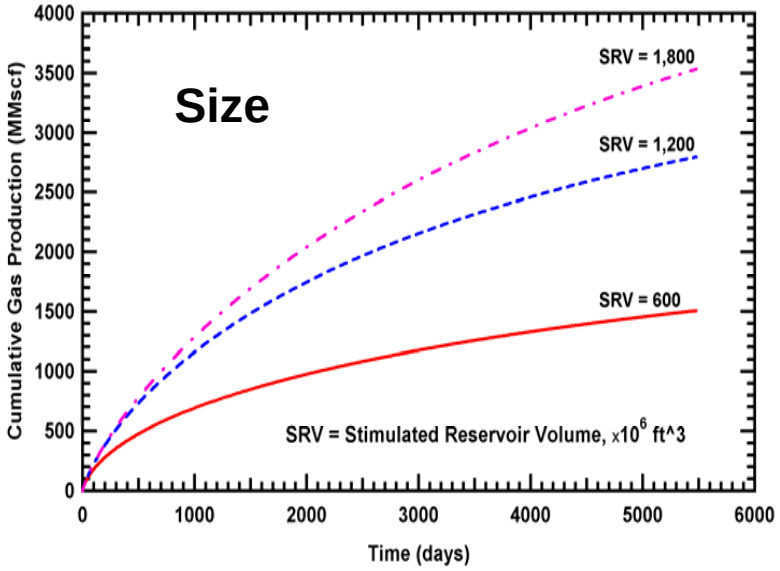
Stimulated Reservoir Volume (Woodford vs Barnett)

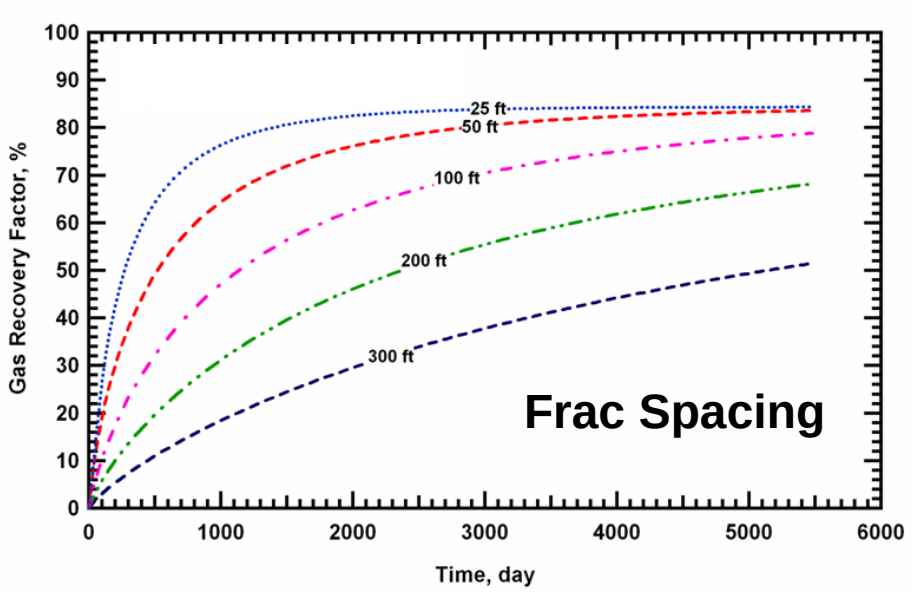


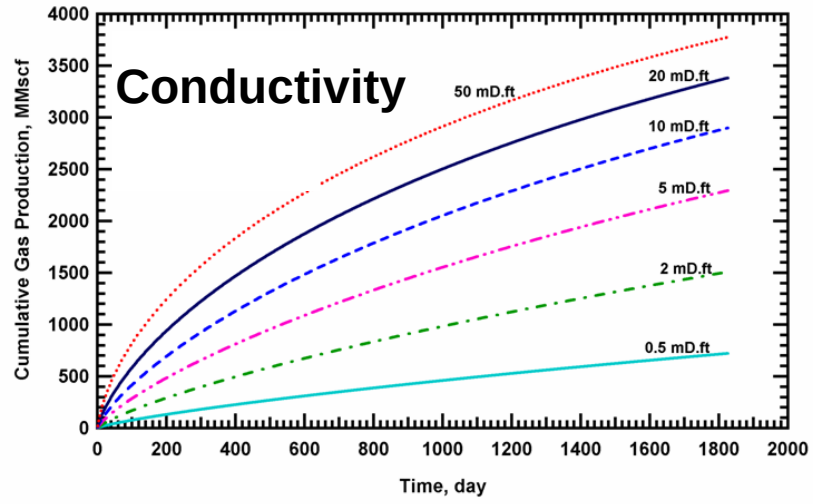
Hydraulic Fracture Network Model



Network Size, Frac Spacing and Conductivity are Key For Production From Shale Networks







Summary

- Mapping completed in three wells in the Woodford Shale
  - Observation distances similar to the Barnett (core area)

- Dominant fracture azimuth is NE (more east-west than in Barnett)
  - Project 1 N57^{o}E Avg.
  - Project 2 N60^{o}E Avg.
  - Project 3 N60^{o}E Avg.

- Indications of complexity (more complex than Barnett)
  - MS data show secondary azimuths
  - Possible fracture network
  - Strong interaction with faults

Summary

- Woodford Fracs fairly contained in the 3 projects
- Network lengths up to 4,000 ft; Asymmetric Growth (Up-Dip in one case)
- SRV's can be similar to the Barnett but complexity is higher
- Mapping indicates that faults and dip can affect the created fracture geometry
  - Reviewing fracture staging strategy
  - Diversion (100 mesh) can help if the fault is relatively small
- Development continues in this field

Questions?