# Use of Fracture-Mapping Technologies to Improve Well Completions in Shale Reservoirs

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## Abstract

Recent innovations in horizontal well drilling and completion techniques have been key factors to the growing success of shale gas production in the U.S. today. In particular, within the past years, significant advances have been made in the fracture completion of shale gas wells. Large waterfracs and horizontal wells along with the ability to directly measure hydraulic fracture network growth with microseismic fracture mapping have pushed the envelope in shale reservoirs such as the Barnett, Woodford and Fayetteville. This paper will present recent case studies on different types of shale fracture completions along with microseismic mapping results of actual fracture network growth. Over two-hundred wells have been mapped in shale reservoirs with microseismic imaging and tiltmeter fracture mapping over the past several years. The fracture mapping allows for direct measurement of the fracture network orientation, height, length and width, as well as interaction with local geology such as faults and karsts. The results have been used to determine well spacing, offset well locations, refracture candidate identification, staging strategies and real-time changes to fracture treatment design and execution in both horizontal and vertical wells. The fracture mapping results generally show that the hydraulic fracture growth is very complex in shales and it is critical to measure the size and orientation of the fracture network to optimize horizontal well planning and placement. Other network parameters such as fracture spacing and conductivity are also discussed. Understanding the impact of fracture network properties on well performance is critical to successfully developing and optimizing production in shale reservoirs.

# Use of Fracture Mapping Technologies to Improve Well Completions in Shale Reservoirs

## 2008 AAPG Annual Convention & Exhibition

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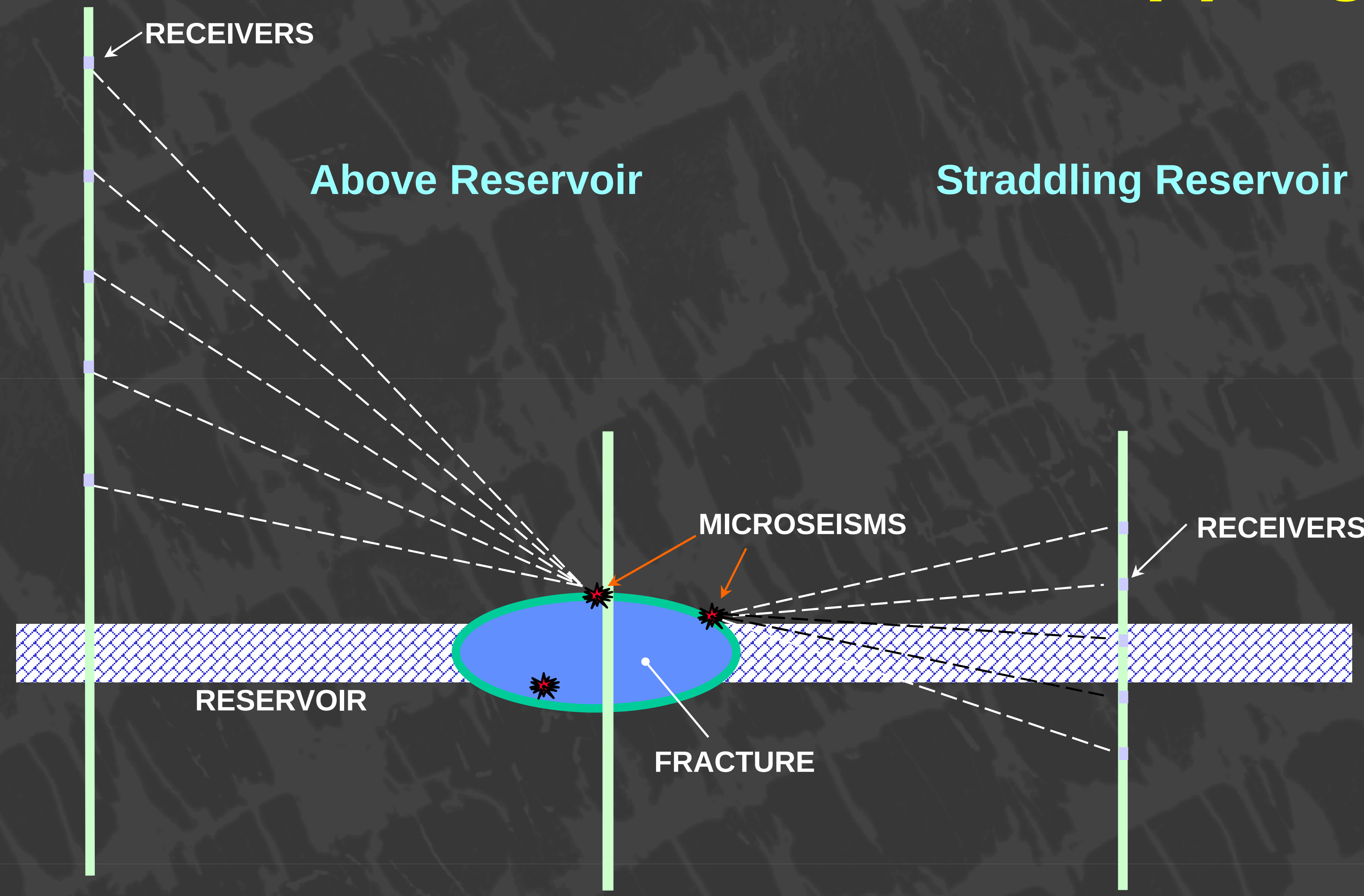
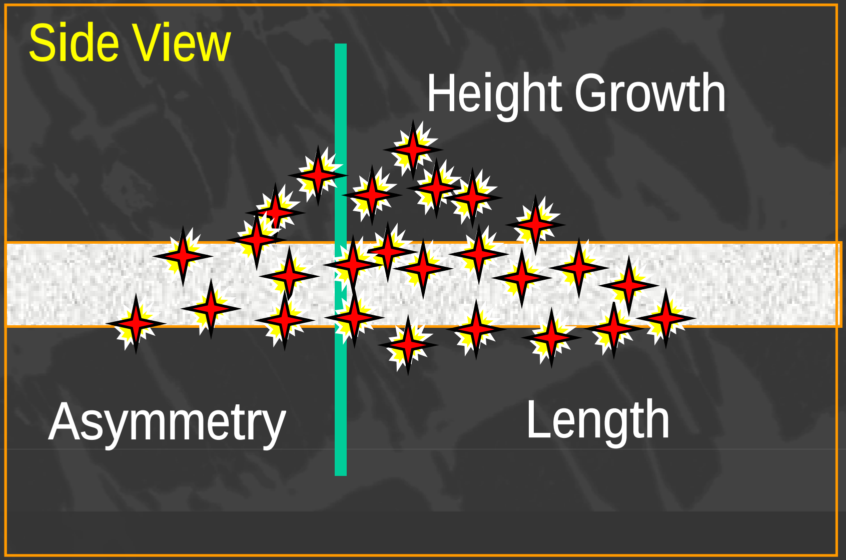
# Microseismic Fracture Mapping



# Microseismic Monitoring

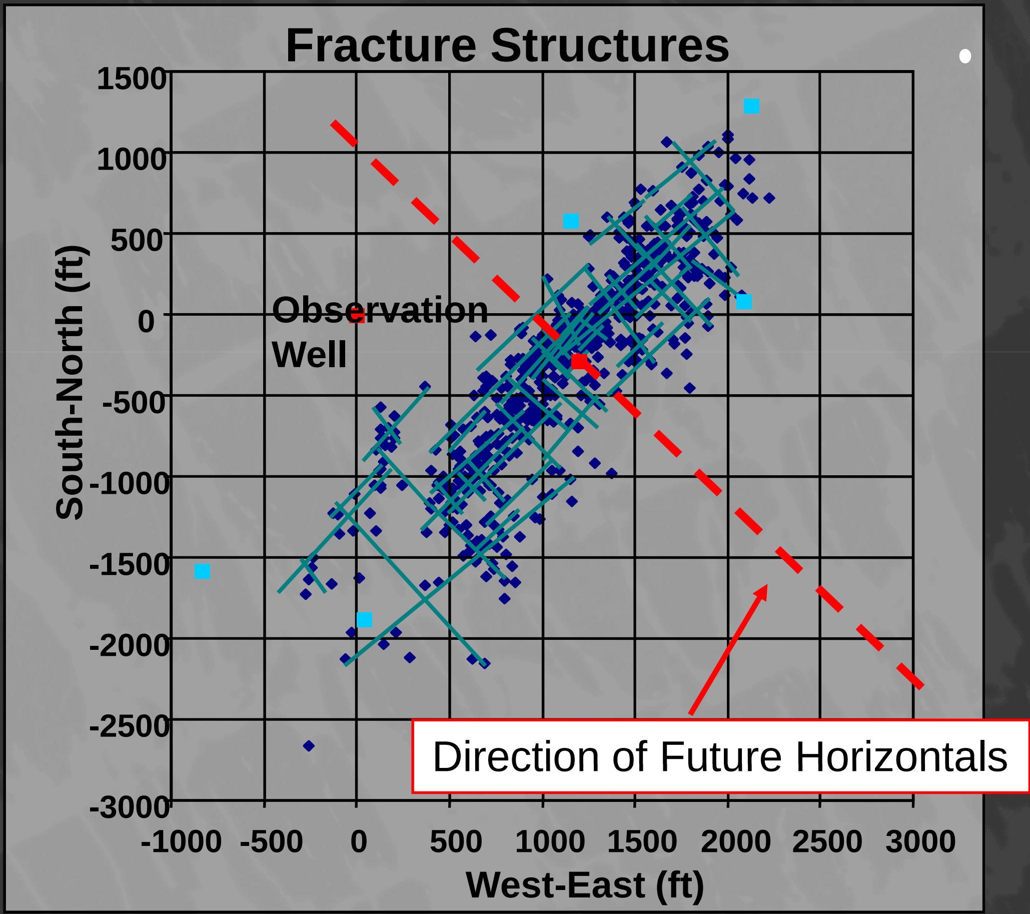
- The Detection And Locating Of Micro-Earthquakes Induced By Hydraulic Fractures To Map Out The Geometry & Characteristics Of The Hydraulic Fracture

## Two “Quantum Leaps” in Shale Completion Technology:

1. Large, high-rate waterfracs with low proppant concentrations to increase stimulation surface area
2. Horizontal Wells to maximize stimulation surface area (Mostly cased and cemented, drilled transverse to principal frac direction)

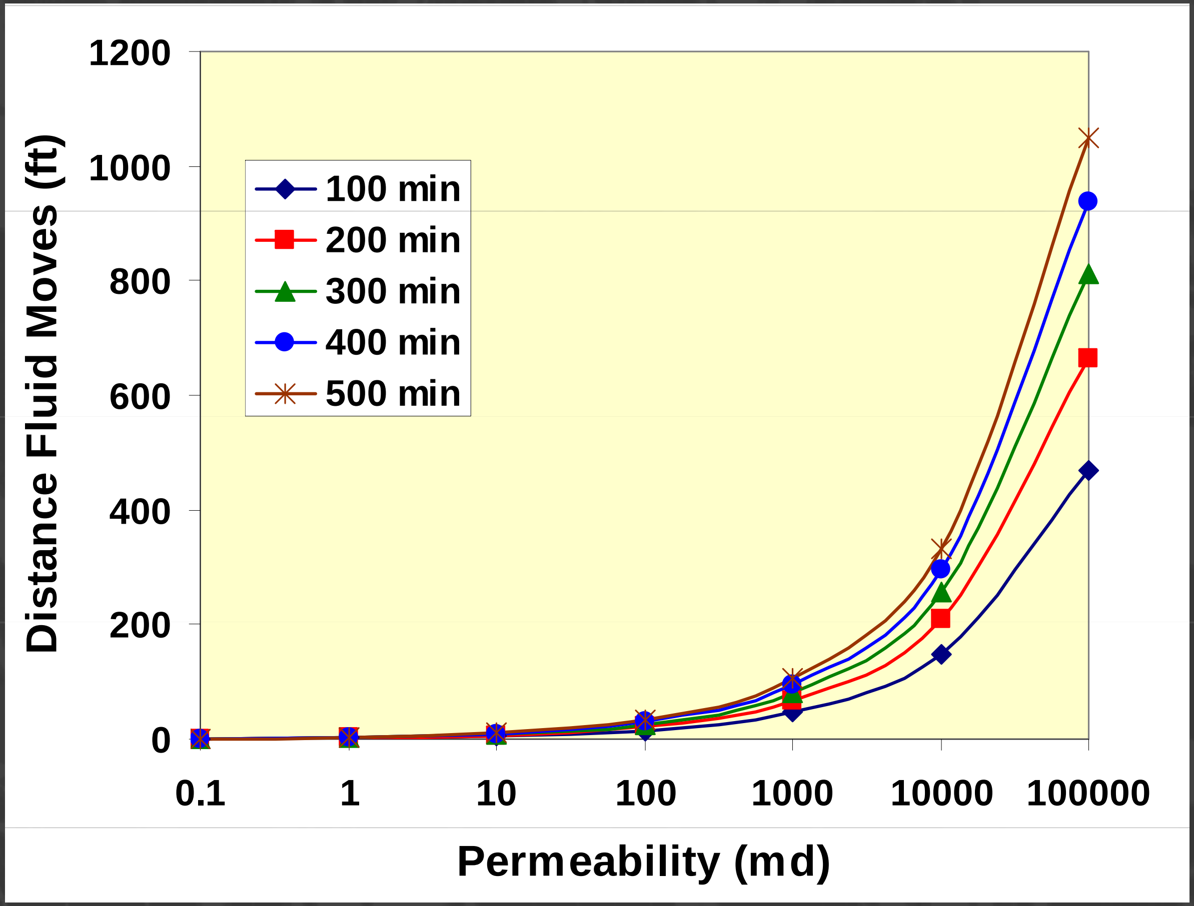
# Fracture Mapping Shows Large Fracture Networks in Shales




- Waterfracs Induce Wide Fracture Networks In Some Shales
  - Evidence:
    - Microseismicity (e.g., SPE 95568)
    - Nearby Wells That Load Up With Stimulation Fluids
      - (e.g., SPE 77411)
    - Surface Tiltmeter: Orthogonal Fractures (40/60 Split)
  - Mechanism
    - Penetration Of Low Viscosity Fluid Into Pre-Existing, Mostly Re-Healed Natural Fractures
    - Full Dilation Of Orthogonal Fractures (e.g., Hydraulic Fractures Propagating In More Than One Plane)
      - Importance Of Low Stress Bias
    - Resultant Conductivity (Proppant And Residual Shear Offset)

# Orthogonal Fluid Flow Estimates

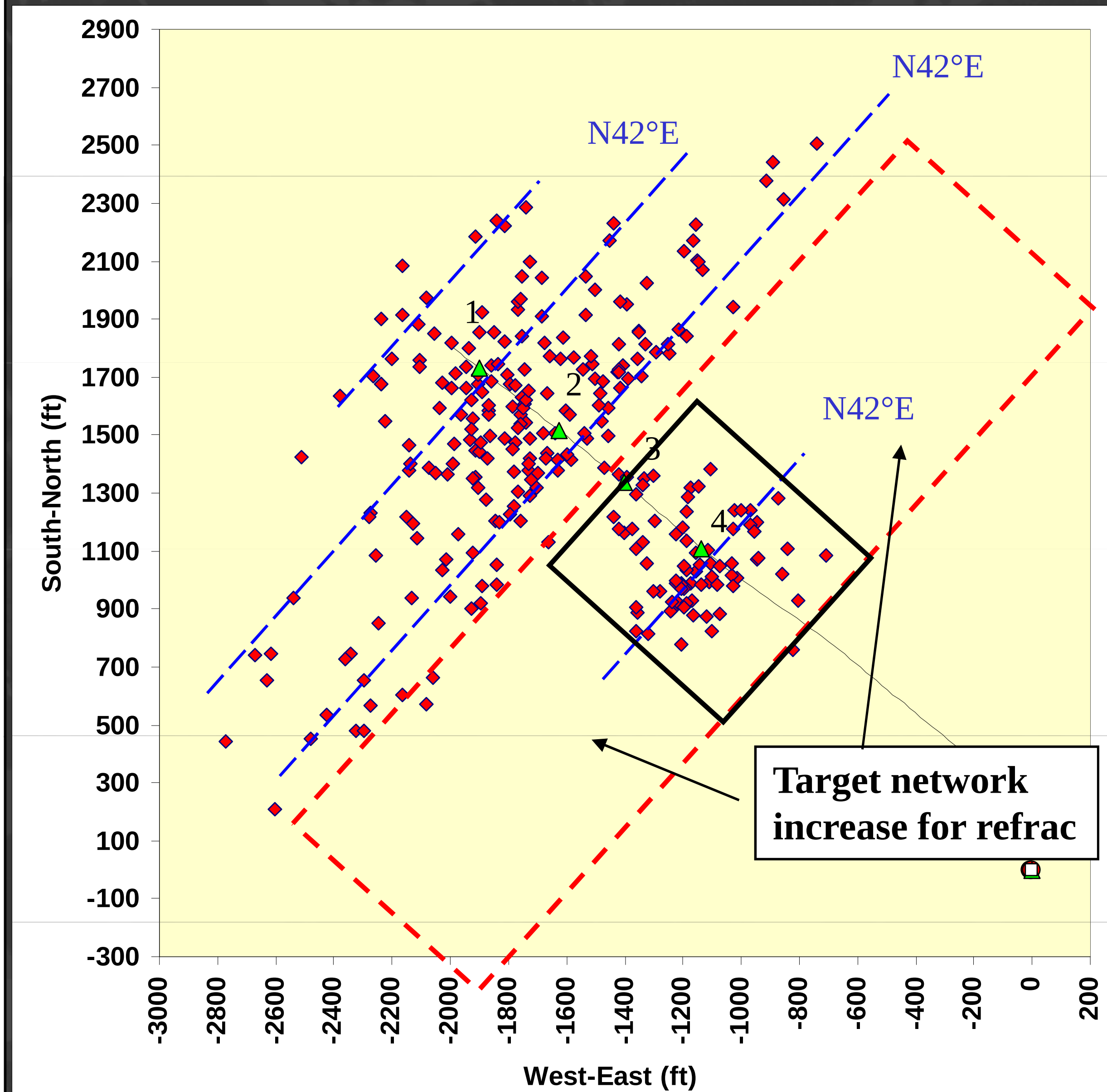
- Estimate Fracture Permeability Necessary To Obtain 500-1,000 ft Offset Fluid Movement
  - Example Viscosity Dominated Calculation
    - Water (1 cp)
    - 2,000 psi Pressure Drop



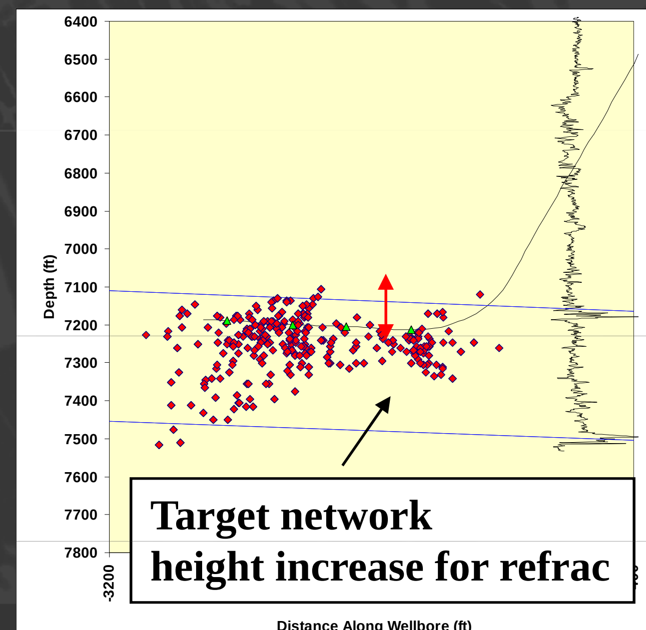

$$y = \sqrt{\frac{2\,k\,t\,\Delta P}{\varphi\,\mu}}$$

Result: Must Have Hydraulic Fractures In Order To Kill Offset Wells

# Early 1-Stage Cemented Horizontal Well

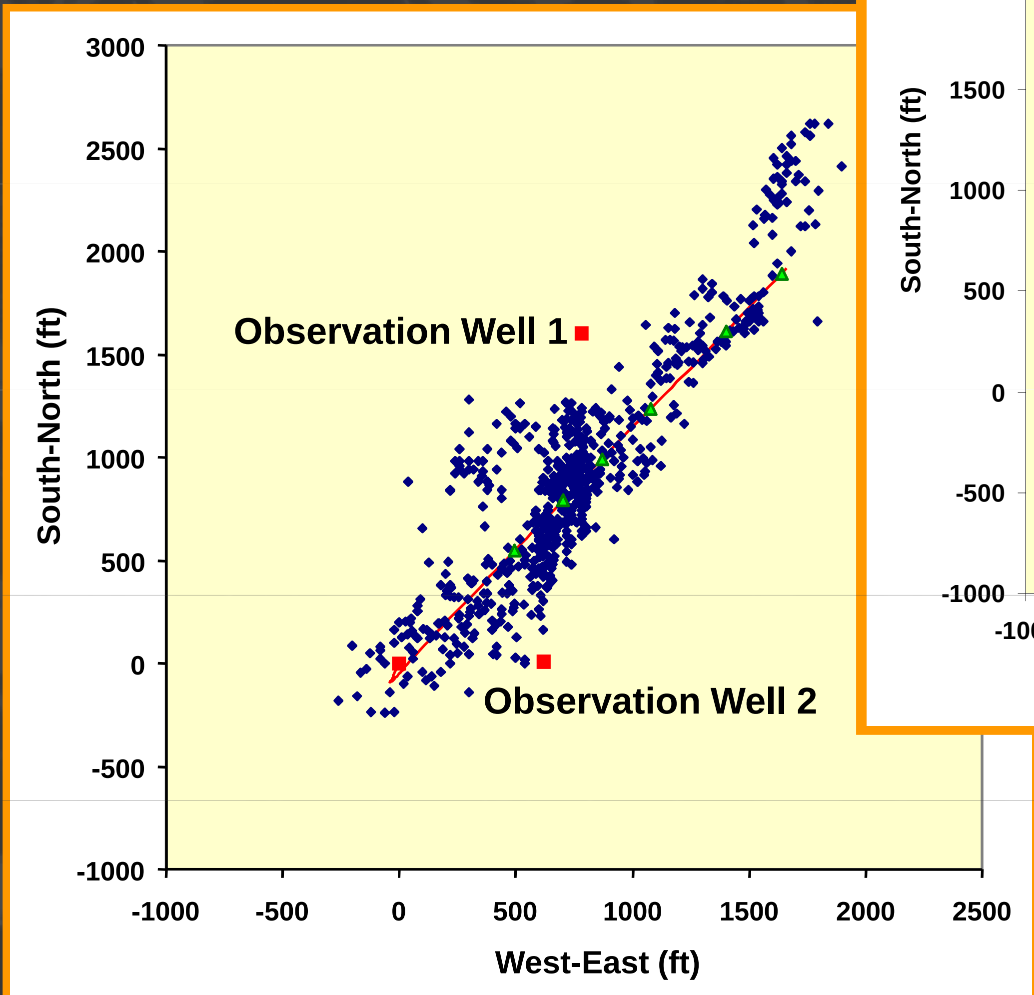


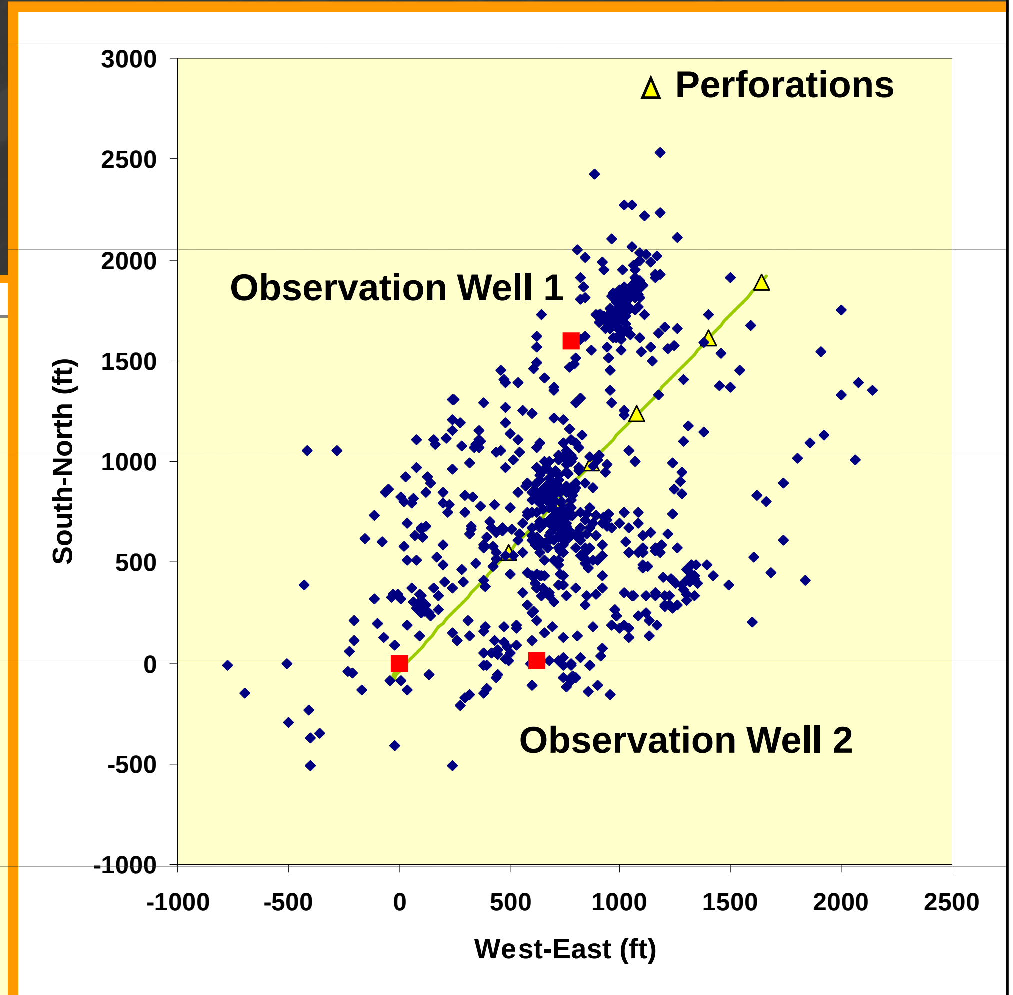

- Tried to frac cemented lateral in one stage – did not achieve adequate network at heel
- Refrac opportunity
- Change future completions by doing more stages



# The Treatment Matters

- Barnett Shale Longitudinal
  - Gel Frac Versus High Rate Waterfrac (Refrac)
  - Increased stimulated volume




SPE 95568 (Devon)

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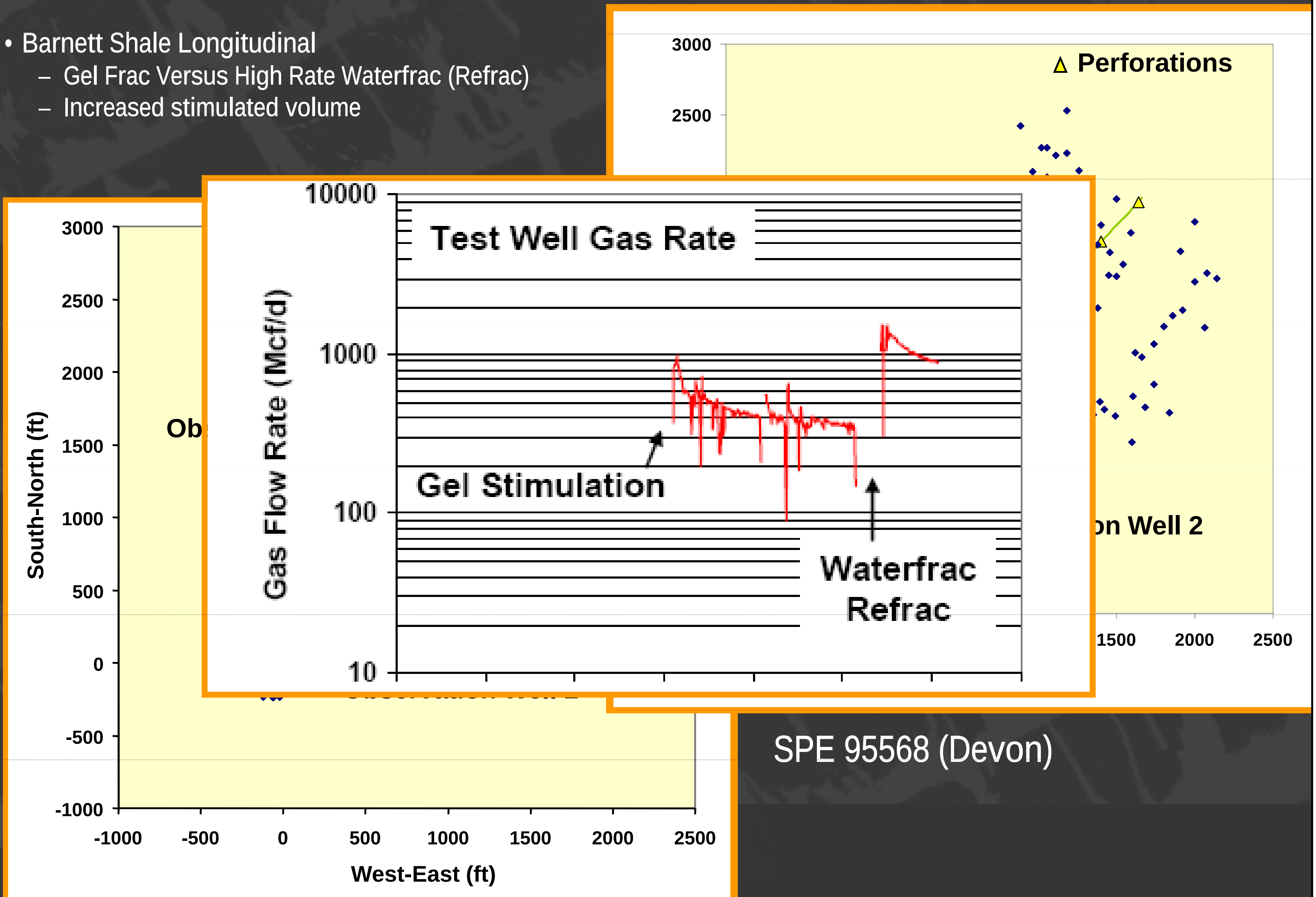
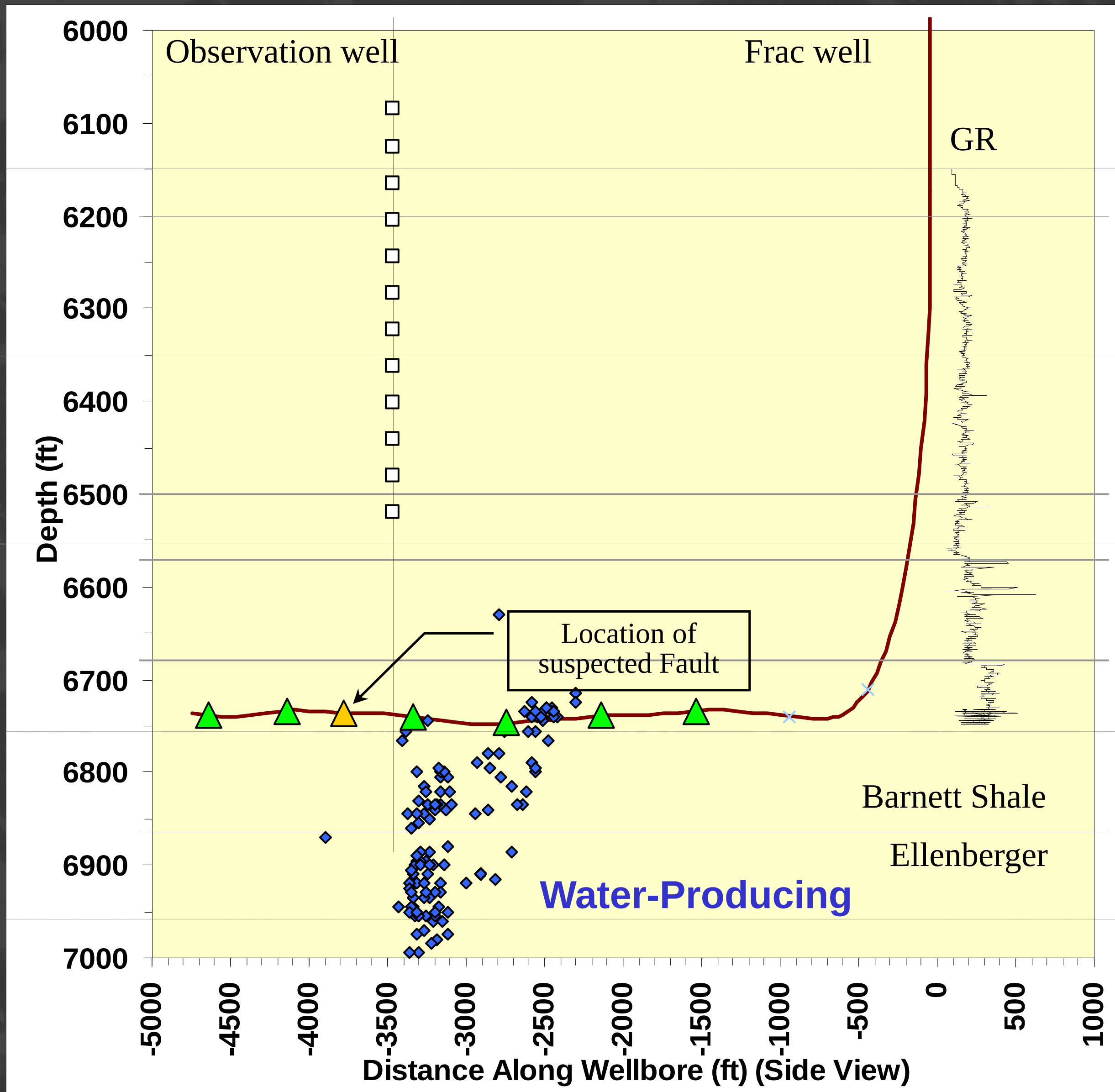
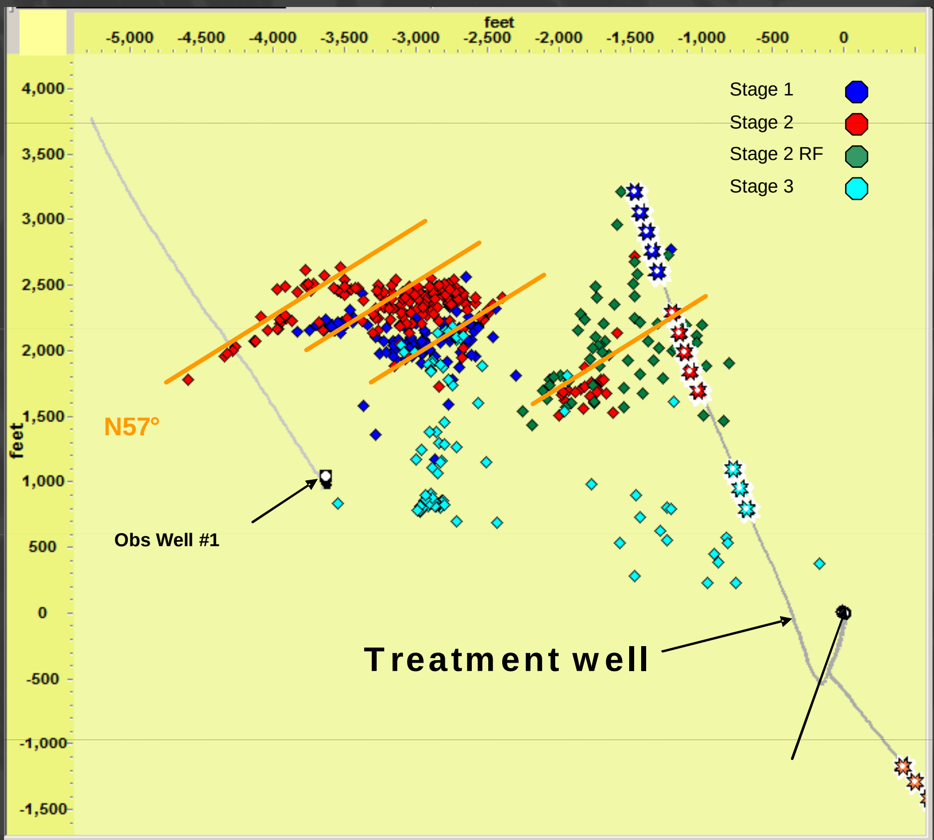


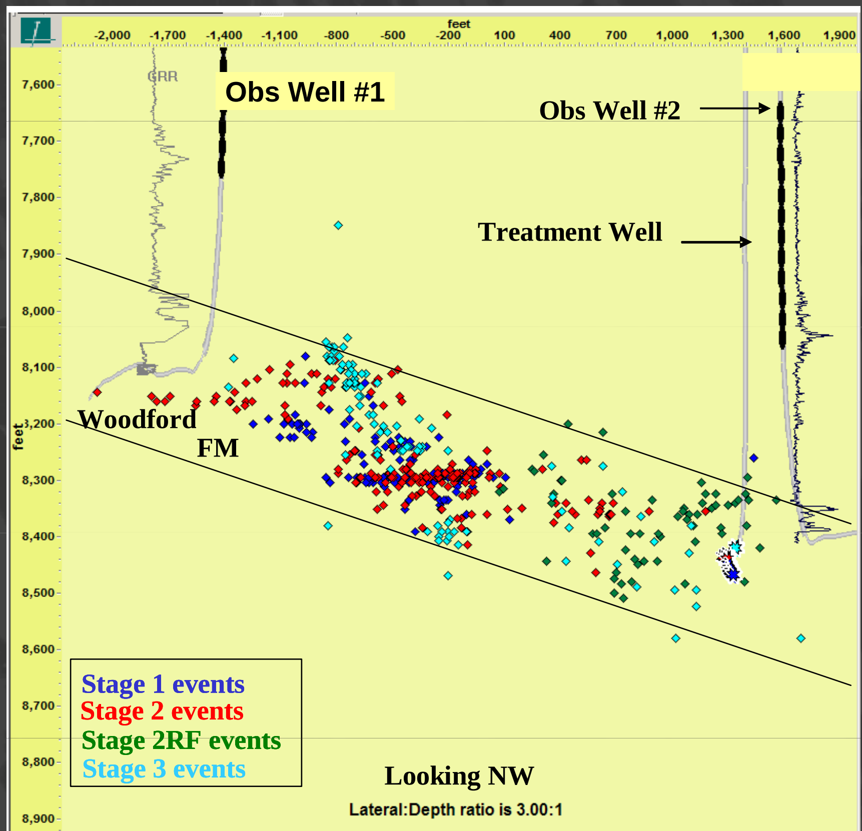

SPE 95568 (Devon)

# Geology Matters: Risk of Growth through Fault into Water-Producing Layer

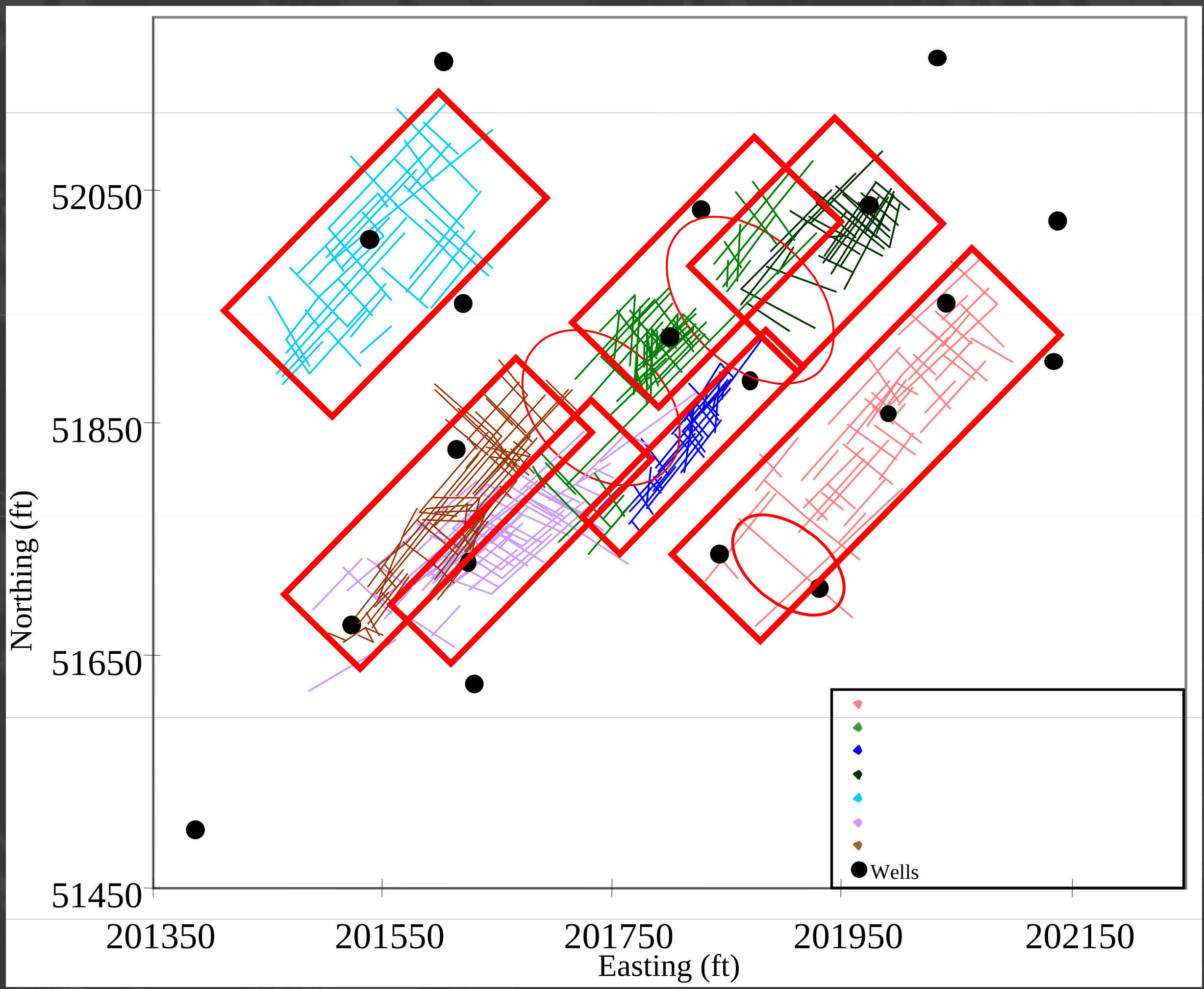


# Woodford Shale –Complex Interaction with Geology

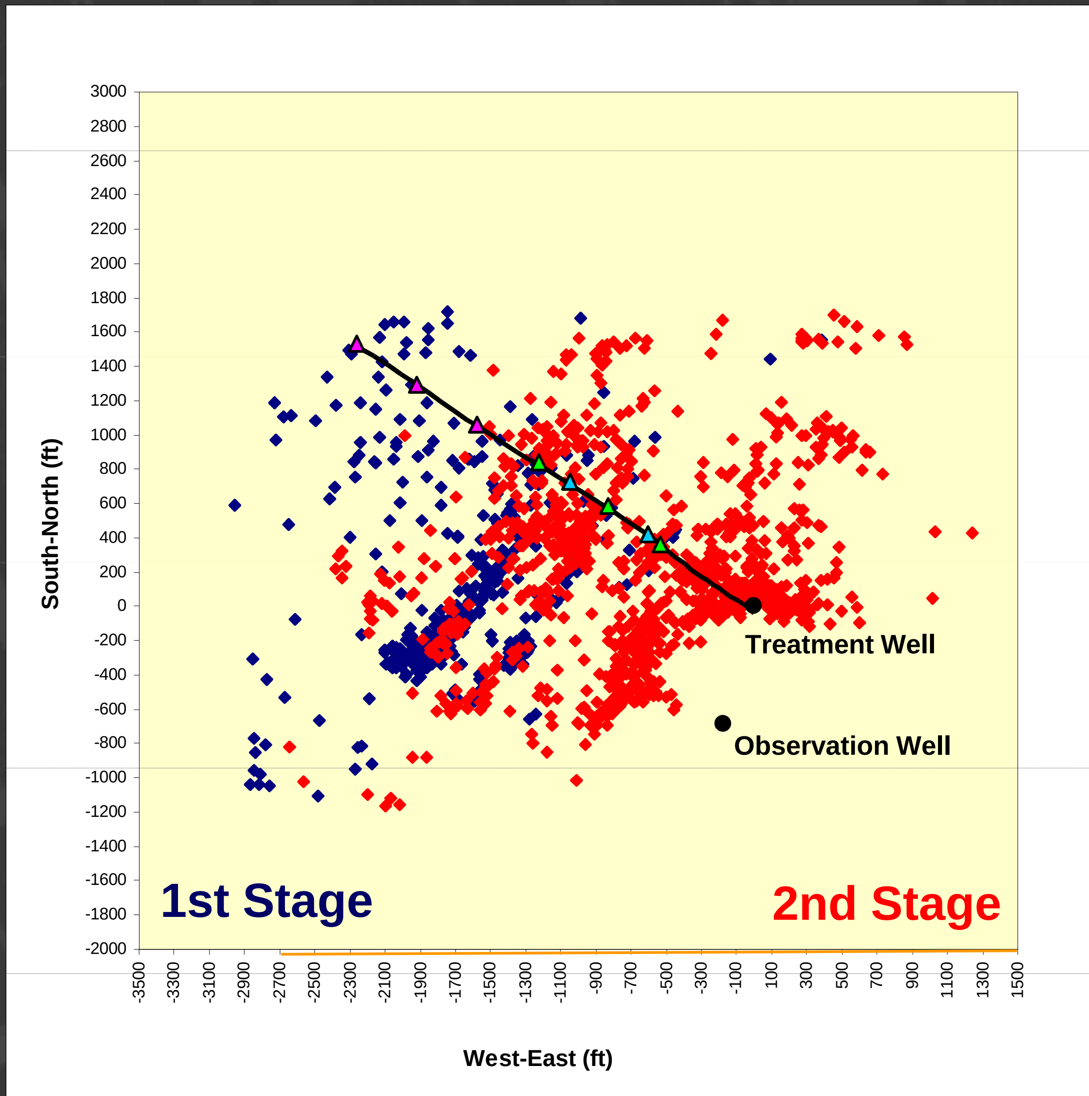


# Using Fracture Mapping for Well Placement & Infill Drilling



# Real-time Mapping Aids Completion




= First Stage Perf Clusters

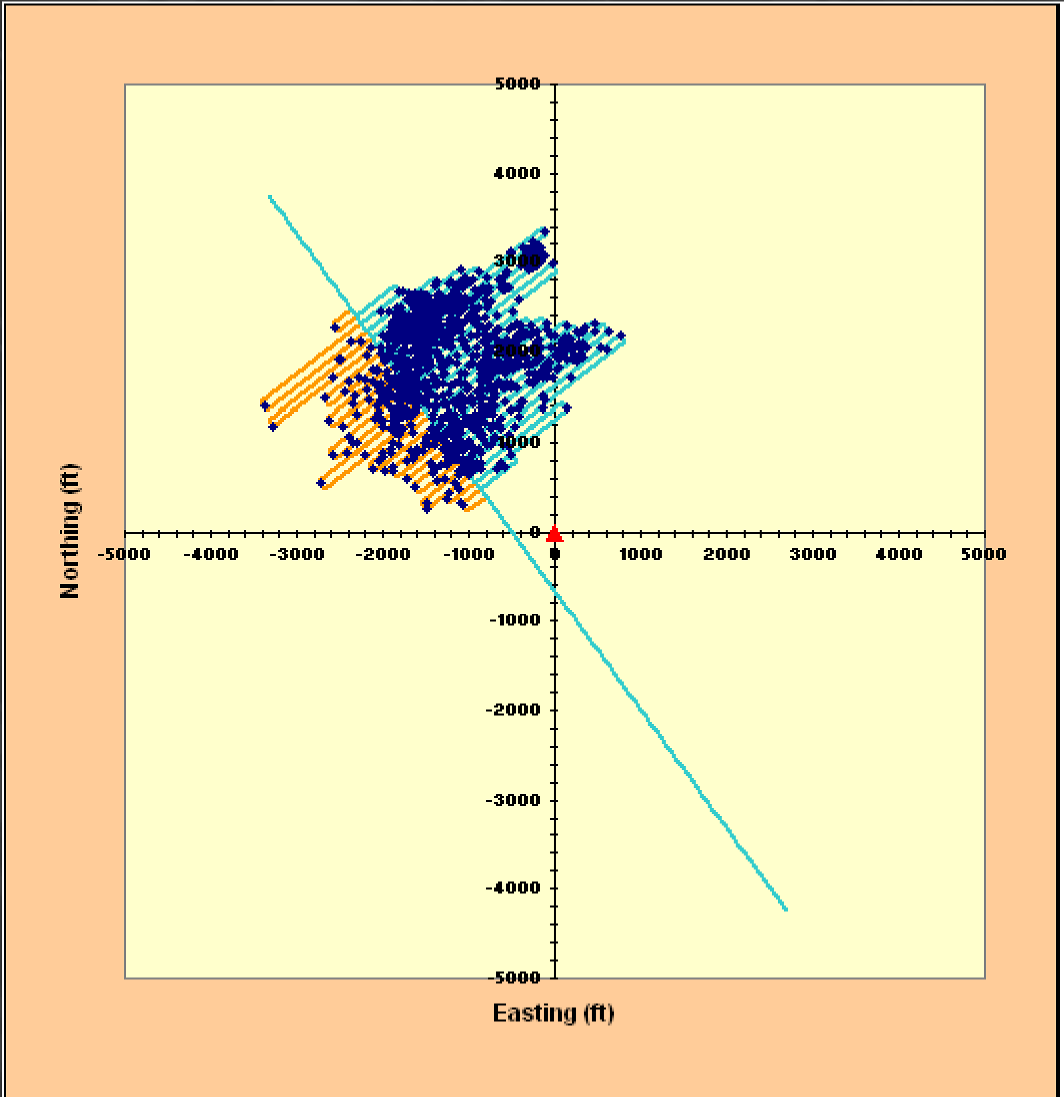
= 2nd Stage Initial Perf Clusters

= Revised 2nd Stage Perf Clusters

# Fracture Network Properties and Production

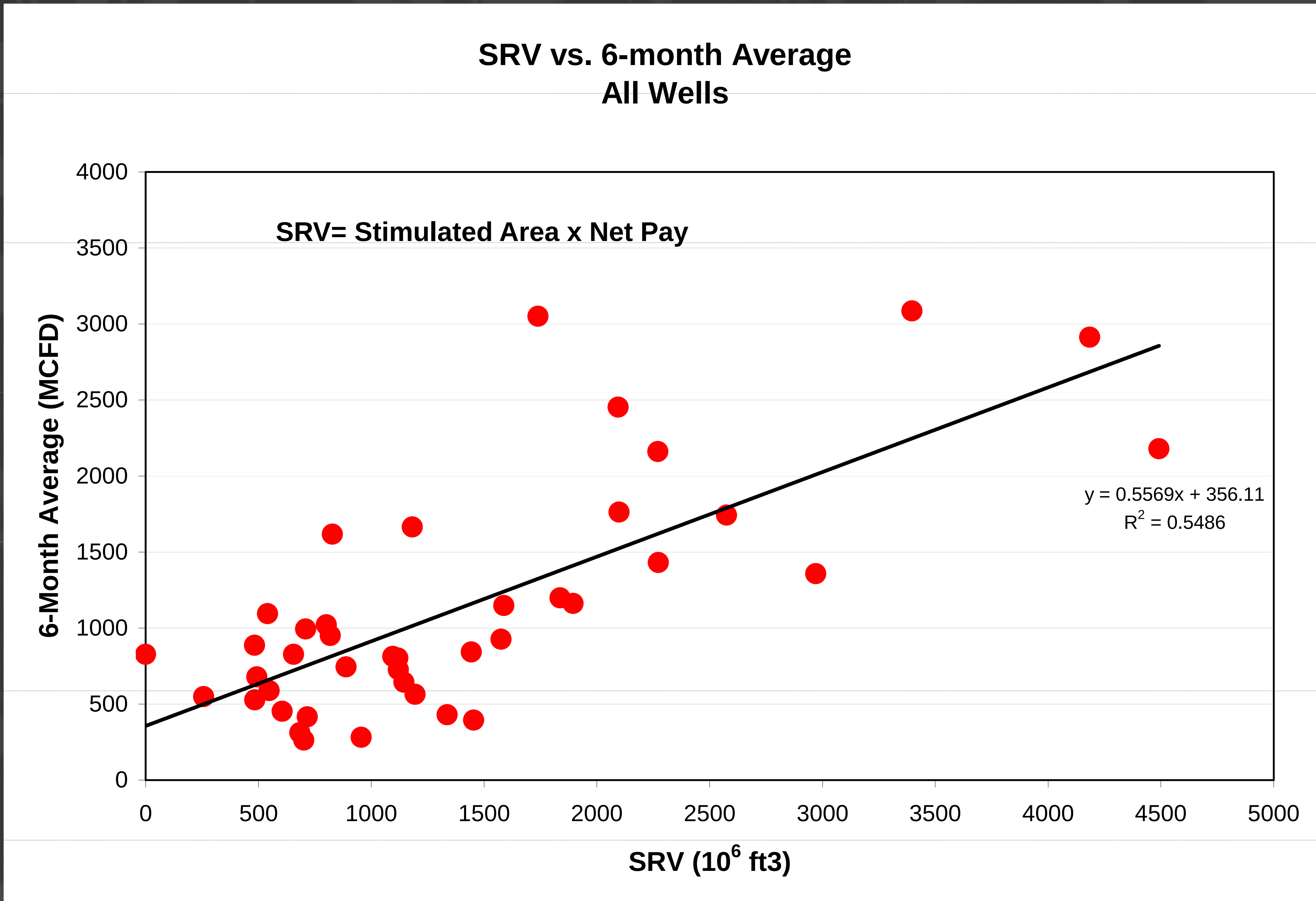
- Understanding the impact of fracture network properties on well performance is critical for frac & completion design and field development
  - fracture network size and density
  - fracture network conductivity

# Stimulated Reservoir Volume (SRV)



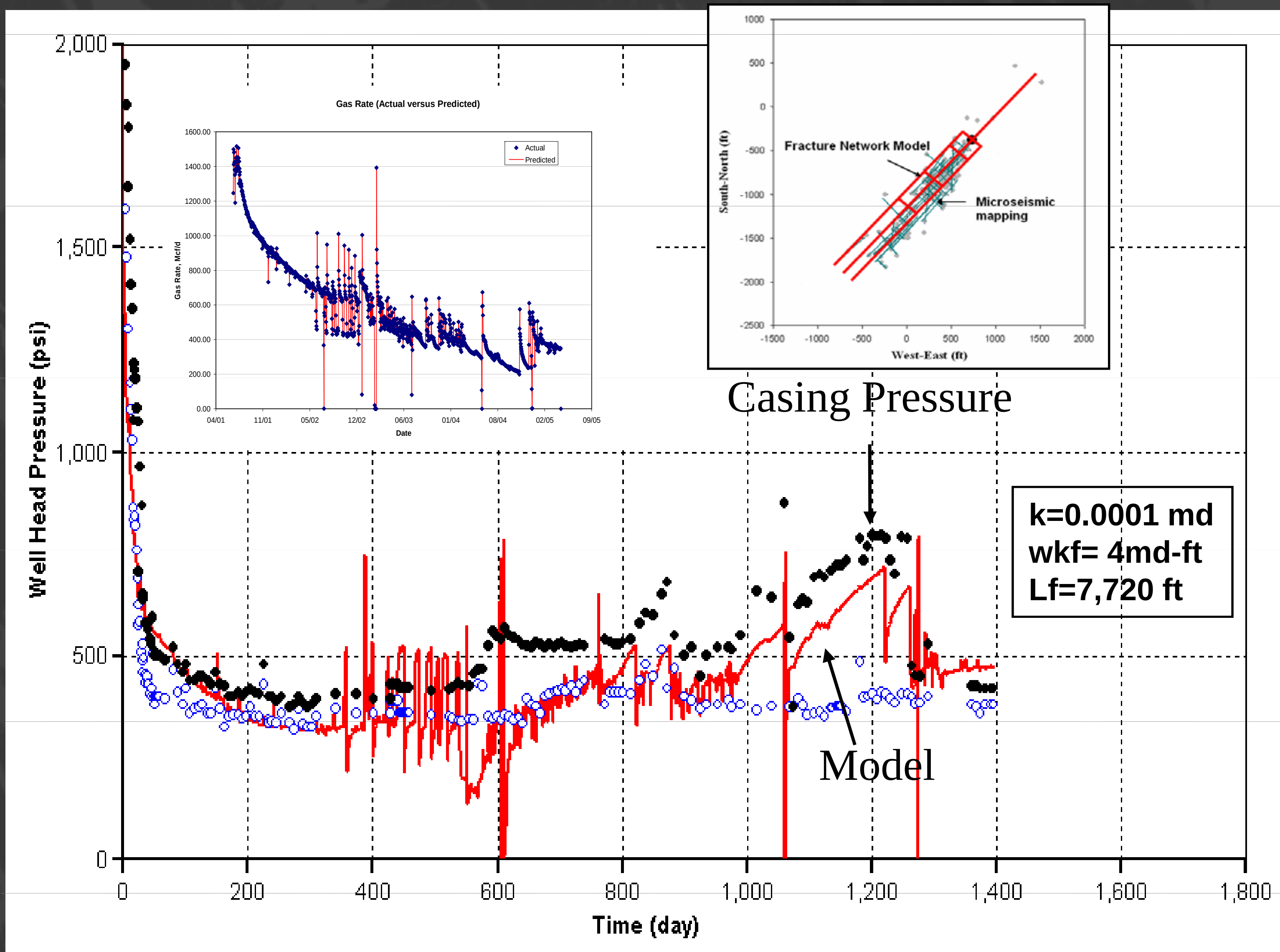

| | |
|---|---|
| As-mapped SRA [ft²] | 5,639,894 |
| Symmetric SRA [ft²] | 7,766,826 |
| As-mapped SRV [ft³] | 1,353,574,530 |
| Symmetric SRV [ft³] | 1,864,038,260 |

$\Sigma$ (SRA X h)



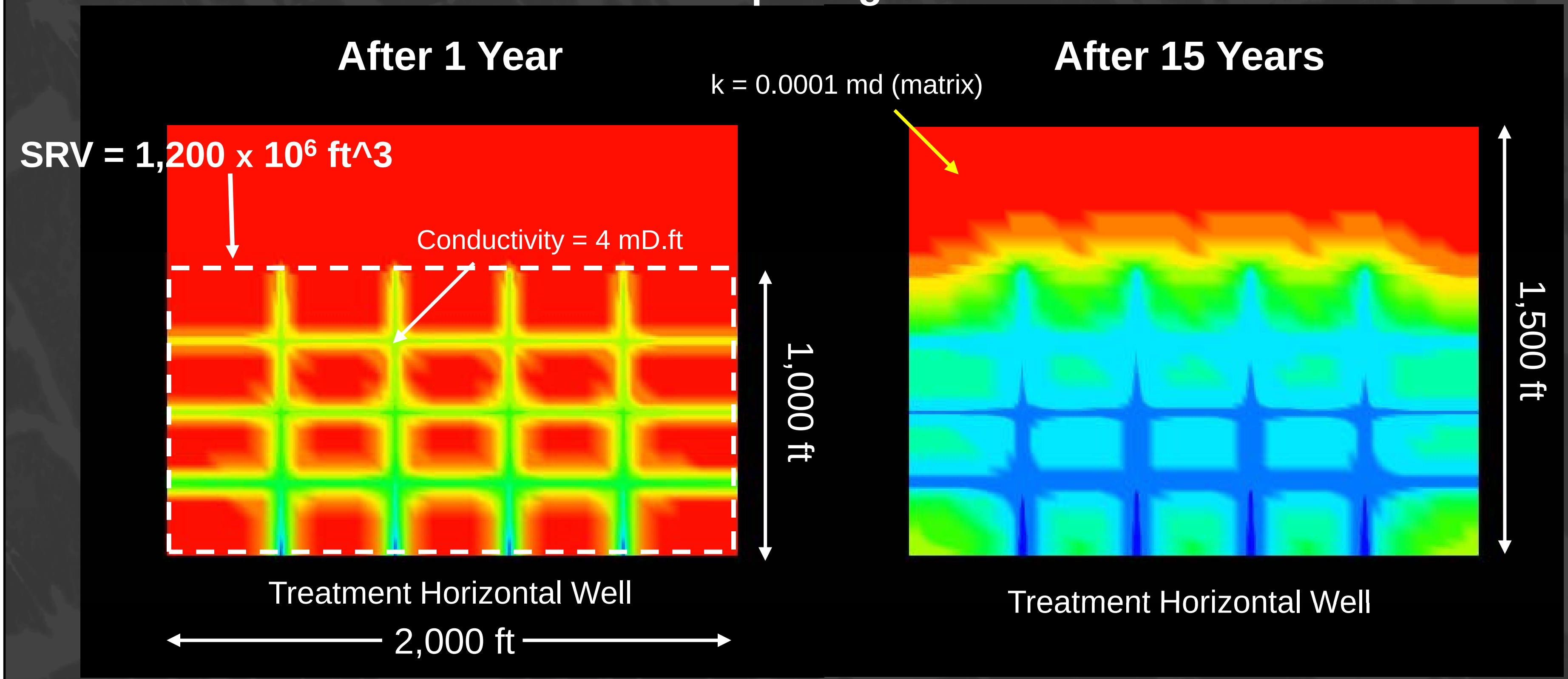
SRV vs. 6-month Average
All Wells
SRV= Stimulated Area x Net Pay
6-Month Average (MCFD)
0
500
1000
1500
2000
2500
3000
3500
4000
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
y = 0.5569x + 356.11
$R^2$ = 0.5486
SRV ($10^6$ ft3)

# Vertical Well History Match

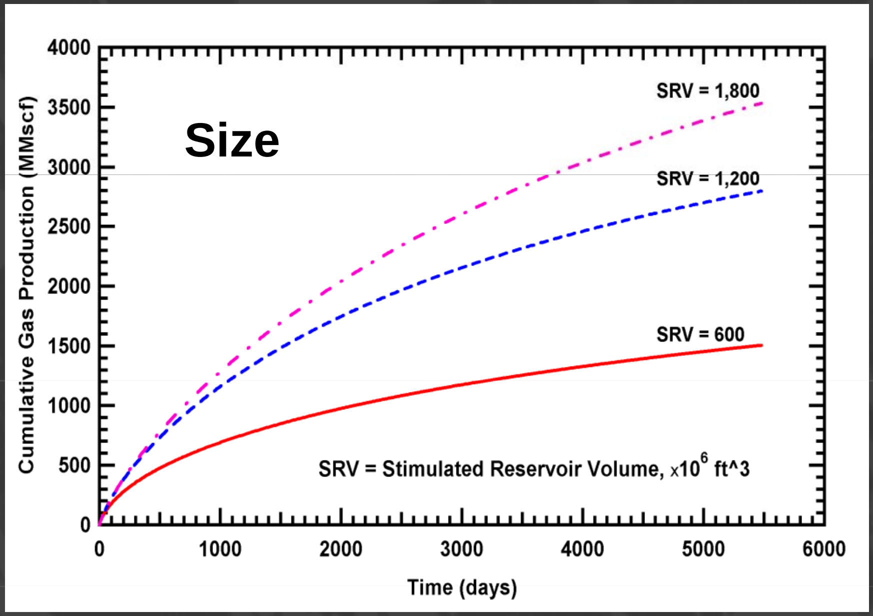


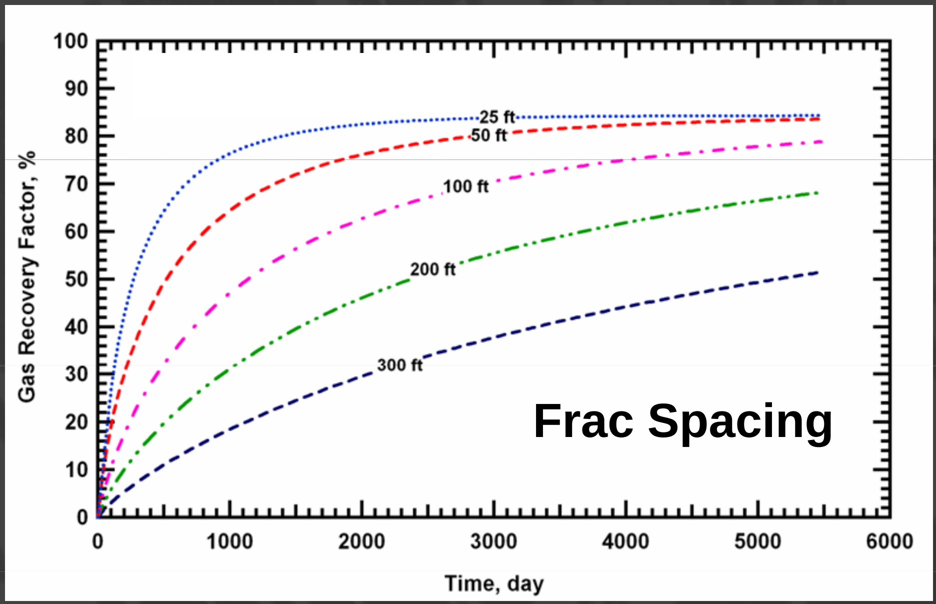
# Horizontal Well Hydraulic Fracture Network Model

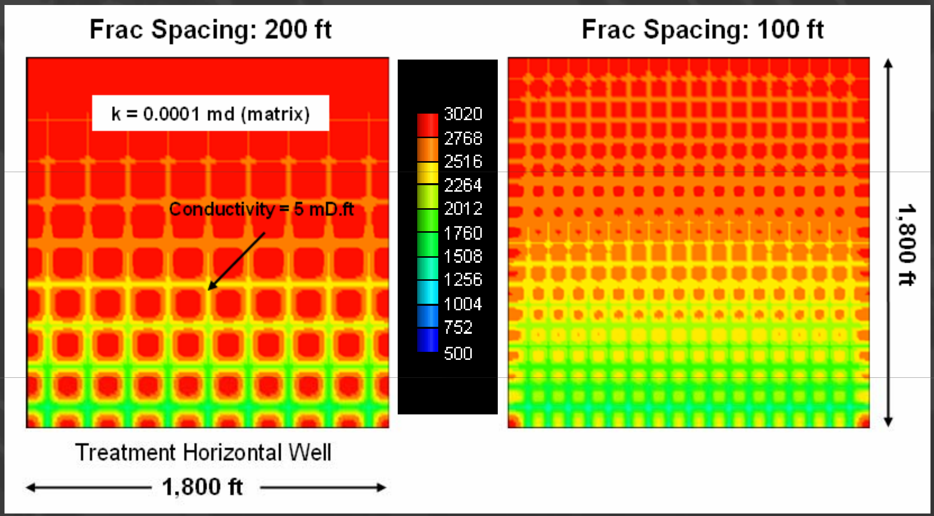
**SRV = 1,200 x $10^6$ ft^3**
**Frac Spacing=400 ft**



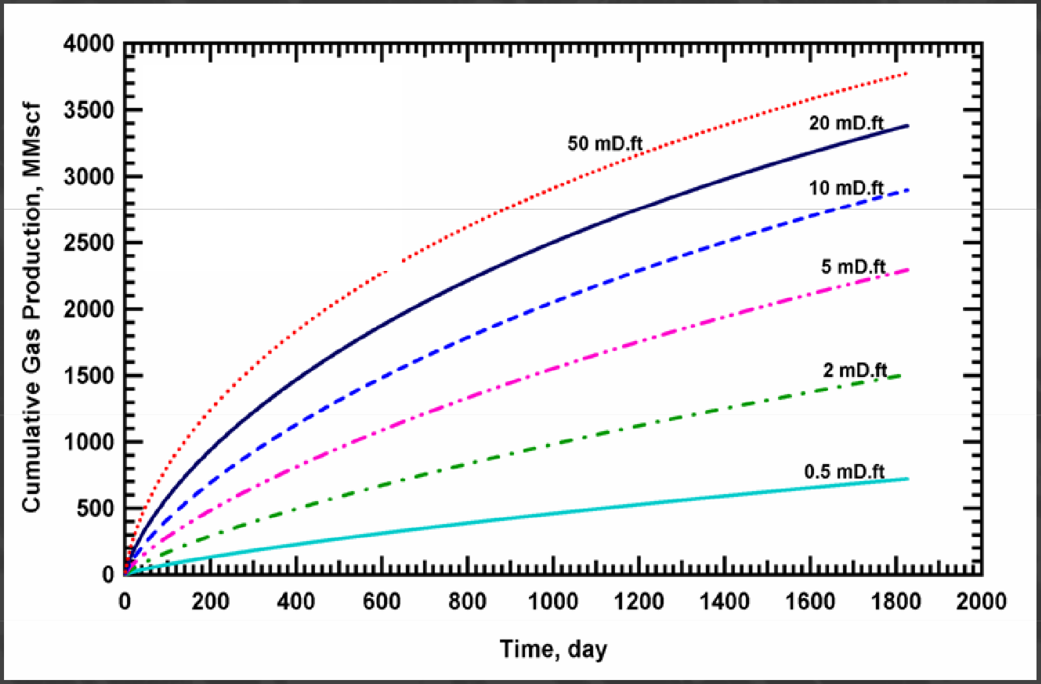
# Network Size, Frac Spacing and Conductivity are Key For Production From Shale Networks

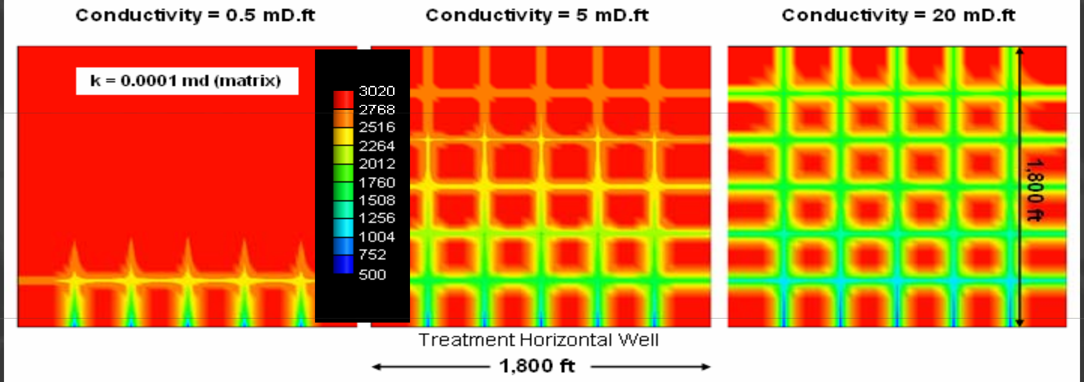


# Fracture Conductivity



# Conclusions

- Fracture mapping is key to understanding the generated fracture network
- Drainage area will largely be confined to the stimulated area due to the sub-microdarcy shale permeability
- Goal is to generate the largest possible fracture network with the highest possible density to achieve maximum fracture surface area and recovery
  - Drill longer laterals, larger jobs, more stages, more perfs
  - Refracs, start/stop fracs, diversion
  - Simultaneous fracs, zipper fracs, etc.
- Balance the creation of a dense fracture network with overall network size (aggressive diversion may be detrimental to generating a larger network)

# Acknowledgements

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