Microseismic Interpretations and Applications: Beyond SRV

Reference: SPE 168596

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MicroSeismic, Inc. User Group Meeting
Wednesday, February 19, 2014

Stimulated Reservoir Volume (SRV)

- First introduced by Fisher et al. (2004), Barnett Shale.
  - Fracture growth may be much more complex in unconventional reservoirs.
  - Microseismic volume could be correlated to production in specific areas.

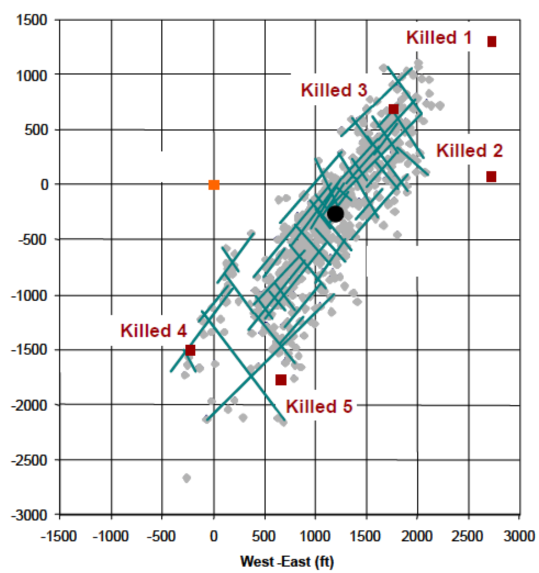


Figure 4 from SPE 90051

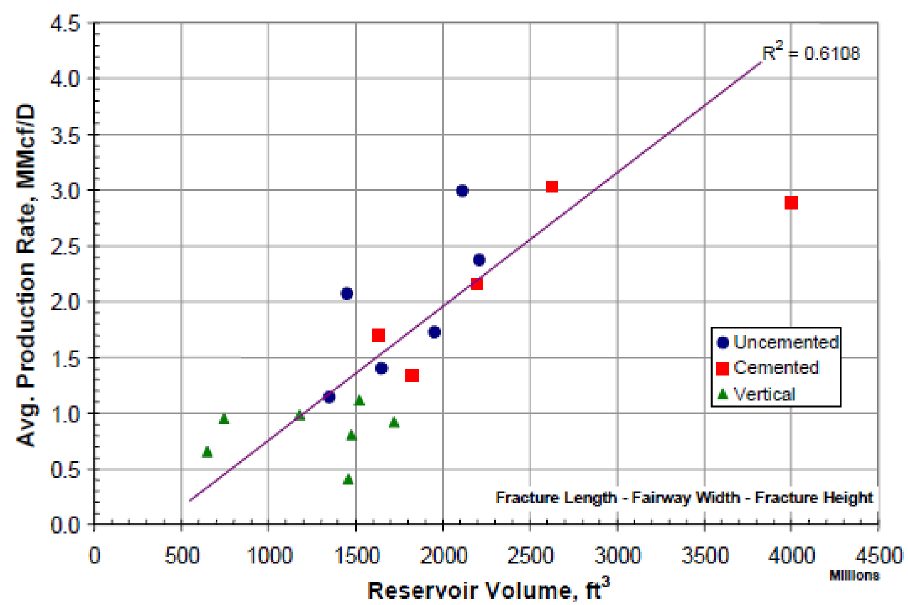


Figure 22 from SPE 90051

Stimulated Reservoir Volume (SRV)

- Further defined by Mayerhofer et al. (2008)
  - Drainage volume may be limited to SRV.
  - Fracture area is a key factor that controls productivity.

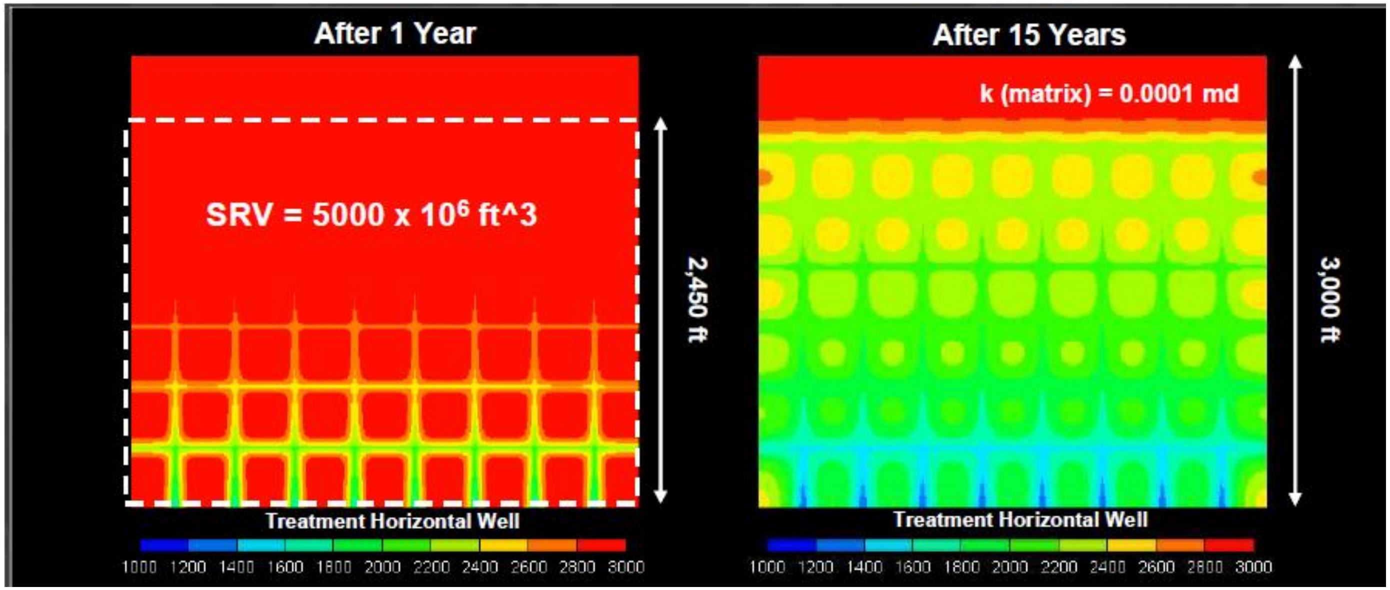


Figure 11 from SPE 119890

SRV-based Production Models

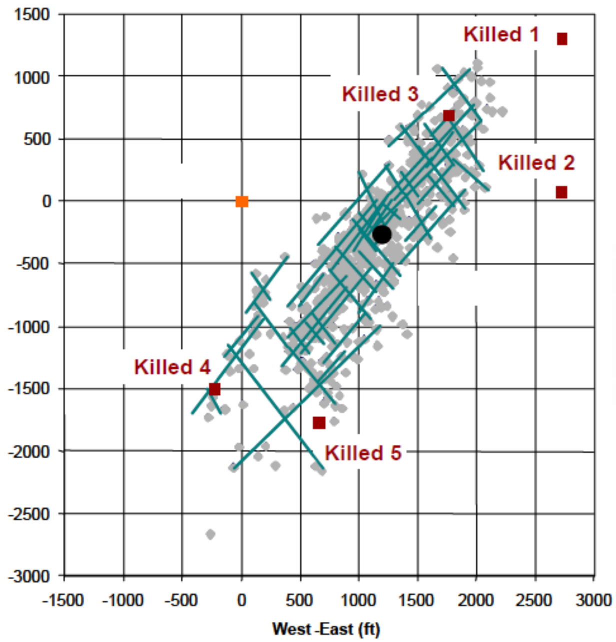
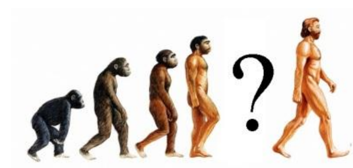
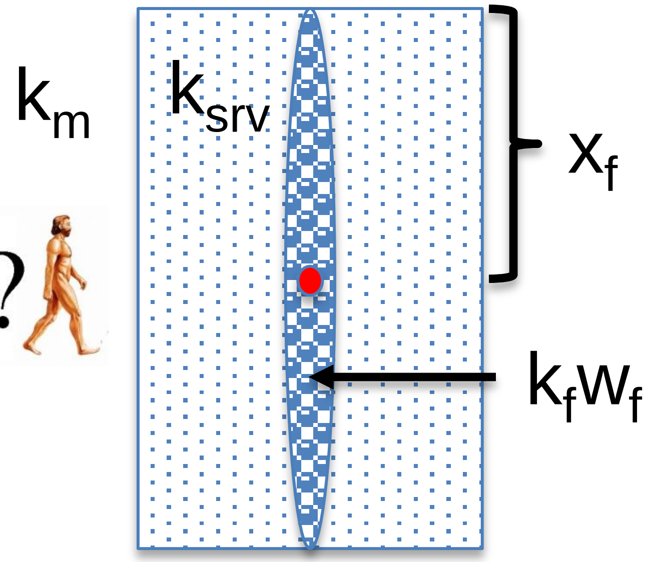


Figure 4 from SPE 90051





The Missing Link

The relationship between fracture *geometry and conductivity* and *well productivity and drainage volume.*

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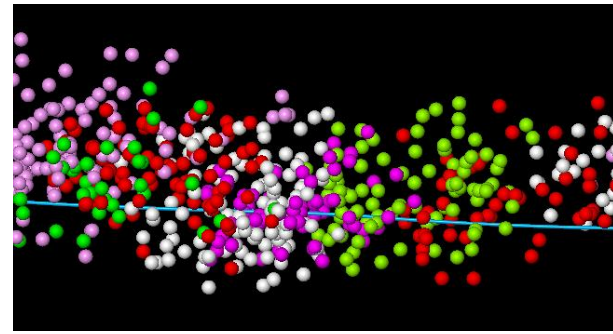
What is Stimulated Reservoir Volume (SRV)?

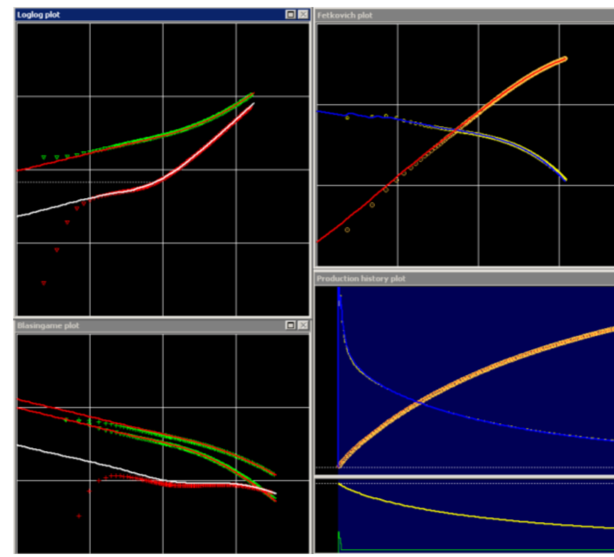
- Completion/Fracturing Engineers
  - Microseismic volume
  - Fracture geometry
  - Maximum drainage distance

- Reservoir Engineers
  - Drainage volume or area
  - Stimulated region permeability, k_{srv}
  - *Effective* fracture length

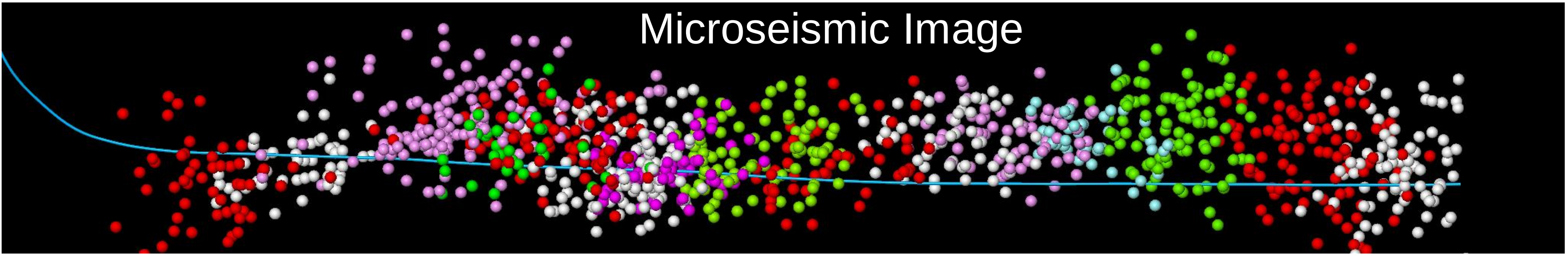
Focus on Microseismic



Focus on Production

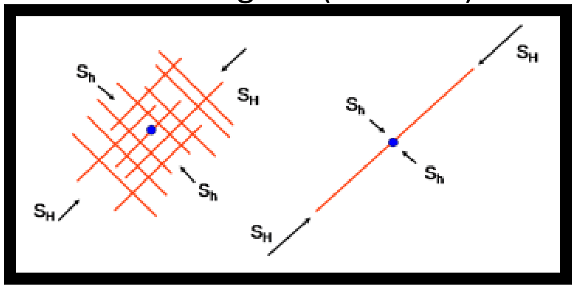


Beyond SRV

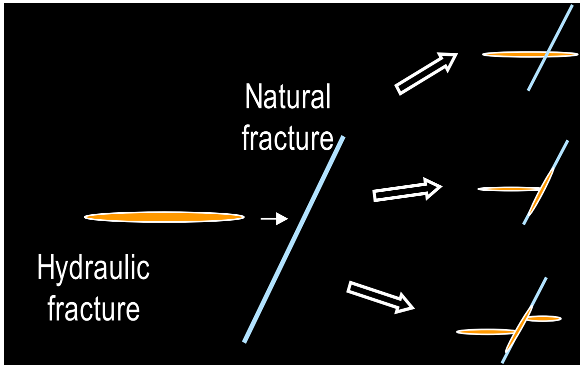


Natural Fractures (DFN)

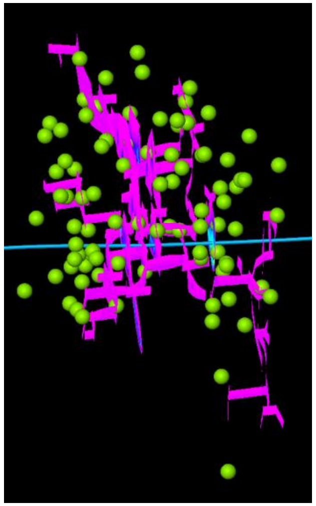
Stress Regime (3D MEM)



Network Fracture Model



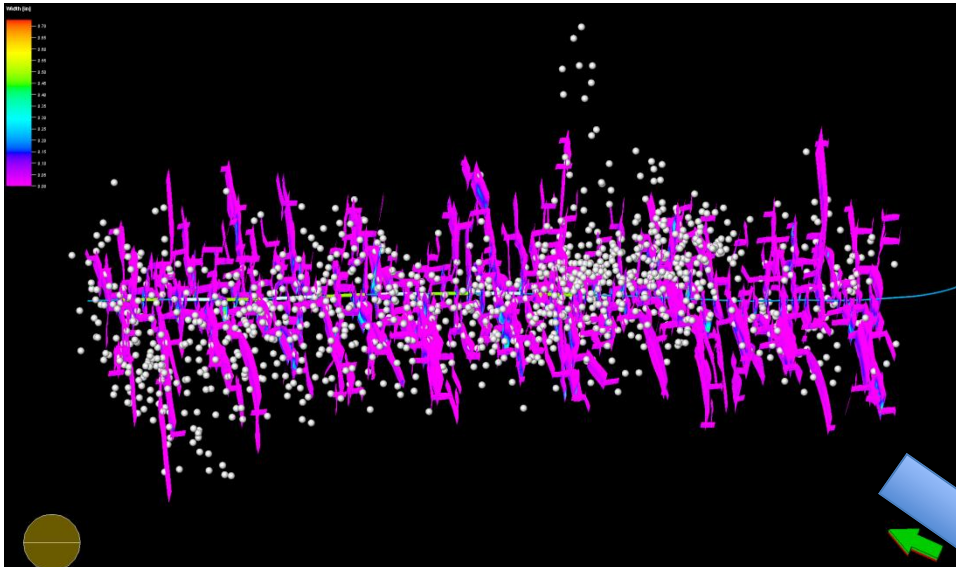
Complex Hydraulic Fractures



calibration using
microseismic data

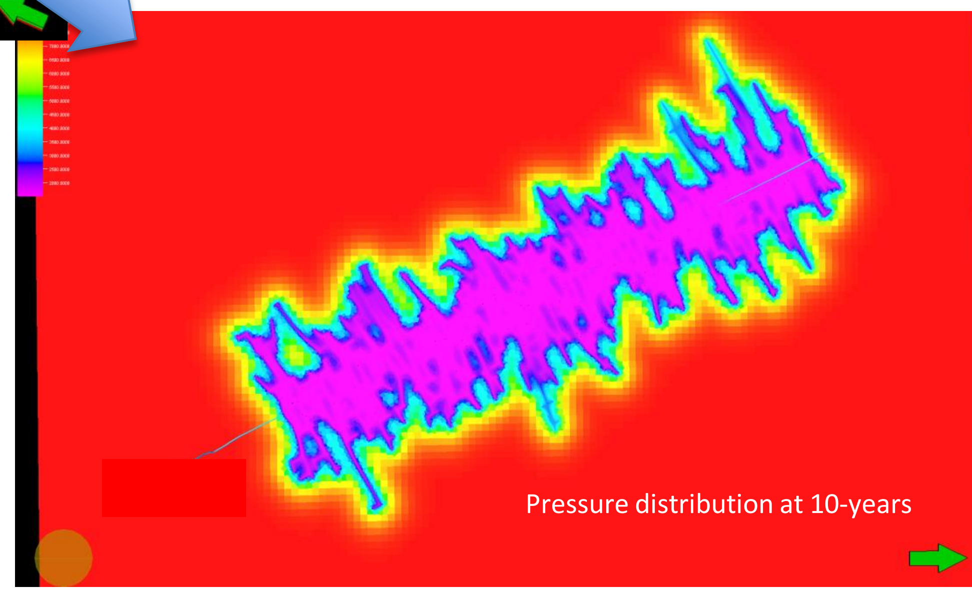
Beyond SRV

Complex Hydraulic Fractures



- Discretely grid the complex hydraulic fracture
- Propped and un-propped fractures
- Stress sensitive fracture conductivity

Numerical Reservoir Simulation

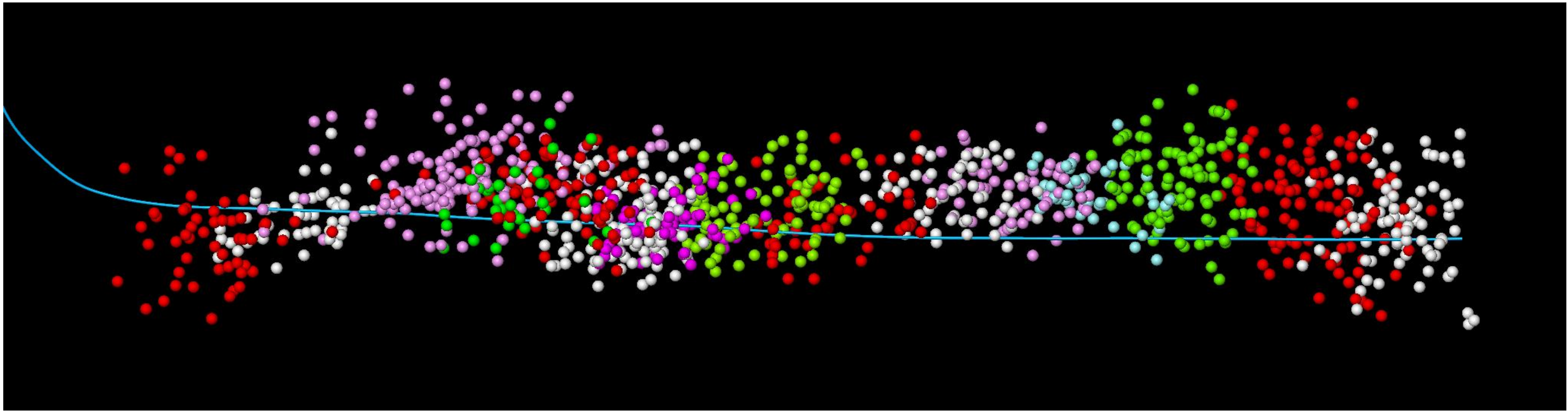


Maintain the fidelity between the hydraulic fracture model and numerical reservoir simulation

HESS

Shale Gas Example: Microseismic

~4500 ft Lateral
Cased & Cemented, Plug & Perf, 4 clusters/stage, 70 bpm
Hybrid Treatment Design: 12% 100-mesh, 75% 30/50 ceramic, 13% 20/40 ceramic



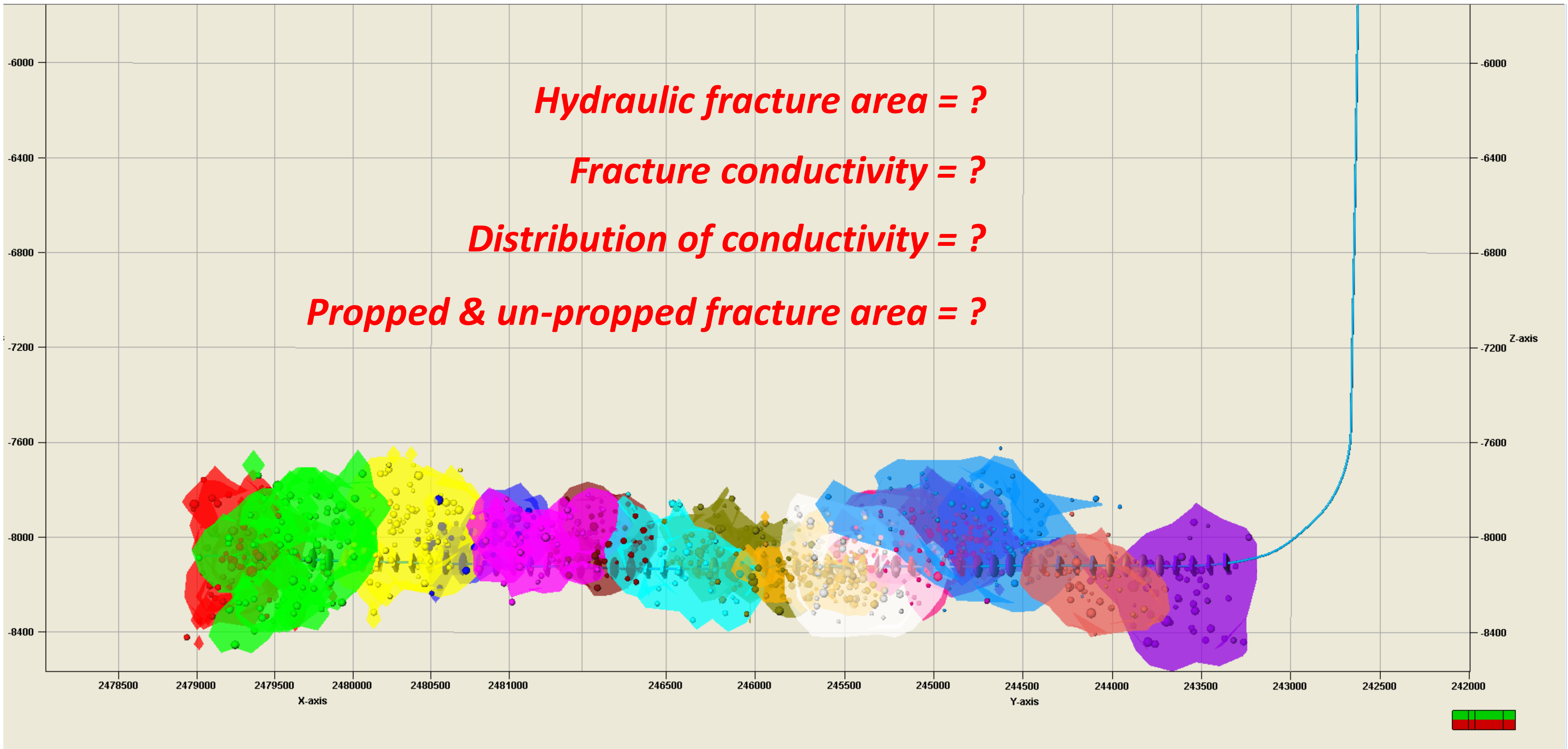
15 stages
109,000 bbls
4,400,000 lbs

P_i =	7650	psi
Ø=	4.7	%
Gas GR=	0.65	
h=	132	ft
T_r=	180	°F

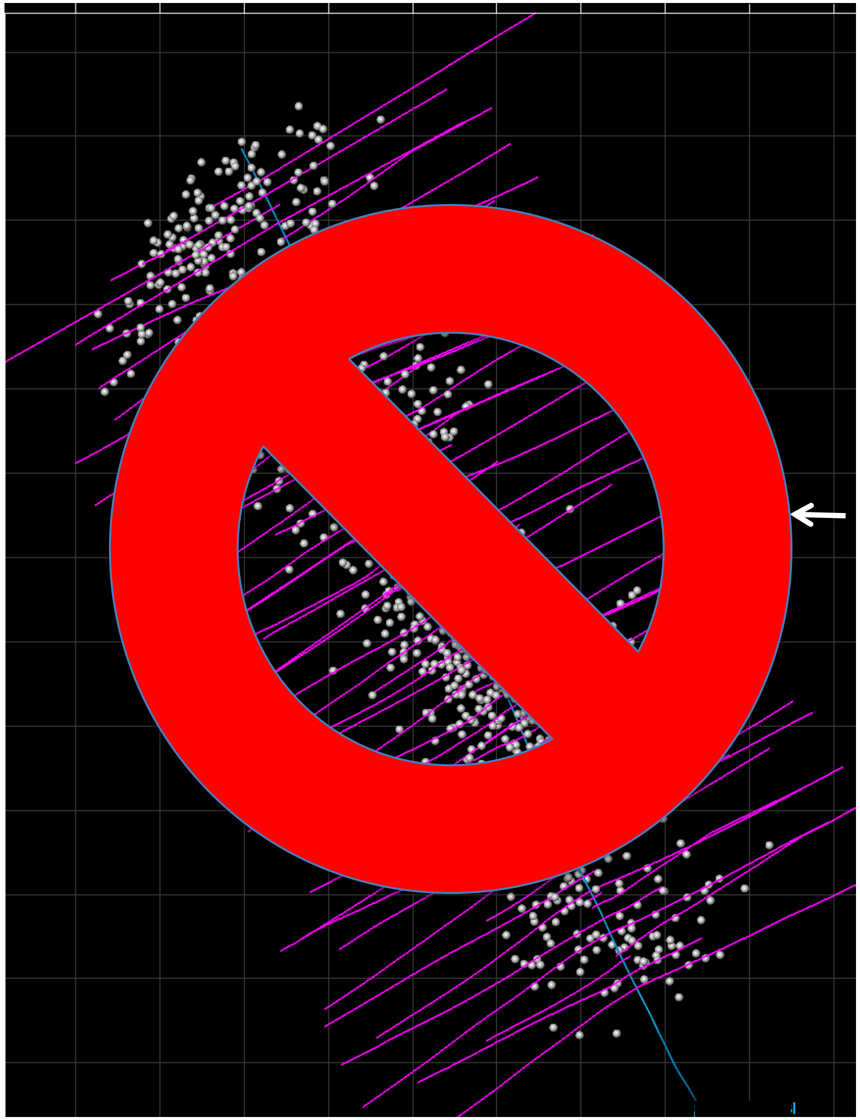
Reference: SPE 168596

Shale Gas Example: Microseismic Volume

SRV/ESV = 1800 MMft^3



Planar Fracture Model



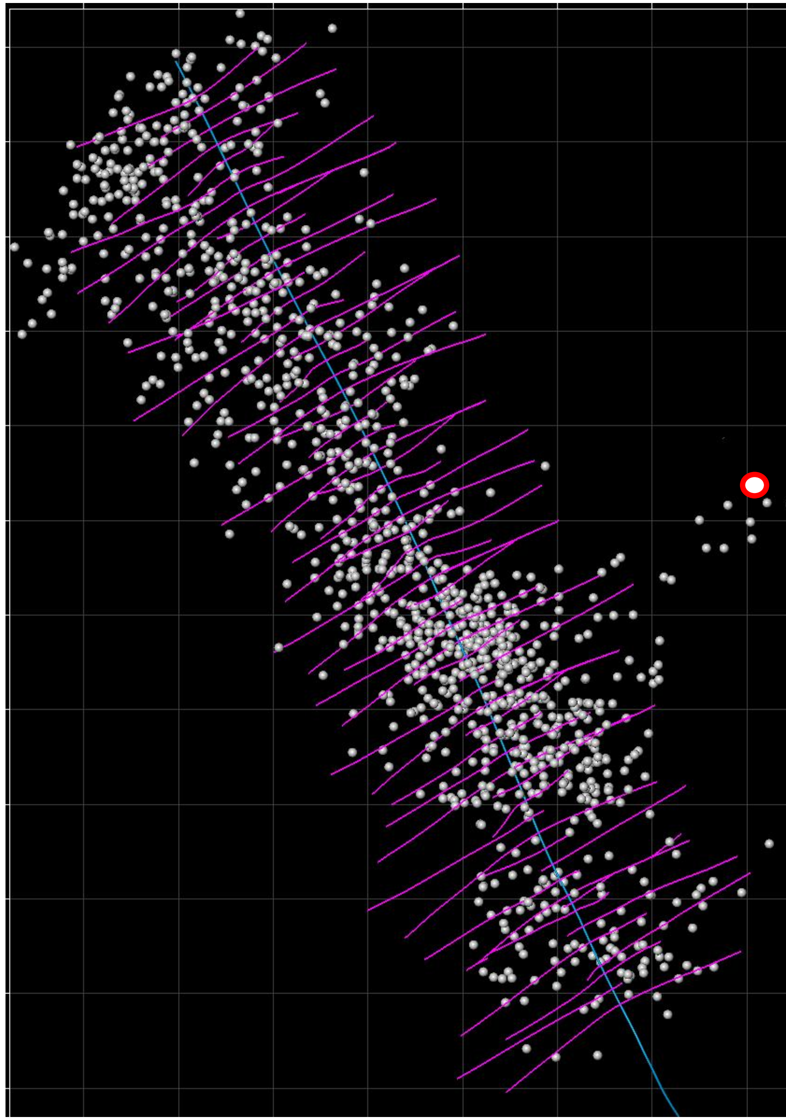
Total fracture area = 36 MM ft^2
Total propped area = 13 MM ft^2

Fracture area-pay = 14 MM ft^2
Propped area-pay =   5 MM ft^2

Microseismic observation well

Fluid Efficiency ~ 76%

Planar Fractures Matched to MSM

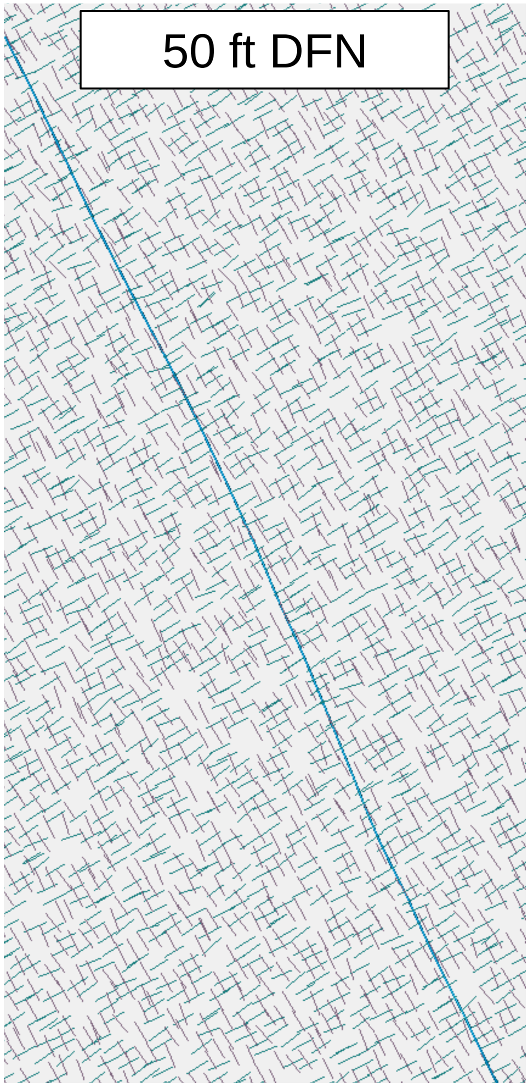


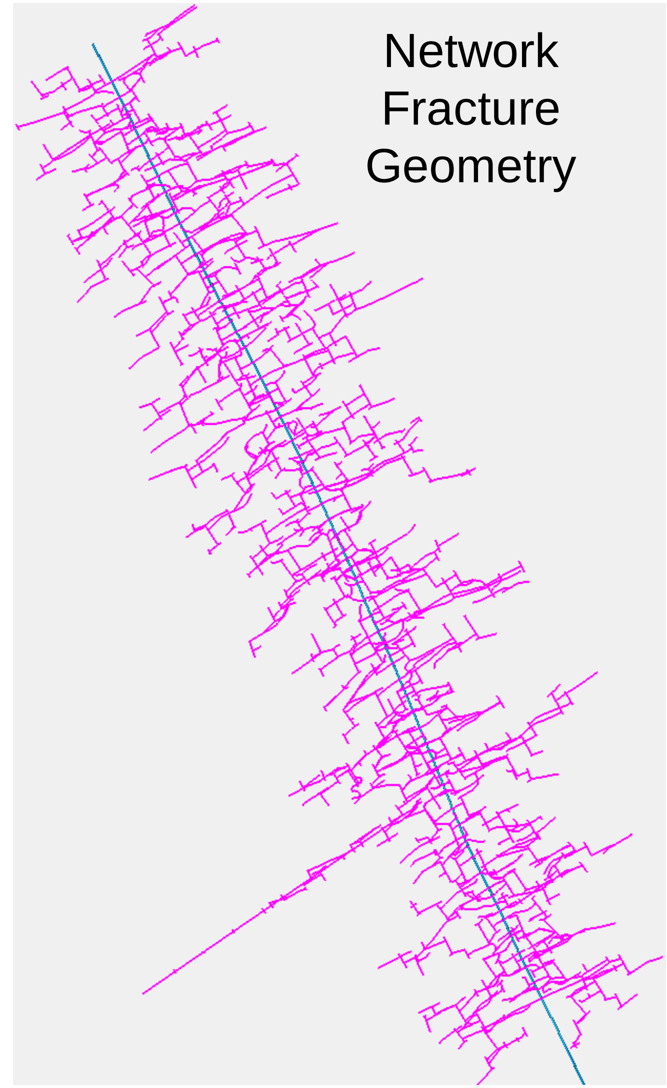
Microseismic observation well

Area	$=17.9$ MMft^2
Propped	$= 7.3$ MMft^2
Area-Pay	$= 12.2$ MMft^2
Prop-Pay	$= 5.4$ MMft^2

Fluid Efficiency ~ 42%

Complex Fracture Modeling: 50 ft DFN





Complex Fracture Modeling: 50 ft DFN

50 ft DFN

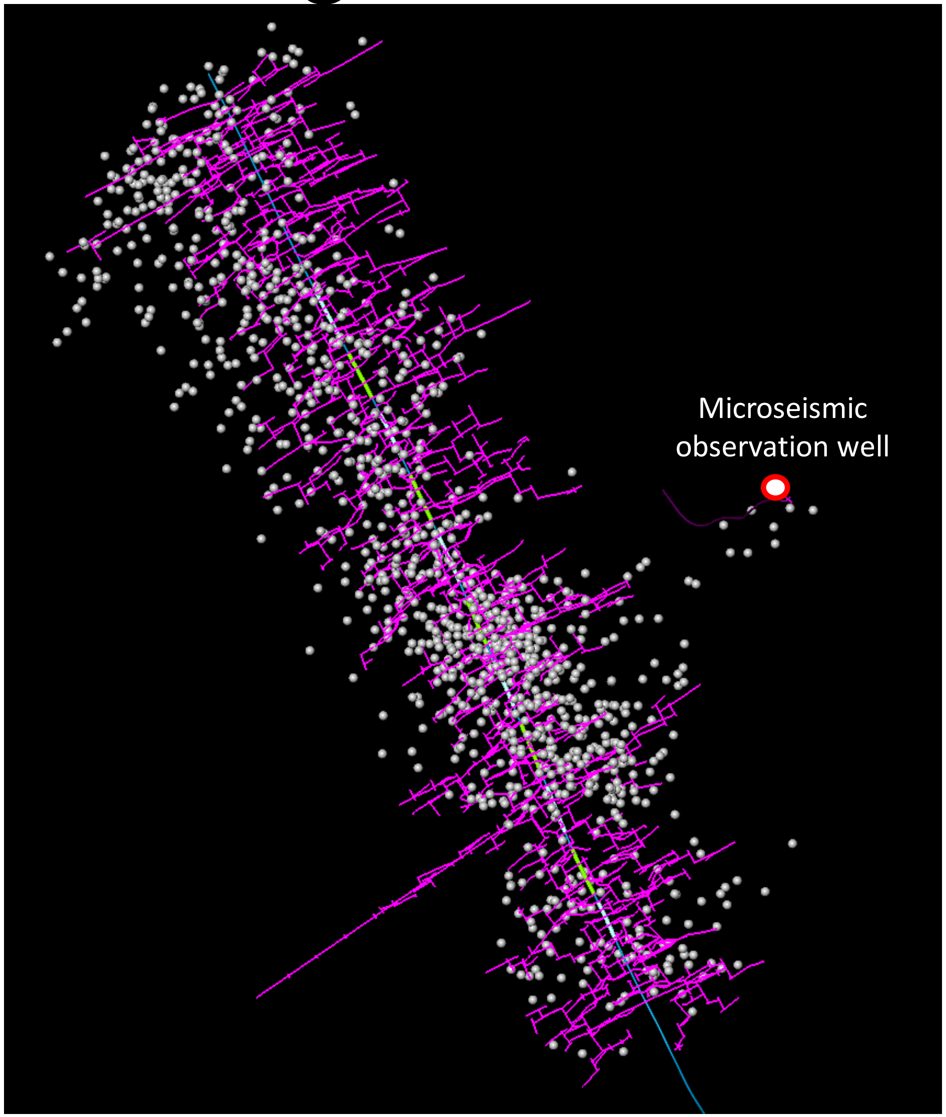
Total fracture area = 29.7MM ft^2
Total propped area = 8.4MM ft^2

Fracture area-pay = 16.1MM ft^2
Propped area-pay = 3.7MM ft^2

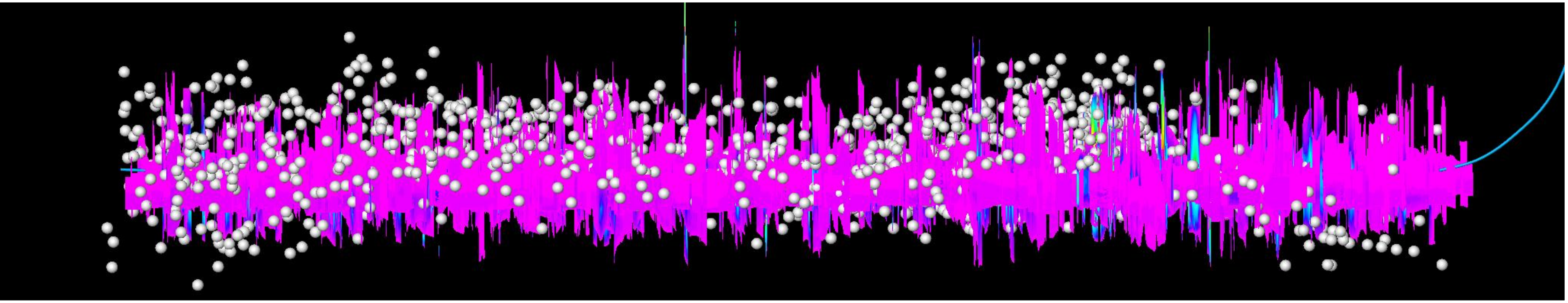
Average x_f ~ 400 ft

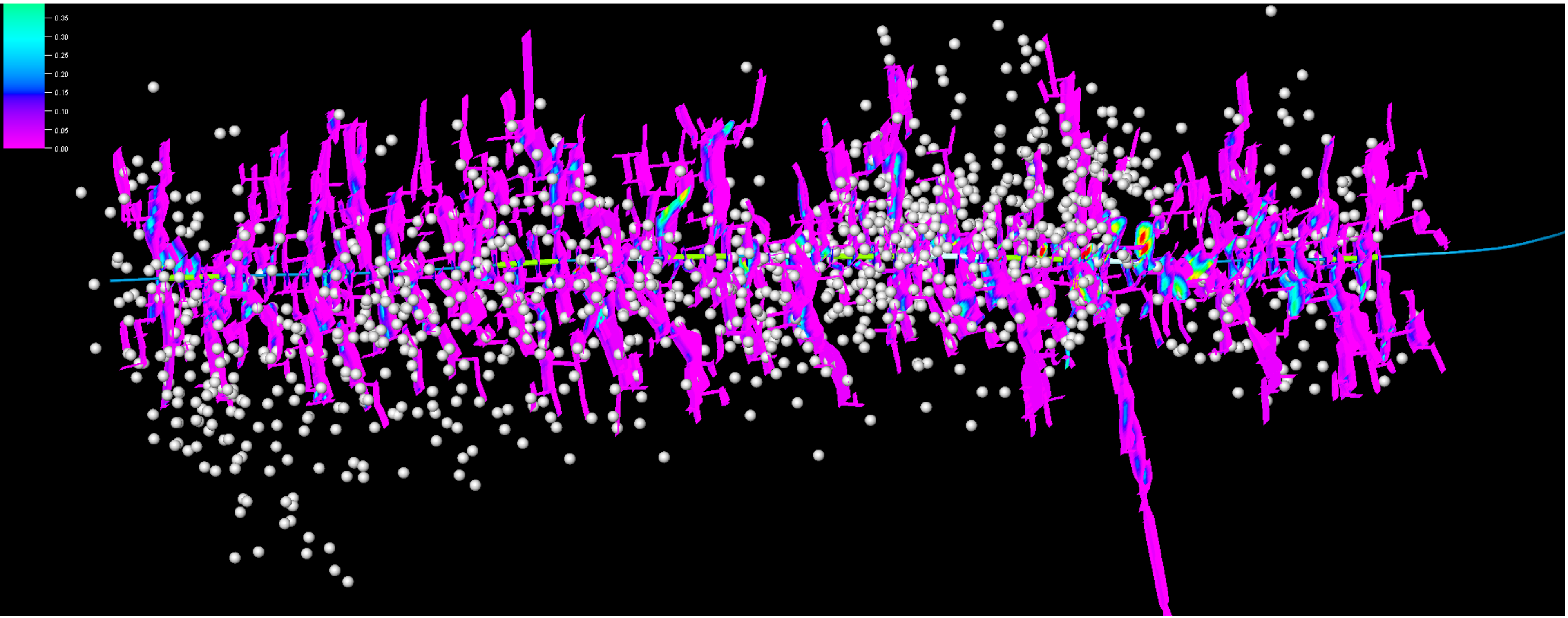
Proppant concentration ~ 0.5 lb/ft^2

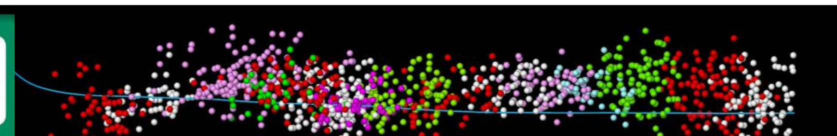
Fluid Efficiency ~ 74%



Complex Fracture Modeling: 50 ft DFN







Production Modeling

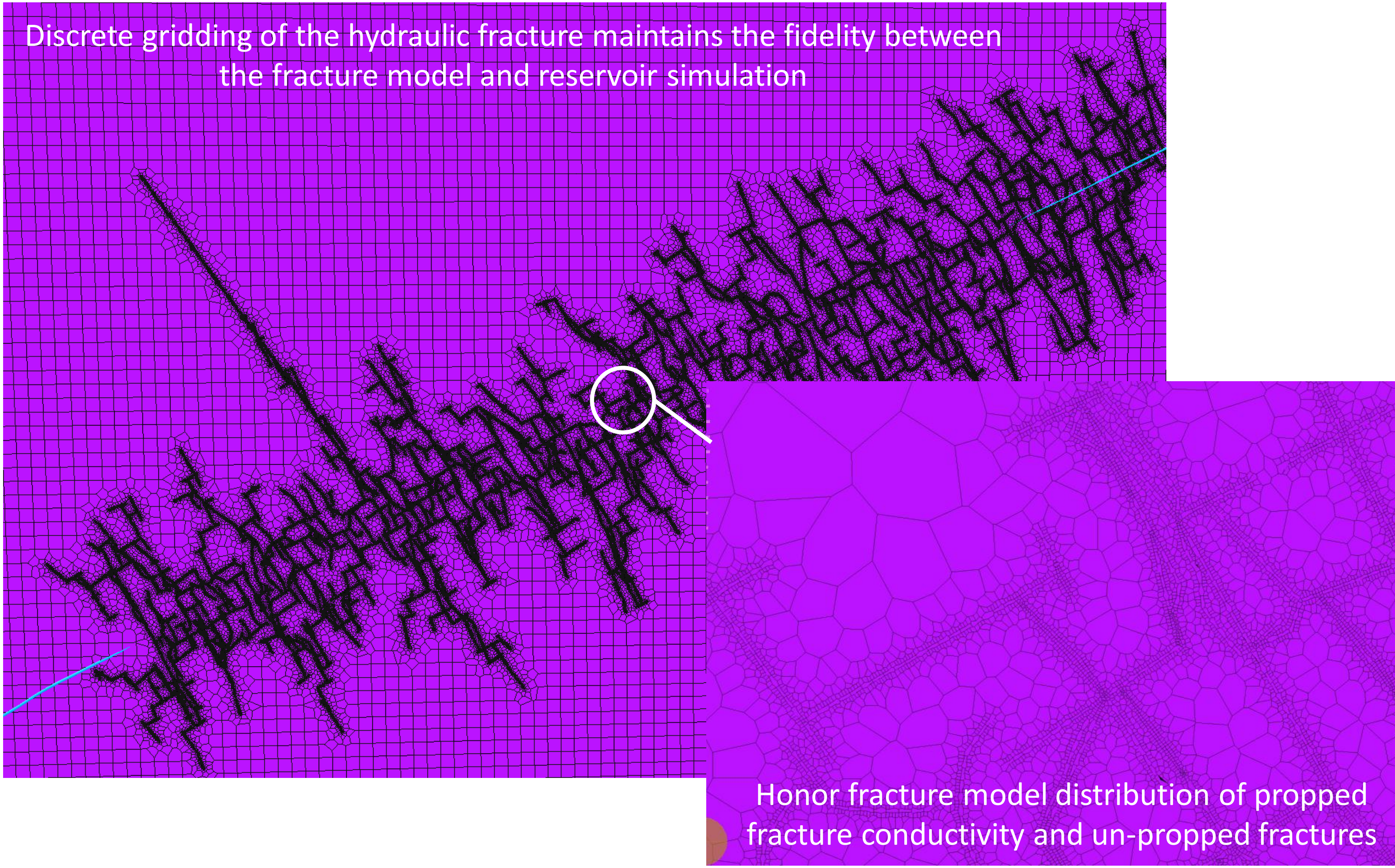
Shale Gas Example

15 stages, 4 clusters/stage

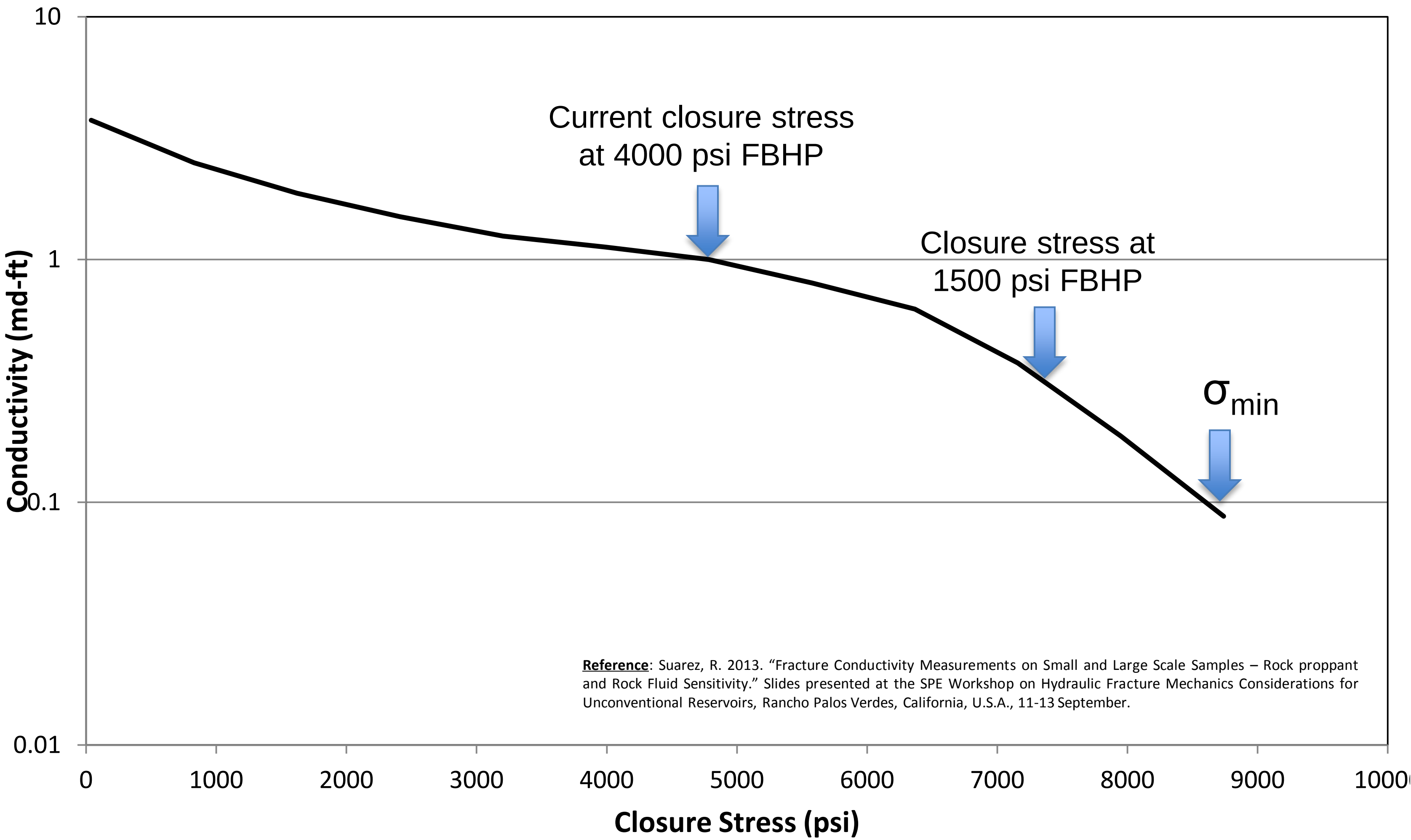
4,571 kgal, 4,430 klbs

Reference: SPE 168596

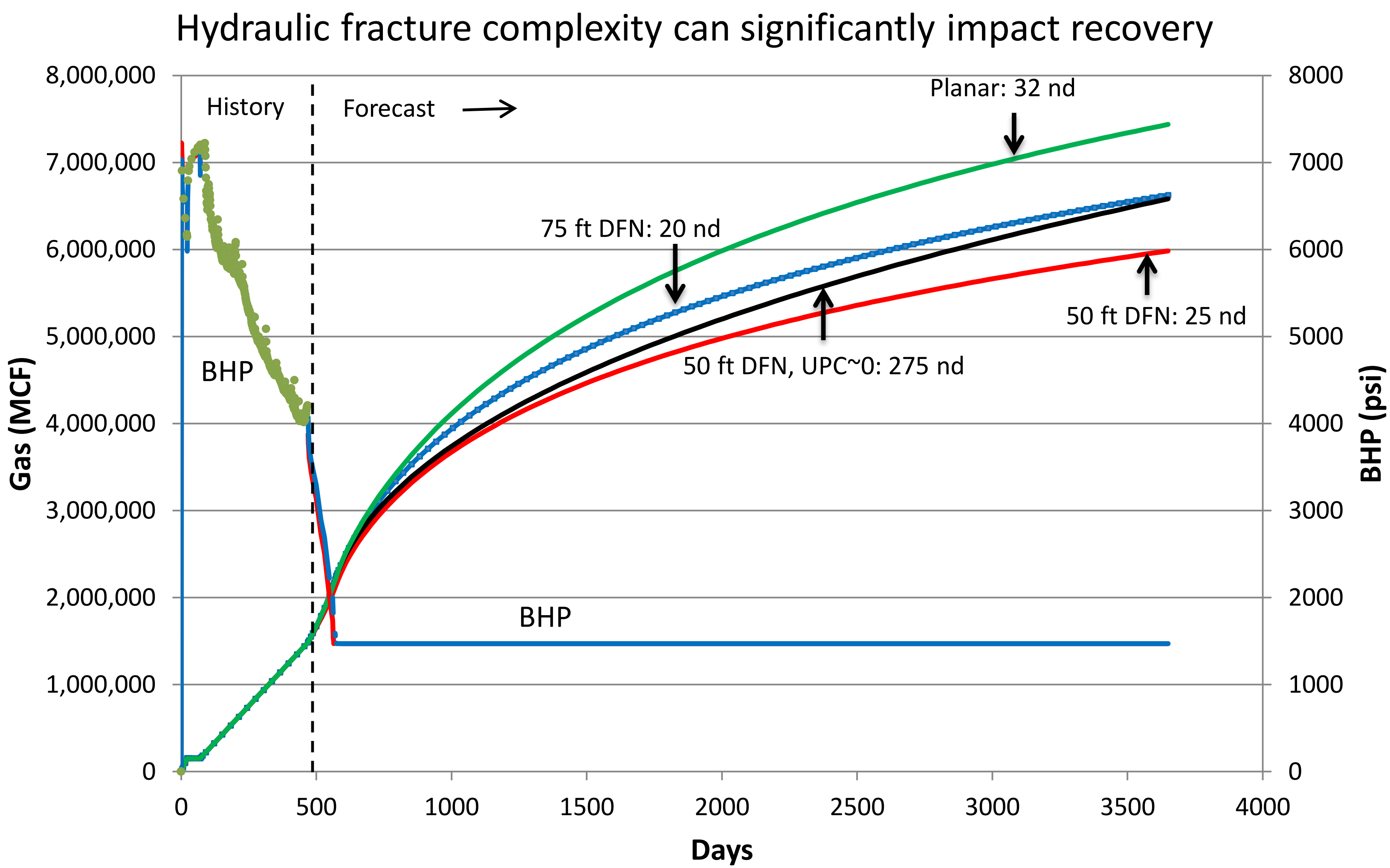
Reservoir Simulation Model Grid: 50-ft DFN



Un-Propped Conductivity



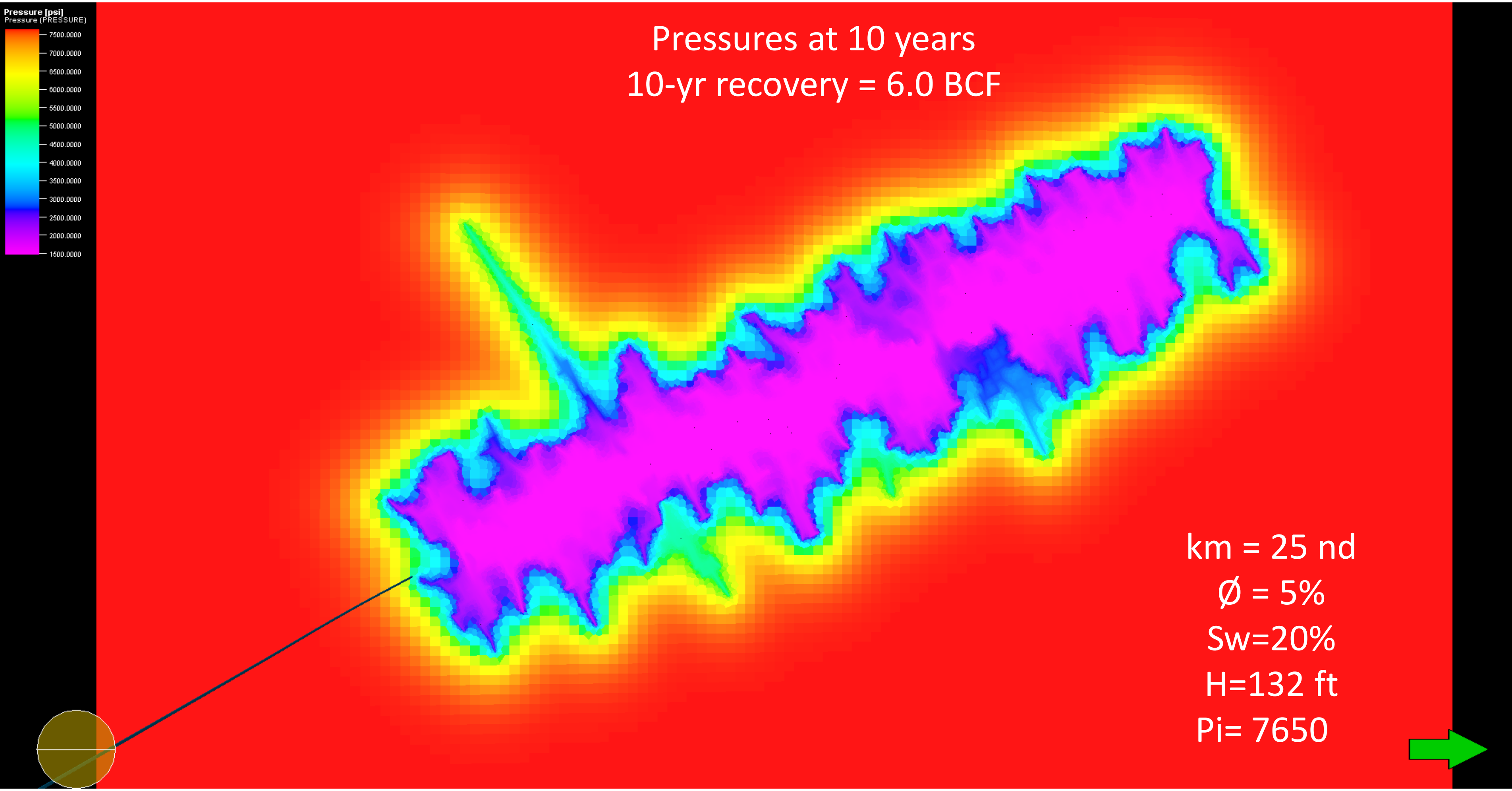
Network Fractures and Planar Fractures



Understanding matrix permeability is important

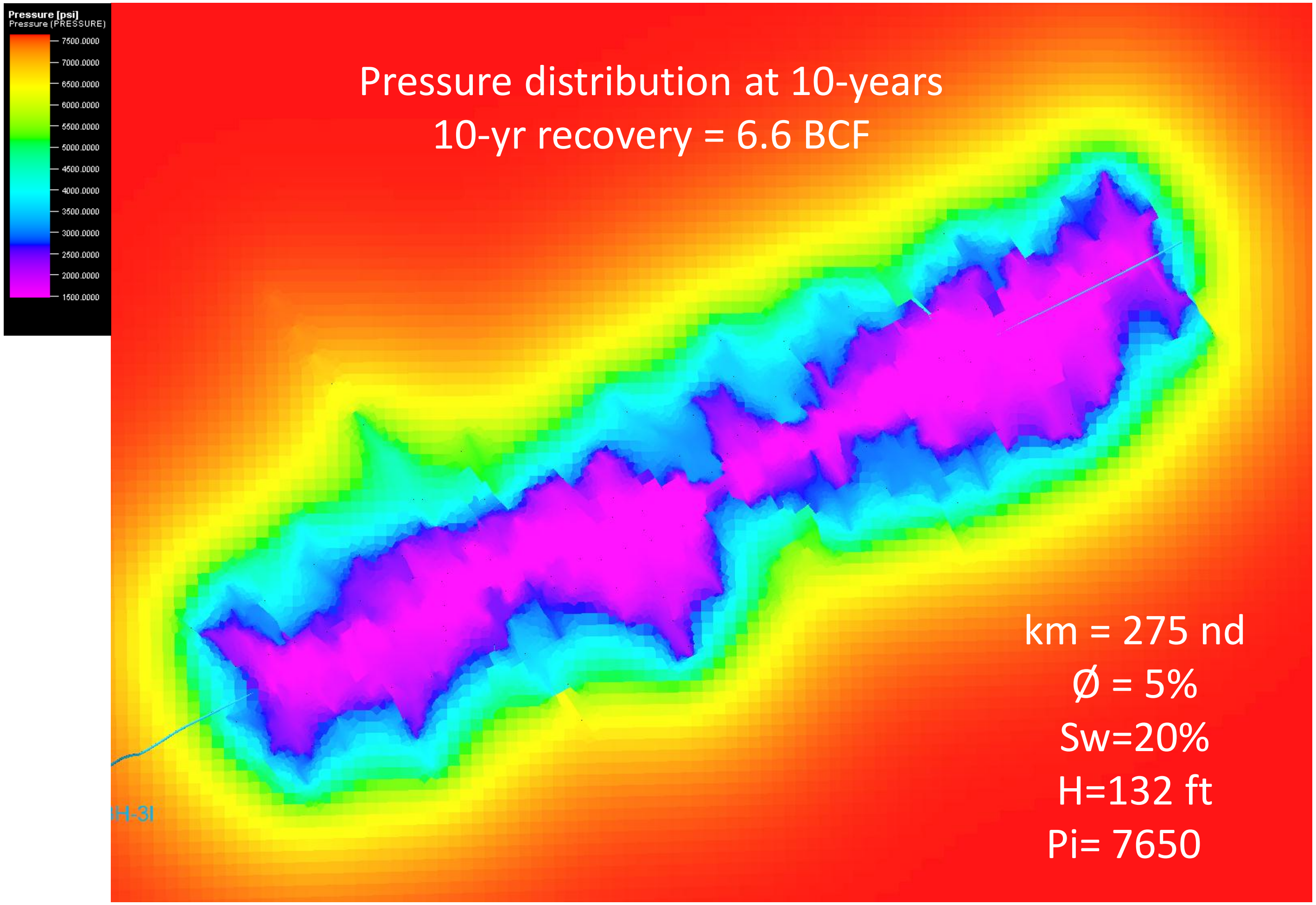
50-ft DFN – Base Case Forecast

Un-propped conductivity may be a key factor when optimizing well spacing



50 ft DFN (UPC~0)

Un-propped conductivity may be a key factor when optimizing well spacing



Stage Spacing

15 stages, 4 clusters/stage

4,571 kgal, 4,430 klbs

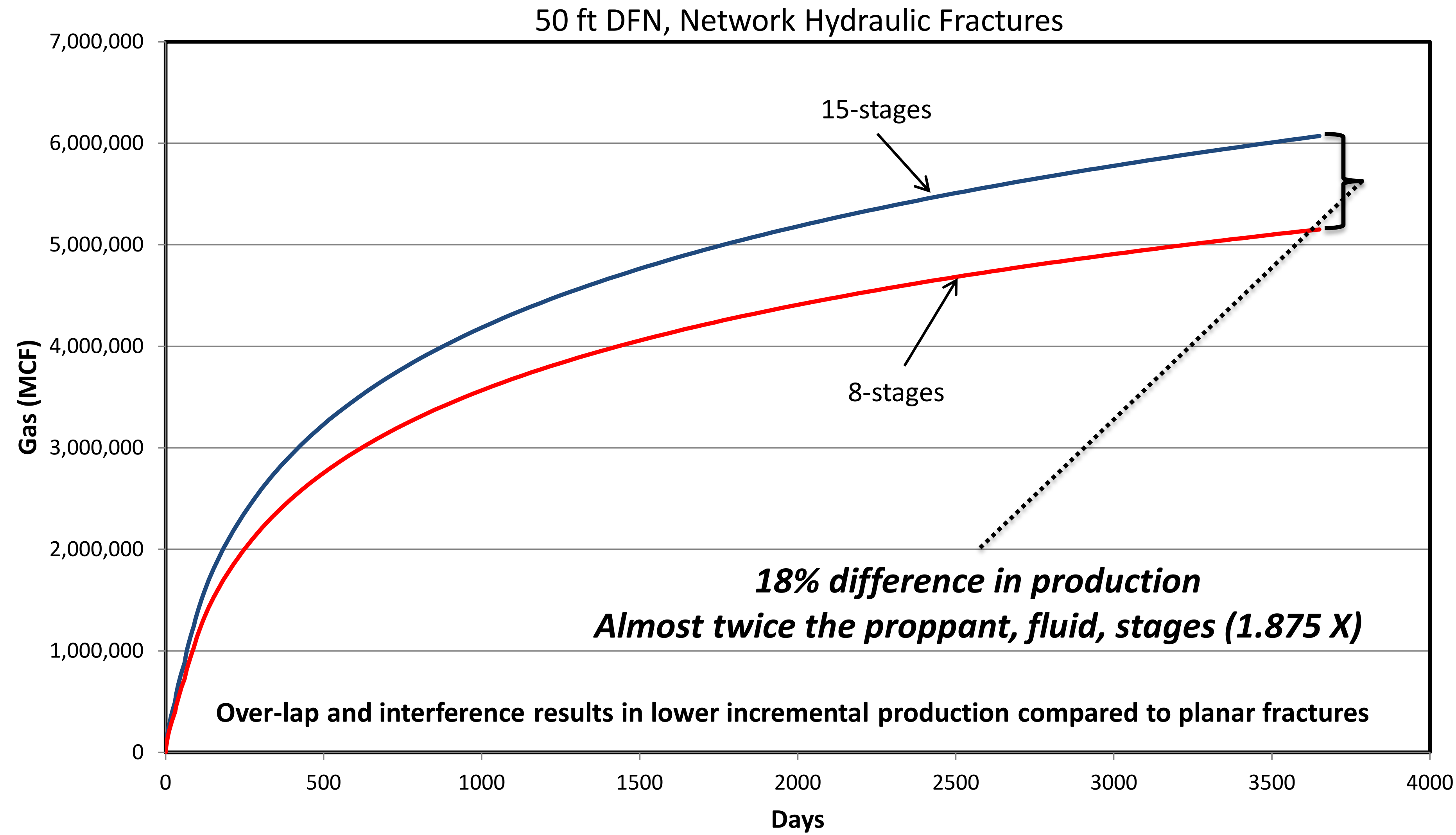
versus

8 stages, 4 clusters/stage

2285 bbls, 2,215 klbs

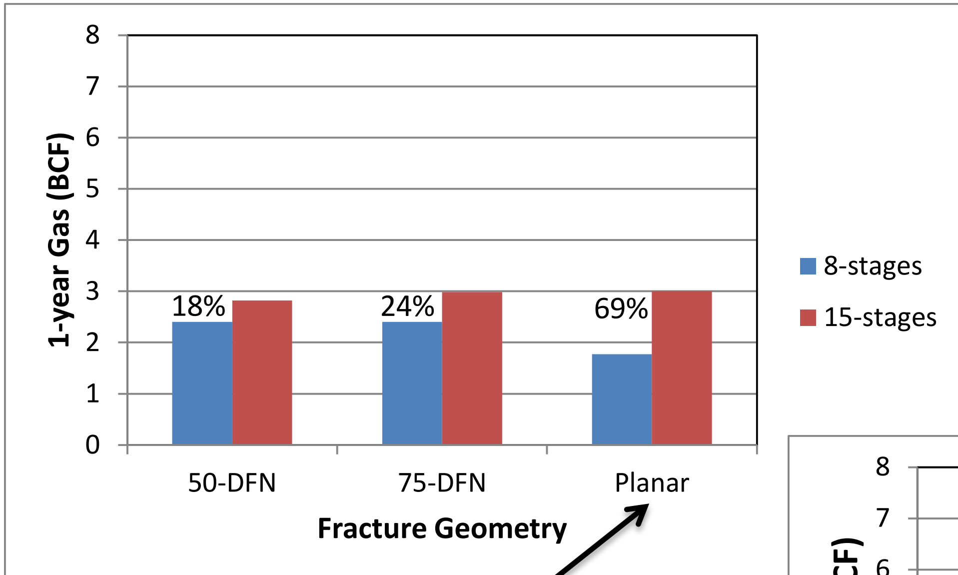
Reference: SPE 168596

Effect of Stage Spacing: 10-yr Recovery



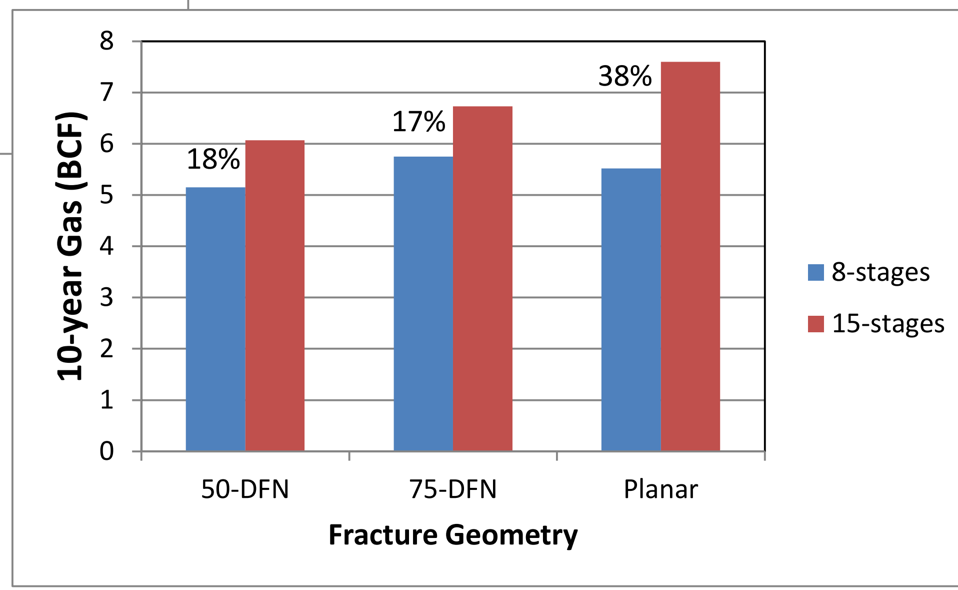
Fracture Complexity & Stage Spacing

1-year



Fracture morphology may significantly impact optimum stage spacing

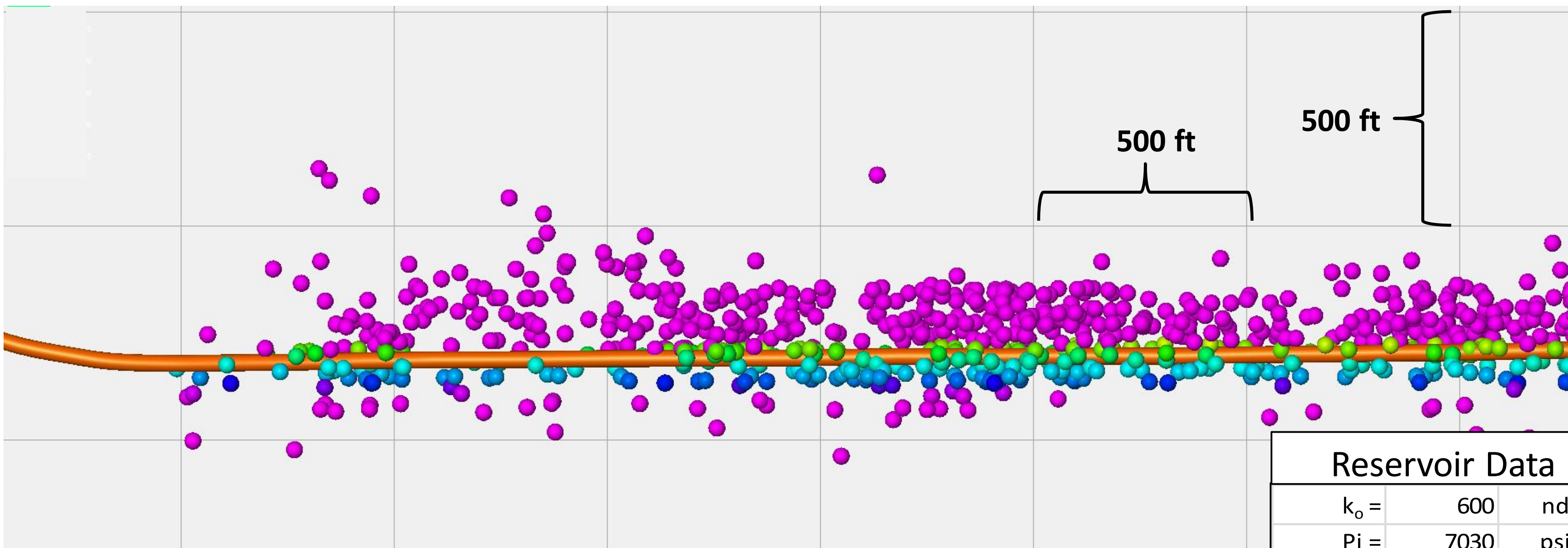
10-years



More Incremental production for planar fractures

Tight Oil Example
Microseismic Data: ~3000 ft section

Un-cemented ball-drop completion with swell packers
45 bpm,1600 bbl XL-gel, 110,000 lbs 20/40 ceramic proppant (per stage)

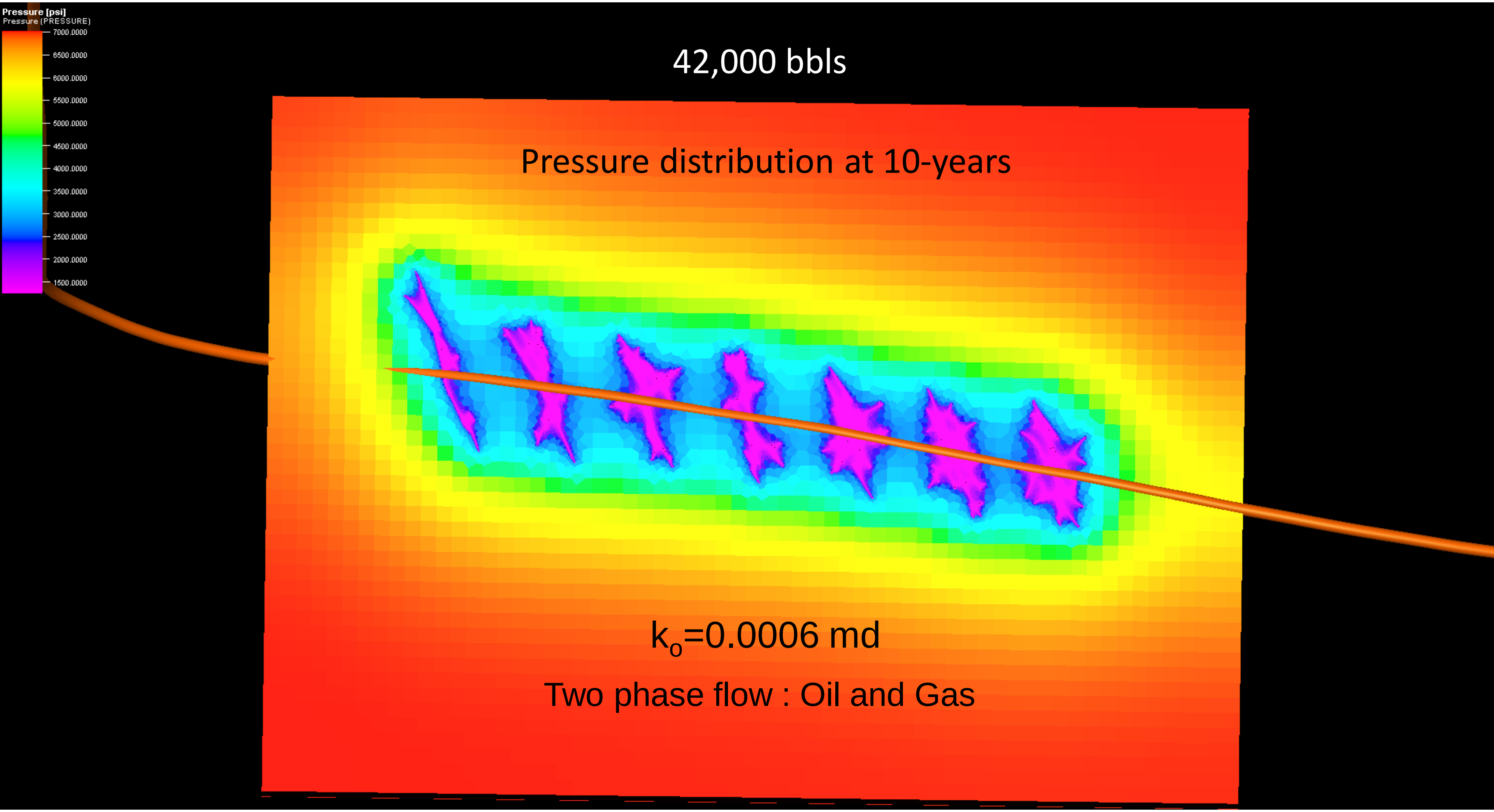


Reservoir Data		
k_o =	600	nd
Pi =	7030	psi
Ø=	5.1	%
B_o=	1.82	STB/RB
P_{BP}=	3150	psi
μ_o=	0.37	cp
c_o=	1.13E-05	psi^{-1}
h=	77	ft
R_{si}=	1552	scf/bbl

- Microseismic data from ~3000 ft of lateral “adapted” from SPE 166274
- Tight oil example incorporates:
  - ✓ Geomechanical study (3D MEM)
  - ✓ Reservoir simulation history match (3-yrs production)

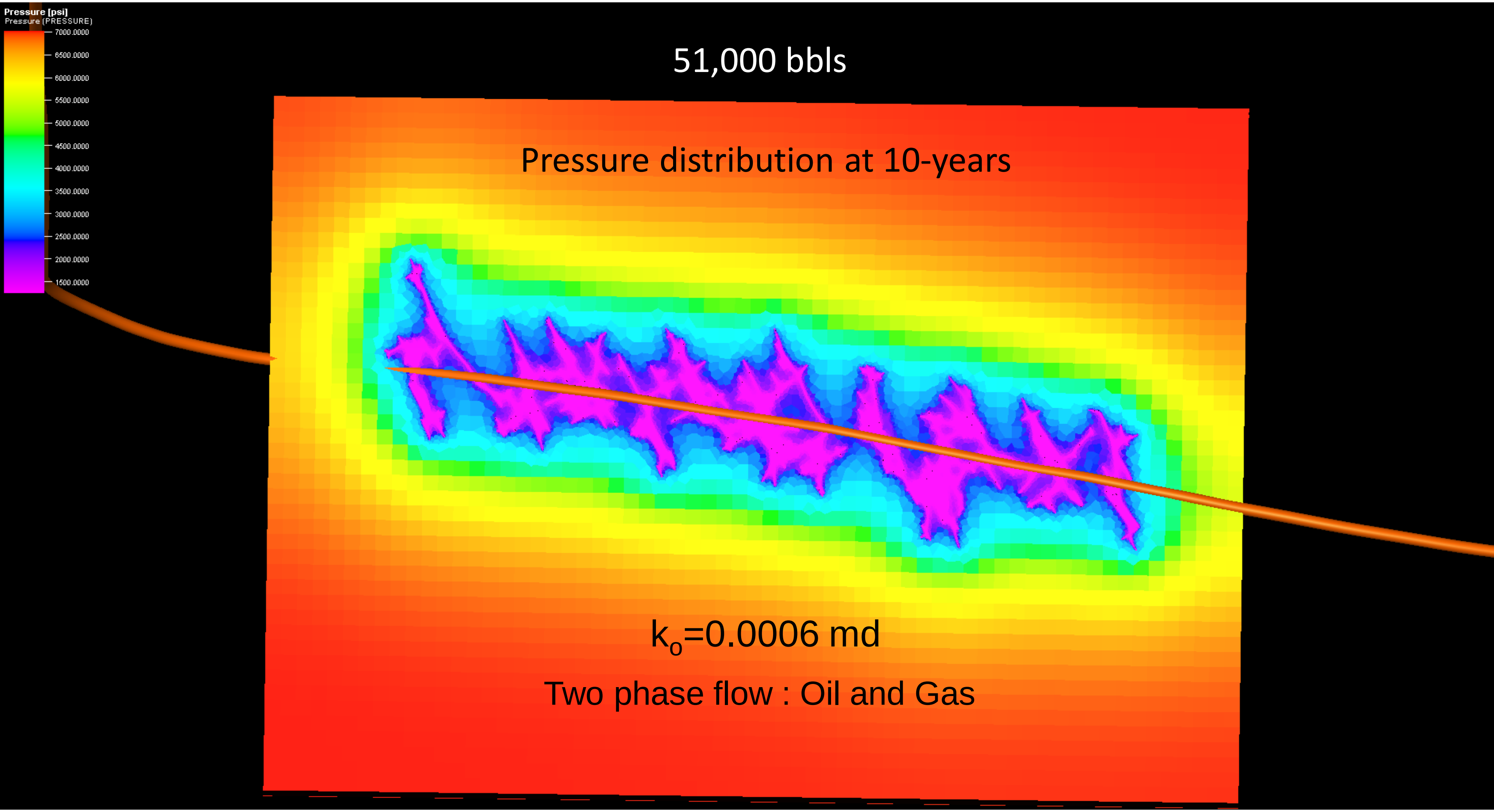
333 ft spacing (30 stages/10,000 ft)

Stage spacing changes fracture complexity and “apparent” system permeability (k_{srv})

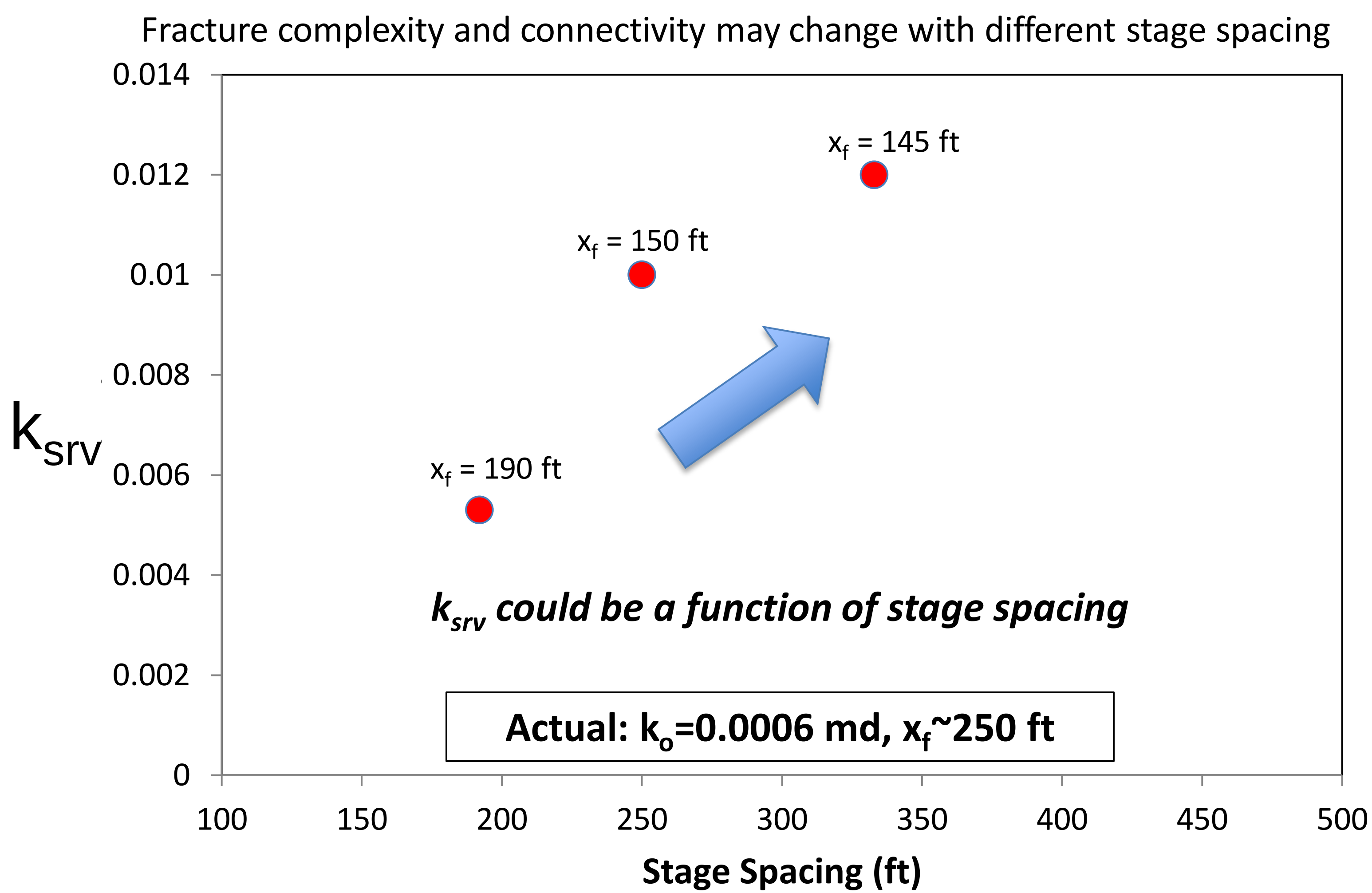


192 ft spacing (52 stages/10,000 ft)

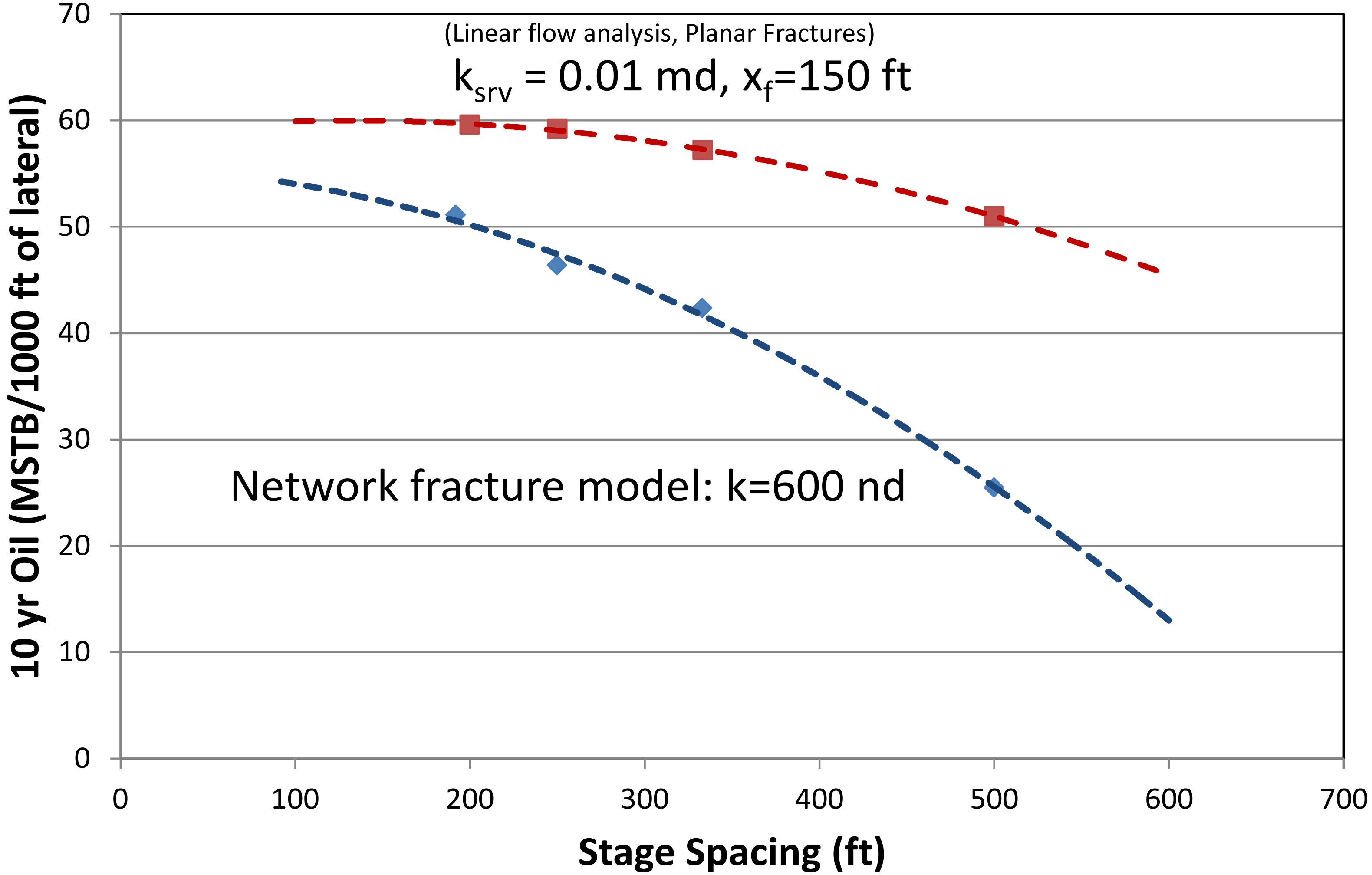
Stage spacing changes fracture complexity and “apparent” system permeability (k_{srv})



Linear Flow Analysis: Network Fractures and Stage Spacing



Fracture Complexity and Permeability Assumptions Effect Optimum Stage Spacing



Conclusions

- The interpretation and application of microseismic images should include mass balance and fracture mechanics.
- Integrating fracture modeling, microseismic data, and production modeling may be required for completion optimization.
- RTA and LFA can provide important insights into well performance, but k_{srv} and x_f may not be appropriate for completion optimization.
- Changes in stage spacing and fracture treatment design will likely result in different “apparent” permeability or k_{srv}.