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Paper SPE-184825
Impact of Well Interference on Shale Oil Production Performance: A Numerical Model for Analyzing Pressure Response of Fracture Hits with Complex Geometries

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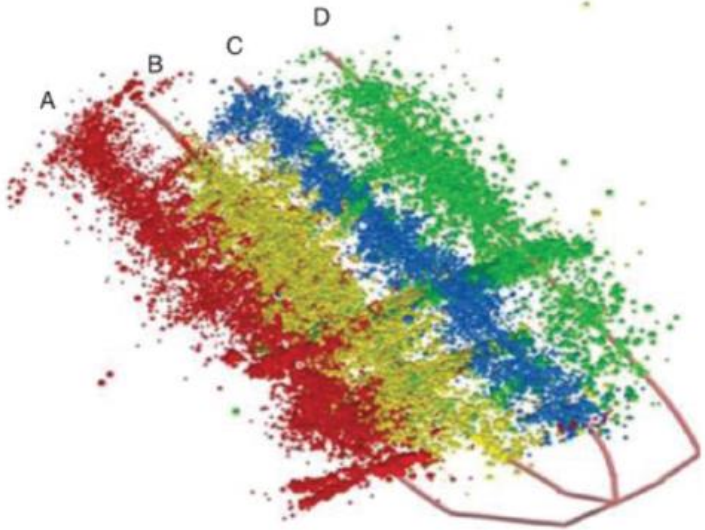
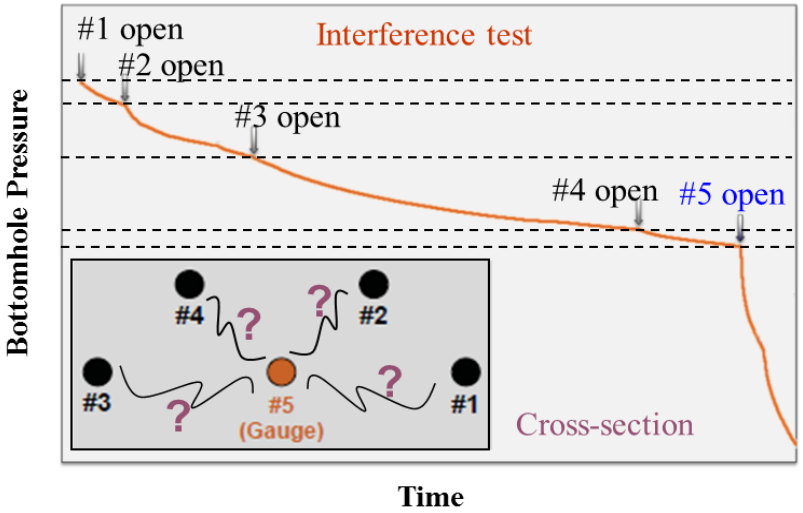
Well Interference

Observations: Microseismic events / Pressure test

Primary reason: fracture connection between wells



Microseismic events
in Eagle Ford shale (SPE 174946)

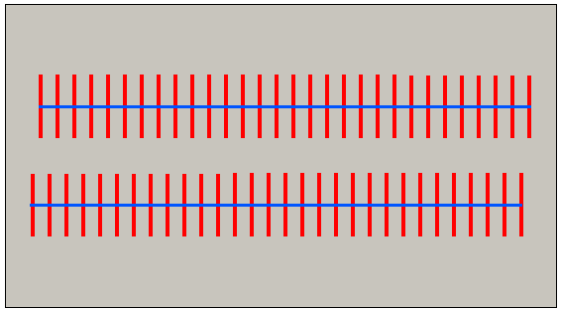


Pressure test of #5 Well
in Wolfcamp shale (URTeC: 2154675)

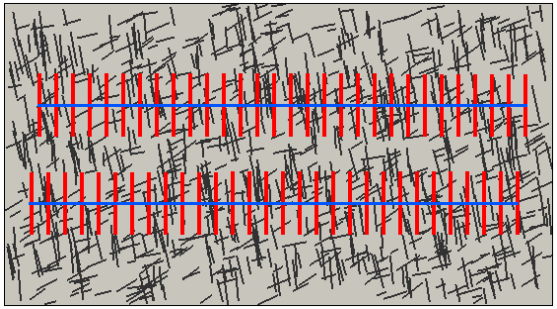
Well Interference Mechanisms

Research Focus

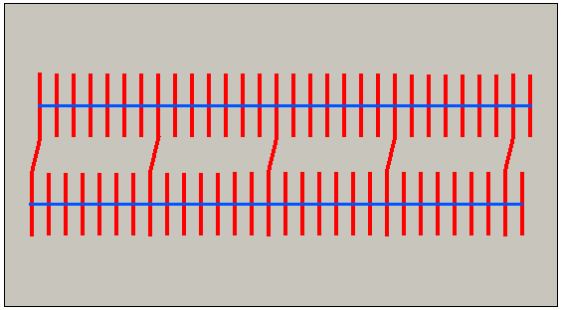
- Develop a numerical model to simulate well interference with complex fracture geometries
- Understand mechanisms and intensity of well interference
- Determine optimal well spacing for maximizing economic production



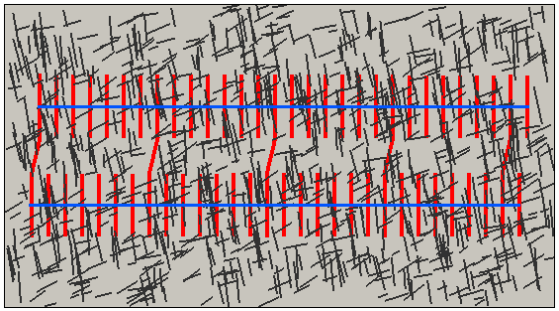
Case 1-through matrix



Case 2-through natural frac

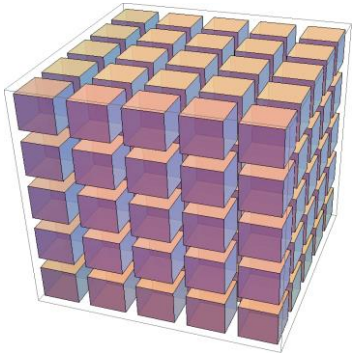


Case 3-through HF hits

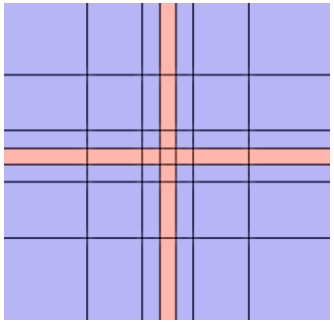


Case 4-combination

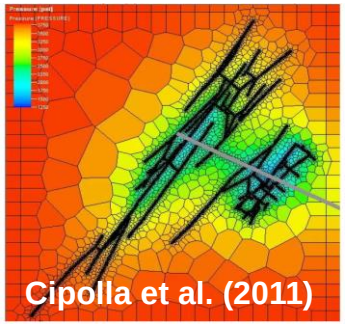
Numerical Method for Fractured Reservoirs



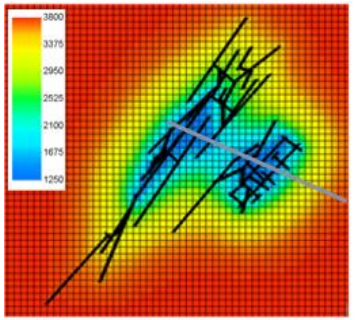
Dual-continuum model



Structured grid (local grid refinement)



Unstructured grid (local grid refinement)



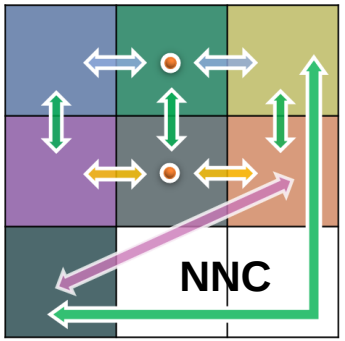
Structured grid (No refinement)

Embedded Discrete Fracture Model (EDFM)

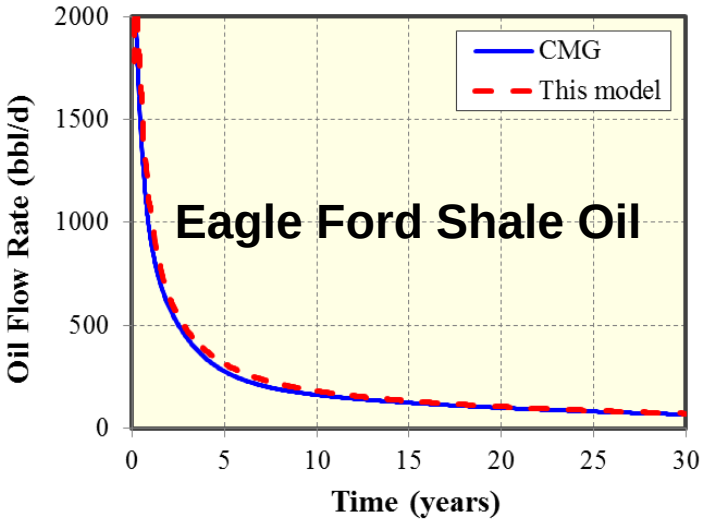
- Use **structured grids** to avoid unstructured grids
- Model **complex fracture** geometries
- Modify **transmissibility** between **matrix grids** and **fracture grids** (non-neighboring connections)

Matrix grids

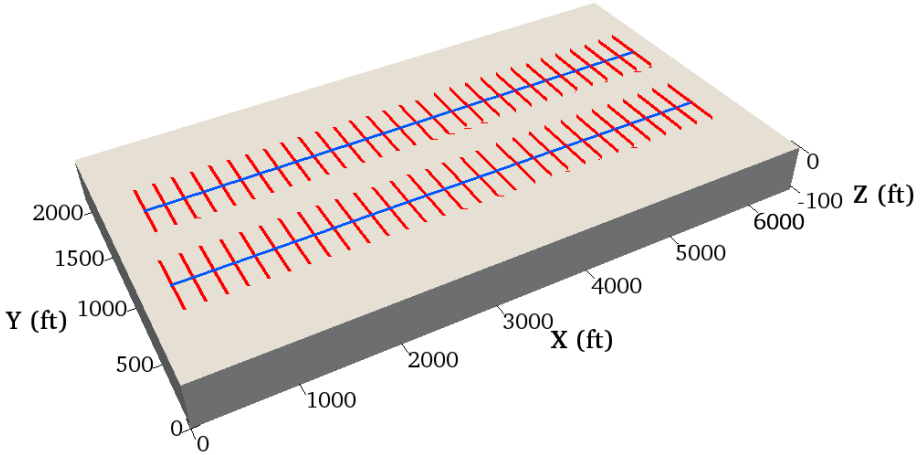
Frac grids

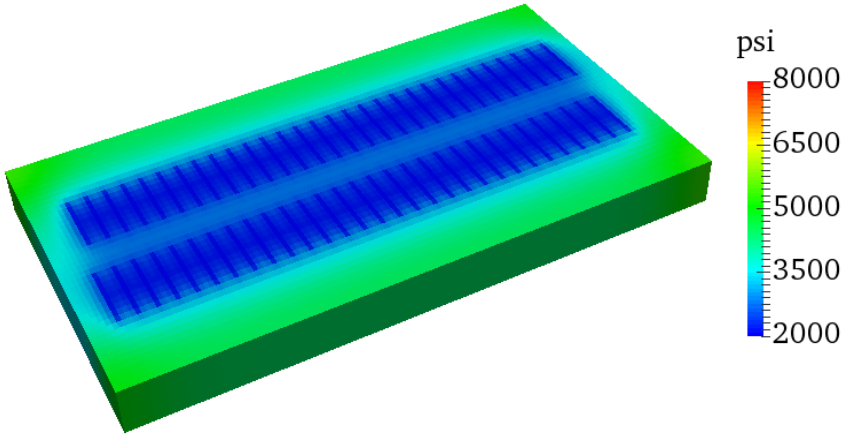


Model Verification

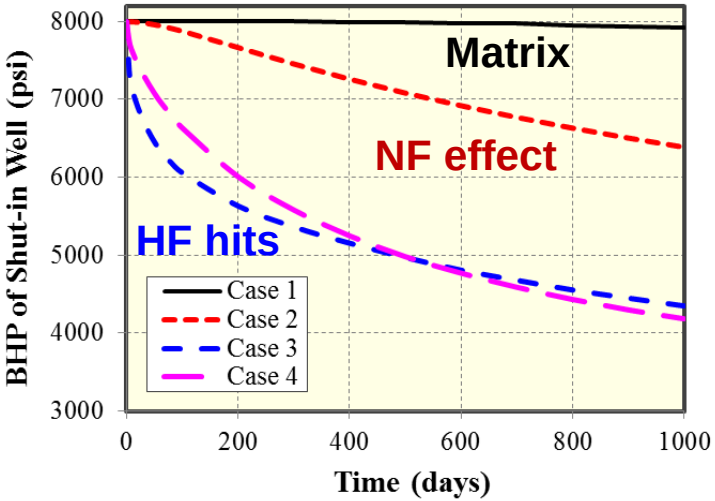


Component	Molar fraction
CO_2	0.01821
N_2-C_1	0.44626
C_2-C_5	0.17882
C_6-C_{10}	0.14843
C_{11+}	0.20828



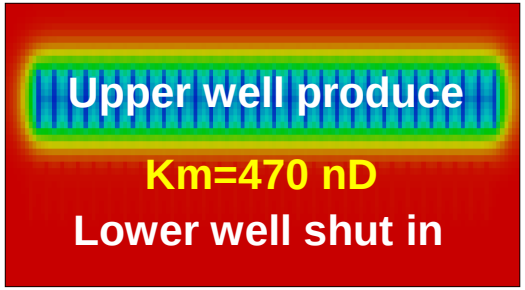


Comparison of Well Interference Mechanisms

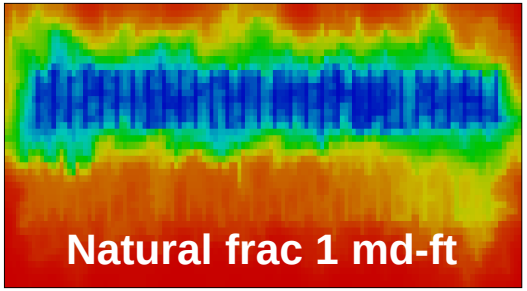


Key message

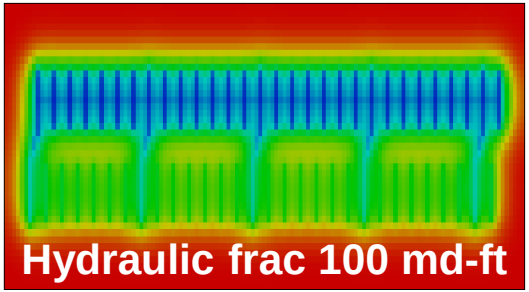
Hydraulic fracture hits are more important for well interference than natural fractures effect in this study



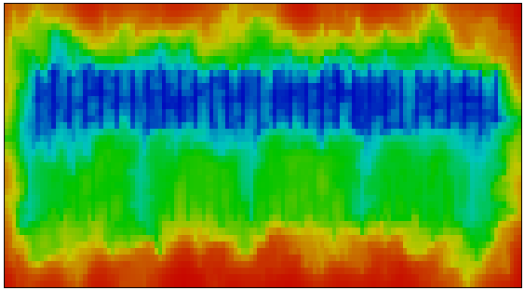
Case 1-through matrix



Case 2-through natural frac



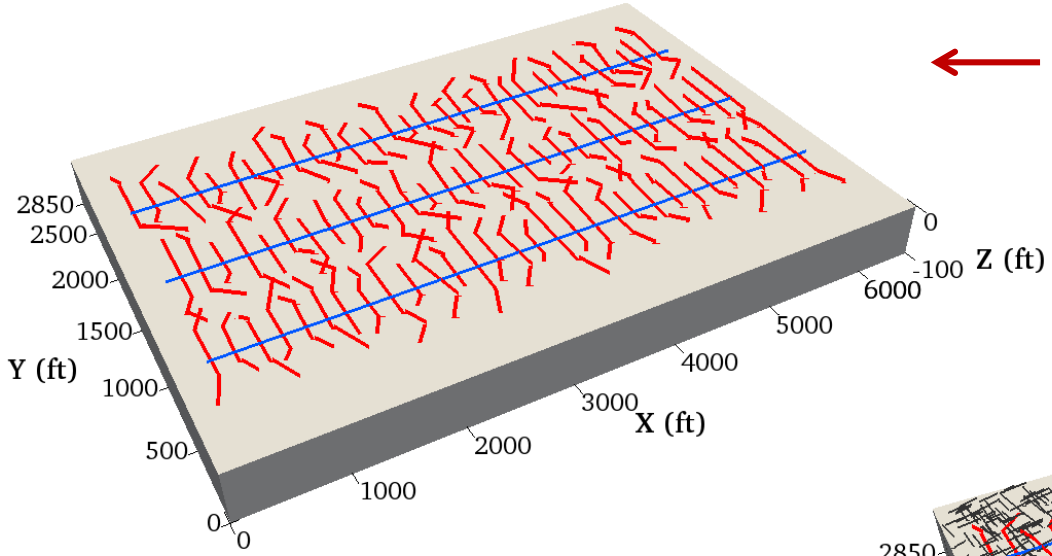
Case 3-through HF hits



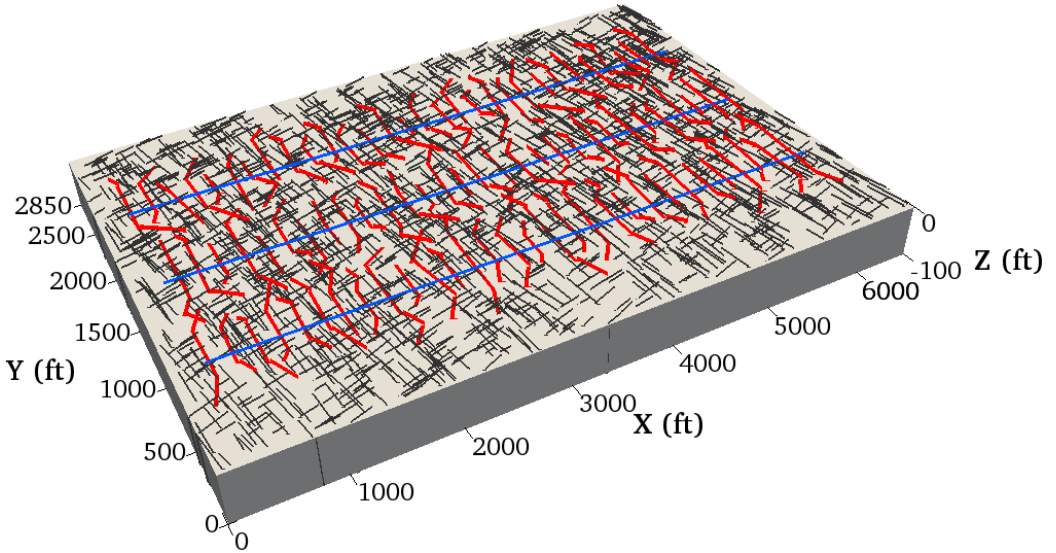
Case 4-combination

Pressure distribution after 1000 days

Well Interference through Complex Frac Hits



← 90 non-planar HFs (100 md-ft)
2000 natural fractures
(1 md-ft)
↓

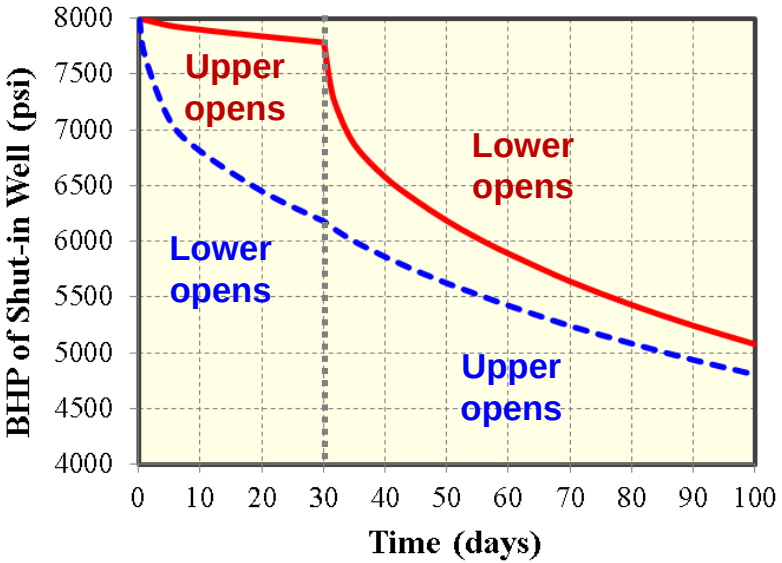


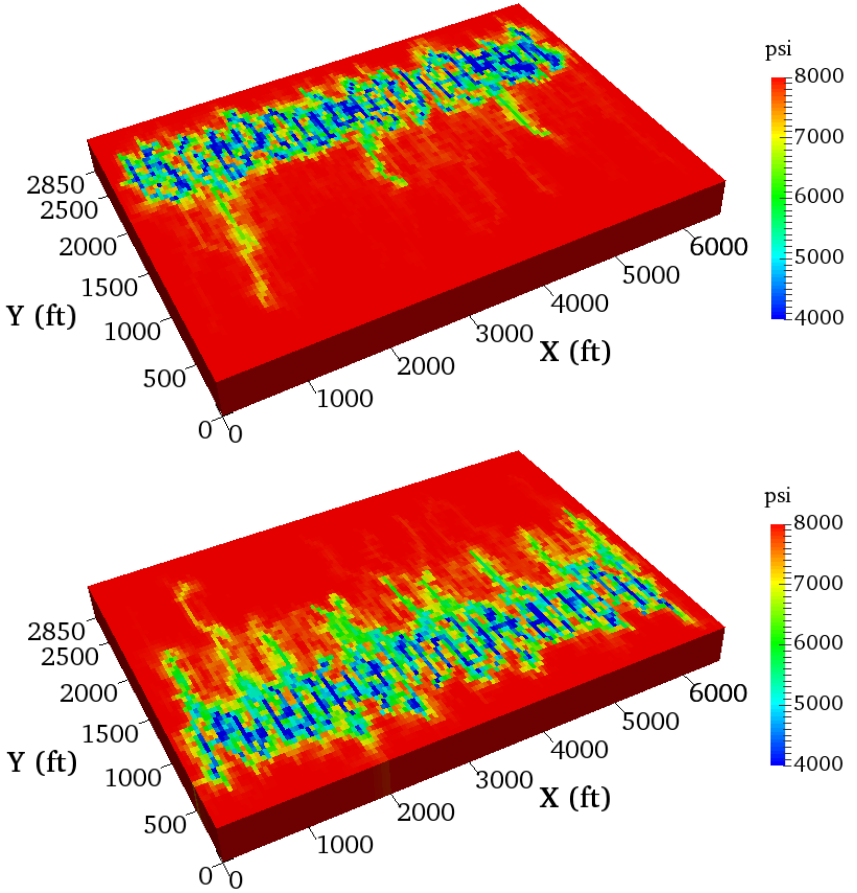
Field well interference test

- **Upper well opens, then lower well**
- **Lower well opens, then upper well**

(middle well shut in)

Pressure Response of Shut-in Middle Well

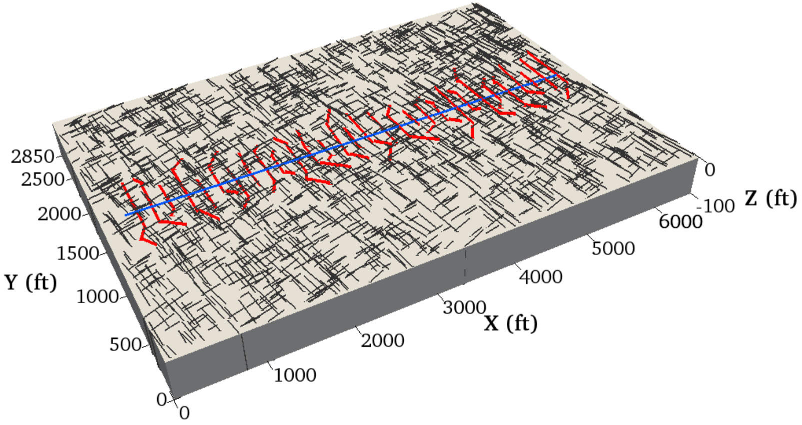


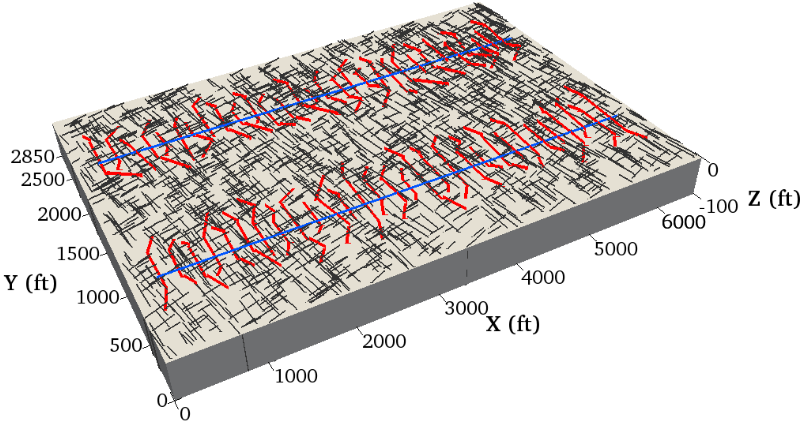


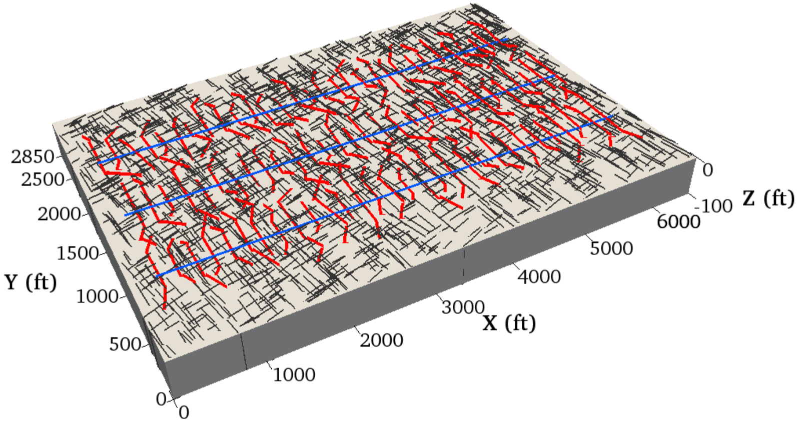
Key message

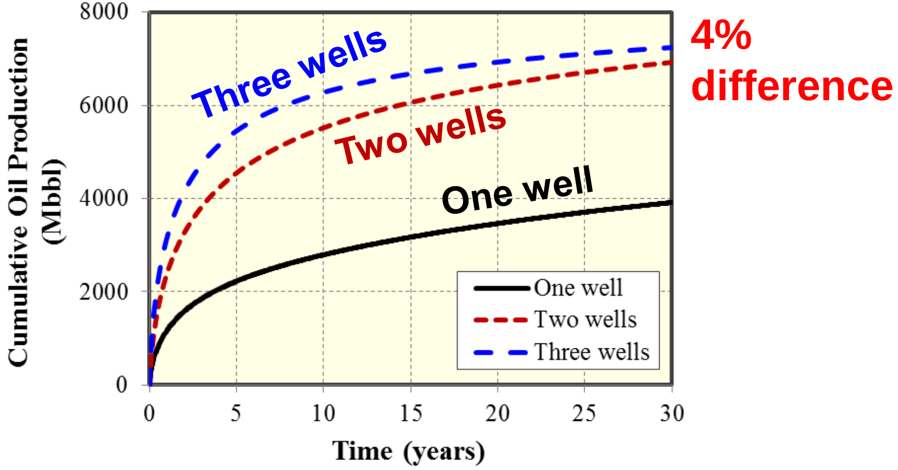
More well interference between middle well and lower well

Well Spacing Optimization

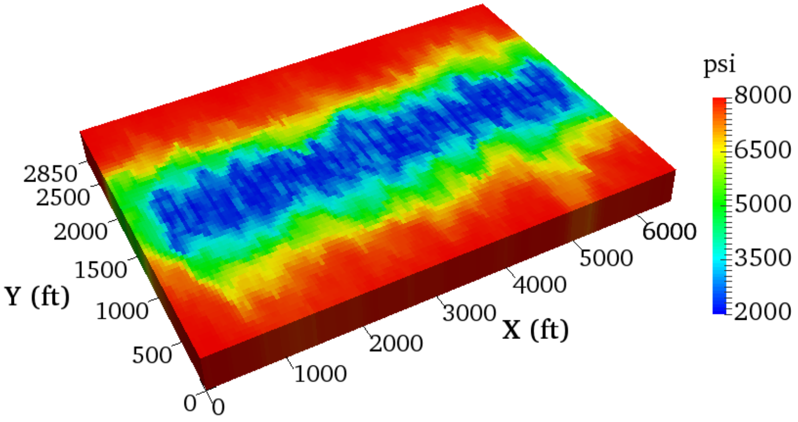


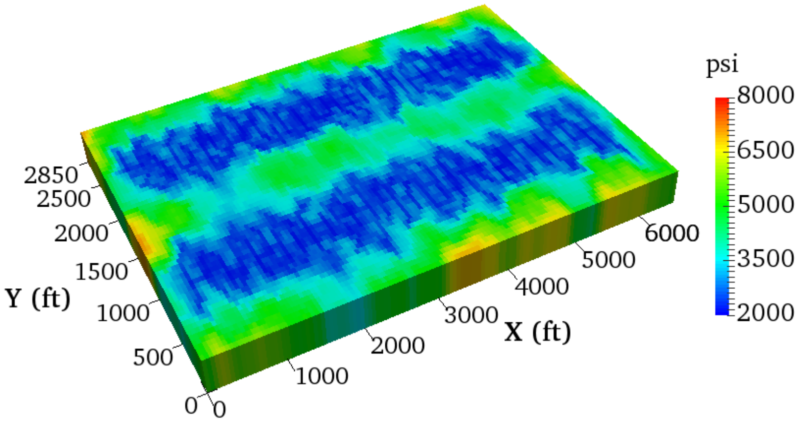


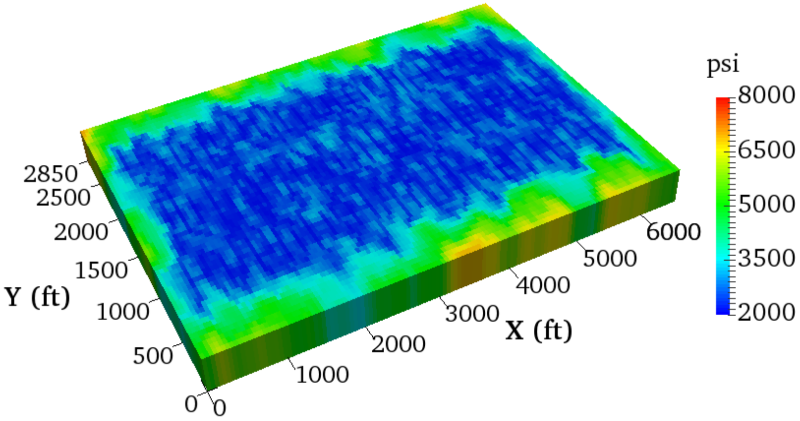




Well Spacing Optimization



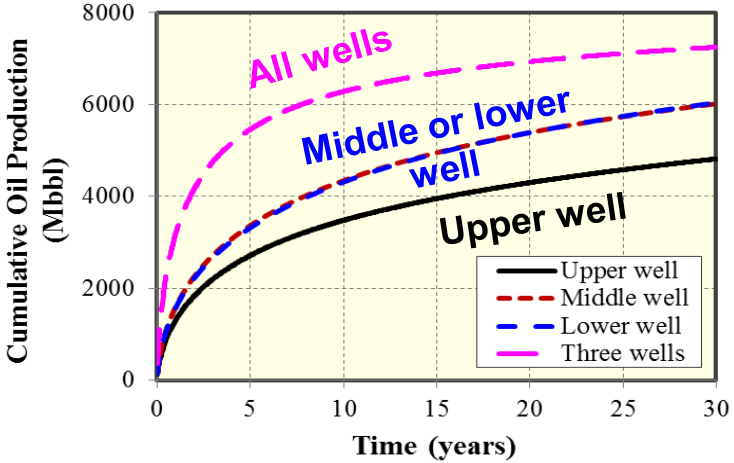


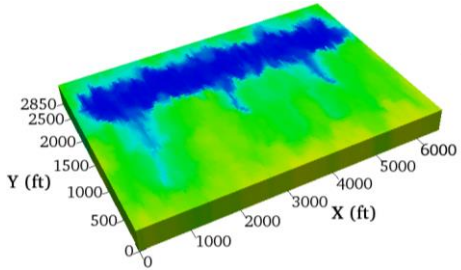


Key message

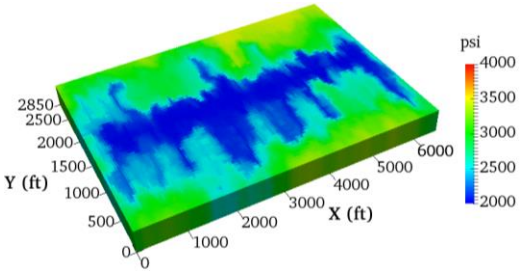
Our reservoir model with 700 ft spacing of 3 wells after 30 years produced only 4% more as compared to two wells spaced by 1400 ft

Well Strategy Optimization

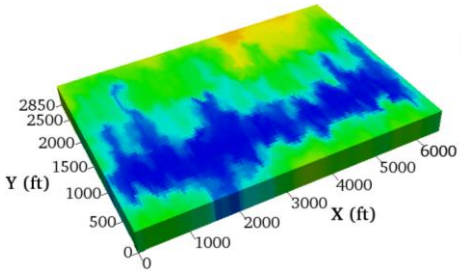




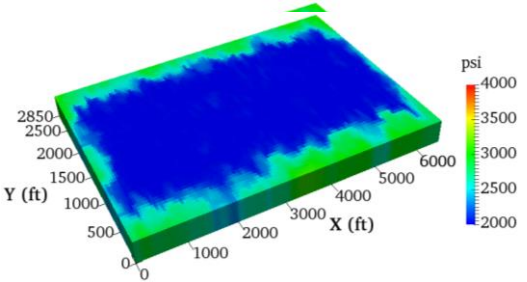
Only upper well opens



Only middle well opens



Only lower well opens



All three wells opens

Key message

Production with only one well open (and three wells completed) delivers after 30 years as much as 83% of cumulative production with all three wells open

Conclusions

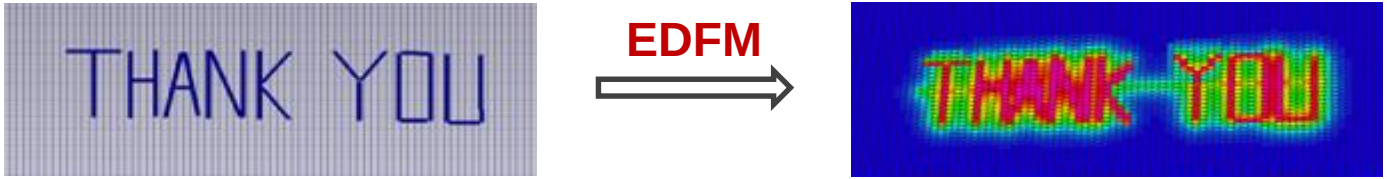
- **Hydraulic fracture hits (100 md-ft) are in our model more important for well interference than natural fractures (1 md-ft) and matrix (470 nD) effects**

- **Well spacing remains the most important element in well design for maximizing production**

- **When tight well-spacing and shut-in tests reveal significant interference between wells occurs, production with only one well open instead of all drilled wells open could be more economic**

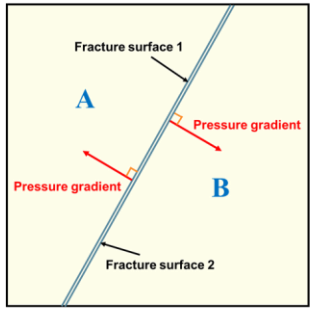
Acknowledgements

The authors would like to acknowledge financial support from **Texas A&M Engineering Experiment Station (TEES)**. Dr. Wei Yu was supported by startup funds from the **Research Group of Dr. Weijermars**. We would also like to acknowledge **Computer Modeling Group** Ltd. for providing the CMG-GEM software for comparison study



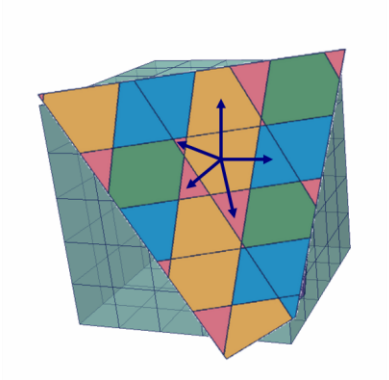
Transmissibility Calculation

Matrix-fracture connection



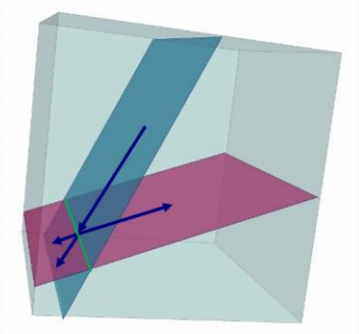
$$T_{f-m} = \frac{2A_f(\overleftrightarrow{K}\cdot\vec{n})\cdot\vec{n}}{d_{f-m}}, d_{f-m} = \frac{\int_V x_n dV}{V}$$

Between fracture segments



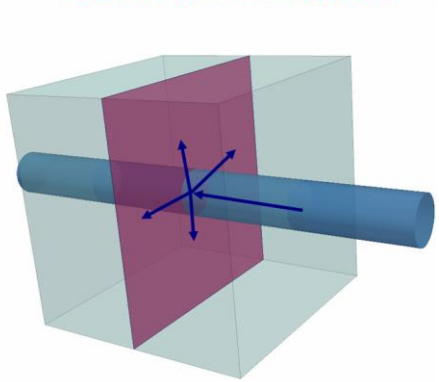
$$T_{seg} = \frac{T_1 T_2}{T_1 + T_2}, T_i = \frac{k_f A_c}{d_{seg,i}}$$

Fracture-fracture intersection



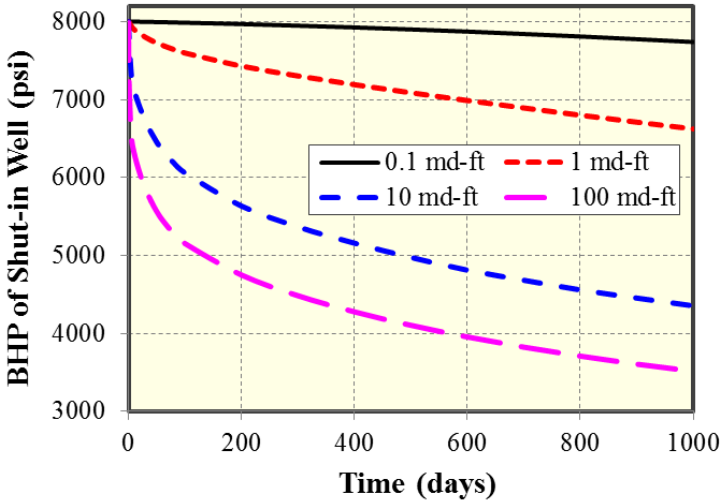
$$T_{int} = \frac{T_1 T_2}{T_1 + T_2}, T_i = \frac{k_{fi} w_{fi} L_{int}}{d_{fi}}$$

Fracture-well intersection



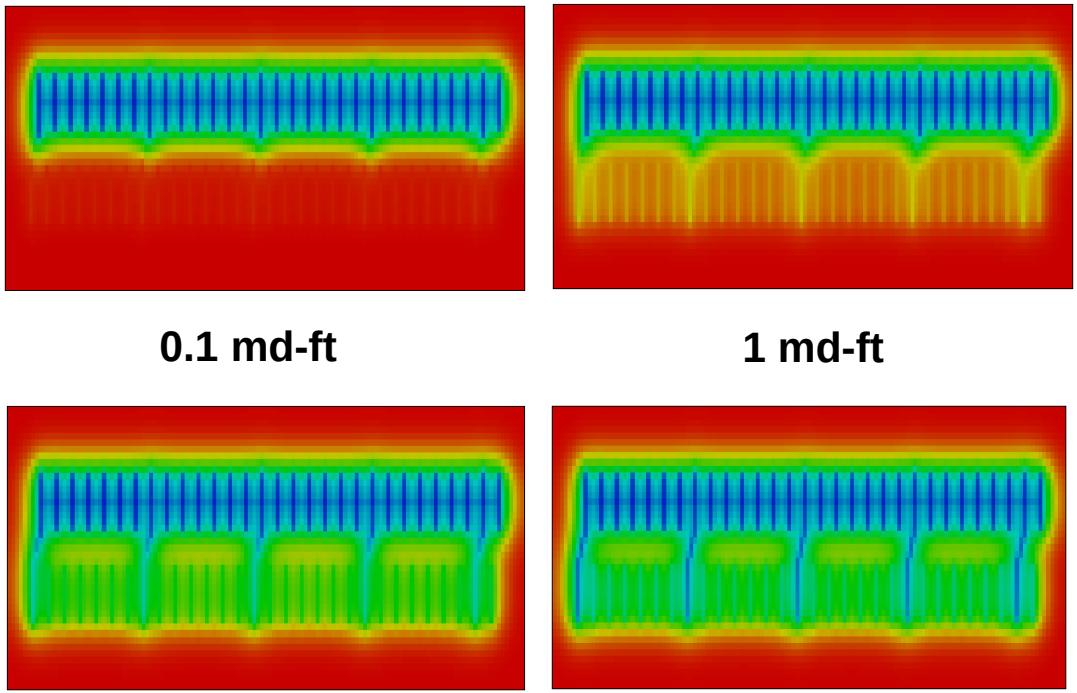
$$WI_f = \frac{2\pi k_f w_f}{\ln(r_e / r_w)}, r_e = 0.14\sqrt{L^2 + W^2}$$

Effect of Connecting Fracture Conductivity



Key message

BHP of the shut-in well decreases most rapidly when the conductivity of the connecting fractures is higher

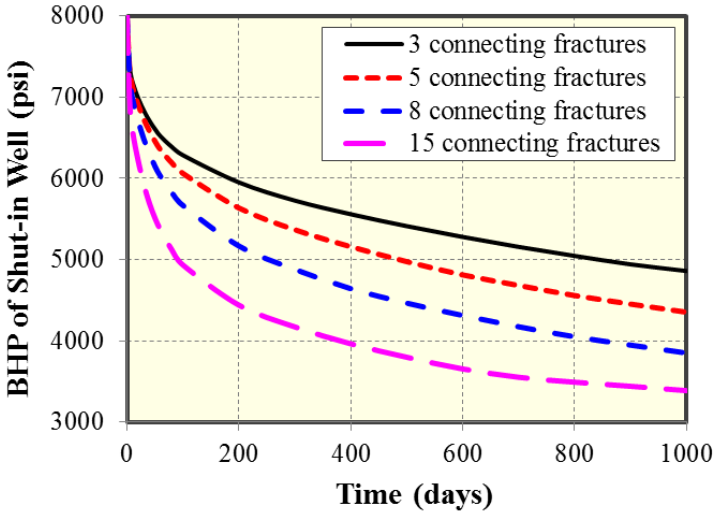


0.1 md-ft | 1 md-ft

10 md-ft | 100 md-ft

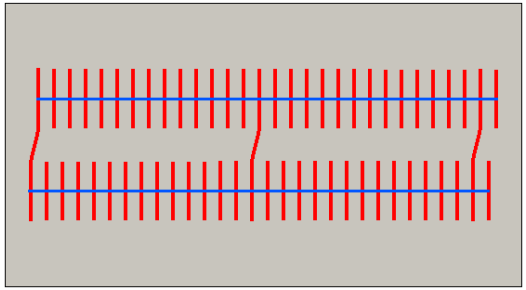
Pressure distribution after 1000 days

Effect of Number of Connecting HFs

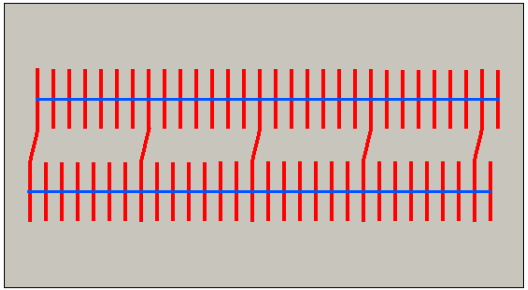


Key message

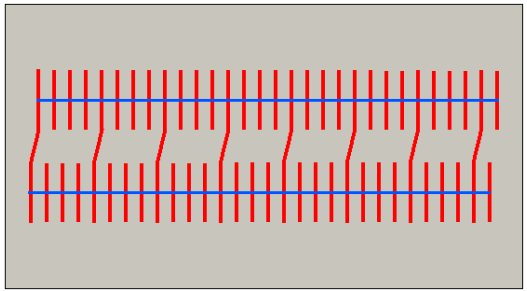
BHP of the shut-in well decreases faster when the fracture hits increase



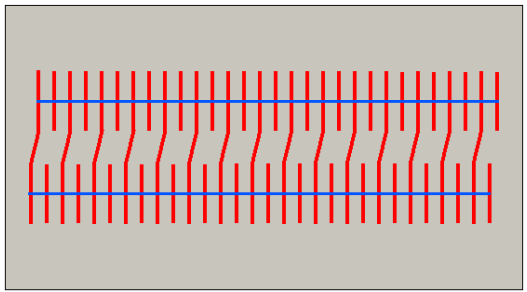
3 connecting HFs



5 connecting HFs

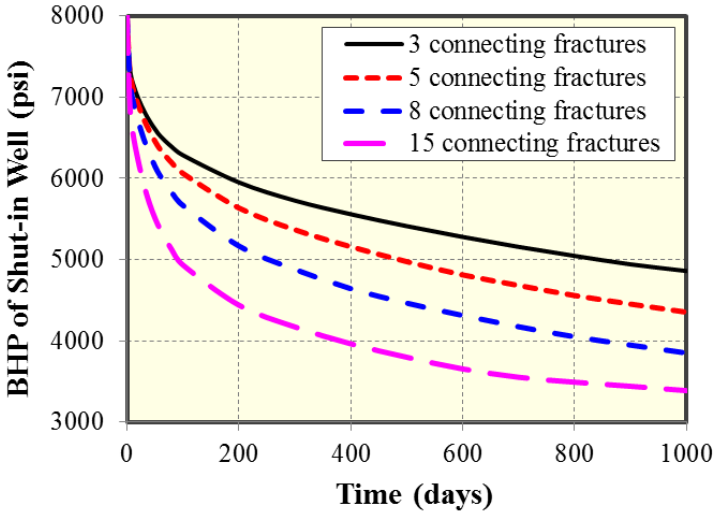


8 connecting HFs



15 connecting HFs

Effect of Number of Connecting HFs



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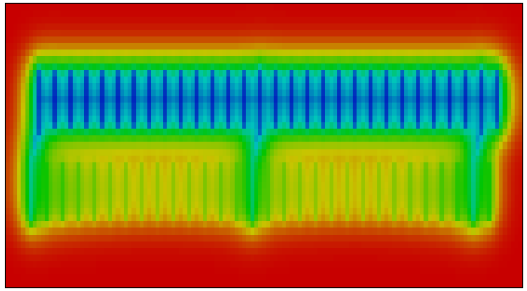
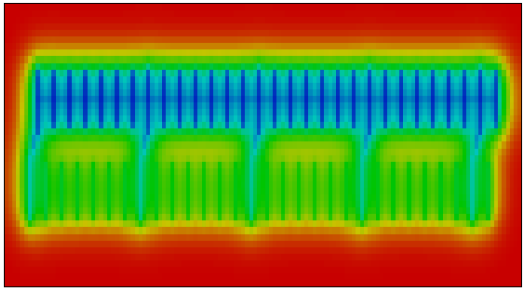
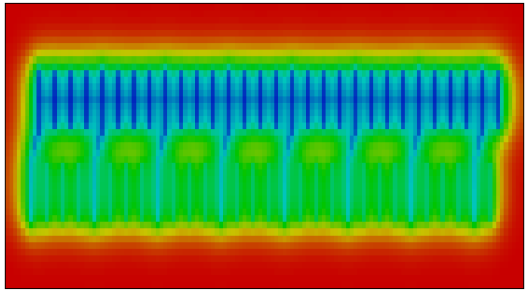


3 connecting HFs



5 connecting HFs



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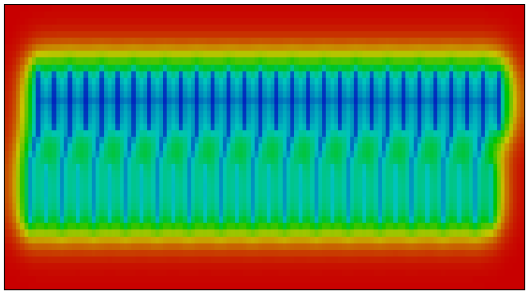
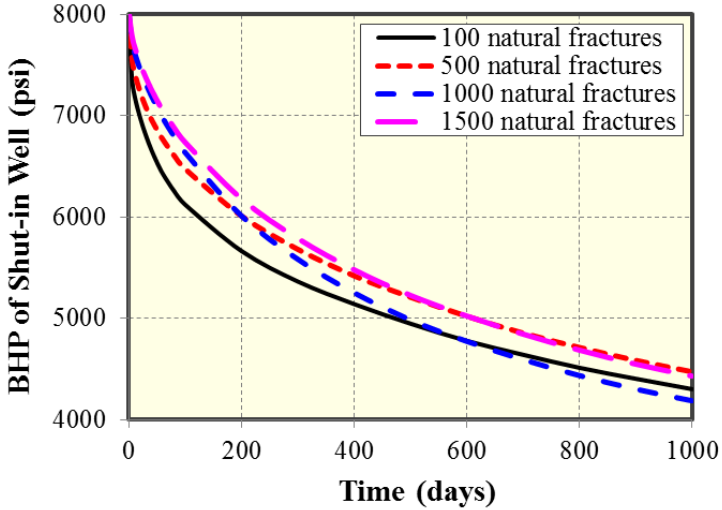
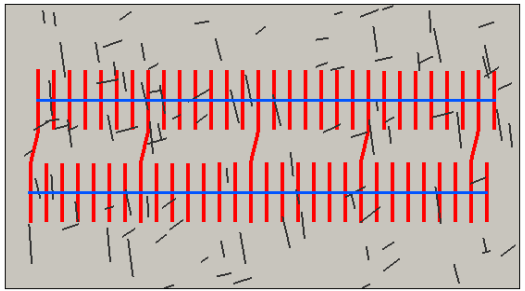


15 connecting HFs

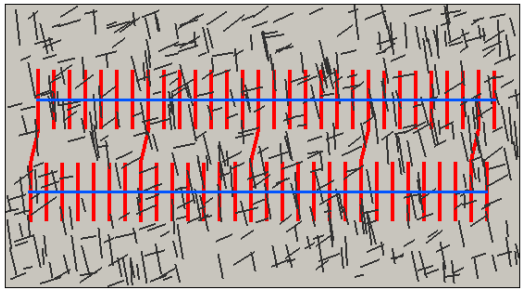
Pressure distribution after 1000 days

Effect of Number of Natural Fractures

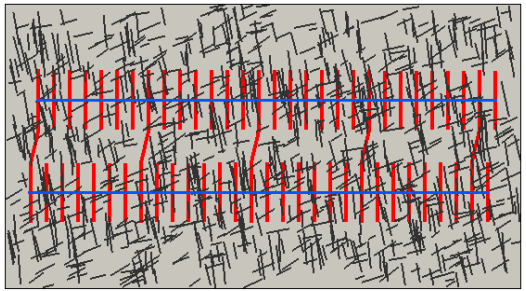




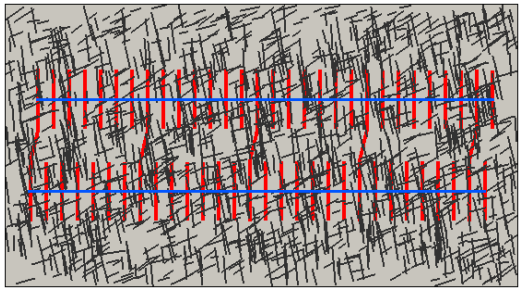
100 natural fractures



500 natural fractures



1000 natural fractures

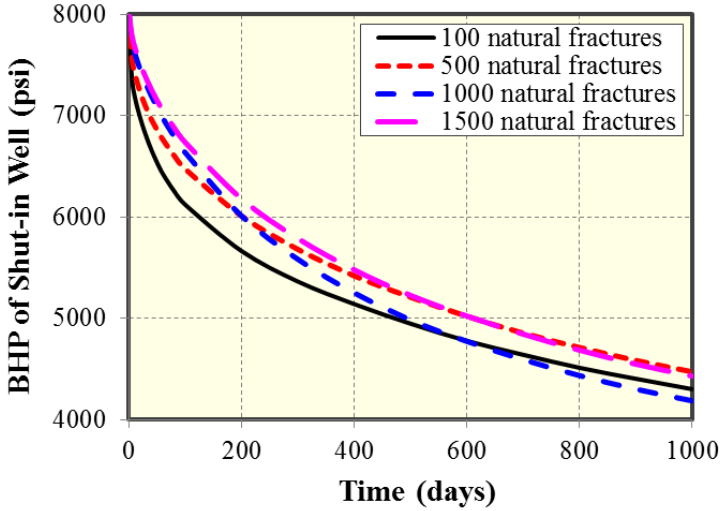


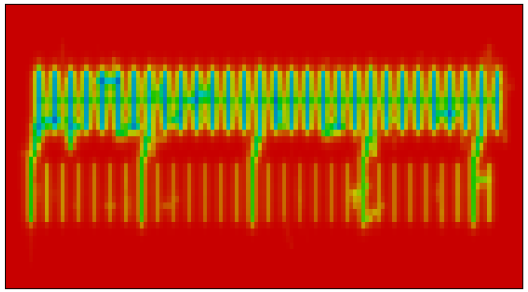
1500 natural fractures

Key message

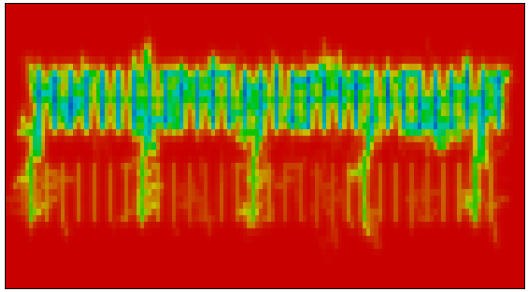
BHP of the shut-in well consistently decreases faster at early times when natural fracture density increases. However, the pressure decline rate is inconsistent at later times

Effect of Number of Natural Fractures

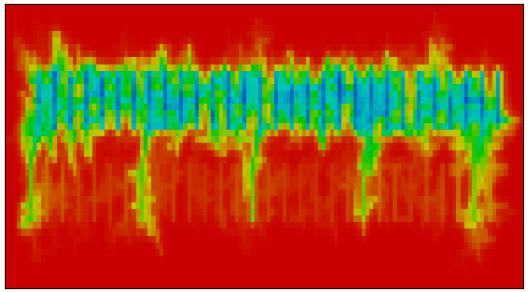




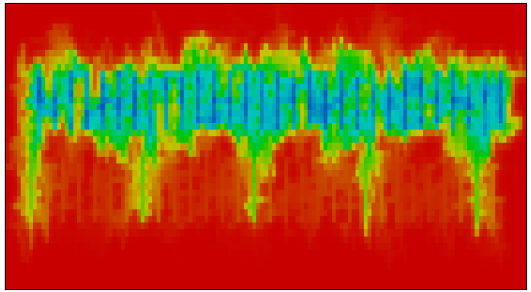
100 natural fractures



500 natural fractures



1000 natural fractures



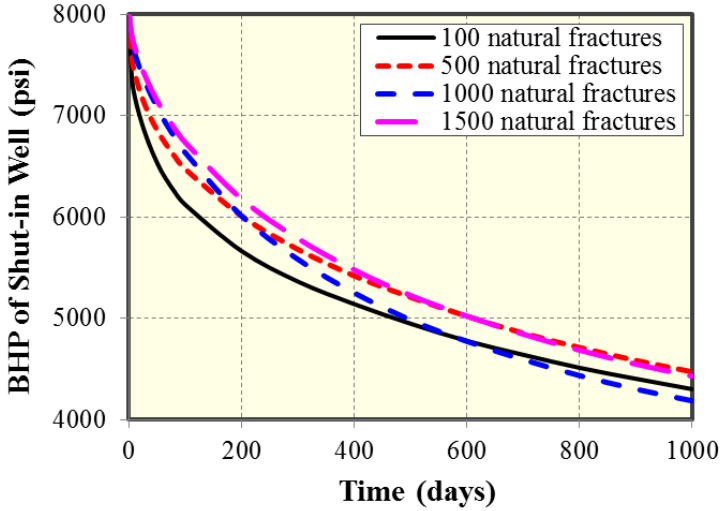
1500 natural fractures

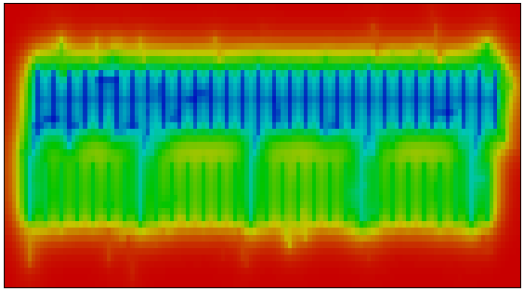
Key message

BHP of the shut-in well consistently decreases faster at early times when natural fracture density increases. However, the pressure decline rate is inconsistent at later times

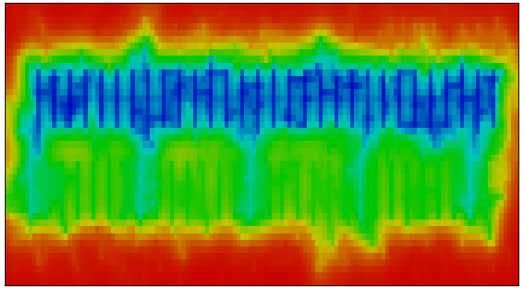
Pressure distribution after 100 days

Effect of Number of Natural Fractures

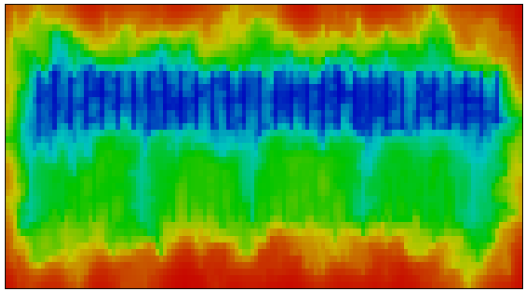




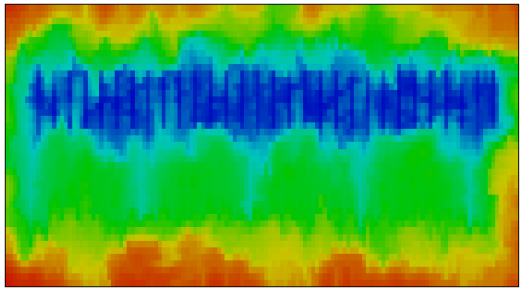
100 natural fractures



500 natural fractures



1000 natural fractures



1500 natural fractures

Key message

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Pressure distribution after 1000 days