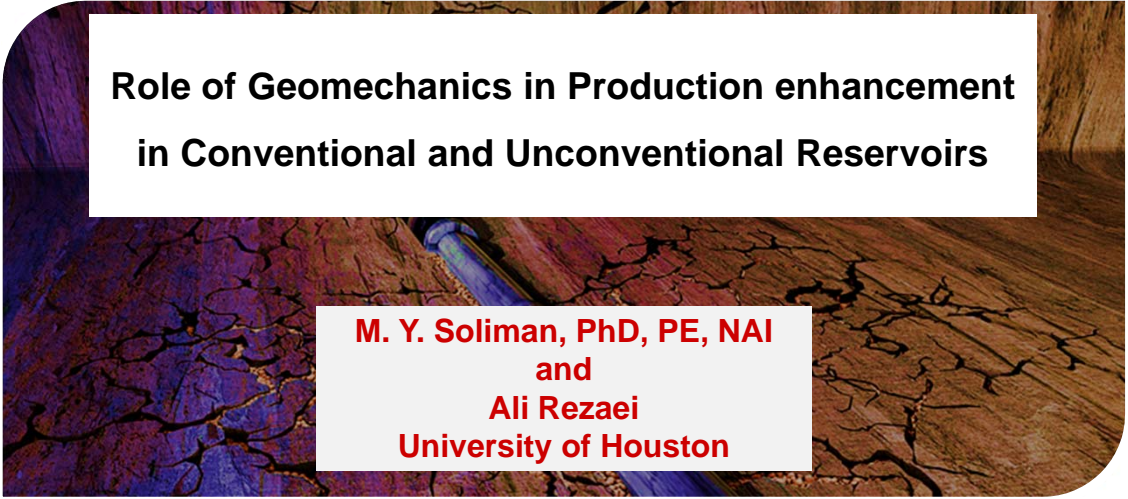


UNIVERSITY of HOUSTON
PETROLEUM ENGINEERING



**Role of Geomechanics in Production enhancement
in Conventional and Unconventional Reservoirs**

**M. Y. Soliman, PhD, PE, NAI
and
Ali Rezaei
University of Houston**

GeoMechanics Congress – April 18, 2018

**UH Petroleum Engineering Department
Energy Research Park**



Our Department Highlights



- Established January 2016
- 13 professors
 - 3 NAE
 - 1 NAI
- 16 Adjunct professors
- 500+ undergraduate students
- 80+ MS students
- 29 PhD students

Outline



- Introduction
 - Early work
- Geomechanical considerations of multi-fractured wells
 - Vertical wells
 - Horizontal wells
 - Conventional
 - unconventional
- Issues and challenges
 - Infill drilling
 - Refracturing in horizontal wells

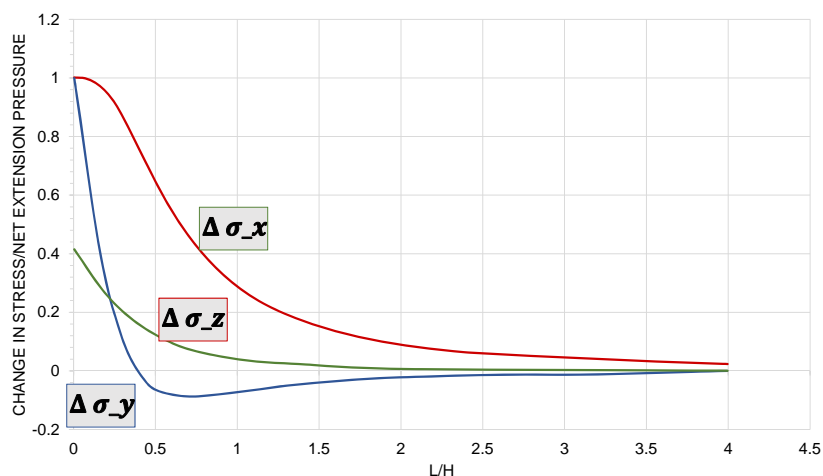
Introduction



- Rock mechanics considerations in fracturing well and stress shadow (interference) is not new.
- Application for multiple fracturing of horizontal and vertical wells is not exactly new
- Treatment issues exist in breakdown, propagation and re-orientation of fractures
- Conventional practices for stimulating horizontal wells must be challenged

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Analytical Solution, Semi-Infinite Fracture



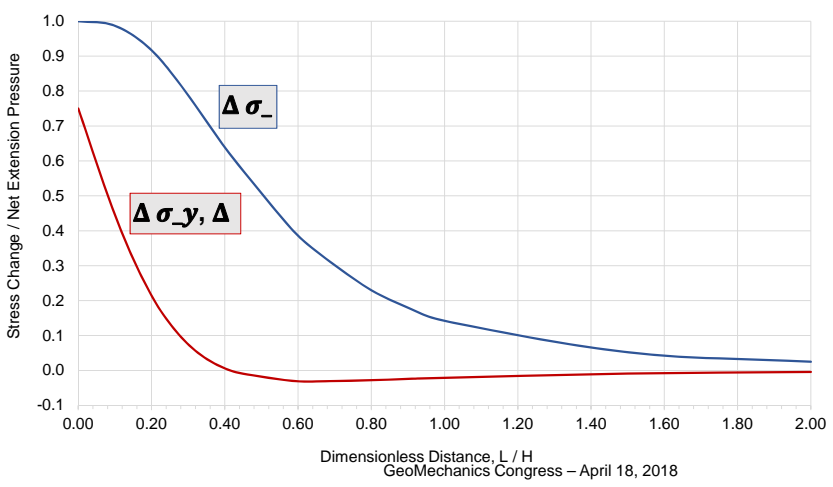
Soliman, et al 2008
SPE 86992

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Analytical Solution, Penny-Shaped Fracture



Dimensionless Stress Variation versus Dimensionless Distance Penny-Shaped Fracture

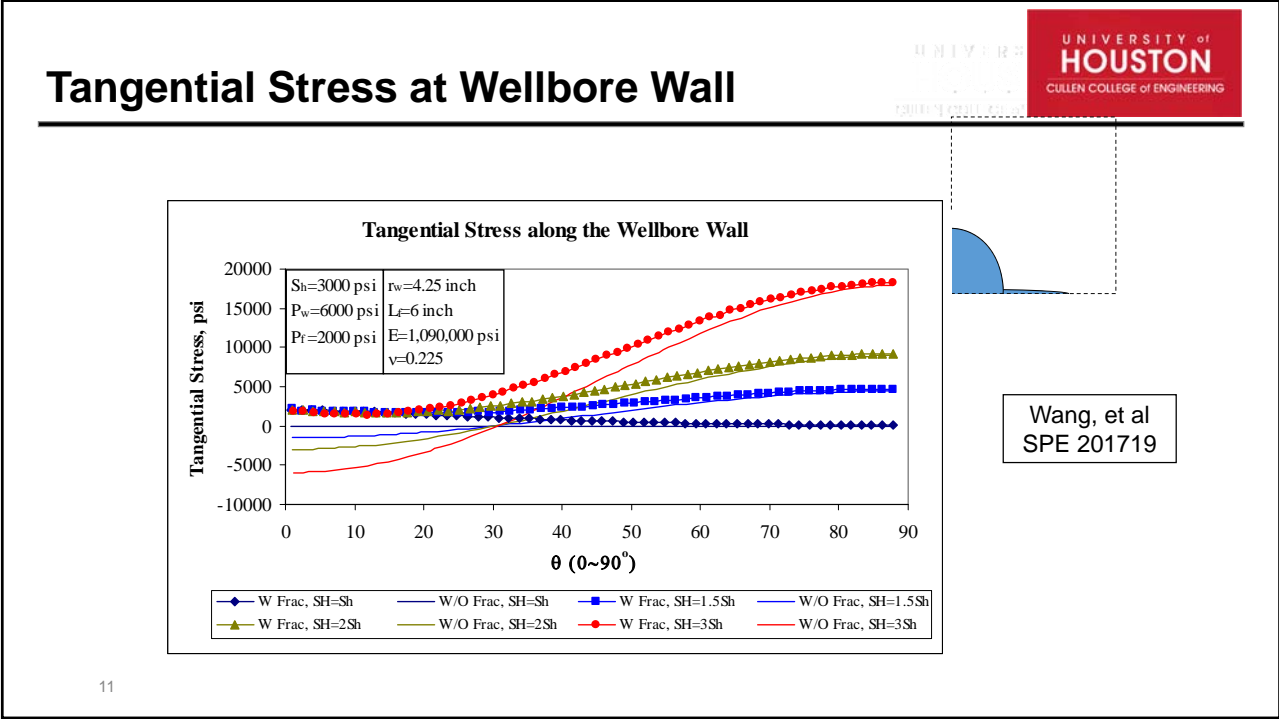
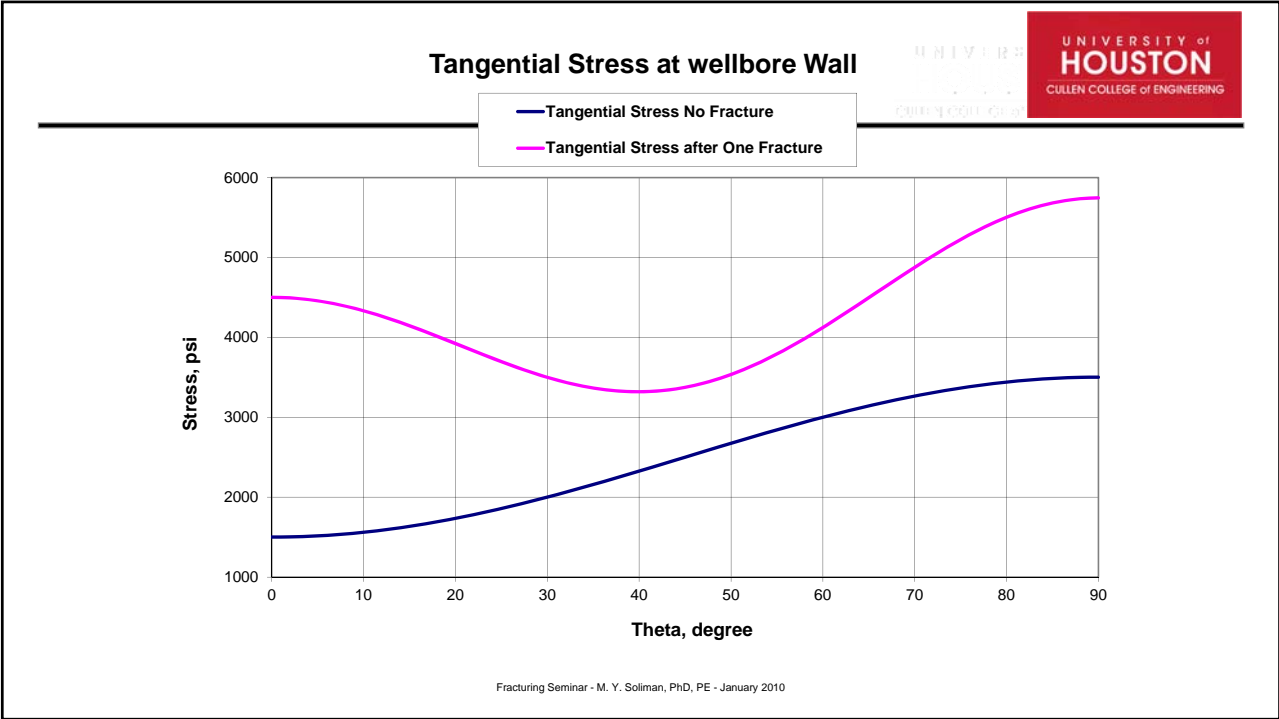


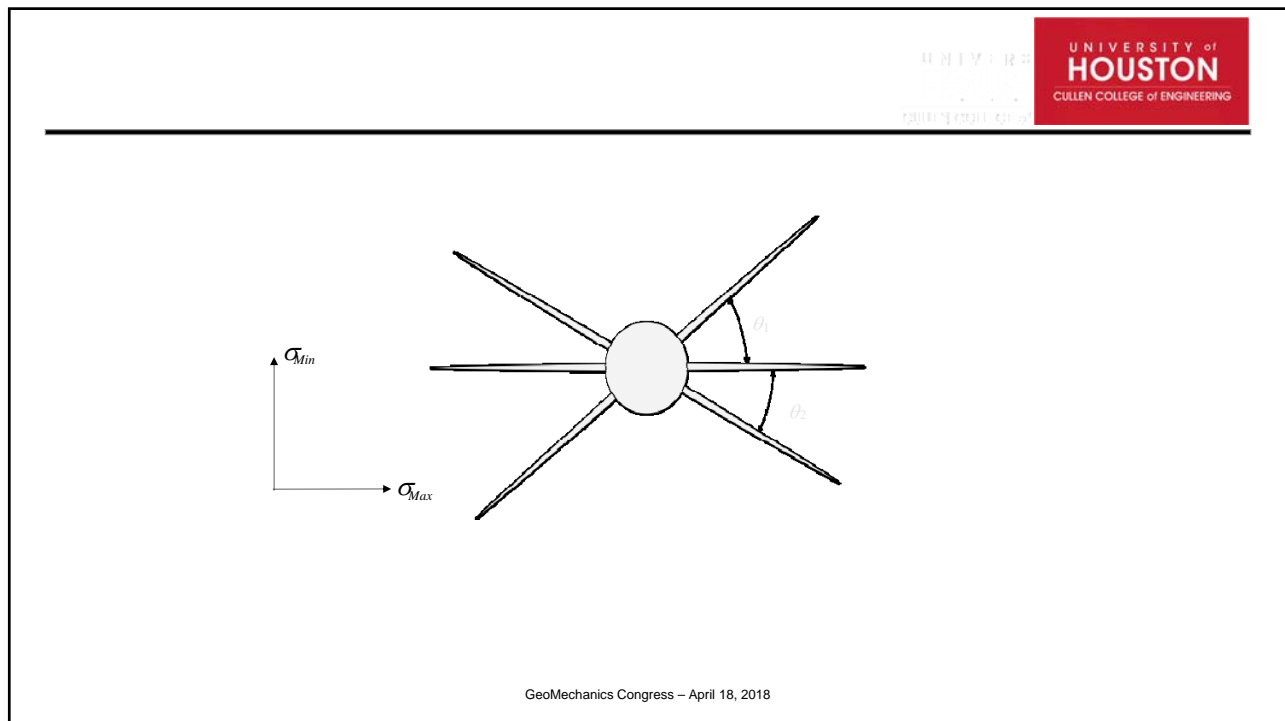
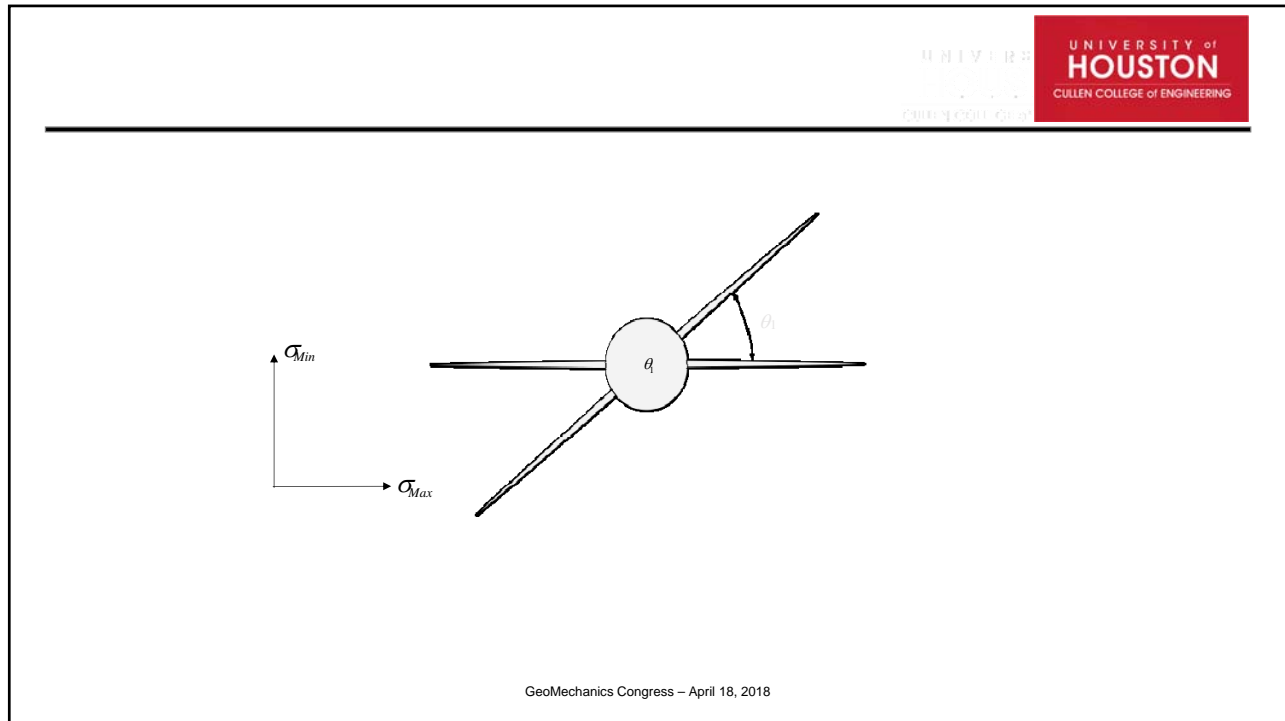
Soliman, et al 2008
SPE 86992

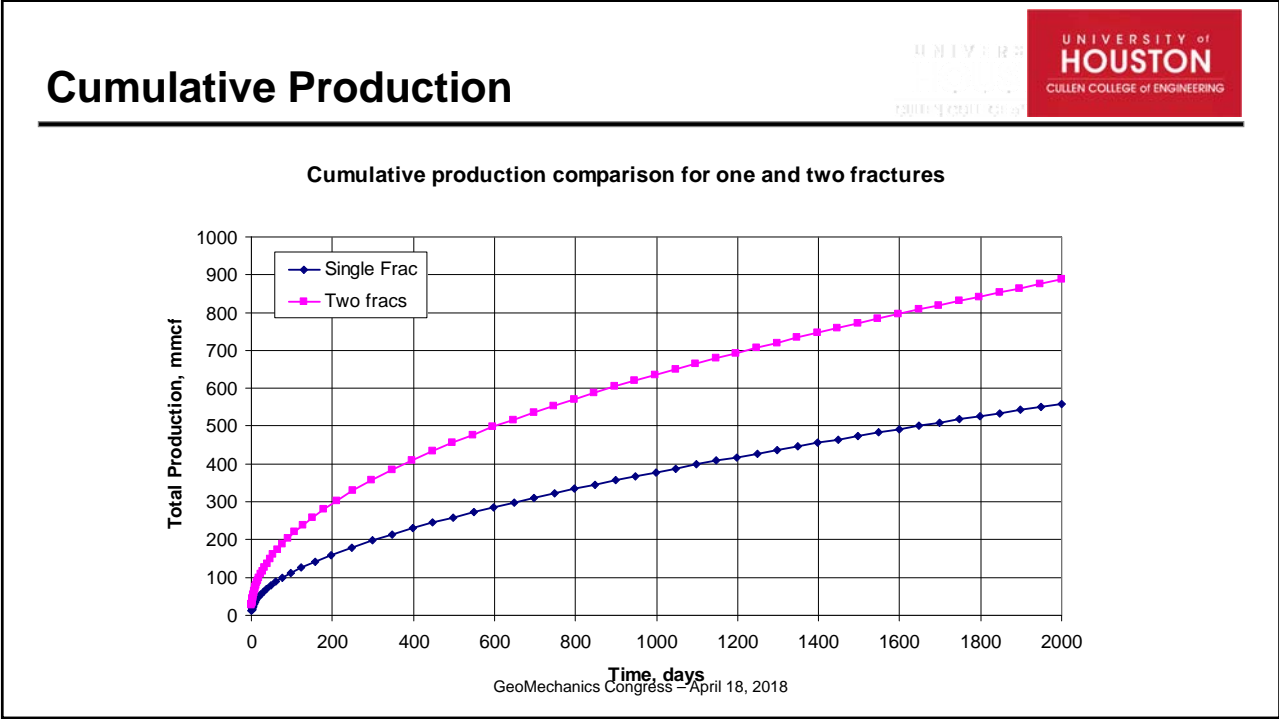
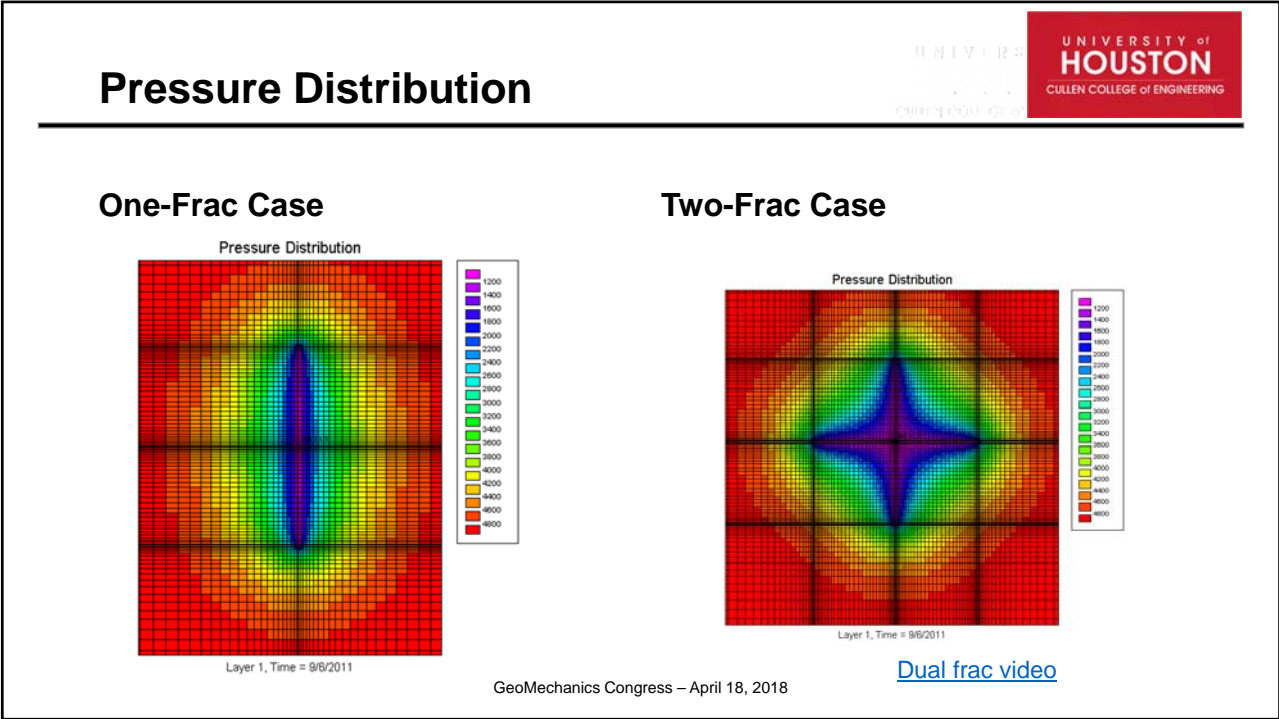
Refrac and multiple fracturing of vertical wells

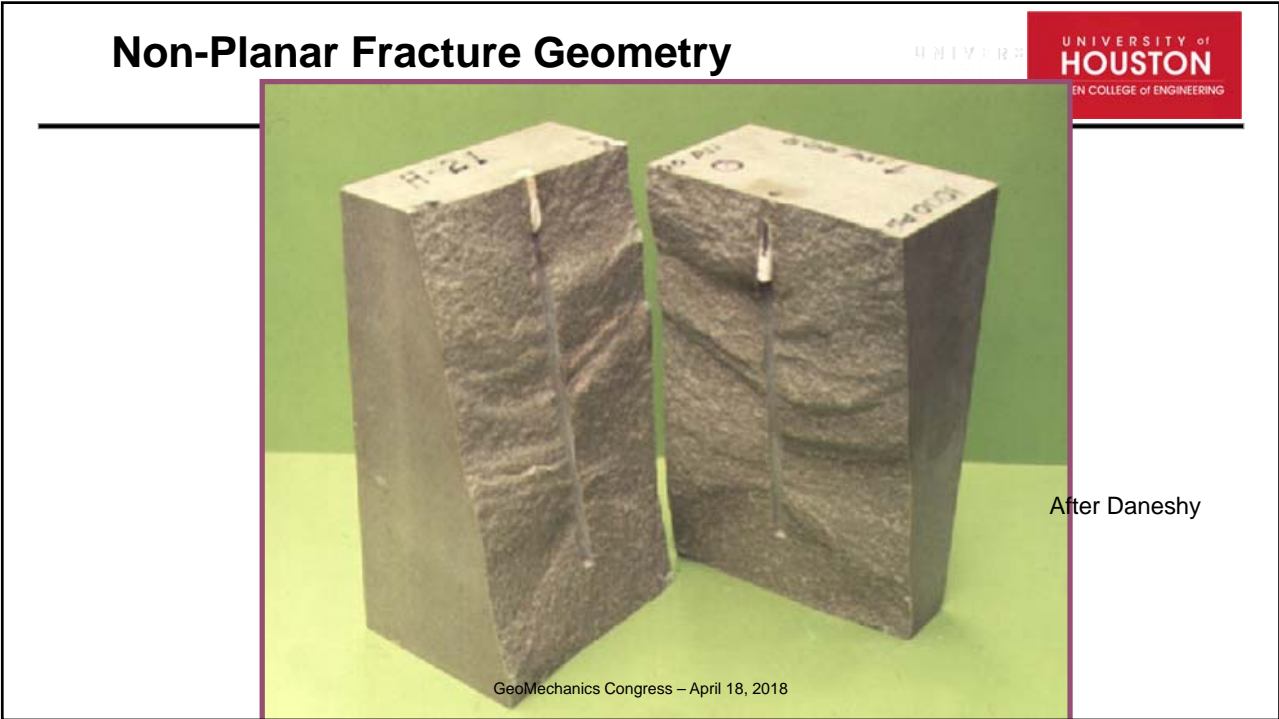
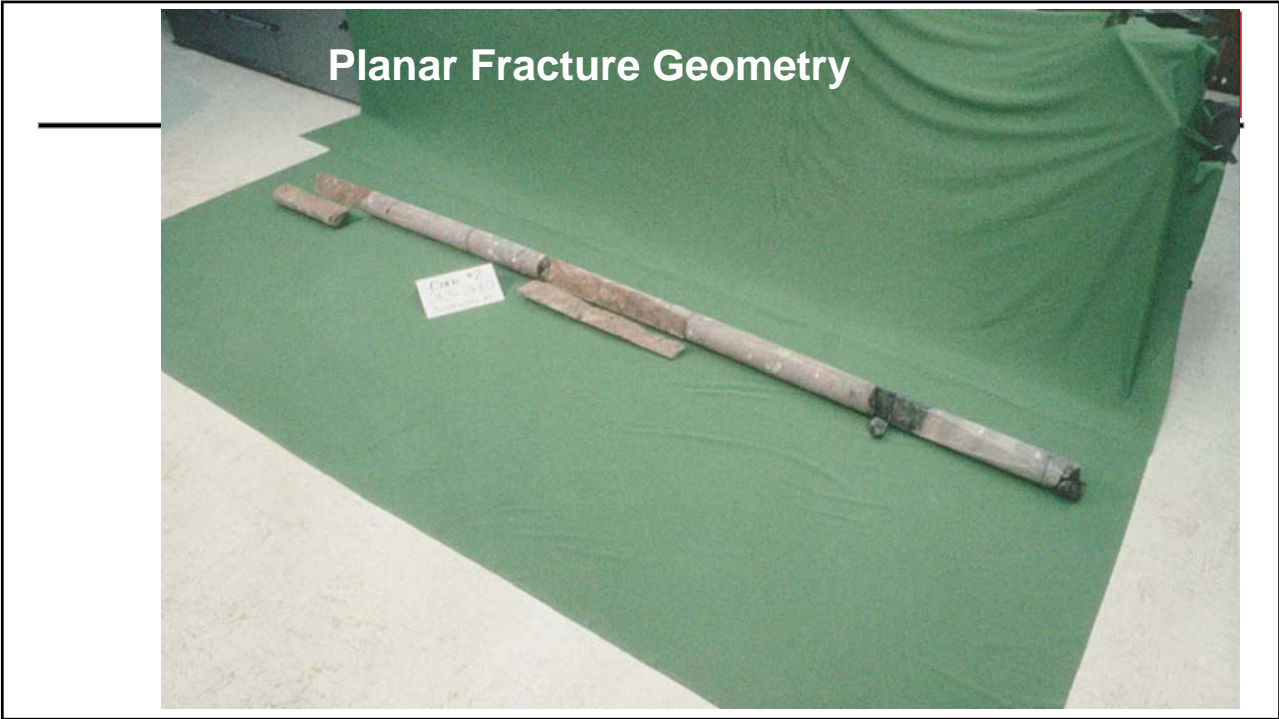


- Proposed for
 - low perm formation
 - Declining fracture productivity
- Observed during drill cutting re-injection

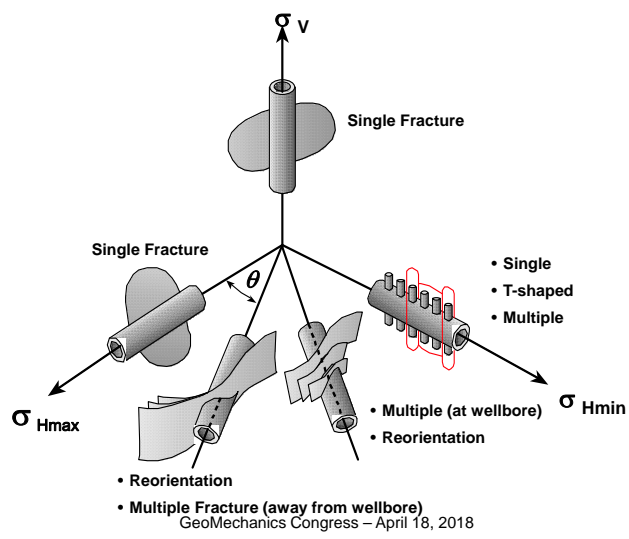








Non-Planar Fracture Geometry

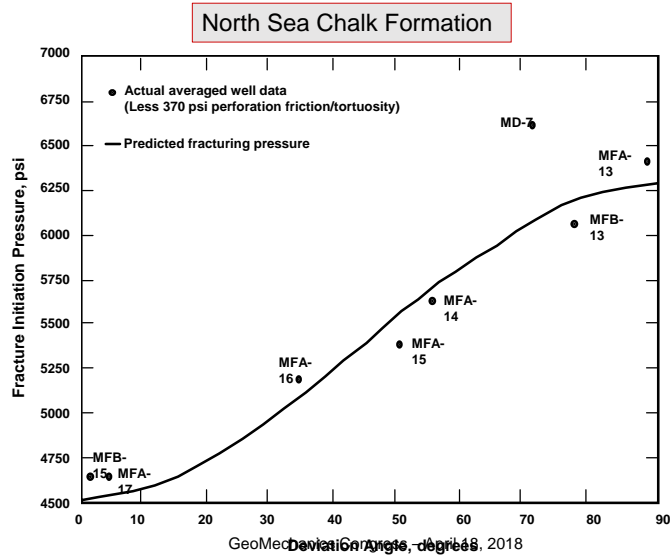


Non-Planar Fracture Geometry



After Warpinski

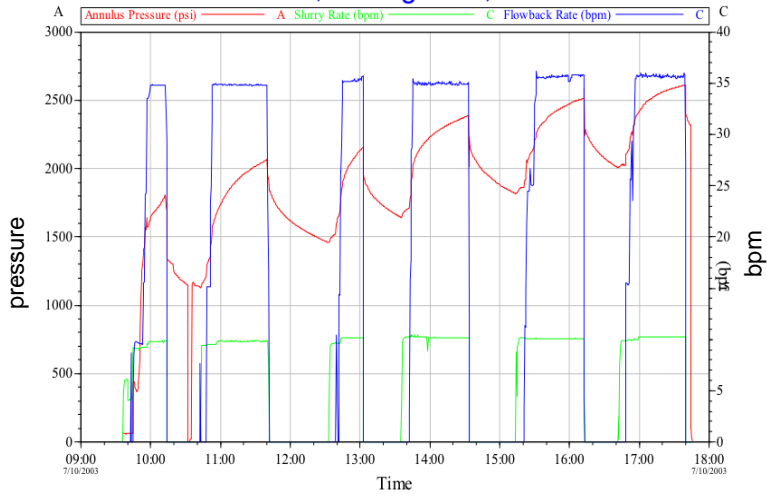
Fracturing Pressures from Arbitrarily Oriented Horizontal Wells



After Owens, et al
 SPE 24822

GeoMechanics Congress, April 18, 2018

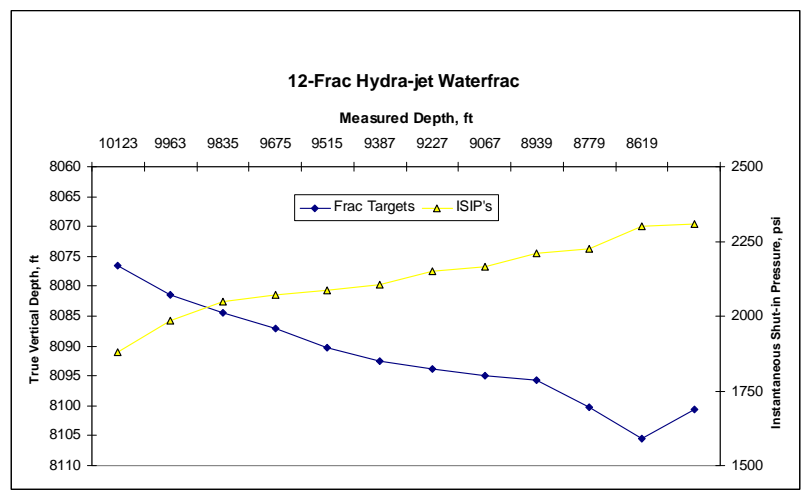
Annulus Pressure, Tubing Rate, & Annulus Rate



Soliman, et al
 SPE 86992

GeoMechanics Congress – April 18, 2018

ISIP's for 12 consecutive Barnett Shale Hydra-jet Waterfracs placed in a single horizontal well in one day



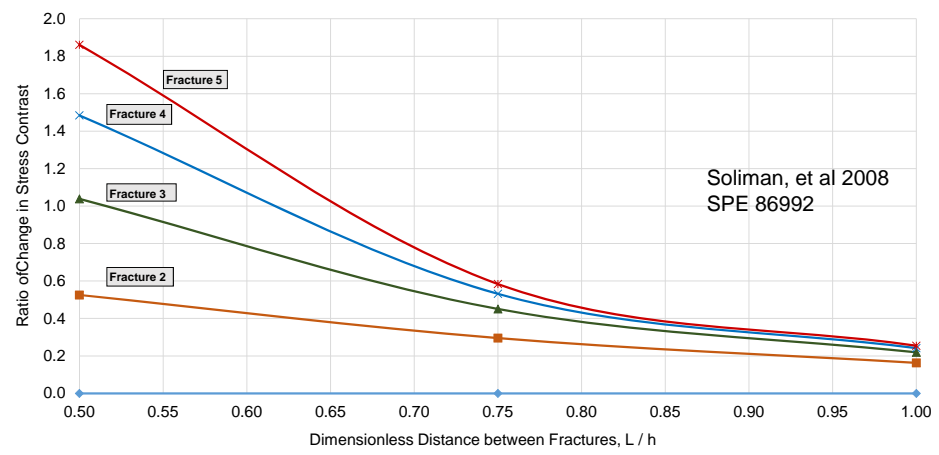
Soliman, et al
SPE 86992

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Change of Stress, Multiple Fracturing of a Horizontal Well



Ratio of Change of Stress Contrast to Original Net Extension pressure During Multiple Fracturing of a Horizontal Well



Soliman, et al 2008
SPE 86992

Soliman, et al 2008
SPE 86992

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Complexity

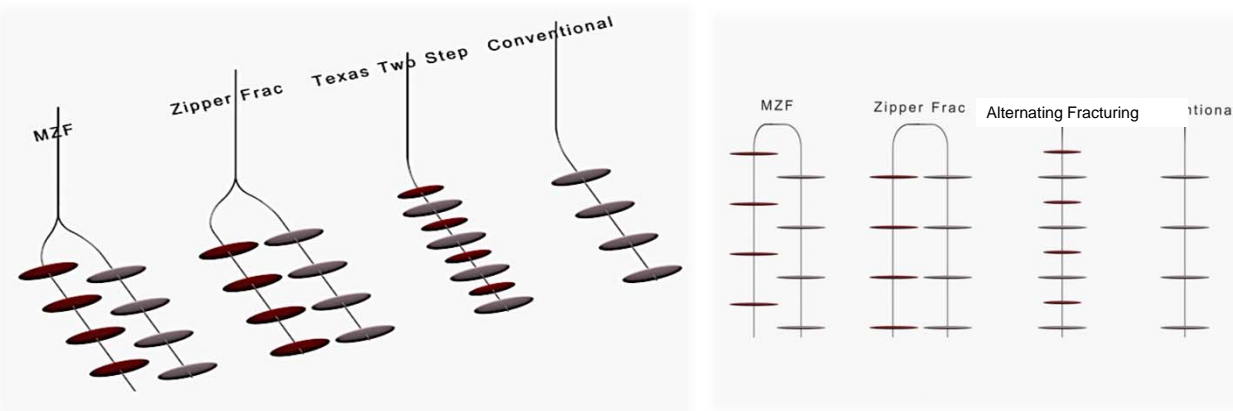


Why it happens and how to maximize it?

- Brittle rock
- Low stress Contrast
- Naturally fractured
- Fracture parts of the formation that are “Brittle”, reduce stress contrast
 - Zipper Frac
 - Alternating Fracturing
 - Modified Zipper Frac

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Different Designs of Fractures



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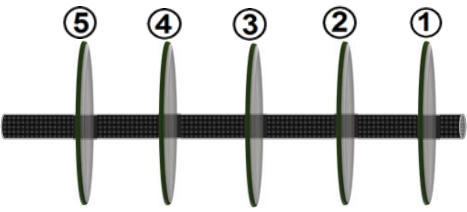
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Geomechanical Considerations of Multi-Fractured Wells

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Consecutive Fracturing



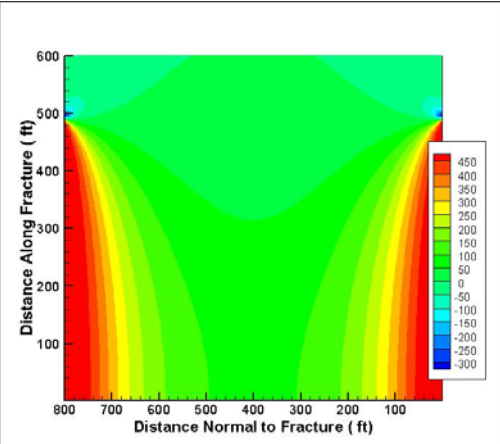
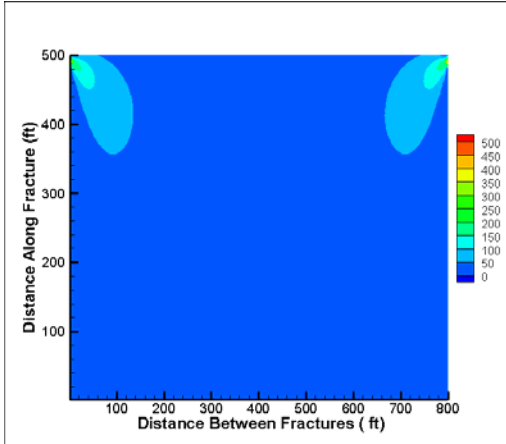
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Change in Stress, Single Fracture



Change in Shear Stress (psi)

Change in Minimum Horizontal Stress (psi)



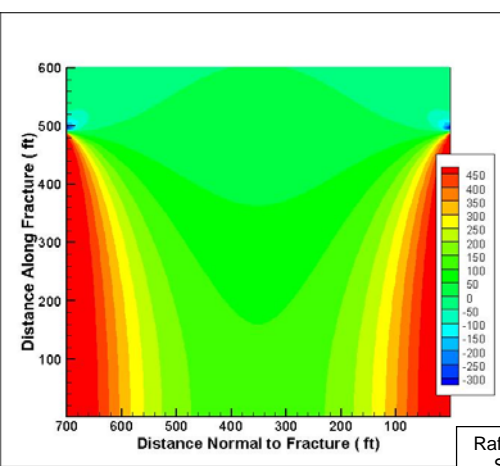
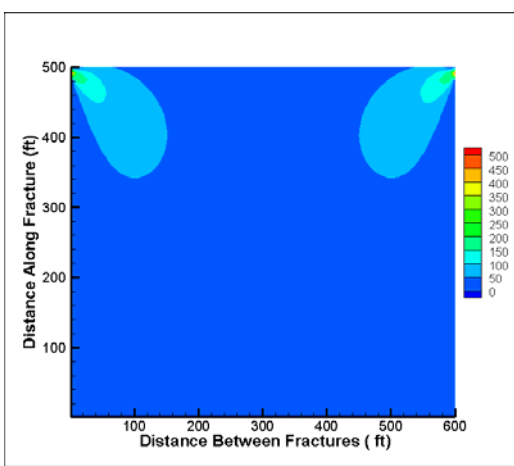
Rafiee, et al 2012
SPE 159786

Change in Stress, Single Fracture



Change in Shear Stress (psi)

Change in Minimum Horizontal Stress (psi)

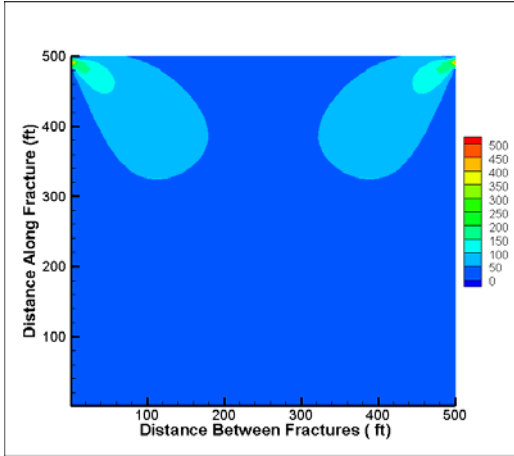


Rafiee, et al 2012
SPE 159786

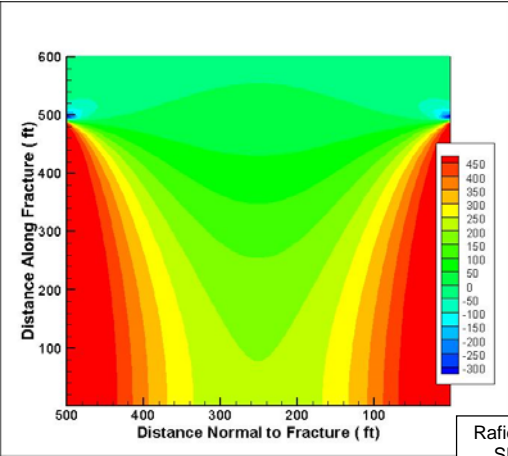
Change in Stress, Single Fracture



Change in Shear Stress (psi)



Change in Minimum Horizontal Stress (psi)

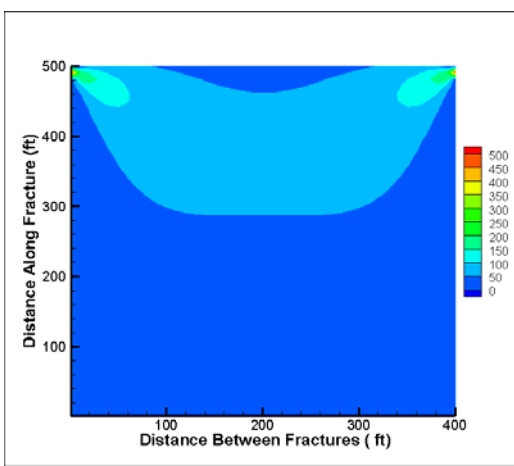


Rafiee, et al 2012
SPE 159786

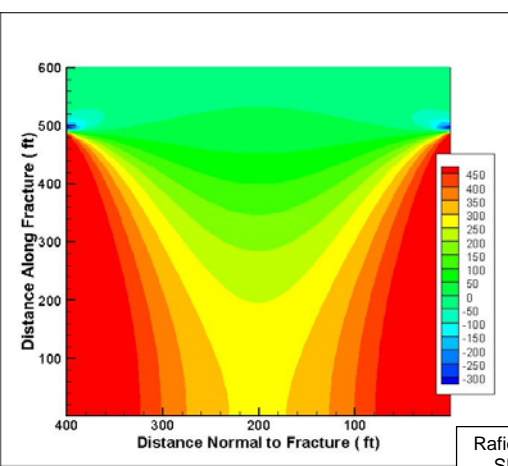
Change in Stress, Single Fracture



Change in Shear Stress (psi)




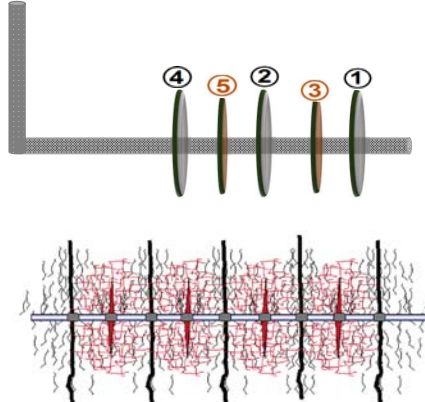
Change in Minimum Horizontal Stress (psi)



Rafiee, et al 2012
SPE 159786

Alternating Fracturing






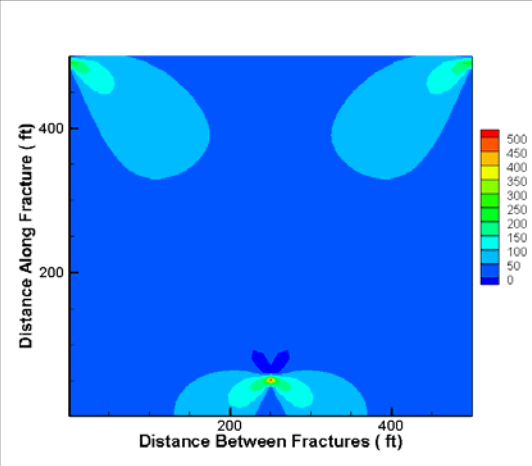
SPE 130043

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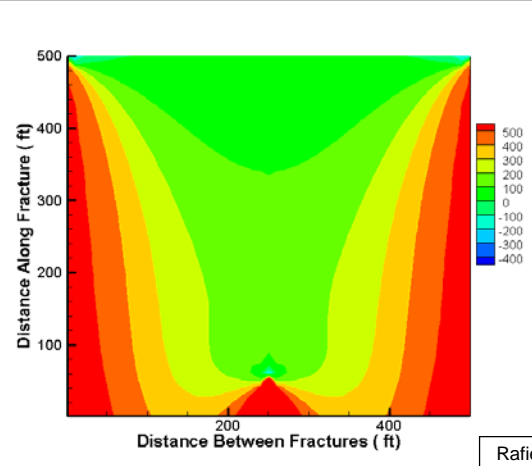
Change in Stress, Alternating Fractures



Change in Shear Stress (psi)

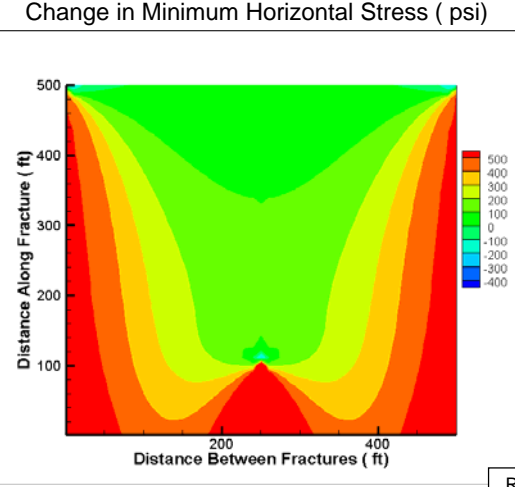
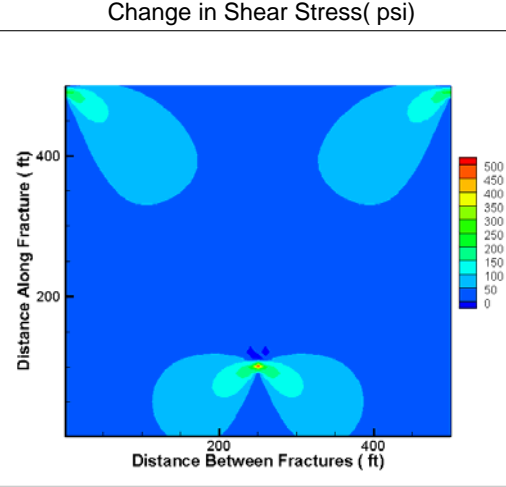


Change in Minimum Horizontal Stress (psi)



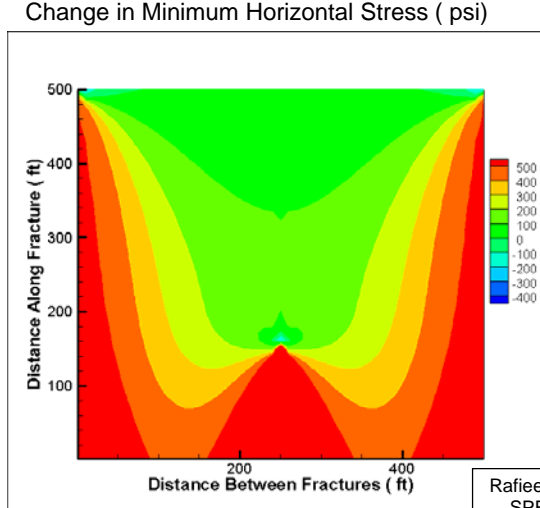
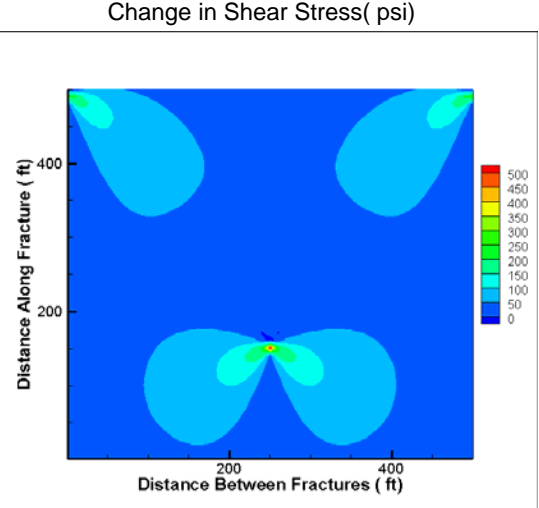
Rafiee, et al 2012
SPE 159786

Change in Stress, Alternating Fractures



Rafiee, et al 2012
SPE 159786

Change in Stress, Alternating Fractures

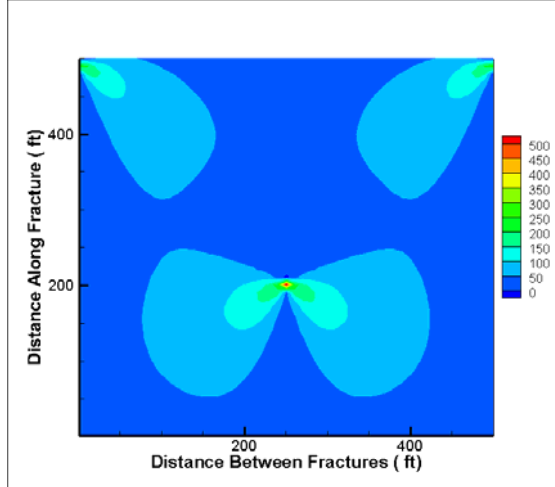


Rafiee, et al 2012
SPE 159786

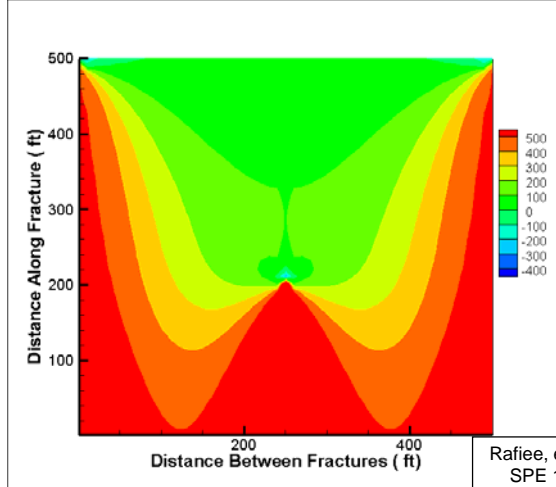
Change in Stress, Alternating Fractures



Change in Shear Stress(psi)



Change in Minimum Horizontal Stress (psi)

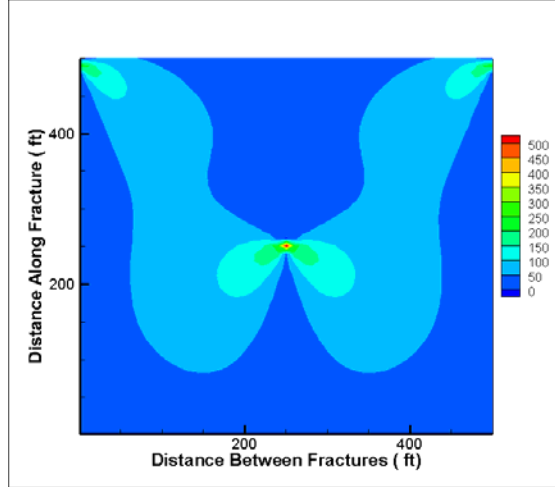


Rafiee, et al 2012
SPE 159786

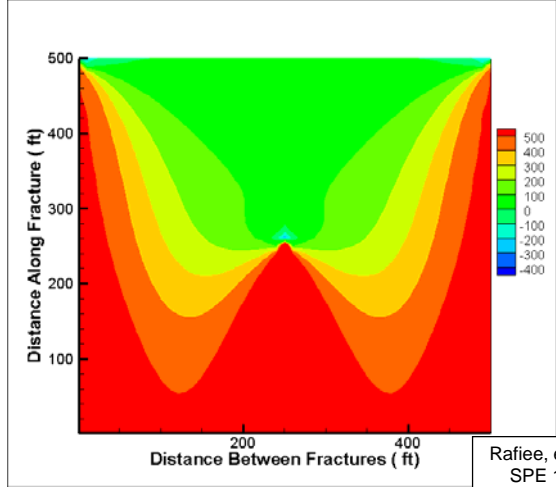
Change in Stress, Alternating Fractures



Change in Shear Stress(psi)



Change in Minimum Horizontal Stress (psi)

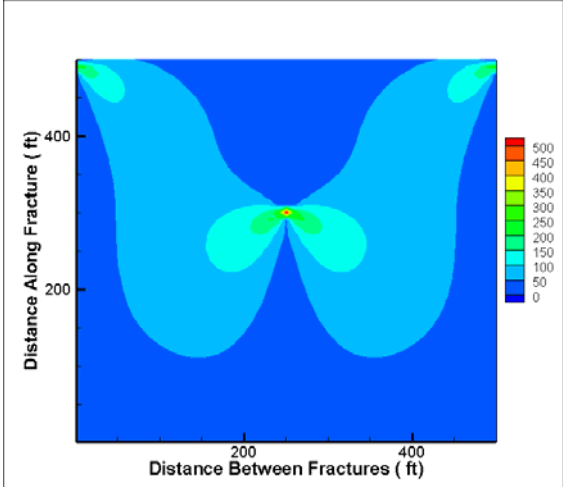


Rafiee, et al 2012
SPE 159786

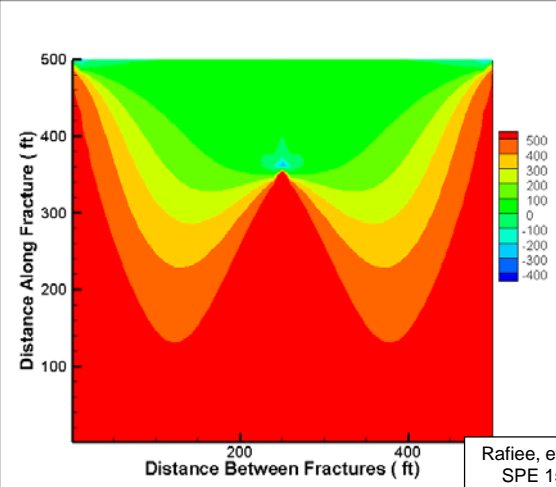
Change in Stress, Alternating Fractures



Change in Shear Stress (psi)

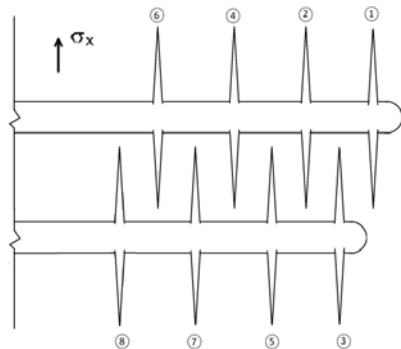


Change in Minimum Horizontal Stress (psi)

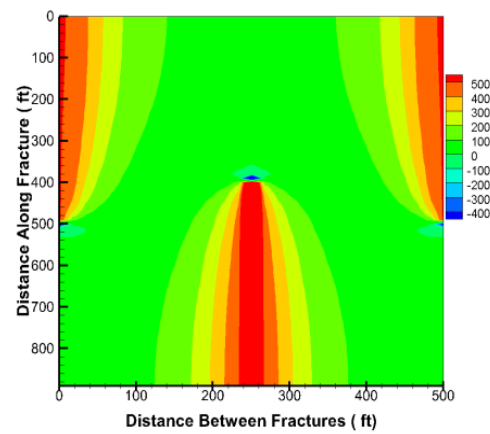
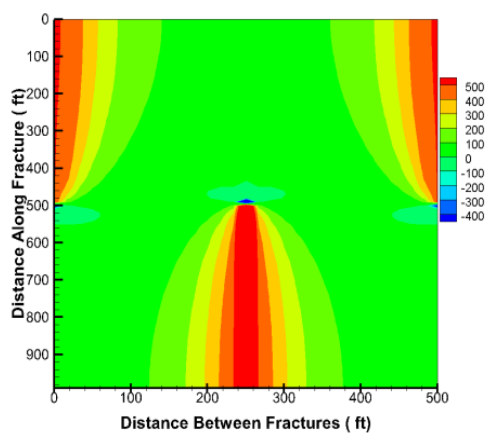


Rafiee, et al 2012
 SPE 159786

Modified Zipper Frac (MZF)



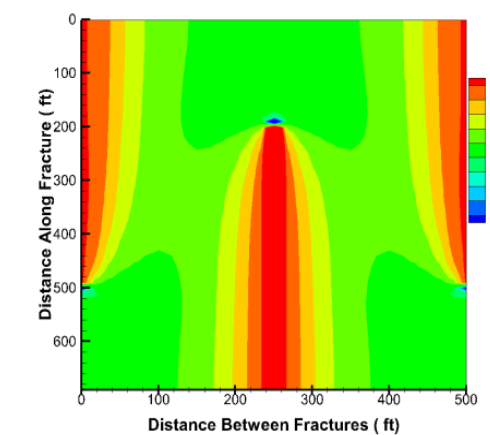
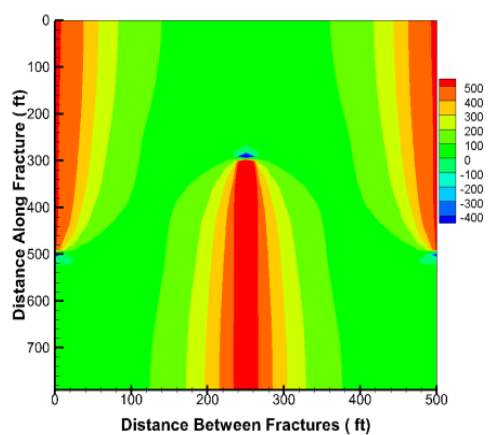
Change in Maximum Horizontal stress



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Rafiee, et al 2012
SPE 159786

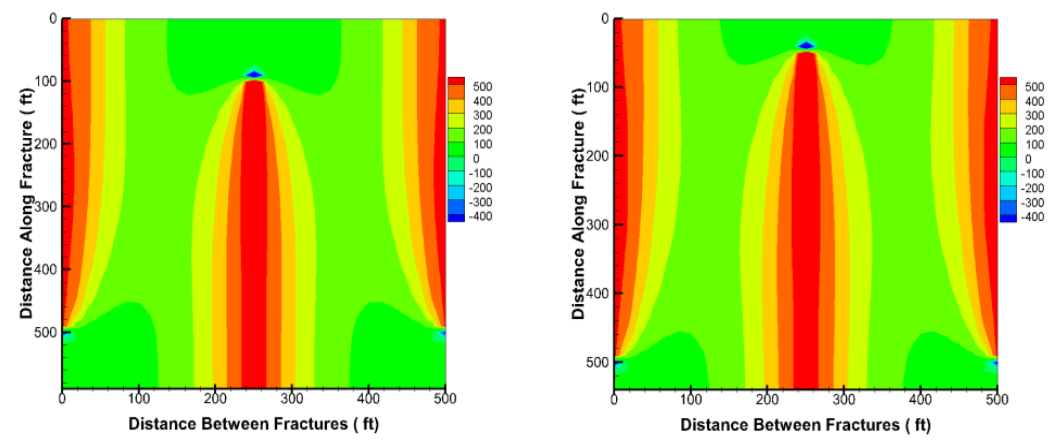
Change in Maximum Horizontal stress



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Rafiee, et al 2012
SPE 159786

Change in Maximum Horizontal stress



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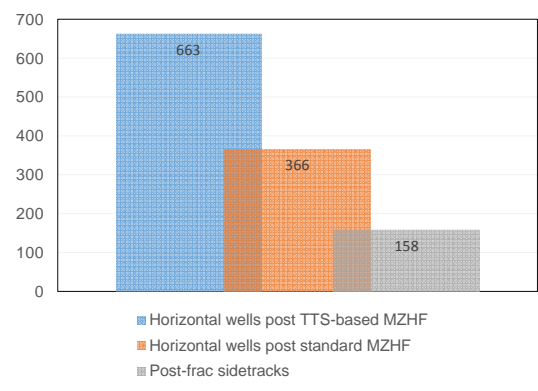
Rafiee, et al 2012
SPE 159786

Implementing Alternating Fracturing (TTS)

Alternating Fracturing Application by LUKOIL

- Eight horizontal wells in 2013/2014 in Western Siberia using TTS
- The horizontal wells post TTS-based MZHF have four times higher flow rate

LUKOIL Group's Average Flow Rates in Western Siberia, bb/d



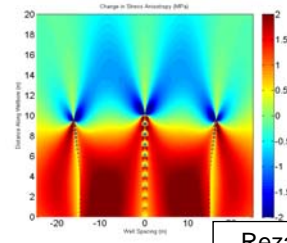
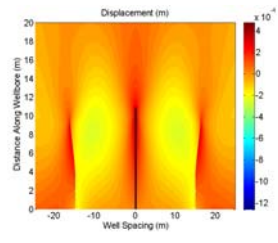
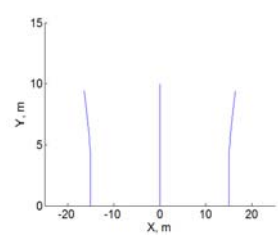
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Propagation of Multiple Fractures (Clusters)

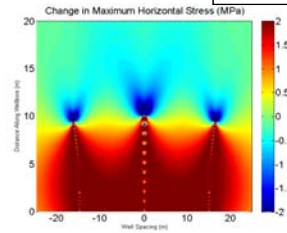
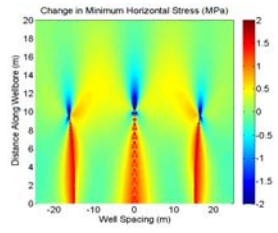
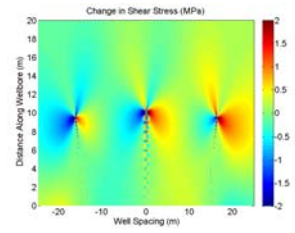


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Propagation of Clusters

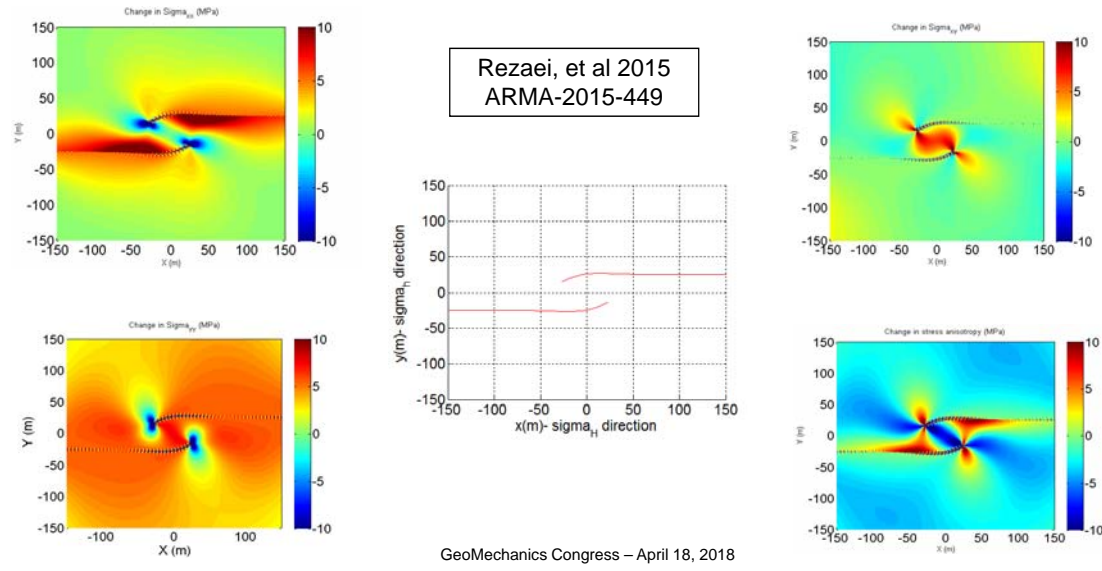


Rezaei, et al 2015
ARMA-2015-449

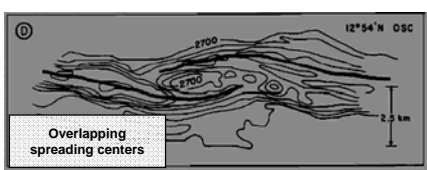
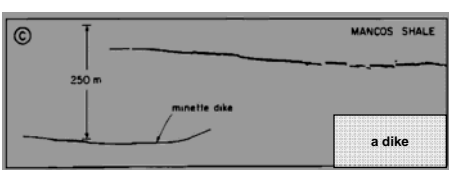
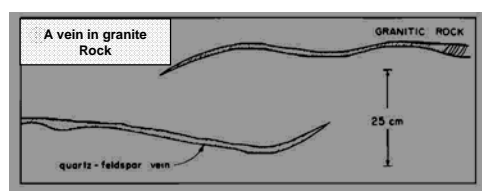
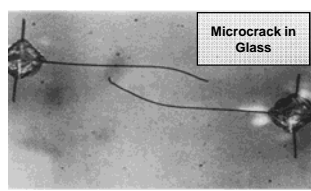


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Overlapping Zones of Two Interacting Fractures



Fracture Interactions in Nature




Swain 1978, Pollard 1984, Atkinson 1987



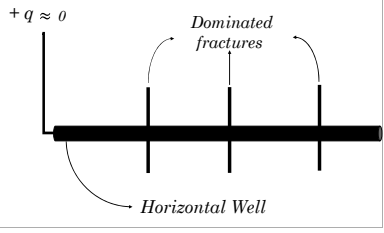
Fully Poroelastic Model

- Infill well fracturing
- Refracturing

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Infill Well Drilling & Refracturing

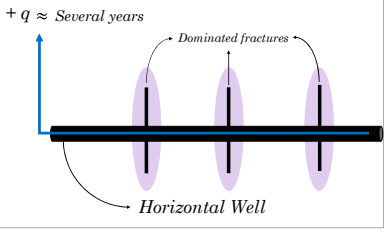


$+q \approx 0$

Dominated fractures

Horizontal Well

Fractures at their final lengths

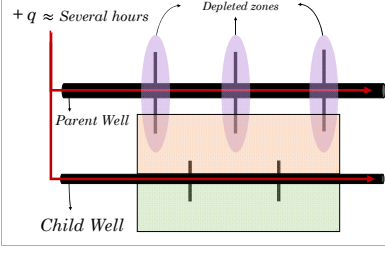


$+q \approx \text{Several years}$

Dominated fractures

Horizontal Well

Depleted area around fractures after production

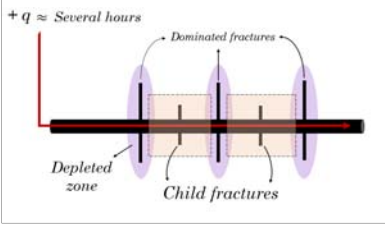


$+q \approx \text{Several hours}$

Depleted zones

Parent Well

Child Well



$+q \approx \text{Several hours}$

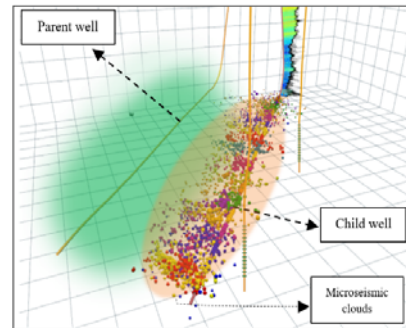
Depleted zone

Child fractures

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Infill Well Fracturing

- Depletion of legacy wells creates a pressure sink that attracts fractures from new infill wells nearby
- The sink moves away from the legacy well with time
- It is desired to mitigate the asymmetric propagation in order to reach to the intact areas of the reservoir



SPE-181656-MS

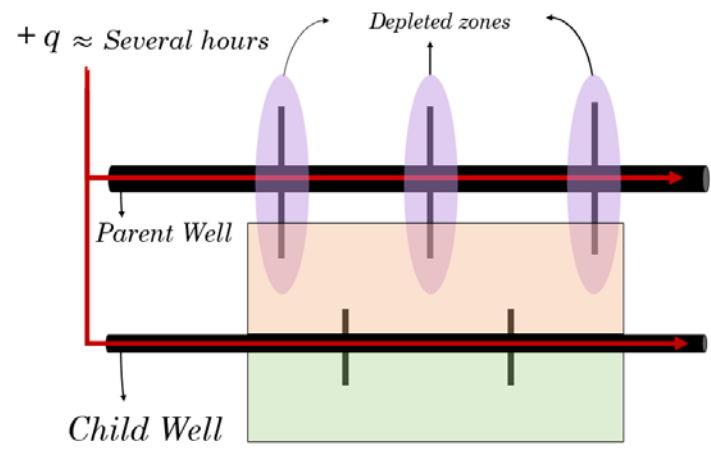
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- Several methods to avoid asymmetric growth of the hydraulic fractures from infill well
- The asymmetry may be observed in both lateral and radial direction of the wellbore
- Study this issue numerically,

SPE-181767-MS

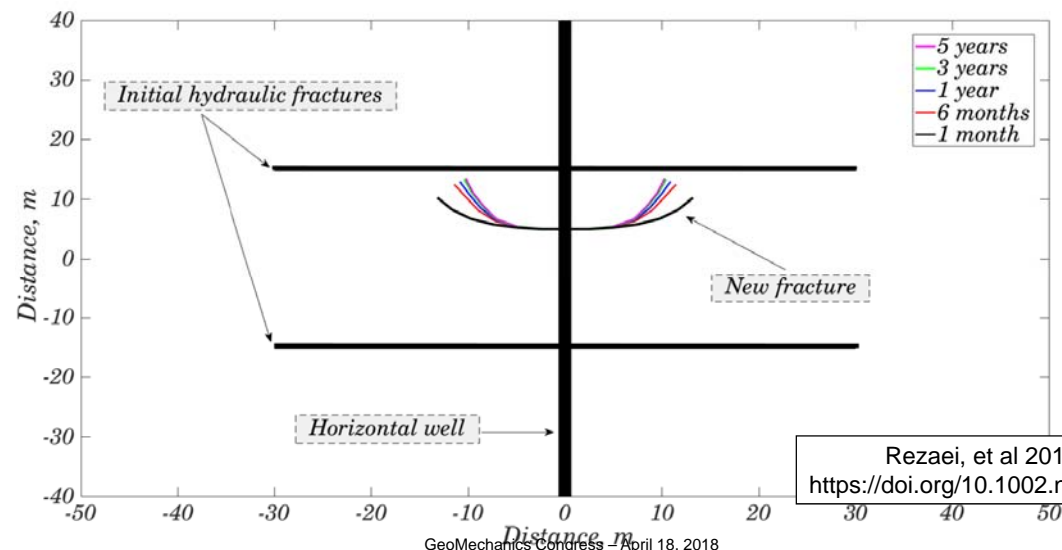
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Infill Drilling



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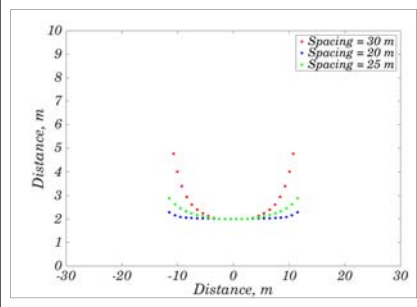
Effect of the Pore Pressure Depletion on Refrac Propagation



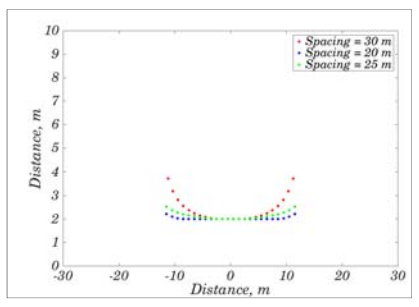
Rezaei, et al 2018
<https://doi.org/10.1002.nag.2792>

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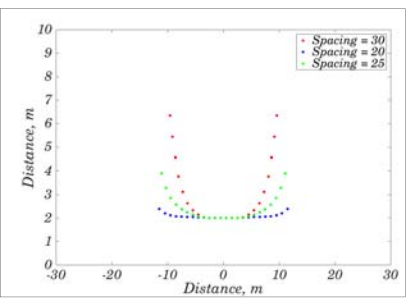
Propagation of the Child Fracture Vs. Spacing



6 months



1 year

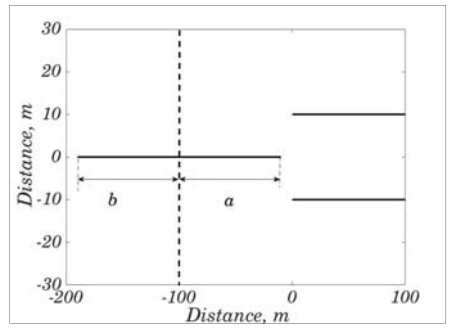


5 years

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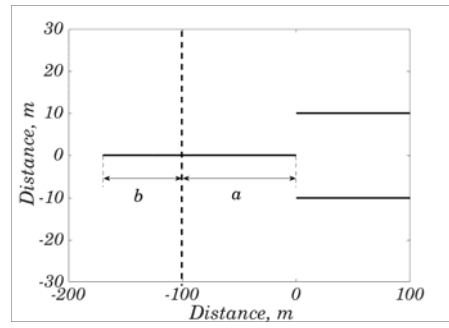
Rezaei, et al 2017
SPE 187055

Asymmetric Child Fracture Half-Length



6 months

$a \approx b$



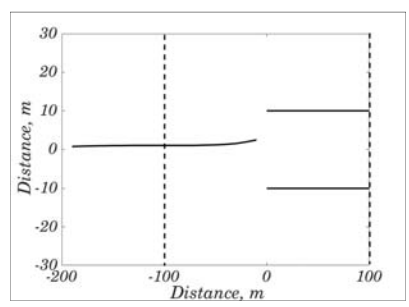
5 years

$a \gg b$

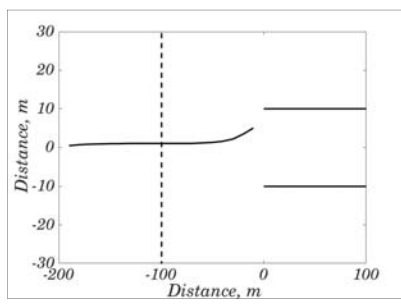
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Rezaei, et al 2017
URTeC 2667433

Asymmetric Propagation Path from a child well



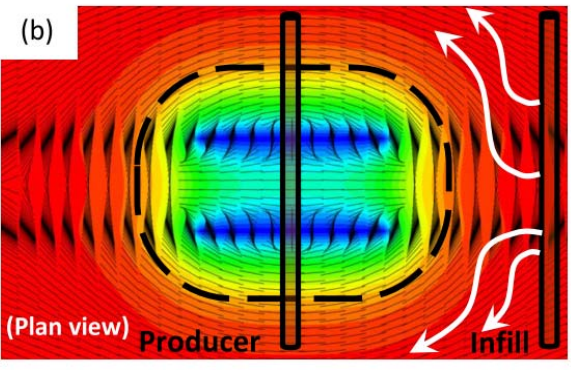
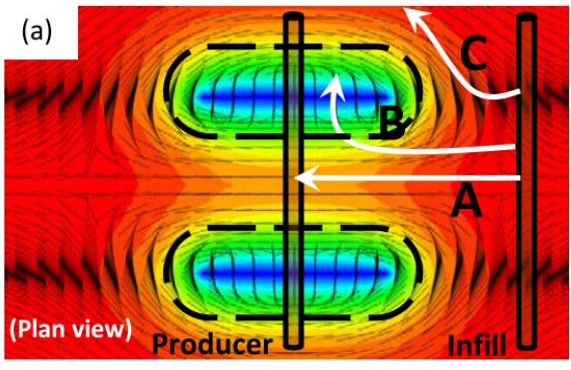
6 months




1 year

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Rezaei, et al 2017
SPE 187055




Safari, et al
SPE 178513



Fast Multipole Fully Poroelastic Model
New numerical technique that has been used in quantum chemistry

<i>Method</i>	<i>Run time, sec</i>
Exact PDDM	8802
FMPDDM - Chebyshev Polynomial degree 3	124
FMPDDM - Chebyshev Polynomial degree 6	431

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Final remarks

- New challenges in stimulation of wells, specially in shale formations
- JPT listed some of those challenges that included
 - Stress shadowing
 - Fracture conductivity
 - Optimization of fracture and fracturing parameters

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