Advancing Reservoir Performance

Preliminary Report

Geomechanical Modeling for the Bone Springs Completion Program, Lea Co., NM

Geomechanics Model

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For Endurance Resources
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Ex# 11-1

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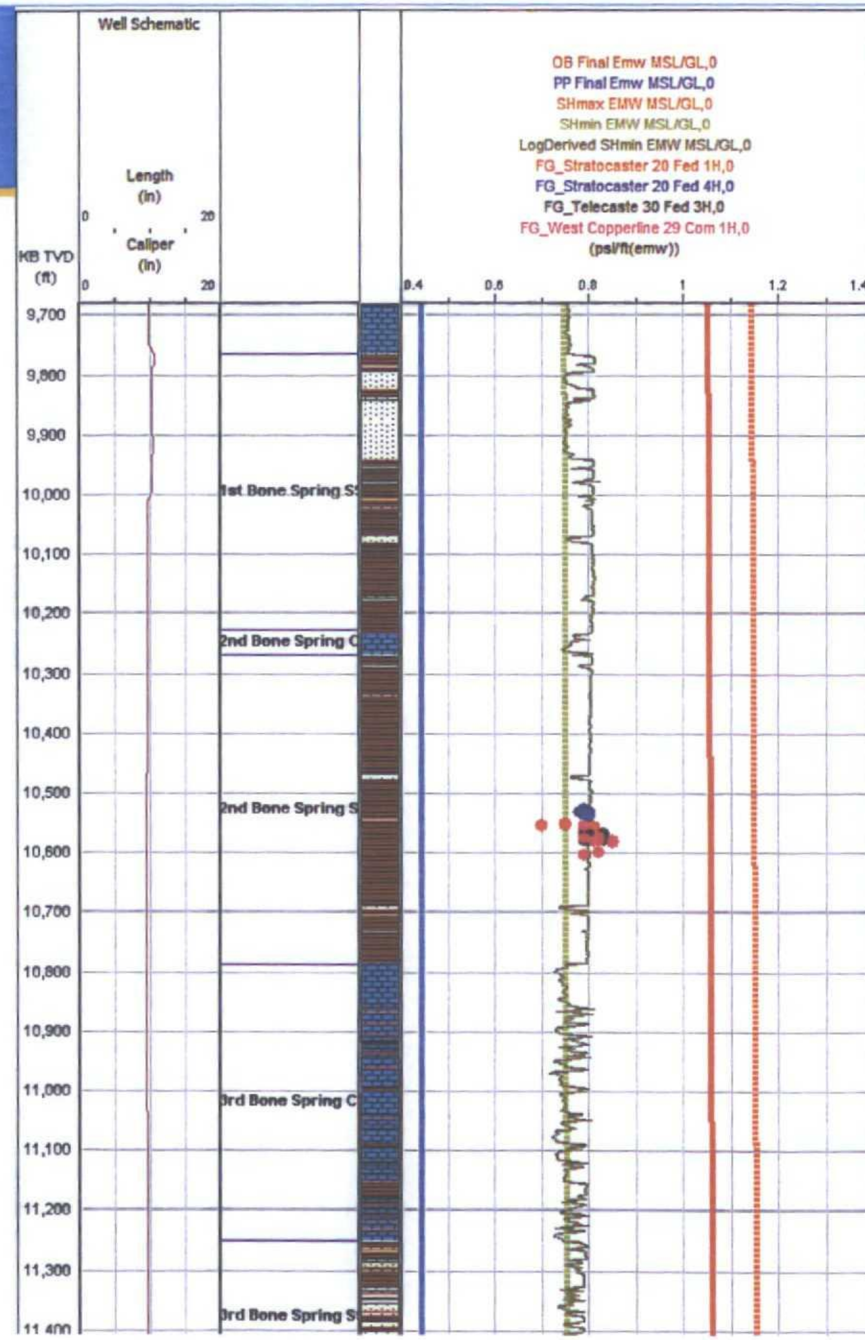
Summary of Results: Geomechanical Model

- The stress regime is most likely strike-slip faulting: $S_{Hmax} > S_v > S_{hmin.}$
  - Pore pressure is assumed to be 0.45 psi/ft (8.6 ppg).
  - Frac closure (S_{hmin}) is estimated from fracture gradient in 4 offset wells and regional experience.
  - S_{Hmax} azimuth of ~80° is assumed from regional experience in Lea Co., NM.
- The model verification shows only intermittent breakouts, which matches drilling experience.
- The geomechanical model suggests that drilling ~N-S (perpendicular to S_{Hmax} orientation) is ideal for transverse hydraulic fracture generation, which may lead to better production. Hydraulic fractures propagate perpendicular to minimum principal stress (S_{hmin} in this model).
- At the current reservoir pressure no natural fractures are critically stressed and prone to slip. At 0.1 psi/ft injection pressure, vertical fractures striking ~N50°E and N°110E start to slip. At 0.3 psi/ft injection pressure, fractures striking N30°E – N130°E with 40-90° dip angle are optimally oriented to slip and become permeable.

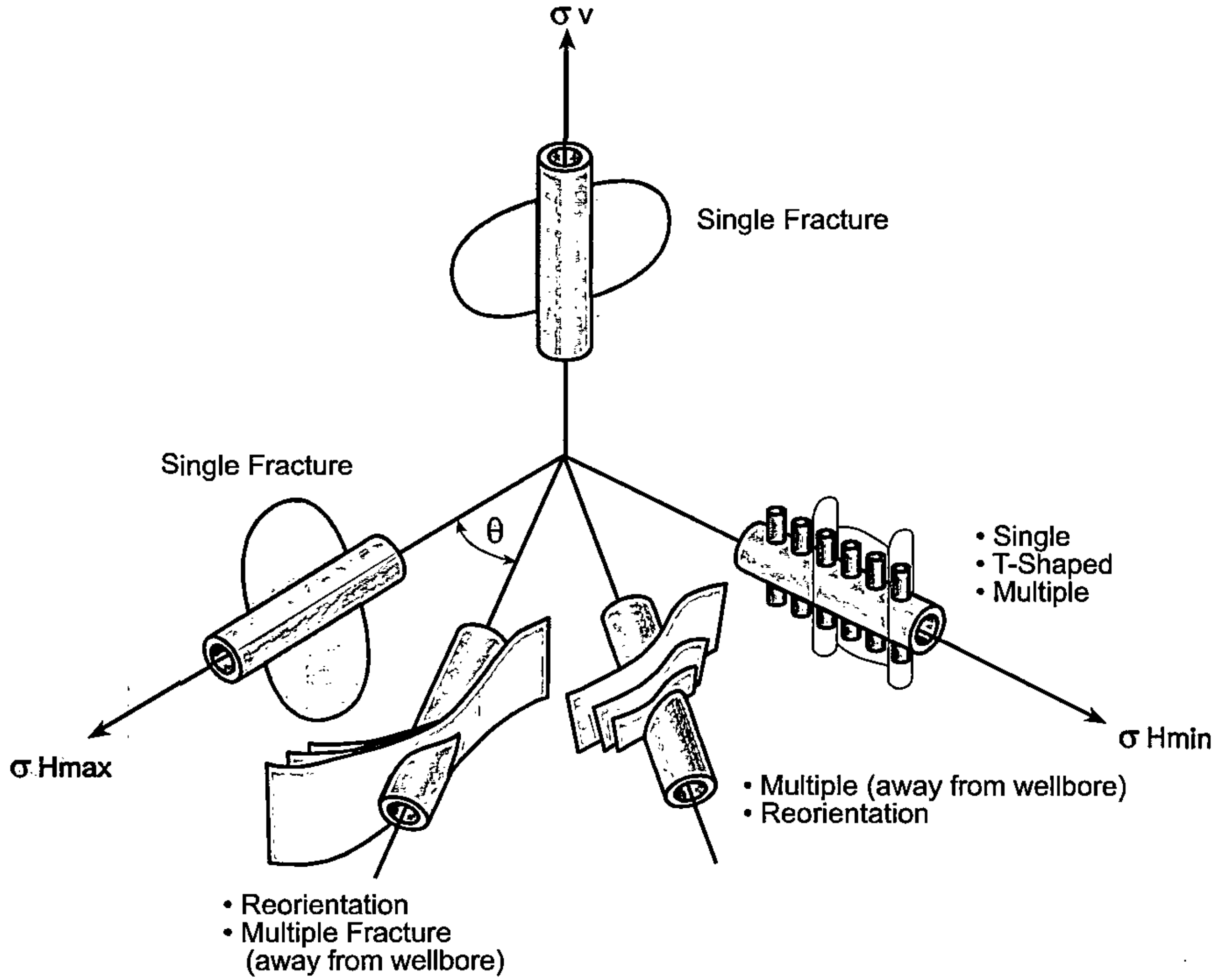
Stress Profile: Paloma 30 Fed 2



- Overburden
- Pore pressure
- S_{Hmax}
- S_{hmin} = 0.75 psi/ft
- Log-based S_{hmin}
- Frac data from Stratocaster 20 Fed 1H
- Frac data from Stratocaster 20 Fed 4H
- Frac data from Telecaster 30 Fed 3H
- Frac data from West Copperline 29 Com 1H

- Strike-slip faulting stress regime: $S_{Hmax} > S_v > S_{hmin}$
- Overburden is calculated from available density data.
- Pore pressure is assumed to be 0.45 psi/ft (8.6 ppg).
- S_{hmin} (~0.75 psi/ft for sand/limestone and ~0.8 psi/ft for shale) is estimated from frac data and regional experience.
- S_{Hmax} magnitude is estimated from regional experience.

Wellbore Orientation Effects on Fracture Geometry: Example



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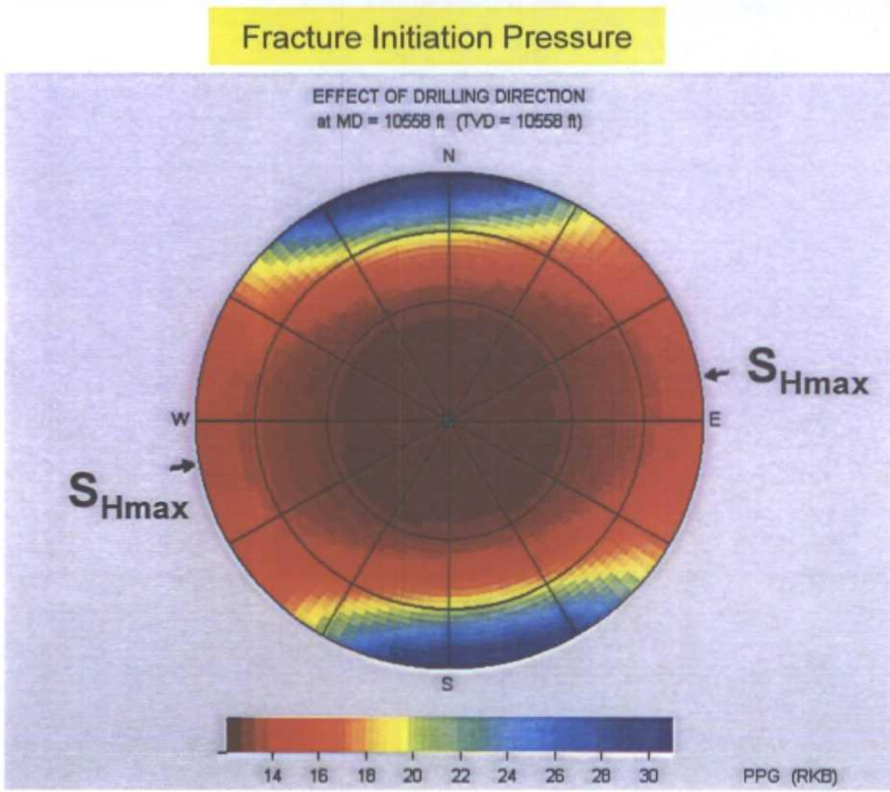
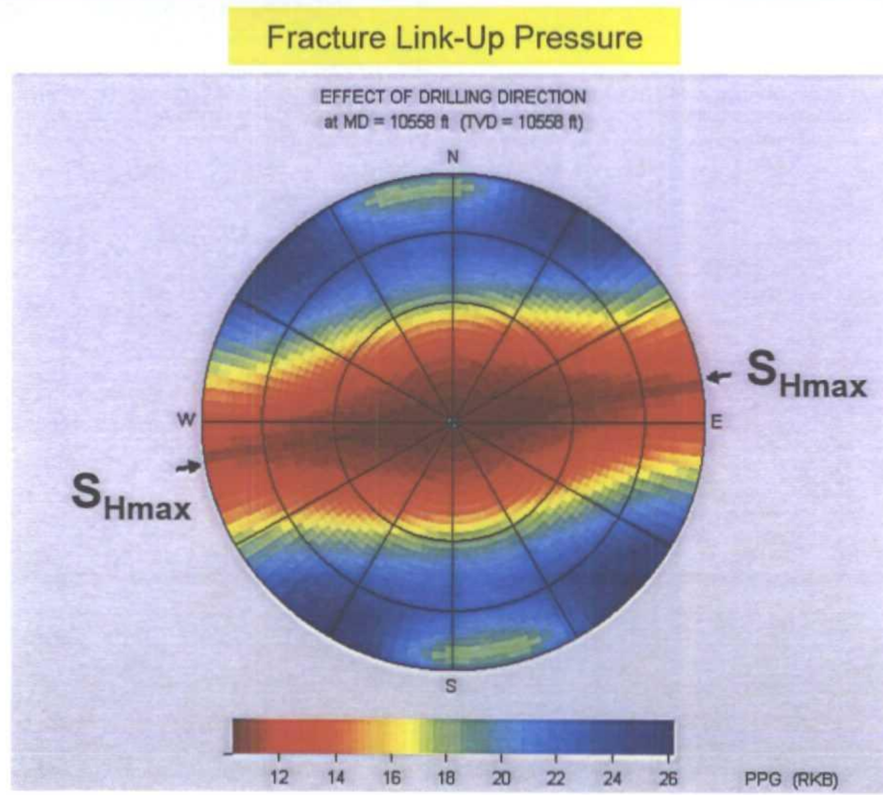
Effect of Drilling Direction on Fracture Initiation Pressure: 2nd Bone Springs





The plots show fracture initiation and link-up pressures as a function of deviation and azimuth. The plots indicate that both deviation and azimuth have an effect on fracture pressure. A horizontal well drilled in the S_{hmin} direction (~N-S) requires much higher pressure to link up or initiate fracs than a horizontal well drilled in the S_{Hmax} direction (~E-W).

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*Note different color scales.

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PART I: GEOMECHANICAL MODEL

FRACTURE PERMEABILITY ANALYSIS - EFFECT OF INJECTION ON NATURAL FRACTURE

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Introduction: Fracture Permeability Analysis

- Fracture permeability depends on the 3D present-day state of stress in the earth and on fracture orientations.
- Good knowledge of stress and fracture populations allows estimation of fracture permeability.
- Well trajectories can be optimized to intersect a maximum amount of permeable fractures.
- Risk for circulation losses into permeable fractures can be assessed.

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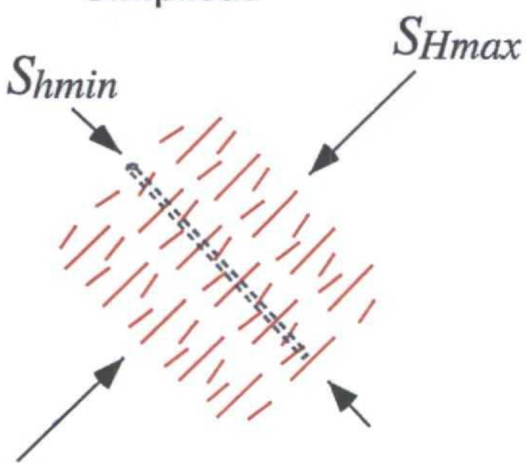
Pre-existing Crack Orientation: Example

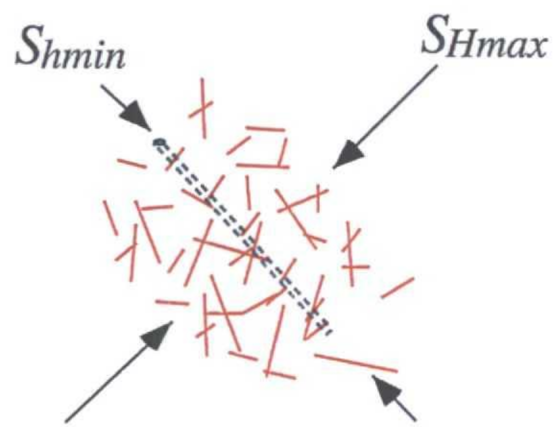
Simplistic

More Realistic

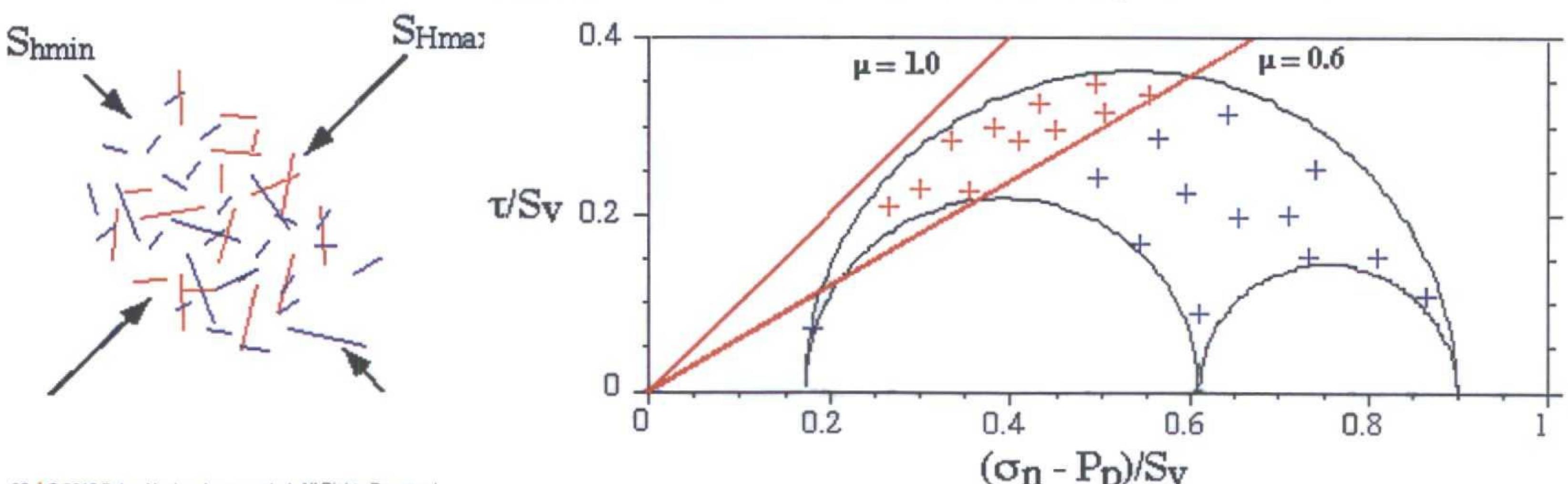
(a)



(b)



Permeable Fractures and Faults are Critically Stressed



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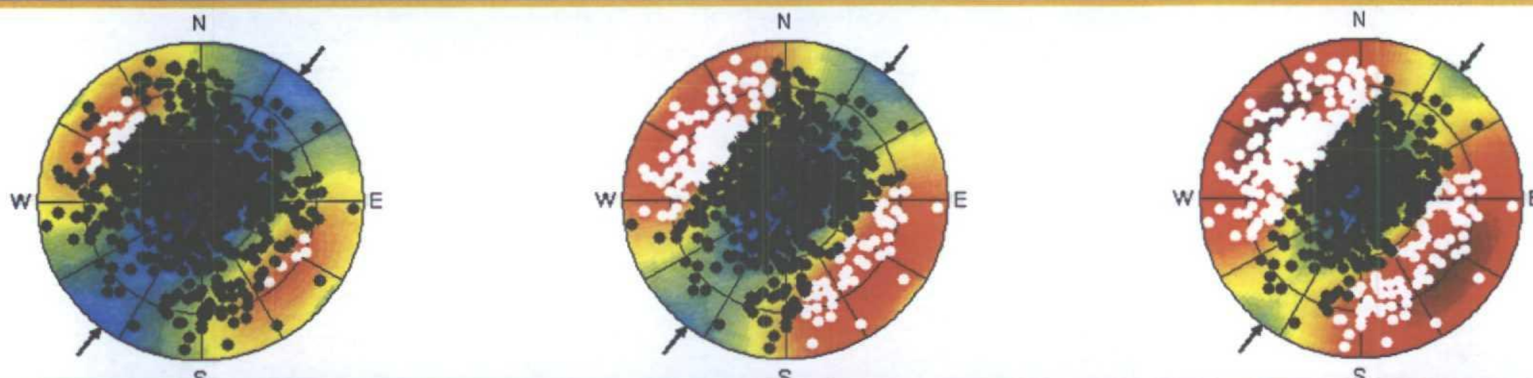
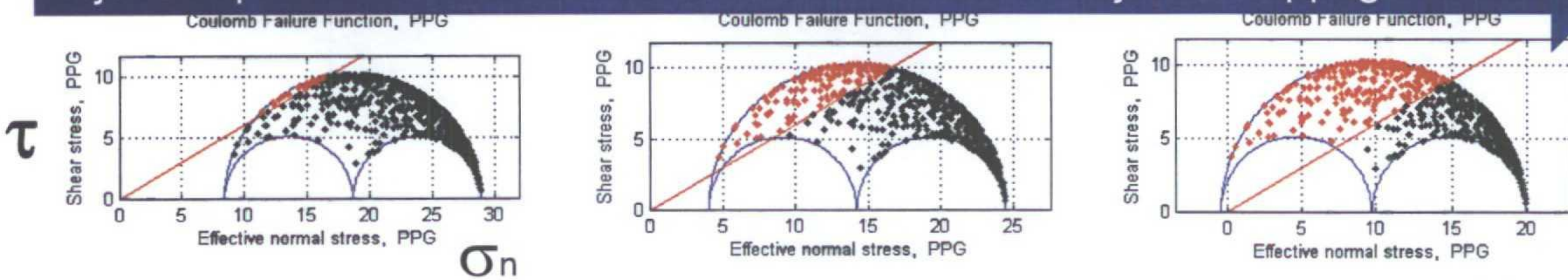
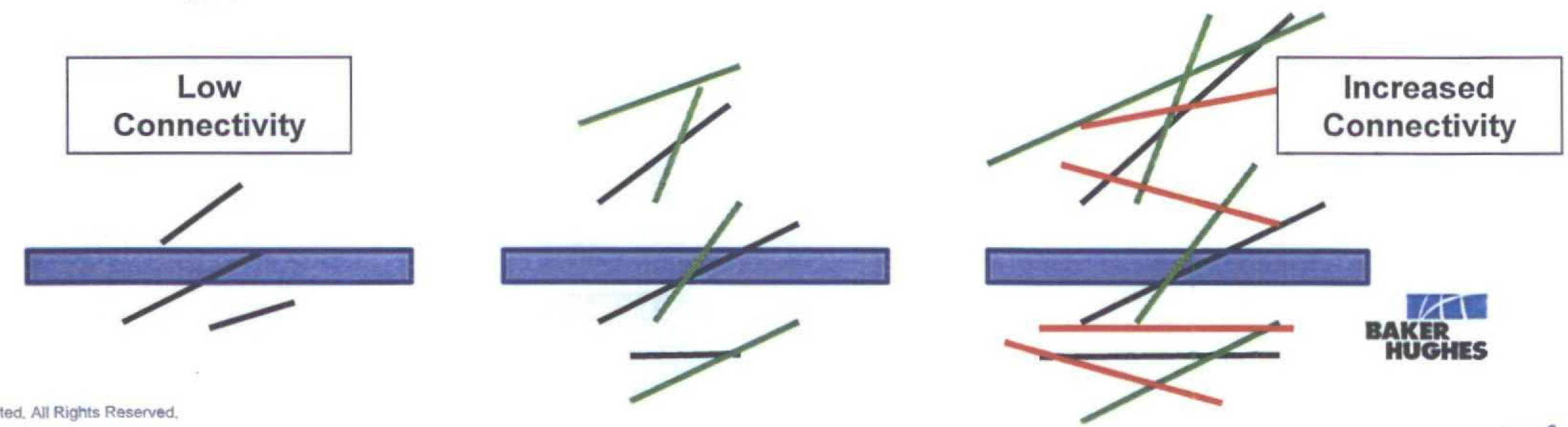
Stimulation Re-Examined: Example



Injection pressures increases number of fractures subject to slippage



Numbers of fractures is just part of the story.



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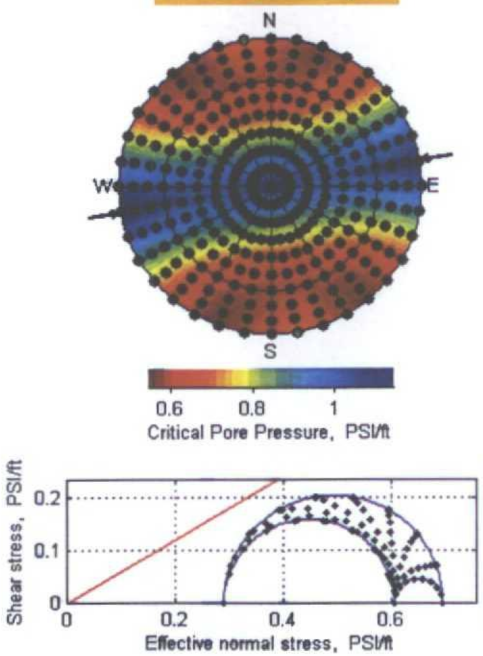
Effect of Injection on Natural Fracture: Paloma 30 Fed 2

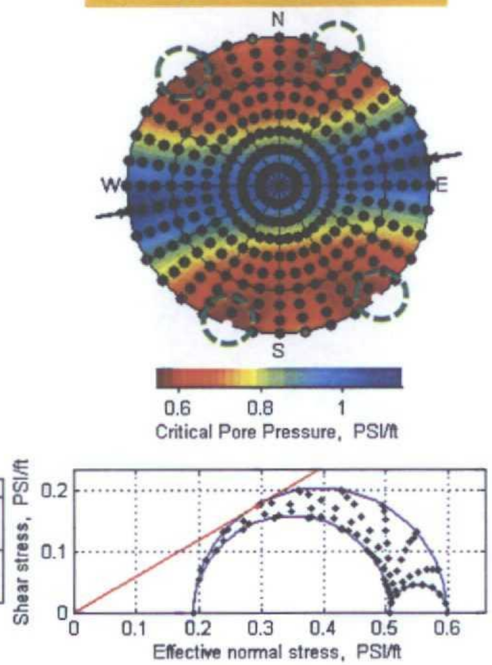
Representative fractures in all directions are plotted to examine the injection pressures required to stimulate (by sliding) natural fractures in the Paloma 30 Fed 2 well (no natural fracture picks are provided from Endurance). Poles to fracture plane are displayed as black (non-critically stress) or white (critically stressed dots). Fractures slip with higher injection pressure and become hydraulically conductive (white dots).

Original P_p



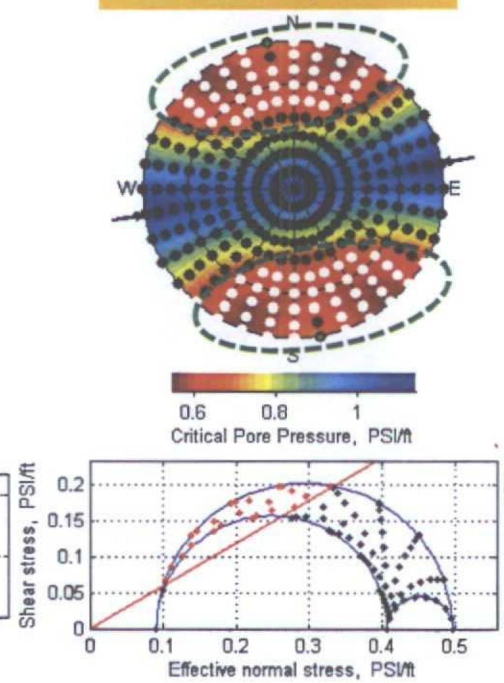
No fractures are critically stress under current stress state.

0.1 psi/ft Injection



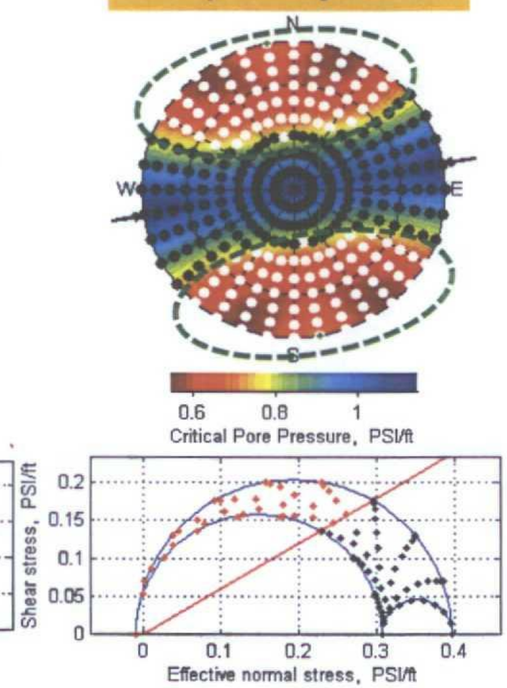
Vertical fractures striking ~N50°E and N°110E start to slip (green circles).

0.2 psi/ft Injection



Fractures striking N40°E – N120°E with 50-90° dip angle (poles within the green circles (white dots)) are optimally oriented to slip and become permeable.

0.3 psi/ft Injection



Fractures striking N30°E – N130°E with 40-90° dip angle (poles within the green circles (white dots)) are optimally oriented to slip and become permeable.

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