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Application of Geomechanical Concepts in Oriented Perforating Design. Whangai formation, East Coast of New Zealand

SLAP 16-34

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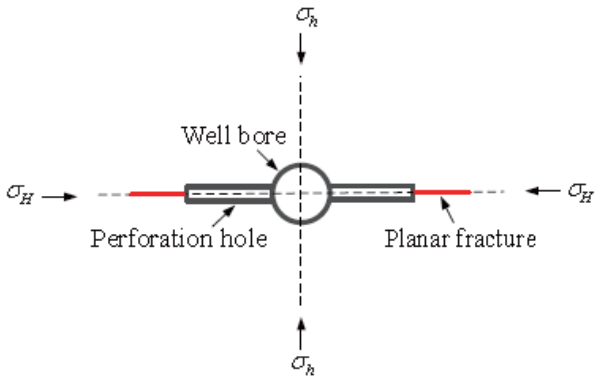
AGENDA

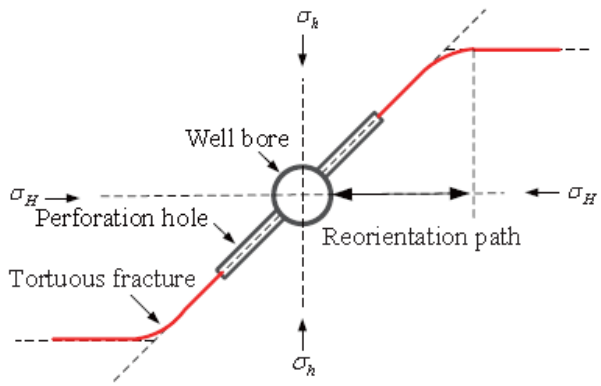
- Part I
  - Introduction: Tortuosity effects
  - Objectives
  - Study Area
  - Geomechanical Properties and Parameters for Oriented Hydraulic Fracturing
  - Geomechanical Analysis - Fracture Initiation and Fracture Link-up
  - Hydraulic Fracturing Analysis – Fracture Geometry
  - Summary

- Part II
  - Discuss some new ideas about oriented perforations applications
  - Shoot in different directions of SH

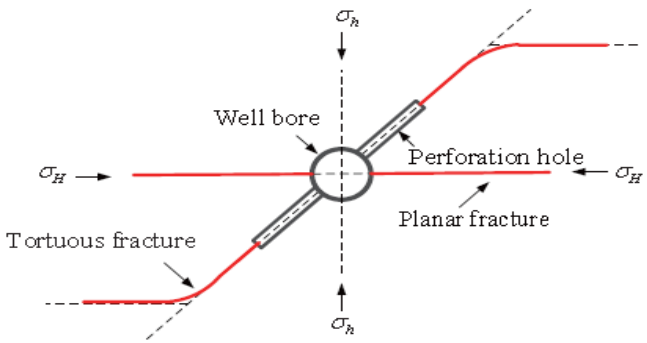
INTRODUCTION



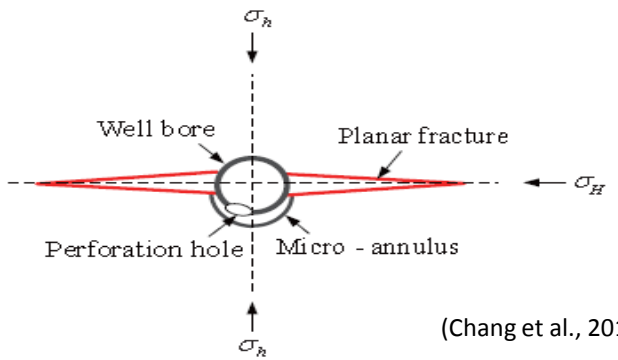
Planar fracture



Tortuous fracture (non-planar)



Multiple fractures (non-planar)



(Chang et al., 2015)

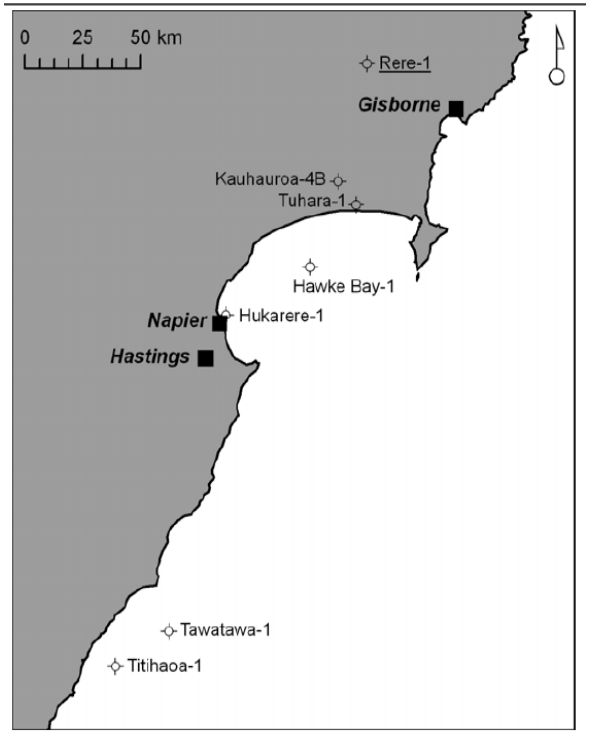
Initiation from the micro-annulus

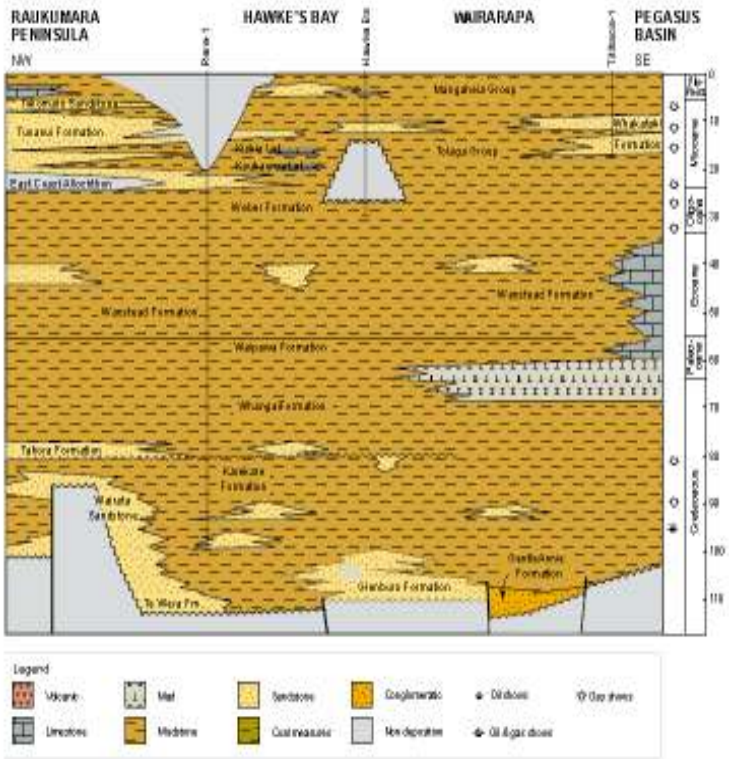
Tortuosity is recognized as a source of additional friction between tubular and borehole, responsible of casing and completions running difficulties, poor cementation and logging quality or casing wear issues.

OBJECTIVES

- Oriented perforations have been traditionally used to minimize tortuosity in vertical wells by shooting at maximum horizontal stress (SH) direction in conventional reservoirs and some cases in unconventional reservoirs (Chang et al., 2015). In order to perform oriented perforations, it is necessary to know the directions and magnitude of in situ stresses, but the stress magnitudes and the type of stress regime is rarely taken into account.
- Perforations far from SH can induce a severe tortuosity in the HF, because HF planes will aligned with the SH direction quickly after formation breakdown.
- The Whangai Formation, located in the East Coast Basin of New Zealand, has been identified as a good potential source rock to become an oil/gas producer. The reservoir properties of Whangai Formation are similar to the Bakken Shale in the U.S., which is currently one of the most-active shale plays.
- In this study was investigated the influence of perforation azimuth angle and tortuosity on fracture initiation pressure, fracture link up pressure and geometry of Whangai fm.

STUDY AREA – WHANGAI FM.





The late cretaceous-paleocene Whangai formation is a siliceous mudstone (unconventional reservoir) and the study area is located in the East Coast of New Zealand. This unconventional reservoir has a mineralogical composition of 20 % quartz, 10% calcite and 70% clay. The TOC varying from 0.5% to 2%.

Geomechanical Properties and Parameters for Oriented Hydraulic Fracturing

Geomechanical Properties of Whangai fm.

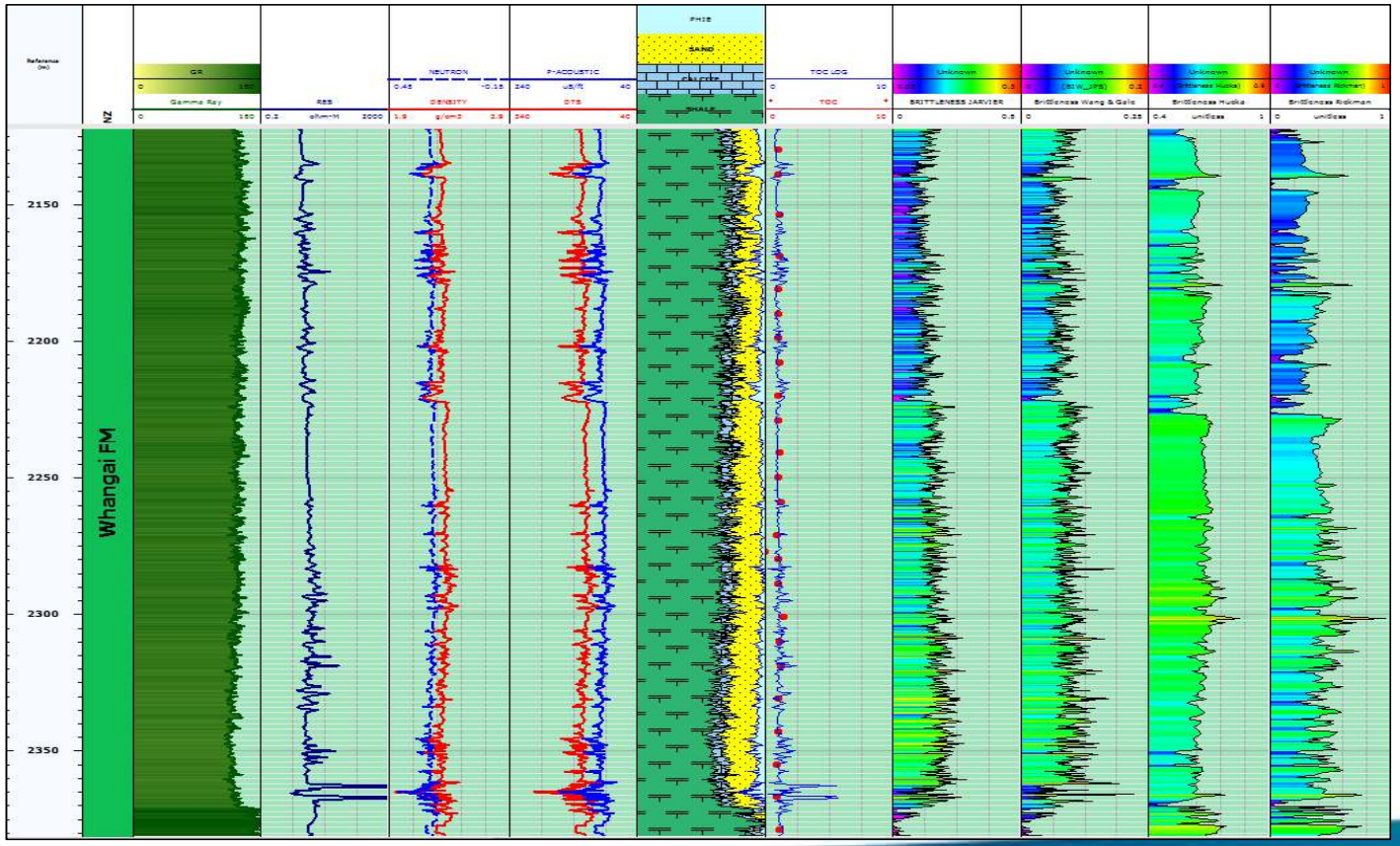
Parameters	Value
Elastic Modulus of Rock (psi)	1890000
Poisson's Ratio of Rock	0.32
Internal Frictional Coeficient	0.60
Unconfined Compressive Strength (psi)	2018
Tensile Strength (psi)	509
Permeability (mD)	0.00020
Porosity (%)	34

Parameters for Oriented Hydraulic Fracturing

Parameters	Value	Fracture Geometry
Perforation Azimuth Angle (^{o})	10	Tortuous Fracture
	80	Tortuous Fracture
	90	Planar Fracture

Parameters	Value
Perforations	25
Diameter (in inch)	0.43
Fluid Type (Reservoir)	gas

PETROPHYSICS PROPERTIES AND BRITTLENESS INDEX OF WHANGAI FM.



Defining the best Interval for hydraulic fracturing Design using Four Brittleness Index

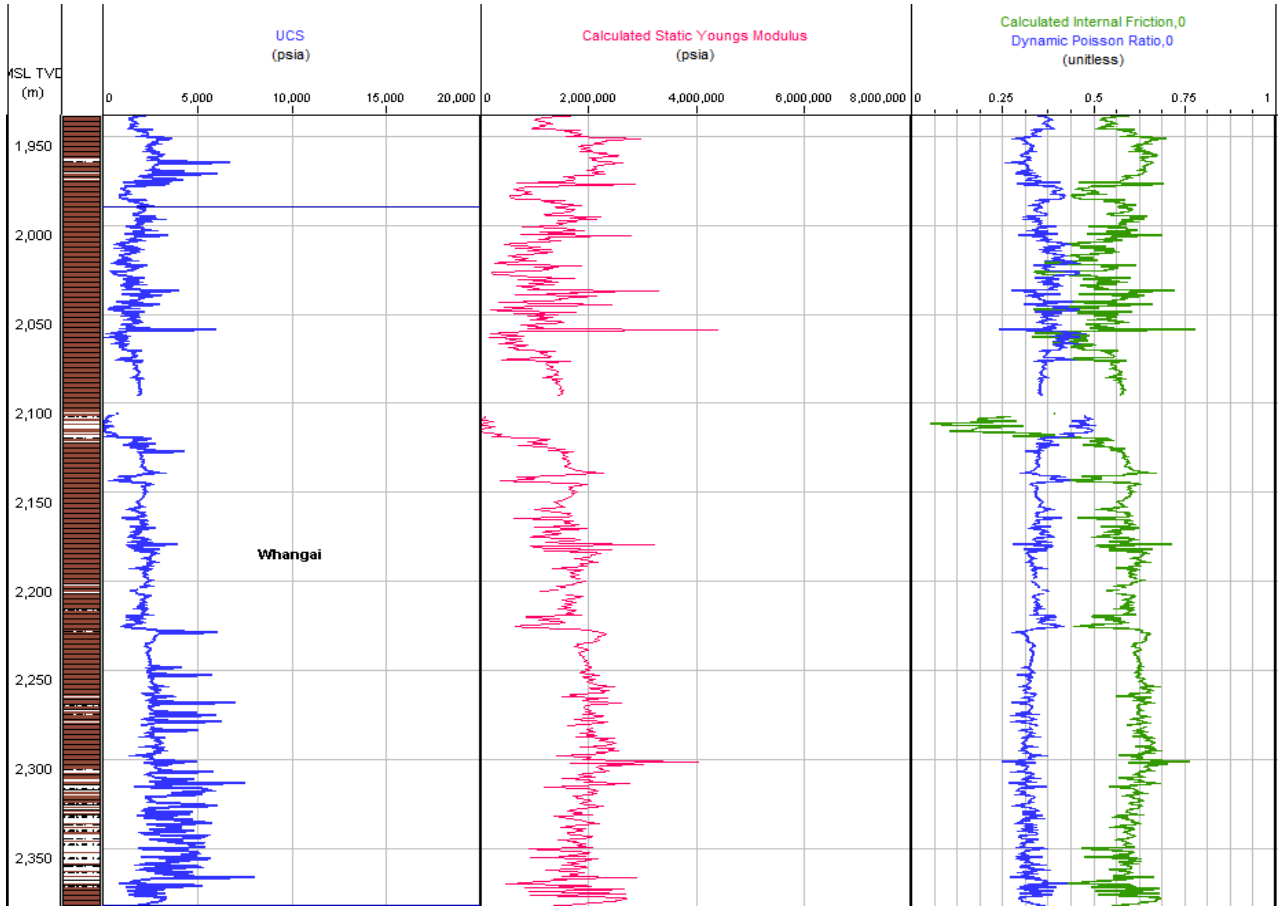
$$BI_{Jarvie} = \frac{Qz}{Qz + Ca + Cly}$$

$$BI_{Wang\&Gale} = \frac{Qz + Dol}{Qz + Dol + Ca + Cly + TOC}$$

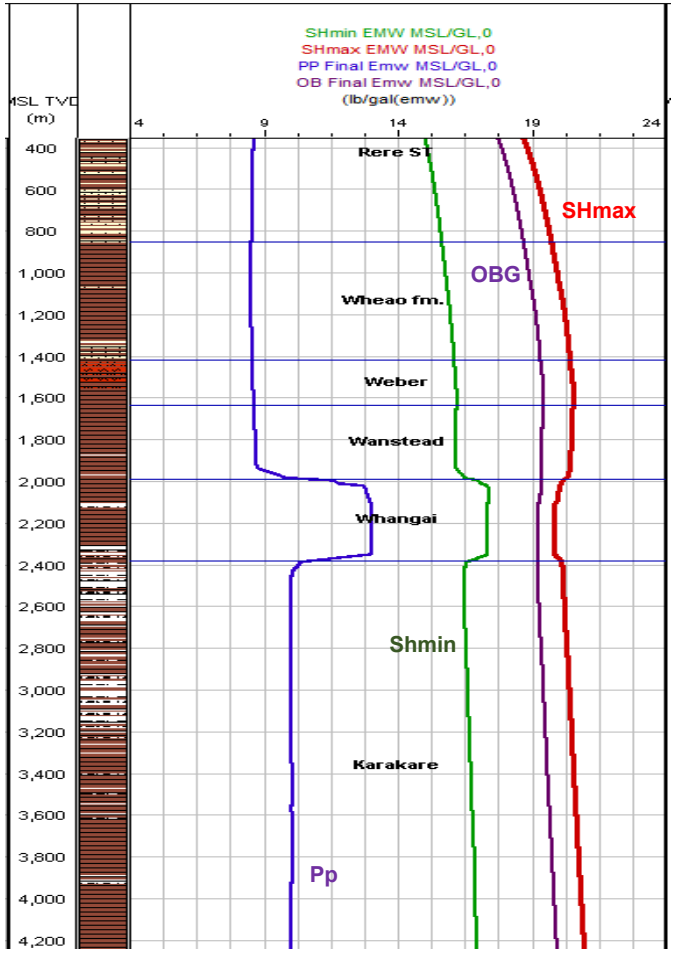
$$BI_{Hucka} = Sin(\varphi)$$

$$BI_{Rickman} = 0.5\frac{100(E_v - E_{v\min})}{(E_{v\max} - E_{v\min})} + \frac{100(v_v - v_{v\max})}{(v_{v\min} - v_{v\max})}$$

ROCK STRENGTH AND ELASTIC PARAMETERS



GEOMECHANICAL MODEL



Strike-Slip Faulting Stress Regime

Overburden (S_V) determined from density log acquired in the well.

Minimum horizontal stress (S_{hmin}) determined using LOT data from offset wells.

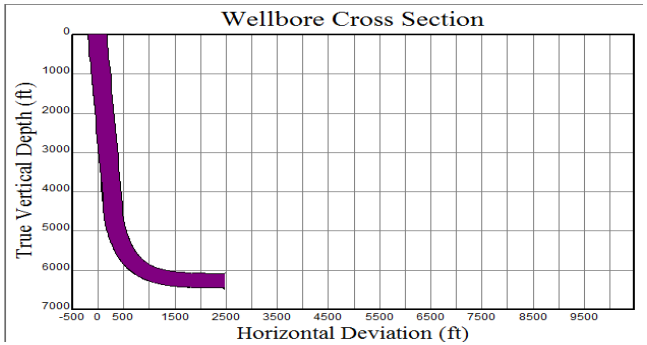
Pore pressure (P_p) prediction using wireline log data.

Maximum horizontal stress (S_{Hmax}) magnitude determined based on analysis of assumed wellbore failures.

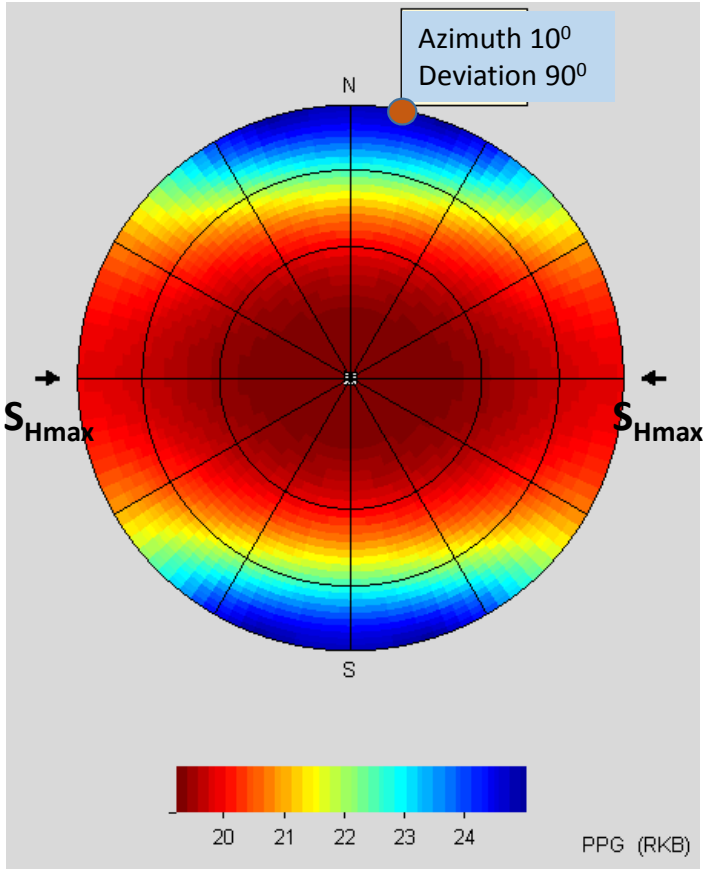
Maximum horizontal azimuth inferred to be 90°N.

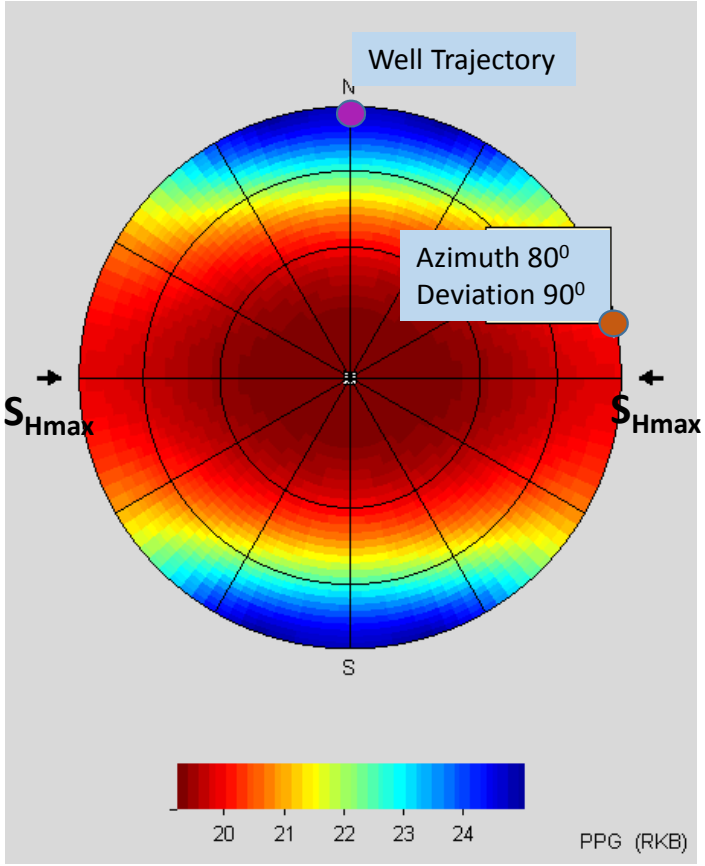
Stress@Stimulation Zone:

S1=SHmax=6495 psi
S2=Sv= 6290 psi
S3= Shmin= 5670 psi



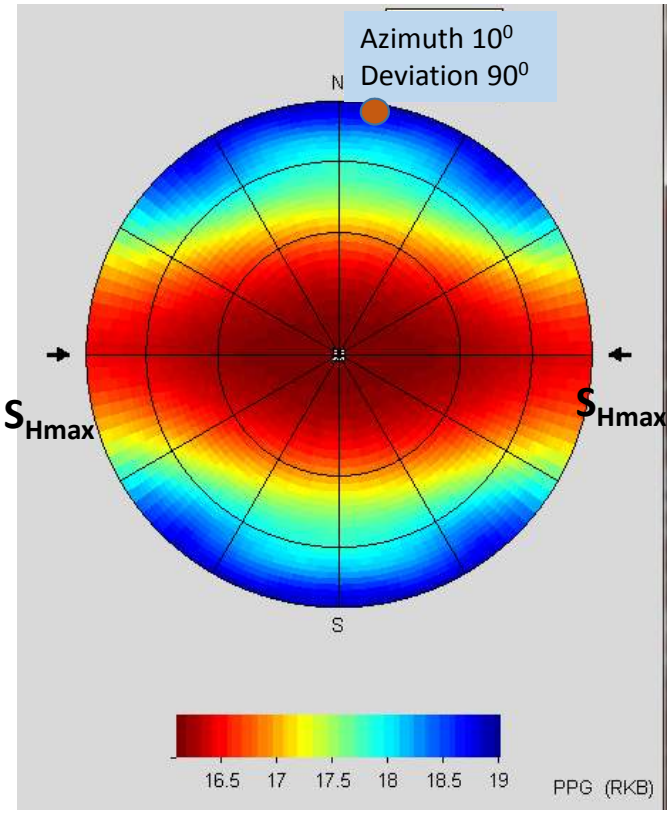
Geomechanical Analysis - Fracture Initiation

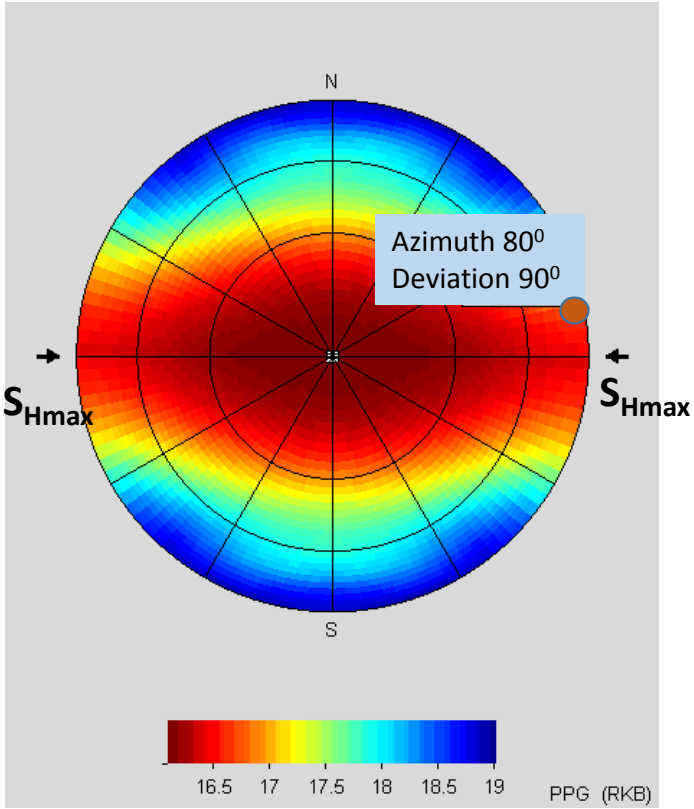




Perforation Orientation:
Fracture Initiation @ 10^0 azimuth = 24.77 ppg
Fracture Initiation @ 80^0 azimuth = 19.91 ppg

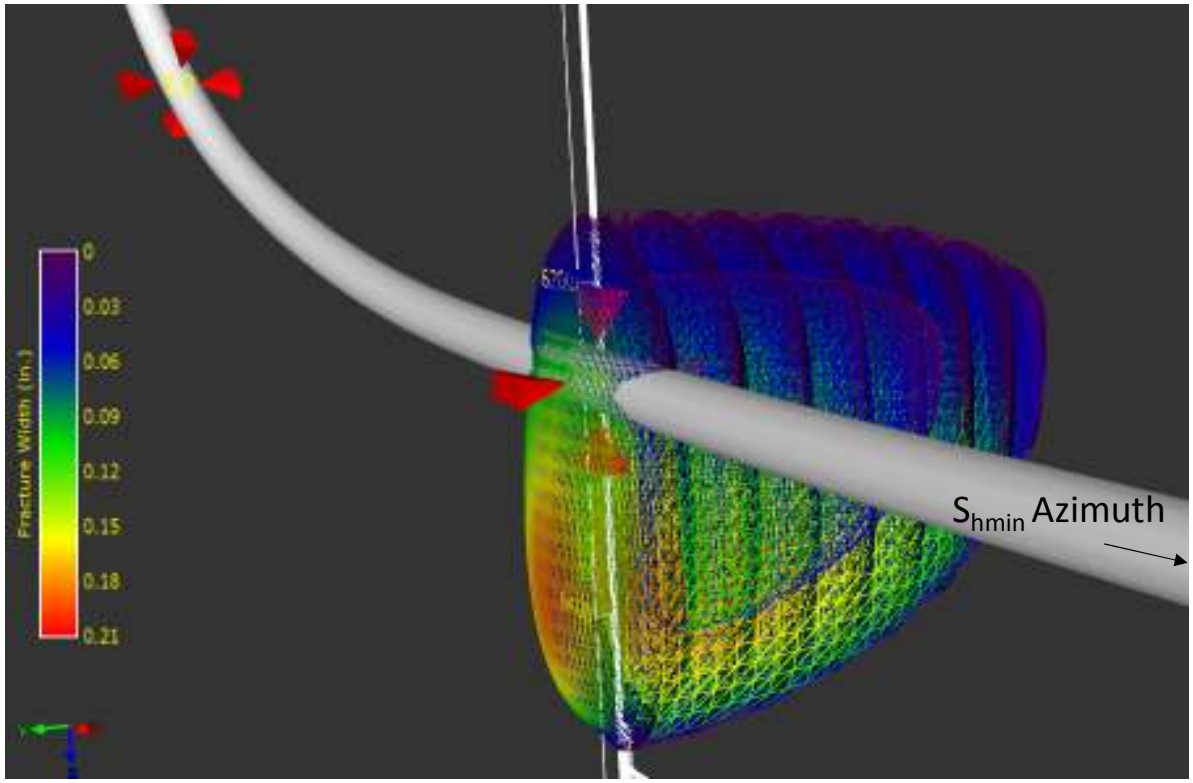
Geomechanical Analysis - Fracture Link-up



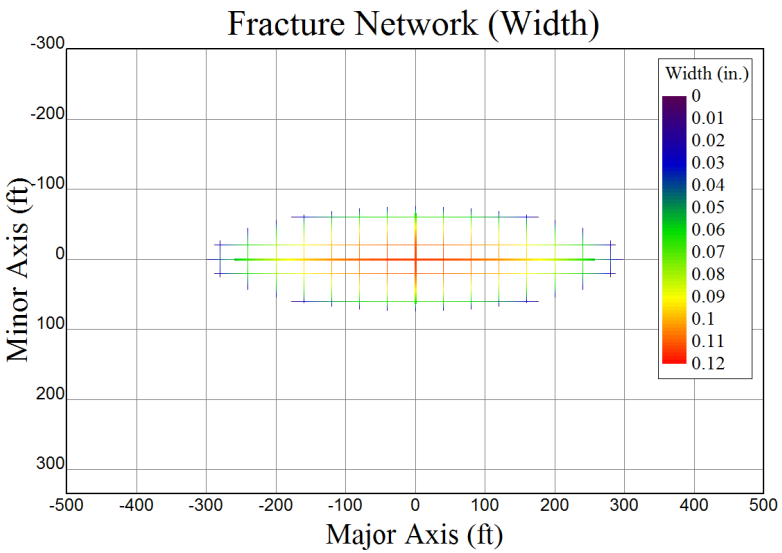


Fracture Link up @ 10^0 azimuth = 18.91 ppg
Fracture Link up @ 80^0 azimuth = 16.62 ppg

Hydraulic Fracturing Analysis – Results

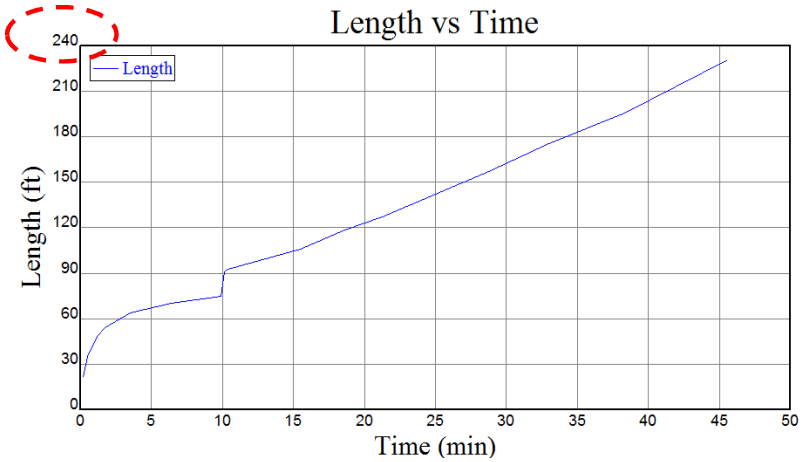


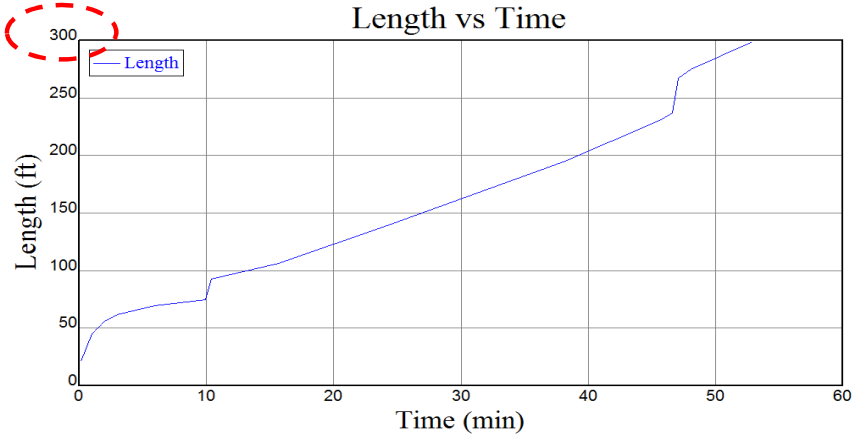
Hydraulic Fracturing Design using DFN Modelling and Considering Stress Contrast/Rock Properties in each perforation direction and Tortuosity effects – Example - Deviation 90^0 and Azimuth 10^0

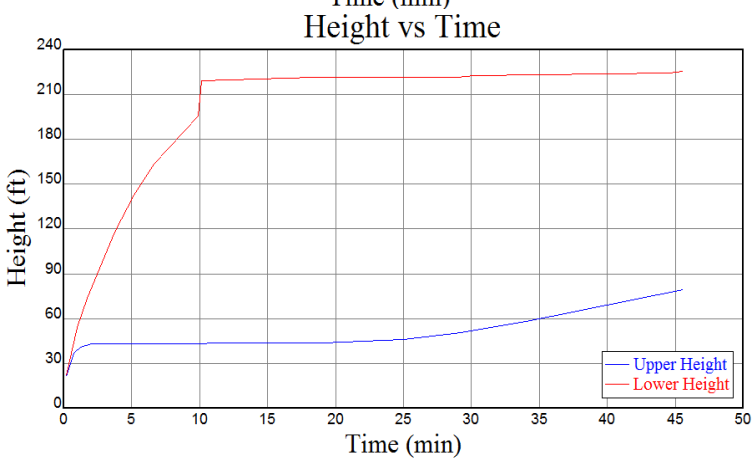


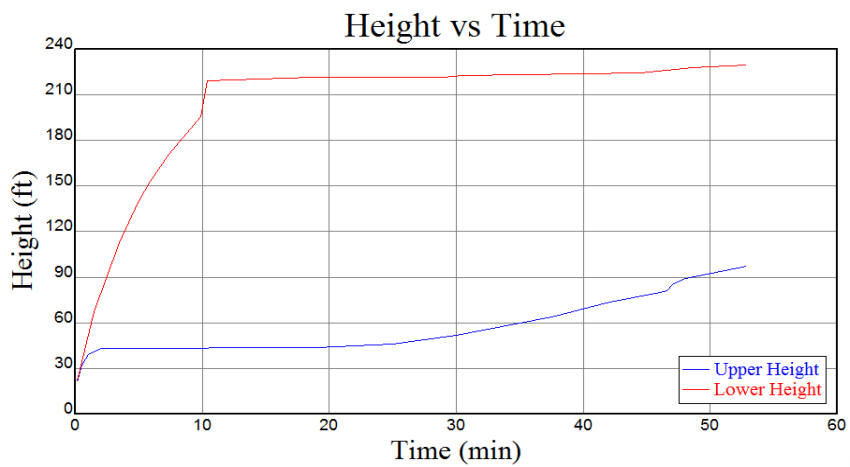
Fracture Widht analysis using DFN Model Example- Deviation 90^0 and Azimuth 10^0

Hydraulic Fracturing Analysis – Results









Perforation Orientation: 10^0 azimuth

Perforation Orientation: 80^0 azimuth

Summary

- In this study was investigated the influence of perforation azimuth angle and tortuosity on fracture initiation pressure, fracture link up pressure and geometry of Whangai fm.

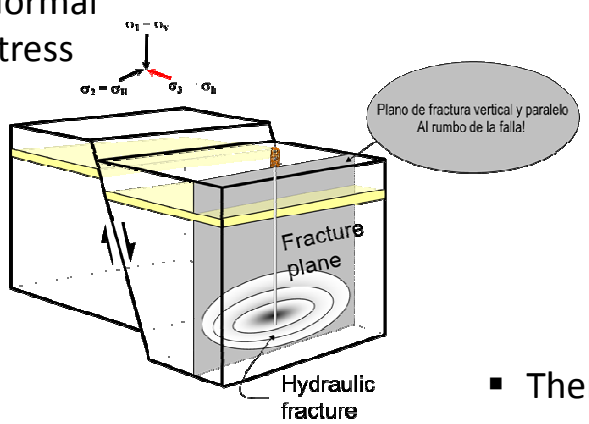
- The geomechanical model indicated an strike slip fault regime with high pore pressure (using Undercompaction), high fracture gradient and high tectonic stress. The Whangai fm. present in some intervals (selected to navigate the horizontal section) an excellent brittleness index using both Petrophysical and geomechanical parameters. SHmax was based on data from World stress and near field wells are indicating an E-W direction.

- The design shows an increase in the drainage area due to reduction of the tortuosity with perforations with azimuth of 80 ^{0} when comparing with azimuth of 10 ^{0} due to a reduction in the stress contrast in the area around the perforations. The High Azimuth (close of SHmax) presented lower tortuosity, lower fracture initiation (breakdown pressure) and fracture link-up, with higher fracture length, with lower effects on fracture height.

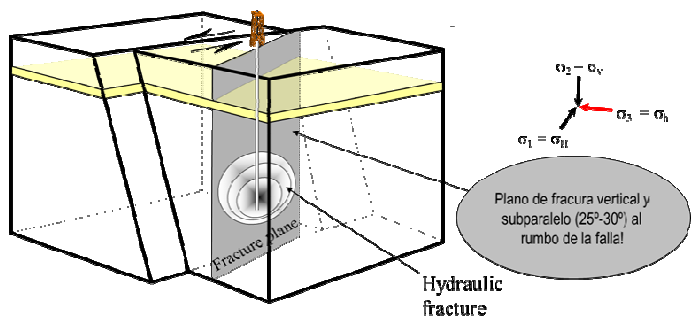
PART II. New ideas about oriented perforations applications

- Oriented perforations have been traditionally used to minimize tortuosity in vertical wells by shooting at maximum horizontal stress (SH). In order to perform oriented perforations, it is necessary to know at least the directions of in situ stresses
- However, is some cases know only the directions is no enough.

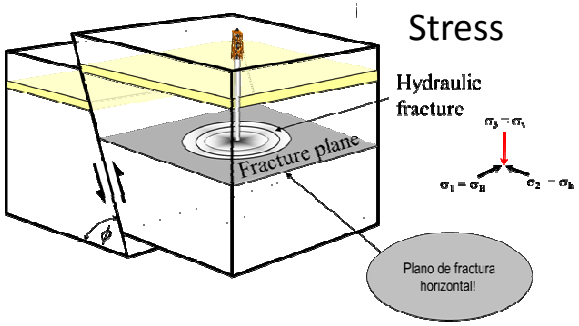
Normal Stress



Strike-slip Stress



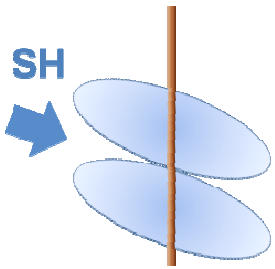
Reverse Stress



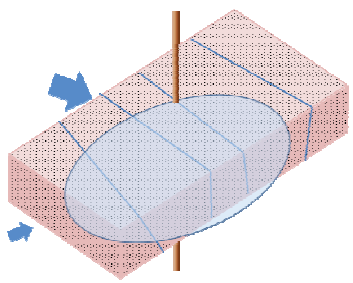
- For instance, in the strike sleep regime, the orientation of the perforations is not relevant, since the IF plane will be horizontal.

- Therefore, not only must know the direction of in situ stresses but also their magnitudes (geomechanical study is necesary).

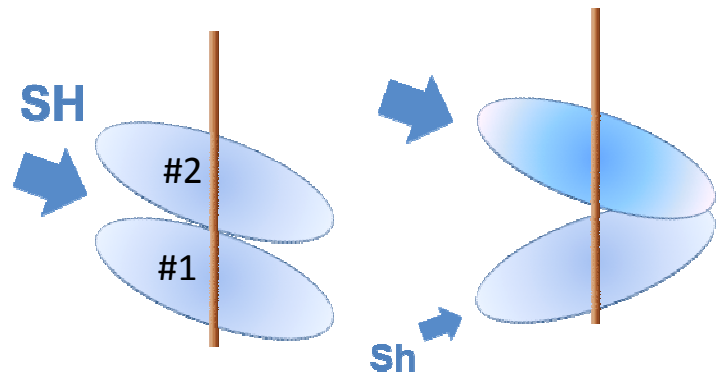
It is sometimes convenient shoot in different directions of SH



Shoot in the direction of SH to minimize tortuosity.



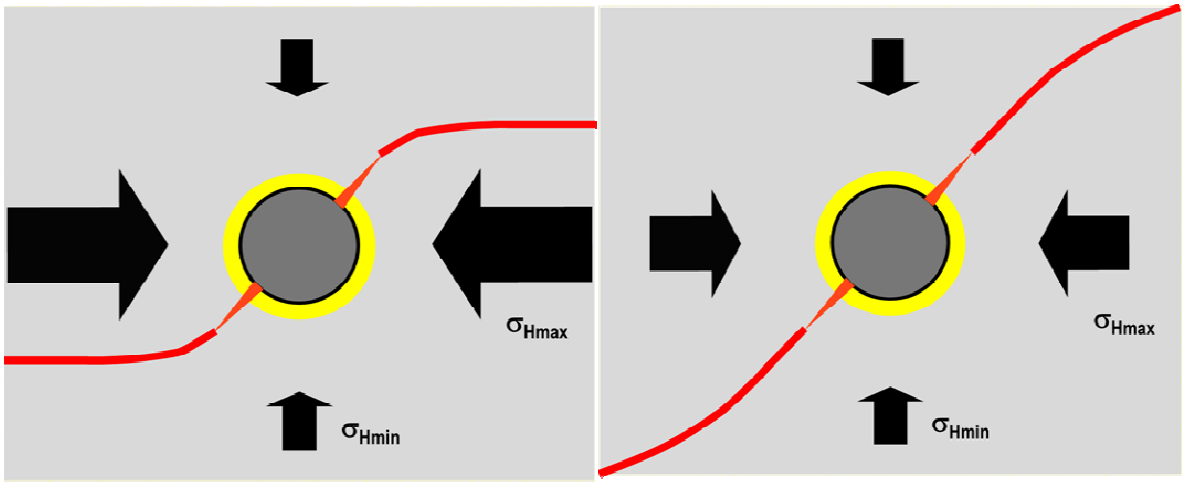
It is sometimes convenient shoot in different directions of SH due to Geological discontinuities (stratigraphic or structural) in the reservoir.



Problem: Shortly after the water arrives to fracture # 1, the water reaches the fracture # 2, probably because both fractures are in the same plane.

We believe that this process can be mitigated, if both fractures were in different planes

Fracturing successfully in different directions of SH, is possible in areas with low stress anisotropy.



Tortuosity severity

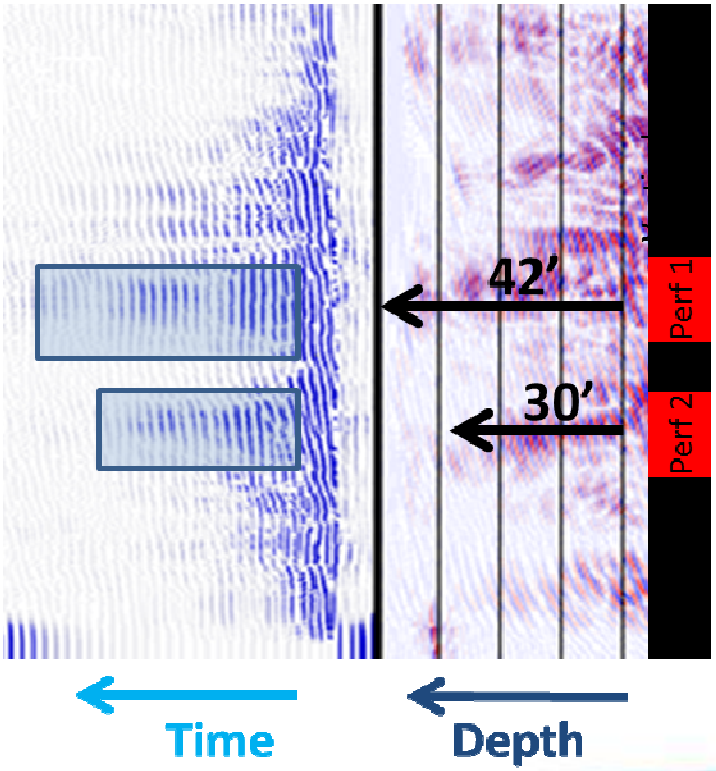
- High severity – High horizontal stress anisotropy
- Low severity – Low horizontal stress anisotropy

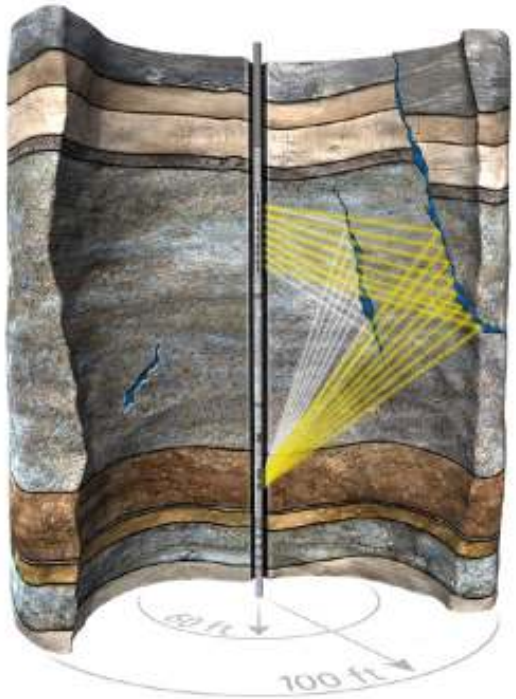
- We can know the horizontal stresses (using a geomechanical study) but,
  - What is the minimum stress contrast to guarantee that the tortuosity will be low?

- For these reasons, it is necessary to measure the tortuosity (microseismic, Acoustic logs, DSWI ..)

Deep Shear Wave Imaging to measure tortuosity

Post-Frac Deep Shear Images





Conclusions

- The mechanics gives us tools to model the IF.
- However, the main challenge is to measure the tortuosity, to validate / callibrate the models. We need to use more technology to guarantee high operational efficiency and low risks.

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Questions?
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