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Completions-Induced Casing Deformations in Unconventionals: What We Think We Know

Dr. Neal B. Nagel

OilField Geomechanics LLC

Casing Deformation Issues are NOT New!

- Production-related casing integrity issues (deformation and failure, "D&F") have been noted since the early part of the 20^{th} century at fields like *Wilmington* (Long Beach, CA) and the Venezuelan heavy oil fields along *Lake Maricaibo*.
- Localized, but significant, attention to casing D&Fs arose with the development of North Sea chalk fields (e.g., *Ekofisk* and *Valhall*) as well as the diatomite reservoirs in California (e.g., *Belridge*).
- The likely high-point of interest in production-induced D&Fs came with the development of *deepwater GoM* reservoirs.

Recent and Future Efforts

SPE Summit: Casing Deformation During Fracturing of Unconventional Wells – Online event, March 2021

COMMITTEE

Co-Chairpersons

Neal Nagel
OilField Geomechanics

George King
Viking Engineering

Committee Members

Adam Aylor
ExxonMobil

Alberto Casero
BP

Alex Crabtree
Oceaneering International, Inc.

Eric Davis
ConocoPhillips Global Wells

Roy Hathcock
Devon Energy

Terry Palisch
Carbo Ceramics

Martin Rylance
BP Russia

Recent and Future Efforts

SPE Casing Deformations Workgroup – under the SPE Well Integrity Technical Section

- Co-Leaders are Dan Dall'Acqua (Noetic) and Adam Aylor (ExxonMobil)
- **Draft Mission Statement**
  - Why? To reduce prevalence and impact of casing deformations in multi-fractured horizontal wells.
  - How? A) Capture current best practices; B) Identify technology gaps and define future opportunities; and C) Share and disseminate learnings

Casing Damage: Where and How Much?

- Most notable plays include: Montney (Canada), Vaca Muerta (Argentina) and Sichuan Basin (China)
- Also reported in:
  - Permian Basin
  - Eagle Ford
  - Australia

A common characteristic appears to be high formation shear stresses

Casing Damage: Where and How Much?

- Pipe ovaling from 6% to >>10%
- Deformation may continue longitudinally for inches or several hundred feet.
- Noted when…….
  1. Casing inspection in one set of **<u>NEW</u>** casing found 6%+ ovality <u>as delivered</u>.
  2. Frac Plug not pumped down to set point.
  3. Restrictions found when milling plugs.

Courtesy G. King

What: Casing Damage during Fracturing

When?

1. After the first 1 to 3 toe stages.
2. Any time in the frac - more so later in frac (# of cycles!).

Where? (common areas, other places as well)

1. Dog Legs in the bend and the lateral.
2. Usually above last frac zone (sometimes hundreds of feet above).

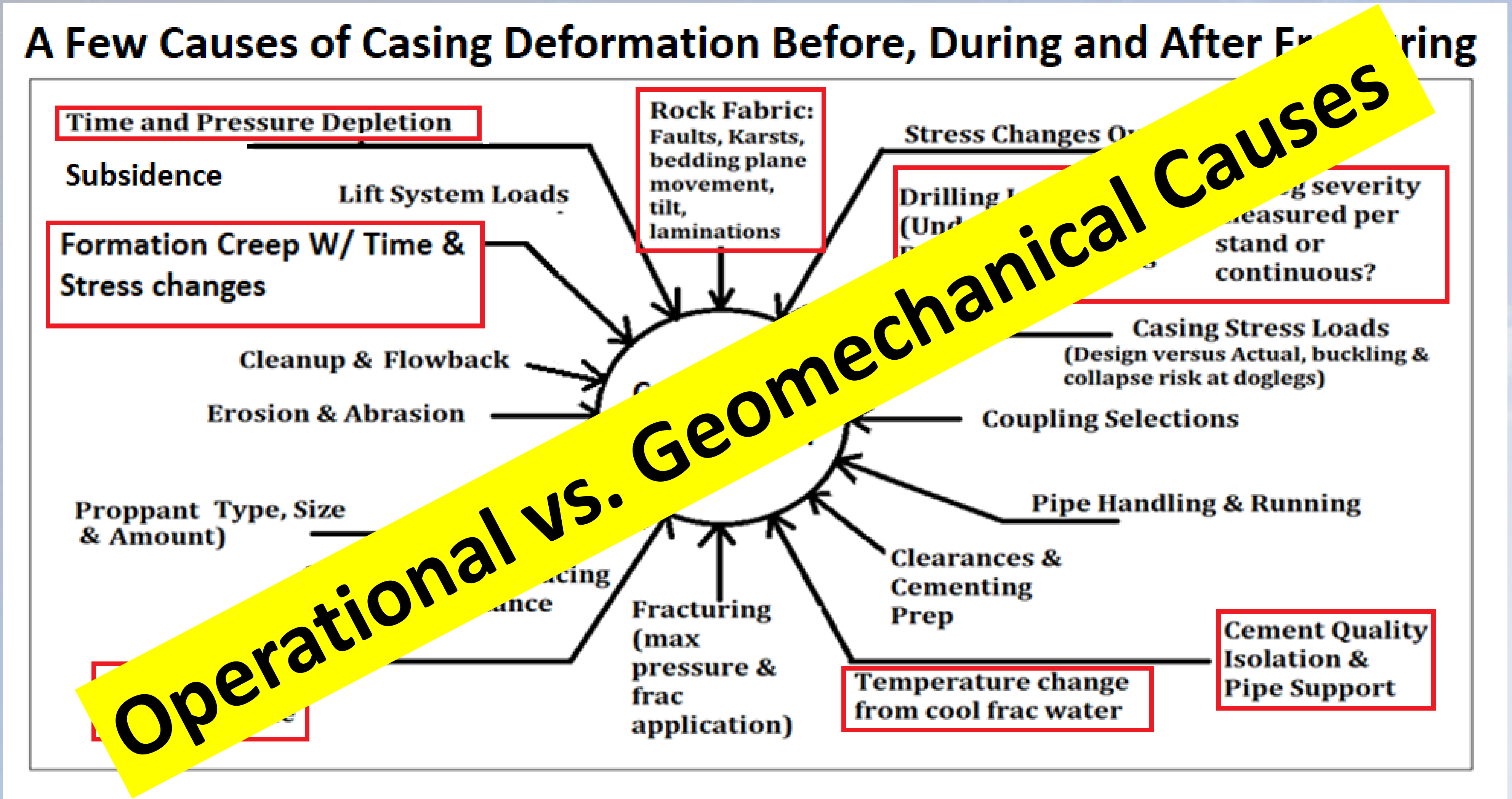
How?

- Design casing limits exceeded by Geological, Mechanical, Physical and Corrosion Events – and don't forget fatigue!

Why?

Courtesy G. King

A Few Causes of Casing Deformation Before, During and After Fracturing



Non-Uniform Loads (from any source) can influence deformation.

Courtesy G. King

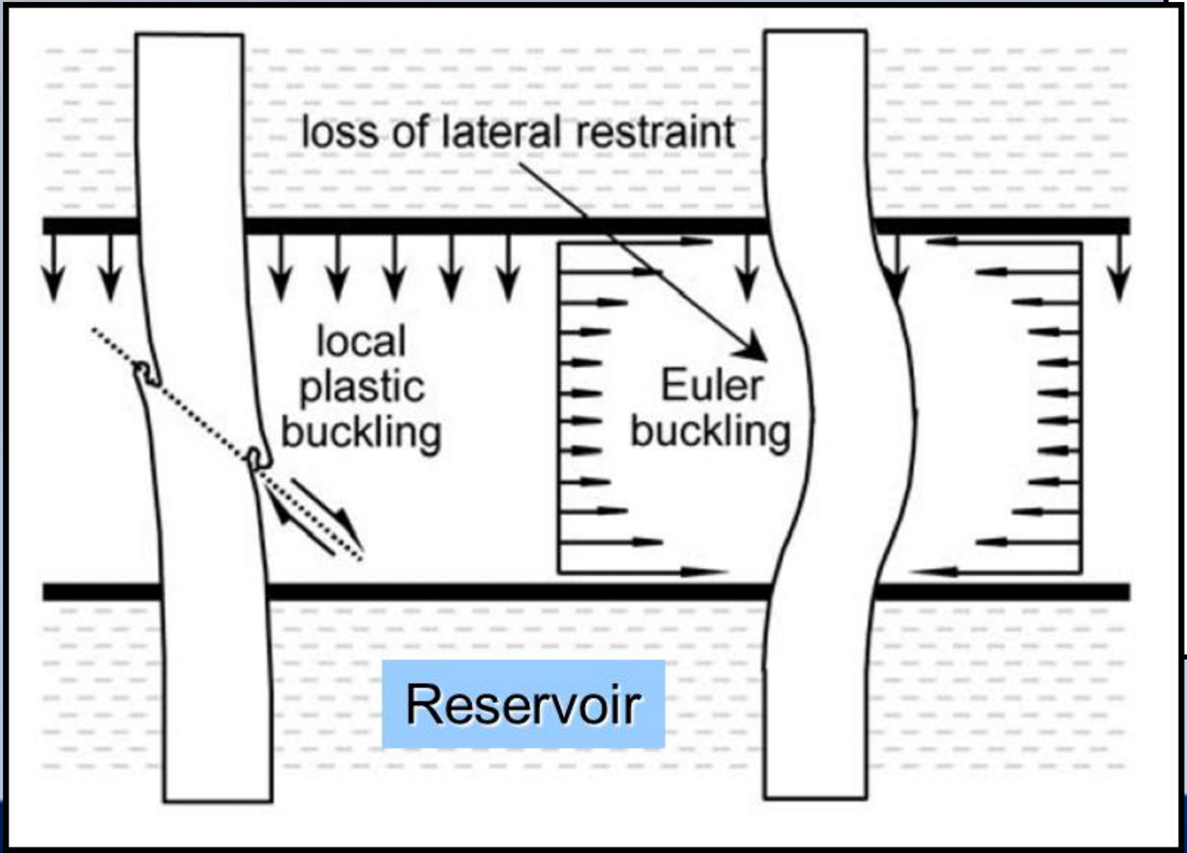
Consensus Forms of D&Fs

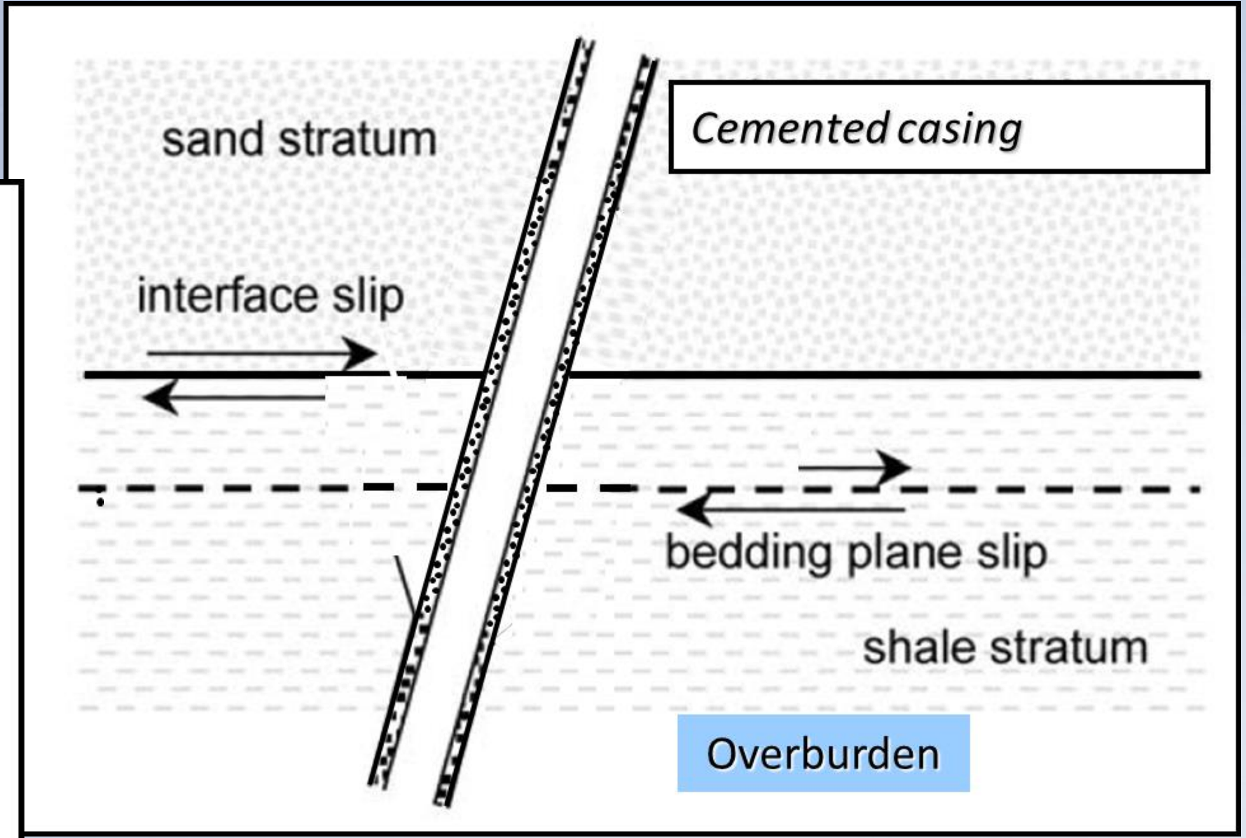
The seminal works on causes and forms of production-induced D&Fs come from Shell (several authors), ***M. Bruno and M. Dusseault***.

Four broad, primary D&Fs have been noted:

- Casing pressure related to thread damage or failure.
- Casing buckling related to reservoir compaction.
- Casing shear related to localized movement (e.g., faults).
- Casing shear related to weak-plane slip (e.g., bedding plane failure).

Consensus Forms of D&Fs

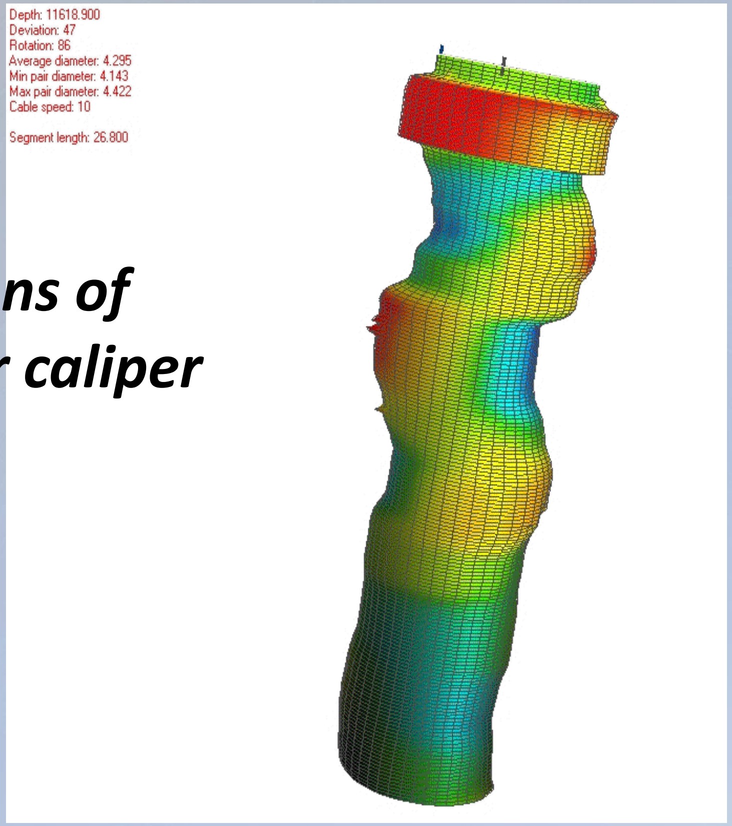




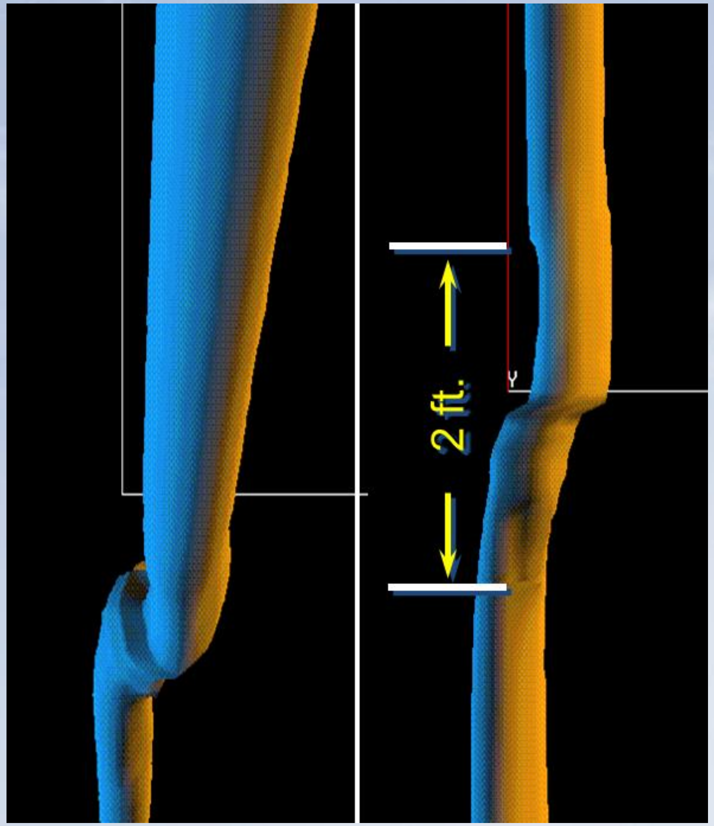
After Dusseault, et al., 2001

Consensus Forms of D&Fs

Visualizations of multi-finger caliper results



Casing Buckle



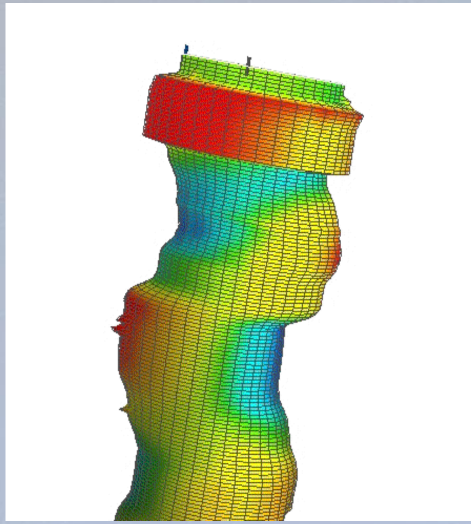
Casing Shear

Common Solutions to D&Fs

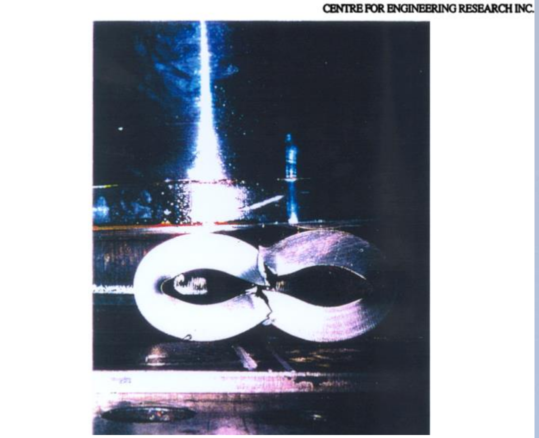
The existing solutions to D&Fs include:

- Slip devices in the compacting portion of a reservoir (for buckling failure).
- High-strength, heavy wall casing (buckling and shear failure).
- Foam-type cements that “flow” around a wellbore (shear failure).
- Underreaming (shear failure).
- High-strength threads/couplings (tensile-type failures).

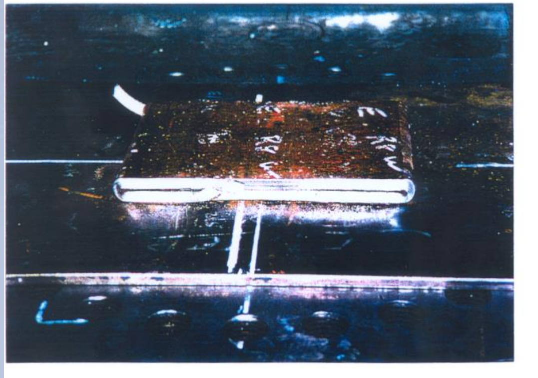
Common Solutions to D&Fs

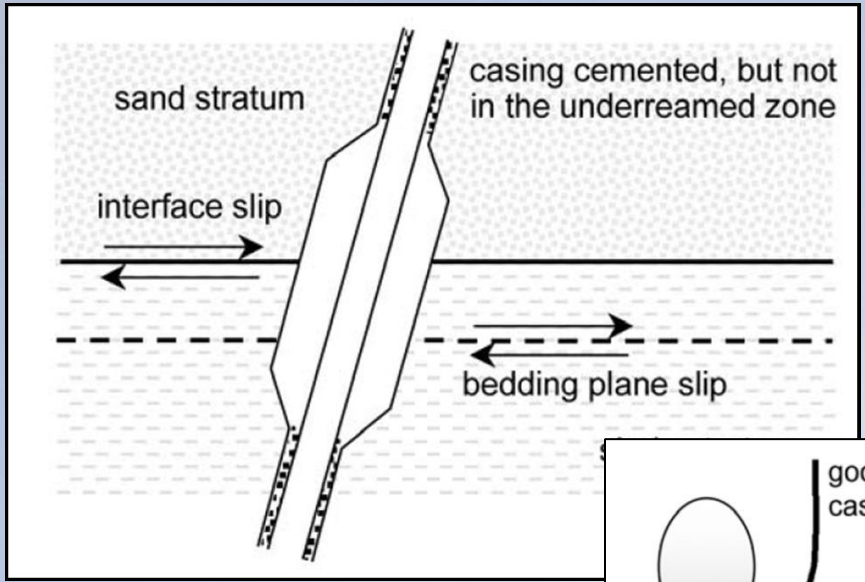


Slip Device



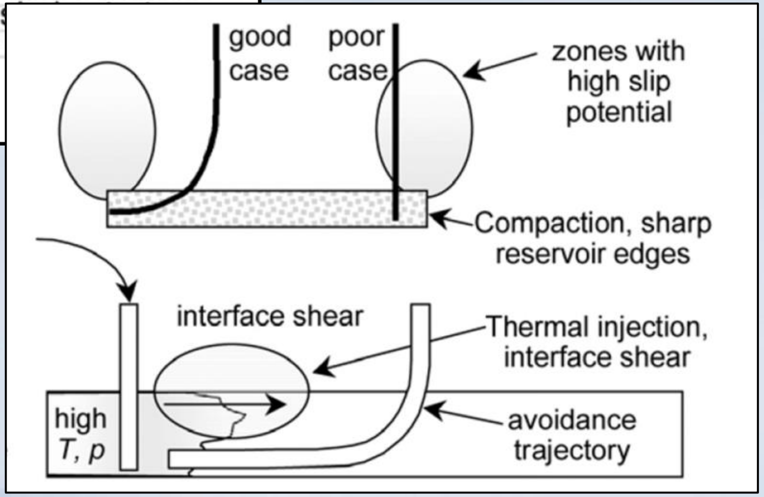
Heavy wall pipe





Underreaming

Avoidance



After Dusseault, et al., 2001

Geomechanics of Casing Deformations

What is Geomechanics?

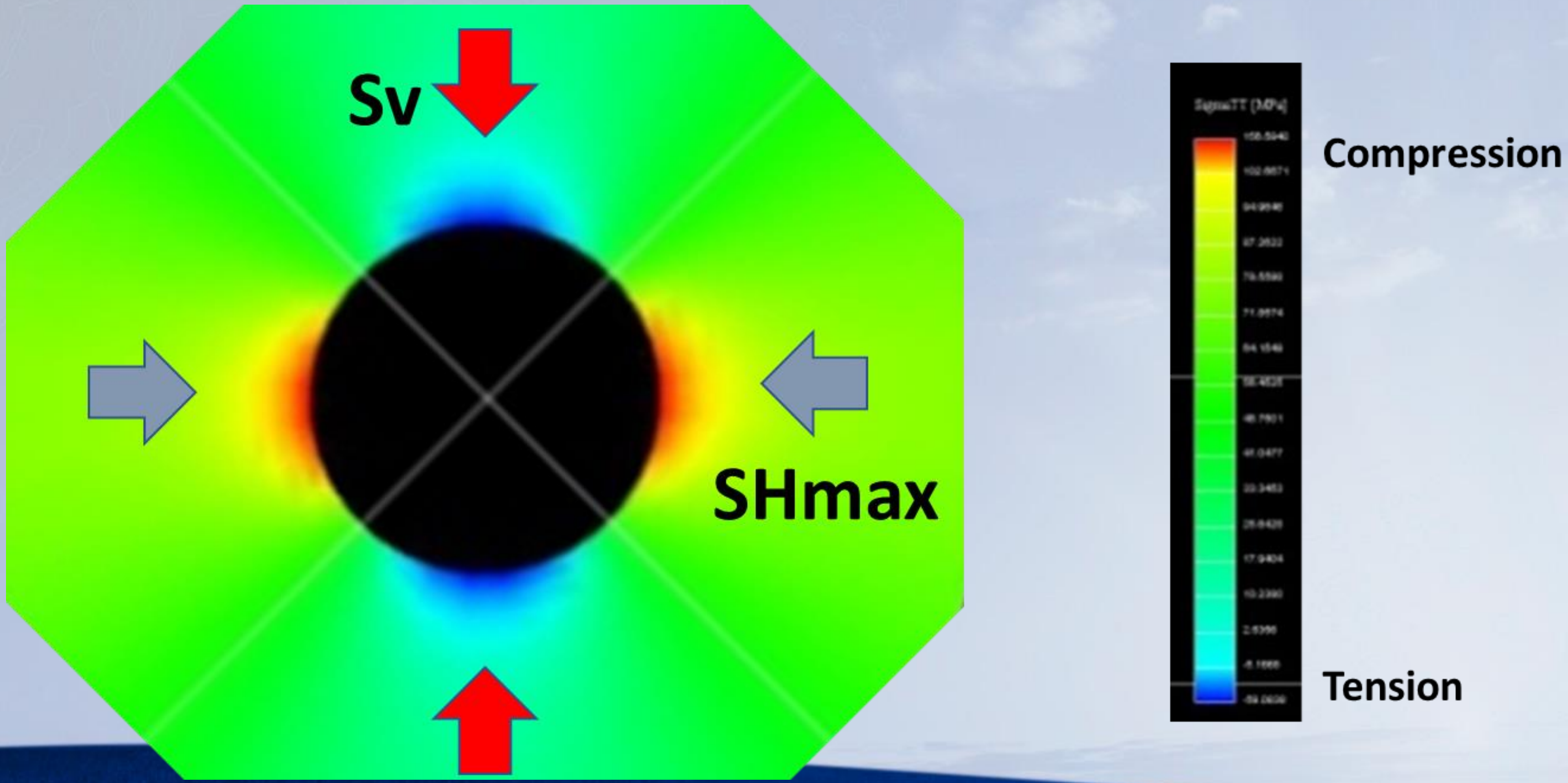
Geomechanics is the engineering evaluation of the behavioral response of rock to:

- *Stress* and stress changes (total and/or effective)
- Pore *pressure* and pressure changes (via effective stresses)
- *Mechanical properties* (deformation and strength)
- *Geometry*

Modifiers: Temperature and chemistry

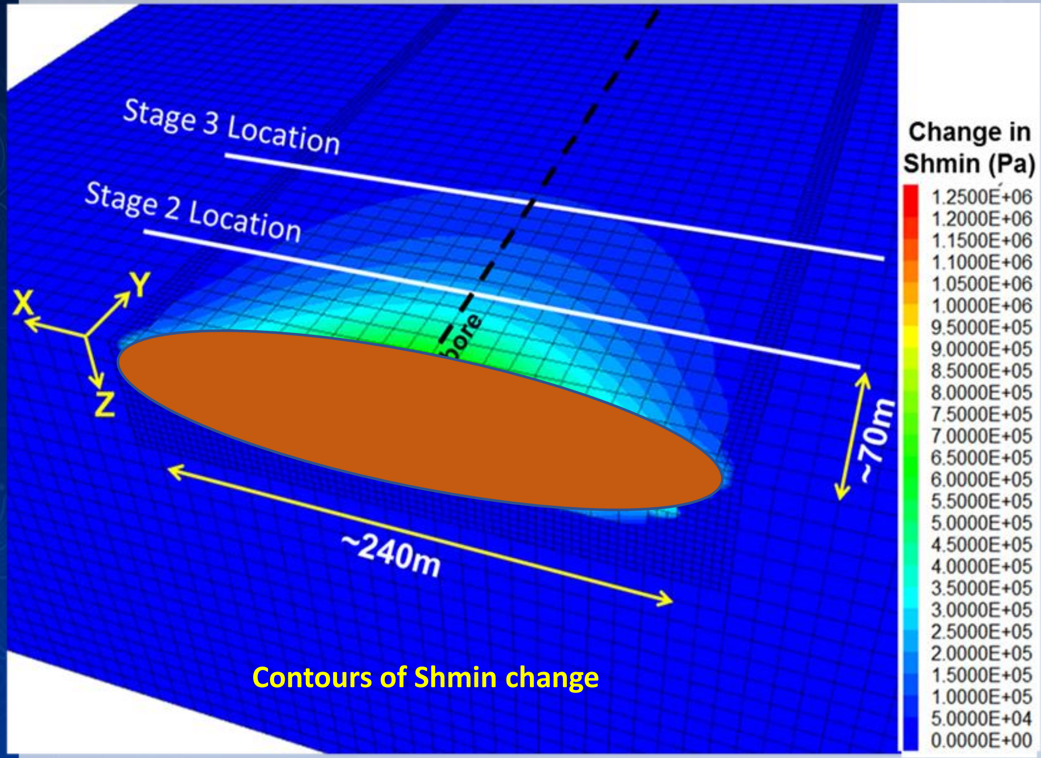
Stress Changes in Unconventionals

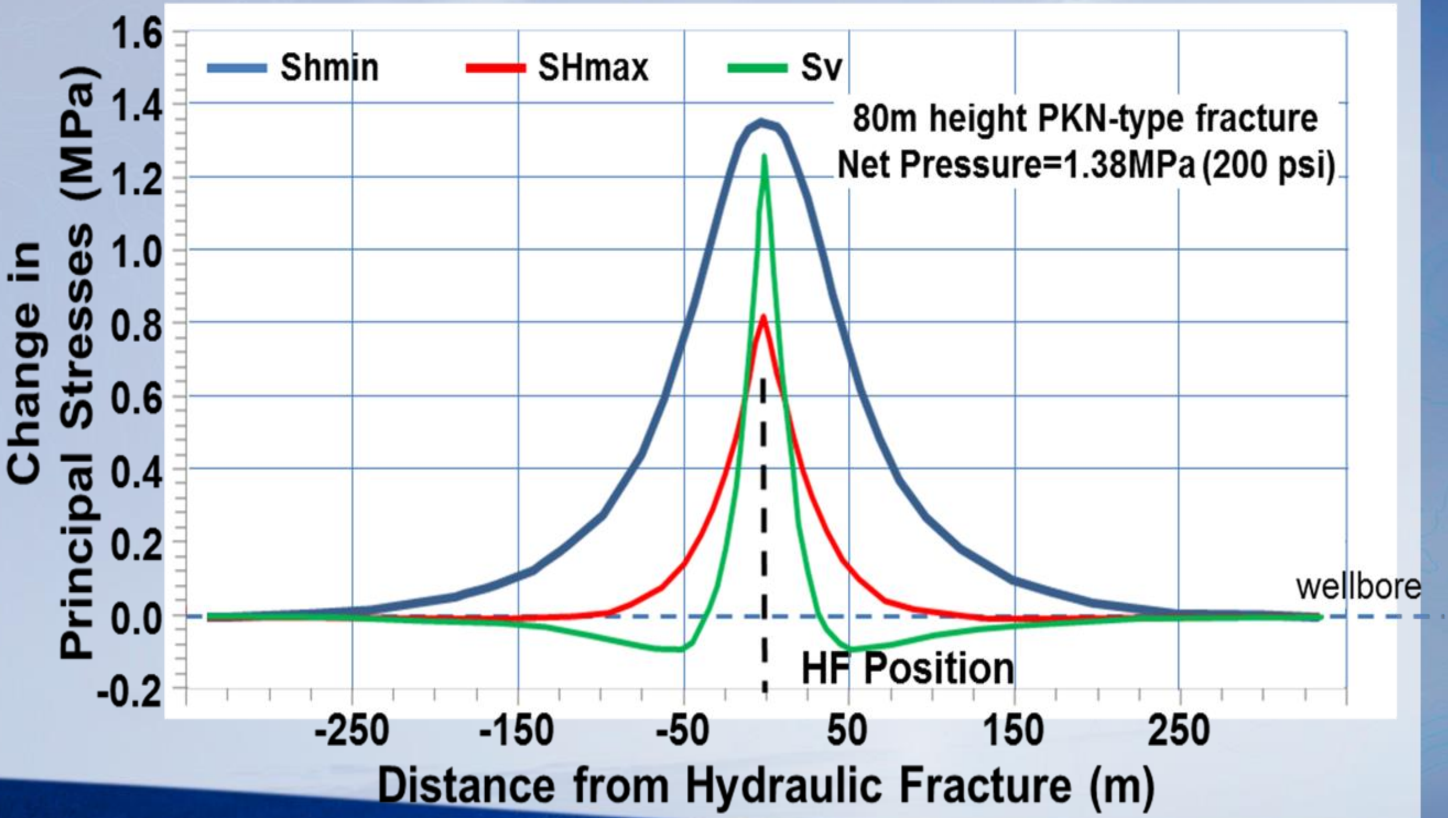
Stresses around a wellbore and perforations:



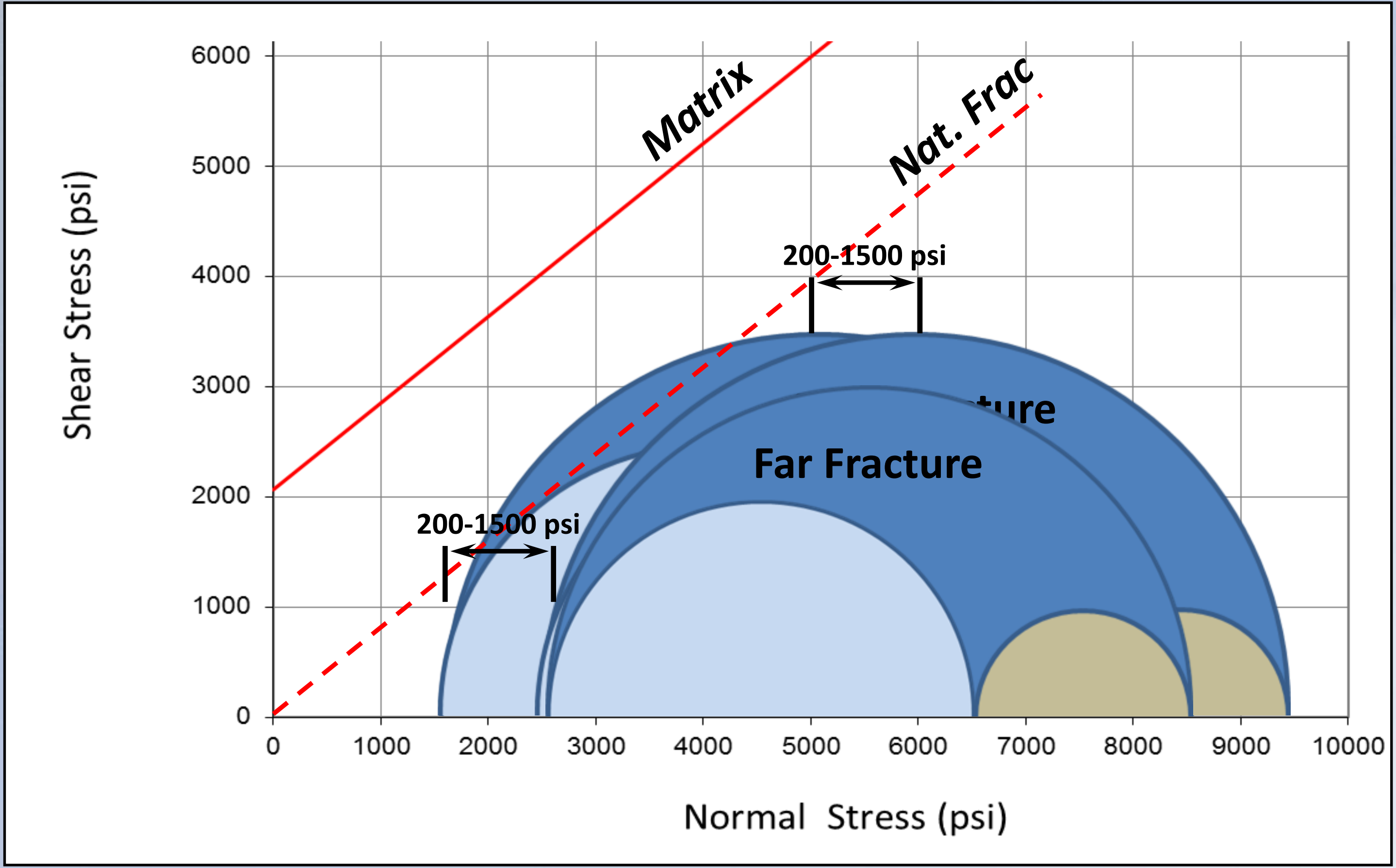
Stress Changes in Unconventionals

Stress Shadows from a single hydraulic fractures:



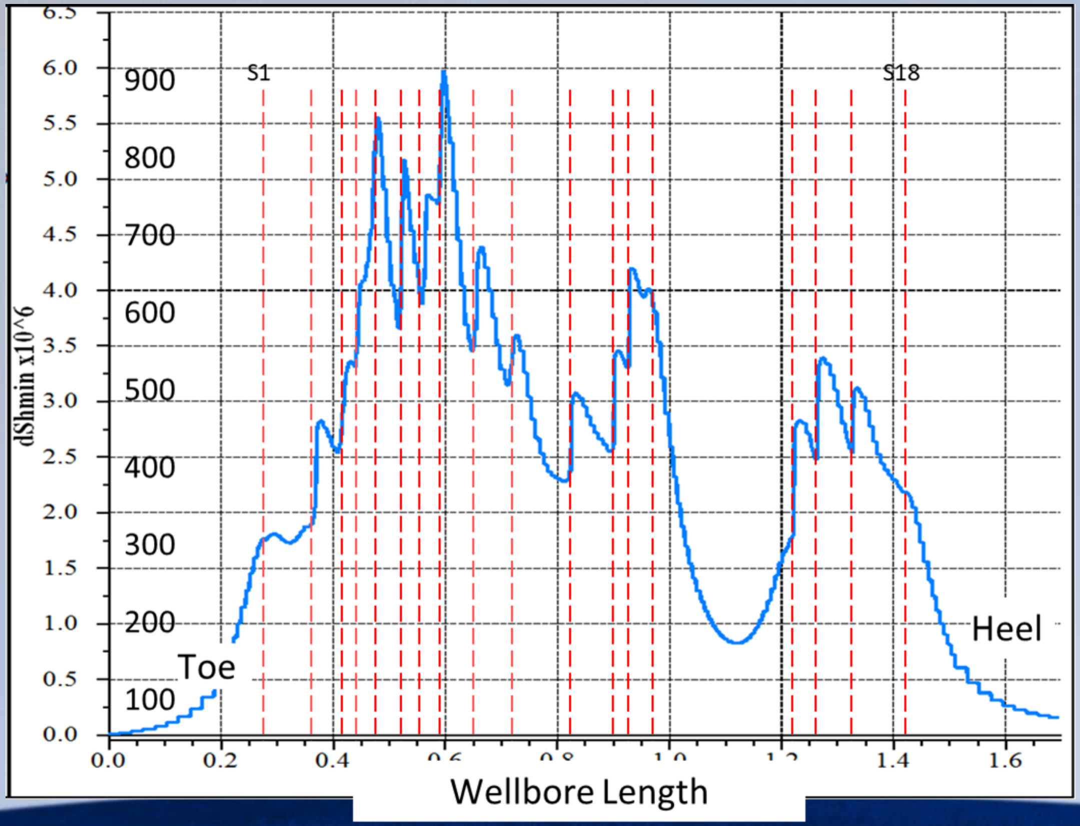


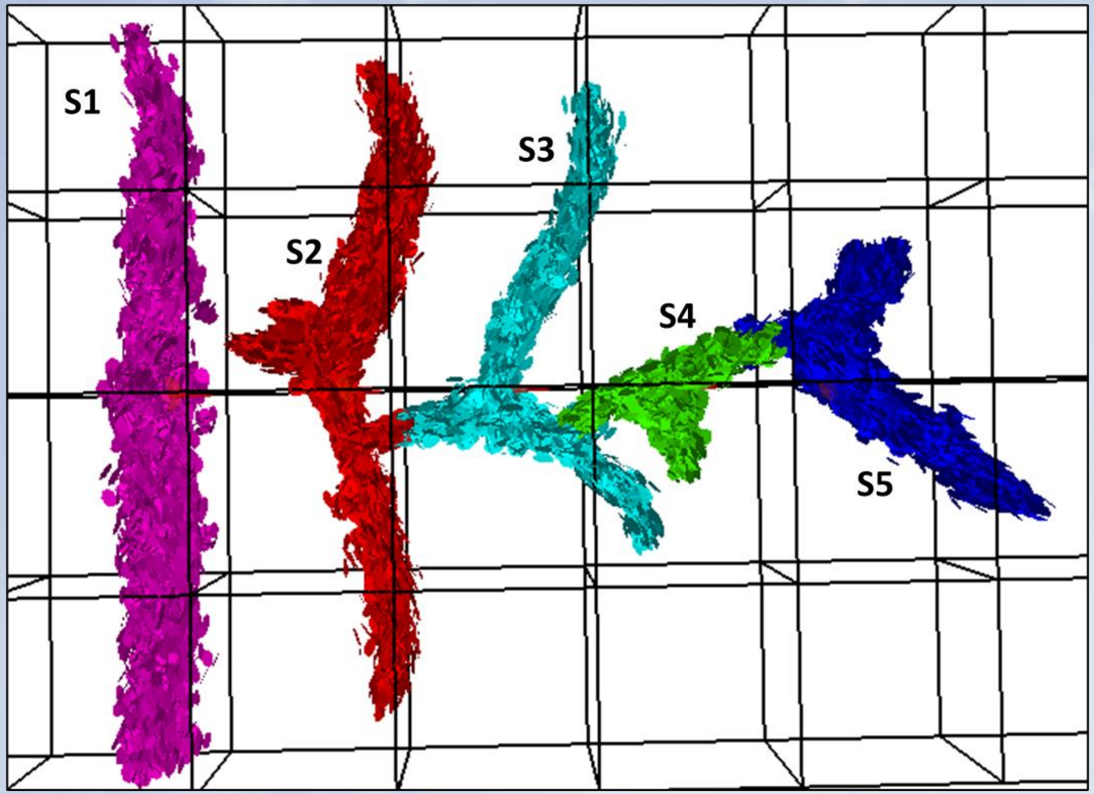
Stress Changes Around HFs



Stress Changes in Unconventionals

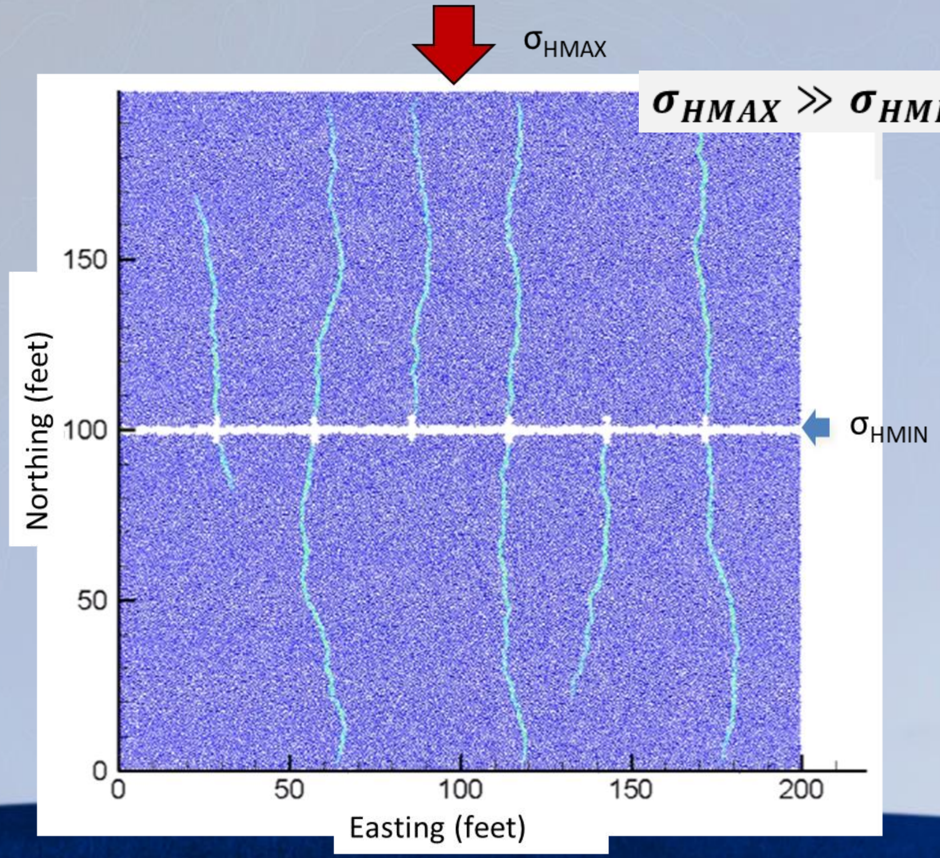
Stress Shadows from multiple hydraulic fractures:

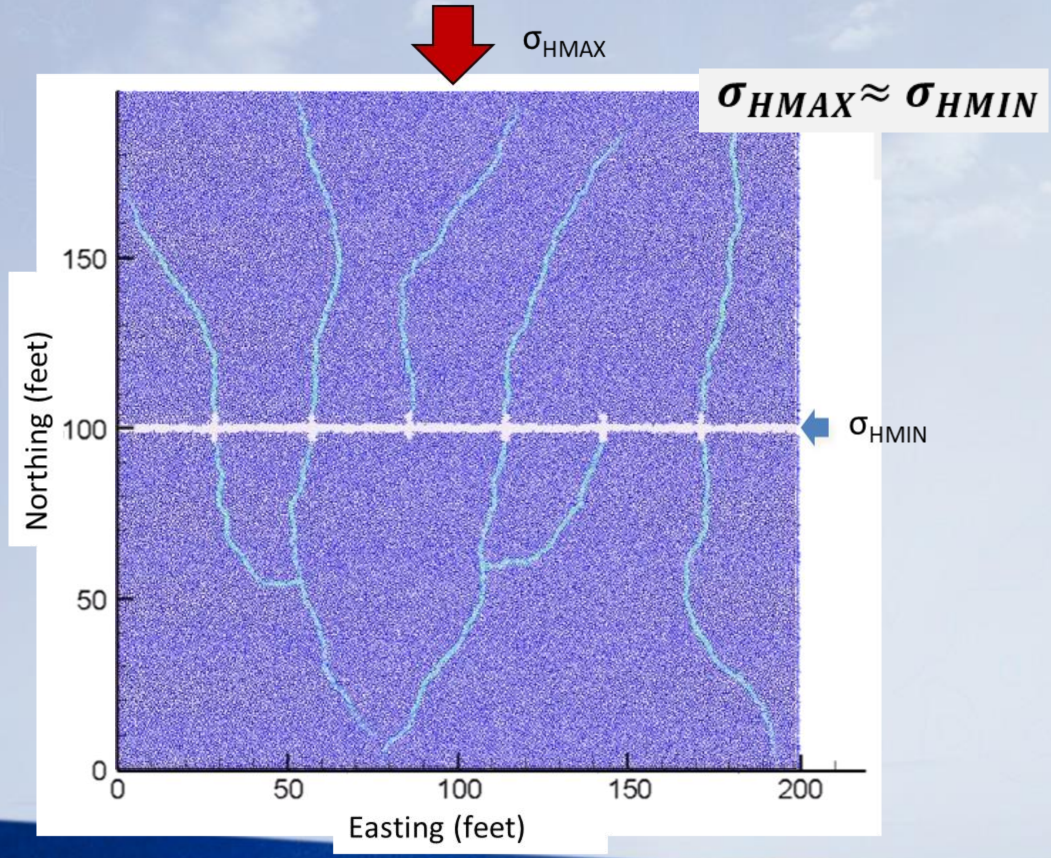




Stress Anisotropy in Unconventionals

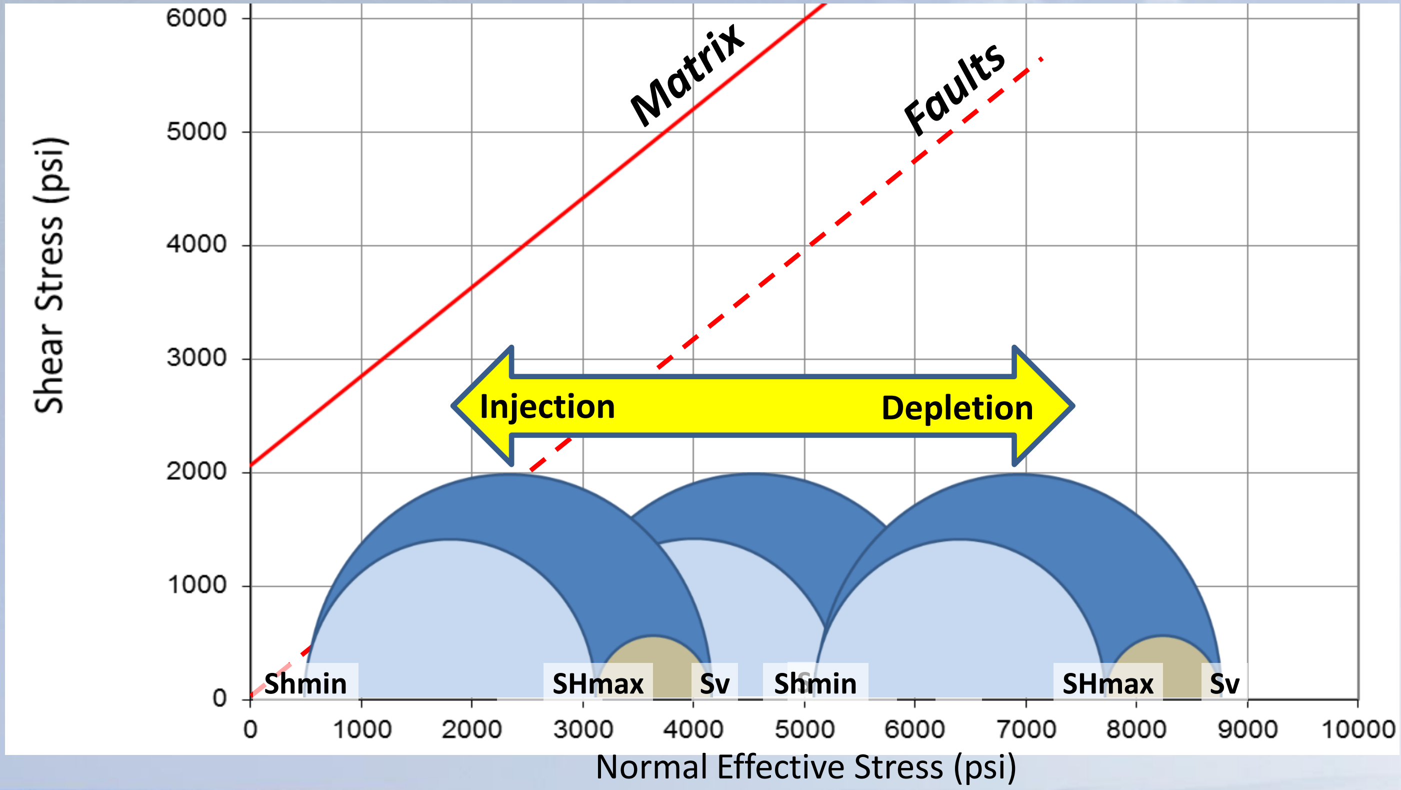
HF Orientation With Stress Anisotropy:





Pressure Changes in Unconventionals

Pressure effects during injection and production:



Pressure Changes in Unconventionals

Pressure depletion effects during production:

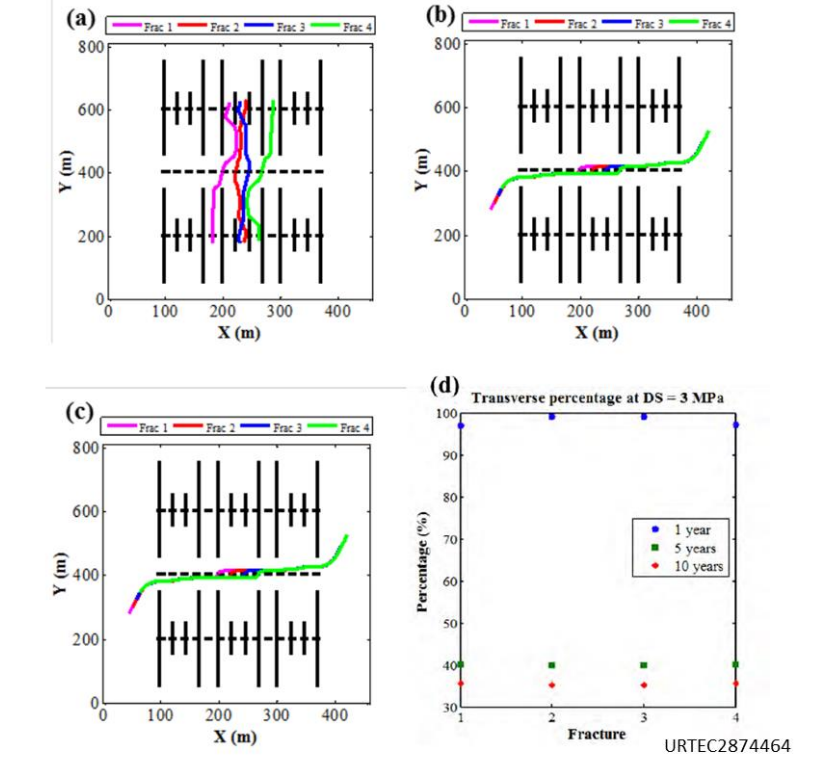


Figure 17: Infill well fracture propagation paths in the non-uniform geometry model after legacy production in parent wells for (a) 1 year, (b) 5 years, and (c) 10 years with differential stress of 3 MPa; (d) the transverse percentages of infill well fractures; infill well fractures are individually modeled

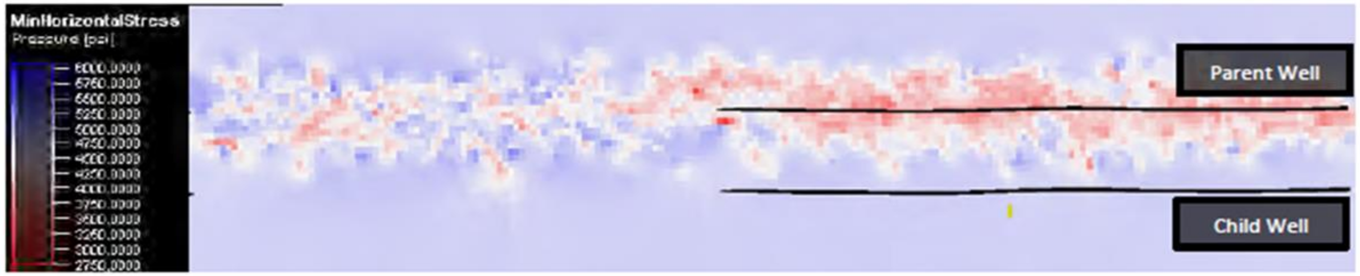


Fig. 45—Minimum horizontal stress change around the parent wellbore calculated through finite element simulation.

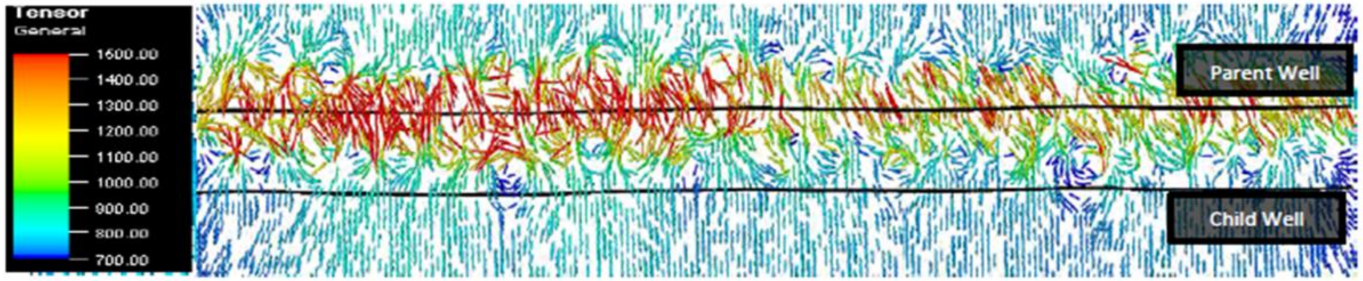


Fig. 46—Maximum horizontal stress direction around the parent wellbore calculated through finite element simulation.

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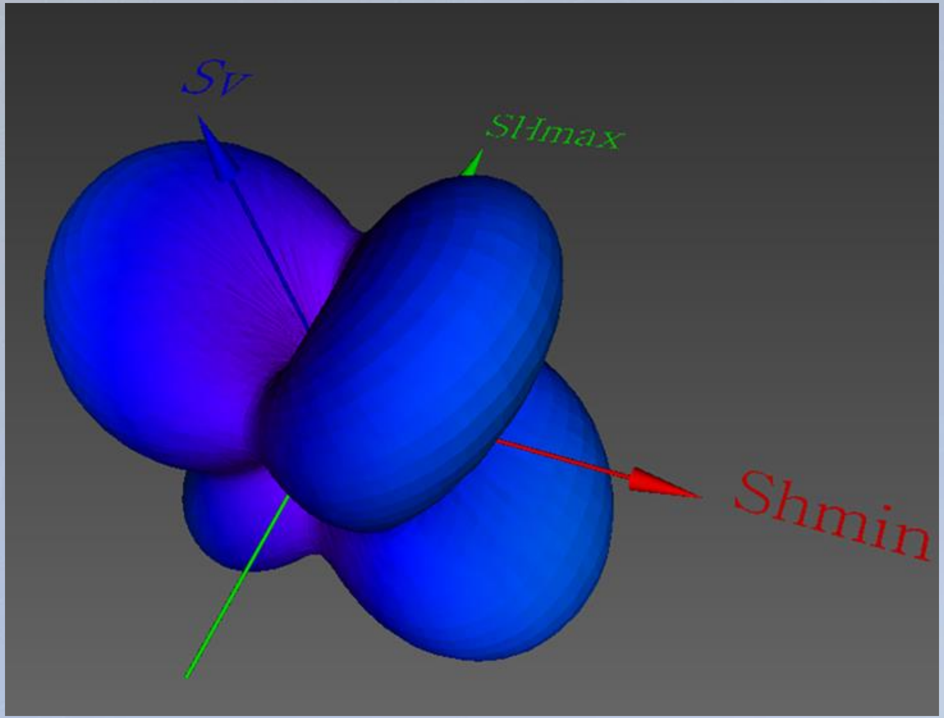
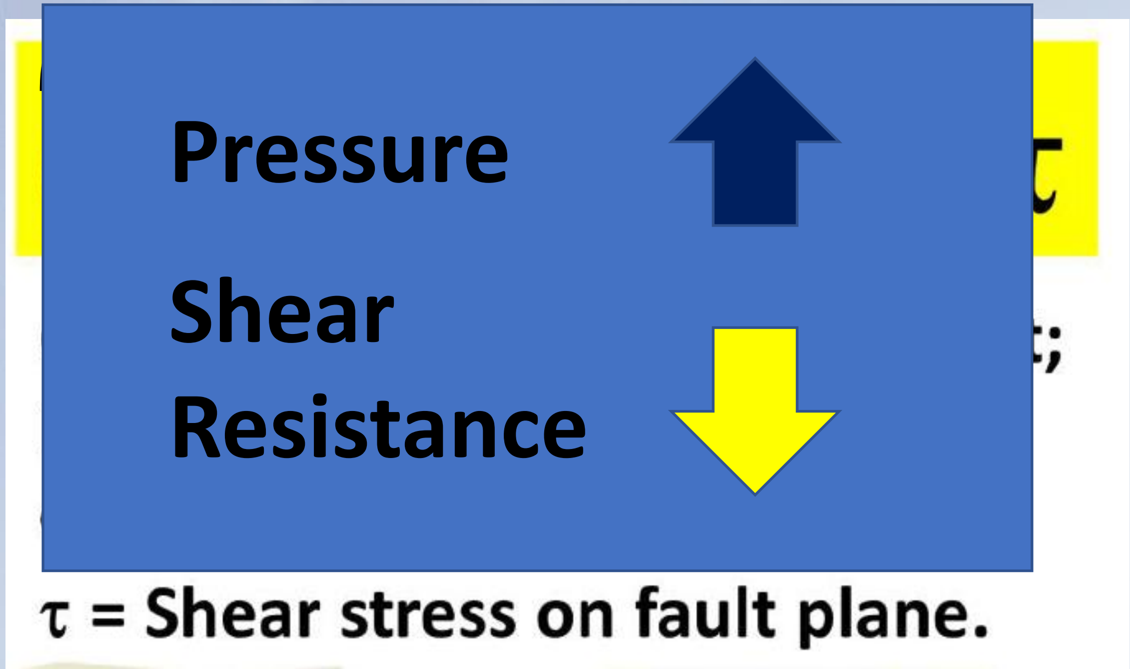
Pressure Changes in Unconventionals

Pressure increases during hydraulic fracturing:



Shear stresses are unaffected by pressure changes

Shear Resistance (SR)

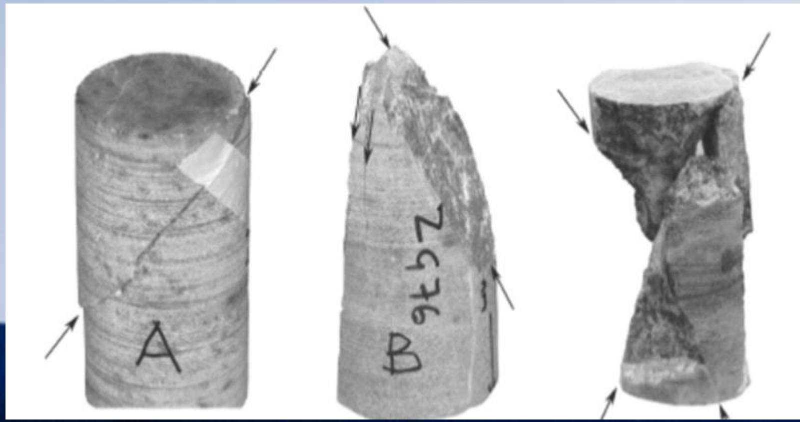


Mech. Prop. Changes in Unconventionals

Formation temperature effects:

Temperature	Stress	Pressure
Increase ↑	↑	↑
Decrease ↓	↓	↓

Chemical effects, particularly on shales:

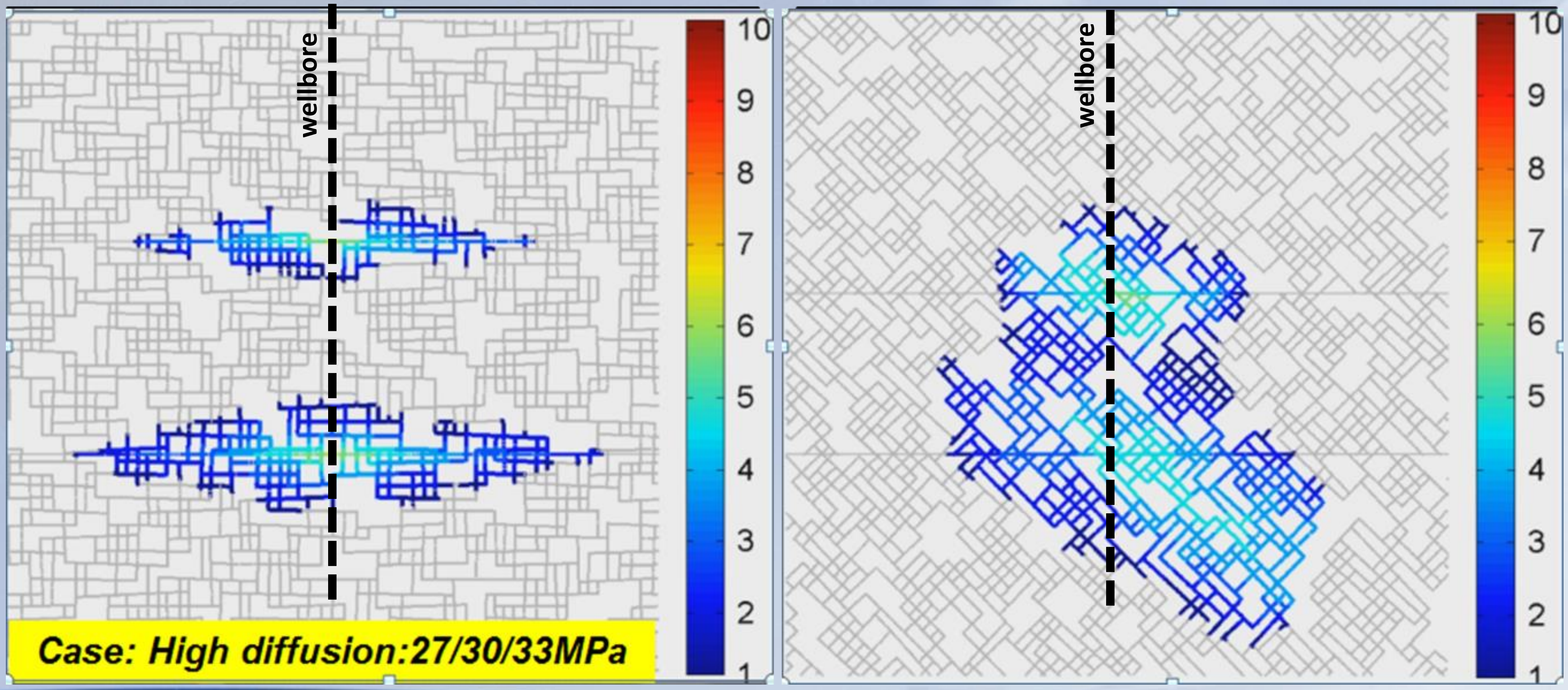


Aqueous effects ↑

Shear Resistance ↓

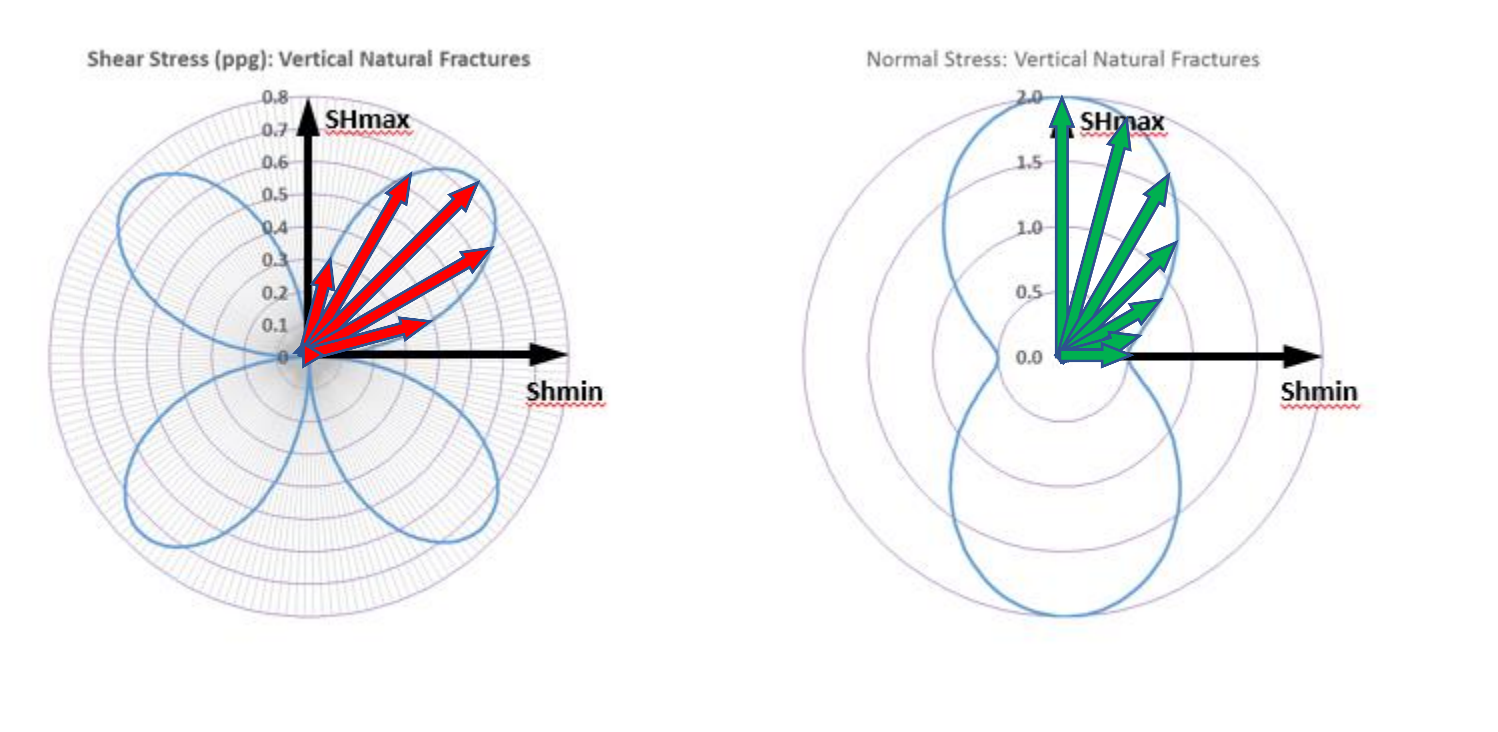
Geometry Issues in Unconventionals

Wellbore and fabric orientation to the stress field:



Geometry Issues in Unconventionals

Orientation of the wellbore and structural features (e.g., faults) in the stress field:



Geomech. Considerations for Casing Def.

- *Must* start by excluding thermal/pressure/cement/dogleg/casing quality effects. This *may not* be trivial.
- While not dispositive, the *major portion* of deformation events appear to be in *high shear stress* environments. This suggests a probability ranking based upon stress environment.
- The focus then, at least initially, should be on causes and drivers for formation shear failure – both local (within the lateral) and far-away (within the build section).