The Bakken Shale Forum
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EERC RPSEA

Bakken Completion Challenges

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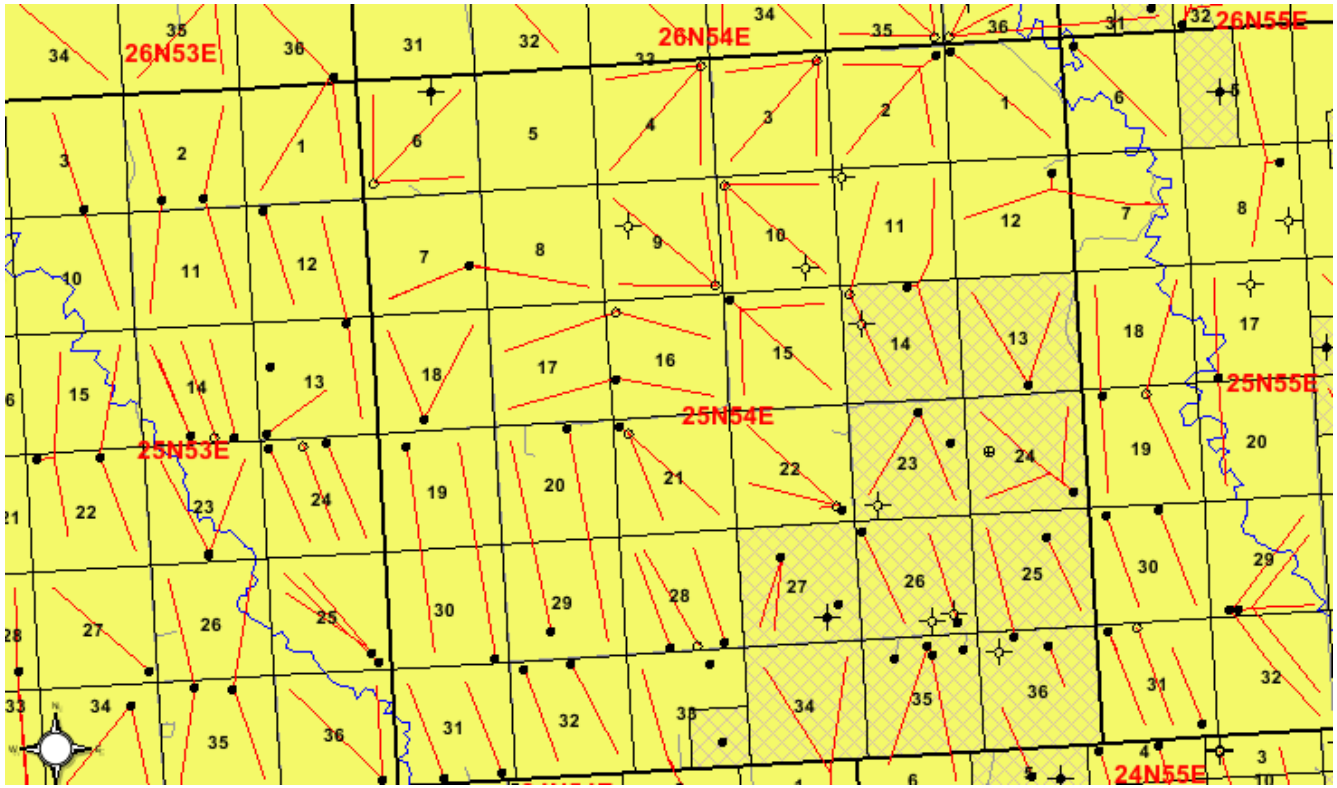
Scope of Discussion

- Horizontal Wellbore
  - Azimuth
  - Length
  - Placement
- Hydraulic Fracture
  - Conductivity
  - Diversion
  - Treatment Volume

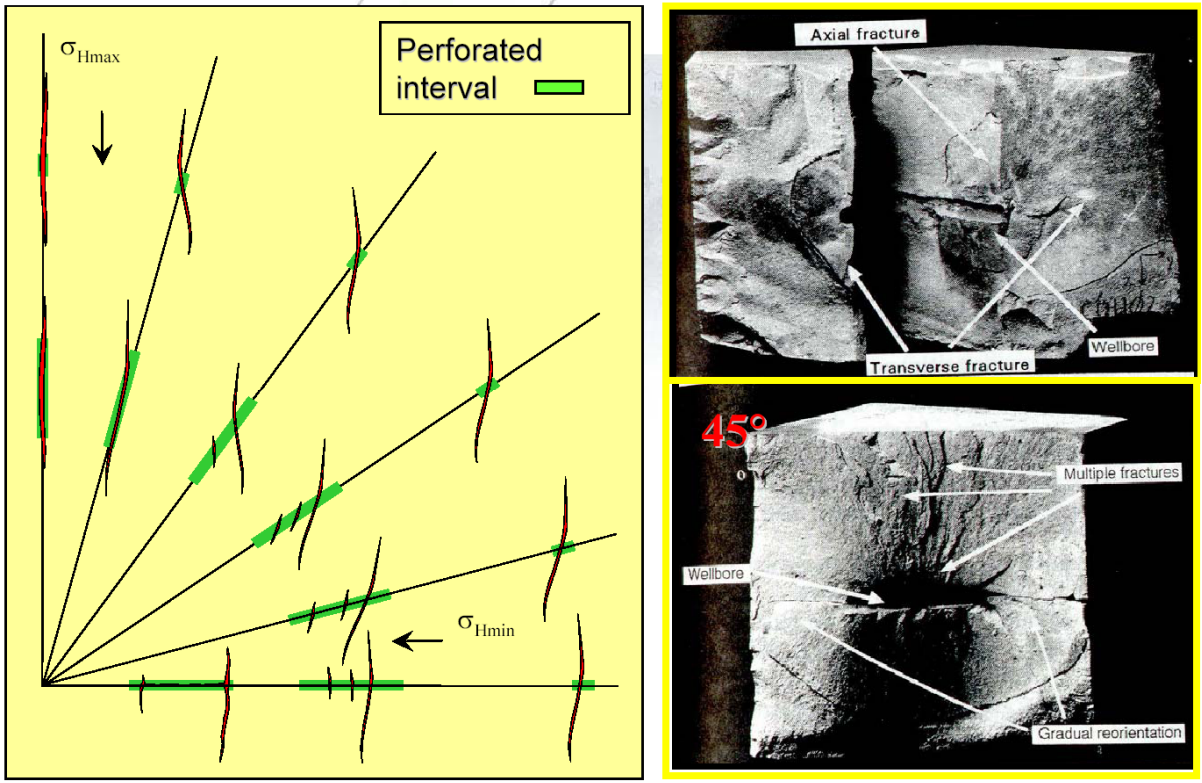
Horizontal Wellbore Azimuth

- What is the Optimum Azimuth?
  - Is Permeability Isotropic?
    - Azimuth of k_x,k_y, and k_z
  - Is Permeability Heterogeneous?
    - Matrix
      - Depositional
      - Secondary
    - Natural Fractures
      - Azimuth
      - Dip

Which is Best?

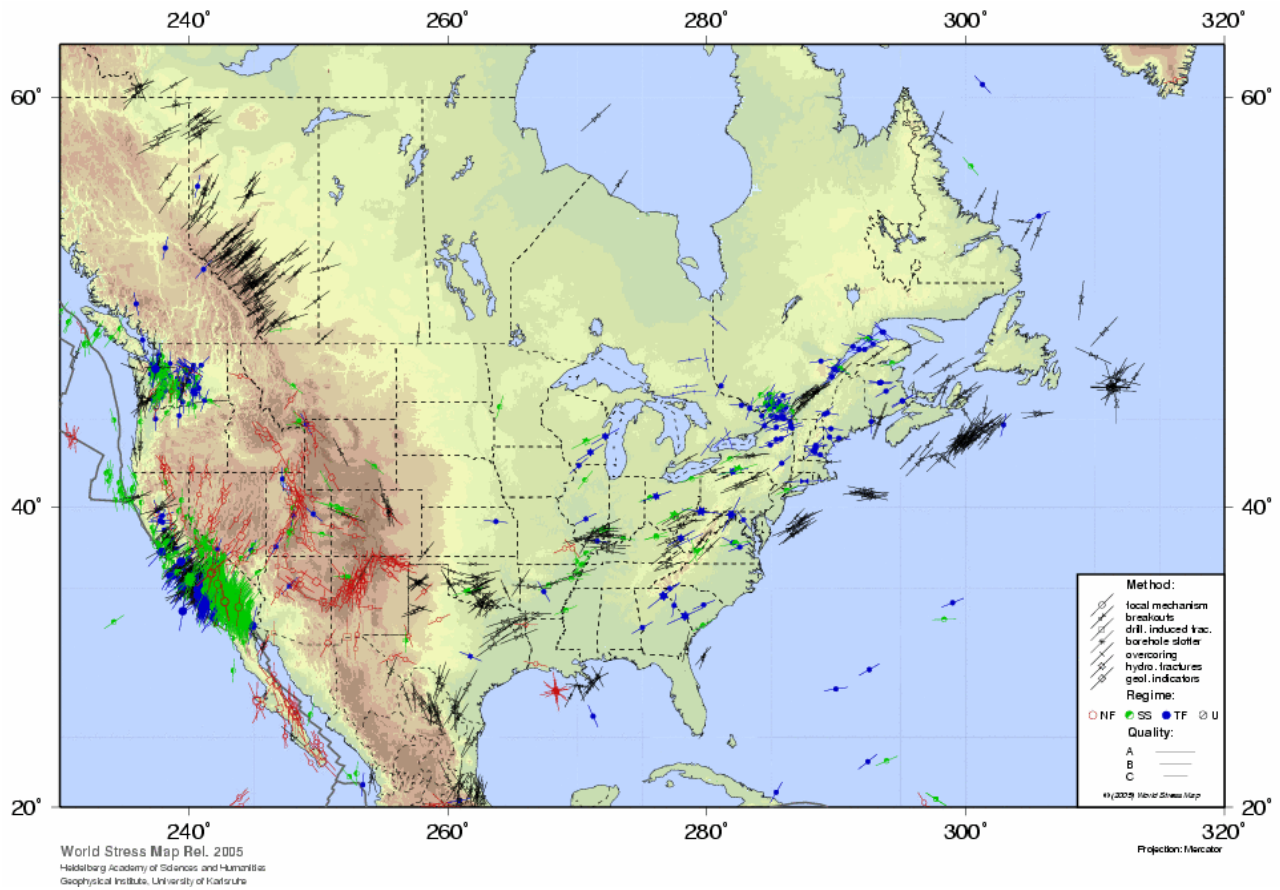


Fracture Initiation and Intersection with Wellbore Depend on Azimuth



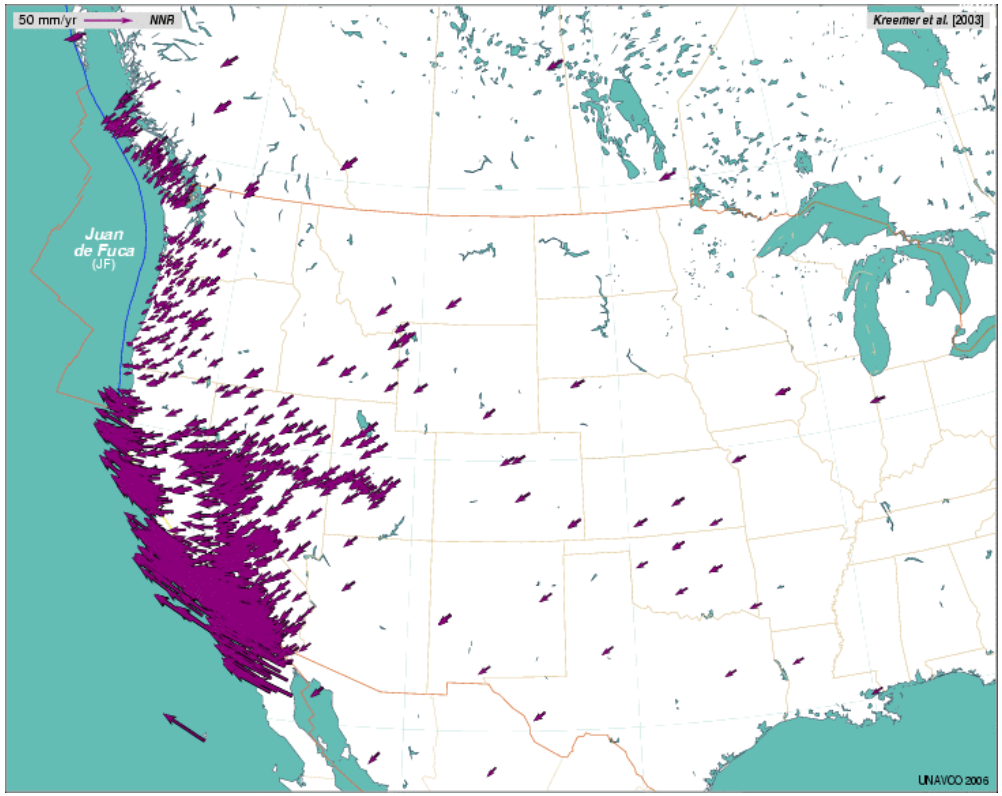
Source: Production Enhancement in Russian Oil and Gas Fields utilizing Horizontal, Sidetrack, Extended Reach and Multilateral wells, ATW 3-6 Feb-2006, Moscow

Tectonic Stress Maps



Source: www.world-stress-map.org

North American Strain Map

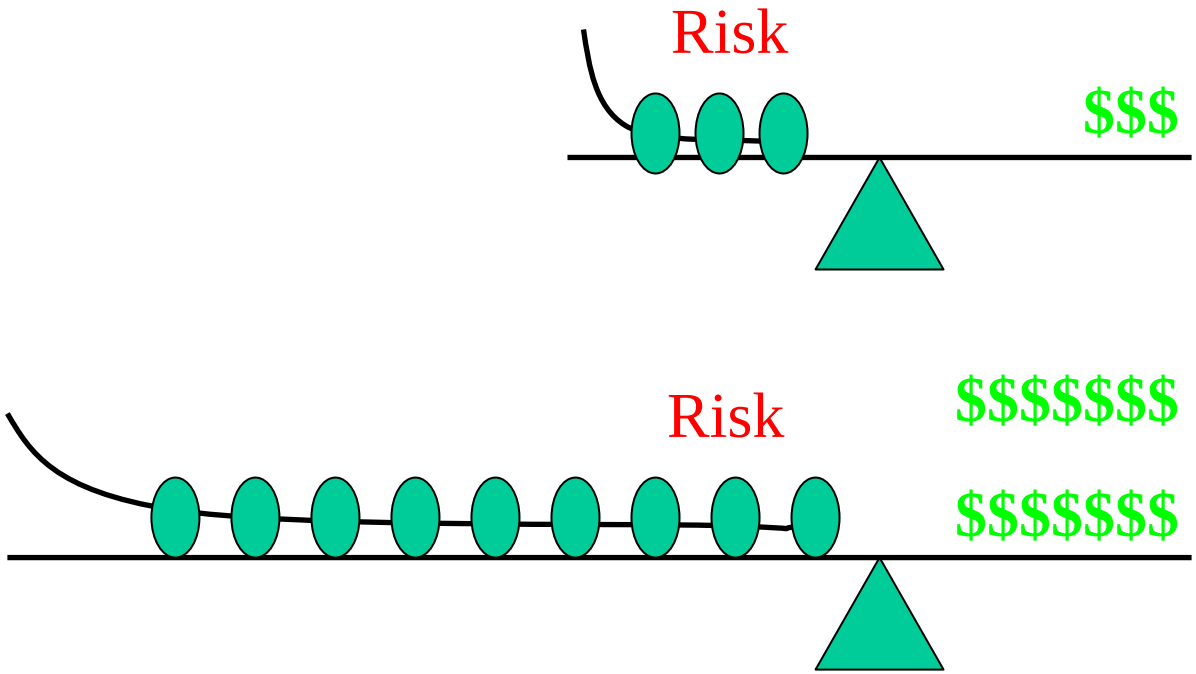


Horizontal Wellbore Length

- What is the Optimum Length?
  - Reservoir Permeability
    - Maximum Permeability Azimuth
    - Minimum Permeability Azimuth
  - Technological Limits
    - Drilling
    - Stimulation
  - Economic Limits
  - Spacing Limits

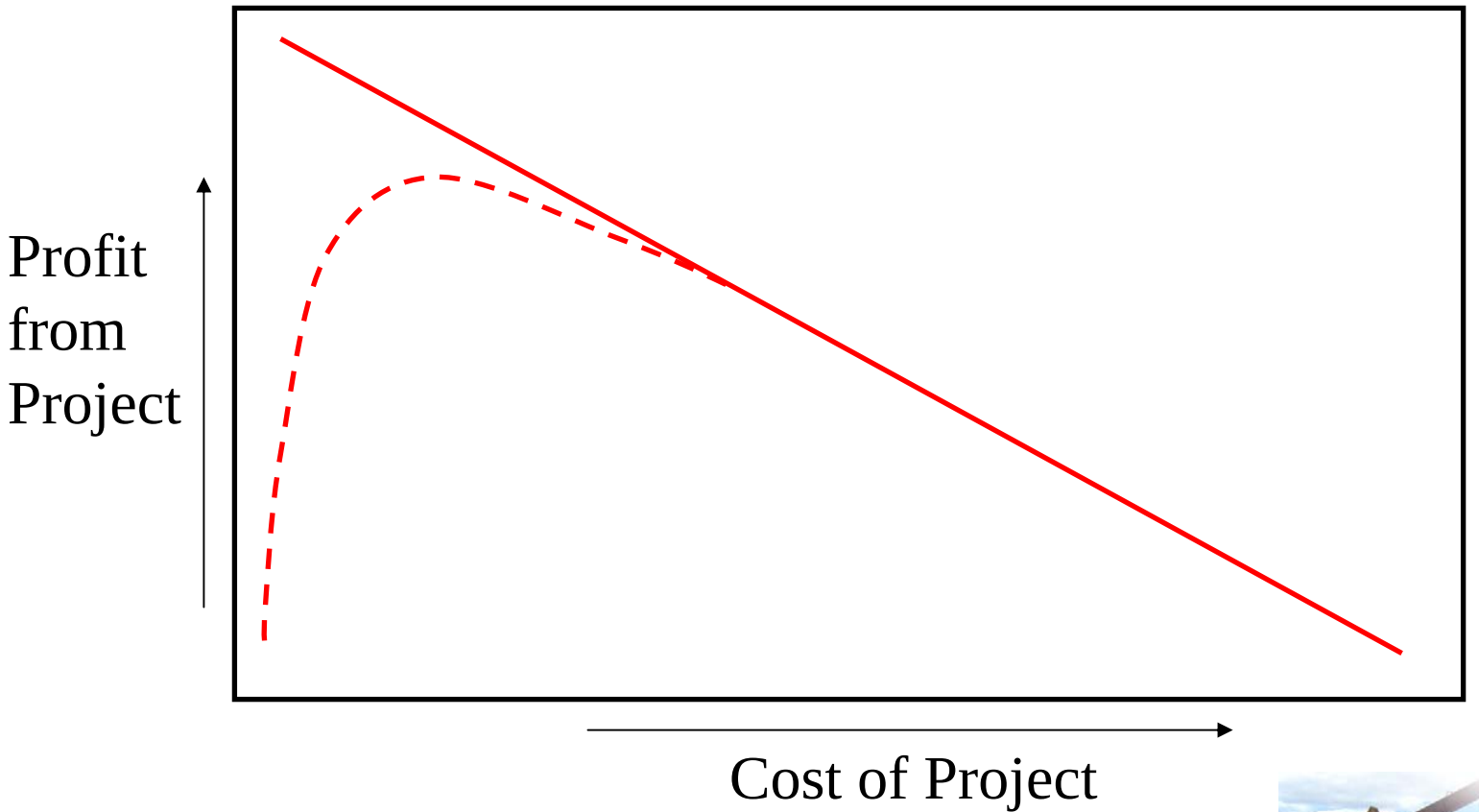
Economics Versus Technology

Technology Viewed as Cost



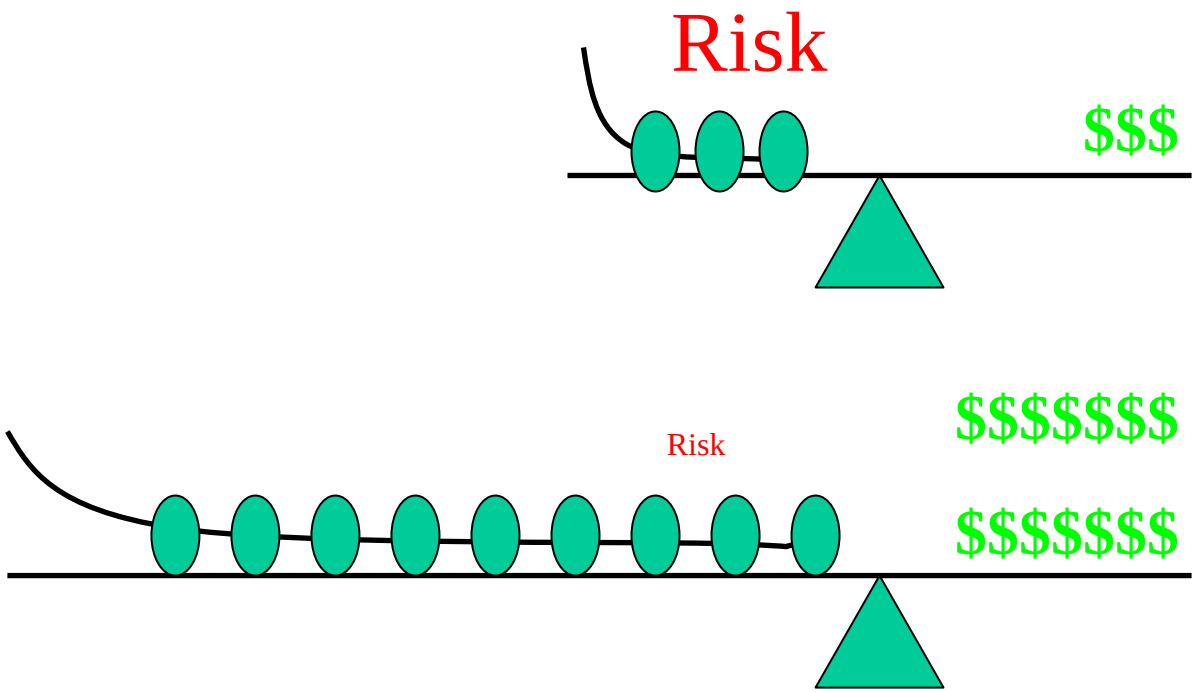
Investment + Action + Magic Happens = Profitable Well

Cost Versus Profit Model



Economics Versus Technology

Effective Technology Viewed as Risk Mitigation

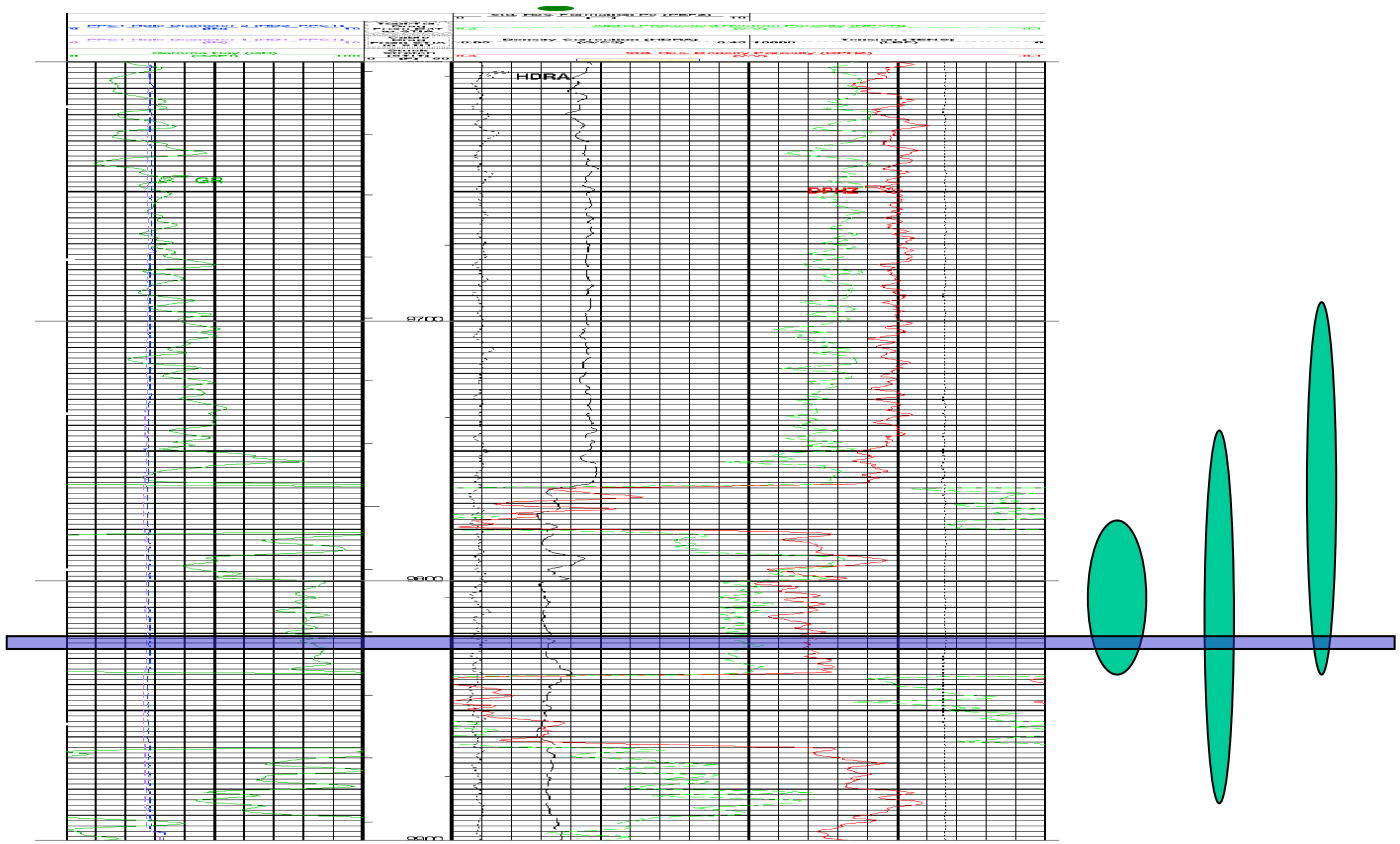


Investment + Reduced Risk + Action = Profitable Well

Wellbore Placement

- What is the Optimum Vertical Placement?
  - Best Quality Pay?
  - Fracture Initiation Point?
  - Vertical Reservoir Permeability?

Optimum Lateral Placement?

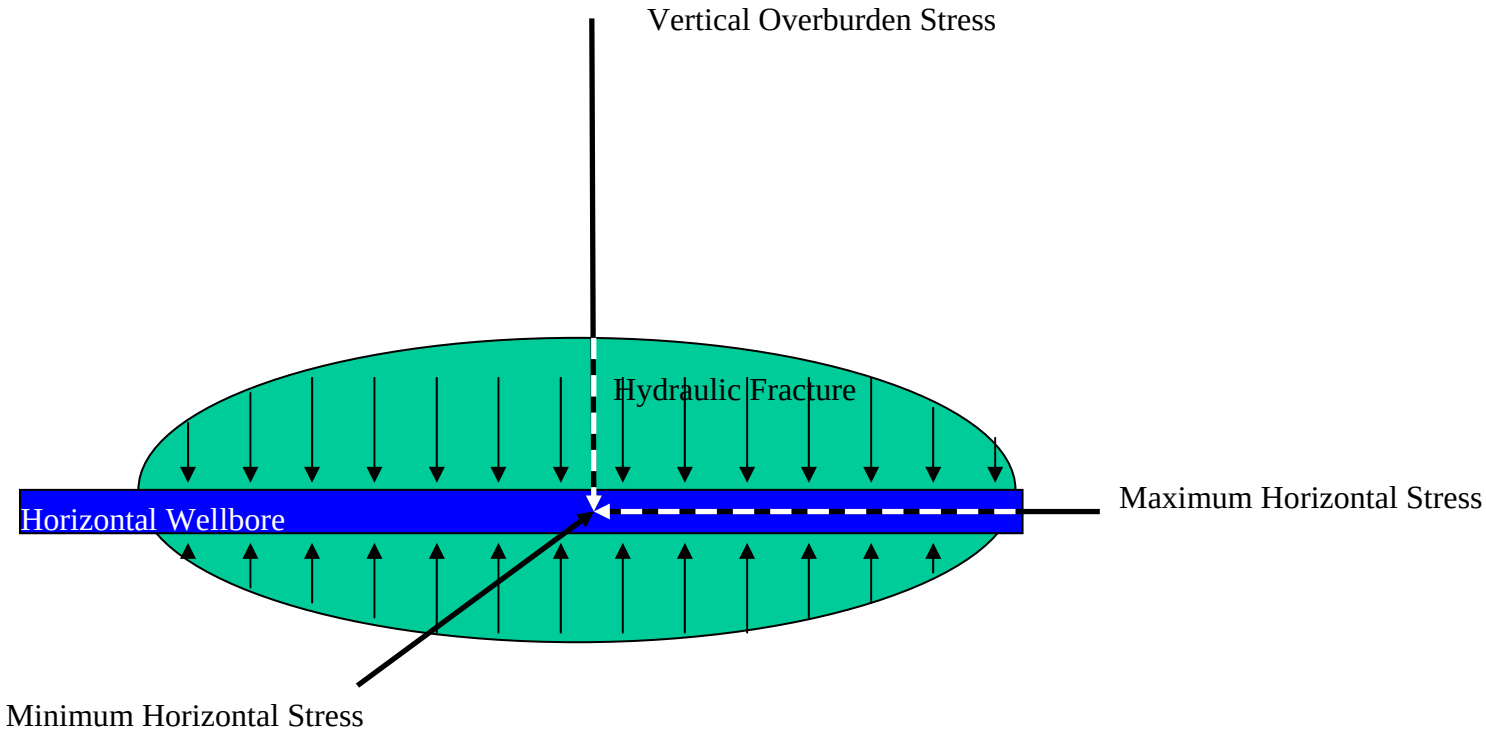


Horizontal Wellbore

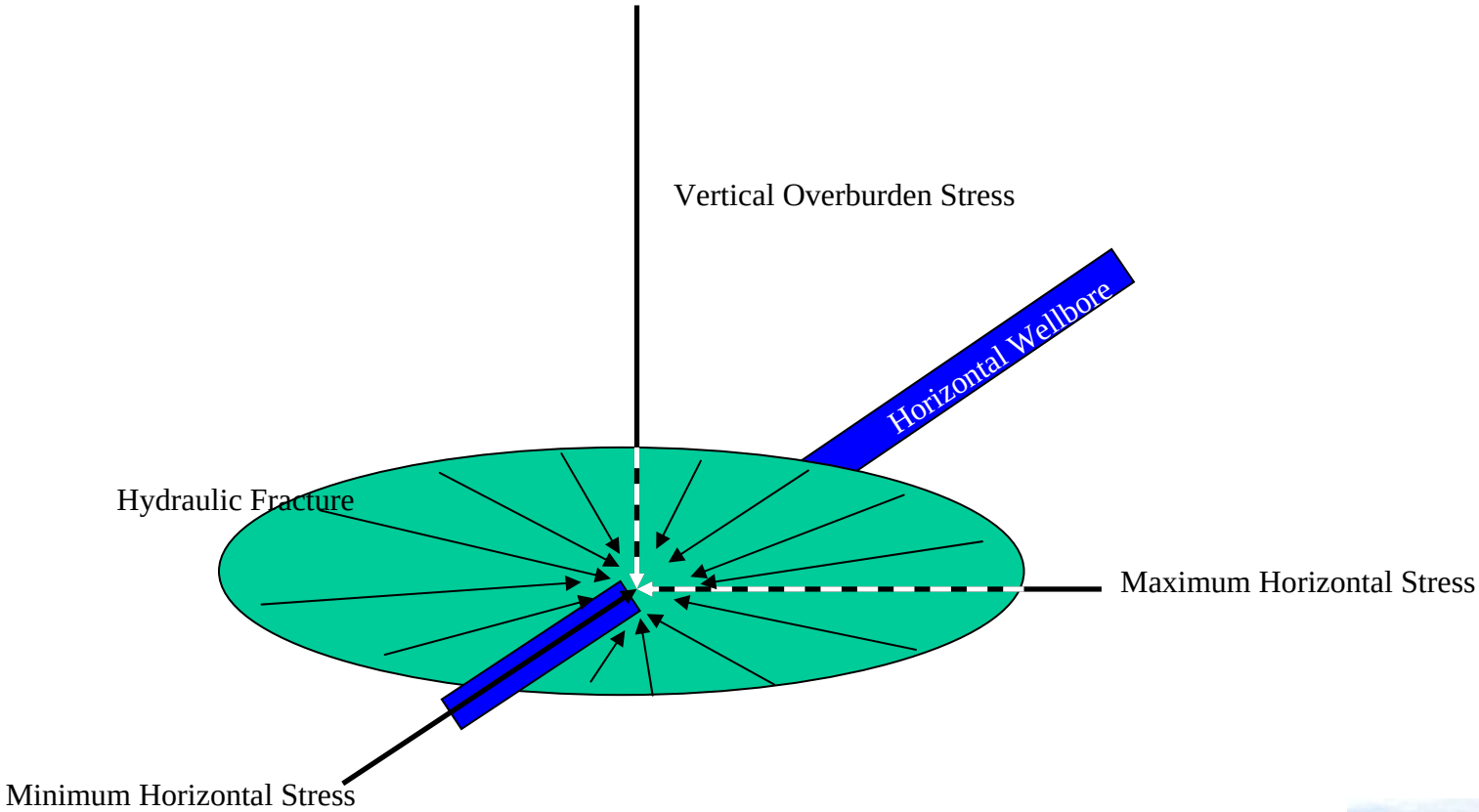
Hydraulic Fracture Conductivity

- Reservoir Permeability?
  - Length Needed for Low Permeability?
  - Conductivity for High Permeability?
- Hydraulic Fracture Azimuth?
  - Longitudinal
    - Minimal Conductivity Requirement
  - Transverse
    - Wellbore and Fracture Connection Critical
    - Convergent Skin Effect

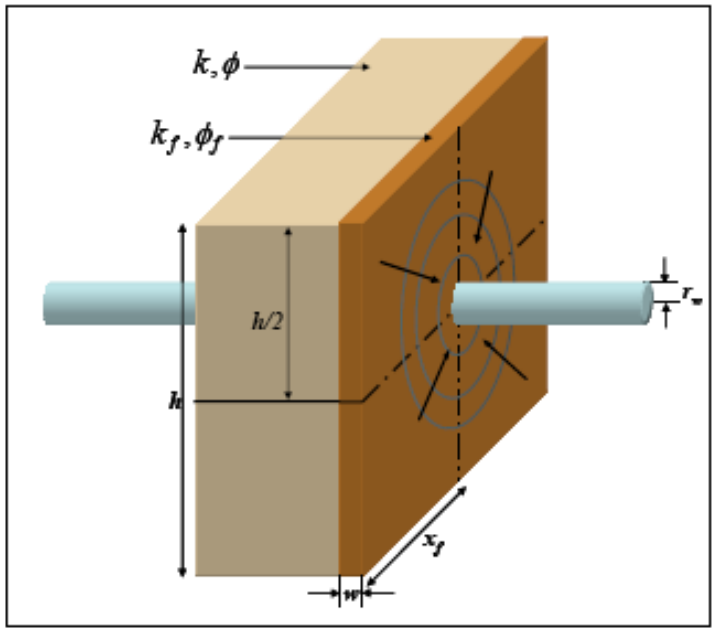
Fluid Flow in a Longitudinal Fracture



Fluid Flow in a Transverse Fracture



Convergent Flow Effect



Choked Skin Calculation

$$s_c = \frac{kh}{k_f w}\left[\ln\left(\frac{h}{2r_w}\right) - \frac{\pi}{2}\right]$$

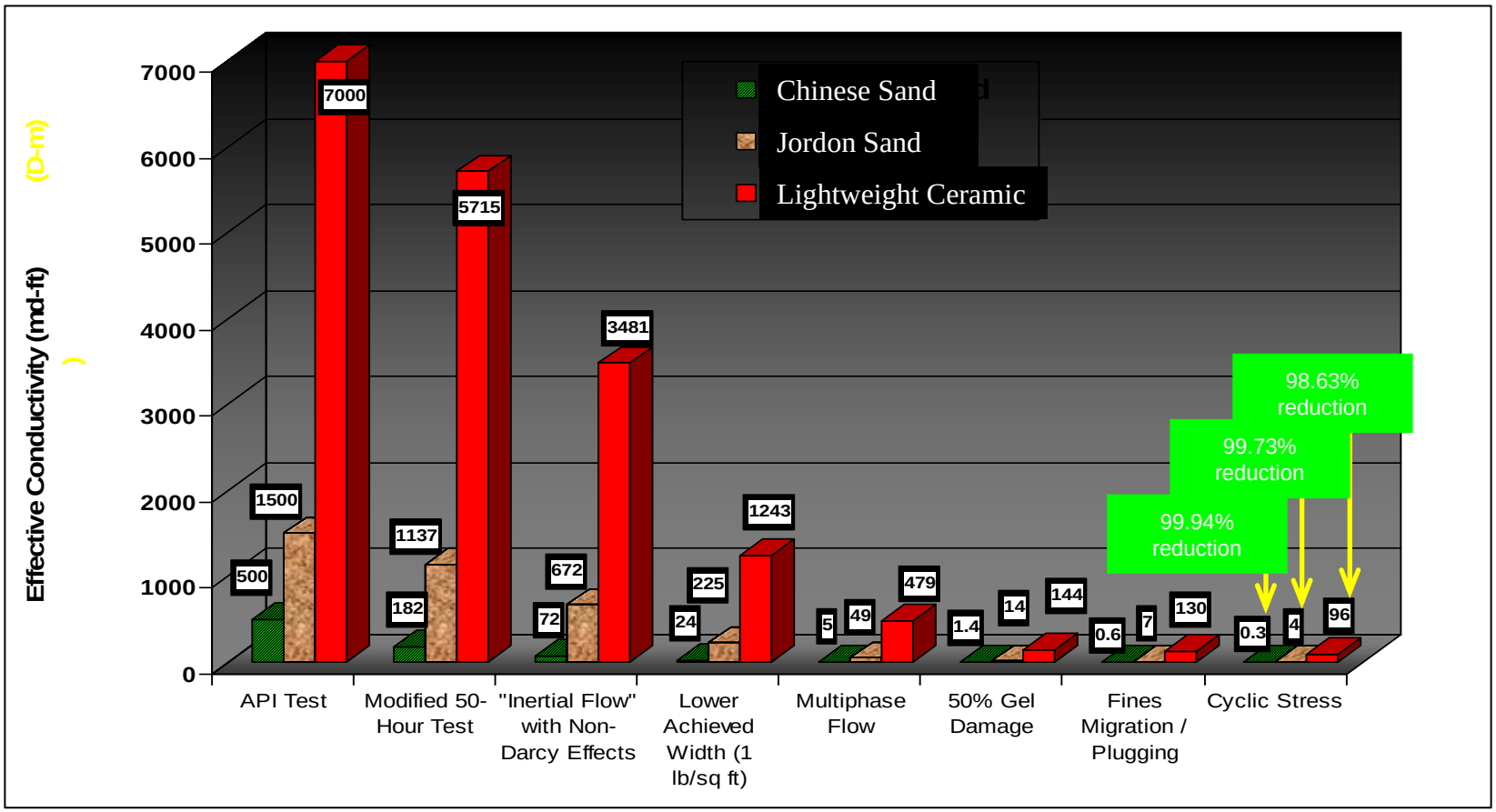
Dimensionless PI for Fracture in a Vertical Well

$$J_D = \frac{1}{\ln\left(0.472\frac{r_e}{r_w}\right) + s_f}$$

Dimensionless PI for Transverse Fracture in Horizontal Well

$$J_{DTH} = \frac{1}{\frac{1}{J_D} + s_c}$$

Realistic Conductivity



Conclusions

- Virtually every parameter we want to optimize in a horizontal Bakken well is somehow connected to the orientation and geometry of the hydraulic fracture.
- More effort must be put forth to acquire this data throughout the basin in a time frame useful to operators.