Horizontal Well Stimulation Applications in the Bakken

Williston Basin Petroleum Conference and Prospect Expo
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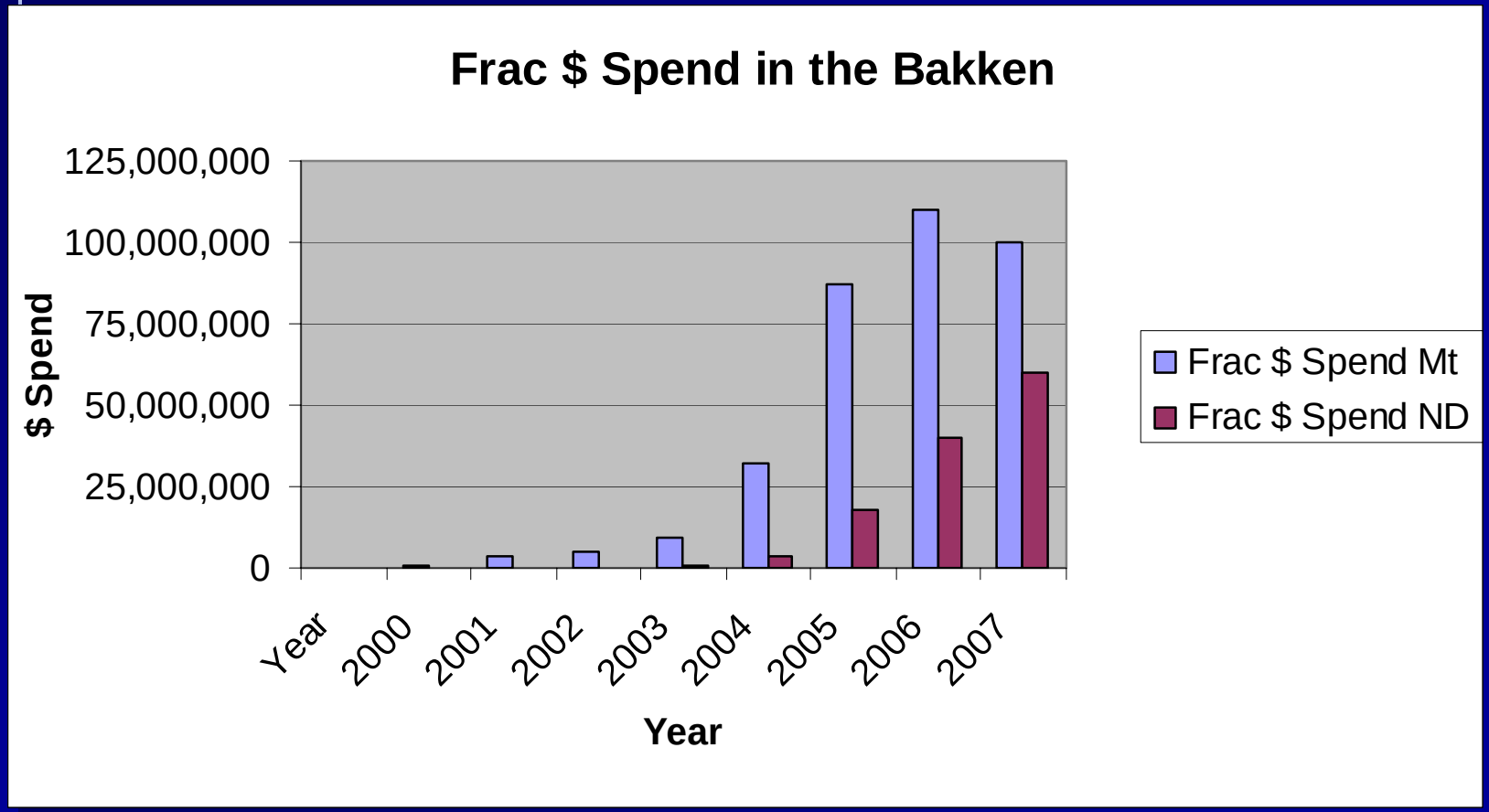
Denver, Colorado

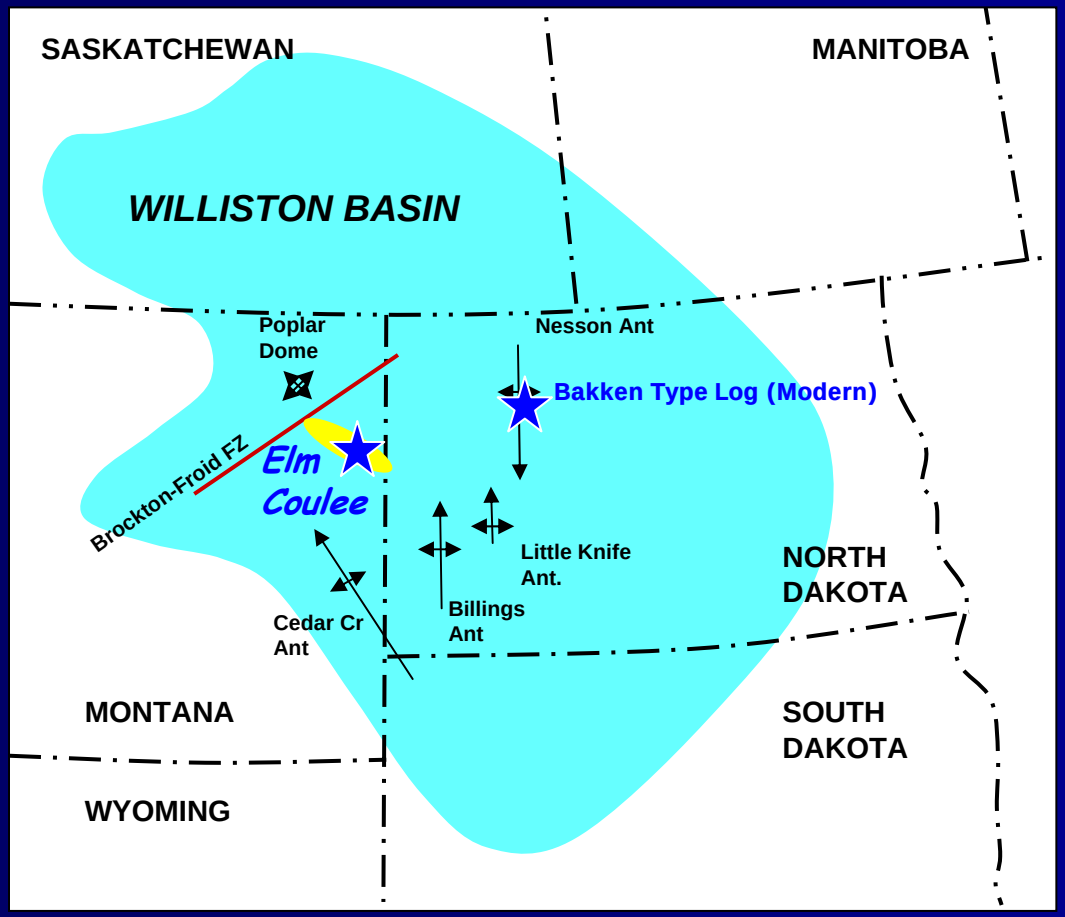
Agenda

- Bakken Shale Play Frac Activity
- Geologic Settings
- Horizontal Well Patterns
- Completion Questions and Challenges
- Horizontal frac theory
- Frac fluid consideration
  - Fluid selection
  - Diversion (Zone Coverage)
  - Proppant Cleanouts
  - Case study
- Summary

US Williston Basin Frac Work Evolution MT to ND

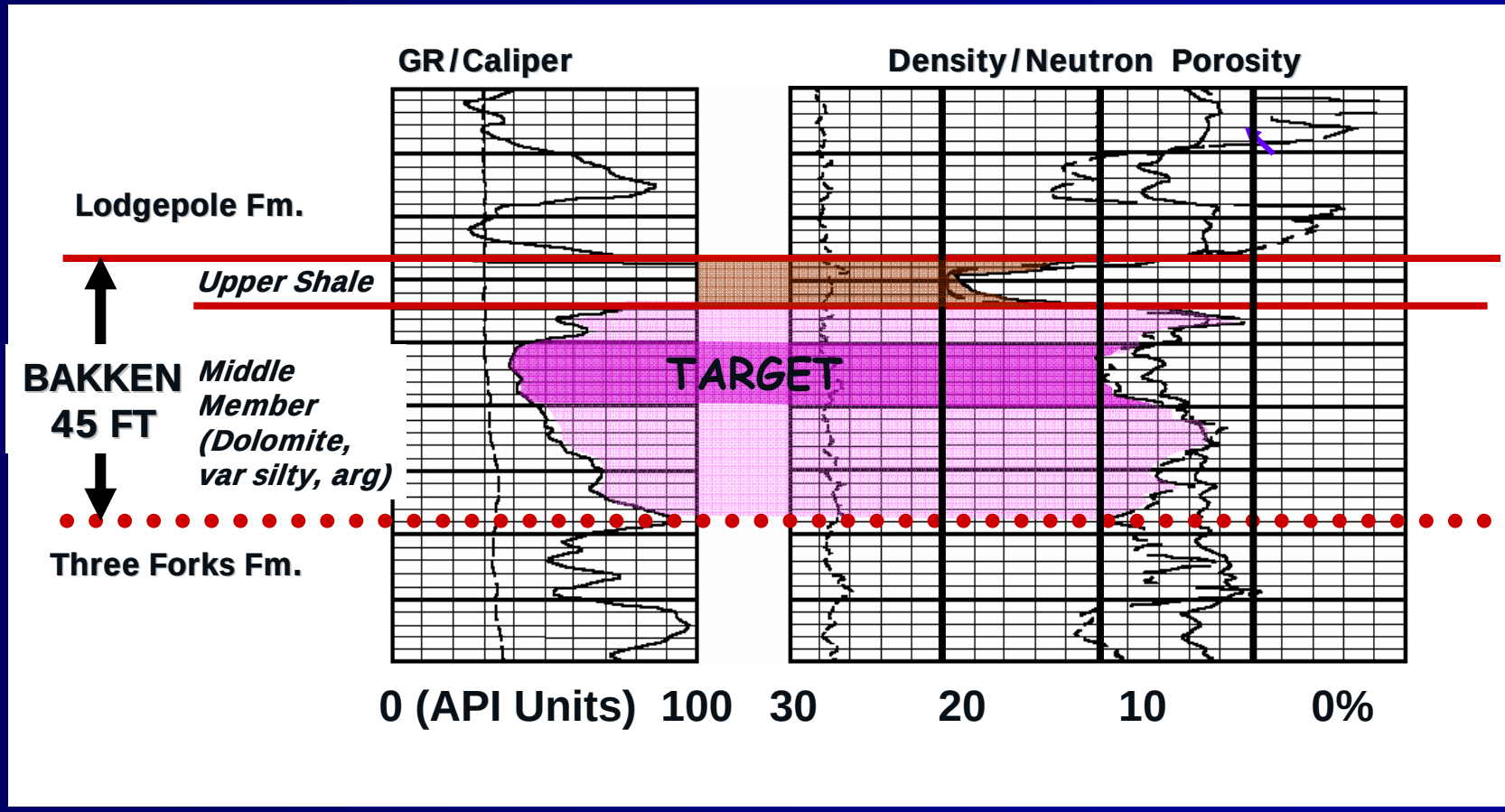


Williston Basin Location



Modified after Heck, R. LeFever, Fischer, and J. LeFever

Elm Coulee Field – Type Log

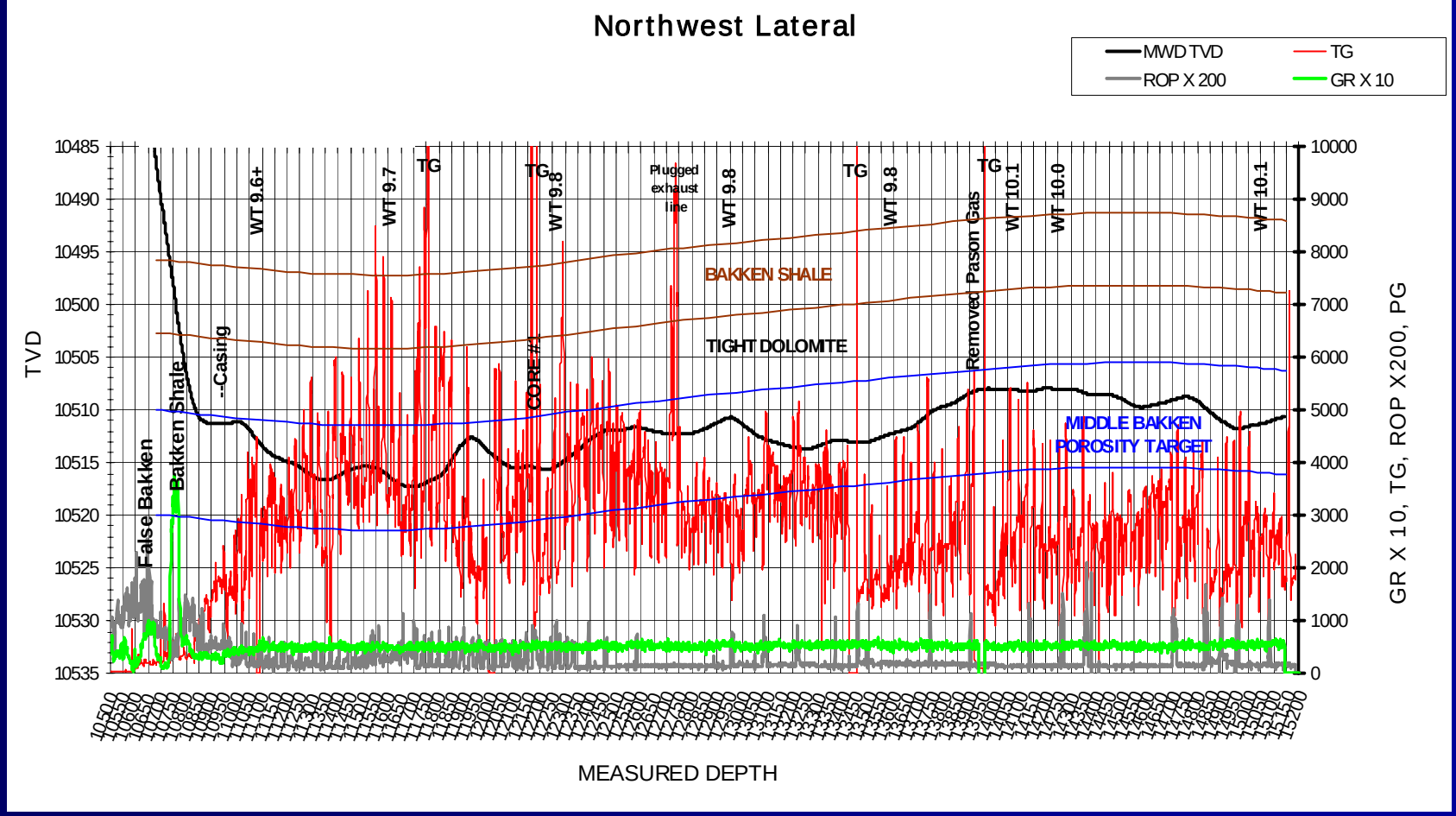


Modified after J. LeFever

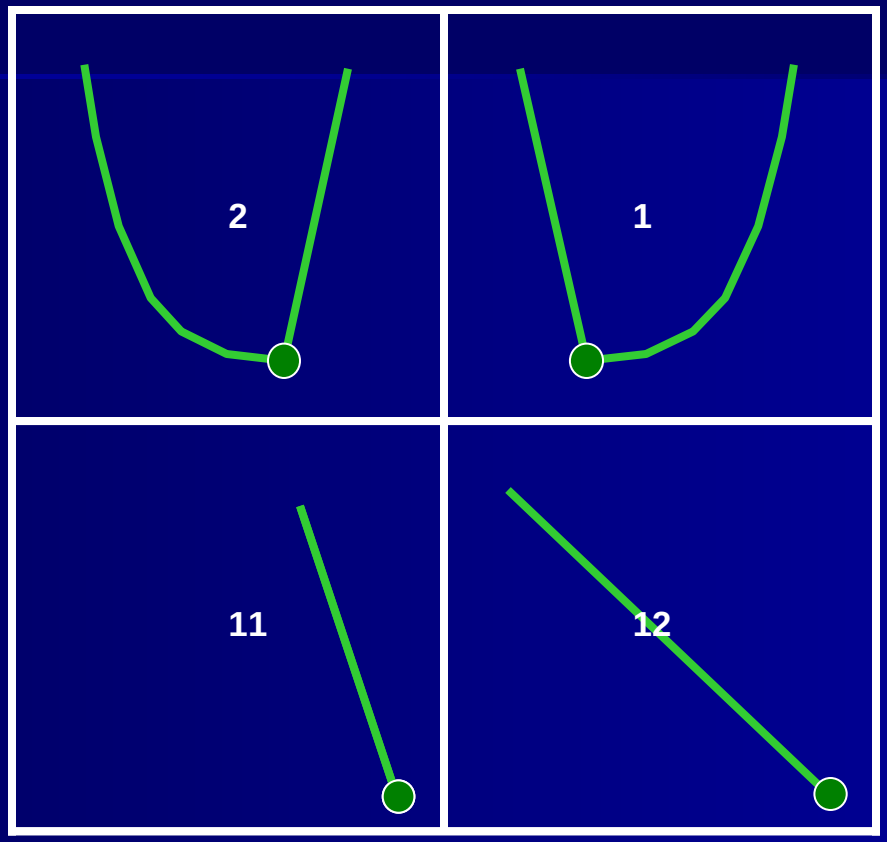
Middle Baken – Reservoir Properties

Lithology:	Fractured Silty Dolomite
TVD:	8,500 to 10,500 ft
BHT:	240 °F
Vertical thickness:	8 ~ 14 ft
Porosity:	8 ~ 10%
Permeability:	~0.05 md
Oil Saturation:	~75%
Initial Production:	200~1400 BOPD, 100 ~ 700 MCFGPD and 5~ 20 BWPD
Oil Gravitiy:	42 °API
GOR:	500 MCFD/Bbl
OOIP (BO/640 acres):	5,000 MBO
Primary Recovery factor:	10%
Primary Oil Recovery:	500 MBO (from decline curve)

Horizontal Well Survey

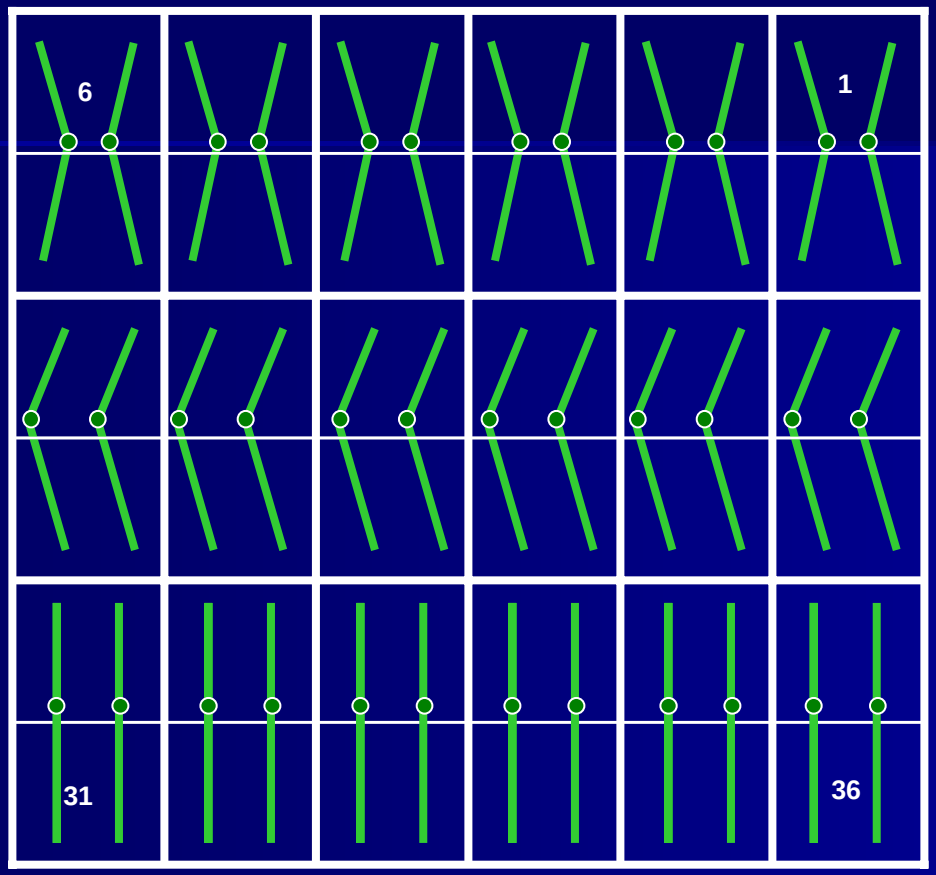


WELL PATTERNS



640-Acre Well Patterns
(One Well per Section)

WELL PATTERNS



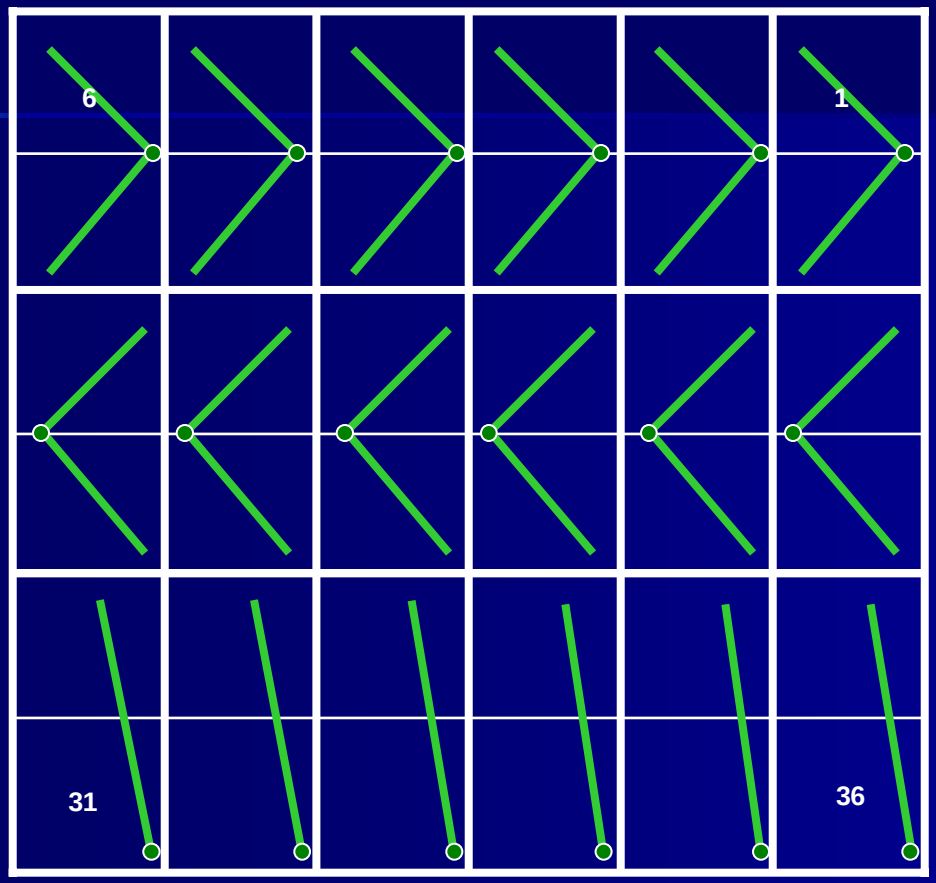
BOW-TIE

CHEVRON

STRAIGHT

1280-Acre Patterns – Two Wells/1280 (Two Square Miles)

WELL PATTERNS

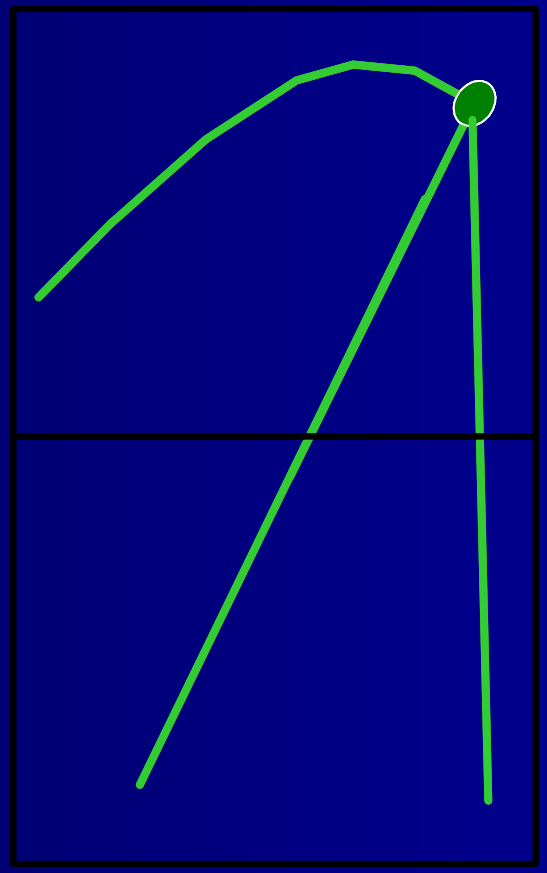


HERRING-BONE

SINGLE LATERAL

1280-acre Spacing Units – Single Well/Two Square Miles

Tri Lateral Layout



Technical Questions

- Lithology… Understanding How Formation Changes throughout the Basin
- Lateral Placement… Which Direction is Best
- Natural Fracture Networks… Identifying and Effects on Stimulation and Production
- Hydraulic Fracture Geometry & Placement… How Many and Orientation to Wellbore
- Stimulation Techniques… Type Prop Fracs vs Type Fluid vs liners with limited entry vs isolation packers ??
- Frac Diversion materials or type of tools
- Total Lateral Length “Opportunity”
- Matrix contribution

Issues Related to Horizontal Well Stimulation

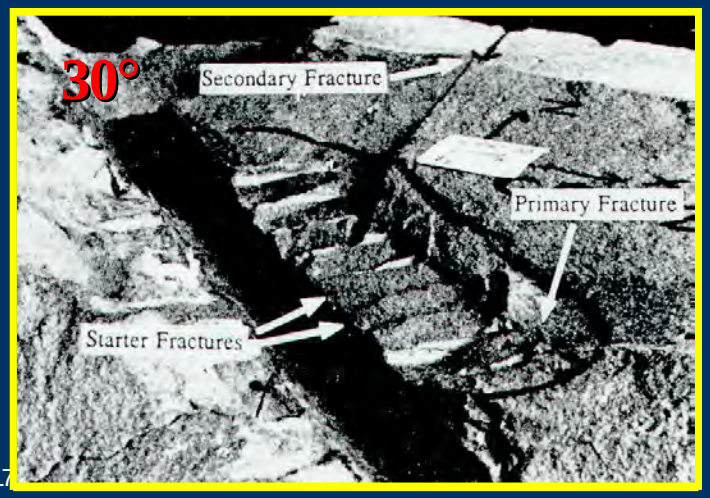
- Length and direction of horizontal well section
- Orientation of hydraulic fractures (relative to wellbore)
  - Longitudinal versus Orthogonal
- Well completion type
  - open hole, cased/cemented, slotted/perforated liner
  - Lateral Isolation
- Perforation placement
- Fracturing treatment design
  - Number of hydraulic fractures along wellbore
  - Length and conductivity of hydraulic fractures

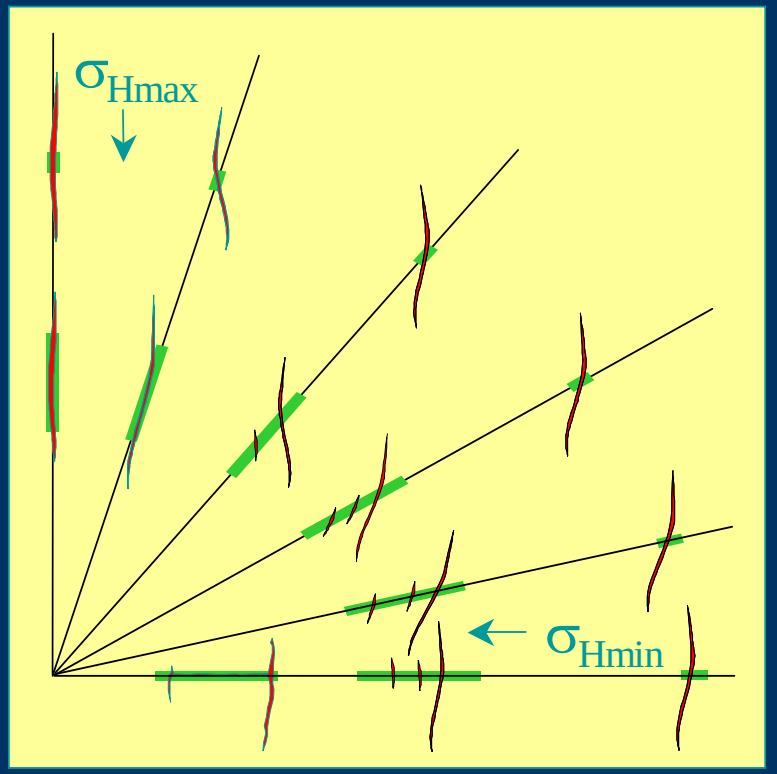
Differences Between the Bakken in Montana and Bakken in North Dakota.

- Montana
- Small contained geographic area more predictable production. Middle Bakken Carbonate
- Varying amounts of technical data has been collected, ie logs, cores, tracers, PL's, frac azimuth.
- Many types of frac designs, lateral lengths, multi laterals, very successful results, majority of prop has been sand.
- Fracs are contained, stress in Middle Bakken is significantly less than bounding layers.
- Max vs min stress direction is minimal
- High consistent Oil Sat and H.
- Good matrix porosity and perm.
- Few tectonic fractures.

- North Dakota
- Large spread out geographic area variable production Middle Bakken Clastic 10 MM + acres leased
- Very little technical data has been collected, ie logs, cores, tracers, PL's frac azimuth.
- Many types of frac designs, lateral lengths, fewer multi laterals, variable success, multiple type props used.
- Fracs are not all contained, stress of all layers is variable from area to area, mostly higher.
- Variable Oil Sat and H.
- Max vs min stress direction more differential.
- Variable porosity and little matrix perm.
- Several of the higher rate wells have had significant tectonic fracture contribution.

Effect of Wellbore Azimuth





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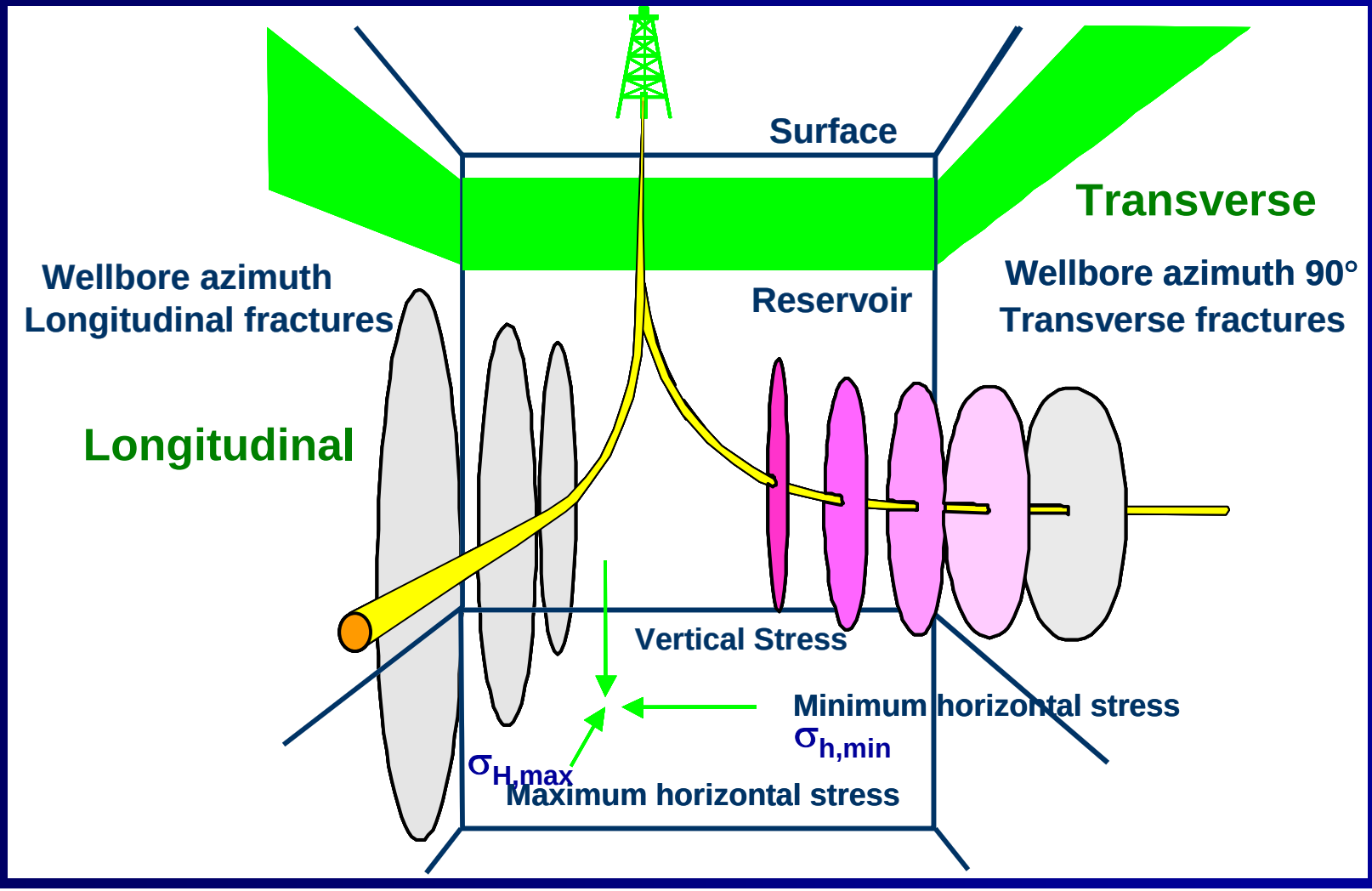
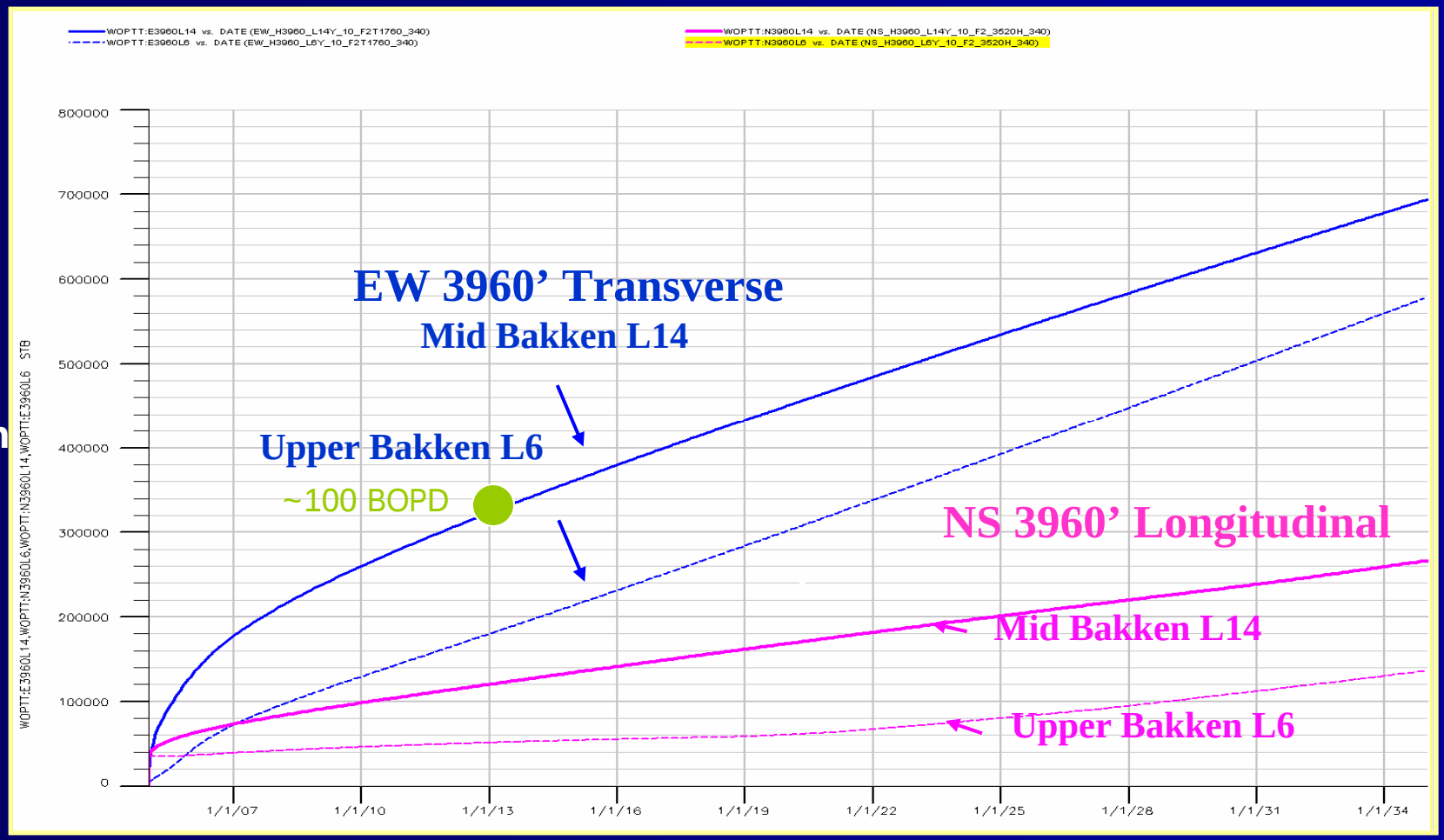
Longitudinal vs. Transverse Fractures



Transverse Fractures



Cum Oil Production (Stb)

TIME (yrs)

Hoop Stress Effects on Open Hole Completions

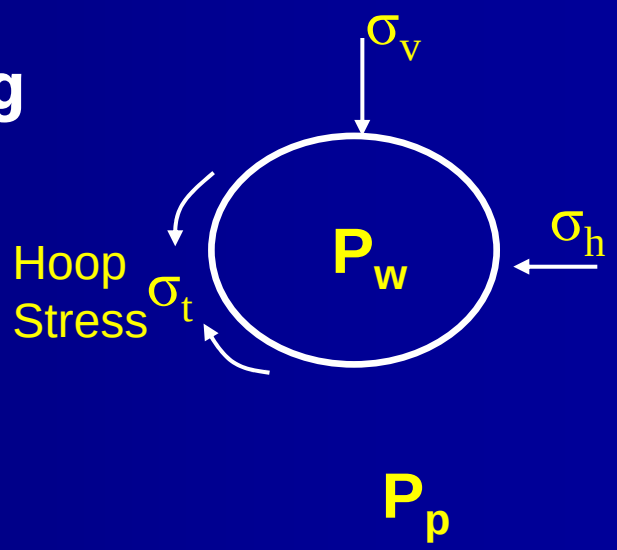
Hoop stress is the additional stress on the rock adjacent to the wellbore, caused by the removal of rock during drilling

Hoop Stress is described as:

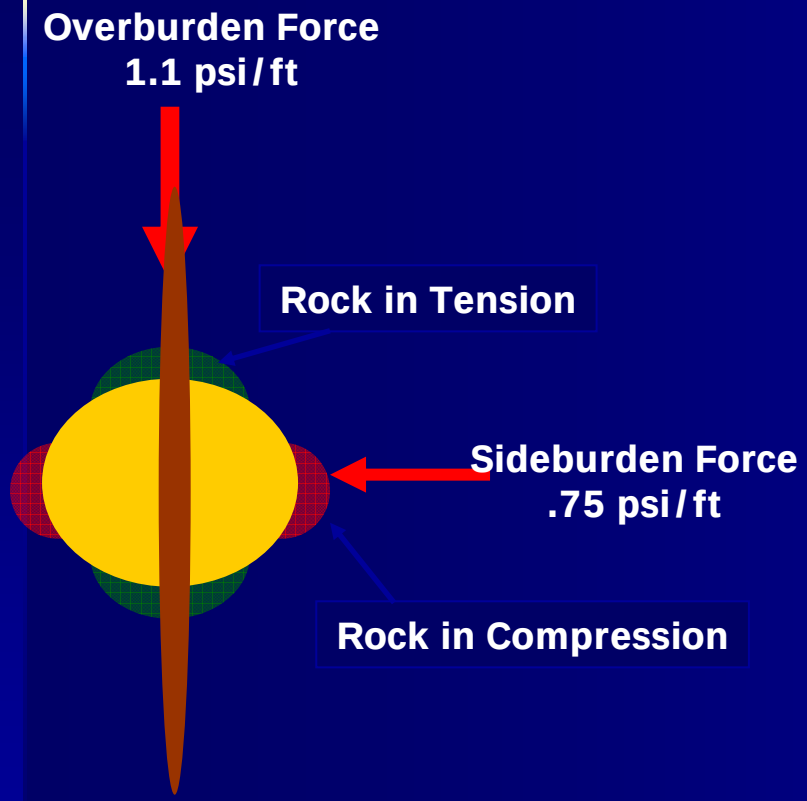
$$\sigma_t = 3(\sigma_v) - \sigma_h - P_w - P_p$$

Where:

σ_v = Vertical Stress
σ_h = Horizontal Stress
P_w = Wellbore Pressure
P_p = Reservoir Pressure



Horizontal Open Hole Hoop Stress and Fracture Initiation



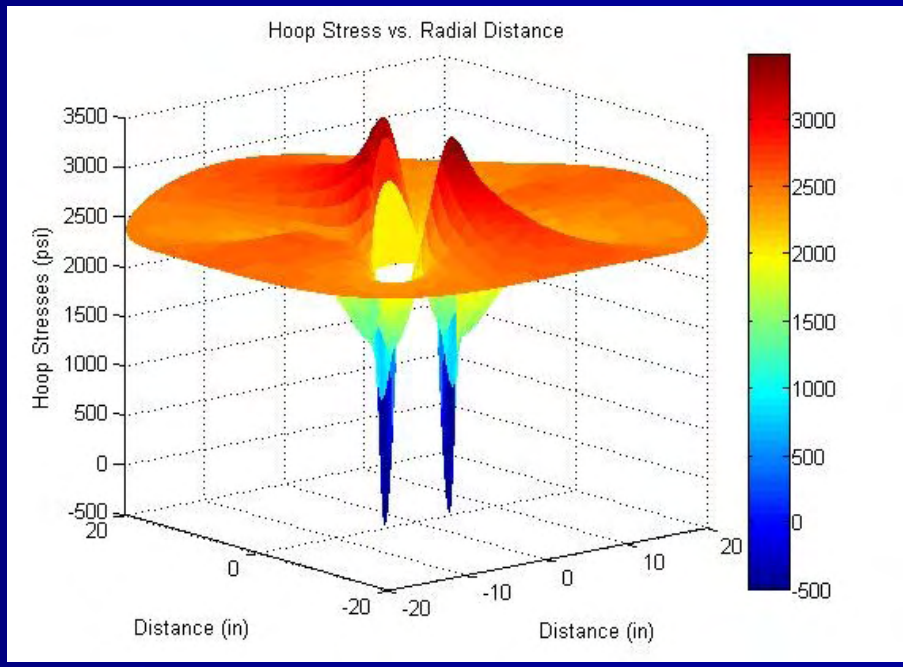
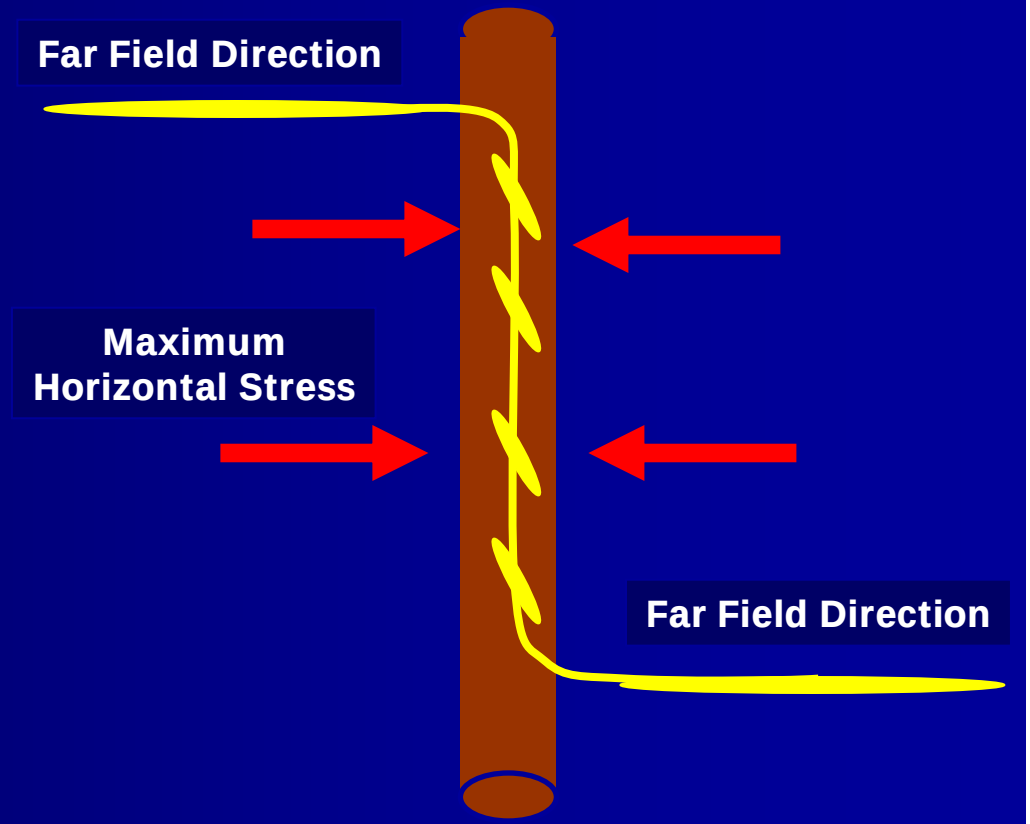


Fig 4.5

Fractures Initiate along the axis of the wellbore

Horizontal Open Hole Hoop Stress and Fracture Initiation

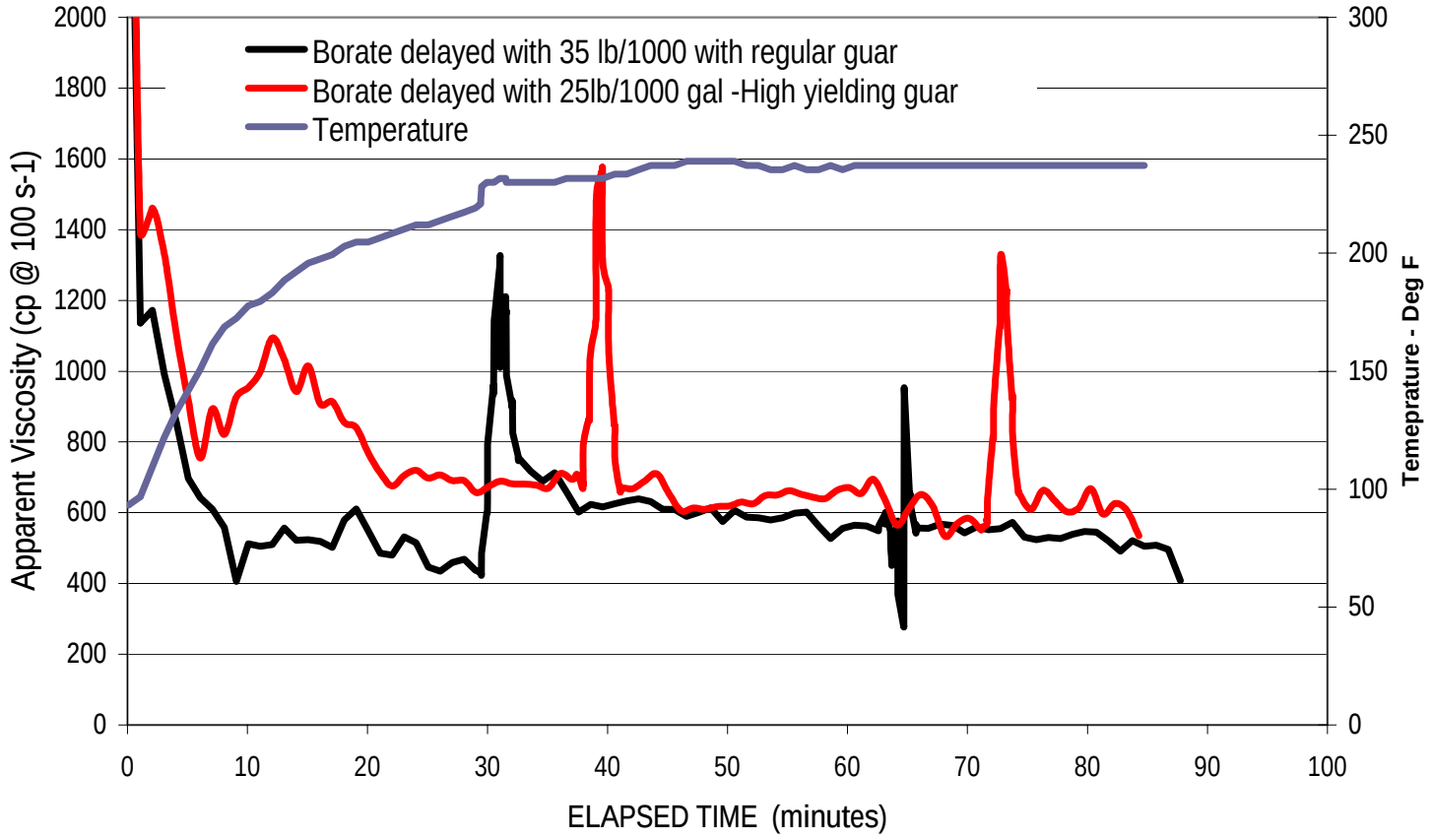
Horizontal Stress Anisotropy in Transverse Wellbores can Create Differential Closure Constrictions



Fracturing Fluid Improvement Needs

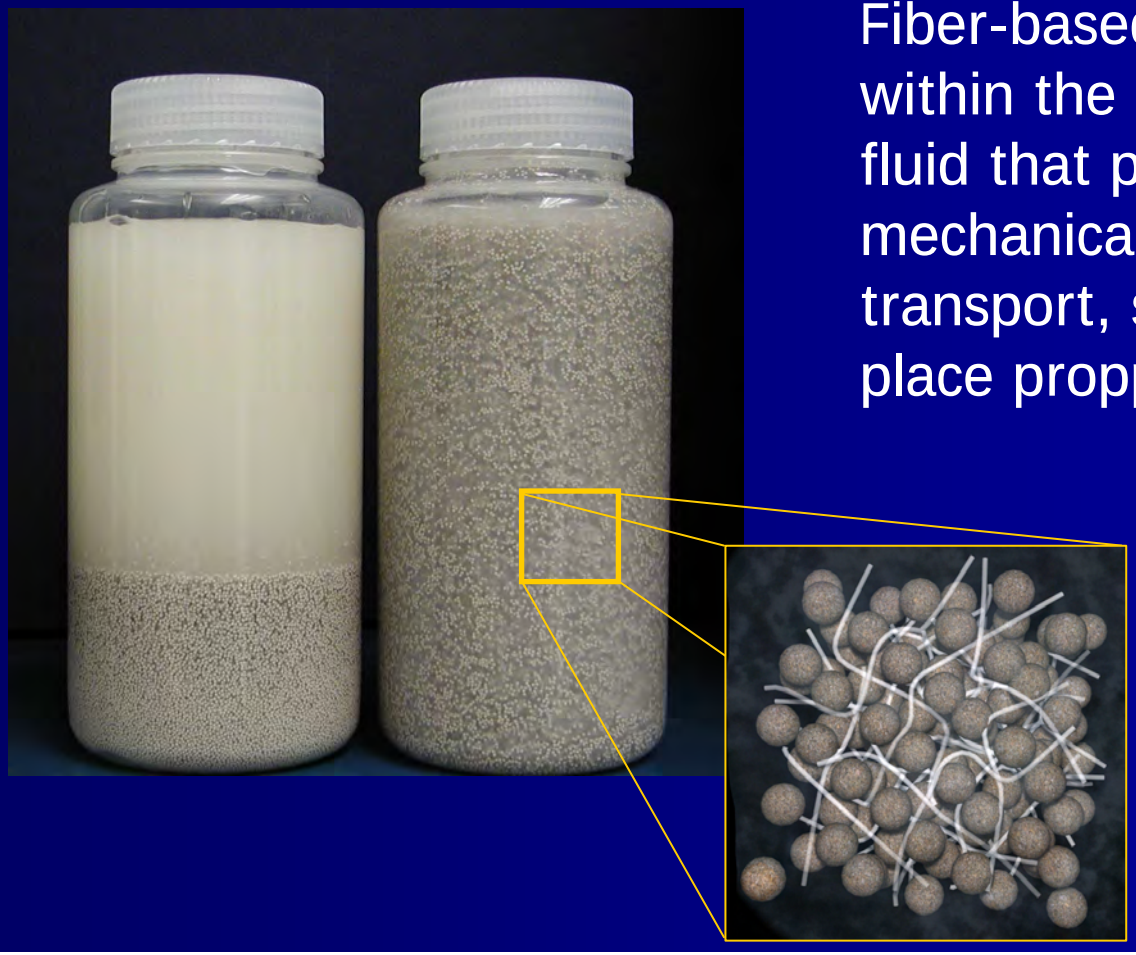
- Improved proppant transport
- Lower Polymer Loads/less damaging
- Better diversion technique or materials

Fracturing Improvements
High Yield Guar - Rheology



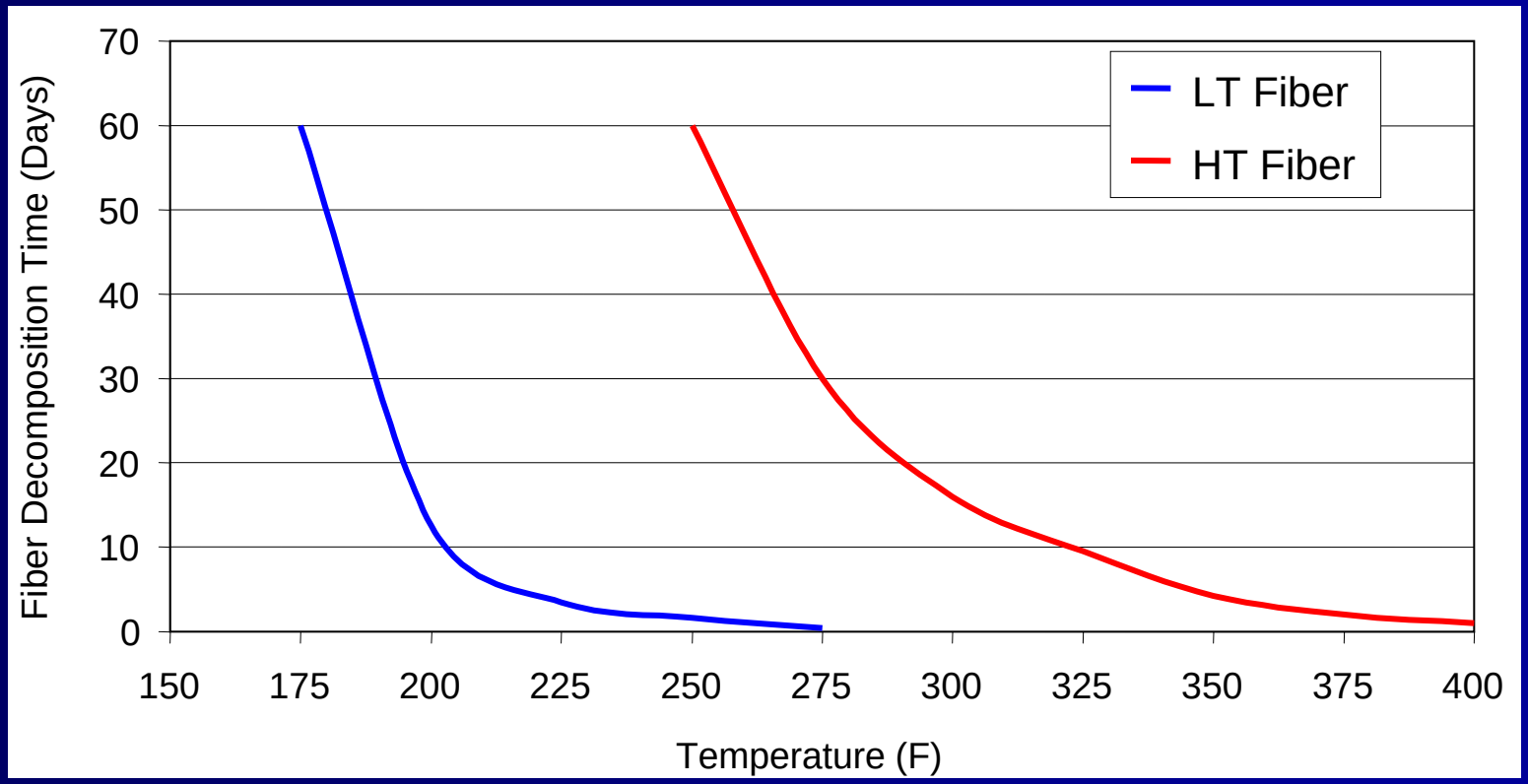
Fiber-laden fluid

20 Pound Linear Gel - 5 PPA Proppant



Fiber-based network within the fracturing fluid that provides a mechanical method to transport, suspend, and place proppant

Fiber Decomposition Time



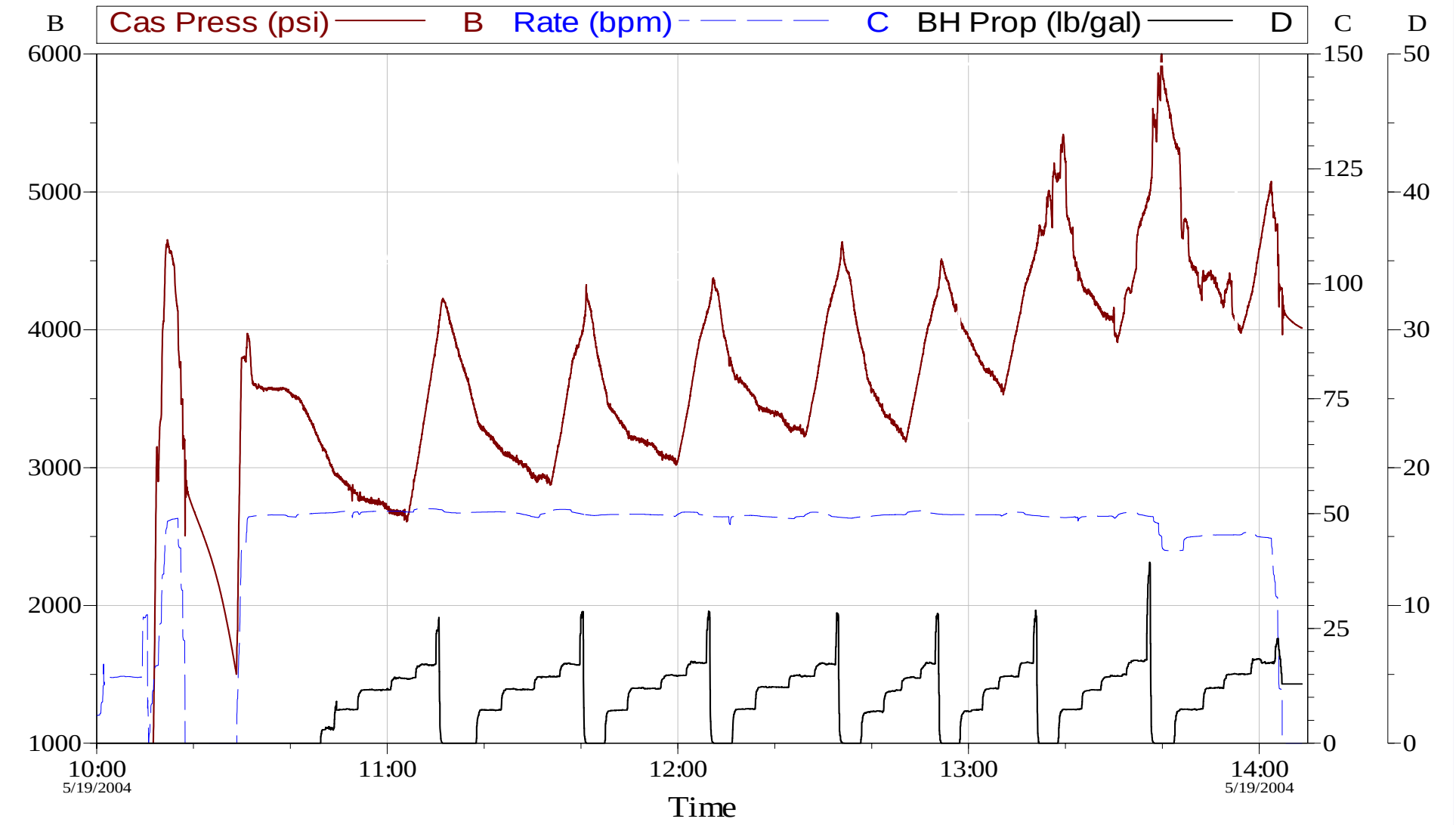
Fracture Diversion

Completion
- Permanent installations
- Pre-perforated liner
- Open Hole

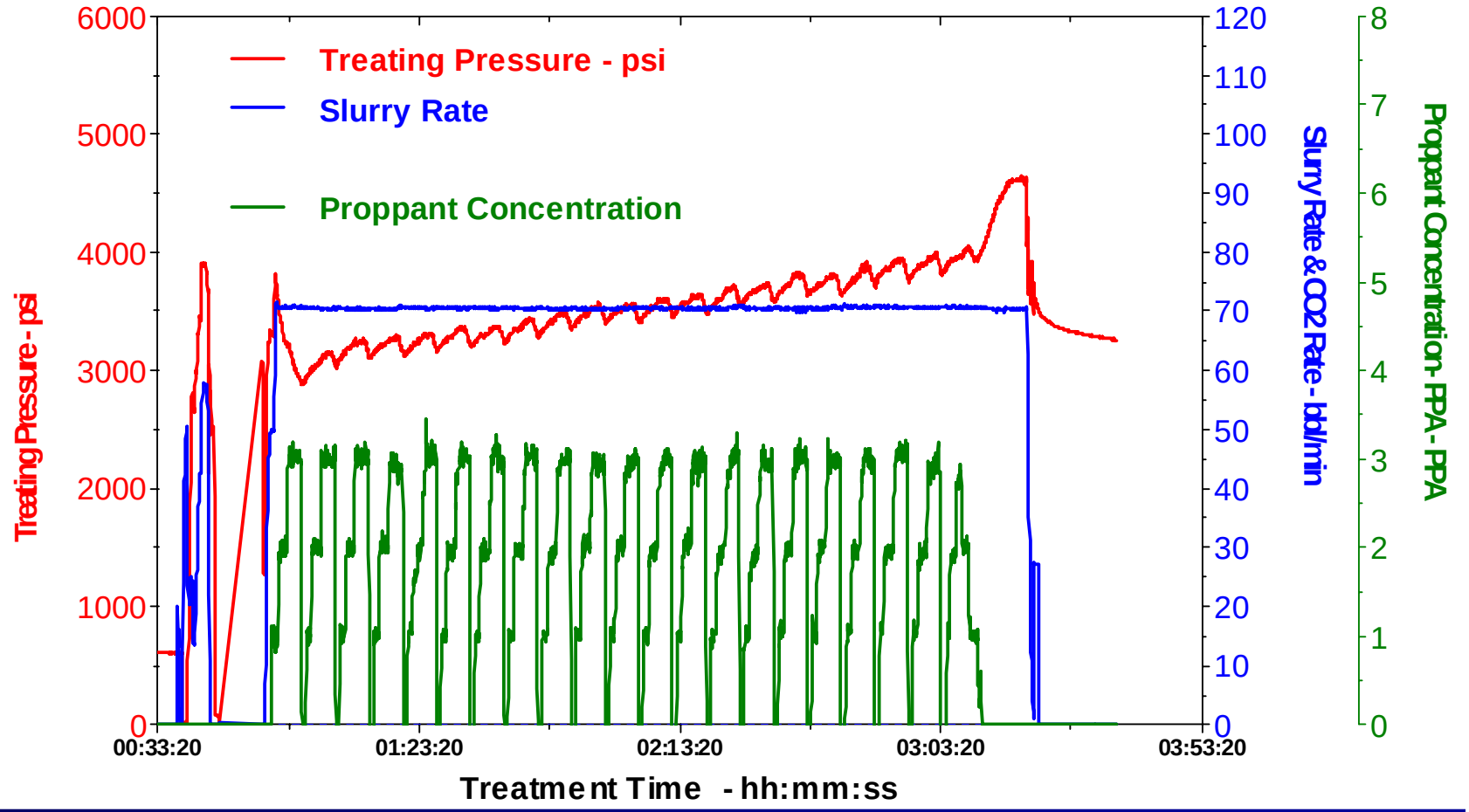
Alternatives
- Ball sealers
- Sand slugs
- Fiber-based

Diagnostic
- Pressure Increase
- RA tracer
- Microseismic

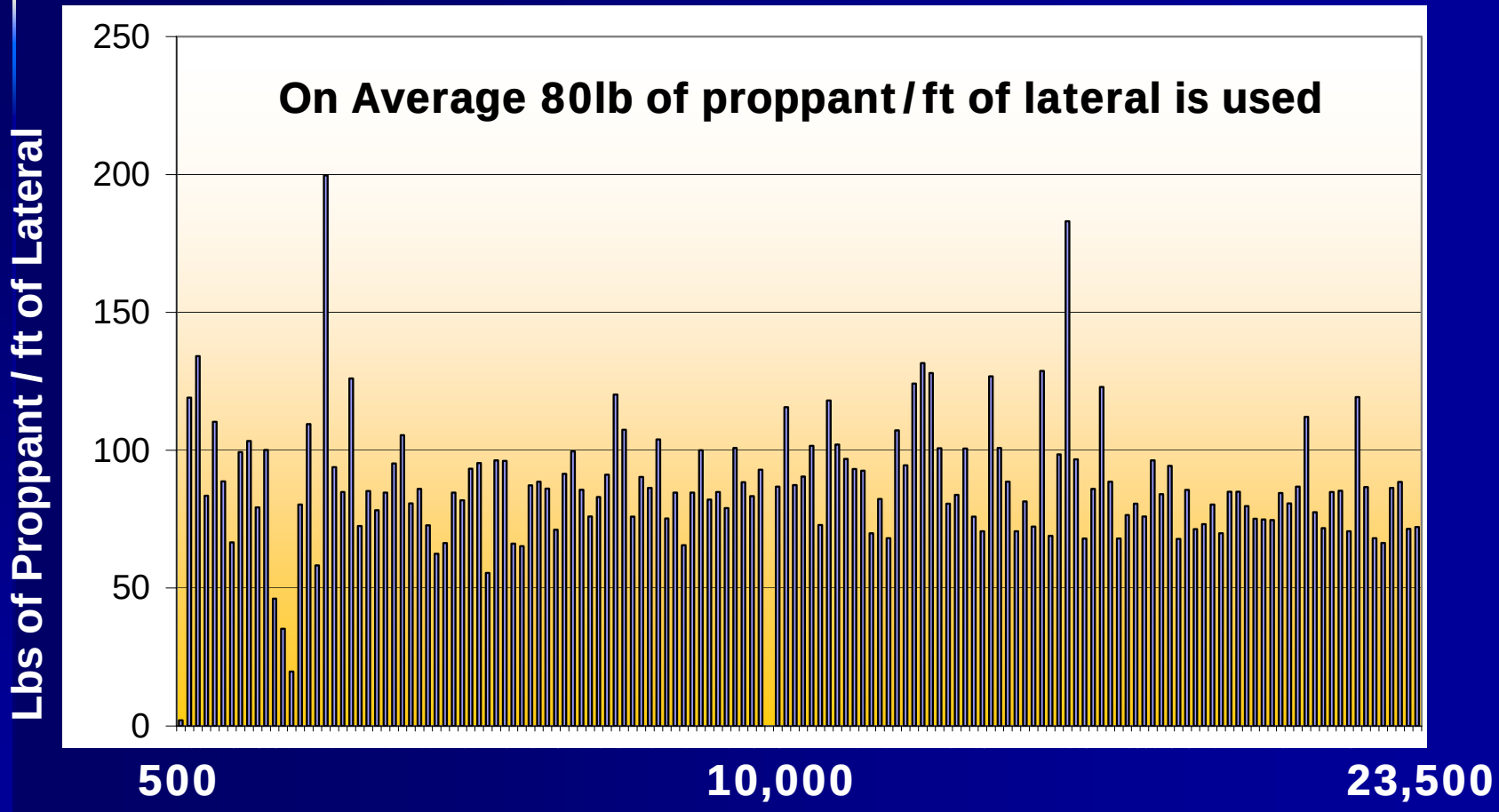
Stimulation Treatment Chart SPE 90697 Liner Limited Entry



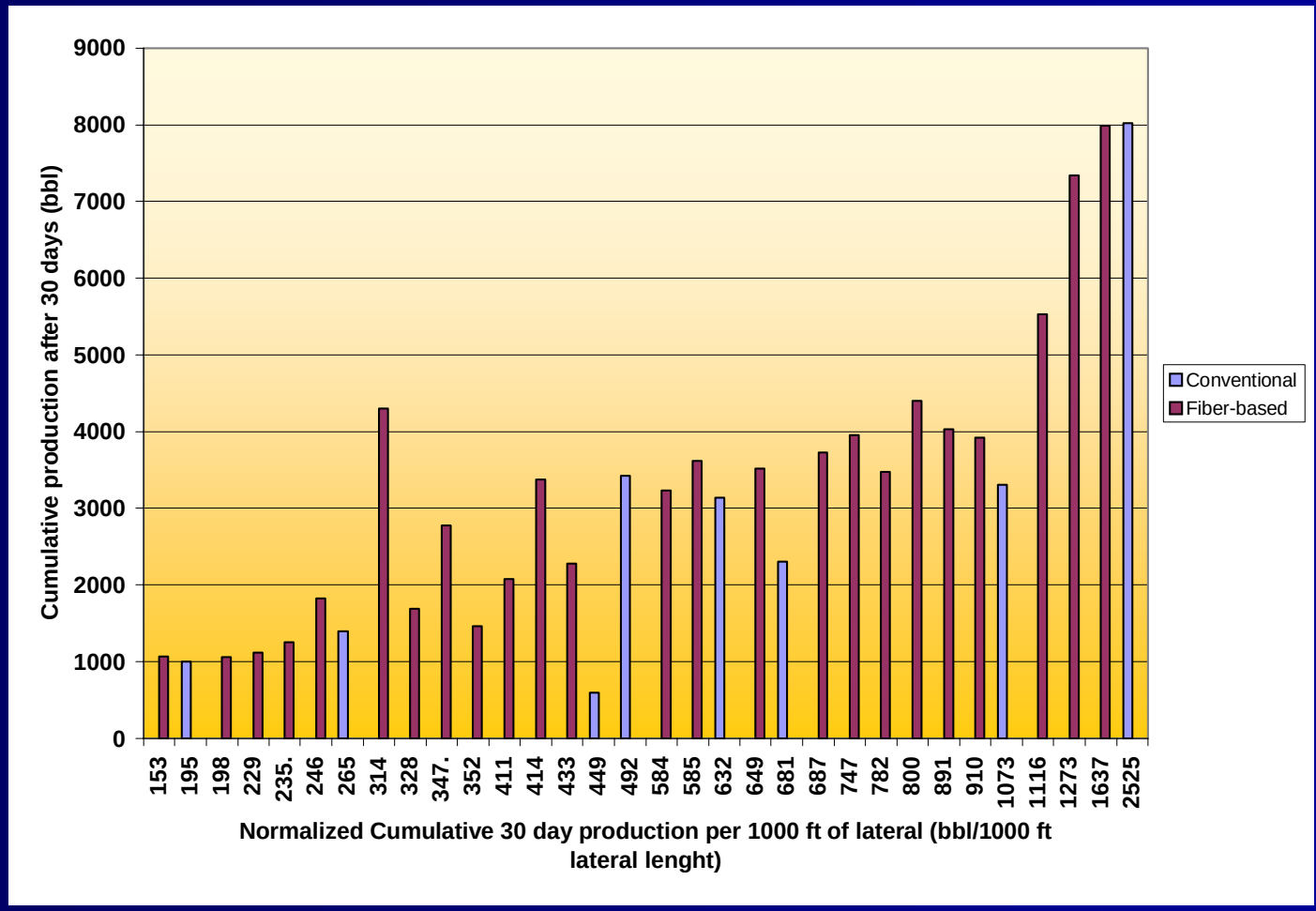
Fiber-laden Job Open Hole



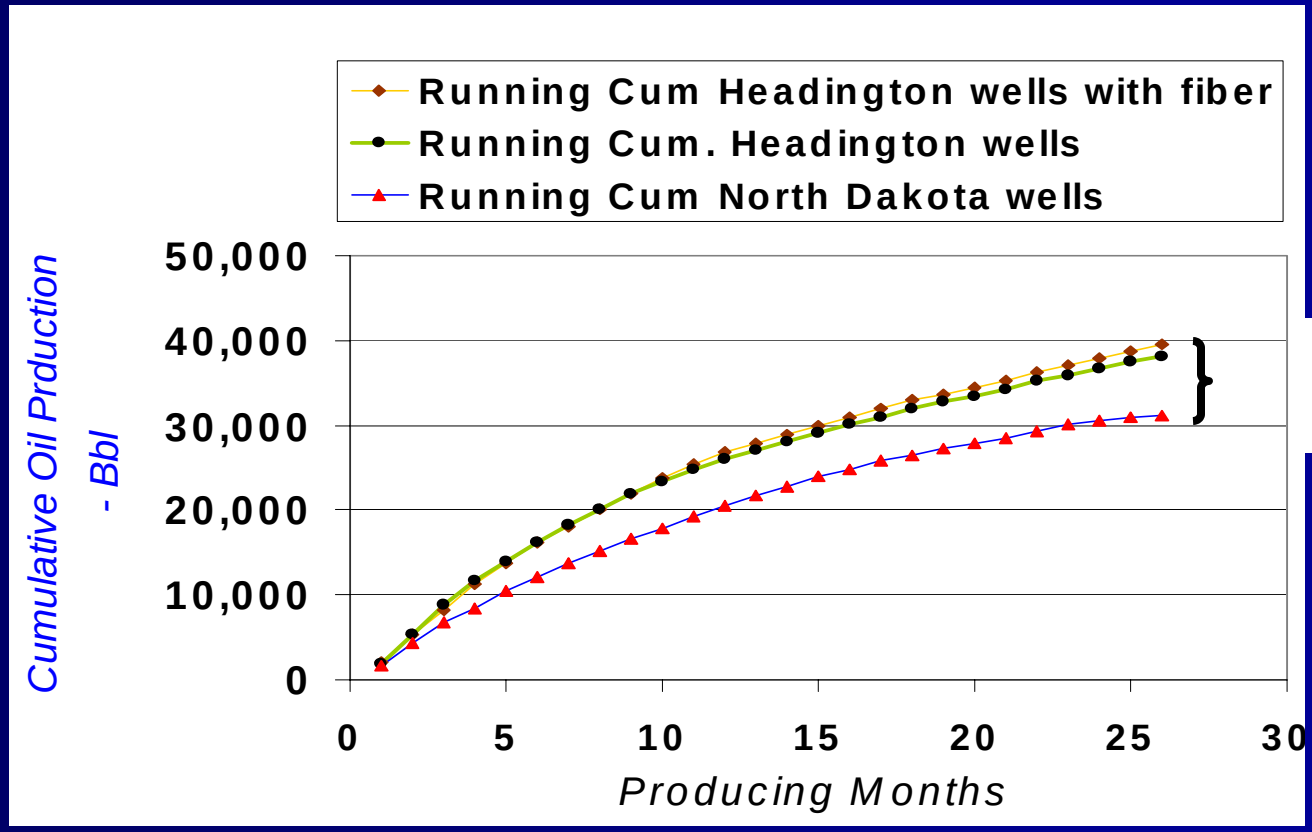
Database Example



North Dakota – DB Example



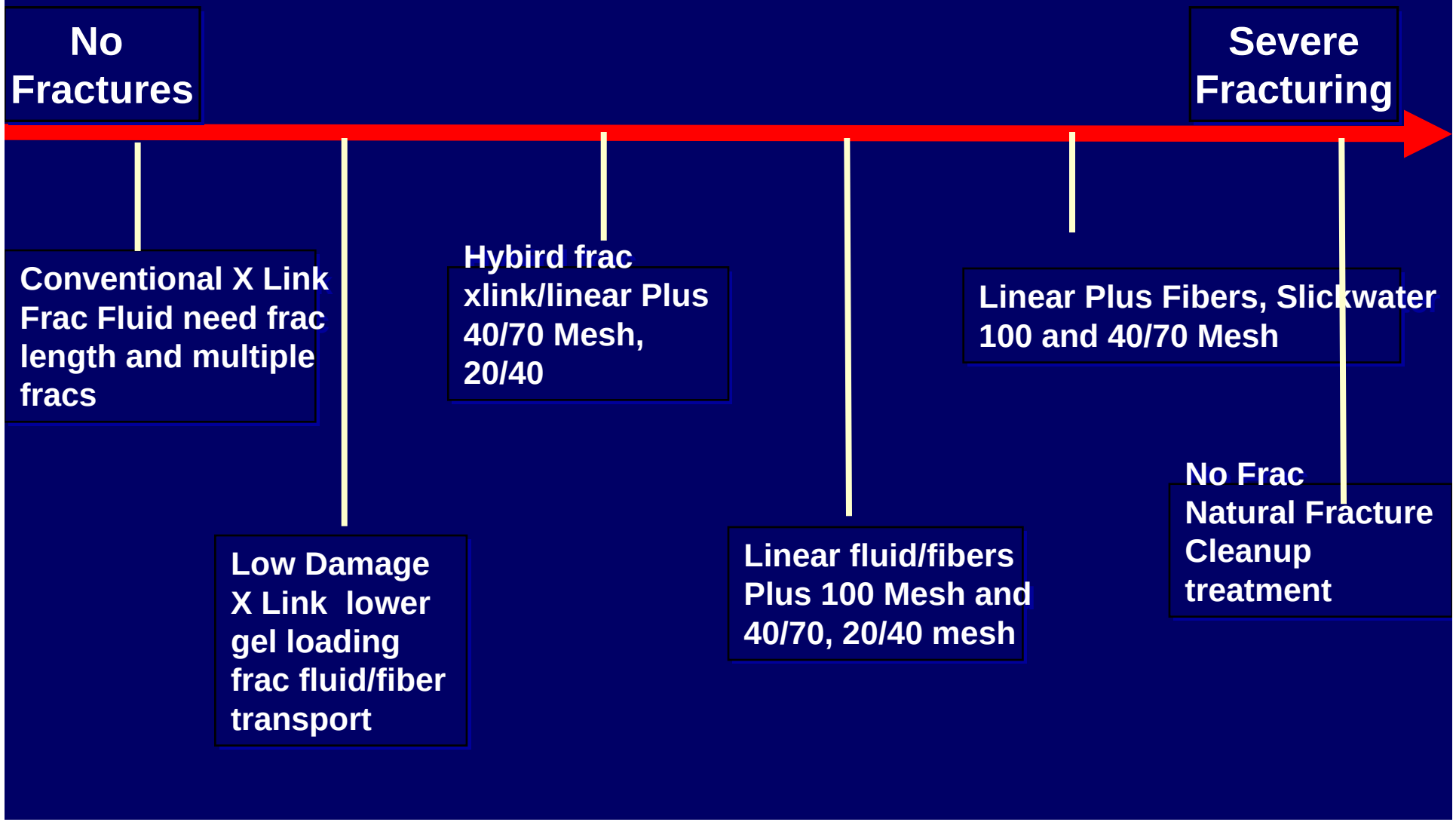
Case Study – North Dakota



22% Incremental

15 Wells with Fiber Diversion/Transport vs
104 Bakken Wells in North Dakota

Natural Fracture Severity Decision line *(GeoSolution) vs Frac Fluid*



Recommended Direction for Fluid Selection in Bakken wells

- Proppant suspension properties and effective fluid breaks adequate to prevent settling in horizontal section, minimize cleanouts, ie fibers
- High near-wellbore conductivity to minimize affects of flow convergence at the wellbore, higher strength prop if frac is transverse, maybe a combination of both.
- Control of fluid loss through natural fractures, fibers.
- Clean fluids to minimize natural fracture damage ie drop gel loading or go to slickwater or non gelled systems
- Postive isolation if possible

Drawbacks and Challenges to Developing Bakken

- Increased service costs drilling, pipe, frac, completion etc
- Lower production results compared to MT.
- Rig availablity
- What data to acquire.
- Cost to benefits of collecting data and applying in a value added manner.
- Cost to benefits of new cleaner fluid technologies
- Lease expiration clock.

Summary

- *Fractures + matrix + thermal maturity = production*
- In North Dakota; Middle Bakken matrix quality decreases to southwest, more reliant on fractures
- In Montana; better matrix properties, less dependent on fractures
- Most mature Bakken Shale in western North Dakota and eastern Montana
- Basement features have a positive influence on production (enhance fracturing??)
- In areas of mature Bakken Shale fracturing from oil expulsion into Middle Bakken
- Continue to evaluate refrac potential

Recent Papers on Bakken well completions

- SPE 10845 – A case study in Bakken Fm changes to hydraulic fracture stimulation treatments. Results in improved oil production and decreased treatment costs.
- SPE 108117 – Refracture treatments proven successful in horizontal Bakken wells Richland County Mt.
- SPE 107979 - Fiber-laden Fracturing Fluid Improves Production in the Bakken Shale Multi-lateral Play.
- SPE 90697 – Improved horizontal well completions in the Bakken Formation, Williston Basin.

Conclusions

- Bakken is a complex and still unpredictable reservoir
- Fiber-laden fluid and High yielding guar system allowed more than 35% polymer reduction
- Fiber-laden helped to eliminate proppant settling/production into the lateral.
- Fiber-laden eliminate/minimize the need for proppant clean out after the frac.
- Fiber-based diverter has helped to improve in zone coverage.
- Production from public DB has been used on this paper.
- Fiber diversion in competent open hole applications may allow for the elimination of slotted liners for a significant cost savings.
- In North Dakota, wells treated with fiber-laden fluid on average accumulate 22% more oil than all other wells.