Evaluating the Production from Over 600 Middle Bakken Wells

"a 20 minute introduction to a 3-day frac school"

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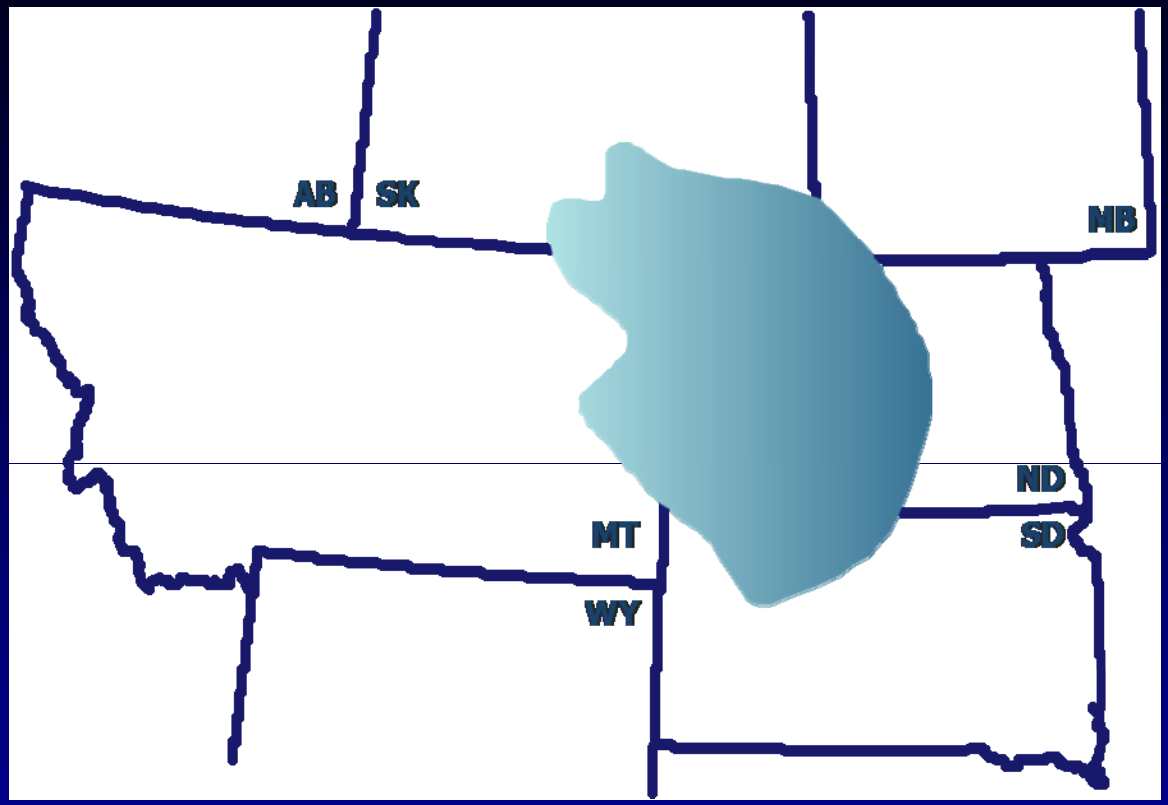
Service companies and operators

SPE 110679

Improving Well Productivity and Profitability in the Bakken-- A Summary of Our Experiences Drilling, Stimulating, and Operating Horizontal Wells

Navigation menu

Williston Basin Location and Variation



The Bakken extends beyond the Williston Basin into SK, MB, AB and northern BC and has been developed with numerous techniques. However this field study focuses solely on Horizontal wells in the Middle Bakken within MT and ND.

MT Middle Bakken = silty, sandy dolomite 6-15 ft thick at 10,000 ft depth
ND Middle Bakken = gray interbedded siltstone/sandstone up to 85 ft thick, 9500-11,000'

Map courtesy of Julie LeFever, North Dakota Geological Survey

Navigation menu

Goal: Identify Best Practices

- Single/Multiple Laterals?
  - 1 to 7 attempted
- Wellbore Azimuth
  - The industry has tried them all!
- Frac size
  - 150,000 lb? 2,000,000 lb ?
- Proppant Size
  - 100 mesh? 16/20?
- Isolation & Diversion. Fluid type. Pump Rate. Mitigate sand flowback. Many other issues.
- All require estimate of frac intersection

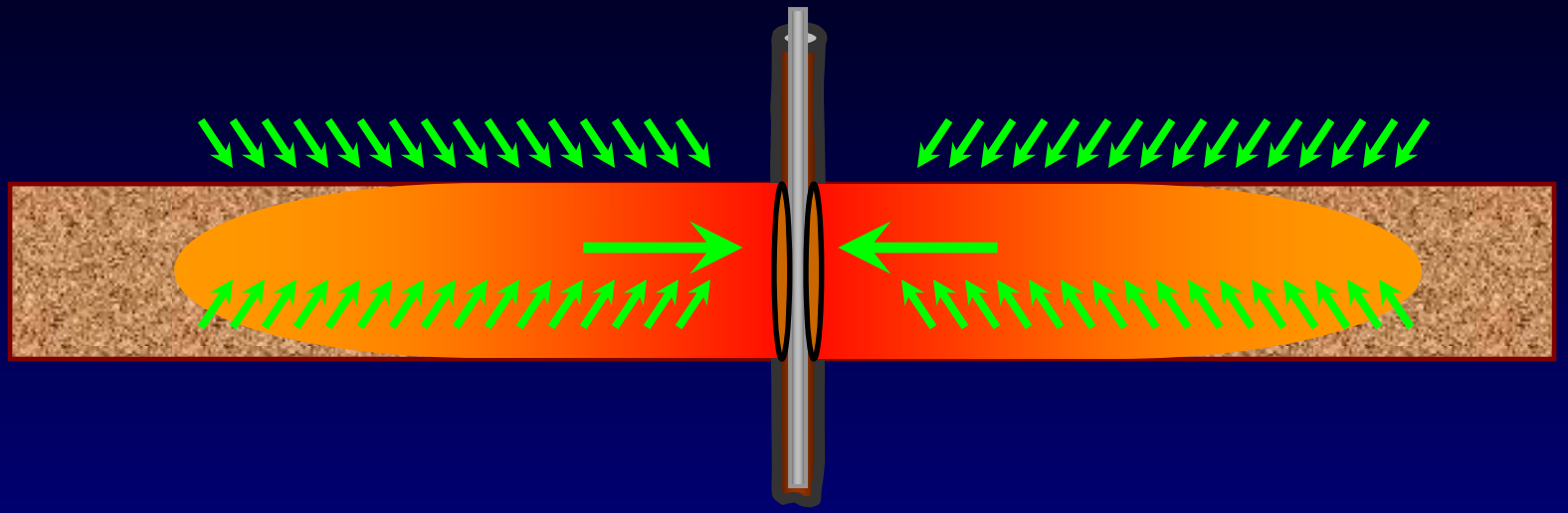
Navigation menu

Why is there no consensus on the best strategy for the Bakken?

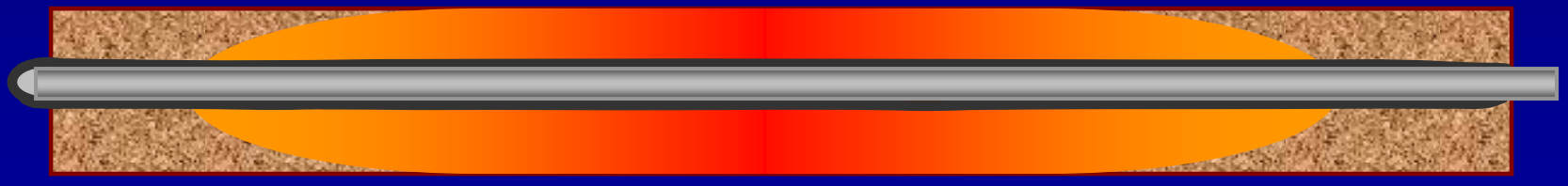
- We have differing notions of how fracs behave
- When horizontal wells are fracture stimulated,
  - one of the most important questions is the orientation of the fracture

Navigation menu

Intersection of Wellbore and Fracture



Vertical Well: Typically conductivity-limited



Horizontal Well with Longitudinal Frac:
Uncemented or fully perforated liner
Good connection, fluid only needs to travel ½ the pay height within the frac.
Proppant conductivity requirements are trivial – almost anything will be fine

ion menu

Intersection of Wellbore and Fracture
Cemented Liner

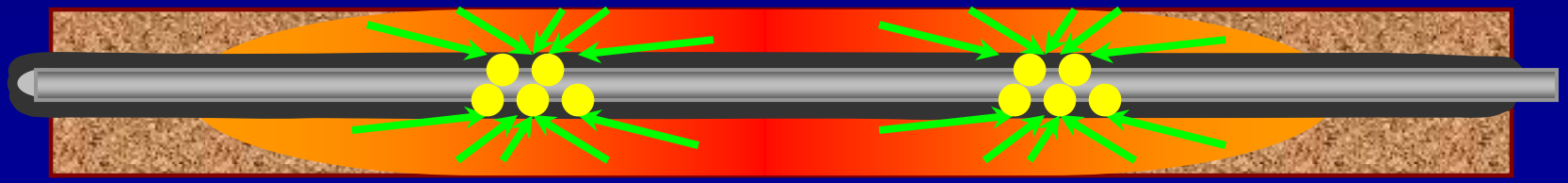
Horizontal Well

Cemented liner with limited perforations

Fluid travels shorter distances within the frac, but there is significant flow convergence around perfs.

Proppant conductivity requirements are a consideration

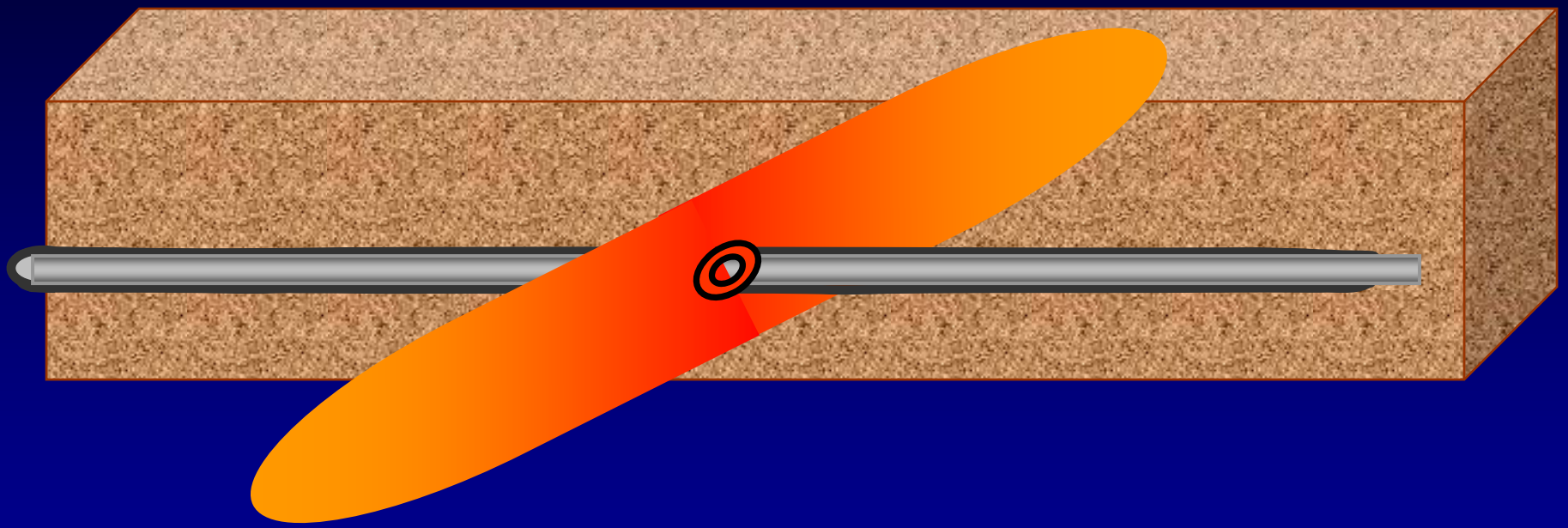
Lyco selected RCS for this completion style (SPE 90697)



Navigation menu

Intersection of Wellbore and Fracture

What if the fracs are NOT longitudinal?



Horizontal Well with Transversely Intersecting Frac:
(Orthogonal, perpendicular, transverse, imperfectly aligned)

Oil/gas must travel hundreds/thousands of feet within fracture, and converge around a very small wellbore – high velocity within frac!

Horrible Connection; Enormous fluid velocity and **proppant characteristics are key!**

gation menu

So the Dilemma:

- Scenario 1 -
  - Longitudinal frac – openhole or fully perforated
    - you don't care about the proppant type, concentration, over-displacing treatment, gel residue, treatment QA/QC, etc.
- Scenario 2 -
  - Longitudinal frac – cemented liner w/ limited entry perforations
    - You probably care.
- Scenario 3 -
  - Transverse frac
    - Proppant type and concentration are critical.
    - Anything you can do to improve near-wellbore conductivity should pay tremendous benefits
    - Fracs are likely longer than we can support

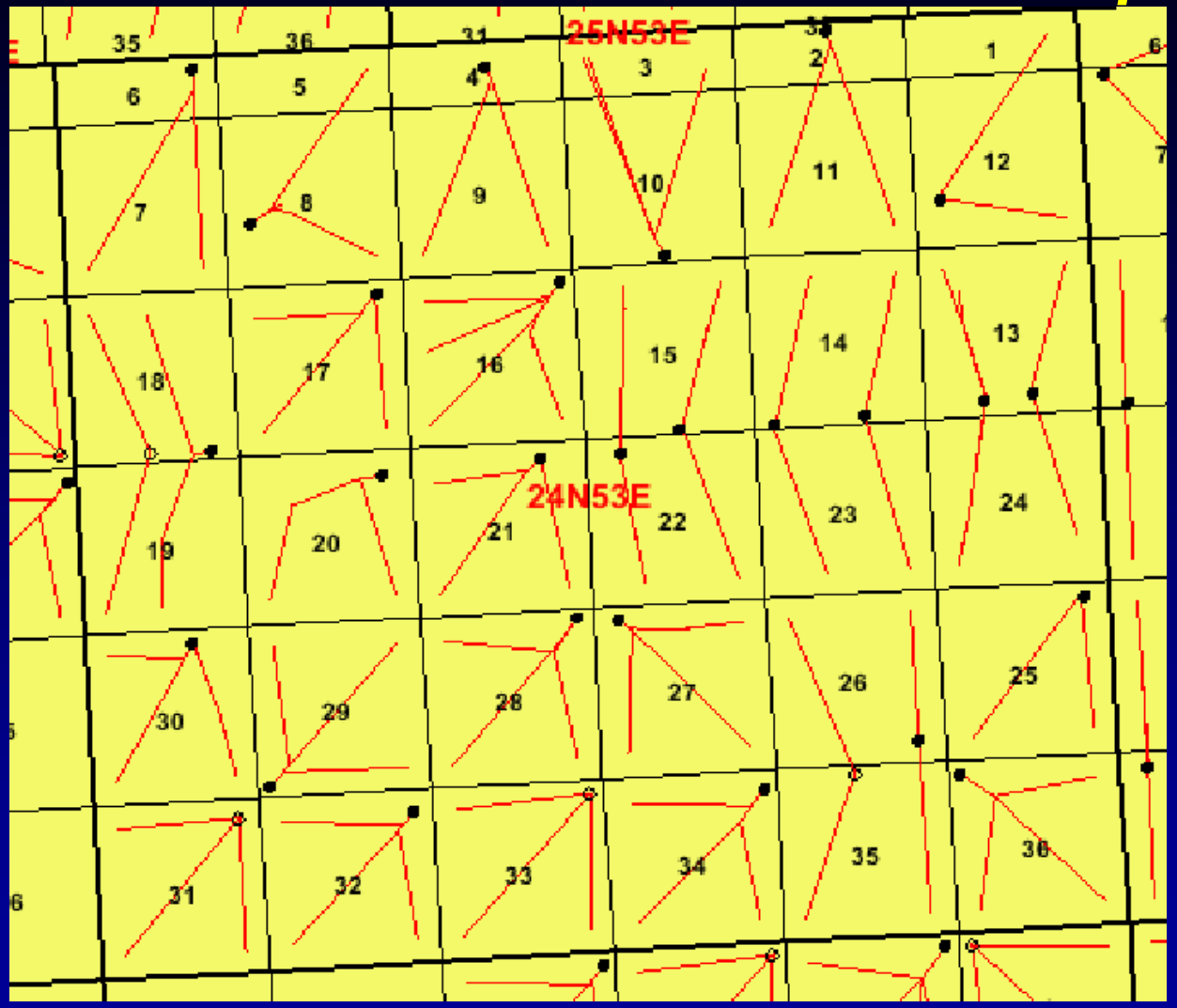
Navigation menu

The Status:

- Many intelligent people are trying wildly diverging things in the Bakken – based on different mental models of these fracs.

Navigation menu

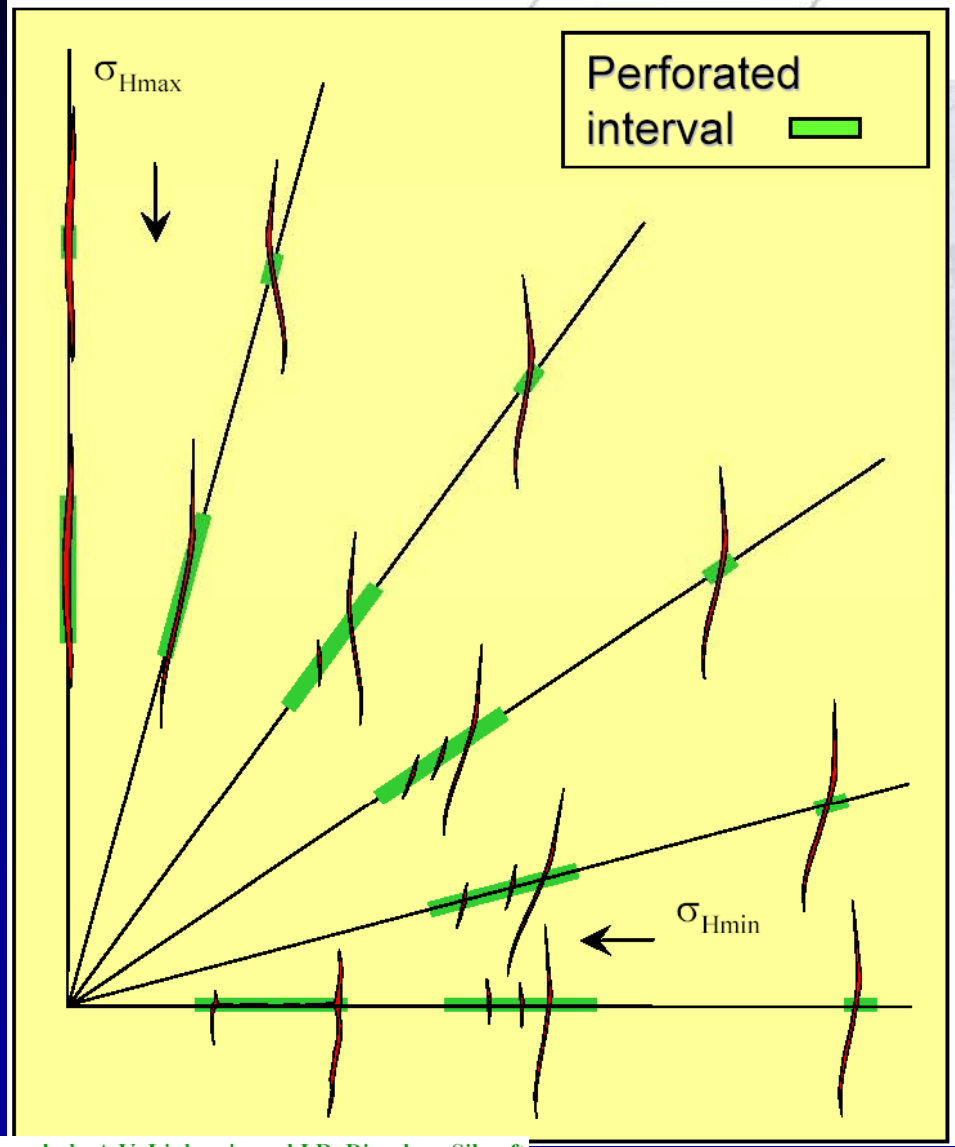
One Montana Township

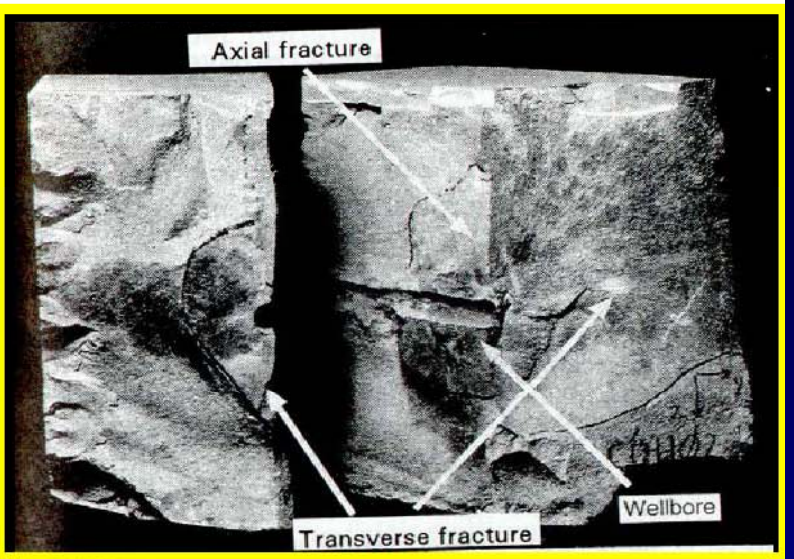


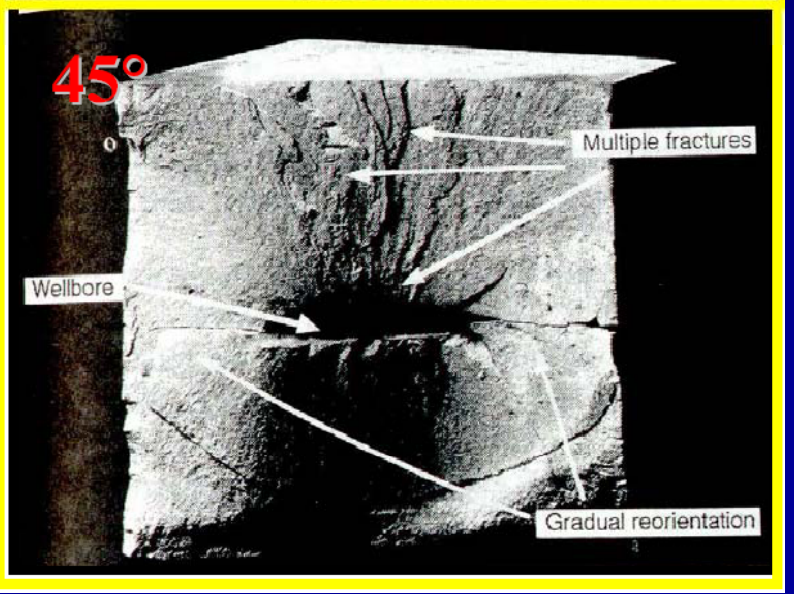
- Various Wellbore Azimuths and Configurations

Navigation menu

Fracture Initiation and Intersection with Wellbore Depend on Azimuth







A.V. Brovchuk, A.V. Liplyanin and I.R. Diyashev, Sibneft
D. Grant Jr., D. Oussoltsev and K.Butula, Schlumberger

Sources: Leen Weijers- photos.

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

Navigation menu

What do we know about frac geometry and orientation?

- At least 5 Bakken wells in ND and MT have been frac-mapped
  - Operators have not disclosed results
- What can we infer from other Bakken information?

Navigation menu

Bakken Frac Orientation

Evidence of Transverse Fracs

- At least 4 treatments have frac'ed into offset wells 1500 to 2200 ft away in transverse direction, pumping sand-laden slurry to surface
- Temporary watercut increase in offset wells (transverse direction)
- Treating pressures often show high net pressures (exceeding both horizontal stresses, suggestive of complex fracturing)
- RA tracer often shows only a small portion of the lateral is treated (discuss uncemented liners)
- Portions of one microseismic mapping job were released by a service company
- With all the various azimuths drilled it is likely we create some transverse components

Evidence of Longitudinal Fracs

- Confident lateral is aligned with max principle stress
- Cylinders "prefer" to split axially
- Hot dogs split longitudinally…
- Models assuming homogeneous reservoirs and uniform stresses generally predict longitudinal fracture initiation
- RA tracer (potentially in annulus of uncemented liner?)

Navigation menu

Do Production Results Indicate Orientation?

- Recall that superior proppants should provide zero value if the fracs are longitudinal
- What do the field results show?

- State Records often inaccurately show “frac sand” as the generic proppant type. Public records were supplemented with the records from service companies, proppant suppliers, and operators.

Navigation menu

Well Production Data - Bakken

Notes/Caveats

- This is not a “controlled trial”
- It is more an “observational study”
- There are many factors we have ***not*** been able to correct for
  - Different service companies, fluid systems, FAT, SMA, additives
  - When the operator runs pumps, tubing pressures
  - We don’t always know the job size on all wells
  - Treating pressures, proppant concentrations, screenouts, displaced/overdisplaced, flowback strategies
  - Some of these wells have been produced naturally prior to stimulation
- Given the large number of uncontrolled variables, does frac conductivity matter? Can we infer whether significant production is coming from transverse fracs?

Navigation menu

Middle Bakken – North Dakota

July 2007: Production data on 157 Middle Bakken horizontal wells. Excluded Bakken recompletions from dataset due to prior depletion

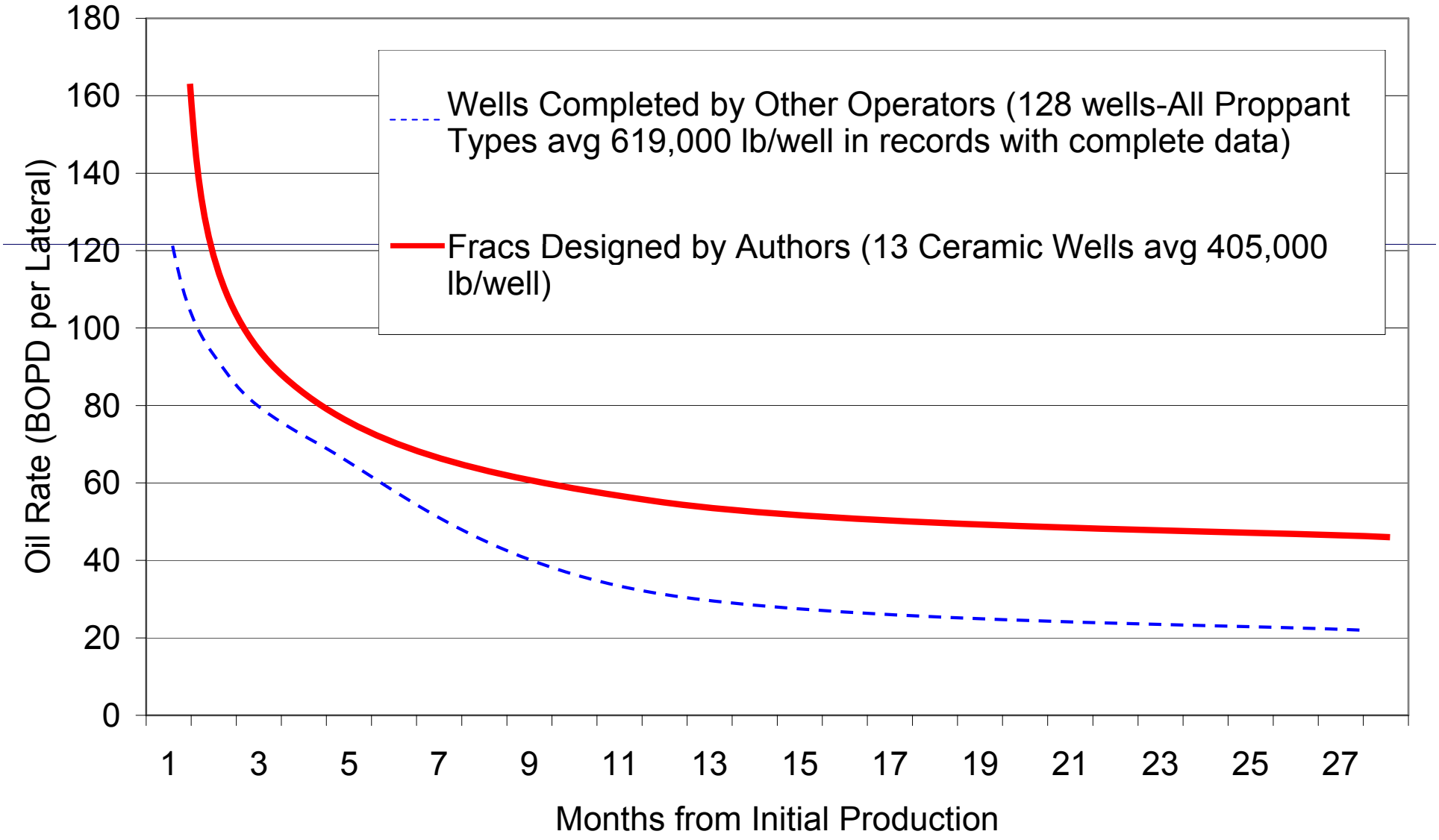
9 of 28 operators used ceramic

28 operators:

Ansbro
Armstrong
Berco
Brigham
Burlington
Continental
Encore
Enerplus
EOG
Evertson
Griffon
Headington
Hess (Amerada)
Kodiak
Mammoth
Marathon
Missouri River
Murex
Nance
PDC
Petro-Hunt
Pogo
Prospective
Samson
Slawson
Texakota
Tri-C Resources
Whiting

Navigation menu

North Dakota Bakken
Production History, bopd
Data through May '07



North Dakota Bakken
Production History, bopd
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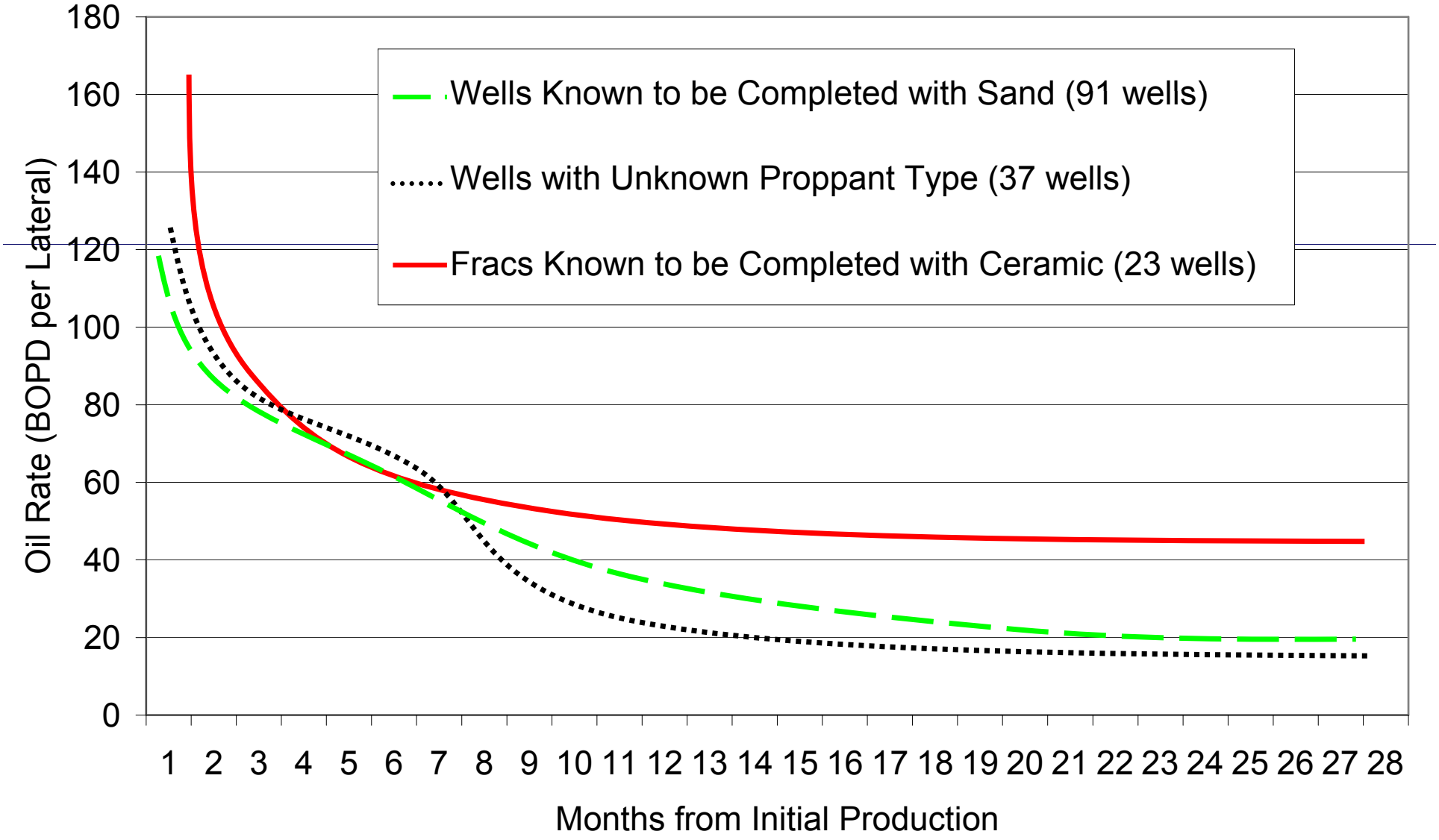


Geological Variation

- Very dangerous to compare wells across this large of an area.
- Instead wells were analyzed compared to offset wells

Navigation menu

Geological Variation

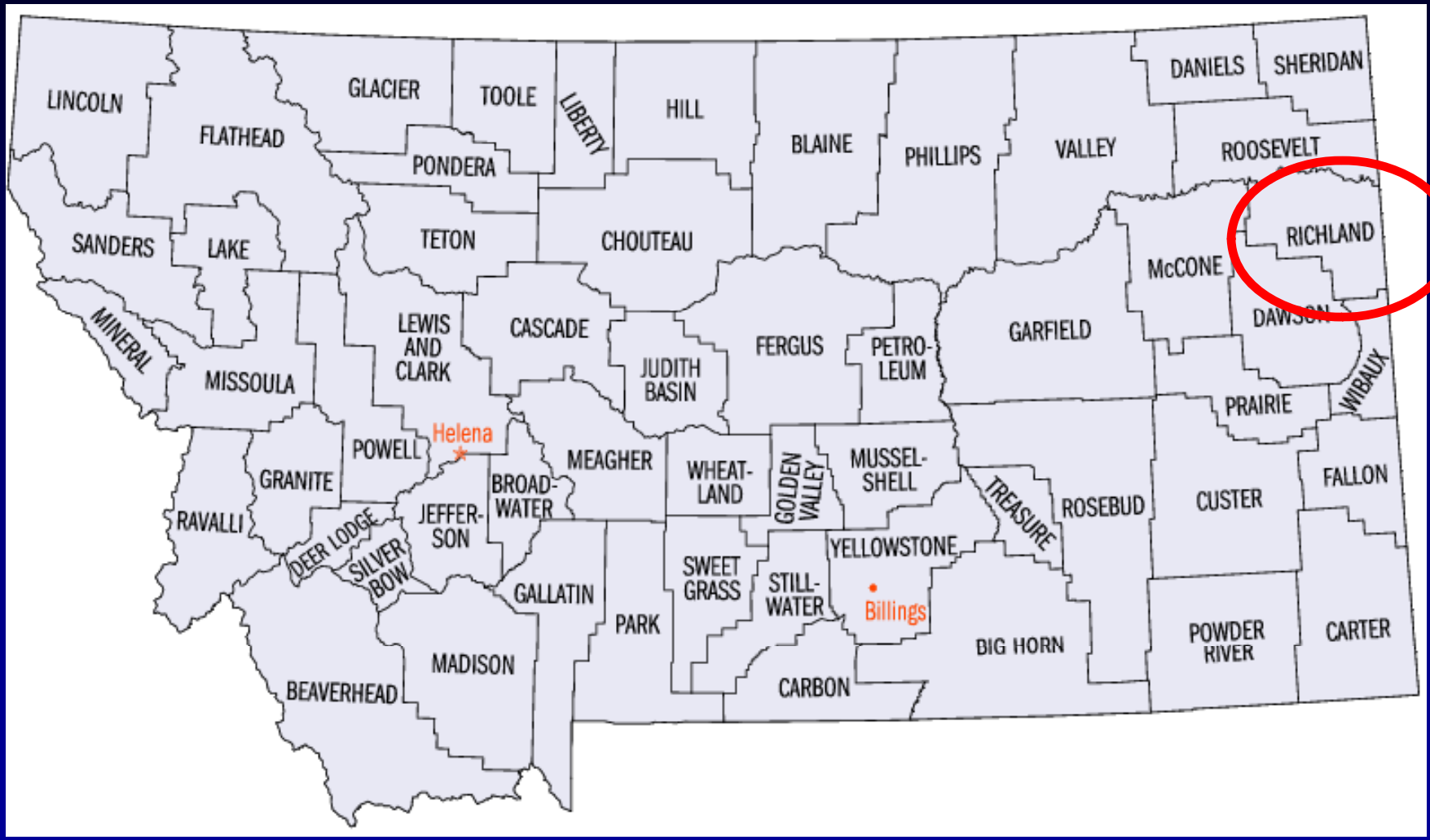
- What do you consider an offset? (low well density in ND)
- What is the least biased way to compare wells?

- There were 9 townships in ND where known ceramic and known sand laterals were present.
- In 6 of 9 townships, ceramic laterals provided substantially higher production.

- Statewide, ceramic completions averaged 441,671 lb/well, while sand completions averaged 630,219 lb/well
- Ceramics were not a “magic bullet”. Four wells stimulated with ceramic produced <25 bopd 6 months after IP. Sustained production requires adequate reservoir quality, treatment design, and execution.
- However, proppant quality appears to impact productivity in North Dakota, suggesting some wells have transverse fracs.

Navigation menu

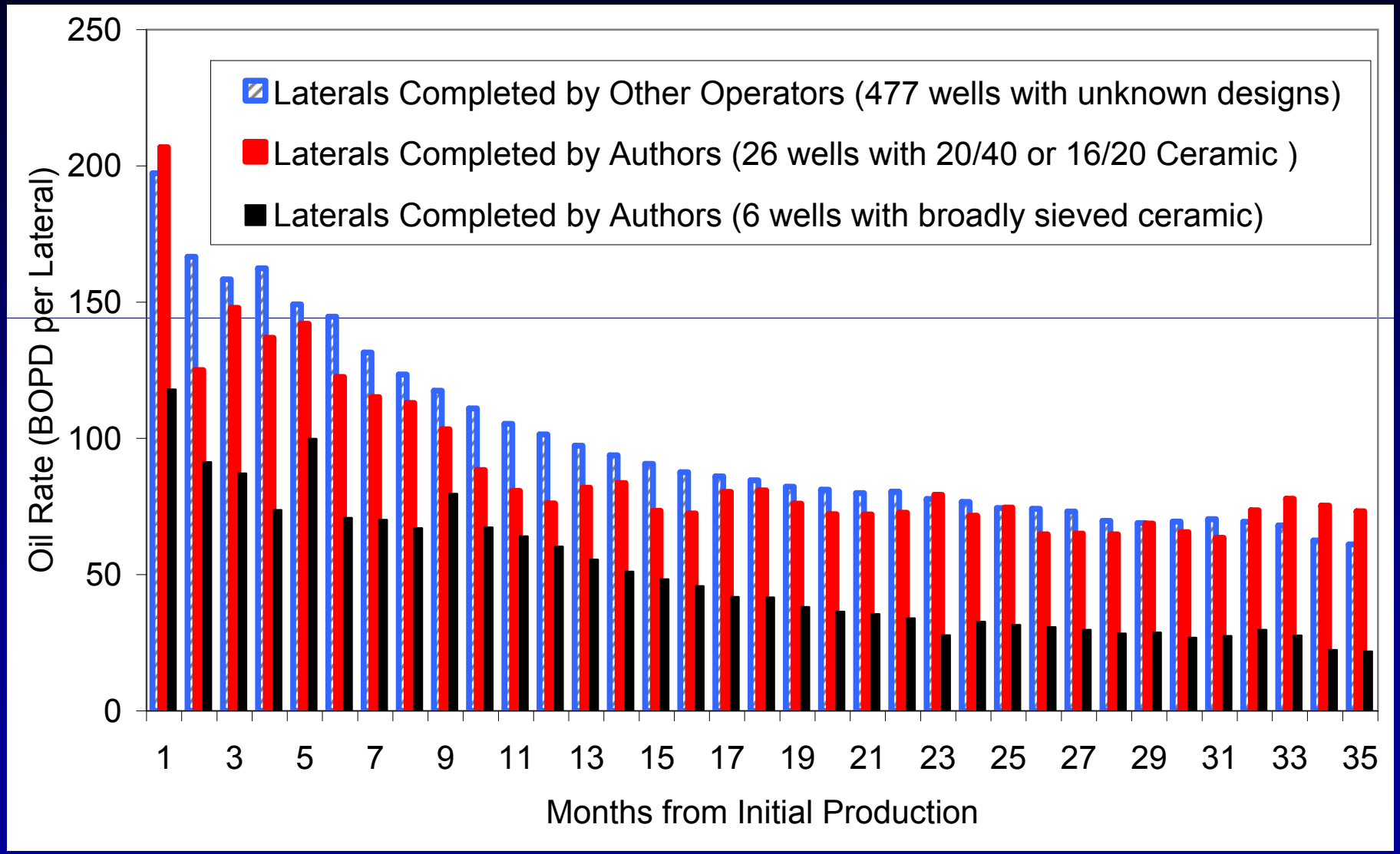
Middle Bakken – Montana



Public data on 509 Bakken wells in Richland County.
State website does not show frac details or proppant type

Navigation menu

Montana Statewide



- Author's Wells don't compare favorably to Statewide Average

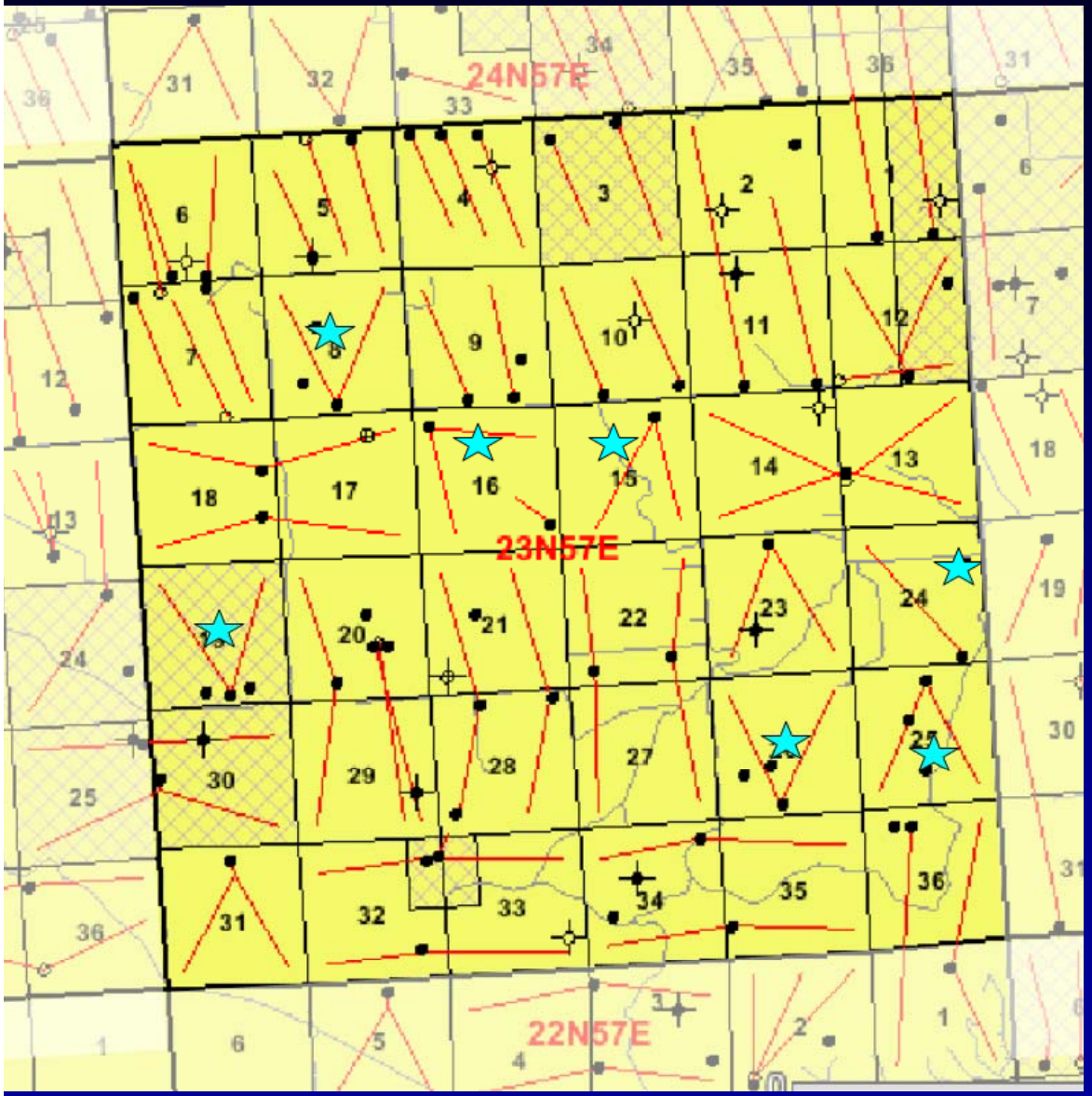
Navigation menu

Geological Variation

- Author's wells are located in only 7 of the 34 productive townships in Elm Coulee Field.
- Only 5 townships have any offset wells for comparison.

Navigation menu

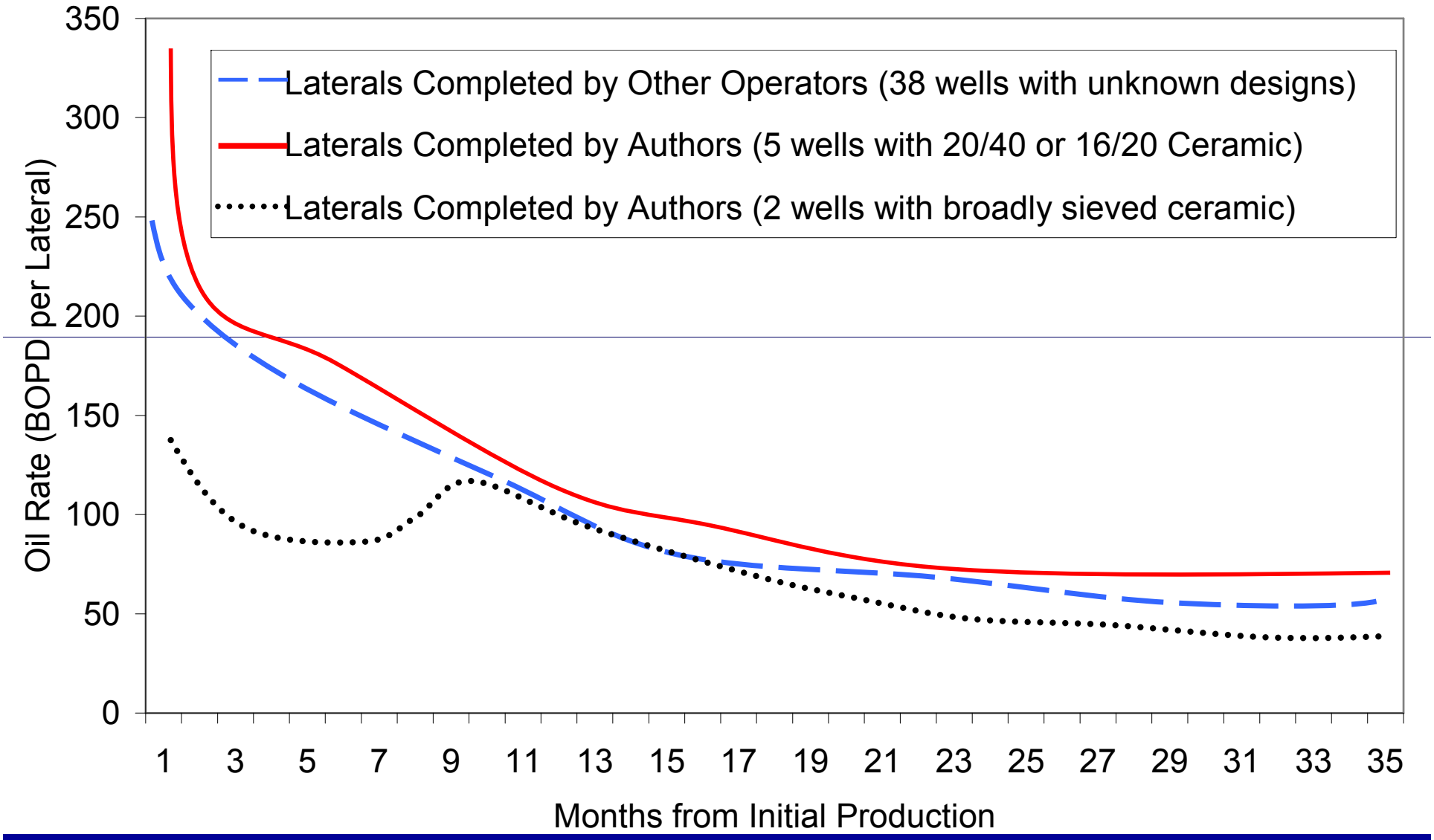
Review Smaller Area to Reduce Geological Variation



- 7 wells completed by authors compared to 38 offset wells completed by 7 different operators

Navigation menu

Review Smaller Area to Reduce Geological Variation



- Although initial rates 85 bopd higher, the average increase is 10 bopd in this township for proppants currently utilized by the authors

Navigation menu

Montana

- It appears by comparisons to offsets, MT laterals with tightly sieved ceramic are exceeding production from offset laterals with unknown proppant type, but not by the wide margin observed in North Dakota.
- A more detailed analysis will require investigating the proppant type and mass in offset wells (not currently available on MT website)

Navigation menu

Economic Analysis

- Bakken Wells ~ $4 to $8 million per well (depends on number of laterals, frac size, etc)
- Ceramic Proppant ~ $.35-$.40/lb premium to white sand
- For 250,000 to 350,000 lbs, cost to upgrade to LWC is $100,000 to $150,000
- This is a lot of money, but only 2% to 4% of the wellcost
- Production results suggest that the well production rate and EUR are easily increased by more than 2 to 4%.
- Note that the authors *reduced* total well cost by using single laterals, shorter drilled length, and reduced frac size (despite more expensive proppant)

Navigation menu

Some of the Conclusions

- Number of laterals, optimal length?
  - Single, short (similar to Brian Wright, IHS analysis-MT)
  - Drill to hold acreage, or to maximize economics?
- Preferred wellbore azimuth?
  - NW-SE (similar to Lynn Helms analysis of ND laterals)
- Effective diversion?
  - Continued emphasis
- Treatment size, proppant type, treating rates, fluids?
  - Smaller jobs, 16/20 LWC, various rates, XLG
- How to mitigate sand or proppant flowback?
  - No proppant flowback with authors' approach

- All of these strategies depend on our understanding of wellbore/frac interconnection. Room to improve!

Navigation menu

- Dilemma + Pinnacle Mapping of other HZ wells
- Fracture Complexity
- 90697
- Frac into Offset Wells – Transverse Fracs?

Production Data
  - North Dakota
  - Montana
  - Slickwater Fracturing

- Decision Making – Case Study
- Pump Failures, Proppant flowback
- Operator List
- Economics
- Valhall

- Bakken Refracs – 108117 (+ other references)

- Other Bakken References, plus Canadian, etc.
- Frac Photo – surface equipment for small Bakken slickwater job
- Additional Questions
- Oil Flow Experiment
- Summary – HZ wells
- Reservoir Contact – fracs versus multi-lateral wells
- Number of laterals?

- Misc Resources (Pinn, Definitions, ASR, etc)
  - Back to Top

Links to Topics

(Appendices removed from this version, a few surplus slides follow)

Navigation menu

Number of Laterals?

- Examined 440 Elm Coulee horizontal wells
  - Wells grouped by number of laterals
  - Determined normalized average production for each well
  - Forecast (extrapolate) production for each category
  - Assumed homogeneous reservoir, identical azimuth, etc
  - Single and dual laterals provide best payout and ROI

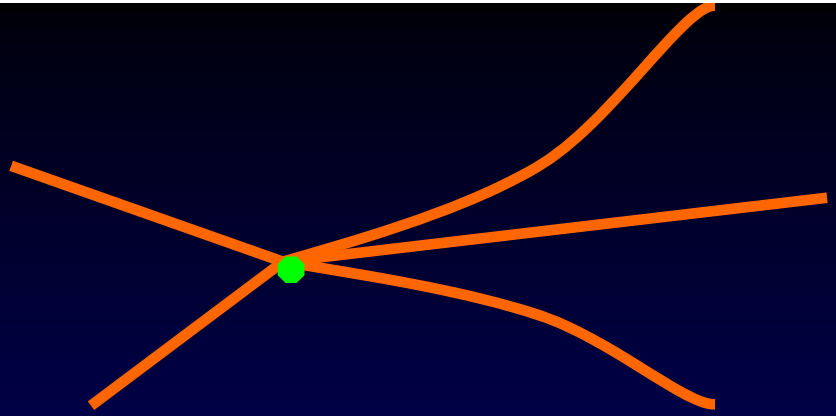
Table 3. A detailed analysis shows single- and dual-lateral wells offer the best returns in the Bakken in the Elm Coulee area.

CONFIGURATION	GROSS OIL EUR MBO	EUR (MMCF)	TOTAL NET INVESTMENT ($)	TOTAL NET CASH FLOW ($)	DISC (10%) FLOW($)	DISCOUNTED ROI	PAYOUT (MO)	LIFE (MO)
Single Lateral (6,000')	379	245	3,500,000	9,526,000	4,200,000	2.20	24	360
Dual Lateral (9,000')	455	360	4,500,000	10,335,000	4,723,000	2.05	23	360
Quad-Lateral (24,000')	538	411	6,500,000	11,566,000	3,972,000	1.61	31	360
Tri-Lateral (17,000')	460	309	5,600,000	9,020,000	3,300,000	1.59	33	360
Five Laterals (24,000')	277	146	7,500,000	1,093,000	740,000	1.10	26	360
Vertical Well	131	87	2,000,000	1,560,000	(166,000)	0.92	102	360
Six Laterals (24,000")	144	101	8,500,000	-4,541.000	-5,168,000	0.39	N/A	360

Brian Wright, IHS Inc. - Nov 2007 E&P (eandp.info)

Navigation menu

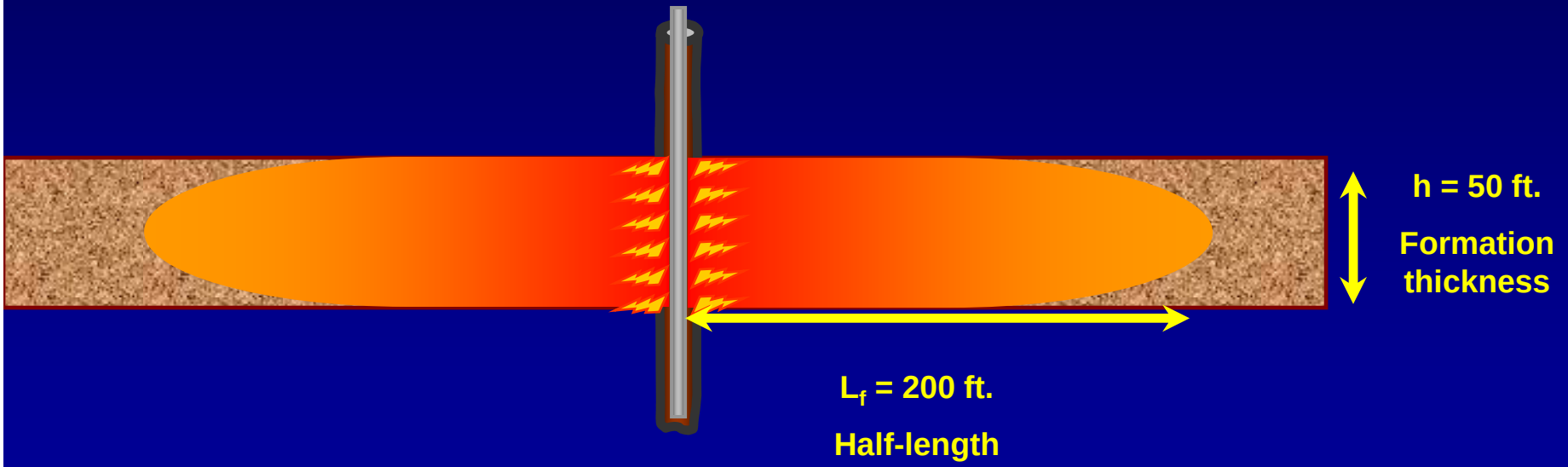
Reservoir Contact



Overhead, map view of 5 laterals drilled from one wellhead.

Multi-Lateral – 15,000 ft of drilled length in 5 laterals

34,000 ft^2 of contact



Tiny frac; perhaps 20,000 lbs of sand at 1 pound per square foot

2 wings * 2 faces * 200 ft * 50 ft = 40,000 ft^2 of contact

Navigation menu

Increasing Reservoir Contact

1) “Tiny” fracs are enormous!
2) Even the smallest propped fracs will contact more reservoir than the most complex horizontal completions
3) It is often preferable to drill a well that can be effectively fracture stimulated instead of simply maximizing drilled length

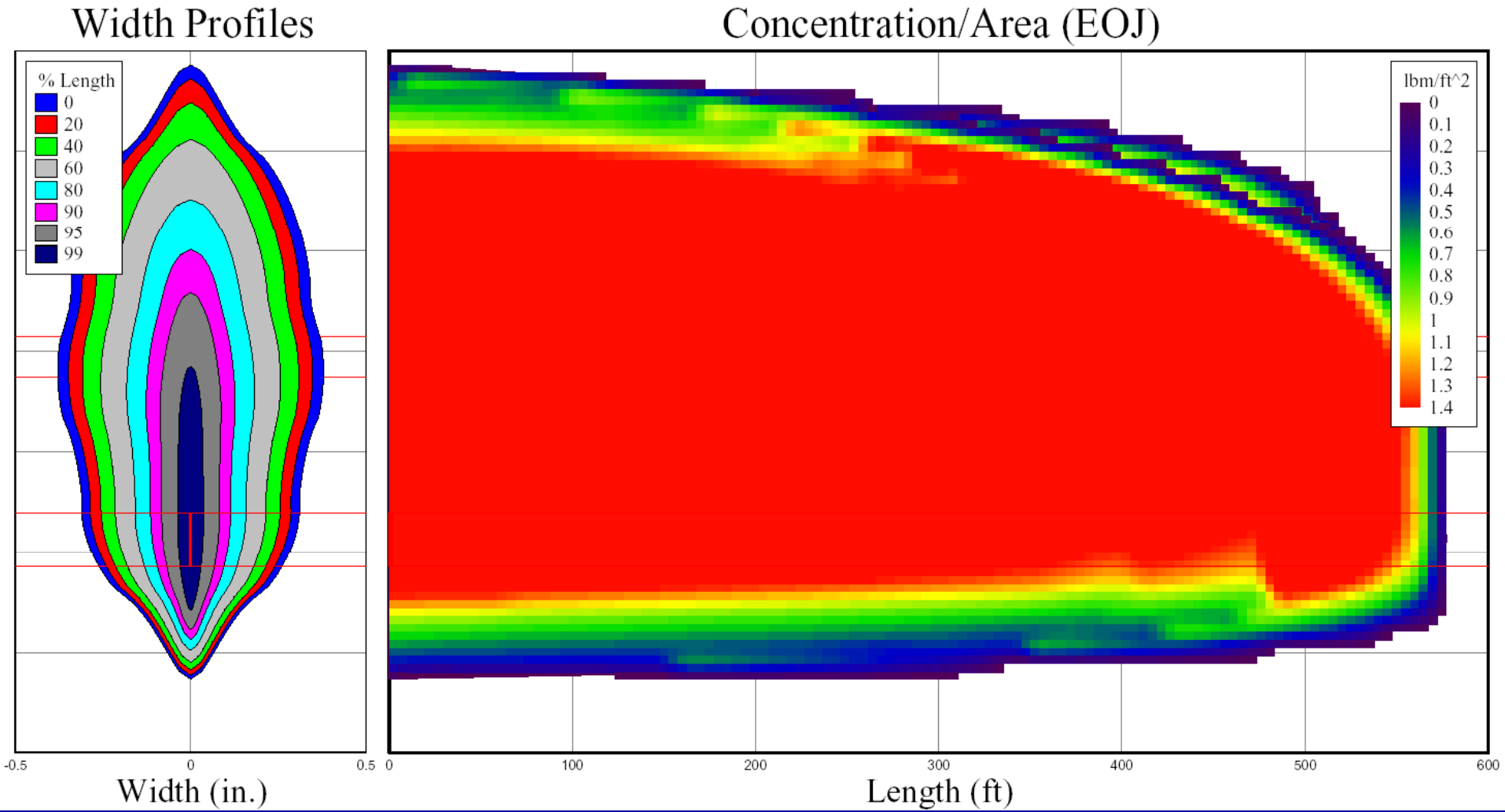
Navigation menu

Summary

- Longitudinal fracs have minimal conductivity requirements
- Transverse fracs have very high conductivity requirements
- Transverse fracs are frequently indicated in the Bakken by treating records, offset well watercuts, radioactive tracer surveys, and fracturing into offset wellbores
- Short laterals with small volumes of high quality proppant are frequently less expensive and more productive than offset wells using high quantities of frac sand

Navigation menu

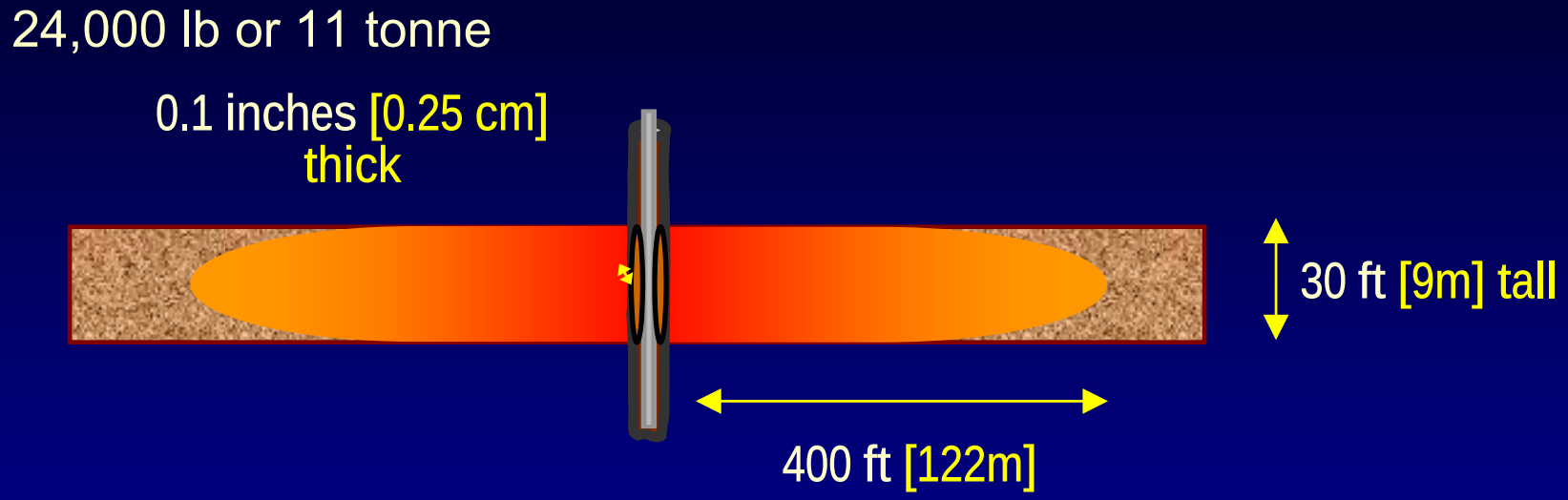
How do we envision fracs?



Navigation menu

Proportions of a (simple, planar) frac

- Generic size of a “small” frac (400 ft X_f) not to scale



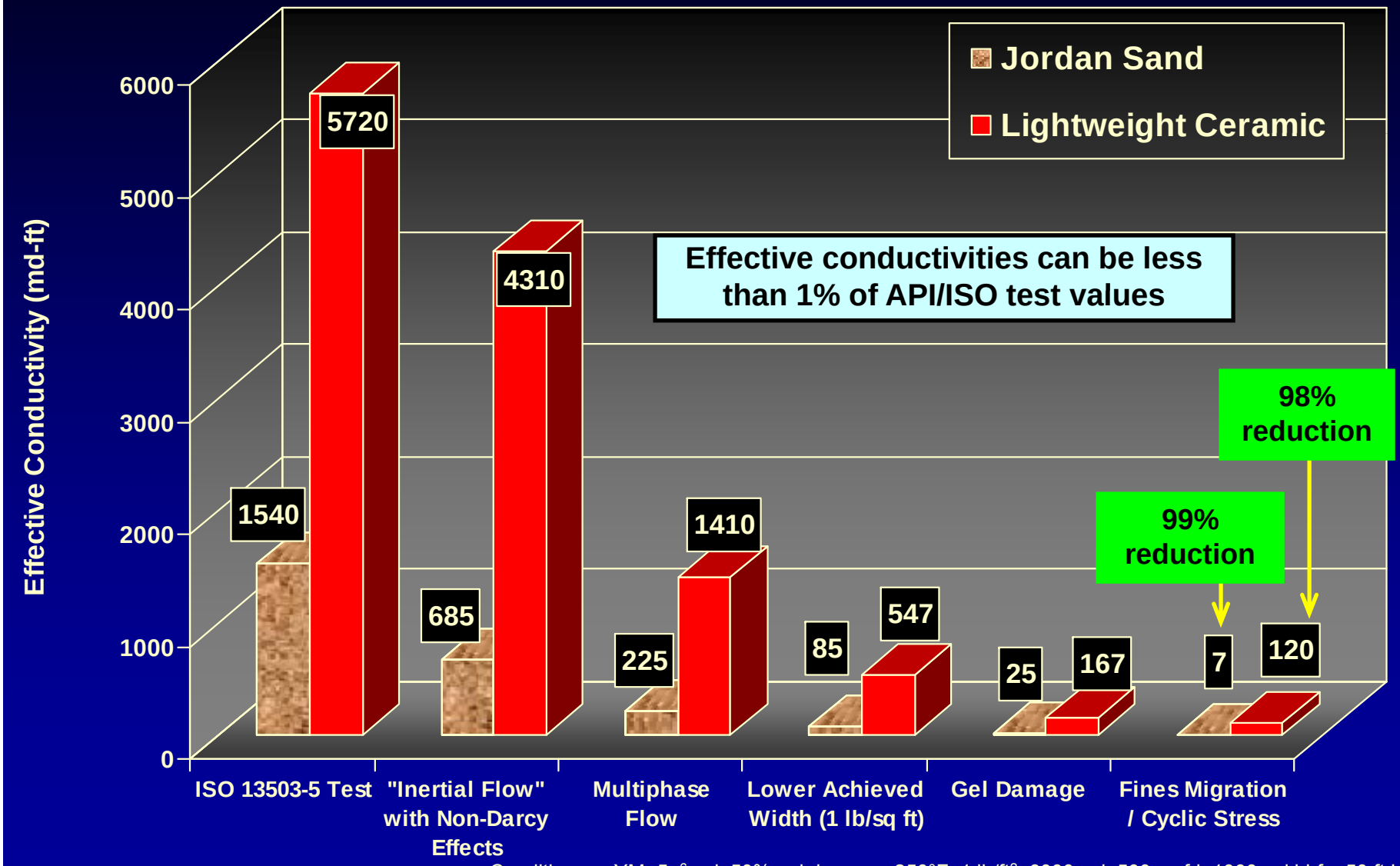
- The length and height are often much larger, but it is rare to have a frac wider than ~0.1 inches (around 1 lb/sq ft [5 kg/m^2] after embedment. - likely much lower after filtercake, spalling, etc)

In the Bakken, half-lengths of 2200 feet have been documented. There is also indication that some fracs grow vertically into the Lodgepole formation

Enormous flow convergence!
Fracture conductivity frequently constrains production!

Navigation menu

Cumulative Conductivity Reductions

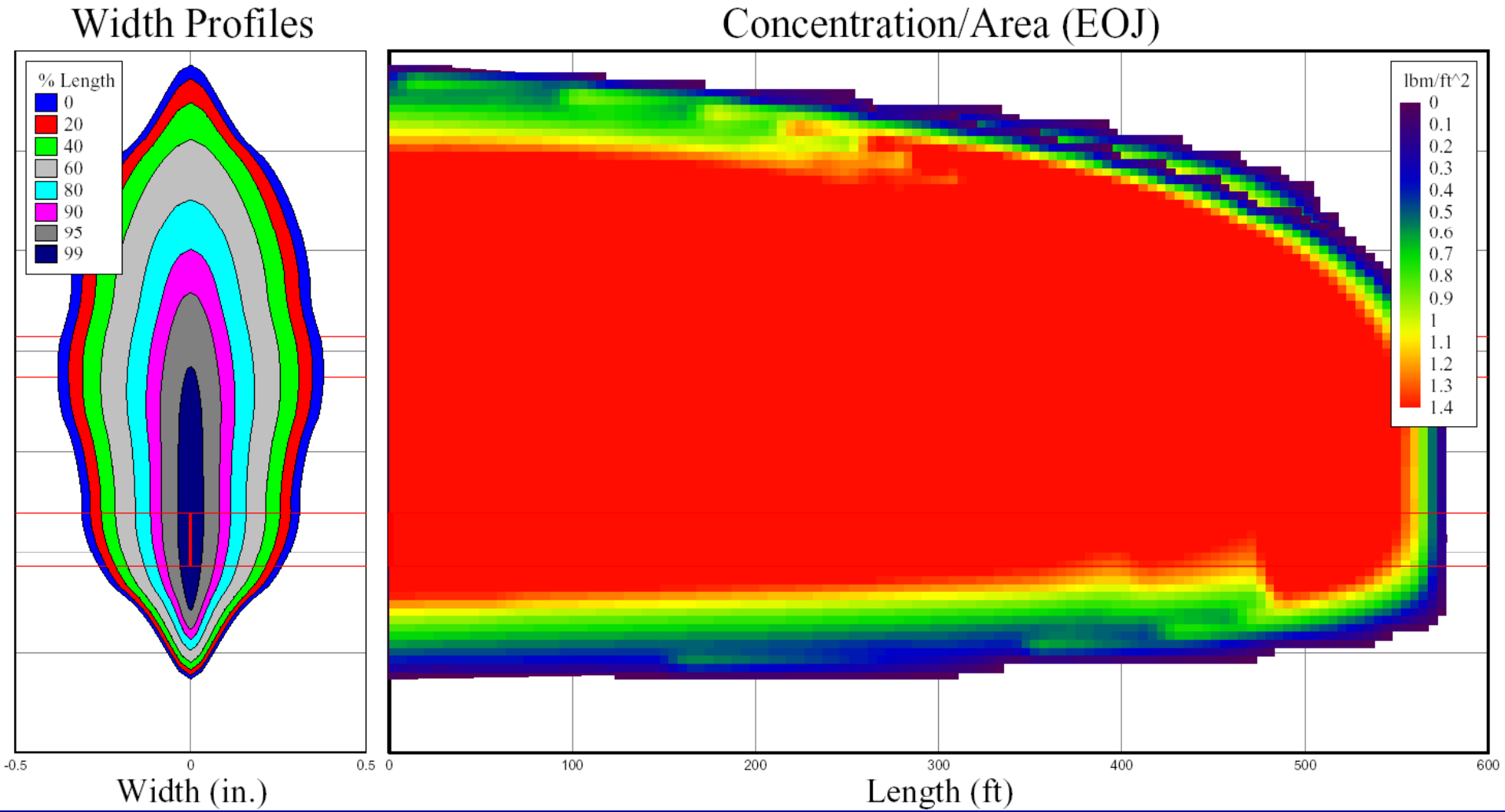


Conditions: YM=5e^6 psi, 50% gel damage, 250°F, 1 lb/ft^2, 6000 psi, 500 mcfd, 1000 psi bhfp, 50 ft H, 2 blpd

References: PredictK & SPE 106301

Navigation menu

How do we envision fracs?



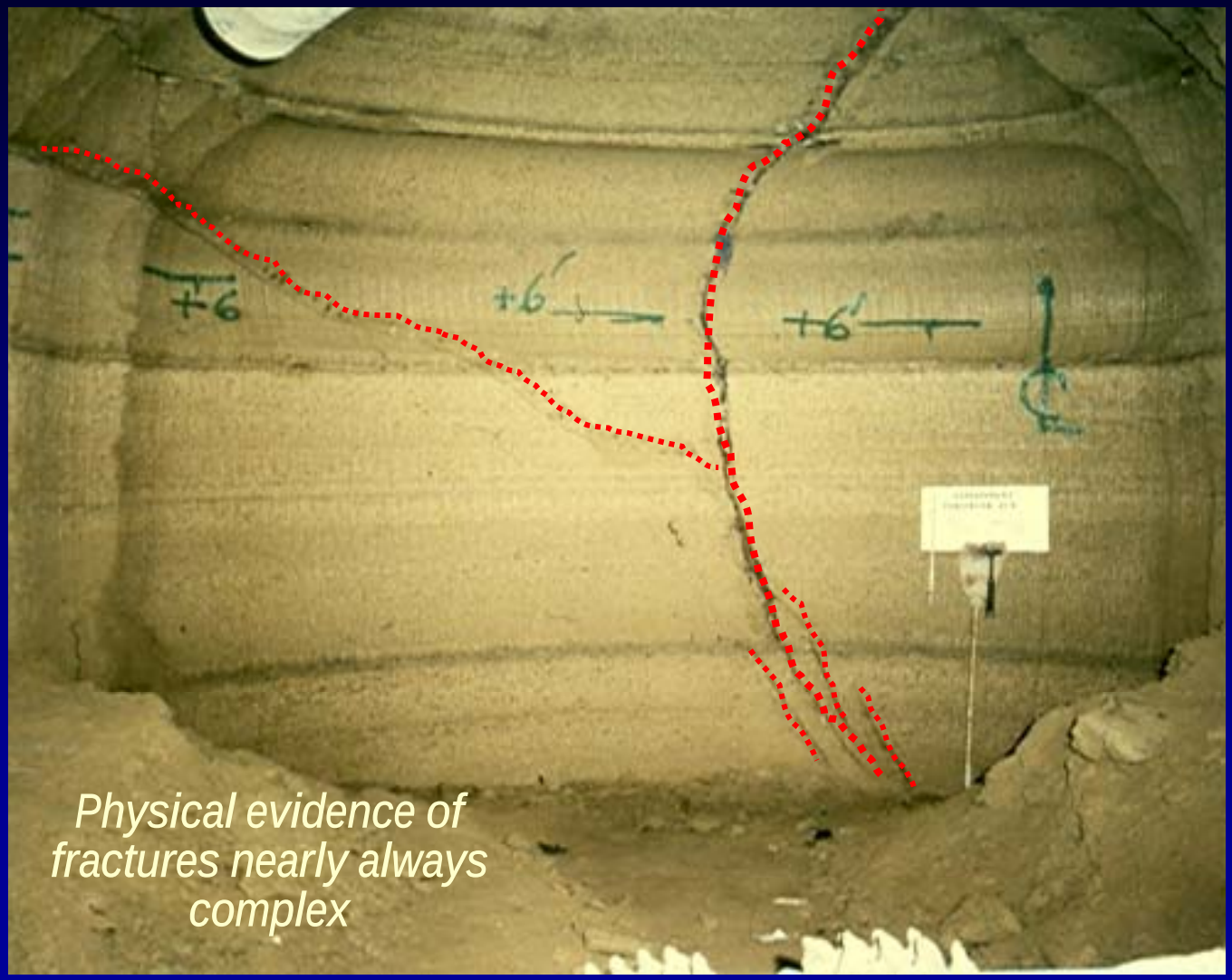
Navigation menu

Multiple Fractures

- Initiation At Perforations
  - Multiple Perforations Provide Multiple Entry Points For Fracture Initiation
  - Five Separate Fractures Are Visible In These Fractures Initiated From Horizontal Wellbore
  - 12 Perforations Total
    - 6 Top & Bottom

Navigation menu

Observations of Fracture Complexity

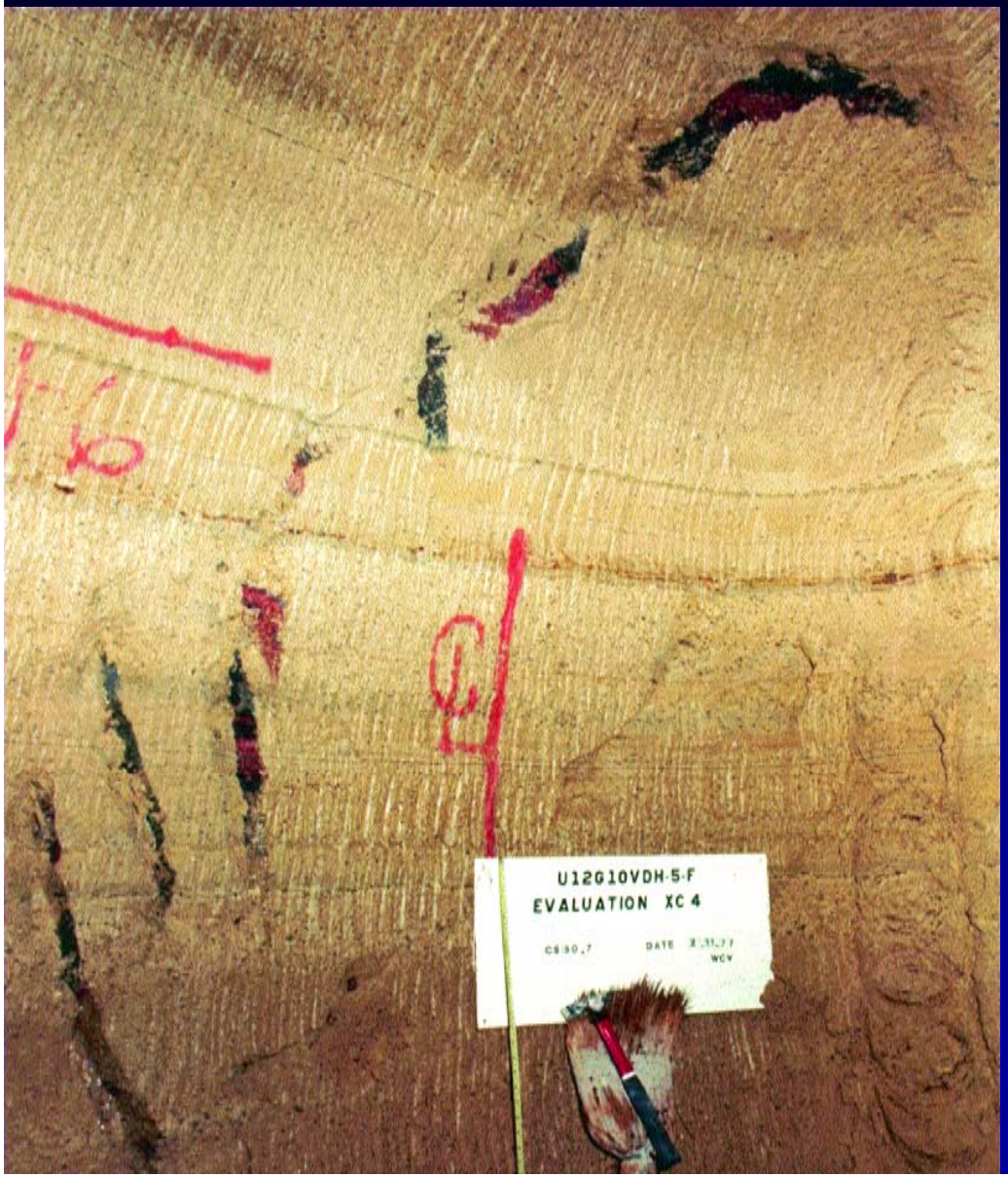


Physical evidence of fractures nearly always complex

NEVADA TEST SITE - HYDRAULIC FRACTURE MINEBACK

Navigation menu

Multiple Strands in a Propped Fracture (Vertical Well)



Physical evidence of fractures nearly always complex

NEVADA TEST SITE
HYDRAULIC FRACTURE
MINEBACK

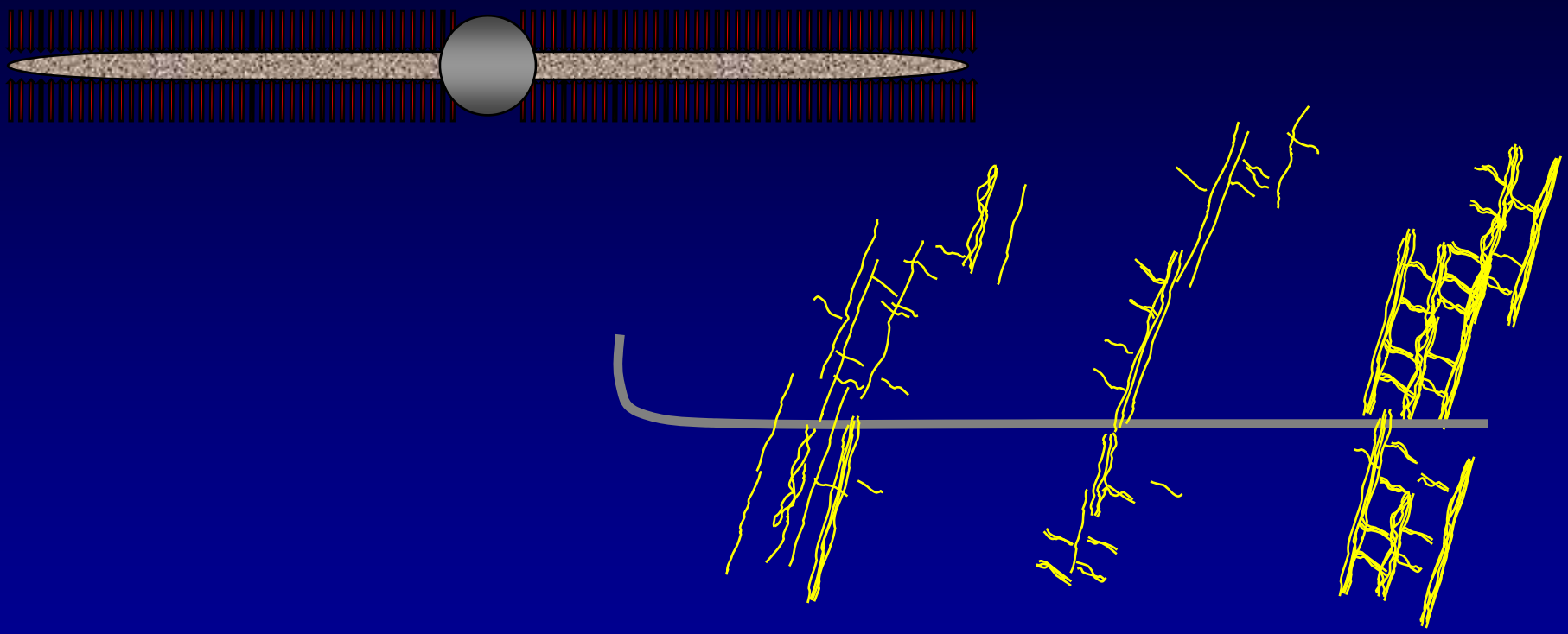
Navigation menu

Continuity or Conductivity Issues?

- Interference?
  - We often frac into offset wells
    - Mapped, slurry to surface, increased watercut, radioactive tracer
    - Demonstrated in Piceance (tight gas), Barnett (shale), Middle Bakken (carbonate), Jonah (tight gas), Dan (chalk)
  - Very often “pulse tests”, “interference tests”, EUR do NOT indicate competition. Often the connection INCREASES recovery of both wells!

Navigation menu

Since the fracture is key to development of tight reservoirs…

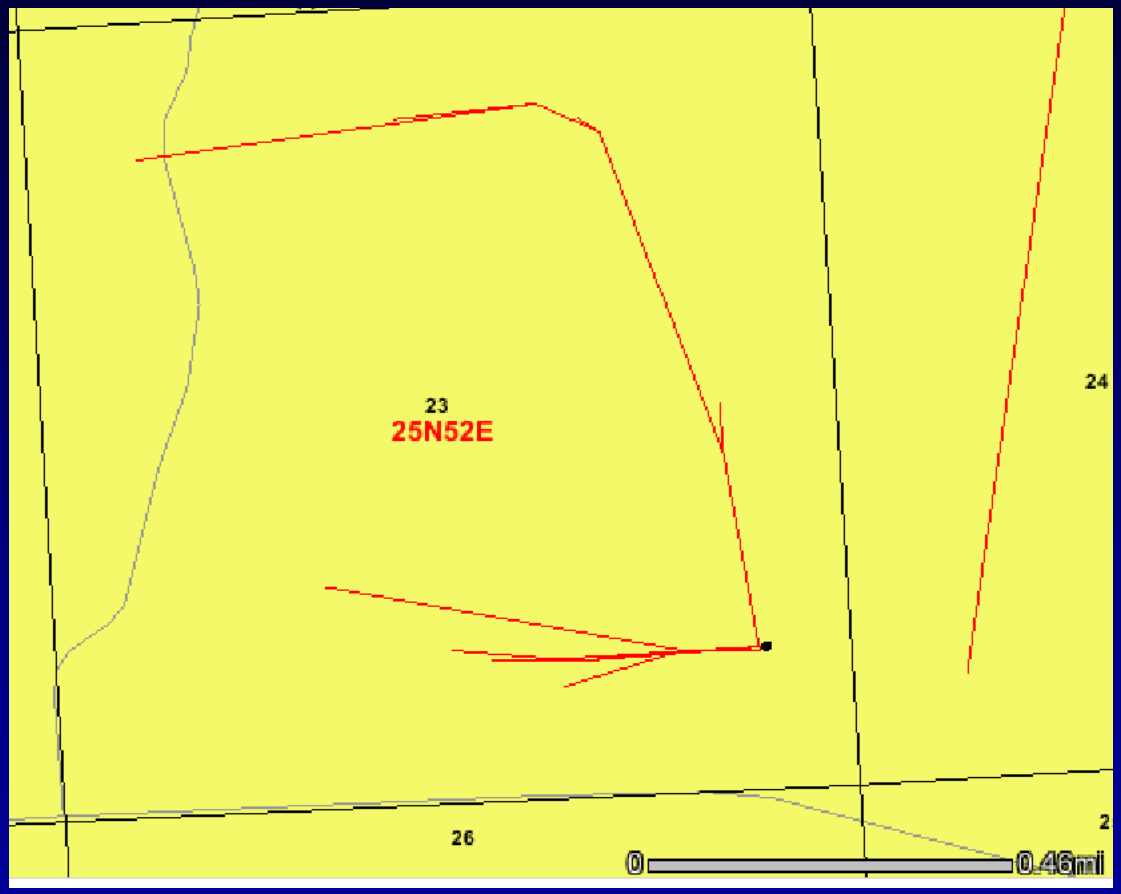


…great effort should be made to optimize the frac design.

Fracs are the most poorly understood and poorly optimized element of the well.

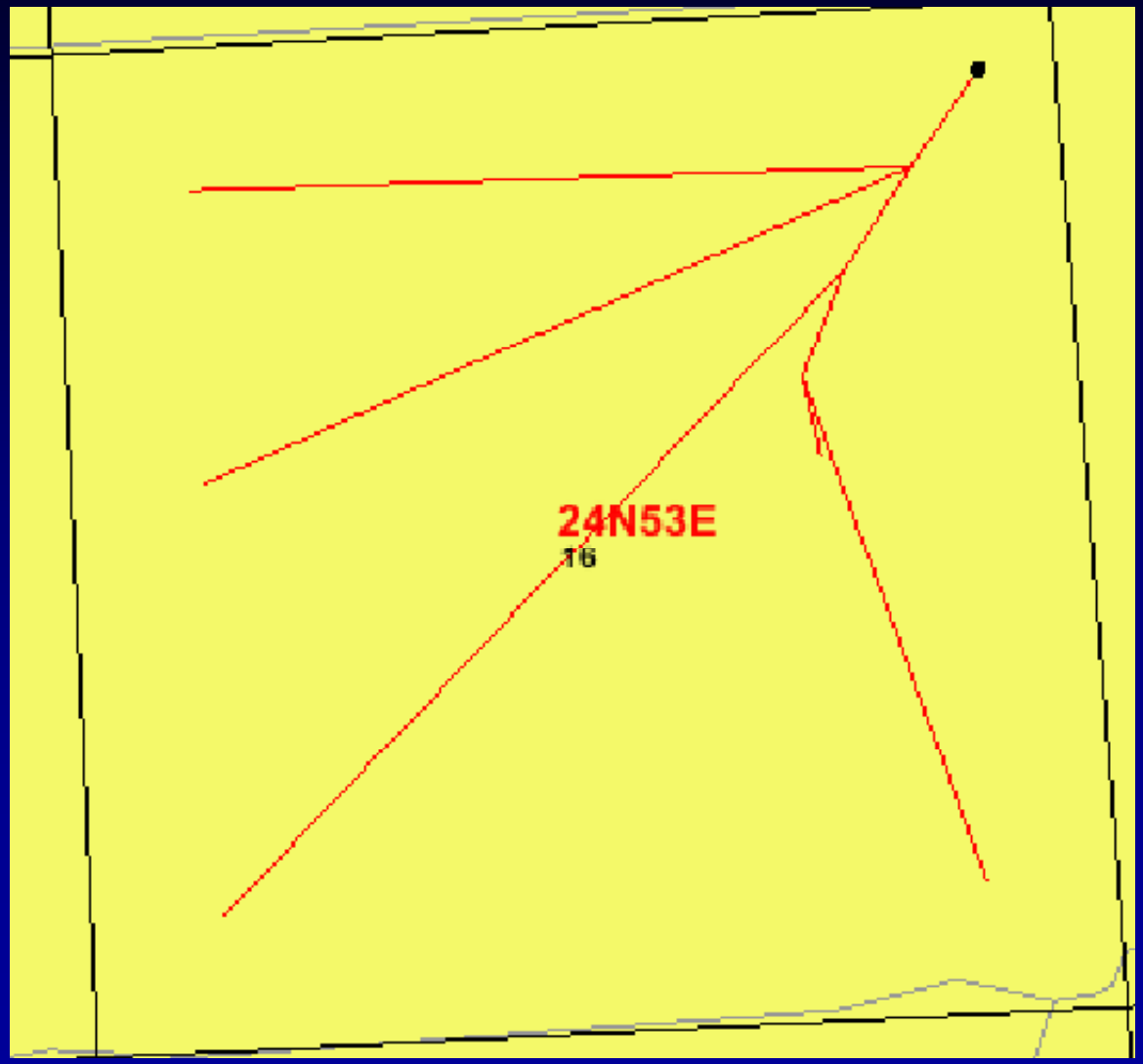
Navigation menu

Well shown as 8 laterals in MT



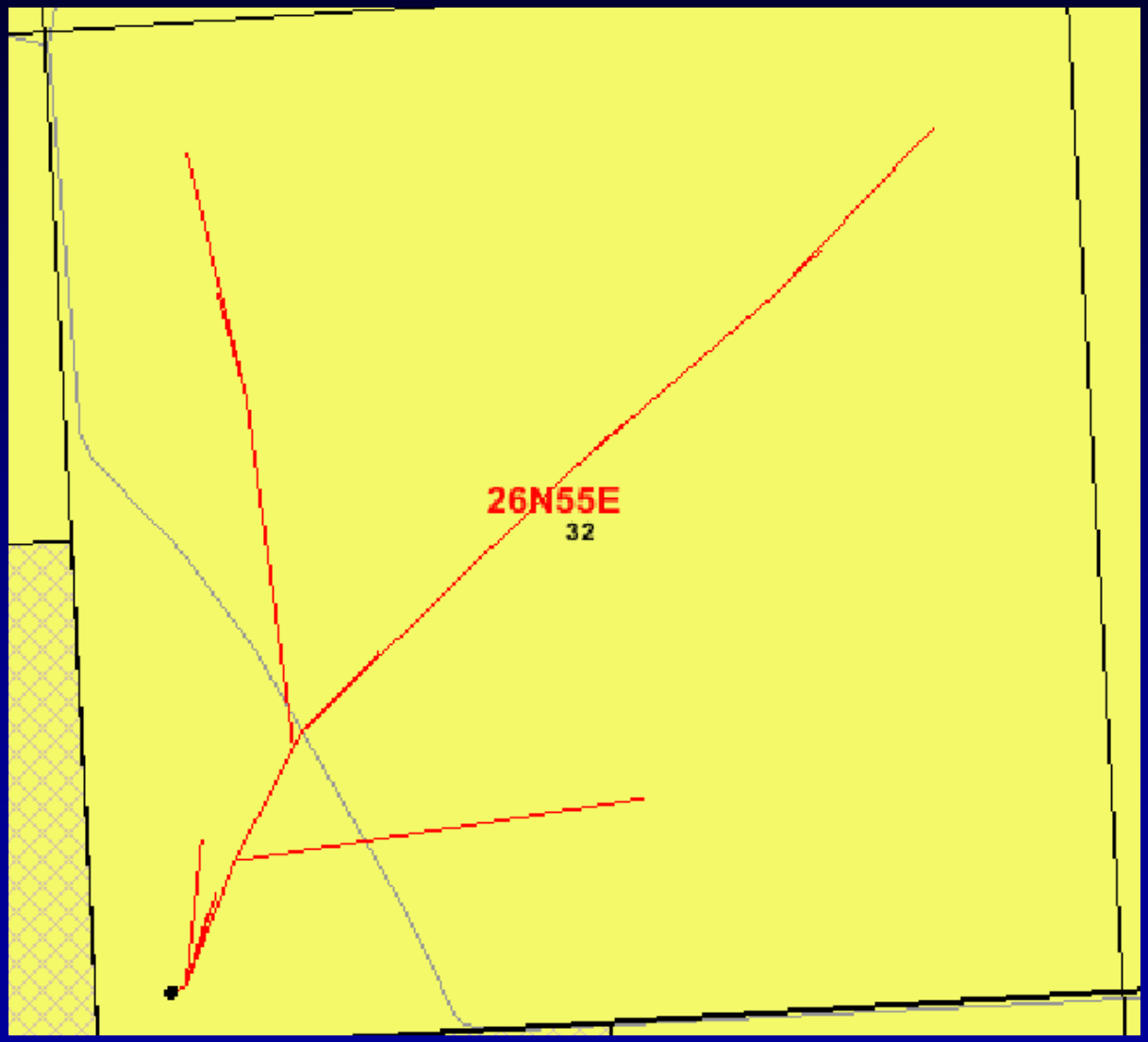
Navigation menu

Well shown as 5 laterals in MT



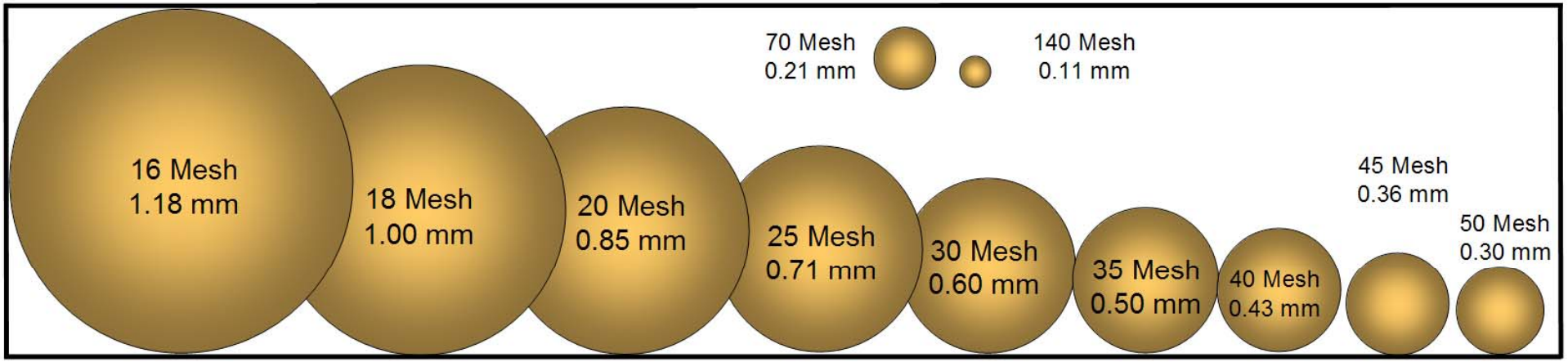
Navigation menu

Well shown as 5 laterals in MT



Navigation menu

Particle Size Distributions



Relative size of proppant particles.

Navigation menu