Distinguished Lecturer Program

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Distinguished Lecturer Program

Fracturing for Sand Control: How Hydraulic Fracturing has Changed Sand Control

Raymond Tibbles

Schlumberger Oilfield Services

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

Sand Control Goal

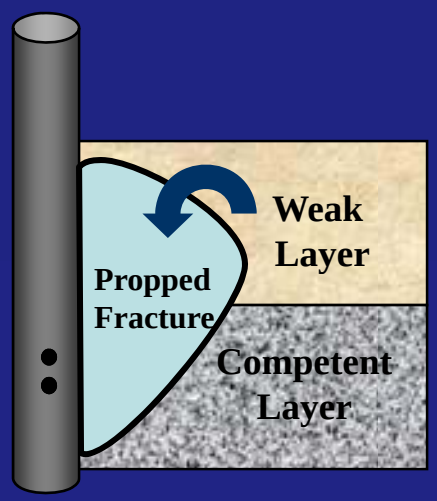
- The big three goals of Sand Control
  - Stop/minimize production of formation solids
  - Maximize production rate/ minimizing impairment
  - Maintain performance over well life
- Has fracturing improved our ability to delivered these goals. And can it continue to do so in the future?

Main SC Completion Types

- Non Frac
  - Cased Hole Gravel Pack (CHGP)
  - Open Hole Gravel Pack (OHGP)
  - Stand Alone Screen (SAS)
  - Formation Consolidation
- Fracturing
  - Screenless Frac Pack
  - High Rate Water Pack (HRWP)
  - Frac Pack
  - Frac followed by Expandable Screen

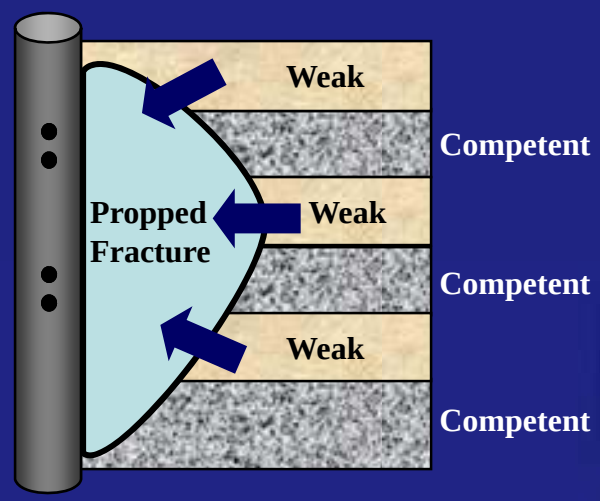
Screenless Frac Pack Completions

Indirect Vertical Fracture



Piltun-Asstokhsky
Sakhalin
SPE 68638

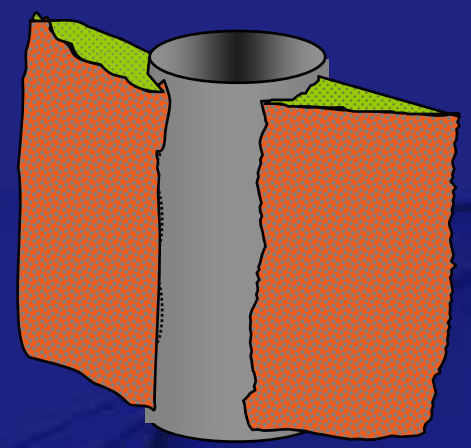
Indirect Vertical Fracture + Intelligent Perforating



Jauf Reservoir
Saudi Arabia
SPE 73724

Optimized Perforating and Fracturing

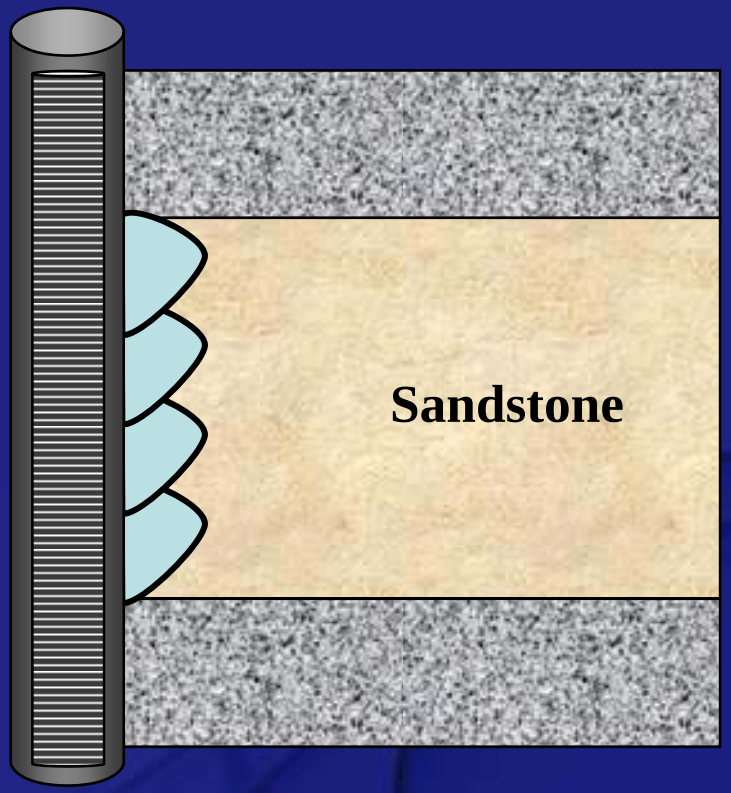
W or WO Resin Consolidation



Main Pass 41
SPE 107440
Yegua Formation
SPE 96289[5]

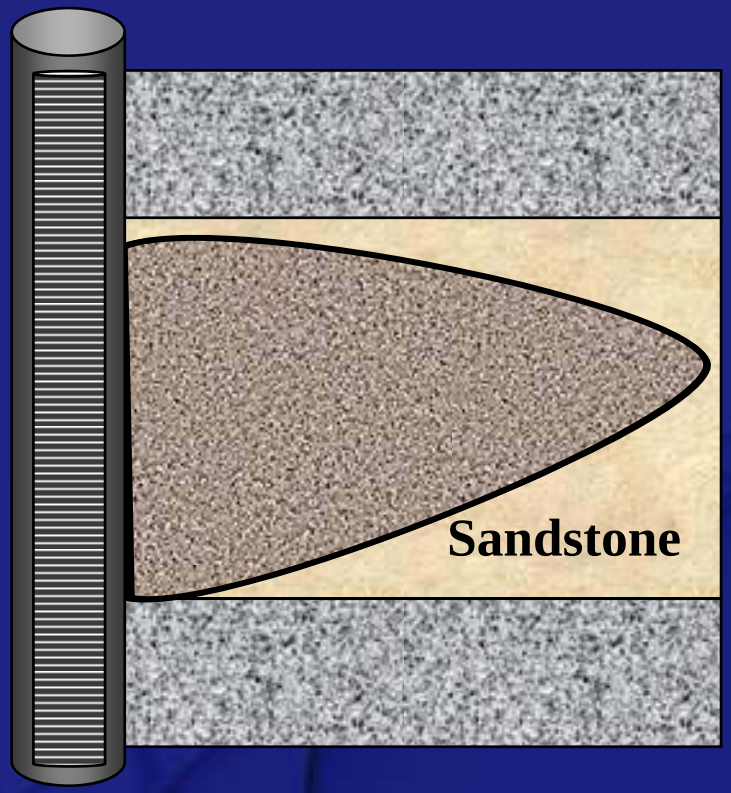
HRWP Completions

- Application
  - Wells where height growth is a concern
  - Equipment for frac pack is not available
- Multiple pad/slurry stages create short fractures.



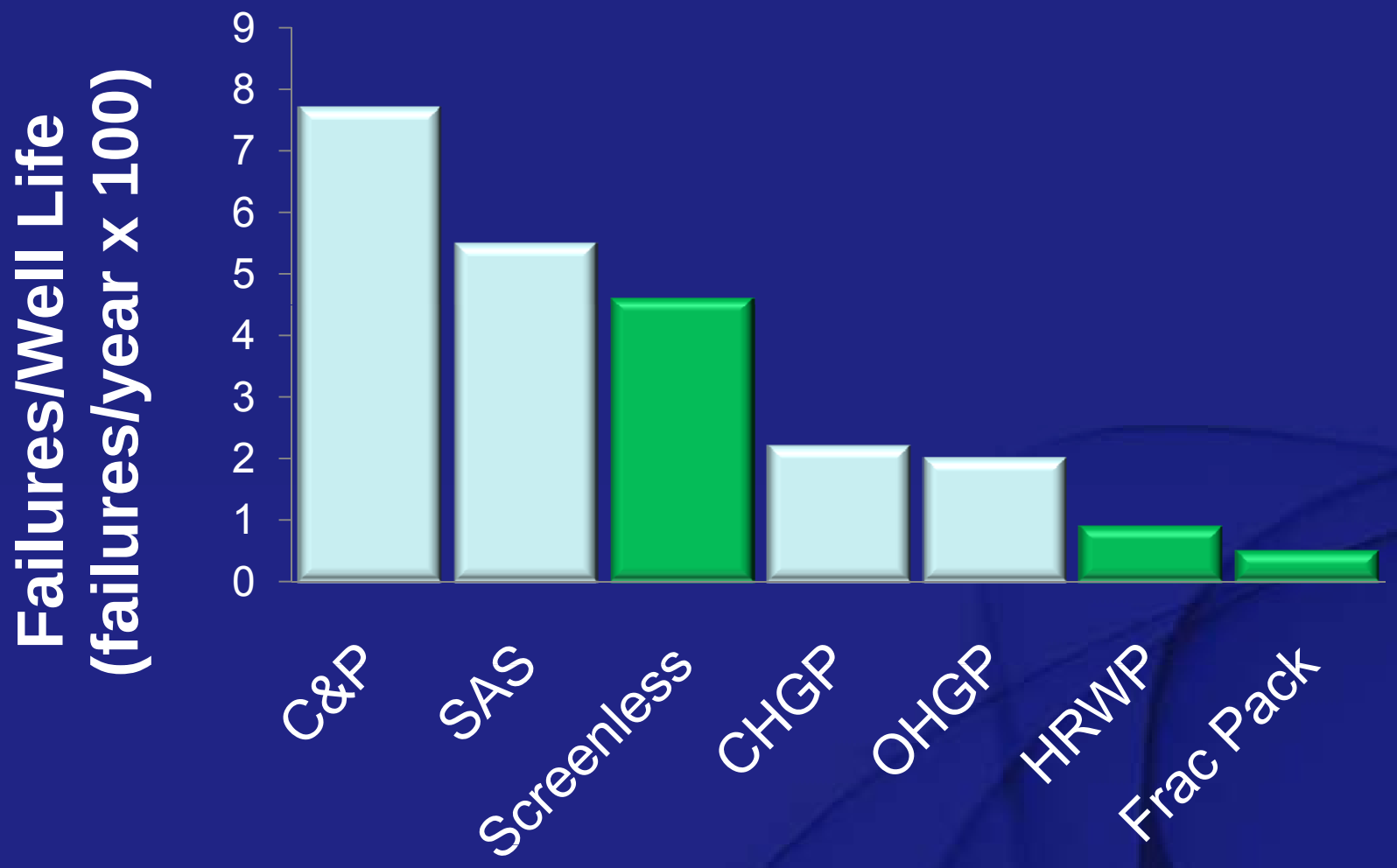
Frac Pack Completions

- Application: Most if not all cased hole completions
- Single Stage of fracturing fluid (pad) followed by multiple slurry stages (ramped prop conc.) with tip screenout design.
- Key design requirement is a wide highly conductive fracture.



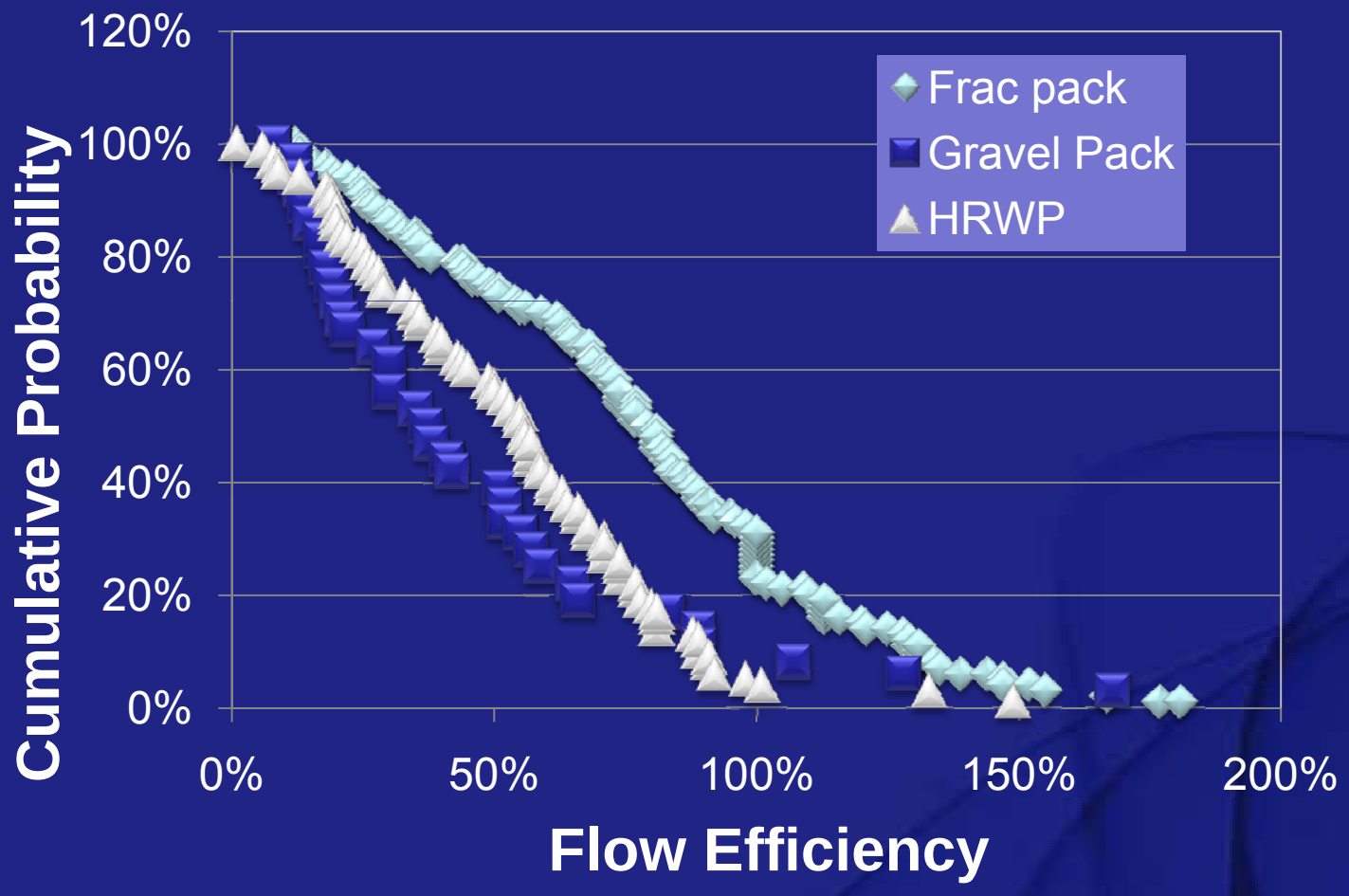
Does Exceeding Frac Pressure Make a Difference?

Fracturing Improves Reliability



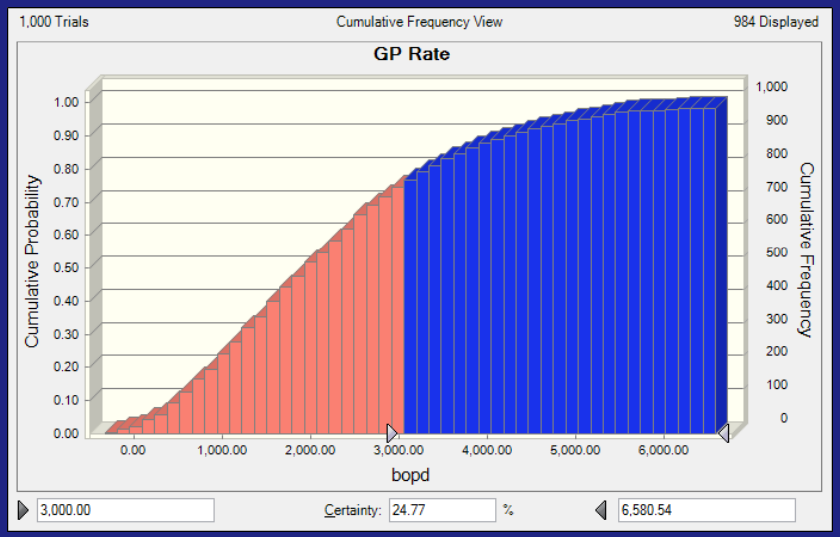
Data courtesy of George King (June 2003)

Fracturing Improves Production

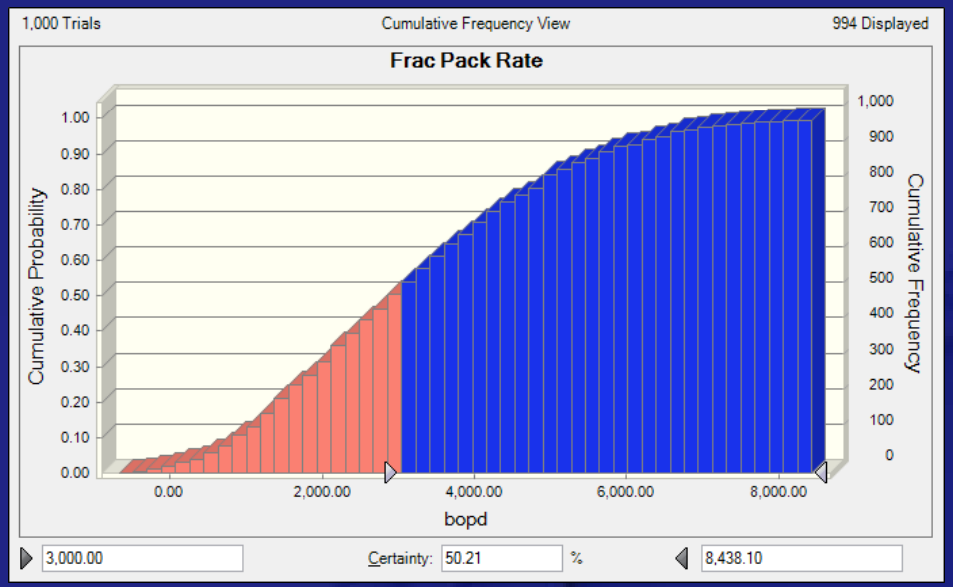


Reference	# Wells
IPTC 11166	4
SPE 103779	8
SPE 110359	2
SPE 111455	1
SPE 30093	17
SPE 30115	7
SPE 30470	36
SPE 31475	17
SPE 36423	12
SPE 36459	8
SPE 38592	10
SPE 39478	10
SPE 63107	4
SPE 68753	25
SPE 73722	35
SPE 77434	6
SPE 78322	4
SPE 84259	10
SPE 86530	1
SPE 87199	31
SPE 96307	7
Grand Total	255

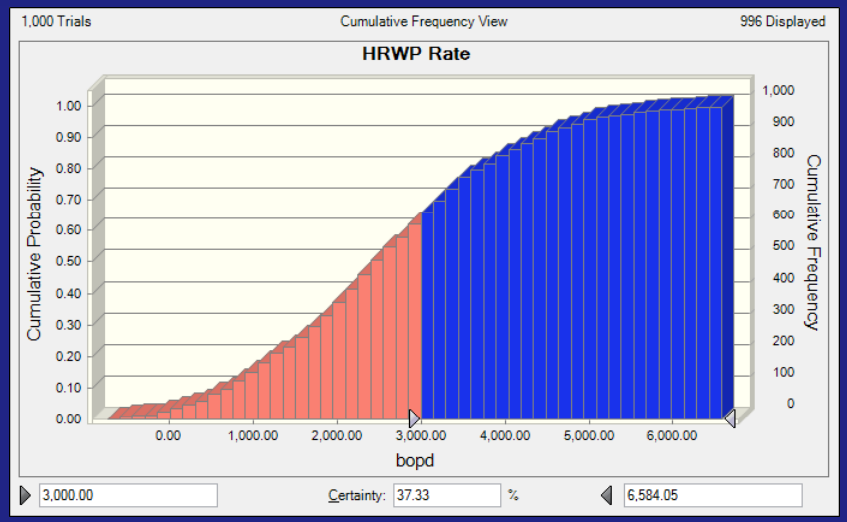
5000 bopd Chance to get 3000 bopd?



24.8% max 6600 bopd



50.2% max of 8400 bopd



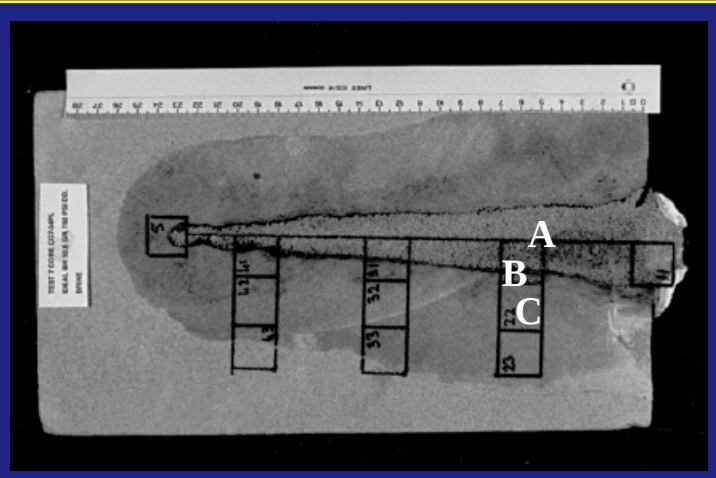
37.3% max of 6600 bopd

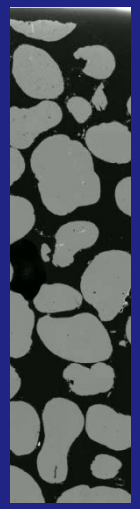
Causes of Low Productivity in Gravel Packs

- Low gravel permeability in the perforation tunnels.
  - Crushed zone;
  - Gravel/sand mixing;
  - Post-perforating fluid loss pills
- Fines migration over time

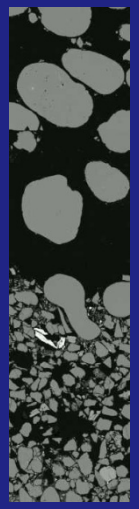
Reality of Packed Perforations

Ideal Perforations

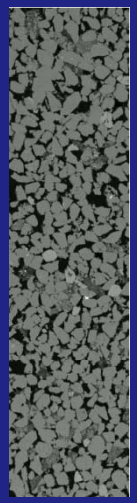




Region A

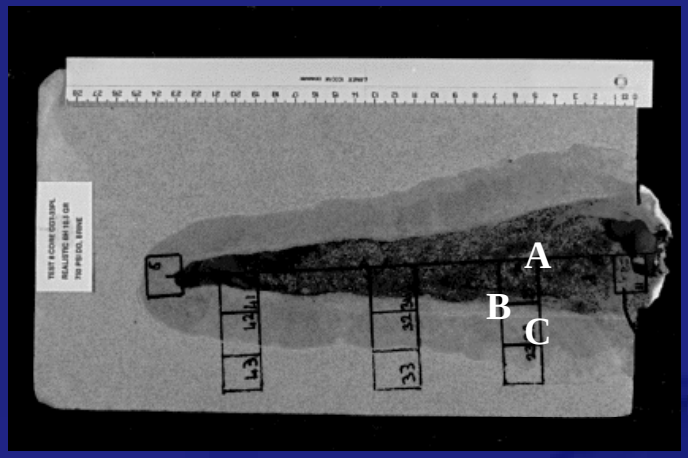


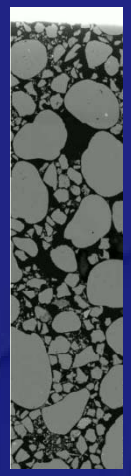
Region B



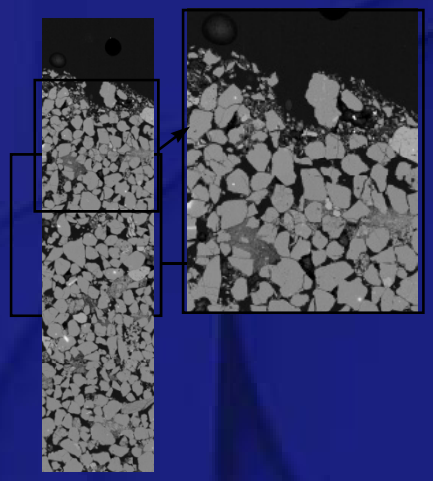
Region C

The Cold Hard Truth

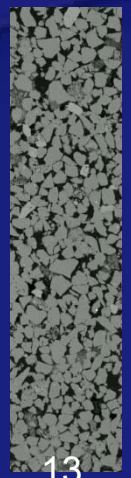




Region A



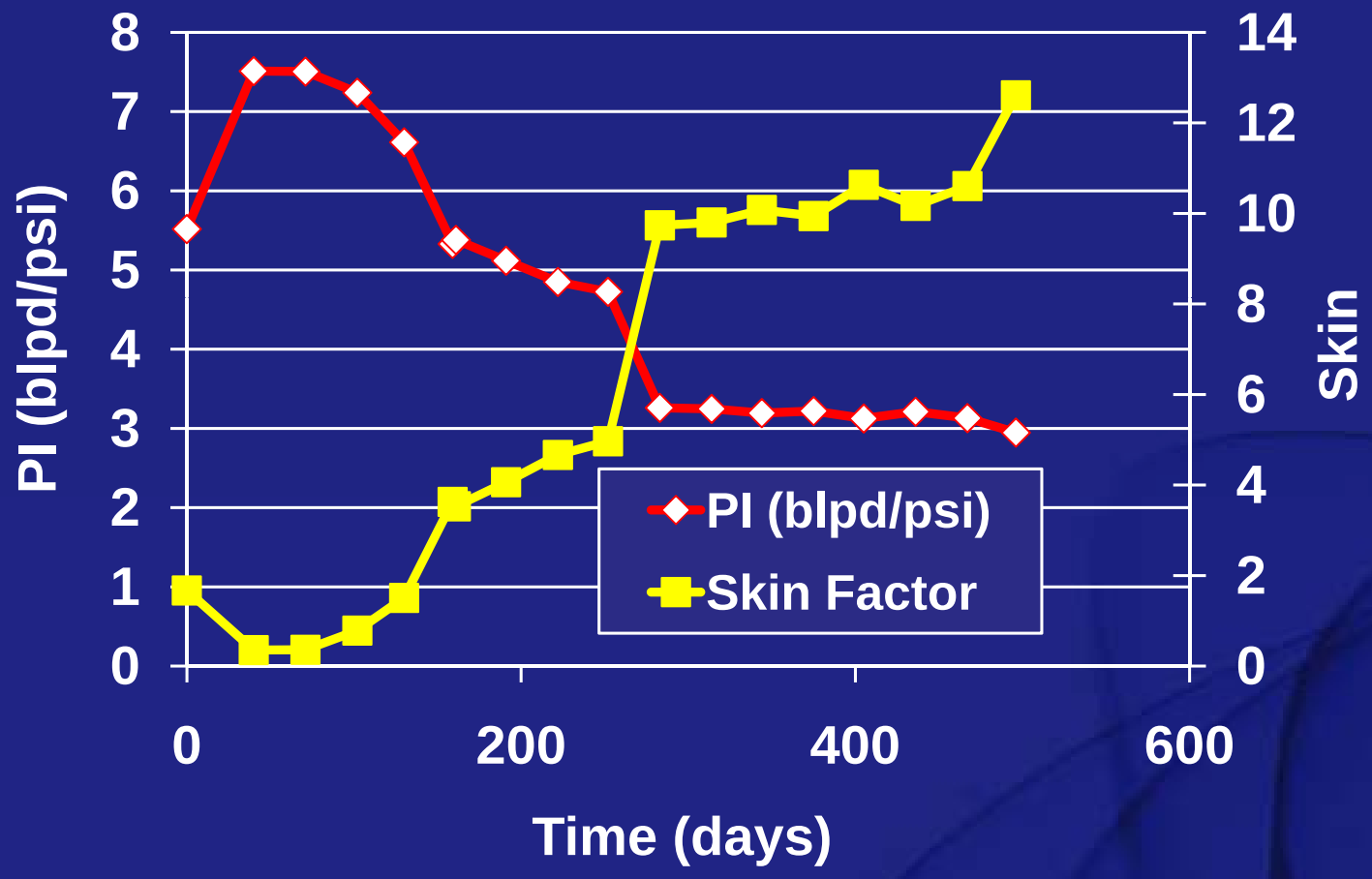
Region B



Region C

Fines Migration in a Gravel Pack

(data supplied by NS Operator)



50% of the PI is lost in the first year.
(26 lb/ft gravel)

What Does Fracturing Do To Help?

- Ensures that the critical area of the perforation tunnel is full of clean gravel free of formation sand or debris ➔ High perm gravel in perfs
- Increases the reservoir contact area.
  - Decreases fluid velocity in the reservoir ➔ Reduced tendency for fines migration

Fracturing Puts More Gravel Through Perforations

- Generally accepted industry value for gravel packing perforations: 25 lb/ft of perforations.
- One NS Operator HRWP Avg: 112 lb/ft of perforations.
- Same NS Operator Frac Pack Avg: 516 lb/ft of perforations

Fracturing Increases Reservoir Contact

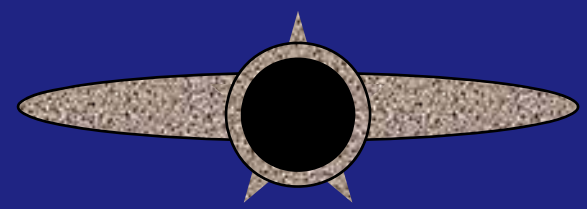
Gravel Pack

200 ft^2

3 ft Half Length Frac

1100 ft^2
82% Reduction In Sand Face Velocity

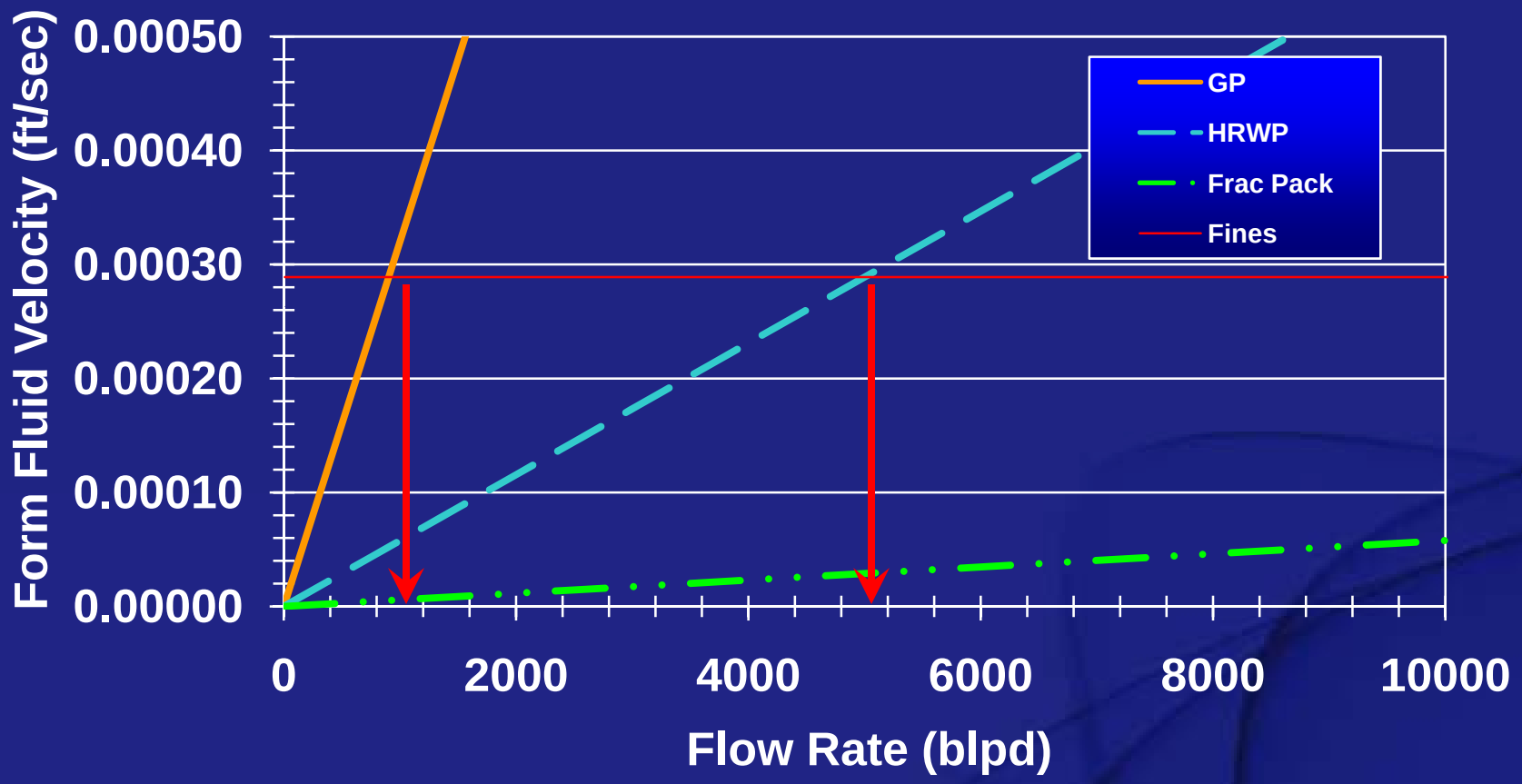
30 ft Half Length Frac



11000 ft^2
98% Reduction In Sand Face Velocity

H = 92 feet
Rw = 8.5 inch
Perf diameter = 0.83 inch
Shot density = 21 spf

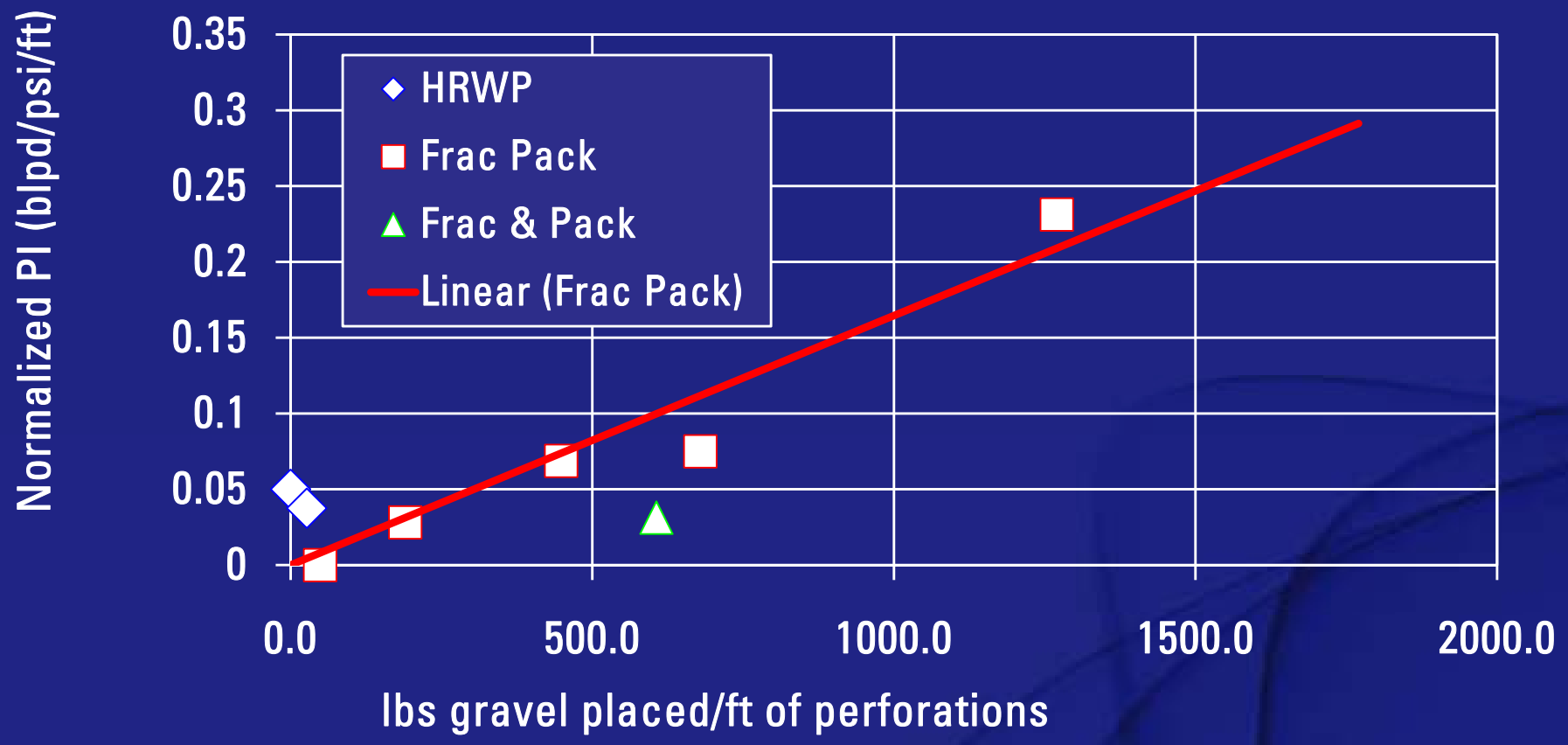
More Area Means No Fines Migration



- Every formation has a different critical fines movement velocity. This is one case where it was 0.00029 ft/sec

Impact of Gravel Volume

(oil well case in a low bhp reservoir)

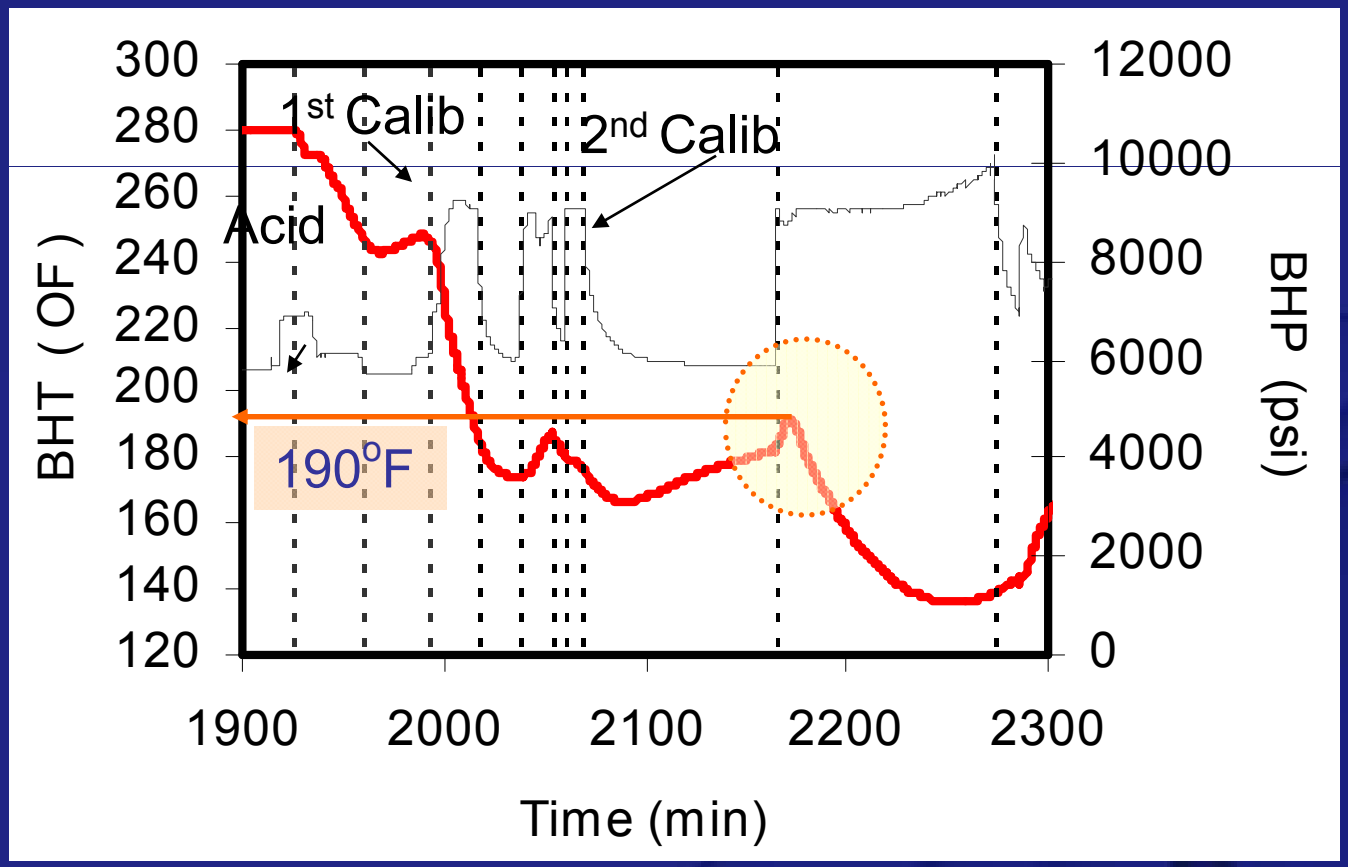


For this example there appears to be a link between gravel mass and Normalized PI. This is not always the case.

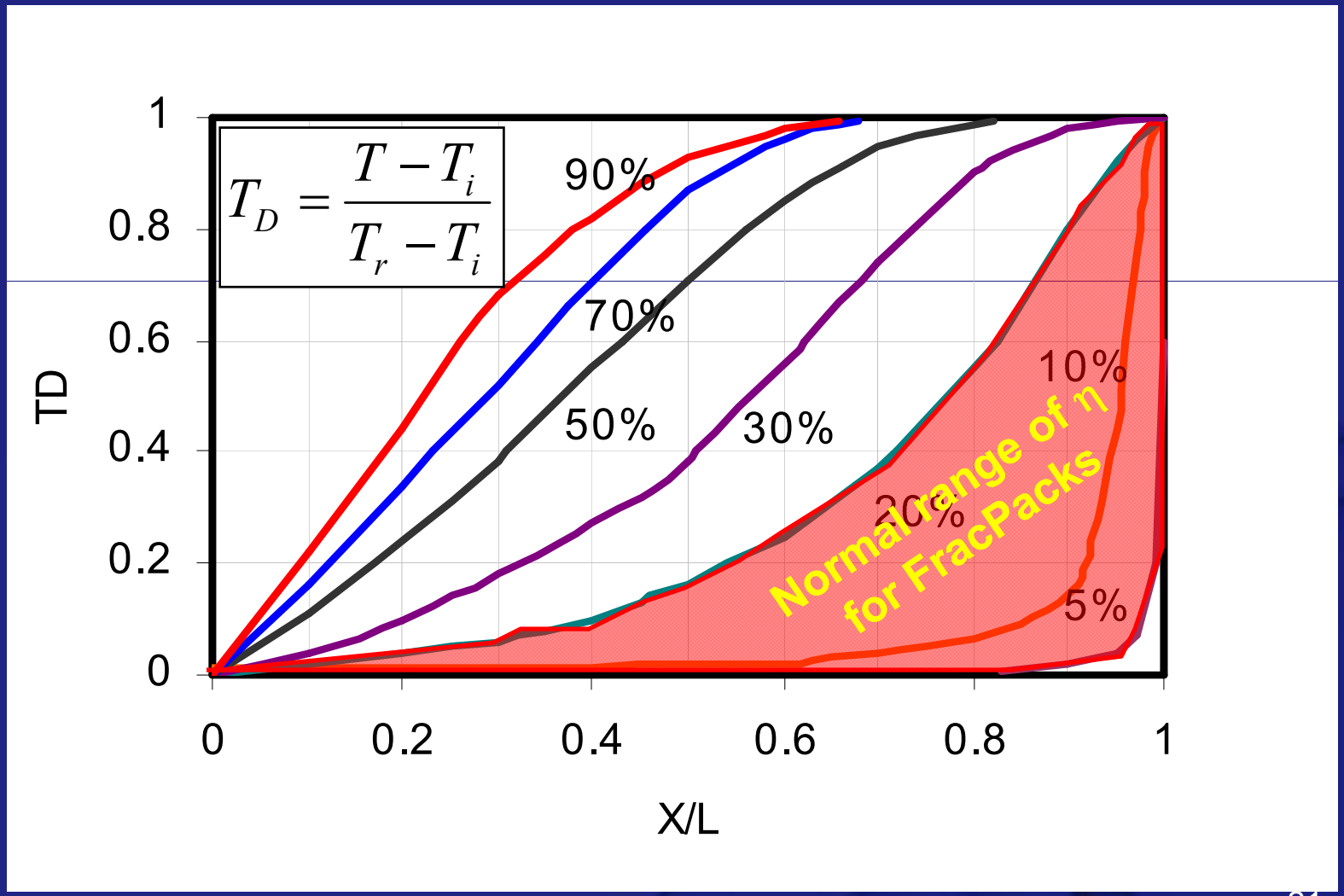
Better Understanding is Improving Results

(SPE 71658 Morales et al)

- Near wellbore temperature cool down from injection of pre-frac and frac-pack fluids.

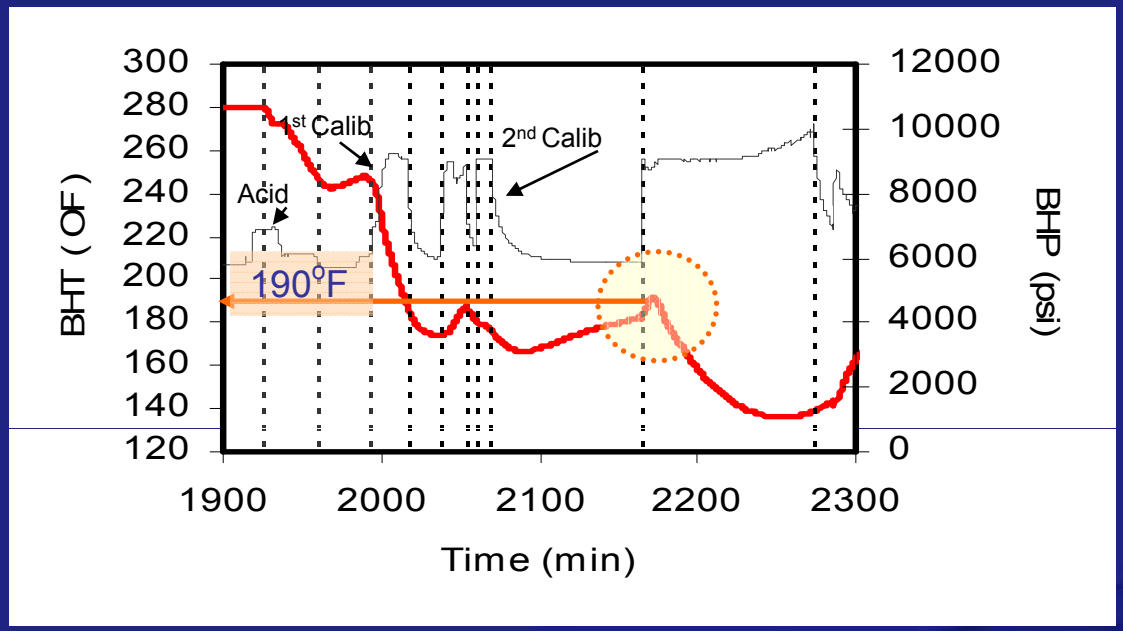


Temperature cool down inside the fracture (after Sinclair)



New Techniques – Fluid Selection

- Cool-Down Based Fluid Selection
  - Improved success rate of achieving Tip Screenout (TSO)
  - Allows optimization of polymer and breaker loading



Bottom hole temperature profile during treatment – Fluid Designed at 190° F

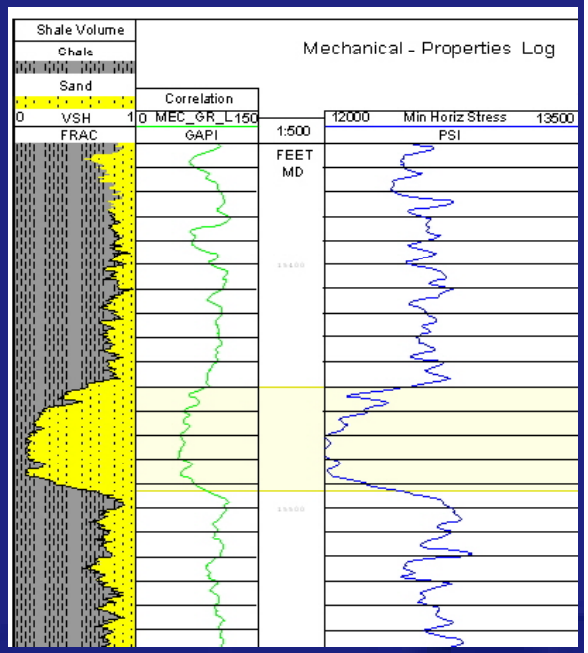
*Tubing Limited

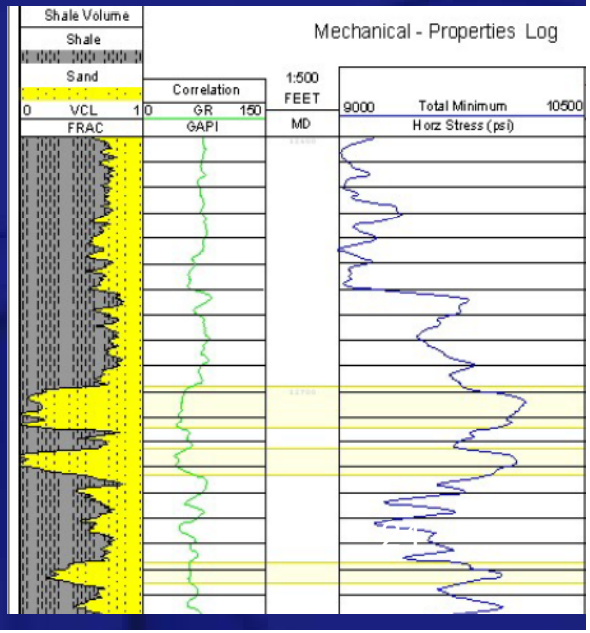
Facing Up To The Challenges?

- Unwanted adjacent water and gas
- Brown fields/depleted reservoirs
- High permeability formations
- Thicker zones (> 500 ft) w/ Multi-lobes
- Emerging area deep water.
- UltraDeep water
  - Deeper
  - Absence of stress barriers
  - Higher Pressure
  - Higher Temperature

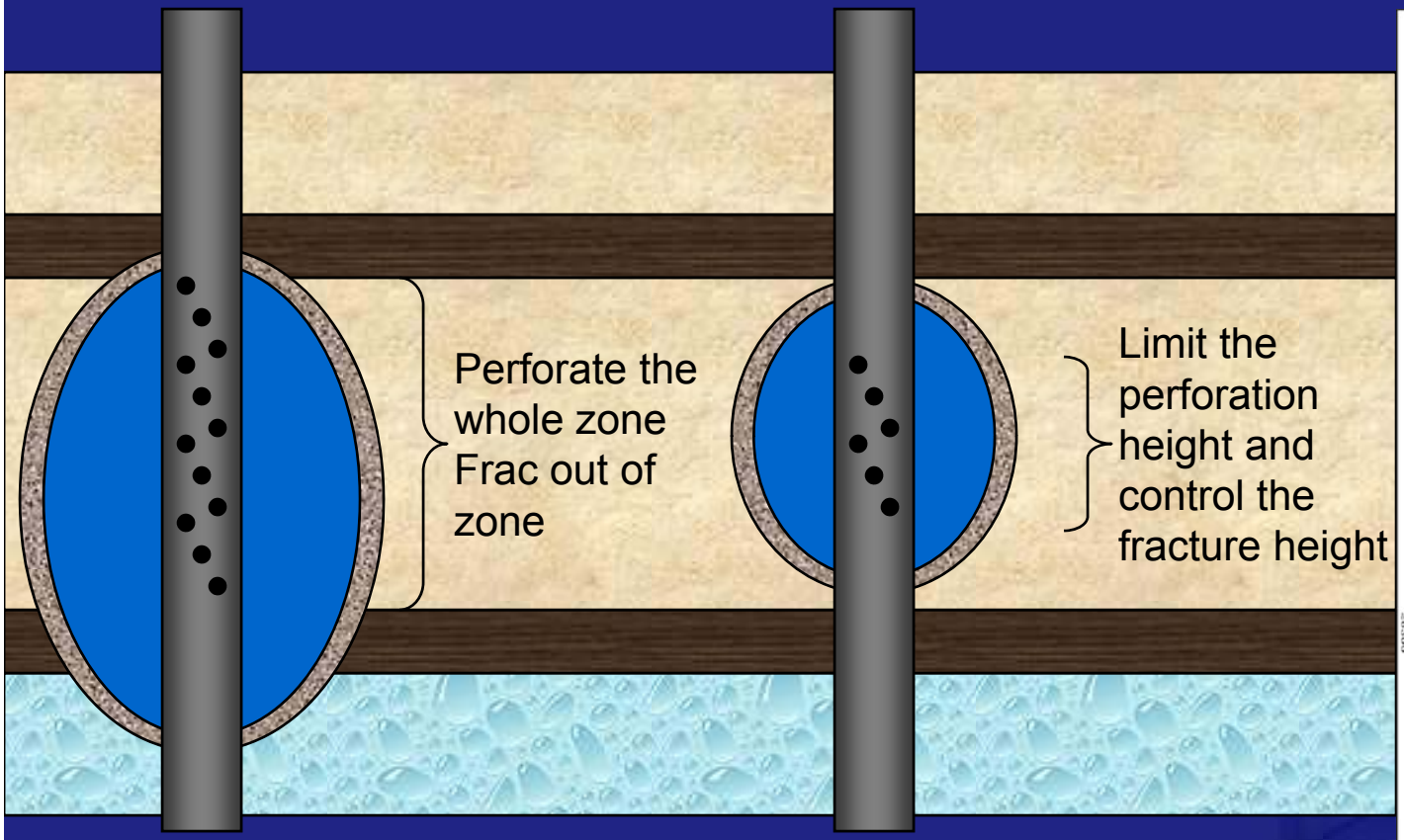
Is Fracturing Out of Zone Really a Problem?

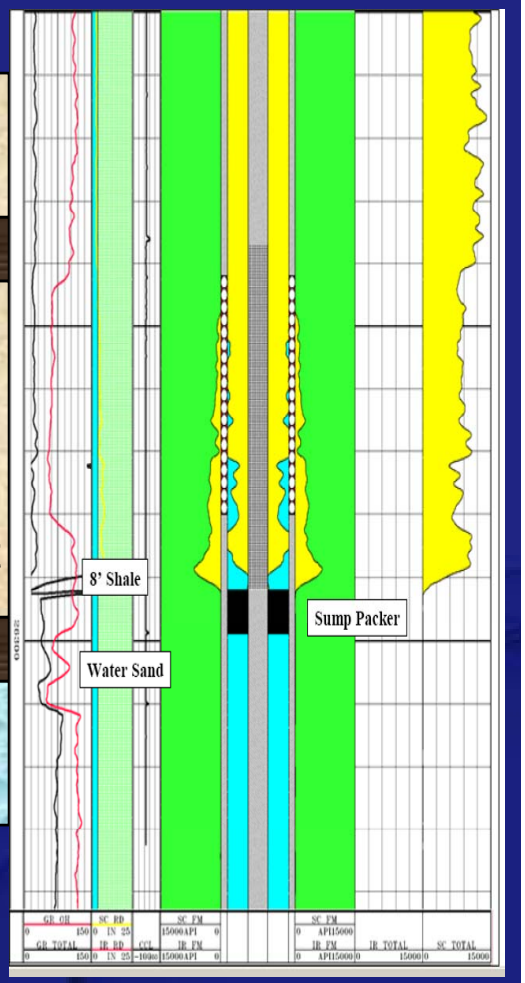
- Soft rocks and standard design limits height growth.
  - Low Young's Modulus
  - TSO inhibits growth
  - Low efficiency frac fluids.
- Proper precautions minimize even severe risk.
  (SPE 73776 Guichard et al.)
- SPE 85259 deals with one of the most difficult cases.





Height Control in Unfavorable Case





Tracer Log

SPE 95987

- 8 ft shale with water below
- Small frac pad
- Small slurry stage
- Fracture did not break through the shale

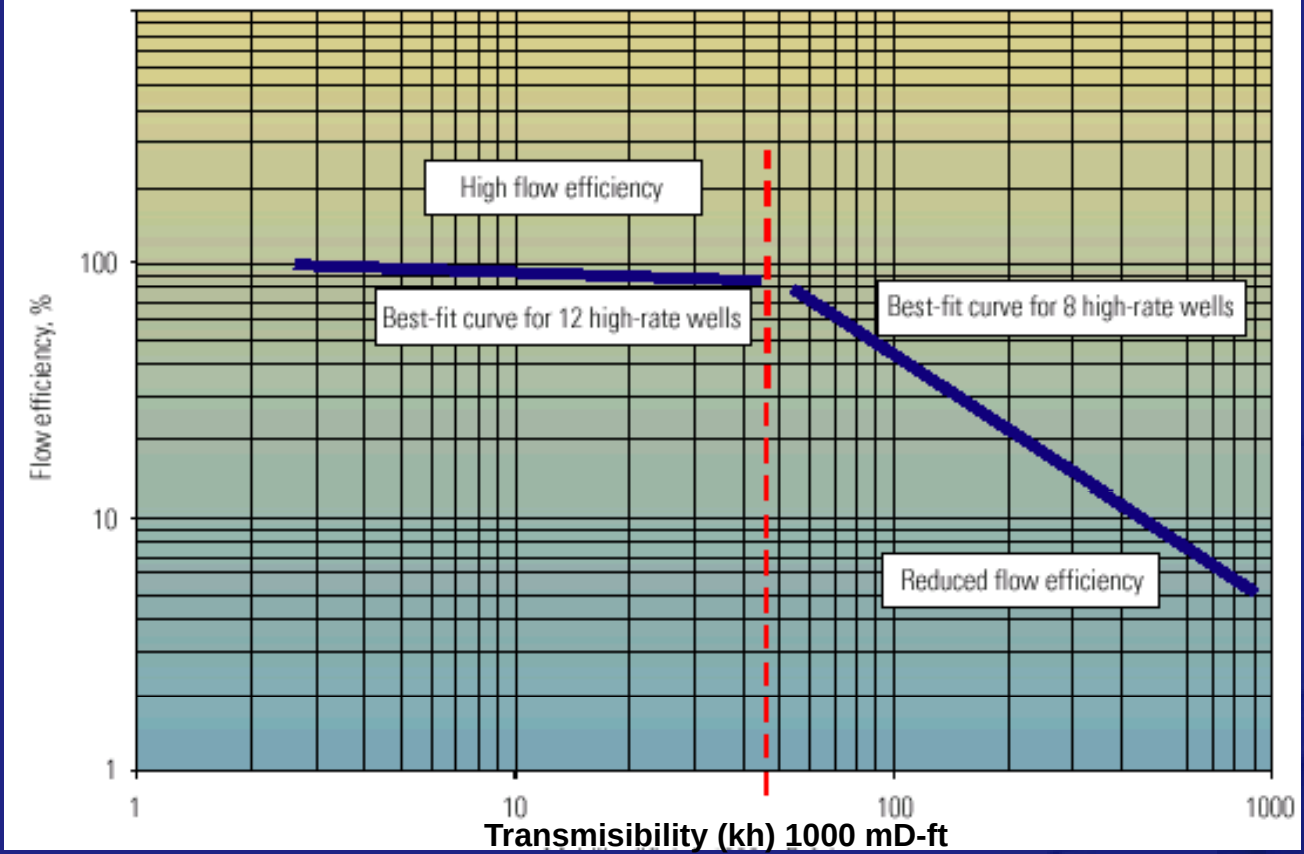
Fracs Deliver in Brown Fields

- Well Data
  - Casing: 5 inch
  - Deviation: 33 deg
  - KH: 5100 md-ft
  - Depth:7550 ft
  - BHST: 200 F
  - Perforation:
    - Density: 24 spf
- Treatment Data
  - Fluid: 30 lb borate xlink
  - Gravel: 16/20 LWC
  - Placed: 1243 lbs/ft
- Results
  - Produced via ESP
  - Post FP PI/Pre FP PI: 1.04
  - Post FP Skin: -0.5

High Permeability Concerns

- SPE39475: limit frac packs
  - Oil Kf < 900 md
  - Gas Kf < 150 md.
  - OH GP for the highest rate wells
- SPE 111455: Frac Packs are the best solution for high permeability formation if the wellbore is properly aligned with the fracture.

Cased Hole Frac-Packs



Openhole Horizontal
or
Openhole Frac-Pack
or
Openhole GP Above Frac Pressure?

Oilfield Review, Summer 2001 (BP, Chevron, EniAgip, M-I, Repsol-YPF, Schlumberger, Shell, Stone Energy, Texaco)

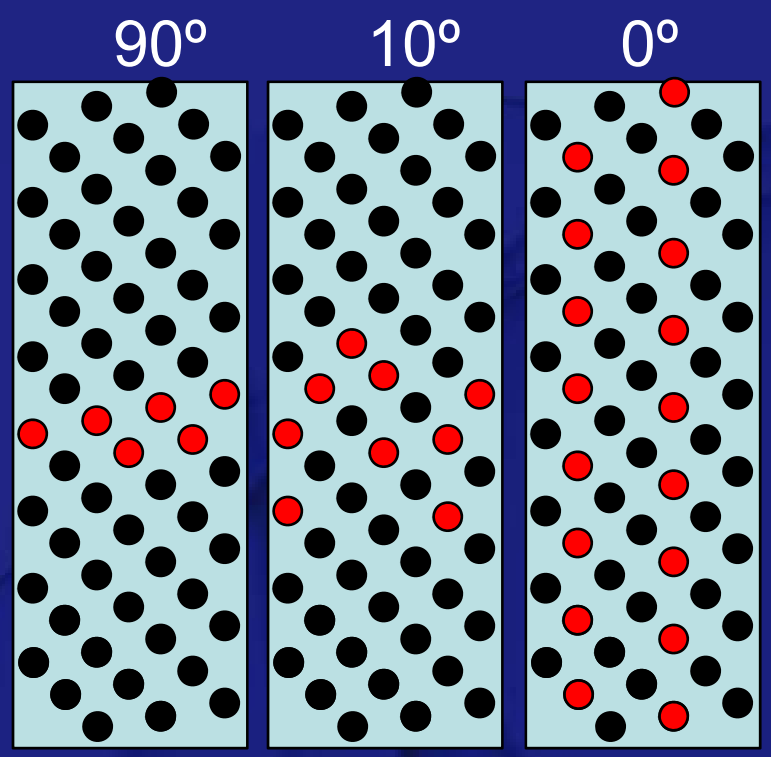
High Rate Limitions

– Pressure Loss in Perforation tunnel (Forchheimer)

$$\Delta P = \frac{0.888\, L\, \mu\, Q}{KA} + 9.1\times 10^{13}\, \beta L \rho \left[\frac{Q}{A}\right]^2$$

Where:

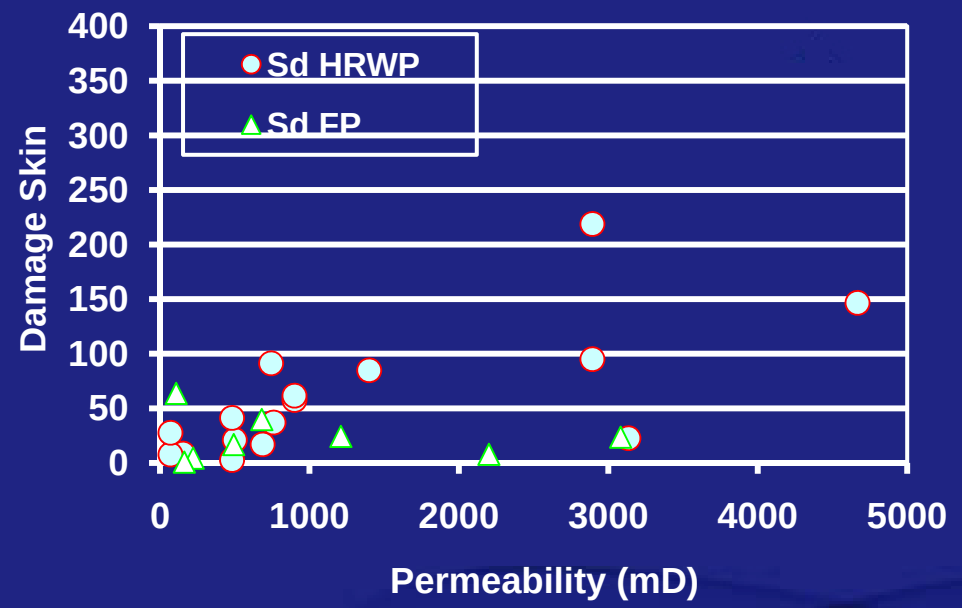
A	=	Perf Cross-Sectional Area (Ft2)
B	=	Inertia Coefficient (Ft-1)
ΔP	=	Differential Pressure (psi)
K	=	Permeability (Darcies)
L	=	Length Of Perforation (ft)
μ	=	Viscosity (Centipoise)
Q	=	Flow Rate (B/D)
ρ	=	Density Of Fluid (lb/Ft3)

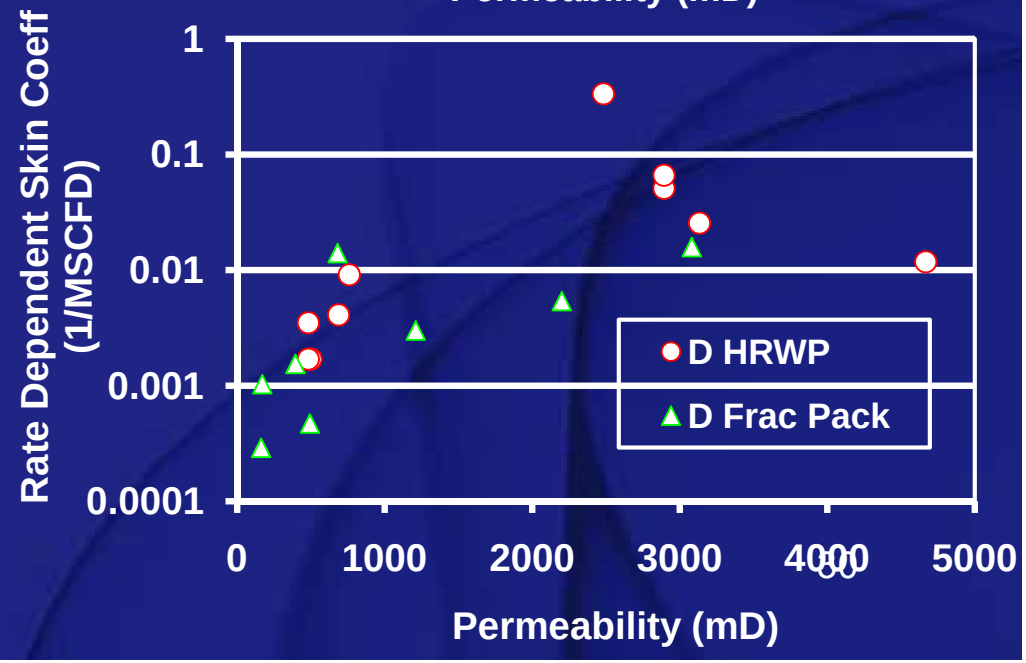


High Rate Gas Skin (SPE 68753)

- Avg Damage Skin
  (Deviation and Partial completion skins removed)
  - All Cases
    - FP = 18
    - HRWP = 55*
  - Less than 1 Darcy
    - FP = 18
    - HRWP = 31*

*Neglected 800 Skin





Frac Packs Can Deliver High Production Rate Completions

- Gas
  - SPE106854 BP Trinidad and Tobago:
    - FP 75-150 MM/day (100 – 600 mD)
    - OH GP: 72 – 320 MM/day (100 – 1700 mD)
- Oil
  - SPE 78322 Total Angola:
    - FP 15,000 – 25,000 bopd (800-2700 mD)
  - SPE 84415 ConocoPhillips USA:
    - FP two wells 22,400 bopd/well
  - FP Non documented GOM – 40,000 bopd
  - SPE 48977 BP North Sea:
    - OH Horizontal – 30,000 bopd

Other Options in Emerging Deep Water

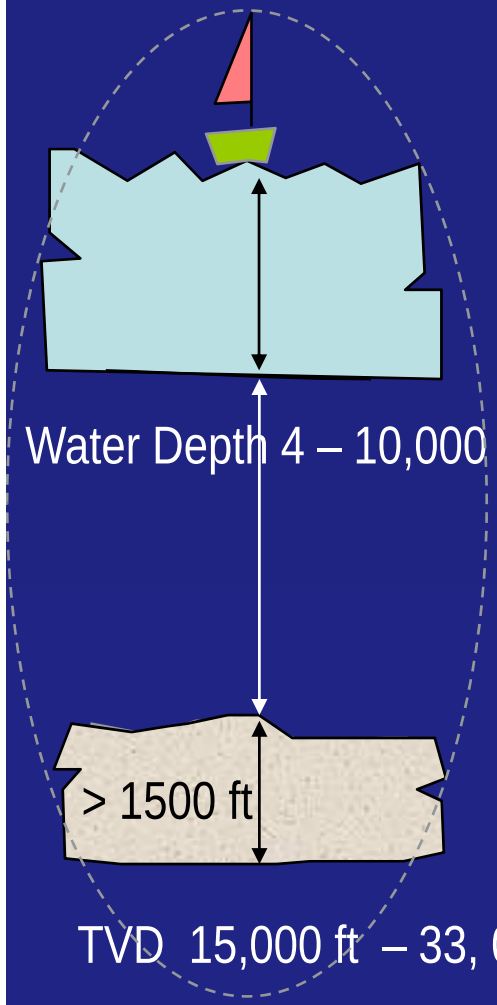
- Rig Based Fracturing
  - Dependent on available deck space
  - Inhibits many rig operations
  - Limited rates and volumes
- Supply Boat Based Fracturing
  - Limited Rates and Volume but more flexibility
  - Minimum impact on rig operations

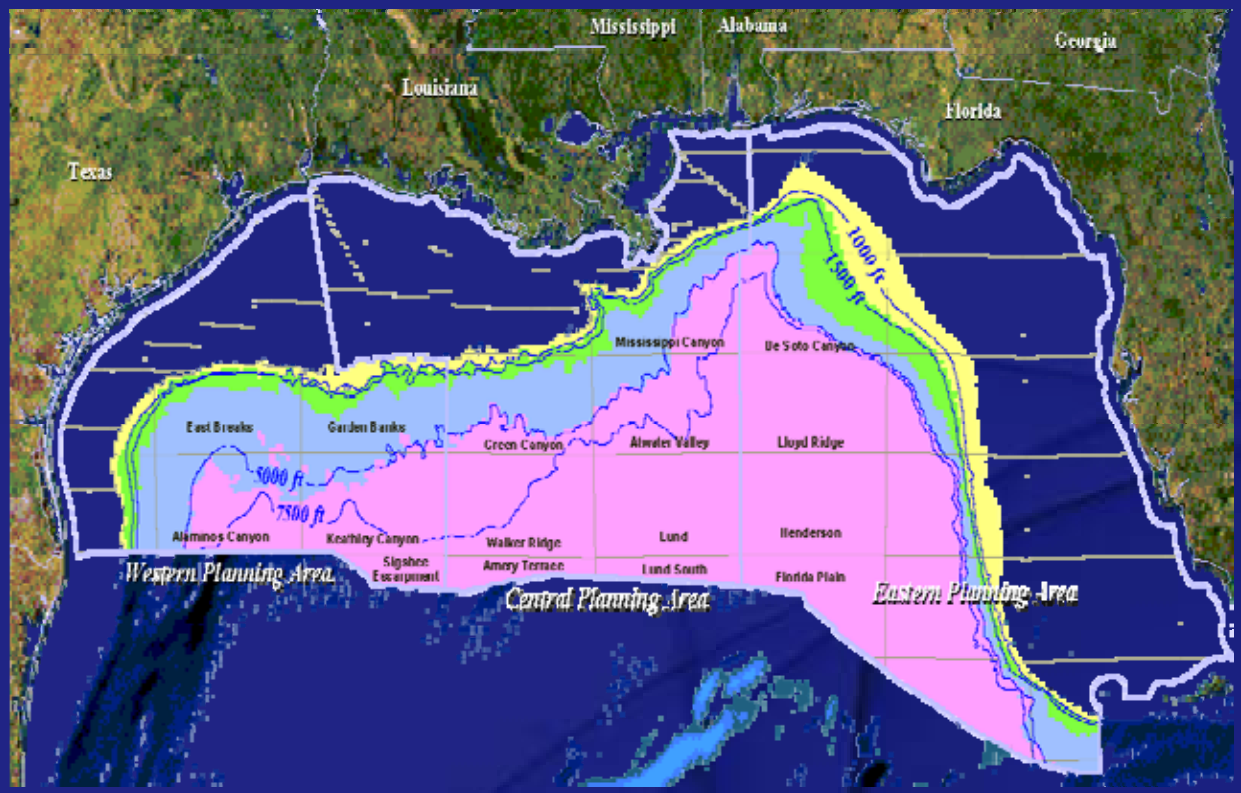
Modular Supply Vessel Operation

(900m2 deck area)

- 650,000 lbm of proppant
- 10,000 psi MWP
- 40 BPM max rate
- 9,000 HHP
- 200,000 gals batch mixed gel stored below deck
- Connected to Rig via 4” 10,000 psi Coflexip hose c/w EQD on TR12 Reel

Lower Tertiary - Miocene and Paleogene





TVD 15,000 ft – 33, 000 ft

BHP 13 ppg – 15.2 ppg

BHT 160 OF – 310 ºF

Challenges and Solutions

- Temperature: No problem we have fluids to handle 400+ degrees F.
- High Pressure:
  - 20000 psi treating equipment - does the market justify the cost?
  - High density frac fluids to help but there are limits. SPE 116007 reported surface pressure reductions from 22 to 39% with an average surface pressure reduction of 34%
- Temperature and Pressure: Still struggling to provide a high density fluid that can work at 325+ ºF

$$\frac{\Delta p}{L} = \frac{2 f \rho V^2}{D}$$

Facing Up To The Challenges?

- Unwanted adjacent water and gas
- Brown fields/depleted reservoirs
- High permeability formation
  - Gas
  - Oil
- Emerging Area Deep Water
- UltraDeep Water Plays
  - Deeper
  - Higher Pressure
  - Higher Temperature

Conclusions

- Sand Control fracturing completions have clearly shown increased productivity in many different environments.
- Many of the challenges to using fracturing have already been overcome
  - Unwanted water/gas
  - High permeability formations
  - Application in developing areas
- Some challenges still require work or may not be applicable
  - Ultra high permeability (especially in gas wells)
  - High pressure especially in combination with temperature above 325 F

Questions?

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http://www.spe.org/events/dl/dl_evaluation_contest.php