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Unconventional Frac Jobs for Unconventional Reservoirs – What Should You Be Concerned About?

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Society of Petroleum Engineers
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Outline of today’s presentation…

- Purpose
- Unconventional reservoirs
- Fluids and proppants
- Conductivity and clean-up
- Proppant transport
- Modeling
- Hydraulic fracturing for reservoir management
- Conclusions

WHY should you be concerned?

- Unconventional reservoirs (UCR’s) are just that - unconventional
- UCR’s are increasing forming our reserve/resource base around the world
- Extrapolation of conventional techniques and conceptsto UCR’s is risky
  - Combination of considerations

Conventional vs. Unconventional

"Unconventional resources…accumulations that are pervasive throughout a large area…not significantly affected by hydrodynamic influences…require specialized extraction technology…"

SPE-PRMS, 2007

Holditch, 2001

Today's presentation focuses on…

- Shale gas (is a "shale" a "shale"?)
  - Micro/nano-Darcy permeability (10^{-6} – 10^{-9})
  - High quartz or carbonate content (typically less than 20-30% clays)
  - High TOC?
- Shale ("liquids rich") oil
- Tight gas
  - What is "tight"?
  - Micro-Darcy permeability
  - Fluvial, laterally discontinuous bodies; blanket sands

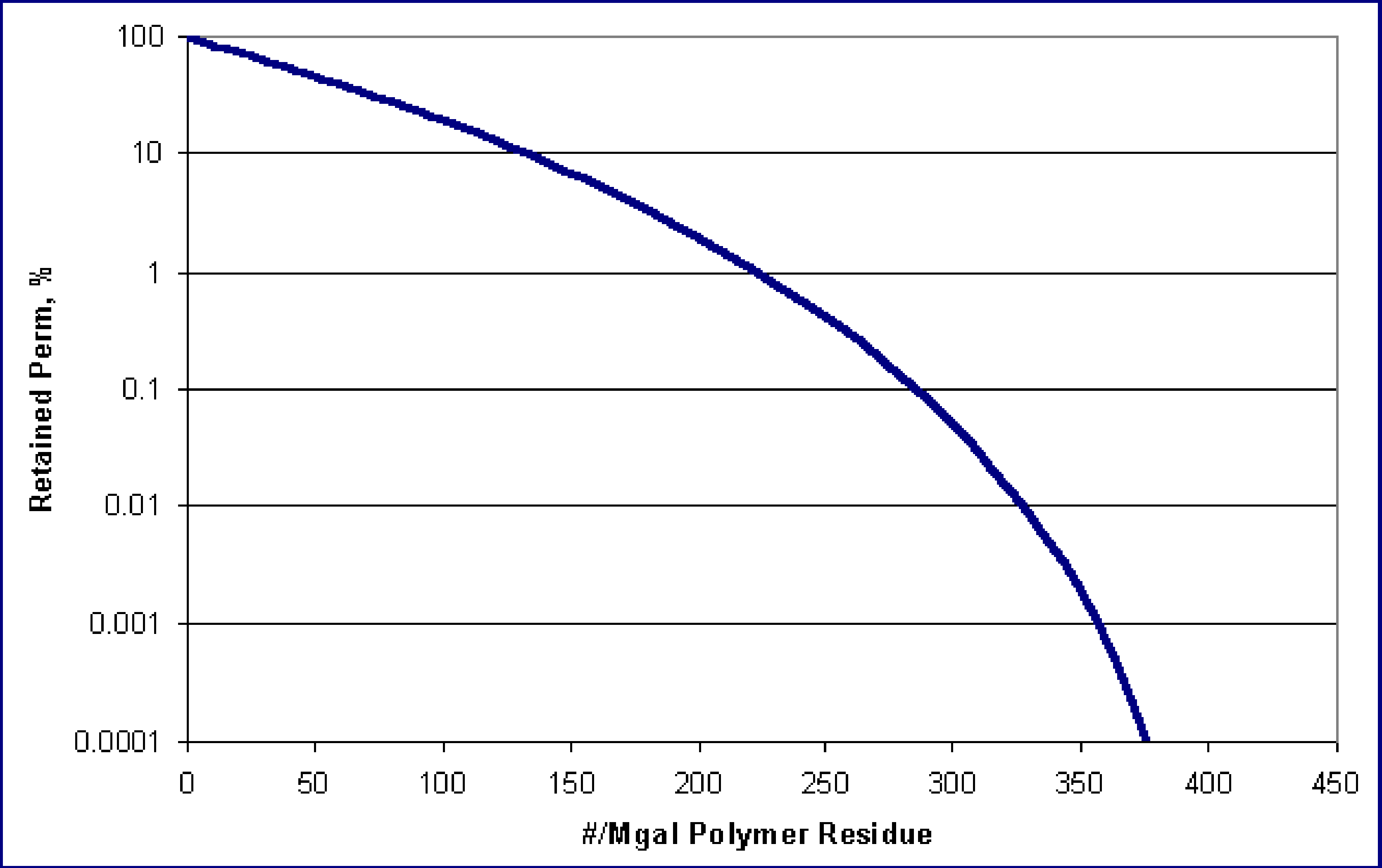
Fluid Systems

- "Slickwater"
  - Minimal polymer loading
  - Polyacrylamide friction reducers
  - 1 – 10 cp fluid system
  - Carrying capacity reduced
- Lighter loaded systems
- Must minimize damage due to the initial low permeability

$$F_{CD} = \frac{k_f w}{k X_f}$$

Courtesy of Stimlab

Retained Permeability With Gel Residue



Stimlab, 2003

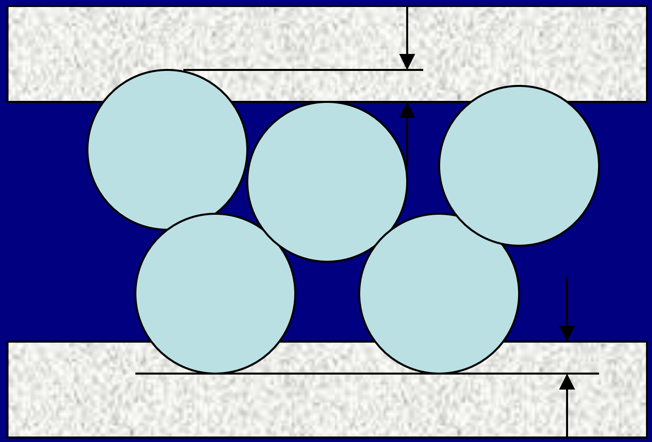
Lightweight/Smaller Proppants

- Use of lower viscosity fluids = difficult to carry high proppant concentrations
- *Velocity* is the transport mechanism, not *viscosity*
- Function of fracture width, Reynolds numbers, densities of proppants and fluids, diameters of proppants
- 100 mesh, 30/50, and 40/70 sizes common

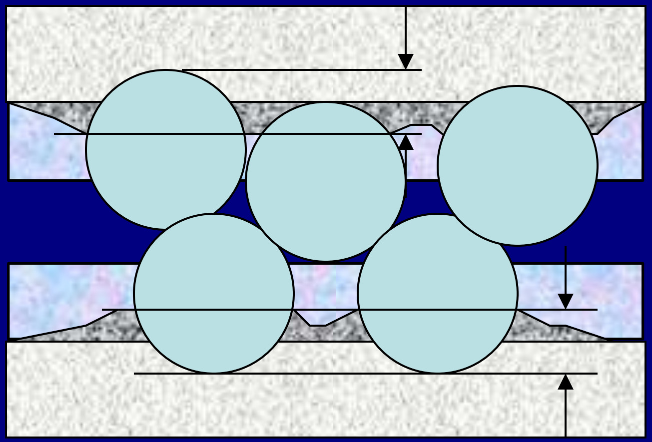
Conductivity and Clean-up

- Fracture conductivity is still critical!!
- Pack width determined by
  – Proppant concentration
  – Closure stress
  – Filter-cake and embedment
- Pack permeability determined by
  – Proppant size and strength
  – Packing and porosity
  – Regained permeability and gel clean-up
  – Non-Darcy and multiphase flow

Embedment, Spalling and Filtercake



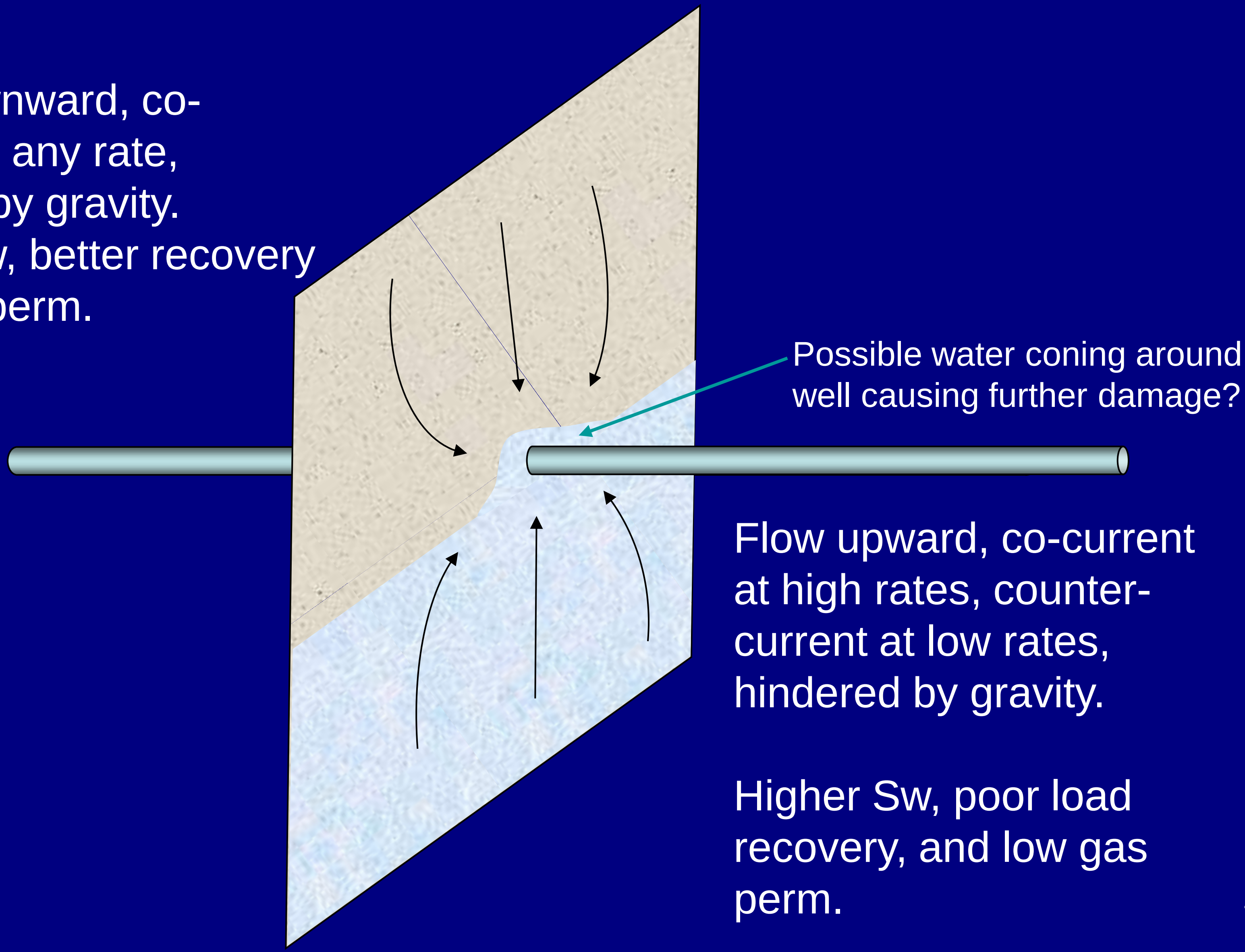
Width loss from embedment only



Width loss from embedment, spalling and filtercake extrusion

Cleanup and Load Recovery is Affected by Gravity, Viscous, and Capillary Forces

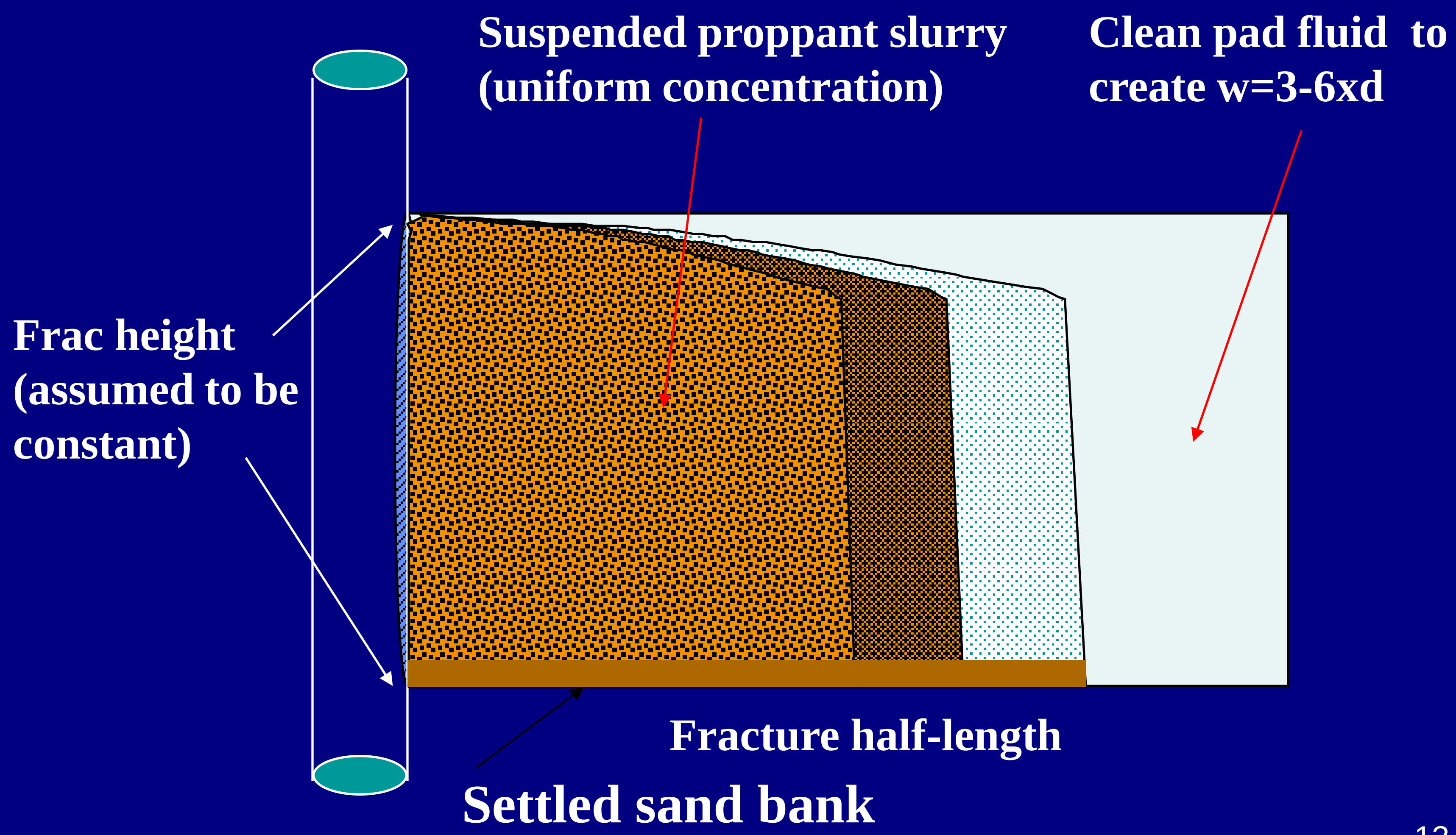
Flow downward, co-current at any rate, assisted by gravity. Lower Sw, better recovery and gas perm.



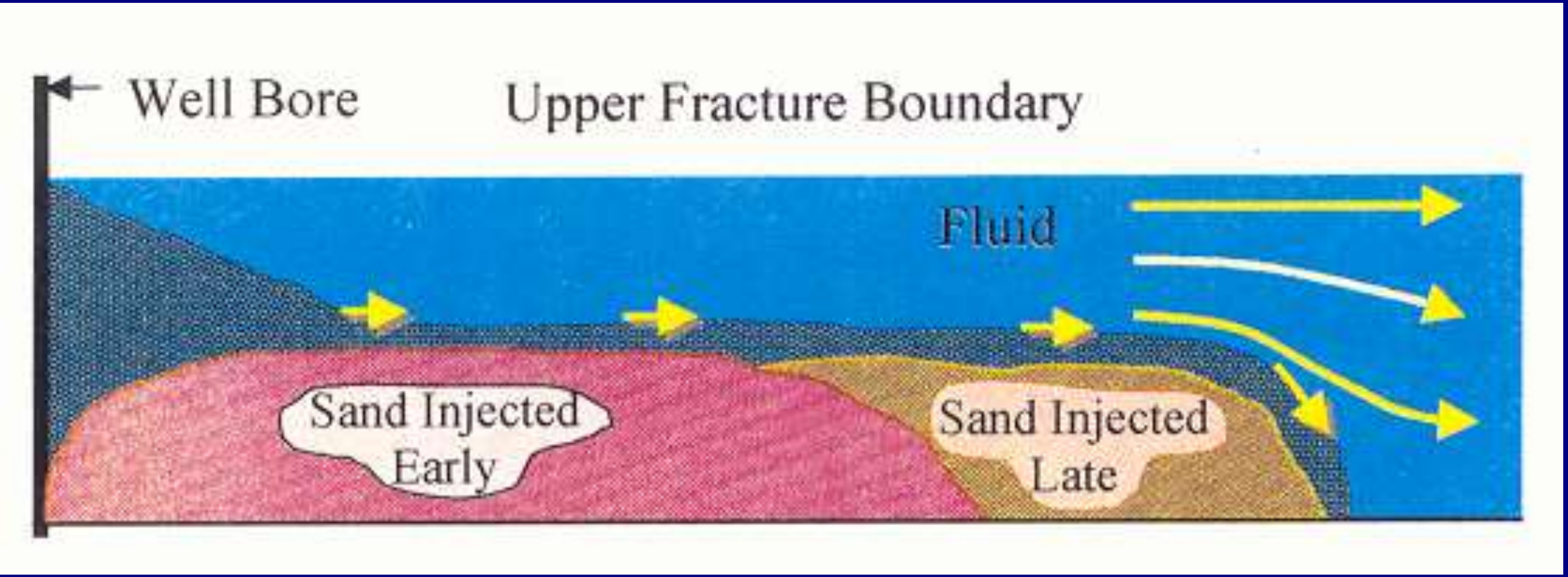
Flow upward, co-current at high rates, counter-current at low rates, hindered by gravity.

Higher Sw, poor load recovery, and low gas perm.

Traditional Prop Transport



Particle Transport



(From Patankar, 2002 and Kern, Perkins, and Wyant, 1959)

Example 1

Courtesy of Stimlab

Example 2

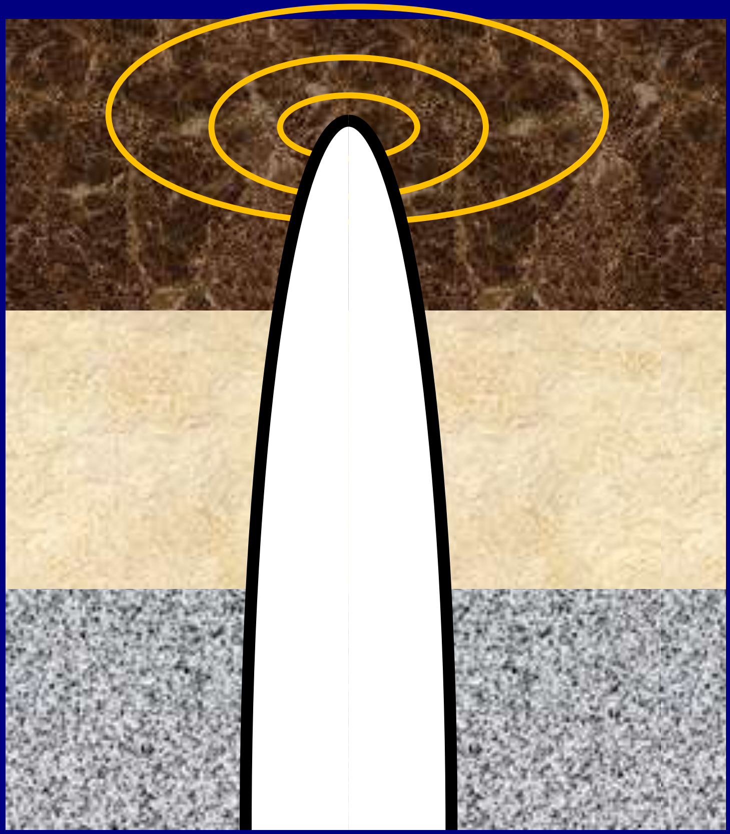
Courtesy of Stimlab

Modeling

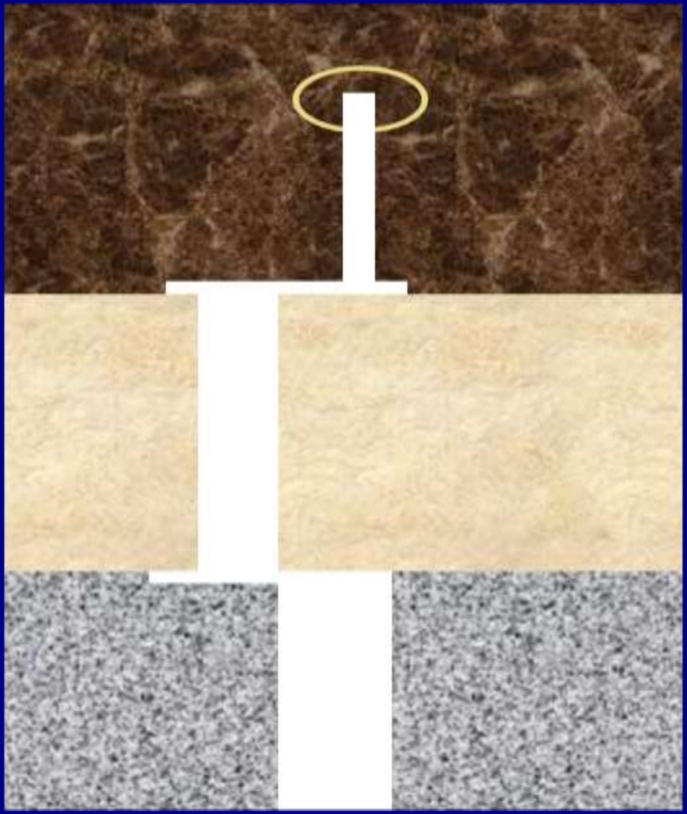
- Remember that fracturing is always the ***path of least resistance***
- De-coupling; vertical resistance (layers; laminations)

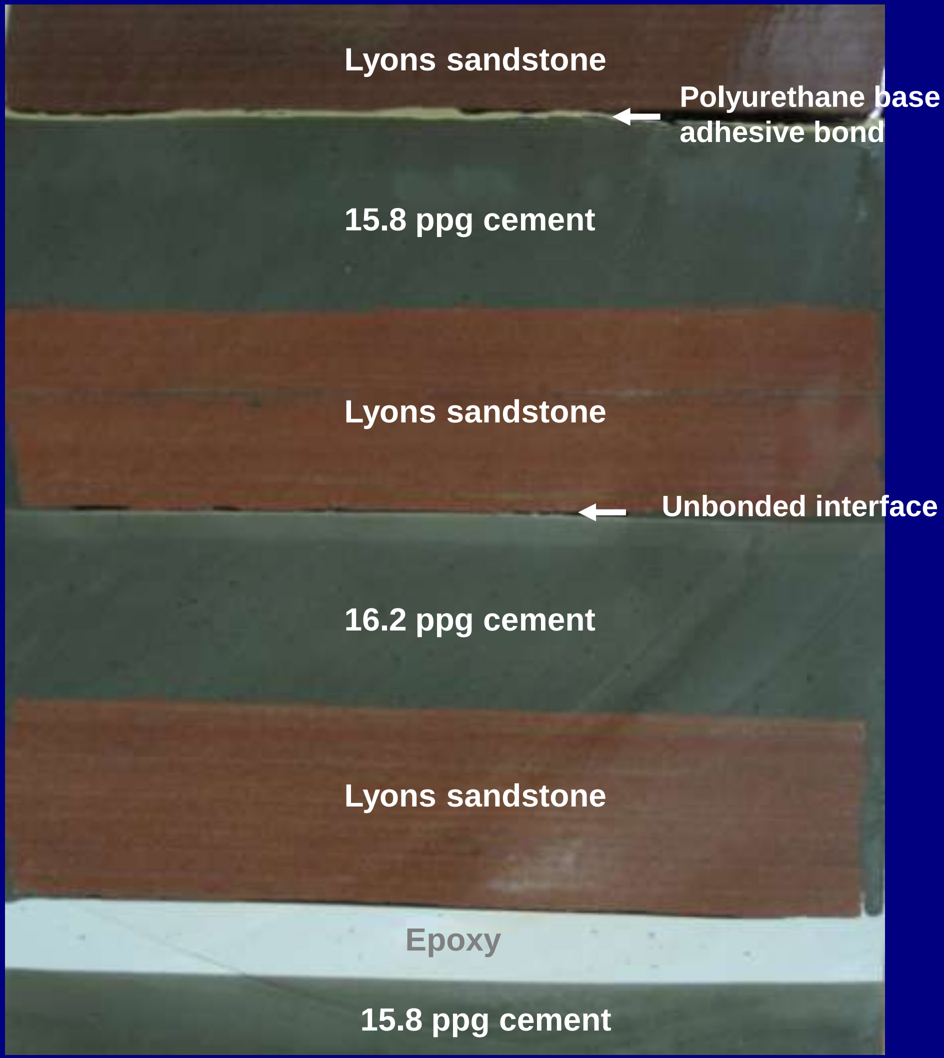
Containment by Shear Decoupling

Coupled System



Decoupled System



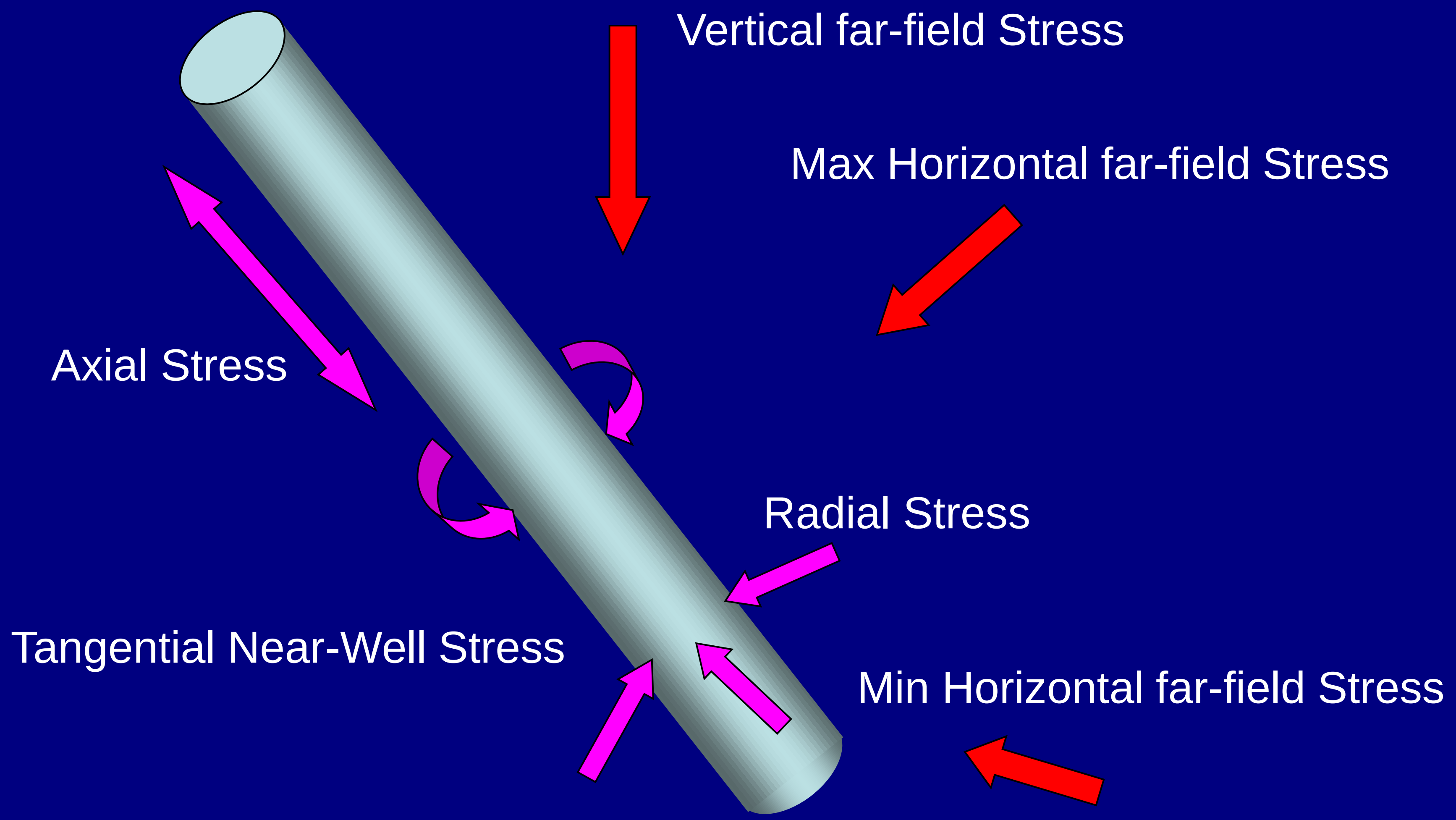


Laboratory experiments – laminated block before hydraulic fracturing (28 cm X 28 cm X 48 cm)

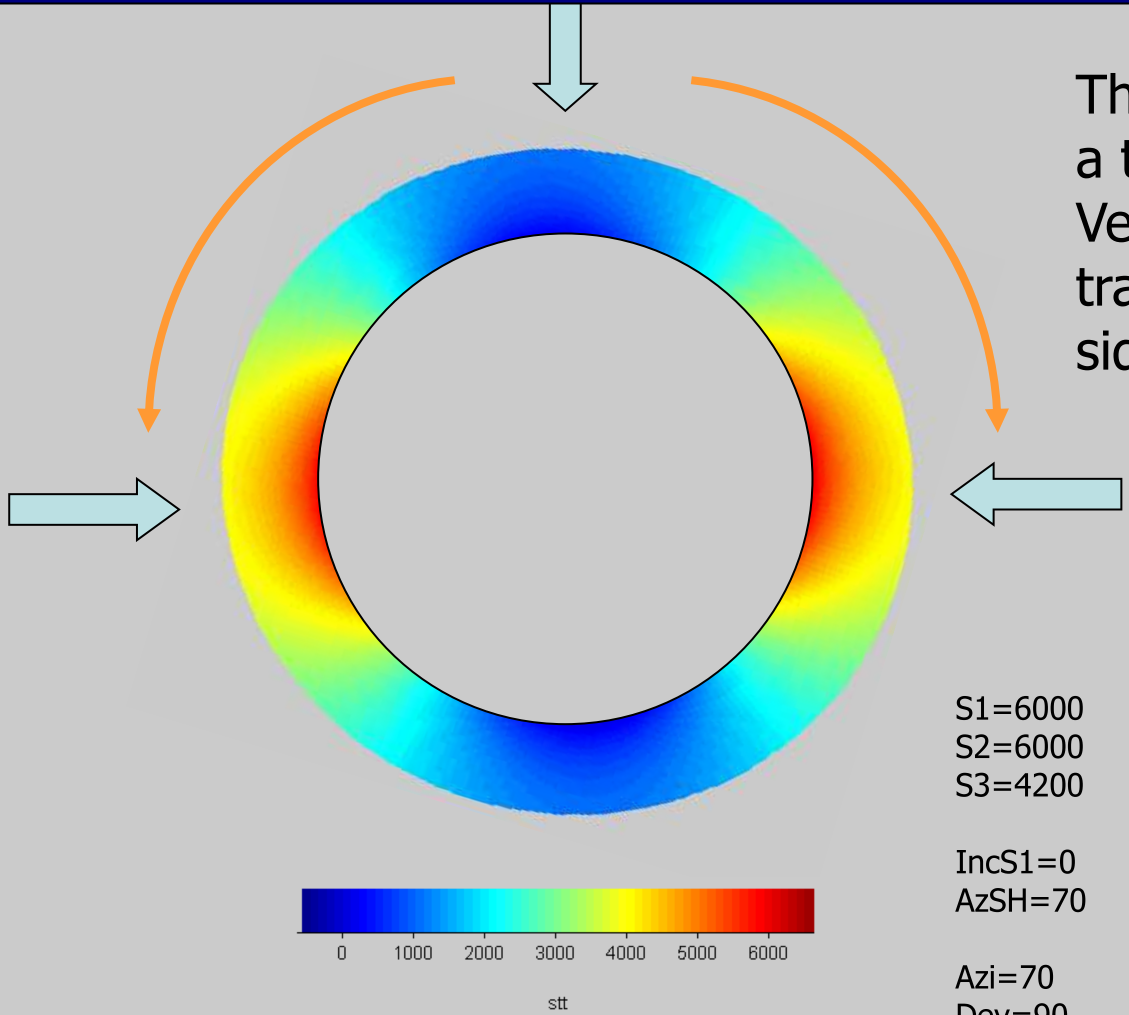
After hydraulic fracturing – notice the complexity for this “simple” system

Athavale and Miskimins, 2008

Near-Well Stresses In Rotated 3D Space



Tangential Stress Distribution Around a Horizontal Well



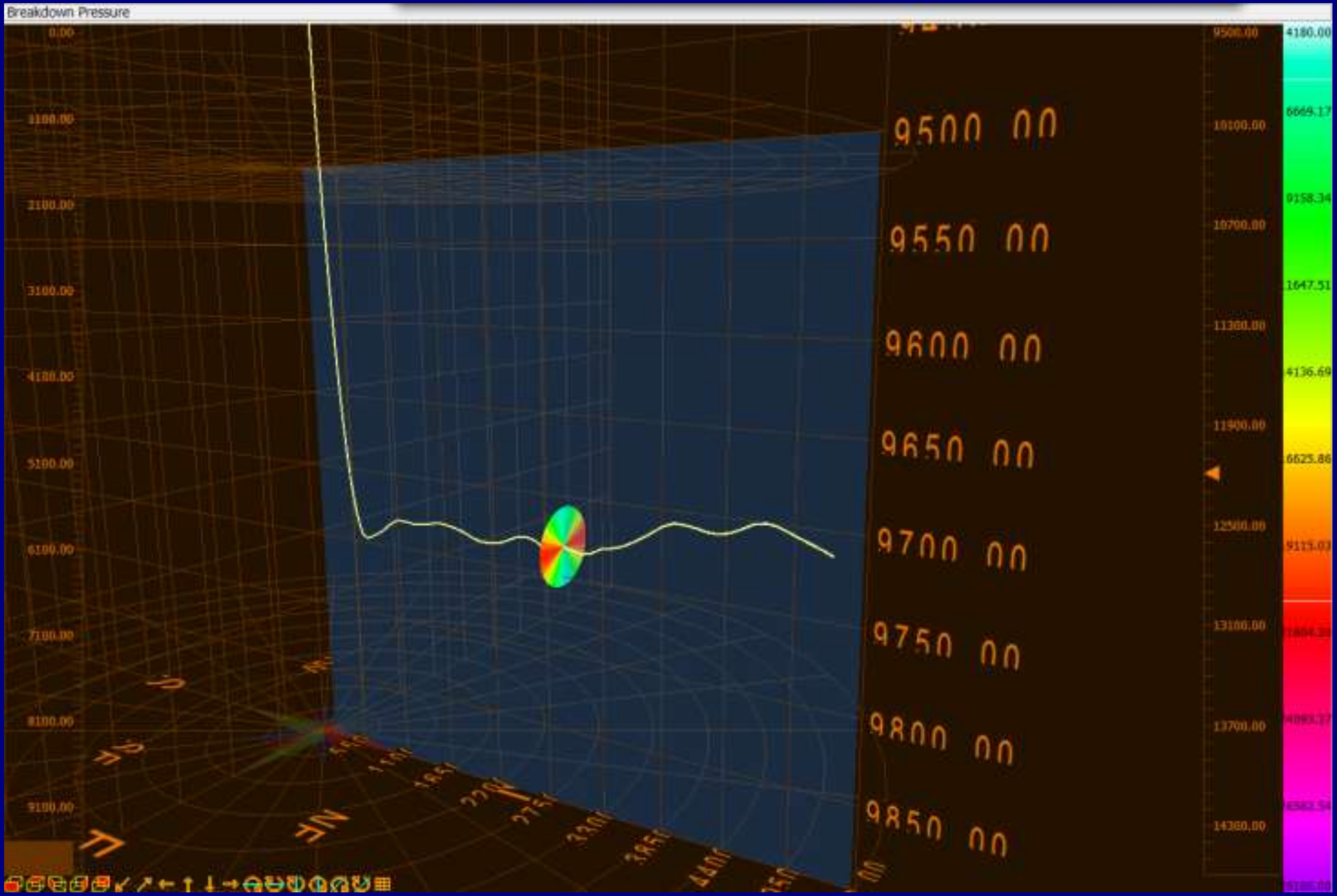
The wellbore acts as a tunnel arch: Vertical stress is transmitted to the sides of the hole

S1=6000
S2=6000
S3=4200

IncS1=0
AzSH=70

Azi=70
Dev=90

Breakdown Example

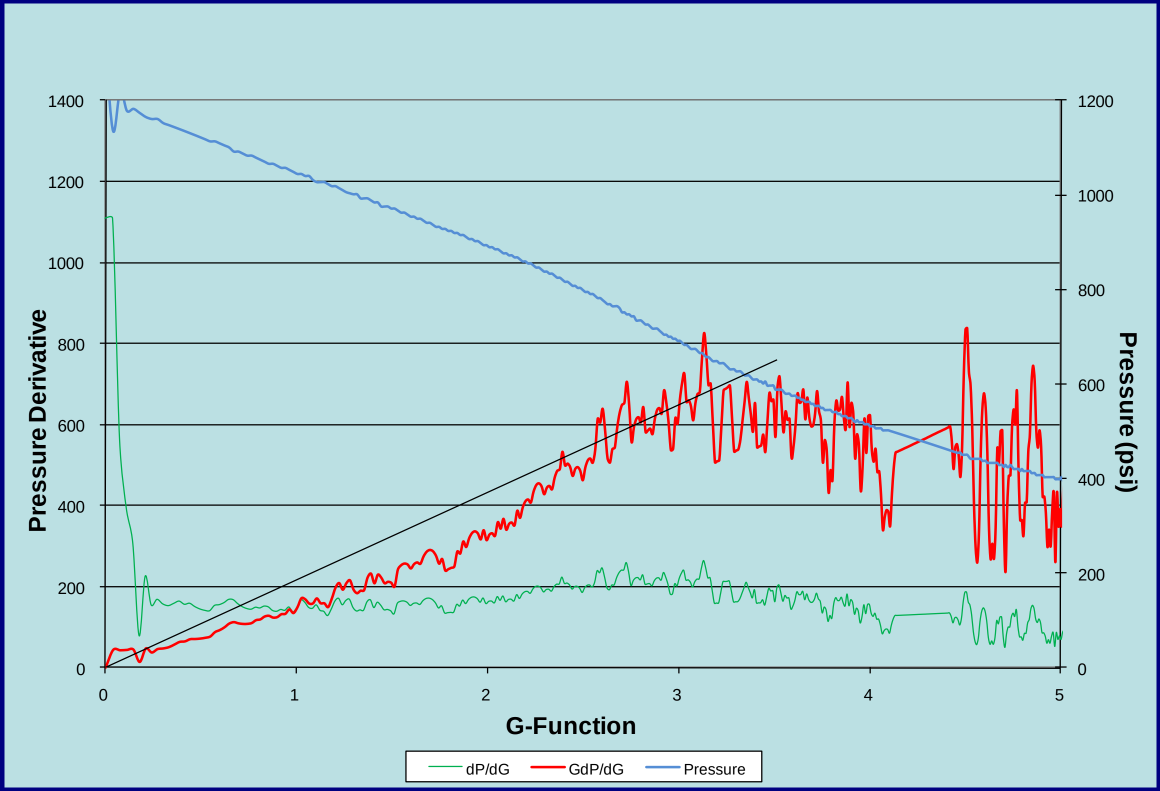


Reservoir Management/Development

- Reservoir characterization
- Stage/cluster spacing
- Need to maximize contact area
  - Low permeability
  - Minimal drainage area
- Re-treatments

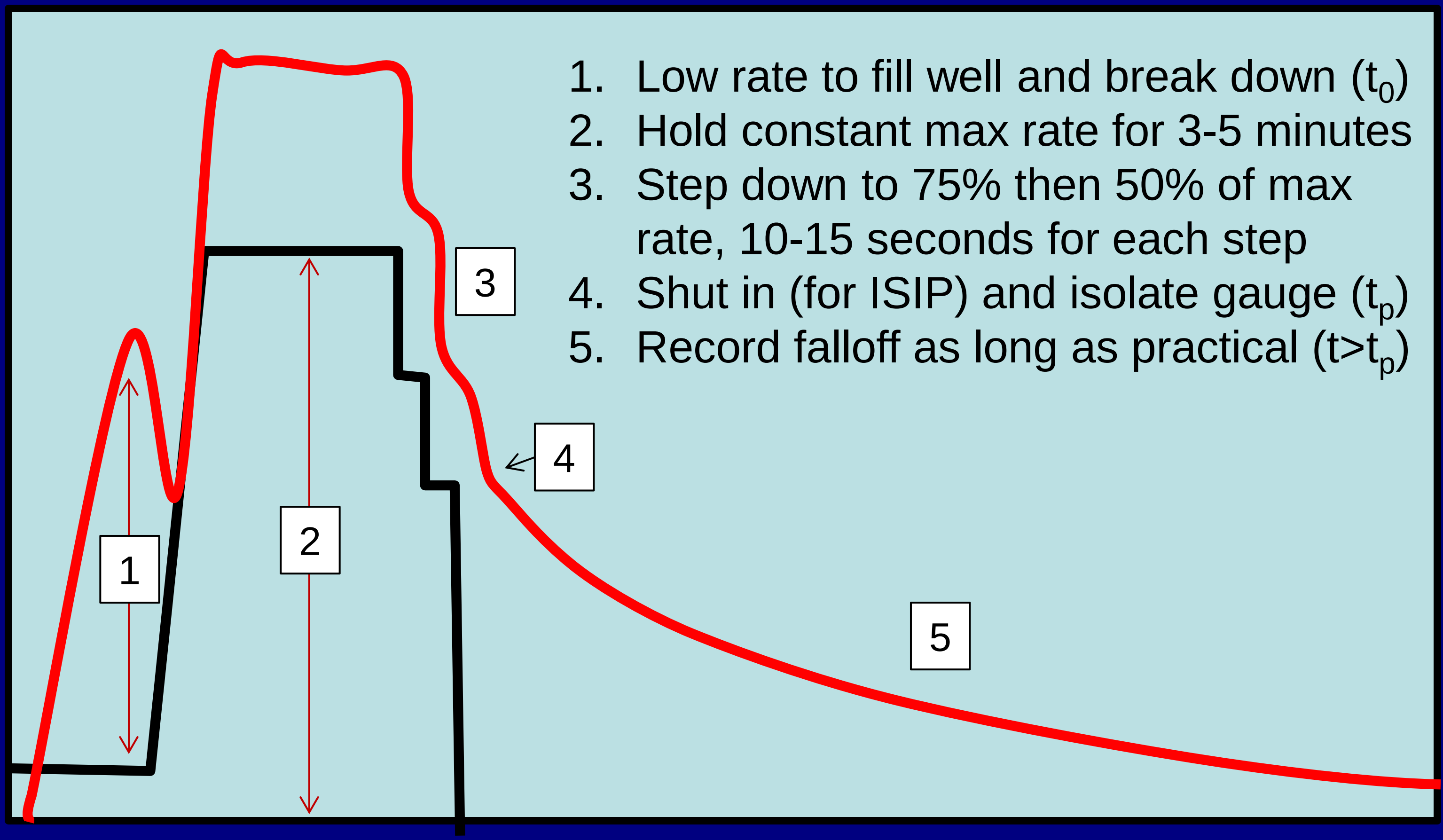
Reservoir Characterization

- Diagnostic injection tests
  - Leak-off behavior
  - Presence of natural fractures
  - Reservoir pressure
  - Permeability
  - Process zone stresses



G-Function Analysis

DFIT Procedure



1. Low rate to fill well and break down (t_0)
2. Hold constant max rate for 3-5 minutes
3. Step down to 75% then 50% of max rate, 10-15 seconds for each step
4. Shut in (for ISIP) and isolate gauge (t_p)
5. Record falloff as long as practical ($t>t_p$)

DFIT Design Constraints

- Time to reach closure is approximately 0.3 * Pump Time / Estimated Perm (md)
  - Five minutes in 0.001 md rock = 1500 min (25 hours)
  - Five minutes in 0.01 md rock = 150 min (2.5 hours)
- Time to establish analyzable reservoir transient is roughly 3 times the closure time
  - Longer created fractures will take longer to transition from pseudo-linear to pseudo-radial reservoir flow
- Gel filtercake or severe face plugging affects the development of the far-field pressure transient and will delay closure and invalidate after-closure analysis

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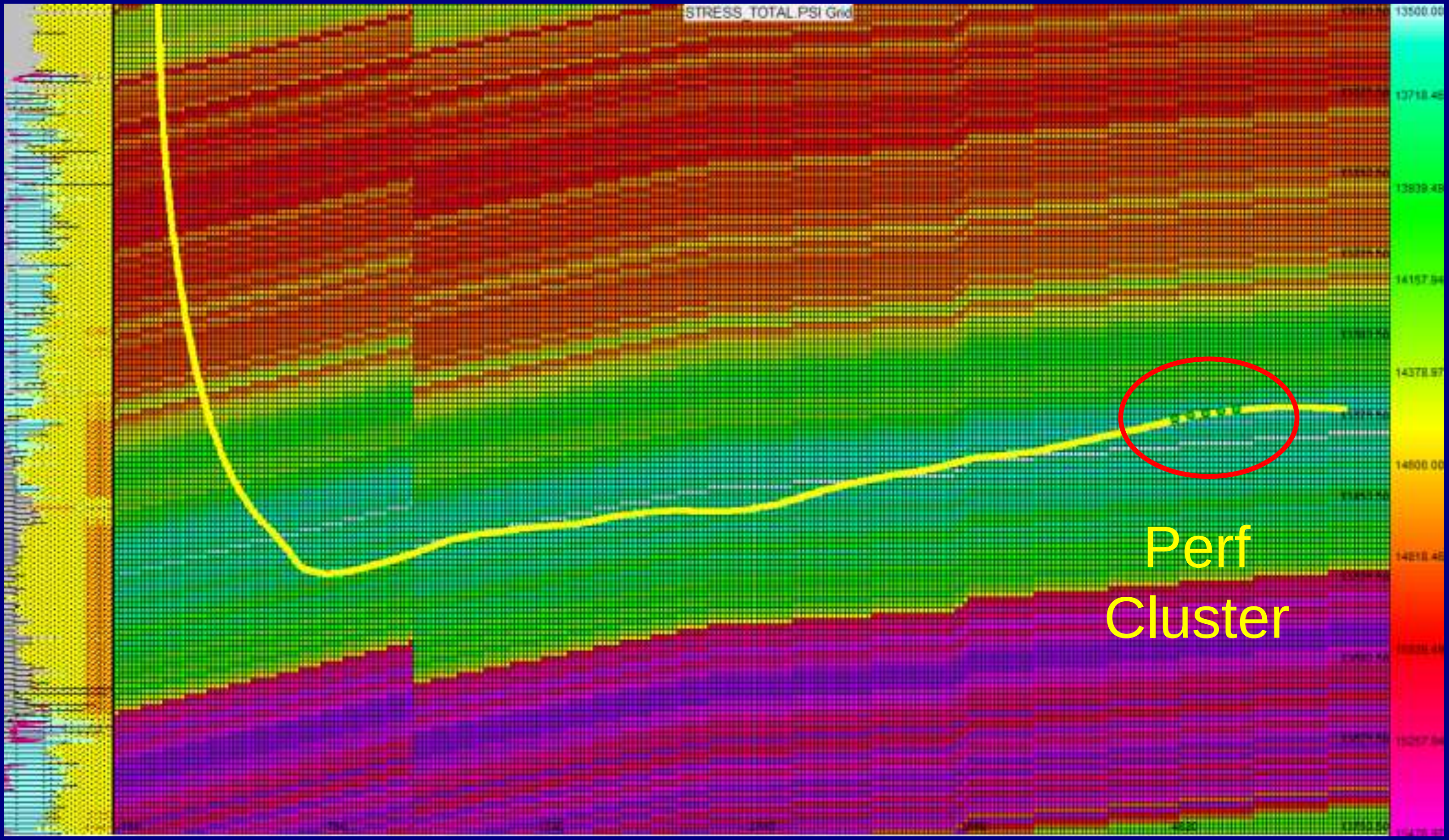
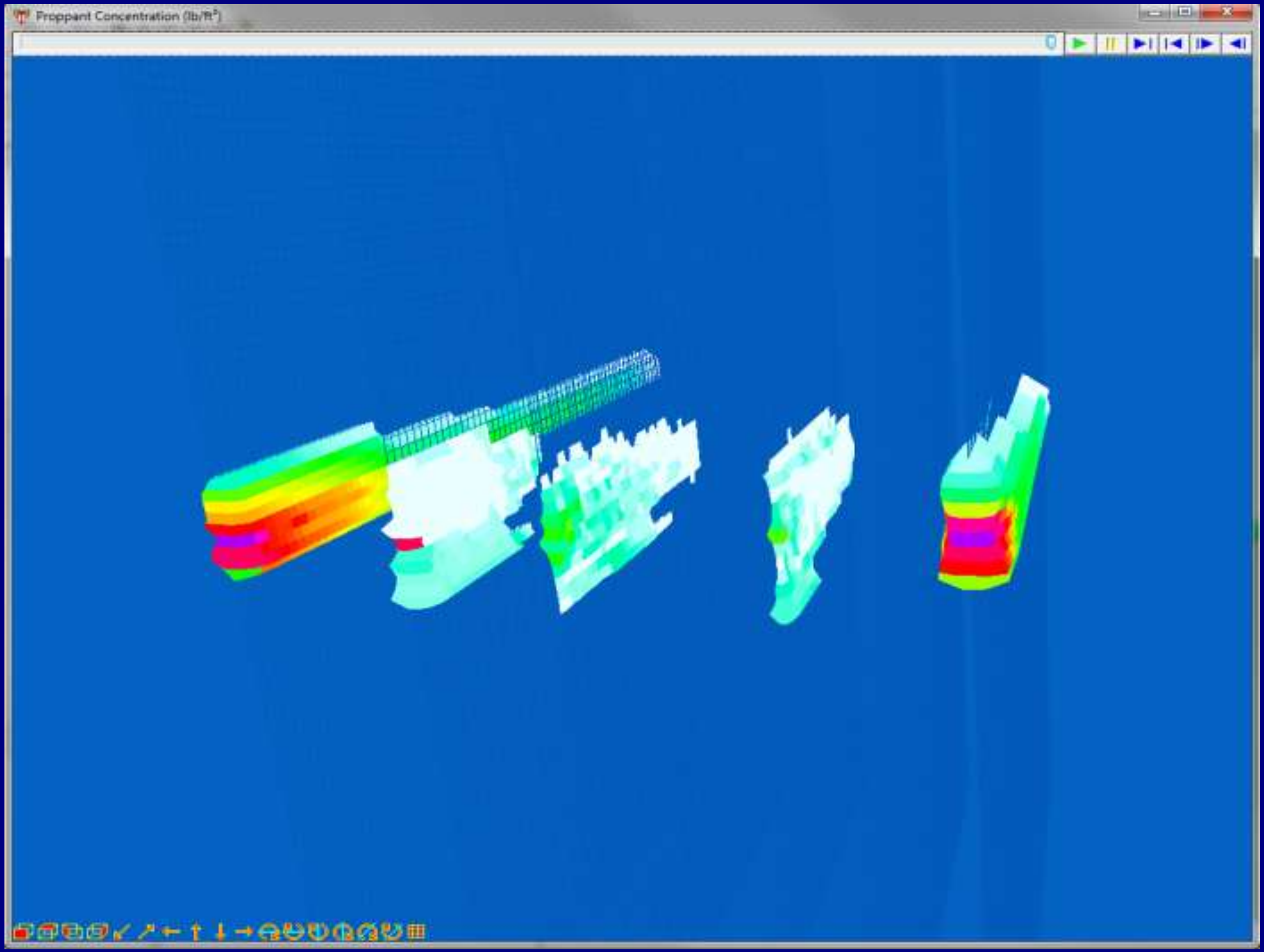
Cluster Spacing Optimization



Stress Shadowing of Clusters



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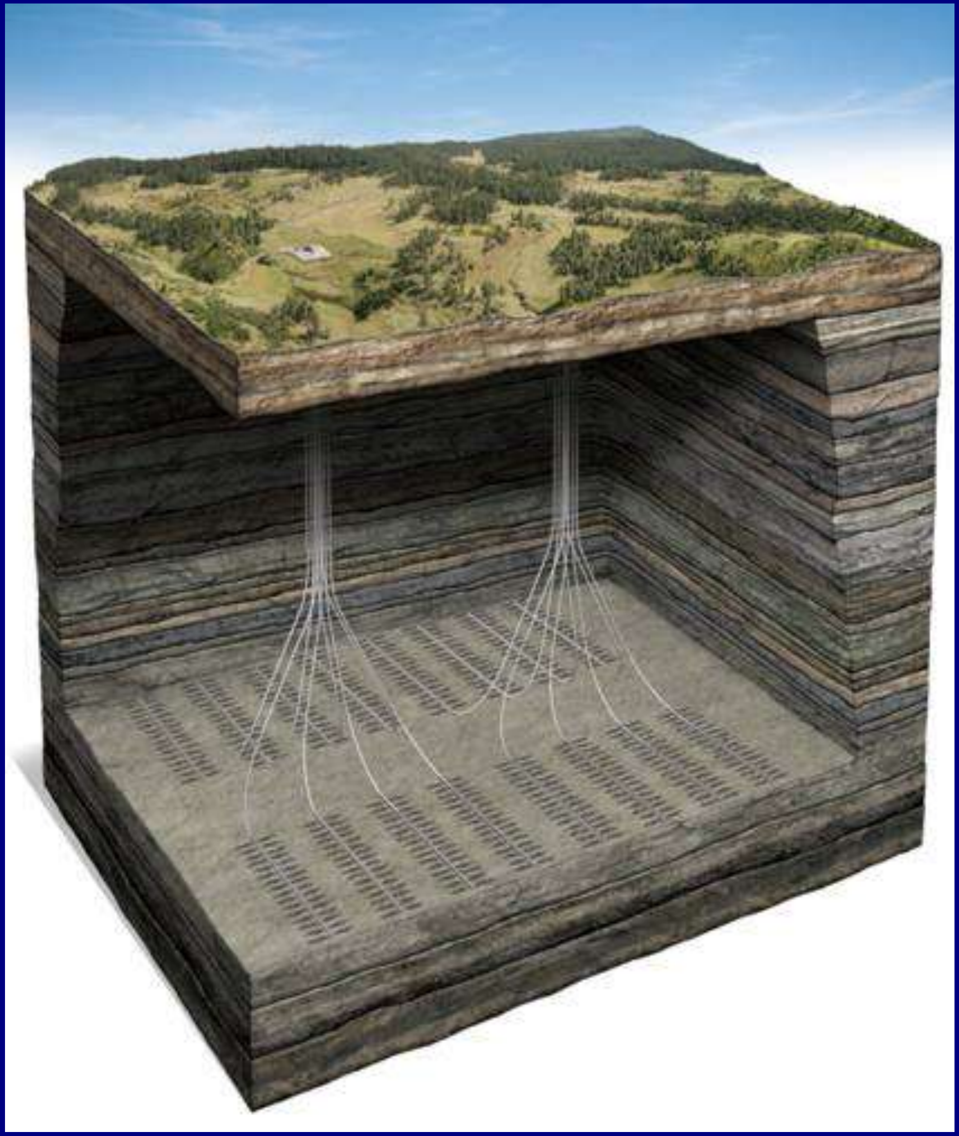
Piceance Basin, Western Colorado, USA

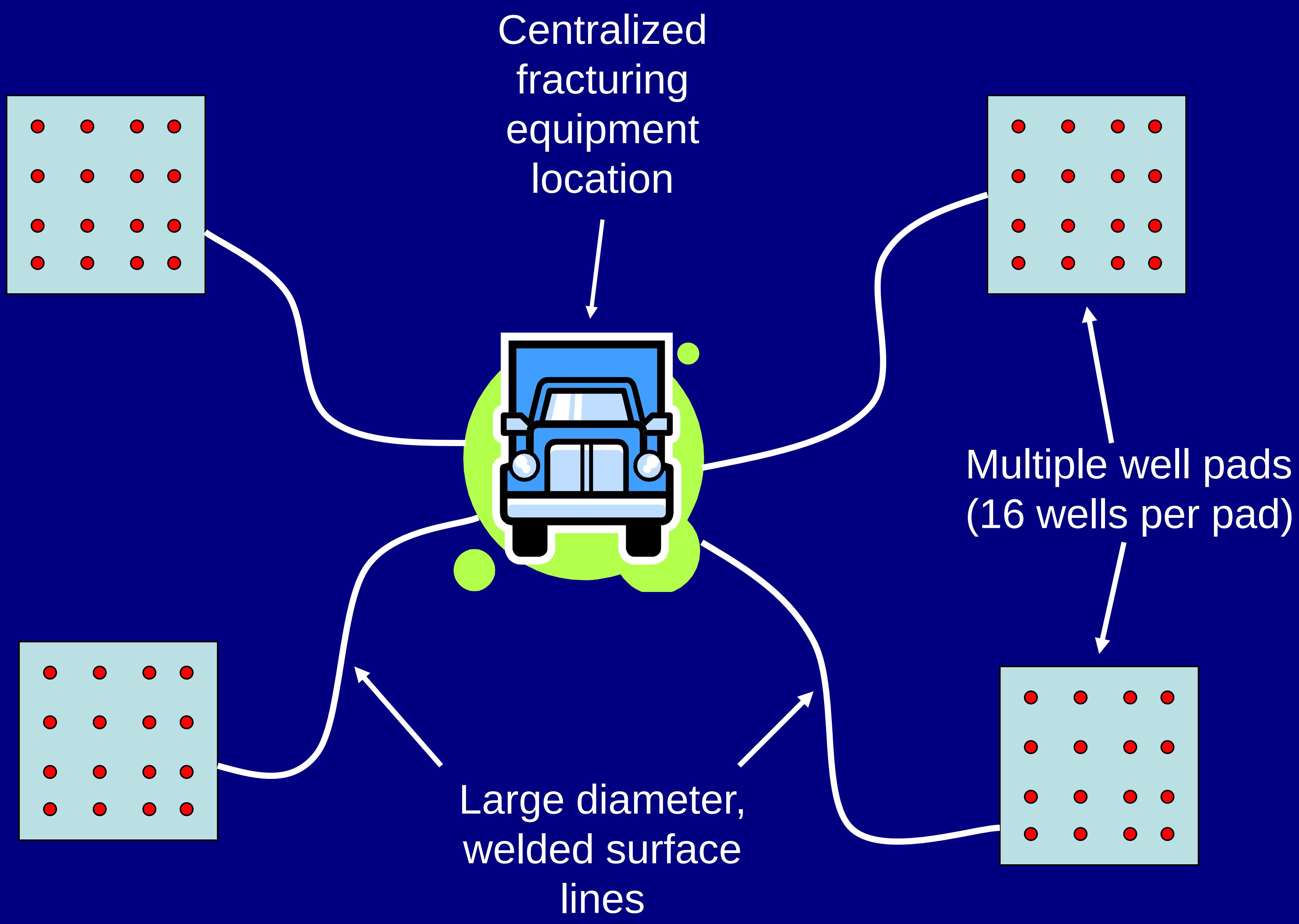
“S-Curve” Development

From www.csug.ca, 2010

Pad Development



Courtesy of
PETROBAKKEN



From Miskimins, 2009

Reservoir Management/Development

- Reservoir characterization
- Stage/cluster spacing
- Need to maximize contact area
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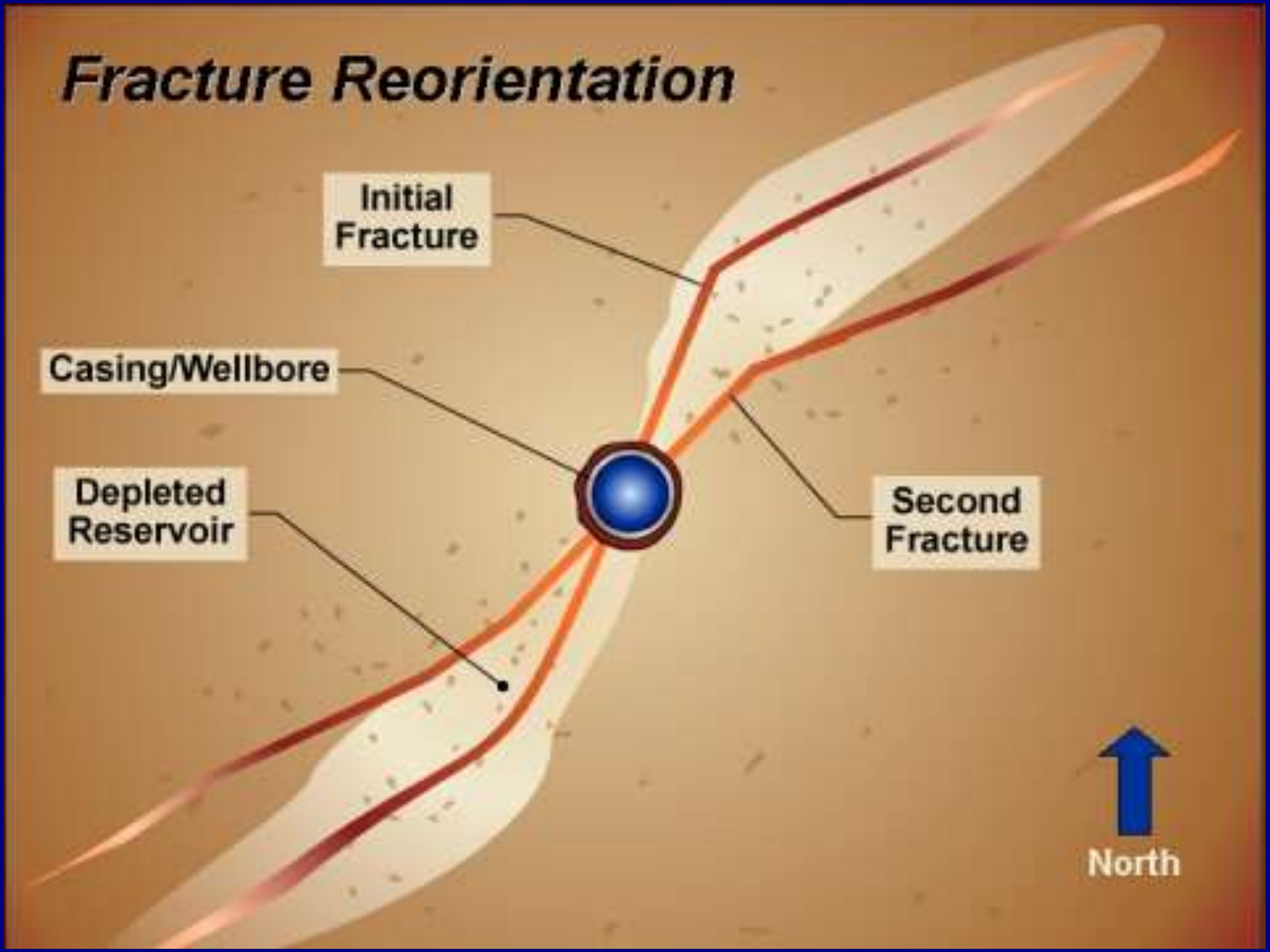
Reorientation/Retreatment??



Courtesy Devon Energy

Conclusions

- Hydraulic fracturing for UCR’s requires combinations of considerations
- UCR’s represent a wide variety of reservoir types and designs must address these differences
  - Materials, complexity, reservoir management
- The learning curve can be shortened by studying other successful applications

Thank you for your time!

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http://www.spe.org/dl/