SPE Distinguished Lecturer Program

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

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

Outline of today's presentation…

- Purpose
- Unconventional reservoirs
- Fluids, proppants, and transport
- Growth complexity
- Hydraulic fracturing for reservoir management
- Conclusions

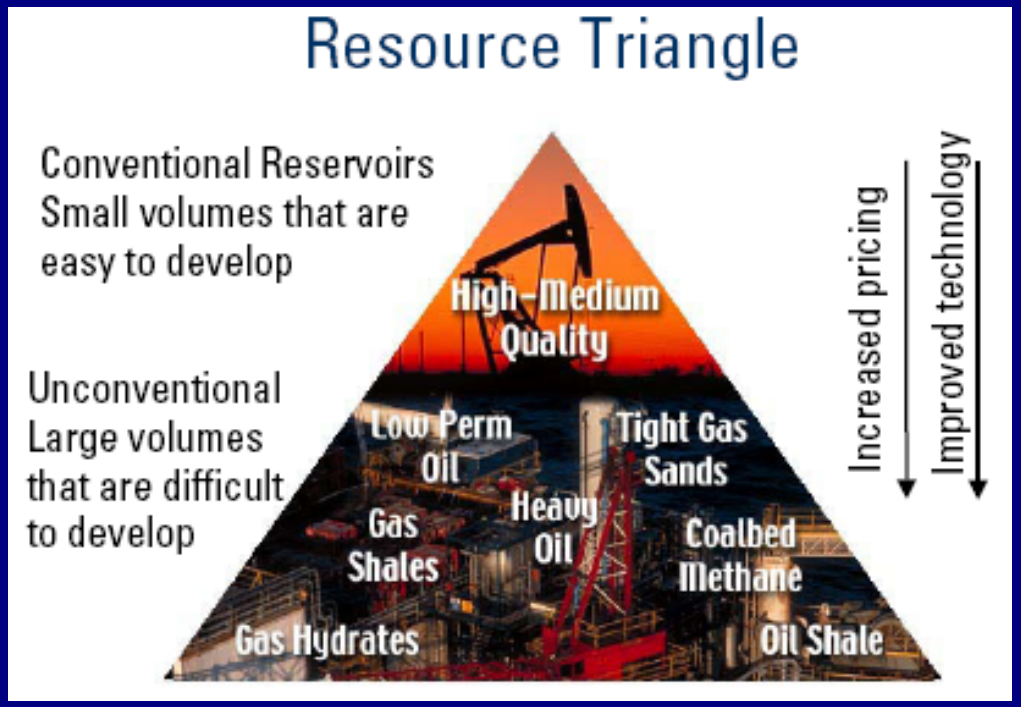
WHY should you be concerned?

- Unconventional reservoirs (UCR's) are just that - unconventional
- UCR's are increasing forming our reserve/resource base around the world
- Extrapolation of conventional techniques to 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"?)
  - Nano-Darcy permeability (10^{-9})
  - High quartz or carbonate content
- Tight gas
  - What is "tight"?
  - Micro-Darcy permeability
- Low perm oil
  - Various lithologies

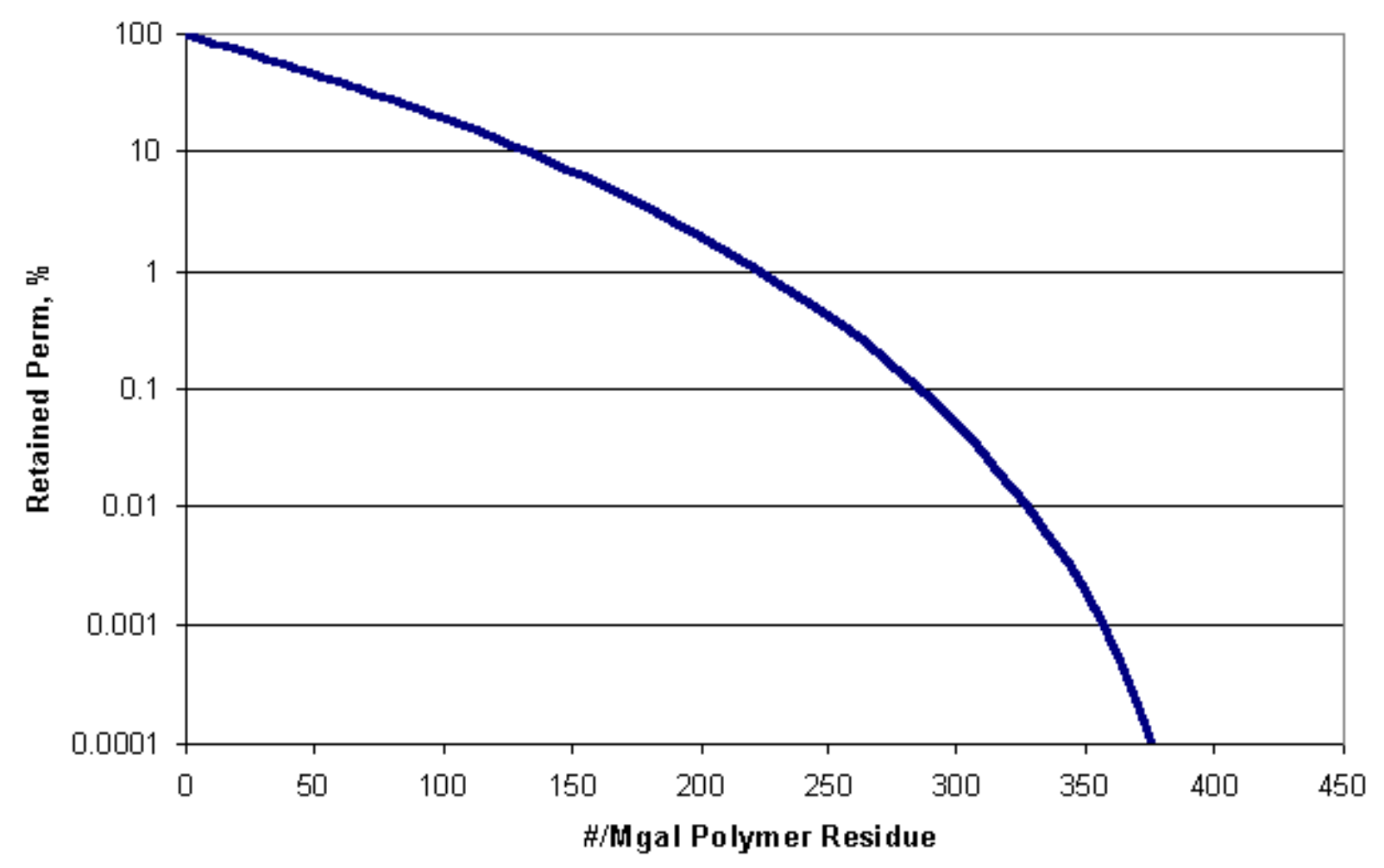
Fluid Systems

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

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

Courtesy of Stimlab

Retained Permeability With Gel Residue

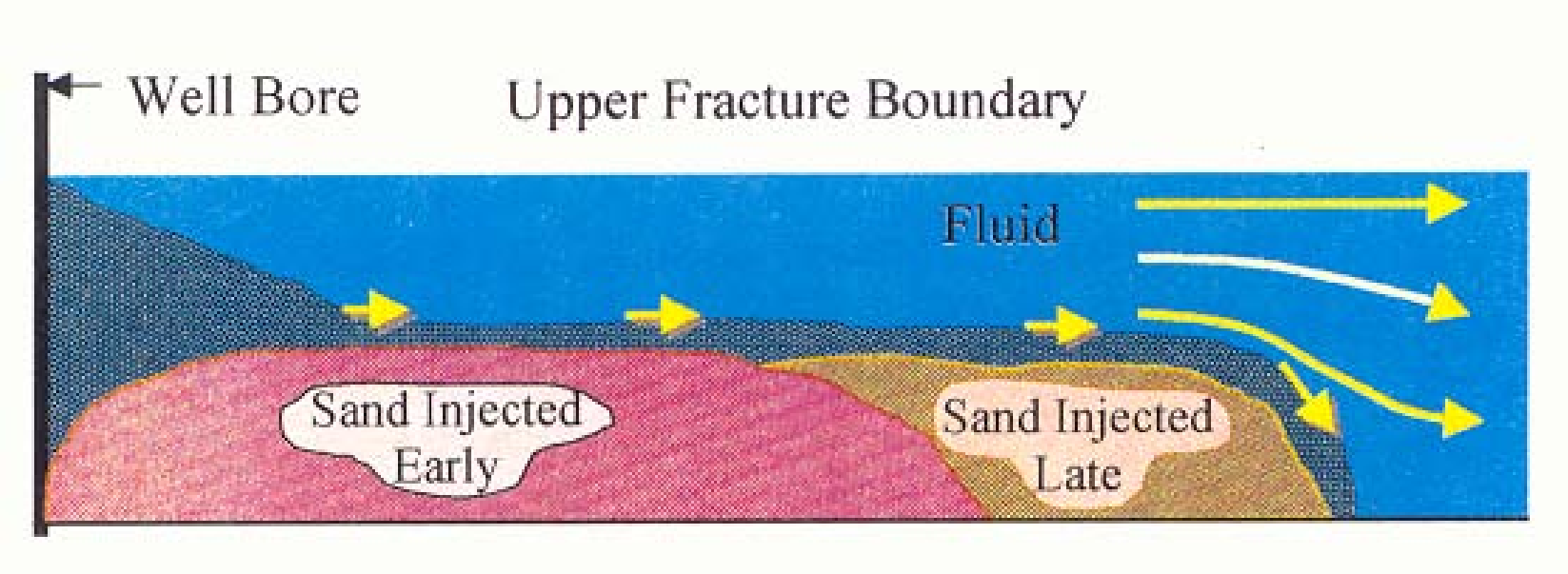


Stimlab, 2003

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
- 30/50 and 40/70 sizes common

Particle Transport



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

Example 1 – Bank Placement

0:08 sec

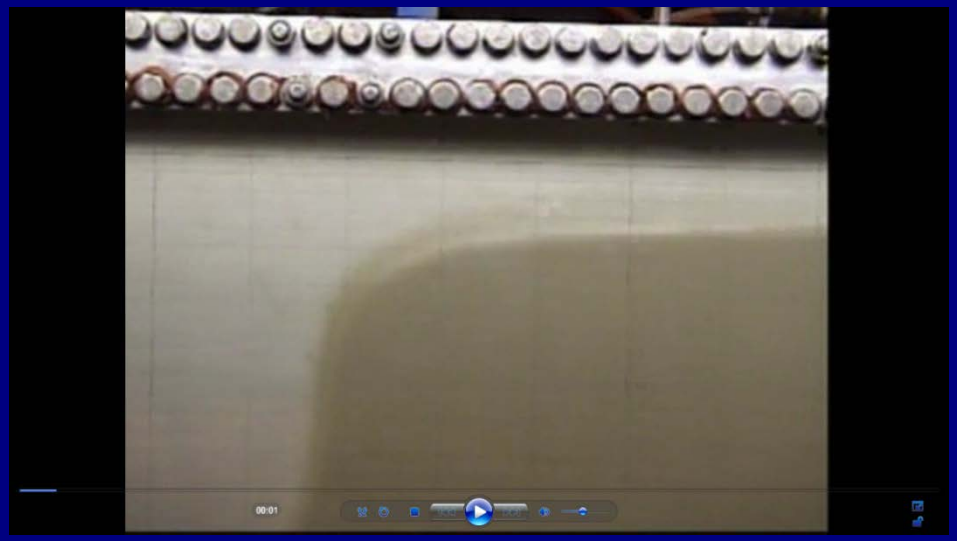
0:35 sec

0:58 sec

1:26 sec

Courtesy of Stimlab

Example 2 – Erosion of Bank



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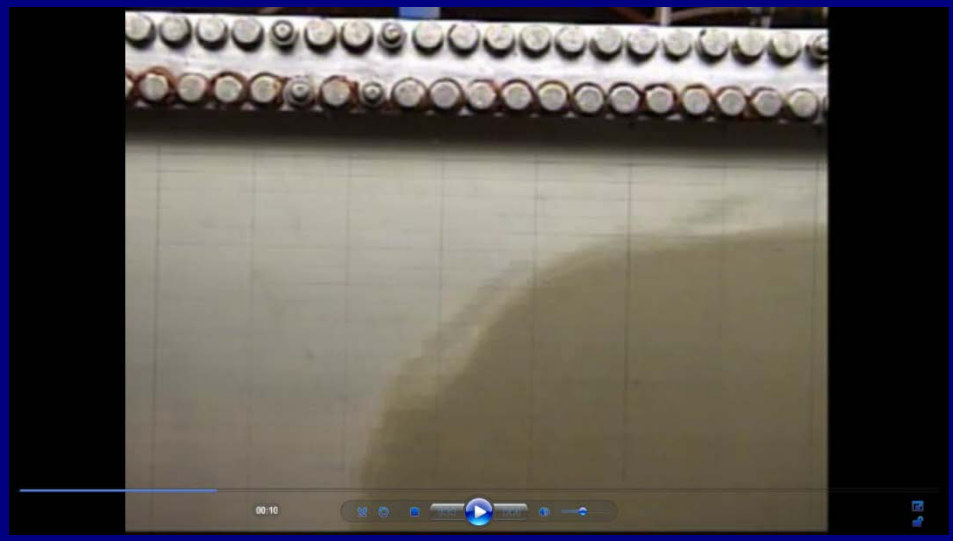


0:10 sec

0:38 sec

0:50 sec

Courtesy of Stimlab

Complexity of Growth

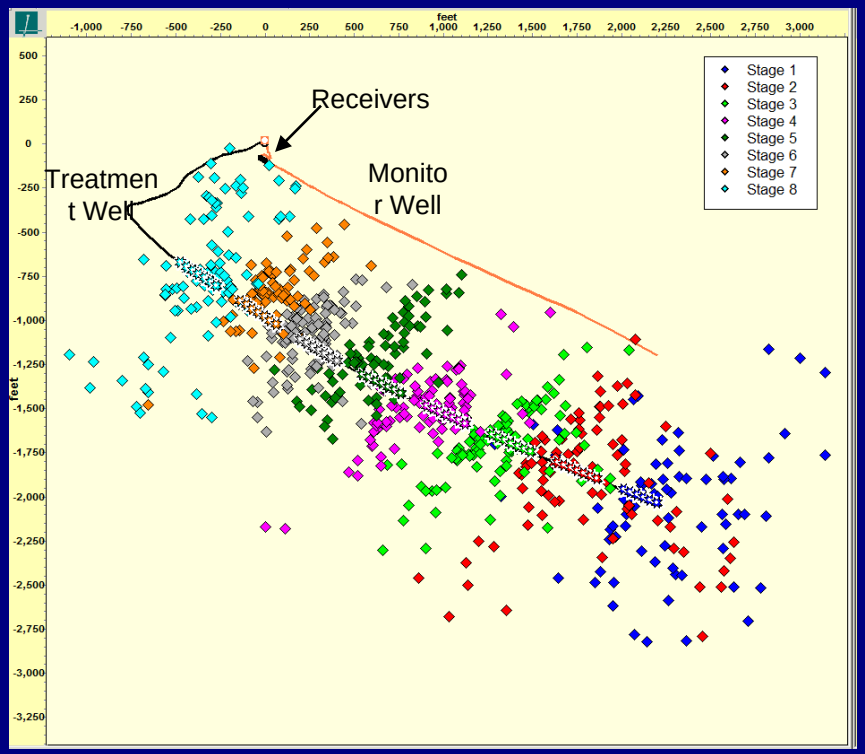
- Remember that fracturing is always the *path of least resistance*
- How complex is complex?
- 3D is no longer really 3D

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

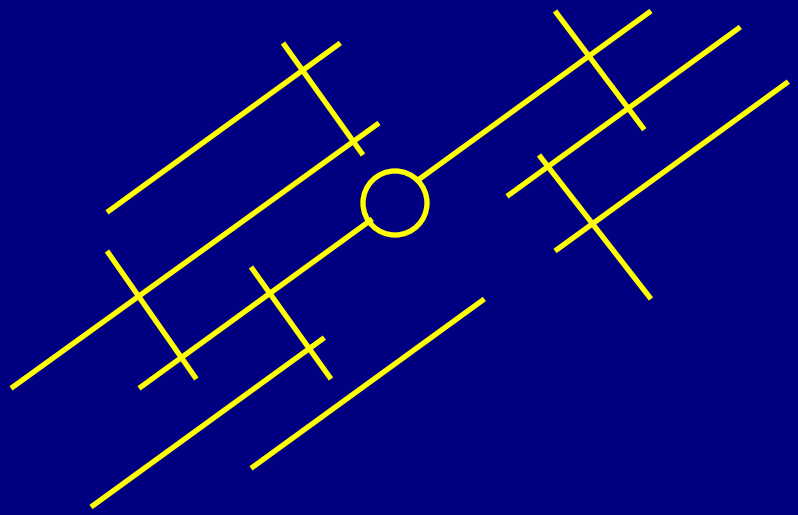
After hydraulic fracturing – notice the complexity for this “simple” system

Athavale and Miskimins, 2008

From the lab to the field – multiple stimulation stages in horizontal wells



From SPE 119896

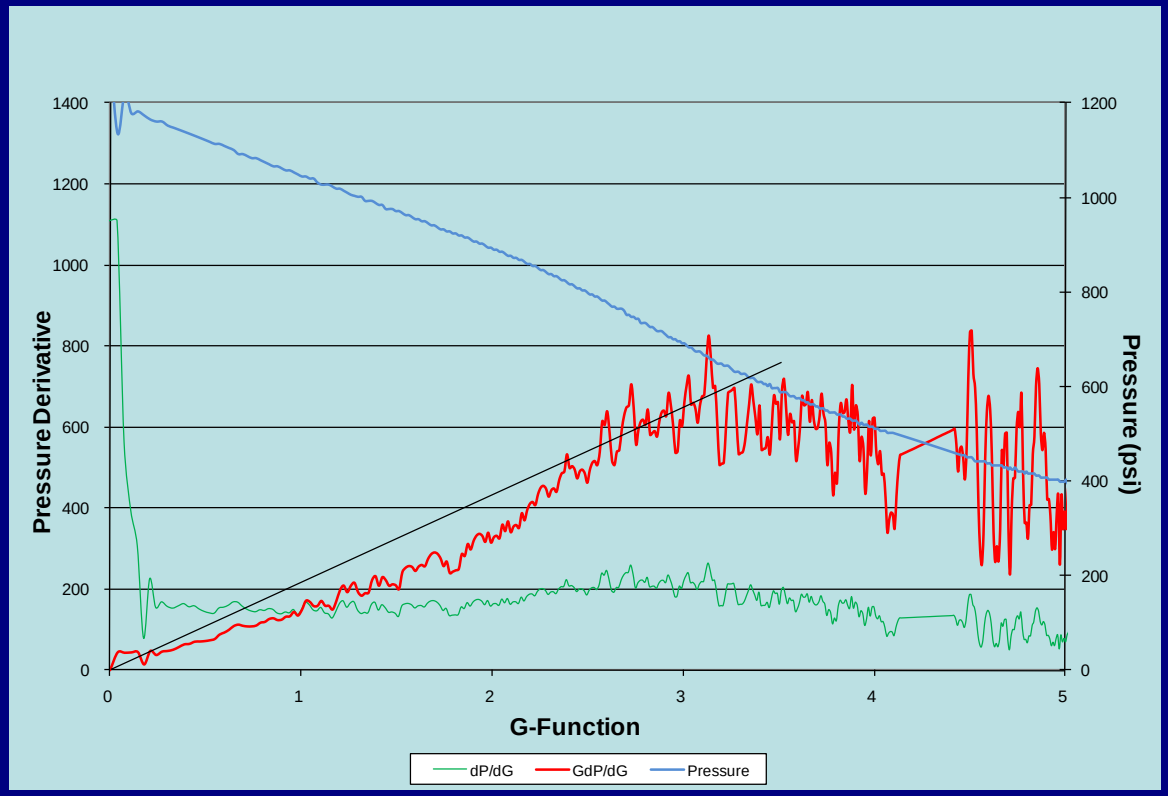


Reservoir Management/Development

- Reservoir characterization

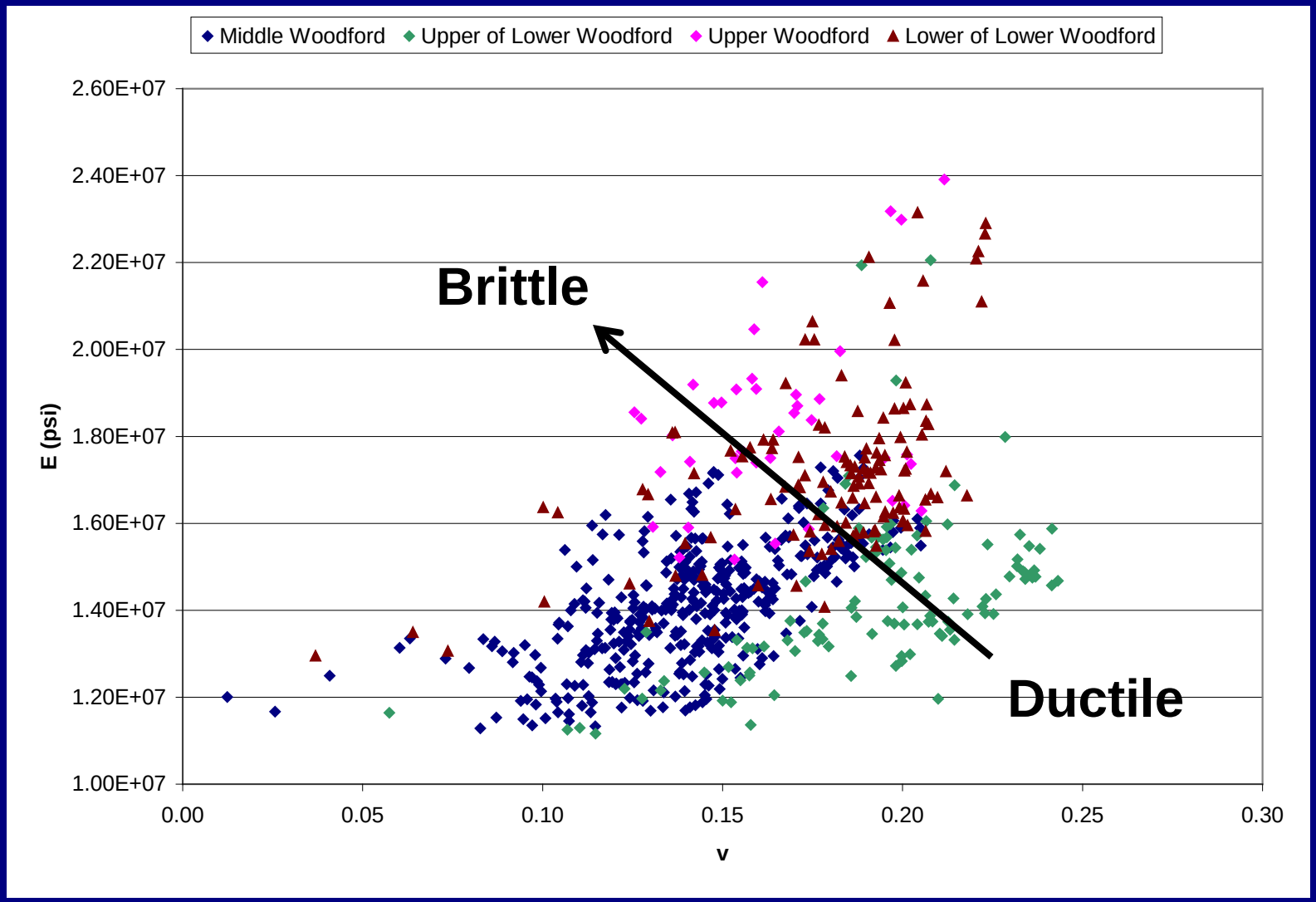
Reservoir Characterization

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



G-Function Analysis

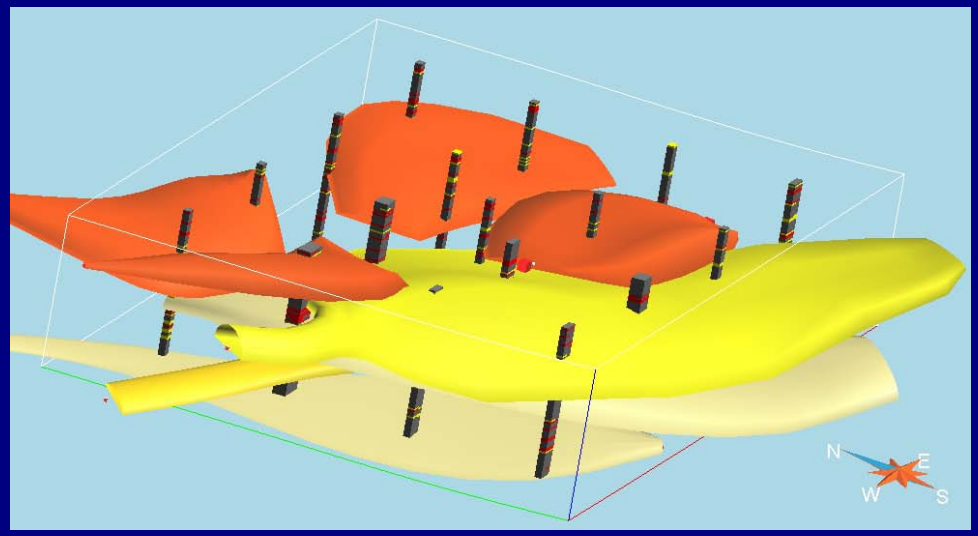
Young's Modulus vs. Poisson's Ratio



From Aoudia et al, 2010

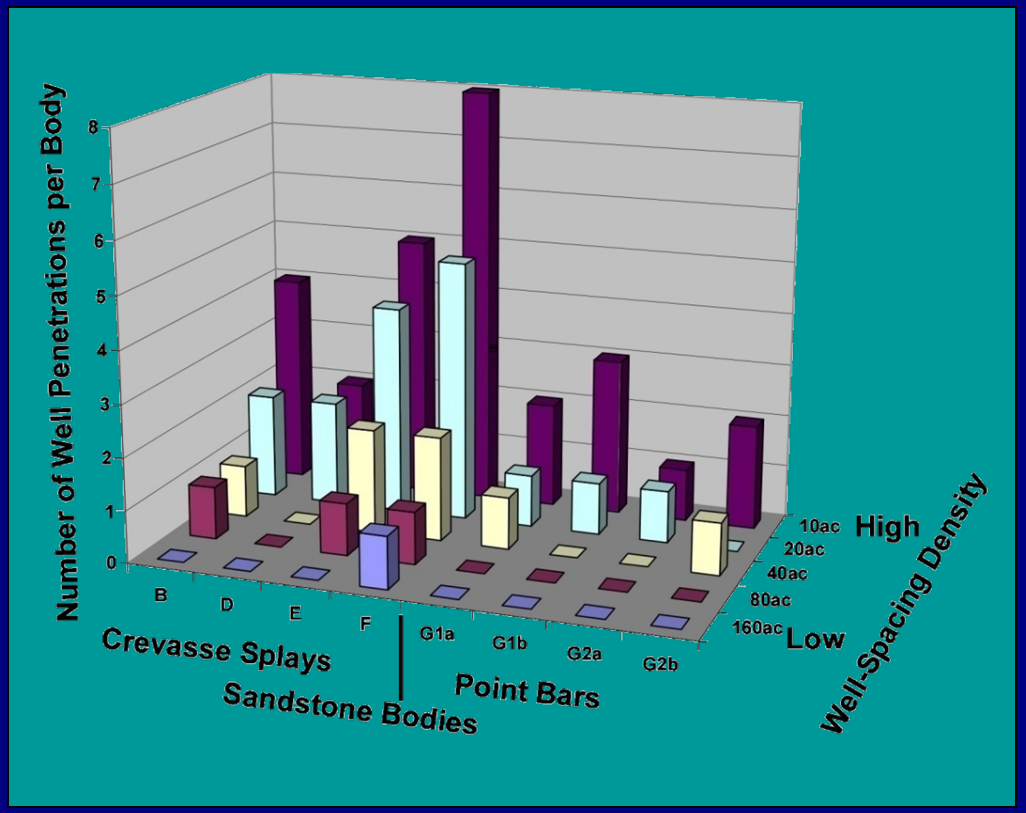
Reservoir Management/Development

- Reservoir characterization
- Well spacing
  - 10-20 acres (4-8 hectares)
- Need to maximize contact area
  - Low permeability
  - Minimal drainage area



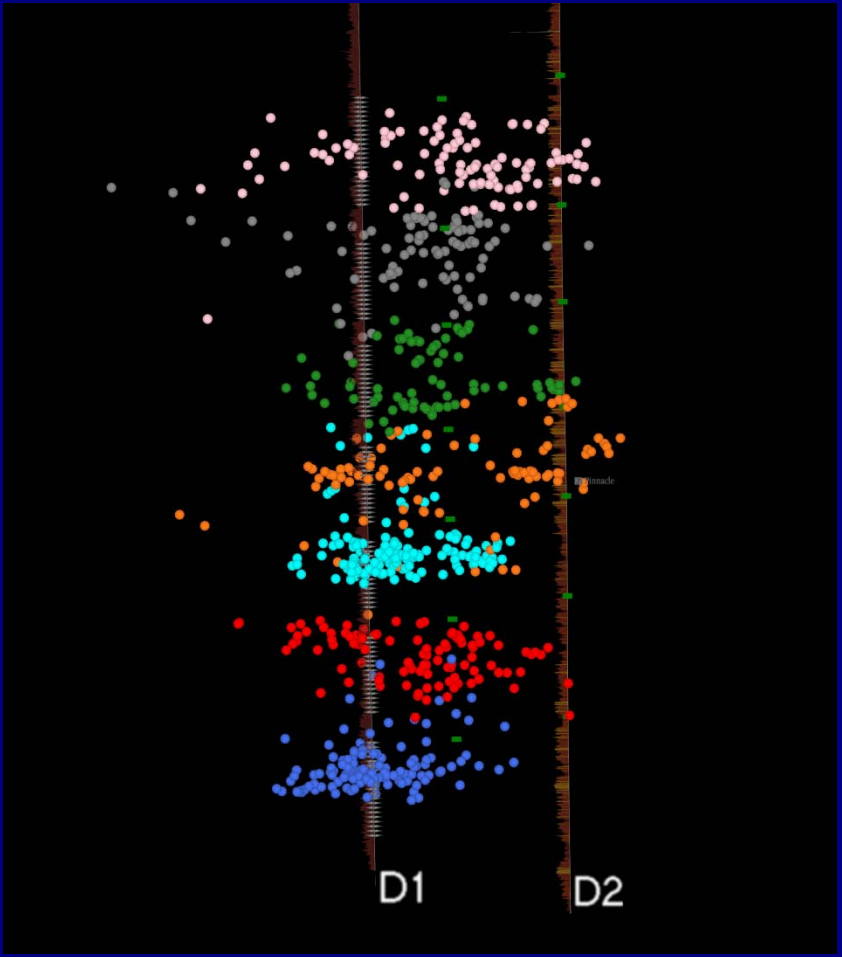
10-ac spacing 3D view of wellbore penetrating fluvial bodies

Body types penetrated as a function of well-spacing densities



Modified from Anderson, 2004

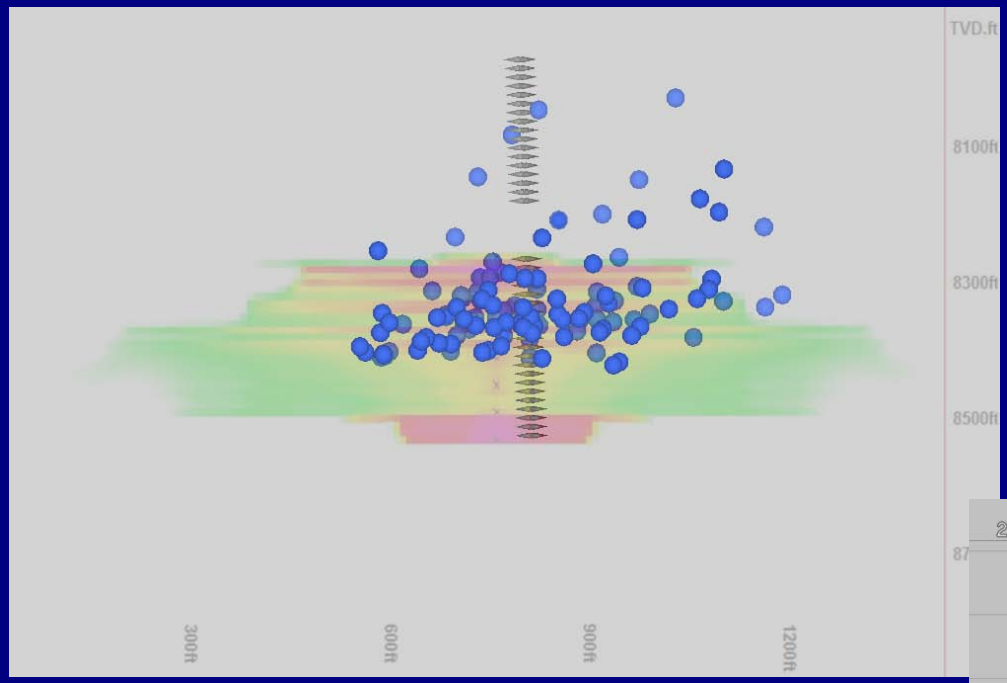
Microseismic Events, Side View



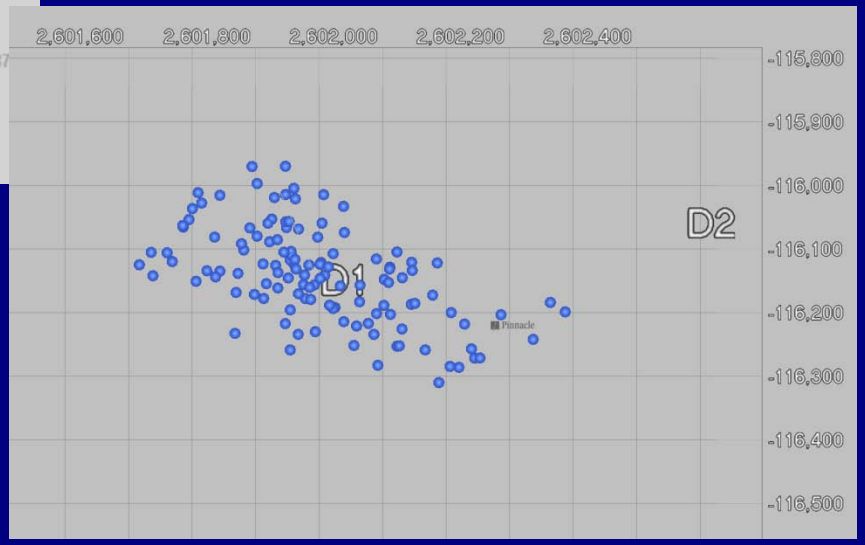
Well D1; Stages 1 – 7

From Mohammad and Miskimins, 2010

Well D1, Stage 1



Microseismic side view with hydraulic fracture model results (proppant concentration, lb/ft^2) superimposed



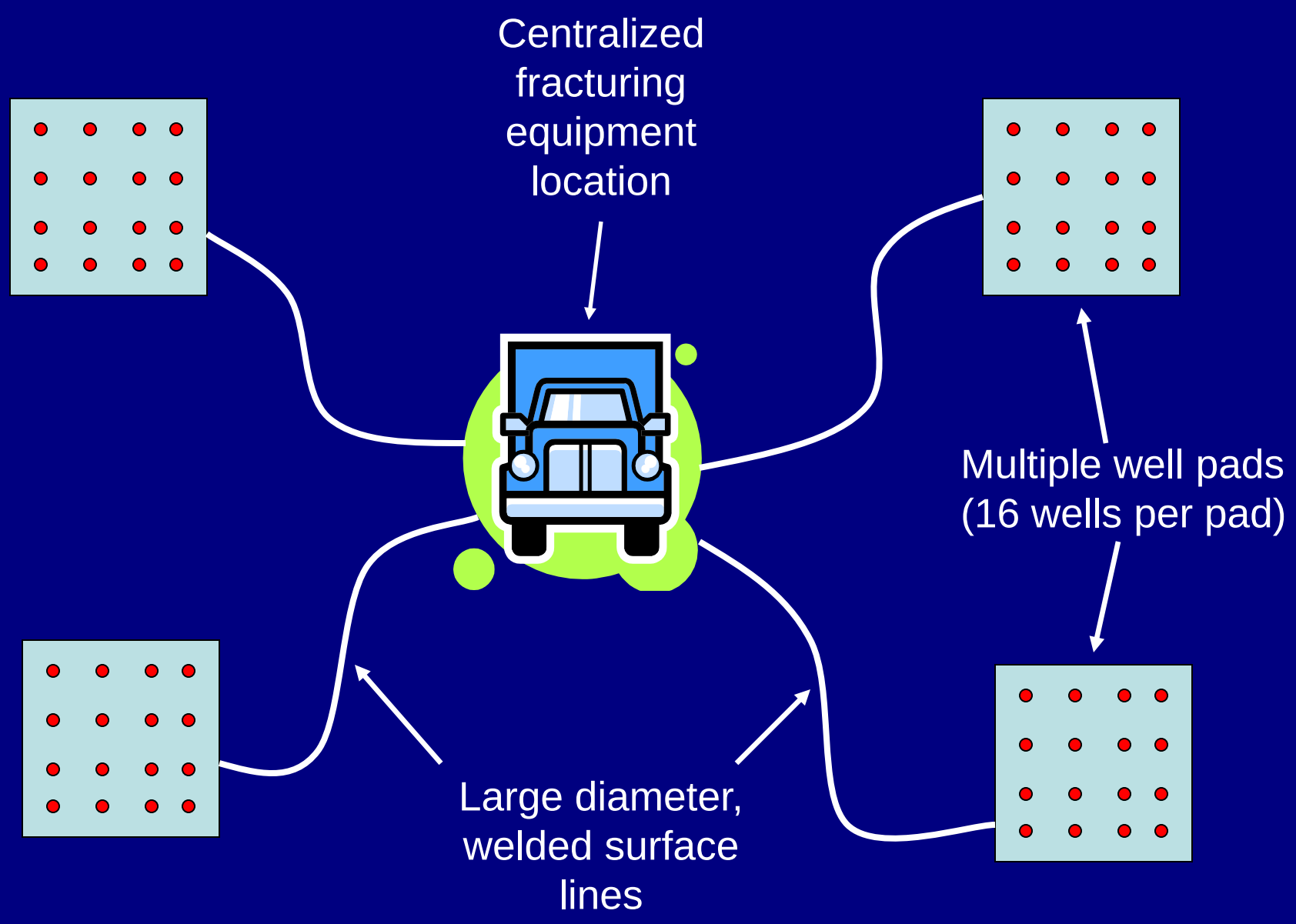
Microseismic plan view

From Mohammad and Miskimins, 2010

Piceance Basin, Western Colorado, USA

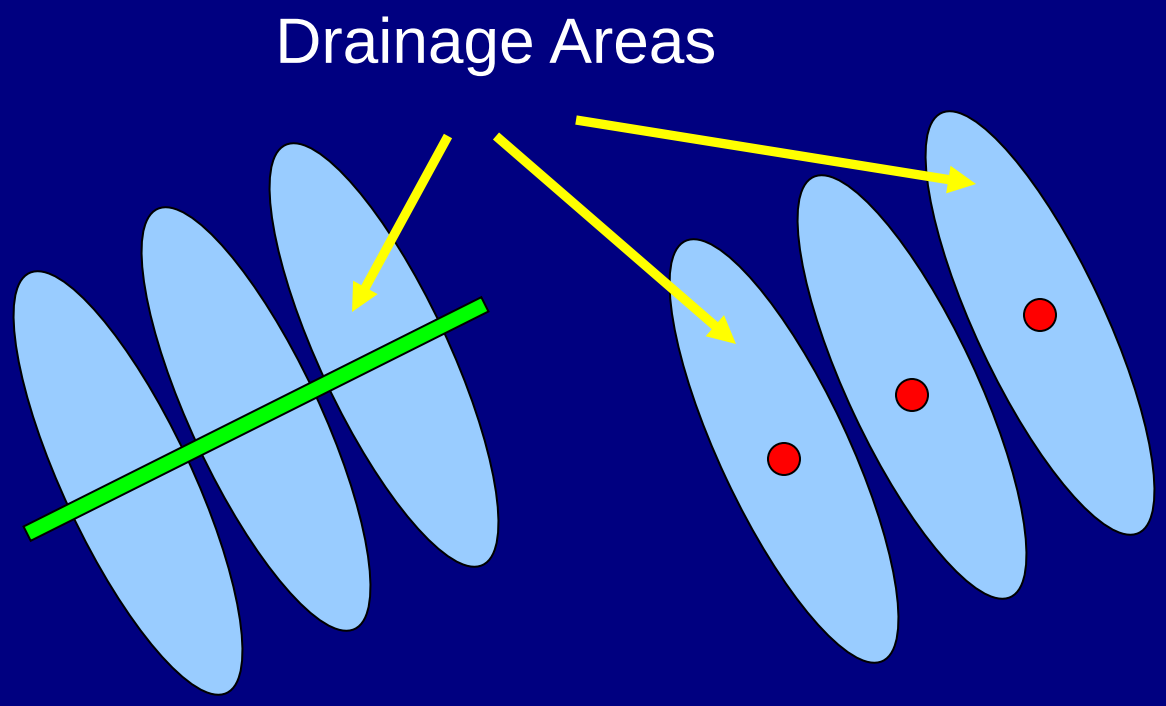
“S-Curve” Development

From www.csug.ca, 2010



From Miskimins, 2009

Shale Gas Reservoir Drainage



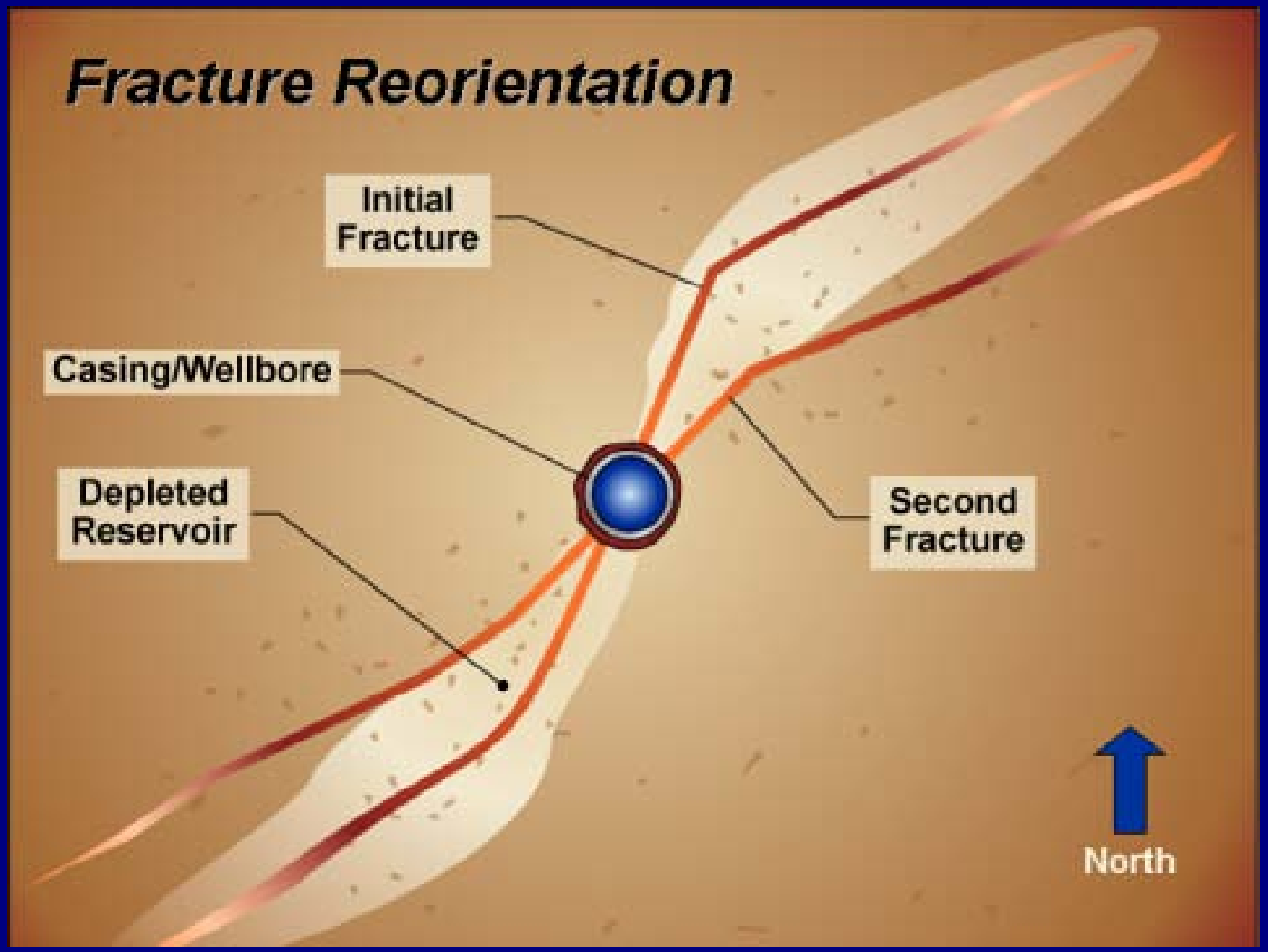
Horizontal well system

Vertical well system

Reservoir Management/Development

- Reservoir characterization
- Well spacing
  - 10-20 acres (4-8 hectares)
- Need to maximize contact area
  - Low permeability
  - Minimal drainage area
- Reorientation

Reorientation Theory



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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