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Society of Petroleum Engineers
Distinguished Lecturer Program
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Unconventional Frac Jobs for Unconventional Reservoirs – What Should You Be Concerned About?

Jennifer L. Miskimins, Ph.D., P.E.
Petroleum Engineering Dept.
Colorado School of Mines
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
“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

• “Slickwater”
  – Minimal polymer loading
  – Polyacrylamide friction reducers
  – 1 – 10 cp fluid system
  – Carrying capacity reduced

• Must minimize damage due to the initial low permeability

\[ F_{CD} = \frac{k_f W}{k X_f} \]
Retained Permeability With Gel Residue

Stimlab, 2003
Lightweight/Smaller Proppants

- Use of lower viscosity fluids = difficult to carry high proppant concentrations
- \textit{Velocity} is the transport mechanism, not \textit{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

Courtesy of Stimlab
Example 2 – Erosion of Bank

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 SPE 119896

From the lab to the field – multiple stimulation stages in horizontal wells
Reservoir Management/Development

• Reservoir characterization
Reservoir Characterization

• Diagnostic injection tests
  – Presence of natural fractures
  – Reservoir pressure
  – Permeability
  – Process zone stresses
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
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/ft²) superimposed

Microseismic plan view

From Mohammad and Miskimins, 2010
Piceance Basin, Western Colorado, USA
“S-Curve” Development
Centralized fracturing equipment location

Multiple well pads (16 wells per pad)

Large diameter, welded surface lines

From Miskimins, 2009
Shale Gas Reservoir Drainage

Drainage Areas

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

Fracture Reorientation

Initial Fracture
Casing/Wellbore
Depleted Reservoir
Second Fracture

North

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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