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

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Barree & Associates
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 concepts 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”?)
  – 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

\[ F_{CD} = \frac{k_f w}{kX_f} \]
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
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.

Possible water coning around well causing further damage?

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

- Suspended proppant slurry (uniform concentration)
- Clean pad fluid to create \( w = 3-6x_d \)
- Frac height (assumed to be constant)
- Fracture half-length
- Settled sand bank
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

Courtesy of Stimlab
Modeling

• Remember that fracturing is always the *path of least resistance*
• De-coupling; vertical resistance (layers; laminations)
• Breakdown considerations in horizontal wells
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

- Vertical far-field Stress
- Max Horizontal far-field Stress
- Min Horizontal far-field Stress
- Axial Stress
- Radial Stress
- Tangential Near-Well Stress
Tangential Stress Distribution Around a Horizontal Well

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

- $S_1 = 6000$
- $S_2 = 6000$
- $S_3 = 4200$
- Inc$S_1 = 0$
- Az$SH = 70$
- Azi = 70
- Dev = 90
Breakdown Example
Reservoir Management/Development

• Reservoir characterization
• Well spacing
  – 10-20 acres (4-8 hectares)
• 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
C.I. = 0.1 psi/ft

Miskimins, 2000
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 ($t>t_p$)

Barree, et al., 2014
Reservoir Management/Development

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Body types penetrated as a function of well-spacing densities

Modified from Anderson, 2004
“Layer-cake” Reservoir

From Cuba, et al, 2013
“Layer-cake” Model Results

From Cuba, et al, 2013
Detailed Reservoir, Well A

From Cuba, et al, 2013
Well A - Rock Properties

- Porosity
- Permeability (md)
- Poisson’s ratio
- Young’s modulus (psi)
Detailed Reservoir, Well A

From Cuba, et al, 2013
Reservoir Management/Development

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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
Centralized fracturing equipment location

Multiple well pads (16 wells per pad)

Large diameter, welded surface lines

From Miskimins, 2009
Reservoir Management/Development

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Reorientation/Retreatment??

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!
Your Feedback is Important

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