What Have We Learned About Hydraulic Fracturing Shales After 15 Years Of Microseismic Imaging?

April 30, 2015

Microseismic Geomechanics: Increased understanding; reduced risk
Hydraulic Fracturing: Where Does It All Go?

Fracture Complexity & Natural Fractures

Natural Fractures
Hydraulic Fractures
Natural Fractures
Hydraulic Fractures
Barnett Shale Development

SPE 77440: 2000 First Barnett Microseismic Image

 Massive Water Fracs
 Horizontal Wells
 Microseismic

Year
1980 1990 2000
0 100 200 300 400
IP (MSCFPD)

Massive Water Fracs Horizontal Wells Microseismic

NNE
0 100 m
Reducing Carbon Emissions

U.S. dry natural gas production
tillion cubic feet

History 2011 Projections


Step on the gas
US electricity generation mix, %

Coal Oil Gas

Nuclear Renewable

U.S. Energy-Related CO2 Emissions
1992 to 2012

Metric Tons (Millions)

Source: Dept. of Energy Carpe Diem Blog

Source: EIA
Microseismic Hydraulic Fracture Applications

Optimize Stimulation Design
- height growth
- injection rate and volume
- fluid type, additives, and diverters
- proppant placement

Validate Completion Design
- completion types and designs
- stage isolation
- stage sequencing
- refracturing

Refine Well Plan
- well orientation
- landing point
- well integrity

Improve Reservoir Management
- well spacing
- well placement
- induced seismicity and fault activation
- reservoir characterization
- production optimization

✓ Fracture direction
✓ Height
✓ Length
✓ Complexity
Project Design for Value

Eng Obj Landing Point

Cross section

Accurate Processing

Target Up

Cross section

Cross section
Project Design for Value

- Accurate Processing

Stages 1-2
120 bpm

Stages 3 – 9
Avg. Rate: 80-120 bpm
Evolution of Monitoring Geometries

How do you decide which option?

SPE159670
Acquisition Footprint

Downhole Array

Shallow Grid
1. Depth Containment
Environmental Concerns

Cartoon:

1. We're going to start fracking under our biggest competitor's headquarters.
2. My plan is to pollute their water and generate earthquakes to destroy their campus.
3. The project code name is "fracking awesome."
Aquifer Protection

1. Spills
2. Well
3. Frac

IEA
Fracture Height Growth
Induced Seismicity

No damage and rare
(several sites and about 70 felt events from 3,000,000 fracs)
Shale Lessons: Heterogeneity

1. Depth Containment
2. Fracture Variability
Geomechanical “Sweet Spots”

Improved well placement using integrated reservoir characterization and microseismic
Shale Lessons: Complexity

1. Depth Containment
2. Fracture Variability
3. Fracture Complexity

SPE77440

Sayers 2010
1. Depth Containment
2. Fracture Variability
3. Fracture Complexity
4. Stimulated Reservoir Volume
Reservoir Drainage

Production Forecast 20 Years

- Un-propped conductivity = 1 md-ft
- Un-propped conductivity = 0.03 md-ft
- 1.5 BCF, 90% increase
- 0.7 BCF, 40% decrease
- Gas Production Volume (Bcf/ft)

Pressure (psi)
Conclusions

Geomechanical interpretation tools key to realize the full value from microseismic

• Microseismic demonstrated complex fracture networks
• Microseismic volume oversimplification
• Microseismic calibration of complex geomechanical fracture model
  ➢ Enables reservoir simulation of well performance
  ➢ Estimates drainage for well spacing