Abstract

The mining of unconventional oil and gas resources has been driven by “cookie-cutter” methods of drilling and completion to deliver thousands of lowest-cost wells. Development goals have focused on change that delivers value: produce more gas/liquids per well NOW, reduce the cost per well and reduce the environmental/operational footprint. In spite of a decade of spectacular success, we have begun to realize that we need to adjust our methods to allow changes and tradeoffs between spending and performance, and between short-term and long-term based decisions. Most shale play capital-intensive investment decisions are made on short-term data but some of these early decisions, which may obviate later efforts to extend the life of the field, can significantly reduce future returns.

Although standardized, geometric placement of wells and hydraulic-fracturing treatments may cost less than custom designs in the short-term, we argue that an increase in upfront investment in information to better optimize well placement as well as the number, location and size of frac stages will pay off in increased long-term productivity. For example, an understanding of why specific fracturing stages are more effective could lead to frac methods that use less material, cost less, produce more and reduce the treatment footprint. We present a simplified workflow and examples that illustrate the use of multi-disciplinary data: surface seismic inversion, microseismic monitoring and advanced image logging in a geomechanical context to support custom-design drilling and hydraulic fracturing treatments.
3D + Log Image Data + Microseismic for Unconventional Targeted Drilling & Treatment

Mark Houston

VSFusion
a Baker Hughes – CGG joint venture company
Monterey Shale
Motivation

• Covers Substantial Area
  – From San Francisco
  – To Los Angeles

• Highly Fractured and Faulted

• Development & Workflow Unique to Monterey Formation
Agenda

• Factory Drilling, Completion & Treatment (DCT)

• Advantages of Targeted DCT

• Workflow for Targeted Drilling
  – Advanced logging for petrophysical properties & TOC
  – Imaging for natural fractures
  – Microseismic monitoring for stimulation control / evaluation
  – Calibration of 3D seismic inversion for rock properties

• Targeted DCT ➔ Increased EUR/$
Workflow for Factory Drilling

Silo Activities

- Geologic Mapping
  - Source Rock
  - TOC
  - Thermal Maturity

- Seismic Mapping
  - Hazard Assessment

- Petrophysics
  - Vertical wells

- Drilling & Completion

- Stimulation

- Production
Workflow for Factory Drilling
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Workflow for Factory Drilling

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MONTHLY DRY SHALE GAS PRODUCTION

BILLION CUBIC FEET PER DAY

Source: Lippman Consulting, Inc. Gross withdrawal estimates are as of February 2012 and converted to dry production estimates with EIA-calculated average.
Workflow for Factory Drilling
Maximize Short-Term Cash Flow – Drive Cost

1. Lease
2. Drill
3. Frac’
4. Production

- 3D Seismic?
  - Geoscience
  - Microseismic

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Microseismic for Risk & Stimulation Assessment

Silo Strategy

- **Spatial Maps**
  - Induced fractures
  - Faults

- **Temporal Maps**
  - Stress (fluid) diffusivity
  - Differential rock behavior
  - Validation of stimulation
But ... All Wells and Stages Are NOT the Same

Production Is Variable, Why??

Comparison of microseismicity to stage-by-stage PLT logged rates

Rates measured by PLT 5 months later

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Targeted Drilling, Completion & Treatment
Understand Well Production Variability – Manage to Lifetime Return

- Acquire High-Def 3D
- Run Early Geoscience
  - Adv logs
  - Petrophysics
- Monitor Stimulation Behavior
- Calibrate Seismic Inversion
- Measure Production Performance
- Predictions of Behavior in Next Wells
Geoscience to Optimize Completions & Treatments

• Measure Petrophysical and Rock Properties along Well
  – Mud Logging
  – Kinetix (Pump-down)
  – Flex, RMD (Wireline / Coiled tubing)

• Image Natural Fractures along Well
  – StarTrack (LWD)

• Design Completions & Stimulations

• Monitor & Assess Frac’ Program
Mud Logging
Petrophysical Measurements

• Recover Samples from Drilling Mud

• Petrophysical Analyses for Rock Properties

• Fluids & TOC Measurements
Kinetix – Fast Tool for Rock Properties
Measure Brittleness, Silica, Sand, Carbonate, Shale while Drilling

GR1
- Fast neutron activation of Silicon emits gamma rays
- Acquired at 10, 15, or 20 ft/min

XLS
- Silicon count rate is an indicator of brittleness

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Use Logs for Custom Completion Design

Design Completions & Treatments

Recommended divisions for frac stages

- TOC indicator
- Porosity index
- Brittleness Index
- Mineralogy
- Gamma Ray
- Well profile

Quartz
Carbonate
Clay

More ductile (more green)
More brittle (more red)

TOC (black)

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StarTrak LWD Imaging Tool for Wellbore Fractures
Measure Natural Fractures

High resolution imaging applications

- Structural analysis
- Sedimentary analysis
- Geosteering
- Geomechanical analysis
- Production information
Completions Recommendations
Design Completions & Treatments

- Aggressive tie-in
- Higher PPG

- Isolate fault

- Move sleeve towards lower packer
- Tail in with higher ppg sand
- Walk away?

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Microseismic Can Show Rock Failure Modes

- Dots show all located events. Color code indicates Frac ' Stage.
- Beach balls show focal mechanism calculated from seismic waveform.

Focal mechanisms show style of fracturing.

Narrow microseismic zones - Wider zones at toe associated with higher net pressure.
Frac direction N46°E
Compare Response with Stimulation Design
RT Microseismic & Frac’ Visualization Movie
Workflow for Targeted Drilling
Integrated Strategy – Leverage 3D Seismic

- Lease
- Drill
- Frac'
- Production

3D Seismic
- Petrophysics
- Geoscience
- Geomechanics
- Microseismic

Seismic Inversion

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3D Seismic to Extrapolate Rock Properties

Seismic Inversion

- Prestack inversion for porosity and lithology prediction, Poisson’s ratio, $V_p/V_s$
- Infer and map fractures from thickness and curvature attributes
- Measure horizontal anisotropy from multi-azimuth surveys
- Integrate velocity analysis with well logs for 3D pore pressure model

Courtesy R. Mayer, Hampson-Russell
Probable Zones of Better Hydraulic Fractures
Seismic Inversion

Map showing zones highlighted in seismic attribute crossplot. Green is where fracture swarms will form, red is where the rocks are more ductile and yellow is where aligned fractures will occur. Note that only about ¼ of this reservoir is optimal for hydraulic fracturing.

Courtesy R. Mayer, Hampson-Russell
Resource development requires reservoir volumetric description – 3D rock properties
Tie Production To Seismic?
Validate

Comparing microseismicity and natural fractures to stage-by-stage PLT logged rates

Rates measured by PLT 5 months later
Shale Gas Requires Multi-Disciplinary Approach

Summary

• Successful development requires a multi-disciplinary approach
  – Geomechanics
  – Geochemistry and petrophysics
  – Rock properties
  – Seismology
  – Reservoir, well, and stimulation modeling

• Data required include
  – Image logs
  – Acoustic and geochemical logs
  – Seismic data (perhaps time-lapse)
  – Advanced microseismic data collection
  – Careful pre-test calibration and monitoring using advanced microseismic collection and analysis, tied to flow and pressure data
Targeted Drilling, Completion & Treatment

3D Seismic + Advanced Logging Data + Microseismic Data

⇒ Increased EUR/$
Thank You.

The Earth speaks ..... We listen