Advanced Fracture Diagnostics
Unconventional Reservoirs
Faster Feedback and Decision Capability

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Unconventional Reservoirs Have Changed Our Industry in Many Ways
Some Good / Some Challenges Still Exist

**Good**

- Horizontal drilling combined with hydraulic fracturing have made it possible to achieve economic success in very low quality reservoir rock
- Improved operational efficiency in both drilling and completion had enabled many unconventional assets to be economically successful at today’s prices for oil and gas

**Challenges**

- Sustaining production requires continuous drilling due to high decline rates
- The need for speed is driving the industry to a well factory approach assuming continuous, consistent quality reservoirs where all wells can be treated the same
- Acceptable well performance today is based on an average that has been significantly lowered due to a host of reservoir assumptions to facilitate operational efficiency
Is Acceptable Good Enough?

- Example in the Barnett transitioning from gas to liquids rich
- Assumptions supported by Barnett gas led to initially targeting a TOC rich portion of the reservoir
- Early field results
  - Inconsistent well performance
  - Generally poor production results
- Changing the landing point by 50 ft. based on modeling (3 months)
  - Consistent performance
    - Elimination of bad wells transformed the economics of this area
  - All new wells better than initial best well

URTeC: 1920572
We Can Rationalize our Actions
What about our Inaction?

What has limited diagnostics data collection
- Too costly to collect data
- Too much time required to interpret results
- Never seem to use the results
- We are satisfied with our current drilling and completion performance
- We are driven to minimize cost and efficiency, not add cost and slow things down

What has recently changed
- Data and information can be acquired at a much lower cost
- Data acquisition, interpretation and information is being delivered much faster, approaching real time
- Meaningful changes can be made to improve well performance
Rock Characterization Impacts Fracture Modeling & Production

Three key categories of the reservoir:

1. **Rock Characterization:**
   - Variations in mineralogy
   - Diagenesis
   - Pore throat size/geometry

2. **Geomechanics of the area**
   - Stress regime & tensile strength of the rock
   - Pore pressure

3. **Fluid flow properties:**
   - PVT properties of reservoir fluids
   - Effective permeability
     - Initial Permeability
     - Permeability as a function of pore pressure
   - Role of natural fractures
Surface Data Logging Can be a Very Effective Tool For Well Placement
Using Vertical Well Control and Lateral SDL and Bit Data Can Enable Advanced Solutions for Well Placement and Completion Optimization
Microseismic, Tiltmeter, and Fiber-Optic Technology

- **Perforation strategy**
  - Limited entry vs. non limited entry
  - Number of perforations per cluster
  - Perforation cluster spacing
  - Number of perforation clusters per stage
  - Stage length

- **Treatment schedule**
  - Injection rate
  - Proppant schedule
  - Fluid design/quality

- **Diverter Effectiveness**
  - Pumping schedule for diverter
  - Quantity of diverter
  - Effectiveness of diverter
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SPE 195524: Insight into Hydraulic Fracture Geometries Using Fracture Modeling Honoring Field Data Measurements and Post-Fracture Production

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DTS for Production Analysis as a Function of Time

- Evaluate production along the entire wellbore
- Be certain the results being evaluated are during steady state flow
- Compare directly to fracture initiation results
Calibrated Fracture Modeling
Calibrated Fracture Modeling
Calibrated Fracture Modeling
Frac Model Calibration (using composite data)

Before Calibration

After Calibration

3D image of different frac stages
Complex Fracture Model (CFM)
Fracture Model Sensitivity Analysis
Observations

- Understanding well performance and variability in unconventional assets requires the integration of multiple disciplines
- This is enabled by in-depth subsurface understanding and sufficient modeling to understand cause and effect behaviors
- Fracture diagnostic technology has progressed significantly
  - Fracture diagnostic solutions that used to require days, weeks or months to interpret can now be captured, interpreted and displayed in real time
  - With proper diagnostics and design of experiment, solutions that used to require months can now be captured on a single well
  - Lessons Learned can be captured and adopted in minutes, not months

- **Visualization and modeling technologies now need to keep pace to erase barriers**
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