“Currently, the hottest play going in unconventional gas is the pursuit of shale gas reservoirs.”*

*Oil and Gas Investor*
The Northeast - Birthplace of U.S. Oil & Gas

- First natural gas well - William Hart - 27’ deep
  - 1821 - Fredonia, New York
- First oil well - E. L. Drake
  - 1859 - Titusville, Pennsylvania
- 1000’s years of experience had anticipated the event
- Problems
  - Accessing it in quantity
  - Storage and transport

The solution was technology
What do these have in common?

EARLY GAS PIPELINES
Meeting the Challenges of the Marcellus Shale Through Technology

Dan Gualtieri
Technology Manager Houston Business Development (Land) and South Texas Business Development Manager Halliburton Consulting and Project Management Services
Decades of ShaleLog® Application

- **1980**: Barnett Discovery

**Steps**
- Quantify
- Construct
- Complete
- Analyze

**Graphs and Charts**
- Gas Rate Sim
- Gas Rate
- Oil Rate
- Oil Rate Sim
The Marcellus Shale

Today's Emerging Opportunity in the Northeast

Marcellus at a glance

Location: Pennsylvania, New York, Ohio, West Virginia

Size: 34 Million Acres

Drilled: 1821 / 2003

Gas in Place: 150 to 500 Tcf

Depth: 4000 to 8000 ft TVD

Pressure: 1500 to 5000 psi

Temperature: 100 to 150º F

Thickness: 50 to 250 ft

Frac Gradient: 0.9 to 1.1 psi/ft
Marcellus Well Economics

Marcellus Type Well (REXX)

Marcellus Well IRR (CXG)

<table>
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<tr>
<th>Natural Gas Price</th>
<th>$3.50</th>
<th>$3.75</th>
<th>$4.00</th>
<th>$4.25</th>
<th>$4.50</th>
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<tbody>
<tr>
<td>$3.50</td>
<td>10%</td>
<td>13%</td>
<td>10%</td>
<td>7%</td>
<td>4%</td>
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<tr>
<td>$4.00</td>
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<td>22%</td>
<td>19%</td>
<td>16%</td>
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<tr>
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<tr>
<td>$7.00</td>
<td>94%</td>
<td>84%</td>
<td>76%</td>
<td>69%</td>
<td>62%</td>
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</tbody>
</table>

At $3.50 gas, Marcellus wells achieve 16% IRRs at current well costs ($3.5 million).
The Marcellus: Major Challenges

- Reservoir understanding
- Drilling and completion effectiveness and efficiencies
- Water and environmental regulations
- Infrastructure development

How is Halliburton applying technology to meet these challenges?
Reservoir Understanding - Formation Evaluation

- Triple Combo: Neutron, Gamma, Resistivity, Density
  - Measure of rock type
  - Clay Content
  - Formation Density
  - Formation Porosity
- ShaleLog® analysis
  - Detailed shale types
  - Clay content
  - Total organic Carbon
  - Thermal maturity
  - Formation Brittleness
- GEM™ - elemental analysis
  - Rock mineralogy without cores
- LaserStrat® Chemostratigraphy Service
  - Chemostratigraphy on well cuttings
  - wellbore steering
  - Fundamental Rock mineralogy Assessment

It's a Roadmap!

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OPTI CEM™ Cement Job Modeling

- Optimized pump rates for mud displacement and erodibility
- Pressure limitations to prevent fracturing
- Volumetric calculations of all fluids
- Fluid positions at all points during job
- Centralization design and standoff calculations
- Gas migration potential
- Surface pressure calculations

Curve: main buildup area for cuttings
Horizontal wells efficiencies and to optimize completion performance.

- Mineral oil based drilling fluids
- Foamed and Acid Soluble Cement
- OH Swellpackers® & DeltaStim® Sleeves
- LaserStrat® Chemostratigraphy Service
- Pulsed Neutron and Neural Networks
- CobraMax® H Coiled Tubing Stimulation
Water and Environmental Regulations

- Environmentally-friendly additives
- Frac fluid chemical technology that allows re-use of flowback water
- Enviro-Floc™ drilling fluid dewatering
- Enviro-Fix™ solids stabilization
- CleanStream™ UV light bacteria control
- Water recycling options
Enviro-Fix™ solids stabilization

• Pozzolanic chemistry process
  – forms an inert, watertight, stable crystalline matrix

• Disposal Options
  – On location
  – Sanitary landfill
  – Road construction
CleanStream™ Trailer - UV Stimulation Fluid Treatment
Marcellus - Local Logistics, Concerns and Infrastructure

- Development in areas new to oil and gas activity causing concerns
- Logistics – remote locations, rugged terrain, access to materials and services
- Permitting slowed by required environmental assessments and water procurement/disposal limitations
- Pipeline infrastructure limited to deliver anticipated production
- Economic feasibility over long term with uncertain natural gas prices and new supply channels
Conventional Hydraulic Fracturing
Technical Command Center (Fracturing Control Center)
Marcellus Shale - This is Not South Texas
Environmental Impact - Lower Pump Rates, More Stages

Footprint Reduction Area
Footprint reduced by 40%
ShaleClean℠ Service Fracture and Formation Damage - AquaStim UC
Capillary Forces – Addressed with GasPerm 1000

- Microemulsion additive
- Concentration 2 gal / 1000 gal
- Reduce capillary end effects
- Aids removal of injected water

- 221% longer frac/ # prop
- 233% higher Net Present “Volume”
- 25% less damage to fracture length
- 25% higher max normalized gas rate
- 5% Lower stimulation treating pressures
Pinnacle Microseismic Monitoring

- Stimulation well generates microseismic events
- Geophones in monitor well identify and map precise location of events
Microseismic Monitoring
Pipeline Leakage Detection

Zone: K3/DL
Temp: -15°C
Distance: 4774m
StimWatch® Stimulation Monitoring system using Distributed Temperature Systems (DTS)

Surface Acquisition System

Swellpacker® Cable system

Delta Stim® sleeve featuring DTS bypass

DTS fiber optic system
StimWatch® Injection Profiling and Production Monitoring

Identified fluid entry points.

Observed steam anomaly.

Allocated flow rates.

V = 5.8 ft/s ~ 6.4 bpm

V = 2.5 ft/s ~ 2.8 bpm

V = 0.8 ft/s ~ 0.9 bpm

V = 0.16 ft/s ~ 0.2 bpm

Rate (stb/d)

Temperature (F)

Depth (ft)
Reservoir Evaluation

Pressure Distribution

- Actual
- Model

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Reservoir Drainage Modeling to optimize field development

Staggering spacing can increase recovery over 20% and avoid well interference
Questions