Northwestern University Technological Institute

Tight Shale Gas-Hydraulic Fracturing Seminar Series

Where are we Today: Reservoir and Completion Quality

Is Tight Shale Gas and Oil the Answer?

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April 30, 2013
What is the Question?

- How to provide Energy to the World

- This is a complicated question, with different interests involved and with different economic and environmental impacts

- Tight Shale Gas and Oil is at least part of the answer and maybe a large part

![World Energy Chart]

- 34% Coal
- 21% Natural gas
- 11% Oil
- 6.4% Nuclear power
- 2.2% Hydroelectricity
- 0.4% Biomass and refuse
- Other renewable sources
Energy Futures Meeting
Washington DC / Crystal City Hyatt

Monday (June 18)
1:00 pm  Andrew May – Welcome / Introductions / Expectations
        Introduction of Andrew Marshall [if his schedule allows]

Oil & Gas Availability Session -- Sid Green
1:30  Worldwide Shale Gas & Oil -- Kyel Hodenfield
2:15  Shale Oil and Liquids -- Trisha Curtis
3:00  Break
3:15  Massive Formations but Sparse Sweetspots -- Bill Maloney
4:00  Comments on Oil & Gas For the Future -- Daniel Yergin
4:45  Discussion -- All
5:30  Adjourn

6:30  Working Dinner--Jaleo (private room)

Tuesday (June 19)
7:30 to 8:00 am  Breakfast
8:00  Summary of First Session -- David Work

Changes in Last ~Three Years

1. Deep Horizon Oil Spill
2. Japan Earthquake
3. Arab Spring
4. Shale Gas Production from Hero-to-
   Somewhat of a Villain
5. Tight Shale Liquids Production
6. Acceptance that North America is heading
   toward oil/gas supply independence
Changes in the Last Year

- Investments have changed from dry gas developments to liquids producing shales developments
- Drilling has changed from drilling to hold leases to drilling for production
- Development has changed from E&P Companies to include the ‘Majors’
- The technology advancement forefront has changed from understanding gas in place to how to recover the gas; .......... and, very importantly, to Environmental Considerations
Production Costs

Lifting costs ($ / Barrel)

- Best Reservoirs in Persian Gulf “easy oil” ----- $10
- Shallow Offshore -------------- $20
- Deep Water ------------------ $30
- Tight Shales ---------------- $50
- Ultra Deep Water -------------- $60
- Oil Sands --------------------- $60
Complex Formations

10 feet

10 microns

10 inches
The Big Invention
<table>
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<tr>
<th>Basin Activity in US</th>
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<tr>
<td>Delaware Basin (Oil)</td>
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<td>Utica - Eastern Ohio (Oil-Gas)</td>
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<tr>
<td>Alberta Bakken (Oil)</td>
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<td>Niobrara (Oil)</td>
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<td>Eagle Ford (Oil-Gas)</td>
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<td>Bakken (Oil)</td>
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<td>Marcellus (Gas)</td>
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<td>Mississippian Lime (Oil)</td>
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<td>Tuscaloosa (Oil-Wet Gas)</td>
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<td>Collingwood (Gas)</td>
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<td>Mowry (Gas)</td>
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<td>Granite Wash (Oil-Gas)</td>
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<td>Monterey (Oil-Gas)</td>
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<td>Brown Dense (Oil-Gas)</td>
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<td>Mancos (Gas)</td>
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<td>Duverney (Oil-Gas)</td>
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Producing Gas / Oil From Shales

Shales, shales everywhere and oh how hard they are to produce!

Reservoir Quality ("RQ")
- porosity, permeability, saturation, TOC, maturation, pore pressure, vertical and horizontal extent
- "gas and/or oil in place"

Completion Quality ("CQ")
- fracture complexity, fracture containment, fracture conductivity, fracture connection, rock-fluid interaction, insitu stresses, rock fabric orientation
- "ability to get the gas or liquids out"

Economic production requires adequate RQ and adequate CQ
Environmental Performance is Required

“Open FRAC”
Fully disclosed fracturing fluids that fully comply with Environmental Standards
Summary

I have covered a lot ----- What I believe is:

• The US is headed toward energy supply independence

• The recovery of gas/oil from shales has changed the world, and in a way that not all agree with

• It took an invention to do this, and this invention came from industry

• Current technology does not give a sustainable process, but it is quite logical to expect very large improvements in efficiency

We are just beginning -------
Questions