What is so unconventional about unconventional oil and gas resources?

Mark E. Willis

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- Christine Erlig-Economides from University of Houston
Outline

- Oil price drop?!—what does that mean?
- What is the difference between resource types?
- Conventional resources
- Unconventional resources
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Oil Prices

Some 2 year windows

http://www.tradingeconomics.com/commodity/crude-oil

World Oil Consumption (1966-2014)

Rest of world oil demand

Major developed market oil demand

Source: Young Research and Macrobond Financial

http://www.youngresearch.com/authors/jeremyjones/global-imperative/

Crude oil + condensate + natural gas liquids

Increase of > 4 million barrels per day

United States (US) Field Production of Crude Oil (Thousands of Barrels per Day)

- Alaska Prudhoe Bay
- Horizontal wells + hydraulic fracturing
- 3D seismic
- Deepwater and ultradeep water
- Shale oil
A Personal Historical Perspective

“Early” times (to 1970’s)
- Oil companies – innovate, build, deploy, support, search, drill
- Academia – builders of foundation

“Middle” times (1970’s to 2000)
- Rise of service companies – tools, services, products
- Oil companies – divest technology, become consumers, interpreters
- Academia – consortia focusing on basic opportunities

“Current” times (since 2000)
- Oil companies – consumers, integrators, investors, partners, automation, data mining
- Independents – rapid uptake, quick moving, low costs
- Service companies – innovate, acquire, implement, streamline
- Academia – sparks of innovation, truth seekers/verification, consultants, international influence, interdisciplinary teamwork, targeted R&D
Likely Effect of Current Oil Price Drop

- Emphasis on short-term cash flow
  - Improving production in existing wells
  - Eliminating low return efforts
  - Market consolidation/redistribution

- Slow down of drilling new wells

- Stop and examine doing a better job
  - Opportunity for innovation
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Comparing Resource Types

Some common Viscosity values

<table>
<thead>
<tr>
<th>Resource</th>
<th>Viscosity (cp)</th>
<th>API</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>5000 - 1 mm</td>
<td>4-10</td>
</tr>
<tr>
<td>Heavy oil</td>
<td>100 - 5000</td>
<td>10-20</td>
</tr>
<tr>
<td>Black oil</td>
<td>2 - 100</td>
<td>20-45</td>
</tr>
<tr>
<td>Volatile oil</td>
<td>0.25 - 2</td>
<td>30-55</td>
</tr>
<tr>
<td>Natural gas</td>
<td>&lt; 0.25</td>
<td></td>
</tr>
</tbody>
</table>

Cander. H., 2012, What are unconventional resources, Search and Discovery #80217
Comparing Resource Types

- **Past**: Conventional Reservoirs, Small volumes, Easy to develop
- **Present**: Unconventional Reservoirs, Large volumes, Difficult to develop
- **Future**: Gas Hydrate, Oil Shale

Dong, Z, et al., 2011, Global unconventional gas resource assessment, SPE 148365, Canadian Unconventional Resources Conference

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World Unconventional Gas

http://pacwestcp.com/

C. Ehlig-Economides, 2015, Has unconventional become conventional, SPE Luncheon, Houston TX
Outline

Oil price drop?!—what does that mean?

What is the difference between resource types?

Conventional resources

Unconventional resources
Conventional Reservoirs

- Explore, find, drill
  - Structural or stratigraphic trap via seismic data
  - Permeability > 0.1 md
  - Oil and gas are produced in shales and migrate to the reservoir

- Produces by
  - Natural reservoir pressure
  - Pumps, artificial lift

- Once pressure drops production is enhanced by:
  - Water or gas injection.
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Unconventionals

- Coalbed methane
- Gas hydrates
- Heavy oil/tar sands
- Tight gas
- Shale oil and shale gas

Unconventionals

- Coal bed methane
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http://gtresearchnews.gatech.edu/reshor/rh-ss02/e-gas.html
Unconventionals

- Coal bed methane
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http://www.theguardian.com/environment/2012/feb/23/eu-tar-sands-vote
Unconventional (Shale) Reservoirs

- Located on a regional basis
  - Large area
  - Extremely low permeability < 0.1 md
  - Oil and gas are produced in shales and they are the reservoir
- Produced by
  - Hydraulic fracturing
  - Area is “mined” by drilling many horizontal wells
- Production is typically only for a few years
  - Optimal placement of wells critical
  - Refracturing is option for increasing production

World Unconventional Shale Gas

Outcrop of the Eagle Ford in South Texas
Close-up Showing Heterogeneity of the Formation

Stephen Galiette
Production Decline Curves

Conventional

Shale Gas Wells

http://www.co2.no/default.asp?uid=175&CID=56
Hydraulic Fracturing – Plug & Perf (or Sliding Sleeve)

- Directional drill well
- Case
- Perforate a zone
- Pump fluids and sand
- Pack it off
- Repeat for next stage

Goal – create network
- Limit vertical extent
- Maximize lateral extent

Hydraulic Injection – Set Plug
Hydraulic Injection – Perf Gun
Hydraulic Injection - Fluid
Hydraulic Injection – Fluid + Proppant
Hydraulic Injection – Fluid + Proppant
Hydraulic Injection – Fluid + Proppant
Hydraulic Injection – Stop Pumping, Pressure Drop
Hydraulic Injection – Stop Pumping, Pressure Drop
Hydraulic Injection – Stop Pumping, Pressure Drop
Hydraulic Injection – Produce Back
Hydraulic Injection – Produce Back
Hydraulic Injection – Produce Back
Hydraulic Injection – Produce back
Hydraulic Injection – Pressure Dropping
Hydraulic Injection – Pressure dropping
Hydraulic Injection – Frac is Propped Open
Monitoring Fracture Progress With Flow Noise

- Distributed acoustic sensing via fiber optics
- Continuous “microphone” in well bore
- Shows location of perfs and their flow

Priyesh Ranjan
Key Success Factors for Hydraulic Fracturing

- Prediction of fracture direction, length and height
  - Regional stress maps
  - Experience in area
  - Completion design

- Monitoring of fracture creation
  - Fluid volumes, proppant placed
  - Microseismic monitoring (borehole and surface)
  - Tilt monitoring
  - Flow noise (via fiber optics)

- Evaluation of fracture performance
  - Production logs
  - Tracer measurements
  - Flow noise
Microseismic Monitoring of Hydraulic Fracturing

- Geophones in a monitor well(s)
- Listen during each frac stage
- Locate the events
- Modify program to ensure you don’t frac out of zone

Microseismic monitoring is a valuable tool for optimizing

- Well layout (trajectory)
- Well spacing
- Stage lengths
- Perf clusters and/or valves & packers
- Stimulation design
- Fracture height and length
- Complexity
- SRV

N. Warpinski
Natural and Induced Aligned Fractures

Geophysical effects
- Directional velocity variation
- Shear wave splitting
- Attenuation
- Diffractions

Geophysical measurements
- Surface seismic
- VSP
- Well logs
- Cores

Scale Modeling of Fractures


FIG. 1. Photograph of the laboratory sample and zoom around the disk-shaped fracture, with ruler units in cm. The sample is cut in half longitudinally to display the fracture without optical deformation by the curvature of the sample. The diameter of the fracture is ~7 mm, and the diameter of the cylinder is 50.8 mm.
Scale Modeling of Fractures

Physical modeling of anisotropic domains: Ultrasonic imaging of laser-etched fractures in glass
Robert R. Stewart* (University of Houston), Nikolay Dyaur (University of Houston), Bode Omoboya (University of Houston), J. J. S. de Figueiredo (Unicamp-Brazil and University of Houston), Mark Willis (ConocoPhillips, Houston), and Samik Sil (ConocoPhillips, Houston)
Vertical Seismic Profiles (VSP)

Surface seismic

In time

VSP

Time and depth

Logs

In depth
Interferometric Imaging of Salt Flanks With VSP data

Diffractions From Hydraulic Fracturing

Diffractions Off Fractures

M.E. Willis, 2014, Estimating frac fluid pathways from rapid time-lapse VSP and microseismic events, SEG Annual Meeting.

Shear-shear scattered travel times off of fracture
Some Innovation Opportunities – Thesis Topics!

Characterization of unconventional reservoir rocks

- Lab measurements of shales, tight gas, oil sands, heavy oils
- Numerical modeling of fractured systems

Determination of reservoir physical properties (before and after stimulation)

- Advanced time lapse analyses

Locating sweet spots

- How to measure and quantify lateral changes

Real-time monitoring of fracturing

- Integrated fiber optic DAS monitoring of flow and seismic properties
- Better microseismic monitoring methods

Determination of propped area (stimulated reservoir volume)

- How to detect proppant, how to dope the proppant
- What measurements reveal the stimulated volume

Prediction of missed pay

- How to locate unfractured and unpropped areas

How to reduce costs while getting better reservoir properties

- How can we streamline our processes
Summary

Conventional resources
- Small size
- Structural or stratigraphic
- High permeability and low viscosity
- Easy to produce

Unconventional resources
- Expansive
- Locked resource
- Low permeability and viscosity
- Requires technology and money to produce
Questions