Second White Specks Formation

New concepts for understanding fractured reservoirs.

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AAPG Playmakers’ Forum
Life Cycle of a Resource Play

**Definition Mode**
- Early Entrant
- Low Land Cost
- Innovator

**De-Risk Mode**
- Competitive
- High Land Cost
- Implement Technology

**Manufacture Mode**
- Entry through Corporate Acquisition
- Low Cost Operator
- Continuous Improvement

### Development Stage
- **Un-named Horizons**
- 2011
- 2012
- Second White Specks Play
- 2013
- Alberta Bakken Play
- 2014
- "?
- Montney
- Duvernay
- Cardium

### Understanding Procedure
The Production of Hydrocarbons from Fine Grained Rock

A fundamental change in theory and practice

• Technical Challenges:
  – How do I know that my company is current with technology?
  – How do I know if my contractor is current?
  – Who is doing the latest research and are they a benefit to me or will they slow me down?

• Social Challenges:
  – What is a social license?
  – Is there a new regulatory system (Frac Procedures)?
Commodity Prices vs. Time

North American tight oil production (January 2005-February 2014)

Monthly dry shale gas production

Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through November 2014 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).
Weekly natural gas rig count and average spot Henry Hub

active rigs

vertical
horizontal
directional
average Henry Hub spot price

$ per MMBtu

$15
$12
$9
$6
$3
$0

Jan-07 Jul-07 Jan-08 Jul-08 Jan-09 Jul-09 Jan-10 Jul-10 Jan-11 Jul-11 Jan-12 Jul-12 Jan-13 Jul-13 Jan-14 Jul-14

Source: Baker Hughes
United States Sources of Carbon Dioxide

- **Transportation**: 34.3%
- **Electric Power**: 38.4%
- **Industrial**: 17.8%
- **Commercial**: 3.9%
- **Residential**: 5.6%
- **Coal**: 28.7% (75%)
- **Natural Gas**: 9.4%
- **Petroleum**: 0.4%
## The new technical order

<table>
<thead>
<tr>
<th>Conventional Reservoirs</th>
<th>Unconventional Reservoirs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Porosity dictates reserves</td>
<td>1. Porosity is poorly defined</td>
</tr>
<tr>
<td>2. Reserves define NAV</td>
<td>2. Cash Flow define NPV</td>
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<tr>
<td>3. Highly competitive</td>
<td>3. Collaborative amongst the companies</td>
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<tr>
<td>4. Defined expl./dev. cycle</td>
<td>4. Expl. is not defined</td>
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<tr>
<td>5. Small land position req’d.</td>
<td>5. Large land base req’d.</td>
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<tr>
<td>6. Defined roles for staff</td>
<td>6. Integrated team</td>
</tr>
<tr>
<td>7. Dislocation to surface issues</td>
<td>7. Surface issues are germane</td>
</tr>
<tr>
<td>8. Efficient drilling requires understanding</td>
<td>8. Efficient drilling requires procedure</td>
</tr>
</tbody>
</table>
The Fundamental Question:

*How do fluids move through the crust?*

- Requires a pathway
- Requires increased Fluid Pressure

**Nano-permeability vs. Fracture systems**

Buoyancy Forces are equal to the density contrast between the generated hydrocarbons and formation water. Generally these are not strong enough to overcome the frictional forces resisting flow (pore entry pressures).
Cardium Horizontal Well Results (2012) Garrington

- ~120 wells
- 88 wells with reported deviation surveys
- 8 wells missed Cardium sandstone by more than 5 metres
Production Data

Cumulative Production (bbls)

Rate (bbl/d)

Garrington HZ Wells Cardium

250 bopd

10% of wells greater

90% of wells lower

50 bopd

90% of wells greater

10% of wells lower

Cumul. P_{10}
Cumul. P_{90}
Rate P_{10}
Rate P_{90}
Averaged decline curve

Explanation:
• All horizontal wells in the Cardium from the Garrington Area
• IP(30), IP(90), IP(180), IP(360), IP(540), IP(1080)
• Back Calculate the average rate
• Use Arithmetic Average
Garrington Horizontal Wells Targeted for Cardium

Wells within the Shale Cumulative Production

Wells within the Cardium Sandstone Cumulative Production

Wells within the Shale Dayrate

Wells within the Cardium Sandstone Dayrate
Linear Transport Laws

Ohms Law

\[ I = \frac{V}{R} \]

Darcy’s Law

\[ Q = \frac{-kA}{\mu} \frac{(P_b - P_a)}{L} \]
**Linear Transport Laws**

**Ohms Law**

\[ I = \frac{V}{R} \]

**Darcy’s Law**

\[ Q = \frac{-kA \left( P_b - P_a \right)}{\mu L} \]

Flow = \frac{Driving Force}{Friction}

\[ \text{Flow} \approx \frac{V}{R} \]
Producing Well

Shut-In

Shut-In

Producing Well

\[ P_3 > P_2 > P_1 \]

Friction to Flow*

\[ \vec{Q} = \frac{-k \cdot A \cdot (P_b - P_a)}{\mu \cdot L} \]

* System will not equilibrate to common water gradient due to friction
Radial Flow:
• Particle A will reach the well bore before particle B
• Pressure Front radiates from the well bore as a function of the radius of the well bore
• Drainage is along straight lines towards the well bore
**Flow in a Two Porosity (permeability) system**

Elliptical Flow:
- Particle A will reach the well bore before particle B
- Pressure Front radiates from the well bore as a function of the radius of the well bore and the difference in permeability between $k_{h_{\text{max}}}$ and $k_{h_{\text{min}}}$
- Drainage is along lines perpendicular to the pressure front creating smooth curve drainage trajectory to the well bore
Fracture Flow:
- Particle B will reach the well bore before particle A
- Pressure Front radiates from the fractures and is a complex relationship between the matrix permeability and the fracture permeability
- Drainage is along tortuous paths in the reservoir and distance is difficult to determine
- A well not connected to fractures likely will not have flow
How does a Shale Reservoir work?
Fractured Reservoir Model

Hydrocarbon generation and micro-fracture development
Second White Specks – Highwood River
Fractured Reservoir Model

Continued hydrocarbon generation and fluid migration
Second White Specks (Upper Cretaceous)
Fractured Reservoir Model

Continued hydrocarbon generation and fluid migration
Vertical migration into meso-fractures
Fractured Reservoir Model

Continued hydrocarbon generation and fluid migration
More Brittle Zones form macro-fractures
Fractured Reservoir Model

Horizontal well

Layer 4

Brittle Inorganic

Layer 3

Brittle/Ductile Inorganic

Layer 2

Organic Lean

Layer 1

Organic Rich
Fractured Reservoir Model

Create Pressure Sink
reduce pressure to P5

\[ Q = \frac{-kA}{\mu} \left( \frac{P_b - P_a}{L} \right) \]
Fractured Reservoir Model

Create Pressure Sink to reduce pressure to P5

Increase pressure differential between Layer 4 and Layer 3

\[ Q = \frac{-kA (P_b - P_a)}{\mu L} \]
Fractured Reservoir Model

Create Pressure Sink
reduce pressure to P5

Increase pressure differential
between Layer 4 and Layer 3

Pressure Sink Propagates
\[ \vec{Q} = \frac{-kA}{\mu} \frac{(P_b - P_a)}{L}. \]
Hydraulic Fracturing
(Well Bore Stimulation)
The Role of Proppant
Issues

1. Ground water protection
2. Water use
3. Airborne Emissions
4. Use of a variety of industrial chemicals
5. Industrial Impact
   - Site fluid storage and containment
   - Trucking
   - Noise
6. Induced Seismicity
Problems

• Pavillion, WY, 2010 – EPA detect drinking petroleum in drinking water (liability not determined)
• Leroy Twp, PN, 2011 – Operational failure led to surface spill
• Mamm Ck, CO, 2006-2011 – frac fluid migrated to ground water – faulty design
• Grande Prairie, AB, 2011 – frac fluid contamination of ground water – faulty operation
• Blackpool, UK, - earthquake linked to frac operation
• Horn River, BC – earthquake linked to Frac operation
Induced seismicity – Blackpool, UK

- Cuadrilla Resources conducts multistage hydraulic frac: April, 2011
- Induced a series of microseismic events with the largest at M=2.3
- UK Government responds to public complaint and puts Moratorium on hydraulic fracturing
- Moratorium lifted in 2014
- Lancashire has 40,000 signatures asking to reject Cuadrilla’s application to hydraulically fracture stimulate its well
- A motion to call a moratorium on “Fracking” was rejected in the House of Commons 308 votes to 52 votes
Situation in the United Kingdom
(a cautionary tale)
35% of all energy consumed in the UK is from Natural Gas
Demand for Affordable Energy
Advancing Technology
and the
Nature of Trial and Error

The Social Contract
And the Public’s
Level of Scientific Literacy
Cost of Mistakes