Technology Applications & Challenges Related To Unconventional Gas Development

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Canadian Division
Presentation Outline
Technology Applications & Challenges Related to Unconventional Gas Development

- Overview of Encana’s strategic focus
- Impact of technology on unconventional gas
- Resource Play Hub development
- Resource play methodology
- Applied reservoir characterization technologies
- Technology challenges and opportunities
Industry Leading Natural Gas Producer
Largest Natural Gas Producer in Canada
North America’s 3rd Largest Natural Gas Producer

- Striving to be North America’s most efficient and profitable developer of natural gas
  - Tremendous asset base
- Growing exposure to oil and natural gas liquids
- Ensuring sustainability in a lower price environment
  - Leveraging technology and expertise
- Technology leader
  - Resource Play Hub development model
  - Highly efficient, repeatable process, leveraging economies of scale
Encana’s Strengths
Portfolio of Land, Reserves & Production*

Land (MM net acres)
- Total land position: 10.9
- Fee land (advantaged royalty structure): 3.6

Reserves & Resources (Tcfe; 100% externally evaluated)
- Proved reserves (P1): 13.1 (262 MT LNG = 3.4 yrs of Japan’s imports)
- Economic contingent resource (C1): 25.4 (508 MT LNG = 6.6 yrs of Japan’s imports)

Production volumes
- **2012 Actual**
  - Natural Gas (Bcf/d): 3.0 (~29% of Japan’s daily consumption)
  - Liquids (Mbbls/d): 31
- **2013 Forecast**
  - Natural Gas (Bcf/d): 2.8 – 3.0
  - Liquids (Mbbls/d): 50 – 60

*Land & reserves as at December 31, 2012; reserves information is based on forecast prices and costs, after royalties, utilizing Canadian protocols; 2013 production forecast as at February 14, 2013.
Tremendous Asset Base
Leading North American Portfolio of Resource Plays

Biased to organic growth:
We have amassed large, concentrated, contiguous land positions in the core of many of North America’s best resource plays – at low entry costs.
Larger Reservoirs
More Difficult to Develop

Smaller Reservoirs
Easier to Develop

Hydrocarbon Resource Triangle
Increased Technology Requirements

- Tight Shales
- Tight Oil
- Coalbed Methane
- Lower Quality Shale Gas
- Undiscovered
- Gas Shales
- Liquid-Rich Shale Gas
- Emerging/Future Resources

- High Quality
- Medium Quality
- Low Quality

- 1000 md
- 100 md
- 1 md
- 0.1 md
- 0.001 md
- 0.00001 md

Increased Cost to Develop
Increased Technology Requirements
Canada’s Natural Gas Resource Base
Marketable Gas Resource has Grown Significantly and Rapidly

- **2000**: 390 TCF, 70 years of supply
- **2010**: 700-1300 TCF, 100+ years of supply

Main growth from unconventional gas

Made possible by the adaptation and evolution of two established technologies: horizontal drilling and hydraulic fracturing
What has Driven Resource Growth?
Advances in technology have unlocked resources

Horn River Well Example

• Over 6000m Total Measured Depth
• 25 – 30 frac intervals per well
• Multiple wells per surface pad
  – Reduces surface footprint
  – Enables manufacturing process

Shale formation
~150-180m thick

~2300m to 2600m Vertical Depth

~3000m to 3400m Horizontal Wellbore
Advancing Resource Play Hub Development
Track Record of Continuous Supply Cost Reductions

• Substantial cost reductions through resource play hub model
• Multi-well pad using fit-for-purpose rig
• Cost savings with minimal surface and environmental impact

Concentrated resource + Pad drilling + Repeatable process = Resource Play Hub
Resource Hub
Fracturing Operations

- Water Delivery
- Horse Power
- Multi-well fluid distribution
- Fluids
- Sand
- 8 well Simul-frac
- Coiled Tubing
- Simul-fracing
- Fracturing Operations
Montney Supply Cost Evolution
Advancing Resource Play Hub Design and Development

Montney Performance History

*Supply Cost is defined as the flat NYMEX price that yields a risked IRR of 9% and does not include land or G&A costs.
Resource Play Methodology

**SCREENING**
- Literature Search
  - Public
  - Internal
- Consortia Data
- Competitor Analysis
- Public Well/Prod Data
- Topography
- Surface Access
- Land Availability
- Infrastructure

**PLAY ASSESSMENT**
- Geological Model
- HC System
- Pressure/Temp Regime
- Aerial Extent
- X-Sections
- Isopach-Tops
- Petrophysical Analysis
  - Mud Logs
  - Porosity
  - Permeability
  - Sw
- Geomechanics
  - Poissons/Youngs
  - Stress Max/Min HZ
- Mineralogy
  - XRD
  - Thin Sections
  - MICP
- Geochem
  - Tmax/Ro
  - Kerogen Type
  - TOC
- Engineering
  - Type Curves
  - Economics

**RESOURCE EVALUATION**
- Play Maps
  - Play Boundary
  - Net Pay
  - Structure
  - Isopach
  - Pressure Gradient
  - Maturity
  - Sw
  - HC Filled Porosity
  - Value
  - Resistivity
  - TOC
  - OGIP/OOIP
  - RHOB
- Type Curves
- Par/Play Economics
- Recommendations
*Must make all maps to determine which ones will be the KEY PLAY DRIVERS for your prospect.*

**PLANNING / EXECUTION**
- Drilling & Completion Design
- Wellbore Placement Planning
- Water Source / Disposal
- Regulatory Issues
- Royalty / Tax Credits
- Restrictions
- Res Modelling / SRV
- Economics
- Type Curves
- Reserves
- Gathering & Processing Costs
- Correlate Attributes to Well Performance
- Recognize Deficiencies

Topics shown in red represent current technology challenges
Geoscience Flow Chart

Review of Geological Data
- Hydrocarbon seeps at surface, cuttings, cores
- Well logs, Mud logs, DST, Salinity Mapping
- Geochemistry / Maturity
- Drilling Issues in upheole zones
- Competitor Activity

Regional Geological
- Structure
- Depositional systems
- Hydrocarbon systems

Regional Geophysics
- Electrical / Magnetic / Gravity
- Seismic

Prospect
- Depositional Environments
- Seismic
- Resource Mapping OOIP/OGIP

Size of the Prize
- Exploration/Development Costs vs.
- Resource Size

Land Capture
- What can we afford to pay?
- Early entry saves $$$

Time
- Pilot
- Horizontal
- Pad Drilling
Key Elements of a Successful Unconventional Gas Play

- Organic Richness
- Maturation
- Gas-In-Place
- Permeability
- Pore Pressure
- Brittleness
- Mineralogy
- Thickness

Productivity
Importance of Geophysical Imaging
Investigating Improved Imaging Techniques

• **Defensive Use**
  – Mapping structures, identify pay & frac barriers
  – Large scale, spatial understanding
  – Mapping faults & understanding geologic setting
  – Horizontal well planning
  – Identifying drilling & completions hazards
  – Geosteering / drilling guidance
  – Long term development planning

• **Reservoir Characterization Use**
  – Thickness & reservoir quality mapping
  – Rock properties, stress estimates
  – Correlate production, post-frac data & seismic
  – Fracture / azimuth orientation
  – Optimization of future pad development
  – Subsurface mapping for frac water source
  – Up-hole potential identification/mapping
Importance of Microseismic Imaging

Investigating Improved Imaging Techniques

- Monitoring fracs early in development is a great benefit for future development (frac growth, azimuth, optimization, cost reduction…)
- Buried array microseismic pad provides valuable data for future completions and development
- Investigating JOGMEC “ACROSS” active seismic monitoring

Microseismic monitoring for unconventional plays

Example of microseismic monitoring on an ECA pad for assessing the effectiveness of completion attempts

Effective Stimulation

Ineffective Stimulation

Higher stress anisotropy
Narrow fracture “fairway”
Wing fracs

Lower stress anisotropy
Wide fracture “fairway”
Box fracs
Importance of Thermal Maturity
Temperature & Time = Level of Diagenesis of Organic Matter

Km of burial

Immature

Liquid Rich

Oil Window

Gas Window
Importance of Geochemistry

- Phase behavior tied to Maturity
- Phase Mapping
- GOR, Oil and Gas gravities tied to Maturity
- Porosity within Organics

Why is geochemistry important?

Sampling and analysis

Transformation ratio mapping

Phase mapping
**Play Assessment Parameters**

**Drill Cuttings Example**

- **Brittleness and Shale Typing**
  - Xray Diffraction

- **Geochemistry**
  - Maturation
  - Vitrinite reflectance profiles
  - Kerogen type
  - Total Organic Carbon

- **Gas Storage**
  - Porosity
  - Adsorption (isotherms)

- Develop correlations
- Combine with logs for calibration and insights
- Identify trends within the basin
Multi-Mineral Analysis Example
Investigating Improved Permeability & Fluid Saturation Measurement

Hydrocarbon
Water
Gas
Calcite
Barite
Kerogen
Pyrite
Quartz
Bound Water
Illite
ELAN_VOLU

Log and Core Input Measurements
Gas Saturation
Water Saturation
Effective Porosity
Mineral Volumes
XRD
Rock Eval TOC

Φ_gas
Sw
Φ_eff
Provides higher resolution images of reservoir pore system
Nanopores in bitumen

- 100% of pores are effective and communicative
- 4.5% effective porosity
- Matches petrophysical calculations
- Grain supported rock matrix
Future FIB/SEM Work: Sequential Imaging for 3D Reconstruction and Quantitative Analysis

Horn River examples from Curtis et al. (2012)

Example from Ambrose et al. (2010)

Future Montney work:
- 3D reconstructions showing distribution of bitumen and pores
- Quantify volumes of bitumen, pores
- Pore size analysis
Integrated Reservoir Characterization
Duvernay Resource Play Example

ATTRIBUTES:
- 100% organic porosity
- Grain supported matrix
- Near zero water saturation
- Massive liquids rich fairway
- Extreme overpressure
- Depth ≠ Maturity
- Fracable rock
## Technology Applications & Opportunities

<table>
<thead>
<tr>
<th>Objective</th>
<th>New Technology Initiatives</th>
<th>In Progress</th>
<th>Future Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Production</td>
<td>Permeability and fluid saturation determination</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Estimates</td>
<td>• Improved production performance predictions</td>
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<tr>
<td></td>
<td>Maturity and phase behaviour predictions and mapping</td>
<td>✓</td>
<td>✓</td>
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<td></td>
<td>• Improved prediction of reservoir fluids</td>
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<tr>
<td></td>
<td>Modelling induced hydraulic fractures</td>
<td></td>
<td>✓</td>
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<tr>
<td></td>
<td>• Improved production and reserve recovery predictions</td>
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<tr>
<td></td>
<td>Low production rate gas measurement (wellbores &amp; flow lines)</td>
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<td>✓</td>
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<tr>
<td></td>
<td>• Improved production performance measurement</td>
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<tr>
<td>Improved Development</td>
<td>Fracture height, azimuth &amp; stimulated reservoir volume imaging</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Planning</td>
<td>• Optimized well bore design, capital efficiency &amp; reserve recovery</td>
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<td></td>
<td>Inexpensive 3-D well planning shared earth software</td>
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<td>✓</td>
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<tr>
<td></td>
<td>• More efficient wellbore planning in complex reservoir settings</td>
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Drilling and Completions Technology in Unconventional Oil and Gas

Dave Thompson
Group Lead Completions, Canadian Division
Tokyo | May 8 | 2013
Outline

Completions Technology in Unconventional Oil and Gas

- What are Completions Operations?
- Horizontal Well Evolution
- Resource Play Hub Efficiencies
- Historical Performance
- Applied Technologies
- Technology Challenges
  - Lateral Length
  - Frac Diversion
Unconventional Completions Operations

Horizontal Wells with Multiple Stage Hydraulic Fracturing

- Horizontal wells 3,000m long
- Wells typically have 12 - 30 frac stages
- One frac stage has equivalent production to a vertical well
Unconventional Completions Operations

The Completions Process

1. Perforate the casing
   • Reservoir access
2. Fracture stimulate the rock
   • Enhance production
3. Isolate the frac
   • Frac diversion
4. Drill-out isolation equipment
   • Enable flow
5. Flow the well on production

Perforating Gun  Frac Sand
Bridge Plug for Frac Diversion
Coiled Tubing - Drilling Bridge Plugs
Completions Strategy
Deliver safe, repeatable and capital efficient operations

- Improve project economics
- Increase horizontal well length
- Implement new frac diversion technology
- Optimize hydraulic frac spacing
- Optimized frac design

Completions operations represents ≈ 60% of Encana’s capital spend.
### Horizontal Well Evolution
Encana Cutbank Ridge Partnership

<table>
<thead>
<tr>
<th>Year</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<td>Horizontal</td>
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<tr>
<td><strong>Technique</strong></td>
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<tr>
<td>Perf and Plug</td>
<td></td>
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<td>Open Hole Packers</td>
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<td>Sand Plug Diversion</td>
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<td><strong>Fluids</strong></td>
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<td>Energized Foam</td>
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<tr>
<td>Slickwater</td>
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<td></td>
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<tr>
<td><strong>Lateral Length</strong></td>
<td>800 m</td>
<td>2000 m</td>
<td>2500 m</td>
<td>3000 m</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Average Fracs Per Well</strong></td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>14</td>
<td>18</td>
</tr>
</tbody>
</table>

- 2006 to 2013 ≈ 300 wells
- Perforate casing with bridge plug frac diversion
- Open hole packers with frac sleeve technology
  - Longer lateral lengths achieved > 3,000m
- Slick-water frac design for increased production and less cost
Resource Play Hub Operations

Multiple Wells on One Location for Operations Efficiency

- One location with six wells represents $40MM of capital
- Well length of 3,000m with 18 frac stages per well
- 108 fracs represents 11,000t of sand and 36,000m$^3$ water
Encana Completions Performance

Industry Leader in Unconventional Oil and Gas Development

- Industry experts
  - 1,200 horizontal wells in Canada since 2006
  - Continued cost reduction
- Design
  - Single to multi-well pads
  - Longer wells
  - Frac diversion technology
- Execute
  - Detailed planning & logistics
  - Direct sourcing commodities
  - Minimize non-productive time

After seven years of continuous improvement, Encana experiences significant cost reduction in Q1 2013!
Evaluating New Technology at Encana

Encana’s Strategy

• Collaboration within Encana
  – Canada and USA
• Evaluate competitor data
  – Data trades
• Engage Encana experts
  – Oilfield service providers
• Manage risk
  – Implementing new technologies
• Measure results
  – Dedicated technical teams
Encana is an industry leader with lateral lengths of 3,000 - 4,000m!
Drilling and Completions Cost / Production

Technology Challenges - Lateral Length

Drilling & Completions Costs Reduced with Lateral Length

Coiled tubing limit in 2011 ≈ 2,800m
Open hole packer limit in 2012 ≈ 3,200m
New Technology Required > 3,200m

New technologies are required to overcome drilling and completions technical limits!
Applied Drilling Technology at Encana

Drilling Initiatives 2012-2013

• Increased penetration rate
  – Hybrid bit technology
  – Down-hole real-time measurement tools
• Well construction optimization
  – Reverse circulate cementing
• Bi-Fuel drilling rigs
  – Replace diesel with natural gas
• Drilling fluid optimization
  – Change oil based mud to brine-water

Encana’s focus on drilling technology is on down-hole tool design, bi-fuel rig conversion and new drilling fluids.
Applied Completions Technology at Encana

Completions Initiatives 2012-2013

- Record lateral lengths
  - 3,000 - 4,000m achieved
- New frac diversion methods
  - Open-hole packers and frac sleeves
  - Radio frequency identification frac sleeves
  - Limited entry frac sleeves
  - Perf and Drop casing tool
  - Dissolvable frac balls
  - Non-mechanical frac diversion

Encana’s focus on technology is longer wells, frac diversion without wire-line or coiled tubing and unlimited stage spacing.
Other Future Technology Opportunities

<table>
<thead>
<tr>
<th>Objective</th>
<th>New Technology Initiatives</th>
</tr>
</thead>
</table>
| **Drilling**         | Rotary steerable systems for small hole diameters  
|                      | • Control well path for extended lateral length  
|                      | Drilling motors and bottom-hole assemblies for high temperature formations  
|                      | • Extended lateral length  |
| **Well Construction**| Casing design for deep high pressure applications  
|                      | • Metallurgy and mechanical properties  
|                      | Bottom-hole equipment design for 15,000 psi pressure rating  
|                      | • Frac Sleeves  
|                      | • Open-hole packers  
|                      | • Reverse circulate cement tool  |
| **Frac Source Water**| Frac water treatment to reduce fresh water use  
|                      | • Saline sources, produced and recycled frac water  
|                      | • Solids filtration  
|                      | • H₂S removal  |
| **Frac Fluid Additives** | Friction reducers  
|                      | • High rate slick-water applications  
|                      | Guar replacement  
|                      | • High demand with reduced supply of guar  |

Other technology opportunities include well construction, water treatment for frac ing and frac fluid additives.
Thank you.