WHAT MAKES A PLAY UNCONVENTIONAL’?
EXPLORING FOR THE UNCONVENTIONAL PLAY

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KEY MESSAGES

• How can we explore for new unconventional resources beyond known commercial operations?
  – Need to draw upon play-based exploration methods

• What makes a play “unconventional”?
  – Petroleum systems approach provides the geological framework for play type designation

• How do we implement play-based exploration methods for new unconventional resources?
  – A workflow that addresses key decision points based on specific areas of investigation
    • From the play fairways to leads to the prospective areas to a developable area
Alternative resources became the legal designation of specified gas resources for tax-breaks

- The US 1980 Windfall Profit Tax Act contained an additional tax-break incentive known as “Section 29” for alternative resources

Later known as “unconventional” in the industry to distinguish from their taxable conventional operations

The trinity of “unconventional” gas that took on most of the credits:
1. Tight Gas
2. CBM
3. Shale Gas
UNCONVENTIONAL: LARGE AND DIFFICULT

• Continued interest and activity post-subsidies driven by:
  – *Resource In-Place* a major driver as the quantity is massive
  – *Technological Progress* provided capability in unlocking these “difficult to develop” resources

Modified after Masters, 1979
• Supply from successful Shale Gas exploitation led to depressed natural gas prices after the 2008 energy price collapse in the North American market
  – Starting in 2009 industry changed focus to unconventional resources of “Shale oil”, “Tight Oil”
REPEATED SUCCESS AND RESULTS IN TIGHT/SHALE OIL

• The shift to liquids-weighted commodity resulted in a dramatic reversal of the declining oil production in the US
  – Decline in production from Eagle Ford, Bakken, and Permian plays expected to begin in 2020-2025

• Tight oil production is a factor in the overall decline of global oil prices
LACK OF SUCCESS WORLDWIDE
BY DIRECT TRANSFER OF TECHNOLOGY

• Exploring for unconventional resources outside of the U.S. has been a slow and costly process
  – Simply exporting technology to unconventional reservoirs has not always been successful

“Some shale formations in Europe and China are impervious to drilling techniques that opened vast reserves of natural gas and oil from Texas to Pennsylvania”

- Rex Tillerson, CEO ExxonMobil 2012
“...the geologic complexity of varied unconventional resources requires new exploration philosophies.” - Holditch and Ayers, 2009

• One “new” exploration philosophy may be to utilize a time-tested method that employs the play concept.

• At its essence, the play concept provides a framework for appropriate expectations on the viability and value of an exploration program
  – Target identification (leads/prospects)
  – Risk characterization (based on previous occurrences)
  – Potential Yet to Find Resource (expectation of new additions)
  – Potential Value (based on previous successes)

• What we need is a geologic context that describes the unconventional play.

But...What is an unconventional play?
UNCONVENTIONAL DEFINITION #1: THE SOURCE IS RESERVOIR

- The source rock retains significant resource depending on expulsion efficiency, etc.

- It is a “continuous” resource that has potential over an extensive area.
UNCONVENTIONAL DEFINITION #2: LOW PERMEABILITY RESERVOIR

- A reservoir containing conventional fluids below some arbitrary permeability level
  - Interestingly, this view diminishes the static aspects of the play and focuses on key dynamic factors (i.e. permeability and fluid viscosity).

![Diagram of reservoir types](image_url)
UNCONVENTIONAL DEFINITION #3
TECHNOLOGY DEFINES THE PLAY

- Access to reservoir offsets low permeability

\[
\text{Flow rate, } Q = \frac{kA}{\mu} \left( \frac{\partial P}{\partial x} \right)
\]

- Thus the unconventional “reservoir cannot be produced at economic flow rates … unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores.” Holditch (2006)
The petroleum system perspective provides the definition of the unconventional play: An expulsed hydrocarbon resource that remains in the generative cell by a capillary seal.
Any play can be constructed on a tiered, hierarchical framework based on the petroleum system:

**Unconventional**
- the source-seal
- the reservoir-source
- the geomechanical setting

**Conventional**
- the source-migration
- the reservoir-seal pair
- the trap type

*GEOHORIZONS*

*The exploration play: What do we mean by it?*

Harry Doust  AAPG Bulletin, v. 94, no. 11 (November 2010), pp. 1657–1672
FIRST TIER: SOURCE-SEAL PAIR

• The geologic characteristics of the source rock and its relationship to a capillary seal are first tier.

• The components of this tier are three-fold and include
  – Depositional setting and traits of organic material accumulation and preservation
  – The generation of hydrocarbons including basin history
  – The capillary seal and its efficiency
SECOND TIER: SOURCE-RESERVOIR CHARACTERISTICS

• The target interval and its relationship between the source of the hydrocarbon designates the second tier of the play type.
  – Target interval is the section accessed by stimulation
  – In its simplest construction, there are three possible pairings,
    1. Source – Reservoir are equivalent
    2. Source – Reservoir are different
    3. Source – Reservoir Hybrid

• It is the target interval that key reservoir characteristics can be measured
THIRD TIER: GEOMECHANICAL STATE

- Geomechanical qualities of the reservoir and surrounding beds directly influence our ability to access the resource beyond borehole.
  - The term geomechanical is used here in its broadest sense, and includes aspects of rock mechanics, fracture mechanics and in-situ stresses.

- Rock properties such as elastic moduli that influence fracture initiation, propagation and closure

- Structural fabric such as Faults, Bedding and Natural Fractures

- In-Situ Stress state and its local variations
BAKKEN IS NOT SIMPLY “THE BAKKEN”

- Although often discussed in singular, the Bakken of North Dakota has been separated in terms of play areas.
BAKKEN PLAY TYPES AND PRODUCTION

- After drilling 1000’s of wells in the basin, it can be shown that the these areas of distinct type curves and EURs
  - Distinctions that would be missed if aggregated into a single play

Hough & McClurg, 2011
THE BAKKEN PLAY TYPES

- We can identify these areas of potentially unique characteristics before drilling 1000’s of wells if we construct the Bakken as a series of unconventional plays.
**SHALE PLAY TYPES ACROSS BASINS**

- Using Play types based on the petroleum system characteristics, plays can be compared across basins

<table>
<thead>
<tr>
<th>Basin</th>
<th>Source</th>
<th>Reservoir</th>
<th>Geomechanics</th>
<th>Play Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Texas Basin</td>
<td>Lt Cretaceous Eagle Ford Shale Over-Pressured</td>
<td>Carbonaceous Laminated shale</td>
<td>Normal Stress Moderate regional fracture intensity</td>
<td>Gas Eagle Ford Shale</td>
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<td></td>
<td>Gas Window</td>
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<tr>
<td></td>
<td>Lt Cretaceous Eagle Ford Shale Over-Pressured</td>
<td>Carbonaceous Laminated shale</td>
<td>Normal Stress Low fracture intensity</td>
<td>Condensate Eagle Ford Shale</td>
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<td></td>
<td>Condensate Window</td>
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<tr>
<td>Appalachian Basin</td>
<td>Mid. Devonian Marcellus Shale Over-Pressured</td>
<td>Siliceous to Carbonaceous Laminated Shale</td>
<td>Strike-Slip Stress Moderate regional fracture intensity</td>
<td>The Marcellus Shale</td>
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<tr>
<td></td>
<td>Gas Window</td>
<td></td>
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<tr>
<td>Horn River Basin</td>
<td>Lt. Devonian Muskwa Shale Over-Pressured Gas Window</td>
<td>Siliceous Laminated Shale</td>
<td>Normal to Strike Slip Stress High regional fracture intensity</td>
<td>Muskwa-Otter Park Shale</td>
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</tbody>
</table>
• Play analogues provide us with means to:
  – When we don’t have access to
    • Key geologic characteristics
    • Productive capability
    • Best practices
• We can apply analogues
  – Within Play Fairway
    • Remaining resource developable area based surface and subsurface access and production characteristics
  – Across basins
    • Analogue correlation for emerging plays
• Comparisons made on several characteristics without regard to play type

<table>
<thead>
<tr>
<th></th>
<th>Shale Prospect</th>
<th>Woodford</th>
<th>Barnett</th>
<th>Haynesville</th>
<th>Marcellus</th>
<th>Eagleford</th>
<th>Bakken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity (%)</td>
<td>5.5</td>
<td>1.8%</td>
<td>~1.5 – 6 (Avg. ~3.8)</td>
<td>8.15%</td>
<td>3.8%</td>
<td>3.15%</td>
<td>2.12%</td>
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<tr>
<td>TVD (ft)</td>
<td>4,100 – 4,300</td>
<td>6,000 – 14,000</td>
<td>5,400 – 9,500</td>
<td>10,500 – 14,000</td>
<td>1,500– 8,500</td>
<td>5,000 – 13,000</td>
<td>8,000 – 11,000</td>
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<tr>
<td>Thickness (ft)</td>
<td>53</td>
<td>100 – 220</td>
<td>150</td>
<td>60 – 350</td>
<td>50 – 300</td>
<td>40–500</td>
<td>6.15Rt 80–8.145 ft</td>
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<tr>
<td>BHT (°F)</td>
<td>160</td>
<td>150.225</td>
<td>159</td>
<td>280.389°F</td>
<td>100–150</td>
<td>150 – 350</td>
<td>100–240</td>
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<tr>
<td>TOC (%)</td>
<td>3.95</td>
<td>3.9%</td>
<td>4.8%</td>
<td>2.5%</td>
<td>3.19%</td>
<td>0.5%</td>
<td>Upper-11.4%</td>
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<tr>
<td>Press Grad (psi/ft)</td>
<td>0.48</td>
<td>0.45–0.68</td>
<td>0.52</td>
<td>0.05–0.093</td>
<td>0.4–0.7</td>
<td>0.4–0.85</td>
<td>0.5–0.6</td>
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<tr>
<td>Frac Grad (psi/ft)</td>
<td>0.7</td>
<td>0.7–0.9</td>
<td>~0.6–0.75</td>
<td>&gt;0.90</td>
<td>&gt;0.90</td>
<td>0.9–1.2</td>
<td>0.7–0.85</td>
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<tr>
<td>Avg Perm (md)</td>
<td>6.1</td>
<td>0.05–0.4</td>
<td>0.05–0.4</td>
<td>&lt;0.005</td>
<td>0.2–2</td>
<td>400–1200</td>
<td>20–500</td>
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<tr>
<td>Sw (%)</td>
<td>27</td>
<td>33%</td>
<td>&lt;35 no free water</td>
<td>&lt;25</td>
<td>&lt;25</td>
<td>25–60</td>
<td></td>
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<tr>
<td>Lithology (%)</td>
<td>Silica rich</td>
<td>Silica: Chert 30.6%</td>
<td>Silica rich 35-50%</td>
<td>Shale is soft (ductile)</td>
<td>Calcrete rich-in areas</td>
<td>Silica rich 35-50%</td>
<td>Variable formation properties</td>
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<tr>
<td></td>
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</tr>
<tr>
<td>YM (x10^6 psi)</td>
<td>3.48</td>
<td>4.8</td>
<td>8.10</td>
<td>2.3</td>
<td>2.5</td>
<td>1.4</td>
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<tr>
<td>PR (%)</td>
<td>0.296</td>
<td>0.15–0.25</td>
<td>0.13–0.25</td>
<td>0.23 – 0.27</td>
<td>0.19–0.23</td>
<td>0.29–0.27</td>
<td>Upper/Lower=2–2.4</td>
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<tr>
<td>Quartz, wt %</td>
<td>54</td>
<td>25–54</td>
<td>40–60</td>
<td>25-52</td>
<td>10–40</td>
<td>1–30</td>
<td>15–70</td>
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<tr>
<td>Plagioclase</td>
<td>19</td>
<td>7.13</td>
<td>2.5</td>
<td>8.17</td>
<td>0–10</td>
<td>0.17</td>
<td>1.3</td>
</tr>
<tr>
<td>Feldspar, wt %</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Calcite, wt %</td>
<td>37</td>
<td>7–20</td>
<td>5.30</td>
<td>13.44</td>
<td>5–20</td>
<td>25.95</td>
<td>15–65</td>
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<tr>
<td>Sillite, wt %</td>
<td>2.8</td>
<td>2–8</td>
<td>1.5</td>
<td>&lt;2</td>
<td>0.23</td>
<td>2.6</td>
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<tr>
<td>Illite, wt %</td>
<td>11.9</td>
<td>17.46</td>
<td>5.25</td>
<td>12.20</td>
<td>25–60</td>
<td>1.50</td>
<td>1.13</td>
</tr>
<tr>
<td>Kaolinite, wt %</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>&lt;2</td>
<td>0.14</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Chlorite, wt %</td>
<td>11.9</td>
<td>1</td>
<td>0</td>
<td>4.7</td>
<td>0–10</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Ro (Maturity of Shale)</td>
<td>1.23</td>
<td>0.75–1.45</td>
<td>0.6–1.6</td>
<td>1–1.2</td>
<td>0.8–3.0+</td>
<td>0.75–2.16</td>
<td>0.45–0.60</td>
</tr>
</tbody>
</table>

**Analog Analysis**
<table>
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<tr>
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<tr>
<td>Western Canadian Basin</td>
<td>Devonian, Restricted shallow marine, Condensate Window</td>
<td>Siliceous Laminated Shale</td>
<td>Normal Low regional fracture intensity</td>
<td>Duvernay Shale Condensate</td>
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<tr>
<td>Appalachian Basin</td>
<td>Devonian Anoxic deep marine Gas Window</td>
<td>Siliceous to Carbonaceous Laminated Shale</td>
<td>Strike-Slip High regional fracture intensity</td>
<td>Marcellus Shale Gas</td>
</tr>
<tr>
<td>South Texas Basin</td>
<td>Cretaceous, Restricted shallow marine, Condensate Window</td>
<td>Carbonaceous Laminated Shale</td>
<td>Normal Low regional fracture intensity</td>
<td>Eagle Ford Shale Condensate</td>
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<td>Devonian Anoxic deep marine Gas Window</td>
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<td>Muskwa Shale Gas</td>
</tr>
</tbody>
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EXPLORING WITH THE PLAY CONCEPT

…the “play” has an almost mythical status—the successful play is the thing of which legends are made, and playmakers are regarded as heroes of the industry. – Doust, AAPG 2010

• Unconventional plays made not through simple discoveries

• Making the play requires a progressive methodology that explores the play’s:
  • Resource accessibility
  • Productive capability
  • Operational capacity
  • Risked economics

• Exploration progression must be within a business context

Making the play = creating value
The exploration process invariably includes key decision points that address investment and resource commitment.

- **Strategic Focus**
  - Petroleum Systems
  - Strategic Alignment

- **Play Fairway High-Grading**
  - Lead Areas
  - Technically Viable
  - Lead Areas Selected

- **Lead Area Evaluation**
  - Prospective Areas
  - Investment Worthy
  - Prospective Area Value

- **Prospective Area Evaluation**
  - Developable Area
  - Investment Ready
  - Investment Magnitude
WORK FLOW DECISIONS SPECIFIC TO AREA OF INVESTIGATION

• Exploration decision points often are specific to an area of investigation and tied to the level of understanding of a play
  – These areas can be associated with key play characteristics that help define and assess the area

Play Fairway
An Area where the Generative source rock is present.
100,000s km²

Lead Areas
Area where the play could be technically successful.
10,000s km²

Prospective Area
An area that has positive value on a risk basis.
1,000s km²

Developable Area
An area within a land base that could be developed.
100s km²
PLAY FAIRWAY MAPPING TO IDENTIFY LEADS

Goal:
Identify and rank Lead areas within a play fairway that have potential to deliver a technically successful unconventional resource

Components:
Play Characterization and Analogue Identification

- Regional Mapping of Key Play Criteria
- High-Grading to delineate Leads
- Lead Area Ranking with value indicators

Results
Selected play Leads for continued analysis
BUILD YOUR OWN PRESENTATION

LEAD AREA ASSESSMENT TO IDENTIFY PROSPECTIVE AREAS

Goal:
Identify prospective area where the play can deliver value and to describe a likely economic and productive scenario

Components:
- Probabilistic Resource-in-place
- Well/Pad Design and Cost Scenarios
- Unit Area Type Curves
- Relative Resource Value by Unit Area

Results:
Risked economics within prospective area that indicate positive value outcomes
Goal:
Assess full cycle, risked economics for developable units that comprise a land base

Components:
• Probabilistic Resource
• Cost Breakdowns
• Production Forecast
• Project Cash-flow
• Commercial Risk and Market Outlook
• Resulting NPV

Results:
Production, Cash Flow and Risked Value for Investment recommendation

<table>
<thead>
<tr>
<th>Investment Metrics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ROR BT (%)</td>
<td>15</td>
</tr>
<tr>
<td>COS (%)</td>
<td>70</td>
</tr>
<tr>
<td>NPV ($MM)</td>
<td>1000</td>
</tr>
<tr>
<td>Gross Recoverable Resource (MMBOE)</td>
<td>280</td>
</tr>
</tbody>
</table>
PLAY-BASED EXPLORATION FOR UNCONVENTIONAL RESOURCES

• To expand the success of unconventional plays outside of US and Canada we can draw upon play-based exploration methods
  – Geologic understanding of the unconventional play by using a petroleum systems approach

• We can implement play-based exploration for new unconventional resources
  – A workflow that addresses key decision points based on specific areas of investigation
  – Uses key information from the play from fairways to leads to the prospective areas to a developable area