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Society of Petroleum Engineers
Distinguished Lecturer Program
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CHARACTERIZING SHALE PLAYS
The Importance of Recognizing What You Don’t Know

SPE 2013-2014 Distinguished Lecturer Series

Brad Berg
Outline

- Huge Global Resource
- Shale Play Characterization Challenges
- Incorporating Uncertainty into Assessments
- The Impact of Decision Behavior
- Conclusions
Global Shale Gas Resource: 7,300 TCF (~200 TCM)
Global Shale Oil Resource: 345 BBO

Map of basins with assessed shale formations, as of May 2013

United States:
Proved Gas Reserves = 318 TCF, Shale TRR = 665 TCF
Proved Oil Reserves = 25 BBO, Shale TRR = 58 BBO

Technically Recoverable Shale Resources

<table>
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<tr>
<th>Rank</th>
<th>Country</th>
<th>TCF</th>
<th>Rank</th>
<th>Country</th>
<th>BBOE</th>
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<td>1</td>
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<td>3,437</td>
<td>Other</td>
<td></td>
<td>127</td>
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</tbody>
</table>

World Total: 7,299 TCF, World Total: 345 BBO

Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.
U.S. Natural Gas Production Forecast

Source: EIA 2013 Early Release Overview
Characterizing Shale Plays - Challenges

- No industry standard for evaluating shale plays:
  - Most attention has been in the last 5-10 years

- Reservoir characteristics are difficult to quantify:
  - Low matrix porosity & permeability
  - Presence of fractures is critical
  - Horizontal drilling and hydraulic fracturing required
  - Effective drainage area is hard to define
  - Commercial boundary is flexible
  - Cost reduction is critical
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Characterizing Shale Plays – Challenges

- Low matrix porosity & permeability

Permeability (D) in different units:
- **Darcy (D)**
- **Millidarcy (mD)**
- **Microdarcy (μD)**
- **Nanodarcy (nD)**

- **Limestone & Dolomite**
- **Sandstones**
- **Tight Sands (Silts)**
- **Shales**

Seals:
- **Weak Seals**
- **Overpressure Seals**
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Characterizing Shale Plays – Challenges

- Horizontal drilling and hydraulic fracturing are required

**Horizontal Drilling**

- Kickoff ~7,000 Ft
- Lateral = 5,000-10,000 Ft
- Separation = 250-1000 Ft

**Hydraulic Stimulation**

For 5000’ Lateral:
- 17 Stages
- 3,500,000 lb Sand
- 150,000 bbls Water
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Characterizing Shale Plays – Challenges

- **Cost reduction is critical**

**Efficiencies Drive Cost Reduction**

- Cycle-Time Improvements
  - 60% Drilling
  - 50% Completions
- 40% Longer Laterals
- Improving Expected Ultimate Recoveries per well
- Additional Opportunities …
  - Improving Target Selection
  - Downspacing
  - Utilizing Spudder Rig
Characterizing Shale Plays - Challenges

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• Measuring success:
  ▪ Geologic information alone is a poor predictor of absolute well performance
  ▪ Success is judged on well production
  ▪ **With well production comes a lot of uncertainty**
Fayetteville Shale Play

- One of the oldest shale targets, drilling began in 2004
- Mississippian-age shale at 1,500 to 6,500 foot depth
- Over 4000 wells drilled
- Examined 933 wells with extended production history
- Production forecasts ‘normalized’ to same completed horizontal length
Challenges to Predicting Reservoir Performance

Fayetteville Shale Play
*Well EUR’s normalized to 3200’ average lateral length*

Legend
*Well EUR’s (MMCF)*
- 250
- 1000
- 2000
- 3000
- 4000
- 5000

Conway County
Faulkner County
Van Buren County
Challenges to Predicting Reservoir Performance

Maverick Eagle Ford Example
Challenges to Predicting Reservoir Performance

Cumulative BOE vs. Production Time (Days)
Challenges to Predicting Reservoir Performance

Fayetteville Shale Play
Well EUR’s normalized to 3200’ average lateral length

Legend
Well EUR’s (MMCF)
- 250
- 1000
- 2000
- 3000
- 4000
- 5000

Divided Into Townships
Measuring Uncertainty in Well Performance

- The uncertainty range, or variance, of the distribution is measured as \( \frac{P_{10}}{P_{90}} \) ratio.

Expected Ultimate Recovery (MMCF)

\[ P_{10} = 2.6 \text{ BCF} \]
\[ P_{90} = 0.7 \text{ BCF} \]

\[ \frac{P_{10}}{P_{90}} = \frac{2.6}{0.7} = 3.7 \]

\[ \text{Mean} = 1.5 \text{ BCF} \]

\[ P_{10} = 2.6 \text{ BCF} \]
\[ P_{90} = 0.7 \text{ BCF} \]

\[ P_{10}/P_{90} = 2.6 / 0.7 = 3.7 \]
Measuring Uncertainty in Well Performance

- Average well performance by area

**Fayetteville**

- Mean = 1.1 BCF, P10/P90 = 6.2
- Mean = 1.5 BCF, P10/P90 = 3.7
- Mean = 2.3 BCF, P10/P90 = 2.4
In the Fayetteville, most areas show a individual well P10/P90 variance of 2 to 6
Well Performance Uncertainty in Shale Plays

Shale Well Variability

* Portions of each play
Q: How useful is a single well as a predictor of productivity?

A: Not very…
Characterizing a Shale Play

50 miles

Probability Distribution of Well EUR's

P90
P50
P10

Reserves/Well (BCF)

10.0
0.2
1.5
10.0

Economic Threshold

Distribution of Well EUR's

P90
P50
P10

Reserves/Well (BCF)

0.2
1.5
10.0

Play Boundary
Planning an Exploration Program

- What defines a prospect area?
- What variability should I use to predict well performance?
- How many wells should I drill in each prospect area?
- What defines the “encouragement” needed to continue drilling?
What Defines a Prospect Area?

Productivity Drivers:

- Reservoir Quality
  - Porosity
  - Matrix Permeability
  - Water Saturation
  - Natural Fractures

- Pressure

- Maturity
  - Fluid Type
Planning an Exploration Program

- What defines a prospect area?
- **What variability should I use to predict well performance?**
- How many wells should I drill in each prospect area?
- What defines the “encouragement” needed to continue drilling?
Well Performance Uncertainty in Shale Plays

Shale Well Variability

Prospect Average EUR (MBOE/Well)

Well Variability (P10/P90 Ratio)

- Fayetteville*
- Marcellus*
- Maverick EagleFord*
- Haynesville*

* Portions of each play
Testing a New Play

Geologic Test

Production Test

Probabilities

Reserves/Well (BCF)

Distribution of Well EUR’s

P90

P50

P10

0.5

1.5

5.0
Planning an Exploration Program

- What defines a prospect area?
- What variability should I use to predict well performance?
- **How many wells should I drill in each prospect area?**
- What defines the “encouragement” needed to continue drilling?
The number of wells needed depends primarily on:

- Uncertainty range of the reserves distribution
- Proximity of the minimum commercial size to the mean of the distribution

**Distribution of Well EUR’s A**

- $P_{10}/P_{90} = 4$
- Mean = 3.7
- Min Size = 2.7

**Distribution of Well EUR’s B**

- $P_{10}/P_{90} = 10$
- Mean = 3.7
- Min Size = 3.2

**Probability Distribution of Well EUR’s**

- **A**:
  - $P_{90} = 6.4$
  - $P_{50} = 1.6$
  - $P_{10} = 3.2$
  - Mean = 3.7
  - Min Size = 2.7

- **B**:
  - $P_{90} = 8.0$
  - $P_{50} = 2.6$
  - $P_{10} = 3.2$
  - Mean = 3.7
  - Min Size = 3.2

The probability distribution of Well EUR's indicates that for Well EUR’s A, the probability distribution is concentrated around a mean of 3.7 BCF with a high P10/P90 ratio of 4, suggesting a high level of uncertainty. For Well EUR’s B, while the mean remains the same at 3.7 BCF, the P10/P90 ratio is lower at 10, indicating a lower level of uncertainty. The diagrams visually represent the confidence levels associated with different well counts, with colors indicating True Positives, Correct Predictions, and False Negatives.
Planning an Exploration Program

- What defines a prospect area?
- What variability should I use to predict well performance?
- How many wells should I drill in each prospect area?
- What defines the “encouragement” needed to continue drilling?
What Defines Encouragement?

**Encouragement**  [en- kur-ij-muhnt]

*noun*
1. Available data indicates that the play has the **potential** to be economically viable.
2. A threshold that recognizes the uncertainty in the data.
3. Results that motivate you to keep drilling.

- The less data you have, the lower your threshold should be.
- **Example thresholds**
  - During the exploration phase: < Breakeven
  - During the appraisal phase: Breakeven
  - During the development phase: Competitive with other opportunities
MODELING DECISION BEHAVIOR

**Play Description:**
- 500,000 acres (~2000 km²)
- 10 Prospect Areas
- EUR potential 1 to 6 BCF/well
- Individual Well P10/P90 = 4
- Breakeven EUR = 2.3 BCF/well
- Competitive EUR = 2.8 BCF/well

**Drilling Program:**
- Drill 3 wells in 3 prospects (9 wells)
- Drill 5 more wells in each “good” prospect
- Test additional prospects.
- Drill 12 more wells in each “good” prospect.
- Test additional prospects.

**Economic Hurdle:**
- 50% of Breakeven
- Breakeven
- Competitive
The Impact of Decision Behavior

**Anticipated Behavior**
*Base Case*

- Drill 3 Wells in 3 Prospects
- Threshold: \( \frac{1}{2} \text{NPV10} = 0 \)

**Stricter Behavior**
*Raise threshold*

- Drill 3 wells in 3 Prospects
- Threshold: \( \text{NPV10} = 0 \)

**Harsh Behavior**
*Cut well count*

- Drill 3 wells in 1 Prospect
- Threshold: \( \text{NPV10} = 0 \)

---

### Chance of Success

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<th>NPV10 1x3</th>
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### Risked Well Count

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<th>NPV10 1x3</th>
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### Risked Resources

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<td>7.3</td>
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<td>4.4</td>
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Conclusions

- Shale play potential is measured through long term production performance.

- Wells in the same area, drilled and completed the same way, can and do perform quite differently from one another.

- Natural variance in well performance can easily fool you into making bad decisions. You can only overcome this if you drill enough wells to achieve statistical significance.

- Decision behavior can have a substantial effect on the chance of success. It’s important to model how you’ll actually behave.

- There are many challenges associated with evaluating shale reservoirs. Perseverance, and an understanding of the uncertainties associated with these plays is needed in order to successfully explore for them.
Your Feedback is Important

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http://www.spe.org/dl/