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Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl
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

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>TCF</th>
<th>Rank</th>
<th>Country</th>
<th>TCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>1,115</td>
<td>7</td>
<td>Australia</td>
<td>437</td>
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<tr>
<td>2</td>
<td>Argentina</td>
<td>802</td>
<td>8</td>
<td>South Africa</td>
<td>390</td>
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<td>Algeria</td>
<td>707</td>
<td>9</td>
<td>Russia</td>
<td>285</td>
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<tr>
<td>4</td>
<td>U.S.</td>
<td>665</td>
<td>10</td>
<td>Brazil</td>
<td>245</td>
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<tr>
<td>5</td>
<td>Canada</td>
<td>573</td>
<td></td>
<td>Other</td>
<td>1,535</td>
</tr>
<tr>
<td>6</td>
<td>Mexico</td>
<td>545</td>
<td></td>
<td>World Total</td>
<td>7,299</td>
</tr>
</tbody>
</table>

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

• Measuring success:
  ▪ Geologic information alone is a poor predictor of well performance
  ▪ Success is judged on well production
  ▪ With well production comes a lot of uncertainty
• 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 Forecasting Production

• How long of a production period do we need from each well?
  - 3 - 6 months after cleanup to estimate initial decline rate
  - 12 - 36 months after cleanup to estimate hyperbolic behavior (b factor)
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

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 P10/P90 ratio.

Fayetteville

Expected Ultimate Recovery (MMCF)

Cumulative Probability

P10 = 2.6 BCF
P90 = 0.7 BCF
Mean = 1.5 BCF

\[
P10/P90 = \frac{2.6}{0.7} = 3.7
\]
Measuring Uncertainty in Well Performance

- Average well performance by area

Fayetteville

- Expected Ultimate Recovery (MMCF)

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

- Fayetteville
- Marcellus
- Maverick Eagle Ford
- Haynesville

Prospect Average EUR (MBOE/Well)

Well Variability (P10/P90 Ratio)
A single well won’t provide the productivity information you need.

Distribution of Well EUR’s:

- P90
- P50
- P10

Reserves/Well (BCF)

Expected Economic Threshold: 1.5 BCF

Play Boundary

50 miles

are we here?
or here?
Characterizing a Shale Play

50 miles

Distribution of Well EUR's

P90
P50
P10

Reserves/Well (BCF)

0.2 1.5 10.0

Distribution of Well EUR's

P90
P50
P10

Reserves/Well (BCF)

0.2 1.5 10.0

Distribution of Prospect Means

P90
P50
P10

Reserves/Well (BCF)

0.2 1.5 10.0

Economic Threshold
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?

Conventional

Unconventional

Field Size Distribution

Average Well Distribution

Total Reserves

Reserves/Well
What Defines a Prospect Area?

Productivity Drivers:

- Reservoir Quality
  - Porosity
  - Matrix Permeability
  - Water Saturation
  - Natural Fractures
- Pressure
- Fluid Type
  - Maturity
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?
Testing a Shale Play

50 miles

Play Boundary

Distribution of Well EUR's

Probabilities:
P10
P50
P90

Reserves/Well (BCF):
0.5
1.5
5.0

5.00.5 1.5
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?
Confidence Range Versus Well Count

• The more wells you drill, the more confidence you’ll have that the wells will represent the average reservoir performance.

Predicting EUR’s:

• Modeled wells from prospect:
  • Average EUR/well = 2.5 BCF
  • P10/P90 = 4
  • Sampled the distribution 10,000 times

• For P10/P90 = 4:
  ➢ 1 Well = 1.1 - 4.3 BCF/well
  ➢ 3 Wells = 1.6 – 3.7 BCF/well
  ➢ 10 Wells = 2.0 – 3.1 BCF/well
Designing An Exploration Pilot

- 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
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

<table>
<thead>
<tr>
<th>Drilling Program</th>
<th>Appraisal Pilot</th>
<th>Early Development</th>
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</table>
| 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

<table>
<thead>
<tr>
<th>NPV10/2</th>
<th>NPV10</th>
<th>NPV10/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x3</td>
<td>51%</td>
<td>87%</td>
</tr>
<tr>
<td>3x3</td>
<td>97%</td>
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### Risked Well Count

<table>
<thead>
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<th>NPV10/2</th>
<th>NPV10</th>
<th>NPV10/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x3</td>
<td>1630</td>
<td>1470</td>
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<tr>
<td>3x3</td>
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<td>900</td>
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### Risked Resources

<table>
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<th>NPV10</th>
<th>NPV10</th>
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</thead>
<tbody>
<tr>
<td>3x3</td>
<td>8.0</td>
<td>7.3</td>
</tr>
<tr>
<td>3x3</td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>1x3</td>
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</table>
Conclusions

- Shale play potential is measured through long term production performance. This takes time. Using early production estimates requires that forecast uncertainty be quantified.

- 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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