**Abstract**

Shale plays typically exhibit much more uncertainty in individual well performance than conventional reservoirs. Understanding this uncertainty is particularly critical during the exploration drilling program when one has relatively few wells on which to base decisions. A systematic approach to understanding and managing this uncertainty can be used to address key questions during the early phases of a drilling program, including "how many wells do I need to drill before I have confidence in the results?" and "does the well performance I’ve seen to date provide the encouragement needed to keep drilling?" To answer these questions, one must quantify the uncertainty surrounding individual well results. Key elements of this evaluation process include:

1. Identifying analogs that can provide insights into the level of well performance uncertainty to expect;
2. Stochastically modeling the potential range of well results from the testing program;
3. Deciding what level of risk is acceptable to the decision-makers; and
4. Planning and executing a testing program that incorporates these elements.

The primary take-away from this presentation is that it is critical to recognize, and properly characterize, uncertainty in shale well production performance when planning an exploration drilling program in shale plays. Without such an approach, the commercial potential of a play may not be adequately characterized, leaving the decision-makers without the information needed to determine the path forward. Understanding the uncertainty in well performance, and planning for it, will lead to more efficient exploration activity, and better informed decision-making.
CHARACTERIZING SHALE PLAYS
The Importance of Recognizing What You Don’t Know


Also
SPE 2013-2014 Distinguished Lecturer Series

Brad Berg
The Character of Shale Plays

• We haven’t been studying them very long
   Most attention has been in the last 5 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
   Recovery efficiencies poorly understood

• Measuring productivity
   Geologic information alone is a poor predictor of well performance
   Success is judged on well production
   **With well production comes a lot of uncertainty**
Fayetteville Shale

- One of the oldest shale targets, drilling began in 2004
- Mississippian-age shale at 1500- to 6500-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
Challenges to Predicting Reservoir Performance

Maverick Eagle Ford Example
Challenges to Predicting Reservoir Performance
Challenges to Predicting Reservoir Performance

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

Legend

<table>
<thead>
<tr>
<th>Well EUR’s (MMCF)</th>
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<tbody>
<tr>
<td>250</td>
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<td>1000</td>
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<td>2000</td>
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<td>3000</td>
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<td>4000</td>
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<td>5000</td>
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Divided Into Townships
Measuring Uncertainty in Well Performance

- The uncertainty range, or variance, of the distribution is measured as P10/P90 ratio.

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Distribution of Well EUR’s

P10 = 2.6 BCF
P90 = 0.7 BCF
P10/P90 = 2.6 / 0.7 = 3.7
Mean = 1.5 BCF
```

Fayetteville
Measuring Uncertainty in Well Performance

- Average well performance by area

<table>
<thead>
<tr>
<th>Area</th>
<th>Mean EUR (BCF)</th>
<th>P10/P90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fayetteville</td>
<td>Mean = 1.1</td>
<td>P10/P90 = 6.2</td>
</tr>
<tr>
<td></td>
<td>Mean = 1.5</td>
<td>P10/P90 = 3.7</td>
</tr>
<tr>
<td></td>
<td>Mean = 2.3</td>
<td>P10/P90 = 2.4</td>
</tr>
</tbody>
</table>
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

Reserves/Well (BCF)

P90

P50

P10

Economic Threshold
Planning an Exploration Program

- What defines a prospect area?
- 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

Source: Wayne Camp, Anadarko Petroleum Corporation
Planning an Exploration Program

- What defines a prospect area?

- How many wells should I drill in each prospect area?

- What defines the “encouragement” needed to continue drilling?
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

**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**
  - $P_{90} = 8.0$
  - $P_{50} = 0.8$
  - $P_{10} = 2.6$
  - Mean = 3.7
  - Min Size = 3.2

**Well Count**

- Probability Distribution
  - Confidence Level
  - True Positives
  - Correct Prediction
  - False Negatives

- **Well Count Range**
  - 1 to 24
What defines a prospect area?

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
**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)

**Economic Hurdle:**
- 50% of Breakeven

**Screening:**
- Technical and commercial screening

**Capture:**
- Identify and capture
- Good Terms: Capture
- Cost Too High

**Exploration Pilot:**
- Drill and test seeking encouragement

**Appraisal Pilot:**
- Drill and test to determine commerciality
- Commercial
- Sub-Commercial
- Does’t Compete

**Early Development:**
- Develop commercial areas
- To Development
- Stop
The Impact of Decision Behavior

**Anticipated Behavior**
**Base Case**
- Drill 3 Wells in 3 Prospects
- Threshold: $\frac{1}{2} \text{NPV}_{10} = 0$

**Stricter Behavior**
**Raise threshold**
- Drill 3 wells in 3 Prospects
- Threshold: $\text{NPV}_{10} = 0$

**Harsh Behavior**
**Cut well count**
- Drill 3 wells in 1 Prospect
- Threshold: $\text{NPV}_{10} = 0$

### Chance of Success

<table>
<thead>
<tr>
<th>Well Count</th>
<th>NPV_{10}/2 3x3</th>
<th>NPV_{10} 3x3</th>
<th>NPV_{10} 1x3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chance of Success</td>
<td>97%</td>
<td>87%</td>
<td>51%</td>
</tr>
</tbody>
</table>

### Risked Well Count

<table>
<thead>
<tr>
<th>Well Count</th>
<th>NPV_{10}/2 3x3</th>
<th>NPV_{10} 3x3</th>
<th>NPV_{10} 1x3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1630</td>
<td>1470</td>
<td>900</td>
</tr>
</tbody>
</table>

### Risked Resources

<table>
<thead>
<tr>
<th>Reserves (TCF)</th>
<th>NPV_{10}/2 3x3</th>
<th>NPV_{10} 3x3</th>
<th>NPV_{10} 1x3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8.0</td>
<td>7.3</td>
<td>4.4</td>
</tr>
</tbody>
</table>
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 are needed in order to successfully explore for them.