Appraising and Developing Your Unconventionals:
How to Avoid Squandering Billions of Dollars Next Time

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Rose and Associates

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The 23 companies shown here acquired acreage in 30+ North American plays.
8 of these failed to deliver positive development value

Period is from 2004-2013
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<th>Reservoir</th>
<th>Wells Drilled</th>
<th># Wells &gt;12% ROR</th>
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Total 1049 220

A company’s experience in 16 low permeability reservoirs during a one year period
• What percentage of U.S. Shale Plays have been commercially developed?
The Staged Approach

Stage 1: Exploration
- Exploration Success
- Exploration Failure

Stage 2: Appraisal
- Appraisal Success
- Appraisal Failure

Stage 3: Demonstration
- Demonstration Success
- Demonstration Failure

Stage 4: Development
- Development Success
- Development Failure

Capital at Risk

Exit

P_G

P_A

P_Dev

P_Dem
General Workflow

- Identify the stage the project is in
- Assess the key uncertainties and risks in that stage
- Define the data and analyses required to make a good decision whether to proceed to the next stage or exit
- Design a work plan, timeline and budget to acquire this information
Project Stage: Exploration

**Screening**
- Target basins with prospectivity and rank opportunities
- Apply criteria for identifying sweetspots
- Collect all existing relevant information
  - Cast a wide net and be resourceful
  - Look for data to fill-in the gaps
  - Evaluate the entire stratigraphic column
- Build maps and spatially composite them
- Identify potential analogs
- Determine chance of geologic success ($P_g$) for defined play segments

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**Exploration**

**Appraisal**

**Demonstration**

**Development**
Spatial Compositing of Maps

- Organic richness (TOC)
- Thermal maturity (%Ro)
- Structure/tectonics
- Gross/net thickness
- Lithofacies/mineralogy
- Acoustic impedance
- Geomechanical properties
- Seeps/slicks
- Surface geochemistry
- Porosity/Permeability
- Fluid saturations (Sg, So, Sw)
- Evidence of overpressure
- Overburden thickness
- Seal thickness/rheology
- Reservoir temperature
- Paleogeography
- Key wells
- acreage held/open
- Restricted/inaccessible areas
- Pipelines, other infrastructure
Project Stage: Exploration

**Discovery**
- Locate a significant quantity of producible hydrocarbons that has the potential for commercial development
- Drill multiple wells if failure is local and not regional
- Determine how many targets to investigate
- Decide what data to gather
- Integrate newly-acquired and existing data
- Acquire open acreage, build land position
- Determine failure criteria & what outcomes trigger an exit
Eagle Ford Exploration

- Porosity
- Reservoir Pressure
- Reasonable well rates

12 Vertical Wells Average 50 Mbo Production

From EOG Investor Presentation, 2010
Project Stage: Exploration

Delineation

• Validate materiality—that the potential is sufficient to justify further investment
• Show that successive wells are as good or better than the discovery well.
• Confirm thickness, lateral continuity, and internal character with 2D seismic, well data
• Demonstrate that wells can be fracced and produce fluids with desirable characteristics
• Determine well count needed to meet a defined percent confidence of achieving some minimum average well rate
• Determine failure criteria & what outcomes trigger an exit
Eagle Ford Delineation

- Vertical wells cored, logged and used for microseismic
- Vertical wells offset by horizontal wells for appraisal

From EOG Investor Presentation, 2010
Project Stage: Appraisal

- Validate the ability to drill, complete, and produce hydrocarbons from individual horizontal wells at a rate/decline above some predetermined threshold
- Use consistent drilling/completion practices
- Identify areas of greatest productivity--will become the sites for demonstration projects
- Obtain key reservoir data (rates, pressures) to help quantify performance variability
- Determine well count needed to meet a defined percent confidence of achieving an average well rate that exceeds the threshold
- Determine failure criteria & what outcomes trigger an exit
Discussion at a Recent Conference....

• A completions engineer presented the results of a sand size trial in a shale reservoir where they pumped a 50-50 mix of 40/70 and 100 mesh sand to see how the wells compared to their traditional 40/70 completions.

• After the presentation he was asked what confidence do you have in the results of this trial? “I’m very confident”, he said, adding:
  • “The trial was done early when the shale was still pristine—we were just beginning to drill it up so there weren’t other variables interfering with you”

• Variables the engineer was thinking about: changes caused by earlier wells (stresses, depletion)

• Variables the engineer was not thinking about: TOC, thermal maturity, fractures, facies changes, porosity, perm, saturation, etc.
High-Grading with Appraisal Wells

Pressure Gradient (psi/ft)

Area 1
Area 2
Area 3

50 miles

Rate Distribution
Rate Distribution by Area
Mean Values by Area

Modified from Brad Berg’s 2013 SPE Distinguished Lecture Presentation
Examples of 5-Well Drilling Programs

P90 = 75, P10 = 750, Mean = 350, Threshold = 300
Let's randomly sample this distribution and generate frequency plots.

Log normal distributions are characterized by straight lines on log probability plots.
Confidence of Achieving Some Minimum Average of 5 wells ≥ 300 bopd 54% of the time

These plots allow us to determine the percent of simulated outcomes that are ≥ 300 bopd for 1, 5, and 25-well programs

1 well ≥ 300 bopd 39% of the time

Average of 25 wells ≥ 300 bopd 72% of the time
Confidence Curves

Assuming a P10/P90 ratio of 10, if we drill a 5-well program, there will be a 54% chance that the average from these wells will exceed our threshold rate of 300 stb/d.

To increase this chance to 80%, we’d have to drill 44 wells.
Project Stage: Demonstration

• Validate that you have a commercially viable project above a prescribed confidence level
• May need multiple demonstration projects
• Determine the well count required to meet the prescribed confidence level
• Confirm type curve(s) and ensure that expected cost improvements are achievable
• Determine the well spacing that maximizes project value
• Use sequential aggregation plots to track performance vs forecast for major elements
• Determine failure criteria & what outcomes trigger an exit
Sequential Aggregation Plot

Showing Best 3 Month Average Gas Rate for 31 Wells Compared to Forecasts
Project Stage: Development

- Proceed if the expected results are competitive with other opportunities in your company’s portfolio
- As development drilling expands, ensure that results from new wells continue to meet expectations
- Use continuous learning and KPIs to reduce costs, optimize well spacing and maximize production & reserves
- Synchronize pad construction, well drilling, completion, fluid gathering and processing to maximize profitability
Hereford Field Example (Niobrara Fm)

1 Year Cumulative Production for 3 Early Wells

Jake 2-01H = 70,410 bbls
Elmer 8-31H = 53,413 bbls
Red Poll 10-16H = 88,157 bbls

From “A Short History of the “Jake” Niobrara Horizontal Oil Discovery…”, Mountain Geologist, July 2015
Production data from the Colorado Oil and Gas Conservation Commission
Hereford Field Example (Niobrara Fm)

1 Year Cumulative Production for 3 Early Wells

Jake, Elmer and Red Poll Wells
Mean = 75,000 bbls
P10/P90 ratio = 2.0

Production data from the Colorado Oil and Gas Conservation Commission
Hereford Field Example (Niobrara Fm)

1 Year Cum. Production for 3 Early Wells + 59 Later Wells

Remaining 59 Wells
Mean = 41,000 bbls
P10/P90 ratio = 7.4

Jake, Elmer and Red Poll Wells
Mean = 75,000 bbls
P10/P90 ratio = 2.0

Production data from the Colorado Oil and Gas Conservation Commission
Hereford Field Example (Niobrara Fm)

Cumulative Production Through 2016

Remaining 59 Wells
Mean = 82,000 bbls
P10/P90 ratio = 11.1

Jake, Elmer and Red Poll Wells
Mean = 186,000 bbls
P10/P90 ratio = 1.05

Production data from the Colorado Oil and Gas Conservation Commission
Hereford Field Example (Niobrara Fm)
Cumulative Production Comparison

Cumulative Production for
3 Early Wells
Jake 2-01H = 187 M bbls
Elmer 8-31H = 188 M bbls
Red Poll 10-16H = 182 M bbls

Cumulative Production for
59 Later Wells
• 2 wells: > 300 M bbls
• 4 wells: 200-300 M bbls
• 10 wells: 100-200 M bbls
• 11 wells: 50-100 M bbls
• 32 wells < 50 M bbls
• P10/P90 ~ 11

Mean Cumulative Oil Per Well ~ 87 M bbls
At $80 oil, need 42.5 M bbls to cover a well cost of $3.4 MM

Production data from the Colorado Oil and Gas Conservation Commission
The Staged Approach

Stage 1: Exploration
Stage 2: Appraisal
Stage 3: Demonstration
Stage 4: Development

Why is it so difficult to consistently implement this process?

Development Success

Development Failure

Portfolio Competitive

Commercial (PV > 0)

Recover Cost

Demonstration Success

Appraisal Failure

Exit

Capital at Risk

Exploration Success

PG

Exploration Failure

PA

Exit

Exit

Exit
The Assurance Process

- **Standards** such as minimum economic metrics and project size
- **Guidelines** including use of the staged approach
- **Workflows** that are discipline specific and tied to the staged decision tree, sets of deliverables, and KPIs
- **Peer assists** conducted with an independent external prospective to help ensure projects are properly focused
- **Documentation** to create a record of what was planned, predicted, and actually achieved
- **Lookbacks** to calibrate the outcomes and make changes that result in closer correspondence between what’s promised and delivered in the future
The Role of the Assurance Team in a Staged Evaluation

- **Executive Team**: Project Selection and Funding
- **Mgmt Team**: Proposal Review & Approval
- **Assurance Team**: Independent Risk & Uncertainty Assessment
- **Project Team**: Technical Assessment
- **Technical Assessment & Calibration**
- **Independent Risk & Uncertainty Assessment**
- **Proposal Review & Approval**
- **Feedback to Commercial & Exec Teams**
- **Post Develop. Assessment & Look Back**
- **Feedback to Technical Teams**

- **Y/N**

- **Proposal Review & Approval**
- **Project Selection and Funding**
- **Implementation**
- **Feedback to Technical Teams**
Key Questions for Decision Makers to Ask

• What is the source of the numbers that justify the recommendation?

• Does the recommendation assume that an approach that is successful in one area will be just as successful in another?

• Is there an over-attachment to a history of past decisions or to a rare but memorable success?

• Is the base case too optimistic? Too pessimistic?

• Were there dissenting opinions leading up to the recommendation? How was this resolved?

• If we delay a decision on this project for one year, what data would you gather in the interim and what impact could this have?
“If I had one wish, it is to see organizations dedicating some effort to study their own decision processes and their own mistakes, and keep track so as to learn from those mistakes.”

Daniel Kahneman – “Thought Leader” by Michael Scrage
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Thank You! Questions?

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