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CHARACTERIZING SHALE PLAYS

The Importance of Recognizing What You Don't Know

SPE 2013-2014 Distinguished Lecturer Series

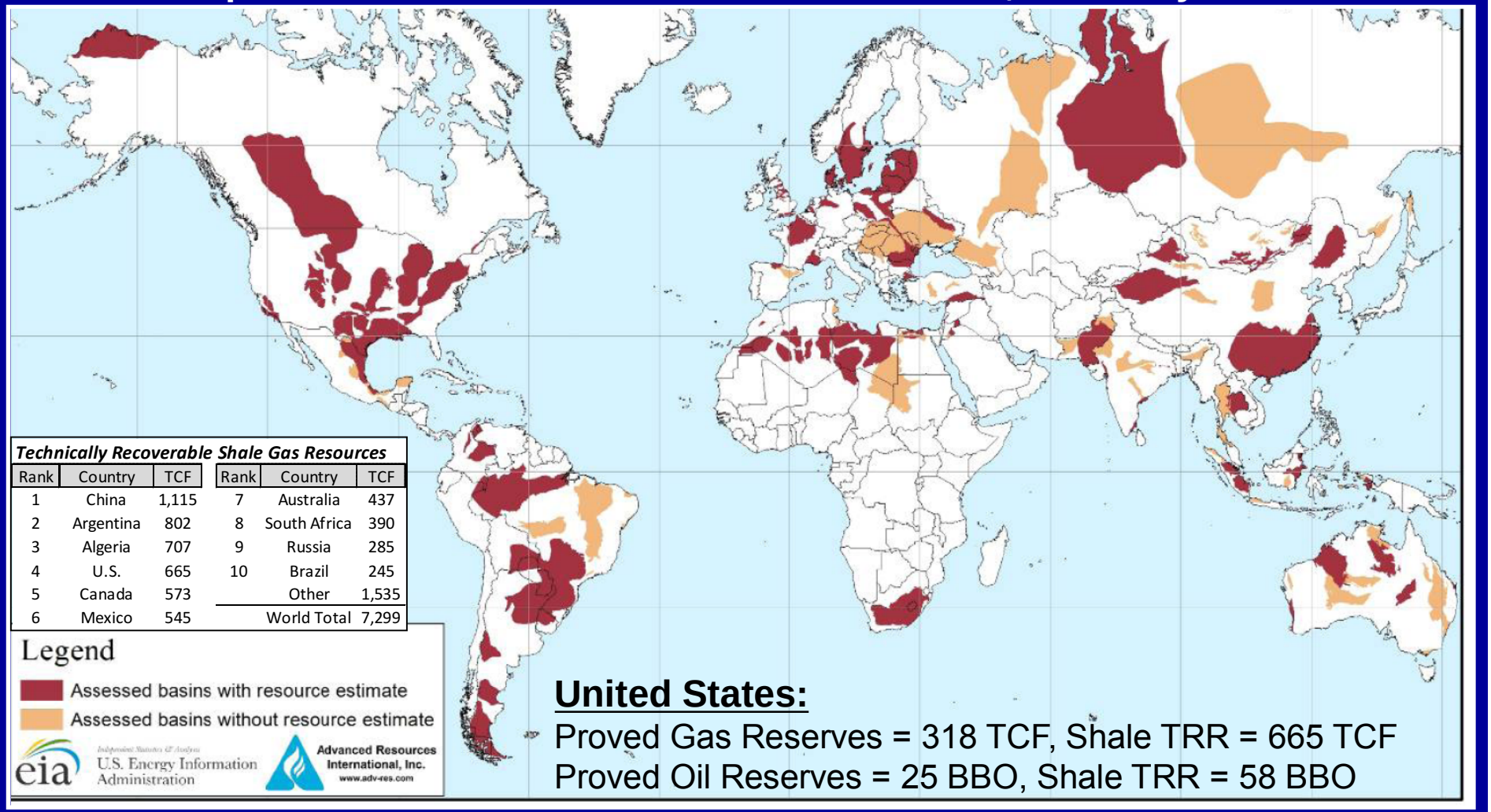
Brad Berg

Outline

- Huge Global Resource
- Shale Play Characterization Challenges
- Incorporating Uncertainty into Assessments
- The Impact of Decision Behavior
- Conclusions

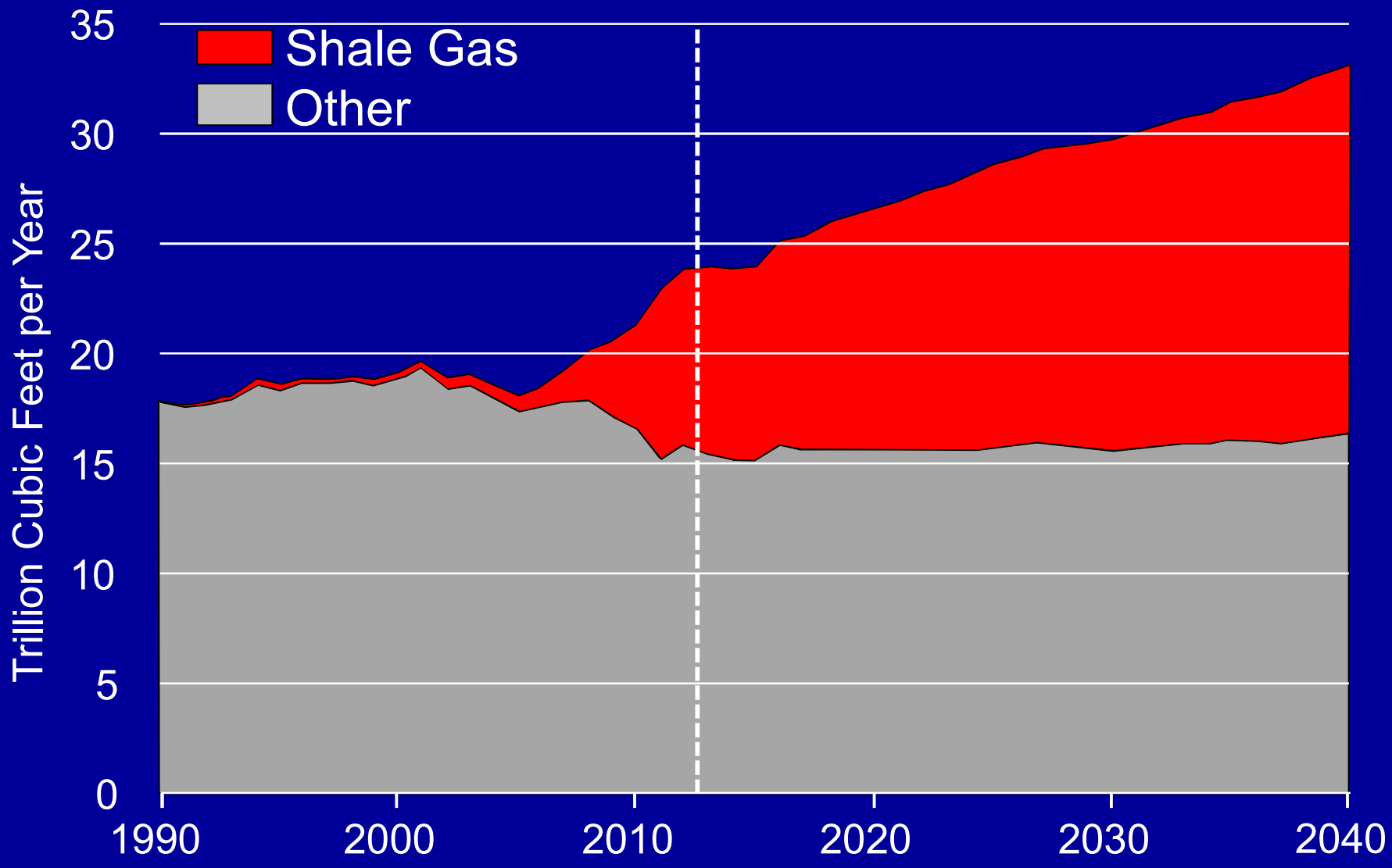
Global Shale Gas Resource: 7,300 TCF (~200 TCM)
Global Shale Oil Resource: 345 BBO

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



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.

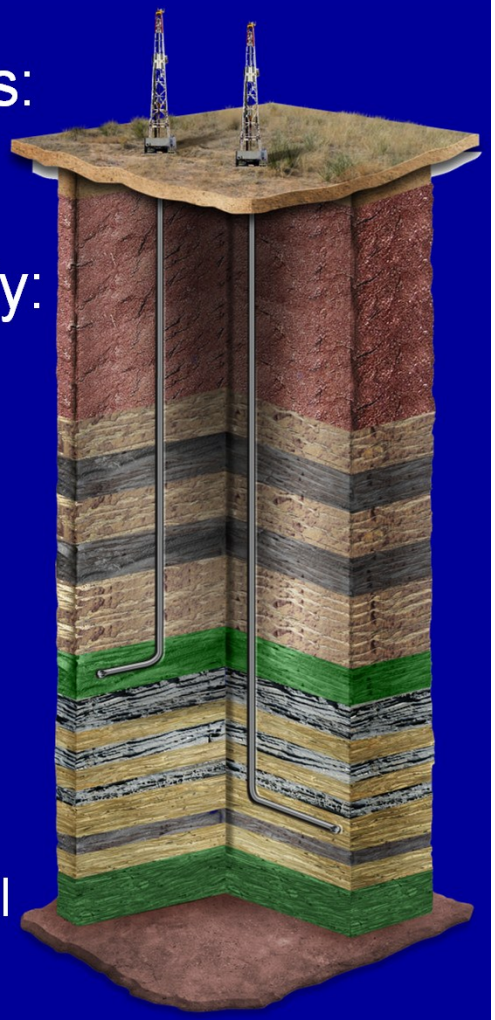
U.S. Natural Gas Production Forecast



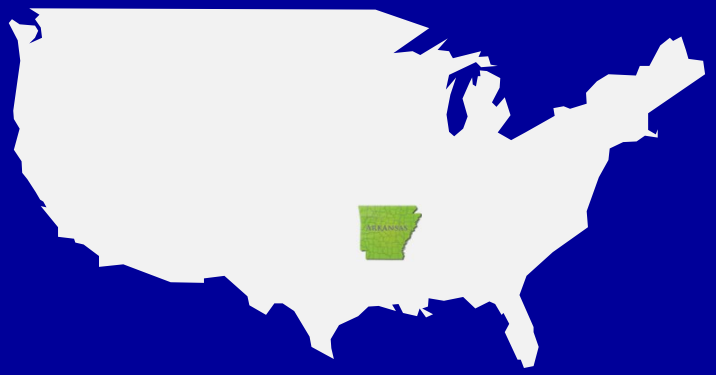
Source: EIA 2013 Early Release Overview

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**



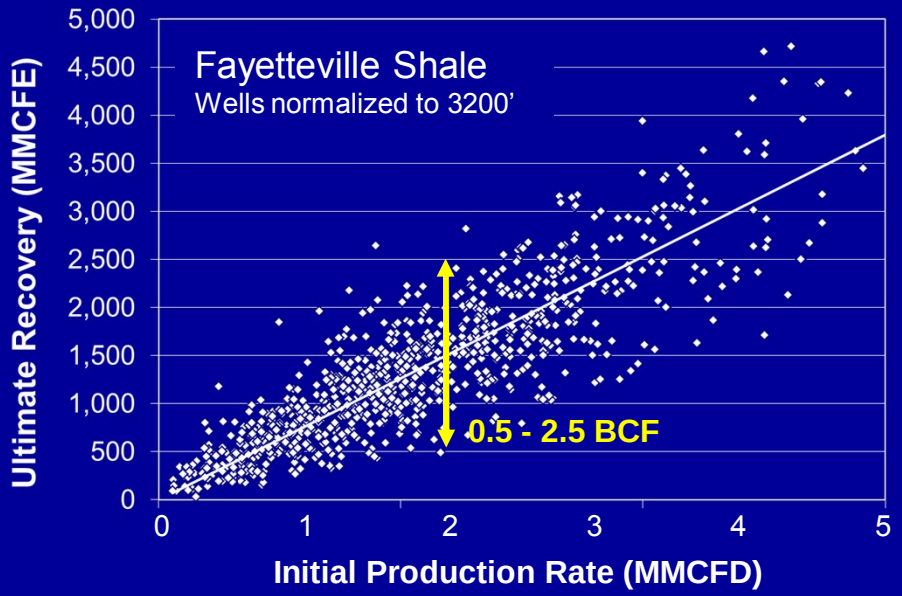
Fayetteville Shale Play



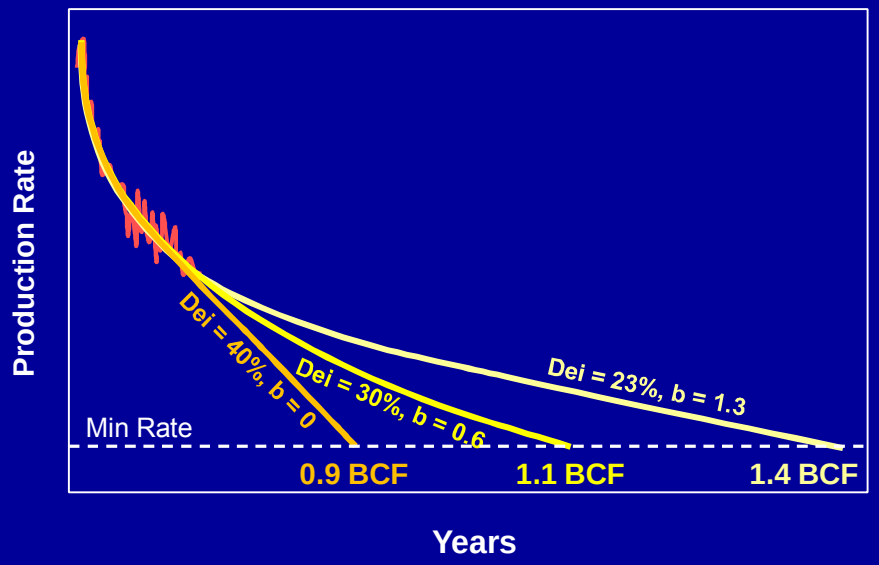
- One of the oldest shale targets, drilling began in 2004
- Mississippian-age shale at 1,500 to 6,500 foot depth
- Over 4000 wells drilled
- Examined 933 wells with extended production history
- Production forecasts ‘normalized’ to same completed horizontal length

Challenges to Forecasting Production

IP as a Predictor of EUR



Early Production as a Predictor of EUR

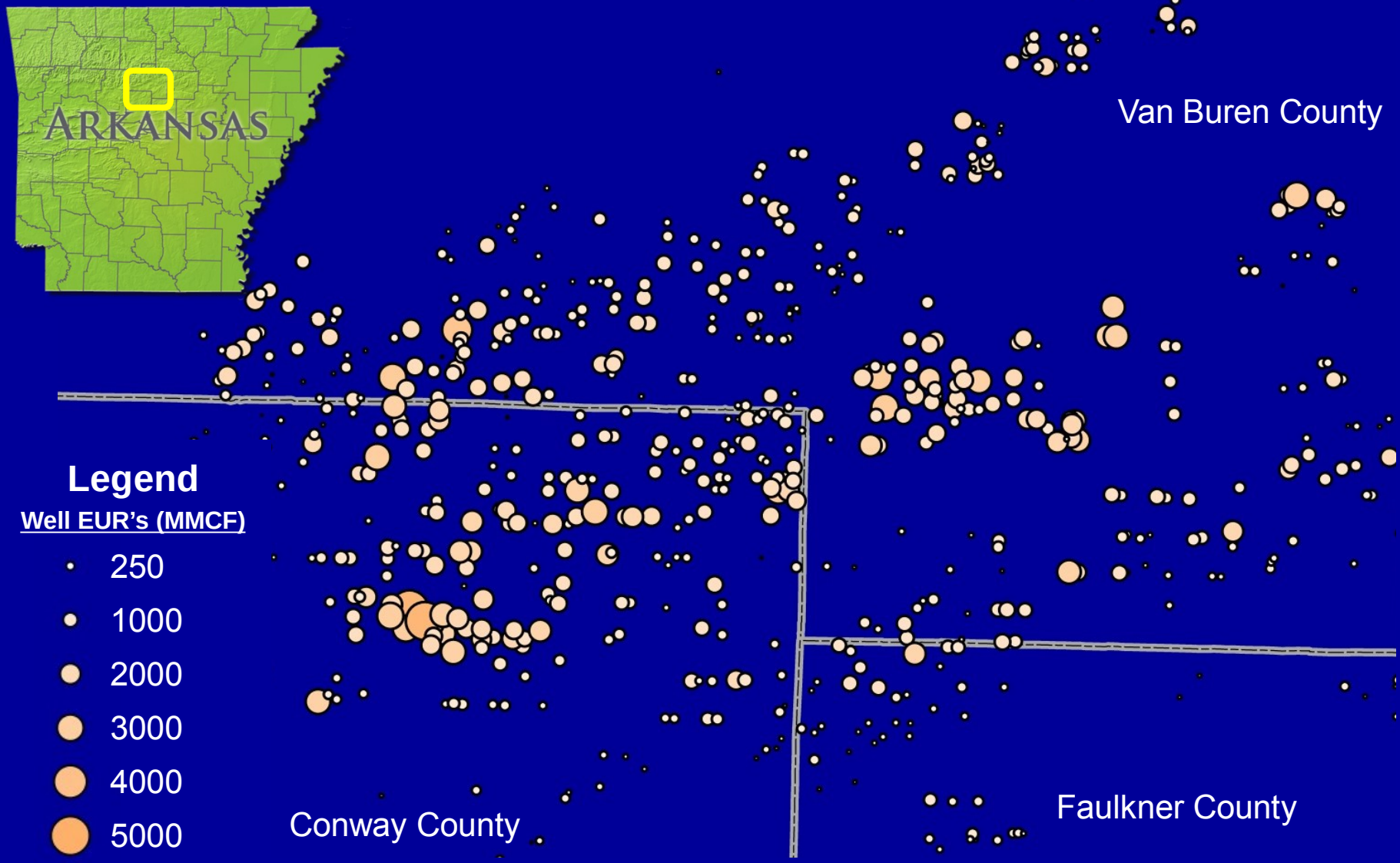


- **How long of a production period do we need from each well?**
  - **3 - 6 months after cleanup to estimate initial decline rate**
  - **12 - 36 months after cleanup to estimate hyperbolic behavior (b factor)**

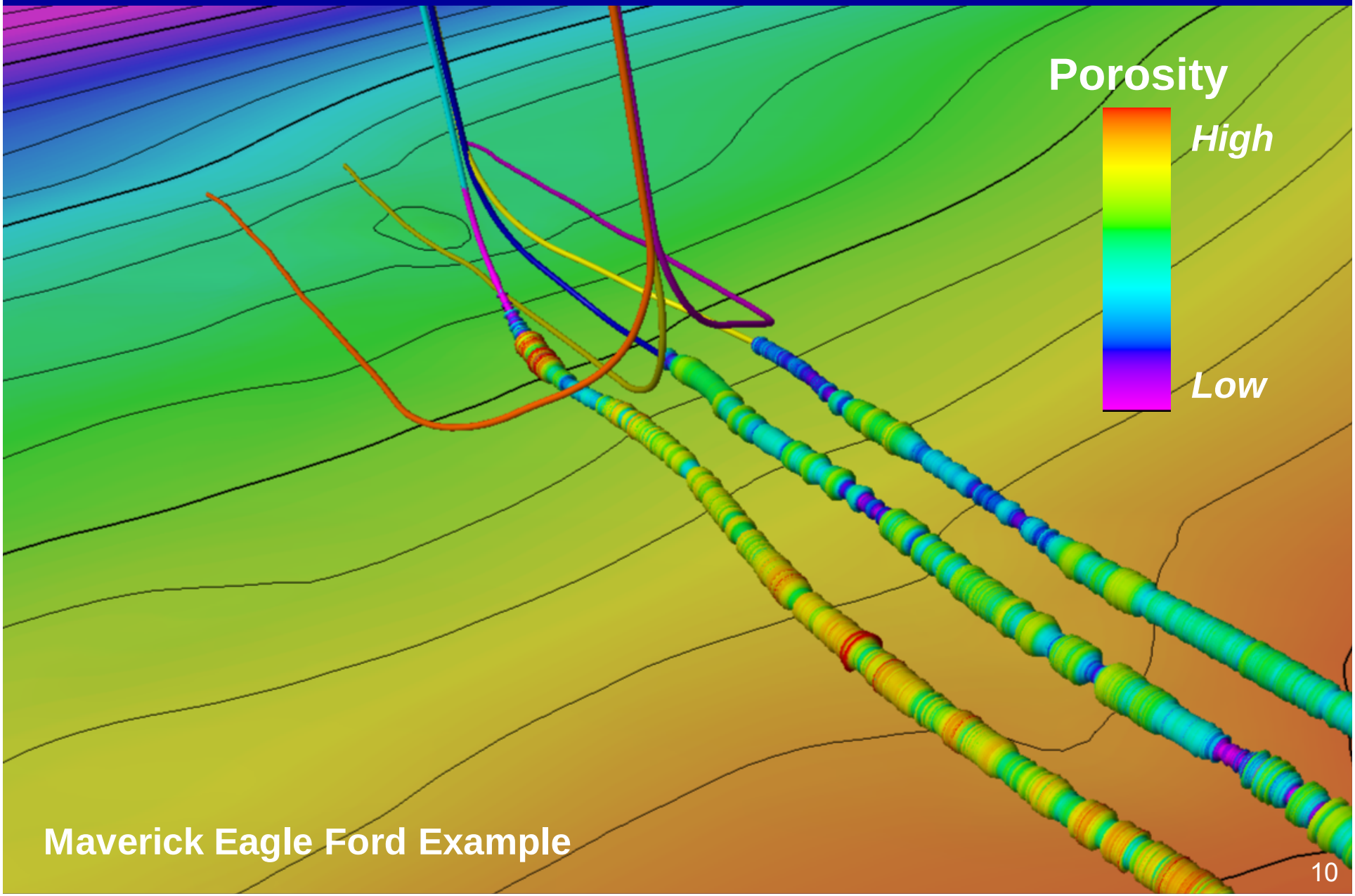
Challenges to Predicting Reservoir Performance

Fayetteville Shale Play

Well EUR's normalized to 3200' average lateral length



Challenges to Predicting Reservoir Performance



Maverick Eagle Ford Example

Challenges to Predicting Reservoir Performance

Fayetteville Shale Play

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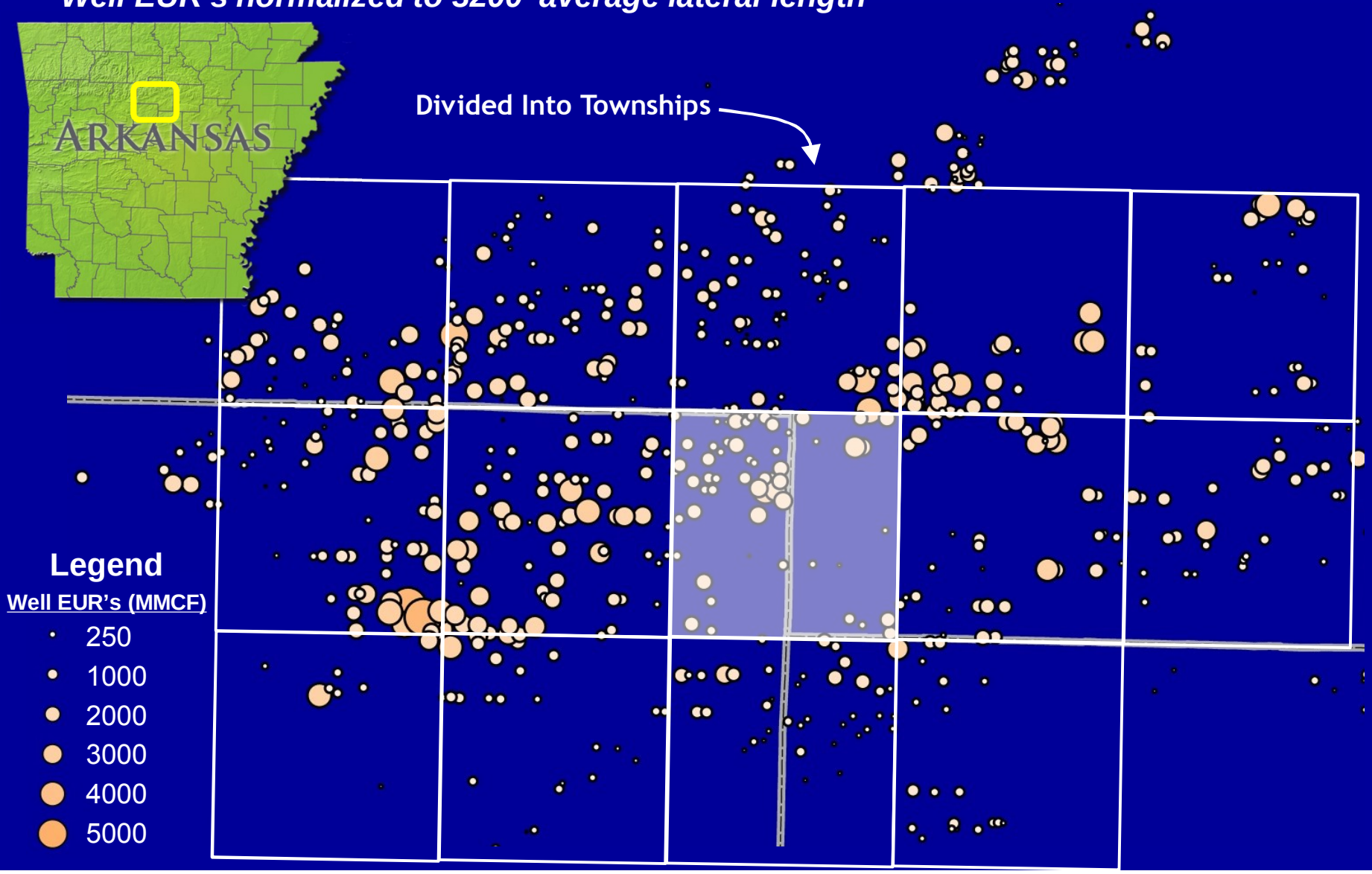
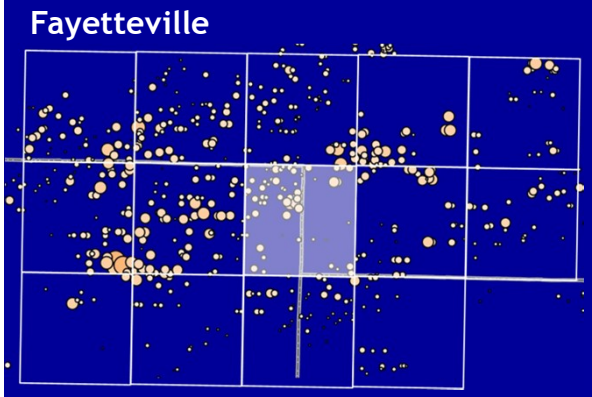
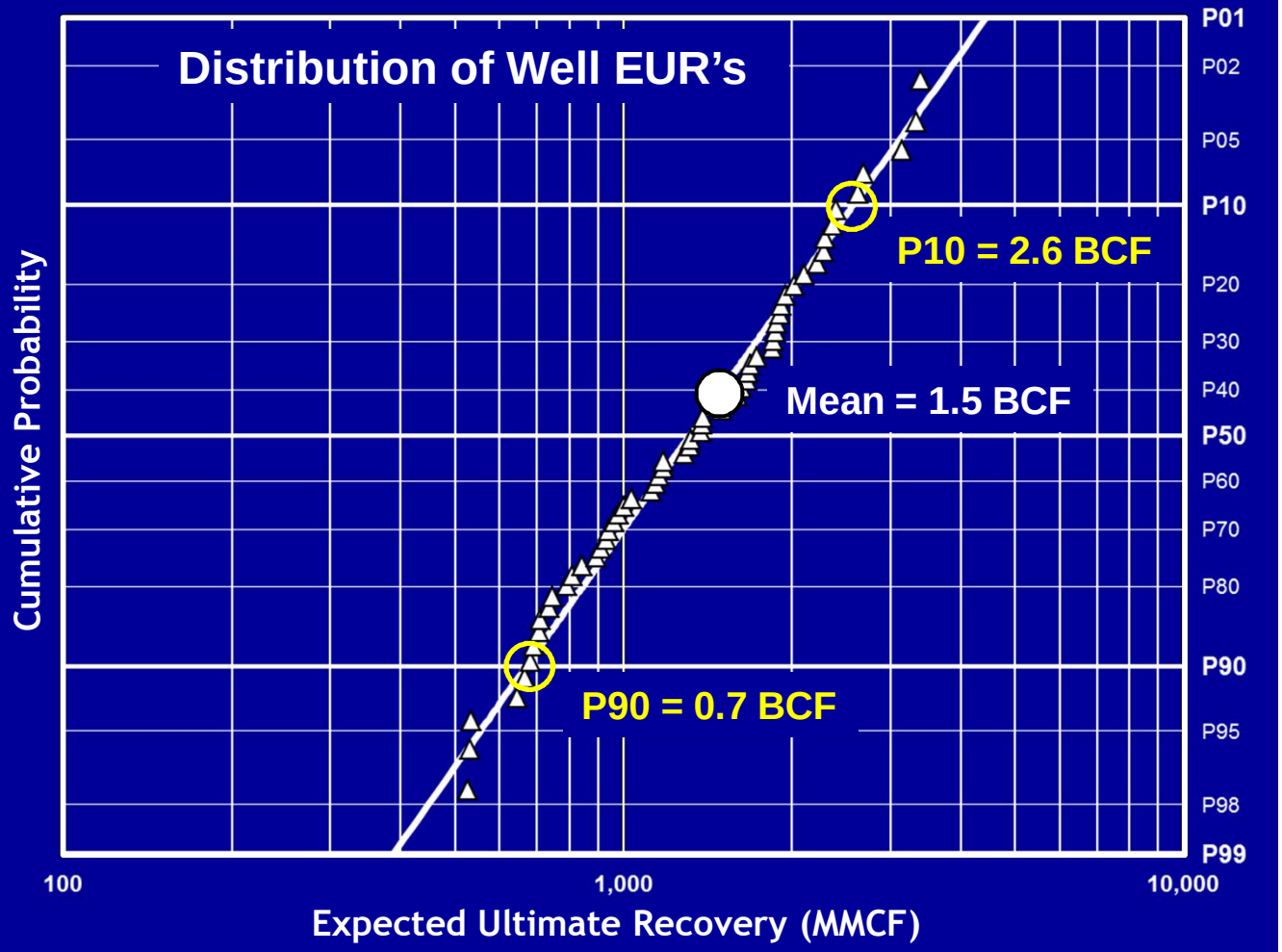


Measuring Uncertainty in Well Performance

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

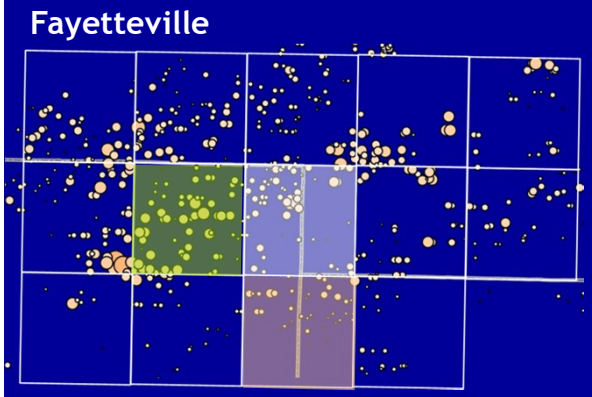


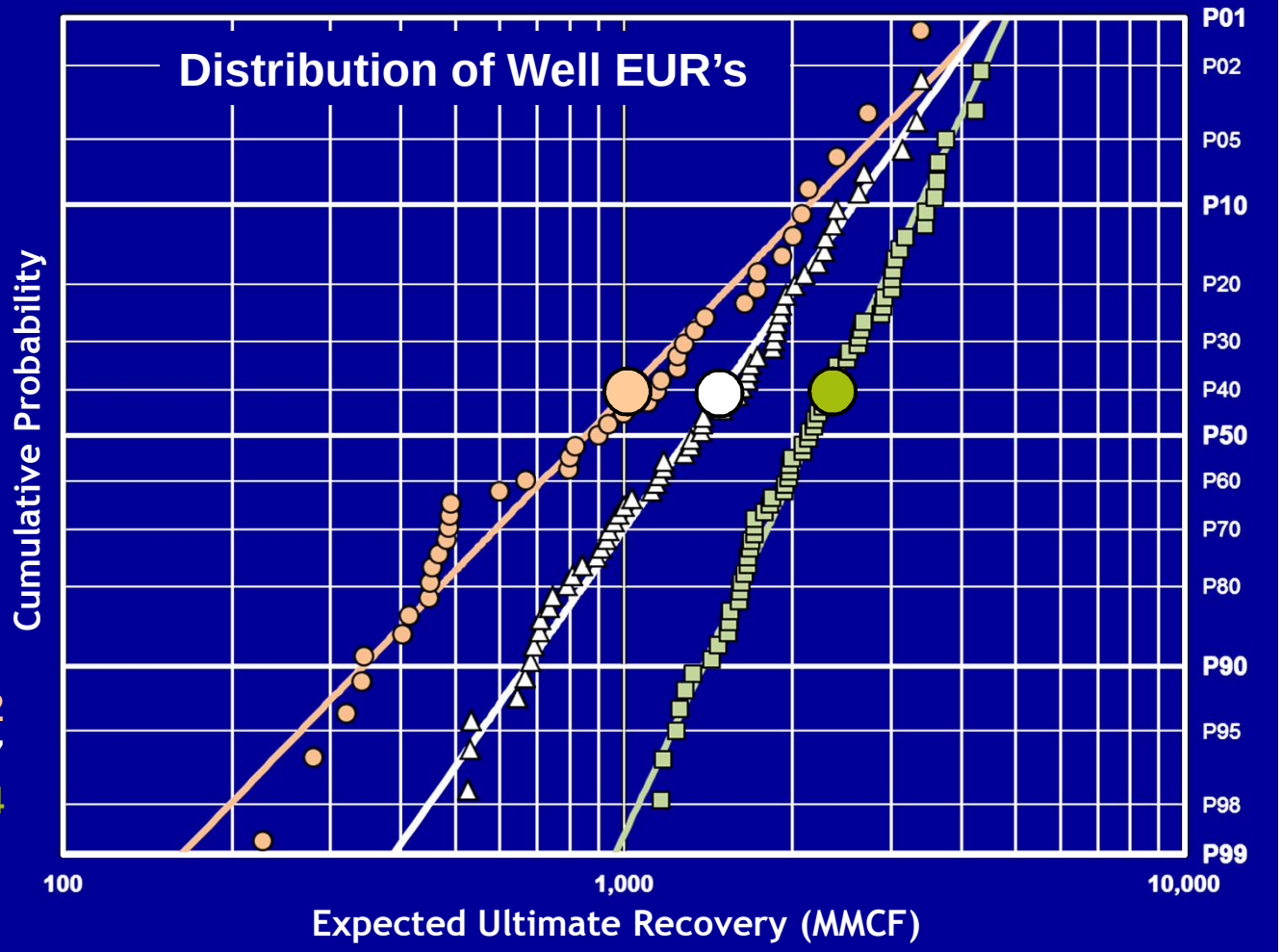


P10/P90 = 2.6 / 0.7 = 3.7

Measuring Uncertainty in Well Performance

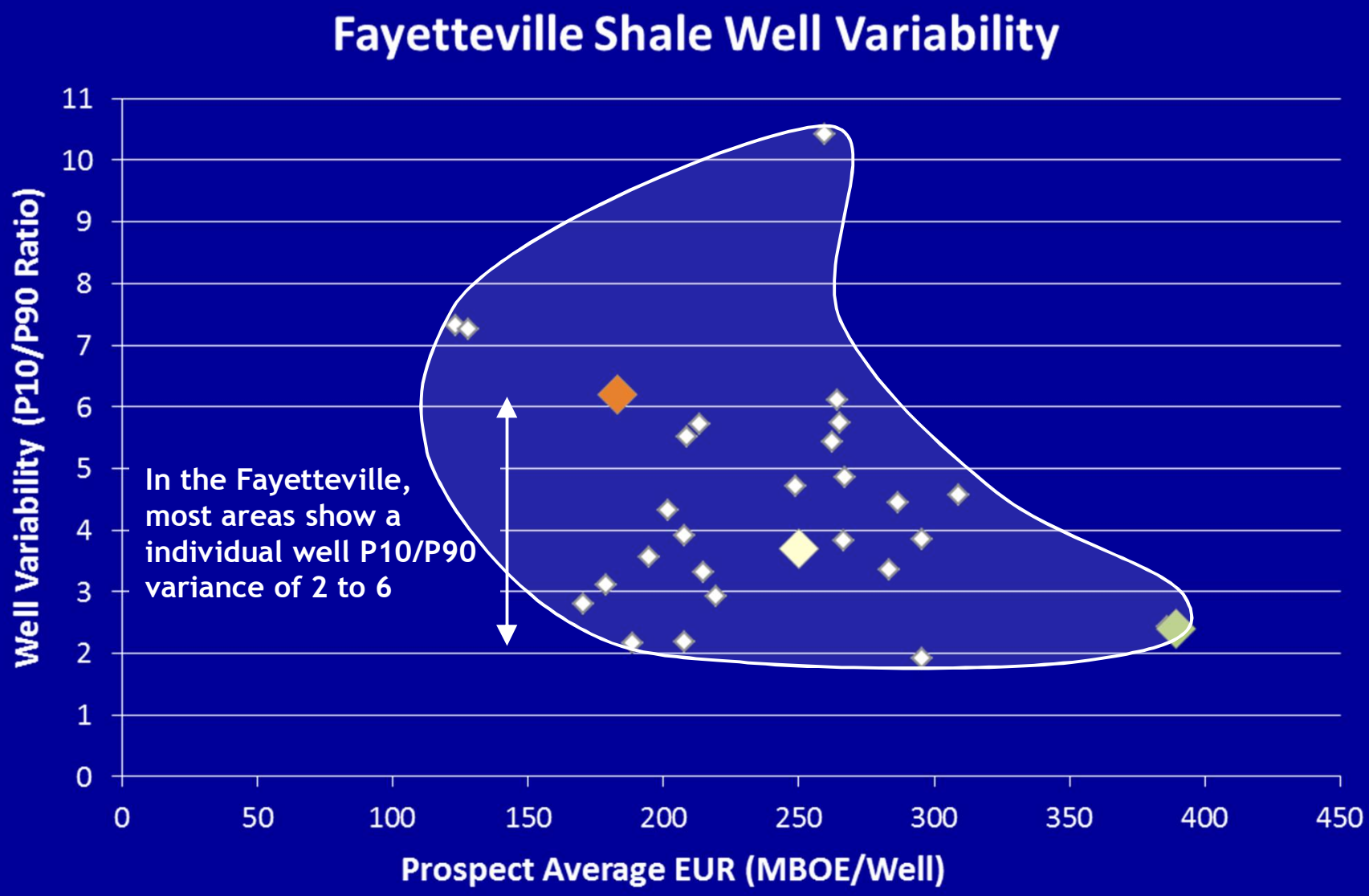
- Average well performance by area



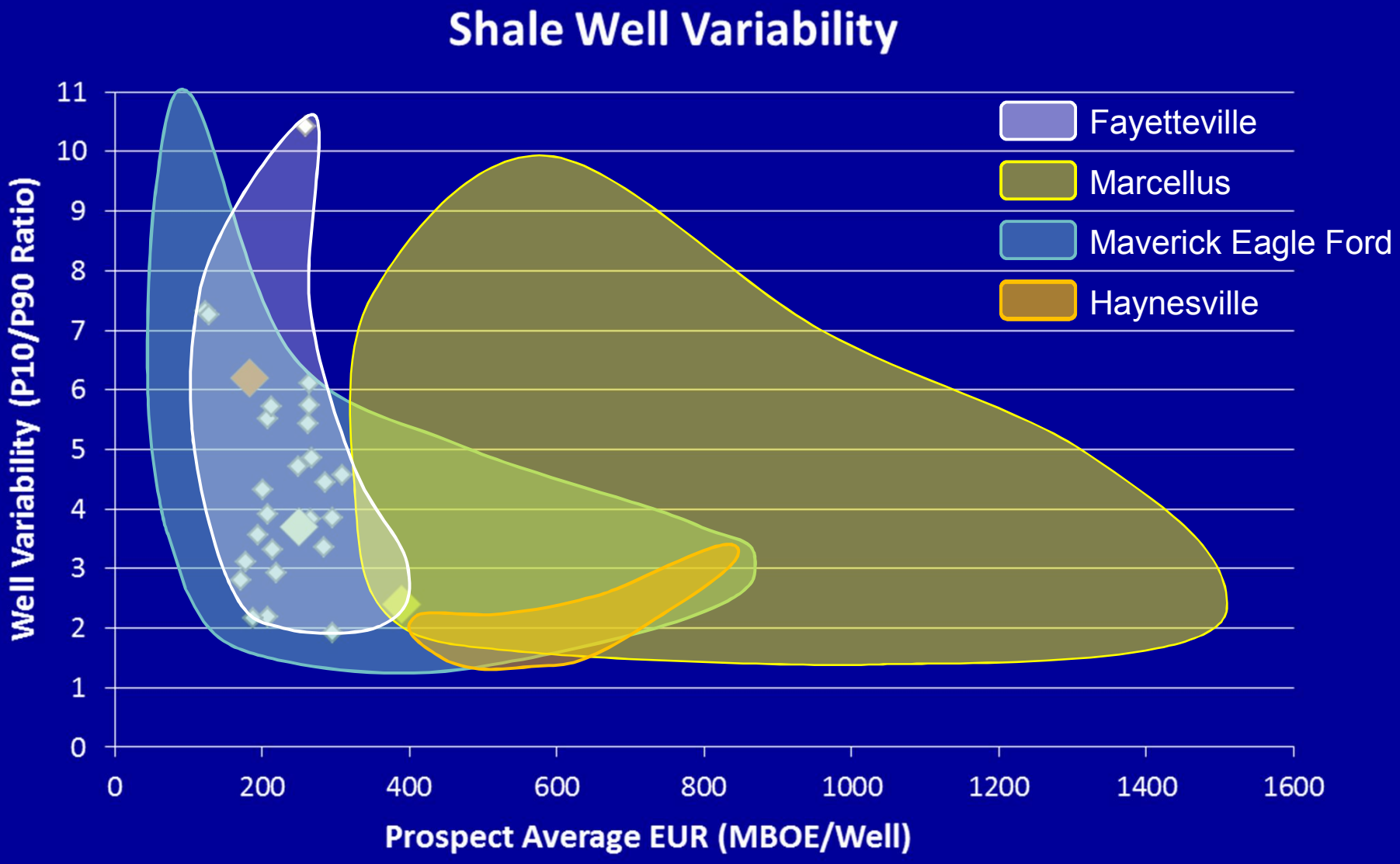


Mean = 1.1 BCF, P10/P90 = 6.2
Mean = 1.5 BCF, P10/P90 = 3.7
Mean = 2.3 BCF, P10/P90 = 2.4

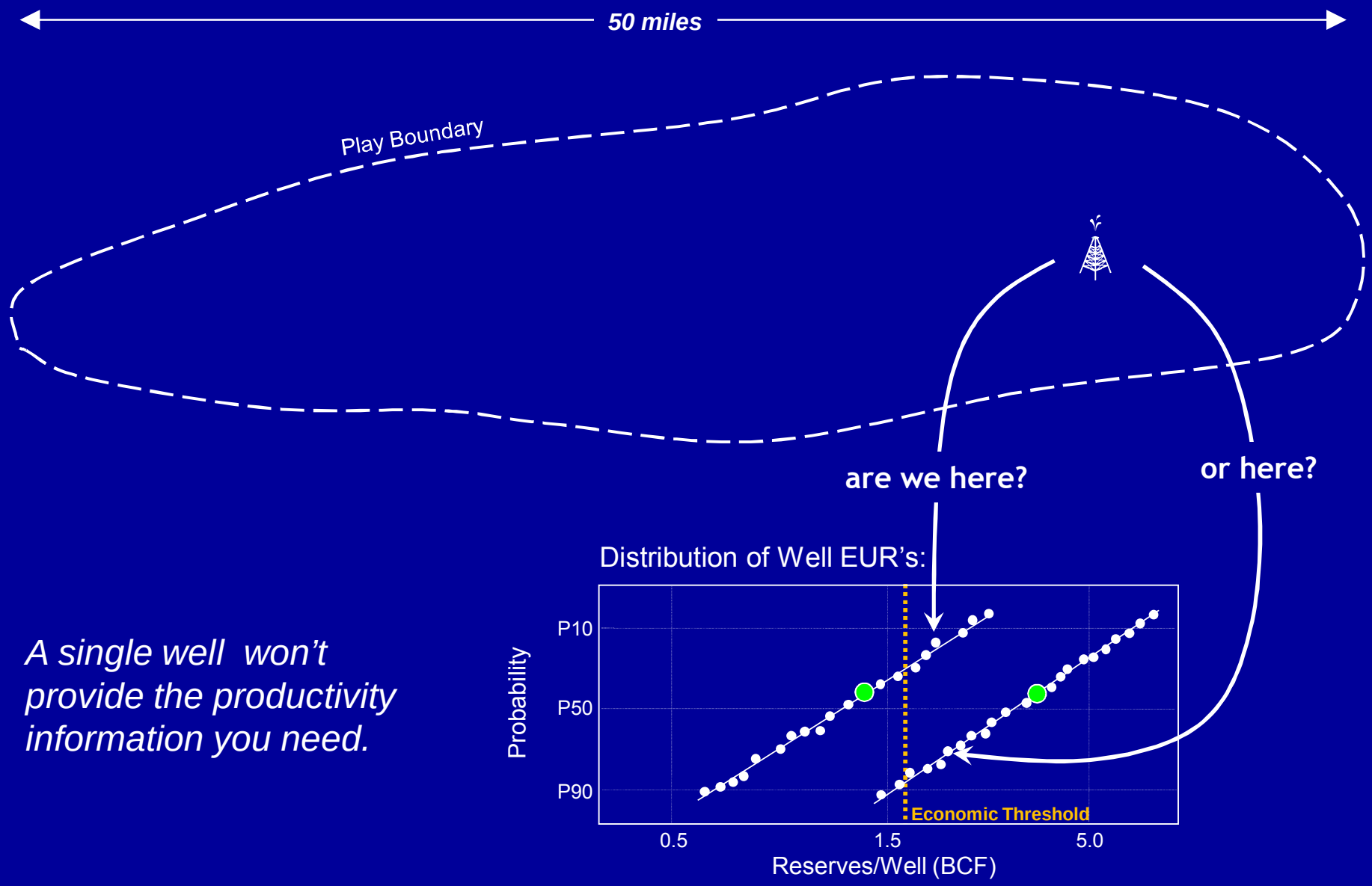
Well Performance Uncertainty in Shale Plays



Well Performance Uncertainty in Shale Plays

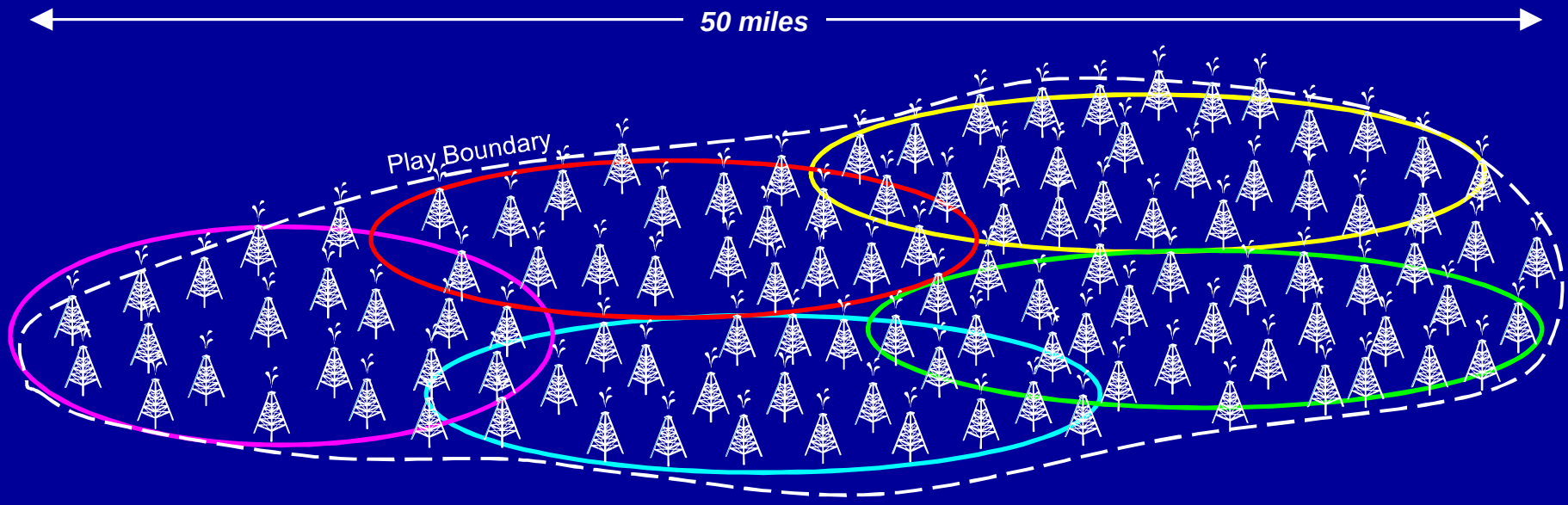


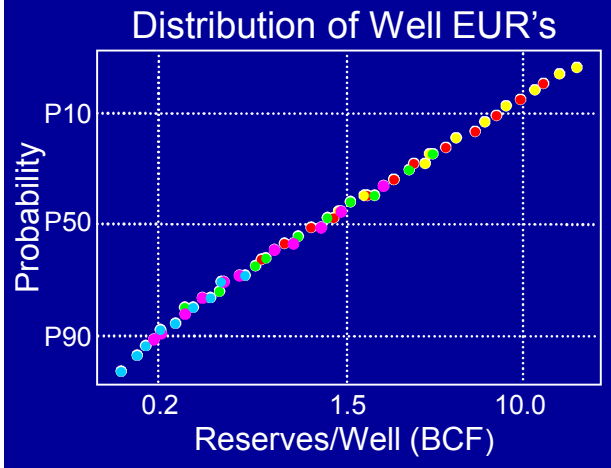
Characterizing a Shale Play

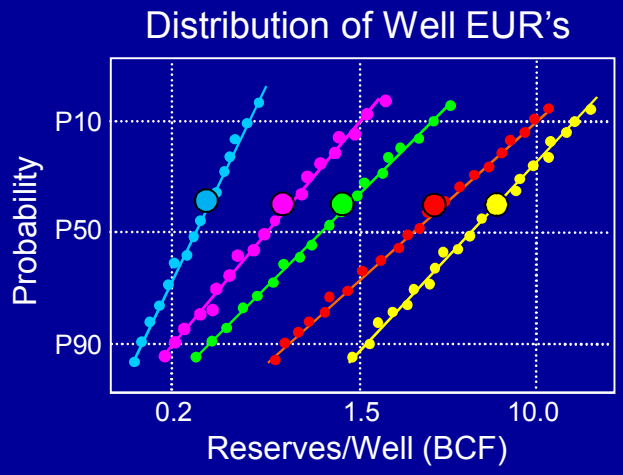


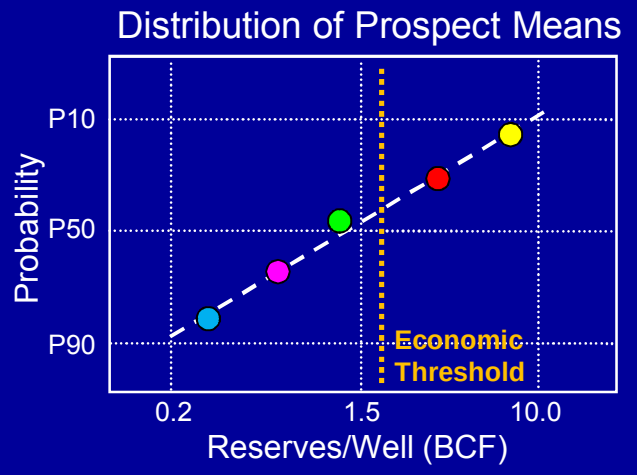
A single well won't provide the productivity information you need.

Characterizing a Shale Play







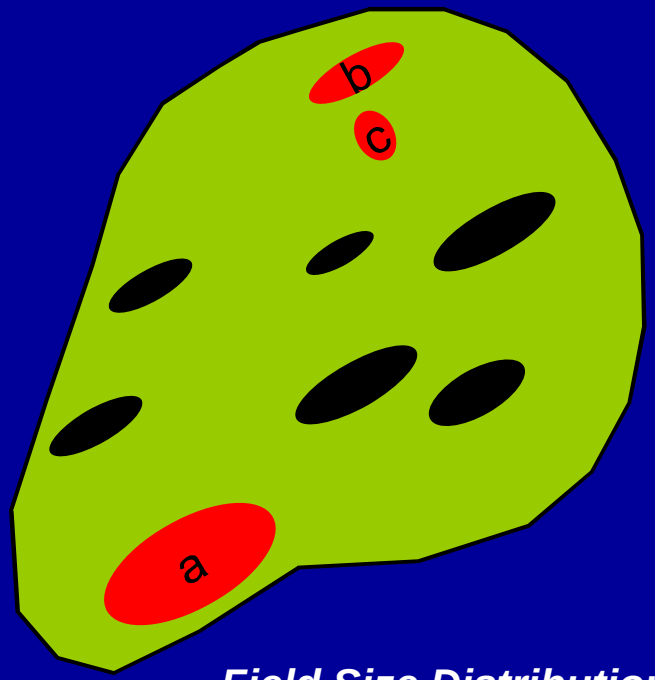


Planning an Exploration Program

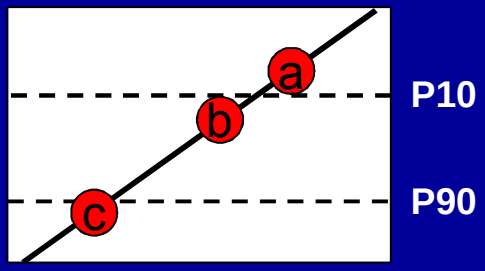
- What defines a prospect area?
- What variability should I use to predict well performance?
- How many wells should I drill in each prospect area?
- What defines the “encouragement” needed to continue drilling?

What Defines a Prospect Area?

Conventional

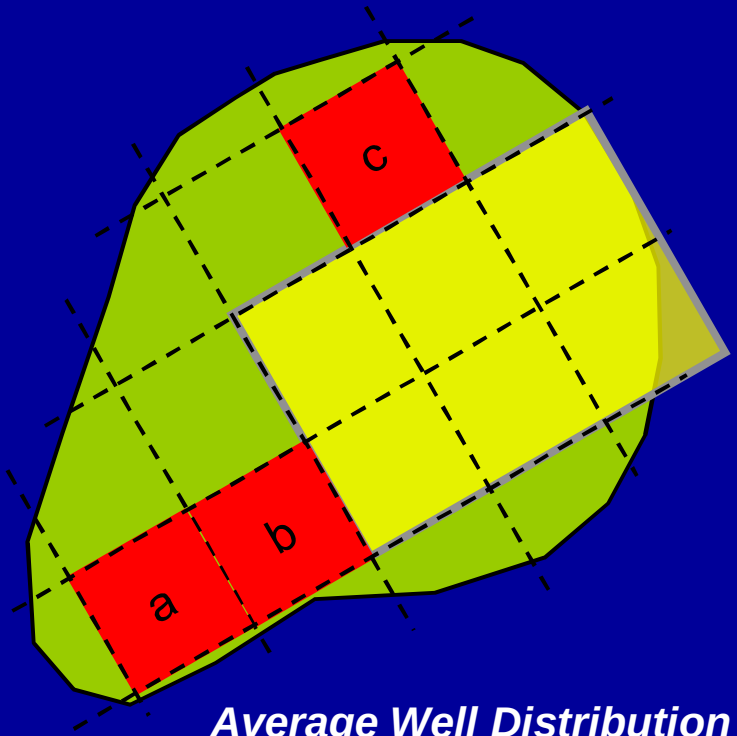


Field Size Distribution

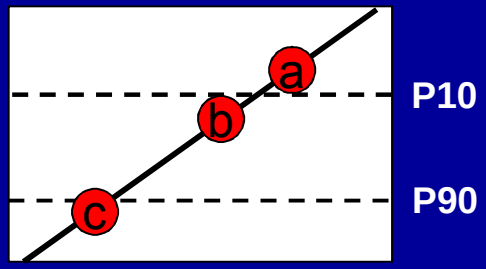


Total Reserves

Unconventional



Average Well Distribution

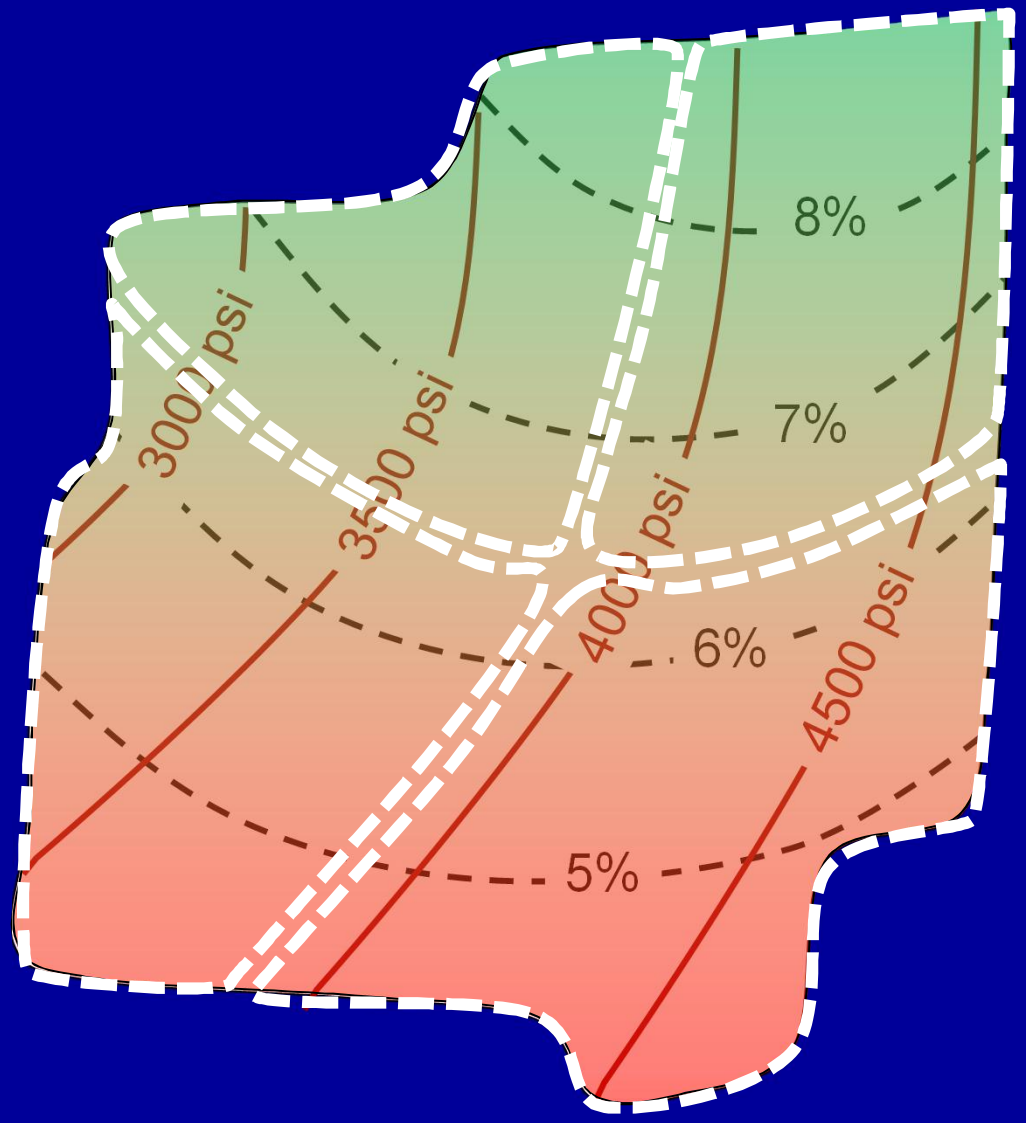


Reserves/Well

What Defines a Prospect Area?

Productivity Drivers:

- Reservoir Quality
  - Porosity
  - Matrix Permeability
  - Water Saturation
  - Natural Fractures
- Pressure
- Maturity
  - Fluid Type



Planning an Exploration Program

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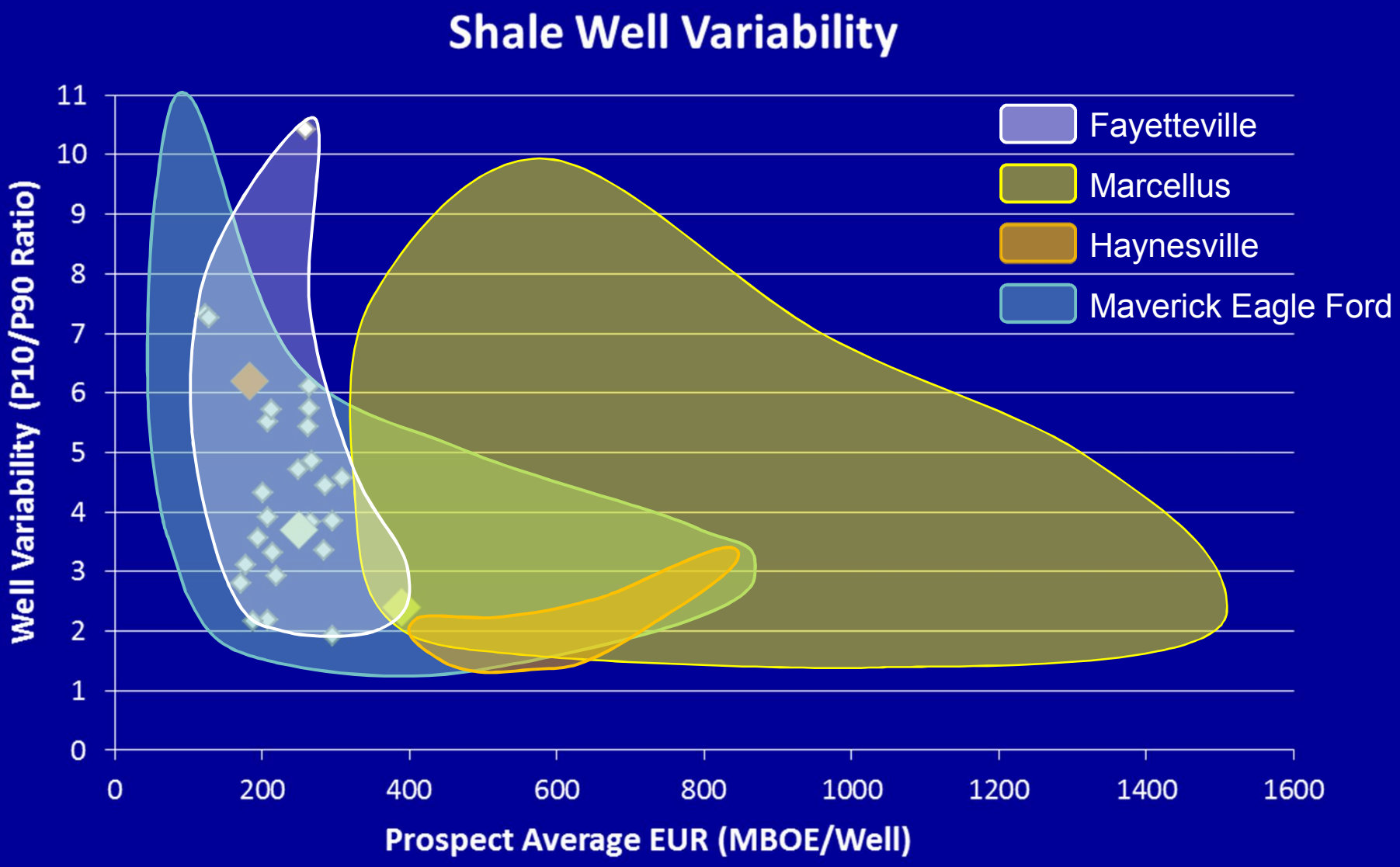
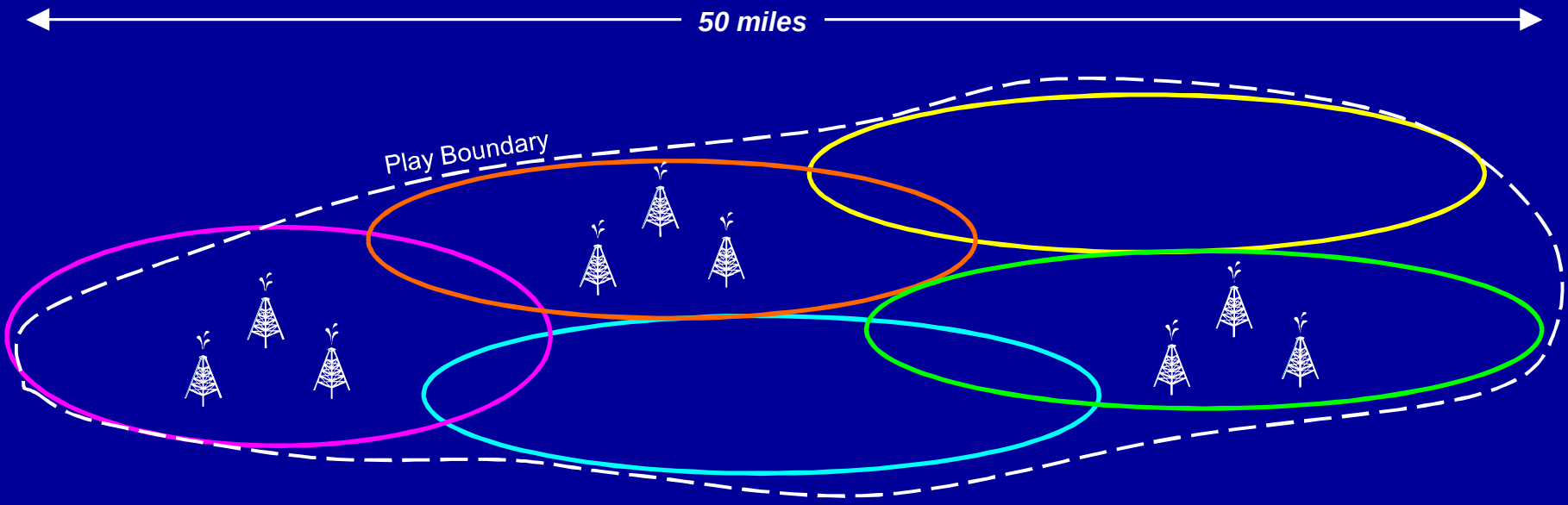
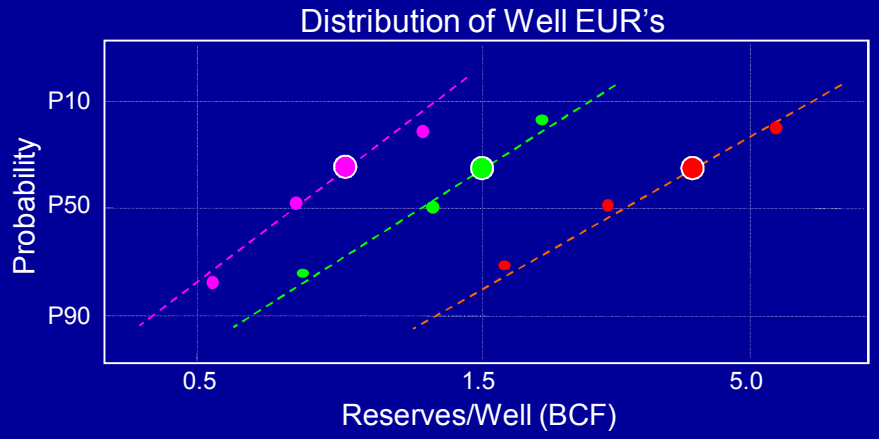
Analog Well Performance Uncertainty



Testing a Shale Play





Planning an Exploration Program

- What defines a prospect area?
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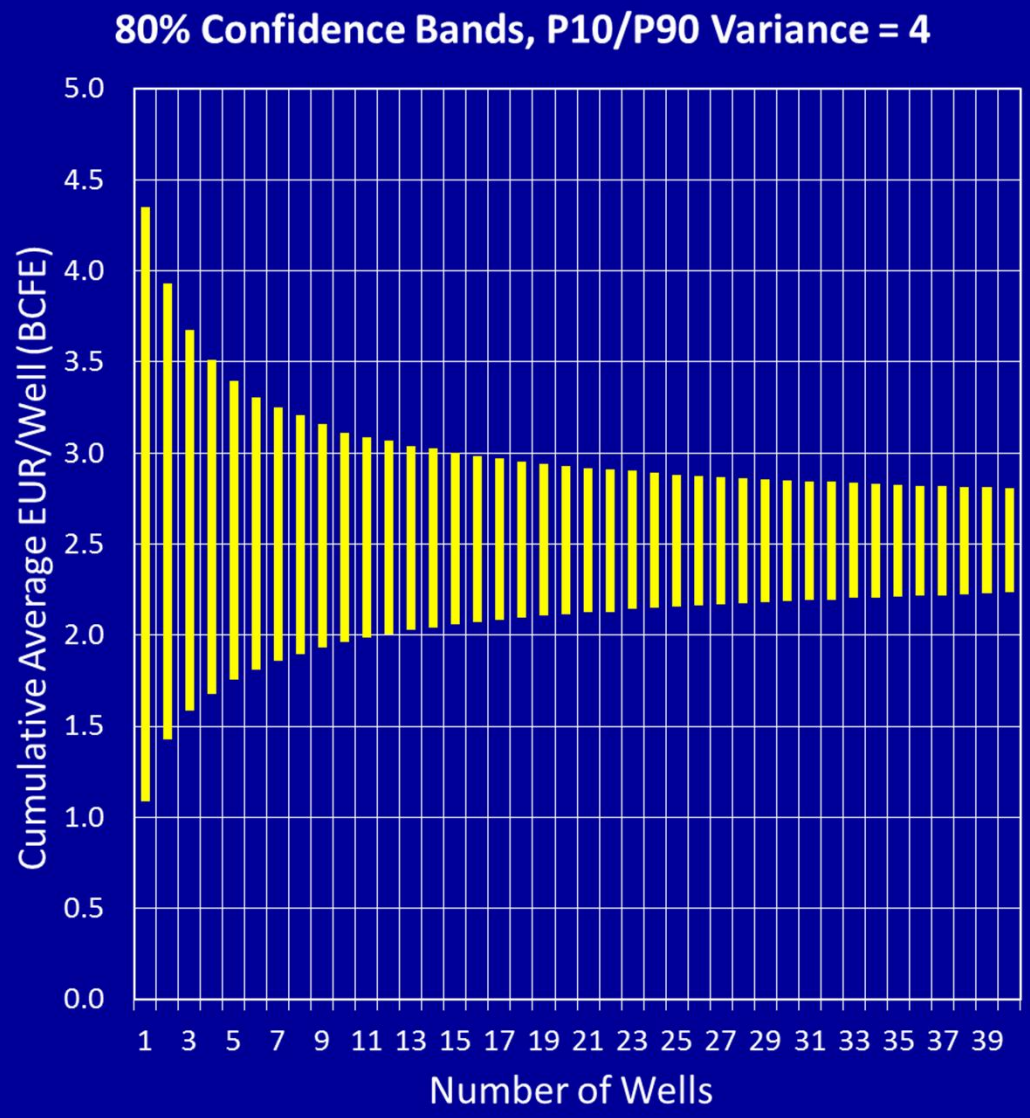
Confidence Range Versus Well Count

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

Predicting EUR's:

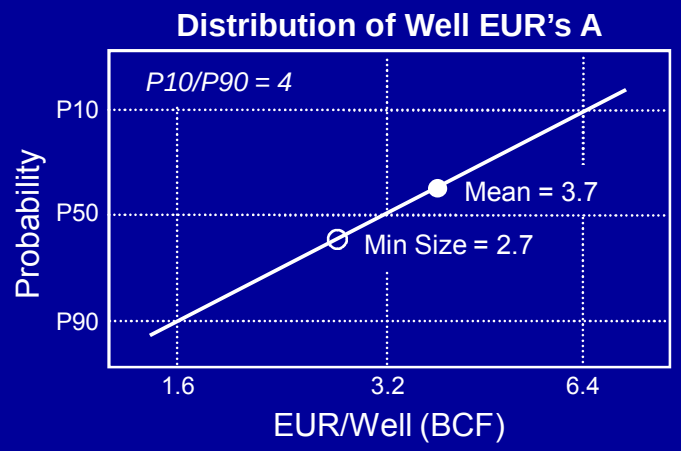
- Modeled wells from prospect:
  - Average EUR/well = 2.5 BCF
  - P10/P90 = 4
  - Sampled the distribution 10,000 times

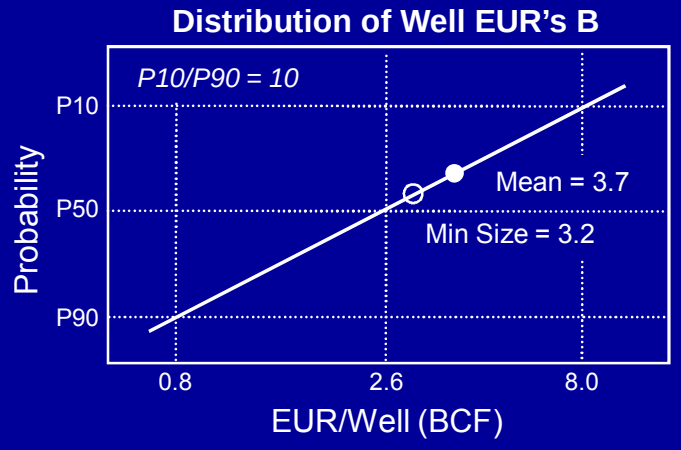
- For P10/P90 = 4:
  - 1 Well = 1.1 - 4.3 BCF/well
  - 3 Wells = 1.6 – 3.7 BCF/well
  - 10 Wells = 2.0 – 3.1 BCF/well

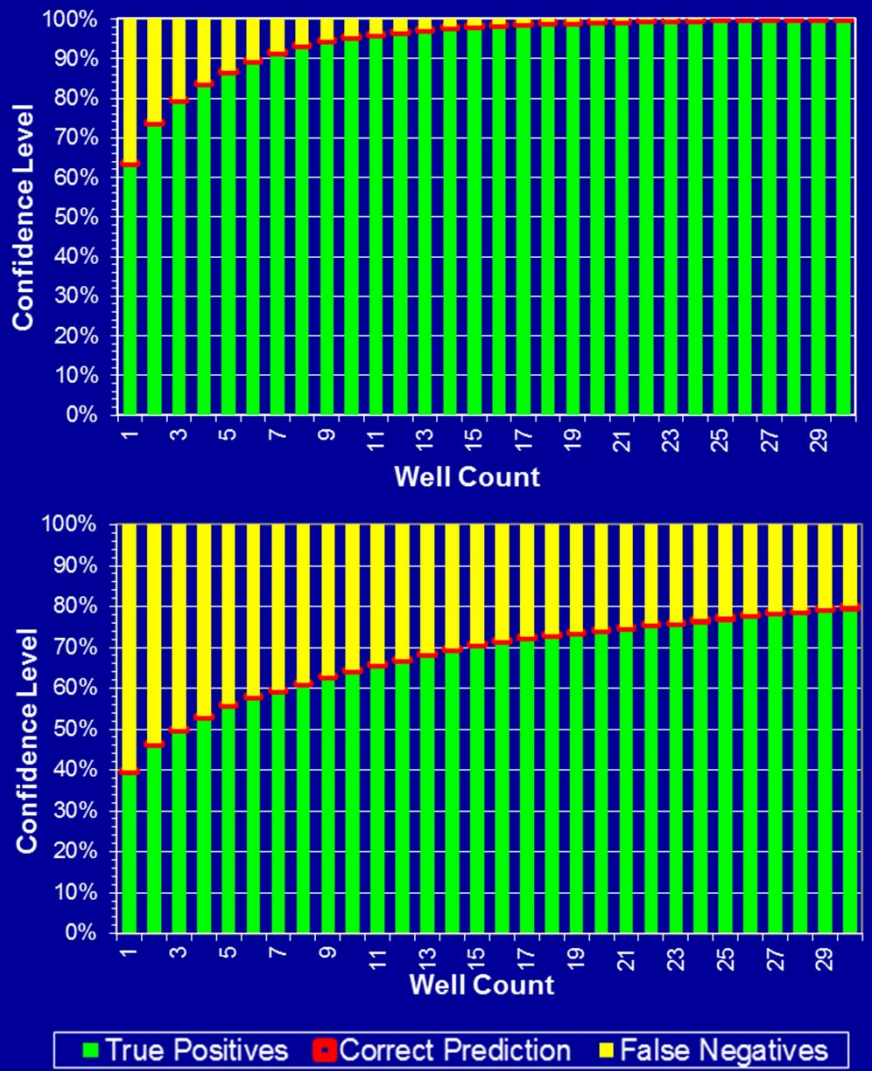


Designing An Exploration Pilot

- 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?
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- How many wells should I drill in each prospect area?
- What defines the "encouragement" needed to continue drilling?

What Defines Encouragement?

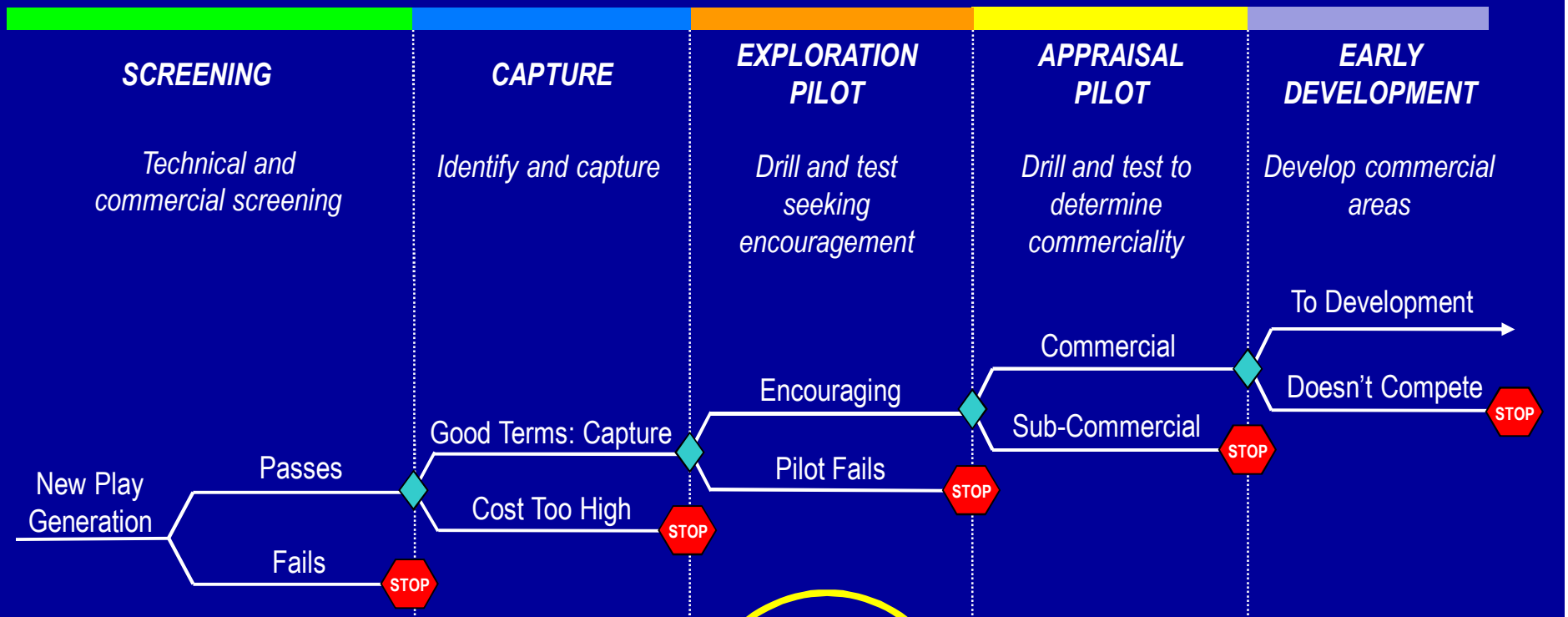
En·cour·age·ment [en-**kur**-ij-m*uh*nt]

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

	EXPLORATION PILOT	APPRAISAL PILOT	EARLY DEVELOPMENT
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: ½ NPV10 = 0**

Stricter Behavior

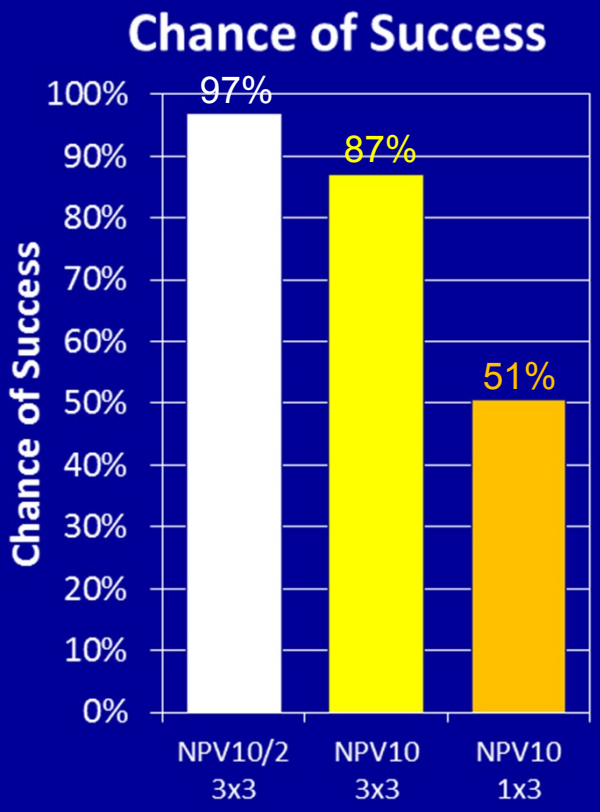
Raise threshold

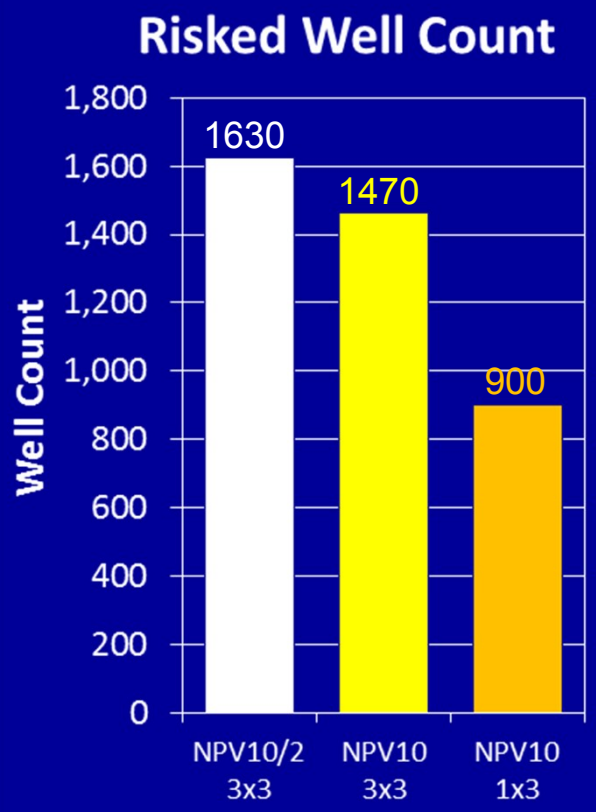
- **Drill 3 wells in 3 Prospects**
- **Threshold: NPV10 = 0**

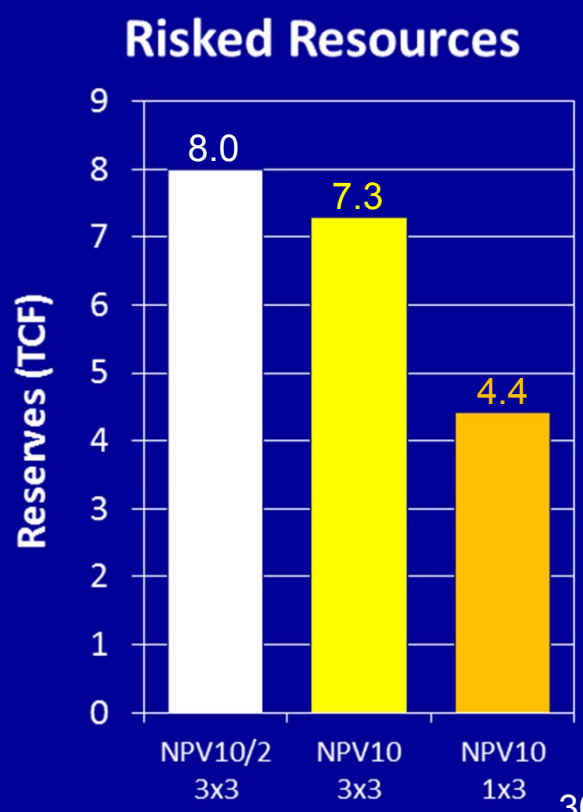
Harsh Behavior

Cut well count

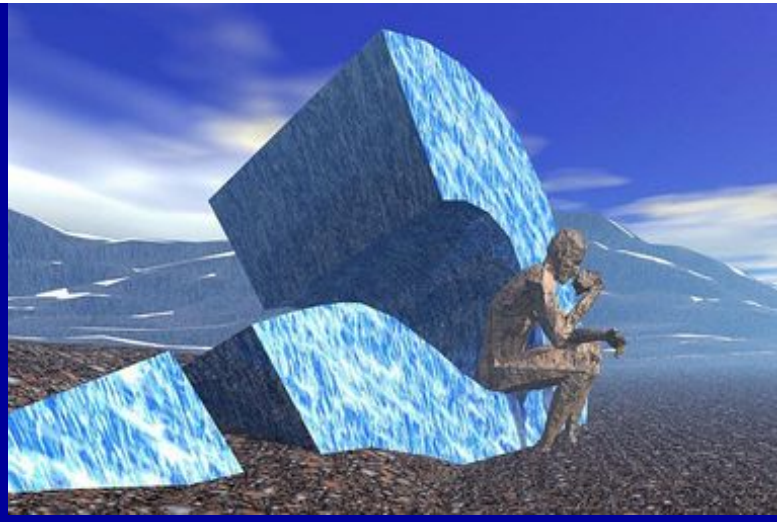
- **Drill 3 wells in 1 Prospect**
- **Threshold: NPV10 = 0**







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.

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