Using “Reliable Technology” for Estimating Oil and Gas Reserves

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(The Usual) DISCLAIMER

- The opinions in this presentation are mine alone and do not represent legal or regulatory guidance by me or any organization. Statements are for education and contemplation as we all seek to understand and comply with reserve requirements.

Presentation Outline

- Background on Reliable Technology
  - How to validate/demonstrate
- Recent literature on Reliable Technologies
- Example: Seismic for water level
- Example: SPEE Monograph 3
- Comments from the SEC
- Q & A

Definition from the "Modernization" of SEC Rules

- SEC "Final Rule" (Dec 2008) states…

"(25) Reliable technology. Reliable technology is a grouping of one or more technologies (including computational methods) that has been field tested and has been demonstrated to provide reasonably certain results with consistency and repeatability in the formation being evaluated or in an analogous formation."

(Note: Emphasis added)

SEC Comments

SEC Compliance and Disclosure Interpretation:

"An issuer has the burden of establishing and documenting the technology (or set of technologies) that provides reliable results, consistent with the criteria set forth in Rule 4-10(a)(25) of Regulation S-X. This information should be made available to the Commission's staff upon request in support of any reserves estimates that the staff may be reviewing."

(Note: Emphasis added)

(from SPE 139494)

Demonstrating Reliable Technology: What did the SEC intend?

- "The SEC will expect persuasive empirical evidence that the application of the technologies has led to correct conclusions when applied in the same reservoir, in an analogous reservoir in the same formation, or in an analogous reservoir in another formation. Persuasive empirical evidence includes drilling results (e.g., demonstrated economic producibility) for locations similar to the proposed PUDs or verified success in locating fluid contacts. In all cases, the sample size should be sufficiently large to establish that conclusions are statistically significant."

(Note: Emphasis added)

(from SPE 129689)

Scientific Method: Steps

1. Define the question.
2. Research the question and formulate a hypothesis (define the theoretical science behind your R.T.).
3. Perform experiments; collect and analyze the data (test your R.T.).
4. Interpret data; draw conclusions; document results.
5. If necessary, revise hypothesis and repeat steps 3 and 4.

(from SPE 129689)

Scientific Method: Adapted to Demonstrating a R.T.

1. Define how the R.T. will contribute to reserve estimation (e.g., define OWC).
2. Research the science behind this application; define when results are valid.
3. Test to validate the hypothesis and demonstrate requirements for R.T. have been met.
4. Document results including conditions needed to achieve reliability (i.e., what are the limits on successful application).

(from SPE 129689)

Scientific Method for R.T. - Some further thoughts

- Include all test data in documentation; selective exclusion of data will cause questions about consistency and repeatability.
- Keep the analysis/documentation updated with new data as the R.T. is used. Does this change your conclusions on limits, application?

Recent Literature on R.T.

Technology	Target Application
Seismic	• Lowest Known HC (Proved Area) • Reservoir Characterization (for STOOIP) • Define level of uncertainty (Ps)
Dynamic Reservoir Simulation	• Estimate Ultimate Recovery (RF) • Static Reservoir Model (for STOOIP)
Combined Geological Modeling and Statistical Methods	• Unconventional Proved Area and related PUD volume
Other	• Lowest Known HC (Proved Area)

see SPE 179991

Steps 1 & 2: Question & Research to Develop a Hypothesis

1. Can seismic reliably identify HC/water contact?

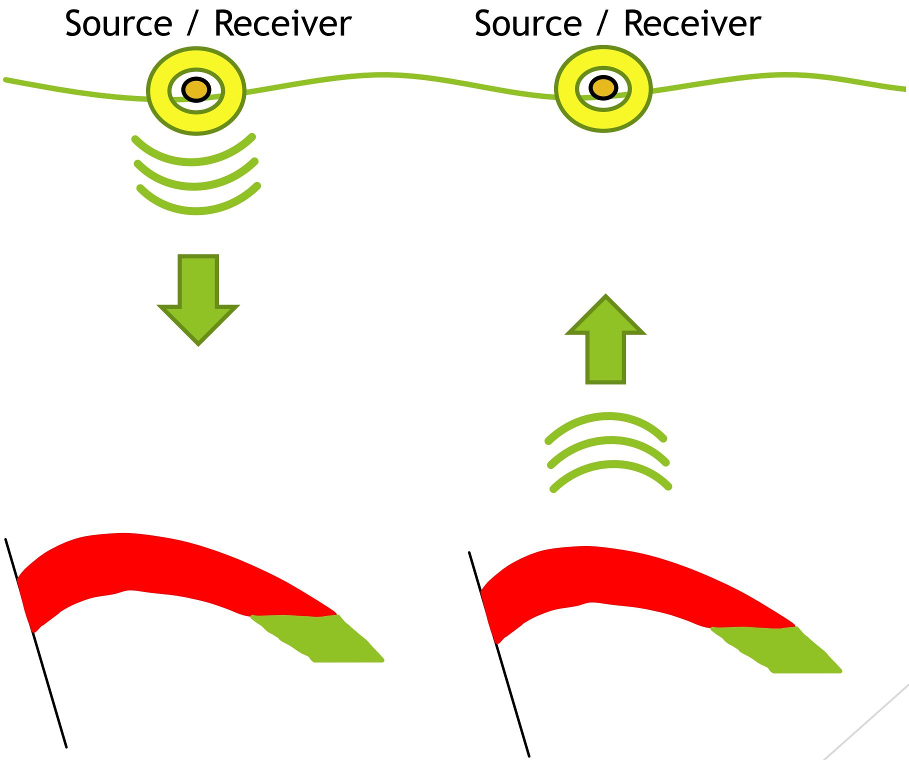
2. The science behind the hypothesis:
   a. Where no interfering effects distort high-quality, 3-D seismic data, the portion of the seismic related to fluid content can be isolated and analyzed.

Steps 1 & 2: Question & Research to Develop a Hypothesis

2. The science behind the hypothesis:
   b. Conclusive interpretation of the fluid contact between a commercial HC reservoir and an aquifer requires the additional condition of distinctly different seismic amplitudes for “pay” v. residual HC saturation or aquifer.

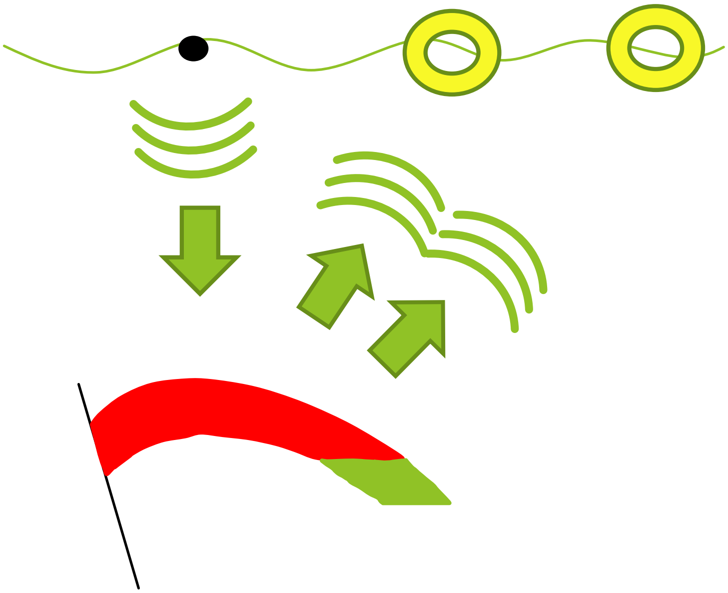
Seismic AVO - Zero Offset

"Amplitude Variation with Offset"



- Reflective event directly below source
- Seismic data captures only the "p-waves" which move in the direction of the propagated wave

Seismic AVO - With Offset



- Seismic reflective signals (amplitudes) are converted waves with both a vertical ("p-wave") and lateral ("s-wave") component
- Shear ("s") waves have different characteristics than p-waves allowing additional information to be extracted from the seismic

Ensure applicability - are all conditions right for success?

- Quality control of data – e.g., well logs provide good, complete data which ties to zero-offset seismic
- Stratigraphy – e.g., no stratigraphic variations that would compromise the fluid signal interpretation
- Structural factors – e.g., good “fit to structure” of the apparent contact
- …and others which develop a checklist

Checklist of qualifying conditions

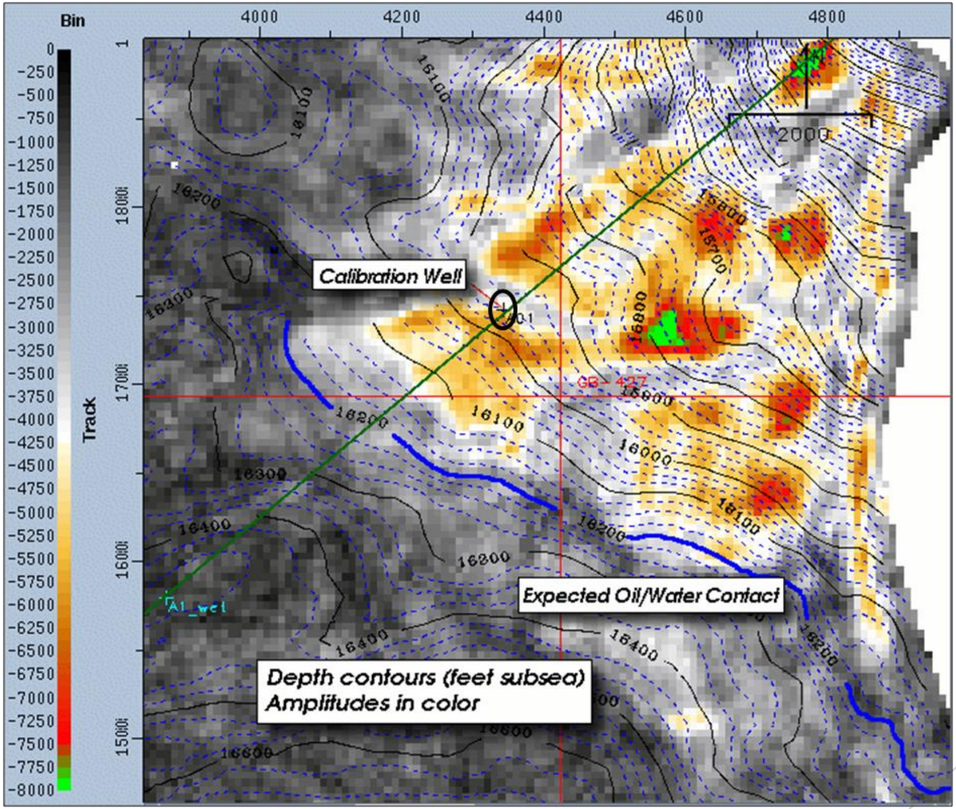
	Evidence
Quality Control	
1a. Log quality	Show sonic, density, gamma ray, caliper
1b. Wavelet correlation	Comparison software output
1c. Zero offset tie	Show tie
1d. AVO tie, updip and downdip	Show tie
1e. Seismic quality	Seismic traverse
Stratigraphy	
2a. Stratigraphic bias	Amplitude map, well data
2b. N/G, well vs HWC	Amplitude map, well data
Structure	
3a. Fit ± 100 ft	Structure map
3b. Seismic HWC	Amplitude map, seismic traverse
3c. Trap failure analysis	Pressure versus depth plot
3d. Residual Rim	Amplitude map
3e. Loop Interference	Seismic traverse
3f. Dip < 30^{o}	Seismic traverse or dip map
3g. Illumination	Seismic traverse or illumination map
Sensitivity	
4a. Sand thickness	Isopach map and tuning model
4b. Pay/residual separation	Monte Carlo histograms
Calibration	
5a. Error radius	Show map
5b. Probability sensitivity	Show map

- Complex technologies can be influenced by many factors
- Key to reliable interpretation is the isolation of target signal from the "noise" of these other factors

Step 3: Test the hypothesis

- The following two example cases (from many used) show the successful application of this method
- One is a success with reliably identifying a water contact
- One is a success as it exposes that an apparent seismic water contact should not be trusted

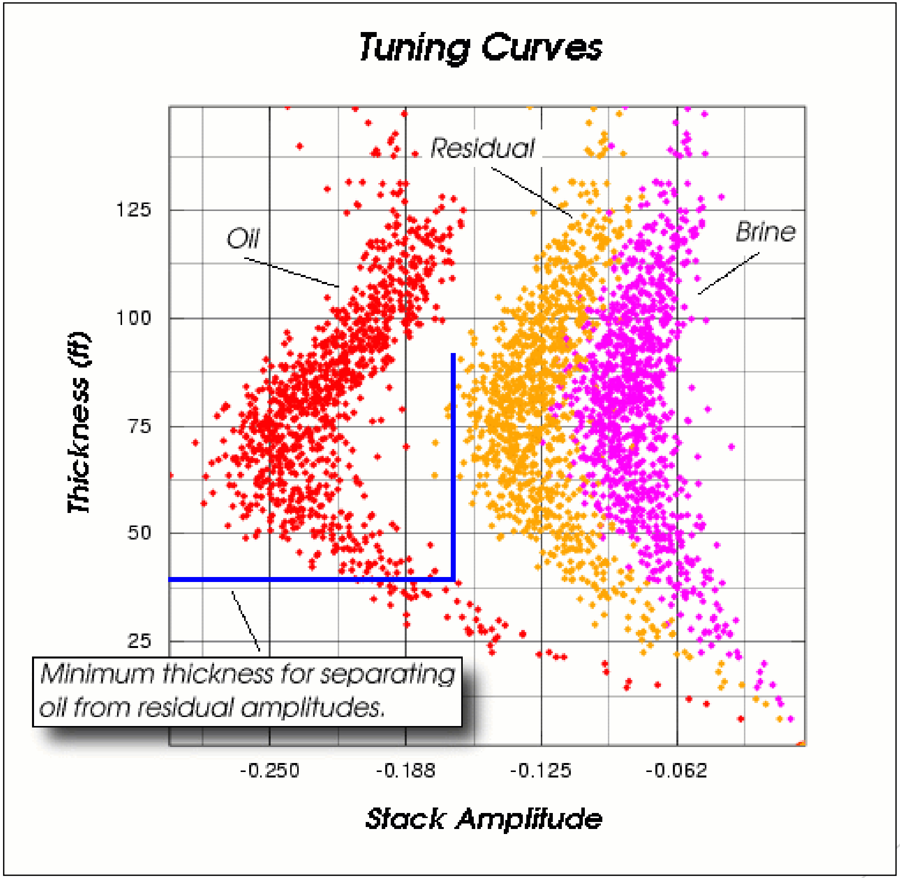
Successful "positive" case



Successful "positive" case

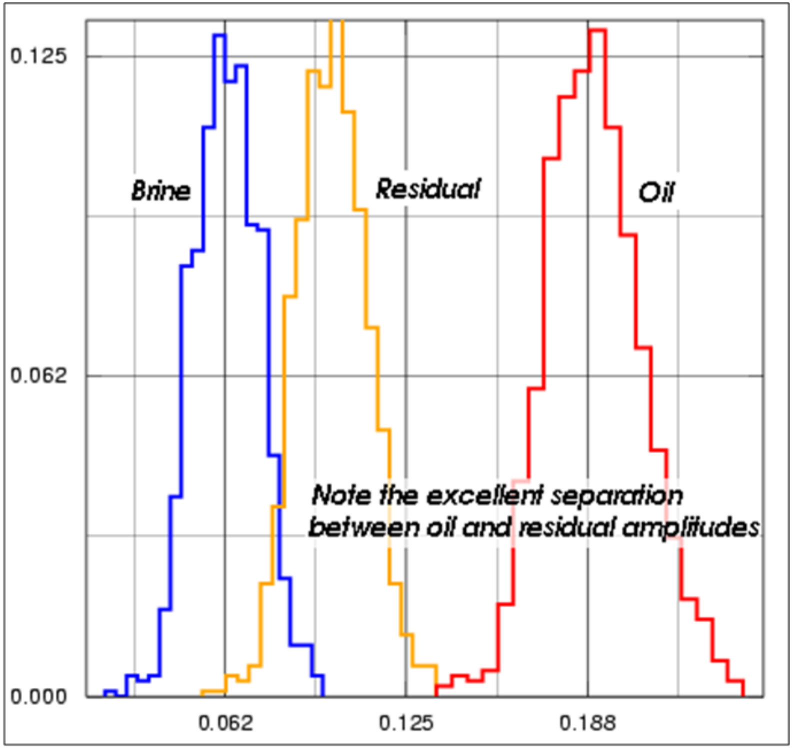
- Confirm "zero-offset" tie: seismic to well log
- Do seismic inversion (simulated seismic)
- Model ranges of unknown inputs: Ø, S_o, etc.
- Develop statistical distribution of seismic data output from Monte Carlo on input distributions

Successful "positive" case



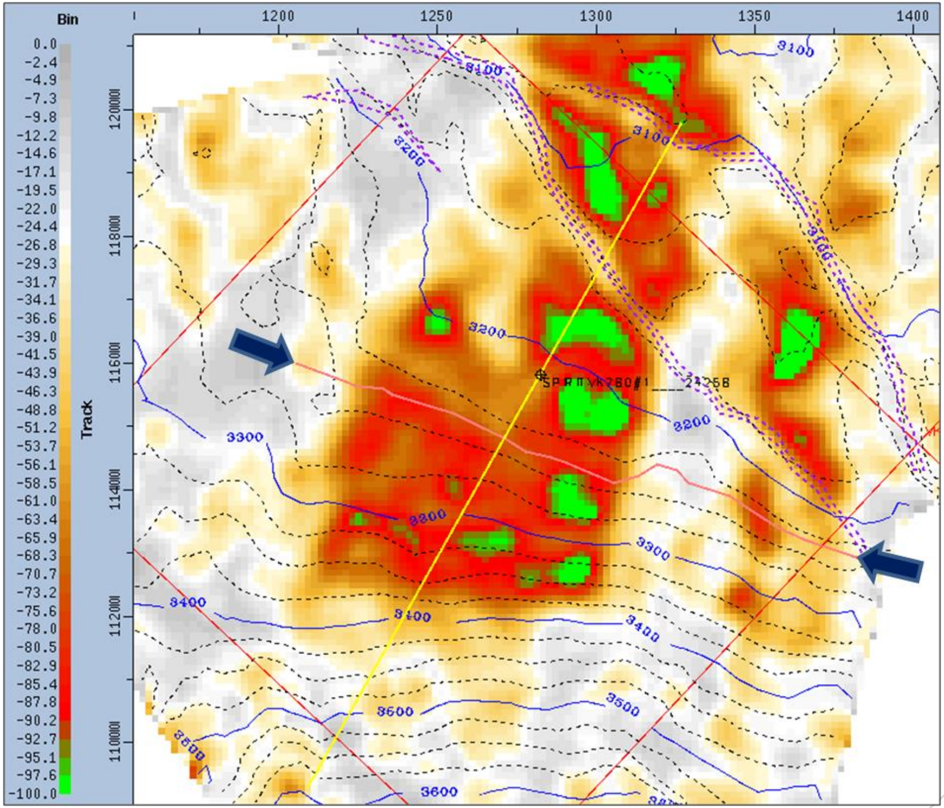
Successful “positive” case

Relative Frequency

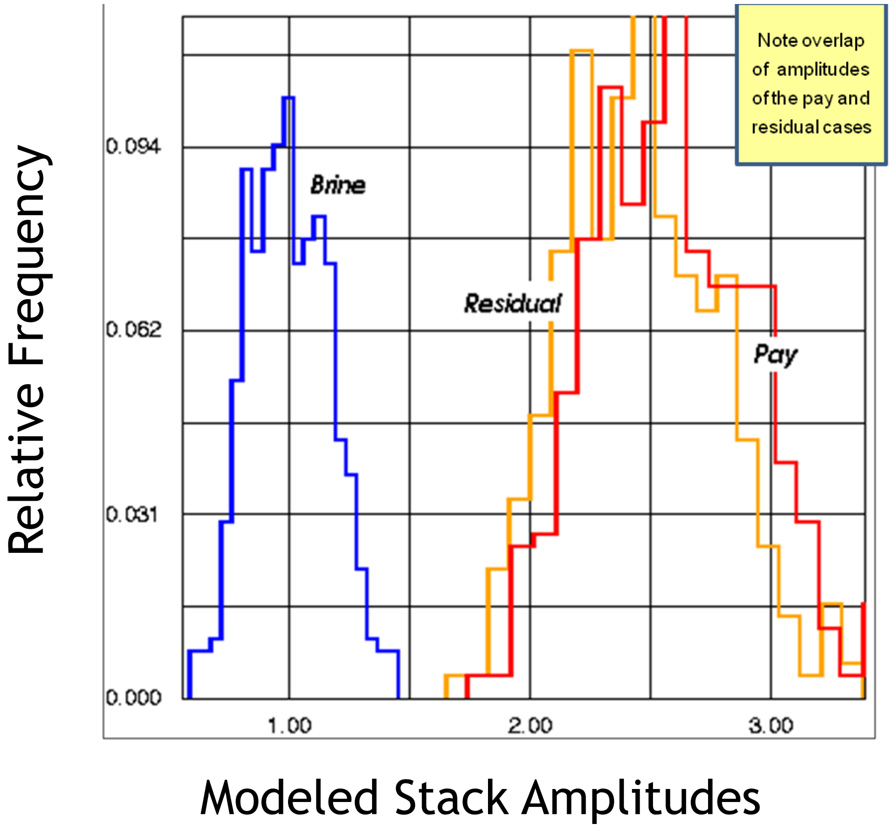


Modeled Stack Amplitudes

Successful "negative" case



Successful “negative” case



Step 4: Document results

- Include all test data in documentation
- Develop process aids to ensure consistency and repeatability as the method is used

➡ Example: Checklist for qualifying conditions

- Keep the analysis/documentation updated with new data as the R.T. is used.

Summary of Key Steps

- Hypothesis
- Establish scientific basis
- Test results must validate
- Document (and update)

SPEE Monograph 3 as "Reliable Technology"

Scientific Method steps are used

- Hypothesis: "Proved" Area can be defined with applied statistical EURs for new wells
- Science: Geologic consistency of productivity and statistically repeatable EUR variations
- Testing: Use existing well EURs to show commercial productivity from analogous wells follows a narrow, high confidence distribution
- Document: Both analysis and ongoing results to continuously validate technology use
  - ✓ (Be ready for the SEC to ask….)

Example: SEC Comment letter

In one letter, the SEC asks about Proved Area:

"In part, your response 10 indicates a significant portion of your proved undeveloped locations are 2 or more offsets removed from a producing well(s). Tell us the statistics of your drilling history for such similarly situated locations, including the success rate by distance/location removed from production."

(Note: Emphasis added)

Thank you

Acknowledgements

Ryder Scott for use of the “SEC Seeker®” application to search SEC Comment Letters

Example: SEC Comment letter

After a description of the technology was provided, the SEC asked about recovery prediction results:

"Please explain to us the revision history due to performance for proved reserves in your Barnett Shale play. Include a comparison between the median values as of year-end 2009 with median initial values for proved Estimated Ultimate Recovery, realized well cost and estimated well cost; producing rate vs. time plot and associated decline curve parameters, producing rate vs. cumulative production plot and estimated future production projection representative of the two median EURs."

(Note: Emphasis added)

SEC Guidance on Comment Letters

"The staff's comments are in response to a company's disclosure and other public information and are based on the staff's understanding of that company's facts and circumstances…These letters set forth staff positions and do not constitute an official expression of the SEC's views. The letters are limited to the specific facts of the filing in question and do not apply to other filings."

Deconvolution of SPEE Monograph 3

- As written, Mono 3 combines geological modeling and statistical methods into one reliable technology:
  - to expand PUD locations beyond one offset

- Restate as a two technologies process:
  1. Establishing proved area
  2. Forecasting recovery from undrilled locations

1. Geological Modeling

Example:

- Define Area of Consistent Geological Conditions
- Establish reasonable certainty of economic producibility

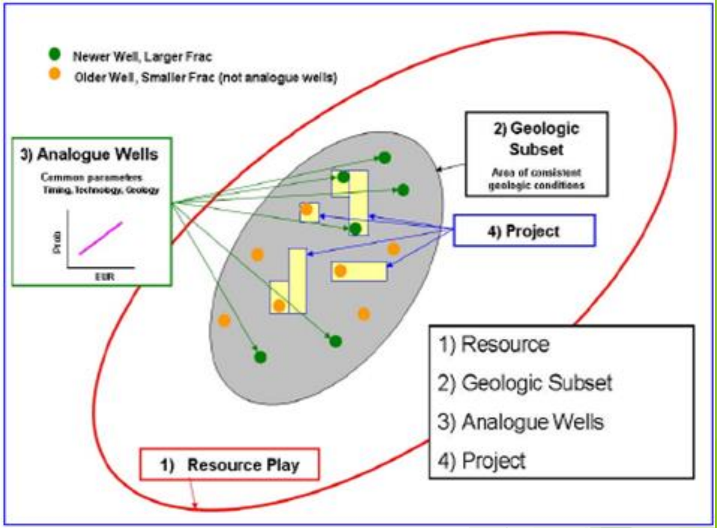
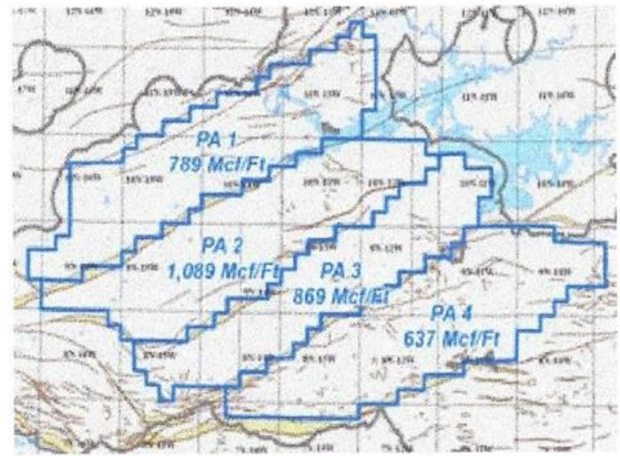


Figure 1

2. Forecast Recovery Methods

Example:

- Define sub-area of analogous production results
- Apply analogy (could be a statistical method as in the figure) to appropriate undrilled locations



Map 5—Project Areas bounded by major fault systems, the proved area and well control.

Figure 2

Other Forecast Recovery Methods

- SPEE Monograph 3 methodology requires spatially independent statistical analysis to assign volumes to undrilled locations.
- The "deconvoluted" technology only requires valid analogy which then allows spatially oriented methods to be considered. Example: Attanasi et al (SPE 107659) uses a "nearby neighbor" weighting approach for a Michigan Antrim example.