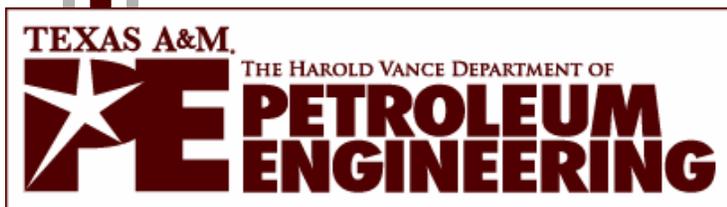


An Update on the Use of Analogy for Oil and Gas Reserves Estimation

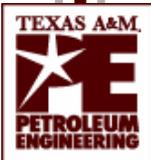
R.E. (Rod) Sidle
to the Houston Chapter of SPEE

3 November 2010



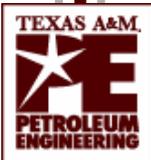
Analogy - Origins

- Term does not appear in 1987 SEC Rule 4-10
- Reference to “analogous reservoirs” appears in SPE Reserve Definitions (1987 & 1997) without clarification
 - 1997 SPE mentions “analogous reservoir with similar rock and fluid properties”
(is it an analogy without?)
- Term appears in SPEE Monograph I (1998) and SEC 2001 Website guidance



SPEE Monograph I (1998)

- Includes Analogy among described Reserve Determination Methods (Section 3)
- Lists 10 characteristics of analog/target where similarity should be considered
- Suggests use on unit-recovery basis (e.g., bbl per acre-ft) rather than well-to-well basis (“least accurate and reliable of reserves estimating techniques”)



SEC 2001 Website Guidance

- In describing IOR PUDs, the SEC guidance defines that the IOR technique must have been “proved effective in that reservoir or an analogous reservoir in the same geologic formation in the immediate area.”
- Definitions for “geologic formation” and “immediate area” were not provided.



SEC 2001 Website Guidance

- Further in describing IOR PUDs, the SEC defines: “An analogous reservoir is one having at least the same values or better for **porosity, permeability, permeability distribution, thickness, continuity and hydrocarbon saturations.**”
- Key points: All 6 must be “same or better”.
- Somewhat confusing as statement seems to define target rather than analog.



Analogy – Recent Treatments

- Defined in SPE Petroleum Reserves/Resources Glossary (2005) and SPE et al PRMS (2007)
- Both cover key characteristics of comparison
- PRMS provides additional guidance:
 - Analog reservoir is in more advanced stage of development (thus more available data)
 - Use of several analogs reduces uncertainty
 - Same geographic area/geological age provides better analogs but not primary consideration
 - Should document similarities and differences



Use of analogy discussed

- SPE 102505 (2006) - "The Selection, Application and Misapplication of Reservoir Analogs for the Estimation of Petroleum Reserves"
- Good summary of topic in general and particularly on comparison of SEC and SPE criteria at that time
- Describes building "a compelling case" as the support for use of analogy
- Lists guidelines to reduce evaluator mistakes when using analogy



SEC “Modernization” – Analogy comments

- SEC proposal: “analogous formation in the immediate area”
- Based on responses, adopted “analogous reservoir” (more consistent with PRMS)
- Also added:
 - (Partial) List of general areas of comparison
 - Basis for validation (similar general comparables but target same/better “in the aggregate”)
 - Additional requirements for Proved analogy



Updated SEC Analog Definition same as PRMS (in Glossary)

- From §210.4-10 (a)(2):
“Analogous reservoirs, as used in resources assessments, have similar rock and fluid properties, reservoir conditions (depth, temperature, and pressure) and drive mechanism, but are typically at a more advanced stage of development than the reservoir of interest and thus may provide concepts to assist in the interpretation of more limited data and estimation of recovery.”



SEC additional criteria

- Further from §210.4-10 (a)(2):
“When used to support proved reserves*, [the target reservoir and analog must have] the (i) same geological formation..., (ii) same environment of deposition, (iii) similar geological structure, and (iv) same drive mechanism.”

Additional instruction: “Reservoir properties must, **in the aggregate***, be no more favorable in the analog than in the reservoir of interest.”

* emphasis added



PRMS additional criteria

- Section 4.1.1 “Analog” provide a partial list of points of comparison:
 - 15 “features and characteristics” of reservoirs
 - 7 processes that form reservoirs which are....



PRMS Analogy “features and characteristics”

- “including but not limited to...”
 - Approximate depth
 - Pressure
 - Temperature
 - Reservoir drive mechanism
 - Original fluid content
 - Reservoir fluid gravity
 - Reservoir size
 - Gross thickness
 - Net thickness
 - Net-to-gross ratio
 - Lithology
 - Heterogeneity
 - Porosity
 - Permeability
 - Development plan

PRMS Analogy “reservoir formation criteria”

- “formed by the same, or very similar, processes with regard to”...
 - Sedimentation
 - Diagenesis
 - Pressure
 - Temperature
 - Chemical history
 - Mechanical history
 - Structural deformation



PRMS additional criteria

- Section 4.1.1 “Analog” also notes the qualifications for production forecast by analogy:
 - comparable development plan including well type, well spacing and stimulation



Compare SEC and PRMS

- Additional criteria from each of the SEC and PRMS provide further clarification of the base definition but on different aspects of analogy.
- Although clarifications are on different aspects, they are compatible and complimentary – no clear conflicts.
- Concept of analogy is aligned between SEC and PRMS



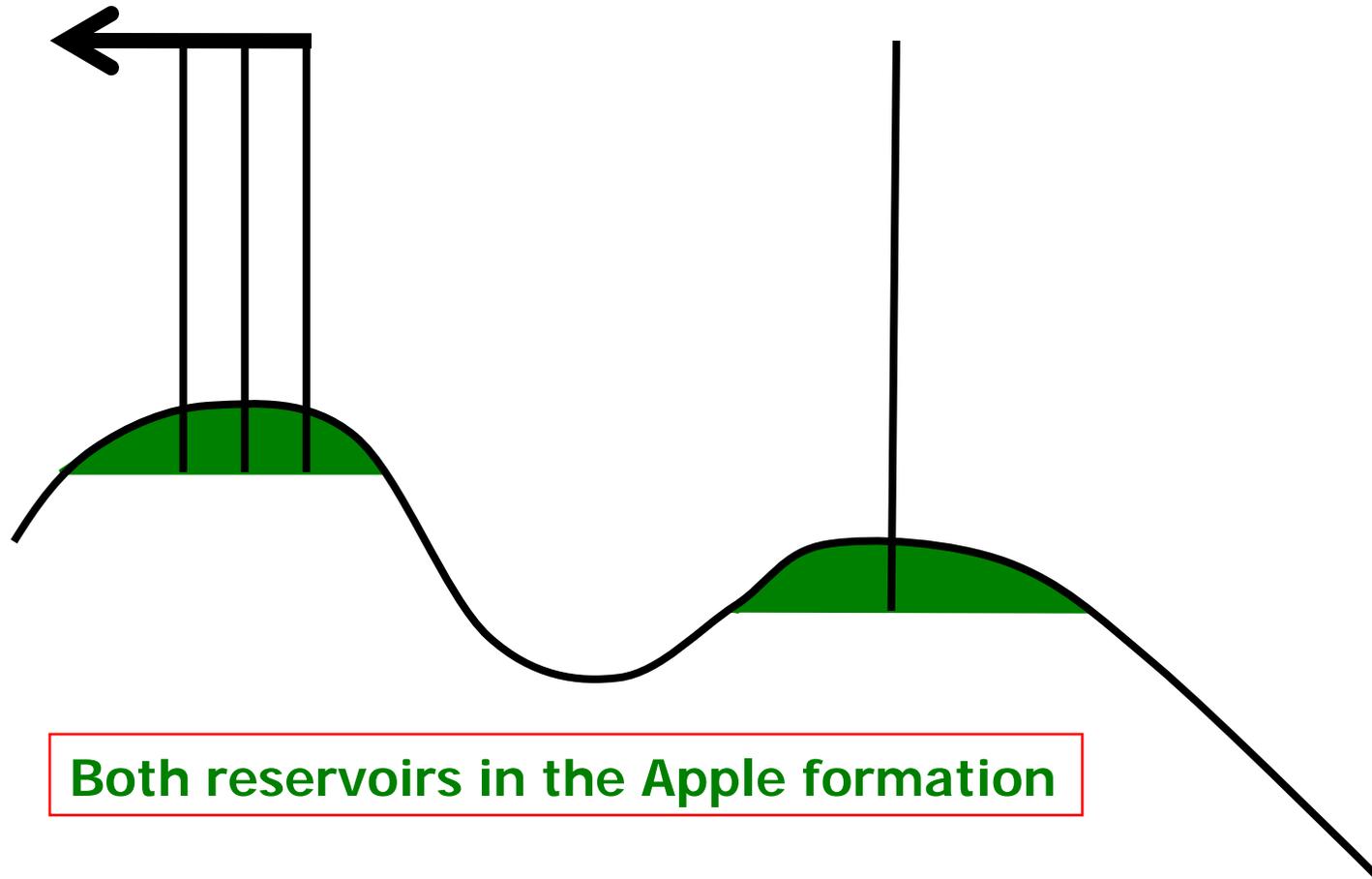
Other key analogy concepts

- Updated SEC rules include the criteria of move favorable properties in the target (subject) reservoir “in the aggregate”.
- Lee in SPE 123793 (2009) explains:
 - ‘In aggregate’ means that properties that most influence reservoir performance in a given situation must be more favorable in the analog and that not all other properties need be more favorable.

“In the aggregate” Example

Jonathan Field
(on production)

Macintosh
Field
(no prod. test)



“In the aggregate” Example

Data from Apple formation	At Jonathan Field	At Macintosh Field
Porosity (ϕ), %	30	29
Permeability (k), md	930	890
Permeability distribution	D-P variance = 0.15	D-P variance = 0.15
Net Thickness (h), ft	150	150
Continuity	Continuous over broad area without faults, etc.	Continuous over broad area without faults, etc.
HC saturation, %	70	70
Oil viscosity (at reservoir temperature) (μ), cp	1.5	0.35
Oil gravity, API°	24	30
Gas-oil ratio, scf/STB	800	1500
Average reservoir depth, ft	6000	8500
Average reservoir pressure psi	2650	3750
Reservoir Transmissivity, (k*h/μ), md-ft/cp	93 x10³	381 x10³

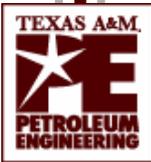
“In the aggregate” Recovery Factor Example

- Use of analogy for recovery factor is a more complex comparison than productivity; many factors can impact overall recovery.
- First, demonstrate similarity of reservoirs, then consider:
 - “Micro” or pore-scale parameters such as mobility ratio
 - “Macro” or field-scale parameters such as well spacing and injection/production well patterns
 - Process specific factors such as moveable oil concentration for thermal recovery, i.e.

$$\left[\phi (S_o - S_{or}) \left(\frac{h_n}{h_g} \right) \right]$$

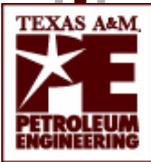
Analogy for Proved reserves

- Proved reserves meet the high confidence standard of “reasonable certainty”
- SEC and PRMS note two approaches to achieve this high confidence:
 - Close physical proximity (vertically and areally)
 - i.e., same age, same area or same geological formation (in addition to certain reservoir elements that must be the same)
 - Multiple analogs supporting the same result



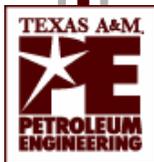
Simulation as an Analog

- Noted in SPE 96410 (2005)
- Where simulation has been shown reliable, it may help “tune” a range of outcomes of field analogies for minor variations in properties
 - Example: Define recovery factor in similar reservoirs with minor differences in well spacing
- Caution: consider application – if for proved reserves, an upward adjustment from an actual analog result is not likely to be high confidence



^{*} Updated Guidelines for Analogy use

- Know reserve classification rules
- List all parameters relevant to analogy – both general (“the 6” and appropriate others) and specific (“in the aggregate”)
- Use a thorough, consistent process to compare parameters – document!
- Consider the analogy valid only if these steps/comparisons satisfy required classification criteria



* Original guidelines from SPE 102505

Other Analogy references

- SEC §210.4-10 (25) “Reliable Technology” includes the term “analogous formation”:
 - 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**.



What is an “analogous formation”?

- A: At the minimum, this is the same as an “analogous reservoir in the same geological formation”. But perhaps more. The analogy proposal must consider and compare the important characteristics of the reservoir, formation and other geologic units that impact the conclusion being drawn to demonstrate the validity of the analogy application.
- Example: Thermal conductivity of the cap for a thermal EOR reservoir



Summary - Analogs in 2010

- New definitions (SEC, PRMS) exist but concepts are the same as prior
- SEC and PRMS see analogs the same: basic definition identical, further clarification are aligned
- New aspects (“in the aggregate”) put qualification emphasis on critical points of effective comparison
- As always, Proved reserves require higher confidence in applicability of the analog



Reservoir Analogs

- Thank you for your interest and attention
- For further reference, see SPE 129688 (2010) by Sidle and Lee (used as source for today's presentation).

