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Houston

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Ryder Scott 2007 Reserves Conference
Uses and Misuses of Pressure Data for Reserve Estimation

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Presentation Outline



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- Introduction
- Pressure Data and Contact Determination
- Reservoir Continuity
- Radius of Investigation
- Material Balance Examples
- Conclusions

Introduction



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- Co-Author Brad Gouge, Ryder Scott Co.
- Deficit in SPE literature regarding reserves interpretation
- Pressure data can be critical; however, interpretations often not of “reasonable certainty”
- Presentation will focus on SEC and SPE/WPC proved definitions; SPE paper (103221) discusses SPE/WPC probable and possible classes as well
- Paper and presentation represent authors’ interpretations of SPE/WPC and SEC guidelines

Pore Pressure Gradient (PPG) Data



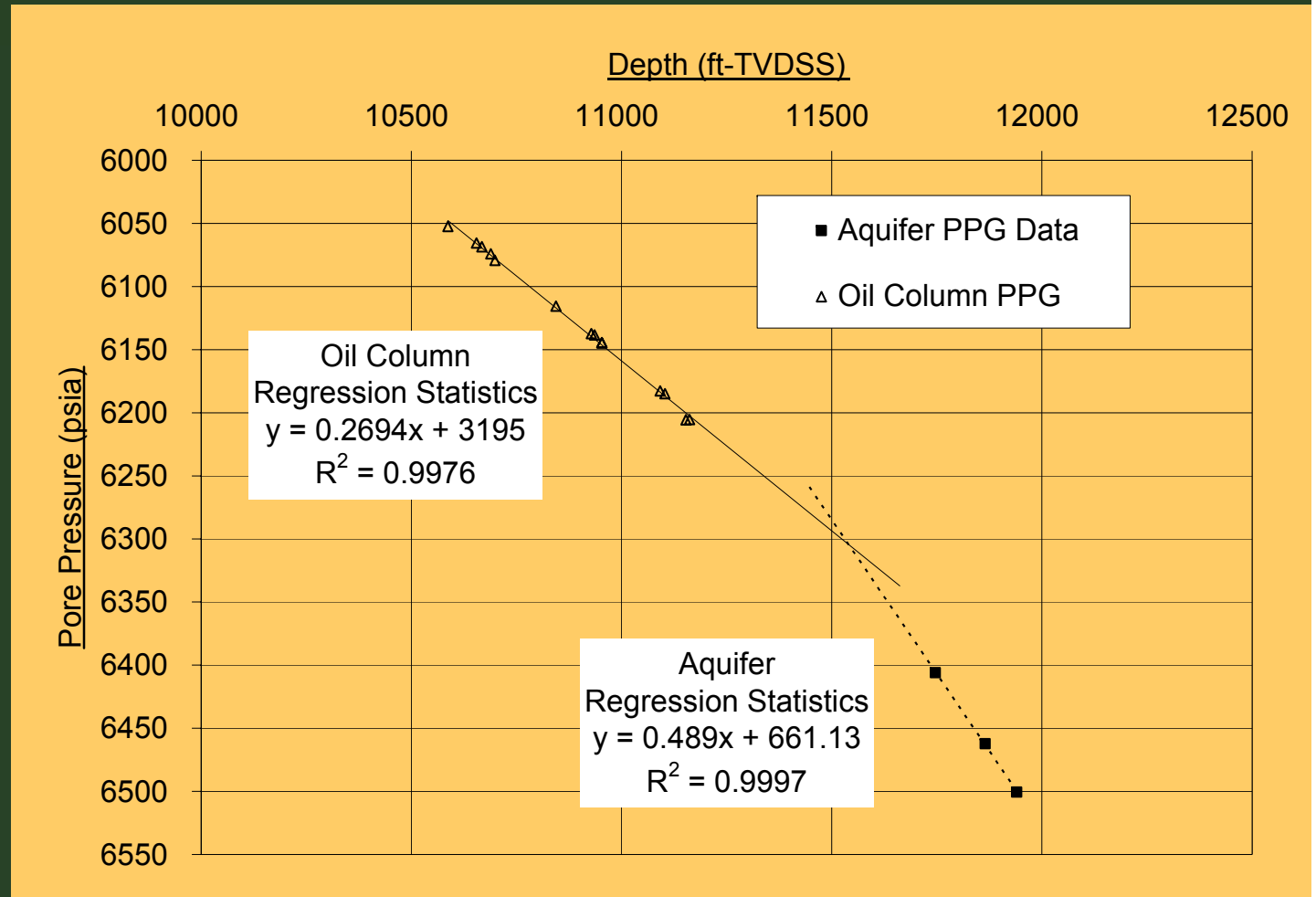
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- QC each data point; review geology; beware 'differential drawdown'

- PPG as primary basis of proved contact

- SPE/WPC = Maybe

- SEC = No



Proved Contacts

SEC vs SPE (1997/2001)



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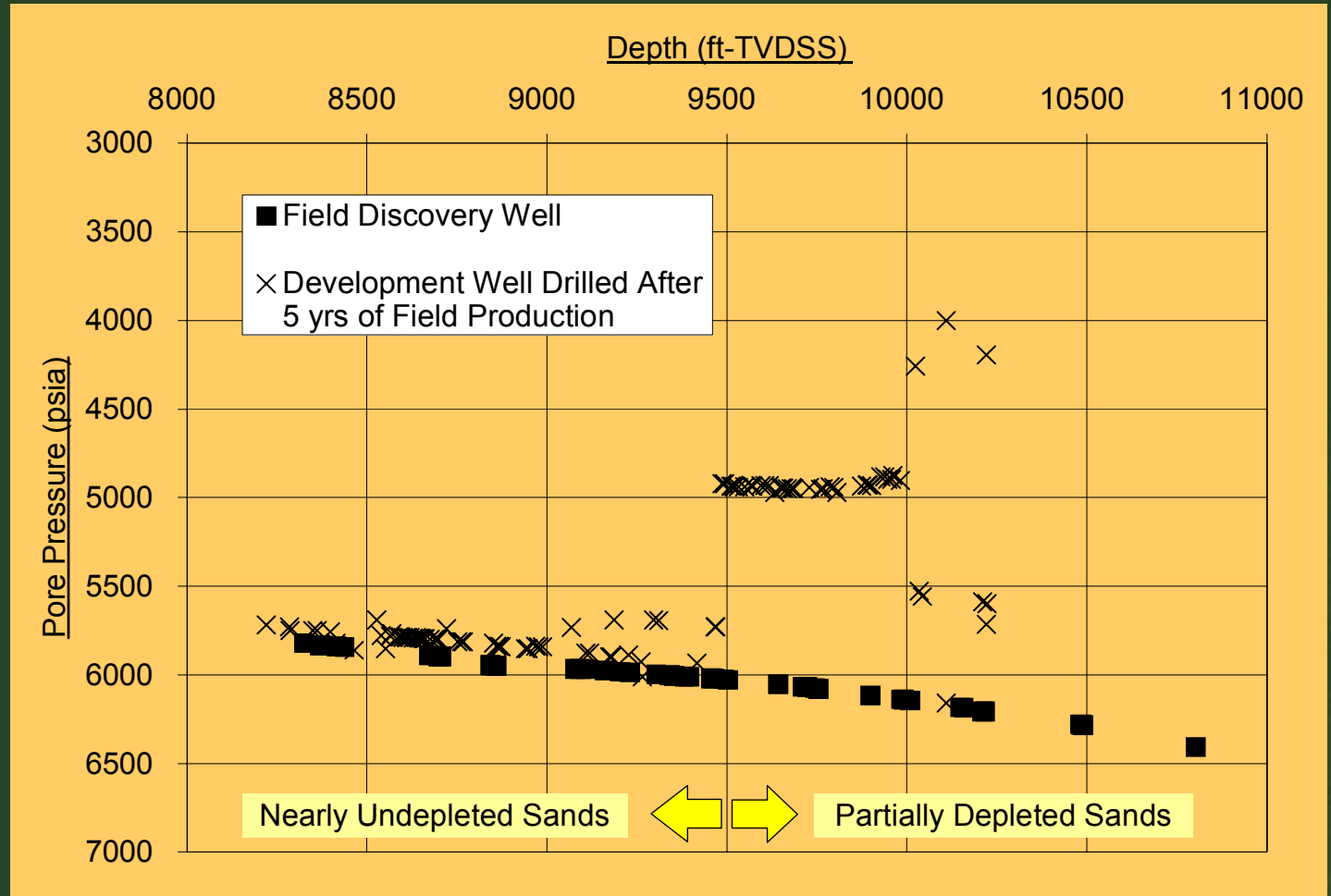
- Water/Oil Contacts
 - SEC guidance states, “...the reserves in the legal and technically justified drainage area around the well projected down to a **known** fluid contact or the lowest **known** hydrocarbons, or LKH may be considered proved.”
 - SPE/WPC guidelines state, “...the lowest known occurrence of hydrocarbons controls the proved limit unless otherwise indicated by **definitive** geological, engineering, or performance data.”
- Gas/Oil Contacts Rules less defined
 - Firms tend to take conservative approach

Proved Continuity With PPG Data



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- QC each data point; review geology
- SEC & SPE/WPC accept differential drawdown
- SPE/WPC continuity threshold lower than SEC





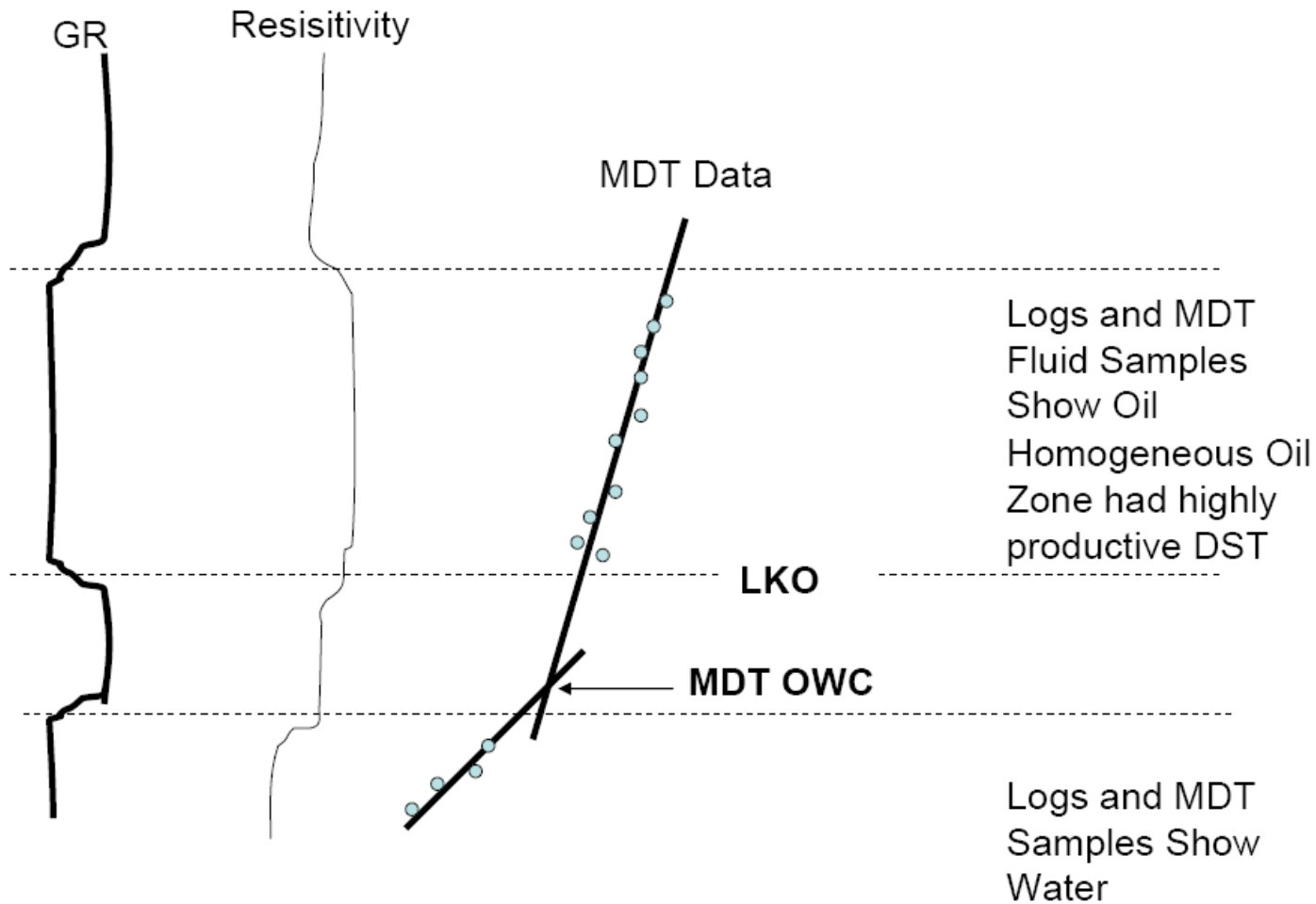
- SEC and SPE/WPC definitions limit PUDs to one-offset locations; but allow exceptions:
 - SEC wording: “Proved reserves for other undrilled units can be claimed only where it can be demonstrated with **certainty** that there is continuity of production from the existing productive formation.”
 - SEC: *certainty* not qualified with *reasonable*
 - ‘Absolute’ certainty disqualifies pre-production PPG data
 - SPE/WPC does qualify certainty: “Reserves from other locations are categorized as proved undeveloped only where interpretations of geological and engineering data from wells indicate with **reasonable certainty** that the objective formation is laterally continuous and contains commercially recoverable petroleum at locations beyond direct offsets.”

Proved Continuity Example 1



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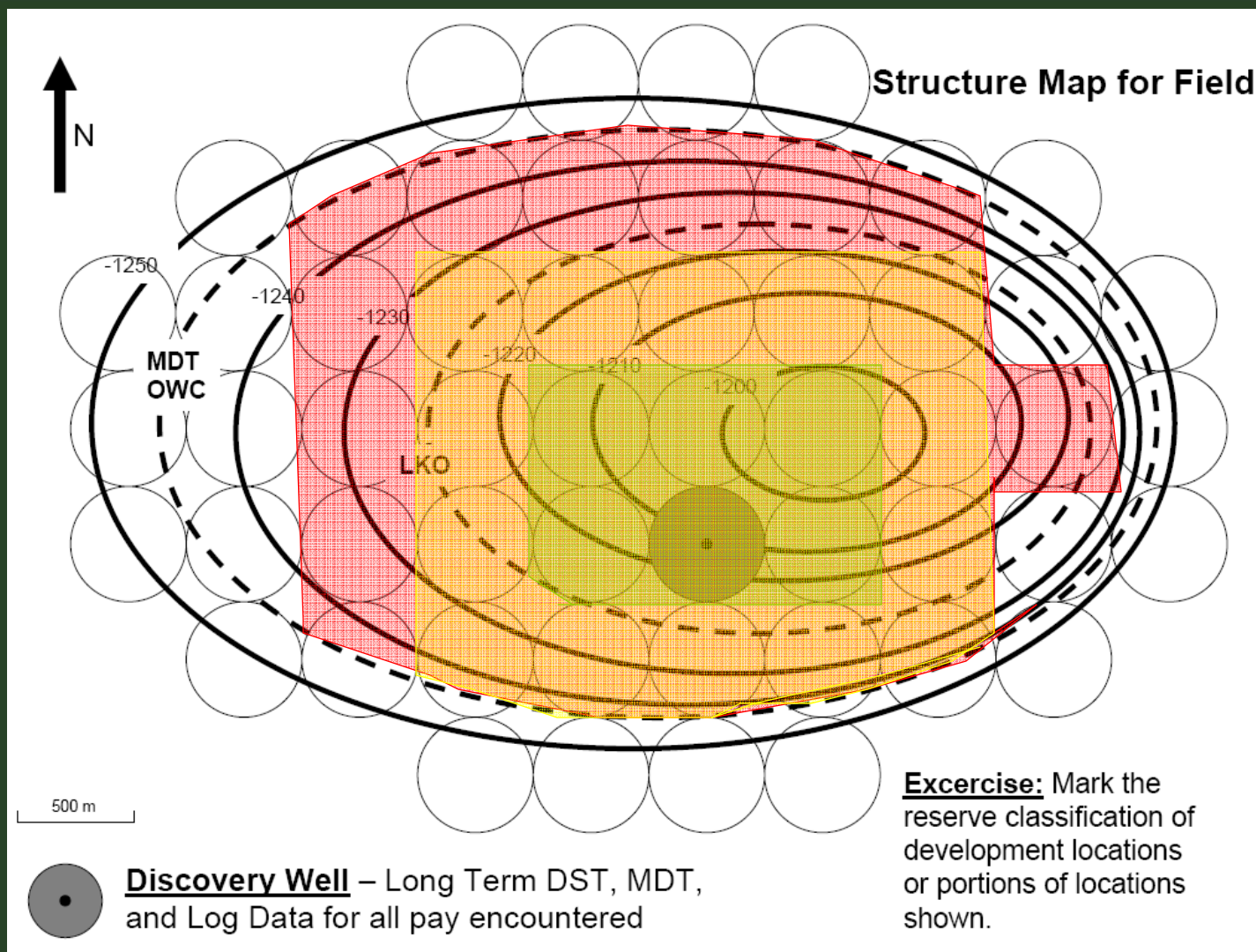
Discovery Well – Long Term DST, MDT, and Log Data



Proved Continuity Example 1...Continued



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Use of Interference Tests



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- 200 hour interference test yielded ~3 psi response
- Uncertainty and non-uniqueness are inherent issues
- Often difficult to reach SEC 'absolute' certainty threshold

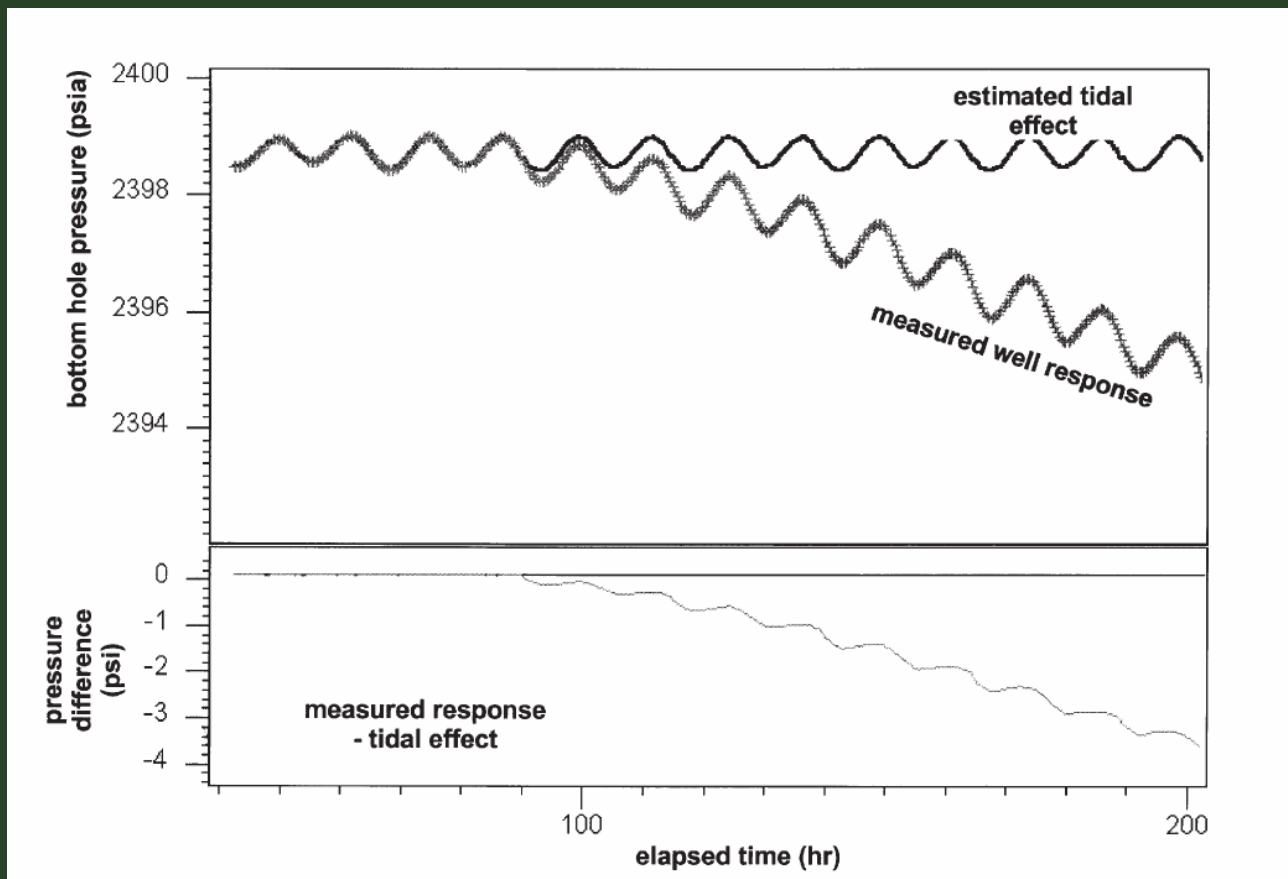


Figure from SPE paper by N. Humphreys *et al.*, "Using Interference Tests During Field Startup to Solve Critical Reservoir Management Issues at the Zafiro Field, Offshore Equatorial Guinea."

Proved Area and Radius of Investigation



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Determination of Radius of Investigation as per Lee...

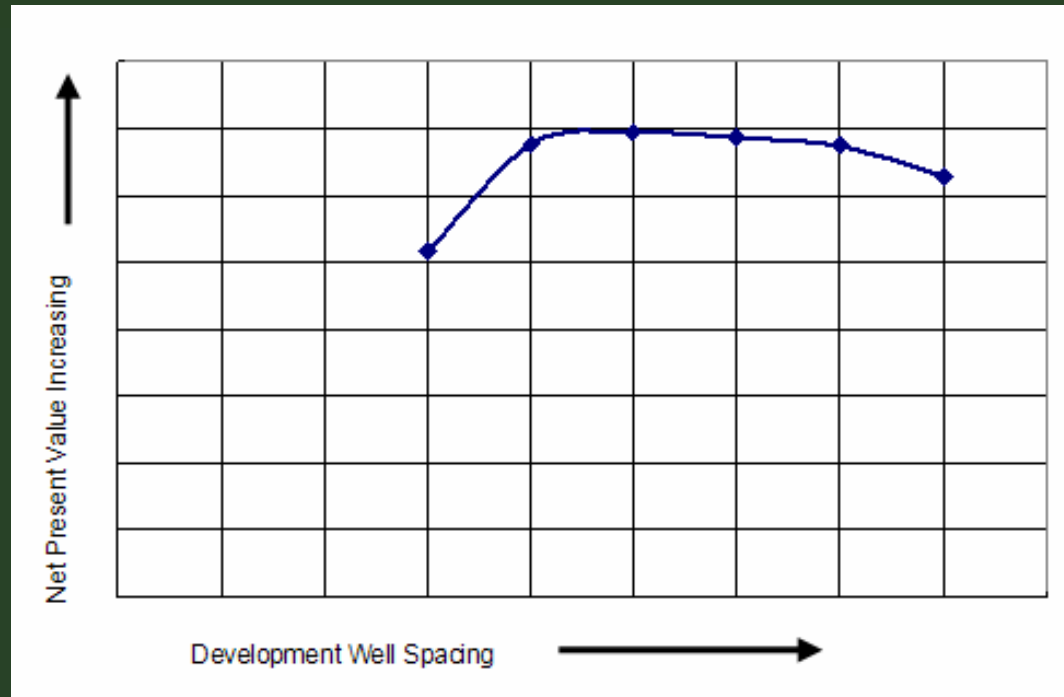
$$r_i = [kt / (948\phi\mu c_t)]^{1/2}$$

- Assumes homogeneous, isotropic, cylindrical reservoir
- Uncertainties (i.e. height used to calculate permeability) mean connected volume calculation is often more useful
- Result often used with an independently calculated recovery factor [*incorrect practice*]

Proved Area and Radius of Investigation...Continued



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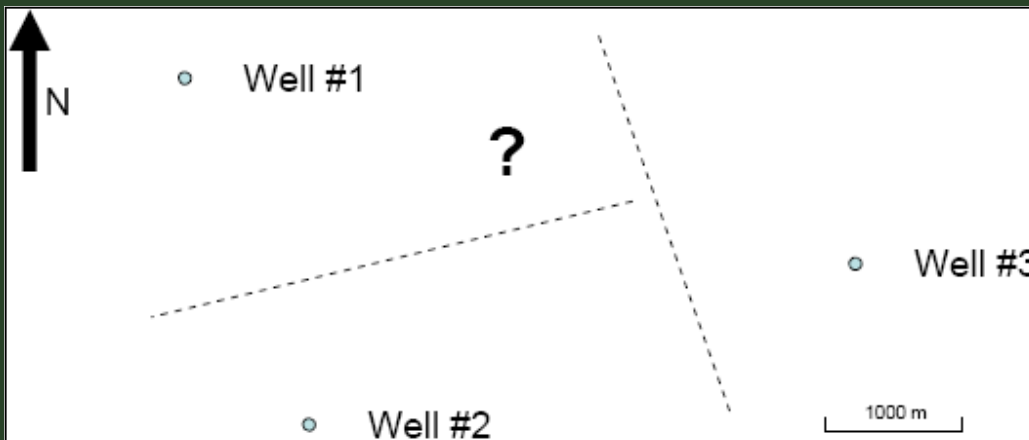
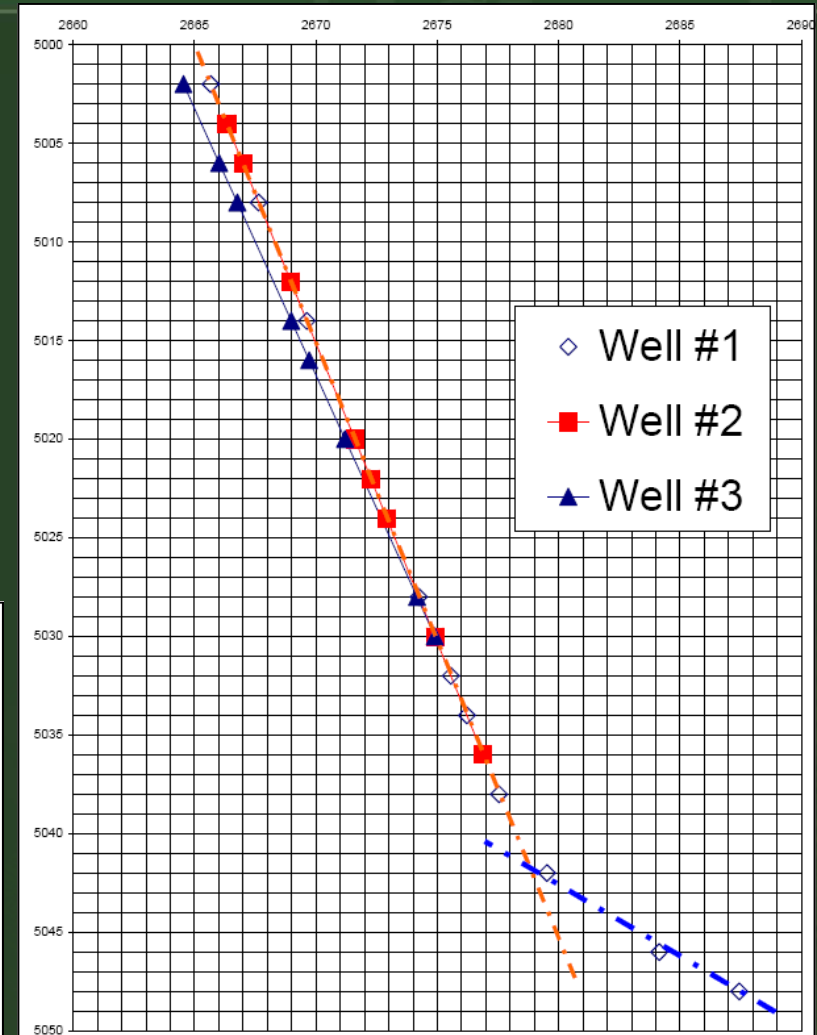
- Well test radius of investigation rarely representative of final drainage area
- Development economics must be considered on individual well and project basis
- Regulatory constraints must be considered

Proved Continuity Example 2



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- Where is the contact for SPE/WPC proved definitions and where is it for SEC?
- Which wells are in “continuity” based on SPE/WPC definitions and what would the SEC rules say about that?



Gas Material Balance for Reserve Determination



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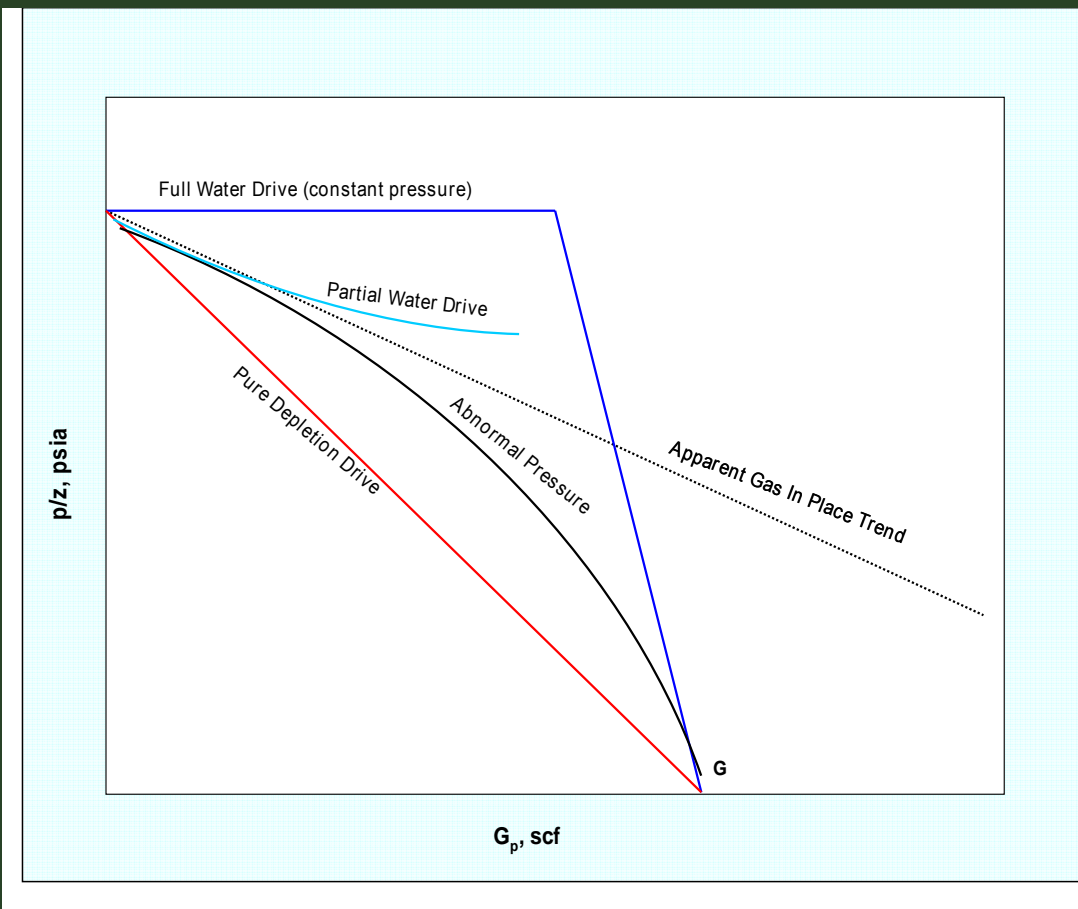


Figure from SPE paper from D.R. Harrell *et al.*: "Oil and Gas Reserve Estimates: Recurring Mistakes and Errors"

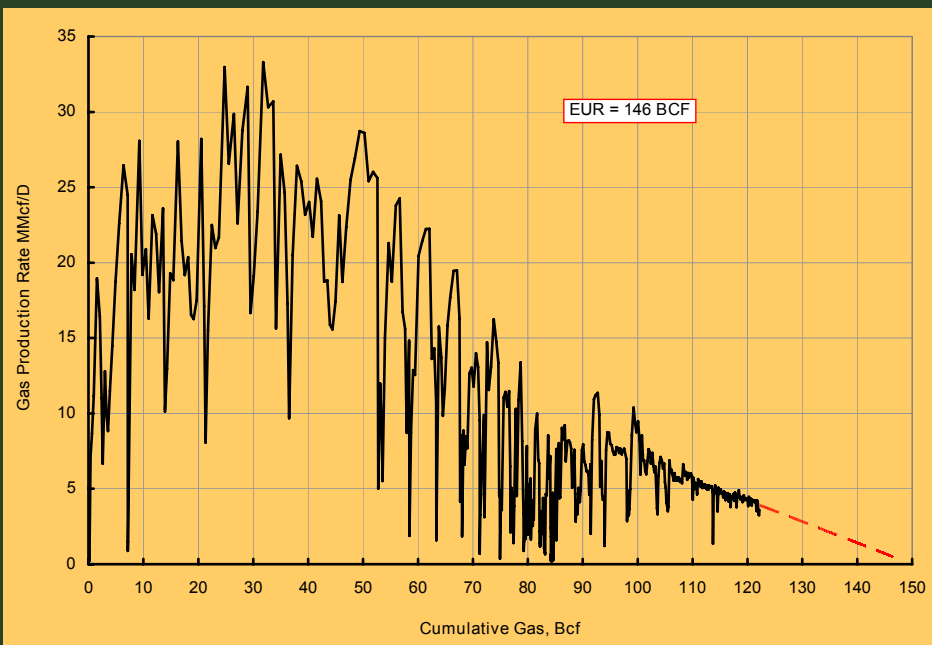
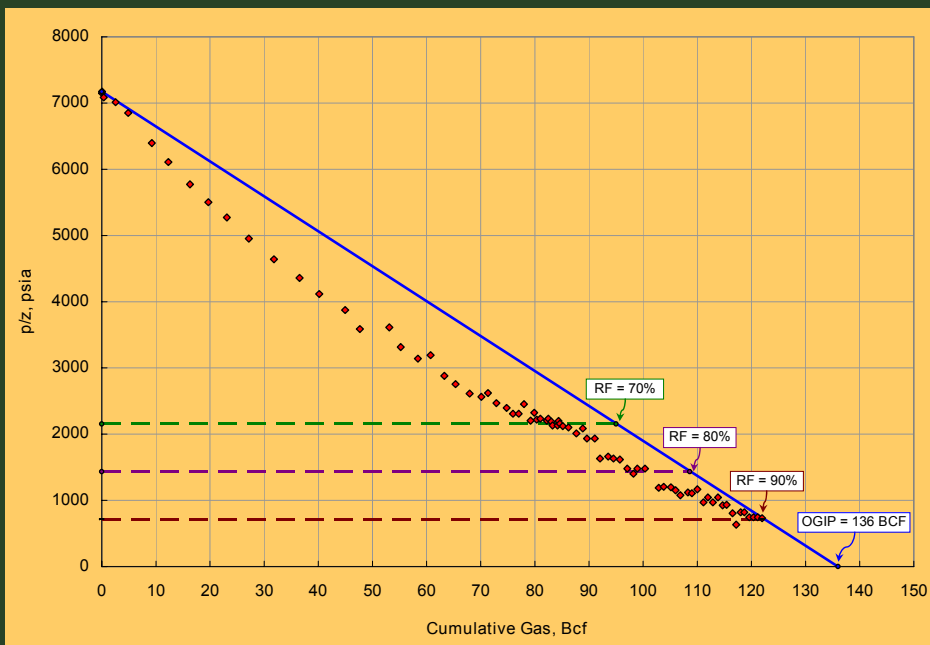
Use caution when...

- Gradient >0.6 psi/ft
- Small pressure change with production (water drive)
- p/z Apparent GIP much greater than Volumetric GIP
- Cumulative production less than 25-40% of expected EUR
- High withdrawal early in life – may mask water influx

Material Balance for Reserve Determination-Tight Gas Example



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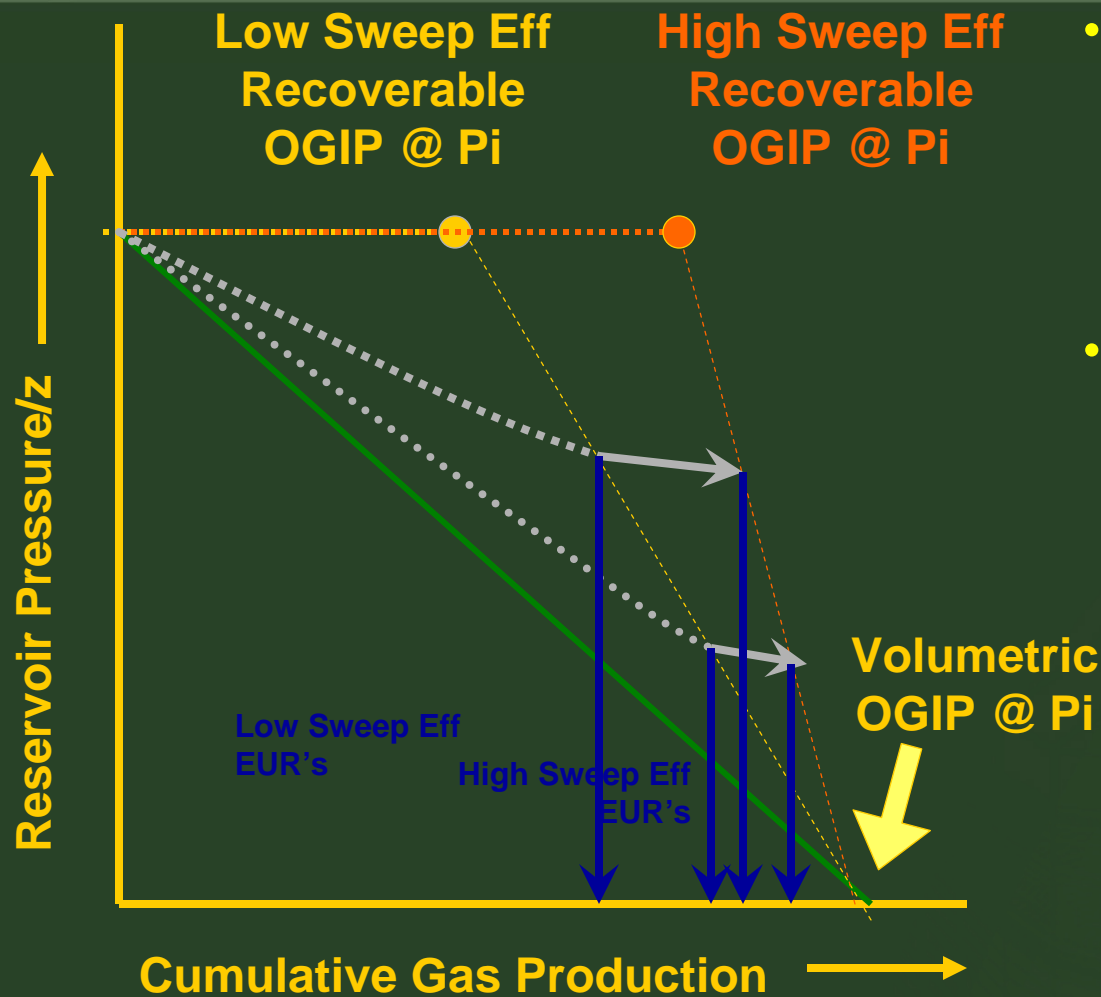


- 24 hr regulatory tests often do not provide the needed shut-in to reach a final pressure that properly represents the reservoir
 - Incomplete buildups \rightarrow underestimated P_{res} \rightarrow underestimated OGIP
- Rate-transient analysis may be an alternative method to determine reserves when sufficient static reservoir pressure is not available

Material Balance for Reserves Determination-Partial WD Gas



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- P/z plots can be of use in partial WD if there are proved analogies for a recoverable OGIP factor and proved volumetrics.
- Each component must be generated using proved components: volumetrics, recoverable OGIP @ p_i , and reservoir pressure trend.

Conclusions



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- Proved SPE/WPC \neq proved SEC
 - Pre-production PPG may be sufficient for contacts and continuity for SPE/WPC, but not SEC
- Lee's r_i not a valid basis for drainage area; especially if recovery factor is calculated independently
- Pressure analysis is a tool; results should be compared with other analysis (i.e. DCA and volumetrics)

Sources Referenced in Presentation



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Slide 5 - "Division of Corporation Finance: Frequently Requested Accounting and Financial Reporting Interpretations and Guidance," Prepared by Accounting Staff Members in the Division of Corporation Finance U.S. Securities and Exchange Commission,
<http://www.sec.gov/divisions/corpfin/guidance/cfactfaq.htm>.

Slides 5 & 7 - "Petroleum Reserves Definitions," SPE,
http://www.spe.org/spe/jsp/basic/0,,1104_12169,00.htm.

Slide 7 - *Regulation S-X*, Reg. §210.4-10, SEC, Washington, D.C. (1978).

Slide 8 - N.V. Humphreys *et al.*: "Using Interference Tests During Field Startup to Solve Critical Reservoir Management Issues at the Zafiro Field, Offshore Equatorial Guinea," *SPEPF* (November 1997) 210.

Slide 9 - Lee, W. John: *Well Testing*, Textbook Series Vol. 1, SPE, Richardson, Texas (1982) 1, 15.

Slide 11 - Harrell, D.R., Hodgins, J.E., and Wagenhofer, T.: "Oil and Gas Reserve Estimates: Recurring Mistakes and Errors", paper SPE 91069 presented at the 2004 SPE Technical Conference and Exhibition, Houston, Texas, 26-29 September