Are Our Proved Shale Reserves Reasonably Certain?

SPEE Houston Chapter
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What's the Problem?

- To forecast for unconventional reservoirs, we are using reserves estimation practices developed during the last century for conventional reservoirs – based on
  - Empirical observation of production declines for over a century
  - Modeling capabilities developed in second half of 20th century generally supporting simple decline models for estimating reserves
- But does this work for unconventionals?

How Do Unconventionals Differ?

- No experience of long-term declines
  - No way to validate models, simple or complex
- No modeling approaches totally, uniquely applicable, and relevant to physical processes involved
  - Long duration transient flow, unlike conventionals
  - Unknown contributions from hydraulic fractures and reopened natural fractures
  - Unknown physical mechanisms that may control multiphase flow characteristics

So We Have a Problem: How Can We Solve It?

- SPE Reservoir Description and Dynamics (RD&D) Committee investigating formation of task force to study issues
  - Active participation from other technical society representatives sought for task force
    - SPEE, AAPG, SEG, WPC included
  - Active participation by representatives from industry ultimately sought

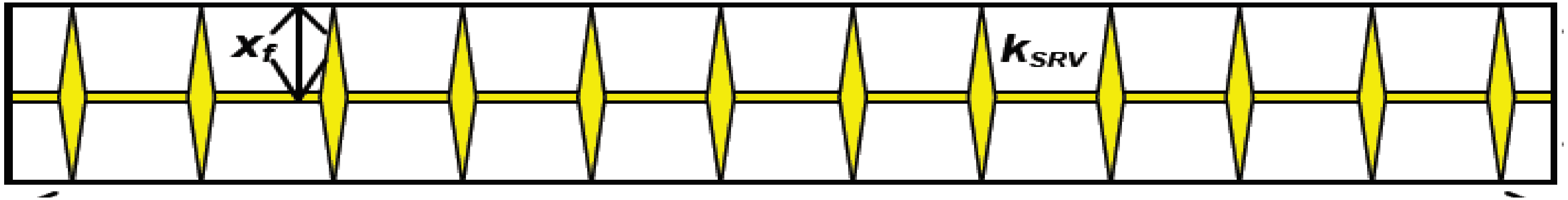
Who Are the Current Task Force Organizers?

- Members of SPE RD&D Committee
  - Oliver Houze, Kappa, Committee Chair
  - Tom Blasingame, Texas A&M, Committee Member
  - John Lee, University of Houston, Committee Member

Meanwhile, What Can We Do Today?

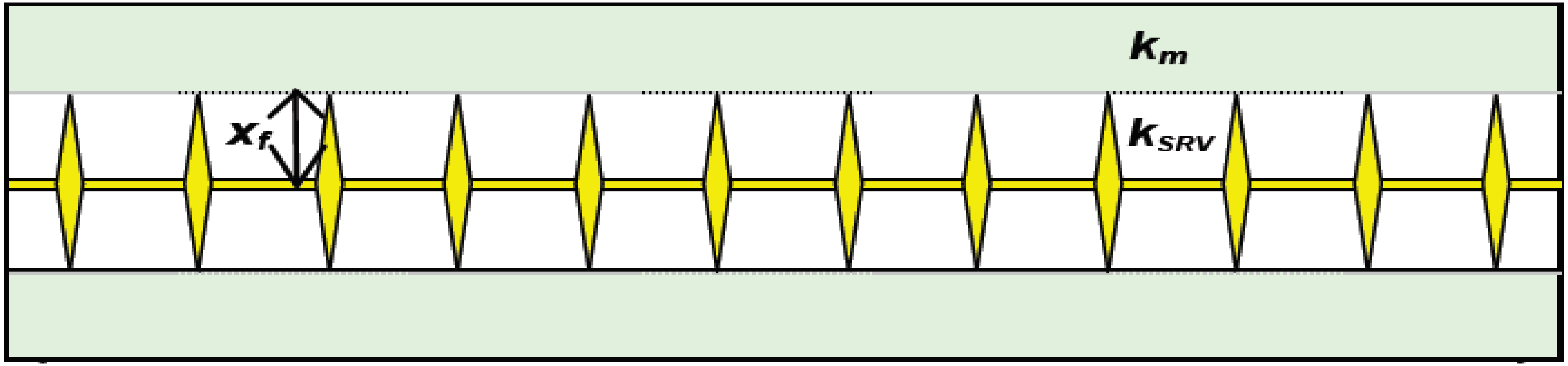
What We Assume Most of the Time

- Horizontal well with multi-stage fractures
  - Production only from Stimulated Reservoir Volume (SRV)
  - Two flow regimes
    - Transient (probably linear) flow to fracture interference
    - Boundary-dominated flow after fracture interference



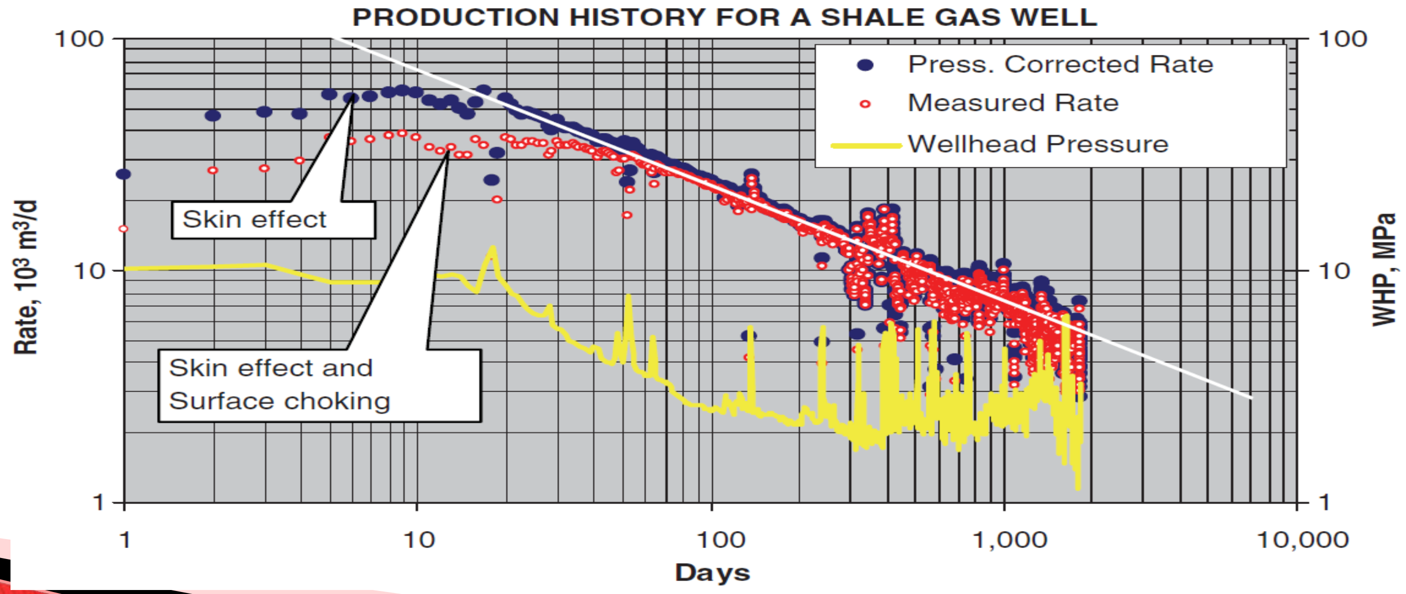
Perhaps Closer to the Truth

- At least four flow regimes
  - Transient linear flow to fracture interference
  - Boundary-influenced flow after fracture interference
  - Transient linear flow from unstimulated matrix into SRV
  - Boundary-dominated flow when entire well spacing drained



Still More "Flow Regimes"?

- Early fracture fluid clean-up (uncorrectable)
- Early decline in bottom-hole pressure (correctable, but possibly time consuming)
- Inclusion of these early data in determining simple decline model parameters (Arps, Duong, Stretched Exponential) inevitably leads to error



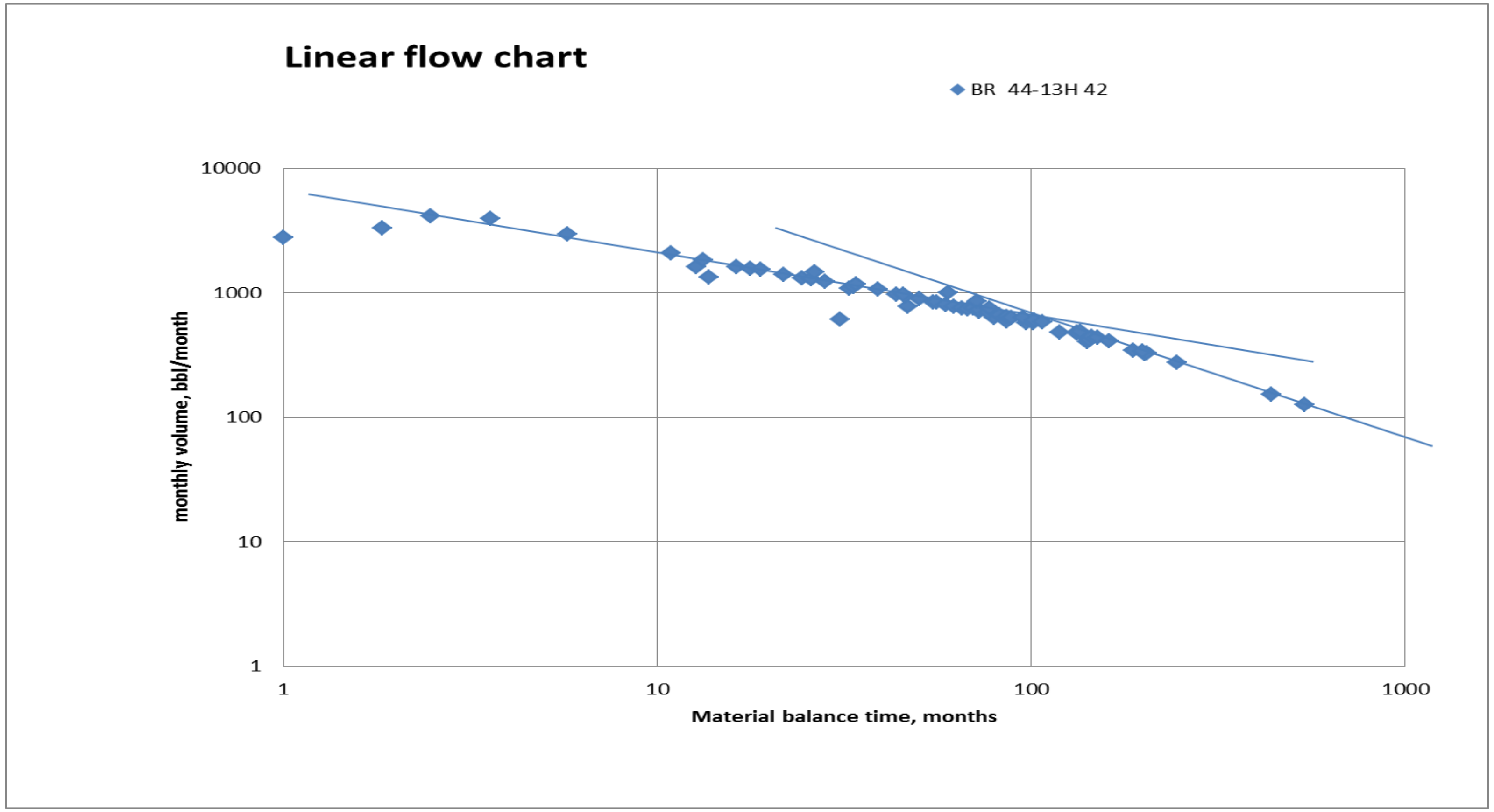
More Complications

- What if fractures aren't equally spaced?
- What if fractures aren't of equal length?
- Are early decline trends likely to be sustained?
  - What if SRV permeability decreases with decreasing pressure?
  - What will be the longer-term effects of multiphase flow?
- How can we estimate reserves with confidence?

How Can We Deal with All This?

- Common approach: simple models
  - Rationale: hundreds of wells to analyze in short periods of time
  - Example: two-segment Arps model
- More time-consuming approach – but still simple
  - Identify flow regimes with diagnostic plot
  - Model each flow regime with appropriate model
  - Example:
    - Discard early data not reflecting longer-term trends
    - Follow with transient linear flow model ($b=2$)
    - Follow with boundary-influenced model (b is what it is)
    - Finally, follow with second transient flow model ($b=2$)
    - Watch for needed final BDF model (if needed, appropriate b found from available data)
- Perhaps ok for "simple" systems, but …

Diagnostic Plot Indicating Early ‘Bad Data,’ Linear Flow, and BDF



Alternative Approach: RTA

- Rate Transient Analysis (RTA) techniques can identify need for more comprehensive modeling
  - Normalizing rates for BHP changes essential
  - Diagnostic plots to identify flow regimes essential
  - Rapid analytical solutions used to match history, forecast
  - Models still may oversimplify complex reservoirs and completions
- Equivalent ‘simple’ models identified at end of thorough study (not at start) to allow efficient processing of large numbers of wells

Another Alternative: Reservoir Simulation

- Good choice for complex situations
  - Variable length fractures
  - Unevenly spaced fractures
  - Complex fractures
  - Pressure-dependent rock and fluid properties
  - Multiphase flow
- Final goals still include equivalent ‘simple’ models for routine forecasting

Thoughts on Work Flow for Forecasting

- When BHP data available and time permits, normalize rates before analysis ($\frac{q}{p_i - p_{wf}}$) or $q_{corr} = q_{obs}\left(\frac{p_i - p_{wf,stab}}{p_i - p_{wf,obs}}\right)$
- Data from first 6-12 months (clean-up) may not reflect longer trends and should usually be excluded from analysis of historical decline
  - Plot water rate vs. time to identify fracture cleanup
  - Don't use data during cleanup, since skin continuously decreasing, won't fall on longer-term trend
- Determine flow regimes in available data
  - Minimum: log q vs. log t
  - Better: add log ($\frac{q}{p_i - p_{wf}}$) vs. log MBT (G_p/q, N_p/q)

Work Flow (Cont’d)

- Estimate time to BDF if not observed in data
  - Minimum: switch time from analogy
  - Better: depth of investigation or analytical model
- Don’t try to fit all history with single model
  - Fit each flow regime with model appropriate for *that flow regime*
  - Extrapolate rate to well life or economic limit only with *final* flow regime observed or expected – earlier flow regimes unimportant for extrapolation

Work Flow (Continued)

- Beyond simple, rapid modeling, may need to consider
  - Flow from unstimulated matrix to SRV and include in model when appropriate
    - Key: observation of new negative half-slope line, following BDF, on diagnostic plot
  - 'Complete' model that *may* include early transient flow, switch to BDF model after fracture interference, switch to linear flow model, final switch to BDF model – if present, each flow regime will appear on diagnostic plot

Summary

- We need a serious examination of forecasting techniques for unconventional resources
- Some in SPE leading exploratory effort to put together task force to examine issues
  - SPEE, AAPG, WPC members have indicated interest
- Simple models, RTA, reservoir simulators (none really validated) available in meantime
  - Logical workflows identified, show promise

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End

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