Qualitative Analysis of Rate-Time Behavior for US Gas Shale Plays
T.A. Blasingame, Texas A&M University
Original Work on Topic

- Unconventional Reserves Team:
  - Discussion of factors affecting reserves for unconventionals.
  - Survey of reserves practices for unconventionals.
  - Discussions of uncertainty.
  - Data-driven commentary on reserves behavior for shale gas plays.

- Conclusions:
  - Can use "similar practices" for unconventional reserves, but must recognize need to evolve.
  - Uncertainty issues will improve with time and technology.
  - Data (for shale gas plays) indicate that reserves are correlated with evolution of completion practices.

Tracy HECKMAN, Anadarko Petroleum Corporation
Grant OLSEN, Pressler Petroleum Consultants
Kerry SCOTT, Pioneer Natural Resources
Bernard SEILLER, Total
Marcia SIMPSON, EXCO Resources
Tom BLASINGAME, Texas A&M University
Most Recent Work on Topic

- Multi-Society Summit:
  - Designed to "marry" reserves and reservoir engineering.
  - Invitation-only event (new format).
  - Multi-Society event to ensure "neutrality" and reduce bias.

- Comments:
  - Probably a bit ambitious.
  - Very good discussions.
  - Need more geoscience input.

- Statements: (i.e., outcome proposals)
  - Value of Information/Flow Physics
  - Time-Rate Diagnostics/Analysis
  - Practices/Production Type Curves
  - Use of Darcy Flow Models
  - Need for Pressure Measurements
  - Need for Downhole Pressure
  - Forum on RTA for Unconventionals
  - Data Analytics/Forecasting EUR
**Themes:**

*Estimating Reserves in Unconventional Reservoirs:*

- It's early
- It's different
- It's about data
- It's about vision

![Lower 48 states shale plays map](http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm)
It's Early: *Tight Oil Will Dominate in 10-15 Years (U.S.)*

**From the Authorities: Oil**

- Tight oil (shale and chalk) production projected to rise sharply over next decade.
**It's Early: Lots of Room to Grow (U.S.)**

**From the Authorities: Gas**

- Shale gas is projected to be the most significant U.S. growth play over the next ~30 years.
- Considerable uncertainty in size and economics of shale gas resources.
- Most shale gas wells have been drilled in the last few years, leaving considerable uncertainty regarding long-term productivity.
It's Early: We are in a period of significant uncertainty!

Factors/Issues:
● Production forecasts
● Estimated Ultimate Recovery (EUR)
● Drilling times
● Completion techniques
● Optimum well spacing (interference)
● Impact on company portfolio
● Business considerations:
  ■ Project financing
  ■ Investor confidence
  ■ Regulatory harmony
It's Different: **Definitions**

**Conventional Reservoirs**
- Localized structural trap
- External hydrocarbons sourcing
- Hydrodynamic influence
- Porosity important
- Permeability > 0.1 md
- Permeability ≠ f(p)
- Traditional phase behavior (PVT)
- Minimal extraction effort
- Significant production history
- Mid-late development life-cycle
- Few wells for commerciality
- Base reserves on volumetrics
- Assess entire prospect before drilling
- Boundary-dominated flow (months)

**Unconventional Reservoirs (Shales)**
- "Continuous-type" deposit
- Self-sourced hydrocarbons
- Minimal hydrodynamic influence
- Porosity may not be important
- Permeability << 0.1 md
- Permeability = f(p)
- Complex (HP/HT) PVT
- Significant extraction effort
- Limited production history
- Early development life-cycle
- Many wells for commerciality
- Base reserves on analogs
- Prospect driven by drilling
- No boundary-dominated flow

**Contributions From:**
- Brad BERG, Anadarko

[Image links to websites for more information on conventional and unconventional reservoirs.]

---

**SPE Asia Pacific Unconventional Resources Conference and Exhibition**

**Qualitative Analysis of Rate-Time Behavior for US Gas Shale Plays**

10 November 2015 | Brisbane, Queensland Australia | T.A. Blasingame | Texas A&M University
It's Different: **Challenges and Methodology**

**Challenges:**
- No industry standard techniques for assessing unconventional exploration plays.
- Stimulation is the major challenge.
- Fractures (induced or natural) are critical producibility factors.
- Success is judged based on production results.

**Methodology:**
- Expect the unexpected. Well performance will vary, despite similar drilling/completion practices, well spacing, etc.
- Unconventional plays are "statistical," many wells must be drilled to assess potential.
- Drilling too few wells is likely to lead to a bad decision(s).
It's About Data: What is Linear Flow?

- Formation Linear Flow
  - Log-log diagnostic plot: \( \log[q(t)] \) versus \( \log[t] \) (slope = -1:2)
  - "qDb" (time-rate) plot: \( \log[q(t)] \log[D(t)] \log[b(t)] \) versus \( \log[t] \)
  - "Traditional" plot: \( q(t) \) versus \( 1/\text{SQRT}[t] \) (straight-line portion)
  - Extrapolation using a linear flow model will over-predict EUR…

Schematic Performance for a Gas Well
(log[\(q_d\)] versus log[\(t\)])

Schematic Performance for a Gas Well
(\(q_d\) versus \(1/\text{SQRT}[t]\))
It's About Data: Log-Log Plots — Linear Flow (Gas Shales)

Data taken from publicly available sources — Horizontal Shale (Dry) Gas Wells ONLY

Discussion:
- "Linear Flow" $\rightarrow b = 2$
- START of "Linear Flow" (~3-6 m)
- END of "Linear Flow" (~9-36 m)

Data taken from publicly available sources — Horizontal Shale (Dry) Gas Wells ONLY

Discussion:
- **START** of "Linear Flow" (~3-6 m)
- **END** of "Linear Flow" (~9-36 m)
- "Linear Flow" is represented by linear trends on these plots.
- Square root time plot used to show linear portion of trend ($G_p(t)$ vs. $\text{SQRT}(t)$ is most clear)

It's About Data: **Square Root Time Plots — Linear Flow (Gas Shales)**

Data taken from publicly available sources — Horizontal Shale (Dry) Gas Wells ONLY

---

Discussion:
- Results are "auto-fitted" and should be considered reasonably accurate.
- Results will vary when data are segregated by geological area, completion practices, spacing, etc.
- Analyses represent an attempt to quantify the RANGE of values.

---

It's About Vision: *Models for Production Forecasting*

- **Most likely scenarios:**
  - Statistical models will remain an alternative to reservoir models.
  - Analytical and numerical models will focus on SRV/beyond SRV.
  - Numerical models will use more microseismic and geomechanics.

- **Developed Reserves: Decline Curve Analysis (DCA)**
  - (present) DCA models are useful to relate "SRV"-based reserves.
  - (future) Beyond the "SRV" will require a reservoir model.

- **Developed Reserves: Probabilistic Methods**
  - Probabilistic (non-deterministic) reserves can provide insight.
  - Probabilistic models will account for changes in completions.
  - Probabilistic approach(s) will continue to evolve...

- **Undeveloped Reserves:**
  - Data mining methods will yield insight into *EUR trends*.
  - *EUR* = \( f(\text{geomechanics, geology, completions, and stimulation}) \).  
  - Seismic can be/will be used to calibrate geostatistical models.
  - Geomechanical properties are/will be the weak link.
It's About Vision: Final Comments

"Progression Cycle" for Unconventional Resources

- Technology Trigger
- Peak of Inflated Expectations
- Trough of Disillusionment
- Slope of Enlightenment
- Plateau of Productivity

- Visibility
- High Gas Prices
- Decarbonization
- Proximity to Domestic Market
- Multi-Fracture Horizontal Wells
- Political Backlash
- Sweet Spot Identification (Statistical Plays)
- Water Management
- Seismic Exploration
- Completion Optimization
- Joint Venture Funding
- Reservoir Modeling
- Strong Oil Prices ( Liquids-Rich Systems)
- High Acquisition Costs
- Low Gas Prices
- Microseismic Monitoring
- High IPI
- High EUR
- "On Demand"

- Years to mainstream adoption:
  - < 2 years
  - 2 to 5 years
  - 6 to 10 years

Technology Maturity for Unconventionals

- Previous Technology Cycle — e.g., Tight Gas
- Maturity (Full Capacity — e.g., ... super-majors)
- Aggressive Development (e.g., Large Independents)
- Testing of Concept (e.g., Small Independents)
- Gesture (Geologic Potential of Shale Gas)

- "Big Bang" (Innovation or vision)
- Potential of Concept is Realized
- Potential for Further Development is Constricted
- Maturity (No More Development)

- "Progression Cycle" plots used to illustrate "product" development.
- Certain features will change position (e.g., microseismic monitoring).
- Non-technology features can doom a "product" (e.g., political issues).

- Graphic explains "Technology Maturity" for unconventional resources.
- The maximum "value" occurs as the potential is realized (i.e., very early).
- The "constriction point" implies too many players/less innovation/value.
Qualitative Analysis of Rate-Time Behavior for US Gas Shale Plays
T.A. Blasingame, Texas A&M University

End of Presentation