What New Tools Do Geoscientists Need in the Next Decade? A Return to Basics*

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*Adapted from oral presentation at Business Forum--Unconventional Exploration and Development Geoscientists' Toolbox: What New Tools Do Geoscientists Need in the Next Decade?, AAPG International Conference and Exhibition, Calgary, Alberta, Canada, September 14, 2010

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General Statement

The tools for the next decade are the same as those that should have been used in the past and present:

- trap definition,
- reservoir presence and quality (natural fracturing, fracture susceptibility),
- charge efficiency,
- seals/hydraulic barriers.

NPV (Net Present Value) not EUR (Estimated Ultimate Resource): big is impressive but not necessarily profitable.
Unconventional plays must be pursued using conventional tools:

- rejection of manufacturing model,
- resource assessment based on analogy vs. fantasy,
- disciplined land strategy focused on geological and economic reality,
- an approach that acknowledges uncertainty—nanodarcy rock may not work in the long run.

Early identification of core areas: emphasis on seismic mapping of structure and stratigraphy, and pilot projects.
Probabilistic methods for EUR and economics.
Acknowledge limitations of type curves and emphasize individual well performance.
Prospect-based risk analysis and peer review.

Acknowledgments

Acknowledgments are extended to Mike Bodell, Allen Brooks, Perry Fischer, Robert Gray, Jim Halloran, IHS, Lynn Pittinger, and Keith Shanley.

References

Knox, Larry, 2010, Critical Factors for CBM – those early fundamental parameters (Presentation): AAPG Geosciences Technology Workshop on Unconventional Gas Resources, June 22-24, 2010, Instanbul, Turkey, unpublished.

Shanley, Keith, 2010, Tight gas in the US Rocky Mountains (Presentation): AAPG Geosciences Technology Workshop on Unconventional Gas Resources, June 22-24, 2010, Instanbul, Turkey, unpublished.

Notes by Presenter Accompanying Slides on Page 8 (Slide 5), Page 18 (Slide 15), and Page 19 (Slide 16)

Page 7 (Slide 5)

The key points here are that the most efficient and diversified companies have a marginal cost (discounted) of $4.75-5.00; therefore, with reasonable hedge positions, these companies make a small profit. Most companies have marginal costs in the $7-8 range and lose money net of hedges. Thus, the question is: What has to change to make shale plays profitable?

Answer is: A more disciplined, science-based approach that optimizes reservoir quality and trap definition, and limits up-front capex on land.

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Page 17 (Slide 15)

This slide is derived from the 2009 10-K filings of these companies. We use the ceiling test value to determine unit cost based on stated discounted future value of reserves. This discounted value removes the problem of dynamic price from the process. The amount of the impairment write-down on a unit basis is calculated from the "realized price" (hedged and un-hedged).

As noted, the relatively higher marginal cost of HK and EXCO is because they are penalized for spending a huge amount on land that has not yet been drilled and converted into reserves. If they eventually drill and prove it all (unlikely), their cost will decrease. Similarly, if they find a third party to buy the land at a premium (also unlikely), their cost goes down. These days, it seems that the best that can be hoped for is a joint venture where the operator still has to pay his share of capex and gets fewer reserves. HK and EXCO "get dinged" because they spend billions on land that basically increases their capital costs by 50%. Less debt-ridden companies do better.

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Page 18 (Slide 16)

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Business Forum: Unconventional Exploration & Production

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Frontiers of Unconventional Thinking: Saddle Up for the Ride

What New Tools Do Geoscientists Need in the Next Decade?

A return to basics

AAPG International Conference & Exhibition Business Forum

Calgary September 14, 2010

Arthur E. Berman

Unconventional Tools for the Next Decade: a return to basics

- The tools for the next decade are the same as should have been used in the past and present:
  - ✓trap definition,
  - ✓reservoir presence and quality (natural fracturing, fracture susceptibility),
  - ✓ charge efficiency,
  - ✓seals/hydraulic barriers.
- NPV not EUR: big is impressive but not necessarily profitable.
- Unconventional plays must be pursued using conventional tools:
  - ➢rejection of manufacturing model,
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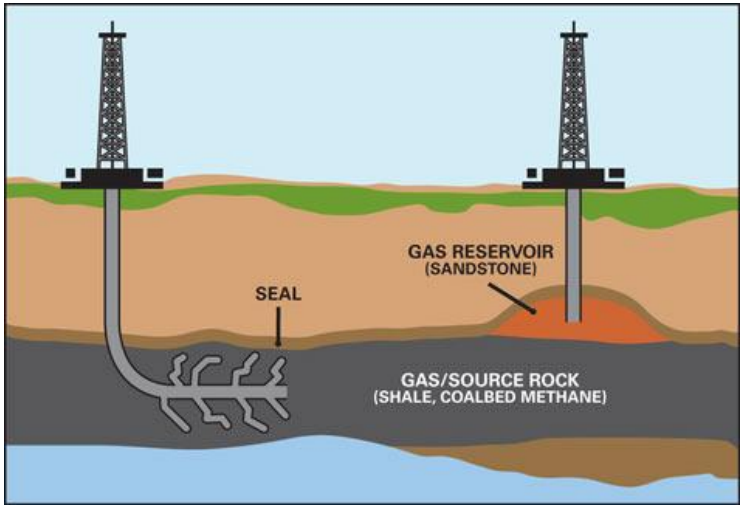
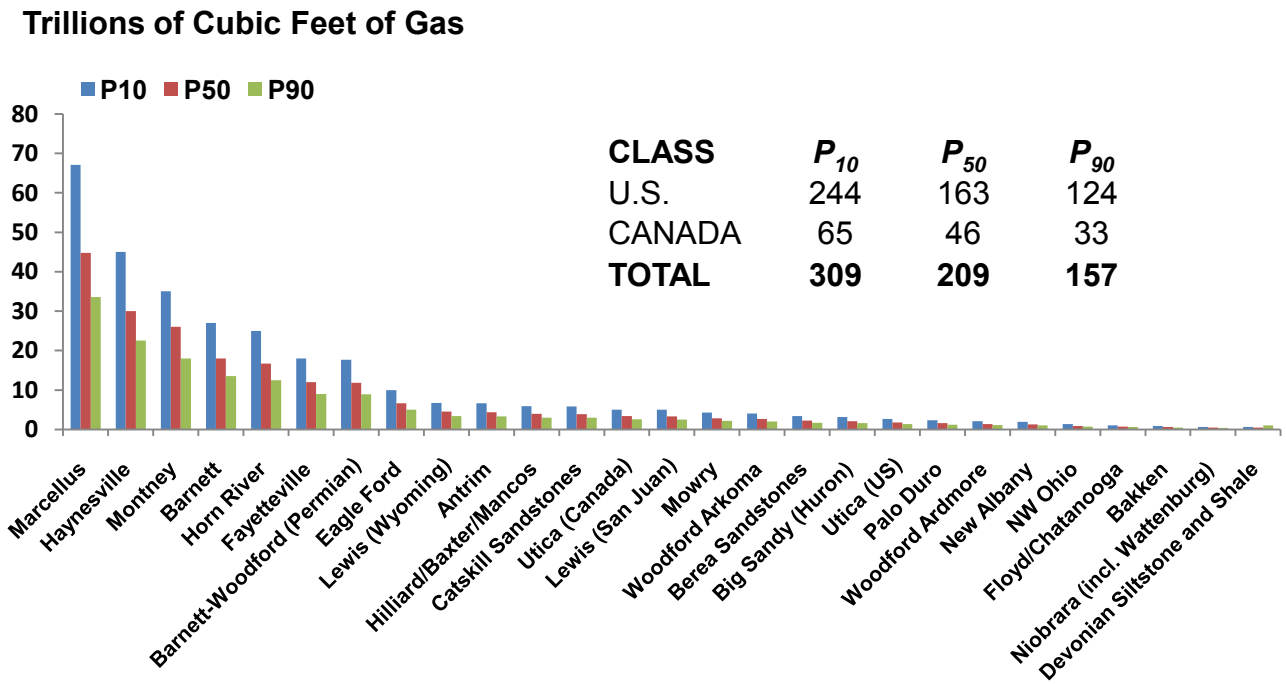
  - ➢ disciplined land strategy focused on geological and economic reality,
  - ➢ an approach that acknowledges uncertainty—nanodarcy rock may not work in the long run.



Unconventional Tools for the Next Decade: a return to basics

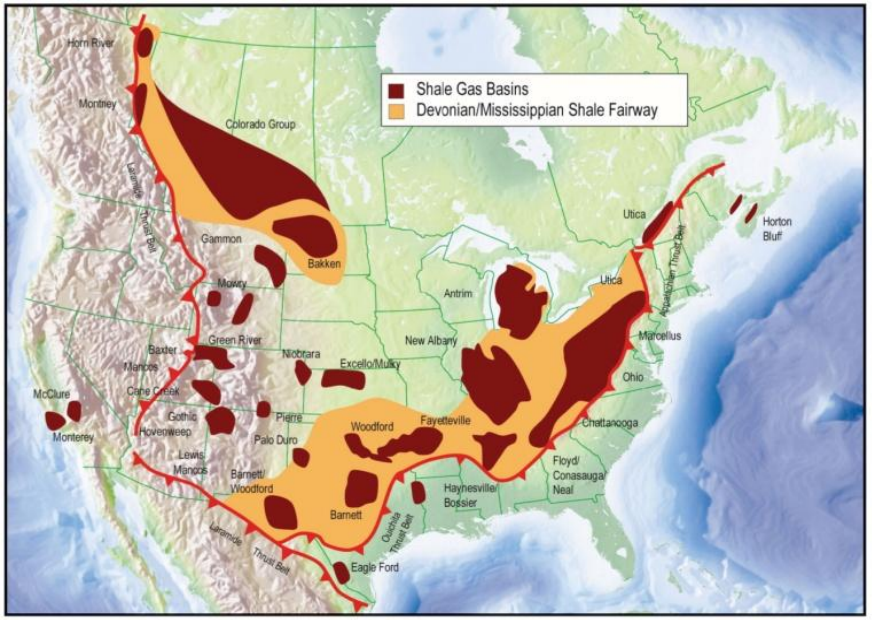
- **Early identification of core areas: emphasis on seismic mapping of structure and stratigraphy, and pilot projects.**
- **Probabilistic methods for EUR and economics.**
- **Acknowledge limitations of type curves & emphasize individual well performance.**
- **Prospect-based risk analysis and peer review.**



CLASS	P_{10}	P_{50}	P_{90}
U.S.	244	163	124
CANADA	65	46	33
TOTAL	**309**	**209**	**157**

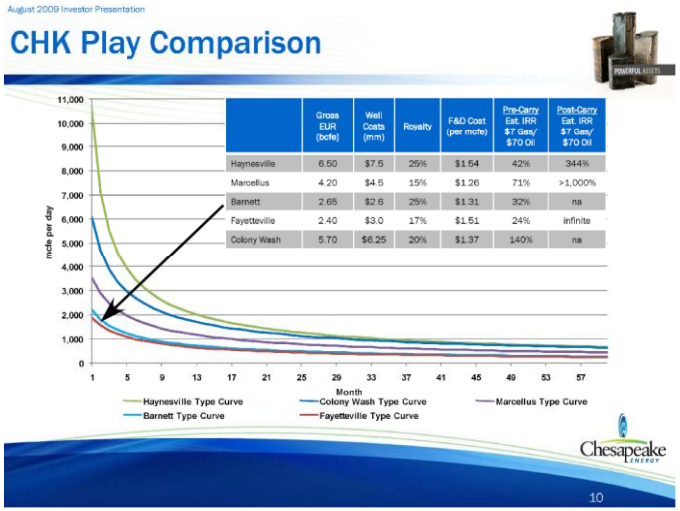
Why there is uncertainty

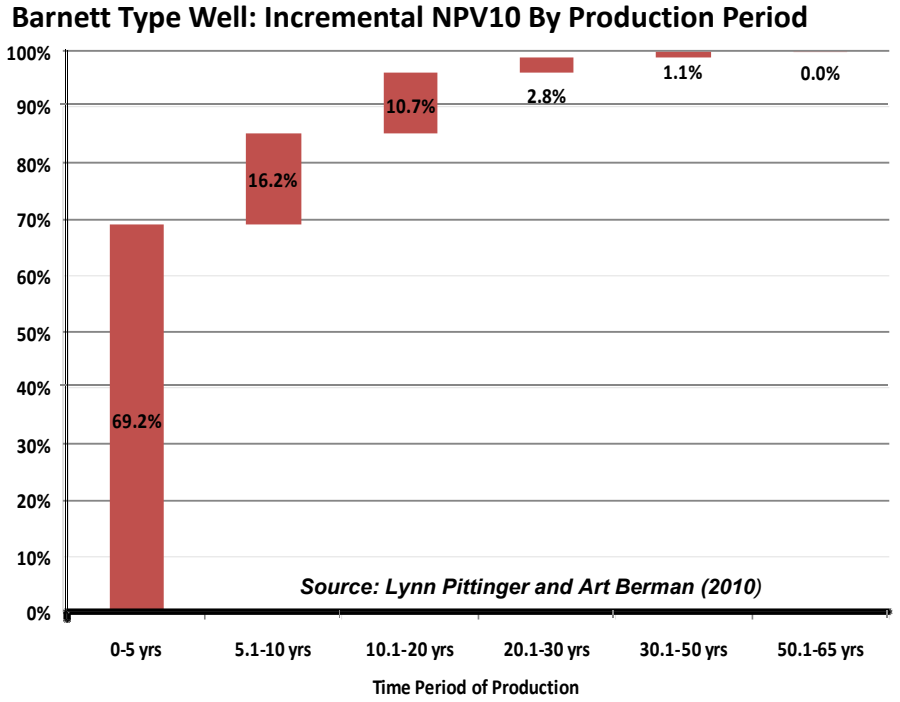
- Shale gas production is a recent phenomenon and assessment is an emerging practice.
- Plays are marginally commercial at best—growth strategies have destroyed value and profit in short term & raised doubt about industry responsibility.
- What we know is based on a few years of production.
- We don't know how long that production will last and what its decline trajectory will look like.
- Discussing shale gas EUR is like planning what to do when we win the lottery (Richard Nehring).



Click to view presenter's notes.

NPV not EUR

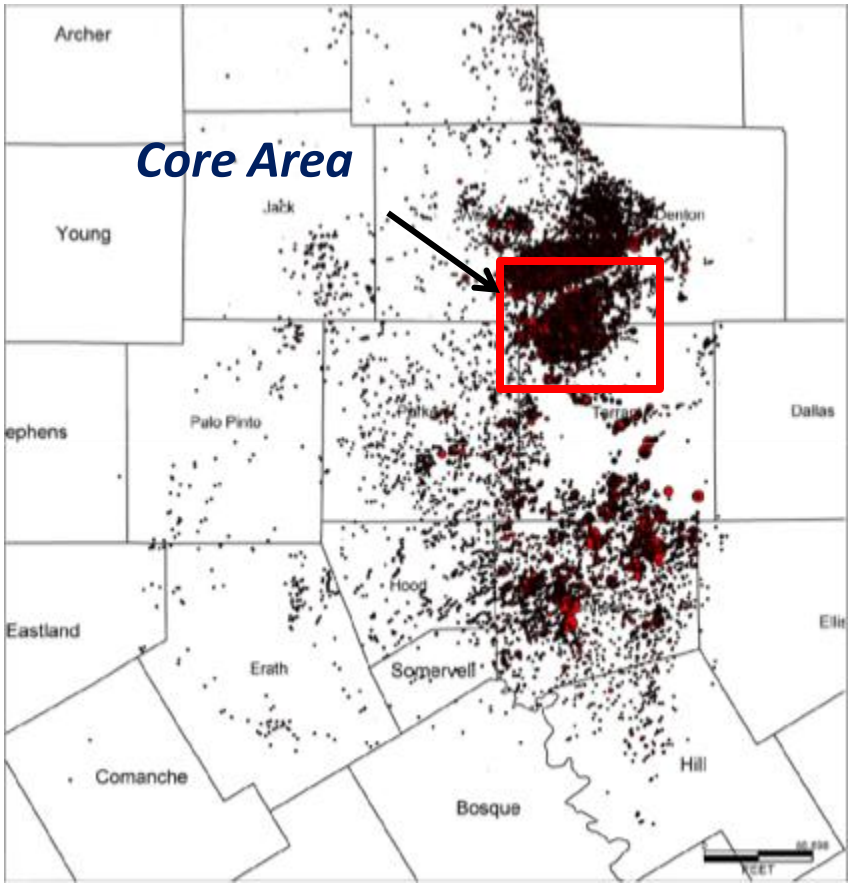




Chesapeake Type Well for the Barnett Play

- **70% of value produced in 1st 5 years, and 85% in 1st 10 years,**
- **Negligible value added after 20 years - yet operators claim significant EUR comes after year 20,**
- **Valueless volumes are being used to dilute finding and development cost numbers, and**
- **Actual Barnett decline rates: 45% of EUR in Year 1, 65% by end of 2nd, 75% by end of 3rd.**

Manufacturing model has failed & must be rejected



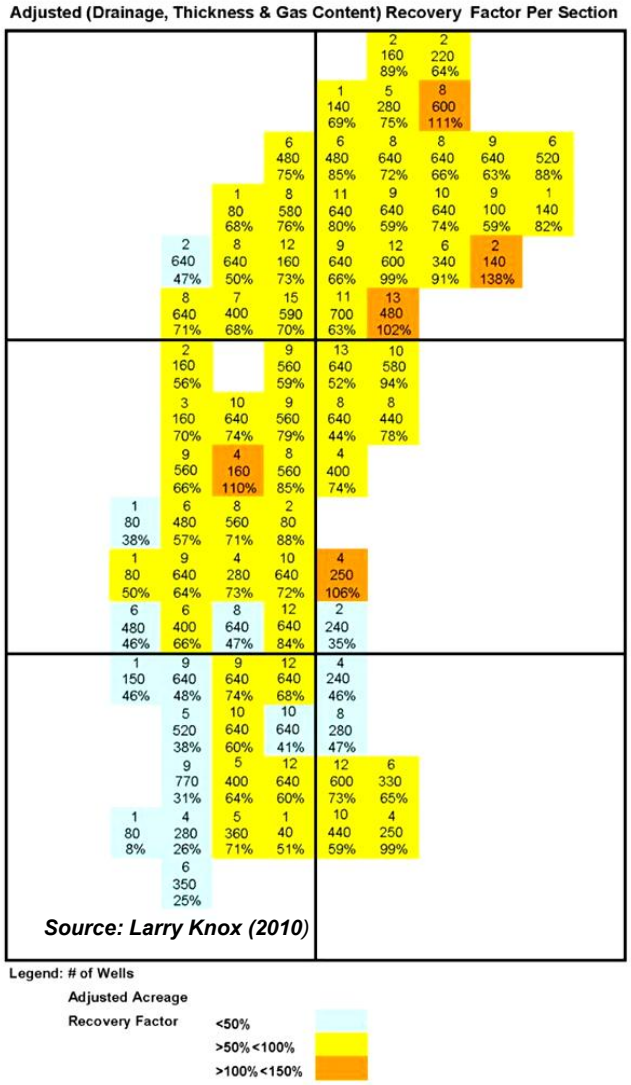
"There was a time you all were told that any of the 17 counties in the Barnett Shale play would be just as good as any other county," McClendon said. "We found out there are about two, or two and a half counties where you really want to be."

--Bloomberg News October 14, 2009

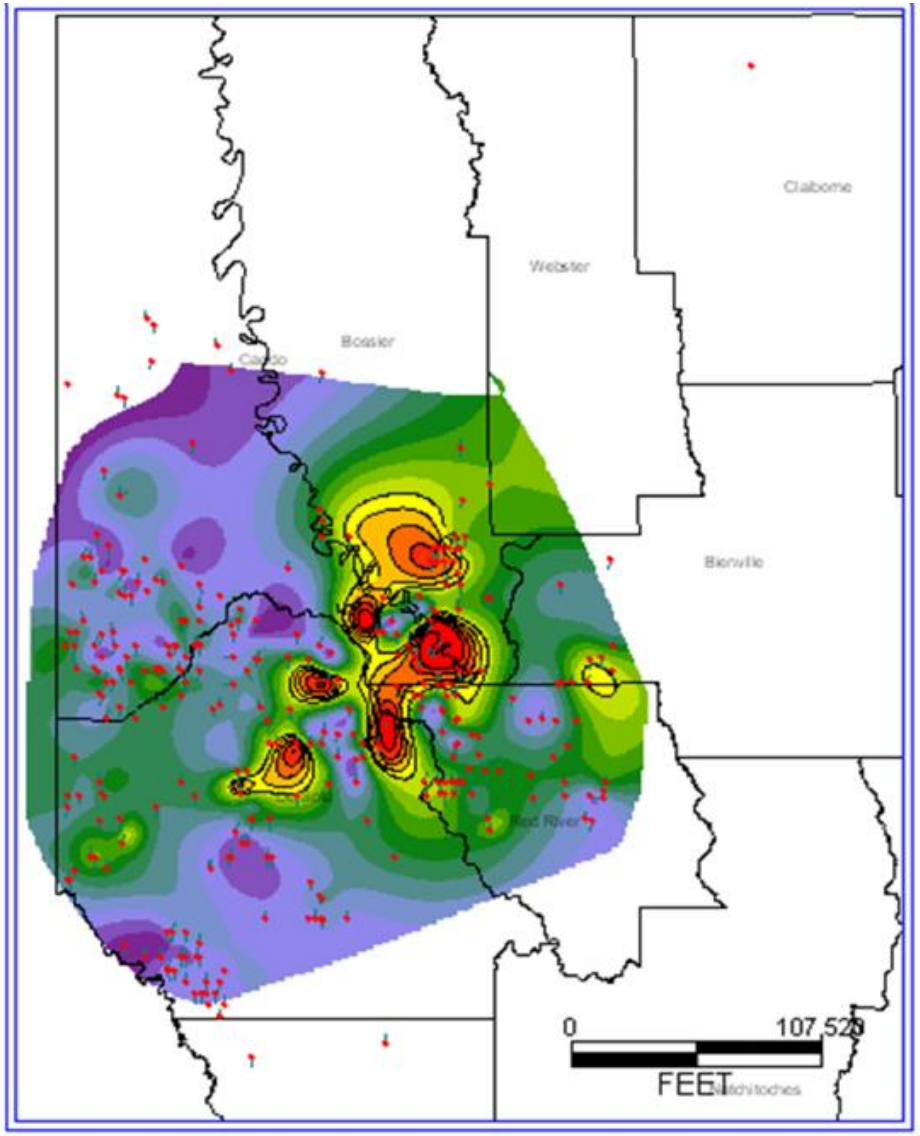
- **Over 14,000 wells drilled and more than $35 billion spent .**
- **As much as $20,000/acre .**
- **Production has peaked.**
- **Core areas not uniform & include many poor wells.**
- **Core area defines where potential exists for commercial production.**

Resource assessment based on analogy not fantasy

- Geochemical methods probably exaggerate shale resources.
- Knox (2010) shows that coal resources over-estimated by as much as 100% based on post-mortem evaluations.
- Similar methods used for shale play resource estimates:
  - shale is more heterogeneous than coal,
  - much less organic material & more variability in type,
  - significantly lower permeability,
  - little production history for calibration.

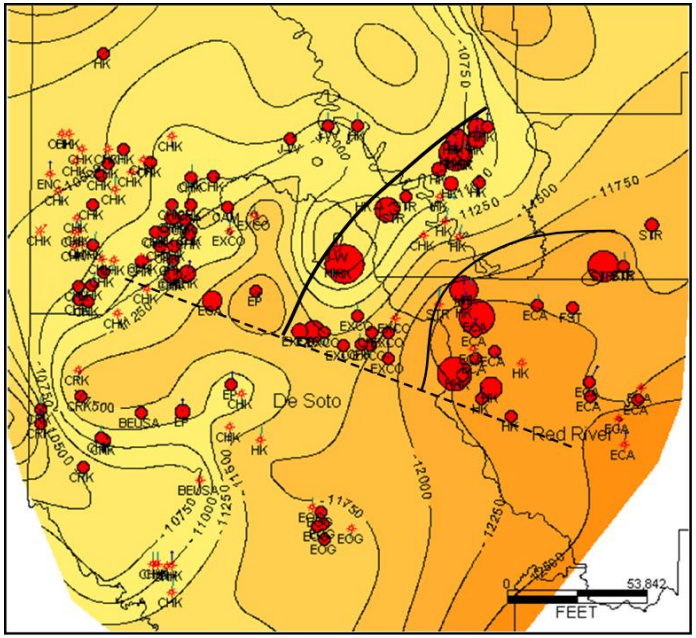


Disciplined land strategy focused on geological and economic reality

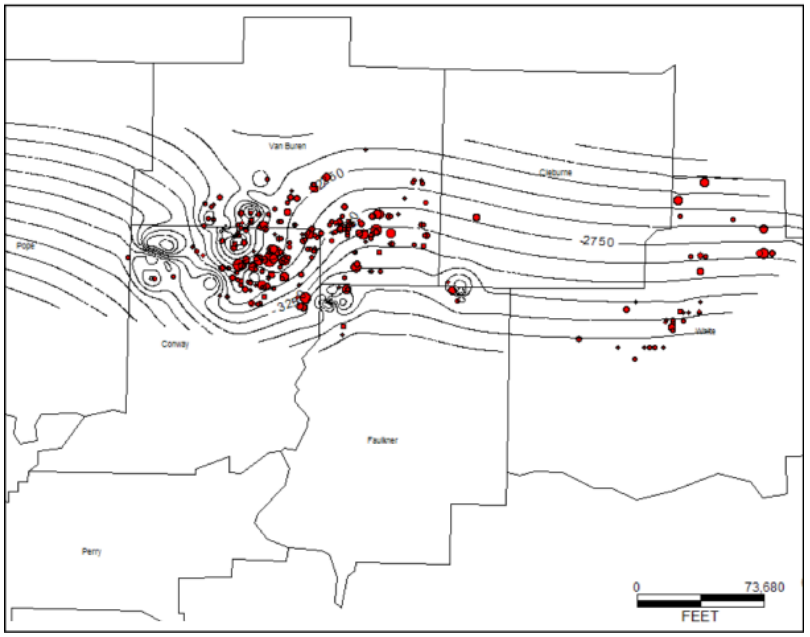


- Haynesville Shale core area based on generous mapping of EUR > 4.5 Bcf—coincides with areas of overlying Cotton Valley and other pre-existing production.
- The core area in this view includes 110,000 acres or about 5 Townships.
- This represents approximately 8% of the play area in Louisiana (~1.5 million acres or 65 Townships).
- 2 years ago, this was promoted as the 4th largest gas field in the world, and the largest in North America (250 tcf)/1.4 million acres).
- Haynesville is a significant resource but probably far less than estimates made in 2007-2008.

Early identification of core areas: emphasis on seismic mapping of structural and stratigraphy, and pilot projects



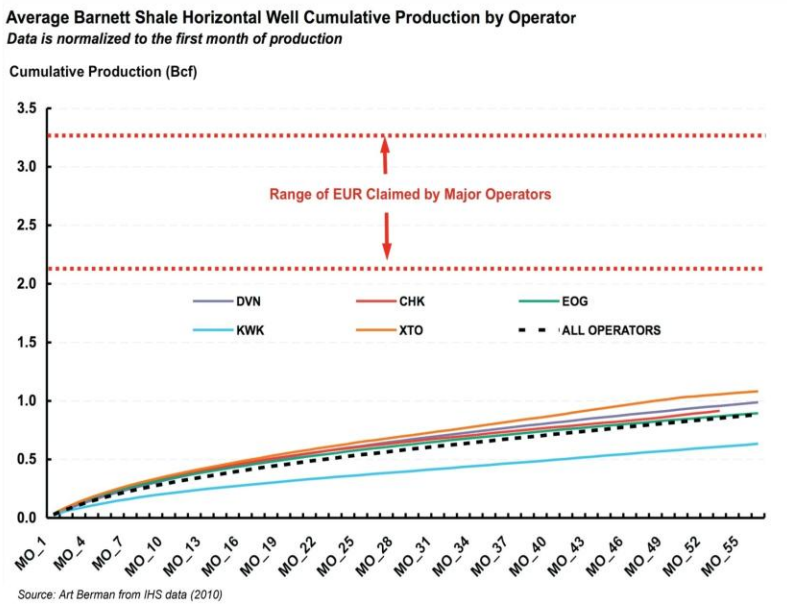
Haynesville Shale
structure map

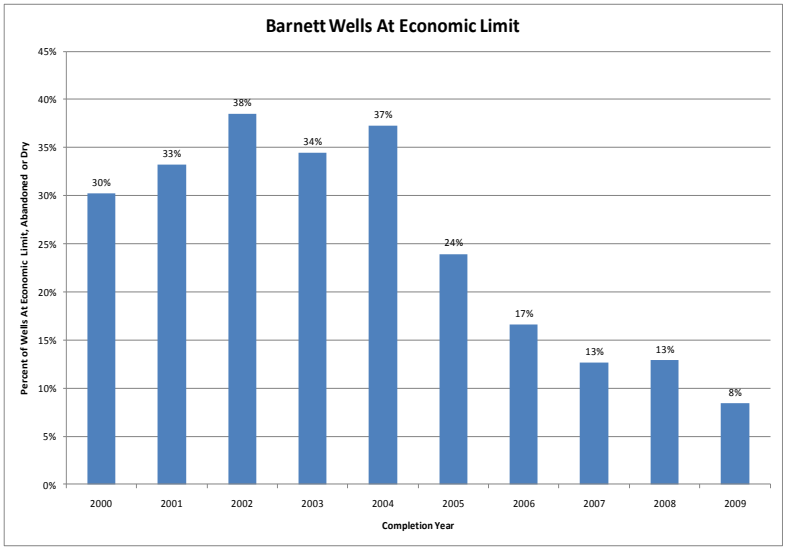


Fayetteville Shale
structure map

- Traps are critical and best production is in discreet areas.
- Pilots appropriate to characterize reservoir and best-practice completion methods.
- Southwestern Energy did extensive pilot work in Fayetteville Shale.

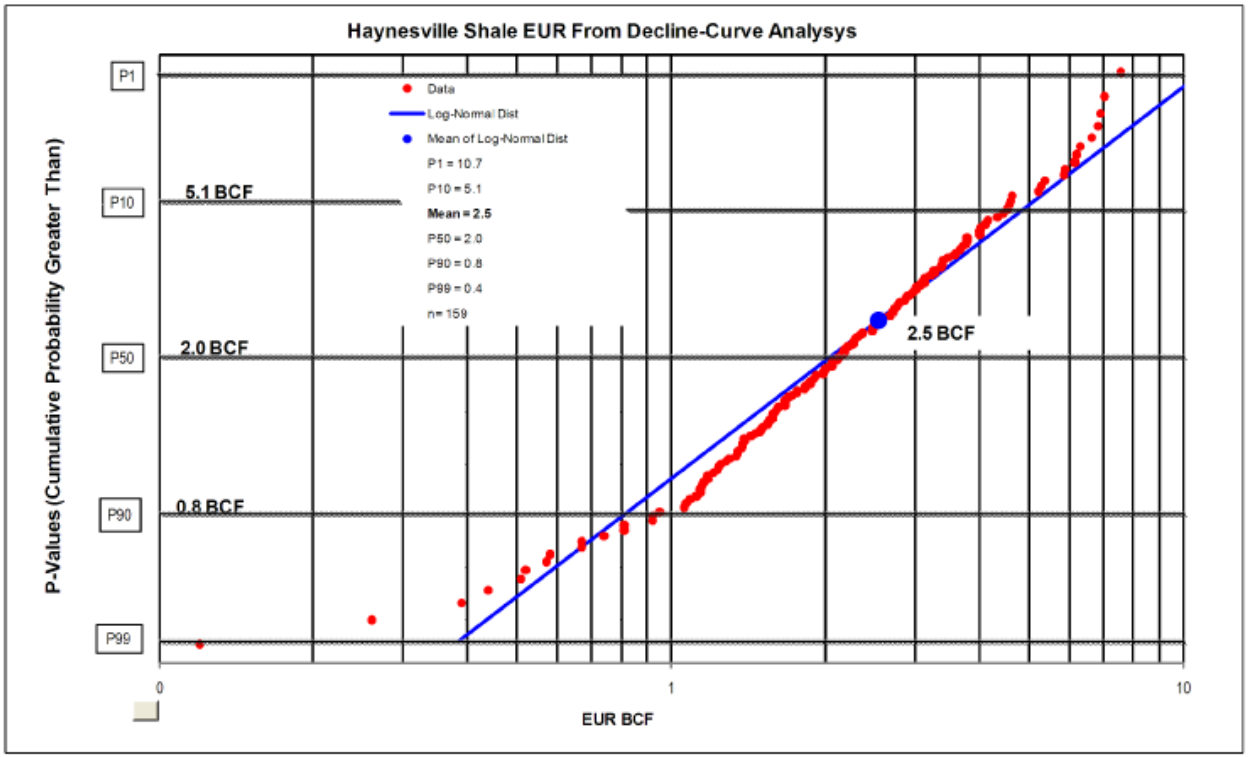
Probabilistic methods for EUR and economics





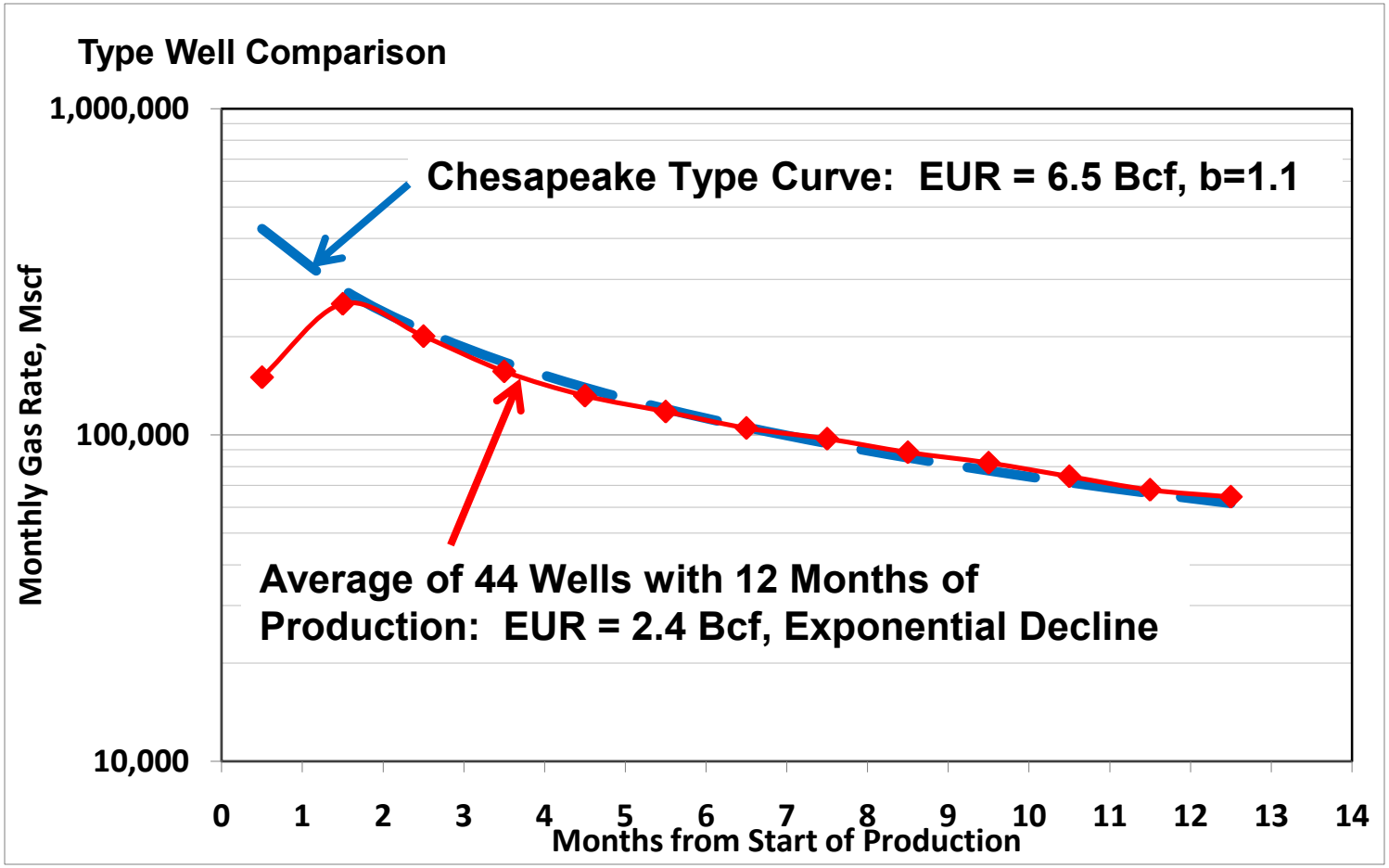
- Reserves based on very long well lives that assume flat decline rates.
- Barnett examples based on cumulative production show that EUR estimates are improbable in a time frame where NPV is meaningful.
- Barnett mortality rate casts doubt on 40-65 year well life.

Probabilistic methods for EUR and economics



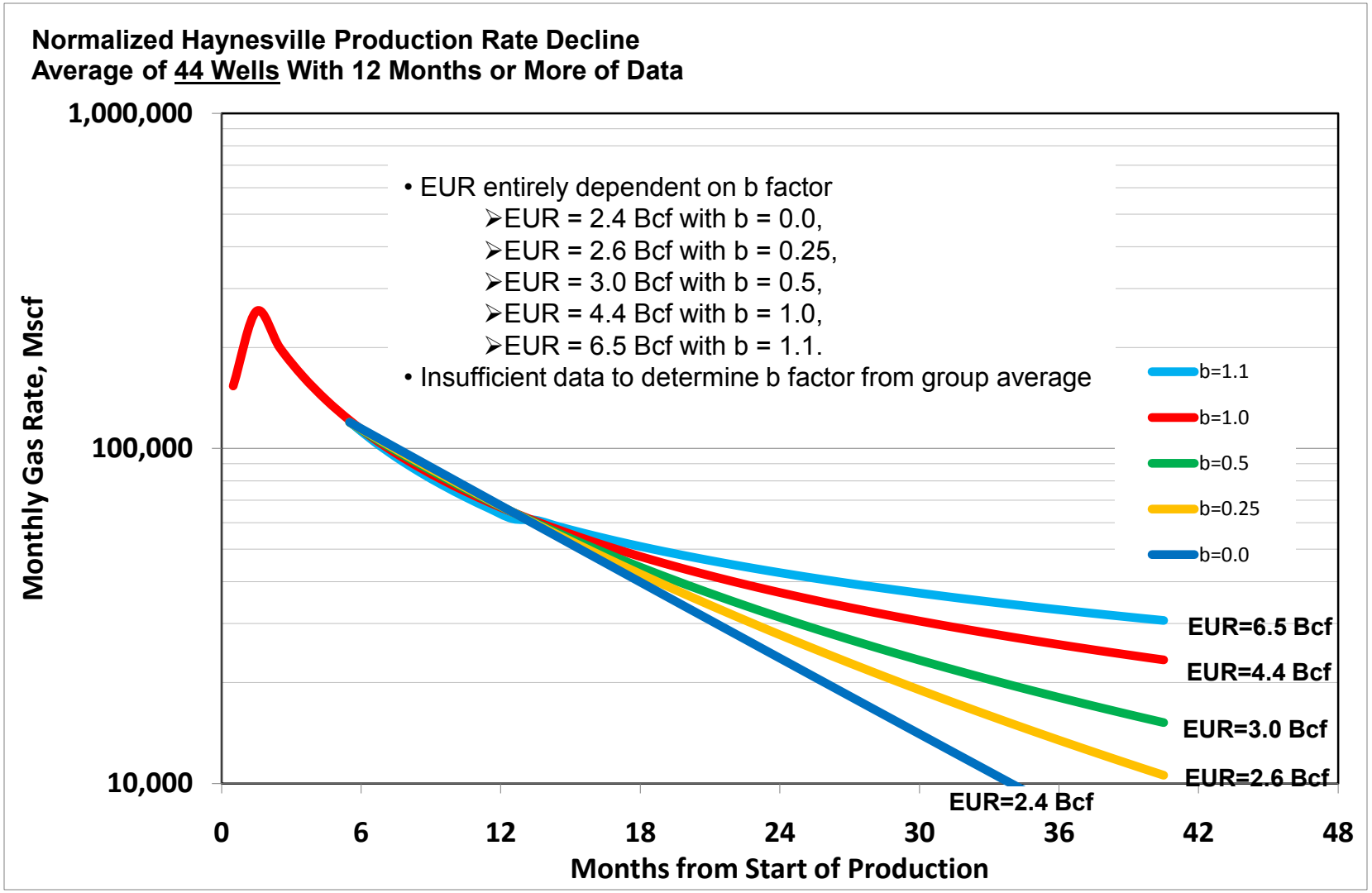
- **Many Haynesville operators claim average well EUR of 6-7.5 bcf.**
- **Our analysis suggests Petrohawk may average 5 bcf or more, but Chesapeake will average less than 2.5 bcf using the same forecasting methodology.**
- **Both cannot be correct: either Petrohawk is under-estimating reserves by 200-300% or Chesapeake is over-estimating by a similar factor.**
- **A probabilistic approach more accurately represents current uncertainty: cannot represent P_5 case as being most likely.**

Acknowledge inaccuracy of type curves: Haynesville example



- The Difference Lies in Forecasting Future Decline Trends.
- Particularly the hyperbolic b exponent.
- Type curves don't work because of survivorship bias & emphasis on mean in a highly variable and small population--commonly over-predict by 50%.

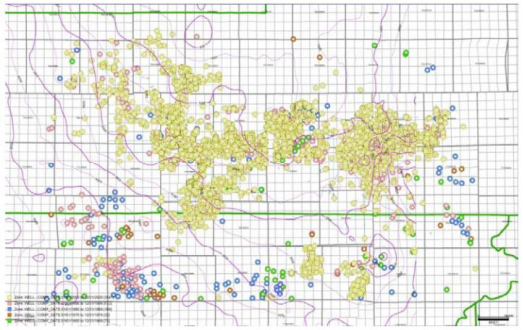
Hyperbolic exponents cannot be whatever we like

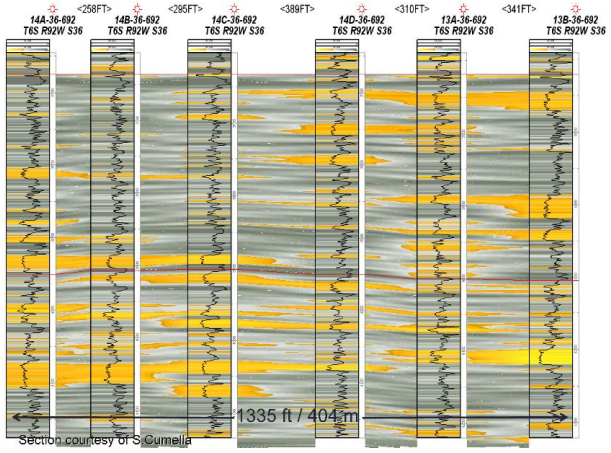


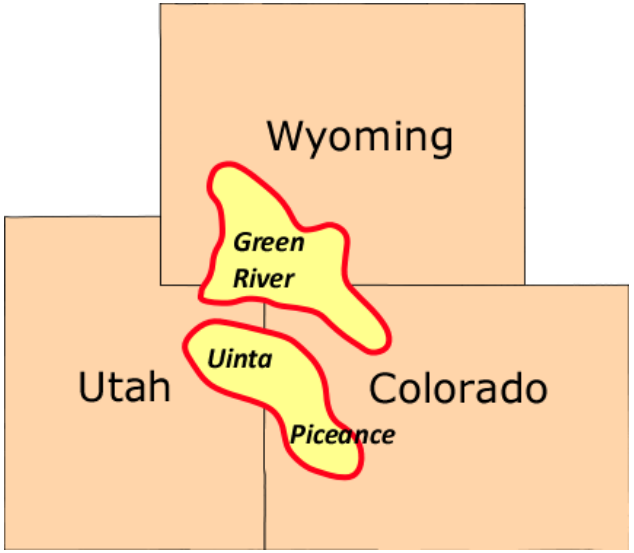
Once EUR is determined, run NPV model to find value limits

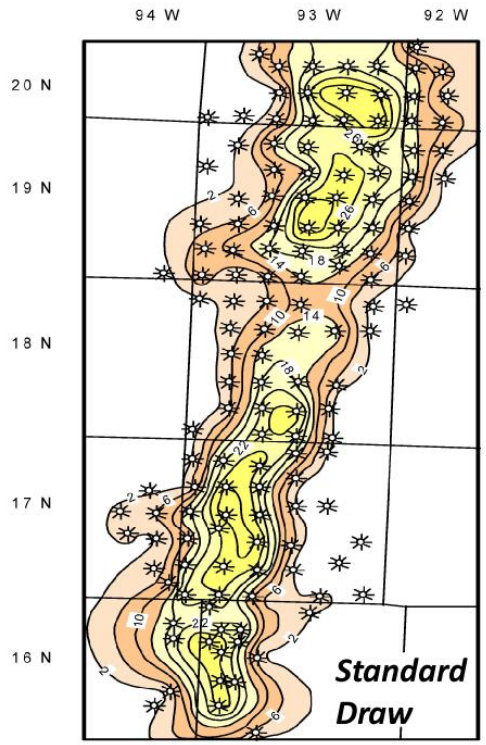
Prospect-based risk analysis and peer review

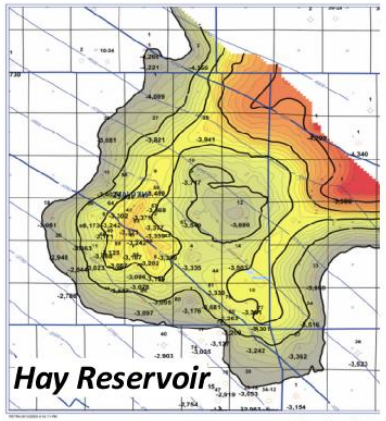
- **Unconventional plays obey the laws of physics.**
- **Three decades of tight sandstone E&P demonstrate that unconventional plays have trap definition, reservoir quality , seal & charge efficiency dimensions.**
- **Tight sandstone plays also mandate need for pilot programs to establish economic feasibility and production optimization.**







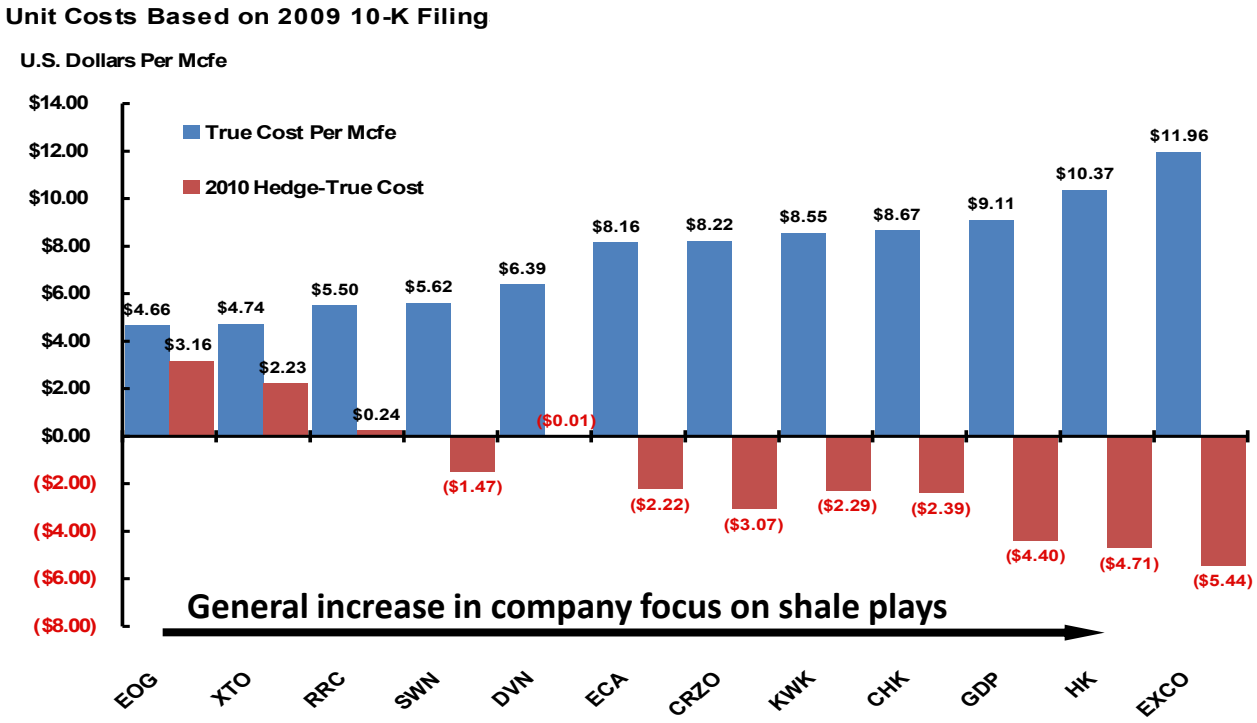




From Shanley (2010)

Click to view presenter's notes.

Prospect-based risk analysis includes realistic economics

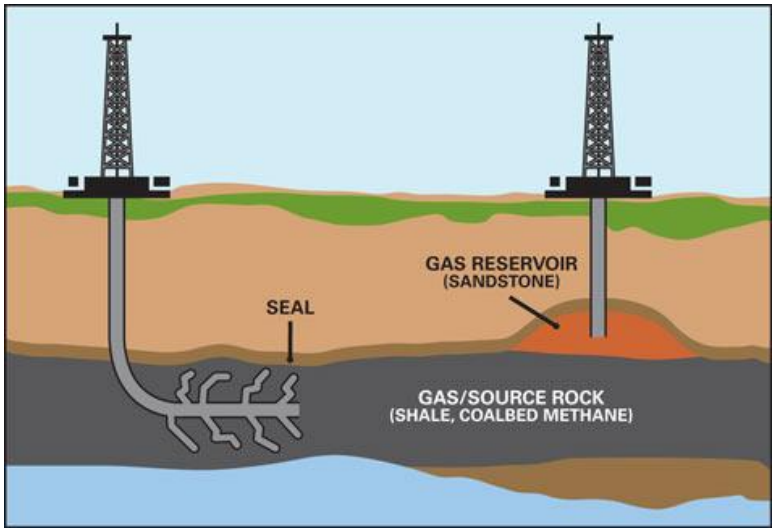


- **Full-cost accounting & full-cycle economics essential for risk evaluation.**
- **Cannot use one set of criteria for SEC and another for investors.**
- **Economics either make sense or not.**
- **Companies must eventually learn to live within cash flow.**
- **Limiting land acquisition to what is thought to be core would limit capital destruction.**

Click to view presenter's notes.

Conclusions: Unconventional tools for the next decade

- **NPV not EUR: E&P is a value proposition & emphasis on enormous resources & growth in the absence of earnings will not work in the long term.**
- **Investors are confused by undisciplined land and drilling strategies especially in a low-price environment--move beyond the manufacturing model.**
- **Some companies are now acknowledging the truth about cost & moving to $6/Mcf price.**
- **Flight to liquid-rich plays only a partial solution—still produce lots of gas and NGL market is saturated.**
- **Attention is focused on the Haynesville Shale because it was over-promoted: a more limited outcome will shine a spotlight on other plays especially the Marcellus Shale.**
- **The tools for the next decade are the same as should have been used in the past and present.**



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