Tulsa Chapter SPEE Presentation Estimating Reserves for Unconventional Shale Resource Plays

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Disclaimer

The materials contained in this presentation are intended to show general information regarding various shale plays. Actual estimates of reserves and resources and other technical and economic factors require specific information about the properties being evaluated and technical expertise in the field of petroleum property evaluations.

Discussion Outline

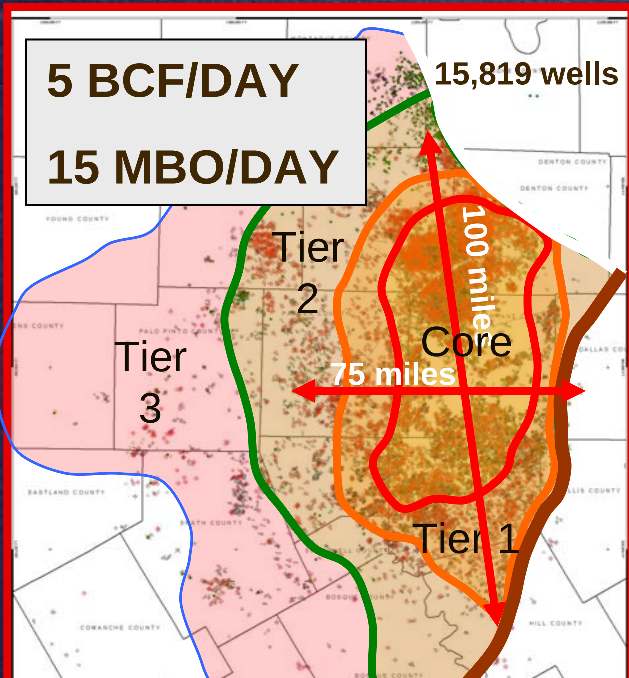
- What is the big deal about the shale plays?
- Estimating Reserves – Critical Issues
  - Early development - Reserves techniques
  - Maturing Plays – Determining Ultimate Well Spacing
- Overview of Selected Plays
  - Barnett
  - Fayetteville
  - Haynesville
  - Marcellus

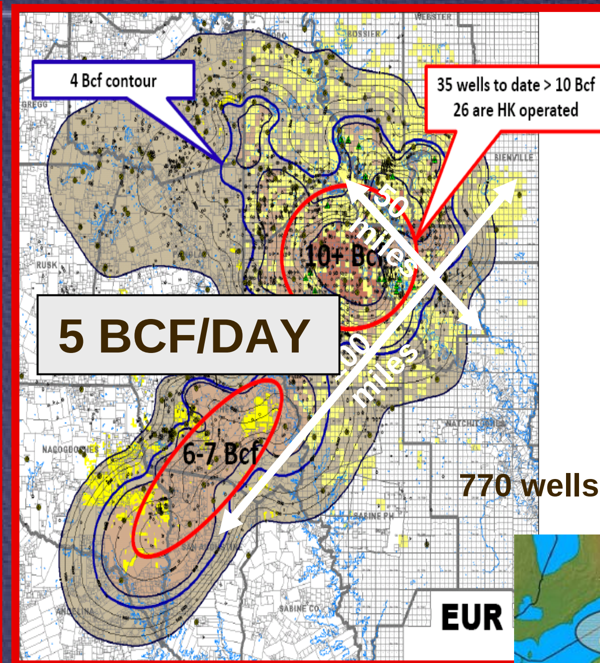
Summary by Shale Play

Shale Basin	Barnett	Fayetteville	Woodford	Haynesville	Marcellus	Eagle Ford
Net Acres (‘000’s)	2,549	2,009	749	3,334	6,600	1,633
Depth (Ft)	6,500-8,500	1,000-7,000	6,000-11,000	10,500-13,500	4,000-8,500	9,000-13,000
Thickness (Ft)	100-600	20-200	120-220	200-300	50-200	100-300
OGIP (TCF)	700	200	90	900	1,000+	250
Est. Rec. Resources (TCF)	64	37	16	109	96	21
Cum Prod (TCF)	9.0	1.7	0.8	1.2	?	0.1
No. of Wells	14,000	3,000	1,200	800	600+	120
EUR/well (BCF)	2.4	2.6	4.3	6.2	4.2	5.1
30-day IP (MMCFD)	2.1	2.5	4.0	9.5	4.5	6.0
Avg Well Cost ($MM)	2.6	2.8	5.0	8.0	3.9	5.5
Break-Even ($/MCF)	4.95	4.06	5.15	4.81	4.17	4.57

Source: BMO Capital Markets – Unconventional Gas (Oct-09), NSAI

Productive Shale Supply Implications





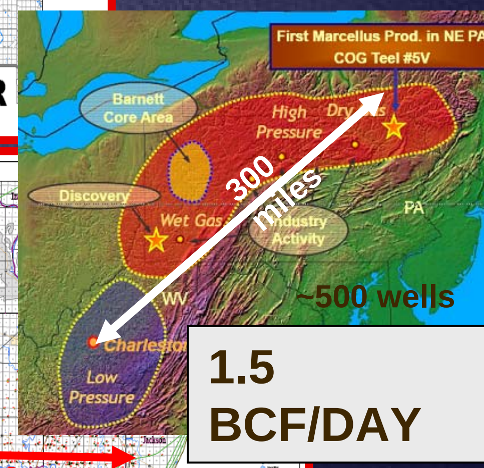
US Gas production

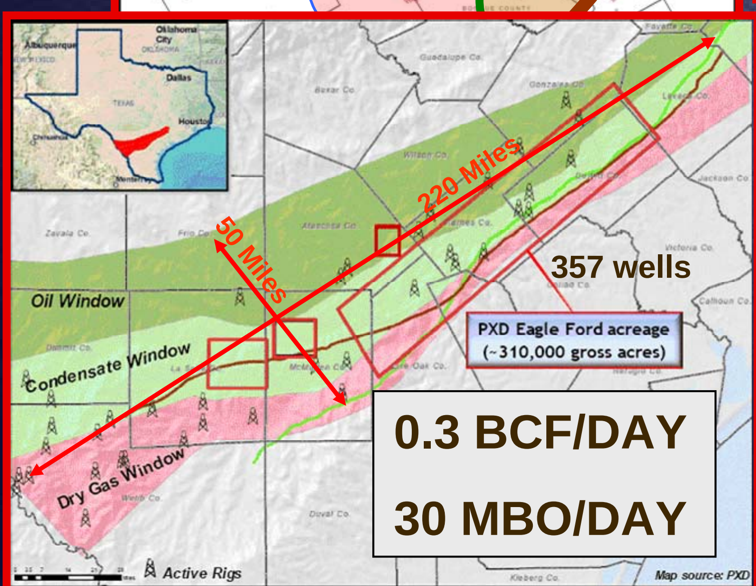
~57 BCF/DAY

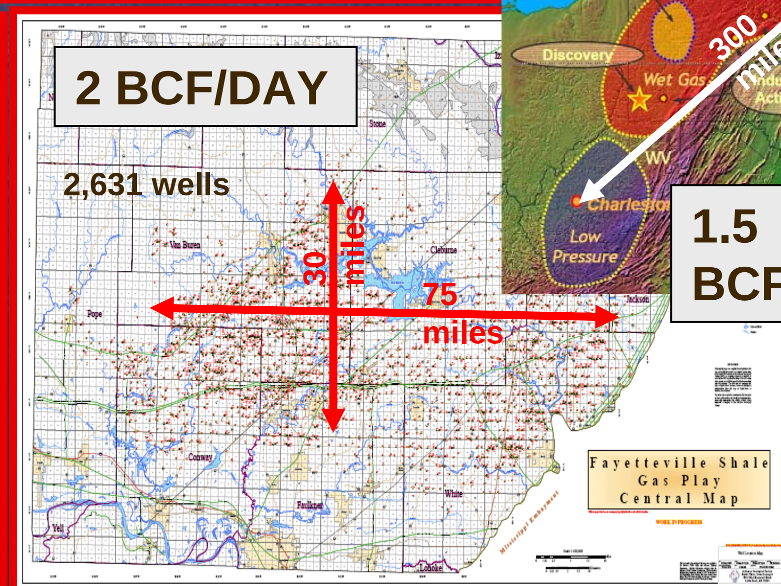
US Shale Gas

~14+ BCF/DAY

20,000 HZ Wells







Recent Acquisitions and Joint Ventures (JVs) 13 Transactions $33 Billion Dollars

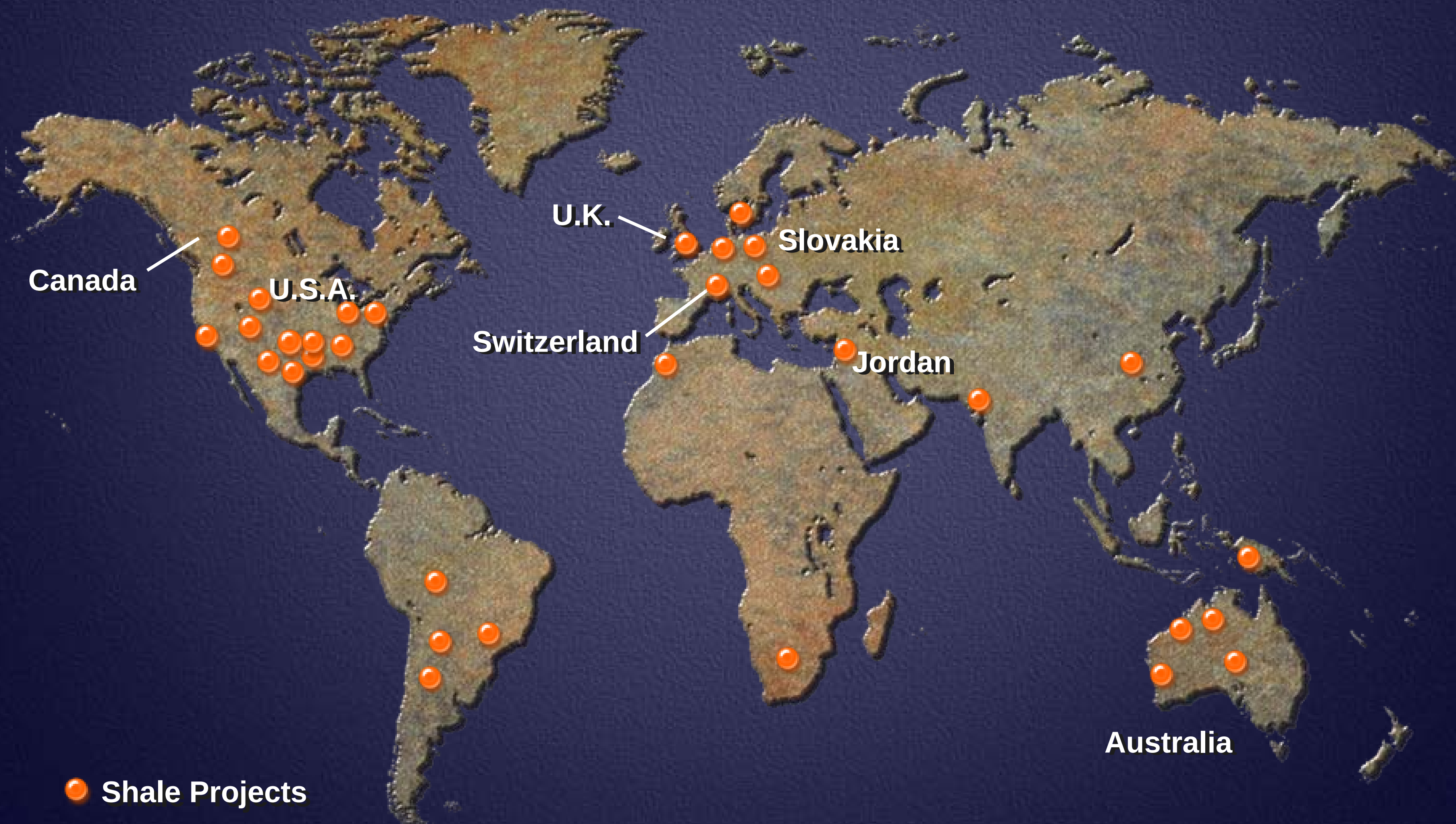
Upstream JV Deals (Chronologically):

- **Total – Chesapeake, Barnett:** January 2010 – 25% interest in 270,000 acres, **$2.25 billion** total split into $800 million cash + $1.45 billion carry of Chesapeake's share of drilling and completion costs. Price ~$33,330/acre
- **Mitsui – Anadarko, Marcellus:** February 2010 – 32.5% interest in approximately 300,000 acres, **$1.4 billion** total with all money being used to carry Anadarko over the next 3 years. This deal allows Mitsui the rights to participate and purchase up to 32.5% in future leaseholds with Anadarko. Price ~$14,360/acre
- **Reliance – Atlas, Marcellus:** April 2010 – 40% interest in approximately 300,000 acres, **$1.699 billion** total split into $339 million cash + $1.36 billion carry of Atlas's share of capital costs. Price ~$14,160/acre. This JV has since acquired an additional ~42,000 acres (at $4,532/acre).
- **Reliance – Pioneer, Eagle Ford:** June 2010 – 45% interest in approximately 263,000 acres, **$1.315 billion** total split into $263 million cash + $1.052 billion carry of Pioneer's share of capital costs and some midstream assets. Price ~$11,110/acre
- **Statoil – Talisman, Eagle Ford:** August 2010 – 50% interest in approximately 134,000 acres **$1.325 billion** total $180 million from Statoil to buy into Talisman's previous approximately 37,000 acres with the rest buying approximately 97,000 acres from Enduring Resources. Price ~$19,780/acre
- **CNOOC – Chesapeake, Eagle Ford:** November 2010 – 33% Interest in 600,000 acres for **$2.16 billion** split $1.08 billion in cash + $1.08 billion carry of Chesapeake's share of drilling and completion costs. This deal allows CNOOC the rights to participate and purchase up to 33.3% in future leaseholds with Chesapeake. Price ~$10,800/acre
- **Sasol – Talisman, Montney:** December 2010 – 50% interest in approximately 57,200 acres for **C$1.05 billion** total C$262.5 million cash + C$787.5 million in drilling and completion costs. Price ~C$36,710/acre
- **PetroChina – Encana, Montney:** February 2011 – 50% interest in approximately 635,000 acres, 255 MMCFED of production, 700MMCFD of processing capability, 3,400 km of pipeline, and the Hythe natural gas storage facility for **C$5.4 billion** total. Price ~C$17,010/acre
- **KNOC – Anadarko, Eagle Ford:** March 2011 – 33.3% interest in approximately 240,000 acres of Eagle Ford shale and an additional 48,000 acres of Pearsall shale for **$1.55 billion** by funding capital costs. Price ~$16,150/acre

Upstream Acquisitions:

- **Shell– East Resources, Marcellus:** May 2010 – Interest in ~650,000 Marcellus acres and 60 MMcfe/d for **$4.7 billion** in cash. Price ~$7,230/acre
- **Hess – TRZ Energy, Bakken:** November 2010 – 167,000 acres for **$1.05 billion** in cash. Price ~$6,290/acre
- **Chevron/Reliance – Atlas, Marcellus, Utica:** November 2010 – 486,000 acres of Marcellus, 623,000 acres of Utica, and 49% interest in Laurel Mountain Midstream for **$4.3 billion** total split 3.2 billion cash and 1.1 billion debt. Price ~$3,880/acre
- **BHP Billiton – Chesapeake, Fayetteville:** February 2011 – 487,000 acres and over 400 MMCFD for **$4.75 billion** in cash. Price ~$9,750/acre

Shale Projects Worldwide



Early Development Techniques

- Analogy to other Shale Plays
  - Use type curves from another shale plays (hyperbolic exponents ranges 0.8 to 1.8)
  - Volumetric analysis – Drainage areas 40 to 160 acres and recovery factors 5 to 30 percent
  - Estimating horizontal well recovery based on multiple of vertical well completions (Generally 3 to 6 times)
  - EUR Distributions from analogous plays (i.e. Tier I Barnett shale area P75-P25 1.0 – 3.0 Bcf)

General Shale Forecast Parameters

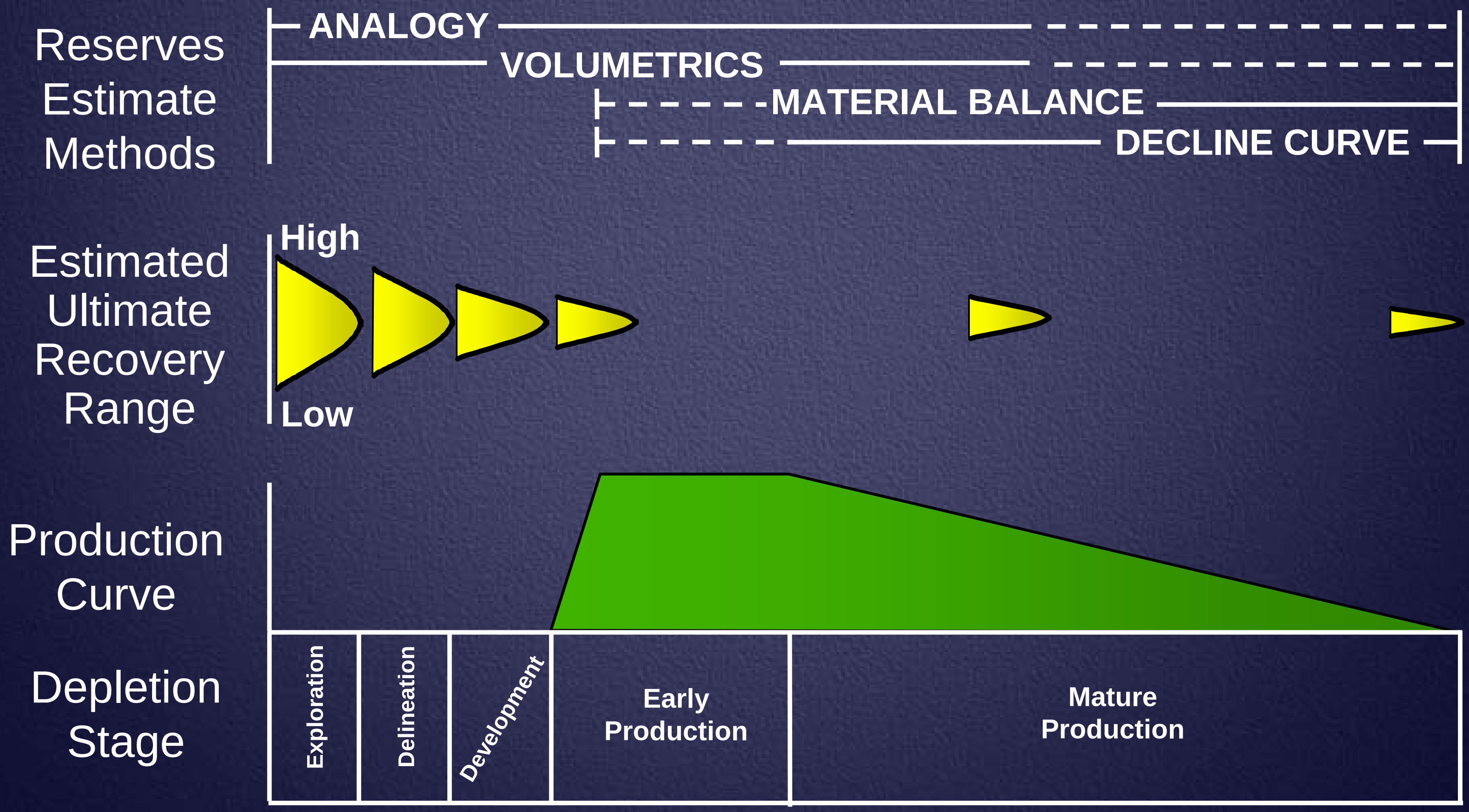
Projection Parameters	Marcellus Horizontal*	Barnett	Fayetteville	Woodford	Haynesville
IP (MCF/Mo)	80,000 – 150,000	80,000 – 90,000	50,000 – 80,000	60,000 – 120,000	300,000 – 700,000
De (%) (instantaneous)	95 - 99	90 – 95	80 – 85	90 – 99	99 – 99.9
N	1.0 – 1.5	1.5 – 1.75	1.0 – 1.3	1.0 – 1.3	0.8 – 1.2
Df (%)	6	6	6	6	6
EUR (BCF) – Tier I**	1.5 – 5.0	1.0 – 3.0	1.5 – 4.0	1.5 – 4.0	2.5 – 7.0
EUR (BCF) – Tier II**	0.5 – 1.5	0.5 – 1.5	0.5 – 2.5	0.5 – 2.0	1.0 – 4.0

** Based on limited data*

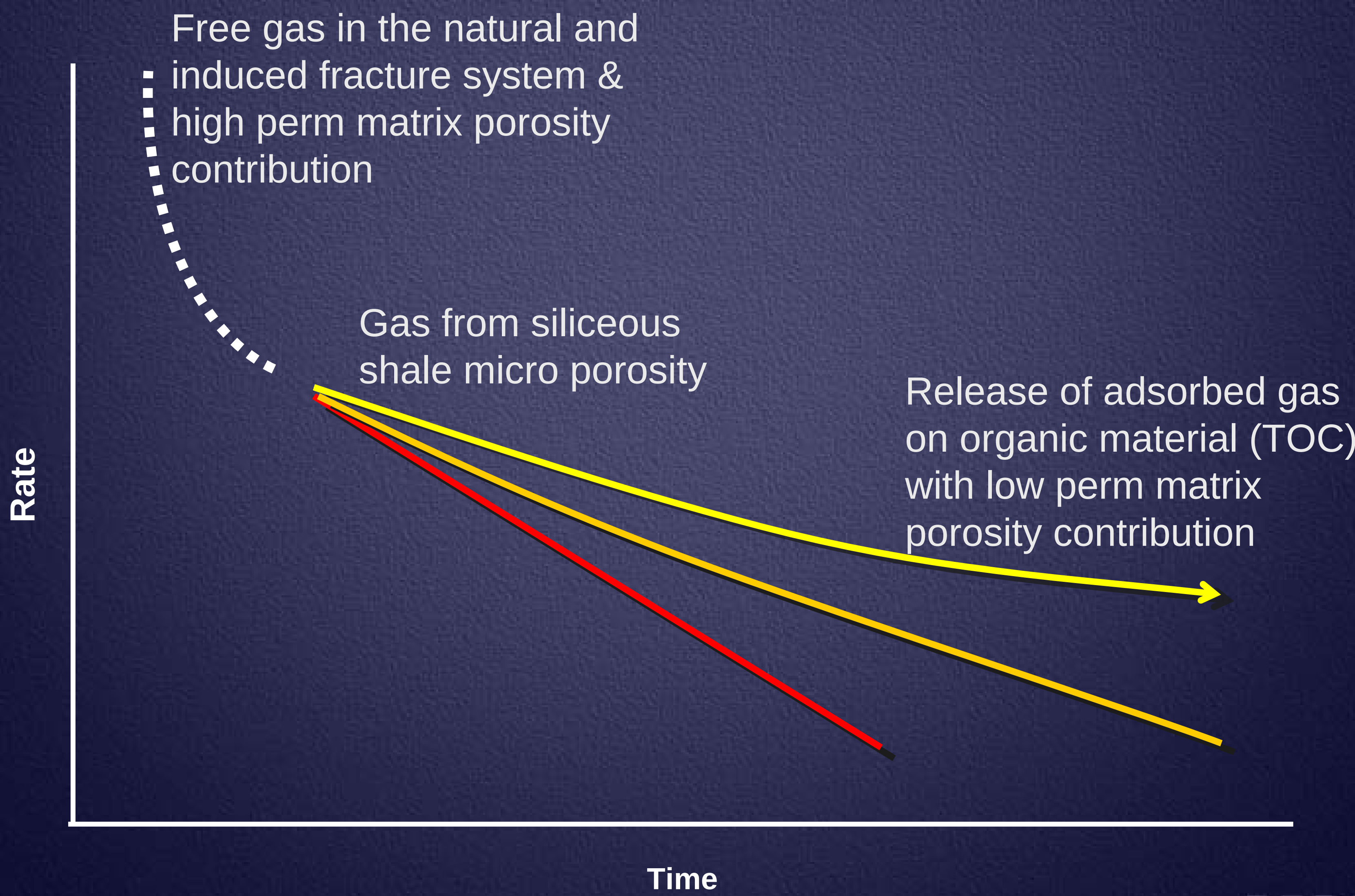
** * P75 – P25 EURs*

This is a generalized interpretation - individual reserves calls require judgment based on specific data

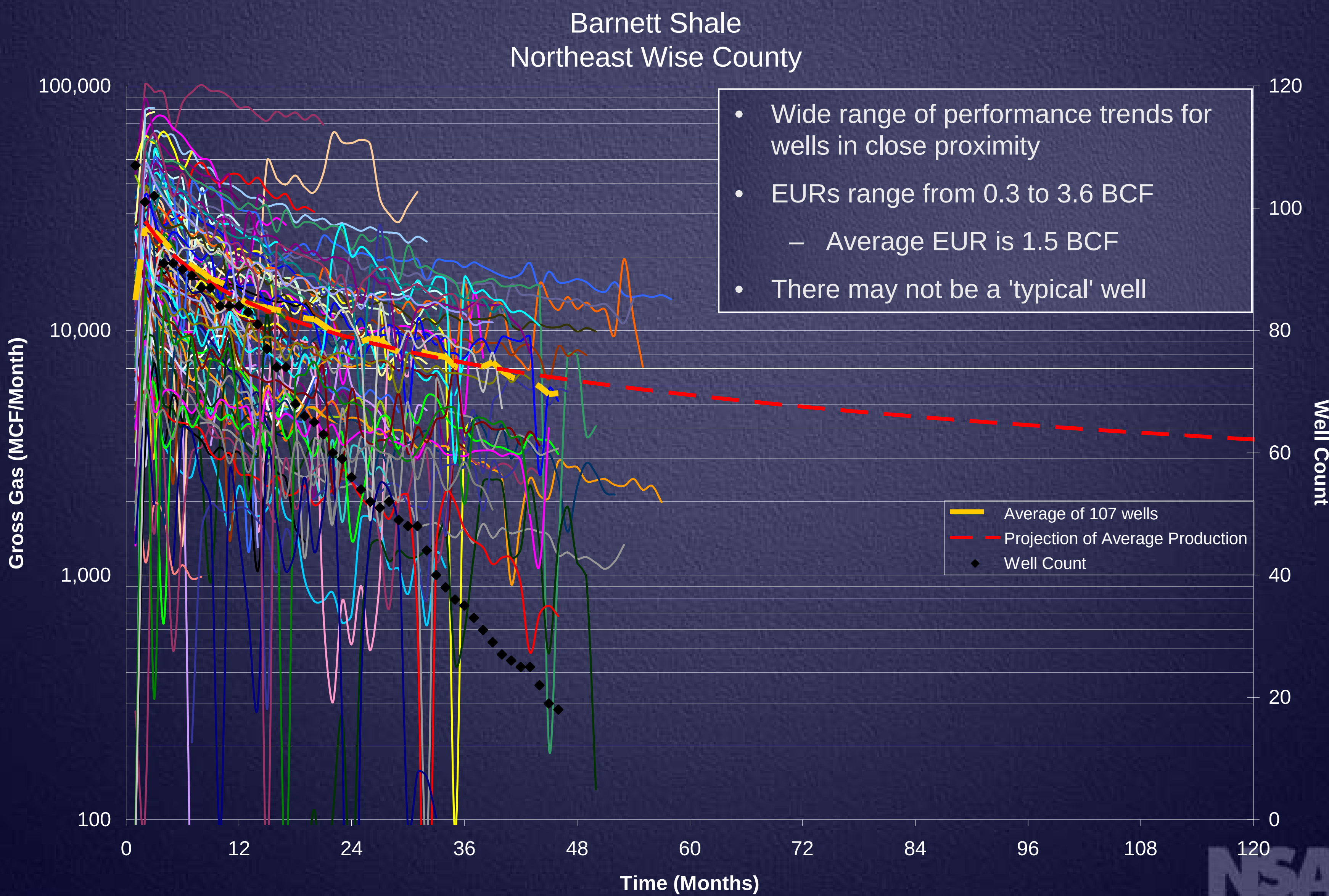
Methodology Life Cycle



Performance Variability

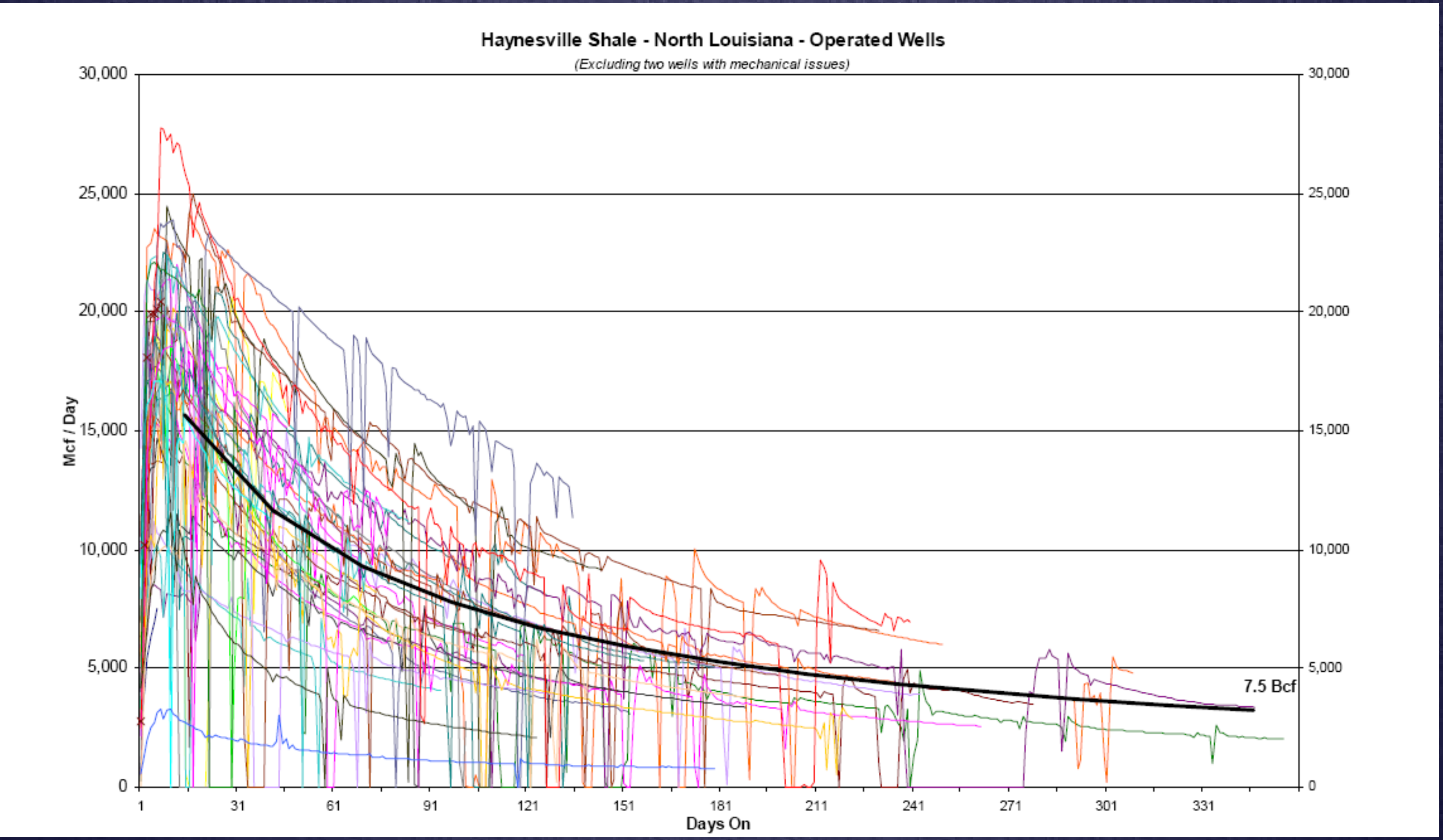


Actual Well Performance Variability



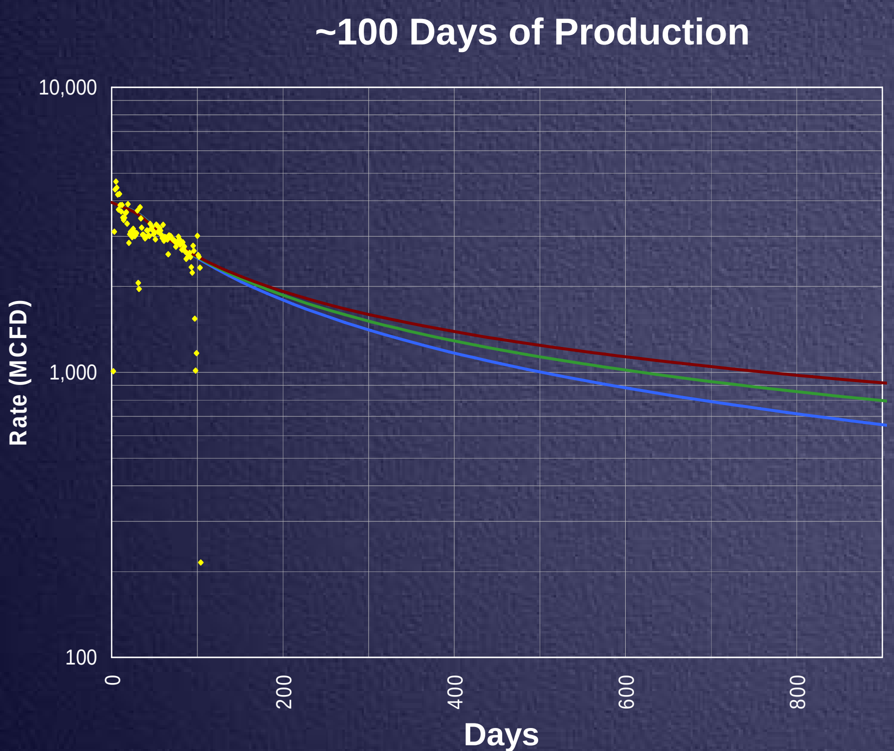
- Wide range of performance trends for wells in close proximity
- EURs range from 0.3 to 3.6 BCF
  - Average EUR is 1.5 BCF
- There may not be a 'typical' well

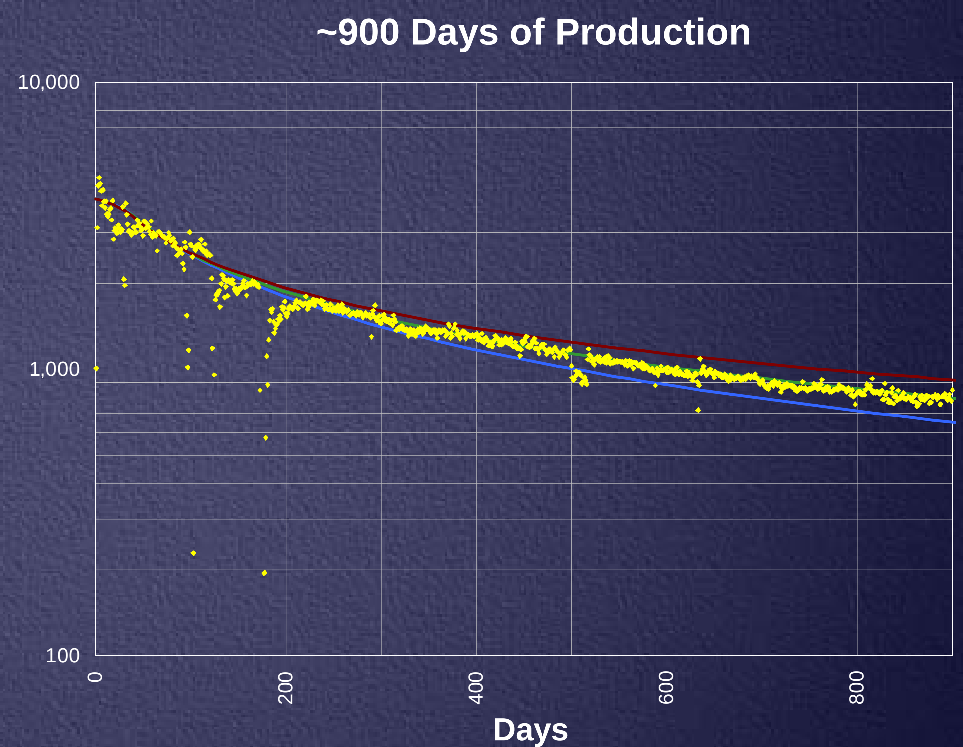
Haynesville Shale Production Variability



From Petrohawk Energy investor presentation

Decline Curve Analysis
How much data is needed?

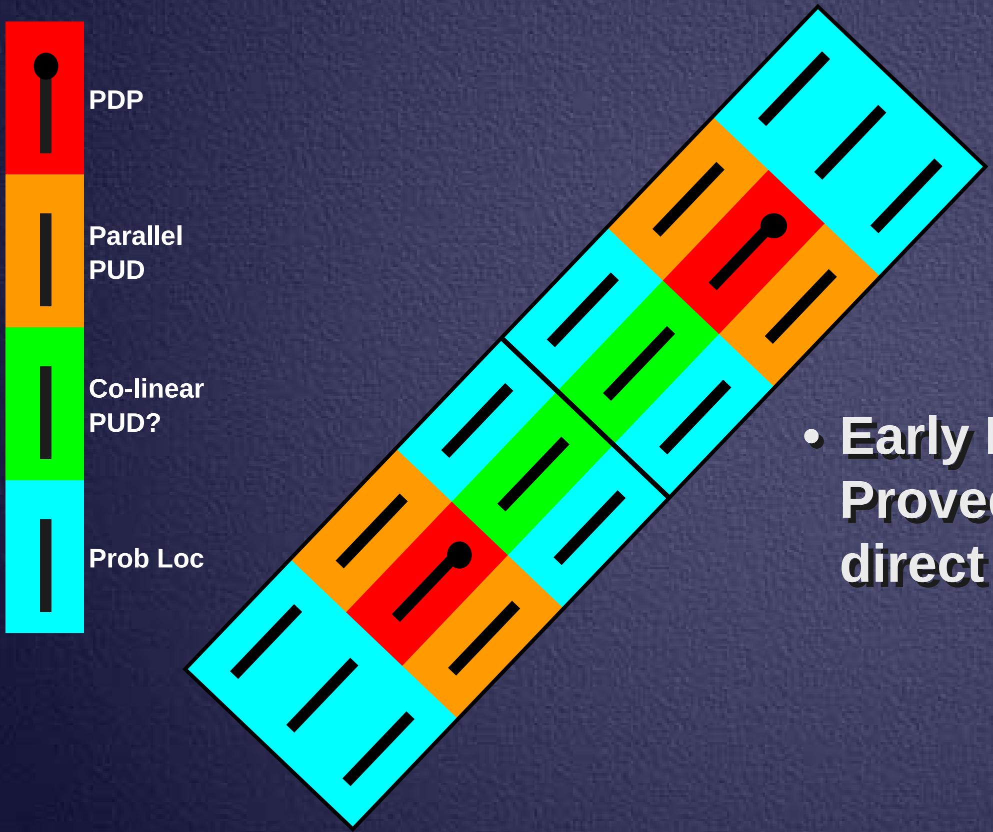




n (Hyp exp)	50-year EUR (BCF)
1.2	3.3
1.5	4.4
1.8	5.5

n (Hyp exp)	Df (%/year)	50-year EUR (BCF)
1.5	4	5.0
1.5	6	4.4
1.5	8	3.8

Horizontal Development – Proved Bookings



- Early Development would limit Proved Undeveloped locations to direct parallel offsets

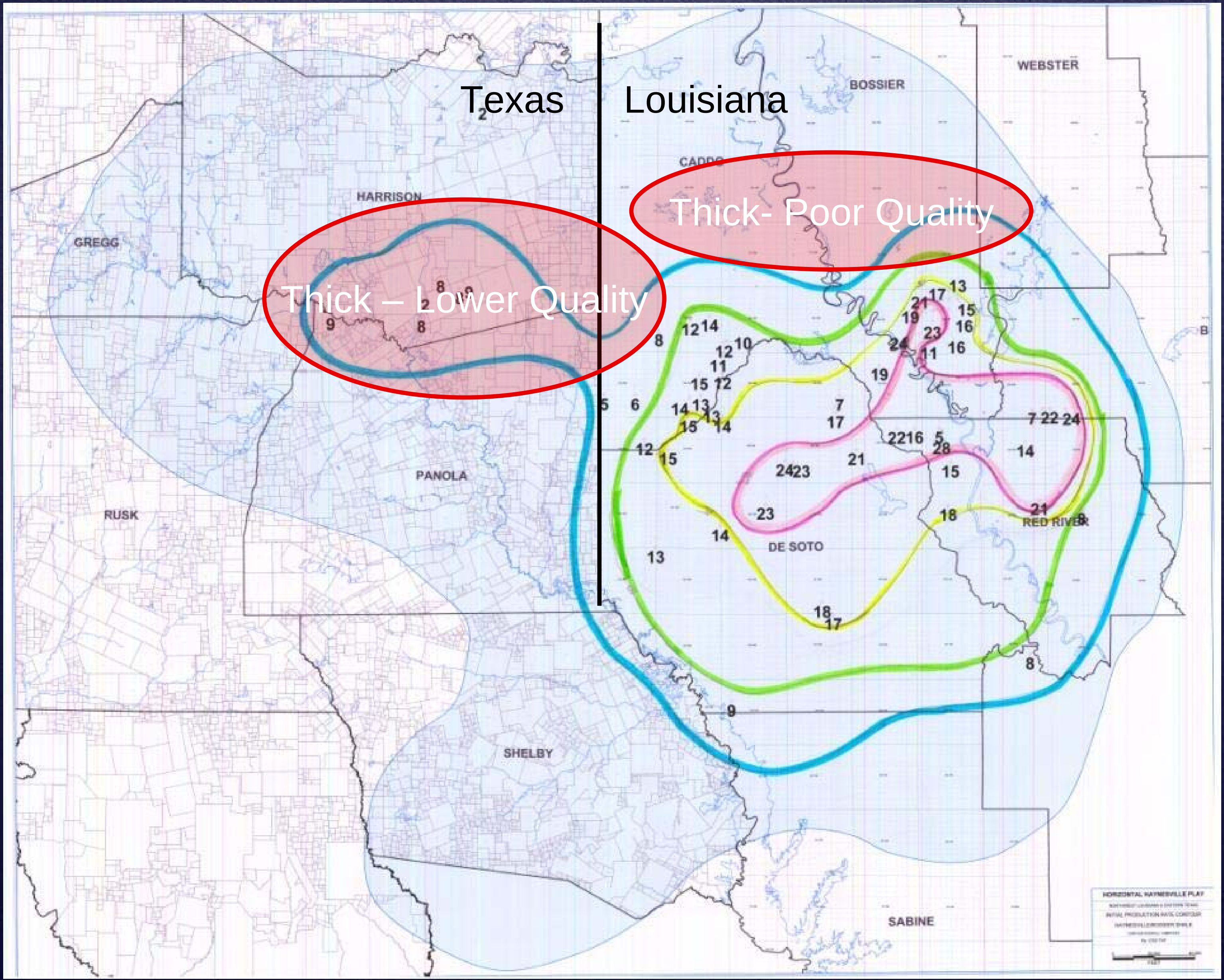
Maturing Plays – Critical Issues

- Regional Overview
- Geological Aspects
  - OGIP
  - Contributing Rock Volume
- Recovery Factor
- Ultimate Well Spacing
- Defining Proved Areas – Reliable Technology

Regional Overview

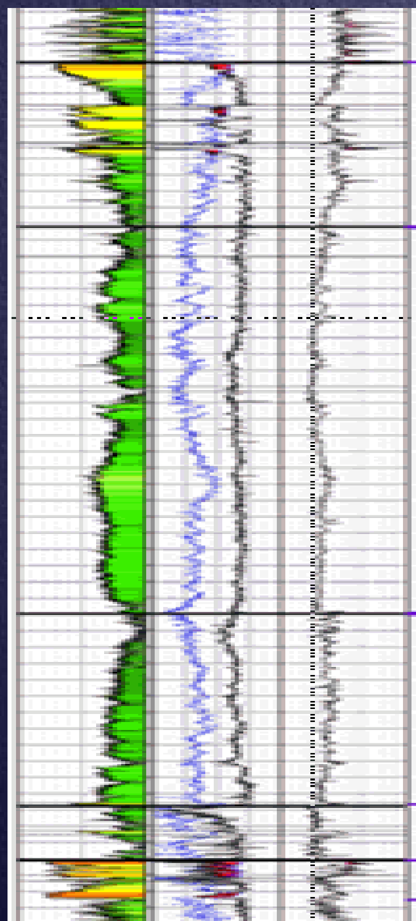
- Barnett Shale
  - Projected ~12,000 wells
  - Analyzed ~100+ logs & 5+ cores
- Fayetteville Shale
  - Projected ~3,000 wells
  - Analyzed ~50 logs & ~10+ cores
- Haynesville Shale
  - Projected ~800 wells
  - Analyzed ~100 logs & ~10+ cores
- Eagle Ford Shale
  - Projected ~200 wells
  - Analyzed ~100 logs & ~10+ cores

Haynesville Initial Potential Map (2008) OGIP - Does not tell the whole story



Target Thickness Versus Gas-in-Place

200 BCF/mi^2
Gas-in-Place

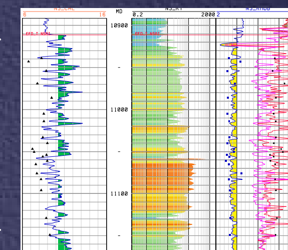


0.1 BCF/Foot

2,000 Feet Thick

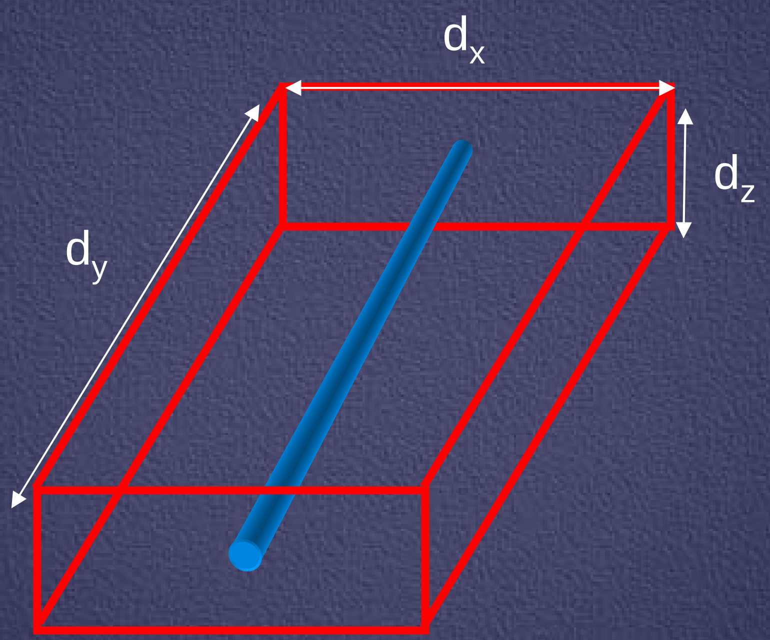
200 BCF/mi^2
Gas-in-Place

200 Feet Thick



1 BCF/Foot

Contributing Rock Volume



d_y = Lateral Length (3,000' to 5,000')

d_x = Well Spacing or Effective Frac Distance (500' to 1,500')

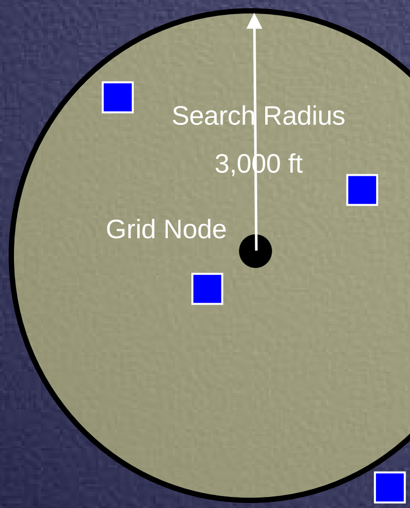
d_z = Net Shale Thickness or Effective Frac Height (50' to 300')

$$\boxed{d_x * d_y * d_z = \text{Contributing Rock Volume}}$$

Shale Performance Analysis
Moving Average Methodology

- **Premise 1**: OGIP, per-well EUR, well spacing, and recovery factor are interrelated.
- **Premise 2**: The statistical nature of shale plays requires aggregation of data in a meaningful way.
- **Premise 3**: Aggregation of data over a square mile is meaningful.

Moving Average Mapping



Search Radius

3,000 feet

648 acres

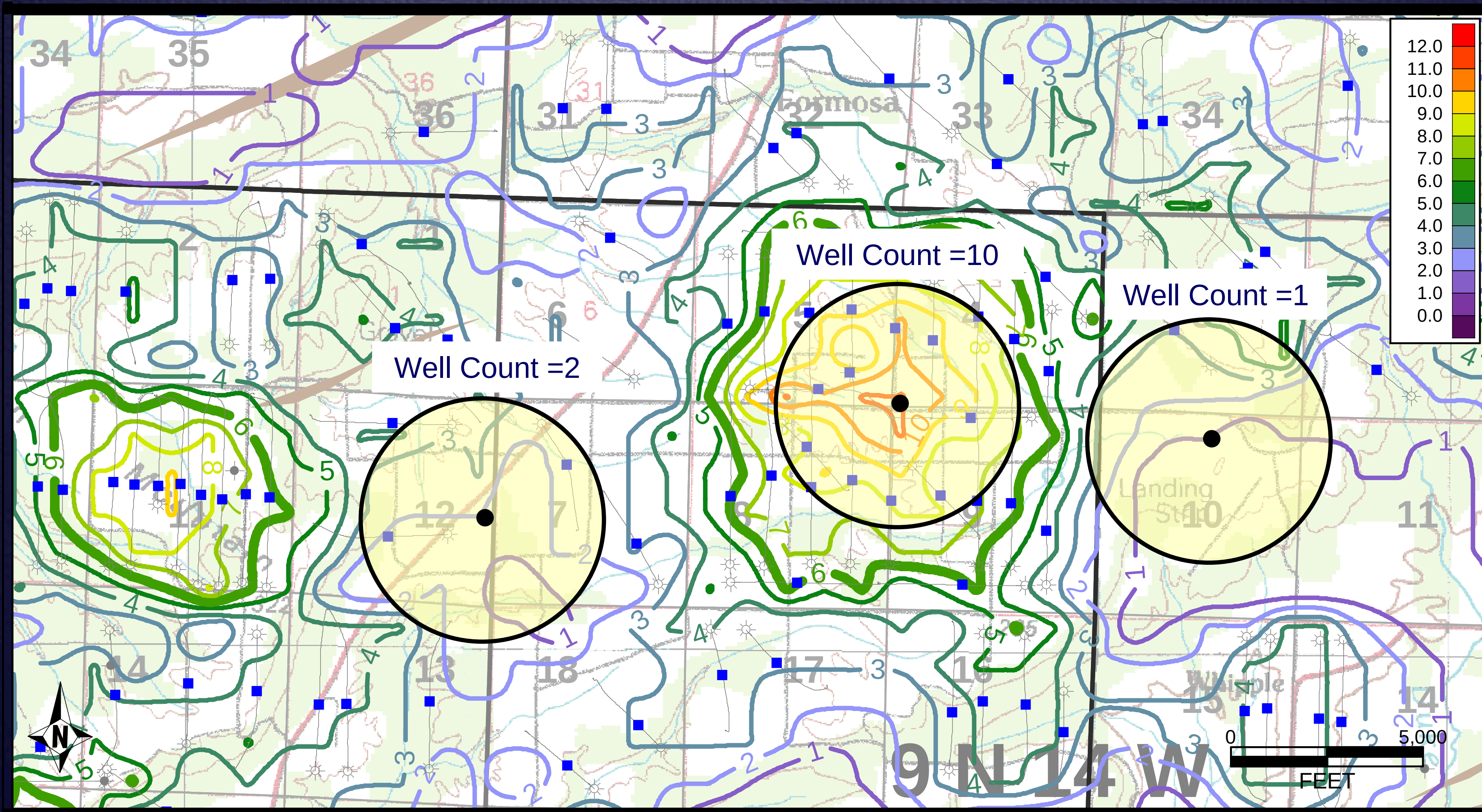
Each Grid Node

- Well Count
- Total EUR
- Average EUR
- OGIP

Moving Average

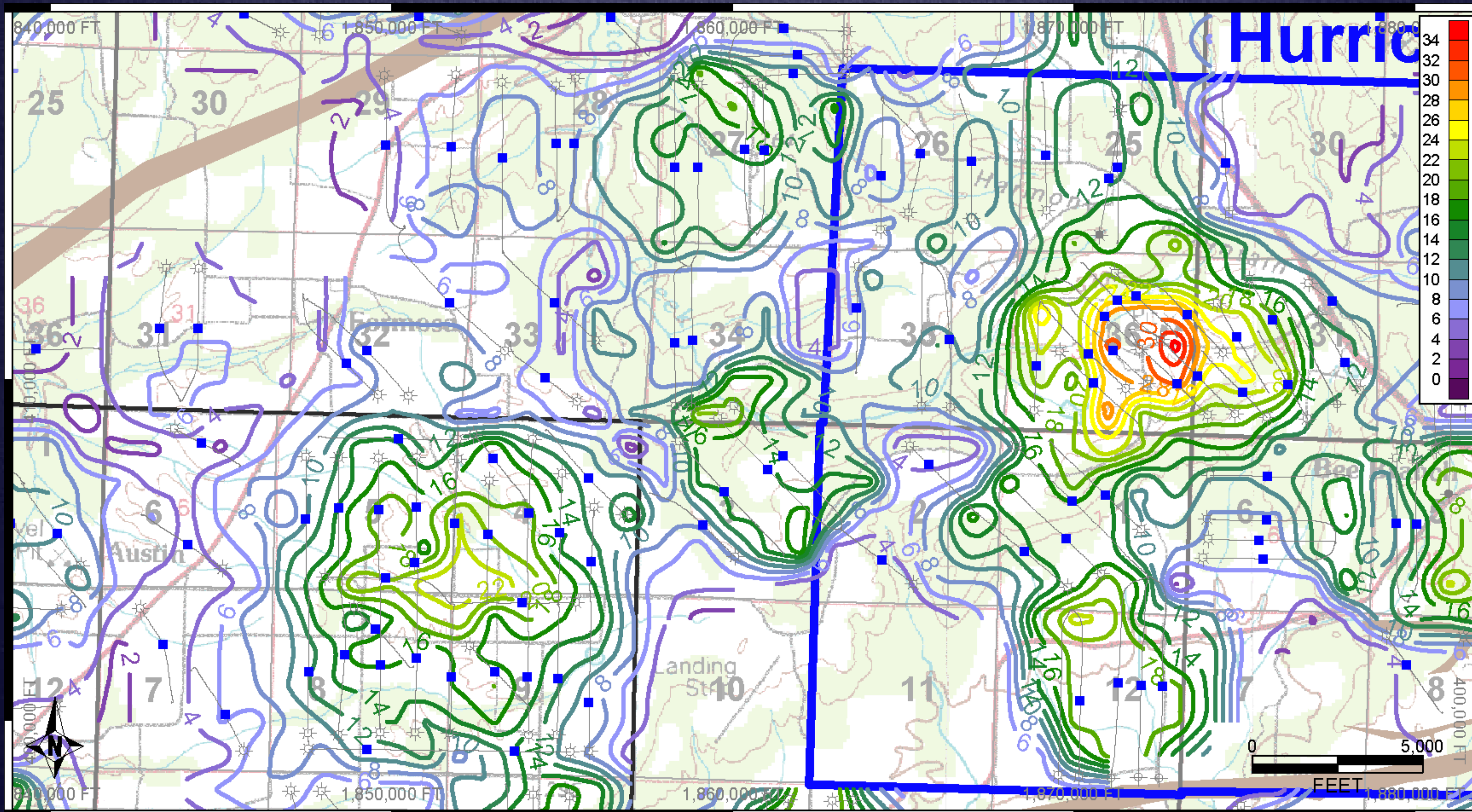
Grid 1,000 ft x 1,000 ft

Example: Well Count Contour Map



Production data posting location (midpoint of perforation data)

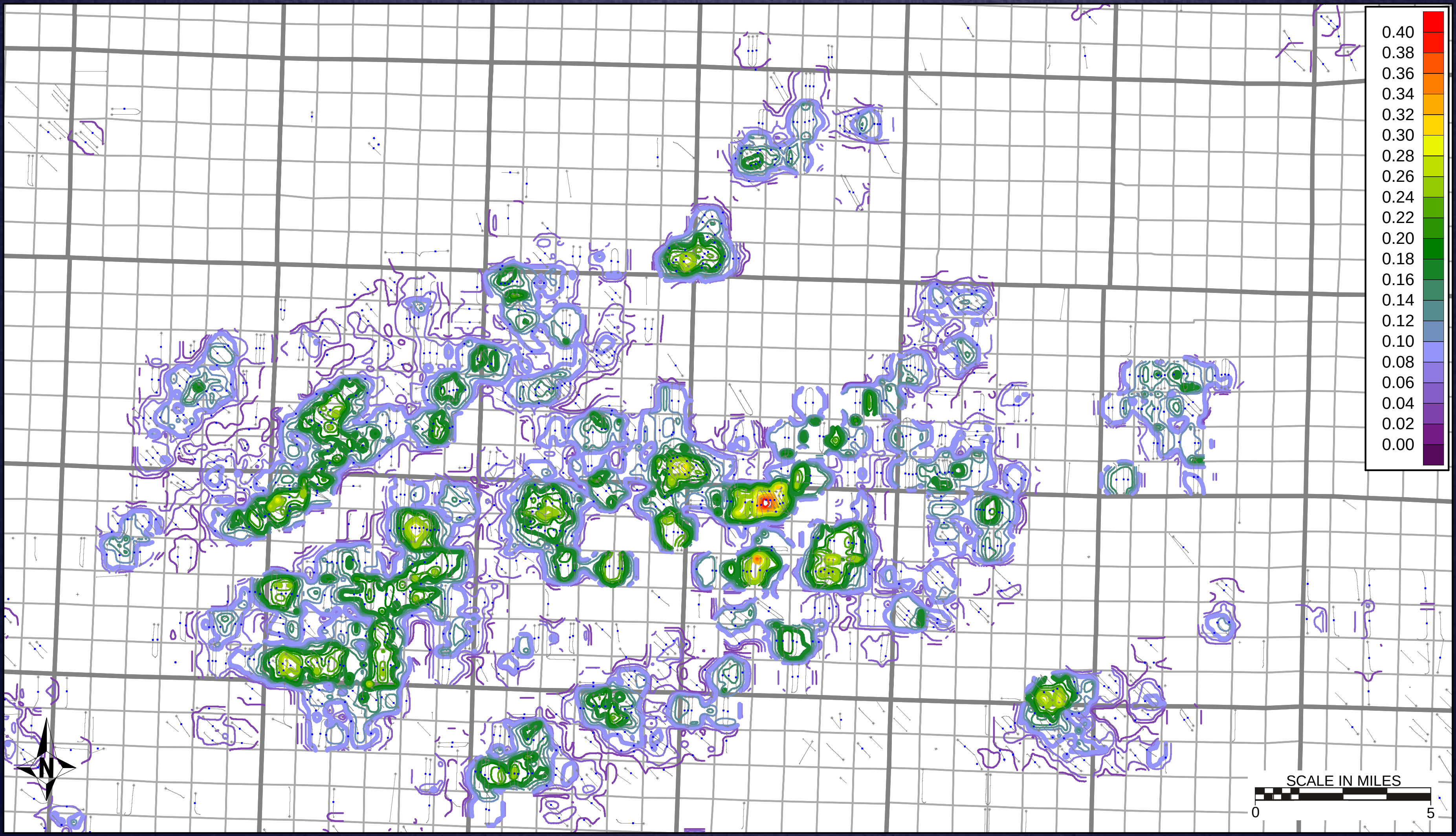
Total EUR (BCF/mi²) Moving Average Map



Influenced by individual well EURs and number of wells per mi²

This is a generalized interpretation - individual reserves calls require judgment based on specific data

Calculated Recovery Factor Map



NSAI Total EUR (BCF/mi^2) / NSAI Screening Total OGIP (BCF/mi^2)

NSAI

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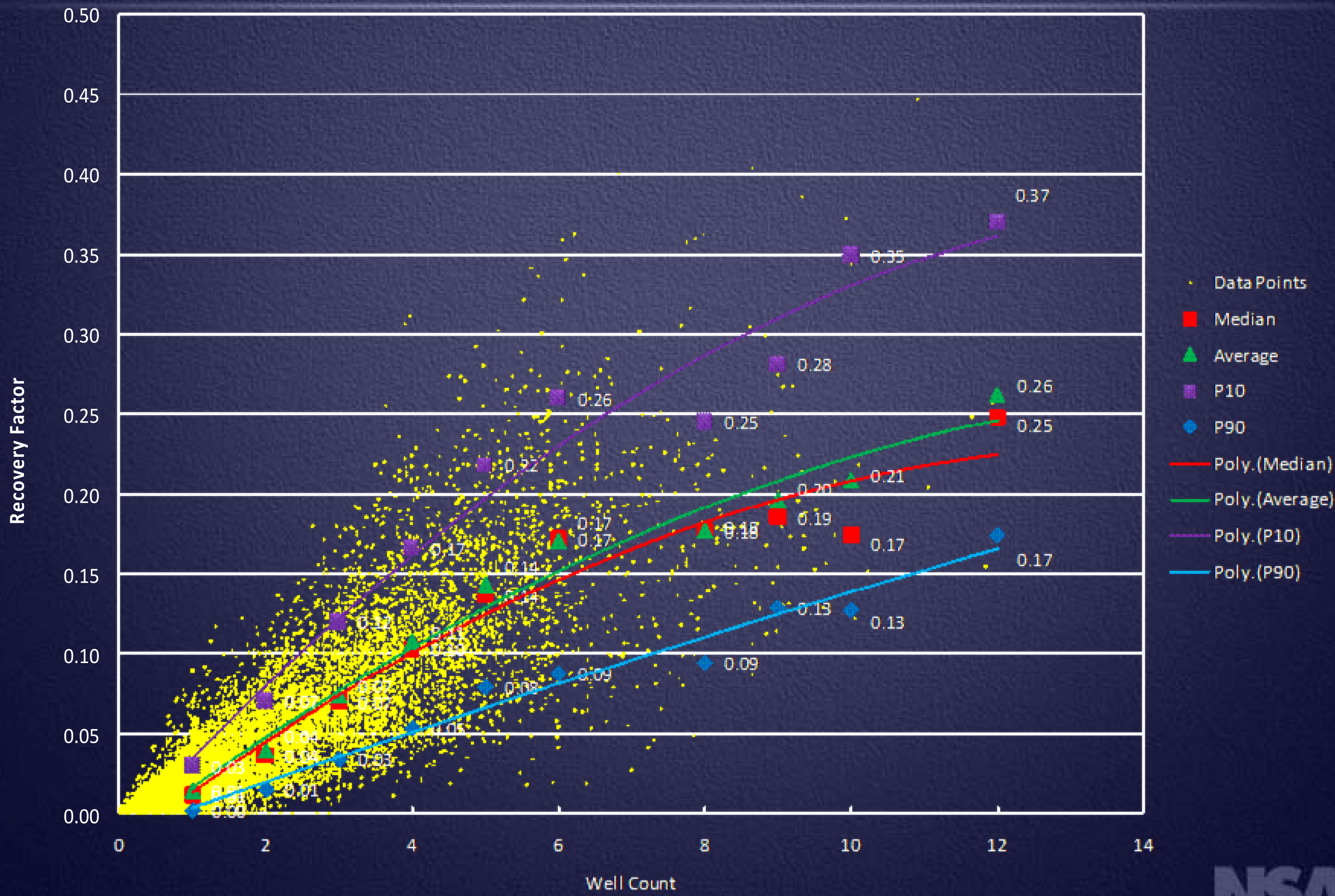
Recovery Factor Versus Well Count



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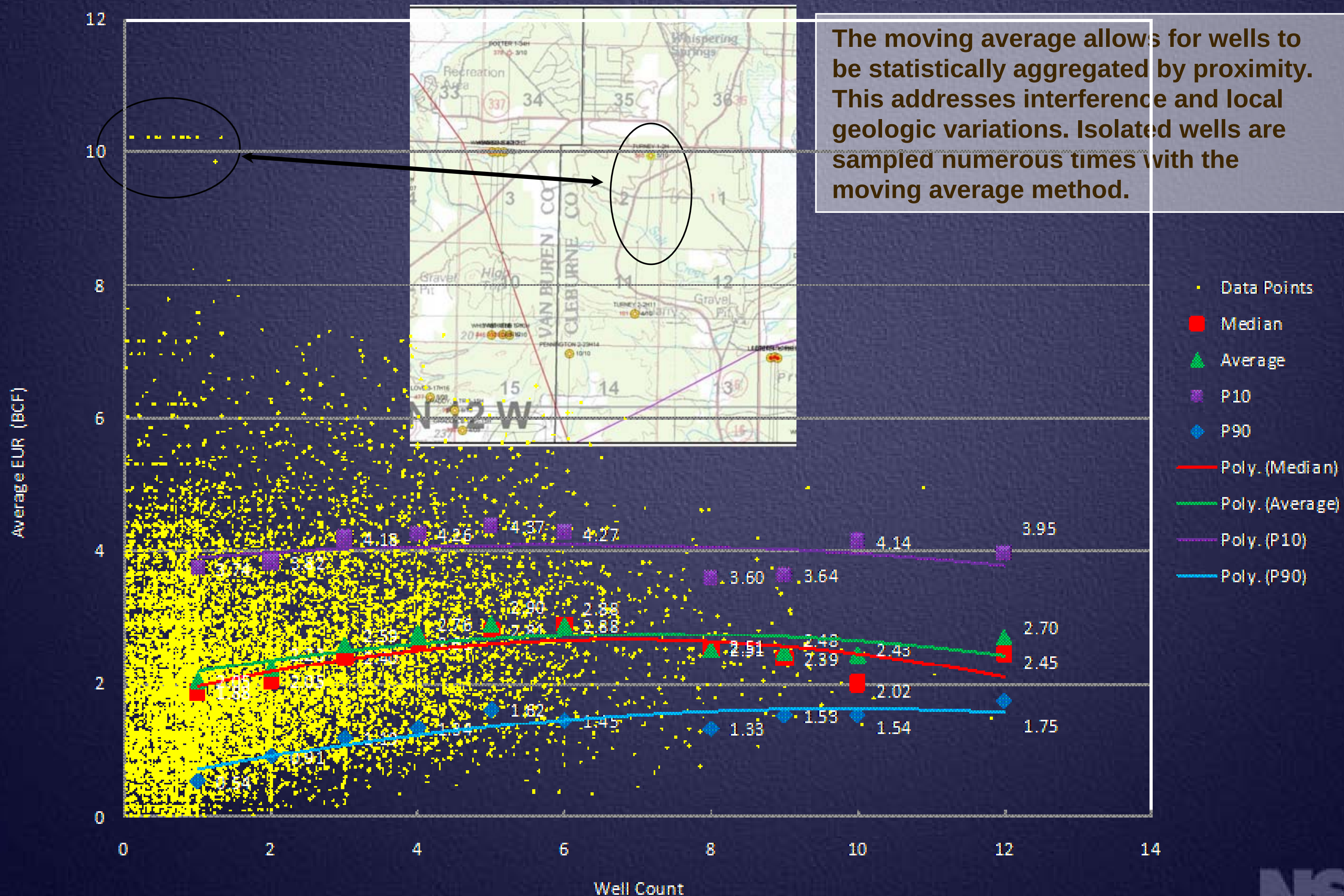
Average EUR Versus Well Count



The moving average allows for wells to be statistically aggregated by proximity. This addresses interference and local geologic variations. Isolated wells are sampled numerous times with the moving average method.

Total Gas Ultimate

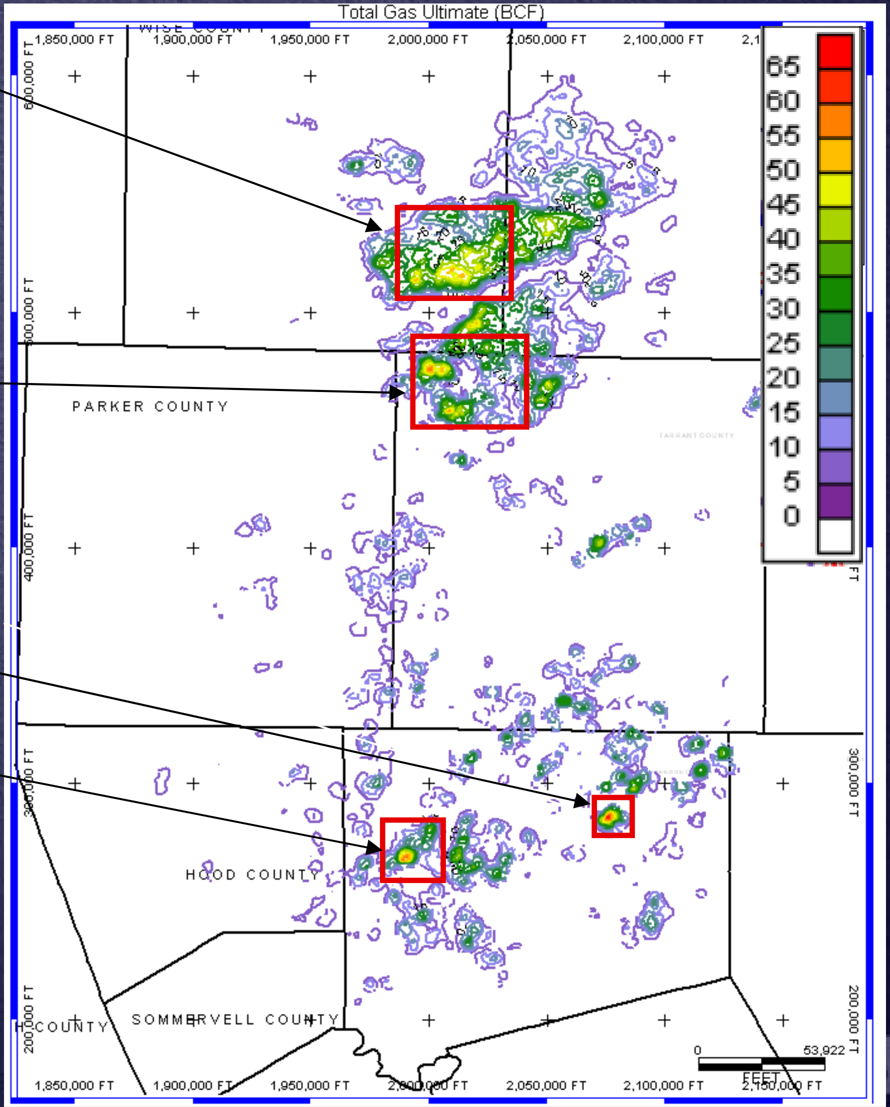
Contours are BCF of estimated ultimate gas recovery per square mile

The second most densely drilled area of the Barnett Shale (39,000 acres, 1,076 wells)

The most densely drilled area of the Barnett Shale (41,500 acres, 1,150 wells)

Successful horizontal development area of the Barnett Shale (1,100 acres, 12 horizontal wells)

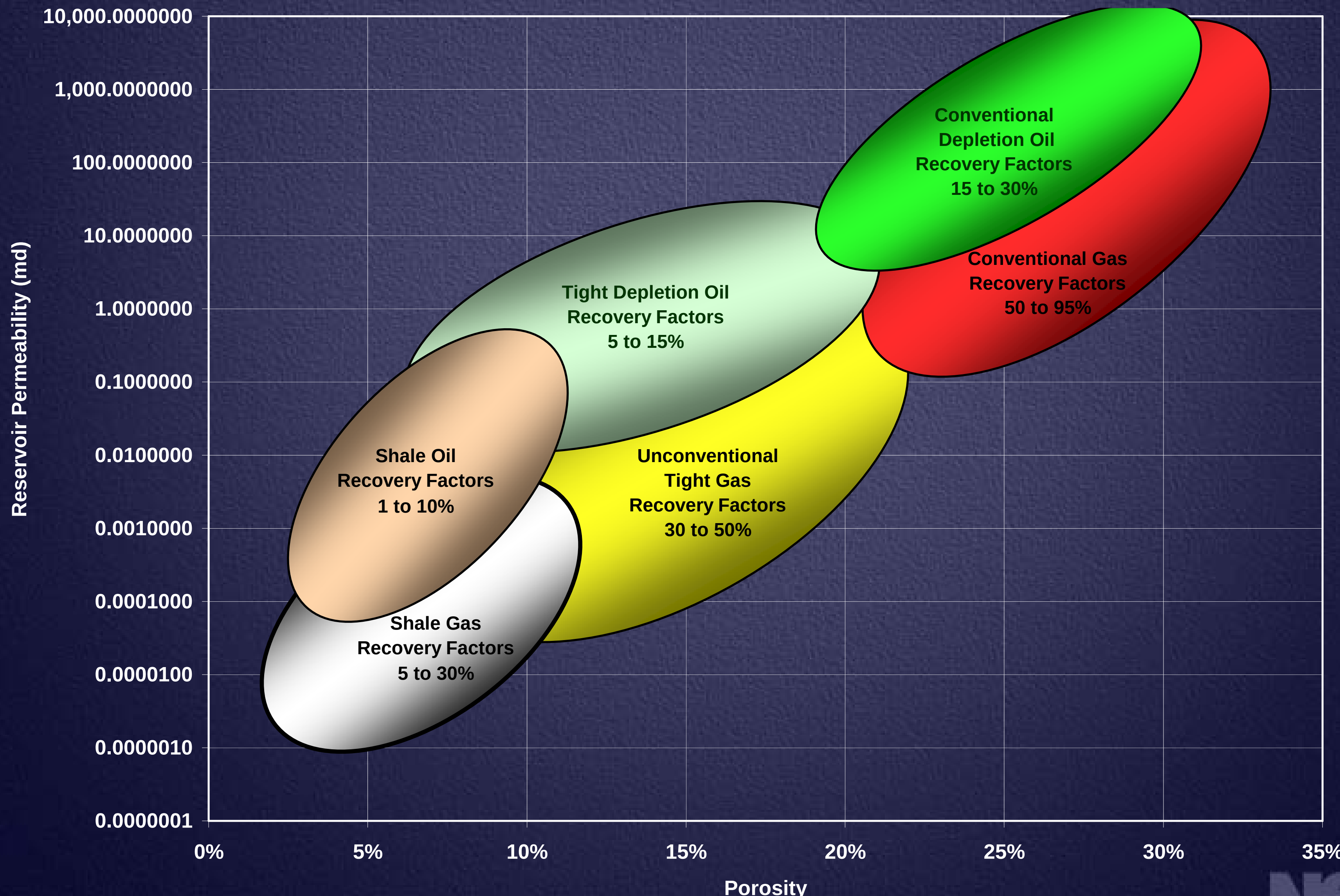
Successful horizontal development area of the Barnett Shale (450 acres, 8 horizontal wells)



This map was created by taking a moving average sum of all individual well EURs in a 1-square-mile area at a ½-mile grid increment.

This is a generalized interpretation - individual reserves calls require judgment based on specific data

Reservoir Permeability versus Recovery Factor



Volumetric and Performance

Barnett Shale Volumetric Analysis

160 BCF OGIP Recovery Factor Well Spacing Analysis

EUR per Well Array (BCF)		Recovery Factor (percent)				
		40%	30%	20%	10%	5%
Well Spacing, acres	160	16	12	8	4	2
	120	12	9	6	3	1.5
	80	8	6	4	2	1
	40	4	3	2	1	0.5

Barnett Shale Decline Curve Performance Analysis

Year	Gas EUR (MMCF) P25	Gas EUR (MMCF) Mean	Gas EUR (MMCF) P50	Gas EUR (MMCF) P75	Avg. Lateral Length (Feet)
2010	4,600	3,700	3,300	2,300	3,055

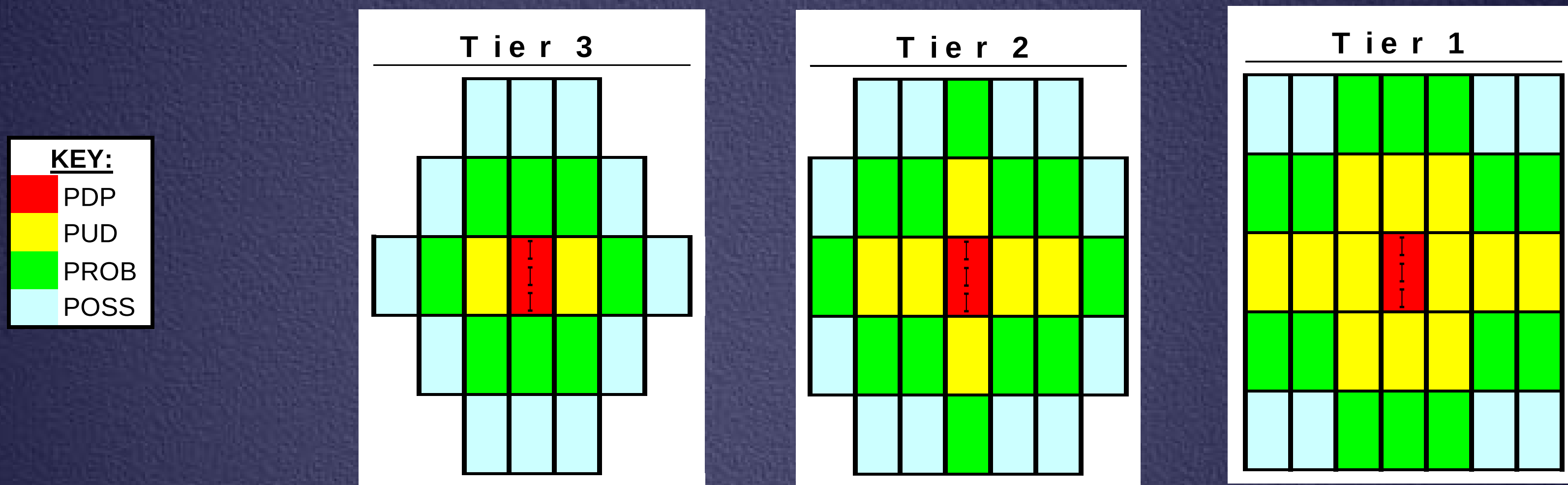
This is a generalized interpretation - individual reserves calls require judgment based on specific data

Critical Considerations for Proved Area

- Enough production data to make reasonably certain EUR projections
  Minimal (months), Sufficient (year), Optimal (years)
- Enough well EUR data to be statistically significant
  Minimal (<10), Sufficient (~40), Optimal (>100)
- Level of EUR relative to economic (PW10)
  Minimal (P50), Sufficient (P75), Optimal (P90)
- EUR versus demonstrated well spacing
  Minimal (pilot down spacing), Sufficient (statistically significant developed areas), Optimal (all wells drilled on constant spacing)
- Data supporting hydrocarbons-in-place
  Minimal (logs), Sufficient (+ production), Optimal (+ core)
- Data supporting geologic consistency
  Minimal (regional mapping), Sufficient (+ local log analysis), Optimal (+ seismically defined structure)
- Data supporting leasehold and certainty of locations being drilled in timely manner
  Minimal (say they will), Sufficient (history of drilling), Optimal (corporate level plan)
- Individual reserves calls require judgment based on specific data

Engineering Geology Company

Resources Plays
Example of Leverage with Horizontal Wells

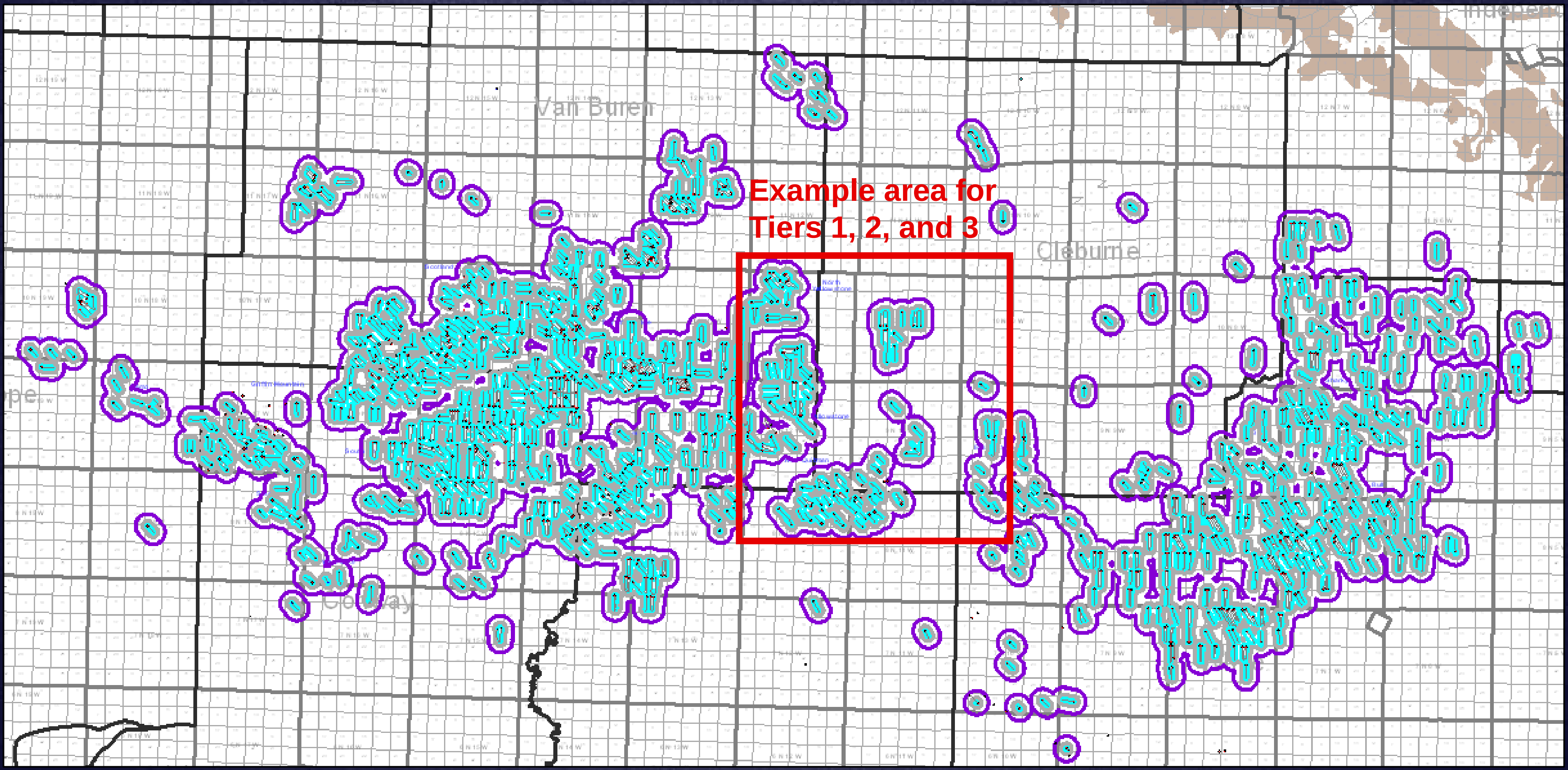


		Tier 3	Tier 2	Tier 1
1.	Property maturity	Early	Moderate	Mature
2.	Data rich/poor	Poor	Good Well Control	Rich
3.	Consistency	?	Good	Very Good
4.	Geologic understanding	Low	Still Learning	High
5.	Analogy to other areas	Low	Good	Good
6.	Economic robustness	Marginal	Strong (most wells)	Very Strong
7.	Leverage effect	?	?	?

"…Evidence using Reliable Technology…"

This is a generalized interpretation - individual reserves calls require judgment based on specific data

Fayetteville Area Well Control



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Significant Local and Regional Data

Enough EUR data to be statistically significant
Minimal (4), Sufficient (20), Optimal (100s)

Purple line designates contiguous development areas.

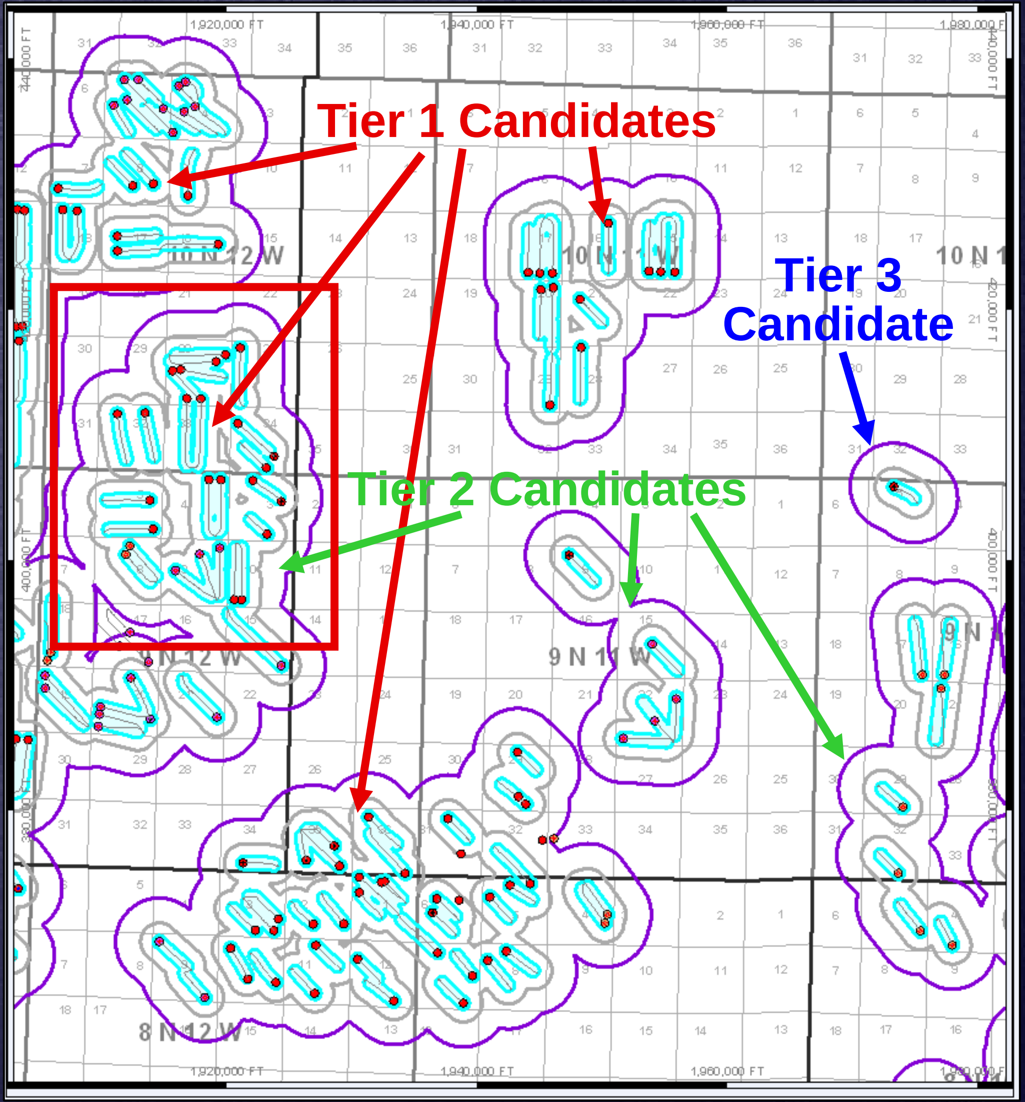
The overall Fayetteville trend area has 100s of wells leading to regionally optimal data set. We have some degree of confidence in the regional distribution of EURs.

Local contiguous development areas are defined by grey line areas.

Areas with statistically significant number of PDP wells (1-3 wells per section) would be considered candidates for Tier 1 areas based on the data concentrations only.

Lesser concentrations of data would be considered as Tier 2 and Tier 3 areas where there would be less leverage from a PDP-to-PUD ratio.

Toe-heel PUDs would be considered in Tier 1 and Tier 2 areas where the data are considerably certain.



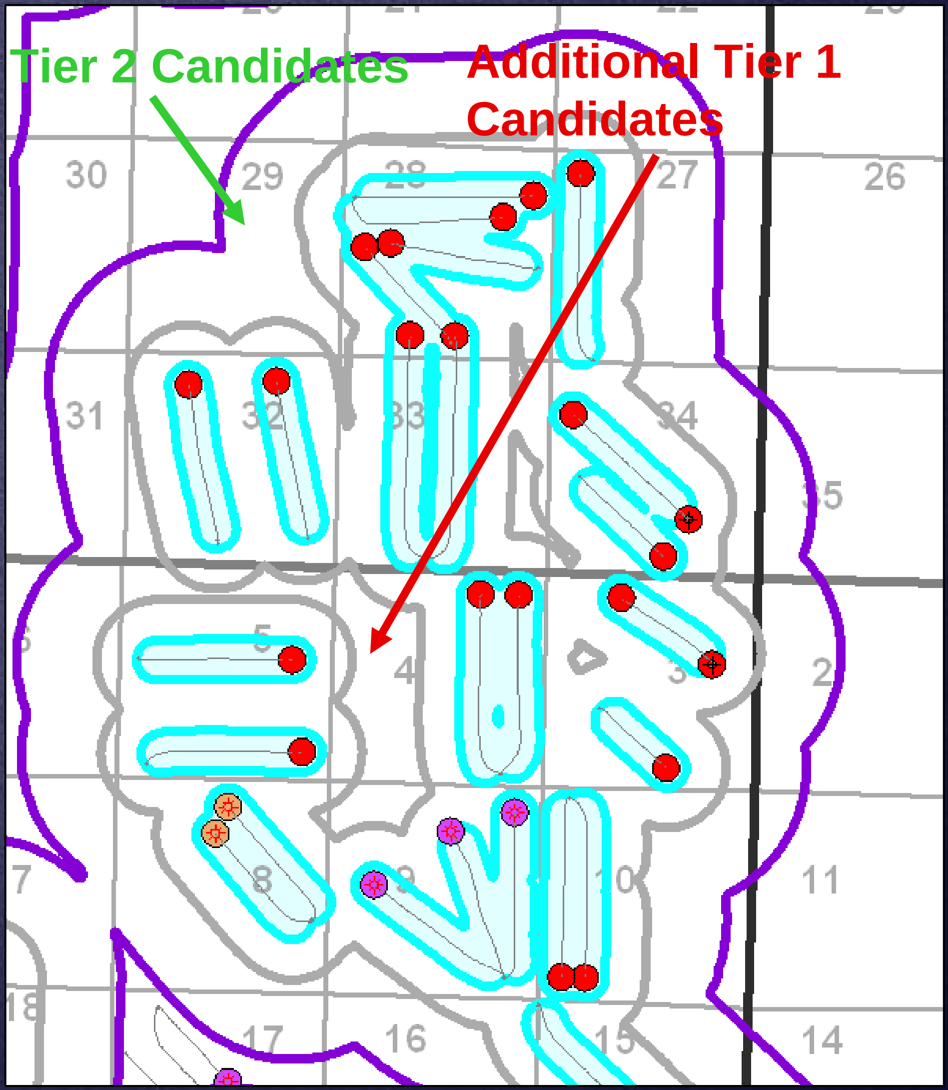
This is a generalized interpretation - individual reserves calls require judgment based on specific data

Quantity and Quality of Local Data

Assuming the EUR distribution in these local areas is **significantly** economic, the area within grey lines could be considered proved, and if the data are consistent, additional areas outside the grey but internal to the surrounding data could also be considered proved.

Not all external area between the grey and purple lines would be considered proved but not necessarily excluded from being proved.

This also assumes gas-in-place, geologic consistency, and leasehold and corporate plan are also documented and supported with a degree of certainty.



NSAI

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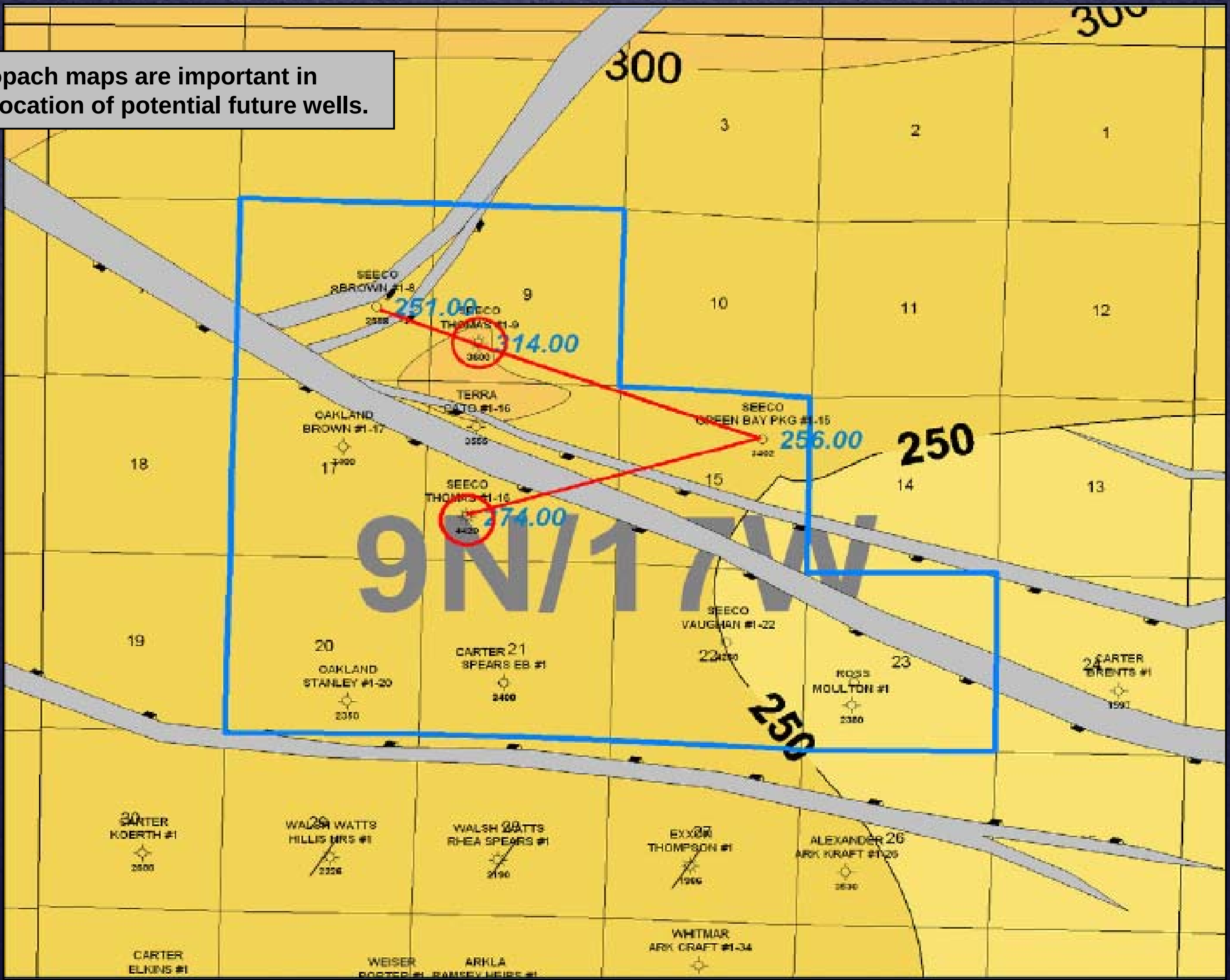
Shale Isopach and Structure

Structure and isopach maps are important in determining the location of potential future wells.



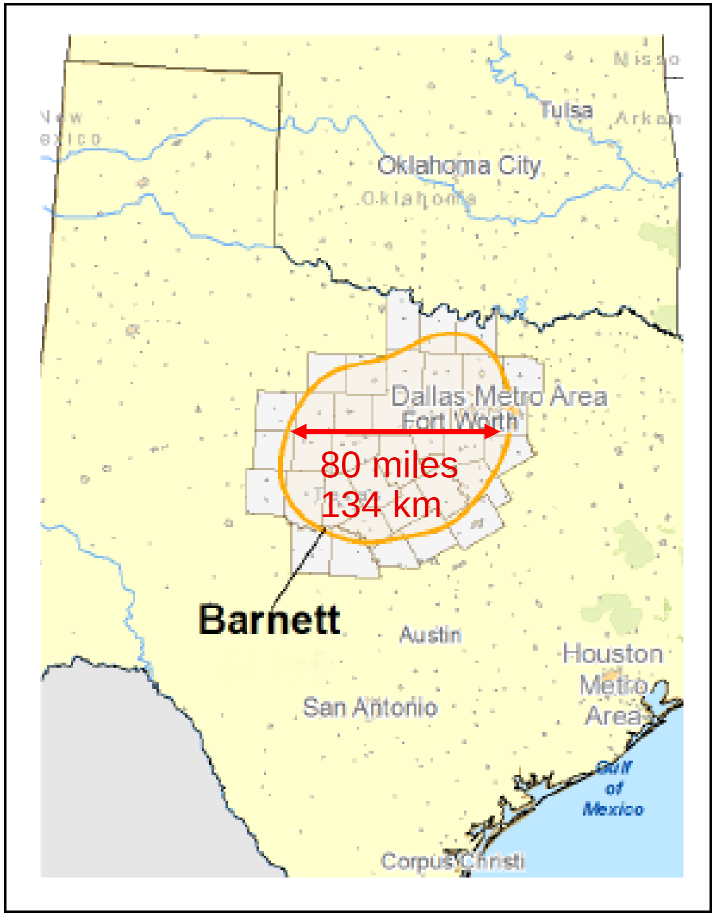
Barnett Shale

EXHIBIT 12: STRATIGRAPHY OF THE BARNETT SHALE

Period			Group/Unit
Permian		Leonardian	Clear Fork Grp
			Wichita Grp
		Wolfcampian	Cisco Grp
Pennsylvanian		Virgilian	
		Missourian	Canyon Grp
		Desmoinesian	Strawn Grp
		Atokan	Bend Grp Marble Falls Limestone
		Morrowan	
Mississippian		Chesterian - Meramecian	Barnett Shale
		Osagean	
			Chappel Limestone
Ordovician			Viola Limestone
		Canadian	Simpson Grp Ellenburger Grp

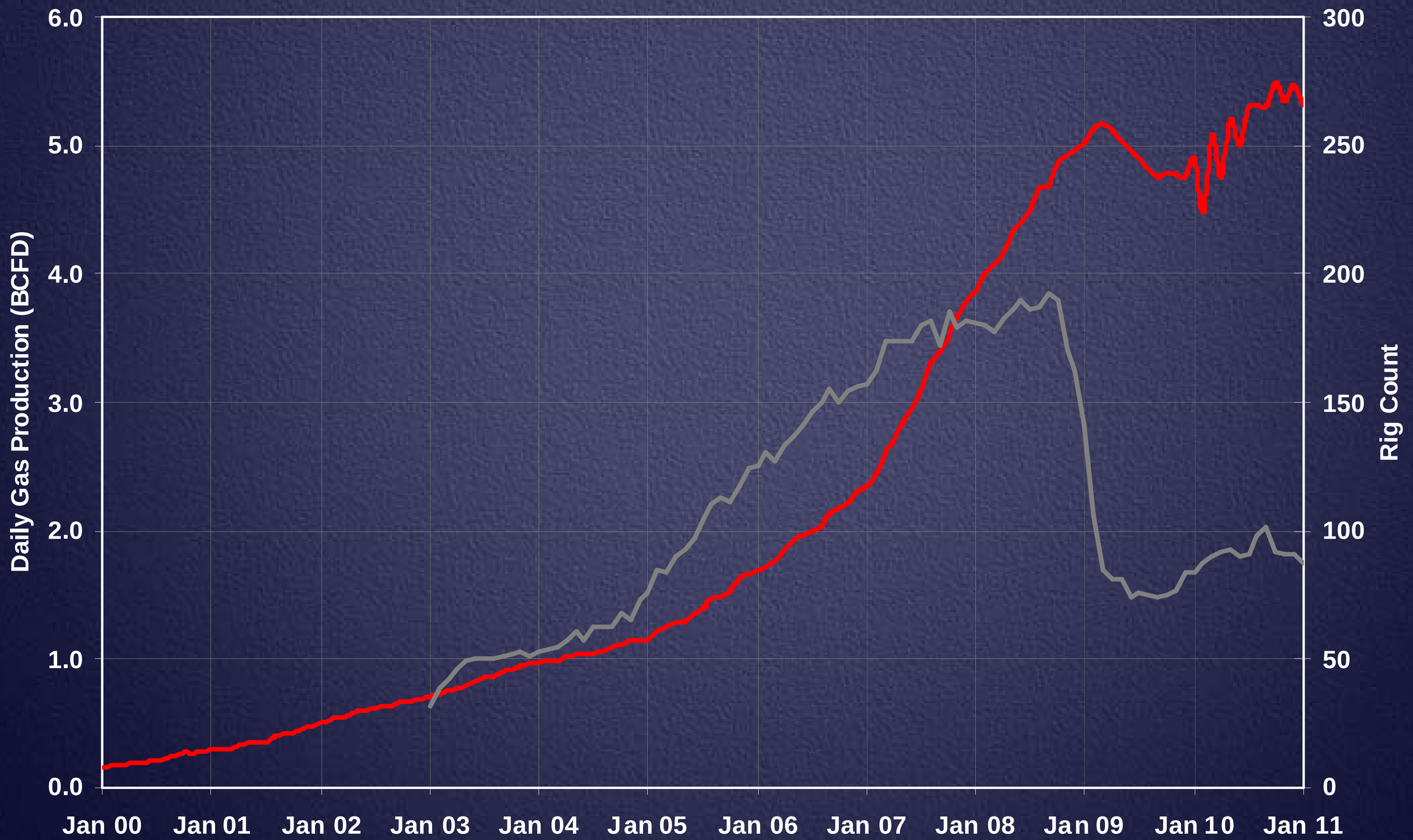
Source: Hayden and Pursell, 2005[129]
AAPG, 1987 [130]

EXHIBIT 13: BARNETT SHALE IN THE FORT WORTH BASIN



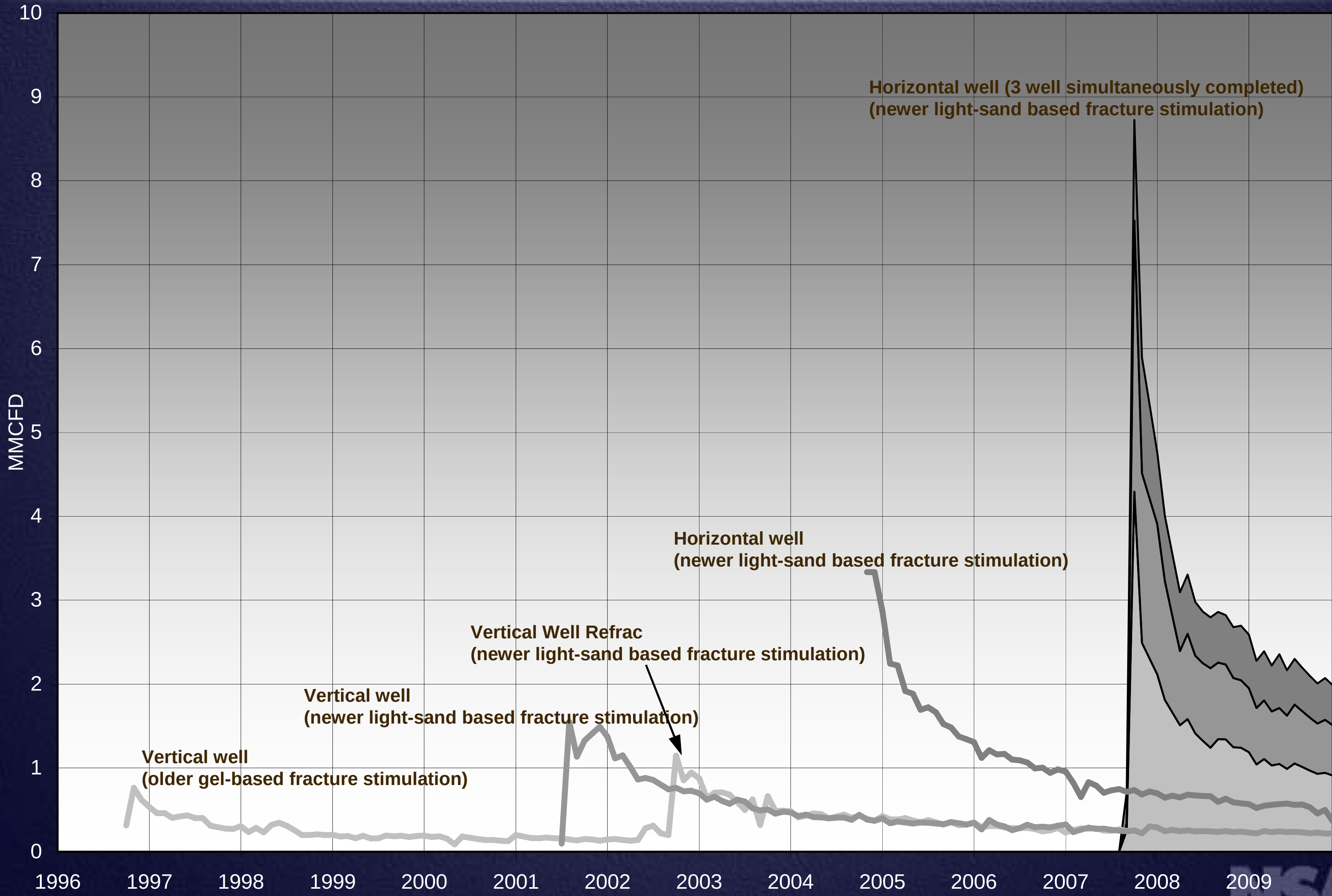
Source: ALL Consulting, 2009

Barnett Production



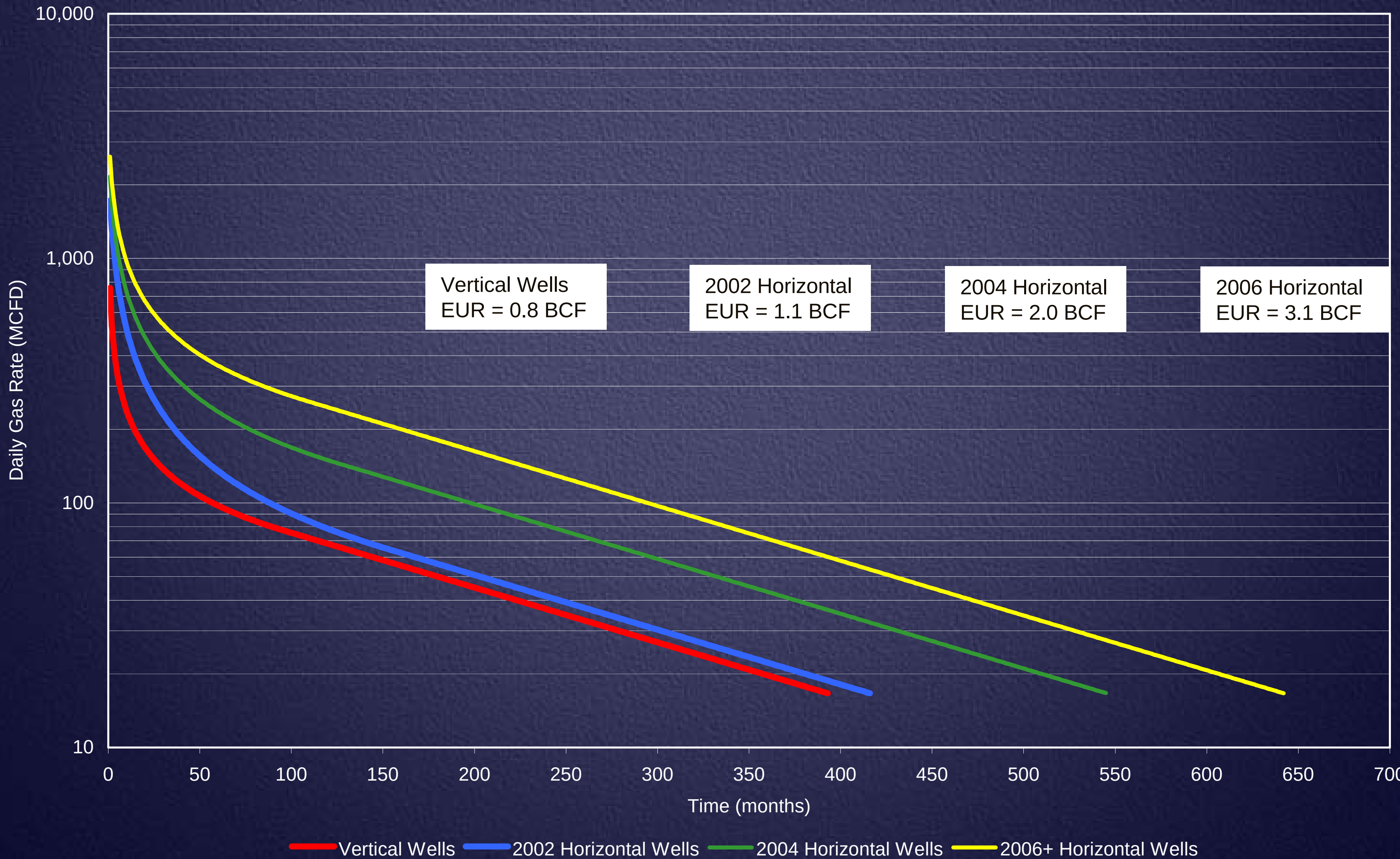
14,000 Producing wells
5.3 BCFD
9,000 BCF Cumulative Gas

Chronology of Barnett Shale Completion Techniques



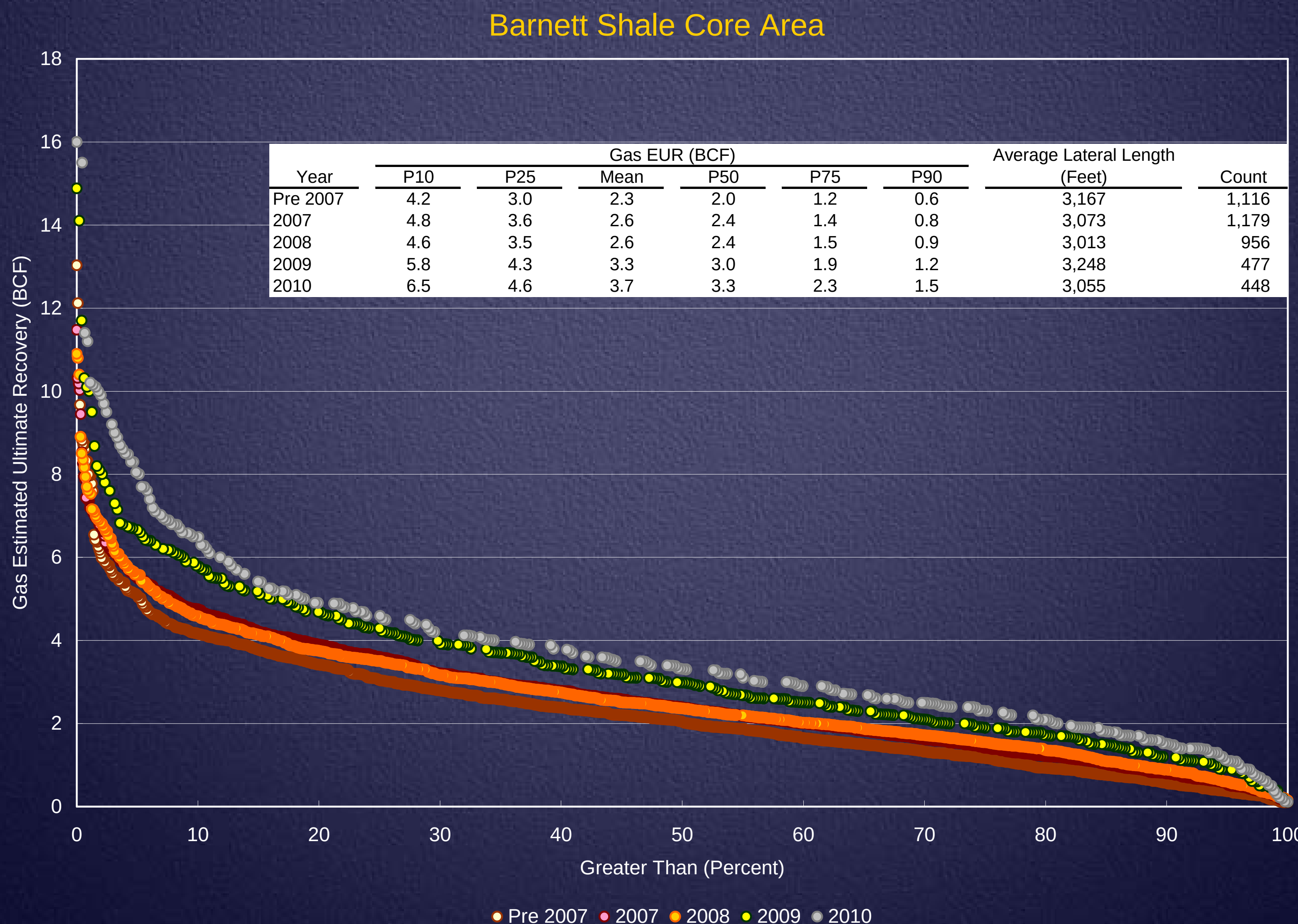
NSAI

Barnett Shale Type Curve



This is a generalized interpretation - individual reserves calls require judgment based on specific data

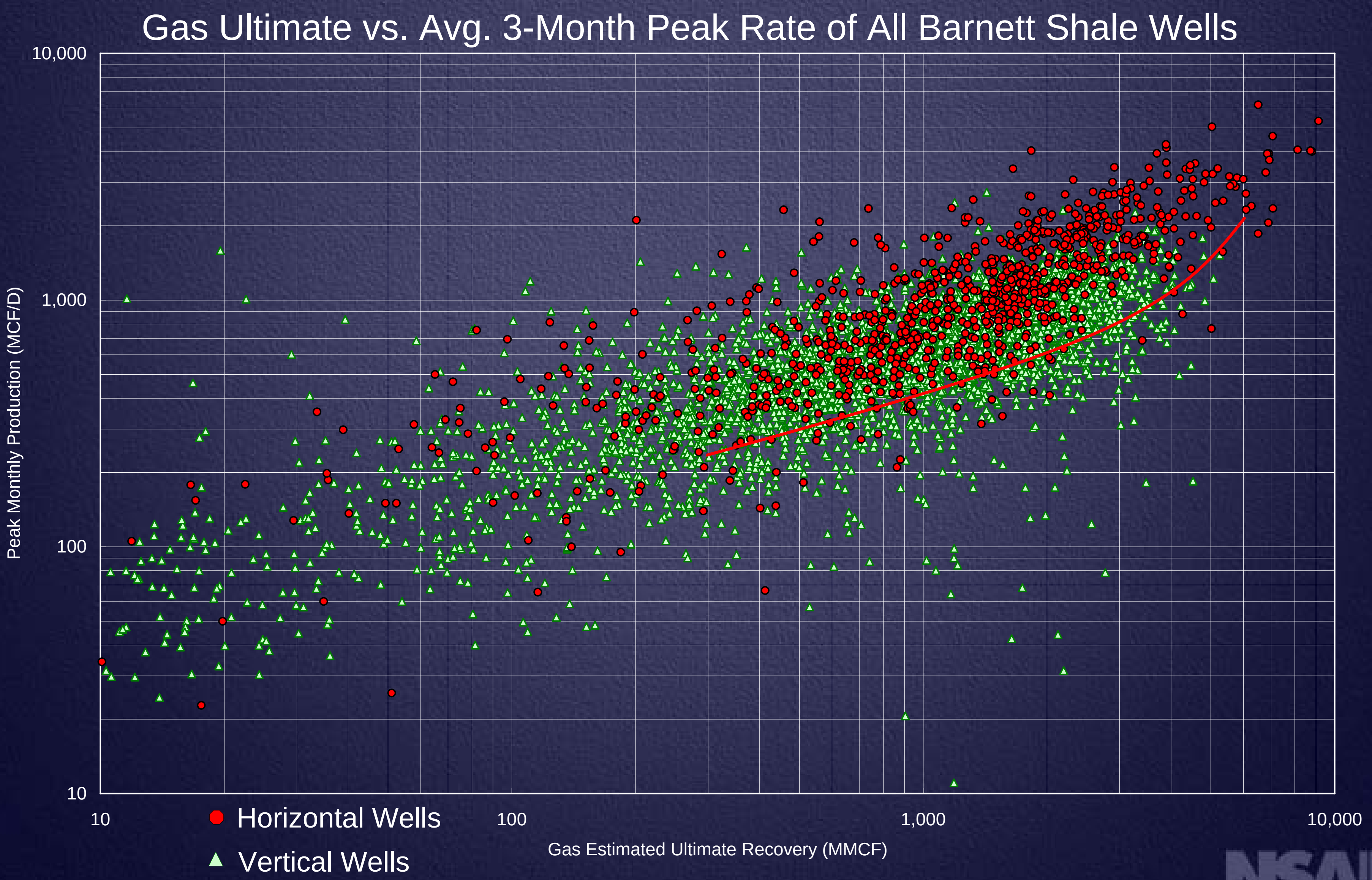
Yearly Gas Ultimate Distribution



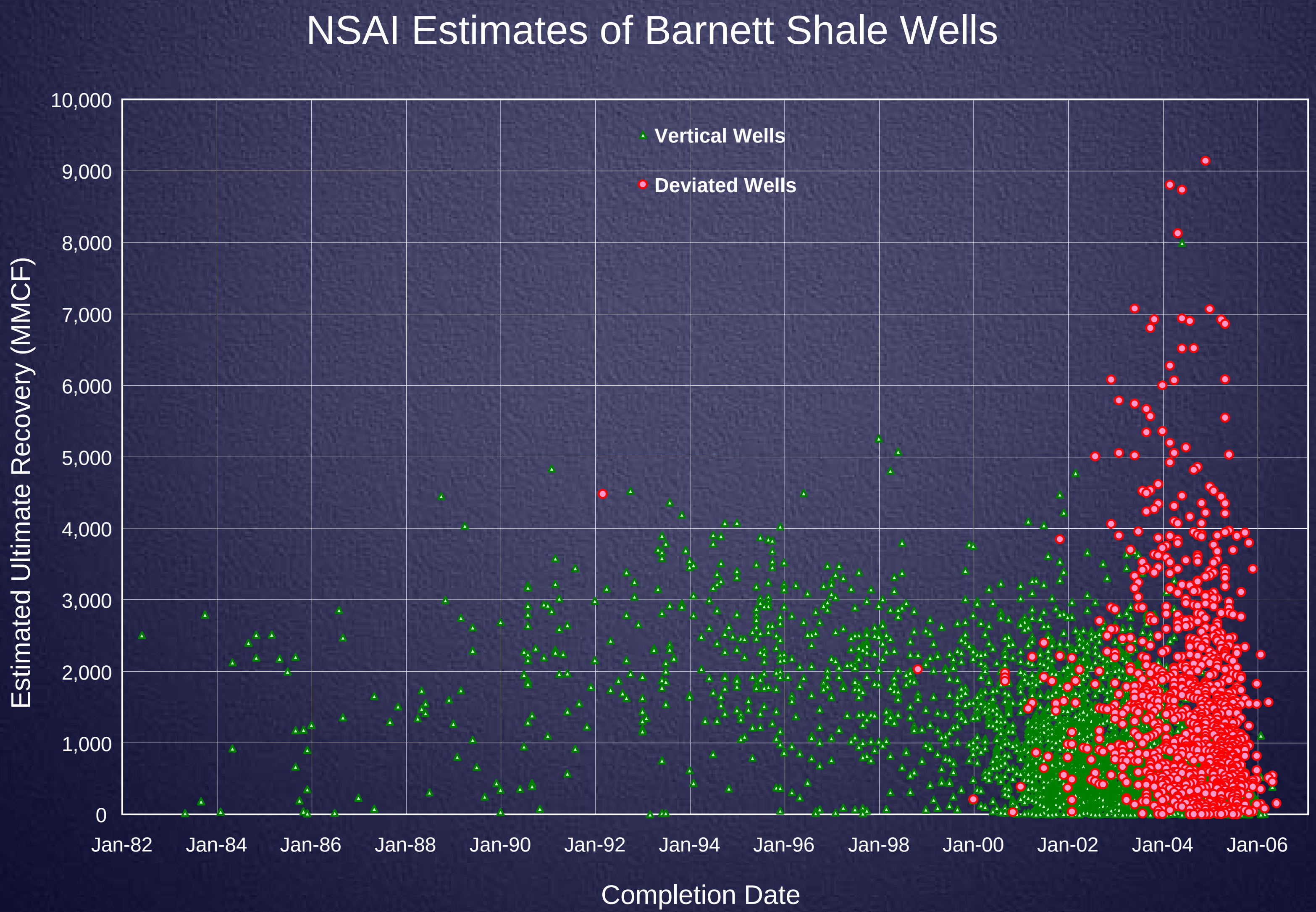
	Gas EUR (BCF)						Average Lateral Length	
Year	P10	P25	Mean	P50	P75	P90	(Feet)	Count
Pre 2007	4.2	3.0	2.3	2.0	1.2	0.6	3,167	1,116
2007	4.8	3.6	2.6	2.4	1.4	0.8	3,073	1,179
2008	4.6	3.5	2.6	2.4	1.5	0.9	3,013	956
2009	5.8	4.3	3.3	3.0	1.9	1.2	3,248	477
2010	6.5	4.6	3.7	3.3	2.3	1.5	3,055	448

This is a generalized interpretation - individual reserves calls require judgment based on specific data

Completion Variability



Completion Variability



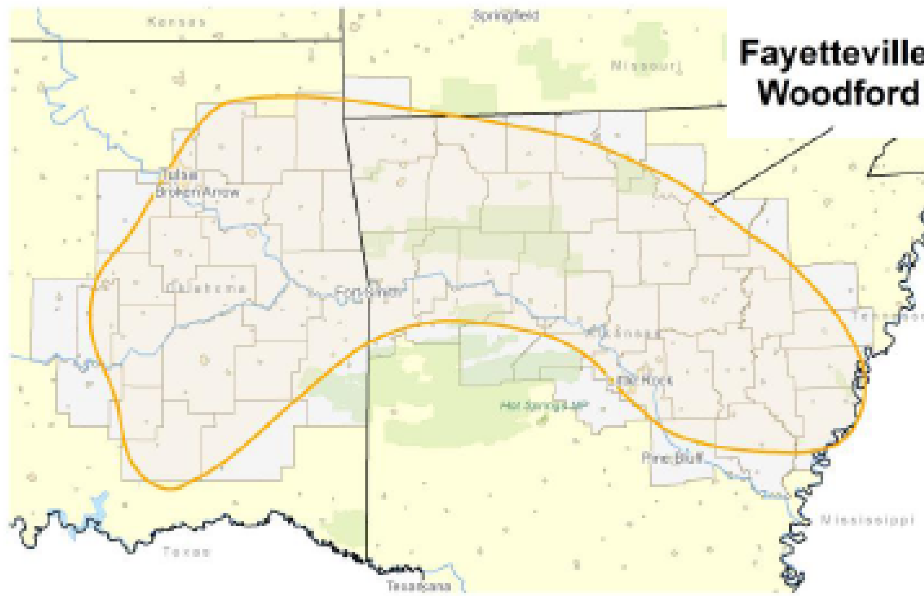
Fayetteville Shale

EXHIBIT 14: STRATIGRAPHY OF THE FAYETTEVILLE SHALE

Period			Group/Unit
CARBONIFEROUS	Pennsylvanian		Atoka
			Bloyd
		Hale	Prairie Grove
			Cane Hill
	Mississippian		(IMO)
			Pitkin
			Fayetteville
			Batesville
			Moorefield
			Boone

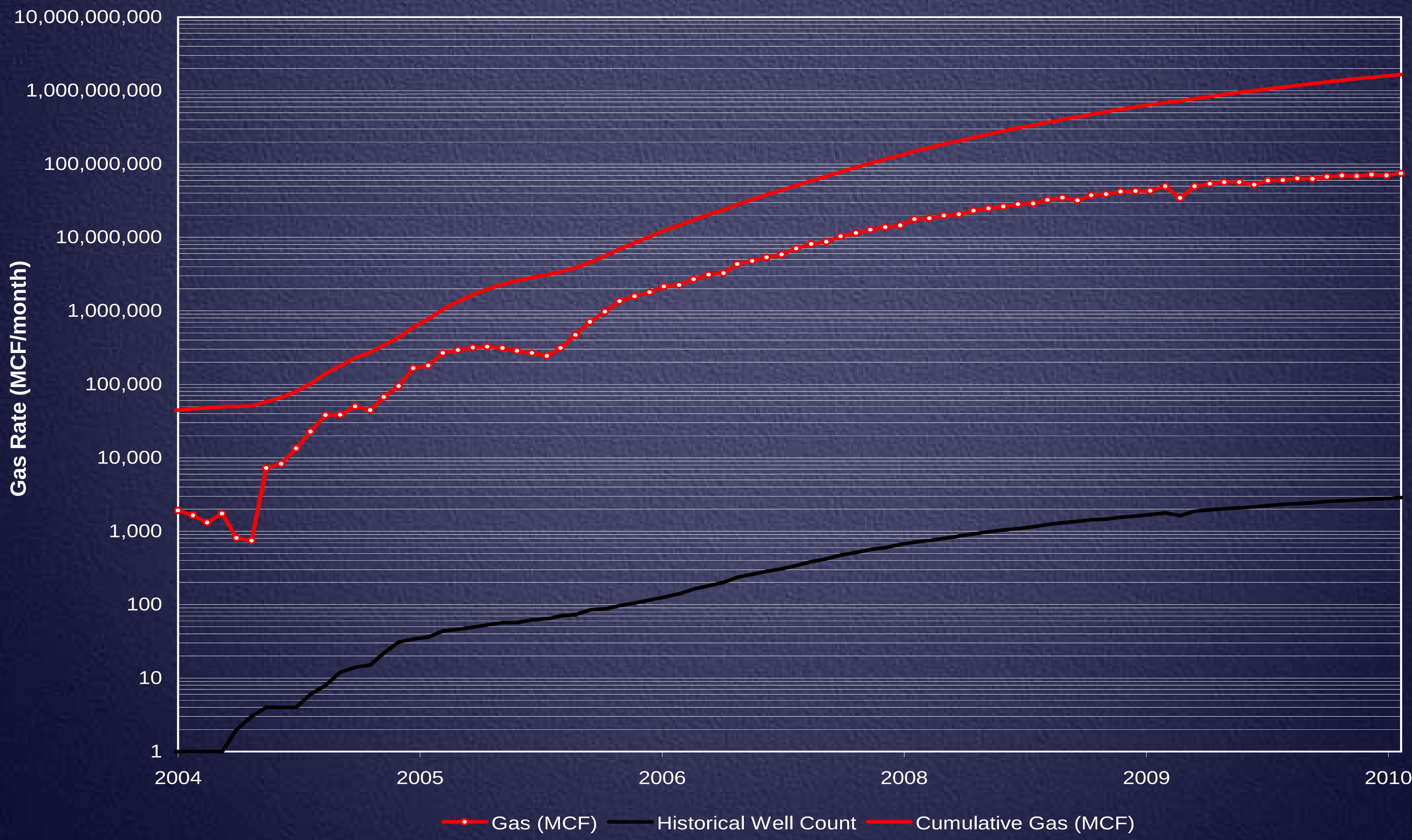
Source: Hillwood, 2007[140]

EXHIBIT 15: FAYETTEVILLE SHALE IN THE ARKOMA BASIN



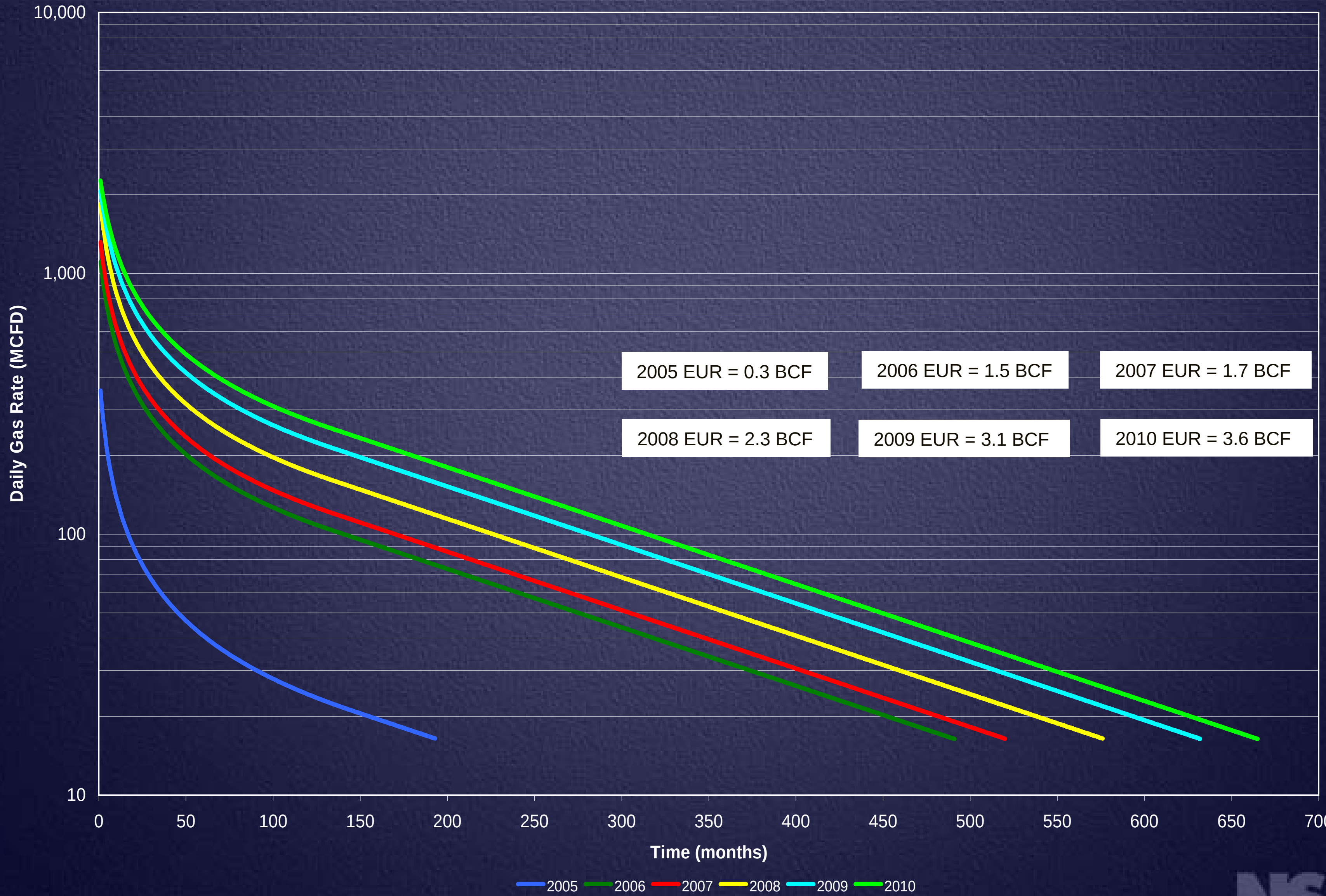
Source: ALL Consulting, 2009

Fayetteville Production



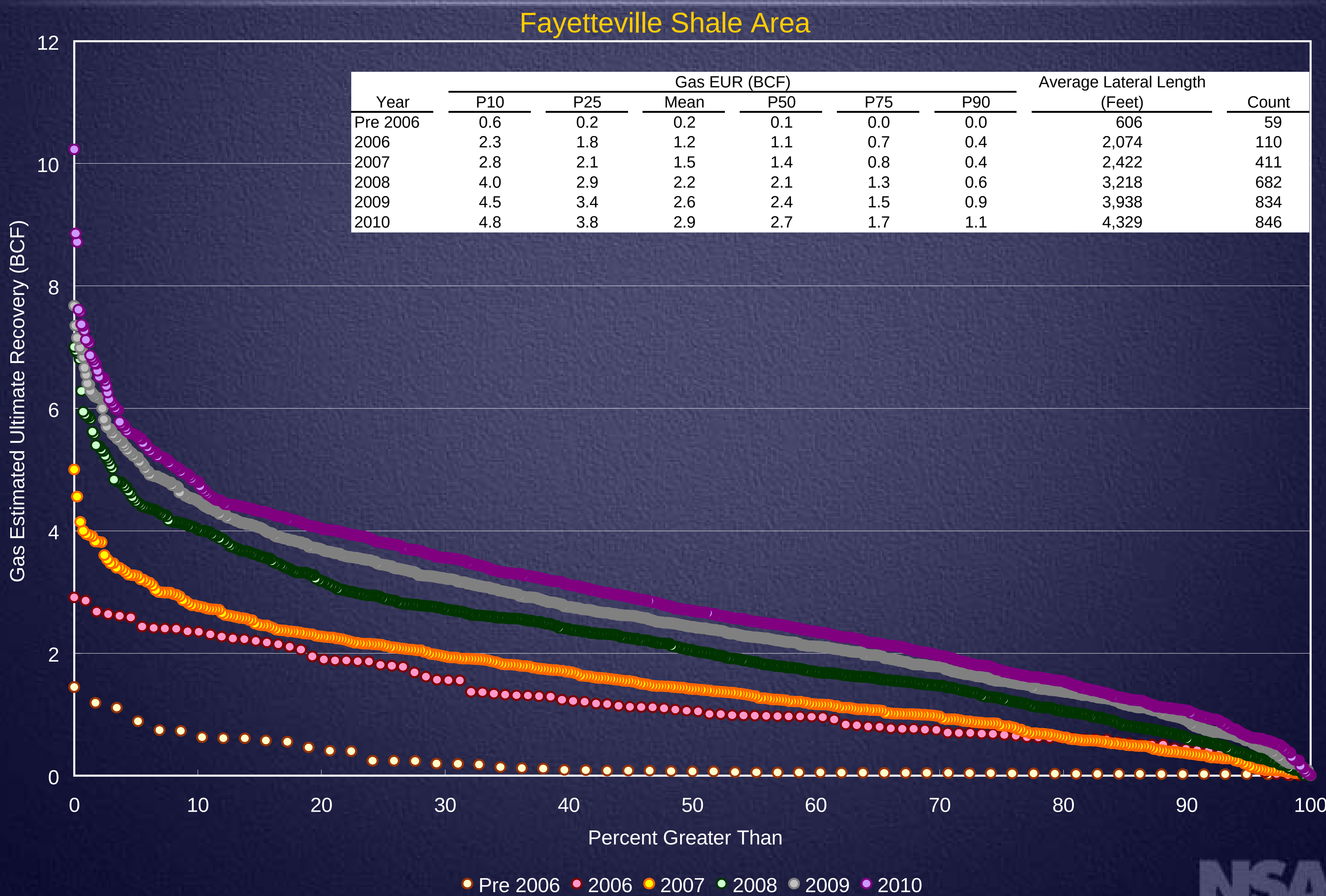
3,000 Producing wells since 2004
2.5 BCFD
1,700 BCF Cumulative Gas

Fayetteville Shale Type Curve



This is a generalized interpretation - individual reserves calls require judgment based on specific data

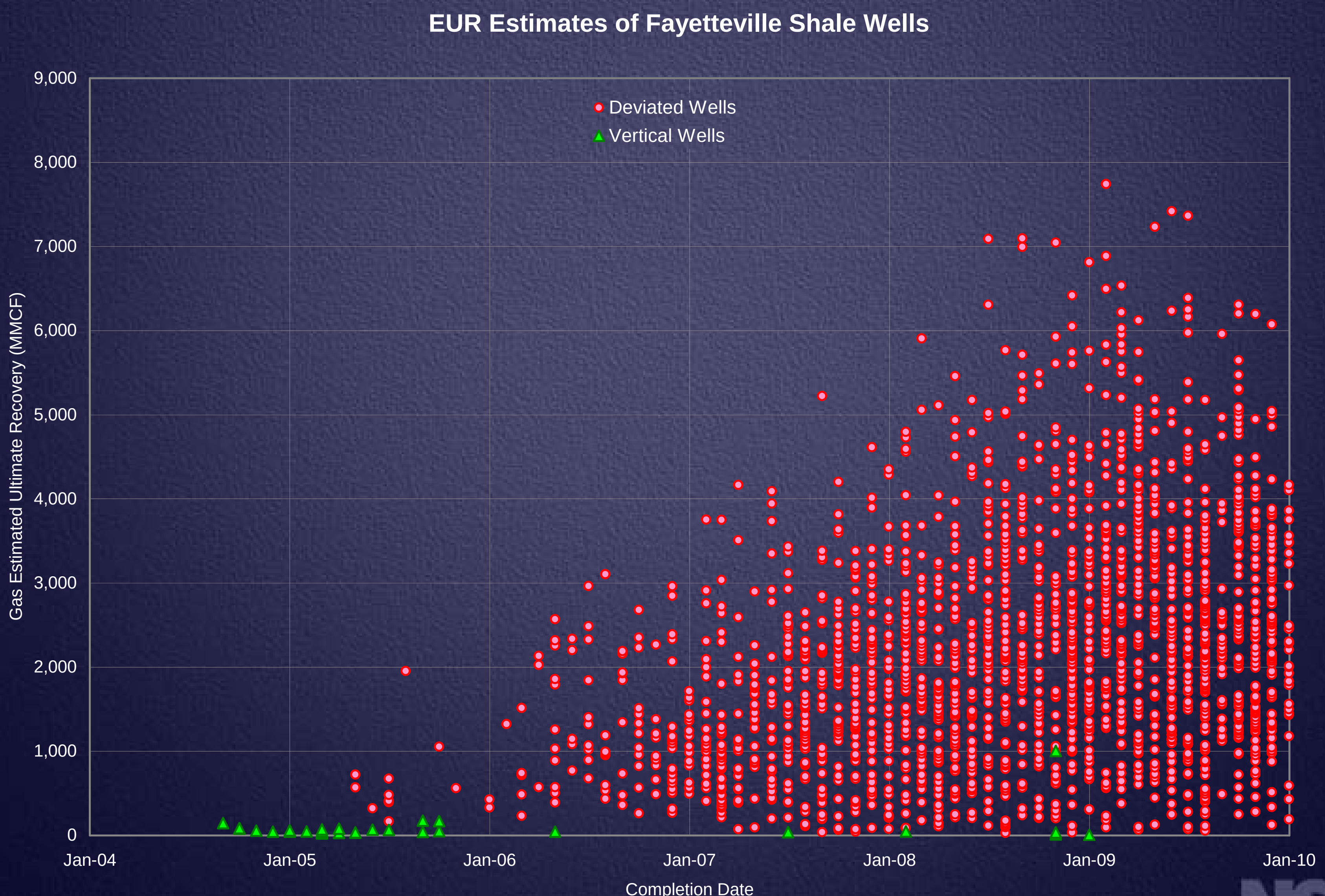
Yearly Gas Ultimate Distribution



Year	Gas EUR (BCF) P10	P25	Mean	P50	P75	P90	Average Lateral Length (Feet)	Count
Pre 2006	0.6	0.2	0.2	0.1	0.0	0.0	606	59
2006	2.3	1.8	1.2	1.1	0.7	0.4	2,074	110
2007	2.8	2.1	1.5	1.4	0.8	0.4	2,422	411
2008	4.0	2.9	2.2	2.1	1.3	0.6	3,218	682
2009	4.5	3.4	2.6	2.4	1.5	0.9	3,938	834
2010	4.8	3.8	2.9	2.7	1.7	1.1	4,329	846

This is a generalized interpretation - individual reserves calls require judgment based on specific data

Completion Variability



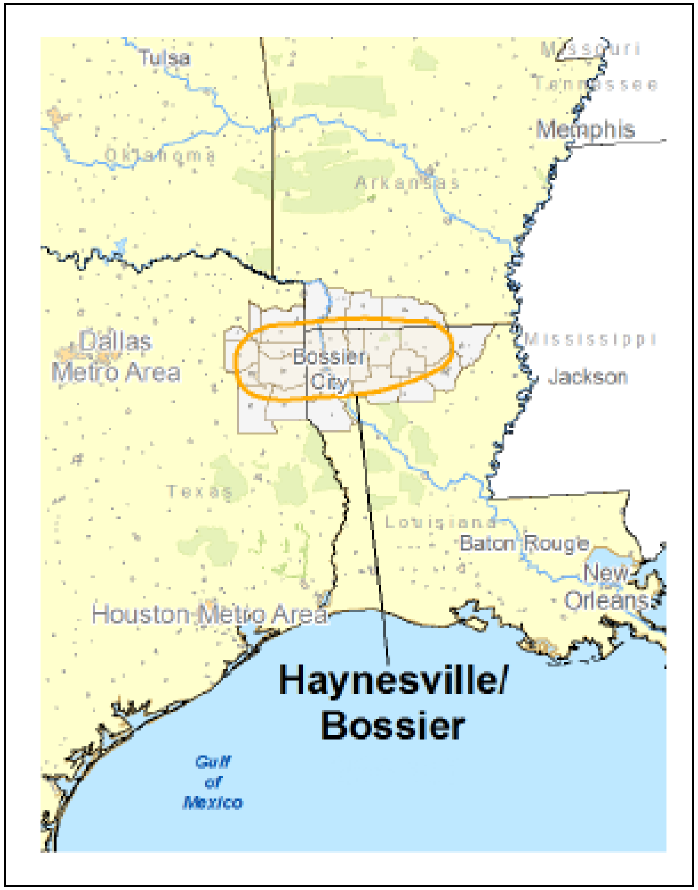
Haynesville Shale

EXHIBIT 16: STRATIGRAPHY OF THE HAYNESVILLE SHALE

Period		Group/Unit
Cretaceous		Navarro
		Taylor
		Austin
		Eagle Ford
		Tuscaloosa
		Washita
		Fredericksburg
		Trinity Group
		Nuevo Leon
Jurassic	Upper	Cotton Valley Group
		Haynesville
		Smackover
		Norphlet
	Middle	Louann
	Lower	Werner
Triassic	Upper	Eagle Mills

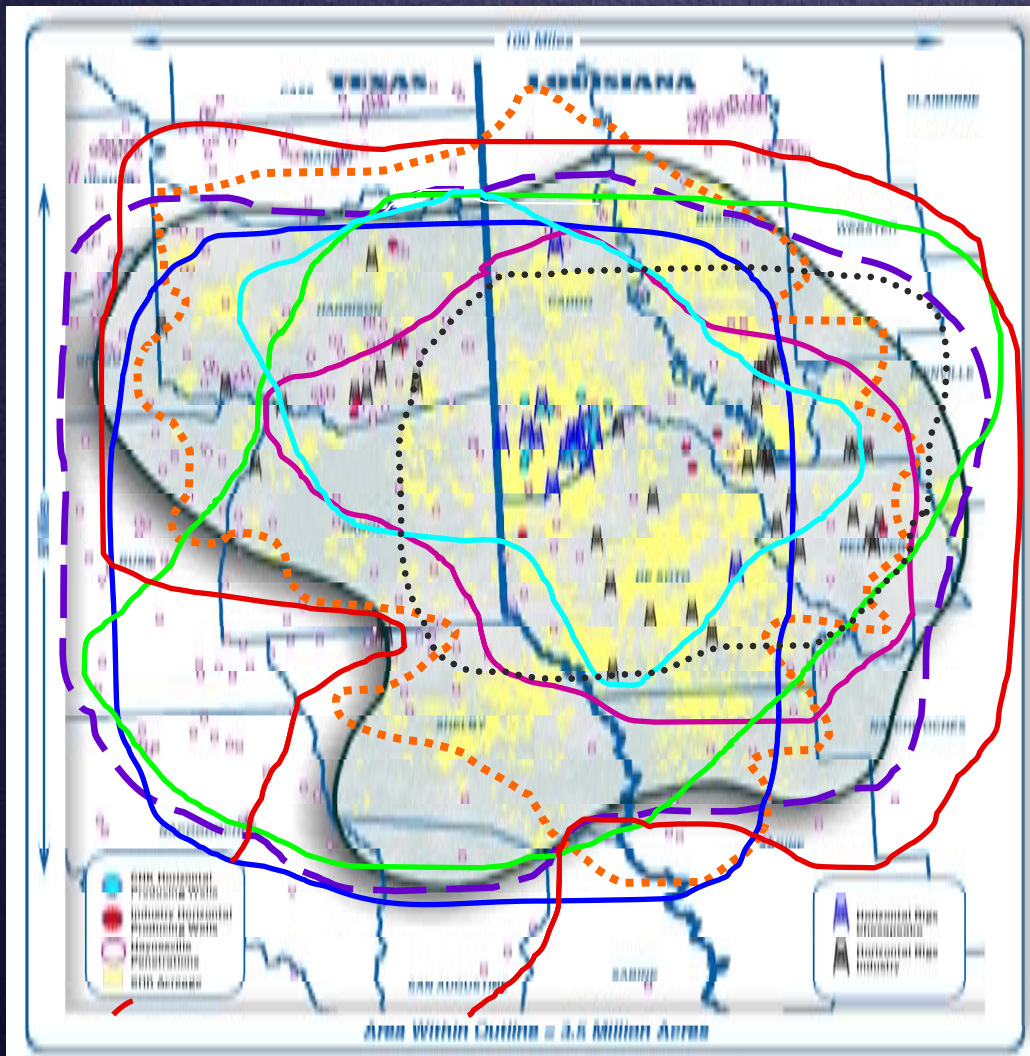
Source: Johnson et al, 2000[143]

EXHIBIT 17: HAYNESVILLE SHALE IN THE TEXAS & LOUISIANA BASIN



Source: ALL Consulting, 2009

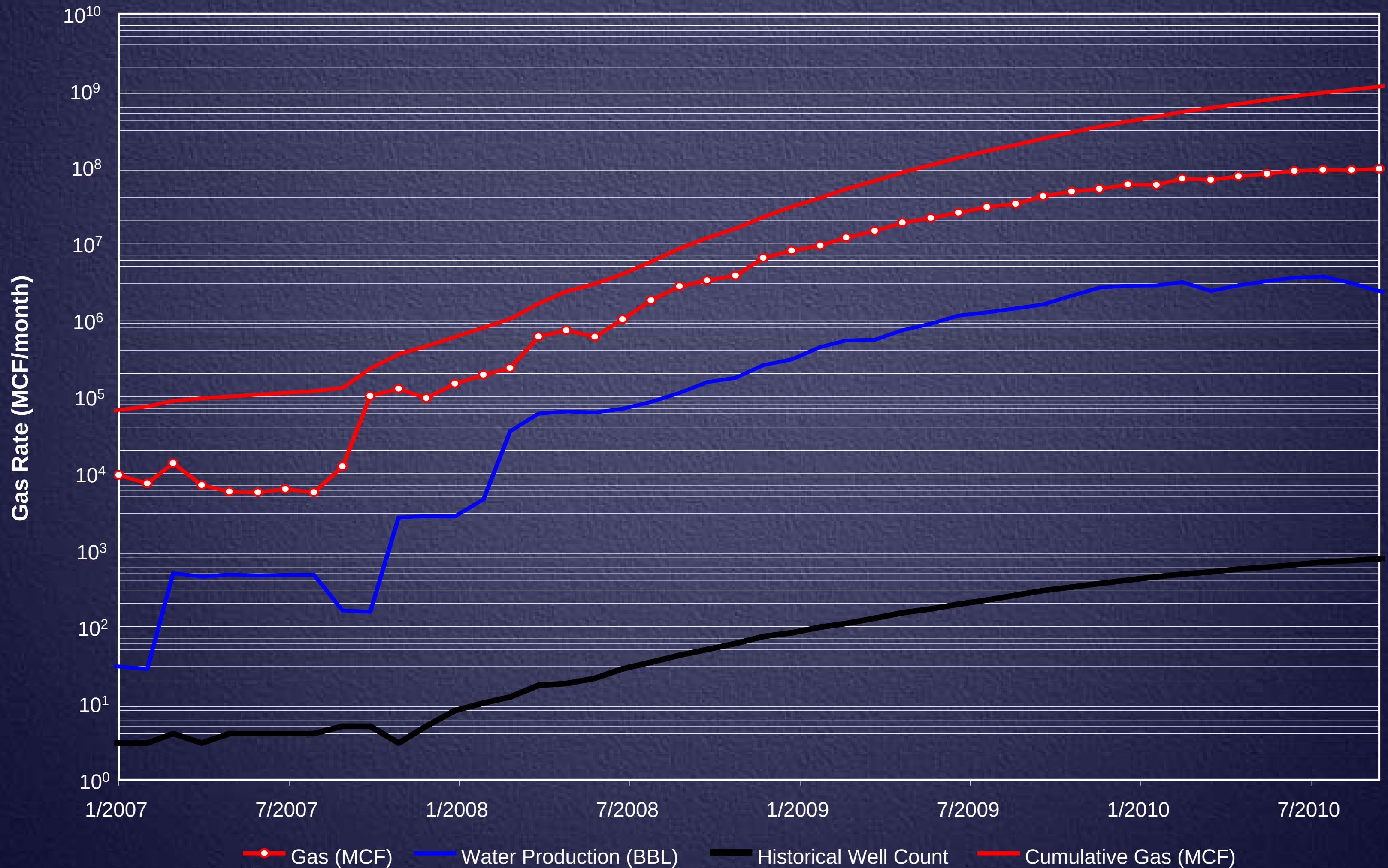
Haynesville Shale Gas Play Limits



- Chesapeake
- Cabot
- Comstock
- El Paso
- EnCana
- Exco
- GMXR
- Petrohawk
- PennVirginia

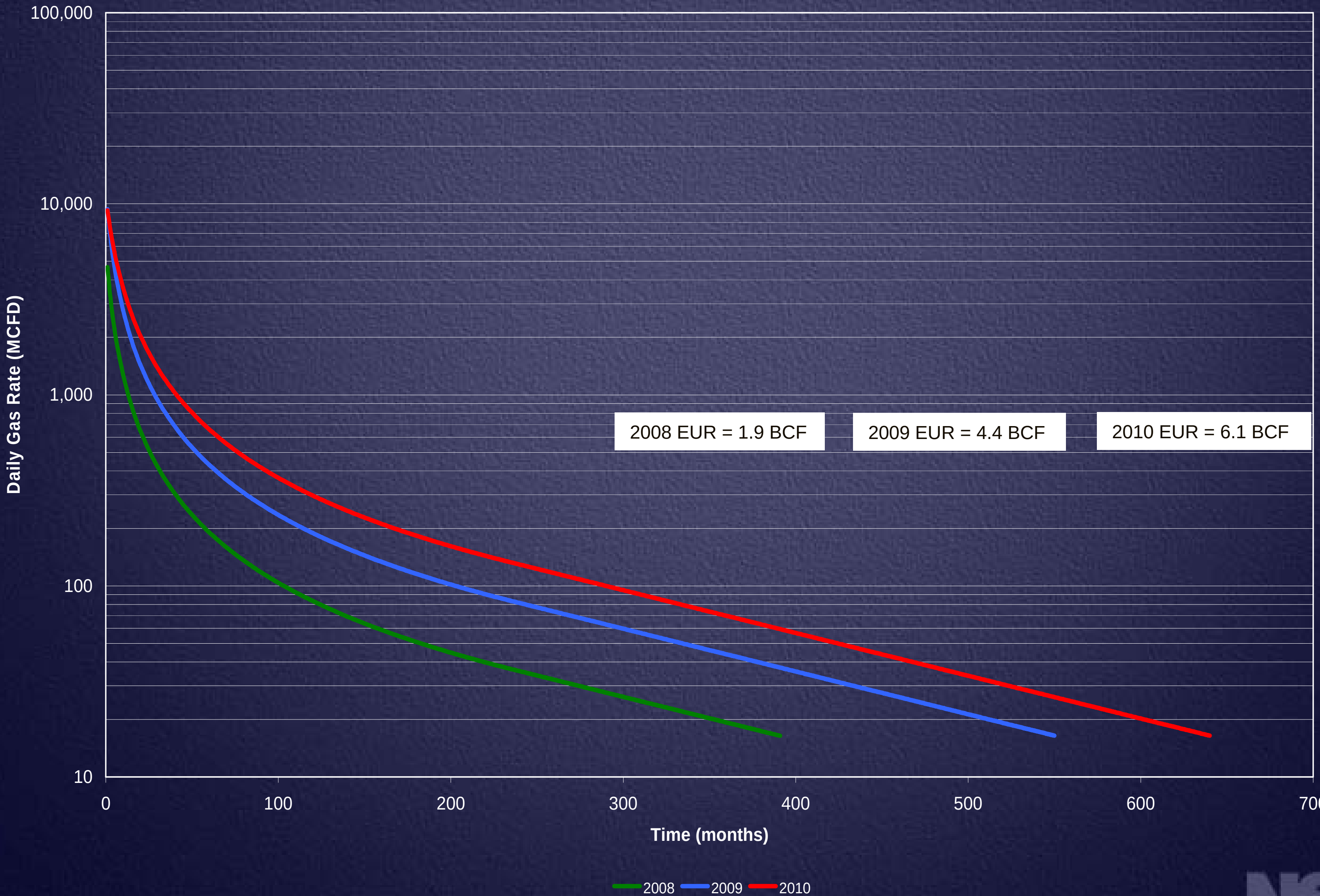
Source of Data
Base Map: Chesapeake 2008 Investor and Analyst Meeting; Haynesville limits by operator: company presentations

Haynesville Production



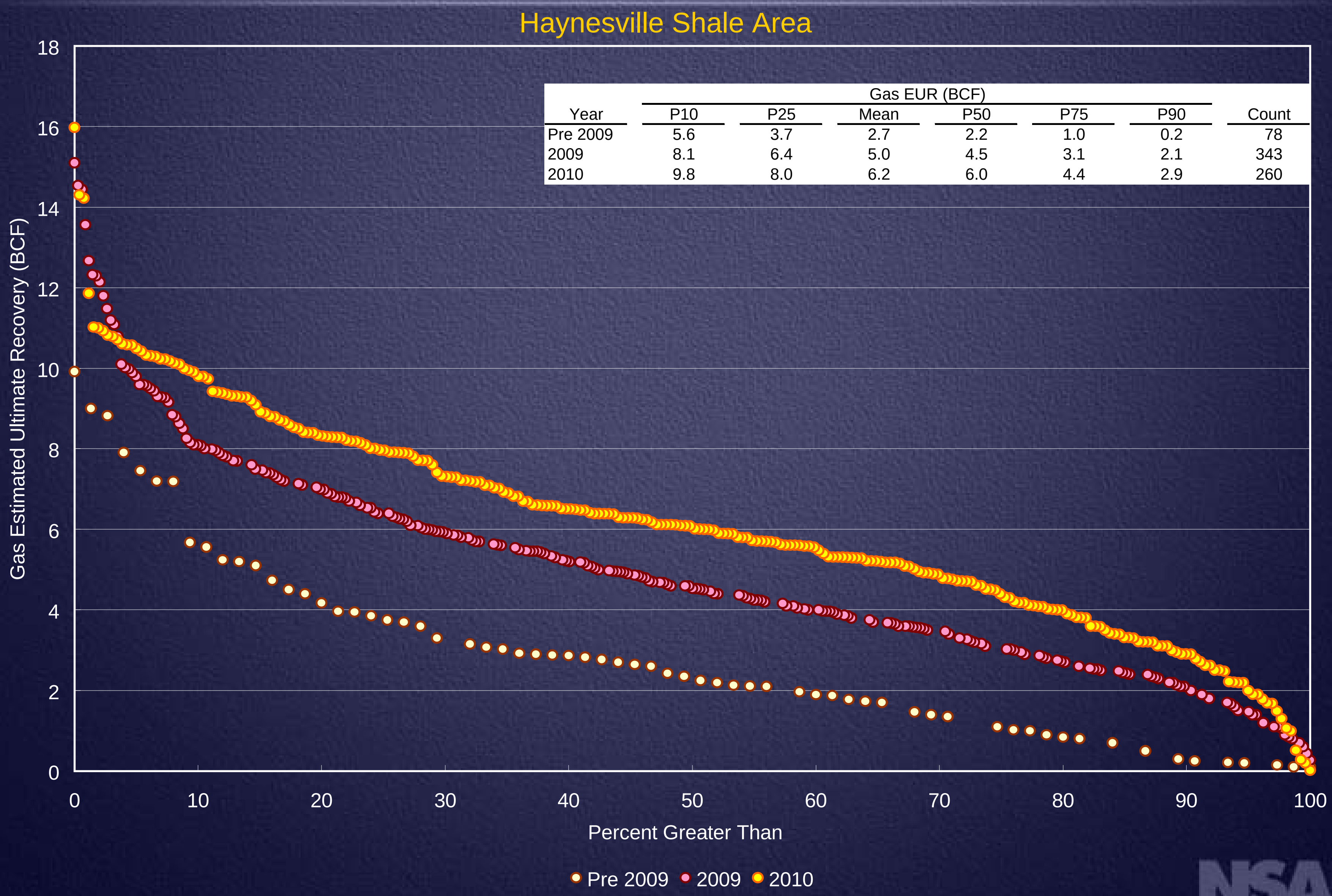
800 Producing wells since 2007
3 BCFD
1,200 BCF Cumulative Gas

Haynesville Type Curve



This is a generalized interpretation - individual reserves calls require judgment based on specific data

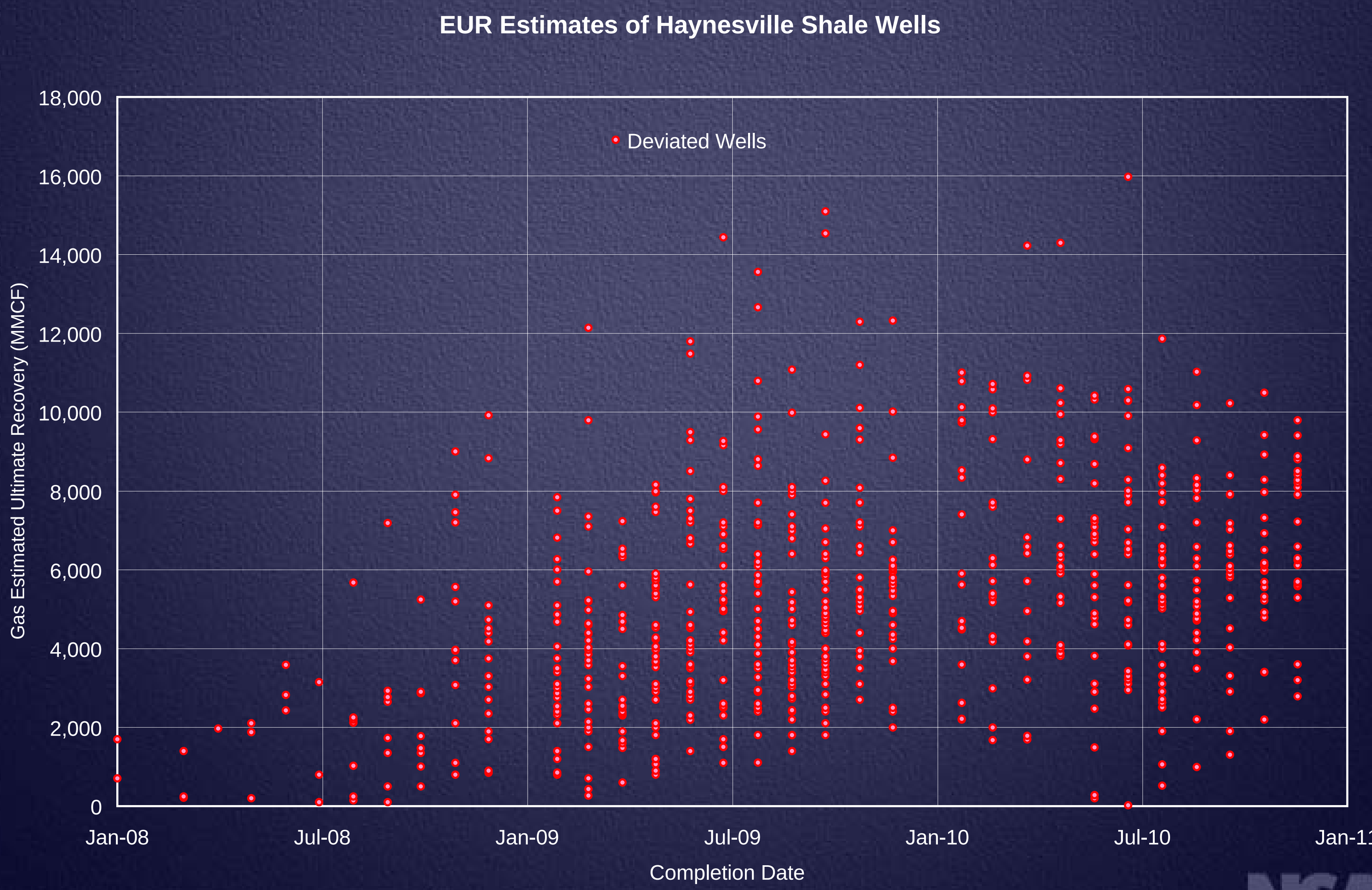
Yearly Gas Ultimate Distribution



Year	P10	P25	Mean	P50	P75	P90	Count
	Gas EUR (BCF)						
Pre 2009	5.6	3.7	2.7	2.2	1.0	0.2	78
2009	8.1	6.4	5.0	4.5	3.1	2.1	343
2010	9.8	8.0	6.2	6.0	4.4	2.9	260

This is a generalized interpretation - individual reserves calls require judgment based on specific data

Completion Variability



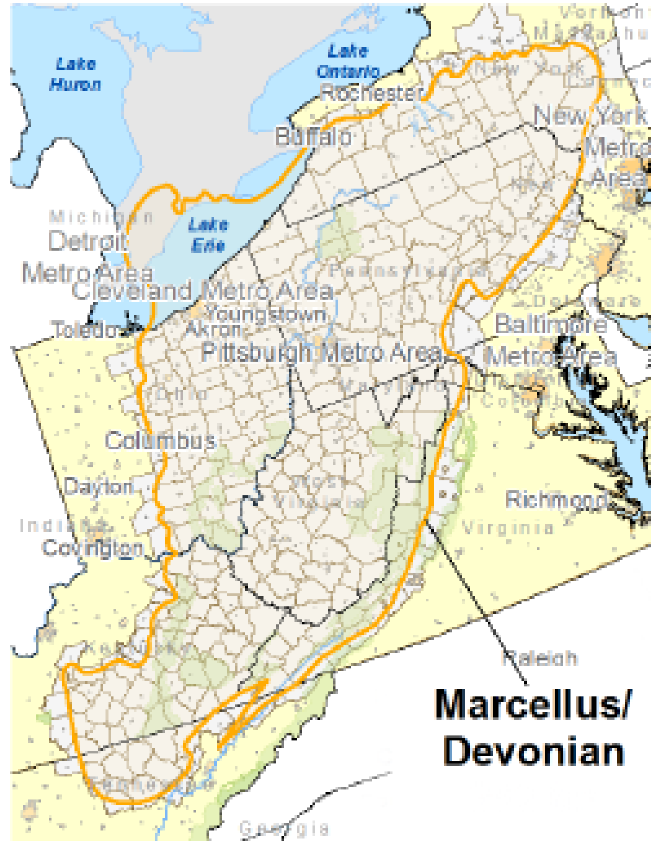
Marcellus Shale

EXHIBIT 18: STRATIGRAPHY OF THE MARCELLUS SHALE

Period		Group/Unit	
Penn		Pottsville	
Miss		Pocono	
Devonian	Upper	Conewango	
		Conneaut	
		Canadaway	
		West Falls	
		Sonyea	
		Genesee	
	Middle	Tully	
		Hamilton Group	Moscow
			Ludlowville
			Skaneateles
			Marcellus
		Onandaga	
	Lower	Tristates	
		Helderberg	

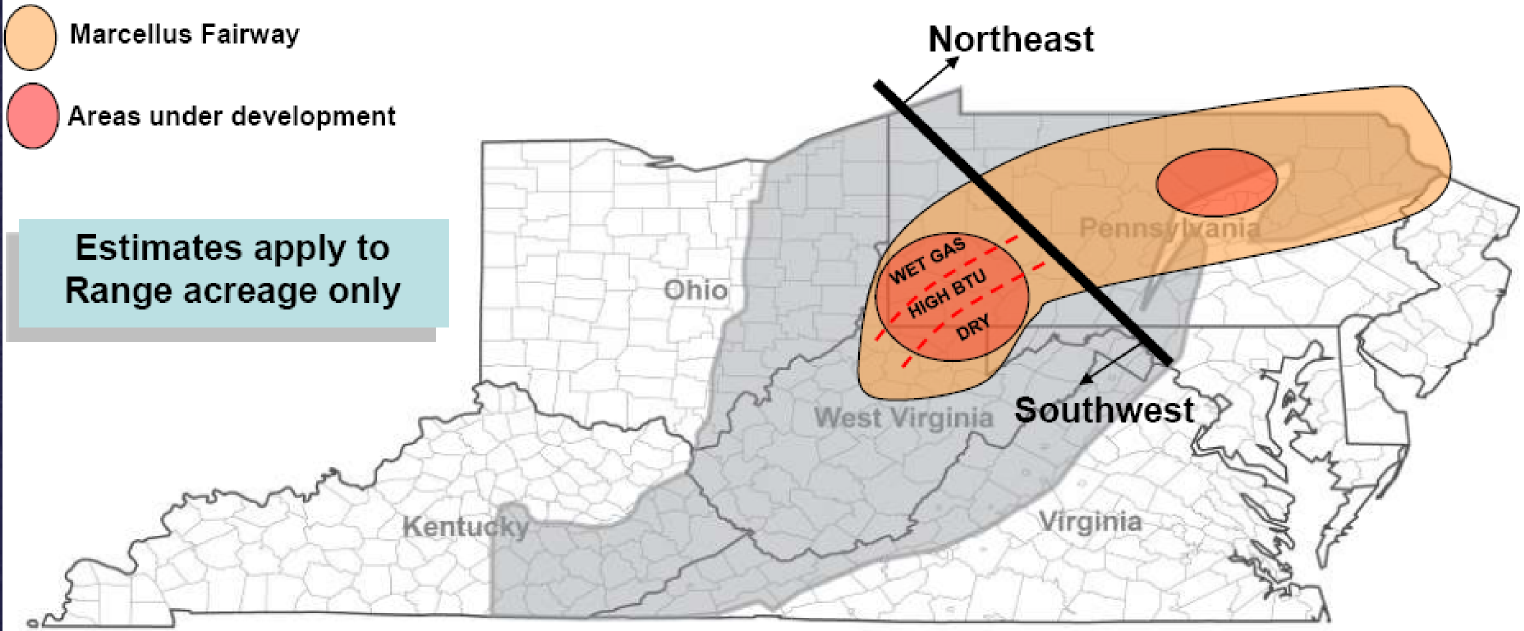
Source: Arthur et al, 2008[148]

EXHIBIT 19: MARCELLUS SHALE IN THE APPALACHIAN BASIN



Source: ALL Consulting, 2009

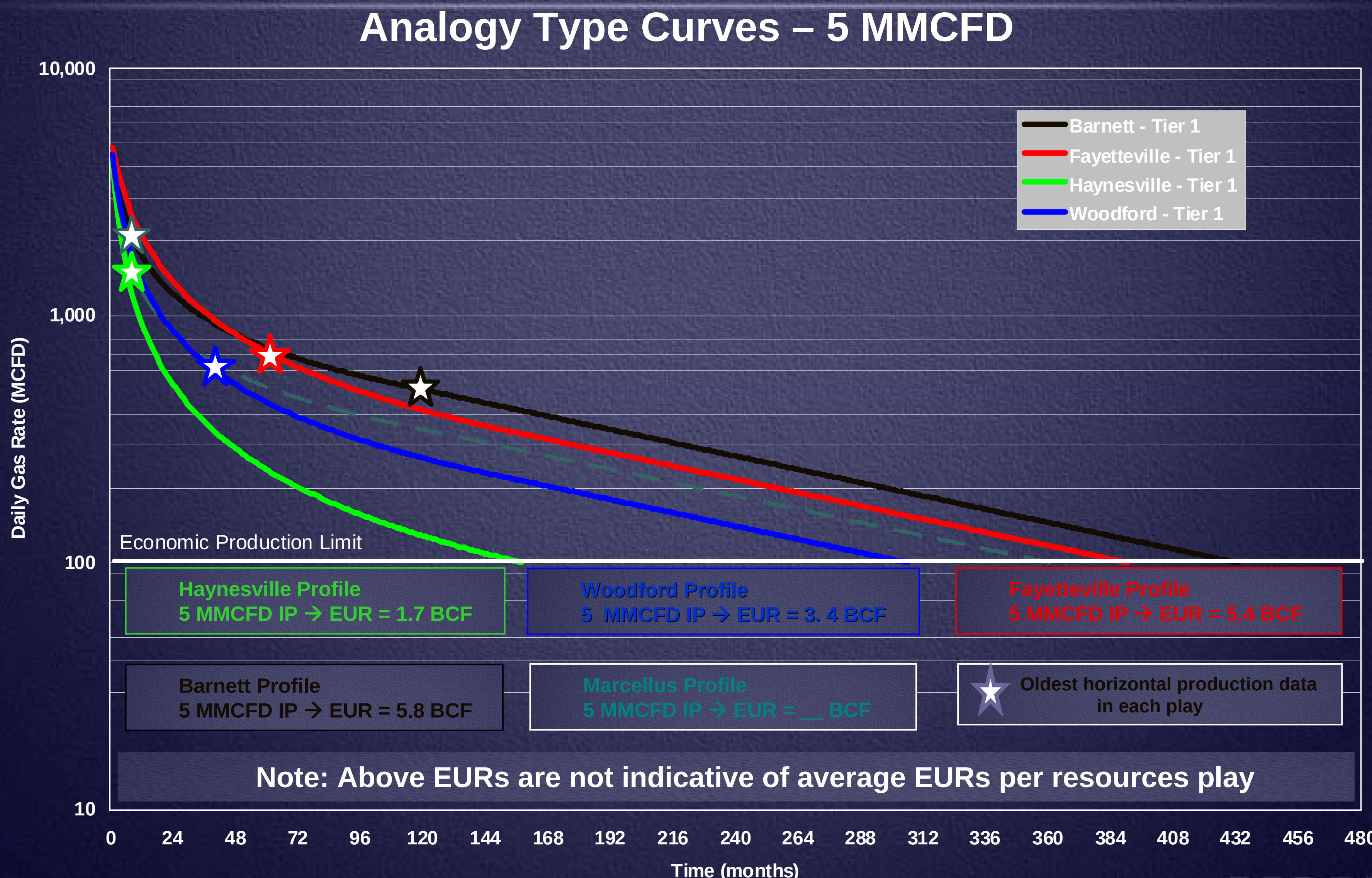
Marcellus Shale
Range Resources EUR Estimates (January 2009)



	Southwest	Northeast	Total
"Fairway" Acreage	~550,000	~350,000	~900,000
Net Reserves per horizontal well	3-4 Bcfe	3-4 Bcfe	3-4 Bcfe
Net Unrisked Potential			
Lower Range	10 Tcfe	5 Tcfe	15 Tcfe
Upper Range	15 Tcfe	7 Tcfe	22 Tcfe

Range Resources "The BMO Capital Markets 2009 North American Unconventional Gas Conference", January 13, 2009, page 21.

Resources Plays – Are All Shale Plays the Same?



Shale Gas is Easy?

NSA

NSA