Comparison of Hydraulic Stimulation Methods of Coals and Carbonaceous Shales in the Cherokee Basin*

Steven Tedesco[1]

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[1]Running Foxes Petroleum Inc., Centennial, CO, USA (s.a.tedesco14@runningfoxes.com)

Abstract

The Cherokee Basin in southeastern Kansas and northeastern Oklahoma produces gas from Cherokee Formation coals and carbonaceous mudstones. From 1990 to 2009, these coals and carbonaceous mudstones were exploited by several operators and peaked at over 1,000 wells per year. Activity ceased with the collapse of gas prices in 2008 to 2009. Several different hydraulic stimulation methods were used as well as types of stimulation design to specifically to stimulate individual or multiple seams. The majority of the wells in the basin have over eight years of production history that allows for analysis of the various stimulation methods. Comparison of individual zone completion versus multiple seam completion was done. This study suggests that that cross-link gel was as effective as slick water. Another conclusion is that stimulating individual zones was significantly more effective than stimulating several zones with the same fracture stimulation. In addition, certain Operators were more effective at maximizing gas production. Several other trends were also identified that will be discussed. While gas prices remain low this analysis allows identification of re-stimulation candidates, behind pipe resources and potential other areas that remain to be exploited.

Reference Cited

Tedesco, S.A., 2014, Reservoir characterization and geology of the coals and carbonaceous shales of the Cherokee Group in the Cherokee Basin, Kansas, Missouri and Oklahoma, U.S.A.: Ph.D. Dissertation, Colorado School of Mines, Golden, CO.

Comparison of hydraulic stimulation methods of coals and carbonaceous shales in the Cherokee Basin

By: Dr. Steven A. Tedesco
Running Foxes Petroleum Inc.
Centennial, CO 80112
www.runningfoxes.com

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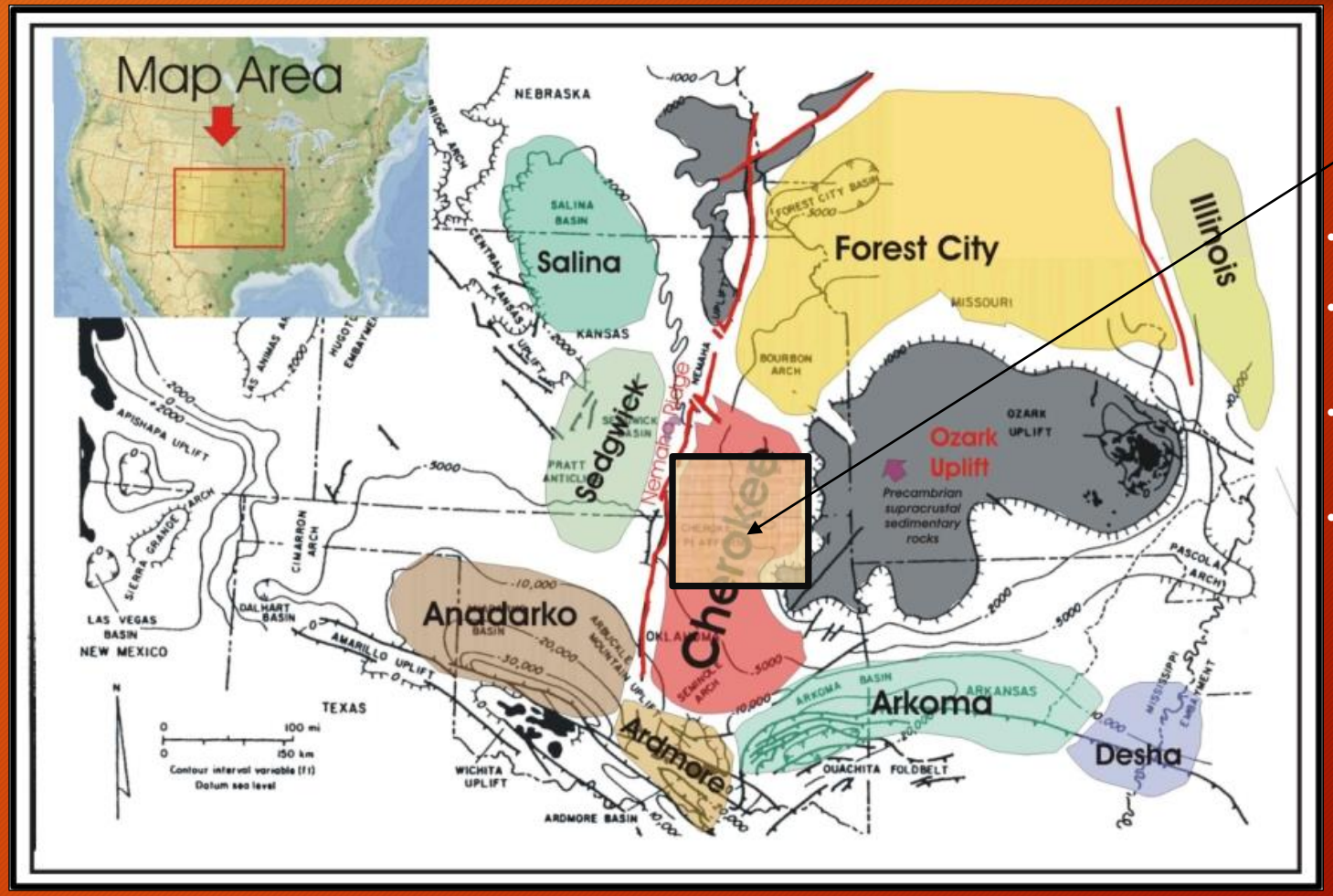
THE ART OF DISCOVERY

Abstract

The Cherokee Basin produces gas from the Desmoinesian and Atoka age Cherokee Formation coals and carbonaceous mudstones at less than 2,000 feet. From 1990 to 2009 the Cherokee underwent an active exploitation of the coals and carbonaceous shales in the Cherokee Basin peaking at over 1,000 wells per year. Exploitation ceased with the collapse of gas prices in 2008 to 2009. Several different hydraulic stimulation methods were used as well as techniques designed to specifically to stimulate individual or multiple seams. The majority of the wells have over ten years of production and allows for analysis of the effectiveness of the various stimulation methods, individual versus multiple seam and by Operator. The result indicates that cross-link gel was as effective as slick water, stimulating individual zones was significantly more effective than stimulating several zones with the same fracture stimulation. Production from wells where two or more zones were fractured stimulated had very steep decline rates whereas those wells where each stimulation stimulated a specific coal or carbonaceous shale were more productive. Several other trends were also identified that will be discussed. While gas prices remain low this analysis allows a re-evaluation of where opportunities are within the existing wellbores.

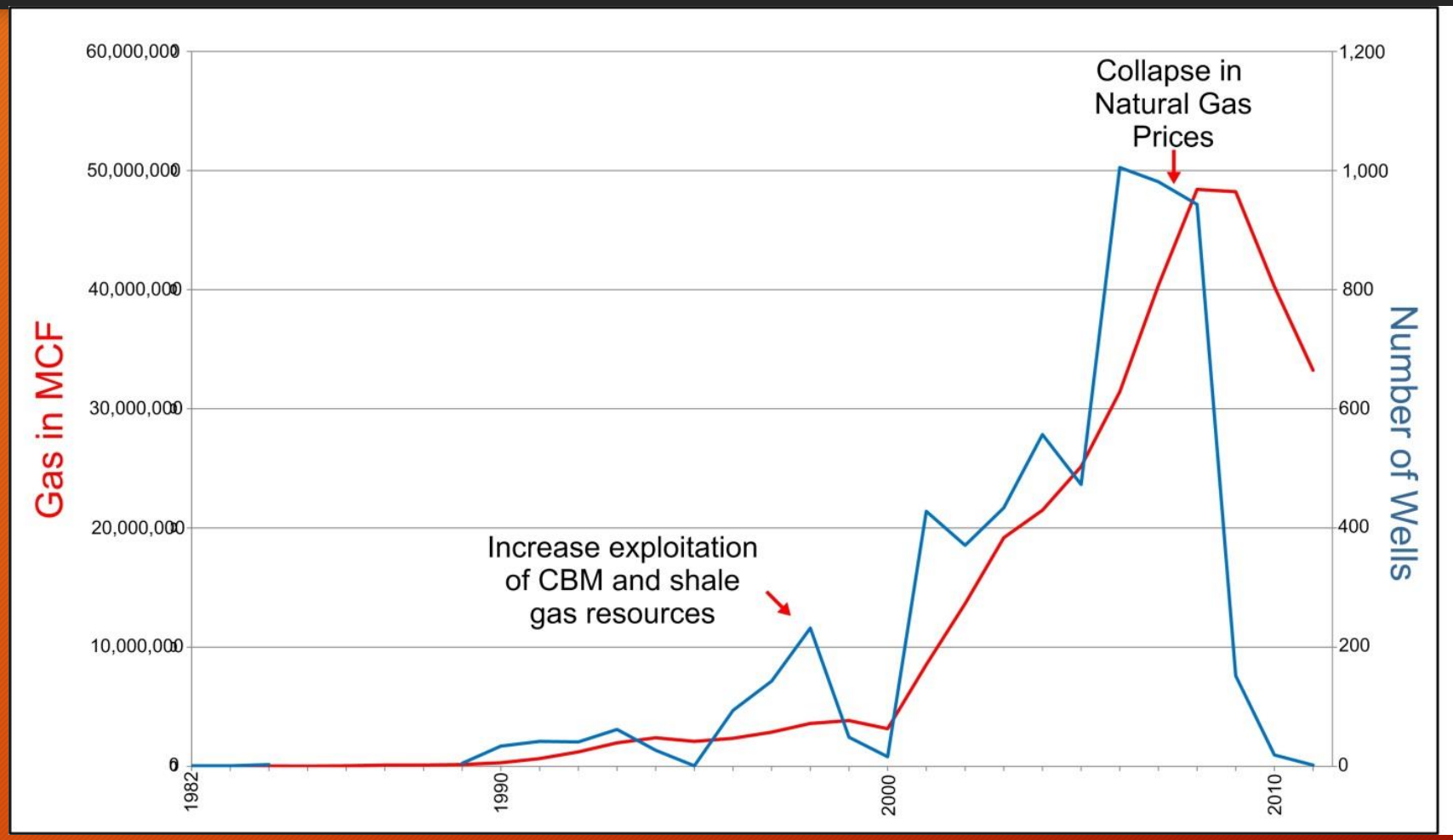
Location of Cherokee Basin



Cherokee Basin

- Shallow intercratonic basin;
- Potential 6 TCF in gas according to the USGS;
- Oil production from 150 to 3,800 feet;
- Gas production from 150 to 2,400 feet.

Gas Production to 2012



The Cherokee Basin was first exploited for unconventional reservoirs in the 1920s from Tulsa to Kansas City;

99% of the wells are vertical;

Extensive gas gathering and pipeline system.

Stratigraphic Column

Carbonaceous Shale

Excello

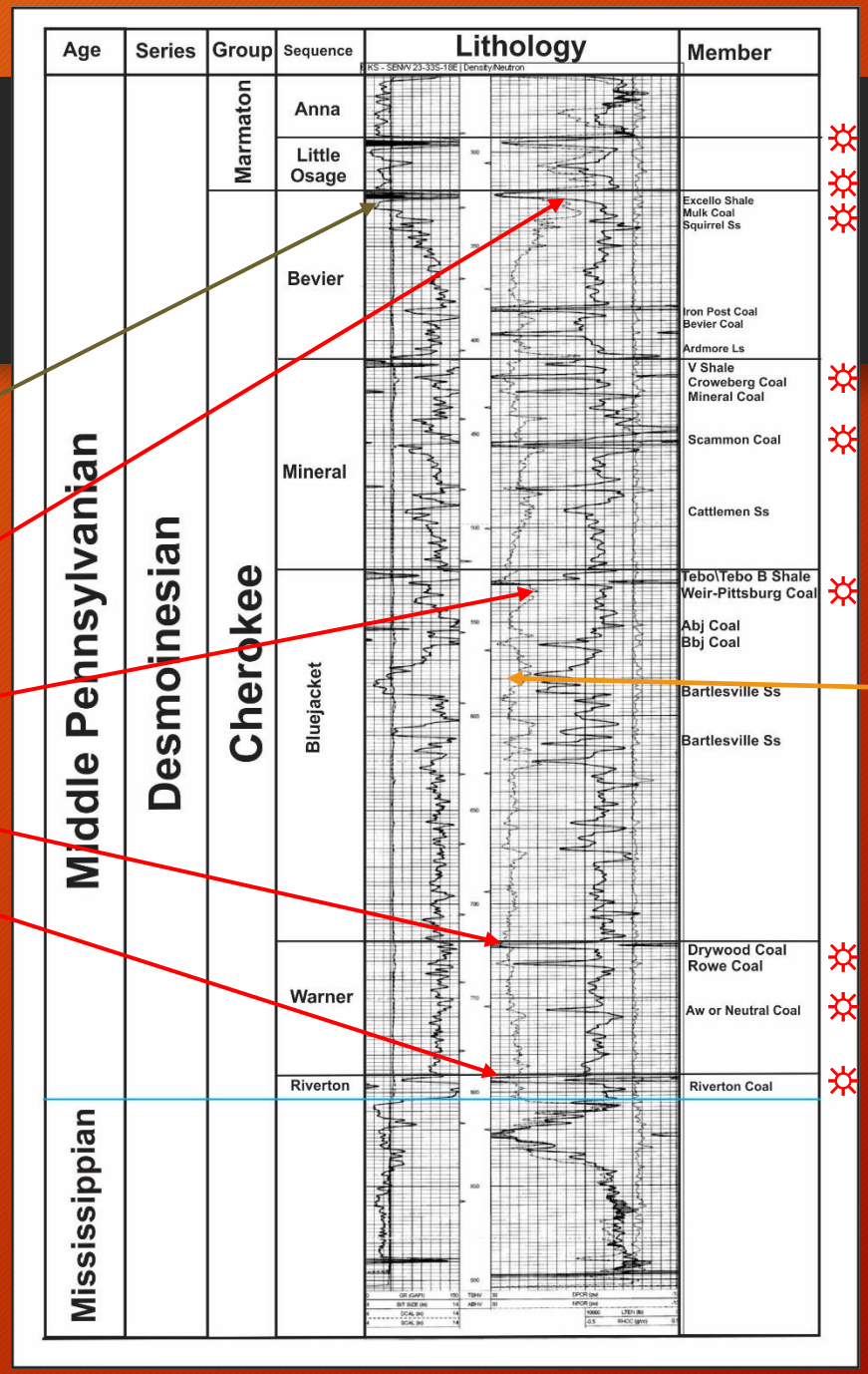
Coals

Mulky

Weir-Pittsburg

Rowe

Riverton



Bartlesville Sandstone – main oil pay zone

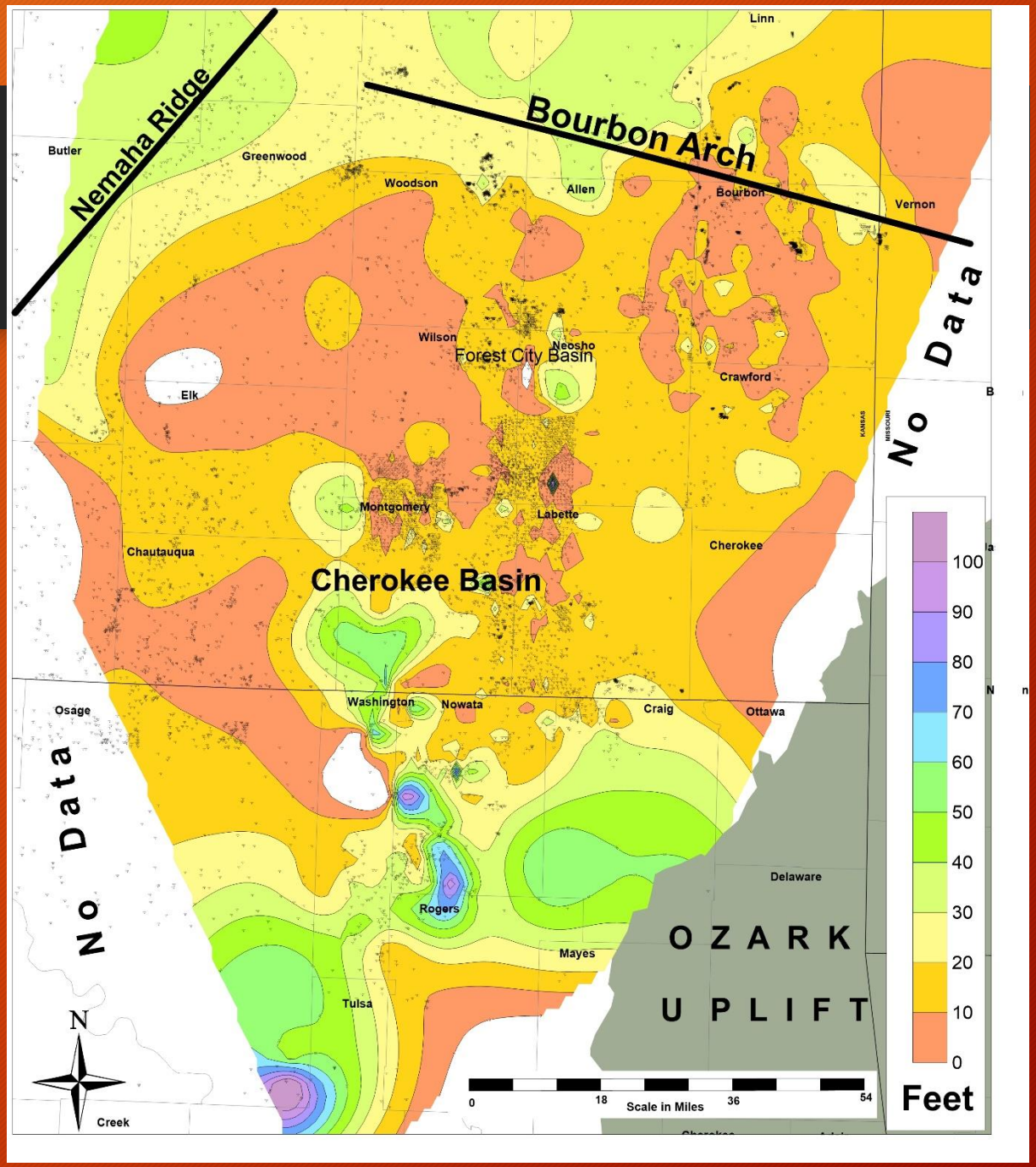
Coal and Carbonaceous Mudstones

Coal reservoir characteristics
- Thin 1 to 2 feet thick;
- High Volatile B to Medium Volatile;
- Poor vitrinite content: 65% to 85%;
- Friable;
- Poorly cleated;
- Bright to dull;
- Laminated;
- High Inertinite and Fusinite;
- High Ash;
- High sulfur;
- No de-watering.

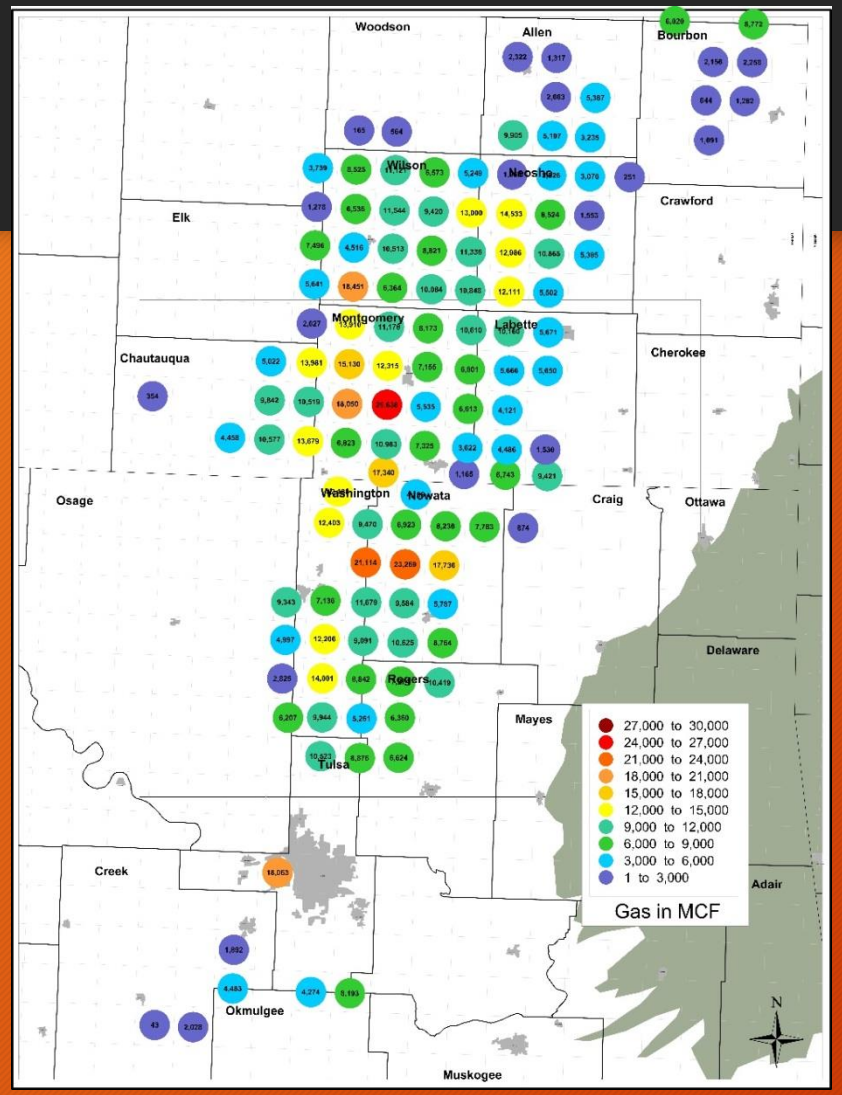
Carbonaceous Mudstones reservoir characteristics
- Thin 1 to 10 feet thick;
- R_o 0.45 to 0.76;
- Marine to terrestrial;
- Quartz and carbonate <50% except Excello Shale;
- Laminated;
- No de-watering.

Basin characteristics
- Underpressured, 0.34 gradient;
- Depth of burial < 6,000 feet;
- Maturation of coals and carbonaceous mudstones related to thin Pre-Pennsylvanian Paleozoic cover;
- Migrating low temeperature hydrothermal fluids.

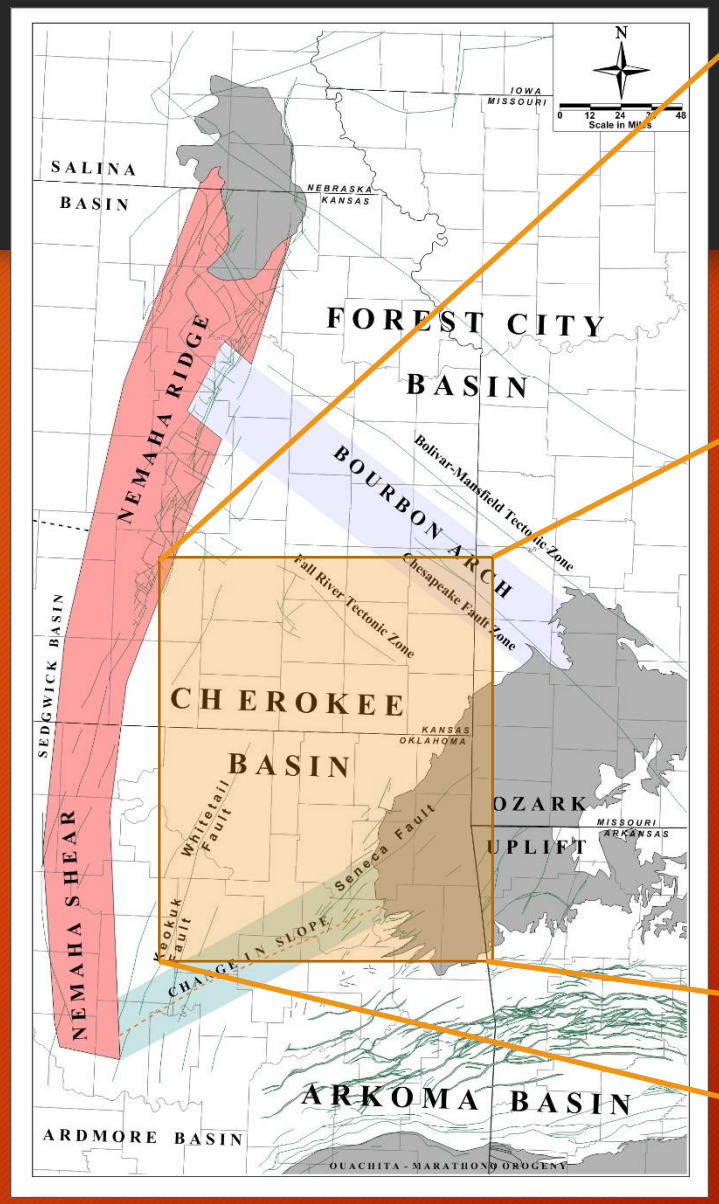
Map of the Riverton Interval



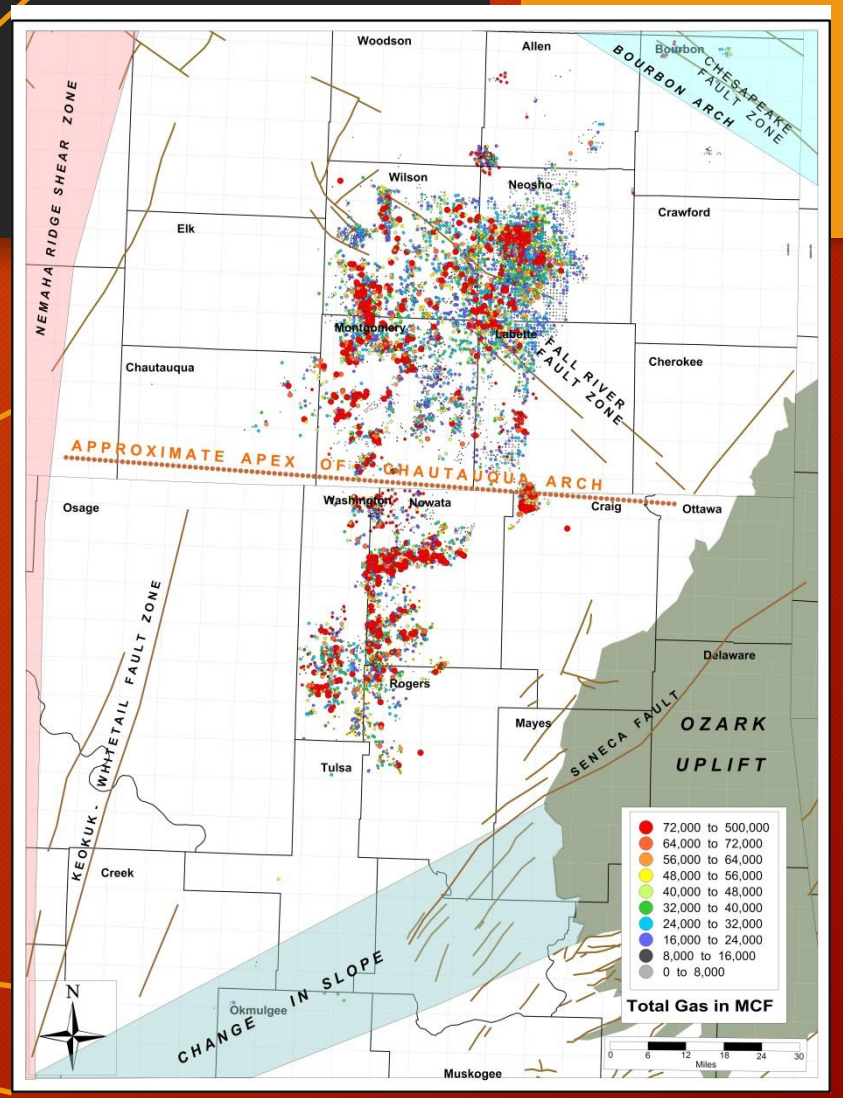
Cumulative Production up to 2011



Gas Production by township fpr 2nd, 3rd and 4th years.

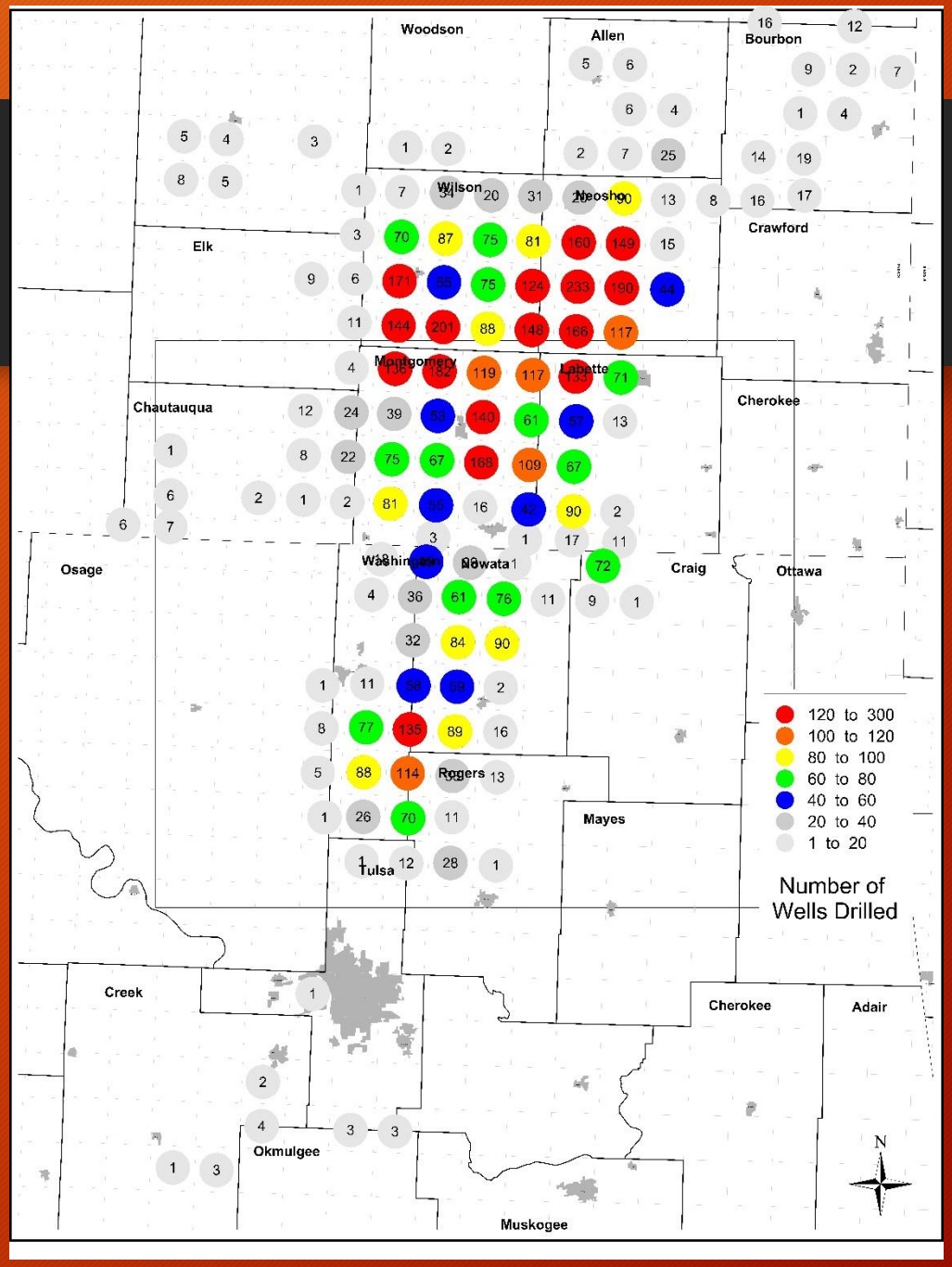


Tedesco, 2014

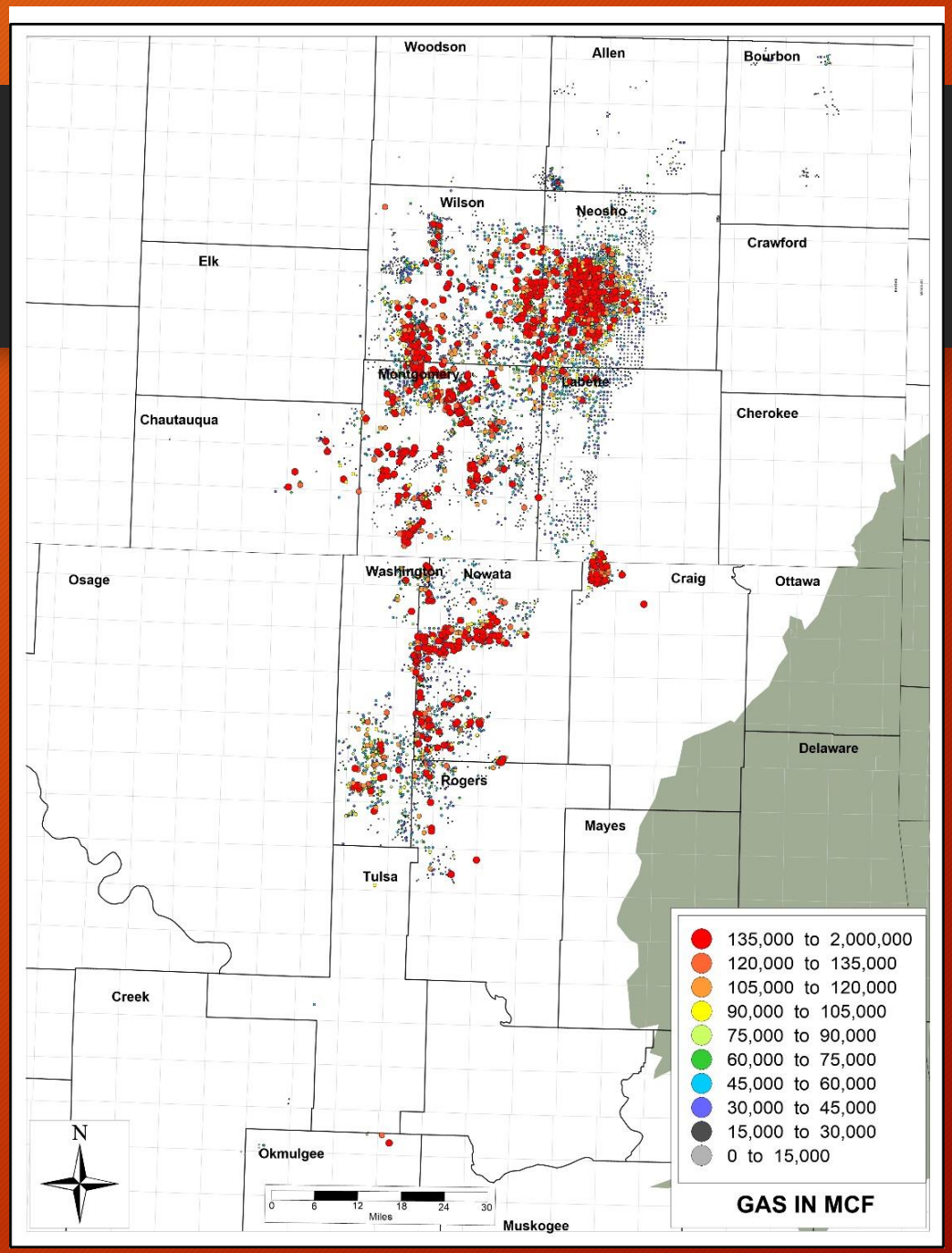


Gas production by well for 2nd, 3rd and 4th years.

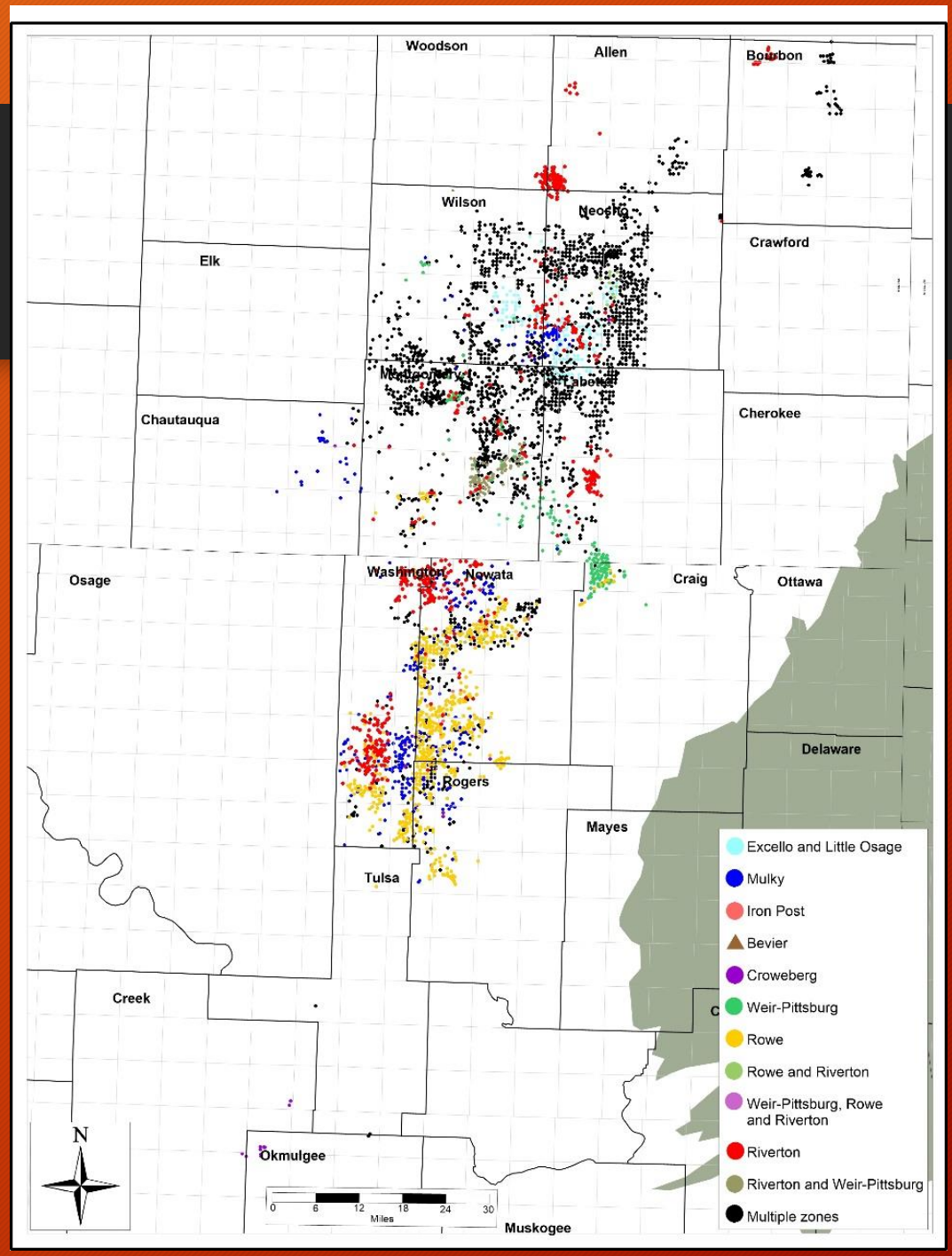
Number of Wells Per Township



Total Gas Production in MCF per Well

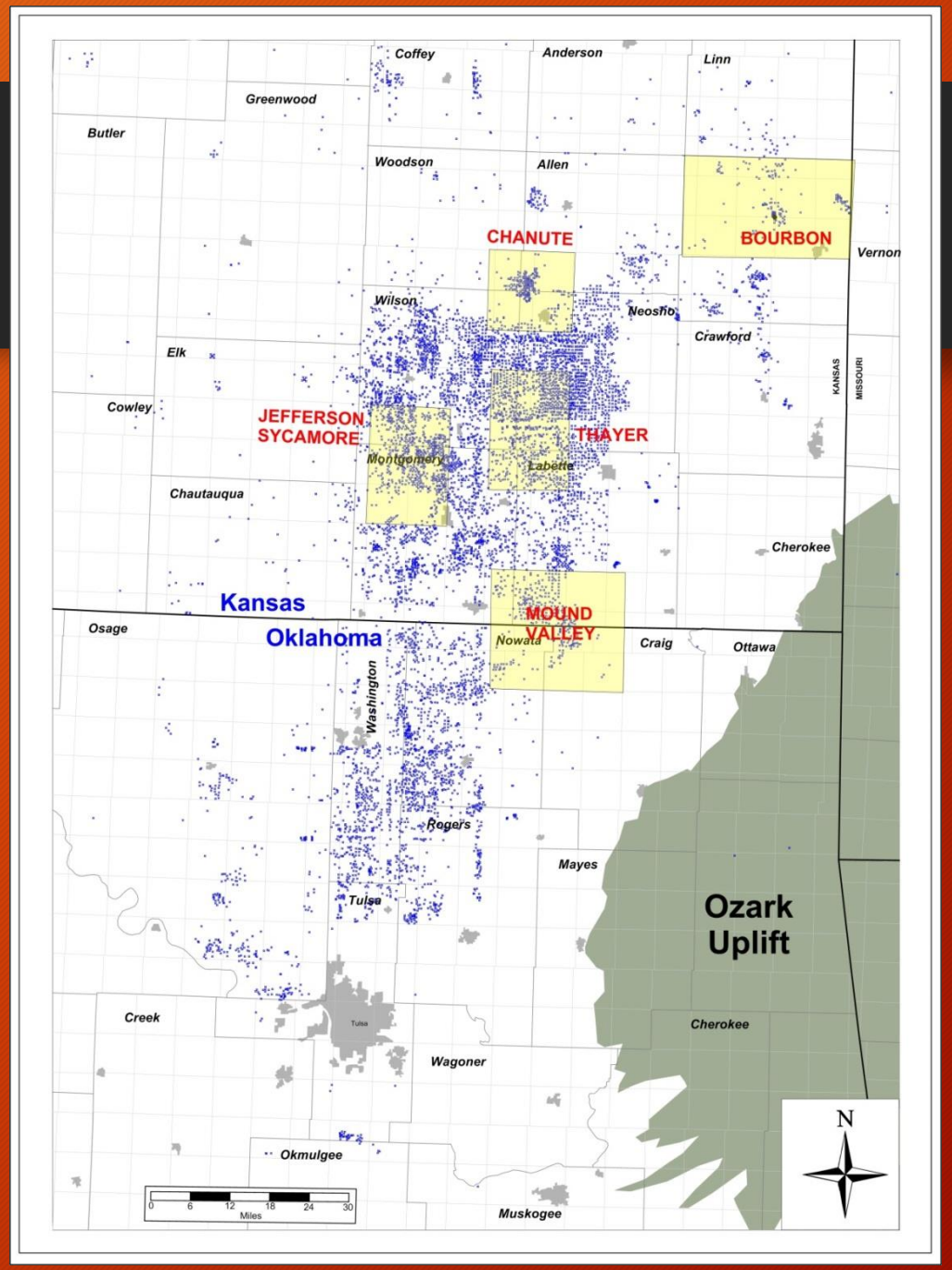


Pay Zone By Well

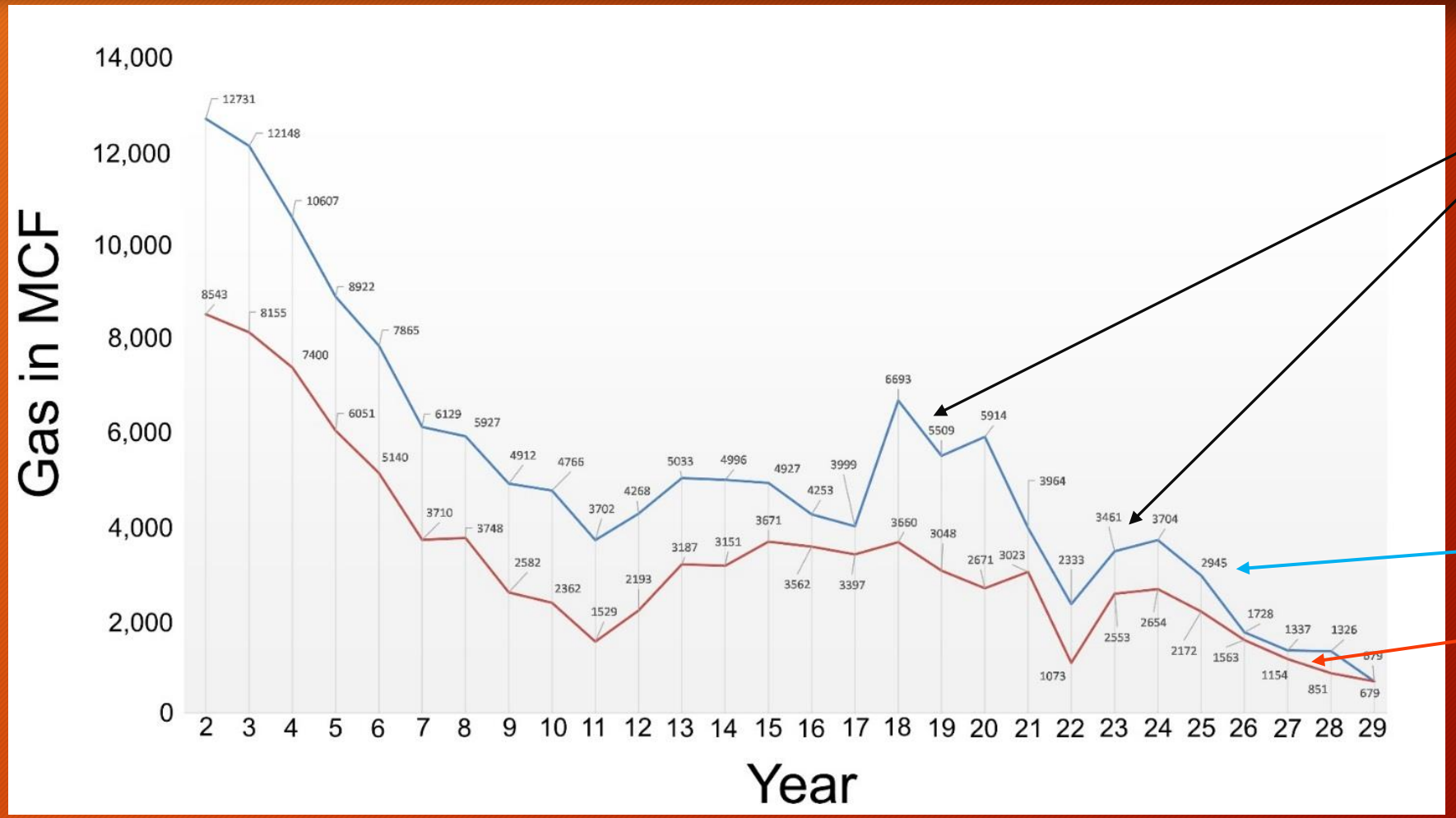


Location of Study Areas

Blue Dots are CBM wells



Average and median production for the basin based from 1990 to 2011

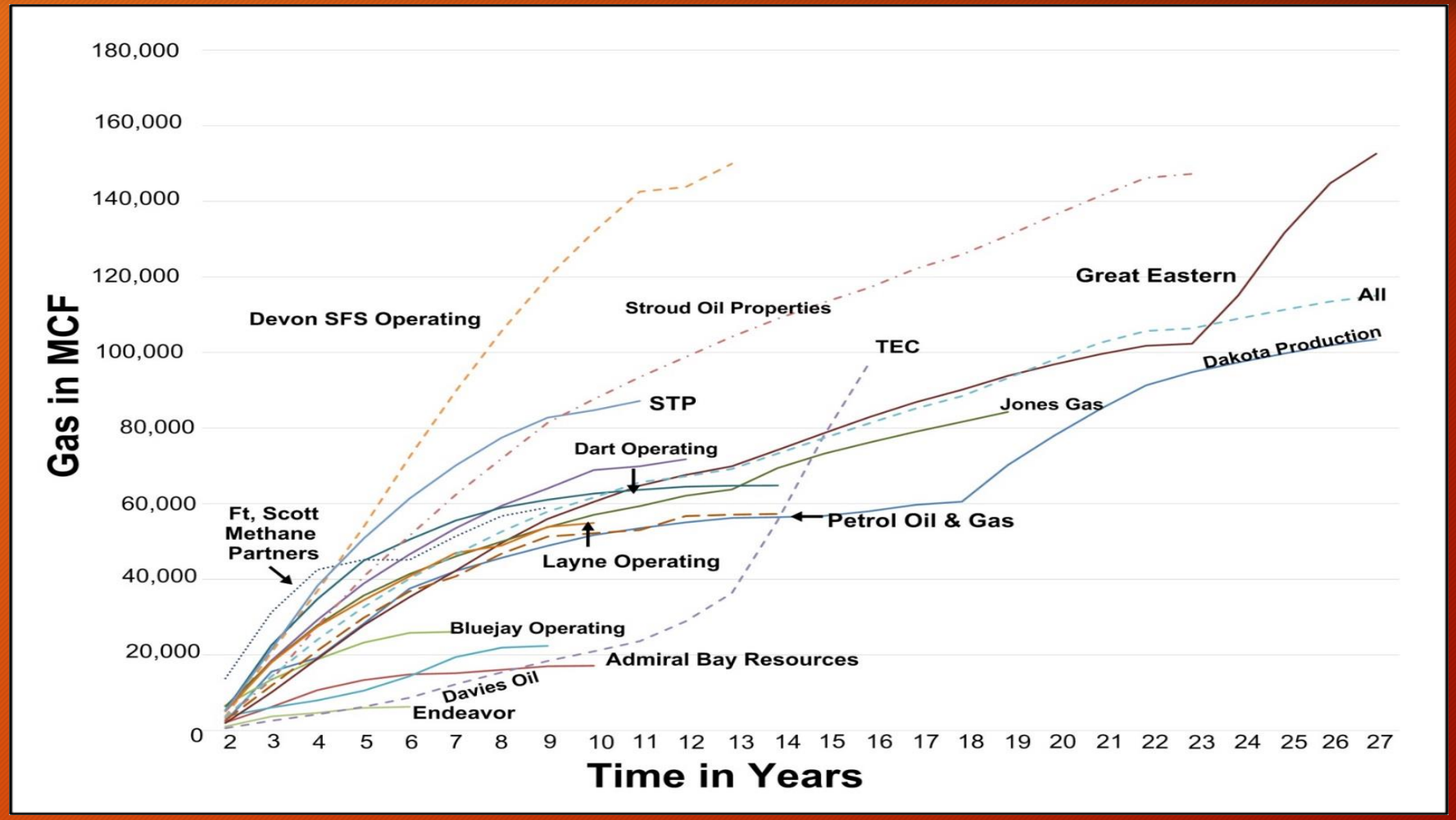


Re-fracture stimulation or new zones open

Average

Median

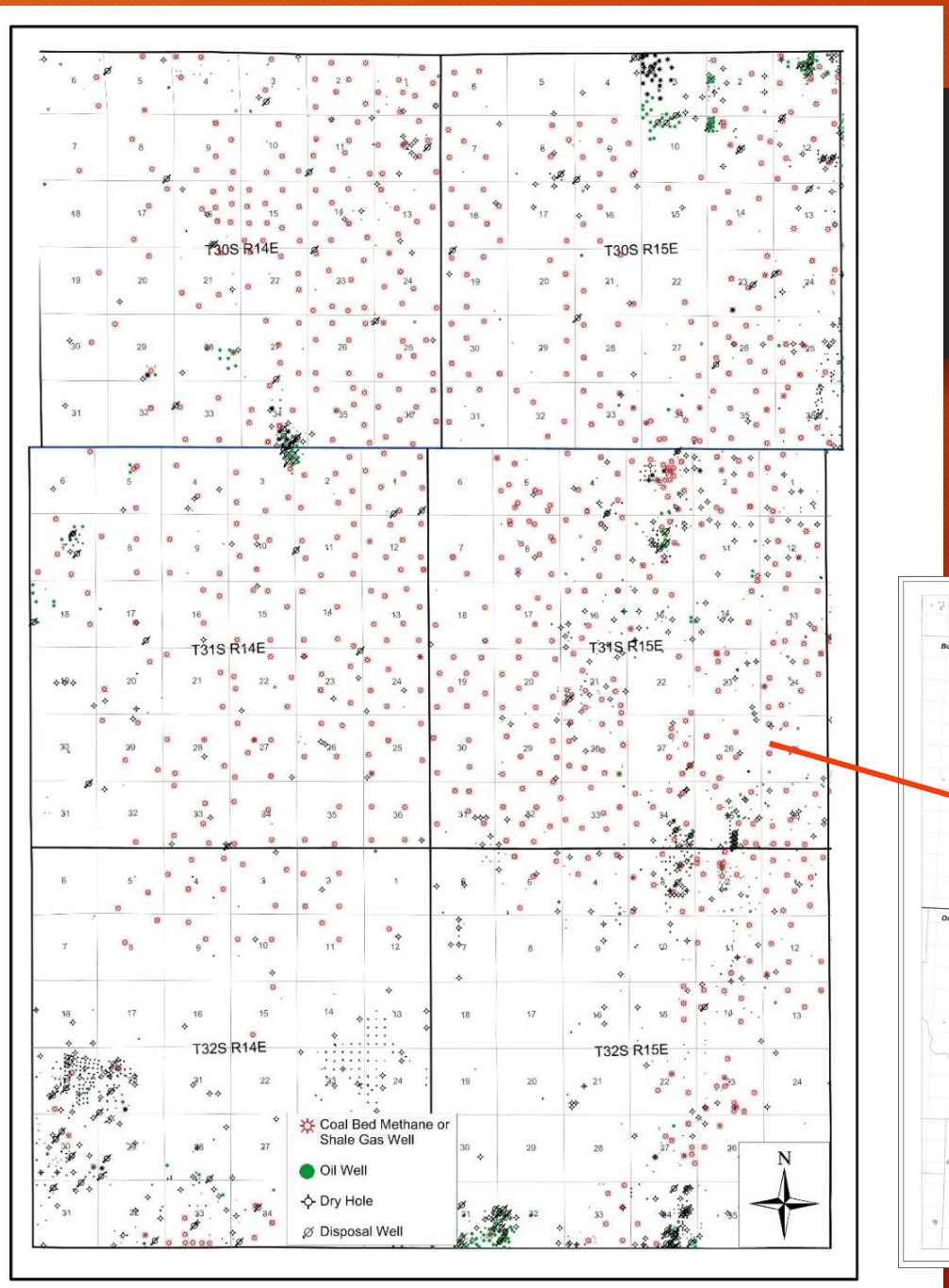
Production Curves (Logarithmic) by year for individual operators

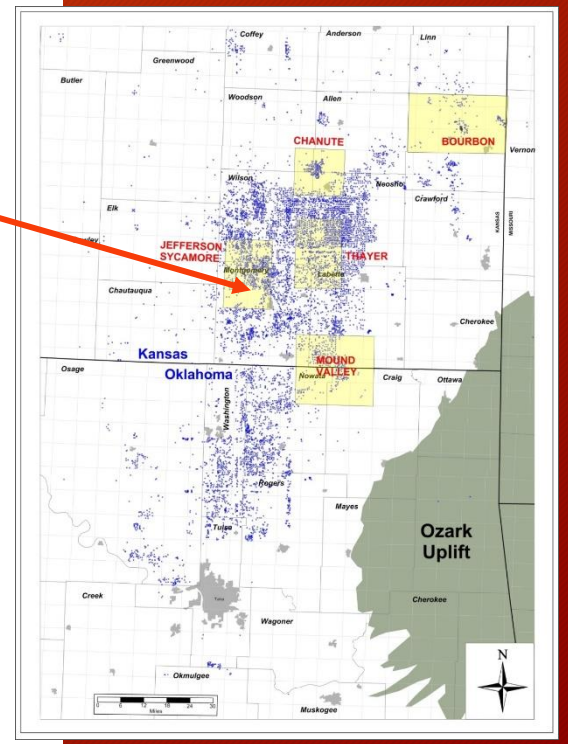


Jefferson-Sycamore Study Area

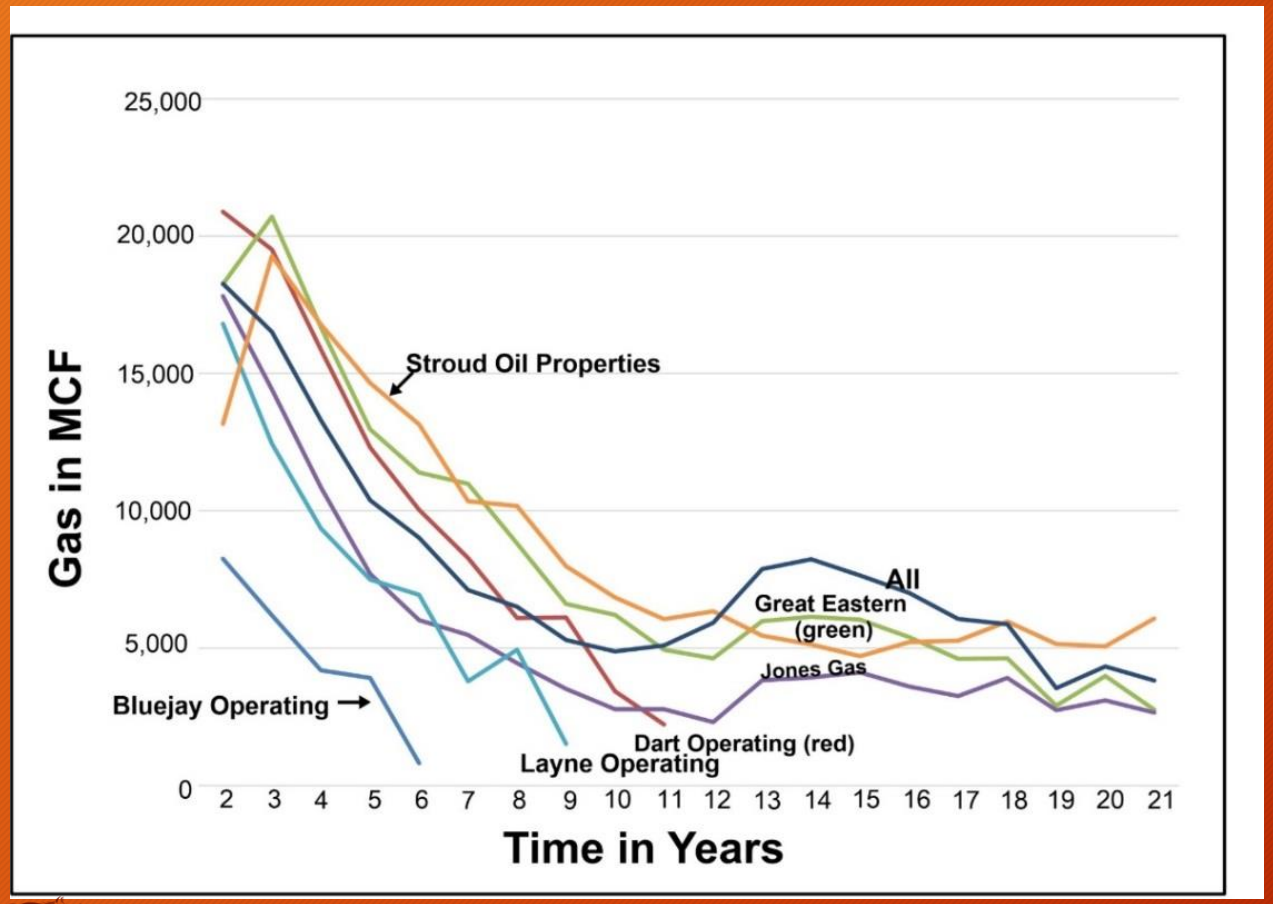
Operators

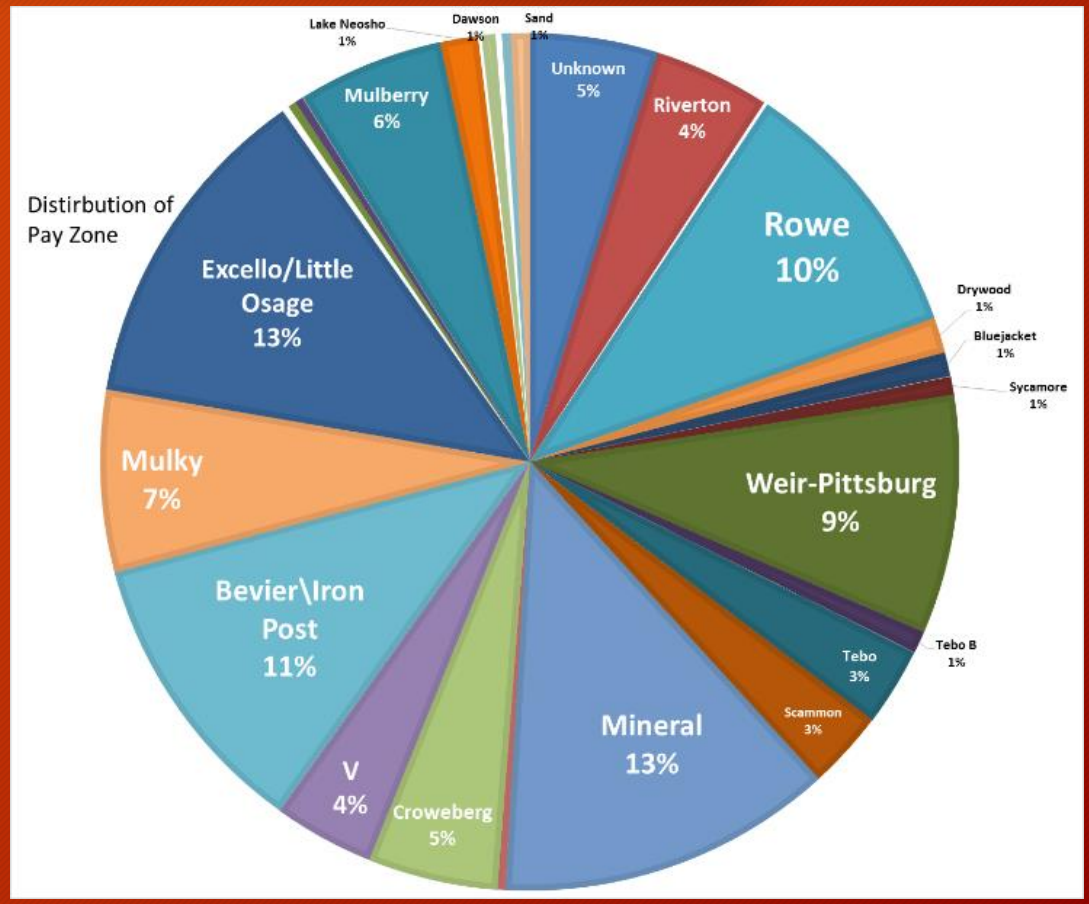
- Bluejay Operating
- Stroud Oil Properties
- Great Eastern
- Jones Gas
- Dart Operating
- Layne Operating



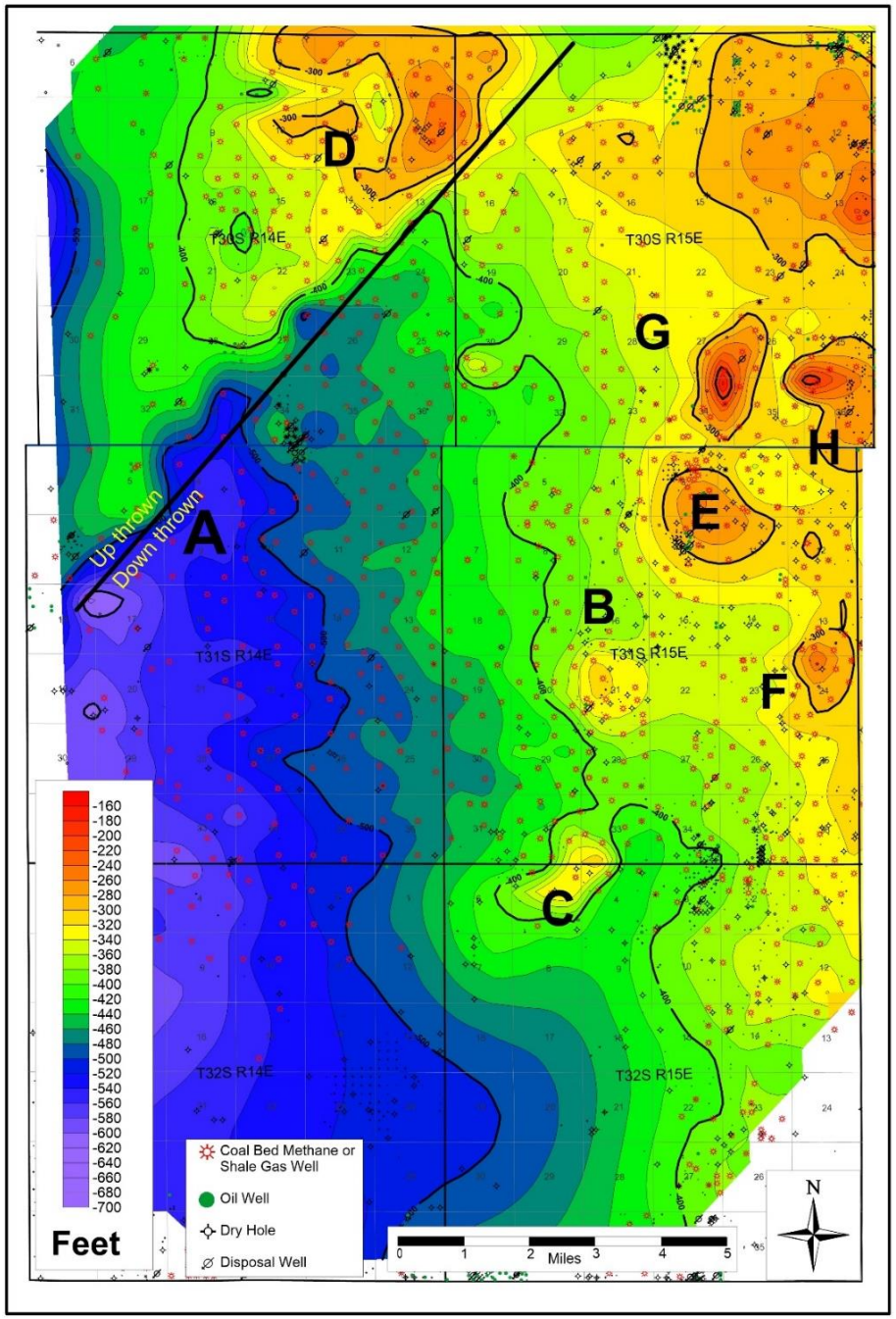


Decline Curve and Pay Distribution for the Jefferson-Sycamore Study Area

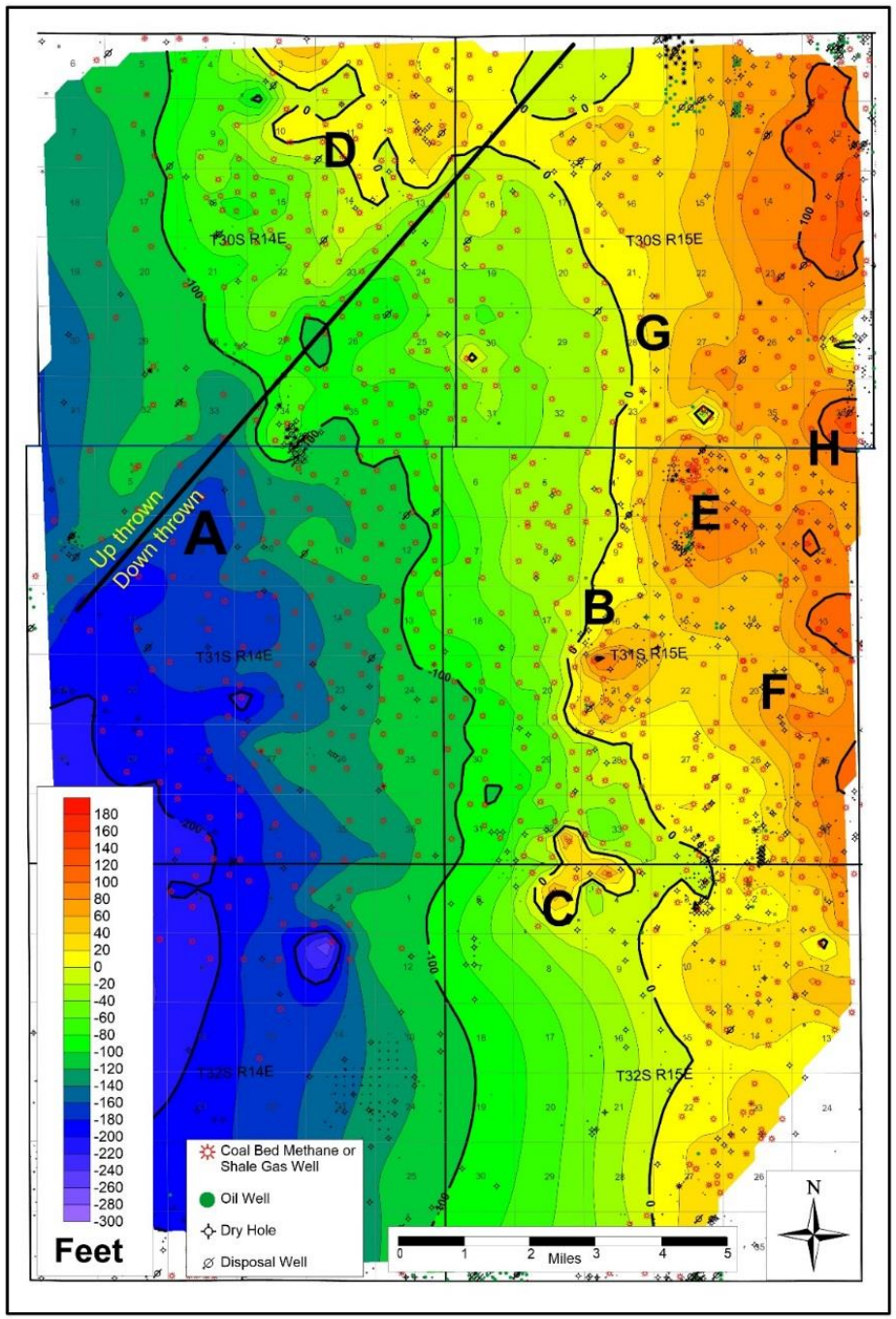




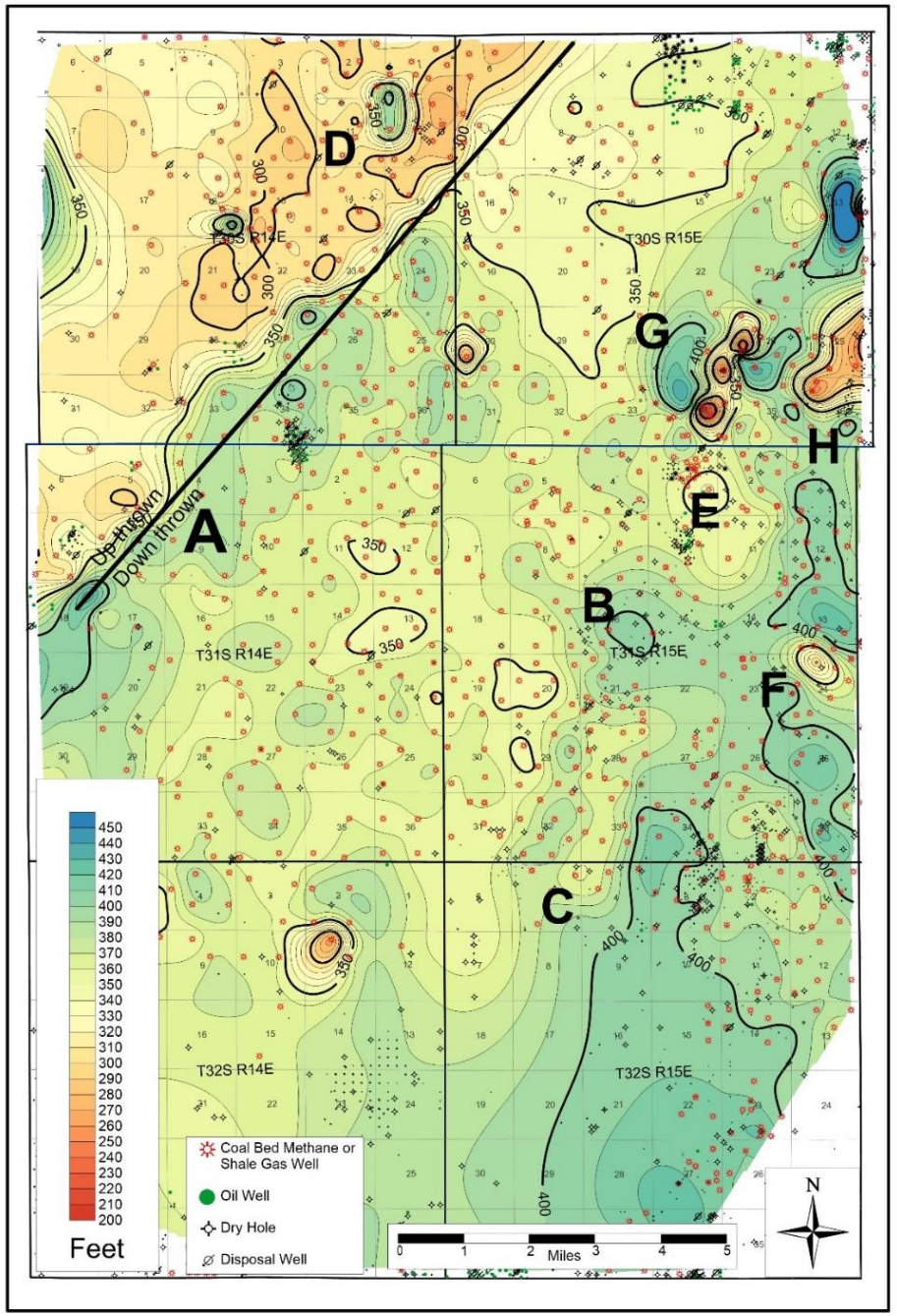
Structure on top of the Mississippian for the Jefferson-Sycamore Study Area



Structure on top of the Cherokee Group for the Jefferson-Sycamore Study Area

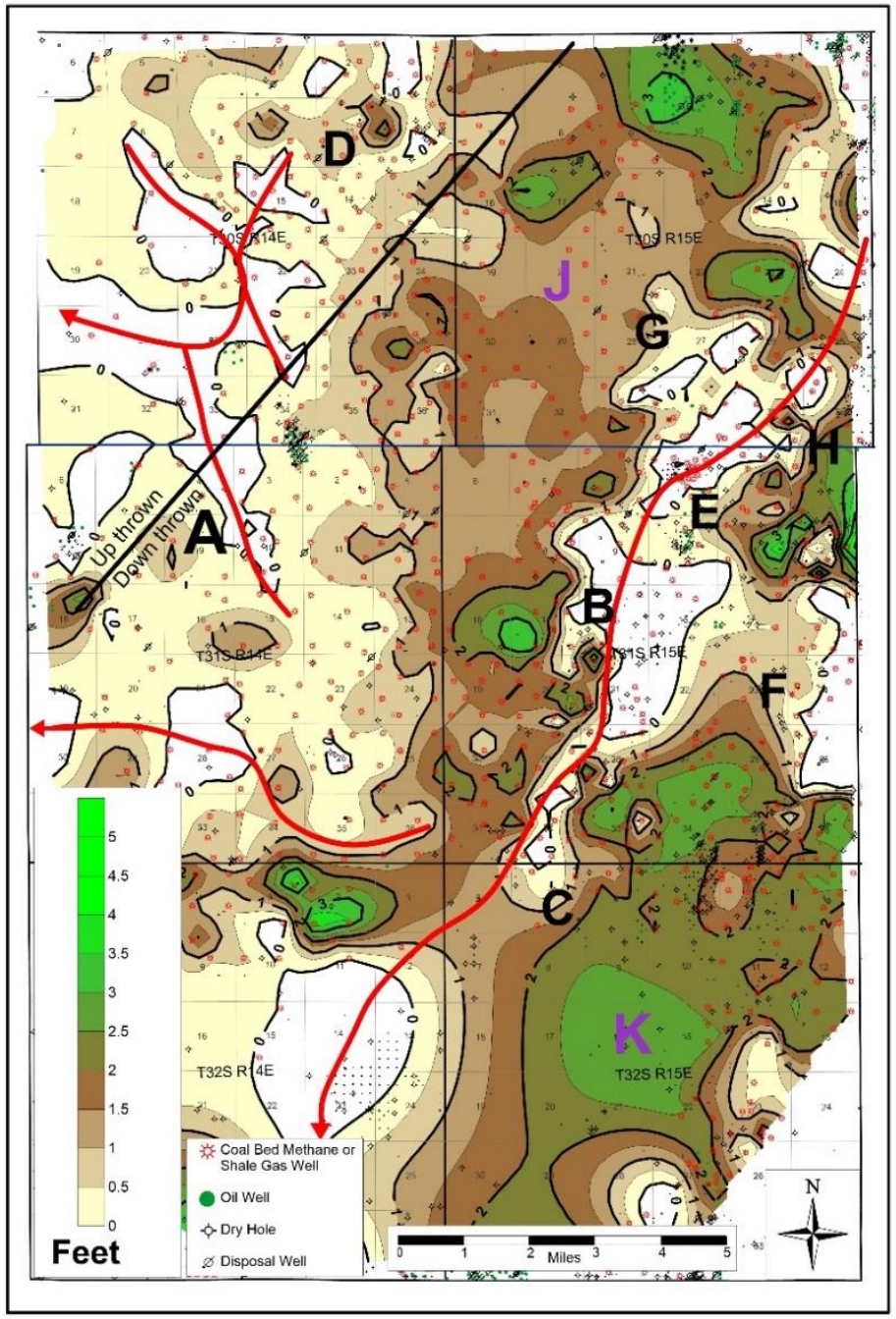


Isopach of the Cherokee Group for the Jefferson-Sycamore Study Area



Isopach of the Riverton Coal for the Jefferson-Sycamore Study Area

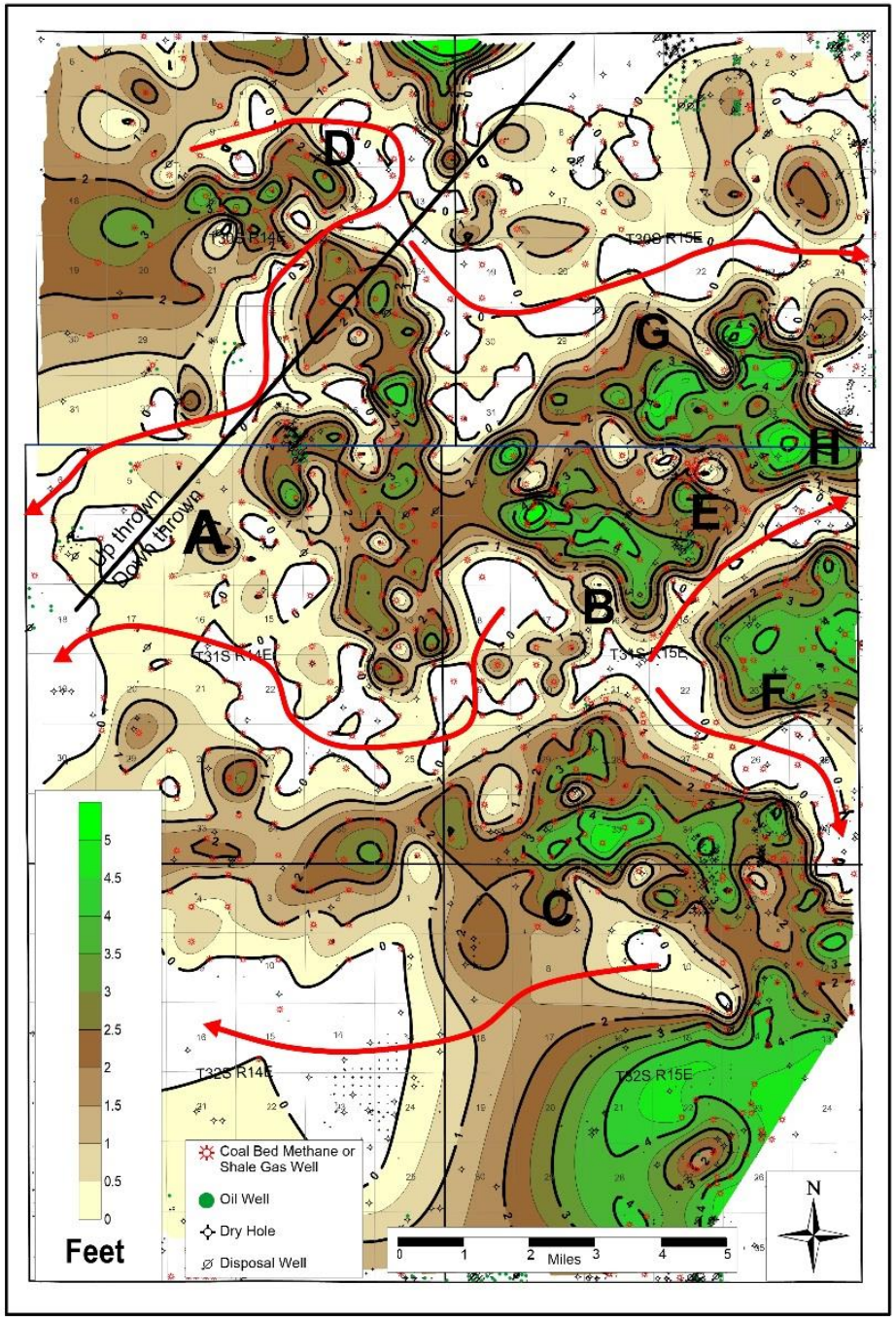
Red arrows and lines represent areas of water flow andf no coal development. In some cases they could be areas that were conducive to swamp development.



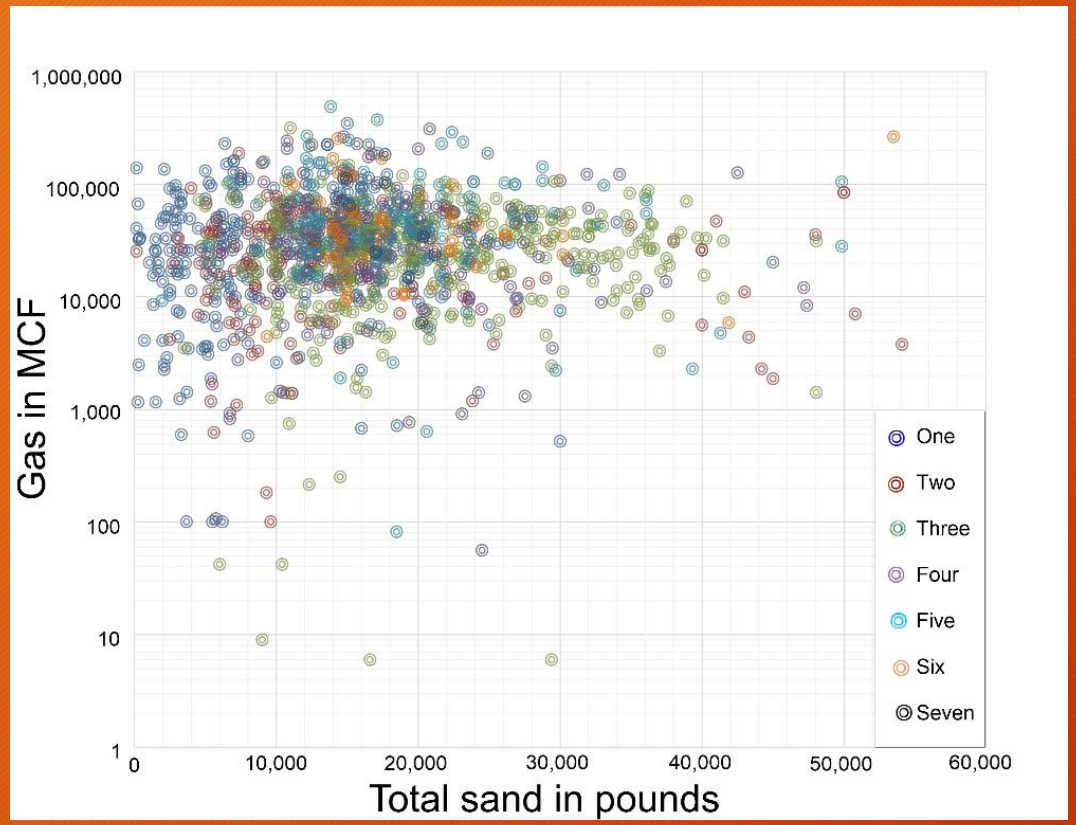
Isopach of the Weir-Pittsburg Coal for the Jefferson-Sycamore Study Area

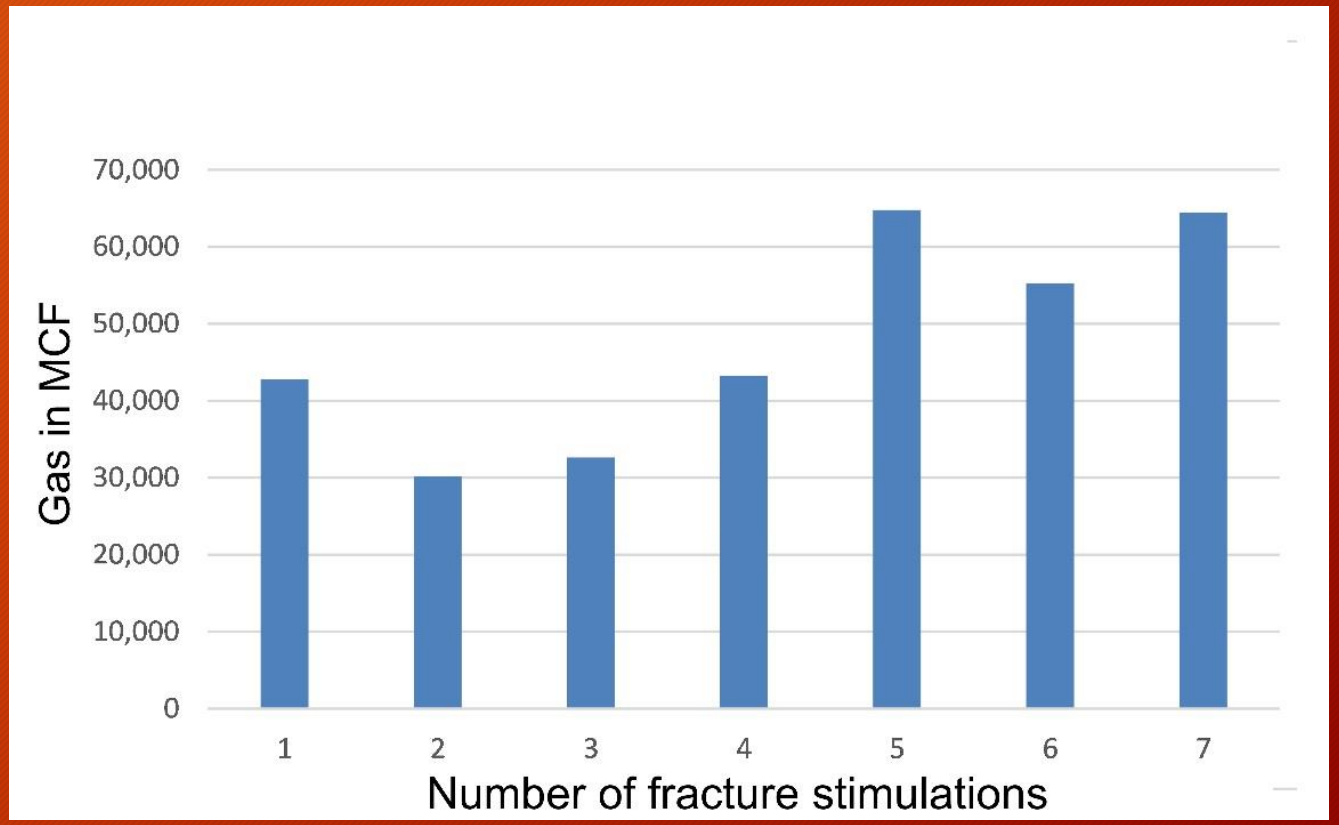
Red arrows and lines represent areas of water flow andf no coal development. In some cases they could be areas that were conducive to swamp development.

Note the lack of similarities between where the Riverton and Weir-Pittsburg coals developed.



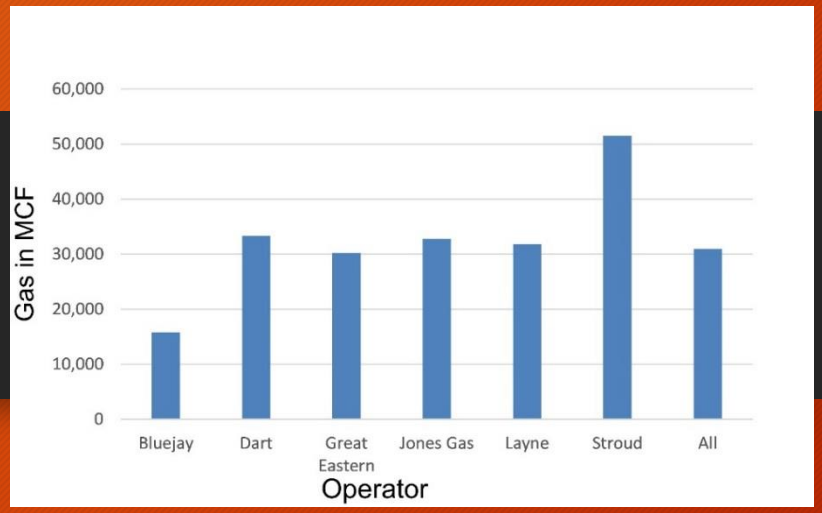
Number of fracture stimulations and Gas Production for the Jefferson Sycamore Area





Fracture Stimulation in the Jefferson-Sycamore Area

2nd, 3rd and 4th years production (Median)	Production in MCF	Total sand in pounds	Total fluid in barrels	Daily production in MCF	No. of fracture stimulations	Total pay in feet	No. of zones open	No. of wells
Slick Water								542
Average	45,991	16,778	1,183	42	4	13	5	
Median	30,962	15,300	1,223	28	4	12	5	
Cross-link								66
Average	50,629	23,957	1,080	46	2	7	2	
Median	31,178	20,750	901	28	1	5	1	
Nitrogen								19
Average	71,401	29,107	452	65	4	10	4	
Median	66,924	28,755	225	61	5	11	5	



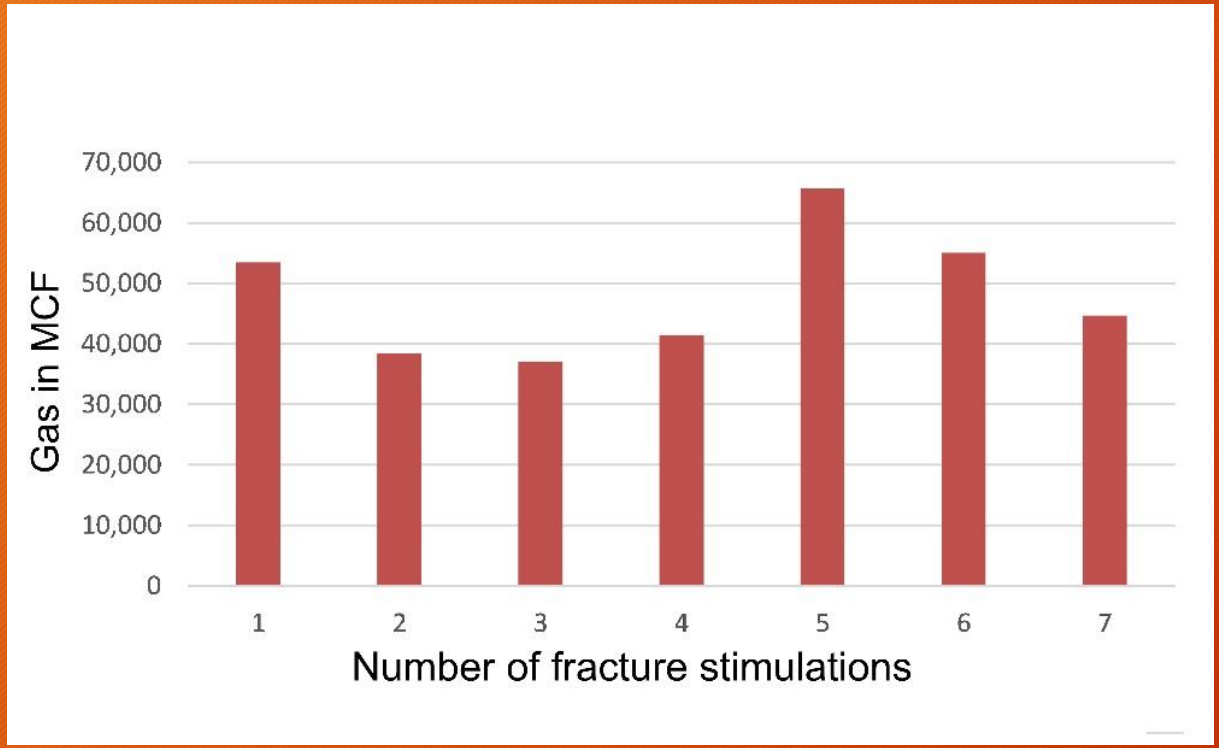
Gas production in 2nd, 3rd, & 4th for each Operator

Operator	Bluejay Operating	Dart Cherokee	Great Eastern	Jones Gas Company	Layne Operating	Stroud Oil Properties	All
No. of Wells	20	302	42	33	166	20	610
COMPONENT							
Sand in pounds	27,500	14,640	15,000	19,600	16,800	28,000	15,405
Sand per foot							
Average	1,931	1,570	2,663	2,321	962	7,288	1,703
Sand in pounds per foot	2,000	1,503	1,916	2,000	885	6,750	1,430
Fluid in barrels		1,205	639	548	1,394	473	1,175
Fluid per foot in barrels		123	85	58	74	158	94
Hydrochloric acid (HCL) in gallons		1,300	413	500	2,190	350	1,500
Total pay in feet	14	10	6	9	19	4	11
No. of fracture stimulations	3	5	6	2	3	1	4
No. of zones open	5	5	2	2	7	1	5
Cumulative production in MCF	25,482	61,229	96,068	70,205	52,915	192,122	58,848
Cumulative production 2nd, 3rd and 4th year	15,800	33,322	30,246	32,774	31,817	51,512	30,999
Median daily production 2nd, 3rd and 4th year	14	28	28	30	29	47	28

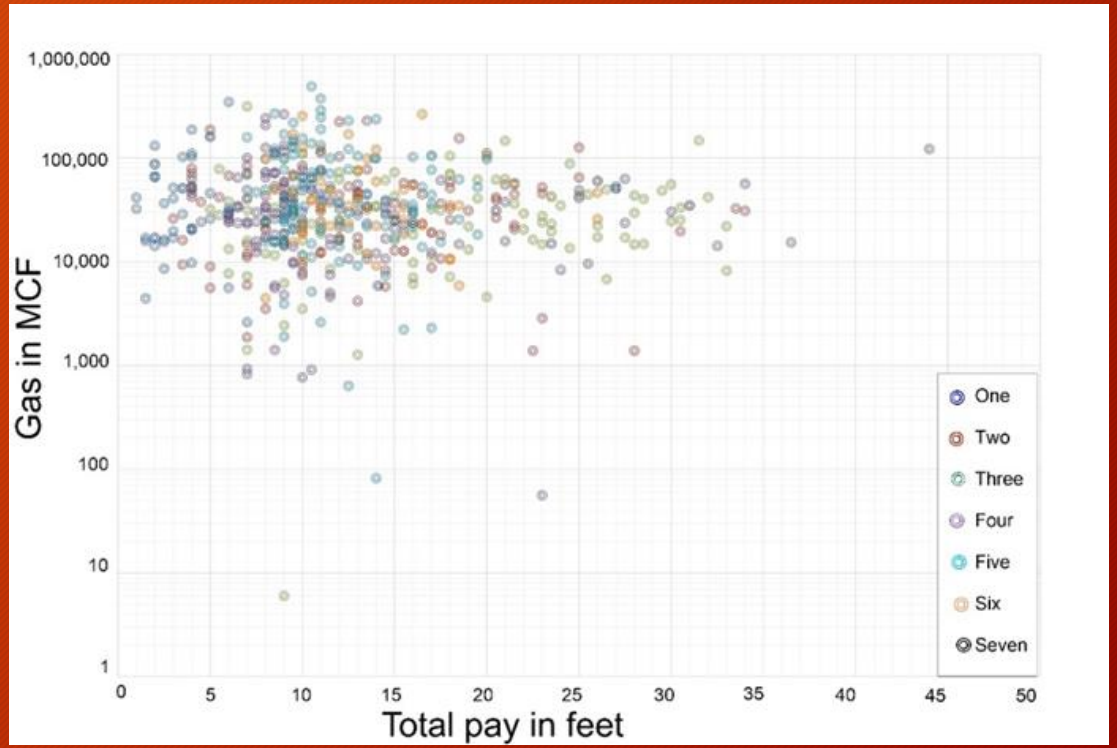
Fracture Stimulation

- Stroud – single fracture stimulation and cross-link gel
- Layne – multiple zone per each fracture stimulation
- Dart – fracture stimulate each individual zone

Total Pay Versus Gas Production in the Jefferson-Sycamore Area



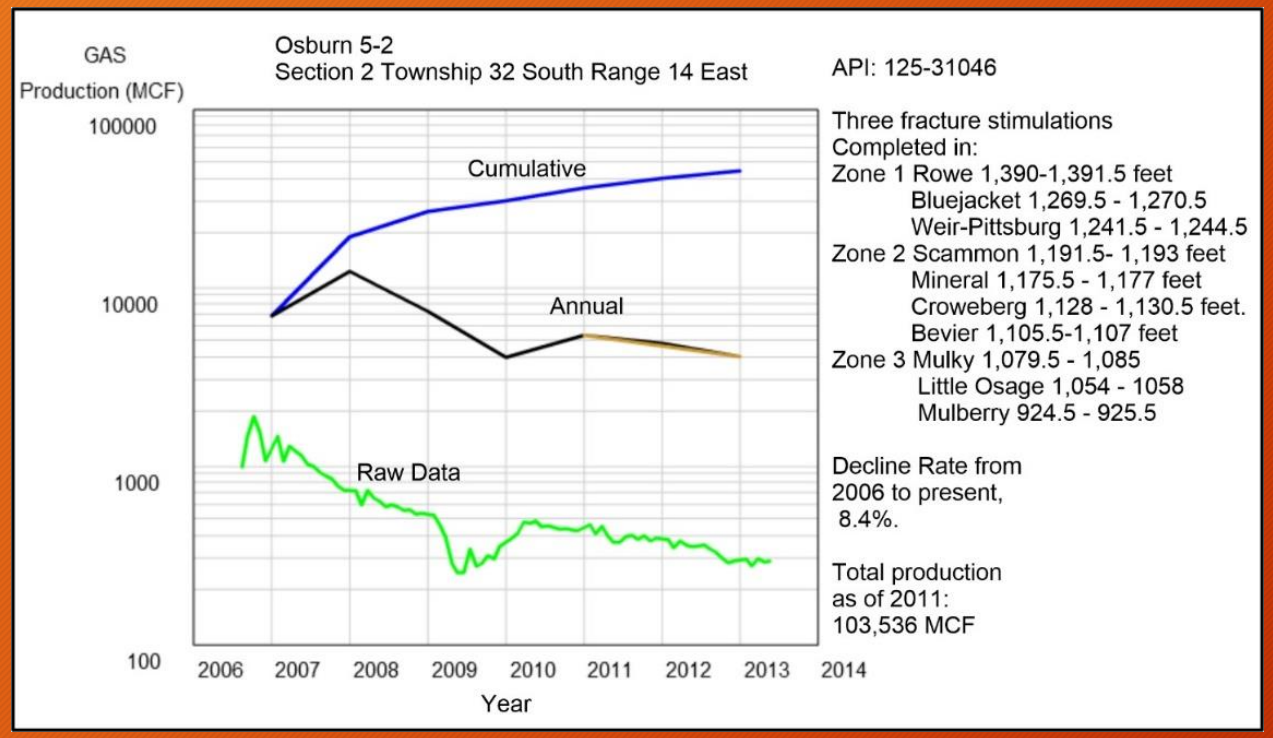
Number of fracture stimulations versus gas production in the 2nd, 3rd and 4th year

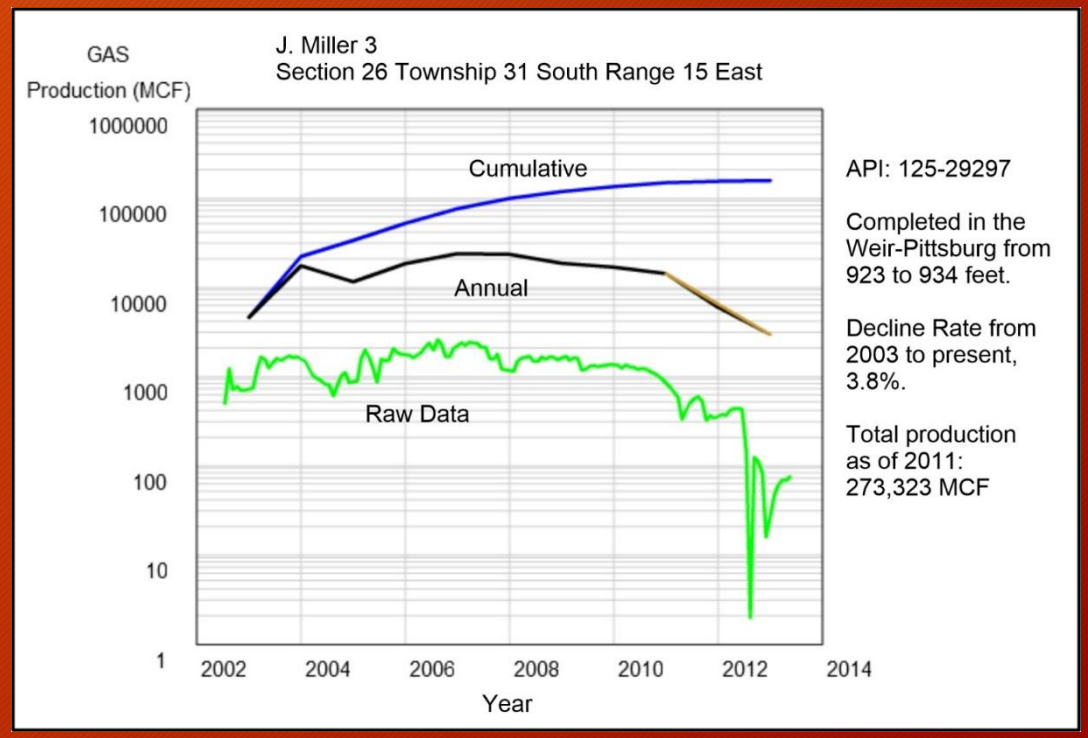


Total feet in pay versus gas production in the 2nd, 3rd and 4th year

Fracture stimulating two to four zones is detrimental to gas production when compared to one stimulation.

Two Wells: Single versus Multiple in the Jefferson-Sycamore Study Area

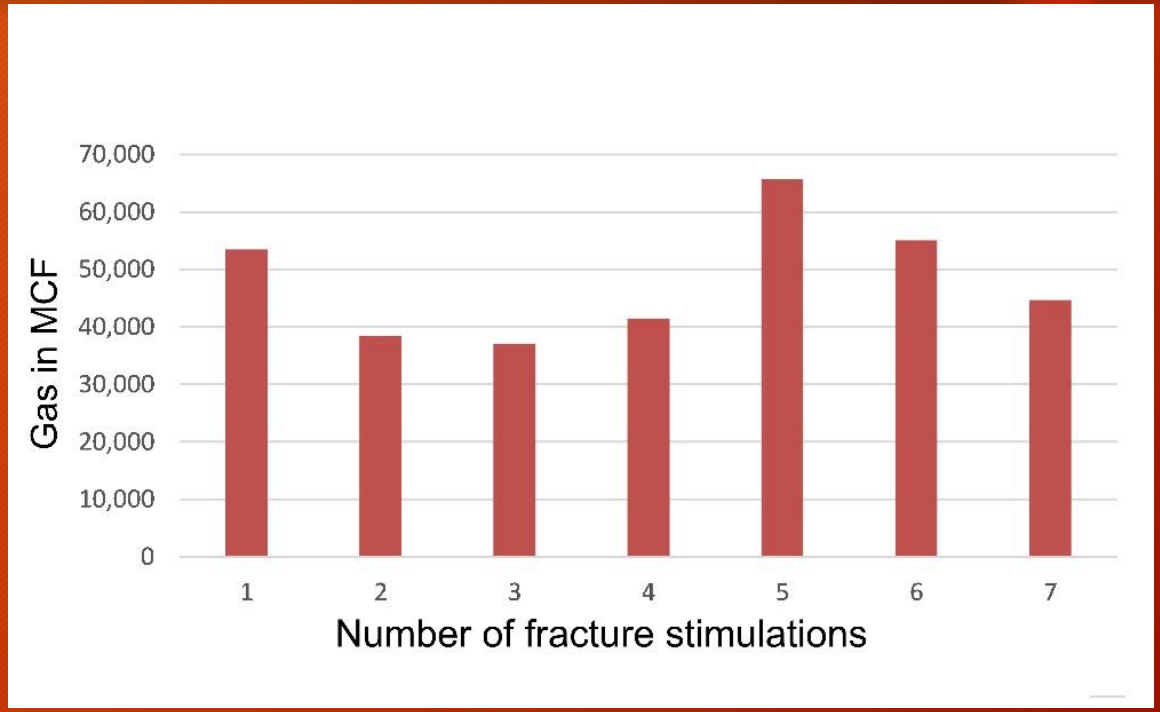




An example of how a multiple zone completion faired poorly when compared to a single zone completion

Combination of the different pays and their associated production in the Jefferson-Sycamore Study Area

Reservoir (Median)	Single Riverton coal	With Riverton coal	With Rowe - Drywood coals	With Weir-Pittsburg coal	With Marmaton - Excello - Little Osage	Without Riverton coal	Without Rowe - Drywood coals	Without Weir-Pittsburg coal	Without Excello - Little Osage	No Marmaton completions
COMPONENT										
Sand in pounds	7,531	15,123	16,402	12,400	15,810	7,500	14,970	15,300	12,400	15,500
Sand in pounds per foot	1,595	582	1,421	3,100	1,422	556	1,442	1,422	2,339	1,472
Fluid in barrels	195	1,769	1,325	307	1,263	413	662	945	1,215	389
Fluid per foot in barrels	78	68	95	102	98	138	49	95	96	91
HCL in gallons	300	74,298	1,608	250	1,500	2,400	1,100	1,500	350	1,200
Average total pay in feet	4	26	13	4	12	14	10	11	4	10
No. of fracture stimulations	1	3	4	1	4	1	3	4	1	3
No. of zones open	1	11	5	1	5	5	4	5	1	4
Cumulative production in MCF	81,002	42,613	61,138	108,003	55,339	107,306	50,326	49,802	77,798	61,046
Cumulative production 2nd, 3rd, and 4th year in MCF	31,463	22,209	34,209	41,475	30,962	45,076	26,160	28,368	31,107	29,936
Average daily production 2nd, 3rd and 4th year in MCF	29	20	31	38	28	41	24	26	28	27
No. of wells	12	134	134	49	459	553	304	333	116	361

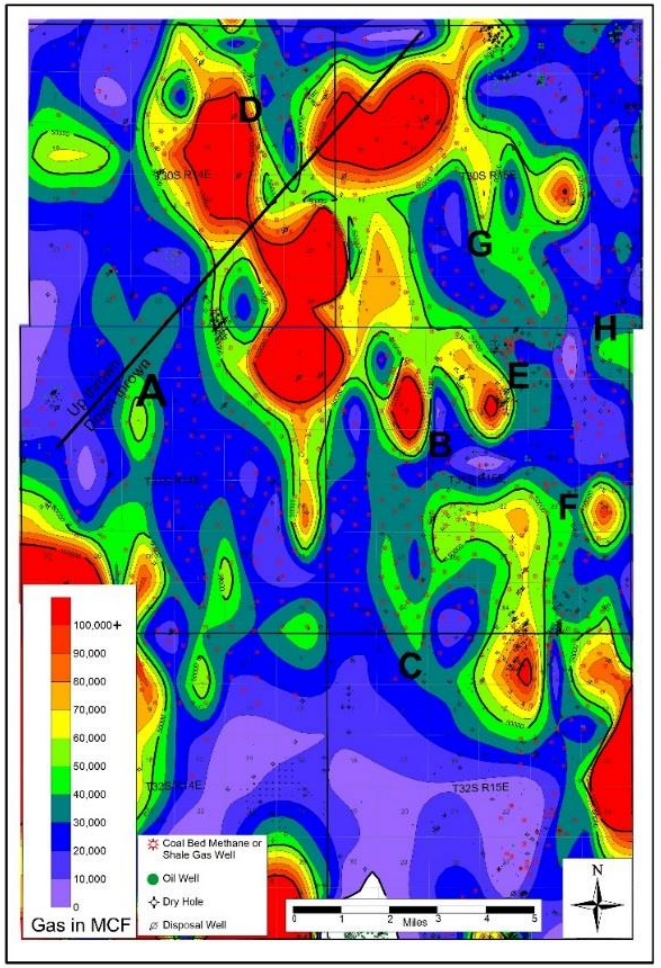


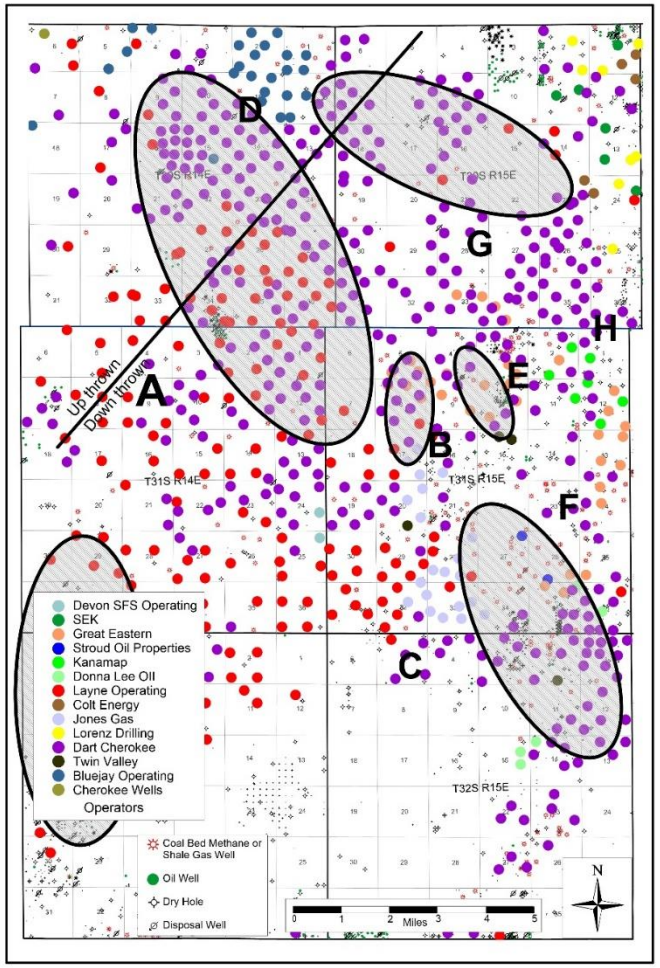
Number of fracture stimulations versus gas production in the 2nd, 3rd and 4th year

Productive Areas versus location by Operator in the Jefferson-Sycamore Study Area

Cumulative gas production up to 2011.

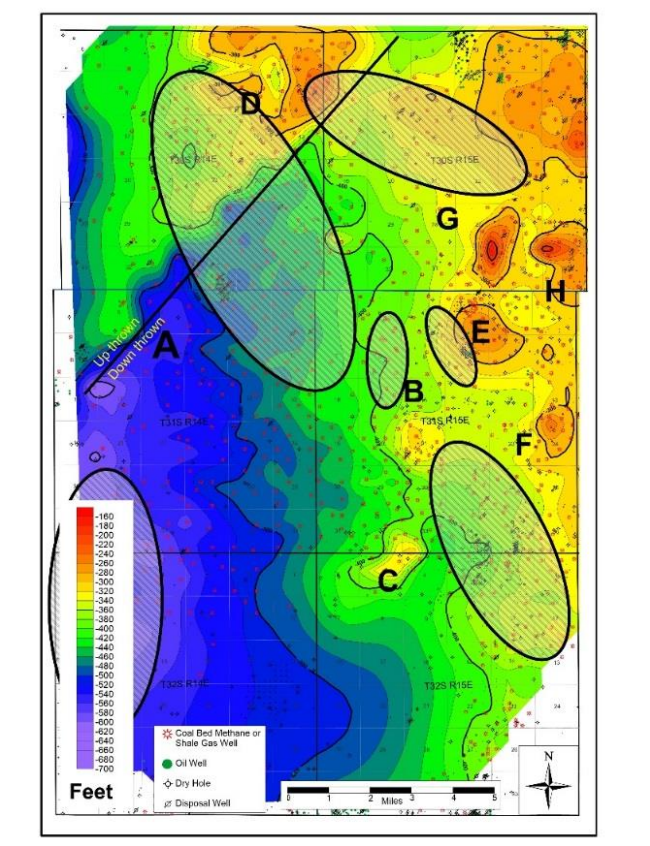
Red is best and purple is worst.



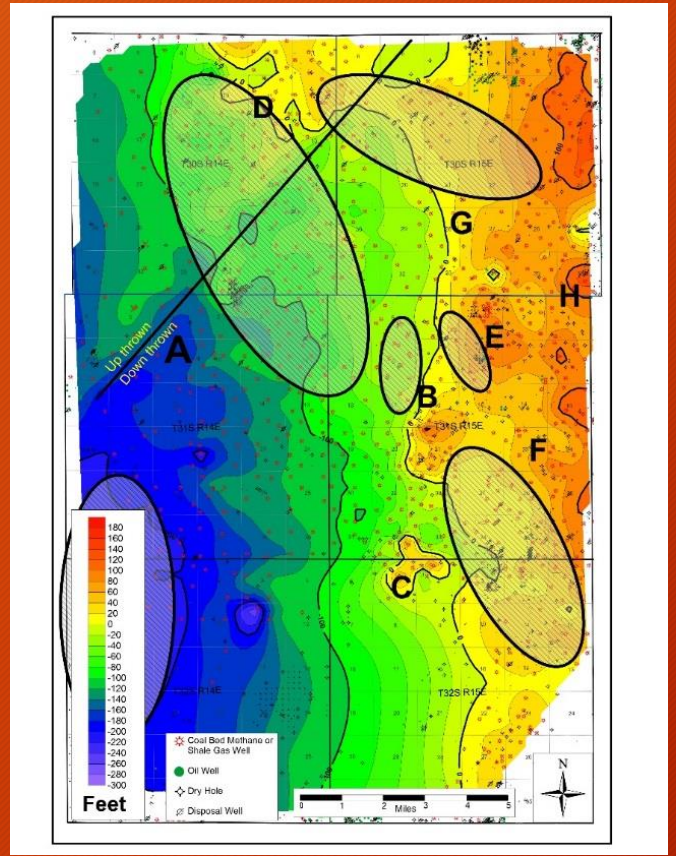


Location of the various operator in the study area (color coded wells with the best productive areas overlain on the map

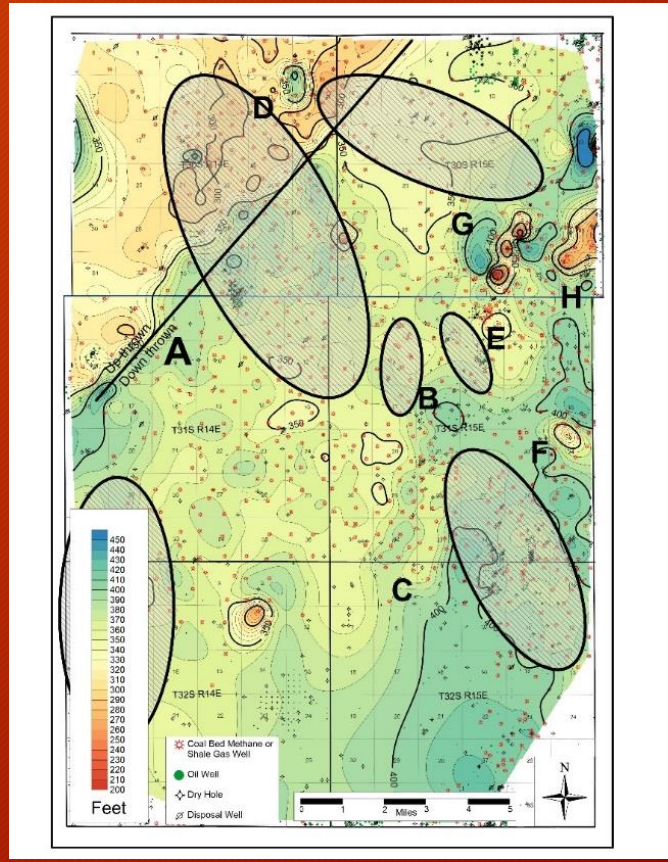
High Productive Areas in relation to structure and thickness in the Jefferson-Sycamore Study Area



Mississippian Structure

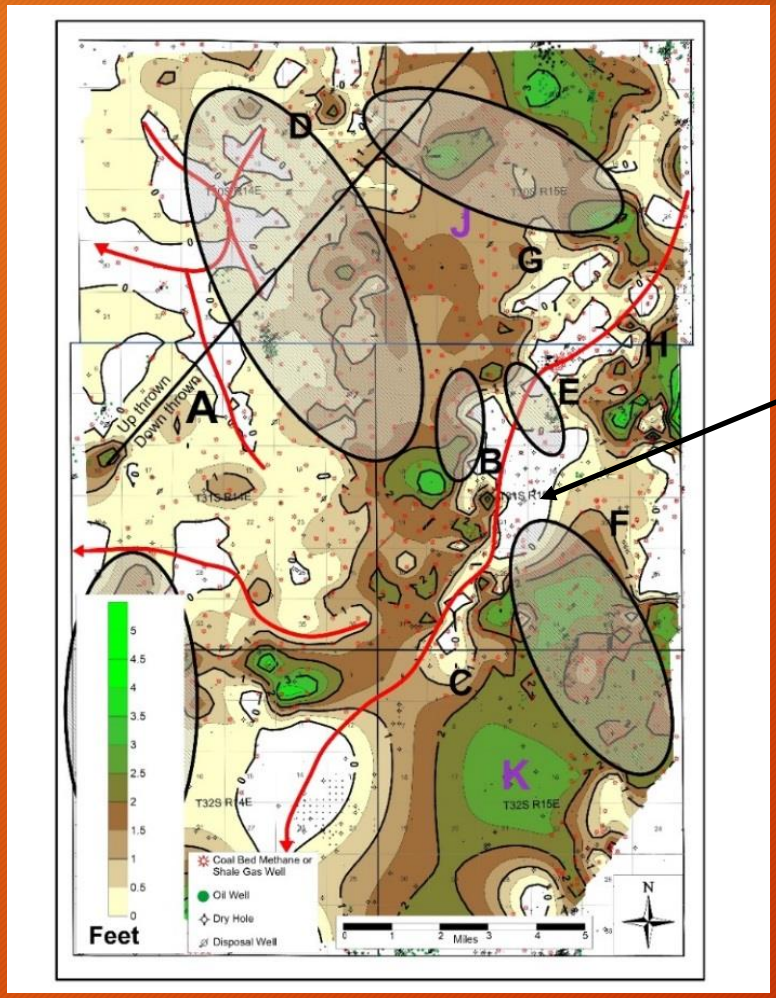


Cherokee Group Structure



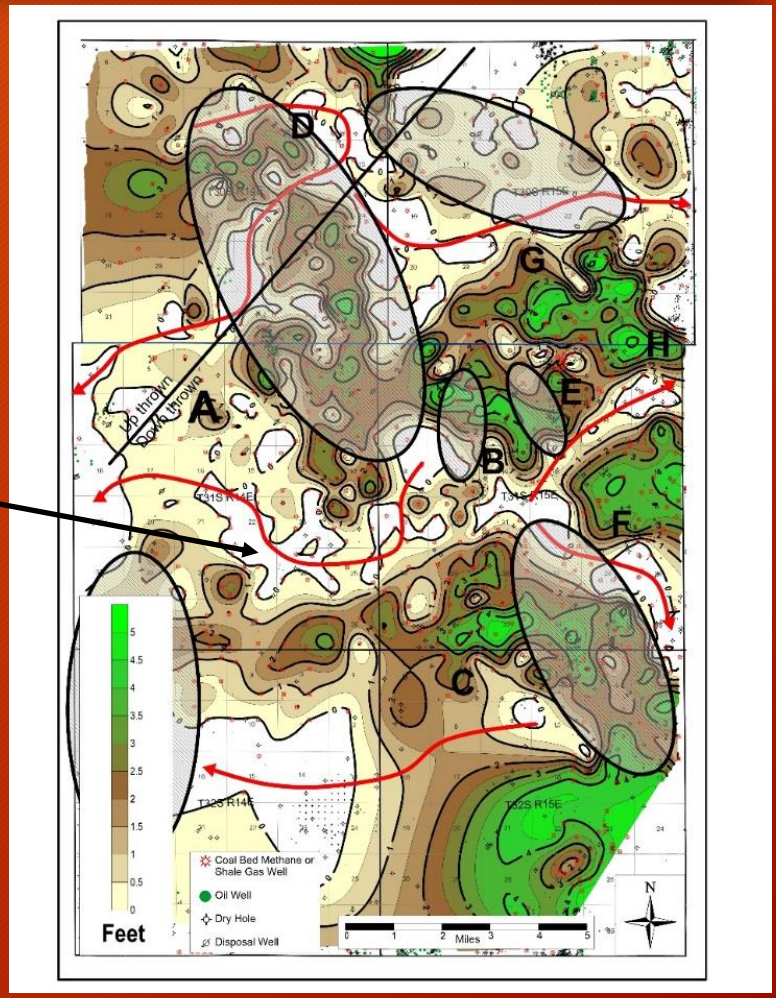
Cherokee Group Isopach

High Productive areas in relation to coal seam thickness in the Jefferson-Sycamore Study Area



Riverton

Weir-Pittsburg



Economics of a Coal-Bed Methane for the Jefferson-Sycamore Study Area

Operator	No. of Fractures	Type of Stimulation	Costs Per Well	Median MCF	Return of Capital*
Layne	3 to 5	Slick water	$140,000	52,915	1.1
Great Eastern	1 to 2	X-link and slick water	$120,000	96,068	1.6
Dart	3 to 7	slick water	$150,000	61,229	1.2
Jones	1 to 2	slick water	$120,000	70,205	1.4
Stroud Oil Properties	1 to 2	x-link	$110,000	192,122	2.1

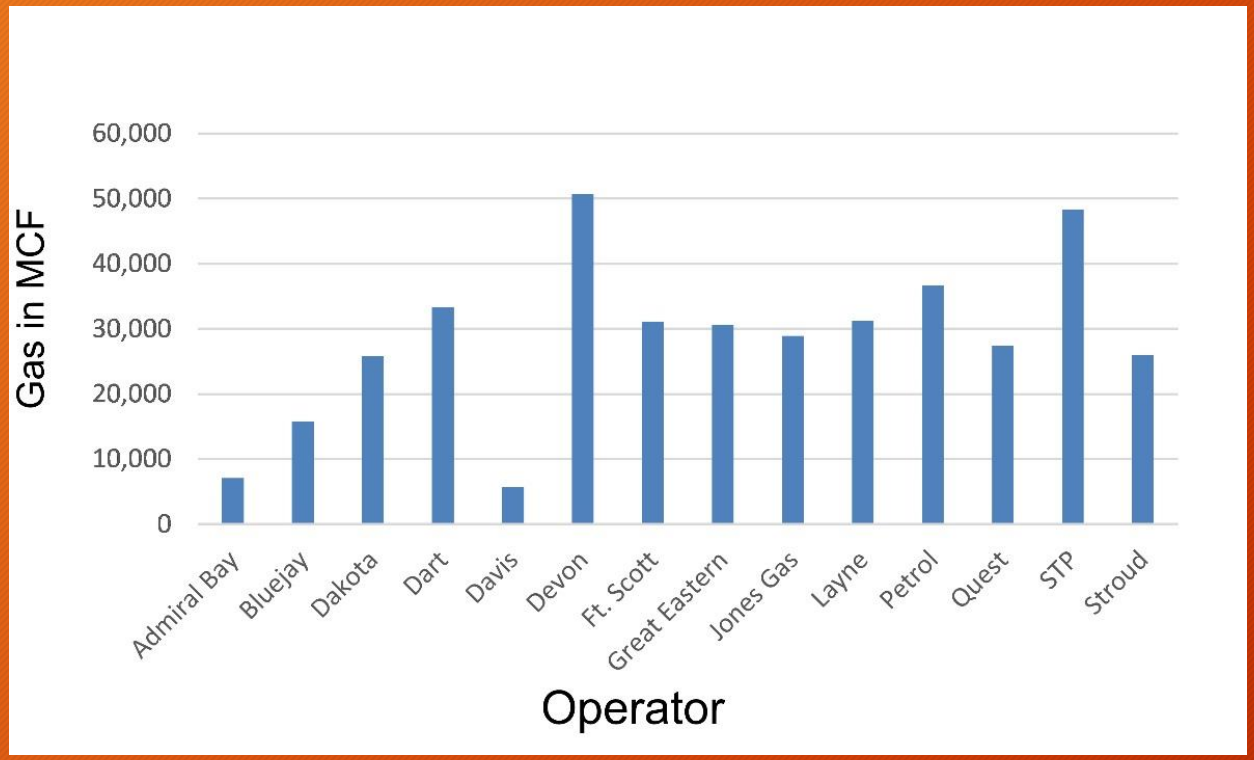
* Based on $6 gas, 80% NRI, $1.50 transportation costs

Comparison from all five study areas

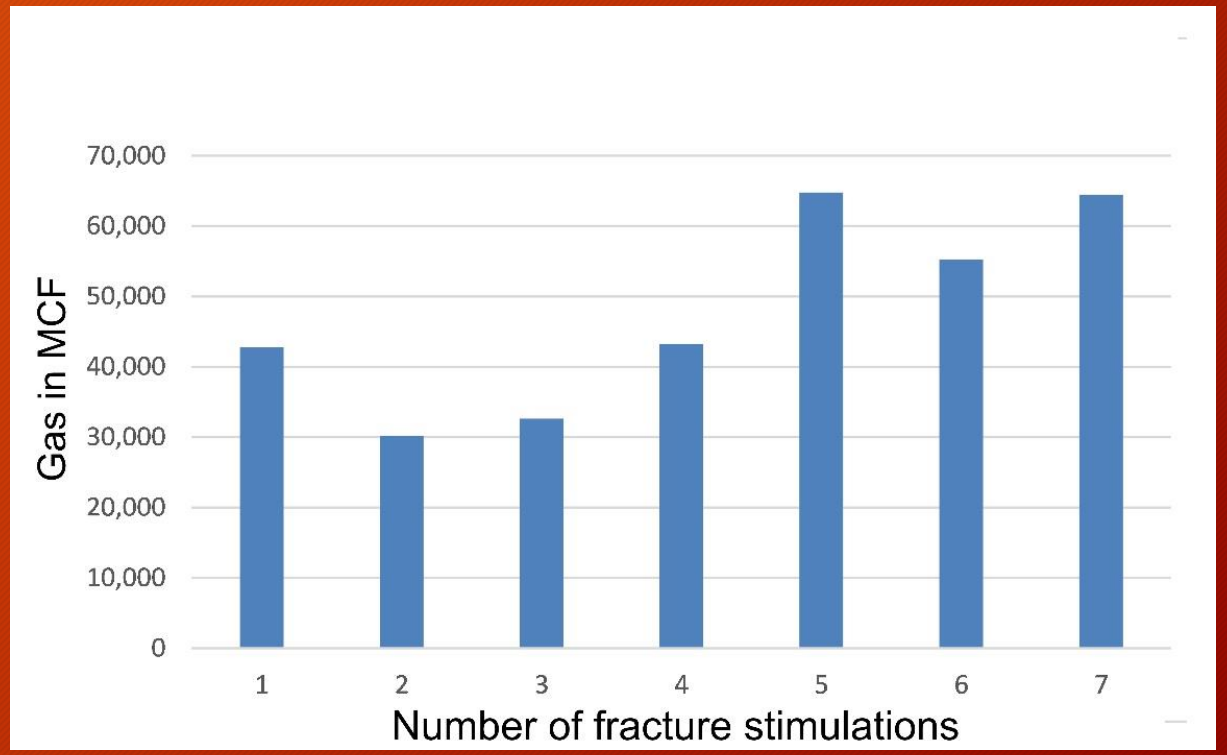
Thayer and the Jefferson-Sycamore study areas have the best production of the five study areas.

Study Area	Jefferson-Sycamore	Thayer	Chanute	Bourbon	Mound Valley
Component					
Sand (in thousands of pounds)	15	17	6	9	14
Fluid (in barrels)	1,175	1,375	470	876	1,156
Total pay (in feet)	11	17	4	13	5
Cross-linked gel (in MMCF)	31	N/A	N/A	N/A	76
Slick water (in MMCF)	31	66	21	7	19
Nitrogen (in MMCF)	67	N/A	N/A	N/A	N/A
One stimulation (in MMCF)	87	65	23	9	40
Two stimulations (in MMCF)	51	65	23	8	29
Three stimulations (in MMCF)	49	44	22	13	11
Four stimulations (in MMCF)	49	133	N/A	N/A	N/A
Five stimulations (in MMCF)	66	N/A	N/A	N/A	N/A
Six stimulations (in MMCF)	60	N/A	N/A	N/A	N/A
Seven stimulations (in MMCF)	112	N/A	N/A	N/A	N/A
Median production (in MMCF)	59	66	21	7	9
Structure necessary	No	No	Yes	Yes	No
Primary producing coal	Riverton and Weir-Pittsburg	Riverton and Rowe	Riverton	Riverton	Weir-Pittsburg
Thinning or thickening of individual intervals or coals	No	No	Yes	Yes	No
Isopach thinning of the Pre-Pennsylvanian Paleozoic rocks	Yes	Yes	Periphery	No	Periphery

Comparison of gas production versus Operators and number of fracture stimulations in all five study areas



Median gas production for operators with more then ten wells for the 2nd, 3rd and 4th years



Median gas production for operators with more then ten wells for the 2nd, 3rd and 4th years versus number of fracture stimulations

Summary

- Gas production is not related to any perceived thickening of coal or carbonaceous shale or structure;
- One fracture stimulation is more economic than two, three or four fracture stimulations;
- X-link gel was generally superior then slick water;
- Nitrogen was significantly better but the number of wells where it was used is small and there is a significant increase in costs;
- Overall based on economics the Cherokee Basin coal bed methane play is a marginally to uneconomic gas resources that is very dependent upon price.

Thank you for coming