

TSOP Annual Meeting

September 12-16, 2010

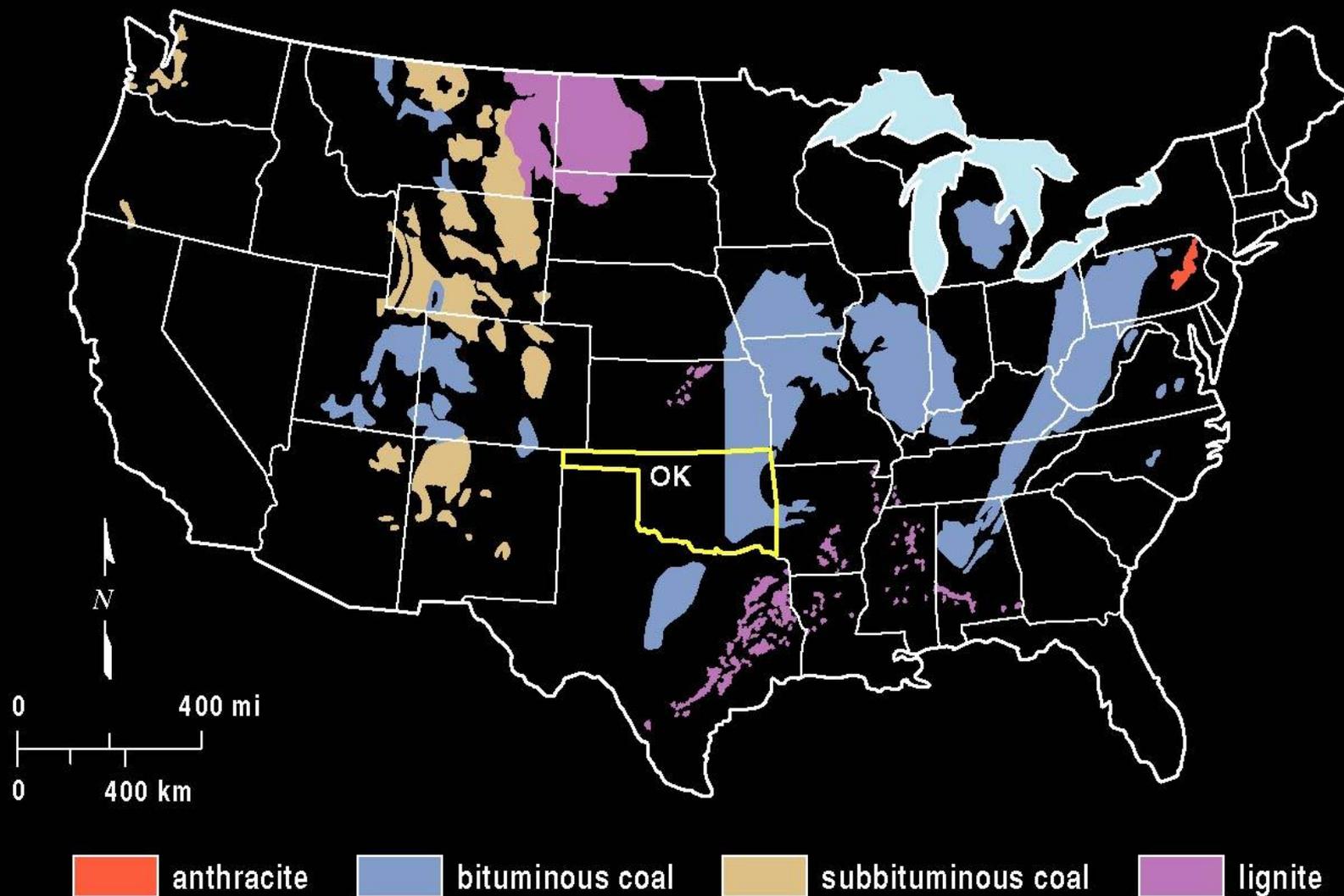
# Hartshorne Coal Rank Applied to Oklahoma Arkoma Basin Coalbed- Methane Activity



**Brian J. Cardott**

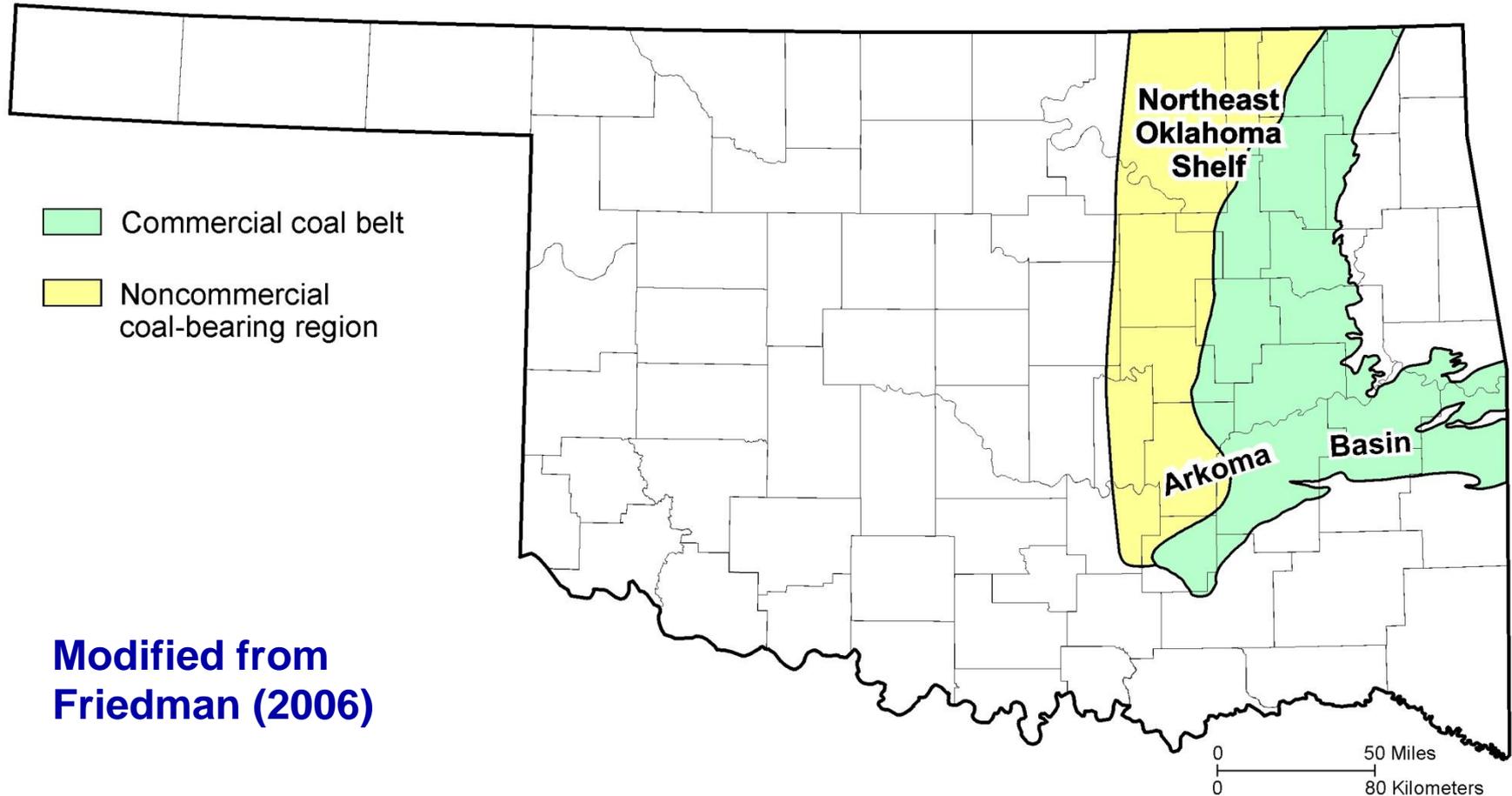
Oklahoma Geological Survey

# Coalfields of the United States

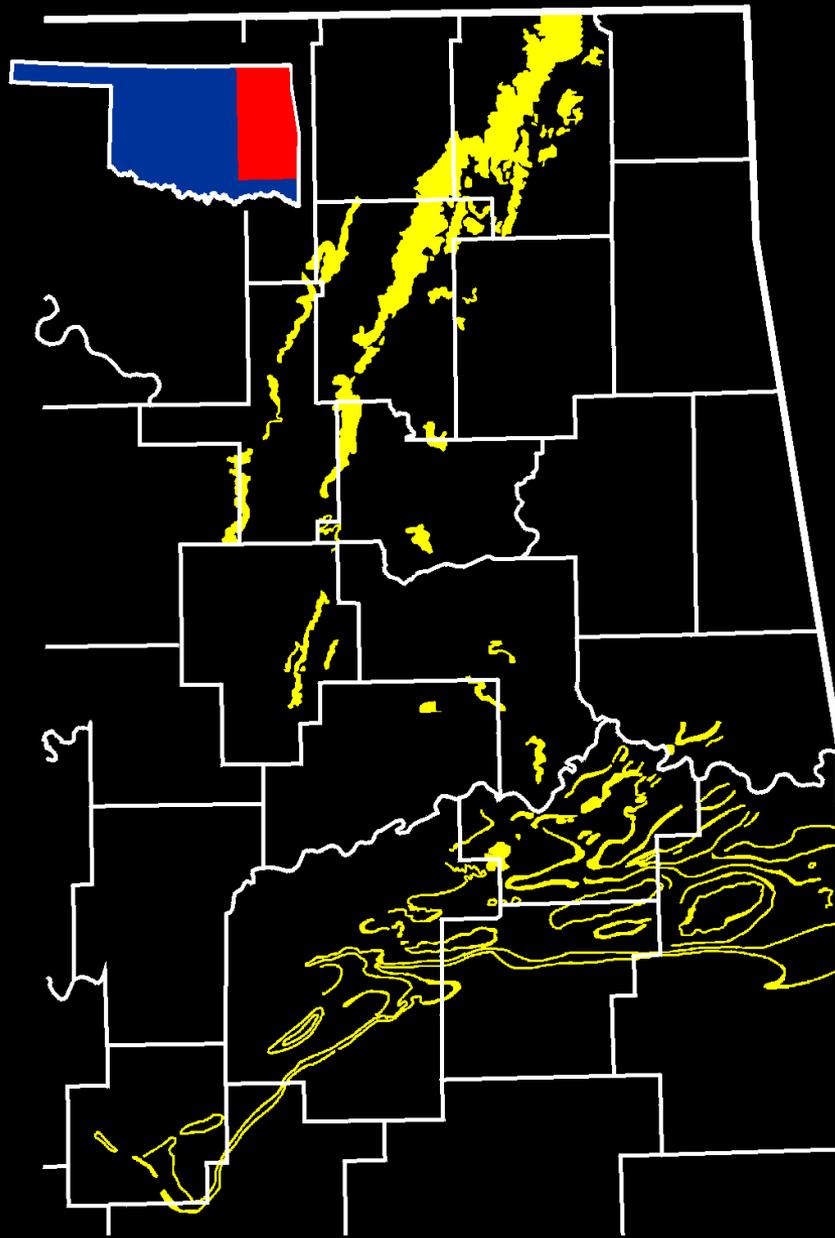


*modified from Trumbull, 1960 (USGS)*

# Oklahoma Coalfield



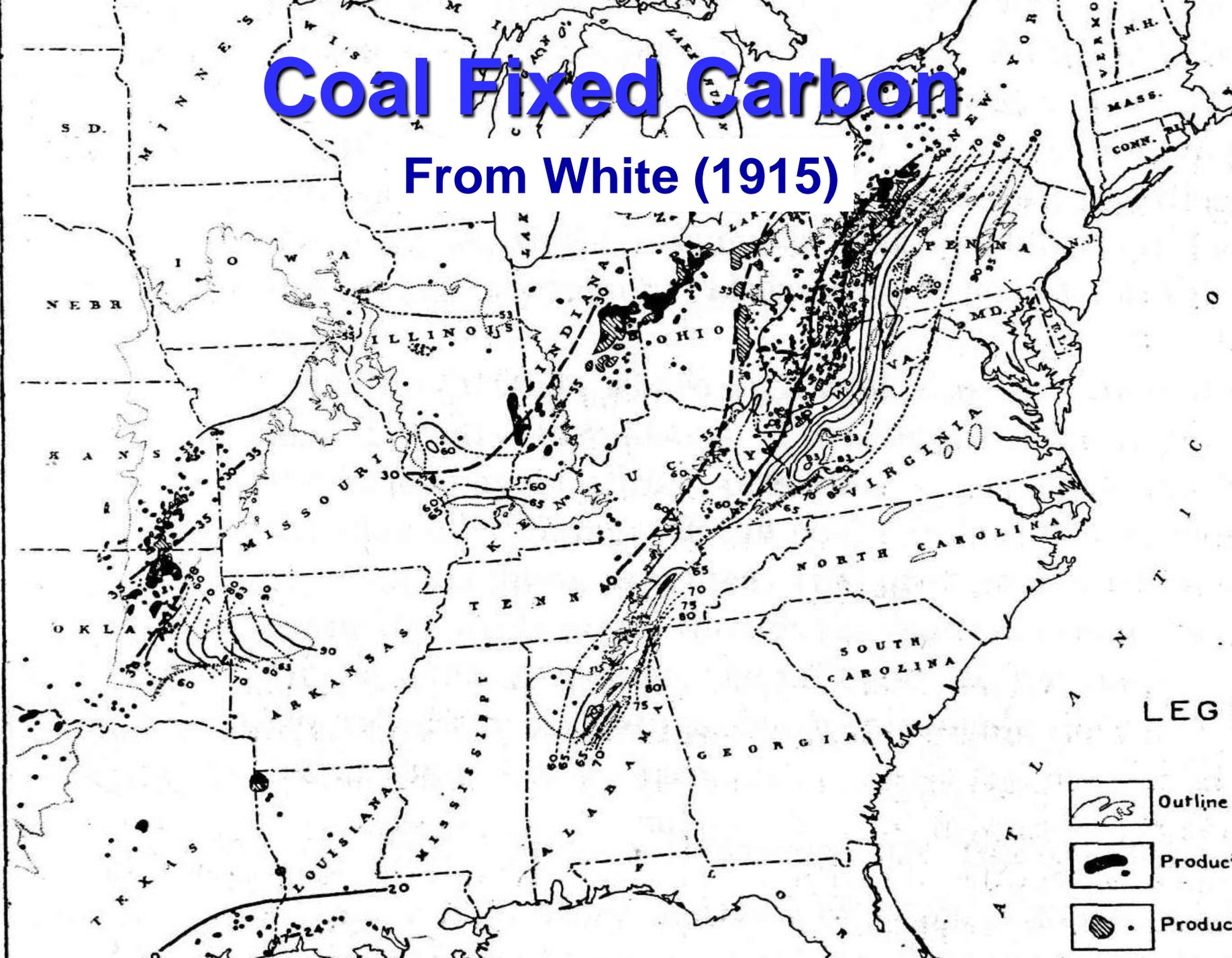
Modified from  
Friedman (2006)

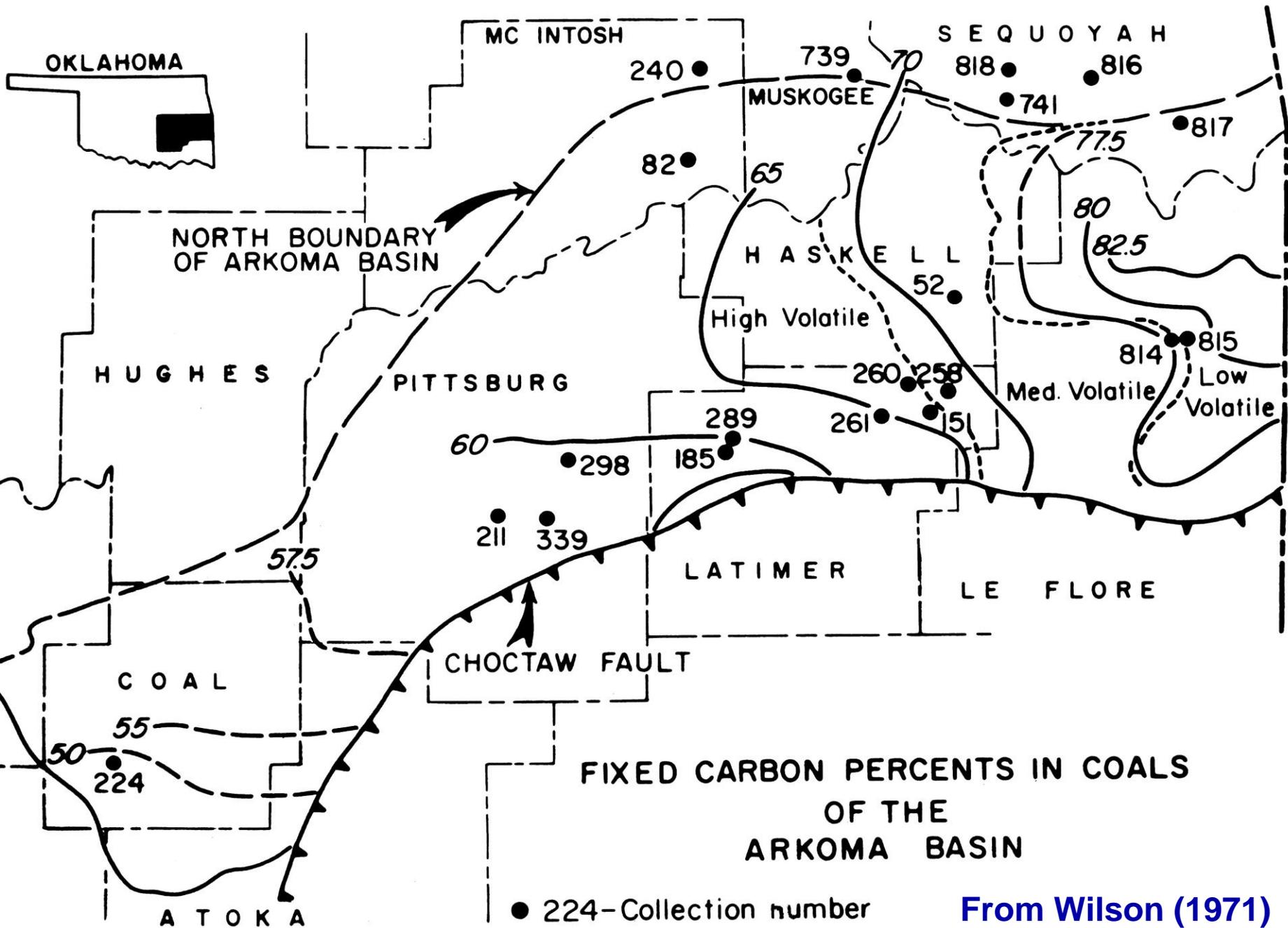


**COAL OUTCROP AND SUBCROP MAP  
OF OKLAHOMA COALFIELD (Friedman, 1982)**

# Coal Fixed Carbon

## From White (1915)

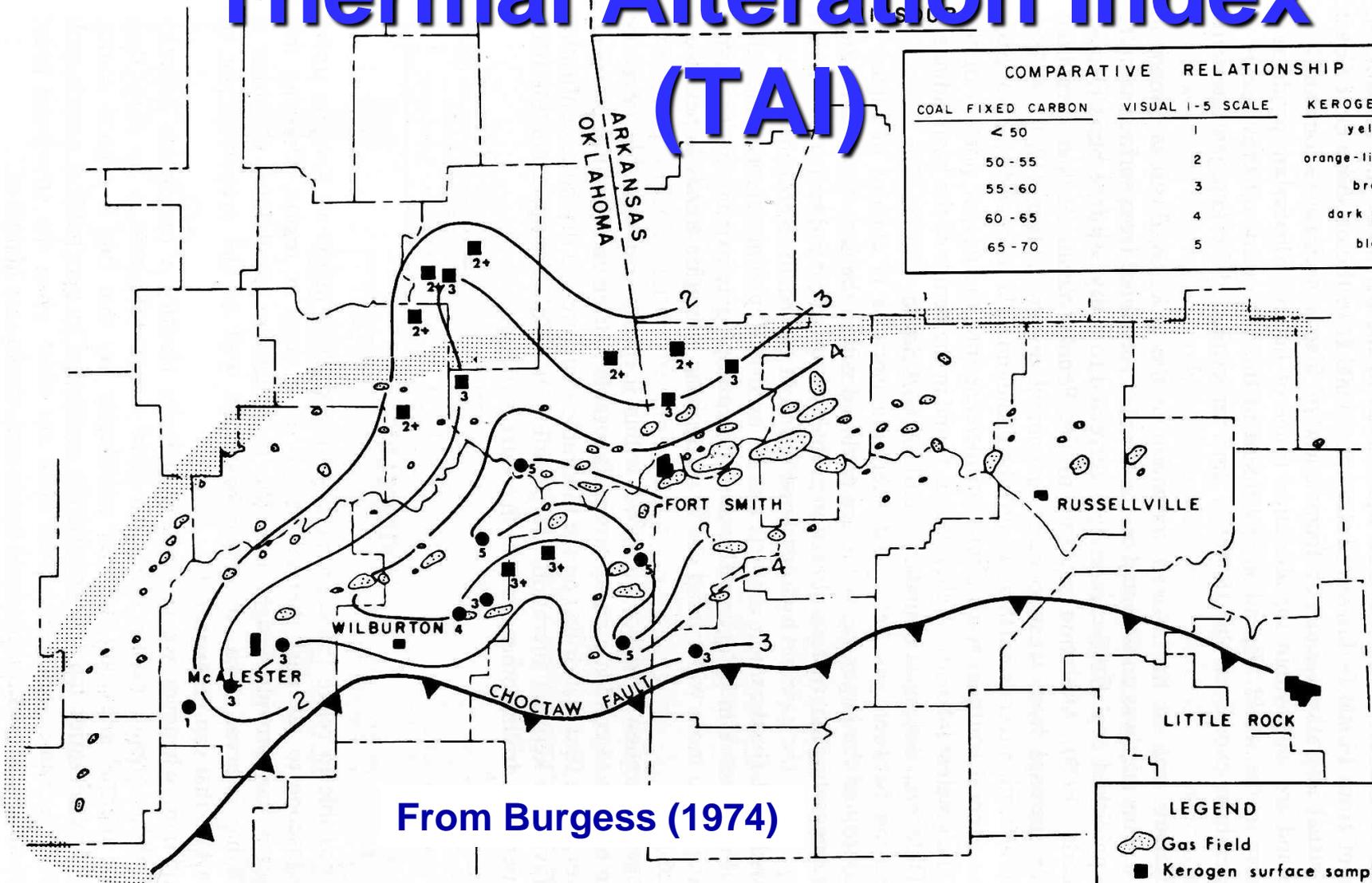




# Thermal Alteration Index

## (TAI)

COMPARATIVE RELATIONSHIP		
COAL FIXED CARBON	VISUAL 1-5 SCALE	KEROGEN COLOR
< 50	1	yellow
50 - 55	2	orange-light brown
55 - 60	3	brown
60 - 65	4	dark brown
65 - 70	5	black



From Burgess (1974)

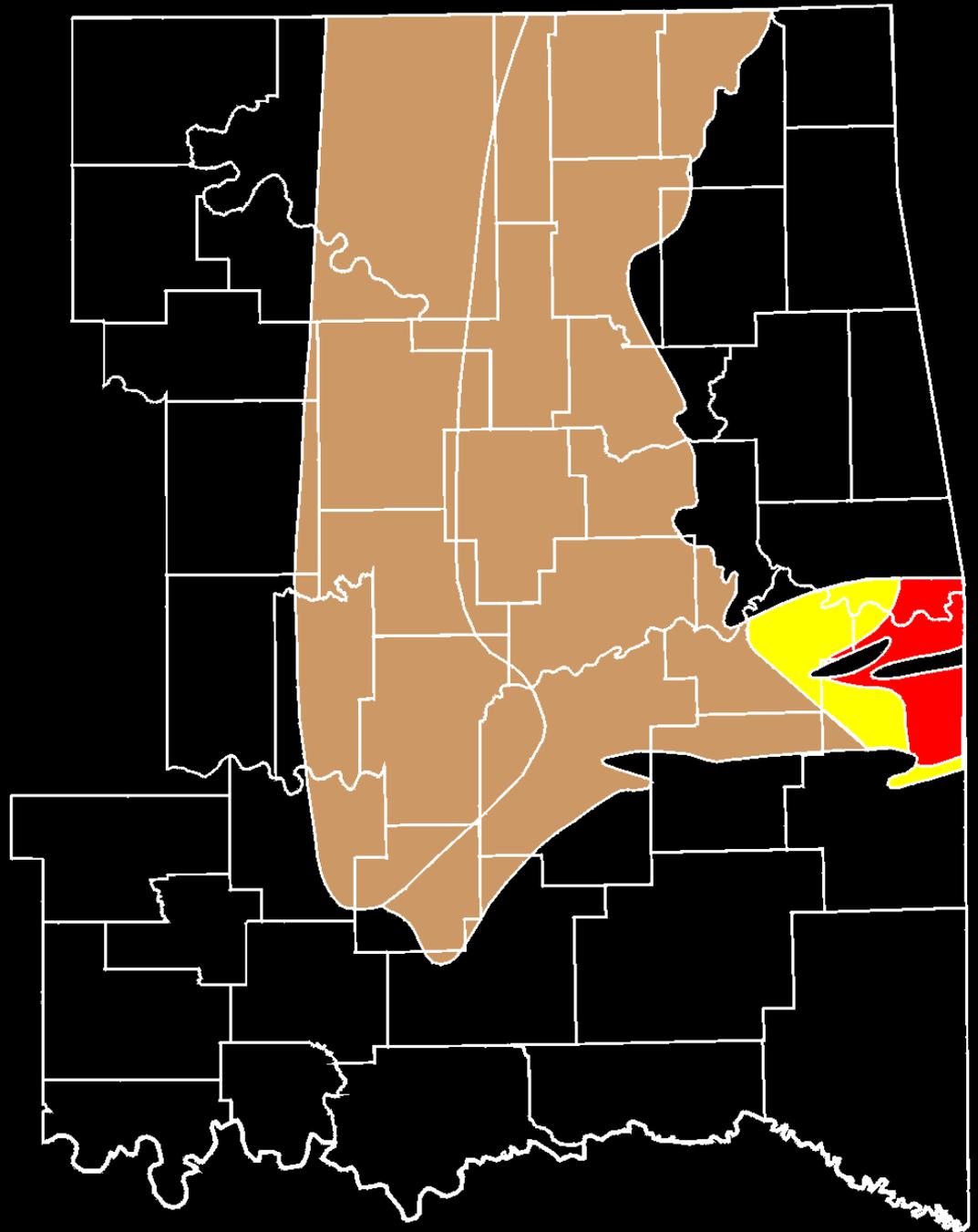
LEGEND	
	Gas Field
	Kerogen surface sample
	Fixed Carbon-Coals

**OKLAHOMA COAL  
RANK generalized  
for all coals, at or  
near the surface**

**High-volatile  
bituminous** 

**Medium-volatile  
bituminous** 

**Low-volatile  
bituminous** 



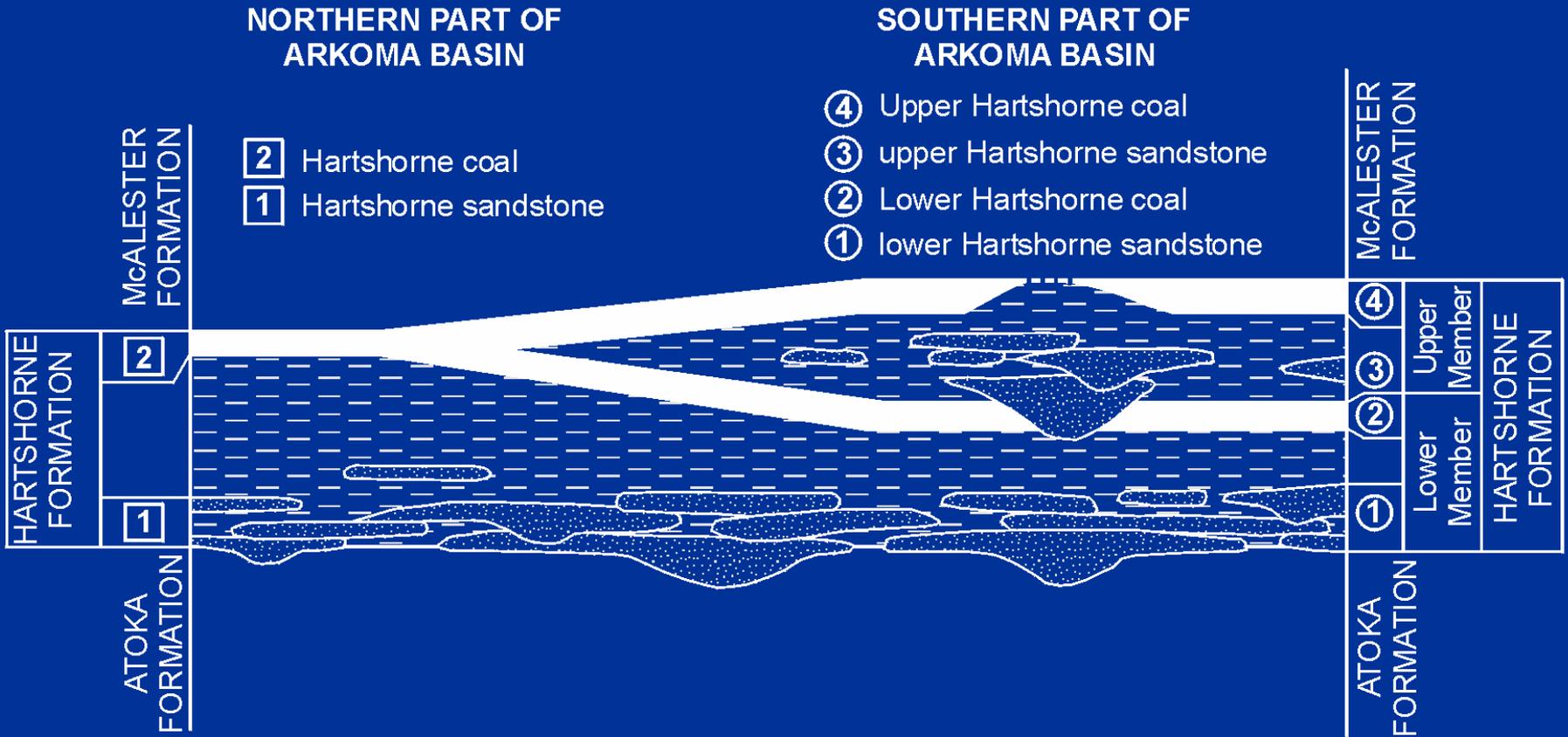
SYSTEM	SERIES	GROUP	FORMATION	LITHOLOGY	THICKNESS (ft.)	UNIT	THICKNESS OF COAL (ft.)				
PENNSYLVANIAN	DESMOINESIAN	CABANISS	Senora		500-900	Croweburg coal	0.6-2.8				
						Tebo (?) coal	0-.06				
			Stuart		0-380	Unnamed coal	unknown — unconfirmed reports from four localities				
				Thurman	0-350						
		KREBS	DESMOINESIAN	Middle Pennsylvanian	Boggy		700-2,150	Unnamed coal	0.8-1.8		
								Bluejacket coal	0.1-0.2		
								Peters Chapel coal	0.1-2.2		
								Secor rider coal	0.1-1.5		
								Secor coal	0.1-4.3		
								Lower Witteville coal	0.1-4.7		
								Savanna	200-2,500	Drywood coal	0-0.1
										Rowe coal	0.3-1.4
										Unnamed coal	0-0.2
										Unnamed coal	0-0.2
										Upper Cavanal coal	1.2-3.2
								Sam Creek coal	0.1-0.2		
		Lower Cavanal coal	0-2.2								

# Generalized Stratigraphy of Arkoma Basin Coal-Bearing Strata

SYSTEM	SERIES	GROUP	FORMATION	LITHOLOGY	THICKNESS (ft.)	UNIT	THICKNESS OF COAL (ft.)		
PENNSYLVANIAN	DESMOINESIAN	KREBS	Middle Pennsylvanian		400-2,830	Spaniard coal	0-0.1		
						Keota coal	0.1-0.4		
						Tamaha coal	0.1-0.3		
						Upper McAlester (Stigler rider) coal	0.2-1.7		
						McAlester (Stigler) coal	1.0-5.0		
						Unnamed coal	0.1-0.2		
						Keerton coal	0.1-1.6		
						Unnamed coal	0.3-1.0		
						Unnamed coal	0.2-0.8		
						Hartshorne	50-316	Upper Hartshorne coal	0.2-4.5
								Lower Hartshorne coal	0.7-7.0
						Atoka	0-15,000	Unnamed coal	0-0.5
								Unnamed coal	0-0.5

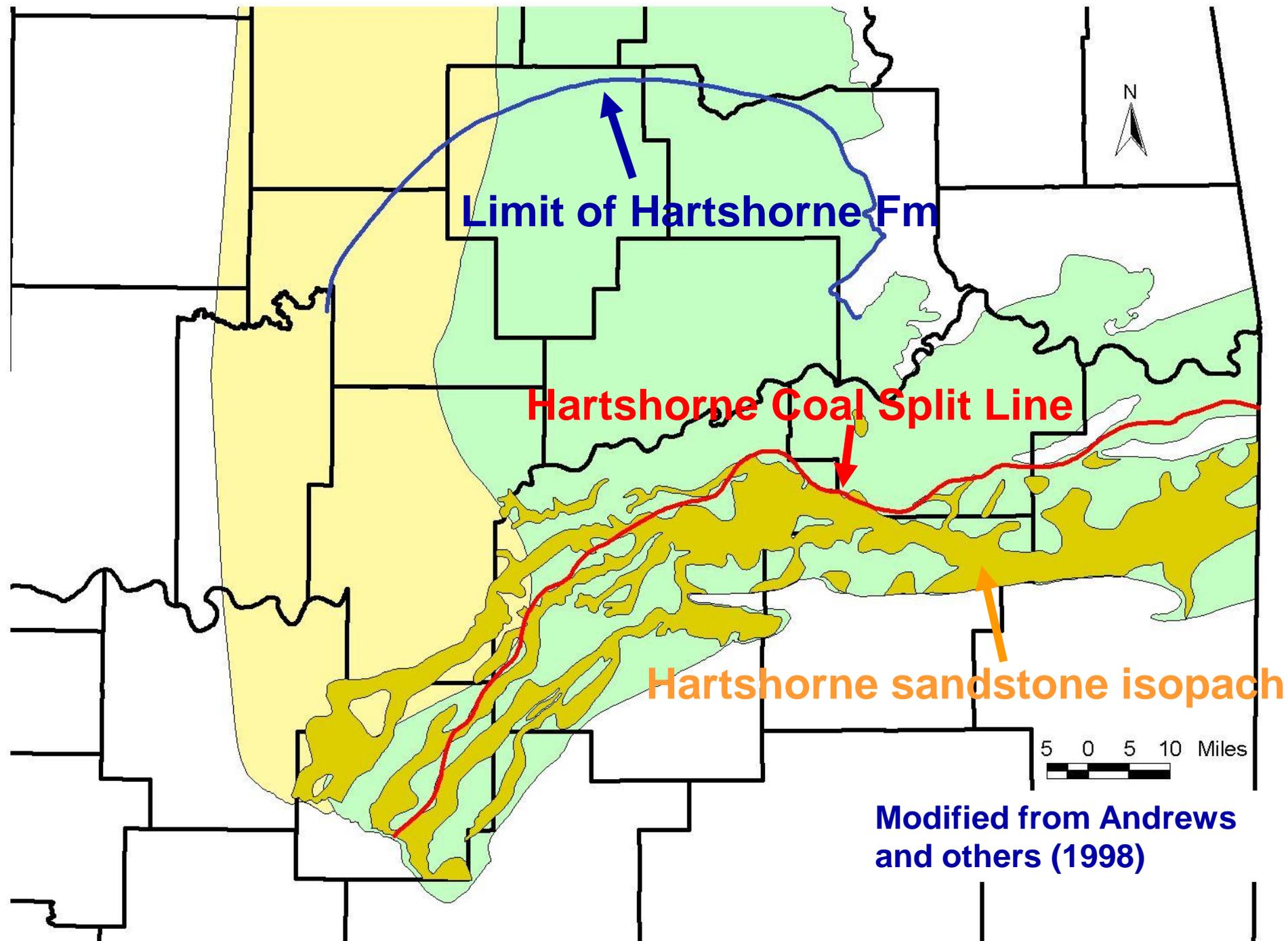
From Hemish (1988)

# Hartshorne Nomenclature



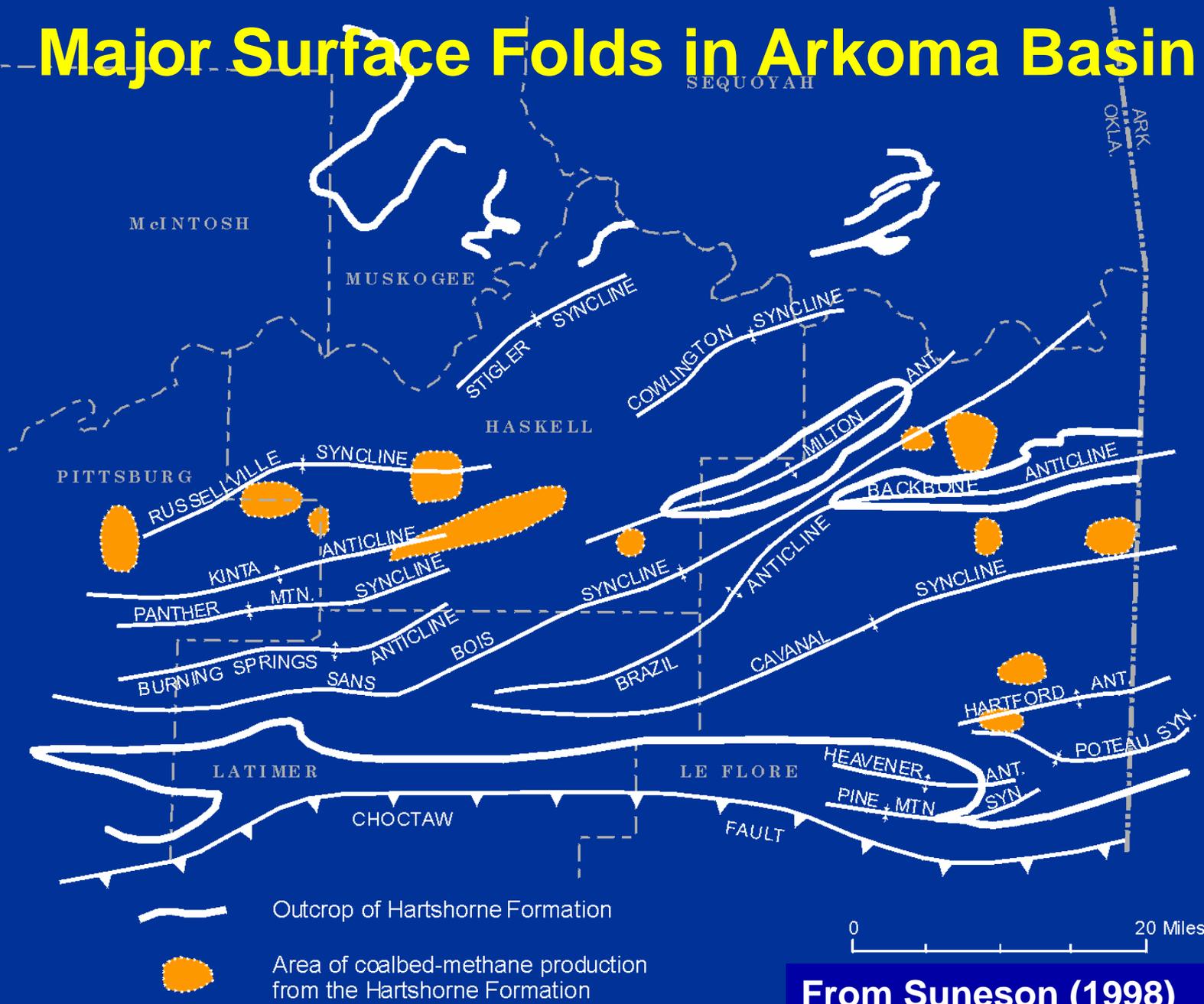
# Photograph of Lower Hartshorne Coal (5.9 ft thick) in Eastern Oklahoma





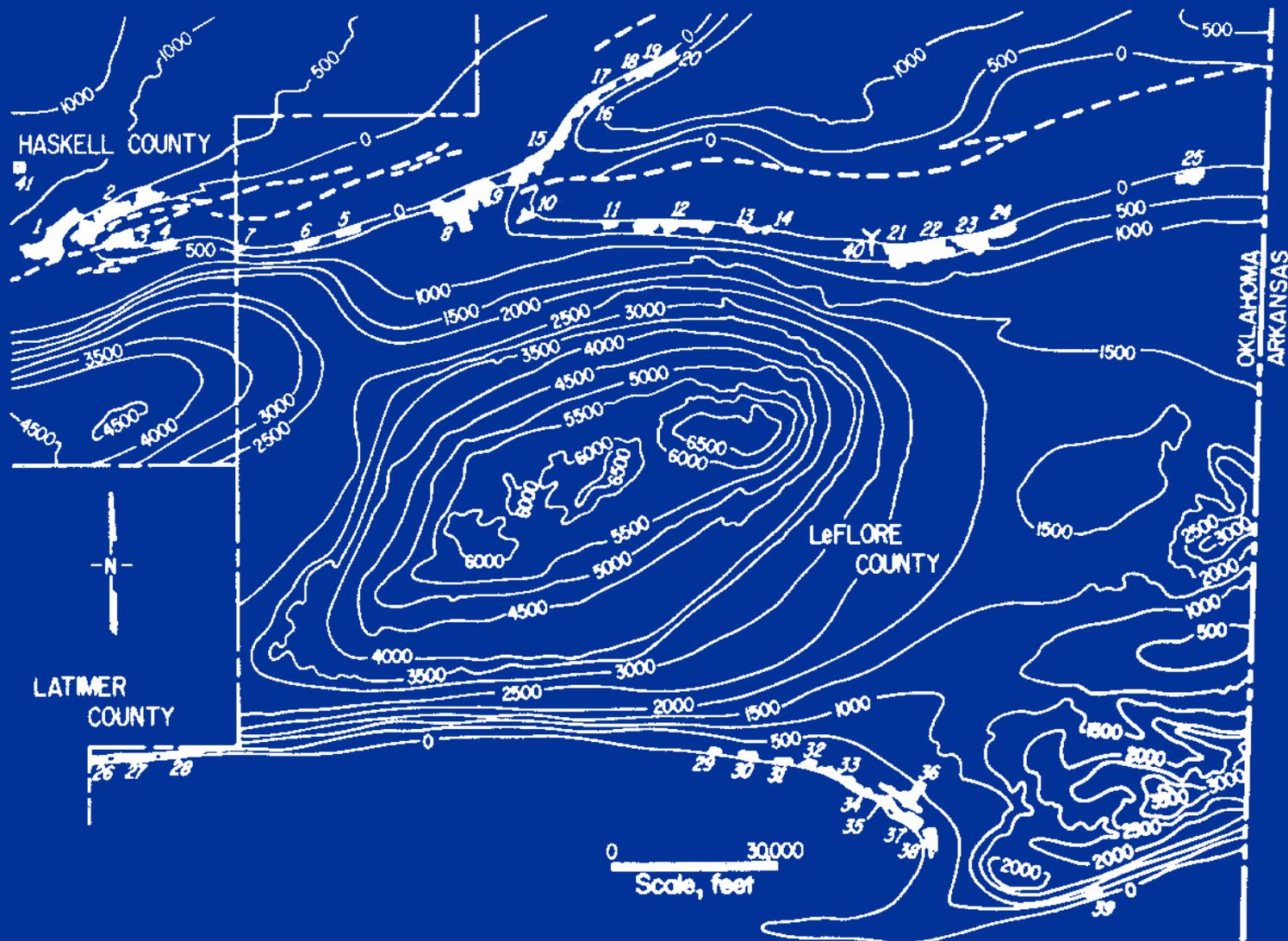


# Major Surface Folds in Arkoma Basin



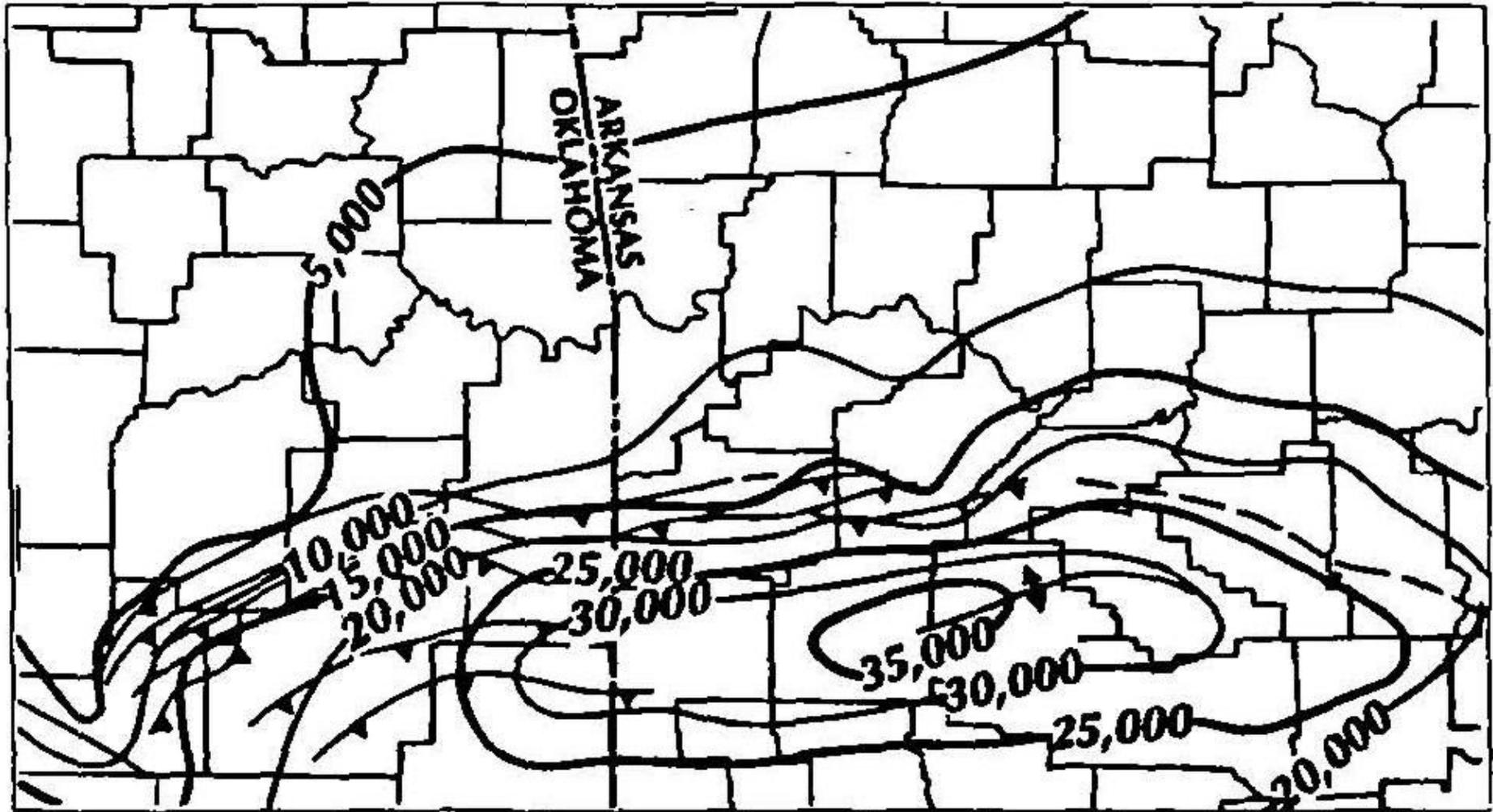
From Suneson (1998)

# Hartshorne Overburden Map



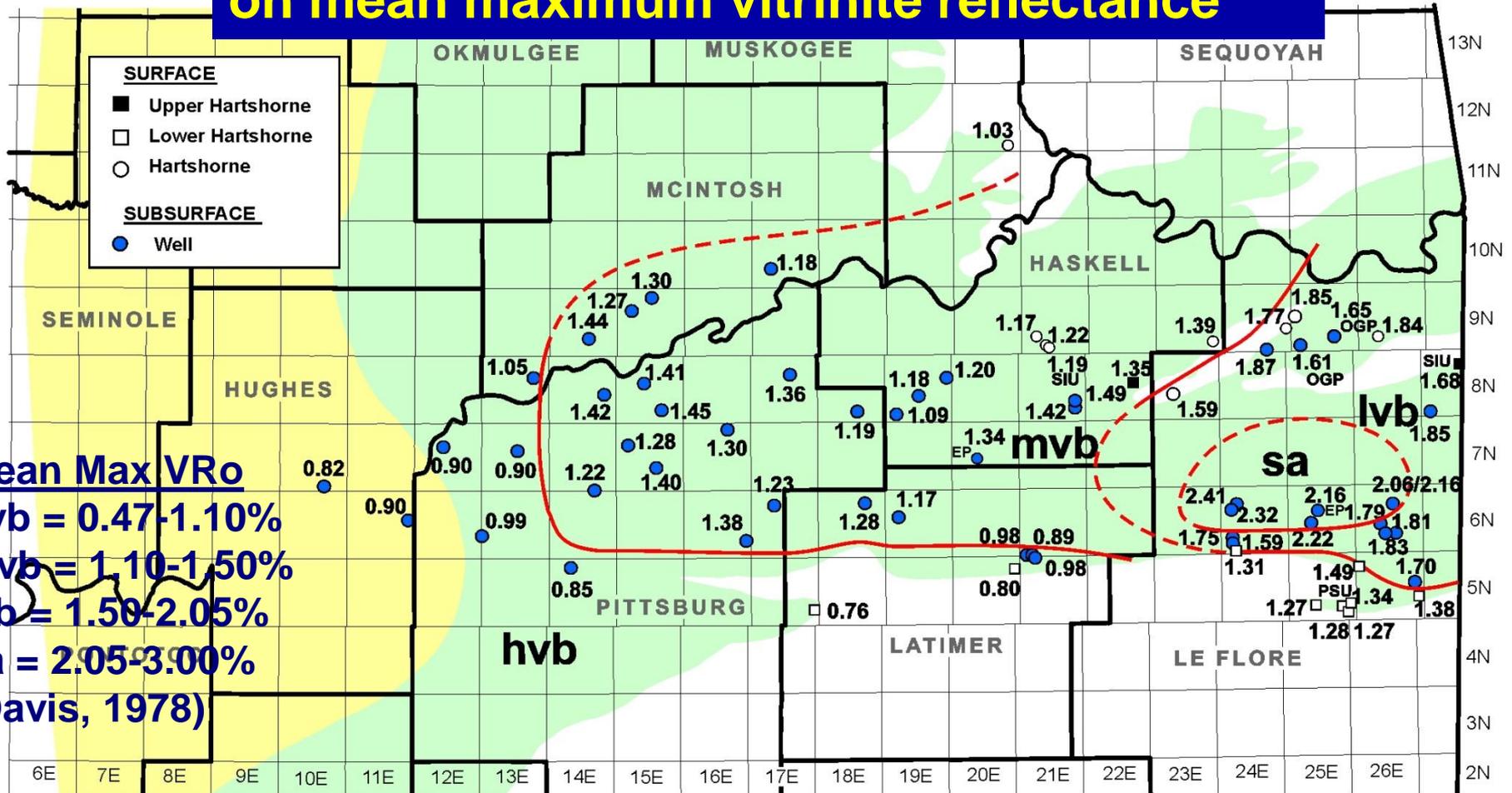
From Iannacchione and Puglio (1979)

# Map of estimated total removed overburden (ft) for intermediate burial model



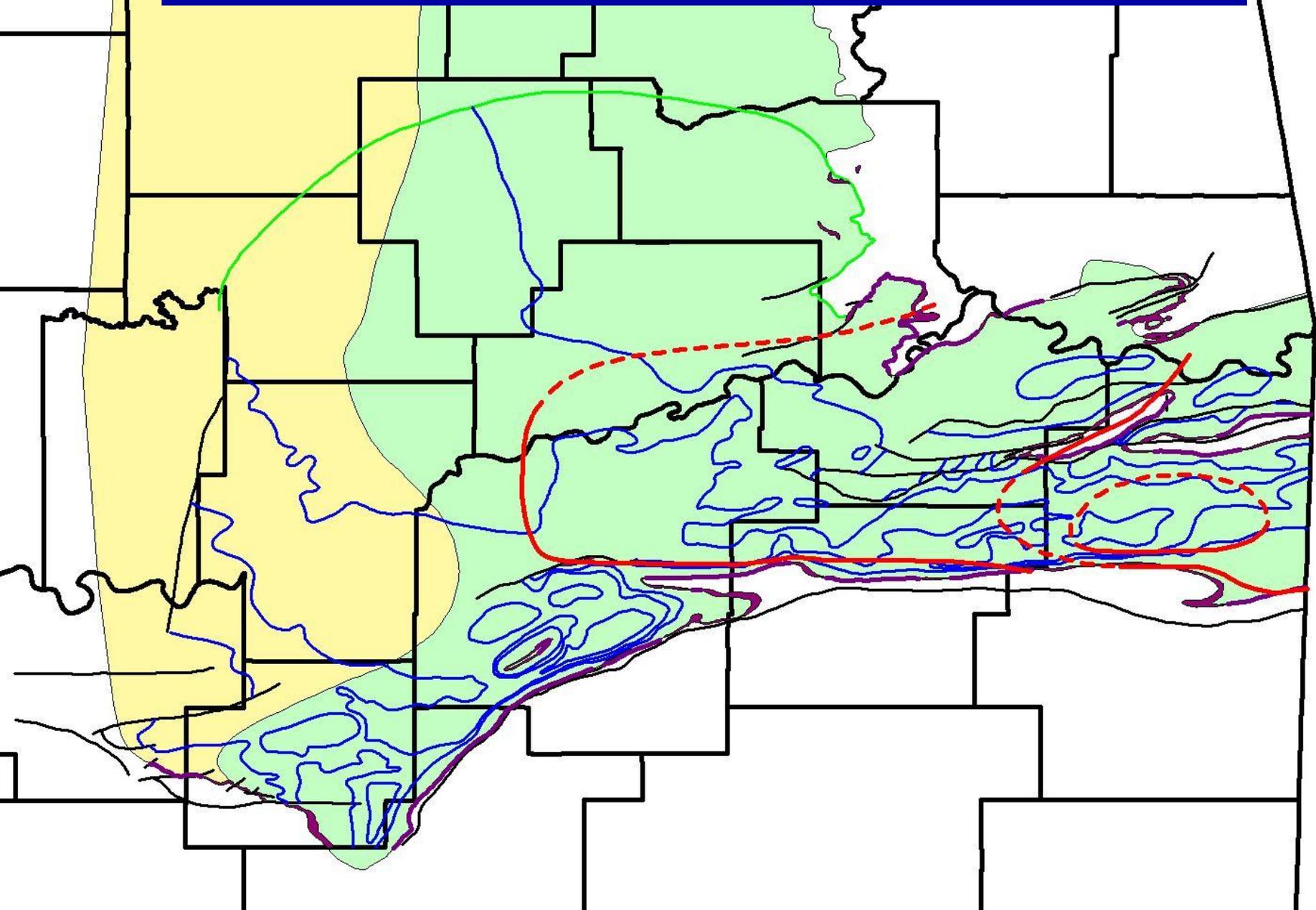
From Byrnes & Lawyer (1999)

# Coal rank map of Hartshorne coal based on mean maximum vitrinite reflectance

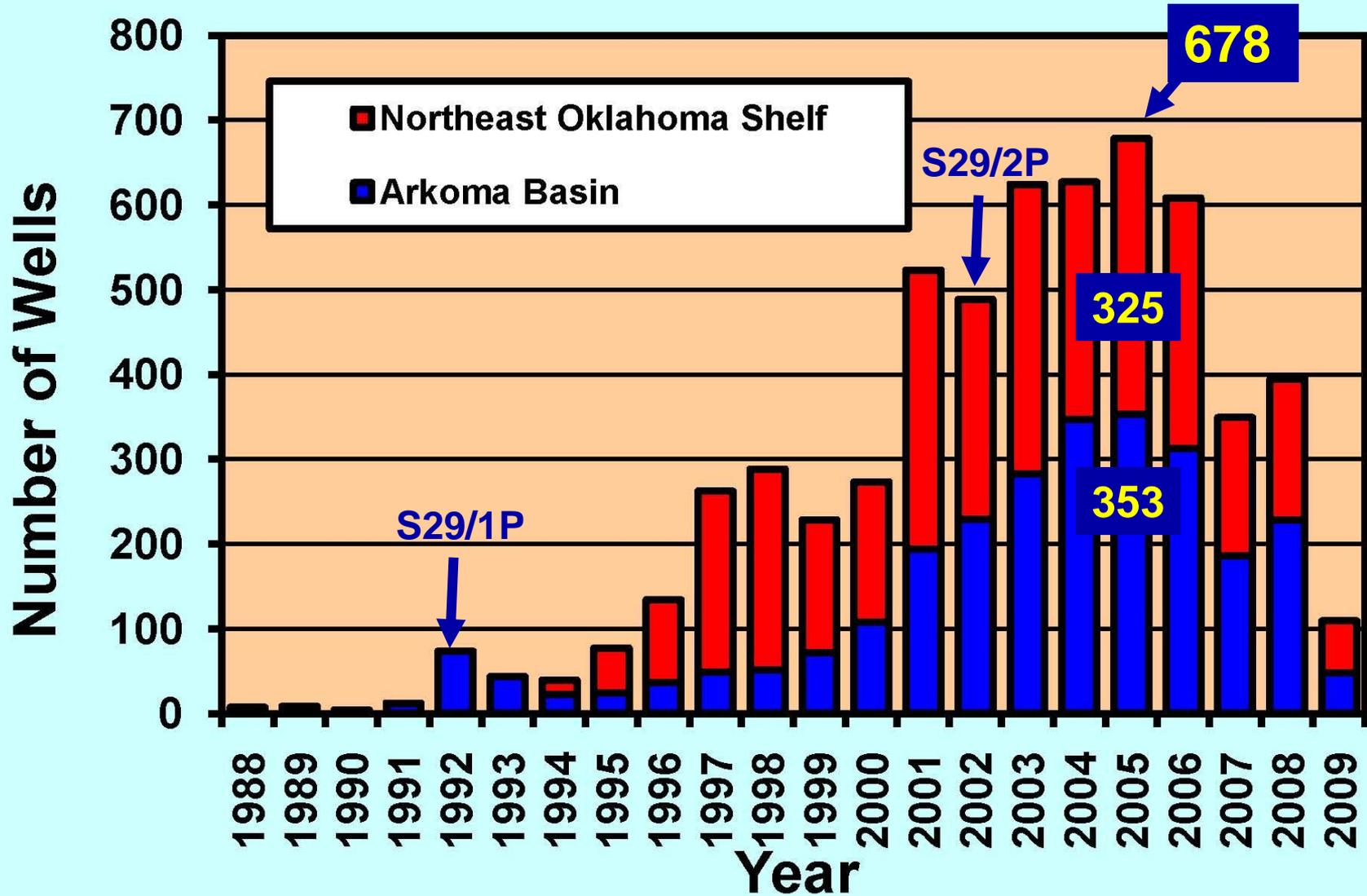


Preliminary coal rank map of Arkoma Basin based on mean maximum vitrinite reflectance of Hartshorne coal samples (hvb = high volatile bituminous; mvb = medium volatile bituminous; lvb = low volatile bituminous; sa = semianthracite). Data by Brian Cardott, Oklahoma Geological Survey, unless specified otherwise. Additional data from OGP Operating (OGP), The Pennsylvania State University (PSU), Southern Illinois University at Carbondale (SIU), and Pratt and others (2004; El Paso cores, EP). Revised 5/2009.

# Hartshorne Rank and Structure



# Oklahoma CBM Well Completions History

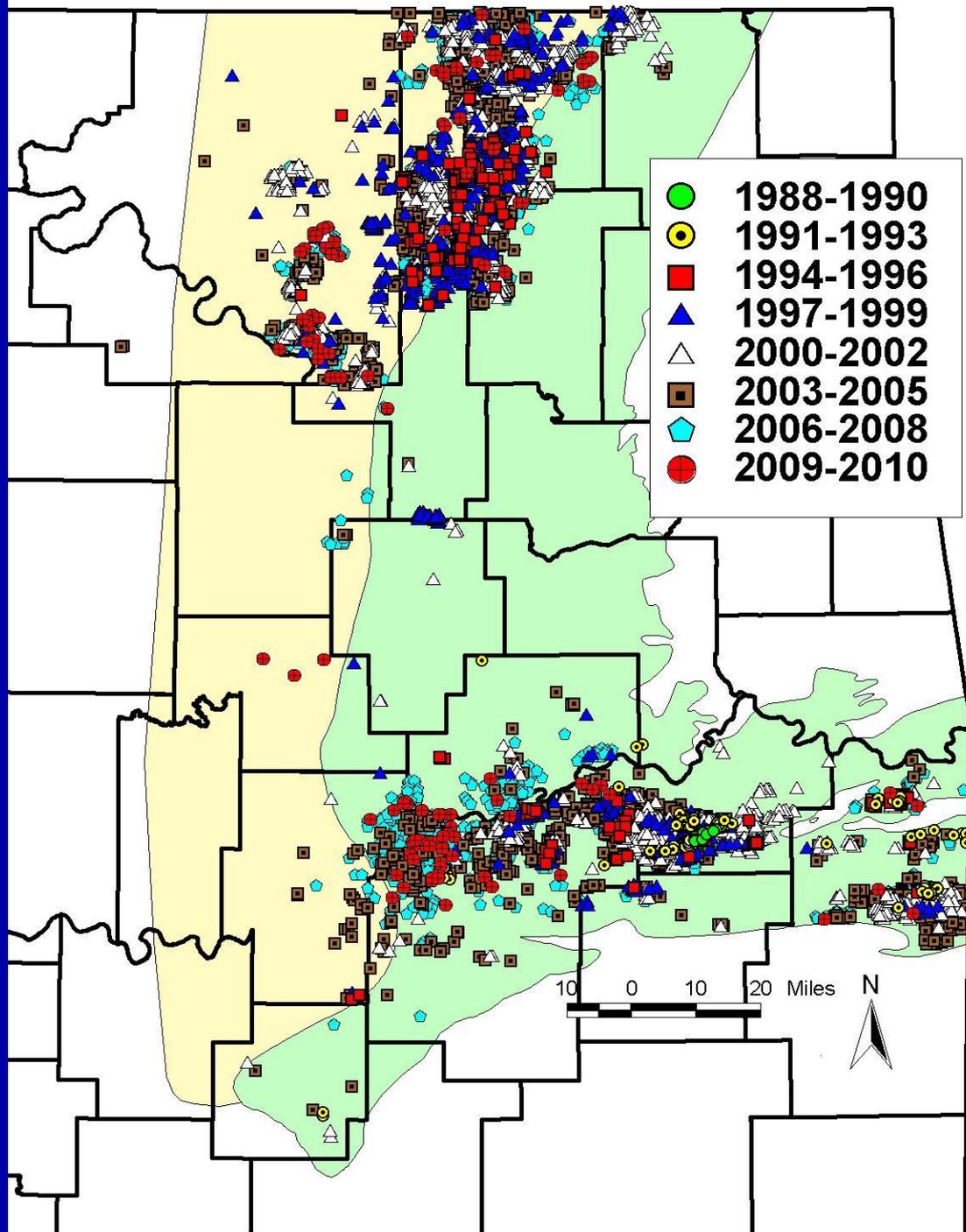


5,847 CBM Completions 1988-2009

109 wells in 2009

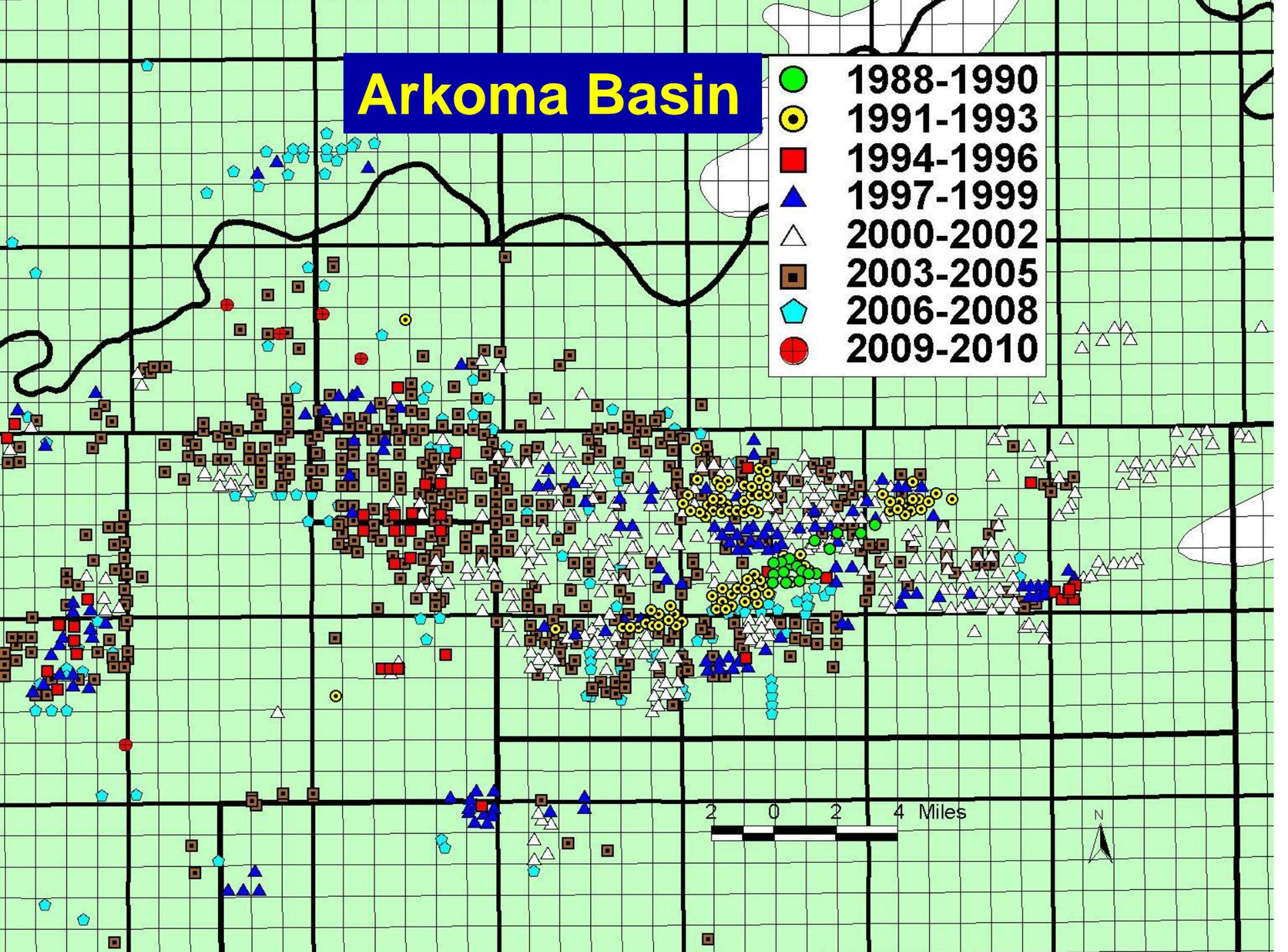
# Oklahoma Coalbed Methane Completions by Year

(5,869 wells)

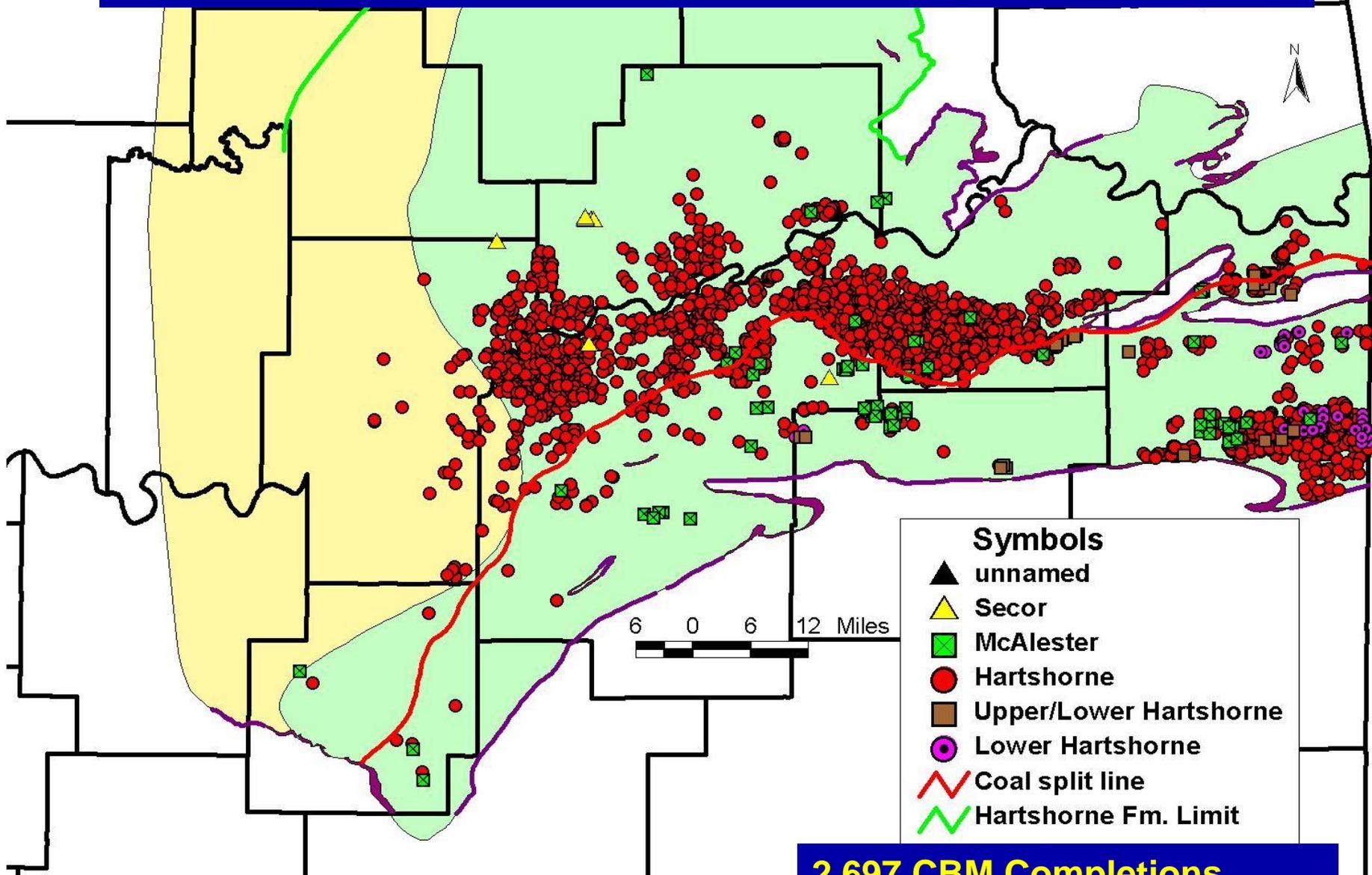


# Arkoma Basin

- 1988-1990
- 1991-1993
- 1994-1996
- ▲ 1997-1999
- △ 2000-2002
- 2003-2005
- ⬠ 2006-2008
- 2009-2010



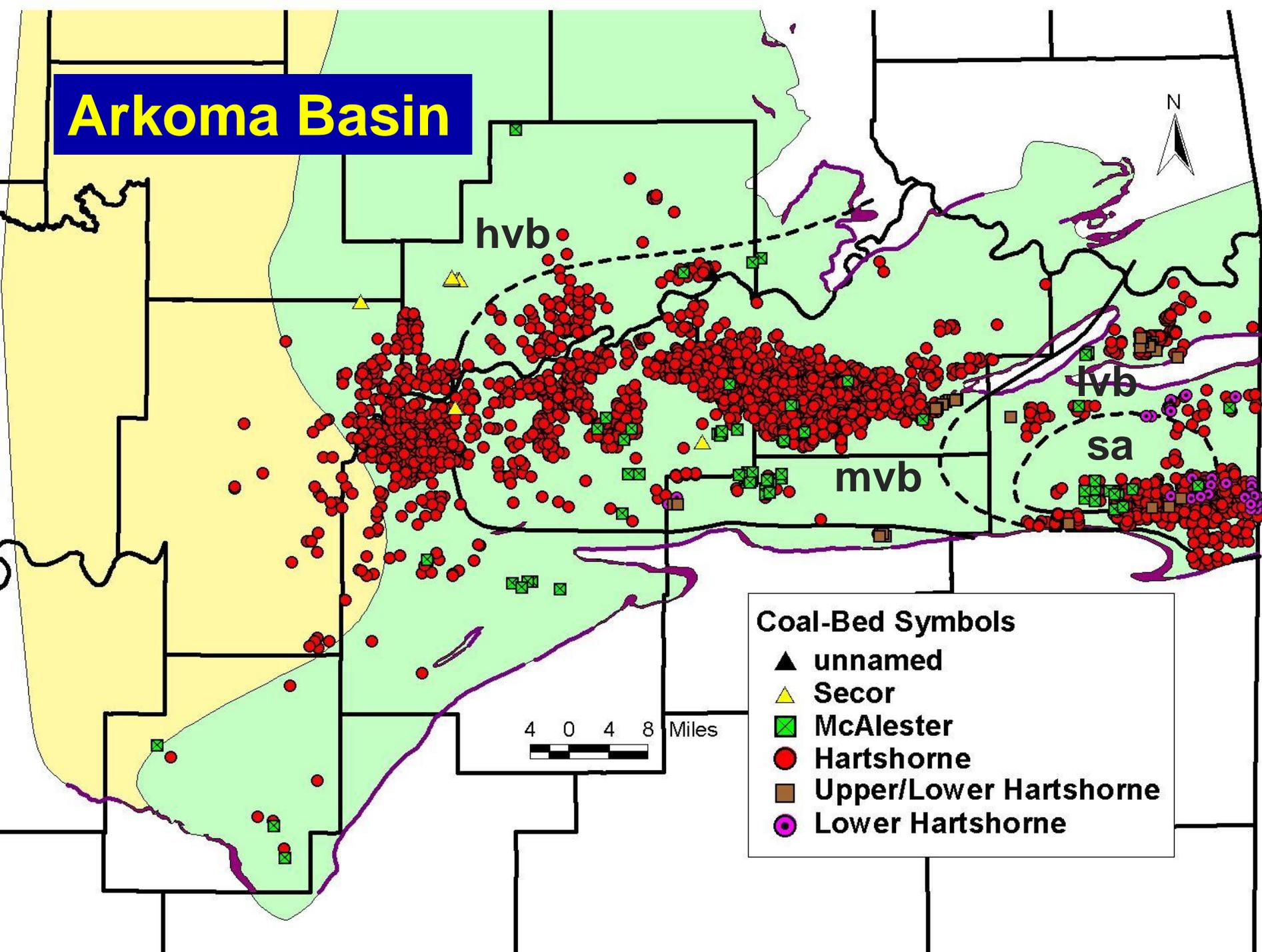
# Arkoma Basin CBM Wells by Coal Bed



- Symbols**
- ▲ unnamed
  - ▲ Secor
  - McAlester
  - Hartshorne
  - Upper/Lower Hartshorne
  - Lower Hartshorne
  - Coal split line
  - Hartshorne Fm. Limit

**2,697 CBM Completions**

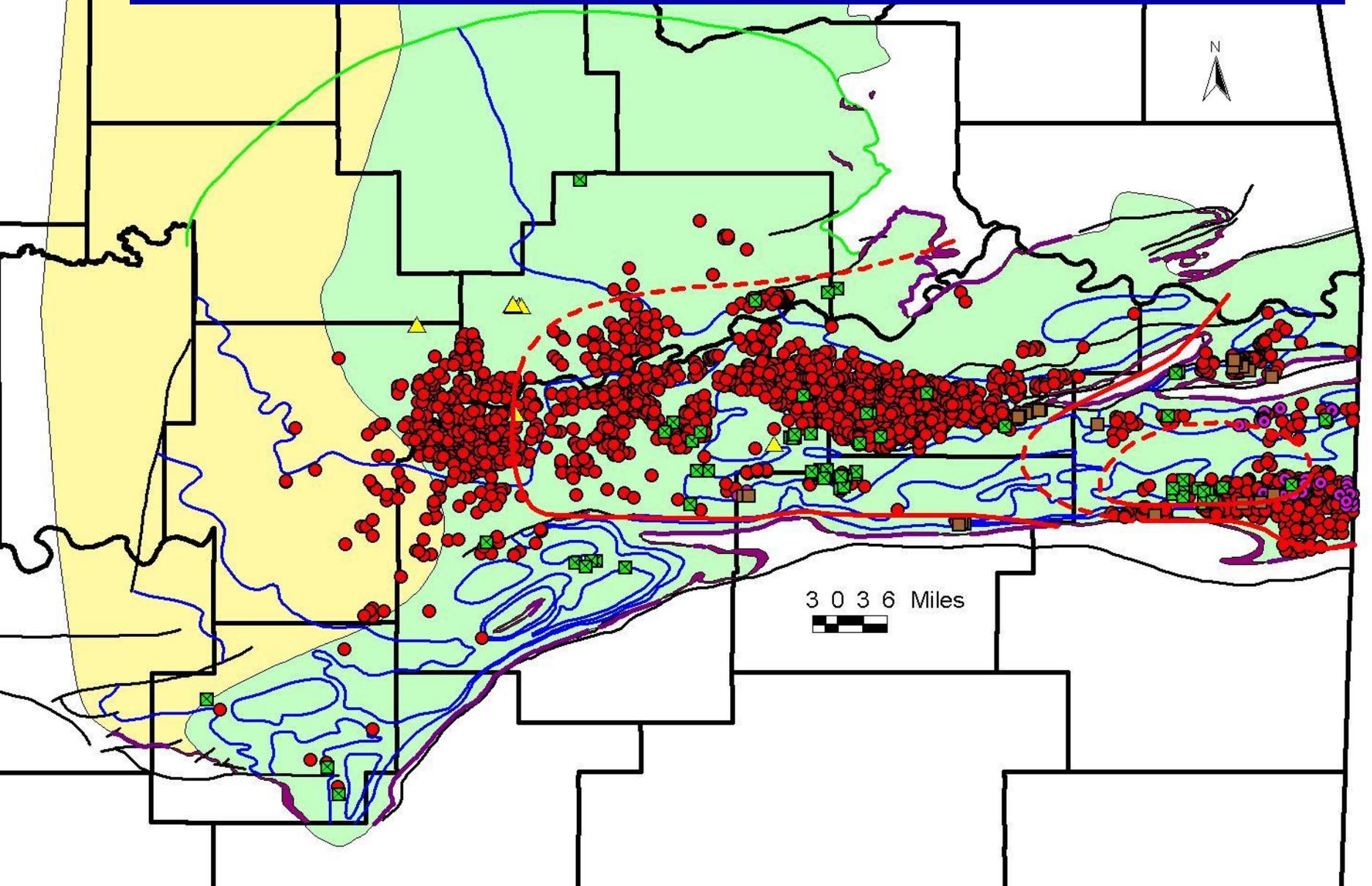
# Arkoma Basin



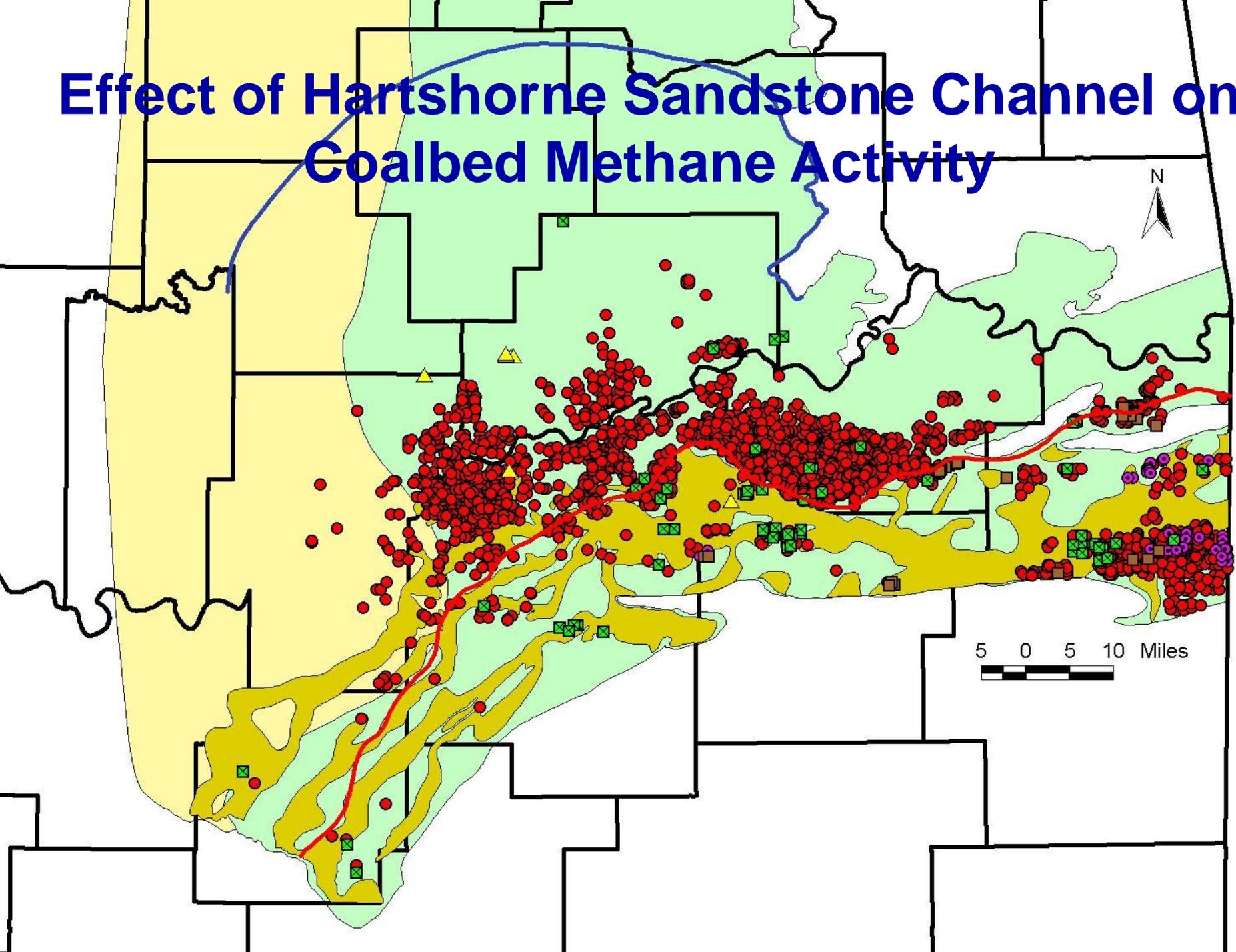
## Coal-Bed Symbols

- ▲ unnamed
- ▲ Secor
- McAlester
- Hartshorne
- Upper/Lower Hartshorne
- Lower Hartshorne

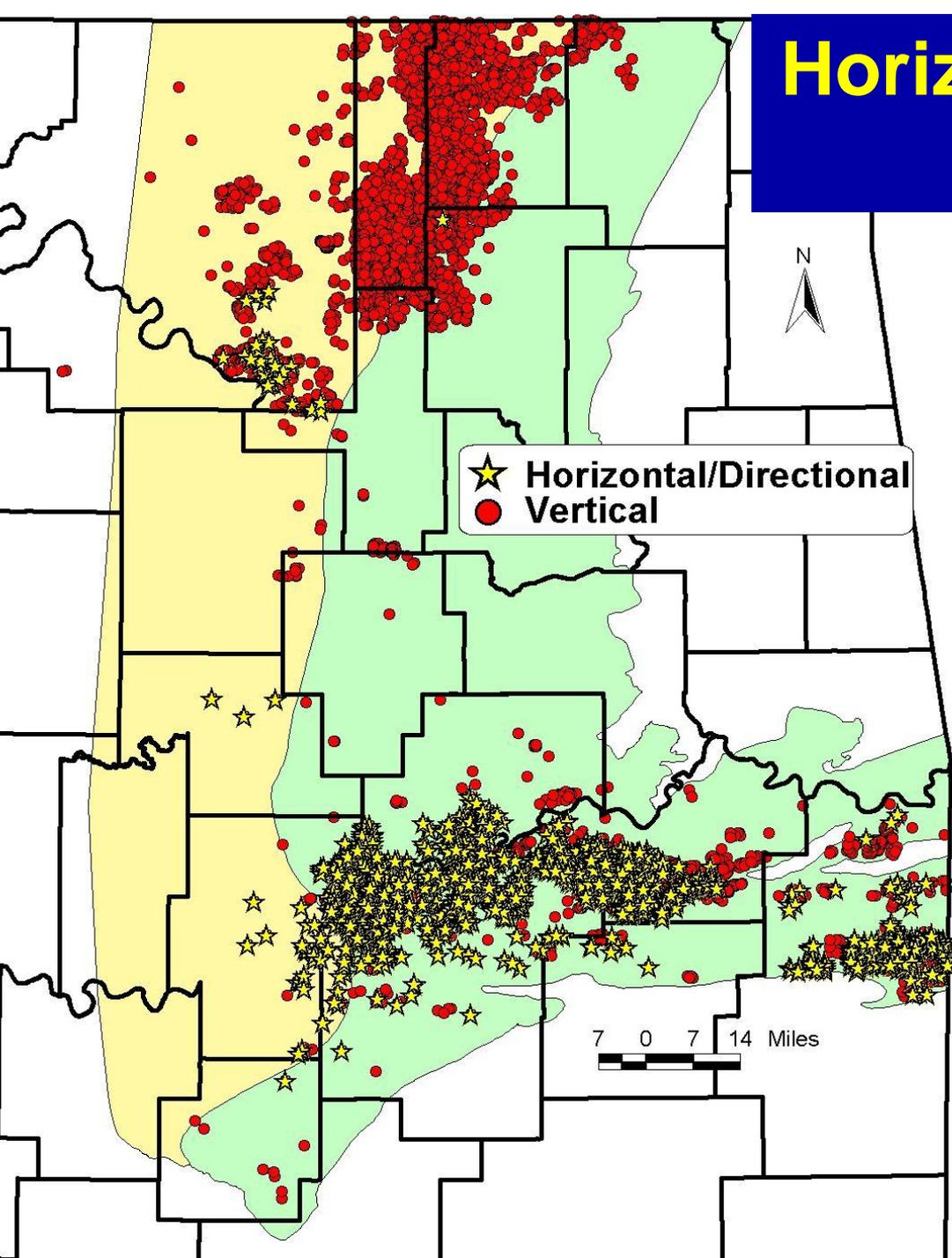
# Coalbed Methane Wells on Hartshorne Structure and Rank Map



# Effect of Hartshorne Sandstone Channel on Coalbed Methane Activity



# Horizontal CBM Wells (1998-2010)

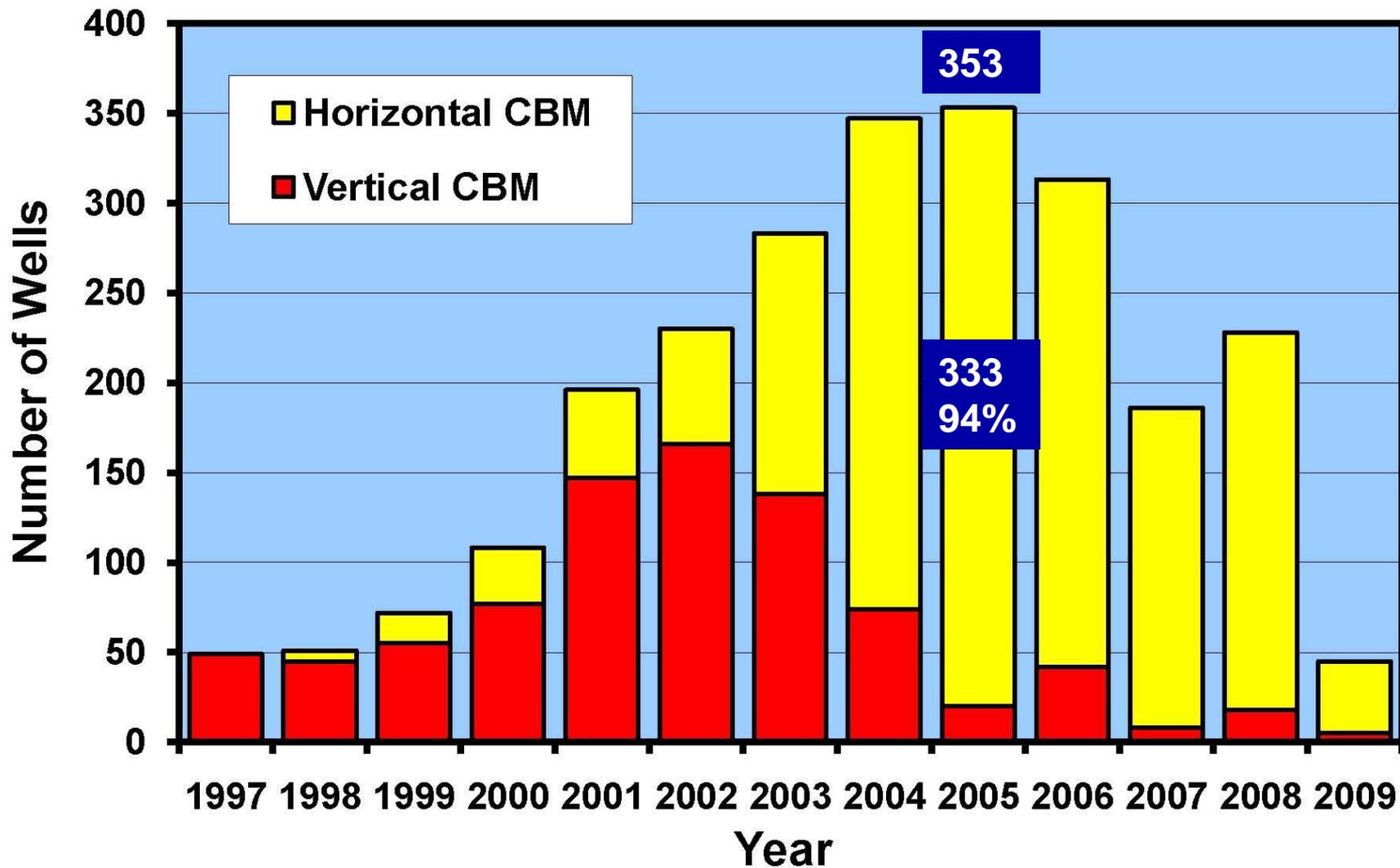


**Coalfield:** 4,203 vertical wells

**Shelf:** 33 horizontal/9 directional wells by Amvest Osage & CEP Mid-Continent (2004-2009)

**Arkoma:** 1,624 horizontal wells

# Arkoma Basin

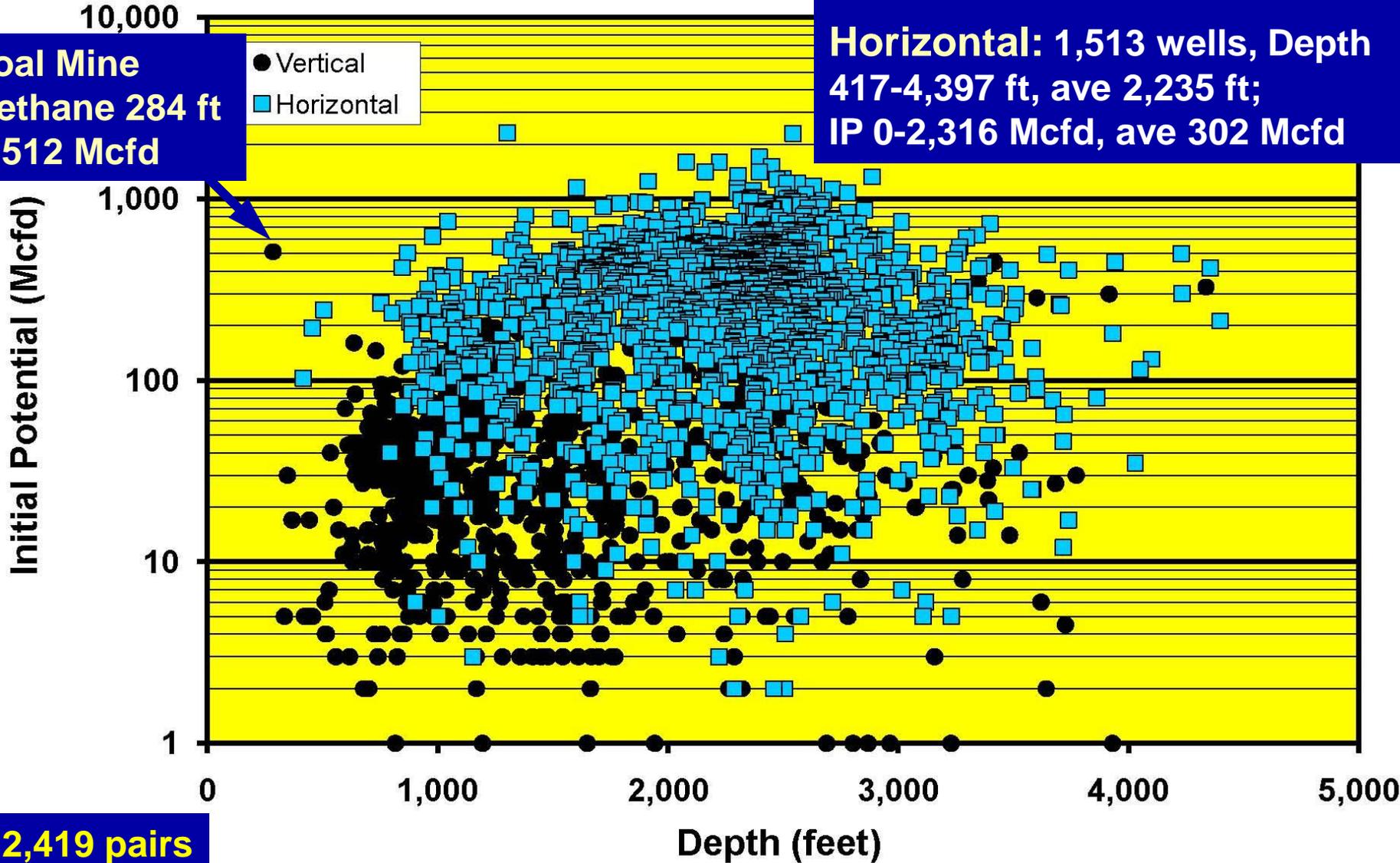


# Arkoma Basin

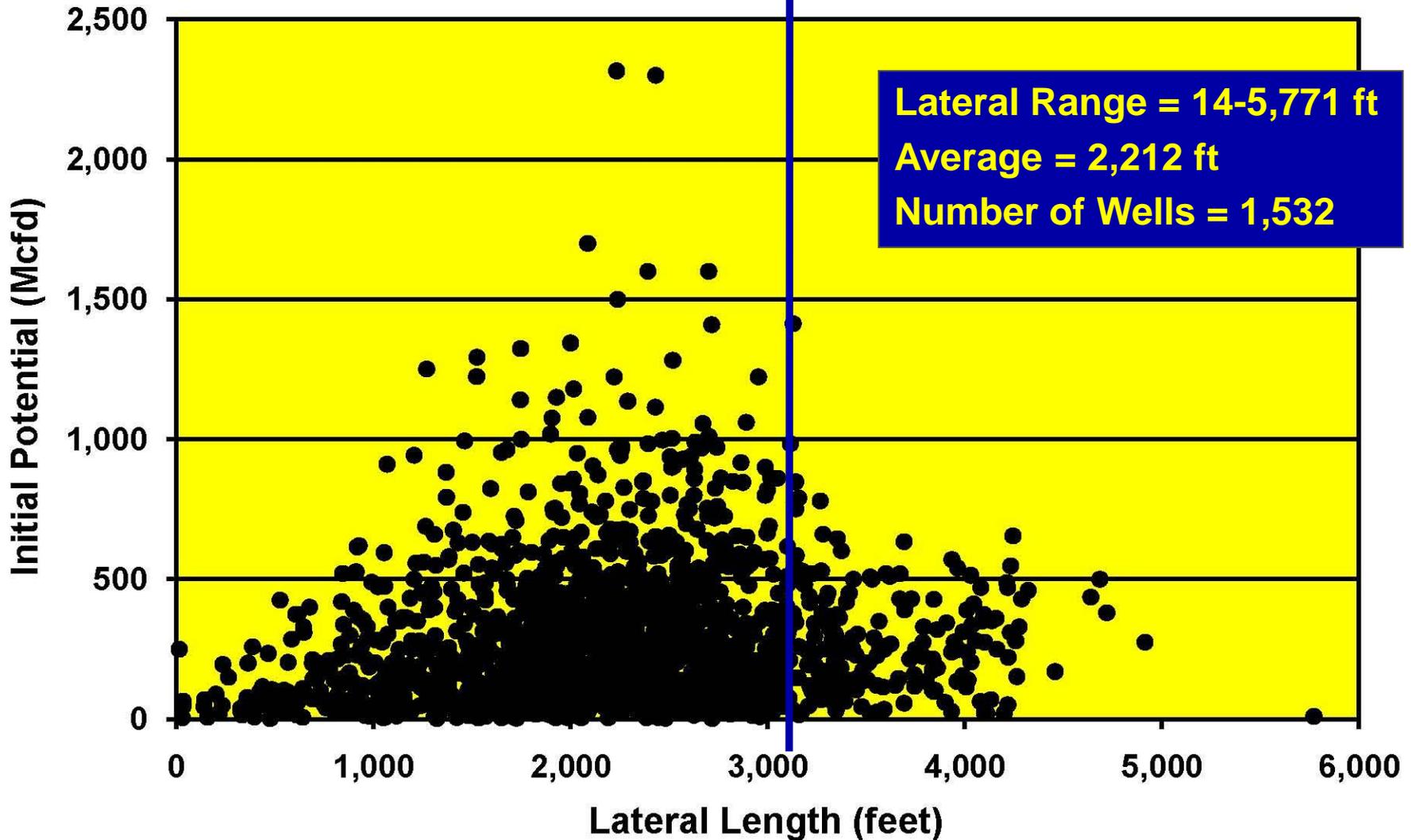
**Vertical:** 906 wells, Depth 284-4,337 ft, ave 1,446 ft; IP 0-512 Mcfd, ave 50 Mcfd

**Horizontal:** 1,513 wells, Depth 417-4,397 ft, ave 2,235 ft; IP 0-2,316 Mcfd, ave 302 Mcfd

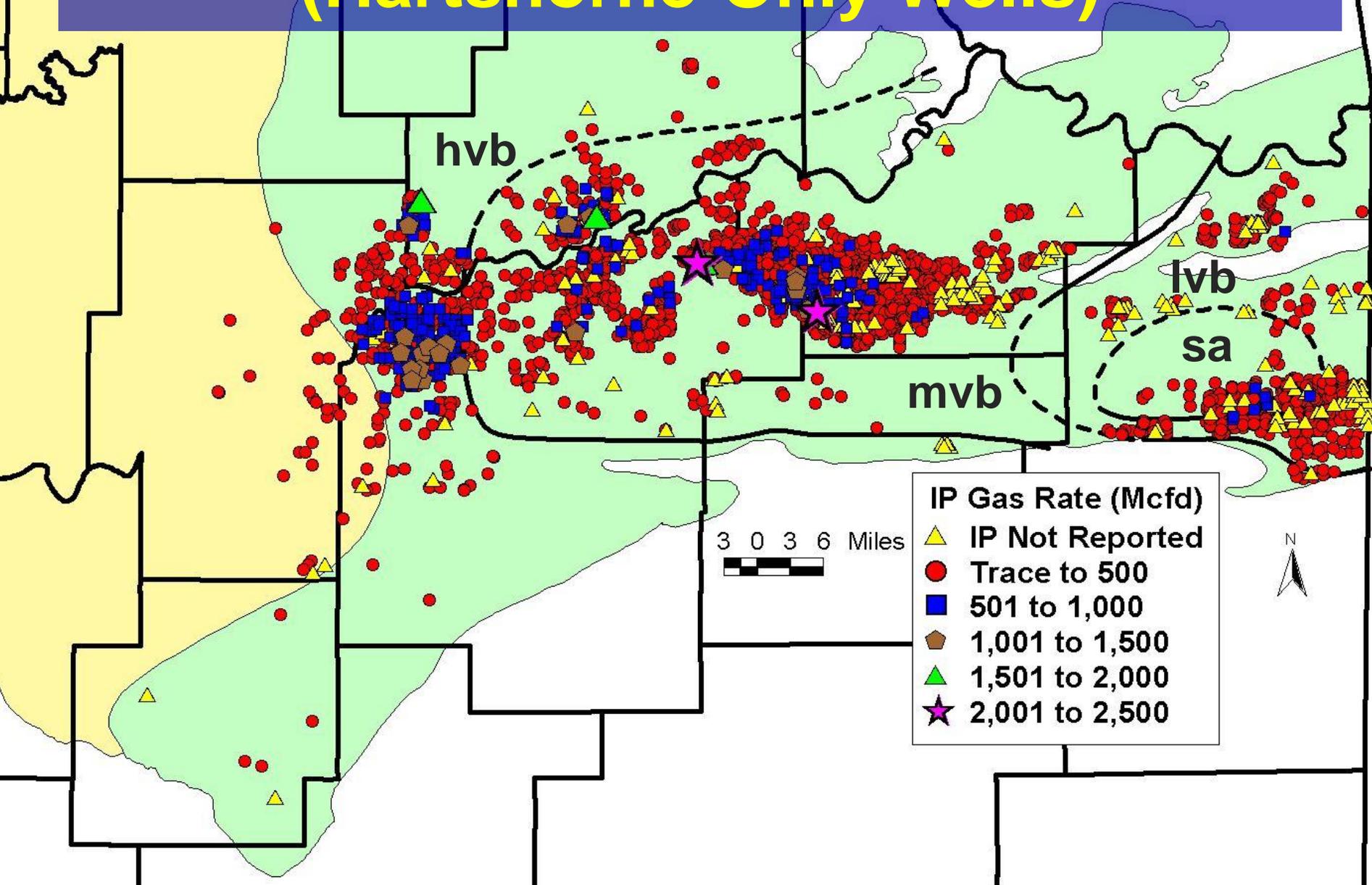
**Coal Mine Methane 284 ft & 512 Mcfd**

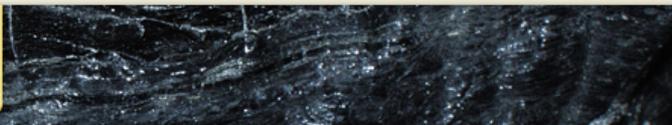


# Arkoma Basin Horizontal CBM Wells



# Initial Potential Related to Rank (Hartshorne-Only Wells)





- ▶ HOME
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- ▶ STAFF
- ▶ CALENDAR
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EARTHQUAKES

EDUCATION,  
OUTREACH

MAPPING

MEETINGS

## COAL AND COALBED METHANE

OKLAHOMA GEOLOGICAL SURVEY

Coal is an organic-rich rock derived from plant material deposited in a swamp, marsh, or bog. Coal varies by grade (percentage of mineral impurities), type (organic composition), and rank (level of coalification). Rank describes the transformation from peat (unconsolidated plant remains) through lignite, subbituminous, bituminous, semianthracite, and anthracite coal (rock) from increasing burial pressure, temperature, and time.

The [coalfield](#) in eastern Oklahoma is divided into the northeast Oklahoma shelf and the Arkoma Basin based on physiographic and structural differences. The commercial coal belt contains coal beds  $\geq 10$  in. thick that are mineable by surface methods at depths  $< 100$  ft and coal beds  $\geq 14$  in. thick that are mineable by underground methods. The noncommercial coal-bearing region has limited information on coal thickness and quality or contains coals that are too thin, of low quality, or too deep for surface mining.

The age of commercial coal-bearing strata in the Oklahoma coalfield is Desmoinesian (Middle Pennsylvanian). Generalized [stratigraphic columns](#) of the northeast Oklahoma shelf and Arkoma Basin show about 40 named and several unnamed coal beds and their range in thickness measured from outcrops, mines, and shallow core samples.

[Coal rank](#), generalized for all coals at or near the surface, ranges from high-volatile bituminous in the northeast Oklahoma shelf and western Arkoma Basin to medium-volatile bituminous and low-volatile bituminous in the eastern Arkoma Basin in Oklahoma. Rank increases from west to east and with depth in the Arkoma Basin, attaining semianthracite in Arkansas.

Remaining identified bituminous coal resources in beds  $\geq 10$  in. thick total 8.09 billion short tons (1 short ton equals 2,000 pounds) in 19 counties in eastern Oklahoma, an area of approximately 8,000 square miles. About 1.5 billion short tons of bituminous coal reserves (the economically recoverable part of coal resources) remain in Oklahoma. Oklahoma ranks 19th of 32 coal-bearing states in the U.S. based on coal reserves. From 1873-2008, 292 million short tons of bituminous coal were produced from underground and surface mines in the Indian Territory and Oklahoma. Peak annual [coal production](#) was 5.73 million short tons in 1981, with smaller production peaks during and immediately following World War I and World War II.

There are many uses for coal, primarily in combustion (generation of electricity, used to make steel), conversion (gasification and liquefaction), and it is used in Oklahoma in electric power plants and lime and cement kilns.

Coal generates and stores large quantities of natural gas (methane). Methane in Oklahoma is in the [northeast Oklahoma shelf](#) and [Arkoma Basin](#).

[Presentations, Reports and Maps](#)

[Coal Bibliographies](#)

[Links](#)

[Coal Database](#)

[Coal Maps and Illustrations](#)

Related interest: [Oil and Gas in Oklahoma](#)

## LINKS

Example of coal and coalbed-methane information available on the OGS Web site  
<http://www.ogs.ou.edu/coaldb.php>

# CBM Completions Table on OGS Web Site

Rec	API Number	Operator	Completion Date	Well Name	Field Name	S	To	I	4th	3rd	2nd	1st	County	Coal Bed	
5829	35-091-21780	Canaan Resources	12/21/2009	1H-5 Natalie	McIntosh County CBM Gas Ar	6	8	N	14	E	NE	NE	SE	McIntosh	Hartshorne
5830	35-121-24319	Canaan Resources	12/5/2009	1H-28 Harjo	Scipio NW	29	8	N	13	E	SE	SE	NE	Pittsburg	Hartshorne
5831	35-121-24320	Canaan Resources	11/28/2009	1H-29 Hayden	Scipio NW	29	8	N	13	E	SE	SE	NE	Pittsburg	Hartshorne
5832	35-121-24326	Canaan Resources	11/28/2009	1H-29 Kathryn	Scipio NW	29	8	N	13	E	NE	NE	SW	Pittsburg	Hartshorne
5833	35-121-24328	Canaan Resources	11/28/2009	1H-29 Craig	Scipio NW	29	8	N	13	E	NE	NE	SW	Pittsburg	Hartshorne
5834	35-121-24275	Canaan Resources	11/3/2009	1H-34 Kathy	Scipio NW	34	8	N	13	E	NW	NW	SE	Pittsburg	Hartshorne
5835	35-121-24285	Canaan Resources	12/18/2009	1H-36 Julie	Scipio NW	36	8	N	13	E	NW	NW	SE	Pittsburg	Hartshorne
5836	35-121-24255	Canaan Resources	11/7/2009	1H-36 Letha	Scipio NW	36	8	N	13	E	SW	SW	SE	Pittsburg	Hartshorne
5837	35-105-40455	NEOK Production Company	8/18/2007	R13-22A Big Creek	Halsell	22	27	N	17	E	WH	NW	SW	Nowata	
5838	35-063-24320	Canaan Resources	1/21/2010	2H-25 Hunter	Hughes County CBM Gas Ar	25	9	N	12	E	SH	SE	SW	Hughes	Hartshorne
5839	35-121-24329	Canaan Resources	1/26/2010	1H-25 Eloise	Scipio NW	24	8	N	13	E	SE	SW	SE	Pittsburg	Hartshorne
5840	35-105-40637	NEOK Production Company	12/23/2009	14-3 Cresap	Halsell	3	27	N	17	E	SW	SW	SW	Nowata	
5841	35-105-40609	NEOK Production Company	12/1/2009	R12-10 Ratcliff	Halsell	10	27	N	17	E	C	SW	NW	Nowata	
5842	35-105-40614	NEOK Production Company	5/1/2009	42-22 Adcock	Nowata County CBM Gas Ar	22	28	N	17	E	SE	SE	NE	Nowata	
5843	35-105-40643	NEOK Production Company	2/25/2010	34-22 Adcock	Nowata County CBM Gas Ar	22	28	N	17	E	SE	SW	SE	Nowata	
5844	35-105-40608	NEOK Production Company	12/1/2009	12-23 Adcock	Nowata County CBM Gas Ar	23	28	N	17	E	SH	SW	NW	Nowata	
5845	35-121-24144	Yale Oil Association	8/1/2008	1-16 Lalli	Pine Hollow S	16	5	N	13	E	SE	SE	SW	Pittsburg	Hartshorne
5846	35-121-24056	Davis Operating Company	12/18/2008	3H-18 Steele	Pine Hollow S	18	6	N	14	E	SW	NW	SW	Pittsburg	Hartshorne
5847	35-121-24055	Davis Operating Company	12/6/2008	2H-18 Steele	Pine Hollow S	18	6	N	14	E	SW	NW	SW	Pittsburg	Hartshorne
5848	35-121-24267	Canaan Resources	2/15/2009	1H-8 Rachel	Scipio NW	8	7	N	13	E	NW	NW	SW	Pittsburg	Hartshorne
5849	35-079-22087	Avatar Energy Limited Liability	9/28/2009	1-22 Solomon	Kinta	22	9	N	25	E	WH	WH	SW	Le Flore	Hartshorne
5850	35-091-21787	Canaan Resources	3/26/2010	1H-1 Lizzy	McIntosh	1	8	N	13	E	NE	NE	SW	McIntosh	Hartshorne
5851	35-091-21774	Williams Production	11/14/2008	5-24H Duke	McIntosh	24	9	N	15	E	NE	SE	NE	McIntosh	Hartshorne
5852	35-091-21757	Williams Production	11/24/2008	2-28H Wiedel	McIntosh	28	9	N	15	E	NW	SW	SW	McIntosh	Hartshorne
5853	35-121-24231	Davis Operating Company	11/18/2009	1-25 Mary	Quinton District	25	7	N	16	E	NE	NE	NE	Pittsburg	Hartshorne
5854	35-091-21786	Canaan Resources	3/29/2010	4H-1 Lizzy	Quinton	1	8	N	13	E	NW	NW	SW	McIntosh	Hartshorne
5855	35-105-40254	NEOK Production Company	5/3/2010	1 Hunter	Nowata County CBM Gas Ar	28	28	N	17	E	SE	SE	NE	Nowata	
5856	35-121-24054	Davis Operating Company	8/20/2009	1H-18 Steele	Pine Hollow S	18	6	N	14	E	SW	NW	SW	Pittsburg	Hartshorne
5857	35-147-27931	Performance Energy Partners	2/5/2009	09-6 Gill	Wann	29	28	N	14	E	NE	SW	SW	Washington	Rowe
5858	35-105-40679	NEOK Production Company	5/10/2010	22-23 Adcock	Wimer	23	28	N	17	E	SH	SE	NW	Nowata	
5859	35-105-40426	Endeavor Energy Resources	8/17/2007	24-2 Moore Gas	Ruthdale SW	24	27	N	14	E	SW	SW	SE	Nowata	
5860	35-147-27084	K & E Field Services	3/25/2004	2-1 Warren Foster	Ochelata N	25	25	N	12	E	NH	NE	NW	Washington	Mulky
5861	35-105-26365	International Asset Management	5/22/2001	1 Holt	Coffeyville S	31	29	N	15	E	SW	NE	SE	Nowata	Mulky
5862	35-121-24256	Williams Production	5/28/2009	2-3H Mays	Pittsburg CBM Gas Area	2	8	N	15	E	SW	SW	SW	Pittsburg	Hartshorne
5863	35-105-40597	NEOK Production Company	7/12/2010	41-10 Ratcliff	Halsell	10	27	N	17	E	C	NE	NE	Nowata	
5864	35-121-24405	Unit Petroleum Company	5/20/2010	5H Duncan	Ulan E	13	7	N	13	E	NW	NE	NW	Pittsburg	Hartshorne
5865	35-121-24408	Unit Petroleum Company	5/16/2010	6H Duncan	Ulan E	13	7	N	13	E	SW	NE	SW	Pittsburg	Hartshorne
5866	35-121-24374	Unit Petroleum Company	5/2/2010	5H Frederick	Pittsburg County CBM Gas Ar	26	7	N	13	E	SW	SW	SW	Pittsburg	Hartshorne
5867	35-121-24383	Unit Petroleum Company	5/3/2010	3H Frederick	Ulan E	26	7	N	13	E	SW	SW	NW	Pittsburg	Hartshorne
5868	35-121-24418	Unit Petroleum Company	5/23/2010	4H Frederick	Ulan E	26	7	N	13	E	NE	NE	NE	Pittsburg	Hartshorne
5869	35-121-24422	Unit Petroleum Company	5/28/2010	6H Frederick	Pittsburg County CBM Gas Ar	26	7	N	13	E	NE	NE	SE	Pittsburg	Hartshorne

5,869