

Presented at Mid-Continent Coalbed Methane and Gas Shale
Symposium II in Tulsa on October 23, 2006

Frontier Gas-Shale Plays of Oklahoma

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Oklahoma Geological
Survey



Gas Shales

Gas shales are varieties of hydrocarbon source rocks (an important part of a petroleum system).

HYDROCARBON SOURCE ROCK CLASSIFICATION

Organic matter type refers to the kerogen or maceral type and can be lumped into gas generative (Type III), oil generative (Types I and II), or inert (Type IV).

Organic matter quantity is determined by the total organic carbon (TOC) content (weight percent, whole-rock basis).

Vitrinite reflectance (%Ro, oil immersion) is the most common **thermal maturity** indicator. Vitrinite is a maceral derived from the woody tissues of vascular plants. The oil window is considered to be from 0.5–1.35% Ro.

Gas Shales

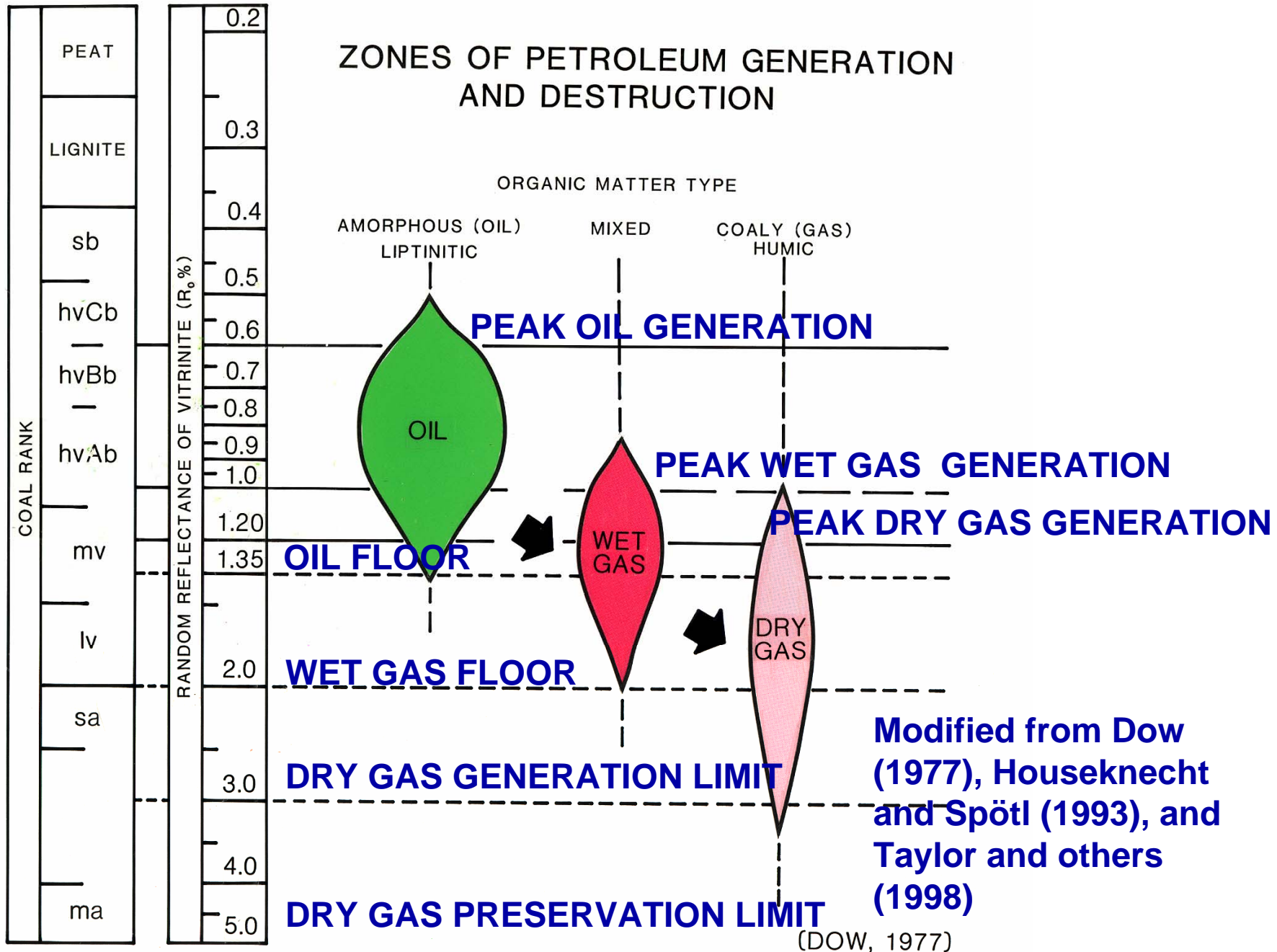
Definition: Gas shales are organic-rich, fine-grained sedimentary rocks (shale to siltstone) containing a minimum of 0.5 wt % TOC.

Gas shales may be thermally marginally-mature (0.4–0.6% R_o) to mature/post-mature (0.6–>2.0% R_o) and contain biogenic to thermogenic methane. Gas is generated and stored in situ in gas shales as both adsorbed (on organic matter) and free gas (in fractures and pores). As such, gas shales are self-sourced reservoirs. Low-permeable shales require extensive fractures (natural or induced) to produce commercial quantities of gas.

Questions to Resolve

- What is the minimum thermal maturity needed for shales containing oil-generative organic matter (Types I and II Kerogen) to be economic gas shales? [**>1.10-1.3%VRo**]
- What is the importance of natural vs. induced fractures
- What is the importance of free gas vs. sorbed gas?

ZONES OF PETROLEUM GENERATION AND DESTRUCTION



Guidelines for the Barnett Shale

VRo Values

Maturity

<0.55%

Immature

0.55-1.15%

Oil Window (peak
oil at 0.90%VRo)

1.15-1.40%

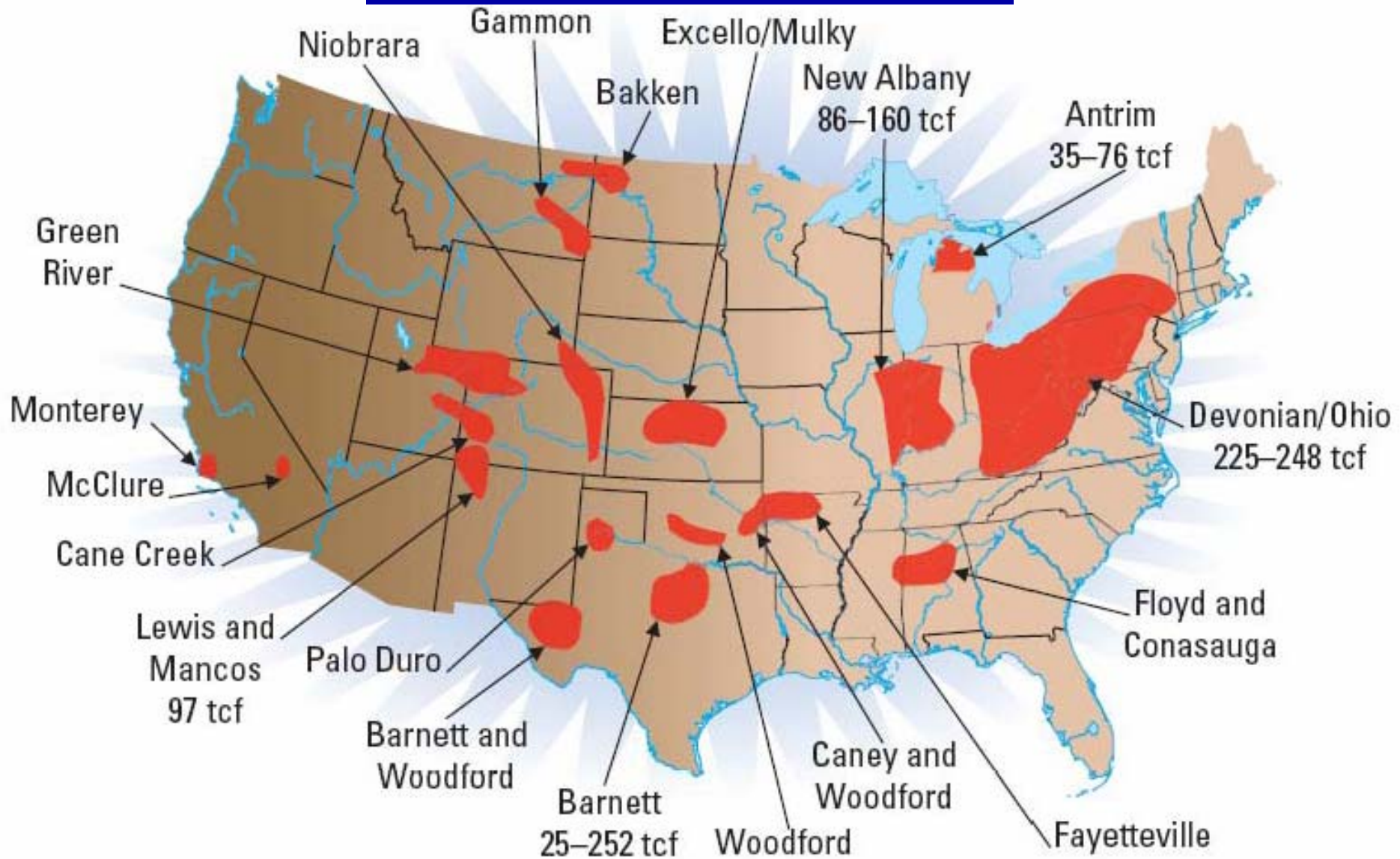
Condensate–Wet-
Gas Window

>1.40%

Dry-Gas Window

Jarvie and others, 2005

U.S. Shale Gas Basins



Source: Schlumberger shale gas white paper, 2005

Hydrocarbon Source Rocks of Oklahoma

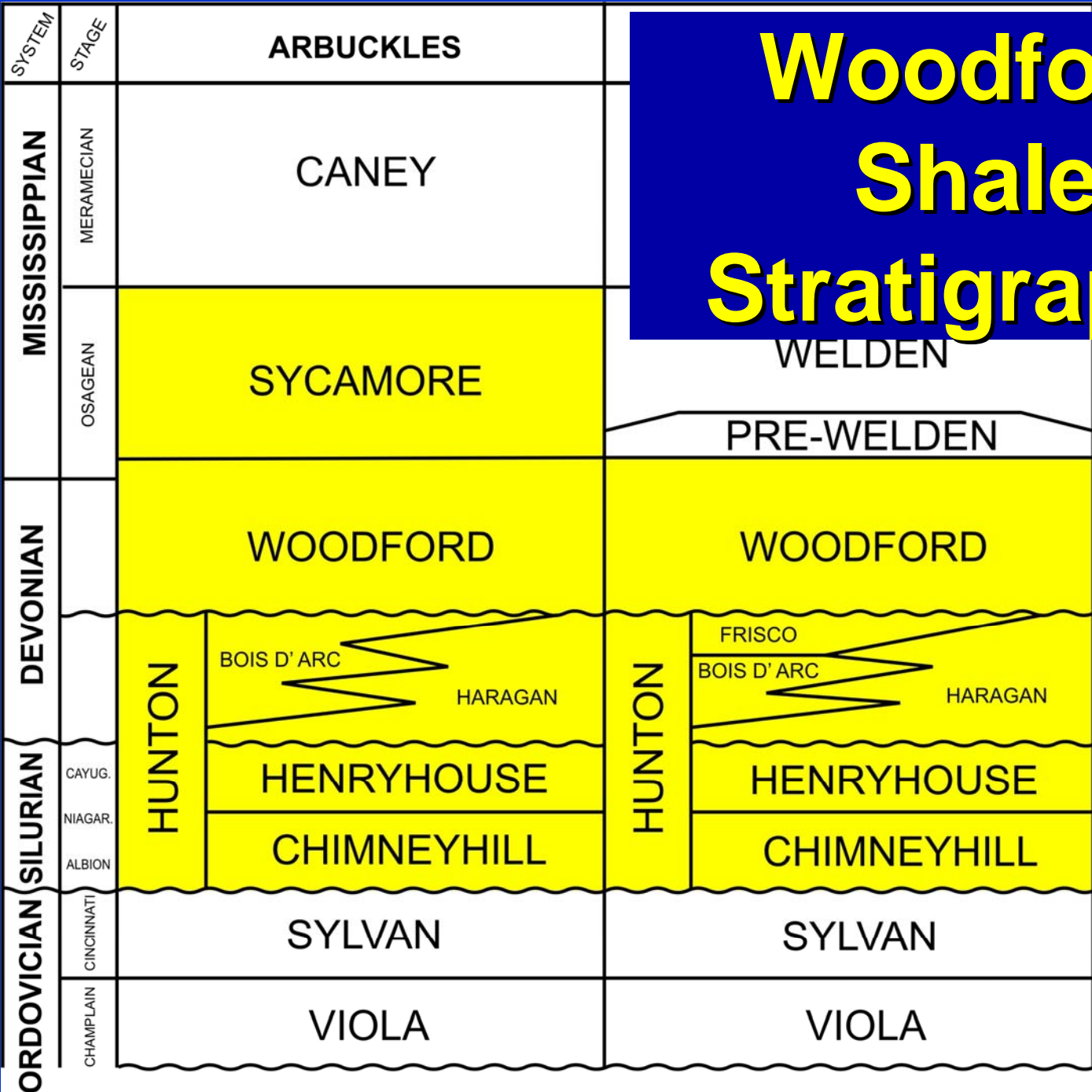
SYSTEM	PRODUCING INTERVAL	HYDROCARBON-SOURCE ROCK	KEROGEN TYPE	TOC %
PERMIAN	PERMIAN (UNDIFFERENTIATED)			
PENNSYLVANIAN	VIRGILIAN	UPPER AND MIDDLE PENNSYLVANIAN	II III	<1-25
	DESMOINESIAN			
	ATOKAN			
MISSISSIPPIAN	MORROWAN	MORROWAN	III	0.5-3.4
	SPRINGER FORMATION	SPRINGER FORMATION	III	
DEVONIAN	PRE-CHESTER MISSISSIPPIAN (UNDIFFERENTIATED)	WOODFORD SHALE	II III	<1-14
SILURIAN	HUNTON GROUP			
ORDOVICIAN	SIMPSON GROUP	SYLVAN SIMPSON GROUP	I II II	<1-9
UPPER CAMBRIAN	ARBUCKLE GROUP			

Johnson and Cardott, 1992

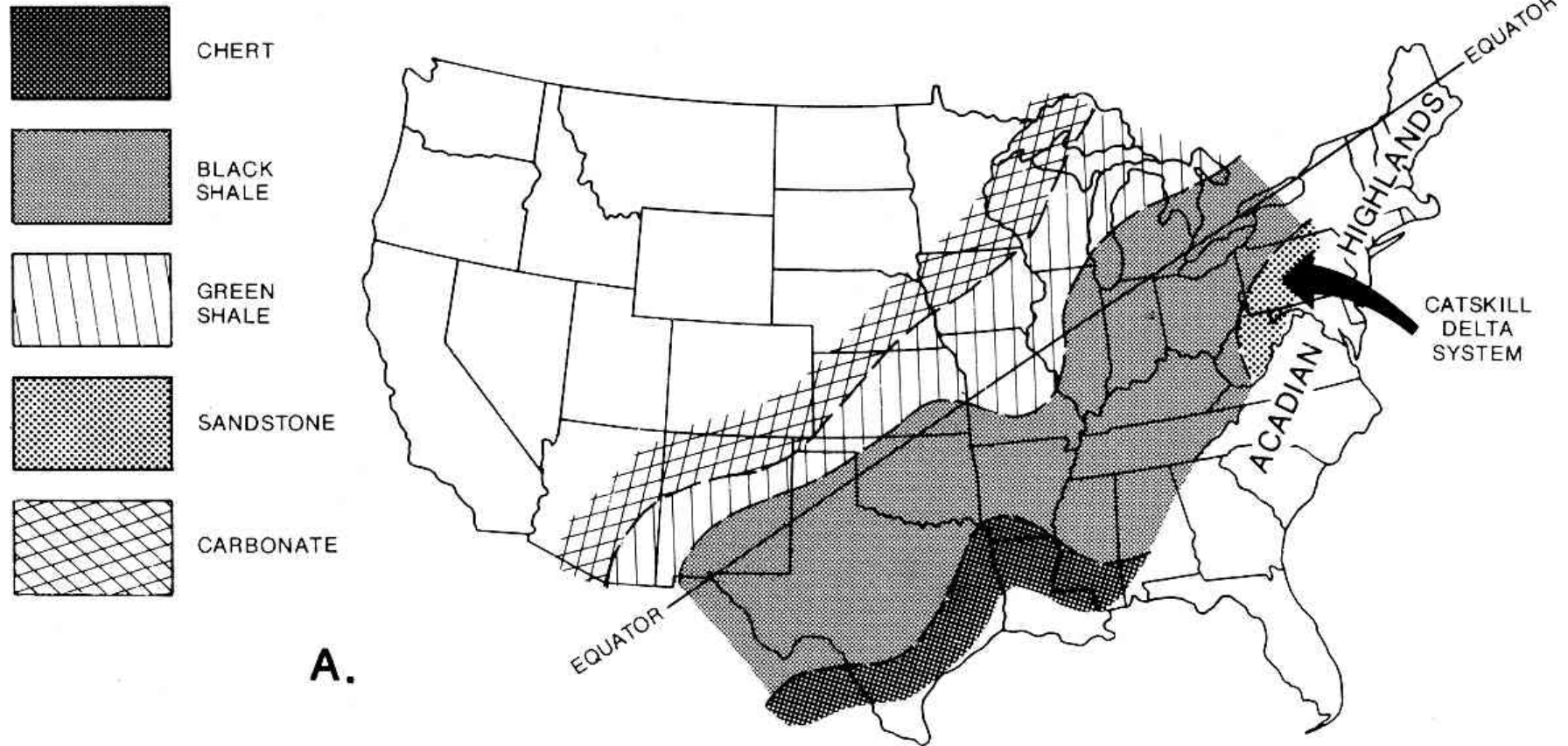
Potential Gas Shales of Oklahoma

FORMATION	TOC (WT %)
Excello Shale (black shale lithofacies)	1-17
Caney Shale	2-8
Woodford Shale	<1-14

Woodford Shale Stratigraphy

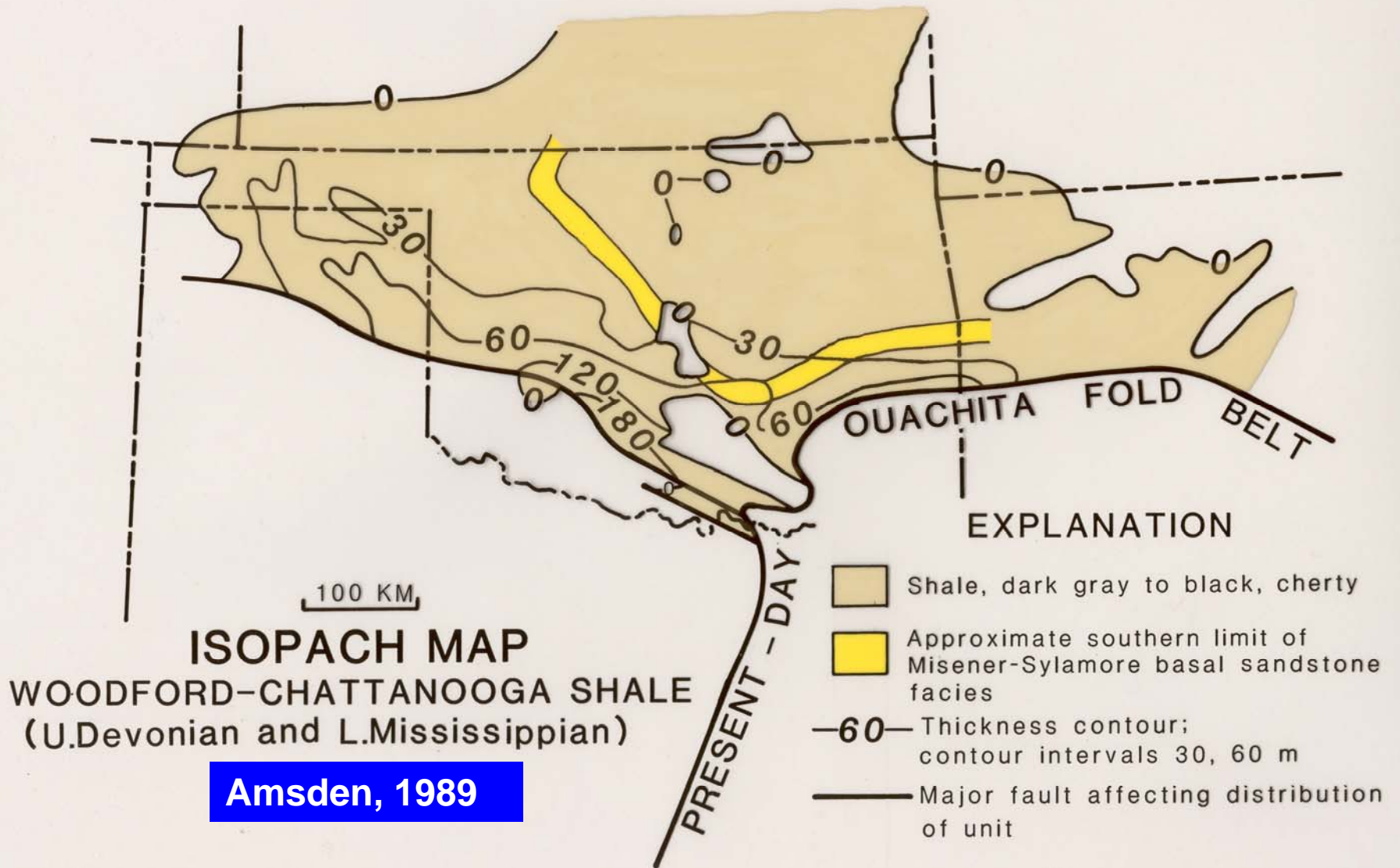


Paleogeography and Facies Distribution in the Late Devonian

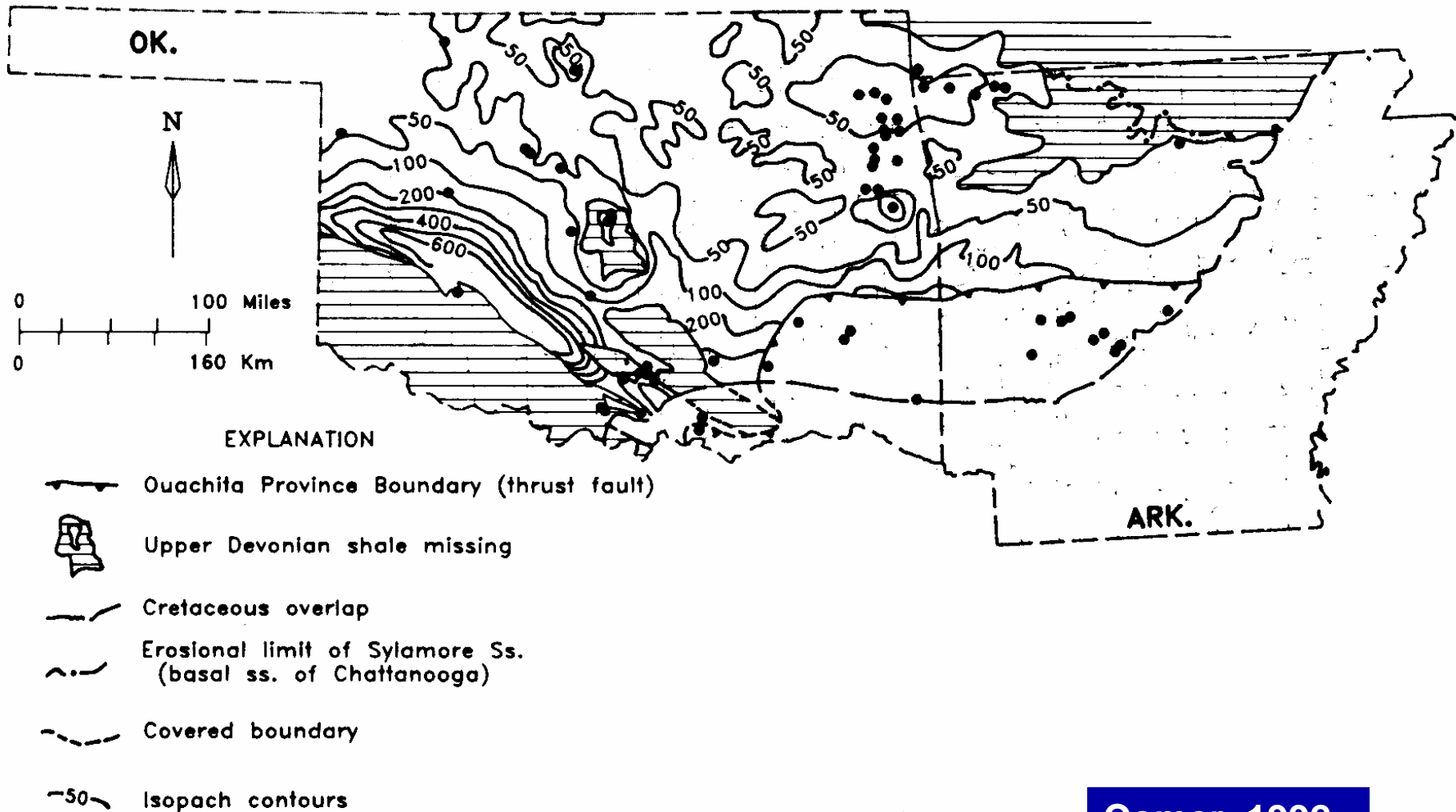


See OGS Map GM-9 for
pre-Woodford rocks

Kirkland and others, 1992



Isopach Map of Woodford Shale

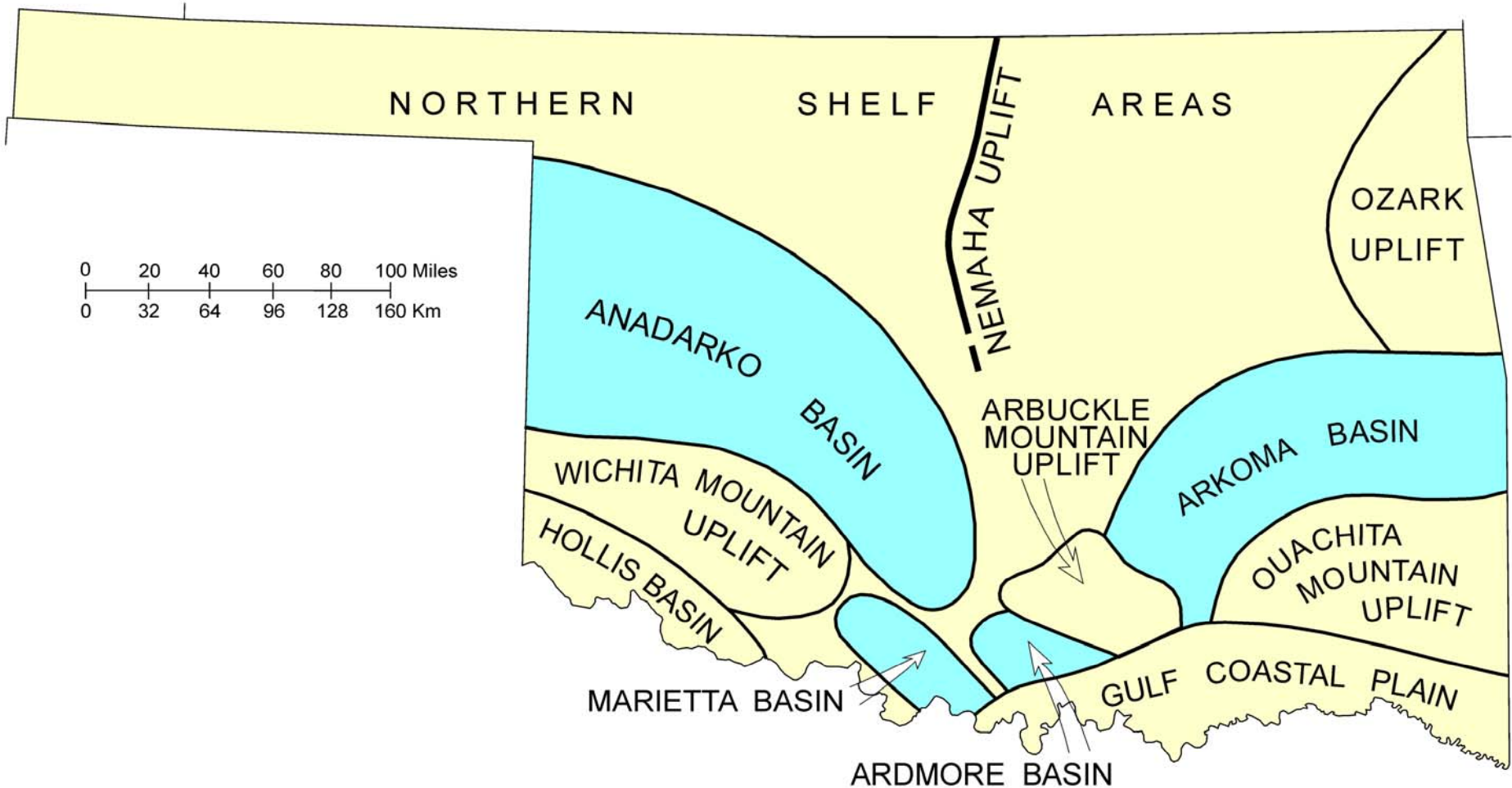


Comer, 1992

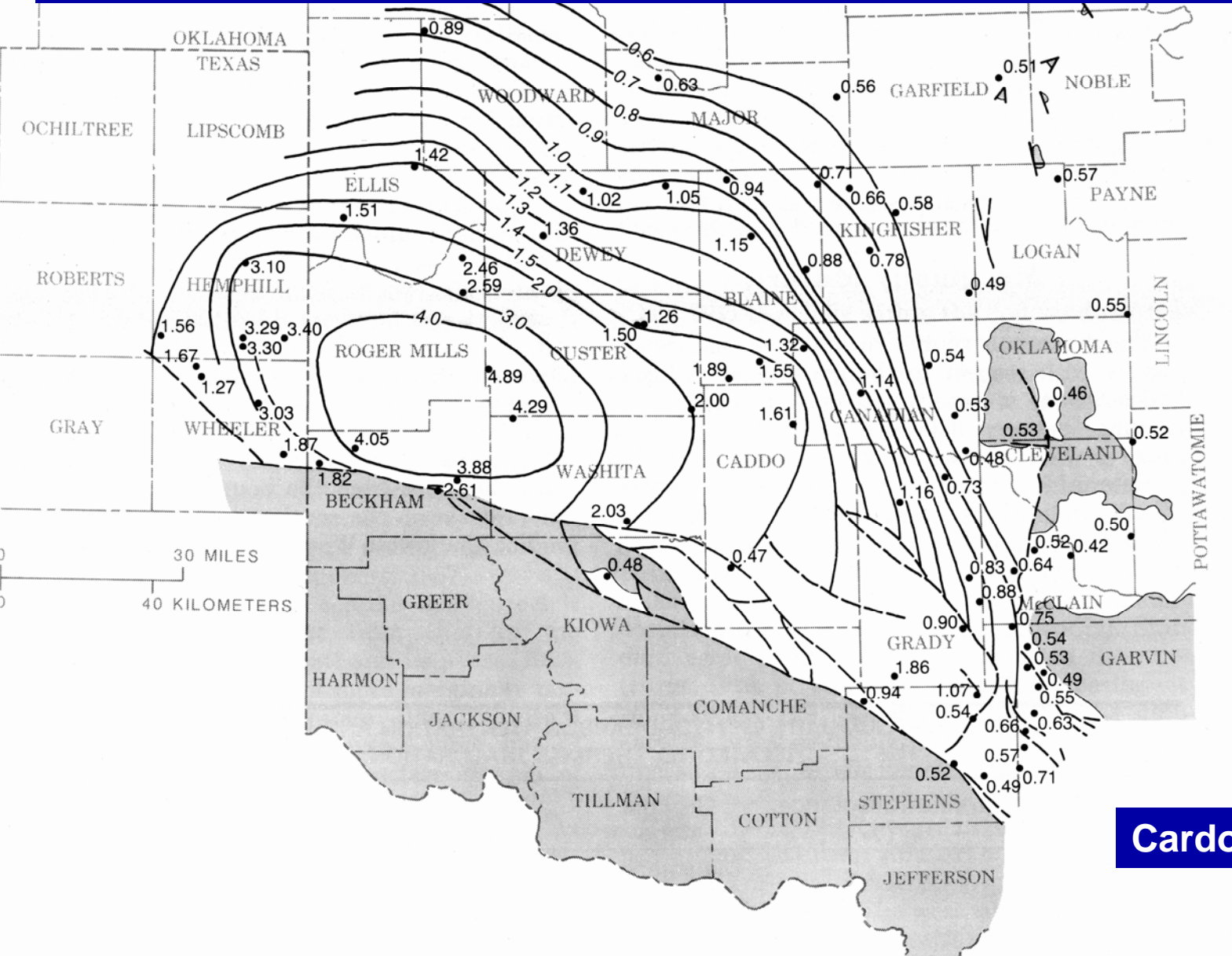


55-87% Quartz

Geologic Provinces of Oklahoma

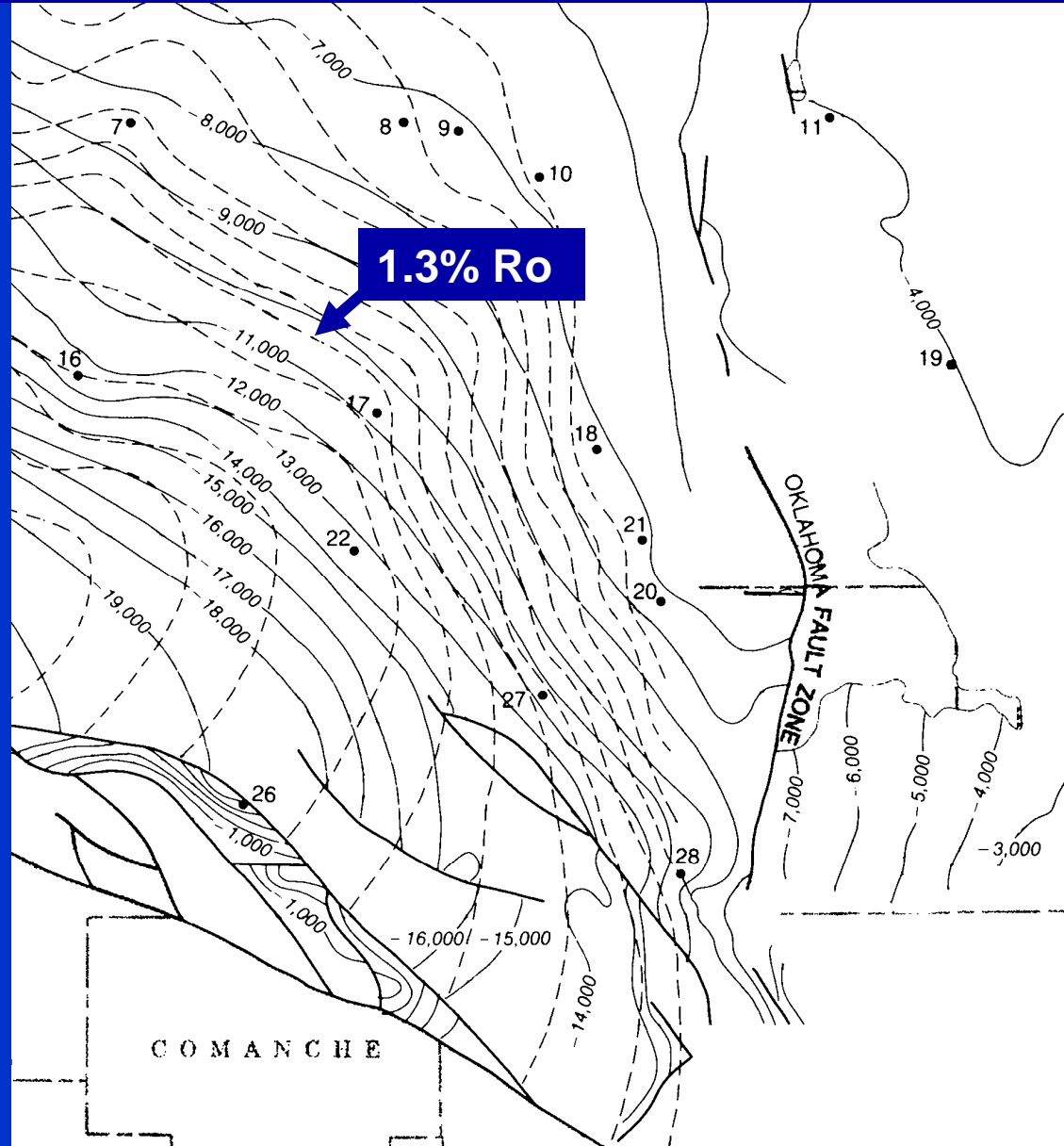


Vitrinite Reflectance of Woodford Shale, Anadarko Basin



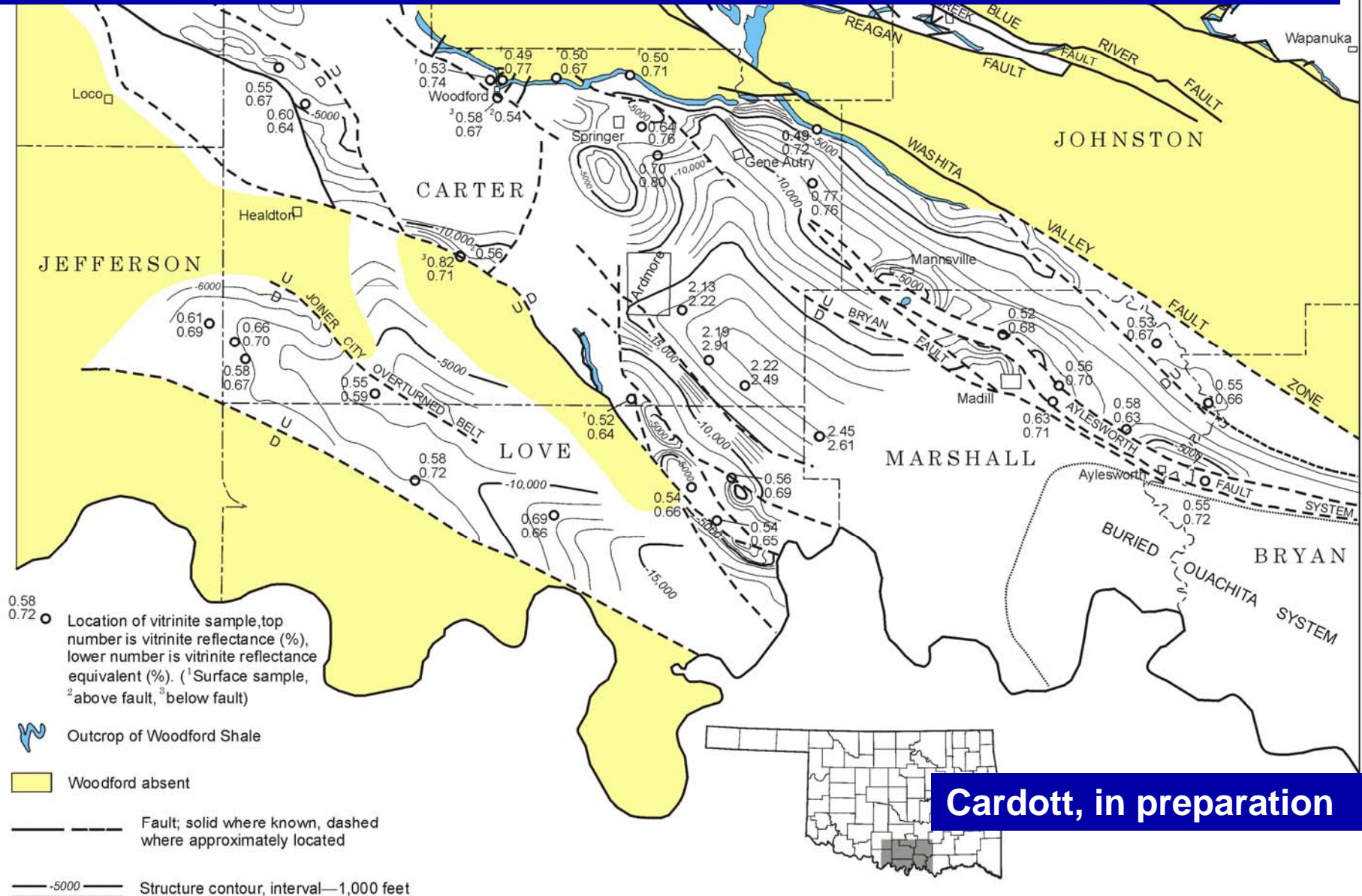
Cardott, 1989

Structure and Vitrinite Reflectance of Woodford Shale, Anadarko Basin

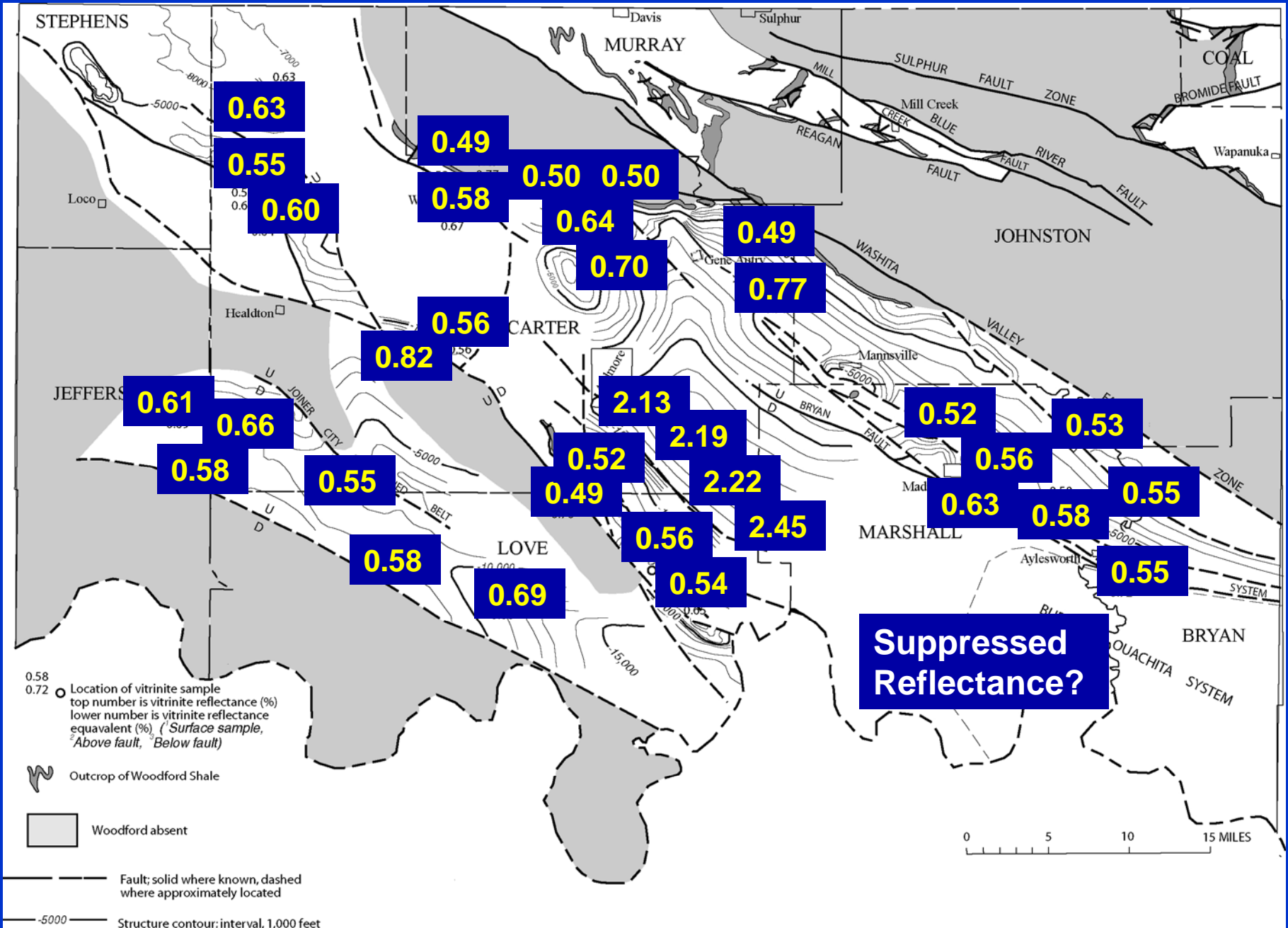


Cardott and
Lambert, 1985

Structure and Vitrinite Reflectance of Woodford Shale, Southern Oklahoma



Cardott, in preparation

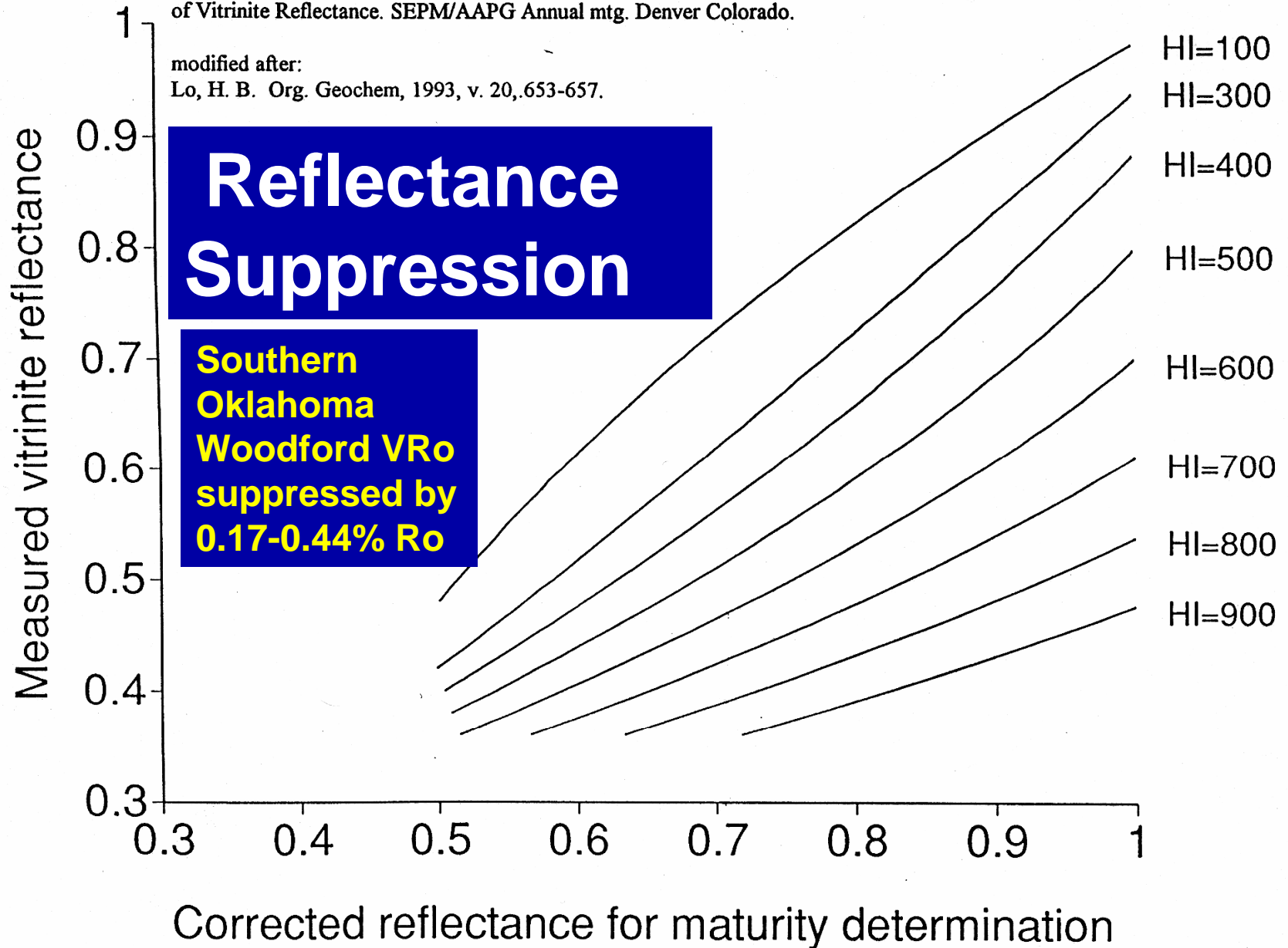


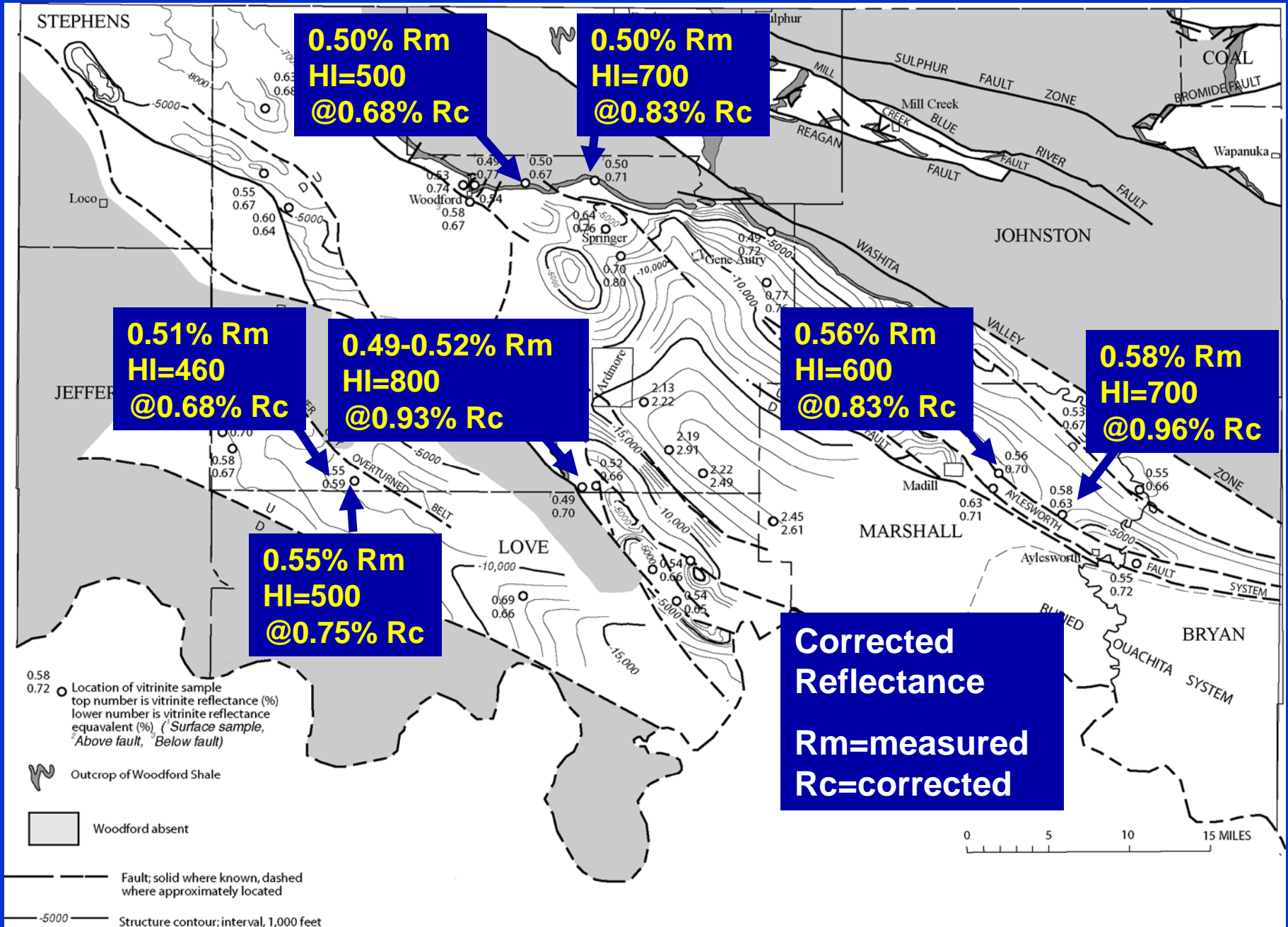
from:

Quick, J. C., Wavrek D. A., 1994, Suppressed reflectance vitrinite: Recognition and correction, Poster Session on: Thermal Maturity in Sedimentary Basins: Uses and Abuses of Vitrinite Reflectance. SEPM/AAPG Annual mtg. Denver Colorado.

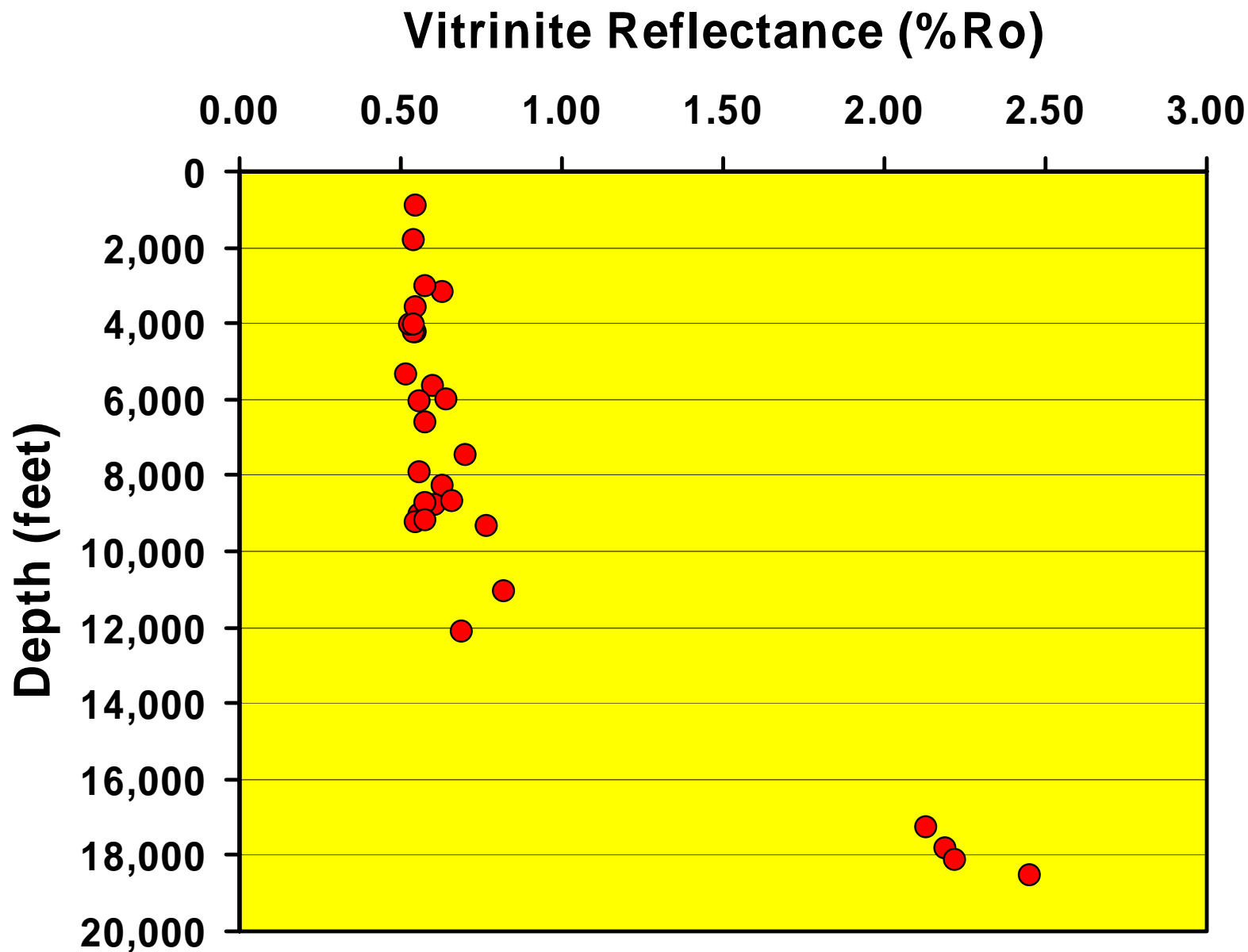
modified after:

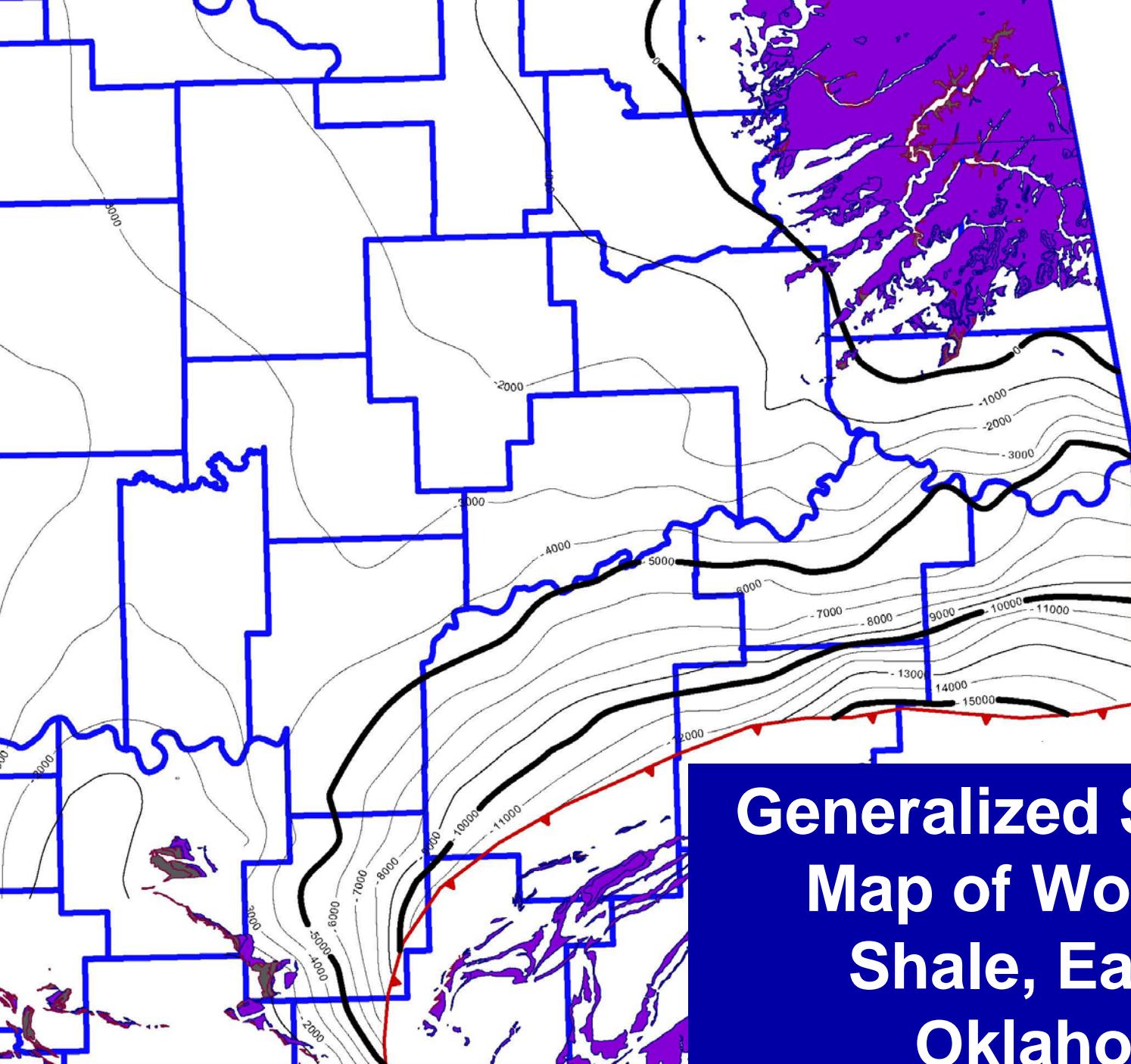
Lo, H. B. Org. Geochem, 1993, v. 20, 653-657.





Southern Oklahoma VRo vs Depth

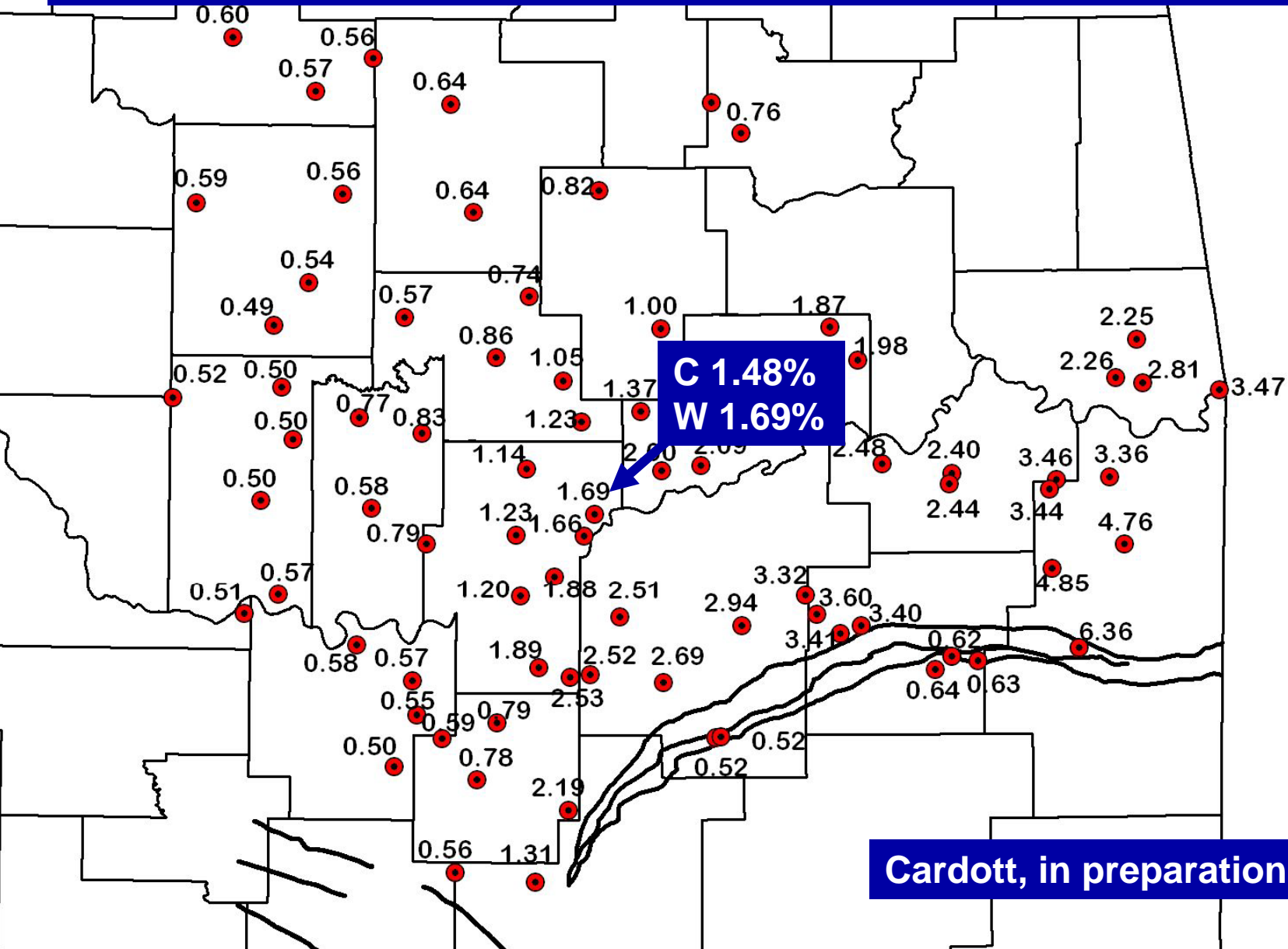




Map prepared
by R. Vance
Hall using
Petra

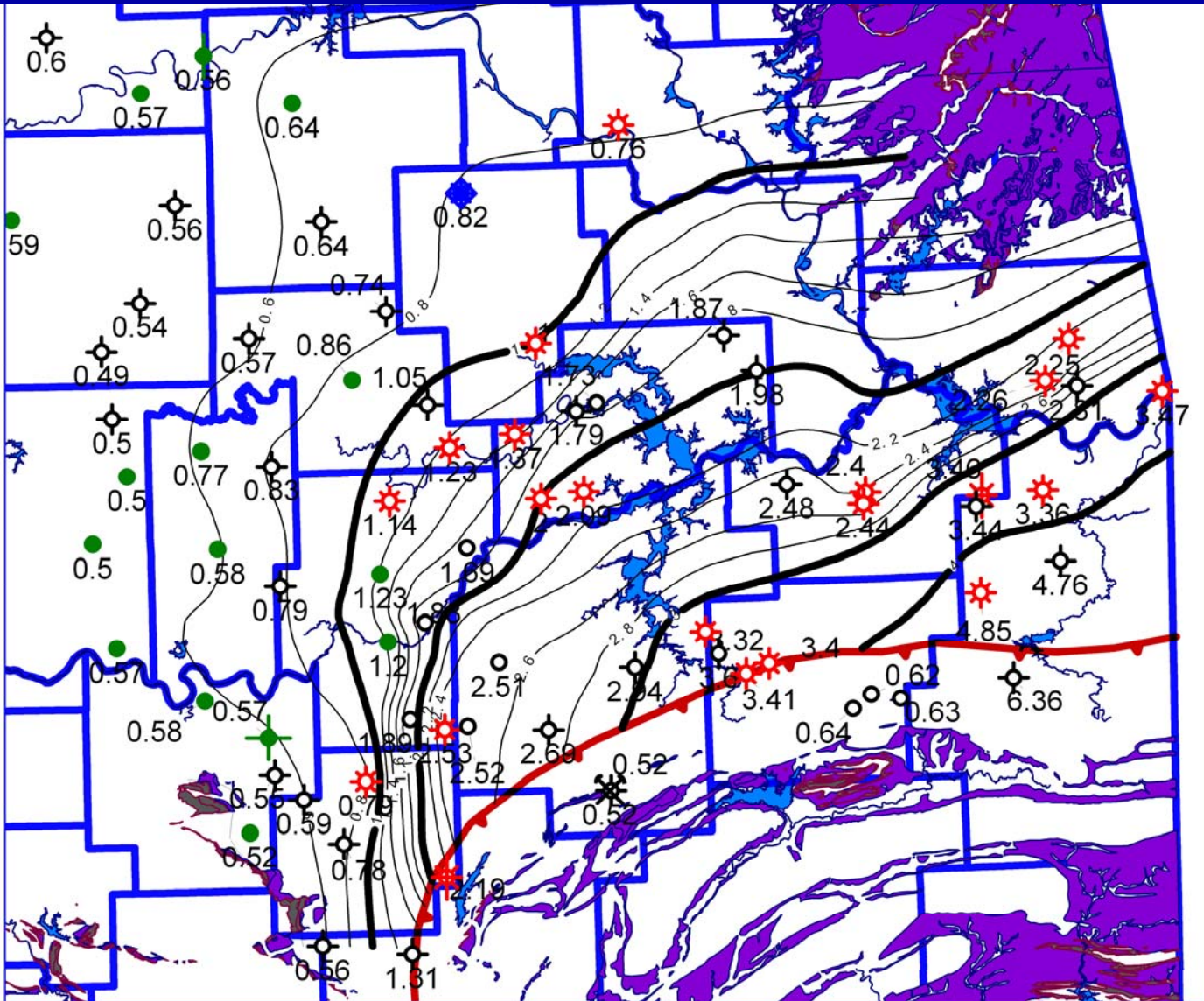
Generalized Structure Map of Woodford Shale, Eastern Oklahoma

Vitrinite Reflectance of Woodford Shale, Eastern Oklahoma



Cardott, in preparation

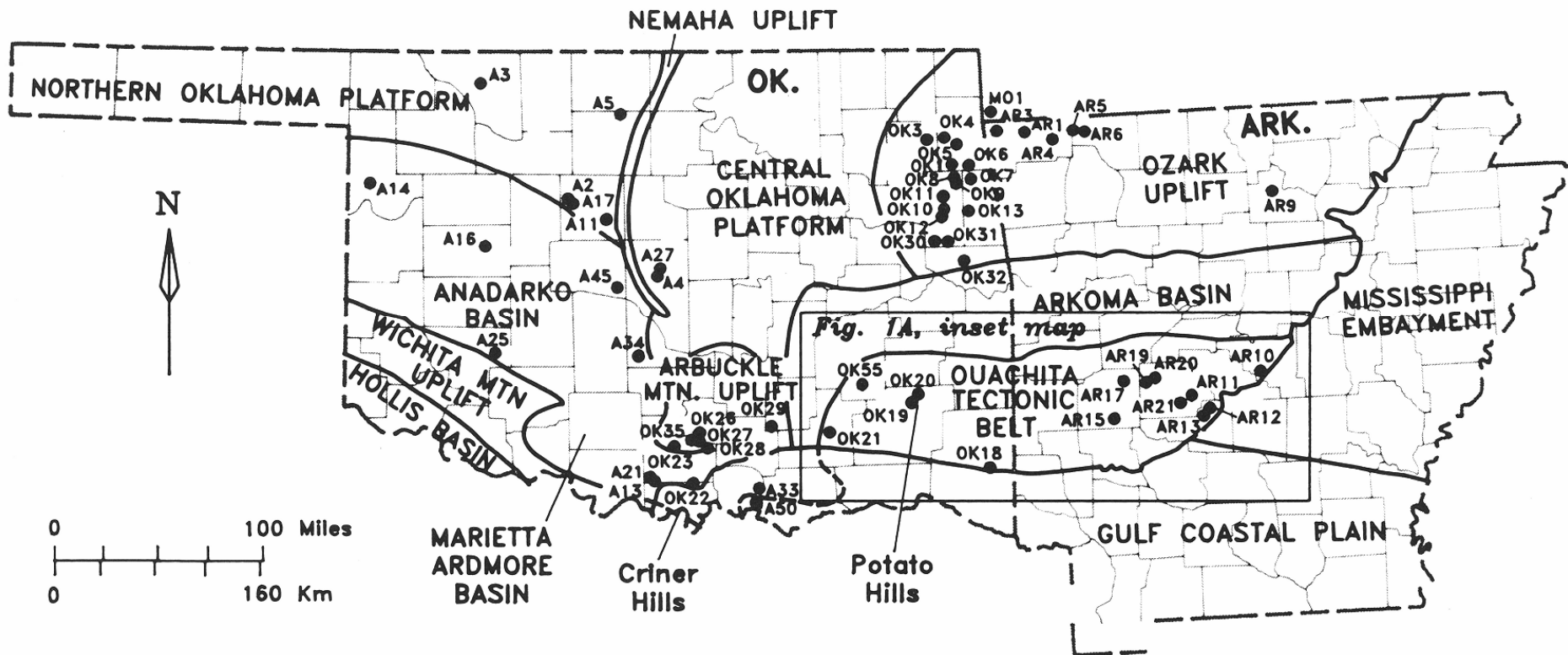
Isoreflectance Map of the Woodford Shale in Eastern Oklahoma

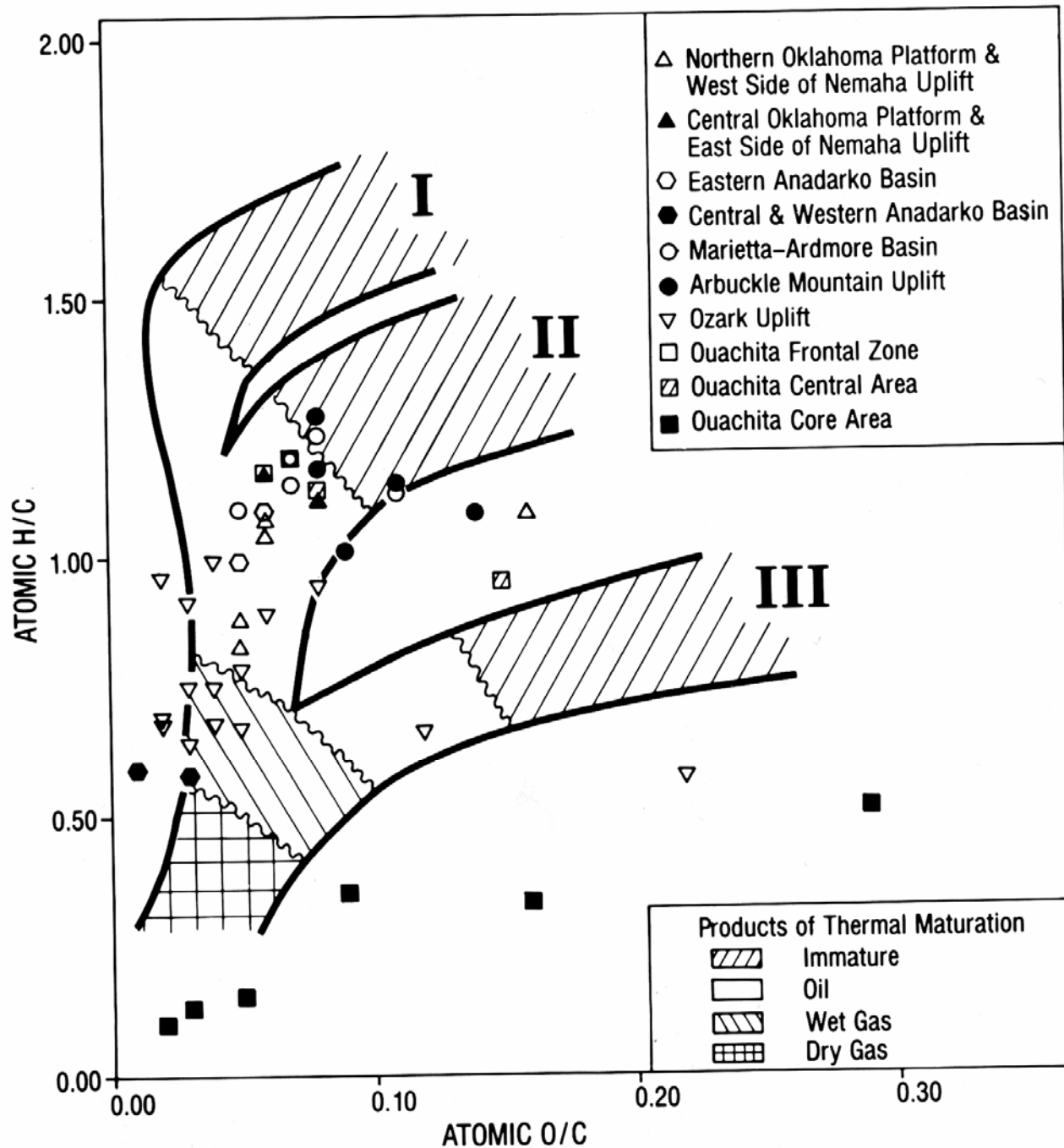


Map prepared
by R. Vance
Hall using
Petra

**Cardott, in
preparation**

Geologic Provinces and Sample Localities of Comer, 1992





Total Organic Carbon Content of Woodford Shale

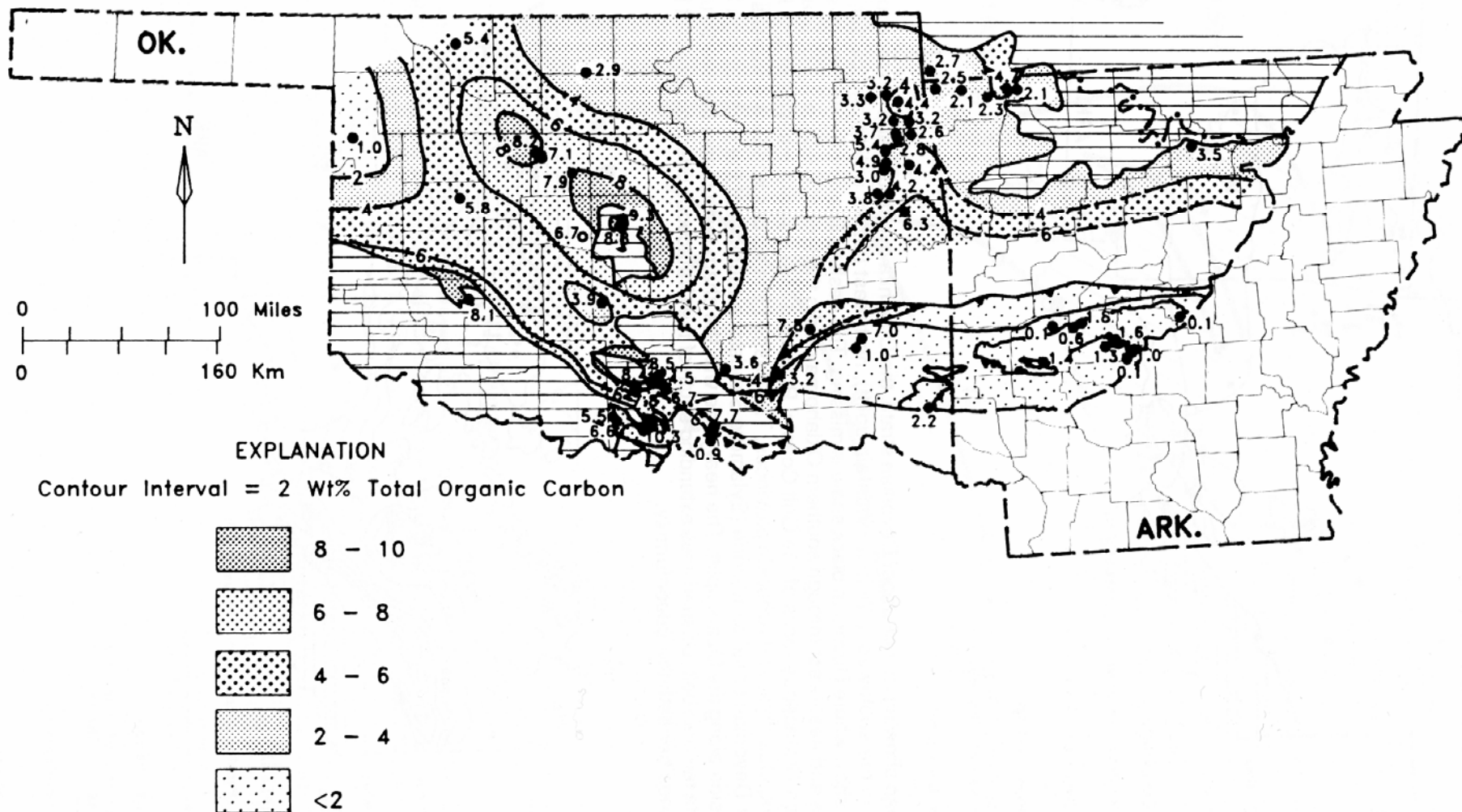
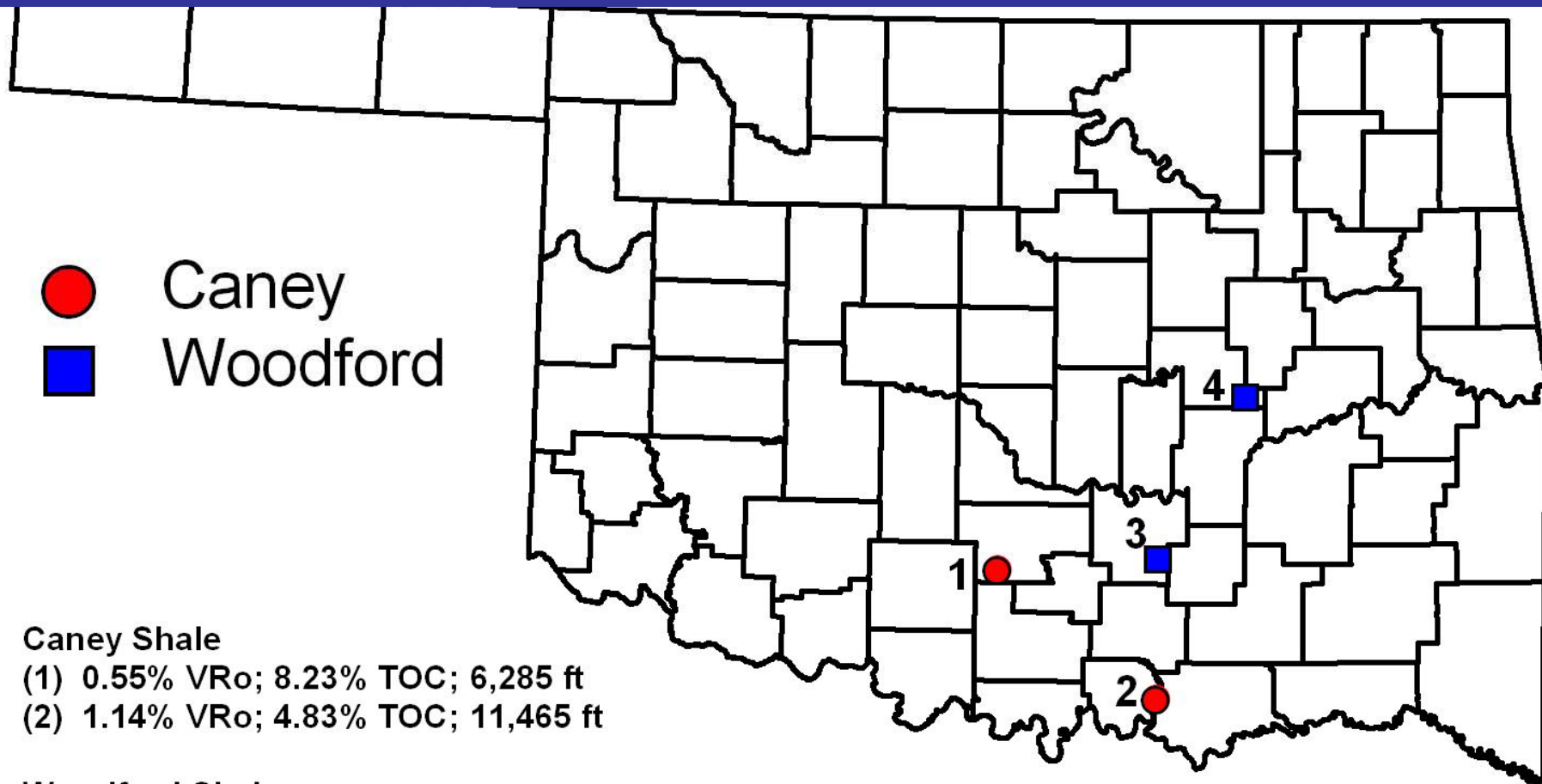


Figure 5. Map showing total organic carbon distribution.

Rock-Eval Pyrolysis Data from Oklahoma Petroleum Information Center (OPIC) Cores



Caney Shale

(1) 0.55% VRo; 8.23% TOC; 6,285 ft

(2) 1.14% VRo; 4.83% TOC; 11,465 ft

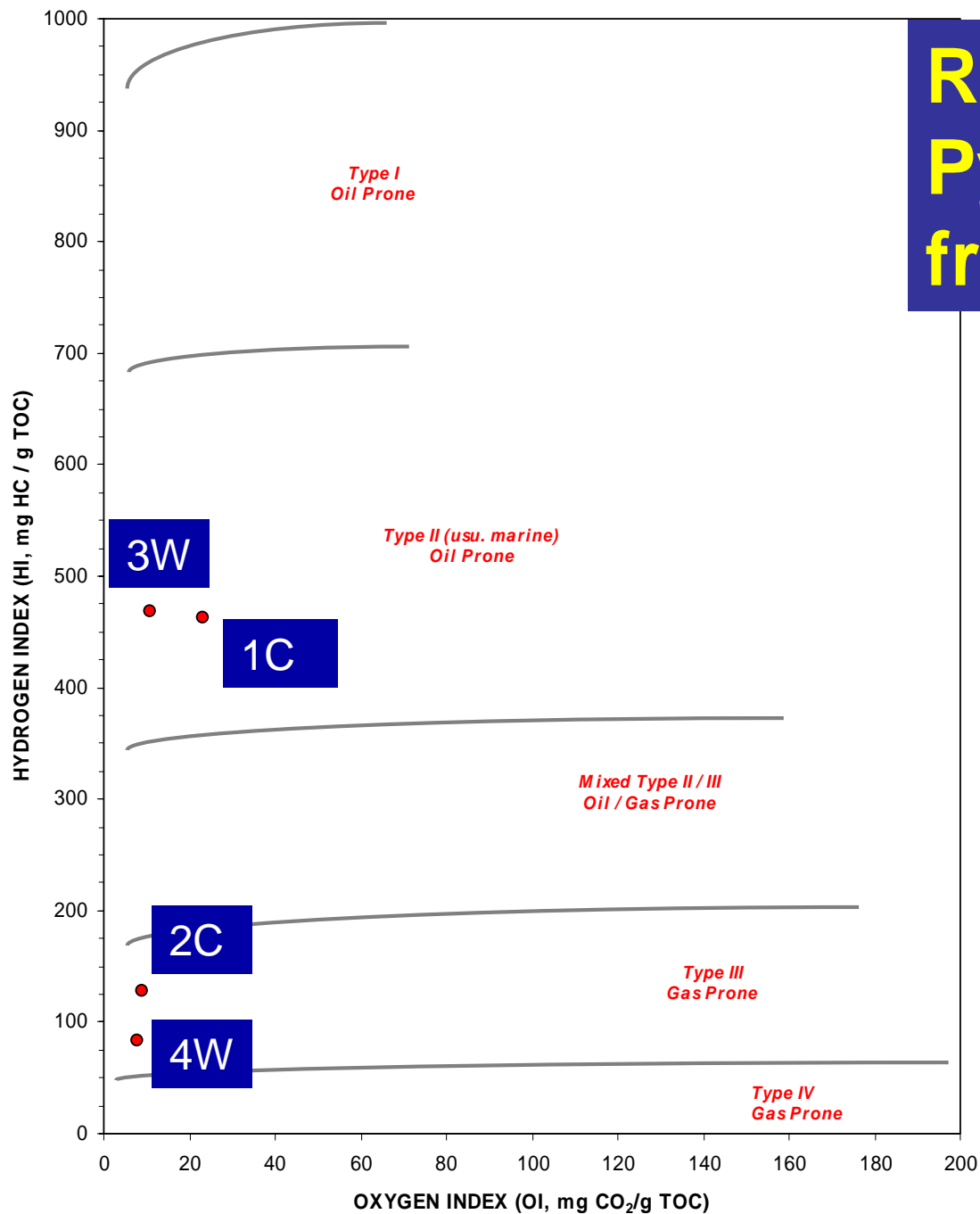
Woodford Shale

(3) 0.50% VRo; 7.18% TOC; 3,266 ft

(4) 1.23% VRo; 3.76% TOC; 3,709 ft

Rock-Eval data compliments of
Humble Geochemical Services

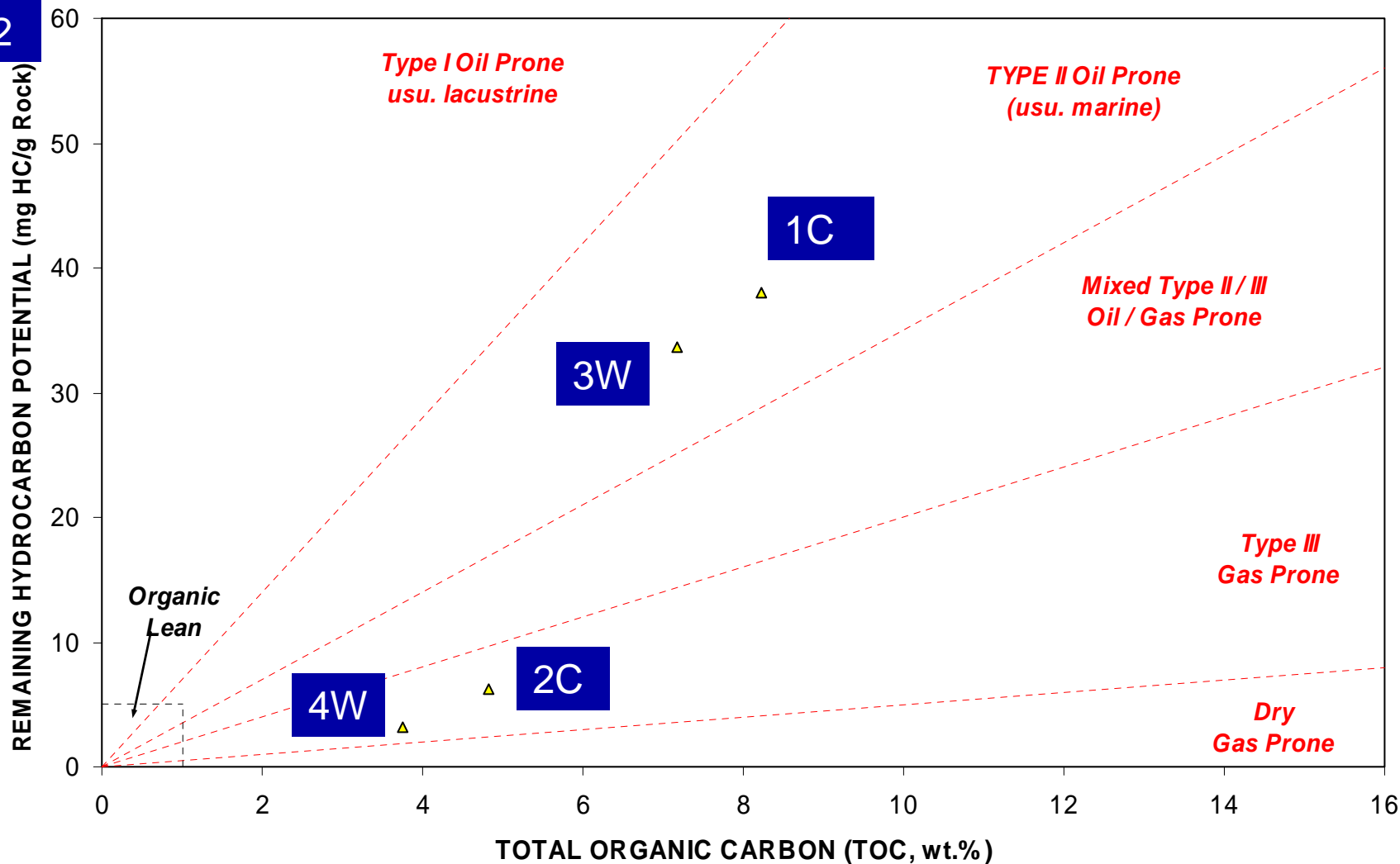
Rock-Eval Pyrolysis Data from OPIC Cores



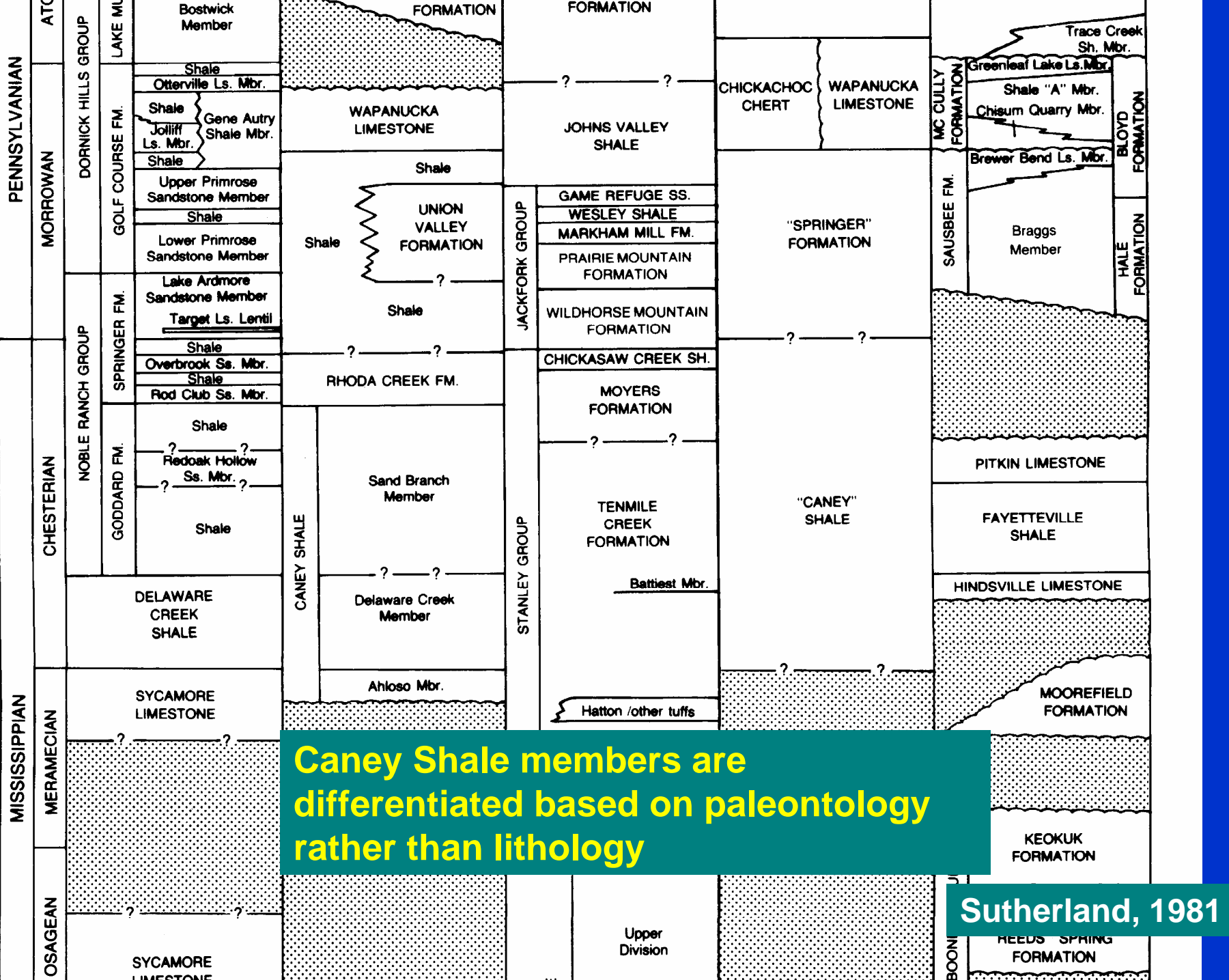
Rock-Eval data compliments of
Humble Geochemical Services

Rock-Eval Pyrolysis Data from OPIC Cores

S2



Rock-Eval data compliments of
Humble Geochemical Services



Caney Shale members are differentiated based on paleontology rather than lithology

Sutherland, 1981

P E

M I S S I S S I P P I A N

M e r a m e c i a n

M C

Union Valle
← *I. Sinuatus*

Cromwell Sandstone
Lower
Upper

Cromwell, Black,
Simons, Papoose,

ausb

gs

rov

Fate

M

“False” Caney

Primrose?

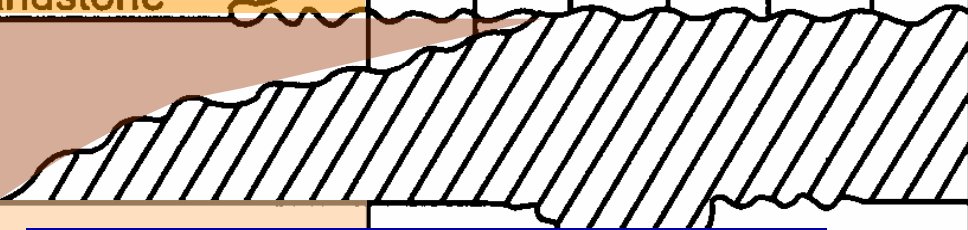
Springer shale

Jefferson sandstone

= Cunningham ?? sandstone

Springer
Goddard
Rhoda Creek

Goddard Shale



“False” Caney

Lower Goddard of Schad, 2006

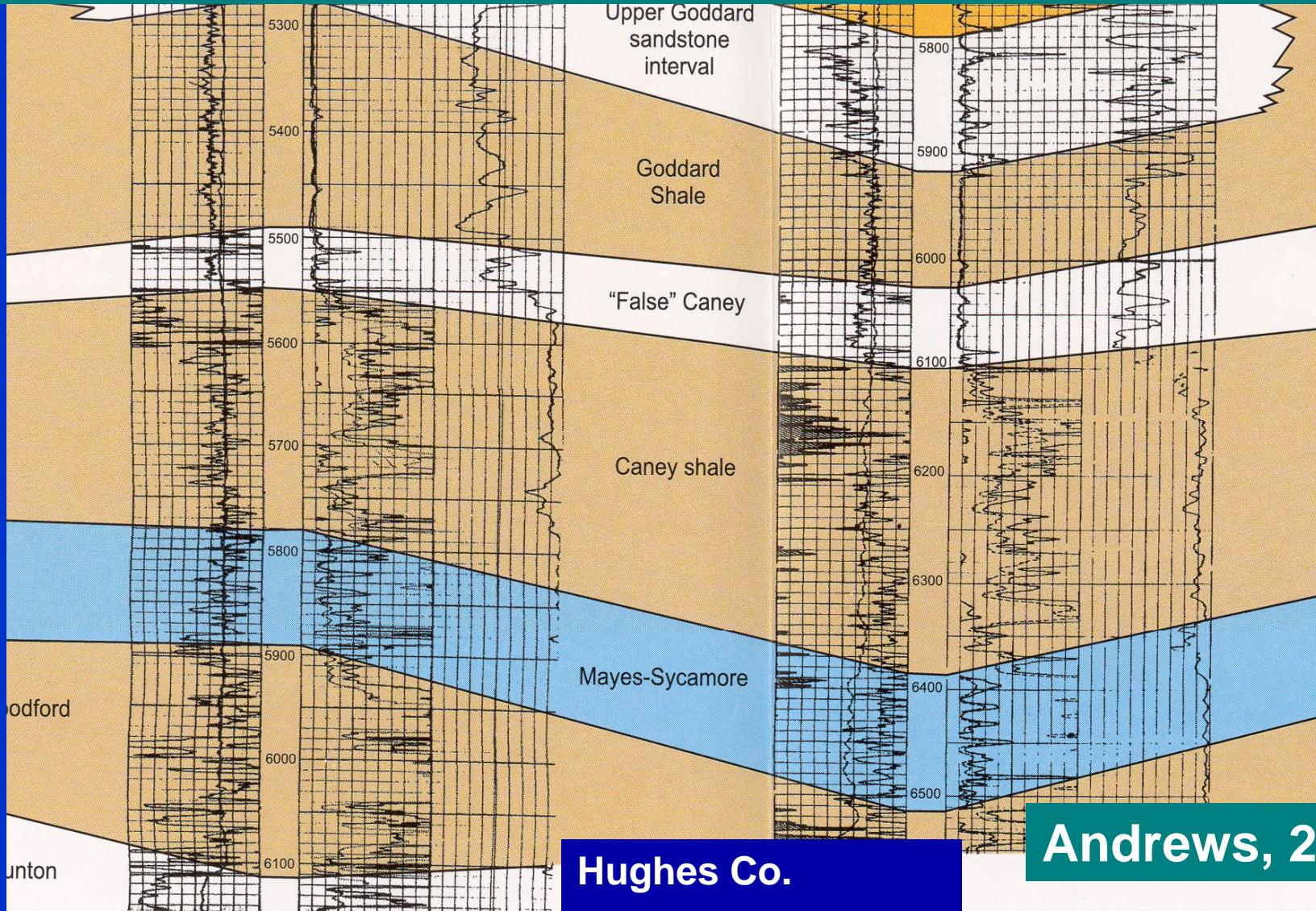
Caney shale

Fayetteville Shale

Mayes Limestone
or Sycamore Ls. in Ardmore Basin

Andrews, 2003

“False” Caney

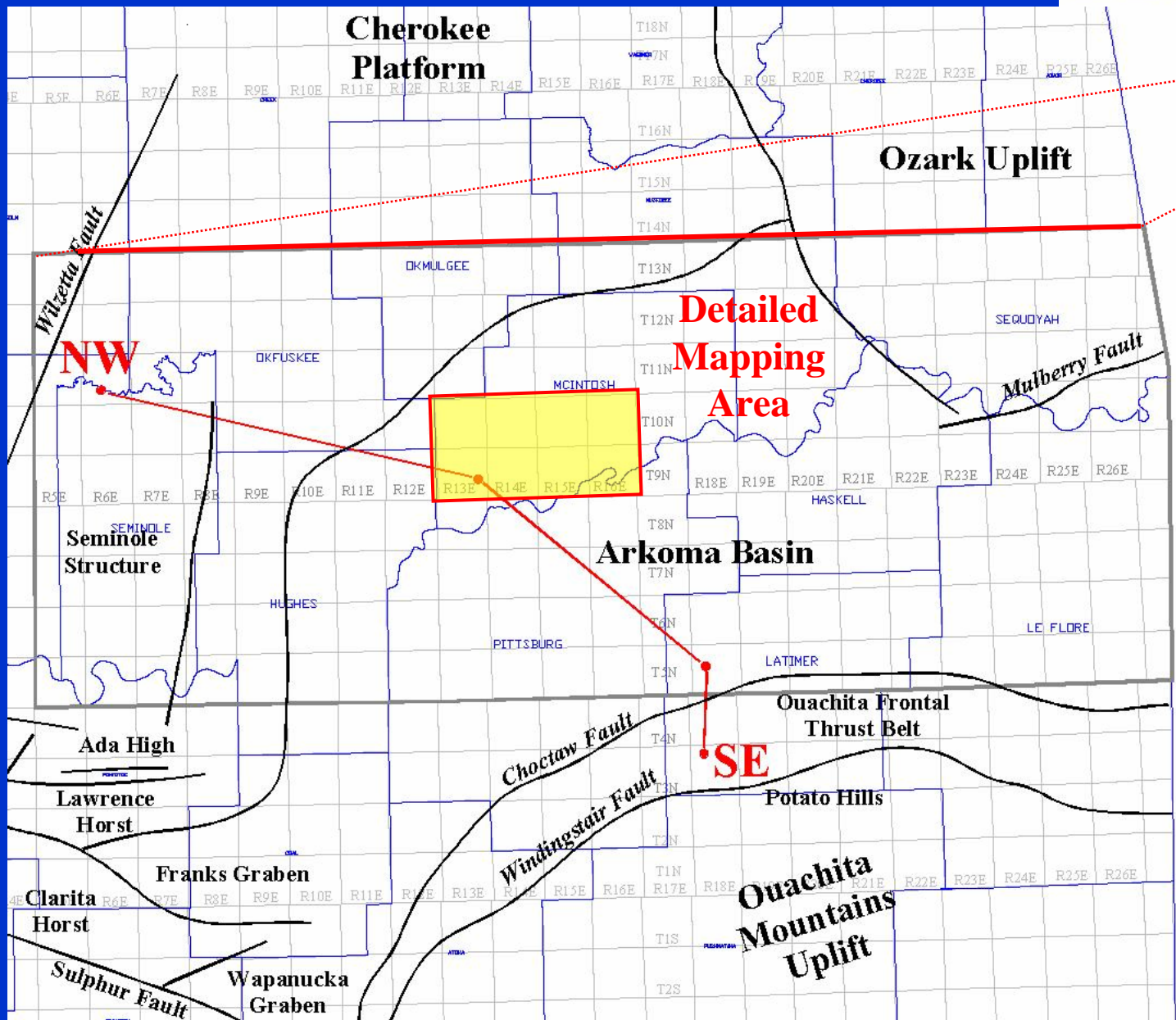


Hughes Co.

Sec. 21, T5N, R11E

Andrews, 2003

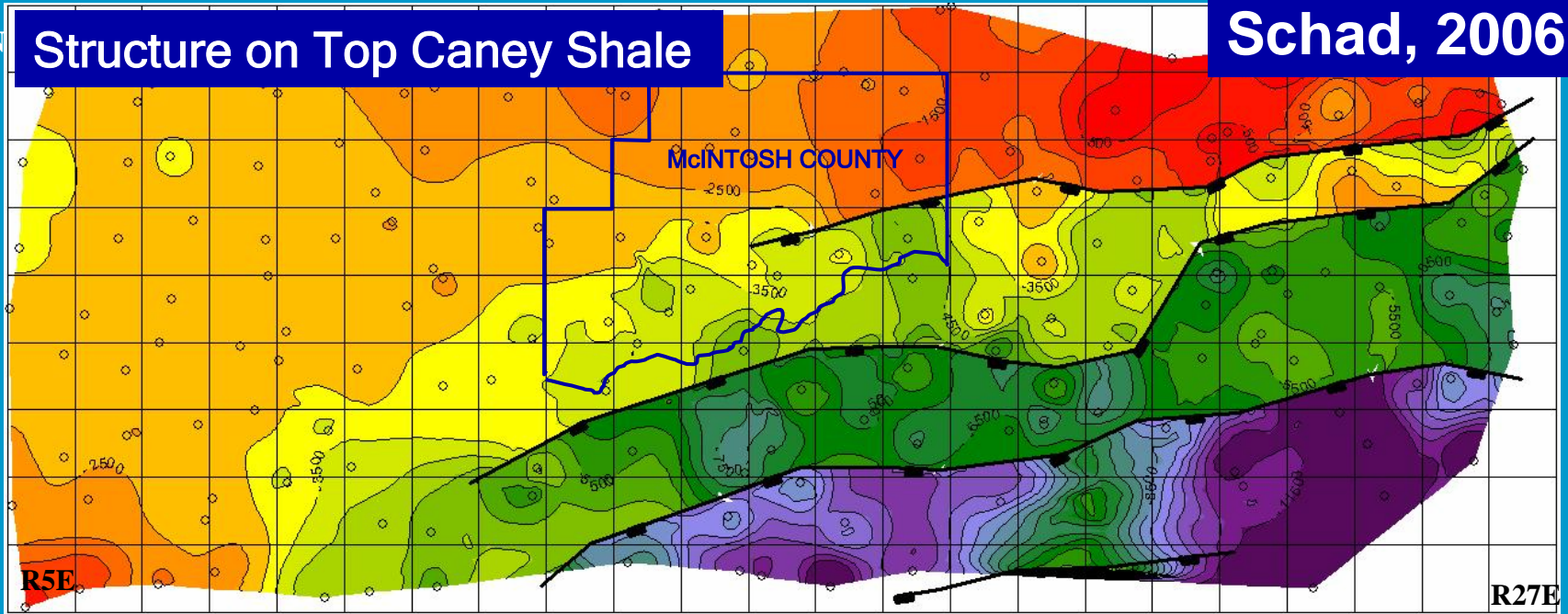
Caney Shale Study Area (Schad, 2006)



T13N

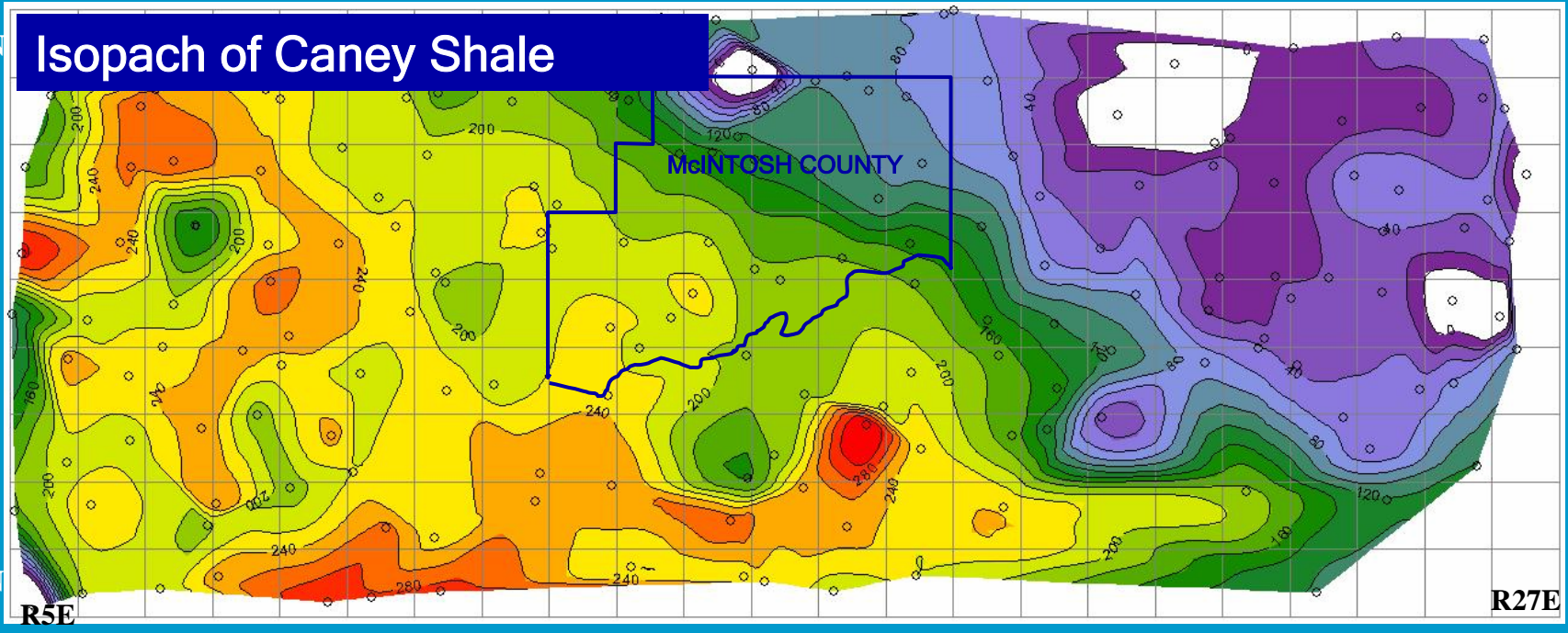
Structure on Top Caney Shale

Schad, 2006

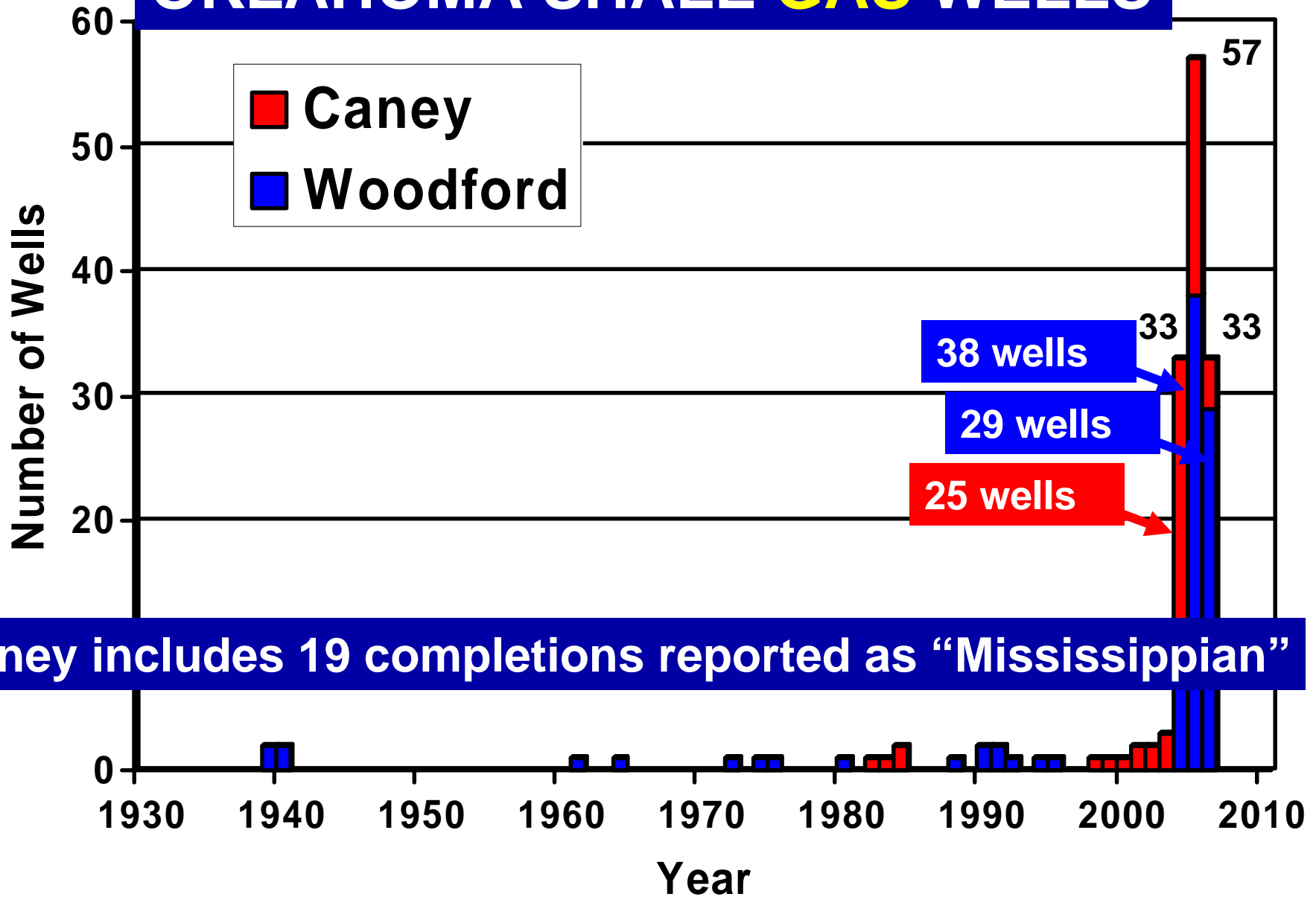


T13N

Isopach of Caney Shale



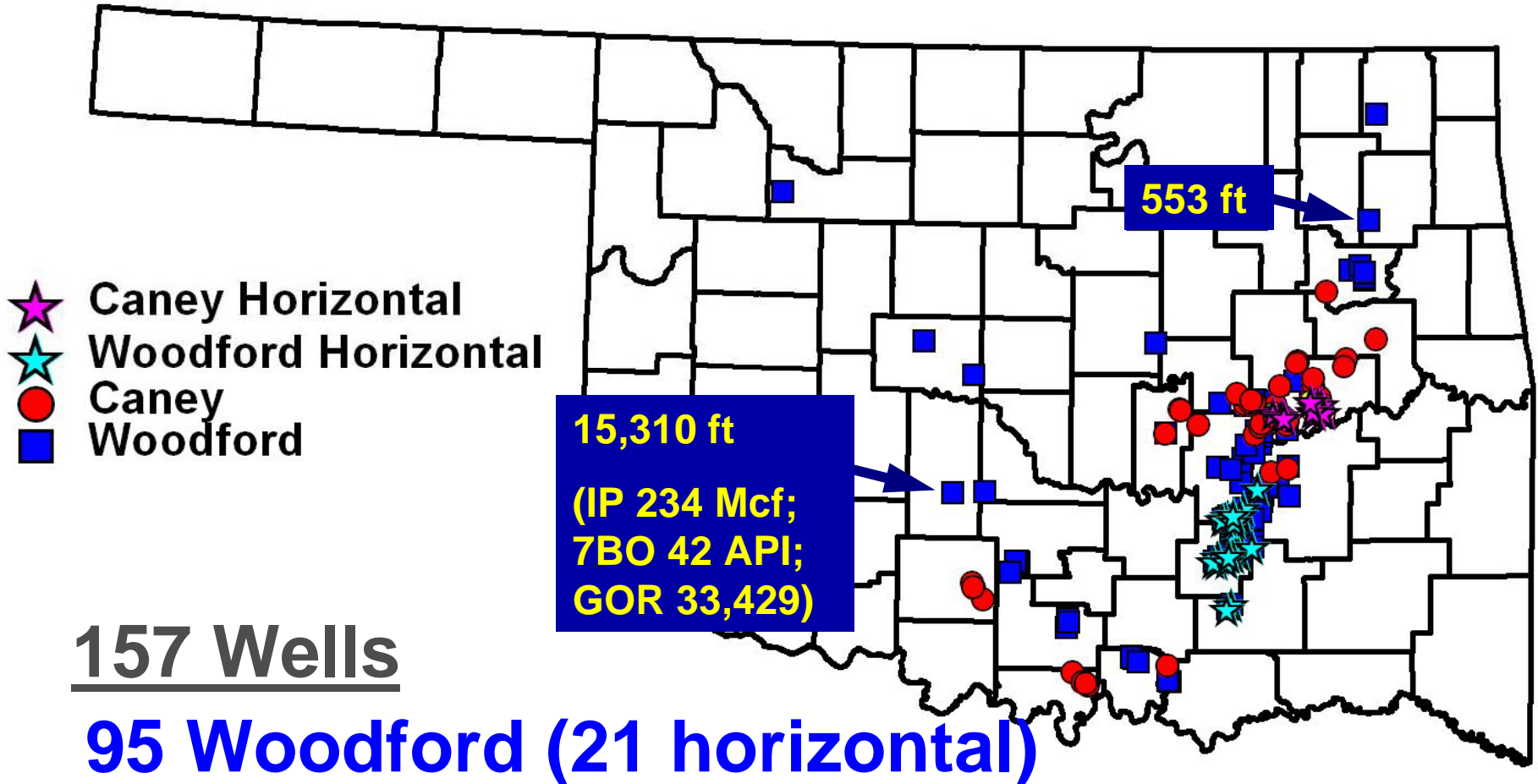
OKLAHOMA SHALE GAS WELLS



Caney includes 19 completions reported as "Mississippian"

Oklahoma Gas Shales

1939–2006



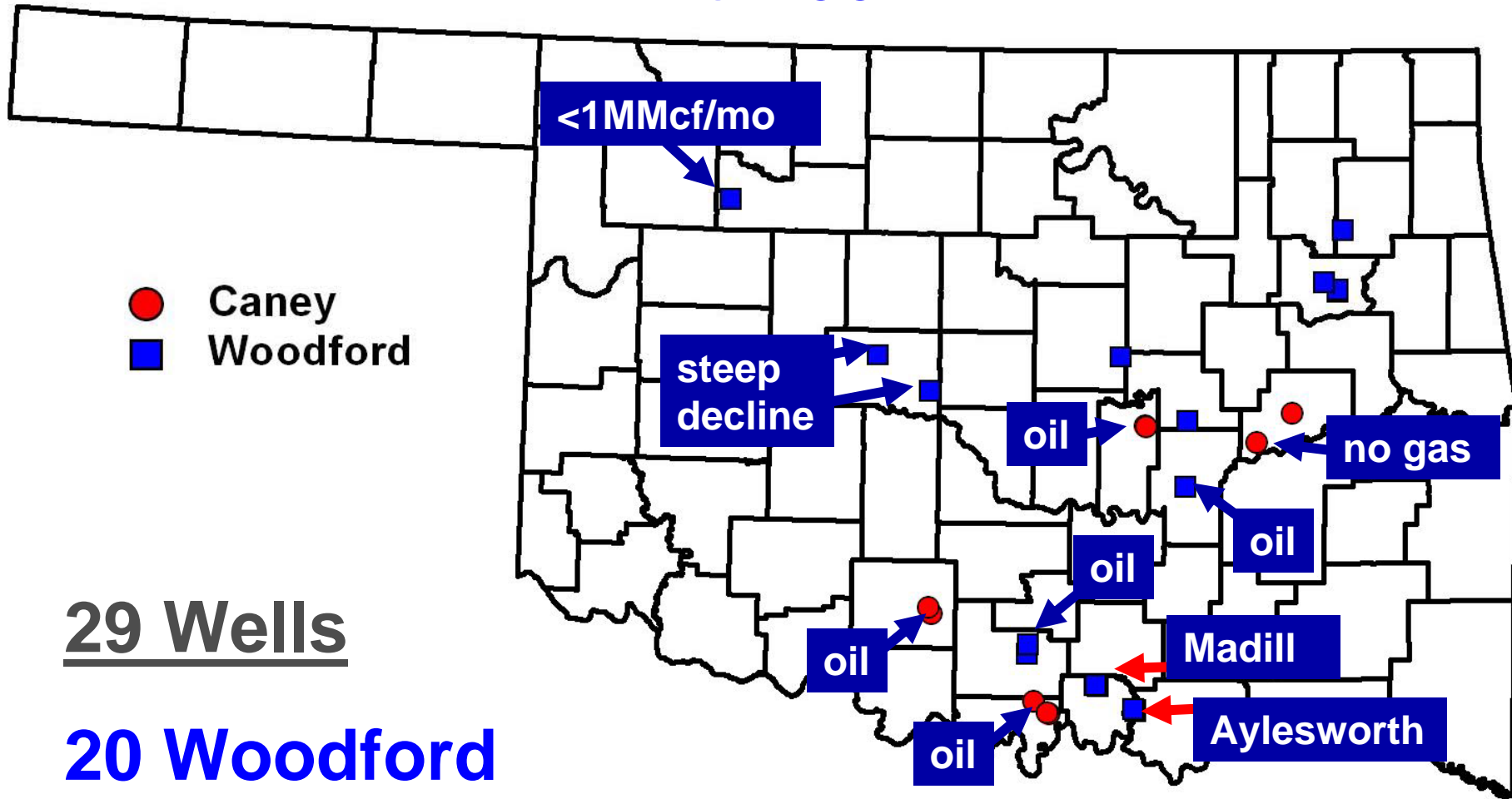
157 Wells

95 Woodford (21 horizontal)

62 Caney (10 horizontal)

Oklahoma Gas Shales

Pre-2002

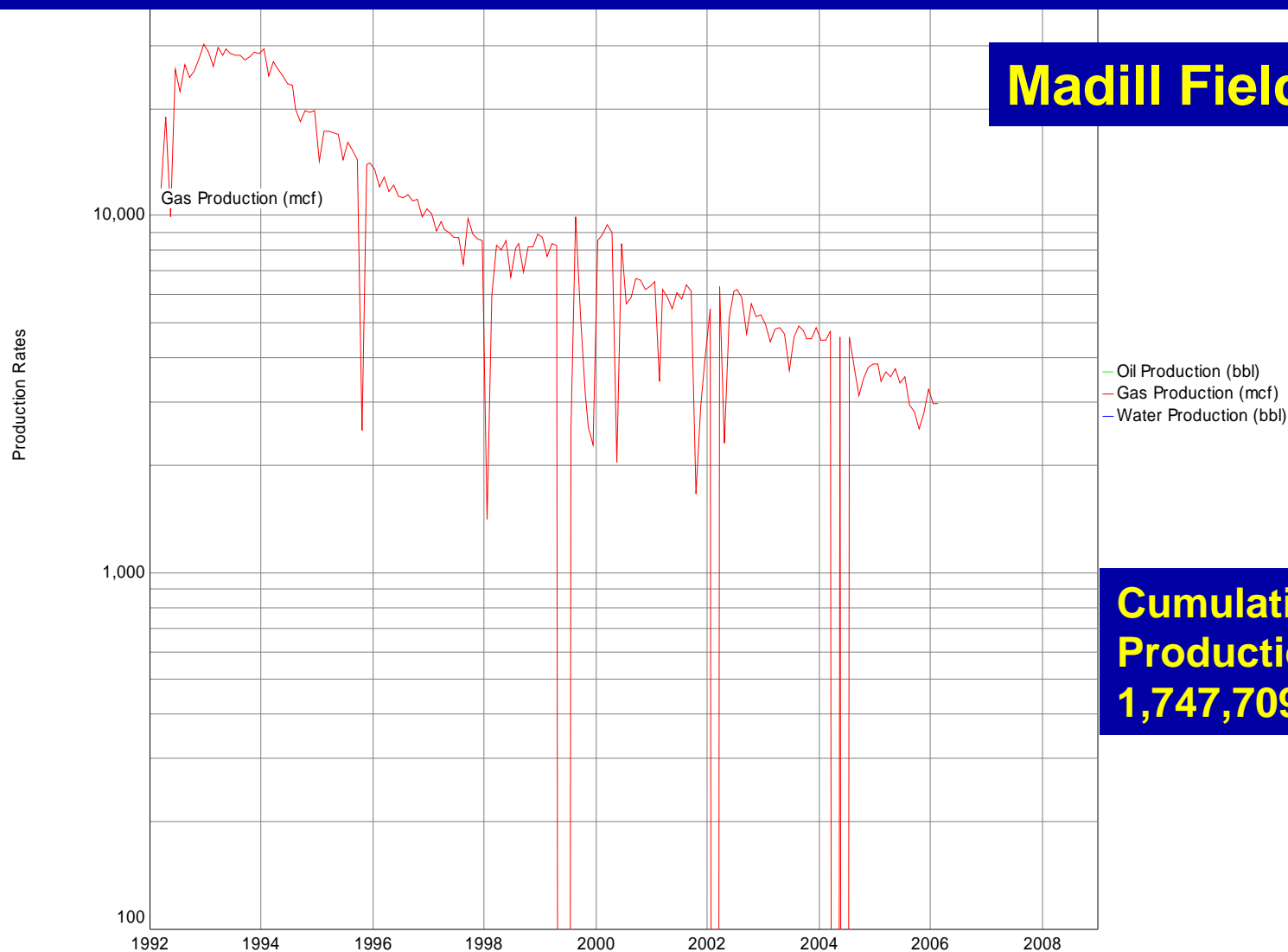


29 Wells

20 Woodford

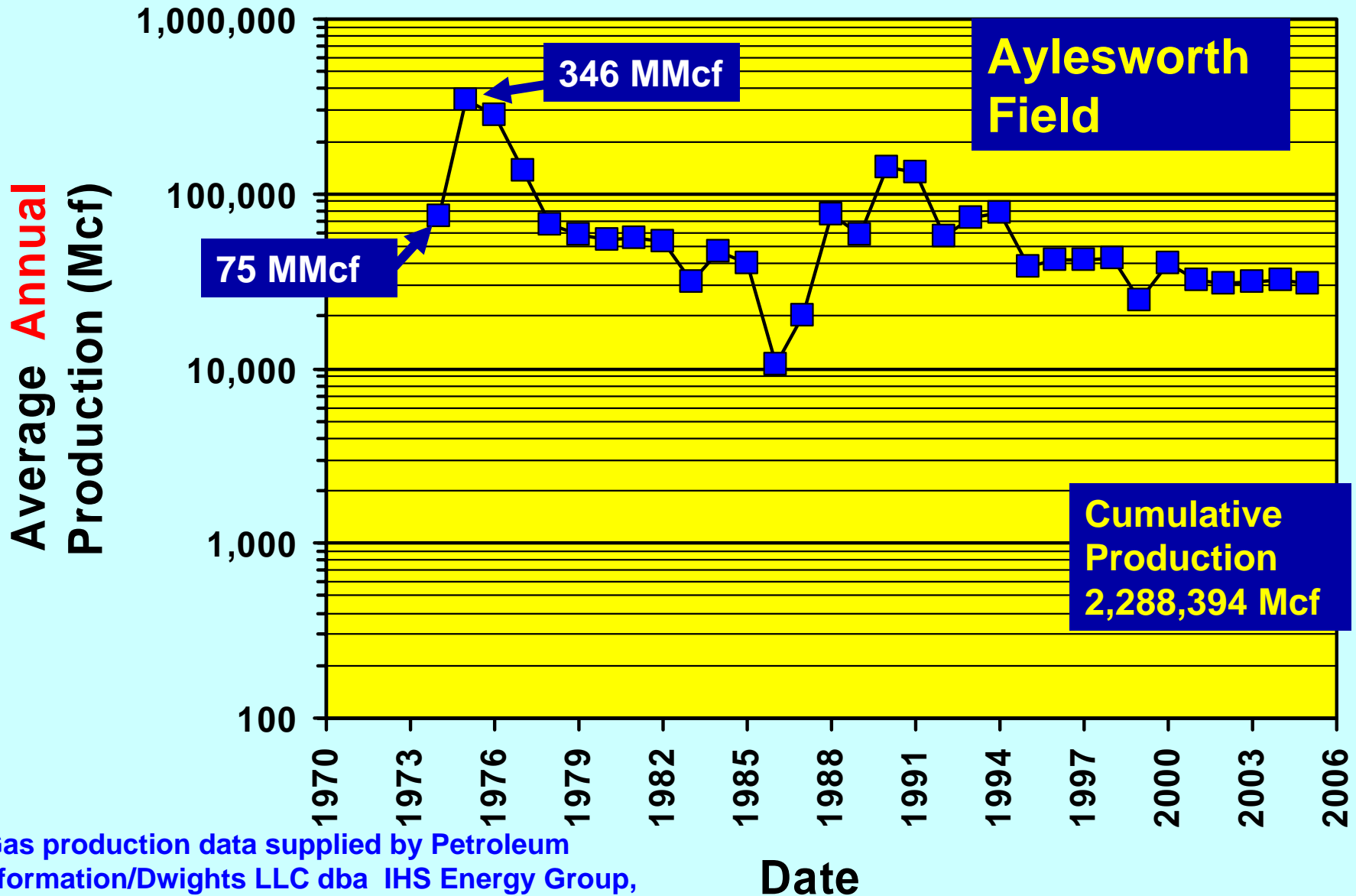
9 Caney

Gruy Petroleum 3 Griffin-Olmstead (Marshall CO, 16-5S-5E; IP 747 Mcfd; 4,052-4,135 ft)



(Gas production data supplied by Petroleum
Information/Dwights LLC dba IHS Energy Group,
© 2006, IHS Energy Group)

Verdad Oil & Gas 1 Mary Haynie (Bryan CO, 22-6S-7E; IP 962 Mcfd; 3,710-4,054 ft)



(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Oklahoma Gas Shales

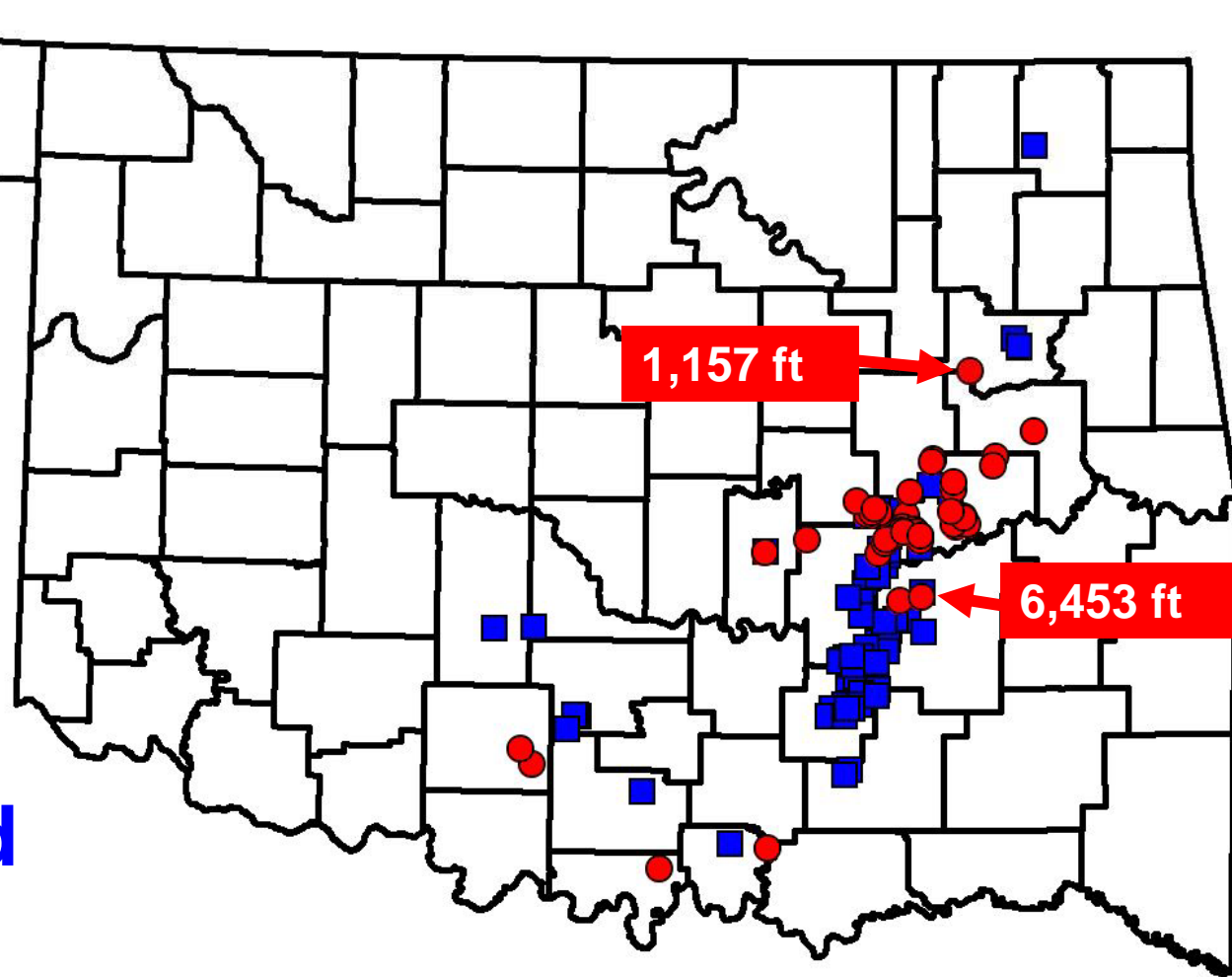
2002–2006

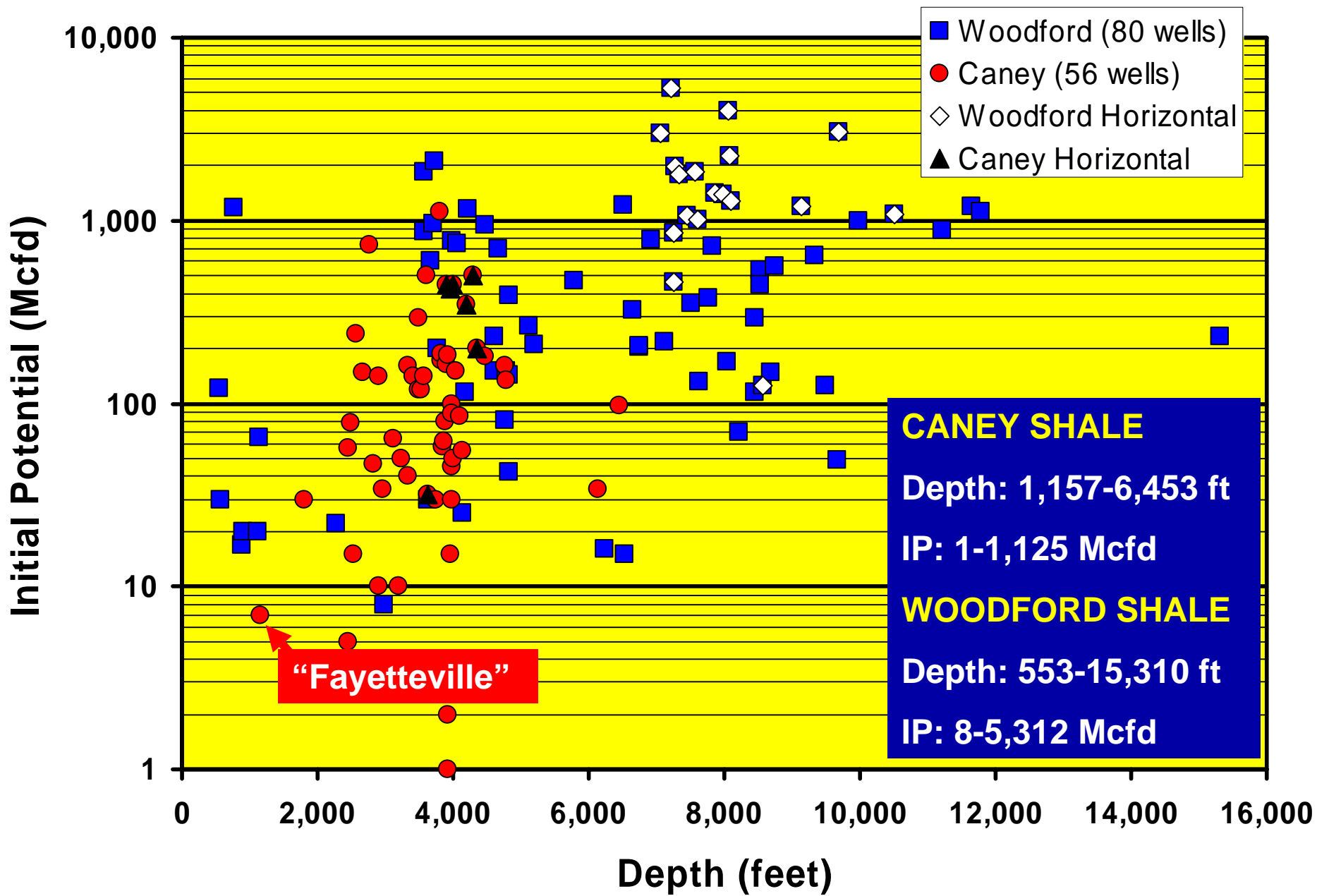
- Caney
- Woodford

128 Wells

75 Woodford

53 Caney

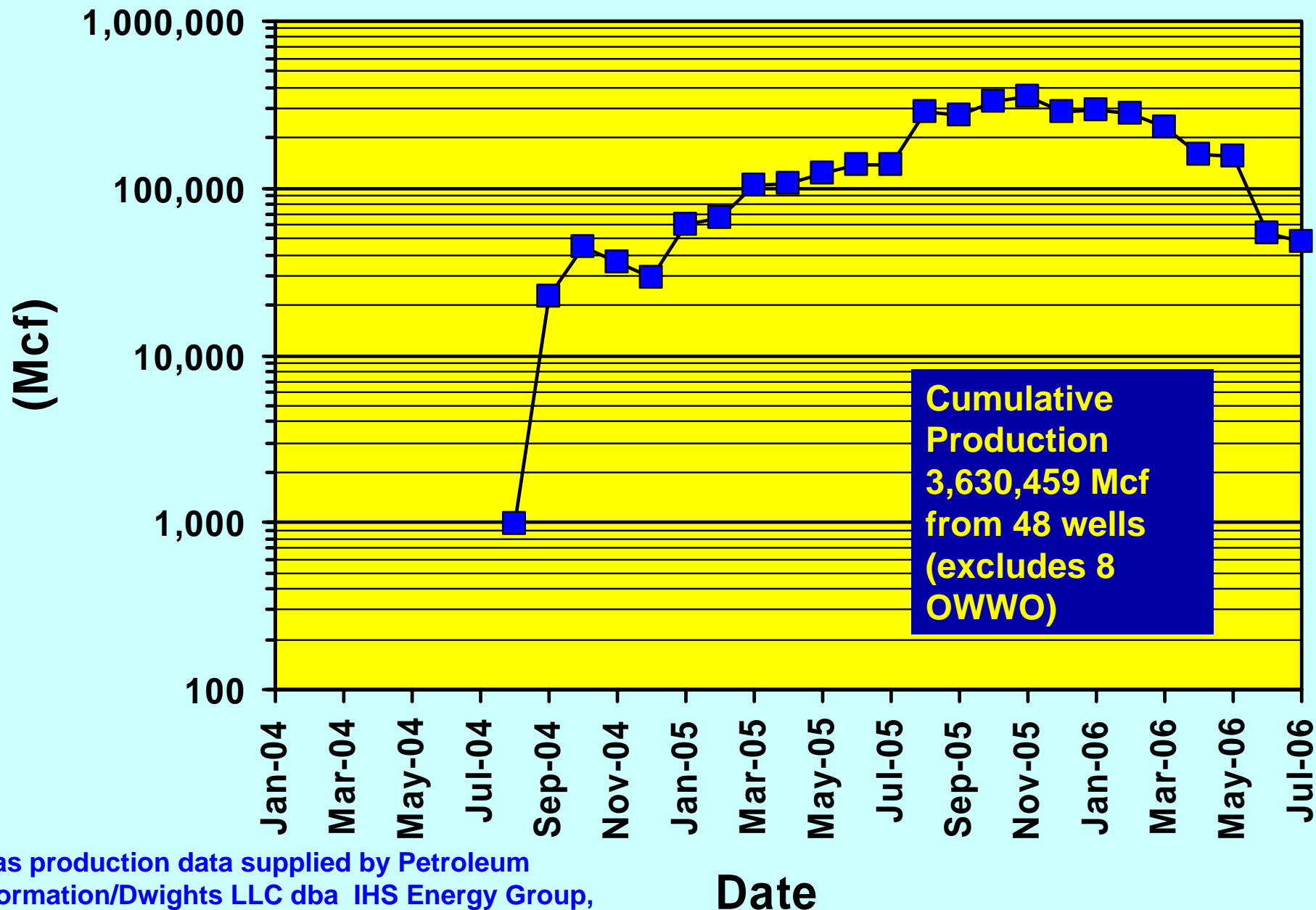




Well Type	Depth (feet)	Initial Potential (Mcf/d)
Woodford (80 wells)	~1,000	~120
Woodford (80 wells)	~1,200	~7
Woodford (80 wells)	~1,500	~60
Woodford (80 wells)	~2,000	~25
Woodford (80 wells)	~2,500	~15
Woodford (80 wells)	~3,000	~8
Woodford (80 wells)	~3,500	~10
Woodford (80 wells)	~4,000	~25
Woodford (80 wells)	~4,500	~40
Woodford (80 wells)	~5,000	~60
Woodford (80 wells)	~6,000	~15
Woodford (80 wells)	~7,000	~25
Woodford (80 wells)	~8,000	~40
Woodford (80 wells)	~9,000	~60
Woodford (80 wells)	~10,000	~100
Woodford (80 wells)	~11,000	~150
Woodford (80 wells)	~12,000	~250
Woodford (80 wells)	~13,000	~400
Woodford (80 wells)	~14,000	~600
Woodford (80 wells)	~15,000	~1,000
Woodford Horizontal	~7,000	~3,000
Woodford Horizontal	~7,500	~5,000
Woodford Horizontal	~8,000	~10,000
Woodford Horizontal	~8,500	~15,000
Woodford Horizontal	~9,000	~20,000
Woodford Horizontal	~9,500	~30,000
Woodford Horizontal	~10,000	~40,000
Woodford Horizontal	~10,500	~50,000
Woodford Horizontal	~11,000	~60,000
Woodford Horizontal	~11,500	~70,000
Woodford Horizontal	~12,000	~80,000
Woodford Horizontal	~12,500	~90,000
Woodford Horizontal	~13,000	~100,000
Woodford Horizontal	~13,500	~110,000
Woodford Horizontal	~14,000	~120,000
Woodford Horizontal	~14,500	~130,000
Woodford Horizontal	~15,000	~140,000
Woodford Horizontal	~15,500	~150,000
Woodford Horizontal	~16,000	~160,000
Caney (56 wells)	~1,200	~7
Caney (56 wells)	~1,500	~15
Caney (56 wells)	~2,000	~30
Caney (56 wells)	~2,500	~50
Caney (56 wells)	~3,000	~80
Caney (56 wells)	~3,500	~120
Caney (56 wells)	~4,000	~180
Caney (56 wells)	~4,500	~250
Caney (56 wells)	~5,000	~350
Caney (56 wells)	~6,000	~500
Caney (56 wells)	~7,000	~700
Caney (56 wells)	~8,000	~1,000
Caney (56 wells)	~9,000	~1,400
Caney (56 wells)	~10,000	~1,800
Caney (56 wells)	~11,000	~2,500
Caney (56 wells)	~12,000	~3,500
Caney (56 wells)	~13,000	~5,000
Caney (56 wells)	~14,000	~7,000
Caney (56 wells)	~15,000	~10,000
Caney (56 wells)	~16,000	~14,000
Caney Horizontal	~3,500	~400
Caney Horizontal	~4,000	~500
Caney Horizontal	~4,500	~600
Caney Horizontal	~5,000	~700
Caney Horizontal	~5,500	~800
Caney Horizontal	~6,000	~900
Caney Horizontal	~6,500	~1,000
Caney Horizontal	~7,000	~1,100
Caney Horizontal	~7,500	~1,200
Caney Horizontal	~8,000	~1,300
Caney Horizontal	~8,500	~1,400
Caney Horizontal	~9,000	~1,500
Caney Horizontal	~9,500	~1,600
Caney Horizontal	~10,000	~1,700
Caney Horizontal	~10,500	~1,800
Caney Horizontal	~11,000	~1,900
Caney Horizontal	~11,500	~2,000
Caney Horizontal	~12,000	~2,100
Caney Horizontal	~12,500	~2,200
Caney Horizontal	~13,000	~2,300
Caney Horizontal	~13,500	~2,400
Caney Horizontal	~14,000	~2,500
Caney Horizontal	~14,500	~2,600
Caney Horizontal	~15,000	~2,700
Caney Horizontal	~15,500	~2,800
Caney Horizontal	~16,000	~2,900

Woodford Shale Production (2004-2006 wells)

Average Monthly Production
(Mcf)



(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Woodford Gas Wells 2004-2006

★ Woodford Horizontal
■ Woodford

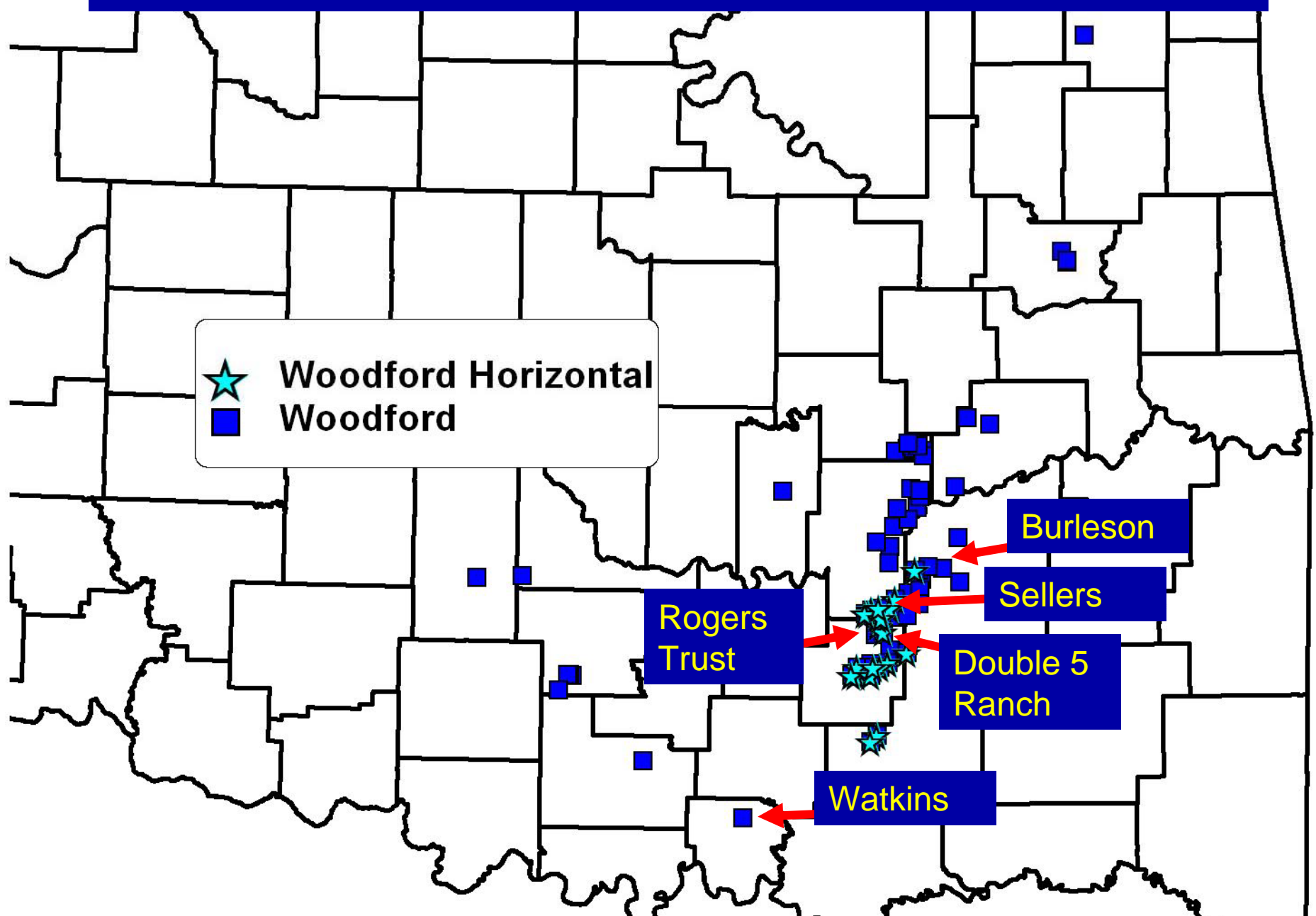
Rogers Trust

Burleson

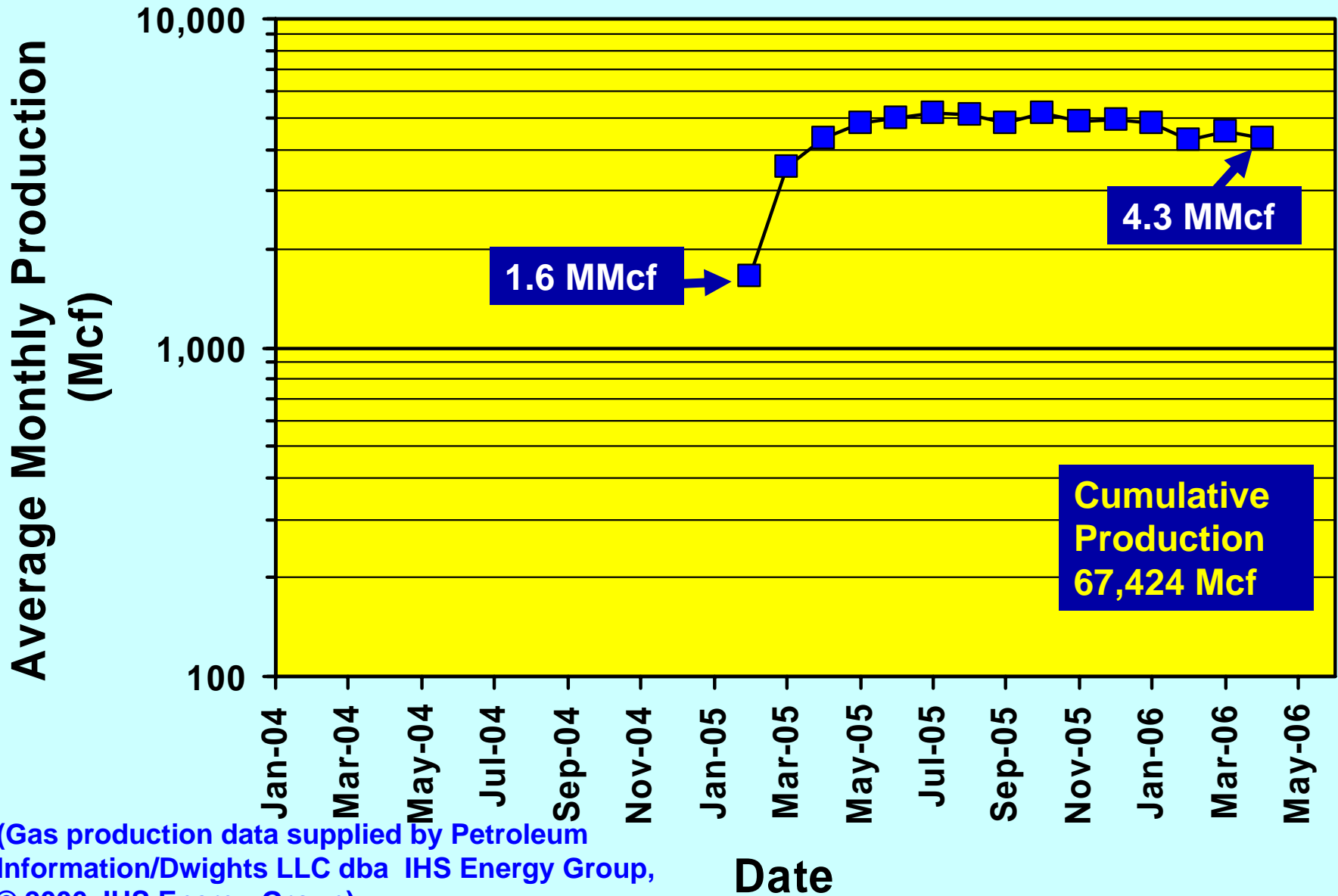
Sellers

Double 5 Ranch

Watkins

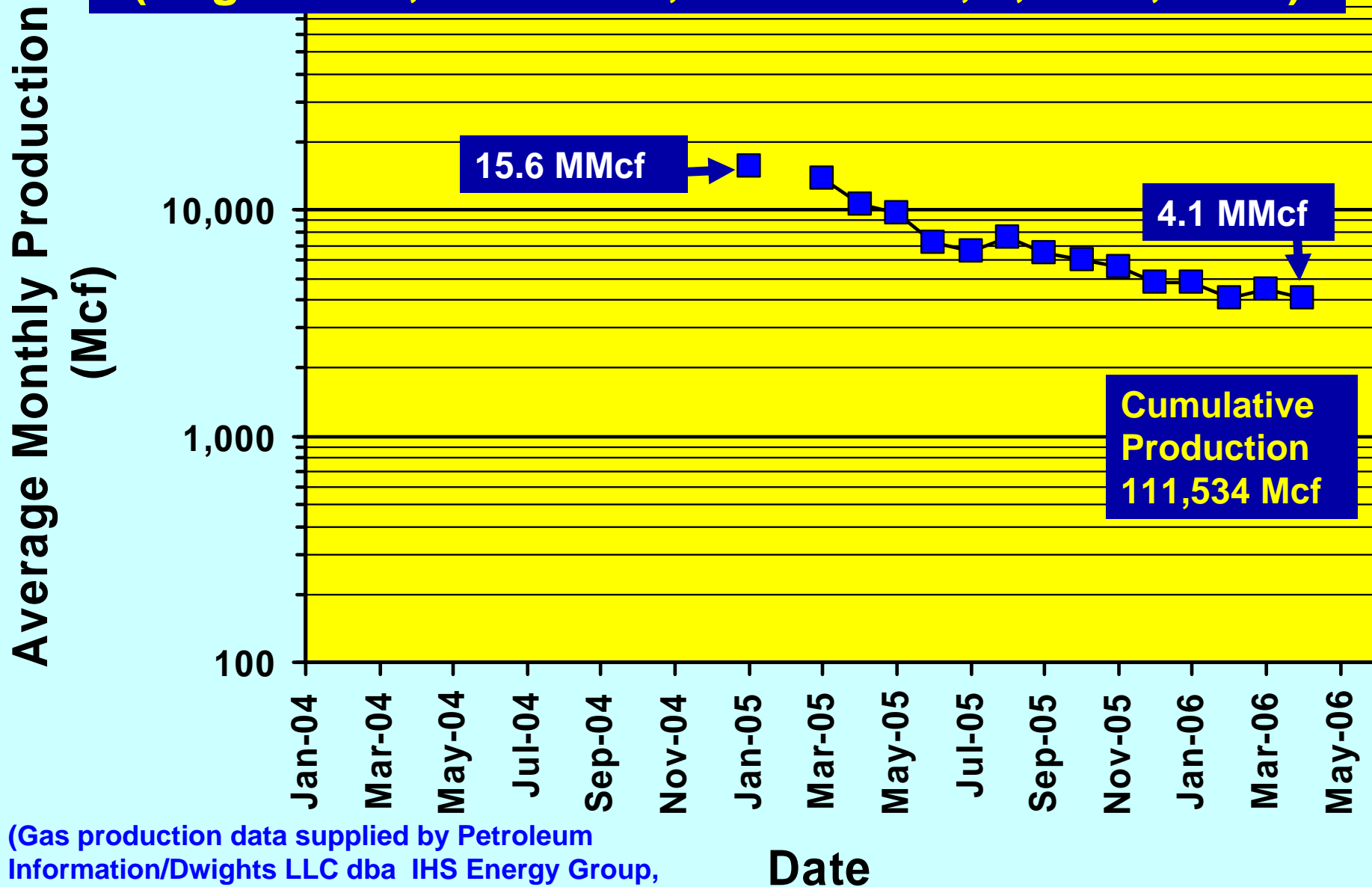


Chesapeake Operating 1-1 Burleson (Pittsburg CO, 1-5N-12E; IP 132 Mcfd; 7,624-7,710 ft)



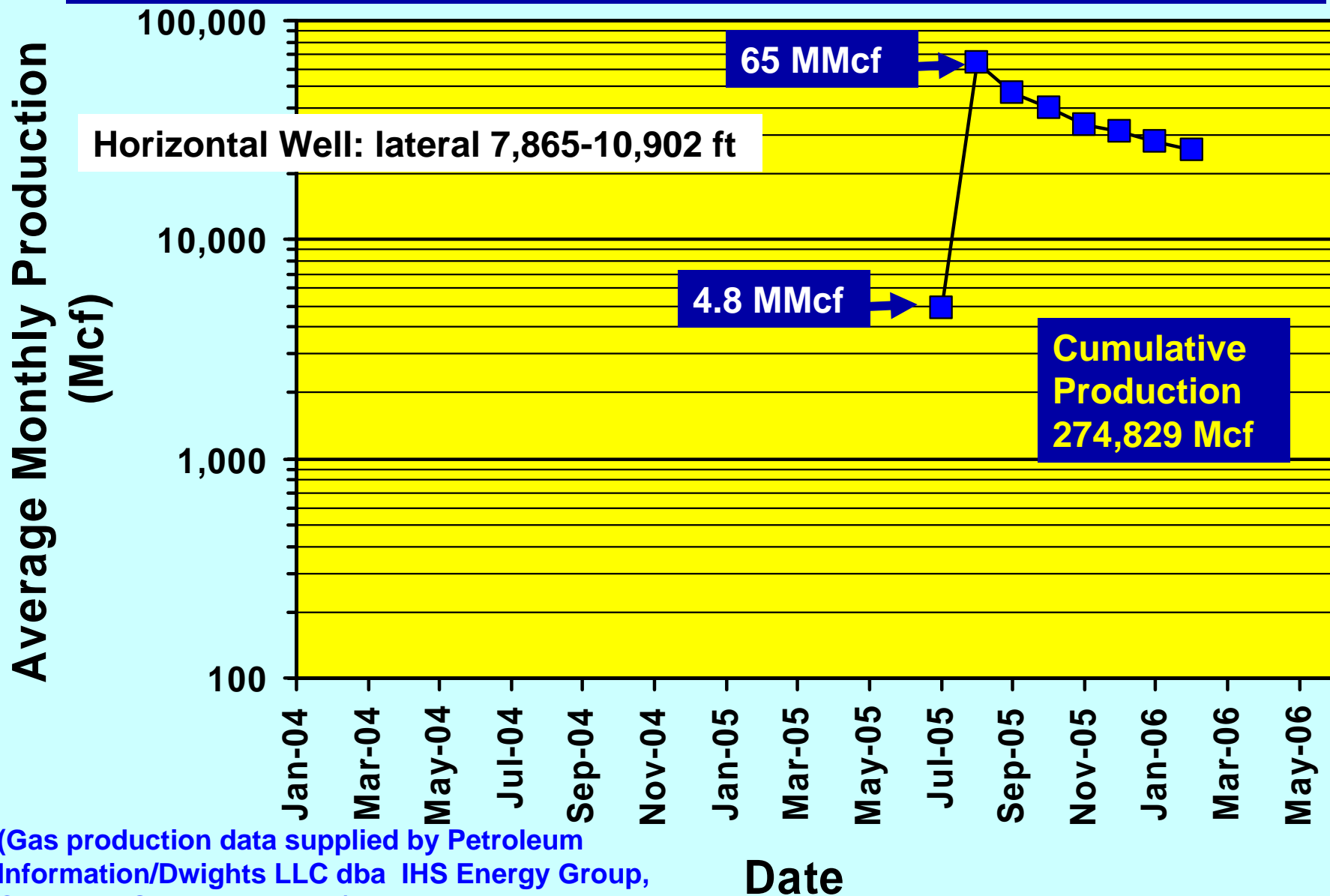
(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Chesapeake Operating 3-35 Sellers (Hughes CO, 35-4N-11E; IP 540 Mcfd; 8,520-8,678 ft)



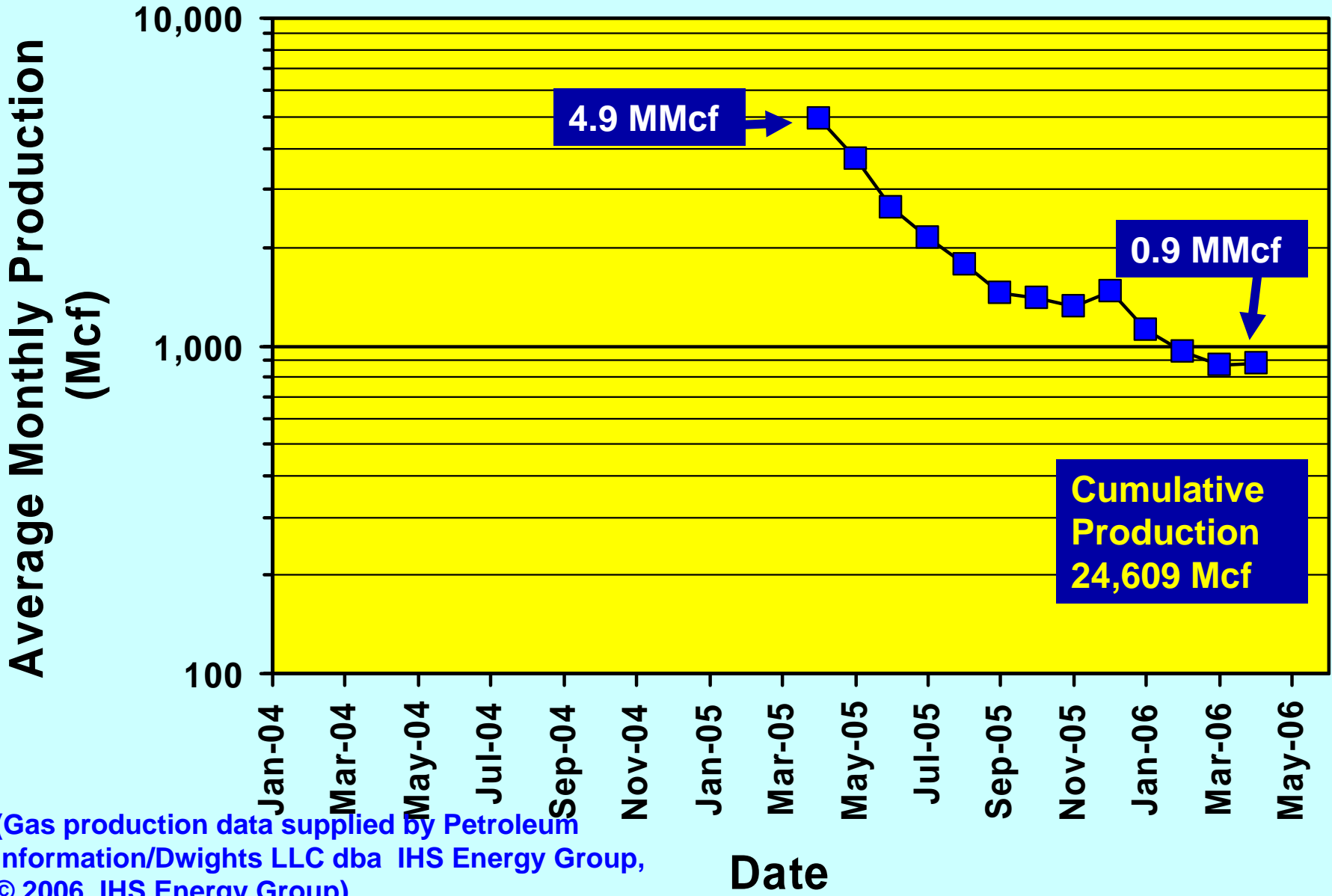
(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Devon Energy 1-12H Double 5 Ranch (Coal CO, 12-3N-10E; IP 1,795 Mcfd; 7,340 ft VD)



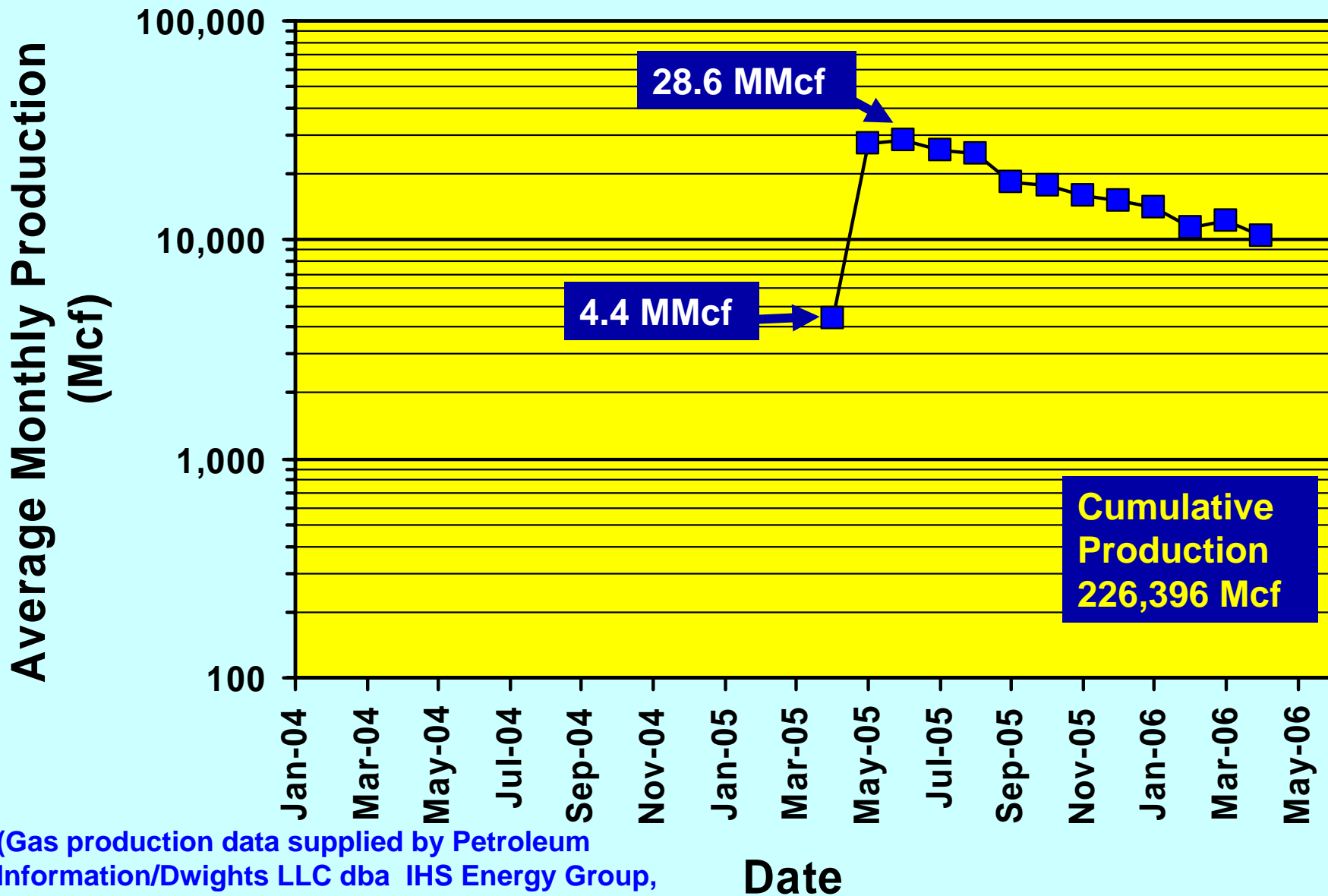
(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Devon Energy 1-24 Rogers Trust (Coal CO, 24-3N-10E; IP 216 Mcfd; 7,120-7,292 ft)



(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Chesapeake Operating 1-23 Watkins Trust (Marshall CO, 23-5S-5E; IP 698 Mcfd; 4,674-4,882 ft)

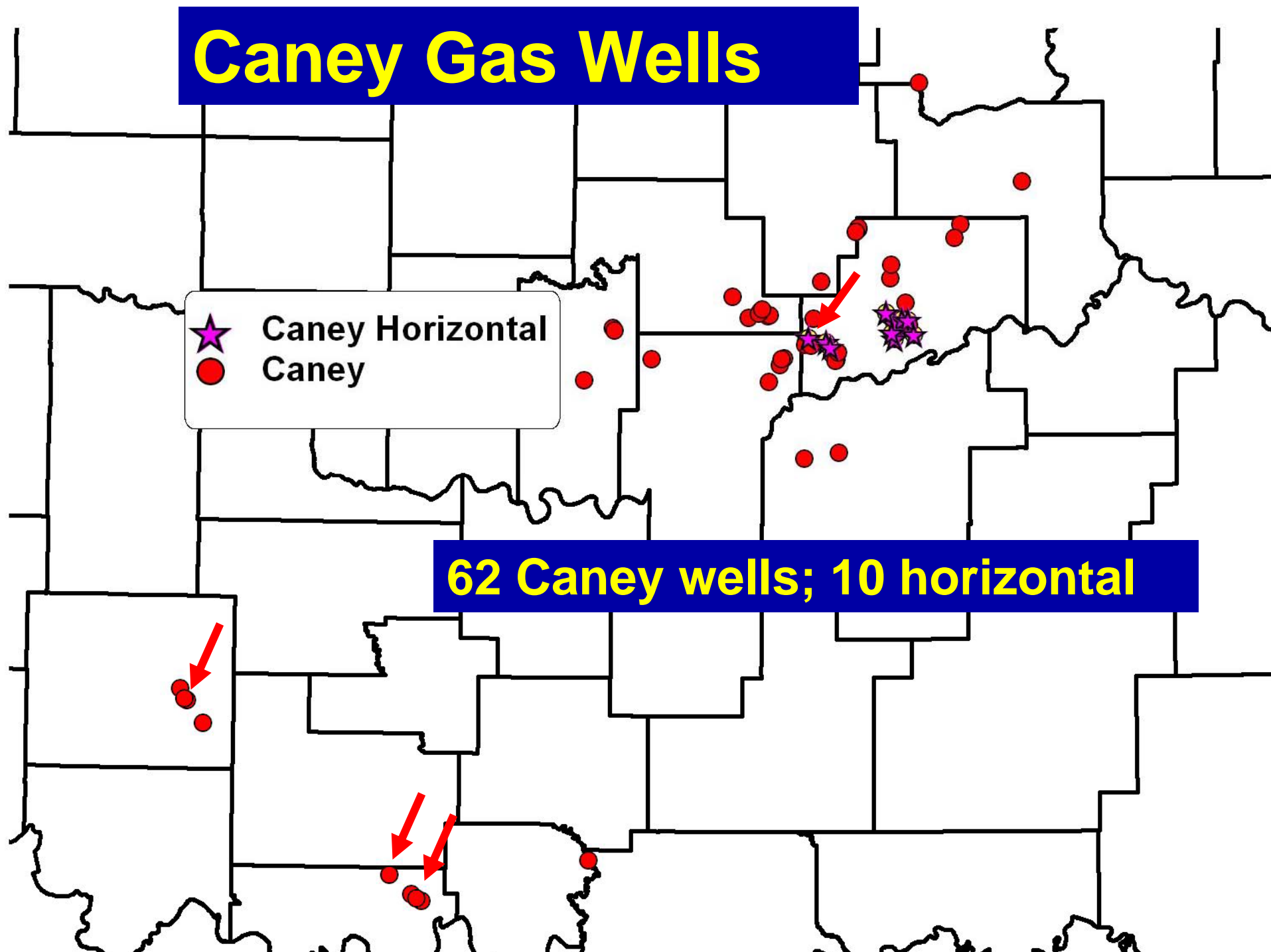


(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

Caney Gas Wells

★ Caney Horizontal
● Caney

62 Caney wells; 10 horizontal



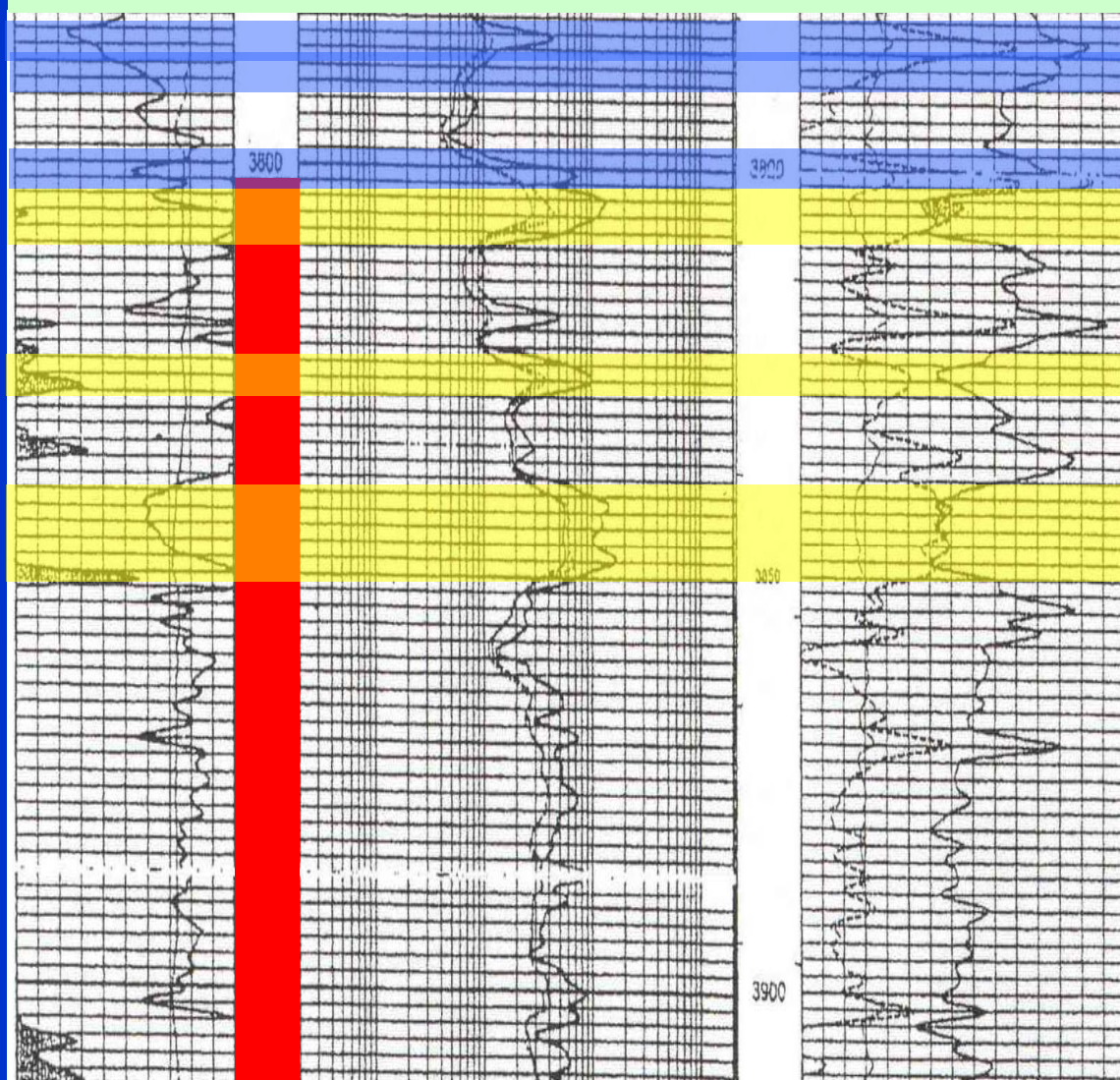
Date: 3/8/04
McIntosh CO
IP: 1,125 Mcfd
Perf: 3,802-3,916 ft

Citrus Energy Wild Turkey #1
Ne Ne 7. T9N-R13E
Cum Prod Wild Turkey: >320 MMCFG to 6-05

From Rick Andrews, 2006

GR & SP	Resistivity			PE	D & N Por	
	1	10	100	30	20	10

Productive Caney Sandstone



Date: 9/13/00

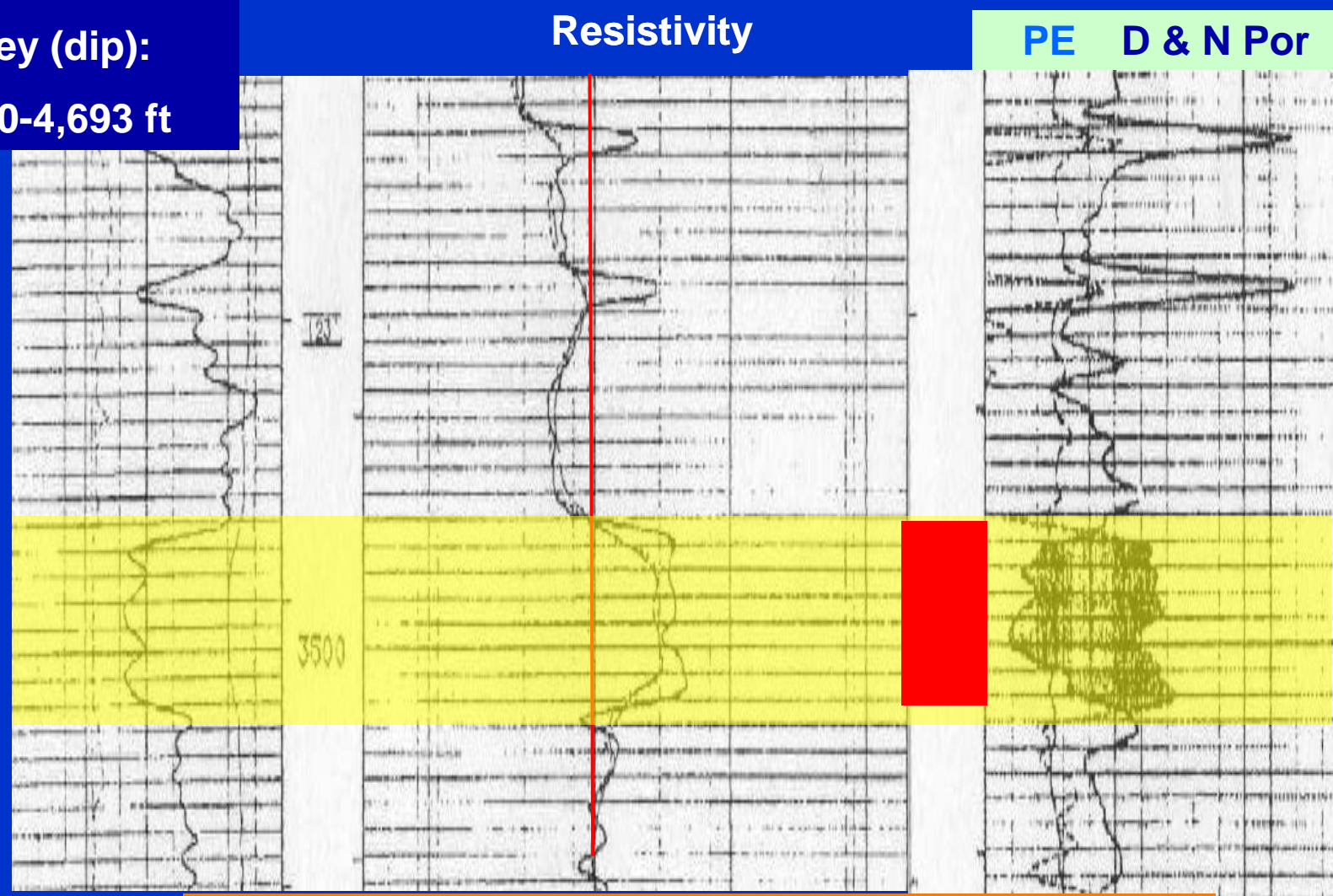
Love CO

IP: 296 Mcfd

Caney (dip):
3,460-4,693 ft

Mack Energy
Hickory Sticks 1-31
Se Ne Nw 31, T6S-R3E
Cum Prod: >5,400 BO and >190 MMCFG to 6-05

From Rick
Andrews,
2006



Productive Caney Sandstone

Mack Energy
Hickory Sticks 1-31
Se Ne Nw 31, T6S-R3E

Cum Prod: >5,400 BO and >190 MMCFG to 6-05

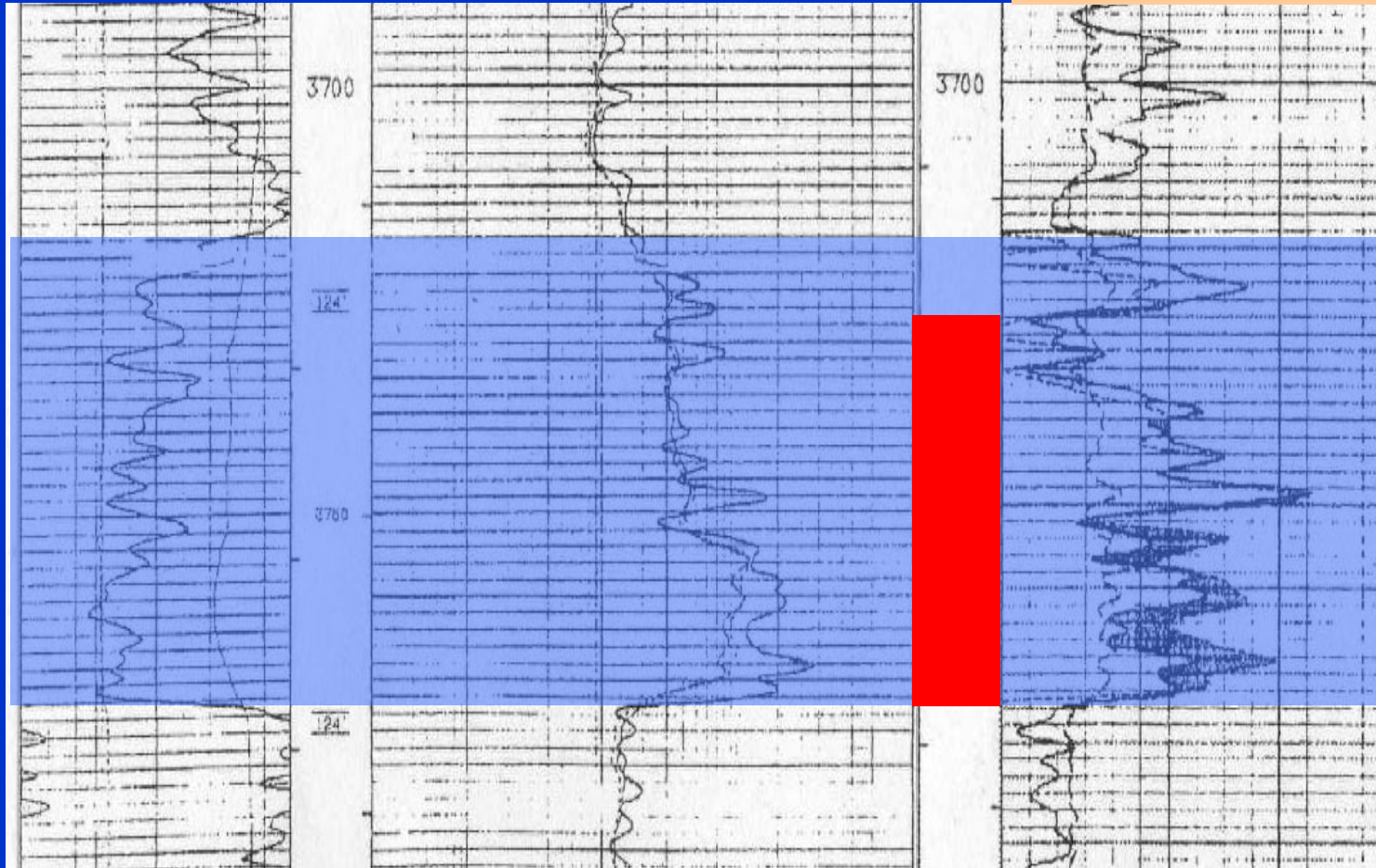
From Rick
Andrews,
2006

GR & SP

Resistivity

PE

D & N Por

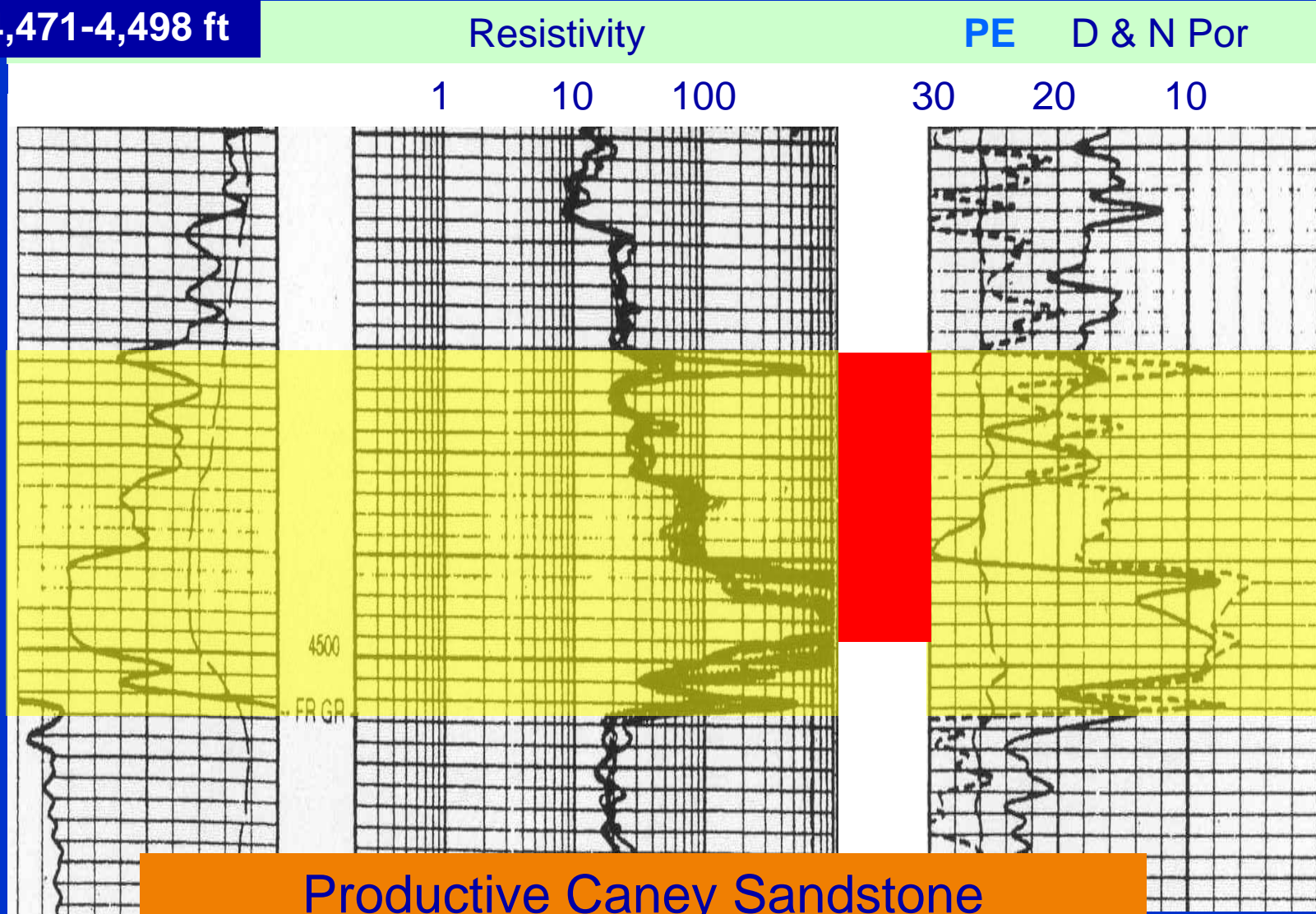


Productive Caney Limestone

Date: 12/6/01
Love CO
IP: 180 Mcfd
Perf: 4,471-4,498 ft

Star Resources
Terri Twin 8-3; Ne Nw 8, T6S-R2E
Cum Prod: ~8 MBO & 56 MMCFG to 6-05

From Rick
Andrews,
2006



Productive Caney Sandstone

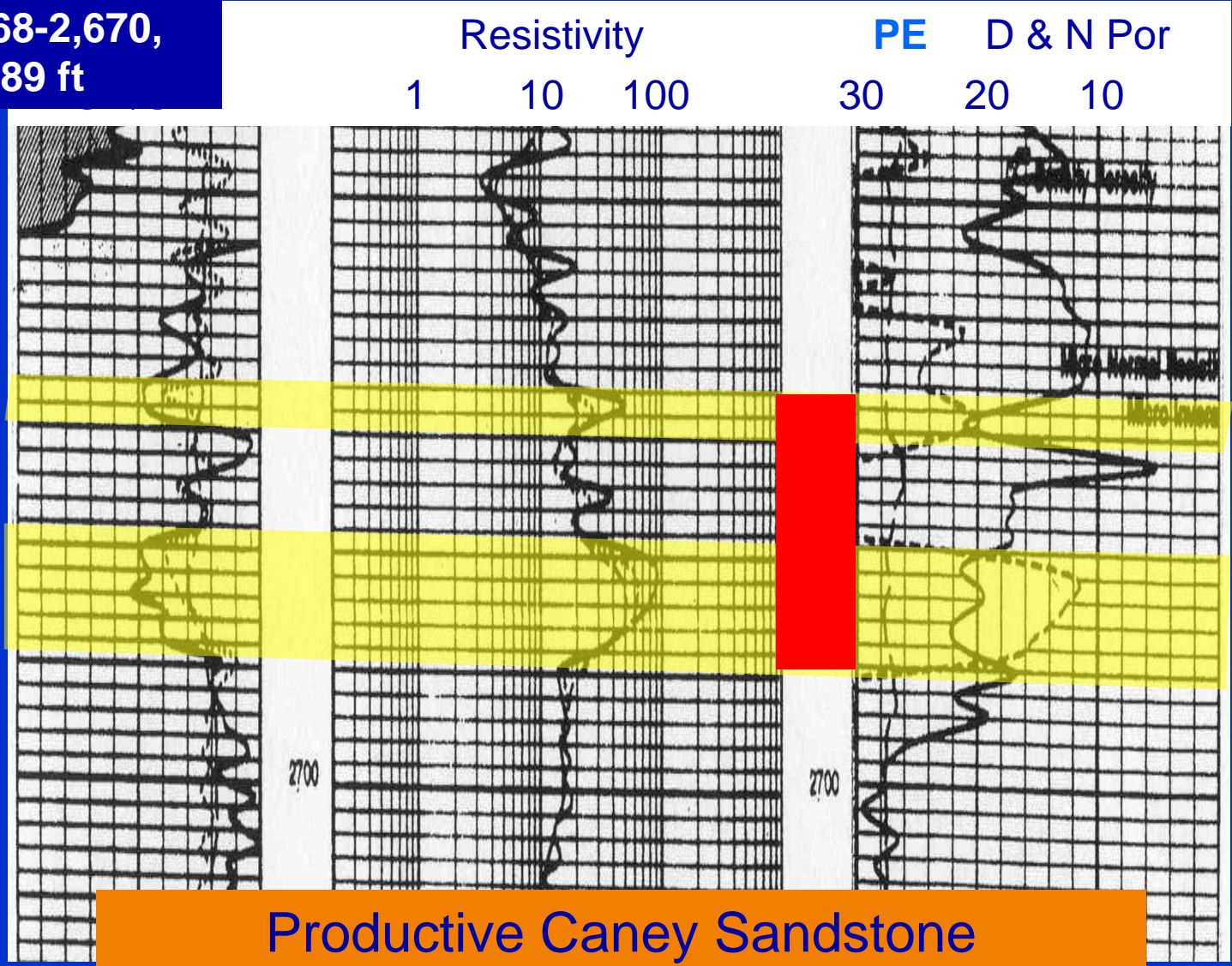
Date: 2/10/98
Stephens CO
IP: 149 Mcfd
Perf: 2,668-2,670,
2,680-2,689 ft

Williford Energy Company

#2 Quinn

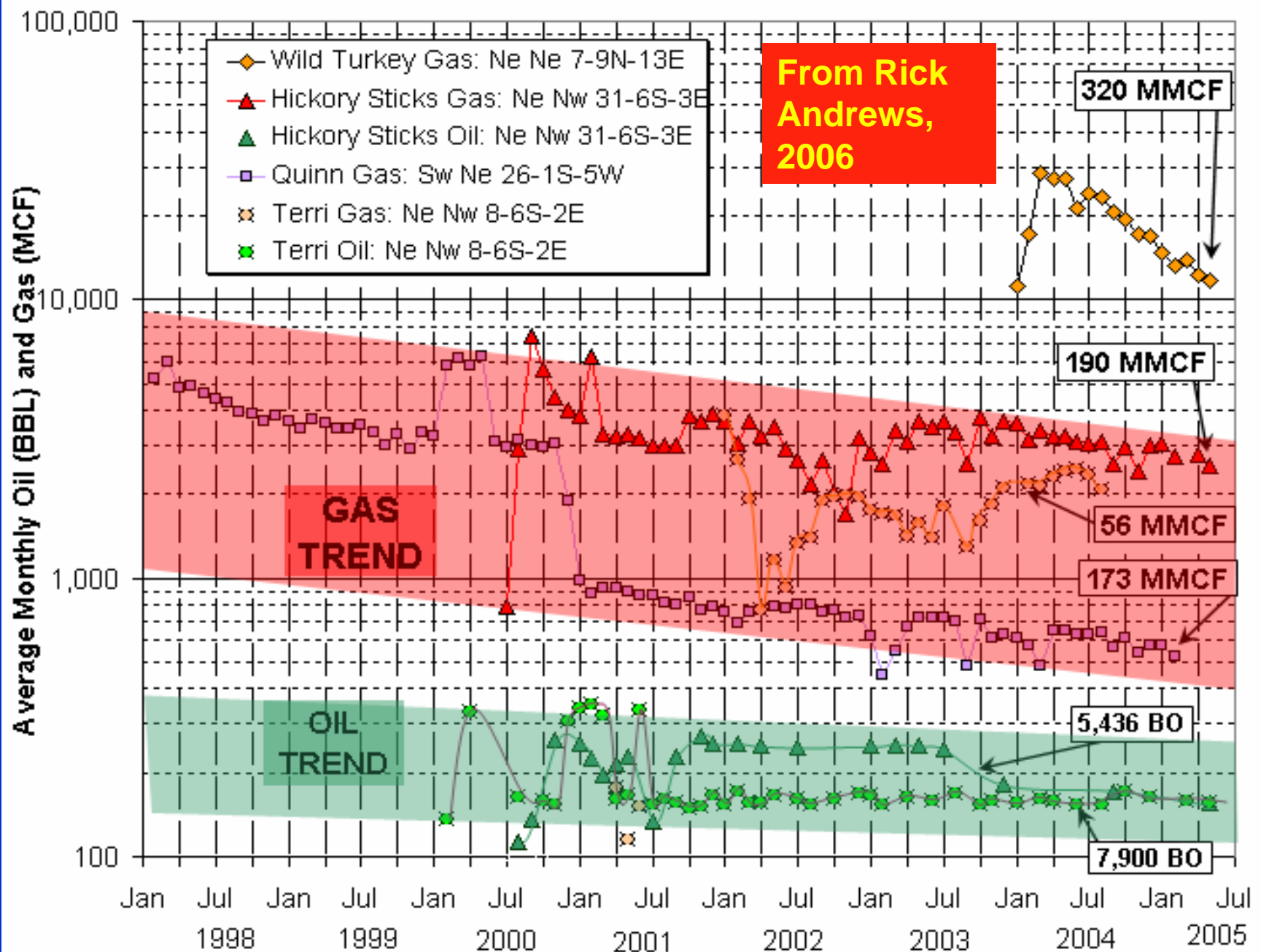
Sw Ne 26, 1S-5W Cum Prod: 173 MMCFG

From Rick
Andrews,
2006



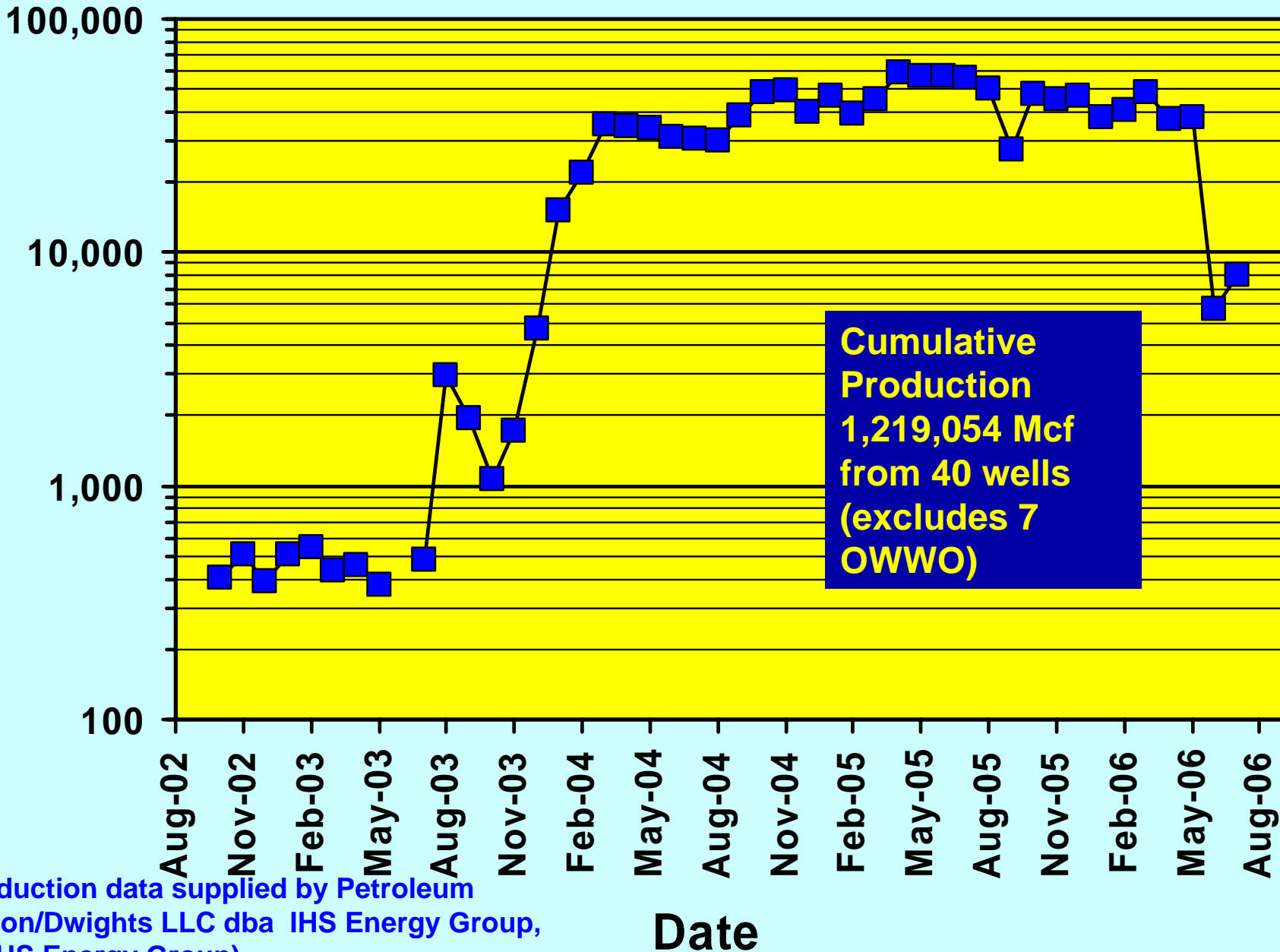
Productive Caney Sandstone

Production Decline Curves of Four Caney Wells



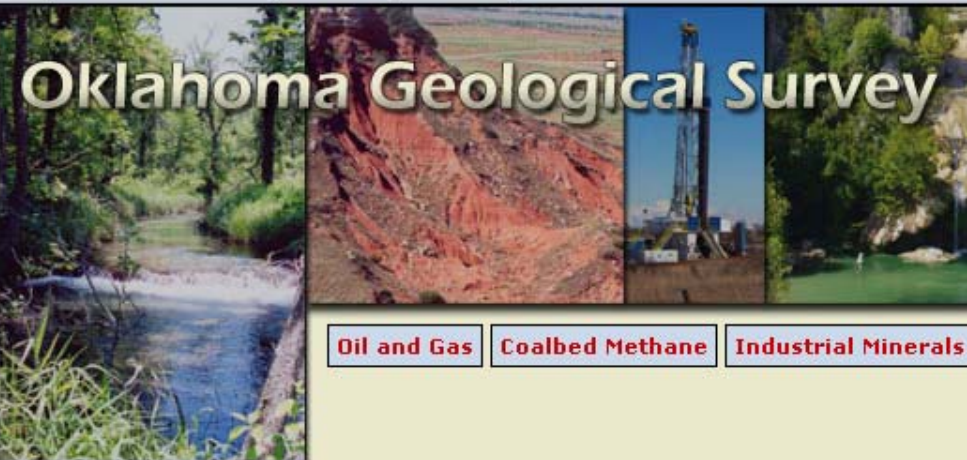
Caney Shale Production (2002-2006 wells)

Average Monthly Production
(Mcf)



(Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)

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30-0N-0E, Wewoka District, Seminole County, OK. Photo by Dan Boyd.



Microsoft Excel - Gas_Shales-3.xls													
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A1 Record #													
A	B	C	D	E	F	G	H	I	J	K	L		
94	93	35-145-22955	Resources Development Tech	3/3/2006	19-2A Collins	Wagoner District SW	19	17	N	18	E		
95	94	35-145-22948	Resources Development Tech	4/6/2006	1-1E Dunkin	Wagoner	1	17	N	17	E		
96	95	35-049-23703	Chesapeake Operating	10/14/2005	1-26 Floyd	Sho-Vel-Tum	26	1	N	3	W		
97	96	35-121-23599	Newfield Exploration	3/2/2006	1-15 Orr	Ashland	15	4	N	12	E		
98	97	35-145-22949	Resources Development Tech	4/11/2006	18-11R Dunkin	Wagoner	18	17	N	18	E		
99	98	35-145-22938	Parsons Engineering	5/2/2006	18-1 Sandpiper	Choska NW	18	16	N	16	E		
100	99	35-063-23749	Newfield Exploration	3/15/2006	1H-36 Parker	unnamed	36	4	N	10	E		
101	100	35-063-23748	Newfield Exploration	5/18/2006	1H-10 Reeder	Ashland N	10	4	N	11	E		
102	101	35-137-22583	Newfield Exploration	9/22/2005	4D F.M. Wood	Sho-Vel-Tum	26	1	S	5	W		
103	102	35-063-23742	Newfield Exploration	5/18/2006	1H-27 Whitlow	unnamed	27	4	N	10	E		
104	103	35-091-21485	Williams Production	11/8/2005	1-23 Missy	Stidham S	23	10	N	15	E		
105	104	35-091-20590	Fortuna Energy	5/19/1984	1-25 Quincy	unnamed	25	9	N	13	E		
106	105	35-091-21482	Williams Production	7/12/2005	1-25 Harvey	unnamed	24	10	N	15	E		
107	106	35-091-21470	Williams Production	7/22/2005	4-6 Scout	unnamed	6	9	N	16	E		
108	107	35-063-23598	EXOK	5/1/2004	1-28 Snell Heirs	Dustin	28	9	N	12	E		
109	108	35-063-23610	EXOK	7/1/2004	1-22 Robert	unnamed	22	9	N	12	E		
110	109	35-029-20737	Newfield Exploration	6/7/2006	1H-28 Wilson	unnamed	28	2	N	11	E		
111	110	35-063-23611	EXOK	4/8/2004	1-27 Roxanna	unnamed	27	9	N	12	E		
112	111	35-091-21352	Enterprise Energy Exploration	2/1/2005	1-19 Paris South	Checotah NW	19	12	N	17	E		
113	112	35-091-21083	Citrus Energy	8/14/2004	1-8R Harmon	Vernon NW	8	9	N	13	E		
114	113	35-091-21480	Centrex Operating	9/9/2005	1-10 Owen	Hoffman	10	12	N	14	E		
115	114	35-091-21400	Centrex Operating	5/20/2004	1-10 Shoffner	Hoffman	10	12	N	14	E		
116	115	35-091-21343	Brower Oil & Gas	12/18/2003	2-9 Jacobs	Pierce	9	11	N	15	E		
117	116	35-091-21453	Williams Production	3/25/2005	1-33H Fisher	Raiford N	33	10	N	15	E		
118	117	35-091-21426	Landmark Energy	12/18/2004	2-25 Crabtree	Raiford SE	25	10	N	15	E		
119	118	35-121-23365	Chesapeake Operating	4/29/2005	2-6 Uselton	Reams NW	6	6	N	14	E		
120	119	35-107-23224	Metro Energy Group	12/22/2004	3-19 Snell-Heirs	Lyons-Quinn	19	10	N	12	E		
121	120	35-107-23201	Southstar Oil & Gas	3/26/2004	1-20 Snell Heirs	Dustin	20	10	N	12	E		
122	121	35-107-23199	Southstar Oil & Gsa	8/9/2004	4-13 Snell Heirs	Lyons-Quinn	13	10	N	11	E		
123	122	35-107-23221	Metro Energy Group	11/8/2004	7-13 Snell-Heirs	Lyons-Quinn	13	10	N	11	E		
124	123	35-107-23222	Metro Energy Group	12/30/2004	8-13 Snell-Heirs	Lyons-Quinn	13	10	N	11	E		
125	124	35-107-23262	Devon Energy	2/1/2006	1-5 Adkins	Lyons-Quinn	5	10	N	11	E		
126	125	35-111-27074	Brower Oil & Gas	8/10/2004	1-16 Pinkston	Hoffman	16	12	N	14	E		
127	126	35-111-27089	Brower Oil & Gas	1/14/2005	1-22 Thomas	Salem N	22	11	N	13	E		
128	127	35-107-23220	Metro Energy Group	9/4/2004	6-13 Snell-Heirs	Lyons-Quinn	13	10	N	11	E		
129	128	35-133-24497	Larron Energy Group	3/1/2005	14 Lima	Wewoka District	8	8	N	7	E		



THANK YOU

**Folds in Woodford Shale, Bengal locality,
Ouachita Mountains, Oklahoma**