Overview of Woodford Gas-Shale Play of Oklahoma, U.S.A.

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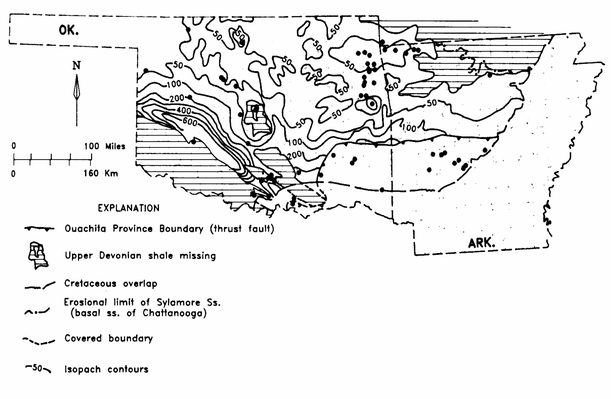
Abstract

The Woodford Shale (Late Devonian-Early Mississippian), an important hydrocarbon source rock in Oklahoma (south-central United States), is age-equivalent to Late Devonian gas shales in the United States (e.g., New Albany, Antrim, Ohio). It exceeds the minimum non-negotiable parameters necessary for an economic gas shale: gas source rock and fracture-able. Abundant oil-generative organic matter (e.g.., Type II kerogen; 2-14% total organic carbon) in the Woodford Shale is the source of thermogenic methane and a bitumen network, beginning in the late oil window, that are sites for gas storage and migration. Abundant natural fractures in silica-rich (30-87% quartz) lithologies of the Woodford Shale in southern Oklahoma exposures illustrate lithologies that develop induced fractures, required to produce gas from shales in the subsurface.

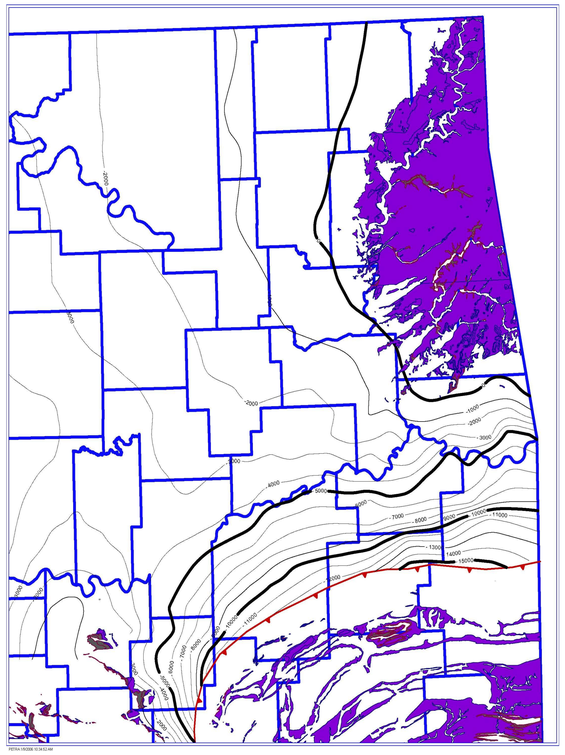
Since 2004, more than 200 Woodford Shale gas wells have been completed in eastern and southern Oklahoma by using advanced completion techniques (e.g., frac technology, horizontal drilling). Most interest is where the Woodford Shale is in the condensate or dry-gas window (>1.15% vitrinite reflectance, VRo), greater than 50 ft thick, and at relatively shallow depth (<12,000 ft) in the western part of the Arkoma Basin where initial potential gas rates up to 11 million cubic ft per day have been realized. Thermal maturity of the Woodford Shale in the Arkoma Basin covers a range of issues from possibly lower gas rates and oil handling in the oil window (<1.15% VRo) to gas composition changes at high thermal maturity (>3% VRo). An additional Woodford Shale gas play in south-central Oklahoma is primarily in the oil window at relatively shallow depth (<7,000 ft).



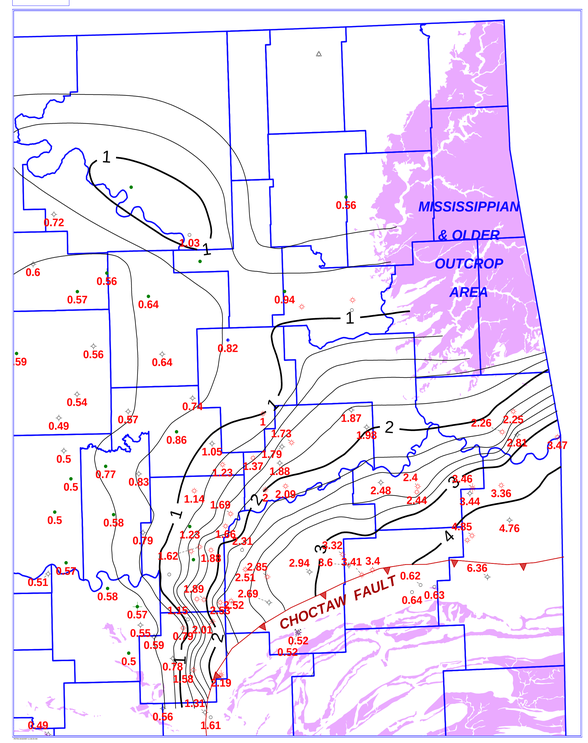
Isopach map of Woodford Shale (from Comer, 1992)

	a	b	c	d	e
Quartz	63-68%	29-87%	30-60%	9-61%	27-53%
K-Feldspar	4%	0-2%	2-10%	2-42%	0-2%
Plagioclase	3%				1-4%
Calcite	10%		5-25%	0-7%	0-11%
Dolomite	6-9%	0-56%	0-5%	0-10%	0-6%
Pyrite	5-7%	0-1%	0-5%	2-30%	1-13%
Total Clays	12-14%				
Illite		8-35%	2-5%	7-53%	13-40%
Illite/Smectite			2-20%		
Kaolinite		1-7%	2-5%	0-2%	0-5%
Chlorinite			2-5%	0-40%	0-5%

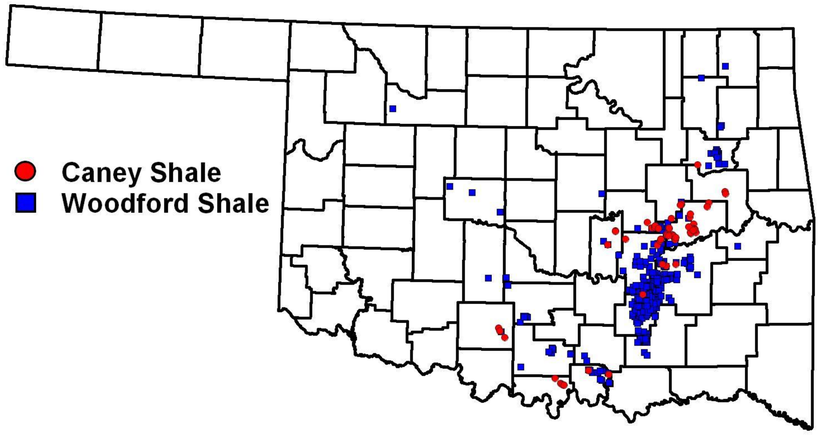
Woodford Shale Mineralogy (a, O'Brien and Slatt, 1990; b, Kirkland et al., 1992; c, Greiser, 2006; d, Branch, 2007; e, Abousleiman et al., 2008)



Generalized structure map of Woodford Shale in eastern Oklahoma (prepared by R. Vance Hall).

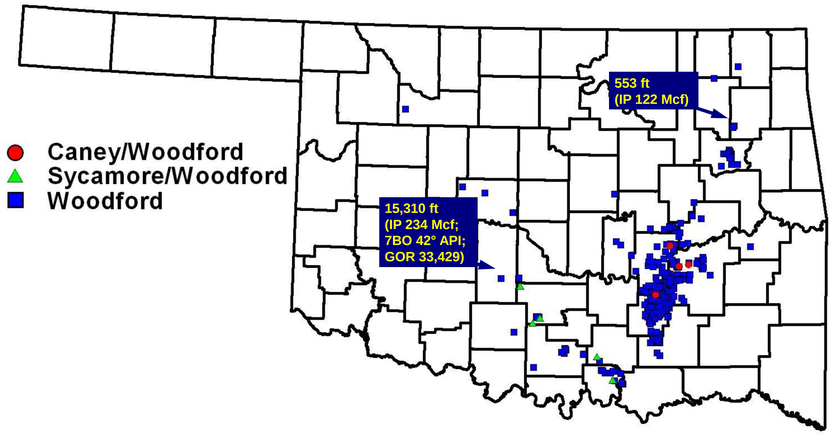


Vitrinite isoreflectance map of Woodford Shale in eastern Oklahoma (contoured by R. Vance Hall from data by B.J. Cardott)



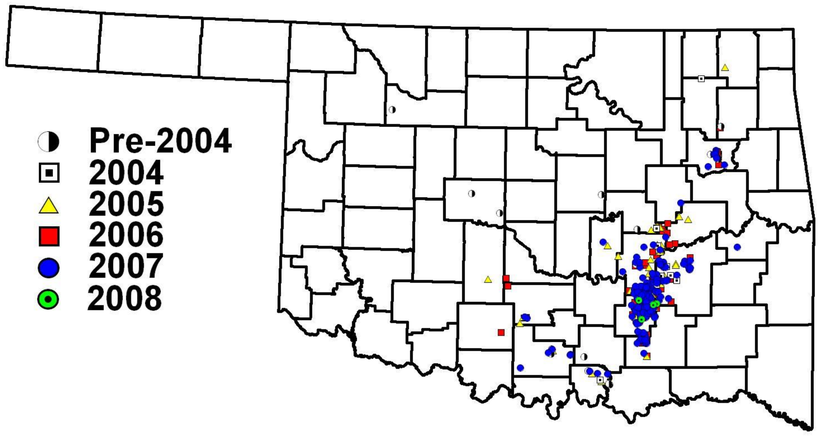
Oklahoma gas shale well completions, 1939-2008

(471 wells; 70 Caney wells; 401 Woodford wells)



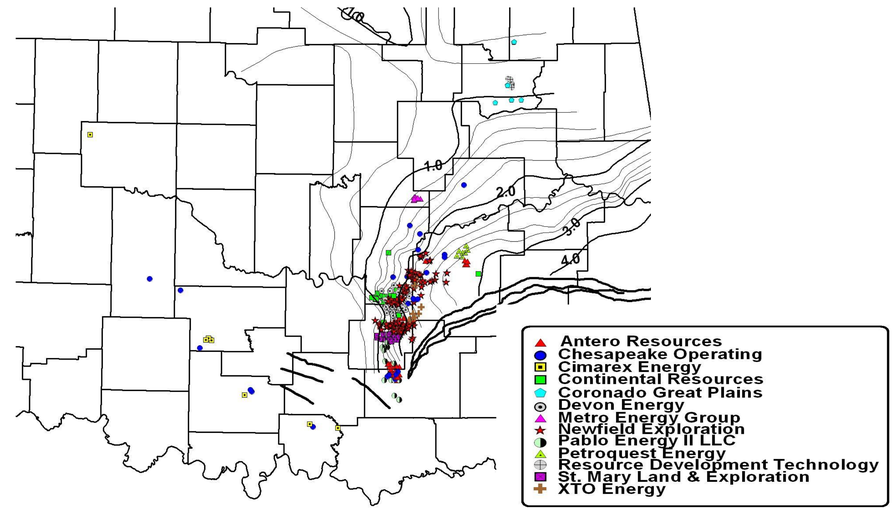
Woodford Shale gas well completions, 1939-2008

(405 wells)

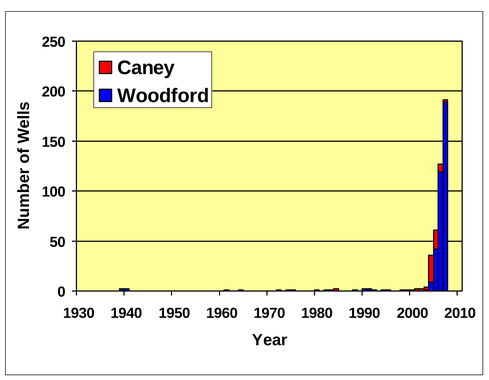


Woodford Shale gas well completions by year, 2004-2008

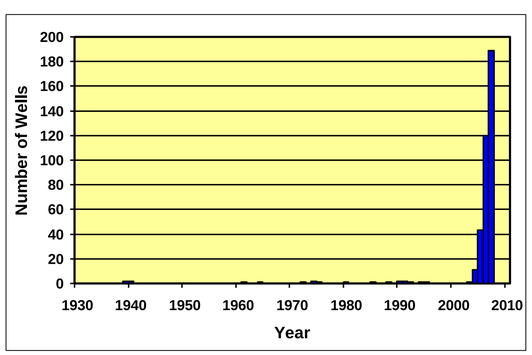
(overlay of 2007 & 2008 wells; 389 wells)



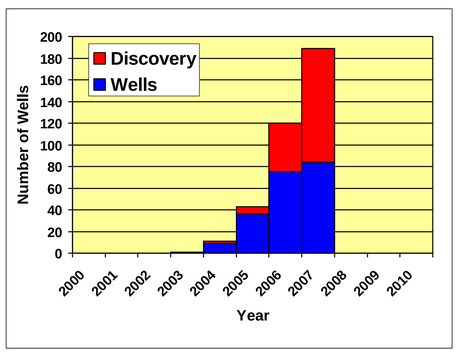
Woodford Shale gas well completions by major operator on isoreflectance map, 2004-2008 (321 wells)



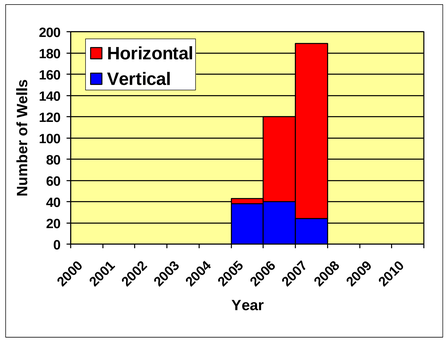
Oklahoma Gas Shale Completion History (1939-2007)



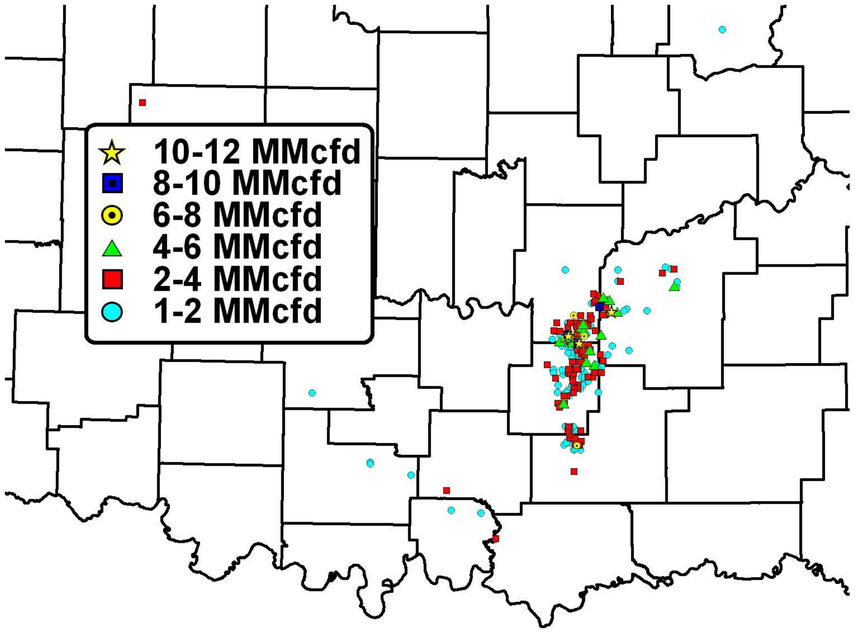
Woodford Gas Shale Completion History (1939-2007)



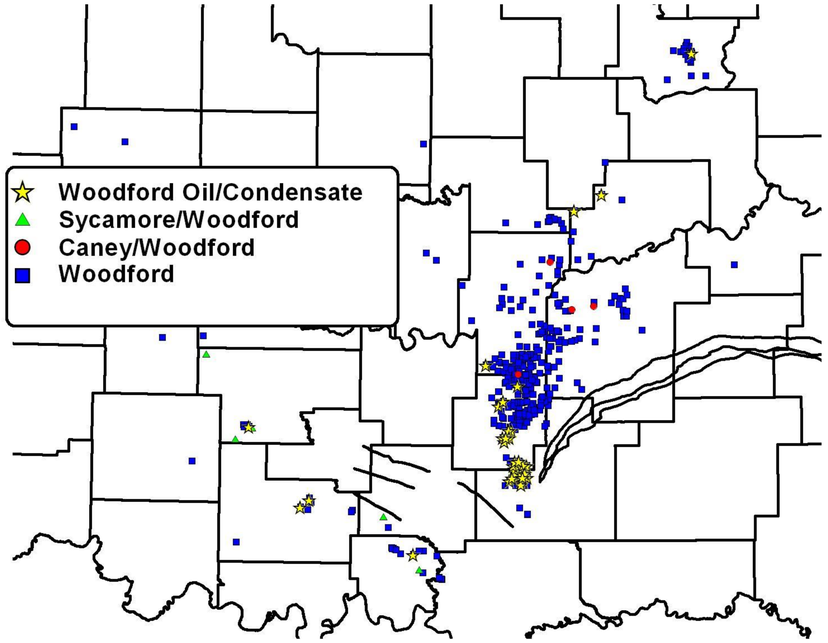
Woodford Shale Gas Field Discovery History



Woodford Shale Well-Type History

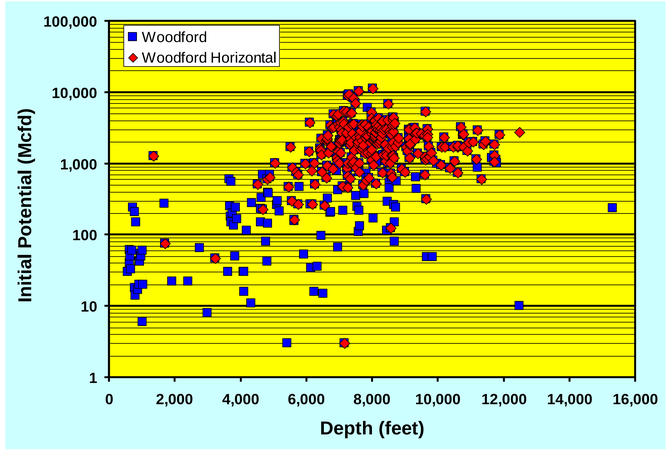


Woodford Shale Wells with Initial Potential Gas Rates >1MMcfd (226 of 405 wells)

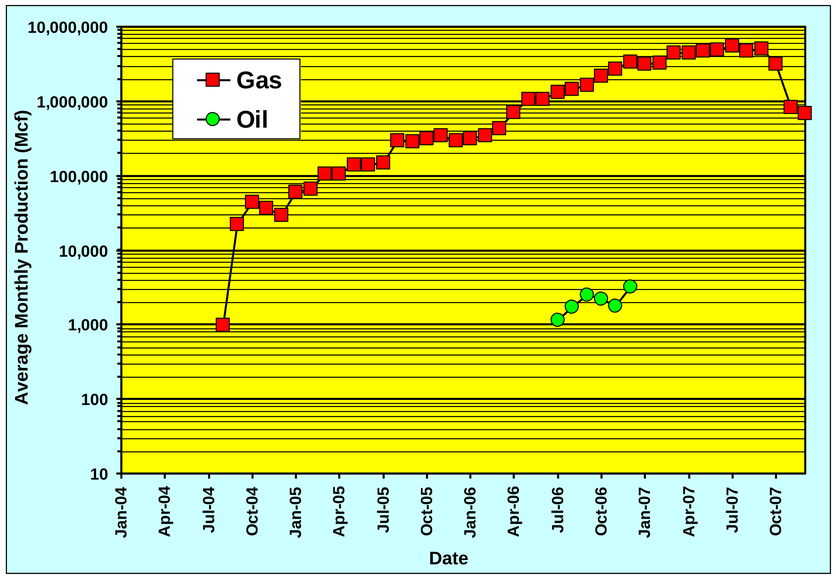


41 Woodford Shale Oil/Condensate Producing Wells (2004-2007)

Initial Potential Gas vs Depth



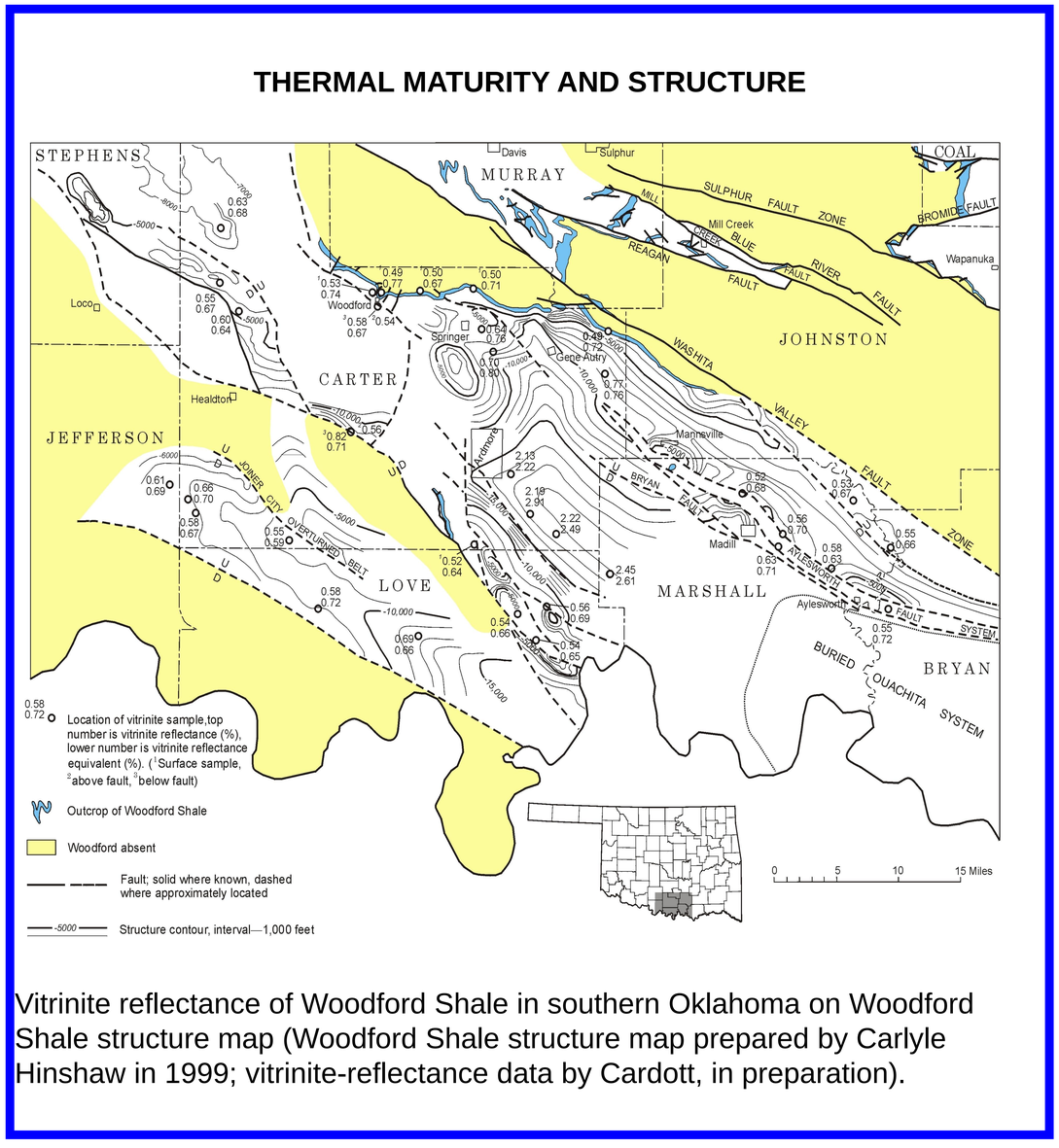
352 Woodford wells (depth & IP pairs): depth 570-15,310 ft; IP 3-11,200 Mcfd.
253 Horizontal Woodford Wells (depth & IP pairs): depth 1,349-12,486 ft TVD; IP 3-11,200 Mcfd.



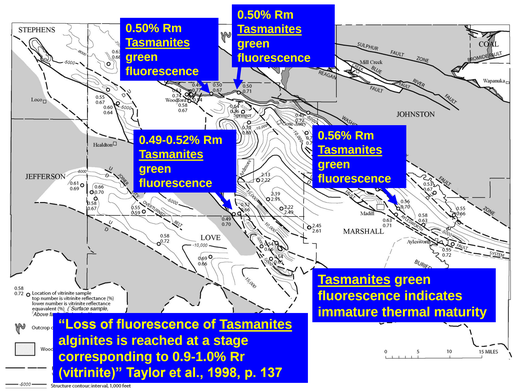
Woodford Shale Production (2004-2007)

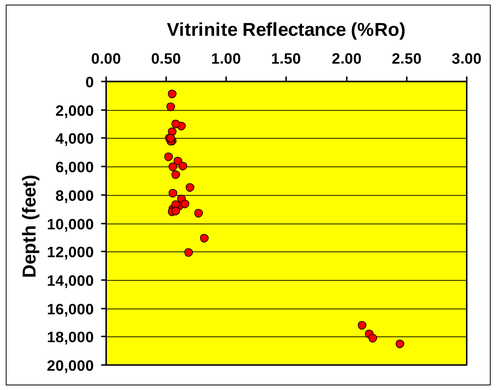
Cumulative production from Woodford-only wells: 63,752,439 Mcf gas, 66,538 BBLS oil/condensate from 279 wells (excluding 23 OWWO; data from IHS Energy)

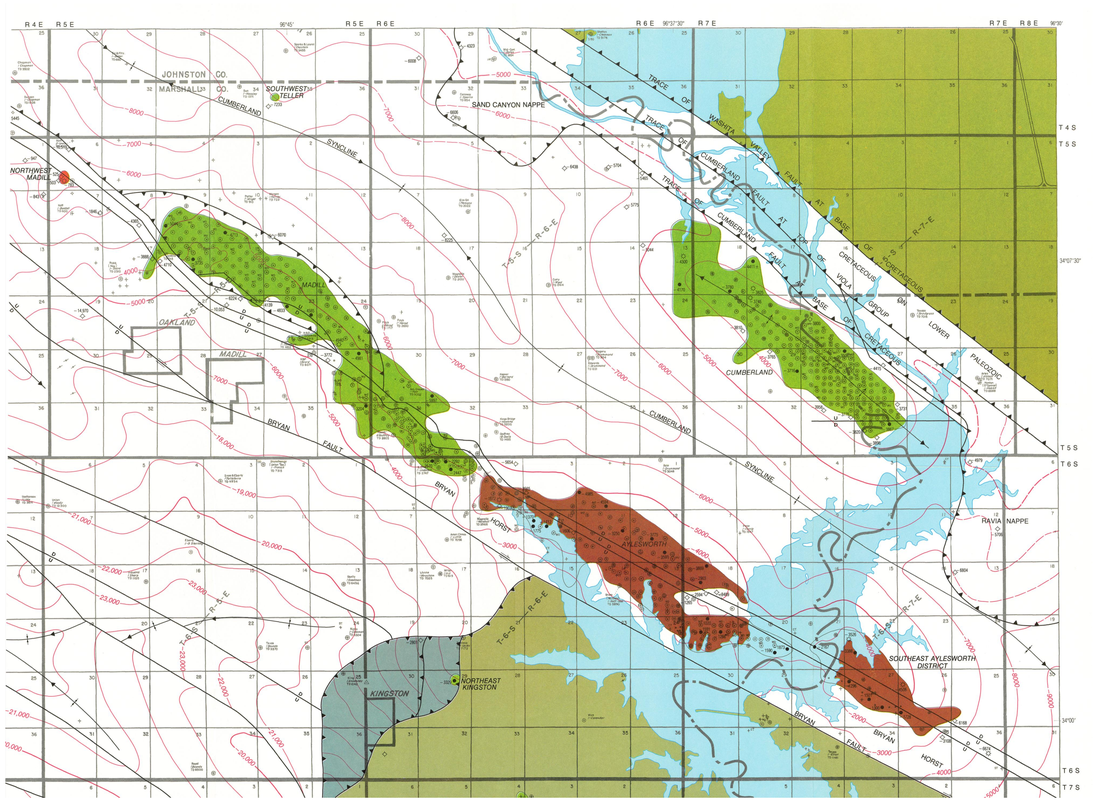
SOUTHERN OKLAHOMA



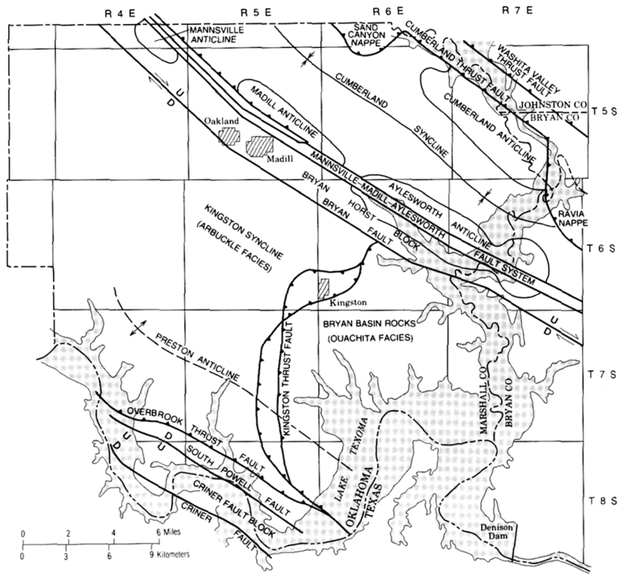
Vitrinite reflectance of Woodford Shale in southern Oklahoma on Woodford Shale structure map (Woodford Shale structure map prepared by Carlyle Hinshaw in 1999; vitrinite-reflectance data by Cardott, in preparation).







Portion of subsurface structure map of Marshall County, OK (modified from Huffman, 1987). Structure contours drawn on top of Viola Group (ft below mean sea level).

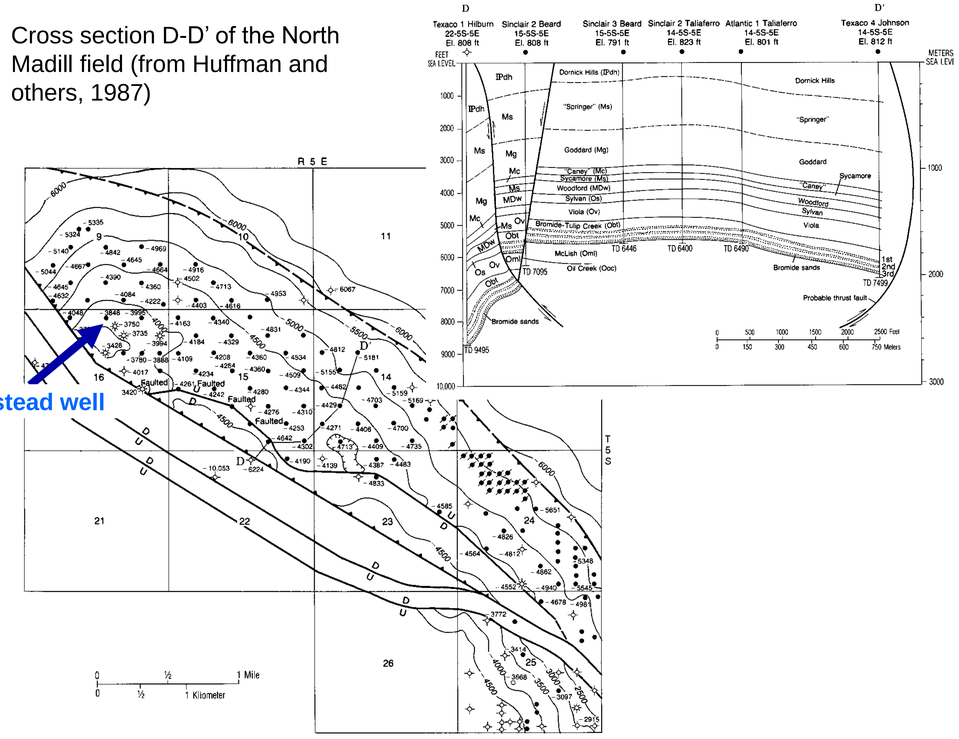


Principal subsurface structural features in Marshall County (from Huffman and others, 1987)

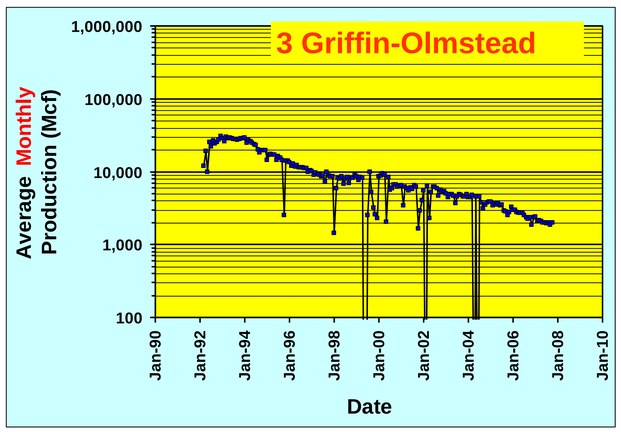
GAS PRODUCTION IN OIL WINDOW

Two examples of gas production from naturally-fractured Woodford Shale in the Madill and Aylesworth anticlines in the Ardmore Basin demonstrate gas production with little or no reported oil production at relatively shallow depths (e.g., @4,000 ft) where the Woodford Shale is in the oil window (@0.6% Ro). Even though Type II Kerogen is capable of generating about 75% of source-rock thermogenic methane by 1.1% Ro (Lewan, 2002), these examples may be special cases where thermogenic gas migrated into the Woodford Shale from deeper in the Ardmore Basin. Gas isotope data from these wells are not available.

Cross section D-D' of the North Madill field (from Huffman and others, 1987)



Structure contour map of the top of the Viola Group (Ordovician) in the North Madill field (from Huffman and others, 1987)



MADILL FIELD

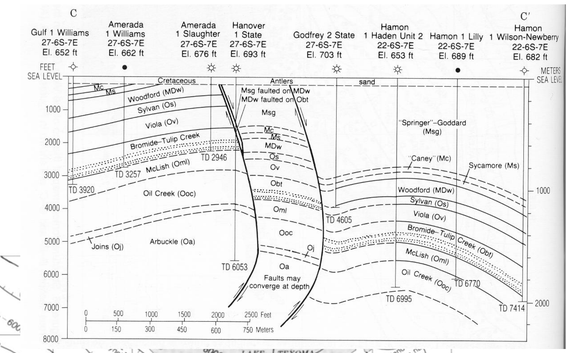
Cimarex Energy of Colorado 3 Griffin-Olmstead well

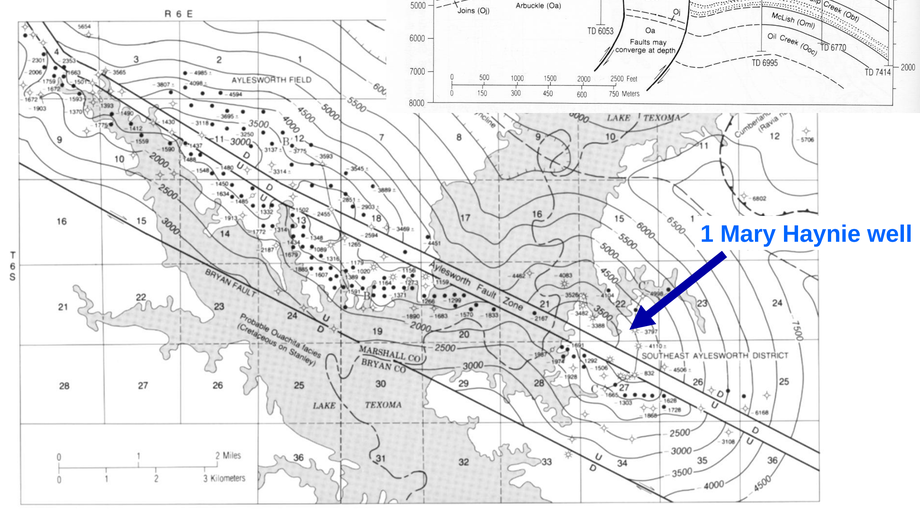
Marshall Co.; NW¼ NW¼ NE¼ 16-5S-5E

Originally completed as oil well in McLlish (6,536-6,544 ft) in 1955, oil workover well in McLish and Bromide (5,664-5,696 ft) in 1956, and gas workover well in Woodford Shale (4,052-4,135 ft) in 1992.

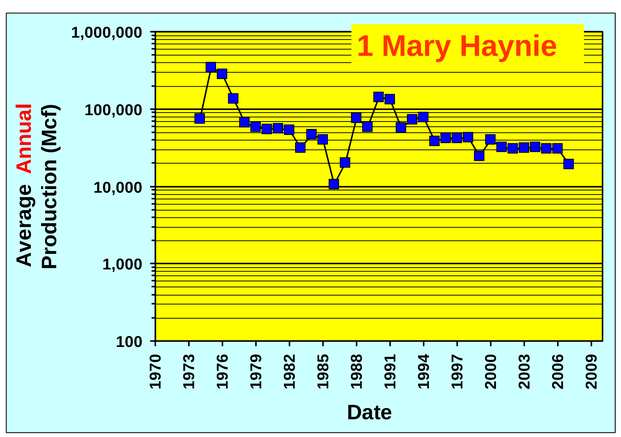
IP 747 Mcfd; Cumulative Woodford Shale gas production of 1,792,734 Mcf from March 1992 to October 2007 (data from IHS Energy)

Cross section C-C' of the SE Aylesworth District field (from Huffman and others, 1987)





Structure contour map of the top of the Viola Group (Ordovician) in the Aylesworth and SE Aylesworth District fields (from Huffman and others, 1987)



SE AYLESWORTH DISTRICT FIELD

Verdad Oil & Gas Corp. 1 Mary Haynie well

Bryan Co.; NW¼ SE¼ SW¼ SE¼ 22-6S-7E

Originally completed as gas well in Misener sand (4,192-4,227 ft) in 1956 and plugged back to Woodford Shale (3,710-4,054 ft) in 1974.

IP 962 Mcfd; Cumulative Woodford Shale gas production of 2,330,605 Mcf from November 1974 to August 2007. Produced 178 bbls oil in 1995 (data from IHS Energy)