Overview of Woodford Gas-Shale Play in Oklahoma

Brian J. Cardott

Oklahoma Geological Survey
Taff (1902) introduced the name Woodford Chert for outcrops north of the town of Woodford in southern Oklahoma.
WOODFORD CHERT: Taff (1902), Gould (1925), Wilmarth (1938), Dott (1952)


Based on conodonts, Hass and Huddle (1965) determined a Late Devonian (Frasnian) age for most of the formation; uppermost part is Early Mississippian (Kinderhookian).
Modified from Johnson and Cardott, 1992
Approximate distribution of Misener Sandstone

From Kuykendall and Fritz, 2001
Pre-Woodford Geologic Map

From Amsden, 1980
Pre-Woodford Geologic Map
Modified from OGS GM-9

Sylvan Shale?
Three informal members based on palynomorphs (Urban, 1960; Von Almen, 1970), geochemistry (Sullivan, 1985), log signatures (Hester and others, 1990; Lambert, 1993)

From Hester and others (1990) [Anadarko Basin]
Woodford Shale in southern Arbuckle Mountains
Woodford Shale in southern Arbuckle Mountains

Modified from Ellis and Westergaard, 1985
Woodford Shale Marker 9 ft below gradational contact with Sycamore Formation
Paleogeography and Facies Distribution in the Late Devonian

From Kirkland and others, 1992
ISOPACH MAP
WOODFORD–CHATTANOOGA SHALE
(U.Devonian and L.Mississippian)

From Amsden, 1989
Isopach Map of Woodford Shale

From Comer, 1992
Woodford Shale Mineralogy

O’Brien and Slatt (1990; Carter County): 63% quartz, 3% plagioclase feldspar, 10% calcite, 6% dolomite, 5% pyrite, 14% total layer silicates.

Kirkland and others (1992; Arbuckle Mountains): 55-87% quartz, 0-7% K-feldspar, 0-3% dolomite, 0-1% apatite, 0-1% pyrite, 8-34% illite, 3-7% kaolin
Woodford Shale is the oldest rock in Oklahoma that contains wood (vitrinite) from the progymnosperm *Archaeopteris* (organ genus *Callixylon*)
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.
Woodford Shale

From Comer, 1992
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% Ro) to mature/post-mature (0.6–>2.0% Ro) 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? \[>1.10-1.3\%V_{Ro}\]

- What is the importance of:
  - natural vs. induced fractures?
  - free gas vs. sorbed gas?
  - mineralogy?
ZONES OF PETROLEUM GENERATION AND DESTRUCTION

ORGANIC MATTER TYPE

AMORPHOUS (OIL) LIPTINITIC

MIXED

COALY (GAS) HUMIC

PEAK OIL GENERATION

PEAK WET GAS GENERATION

PEAK DRY GAS GENERATION

OIL FLOOR

WET GAS FLOOR

DRY GAS GENERATION LIMIT

DRY GAS PRESERVATION LIMIT

OIL

WET GAS

DRY GAS

Modified from Dow (1977), Houseknecht and Spötl (1993), and Taylor and others (1998)
<table>
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<tr>
<td>&lt;0.55%</td>
<td>Immature</td>
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<td>0.55-1.15%</td>
<td>Oil Window (peak oil at 0.90%VRo)</td>
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<td>1.15-1.40%</td>
<td>Condensate–Wet-Gas Window</td>
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<td>&gt;1.40%</td>
<td>Dry-Gas Window</td>
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From Jarvie and others, 2005
Type II Kerogen Gas Generation (Hydrous Pyrolysis)

Figure 1: Generation of oil and gas from an 80-Ma source rock with Type-II kerogen and associated crude oil. Curves are based on kinetic parameters determined by hydrous and hydrothermal pyrolysis and EASY%Ro (Swweeney and Burnham, 1990).

From Lewan, 2002
Figure 2: Volume of hydrocarbon gas (C1-C5) generated by hydrous pyrolysis from thermally immature source rocks bearing different kerogen types (Lewan and Henry, 2001).
U.S. Shale Gas Basins

Source: Schlumberger shale gas white paper, 2005
Structure and Vitrinite Reflectance of Woodford Shale, Anadarko Basin

From Cardott and Lambert, 1985
Structure and Vitrinite Reflectance of Woodford Shale, Southern Oklahoma

Cardott, in preparation
Reflectance Suppression

Southern Oklahoma Woodford VRo suppressed by 0.17-0.44% Ro

from:

modified after:
0.55% Rm
HI=500
@0.75% Rc

0.50% Rm
HI=500
@0.68% Rc

0.50% Rm
HI=700
@0.83% Rc

0.51% Rm
HI=460
@0.68% Rc

0.49-0.52% Rm
HI=800
@0.93% Rc

0.56% Rm
HI=600
@0.83% Rc

0.50% Rm
HI=500
@0.68% Rc

0.50% Rm
HI=700
@0.83% Rc

0.58% Rm
HI=700
@0.96% Rc

0.55% Rm
HI=500
@0.75% Rc

Corrected Reflectance
Rm=measured
Rc=corrected

Location of vitrinite sample
Top number is vitrinite reflectance (%)
Lower number is vitrinite reflectance equivalent (%)
Surface sample, Above fault, Below fault

Outcrop of Woodford Shale

5000

Fault, solid where known, dashed where approximately located

Structure contour interval, 1,000 feet
Tasmanites green fluorescence indicates immature thermal maturity.

0.49-0.52% Rm Tasmanites green fluorescence

0.50% Rm Tasmanites green fluorescence

0.50% Rm Tasmanites green fluorescence

0.56% Rm Tasmanites green fluorescence

Tasmanites green fluorescence indicates immature thermal maturity.
Generalized Structure Map of Woodford Shale, Eastern Oklahoma

Map prepared by R. Vance Hall using Petra
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
Woodford Shale GAS Wells

143 Wells, 1939–2006
Woodford Gas Shales
1939–2006

15,310 ft
(IP 234 Mcf; 7BO 42° API; GOR 33,429)

143 Wells
3 Caney/Woodford
3 Sycamore/Woodford
Woodford Gas Shales
1939-1996

21 Wells
1 Sycamore/Woodford

<1MMcf/mo
steep decline
Madill
Aylesworth

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

Madill Field

Cumulative Gas Production
1,747,709 Mcf

Completed as OIL well in McLish 6,536-6,544 ft on 11/4/55;
OIL-WO well in McLish and Bromide 5,664-5,696 ft on 5/18/56;
GAS-WO to Woodford on 3/21/92

(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)

Completed as GAS well in Misener 4,192-4,227 ft on 6/27/58; GAS-WO (plugback) in Woodford on 11/22/74

Cumulative Production 2,288,394 Mcf

Average Annual Production (Mcf)

Aylesworth Field

346 MMcf

75 MMcf

(100)

(1,000)

(10,000)

(100,000)

(1,000,000)

1970

1973

1976

1979

1982

1985

1988

1991

1994

1997

2000

2003

2006

Date

Cumulative Production Data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group, © 2006, IHS Energy Group)
Woodford Gas Shales

2004–2006

122 Wells
3 Caney/Woodford
2 Sycamore/Woodford
Depth: 553-15,310 ft; IP: 6-6,897 Mcfd
Woodford Shale Production (2004-2006 wells)

Cumulative Production
11,757,701 Mcf gas,
9,048 BBLS oil/condensate
from 98 wells (excludes 11 OWWO)

Average Monthly Production (Mcf)

Date

Jan-04 Mar-04 May-04 Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05 Jan-06 Mar-06 May-06 Jul-06 Sep-06 Nov-06

(Gas production data supplied by PI/Dwights LLC, © 2007, IHS Energy Group)
Woodford Shale Oil/Condensate Production (2004-2006 wells)

@0.75% Ro
40° API oil
GOR 22,776

@0.6% Ro
55° API condensate
GOR 87,555

@1.3% Ro
55° API condensate
GOR 87,555

@1.3% Ro
40° API oil
GOR 22,776

@0.6% Ro
GOR 41,210

@1.4% Ro
http://www.ogs.ou.edu

For more information, please visit the Oklahoma Geological Survey Web Site

Oil and Gas

- About Oil & Gas
- Commonly Asked Questions
- Sources of OK Data
- OGS Oil and Gas Related Publications

Type Logs
- Oklahoma Stratigraphic Columns

Links
- Available Publications

Oklahoma Hydrocarbon Source Rocks and Gas Shales

- References
- Presentations & Reports
- Oklahoma Gas-Shale Completions Map, 1939-2006
- Oklahoma Gas-Shale Completions Map, 2002-2006
- Gas Shales Database

Gas Well: Mustang Production Co. #1-29 Dobbins, located in Sec. 29-T.15N., R.11W., Blaine County, OK. Photo by Rick Andrews.
References

Brian J. Cardott  
Oklahoma Geological Survey

Bibliography of Caney Shale
Bibliography of Excello Shale  
Bibliography of Woodford Shale  
Bibliography of Oklahoma Asphalt  
Bibliography of Oklahoma Rock-Eval

Bibliography of Oklahoma Solid Hydrocarbons  
Bibliography of Oklahoma Gas Shales  
Bibliography of Oklahoma Hydrocarbon Source Rocks

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Typical Calf Creek point of Woodford chert found in Haskell County, Oklahoma
(Norman Transcript, March 11, 2007, p. E1)