Overview of Unconventional Energy Resources of Oklahoma

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Unconventional Energy Resources of Oklahoma

- Coalbed Methane
- Gas Shales
- Oil Shales
- Tight Gas and Ultra-Deep Reservoirs
- Oil (Tar) Sands
Coalbed methane, gas shales, and tight gas reservoirs are commonly referred to as continuous gas accumulations because they are regionally pervasive and generally not buoyancy-driven accumulations, commonly independent of structural and stratigraphic traps.
Non-conventional (or unconventional) fuels that were eligible for tax credits under the Internal Revenue Service Code Section 29 from 1980–2002

- oil from shale
- oil from tar sands
- natural gas from geopressured brine, coal seams, Devonian shale, or tight sands
- liquid, gaseous, or solid synthetic fuel, including petrochemical feedstocks, (other than alcohol) from coal liquefaction or gasification facilities
Non-conventional (or unconventional) fuels that were eligible for tax credits under the Internal Revenue Service Code Section 29 from 1980–2002

- gas from biomass (including wood)
- steam from solid agricultural by-products
- qualifying processed solid wood fuels
Coalbed Methane

See “Coalbed-Methane Activity in Oklahoma, 2004 Update”
Gas Shales

Gas shales and oil shales are varieties of hydrocarbon source rocks.

HYDROCARBON SOURCE ROCK CLASSIFICATION

**Organic matter type** refers to the kerogen or maceral type and can be lumped into gas generative, oil generative, or inert.

**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 0.5–1.3% 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% Ro) to mature (0.6–2.0% Ro) and contain biogenic to thermogenic methane. Gas is generated and stored in situ in gas shales as both sorbed (on organic matter) and free gas (in fractures and pores), similar to natural gas in coals. As such, gas shales are self-sourced reservoirs. Low-permeable shales require extensive natural fractures to produce commercial quantities of gas.
Gas Shales of the United States

Figure 1: Distribution of Fractured Shale Reservoirs

Hill and Nelson, 2000
## Hydrocarbon Source Rocks of Oklahoma

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>PRODUCING INTERVAL</th>
<th>HYDROCARBON-SOURCE ROCK</th>
<th>KEROGEN TYPE</th>
<th>TOC %</th>
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<td>SIMPSON GROUP</td>
<td>II II</td>
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<td>ARBUCKLE GROUP</td>
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Johnson and Cardott, 1992
Van Krevelen Diagram

Burruss and Hatch, 1989
### Potential Gas Shales of Oklahoma

<table>
<thead>
<tr>
<th>FORMATION</th>
<th>TOC (WT %)</th>
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<td>Excello Shale (black shale lithofacies)</td>
<td>1-17</td>
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<tr>
<td>Caney Shale</td>
<td>2.02-5.4</td>
</tr>
<tr>
<td>Woodford Shale</td>
<td>&lt;1-14</td>
</tr>
</tbody>
</table>
Woodford Shale Stratigraphy
ISOPACH MAP
WOODFORD-CHATTANOOGA SHALE
(U.Devonian and L.Mississippian)
Amsden (1988)

EXPLANATION
- Shale, dark gray to black, cherty
- Approximate southern limit of Misener-Sylamore basal sandstone facies
- Thickness contour; contour intervals 30, 60 m
- Major fault affecting distribution of unit
Map of Mature Woodford Shale

Adapted from Carr (1987), Cardott (1989, 2001a, 2001b), and Comer (1992)
Woodford-Only Oil & Gas Leases

- 24 Woodford-only gas leases
- 48 Woodford-only oil leases
  (oil and associated gas)

Map of oil and gas lease production was generated by Scott March with Geo Information Systems from Natural Resources Information System (NRIS) data files.
Woodford Gas Wells

27.1 Bcf gas was produced from 19 Woodford-only wells at 1,400–12,702 ft from June 1961 to November 2003

Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group © 2004
Caney Shale members are differentiated based on paleontology rather than lithology

Sutherland, 1981
“False” Caney

Andrews, 2003
“False” Caney

Andrews, 2003
Caney Shale TOC Content

• 2.02-4.04% in the Arkoma Basin (16 samples; Hendrick, 1992)
• 4.4-5.4% in the Ouachita Mountains (3 samples; Cardott, 1994)
Caney-Only Gas Leases

Map of gas lease production was generated by Geo Information Systems from Natural Resources Information System (NRIS) data files.

7 gas-only leases, 1979-9/2003
Caney Gas Wells

701 MMcf gas was produced from 4 Caney-only wells at 2,668–3,872 ft from February 1998 to August 2003

Gas production data supplied by Petroleum Information/Dwrights LLC dba IHS Energy Group © 2004
Excello Shale Stratigraphy

Ece, 1989
- OK Outcrop samples
- OK Core samples from western OK (5,560-9,541 ft)

Black shale lithofacies have 1.1–16.8% TOC, ave. @10%

Ece, 1989
Excello Shale Thermal Maturity

0.51-0.63% Ro along outcrop

0.61-1.44% Ro from cores includes recycled vitrinite

Ece, 1989
Excello Shale gas production is included with Mulky coalbed-methane production
“any shallow rock yielding oil in commercial amount upon pyrolysis is considered to be an oil shale”
Oil Shales

- Mudstone, siltstone, marlstone, or carbonate
- Cambrian to Tertiary in age
- Thermally immature to mature
- Organic–rich (minimum of 5 volume percent types I and II kerogen; not related to TOC)
- Near surface
Woodford Shale in Arbuckle Mountains

Hyrudrude (1986) hydroretorting assay test

Hunton Quarry
- Marginally mature
- Surface exposure
- Type II kerogen
- 9.5 wt% TOC
Hy crude (1986) hydroretorting assay test

- Hydroretorting is the heating (>540°C) of shale in a retort under a hydrogen-rich atmosphere at elevated pressures (@1,000 psi).
- Evaluated 90 pounds of Woodford Shale
Hycrude (1986) Results

- Fischer Assay oil yield, 8.4 gal/ton
- Raw Shale hydroretorting assay oil yield, 22.9 gal/ton
  Highgraded for 120 minutes
- Highgraded Fischer Assay oil yield, 20.3 gal/ton
- Highgraded hydroretorting assay oil yield, 46.8 gal/ton
Tight Gas and Ultra-Deep Reservoirs

“Tight gas sands are low-permeability gas-bearing reservoirs (in a variety of rock types) that have an in situ permeability to gas of less than 0.1 md, exclusive of natural fracture permeability. The reservoirs are areally extensive, usually abnormally pressured, and often (but not always) found in basin-center settings.”

(Kuuskraa and Bank, 2003)
Tight Gas in the United States

Figure 13. Map of the United States showing the geographic distribution of known and potential BCGAs.

Law, 2002
Tight Gas in Oklahoma

Anadarko Basin
Red Fork
Cleveland
Granite Wash

Arkoma Basin
Atoka
Prouty, 2001
Tight Gas in Oklahoma

The Red Fork play has an average EUR of 2,200-8,800 MMcf/well at a depth of 9,000-13,000 ft, net pay of 7-200 ft, porosity of 1-18%, permeability of 0.1-20 md, and estimated ultimate recoverable of 2,890.6 Bcf.

Prouty, 2001
Tight Gas in Oklahoma

The Cleveland play has an average EUR of 1,000 MMcf/well at a depth of 5,500-12,000 ft, net pay of 6-55 ft, porosity of 3-14%, permeability of 0.001-20 md, and estimated ultimate recoverable of 702.9 Bcf.

Prouty, 2001
Tight Gas in Oklahoma

The **Granite Wash** play has an average EUR of 1,500 MMcf/well at a depth of 6,500-11,500 ft, net pay of 10-60 ft, porosity of 4-12%, permeability of 0.0009-1.4 md, and estimated ultimate recoverable of 349 Bcf.

Prouty, 2001
“Oil sands (also called tar sands in the U.S.) are sandstones or carbonate strata containing bitumen or other hydrocarbons of such high viscosity as to be immobile under normal reservoir temperatures.”

Rottenfusser, 2003
Oil (Tar) Sands

“In order to be utilized, the hydrocarbons must be mined or extracted *in situ* from the rock by the use of heat or solvents.”

Rottenfusser, 2003
Petroleum-Impregnated Rocks of Oklahoma

Adapted from Jordan (1964)

- △ Petroleum-impregnated rocks
- Outcrop of Ordovician and older rocks
Dougherty Asphalt Quarry

In-Place Bitumen Resource of 3.6 million barrels

Production of bitumen-impregnated limestone > 1 million short tons from 1890 to 1960

Asphalt-saturated Viola Group limestone

Cardott and Chaplin (1993)
Sulfur Asphalt Quarry

Cardott and Chaplin (1993)

In-Place Bitumen Resource of 46.4 million barrels

Production of bitumen-bearing sandstone > 1.5 million short tons from 1890 to 1962

White silica veins in asphalt-saturated Oil Creek Formation sandstone
Bitumen-impregnated rock was quarried from the Dougherty and Sulphur districts and taken by truck to the crushing, screening, and mixing plant near Dougherty. The blended asphalt product was used as road-paving material. Synthetic crude oil has never been a product of the Oklahoma asphalt deposits.
Geologists with Suncor Energy Inc. (Canada) evaluated the Sulphur oil sand deposit in 1998 as part of a worldwide exploration for oil sand reserves. Brian McKinstry (formerly with Suncor Energy; personal communication June 2003) indicated that the Oklahoma deposits were structurally complex (dipping at steep angles) and had limited bitumen resources for an economic oil sand operation.
Technically Recoverable U.S. Natural Gas Resources as of January 1, 2002 (trillion cubic feet)

- Proved: 183 trillion cubic feet
- Inferred nonassociated: 232 trillion cubic feet
  - Offshore: 78 trillion cubic feet
  - Onshore: 154 trillion cubic feet
- Undiscovered nonassociated: 222 trillion cubic feet
  - Offshore: 82 trillion cubic feet
  - Onshore: 140 trillion cubic feet
- Unconventional: 475 trillion cubic feet
  - Coalbed methane: 350 trillion cubic feet
  - Shale gas: 60 trillion cubic feet
  - Tight gas: 40 trillion cubic feet
  - Lower 48 associated-dissolved: 25 trillion cubic feet
- Other unproved: 168 trillion cubic feet

Total: 1,279 trillion cubic feet