Overview of Unconventional Energy Resources of Oklahoma

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Presented at OGS Conference on “Unconventional Energy Resources in the Southern Midcontinent” in Oklahoma City on March 9, 2004

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

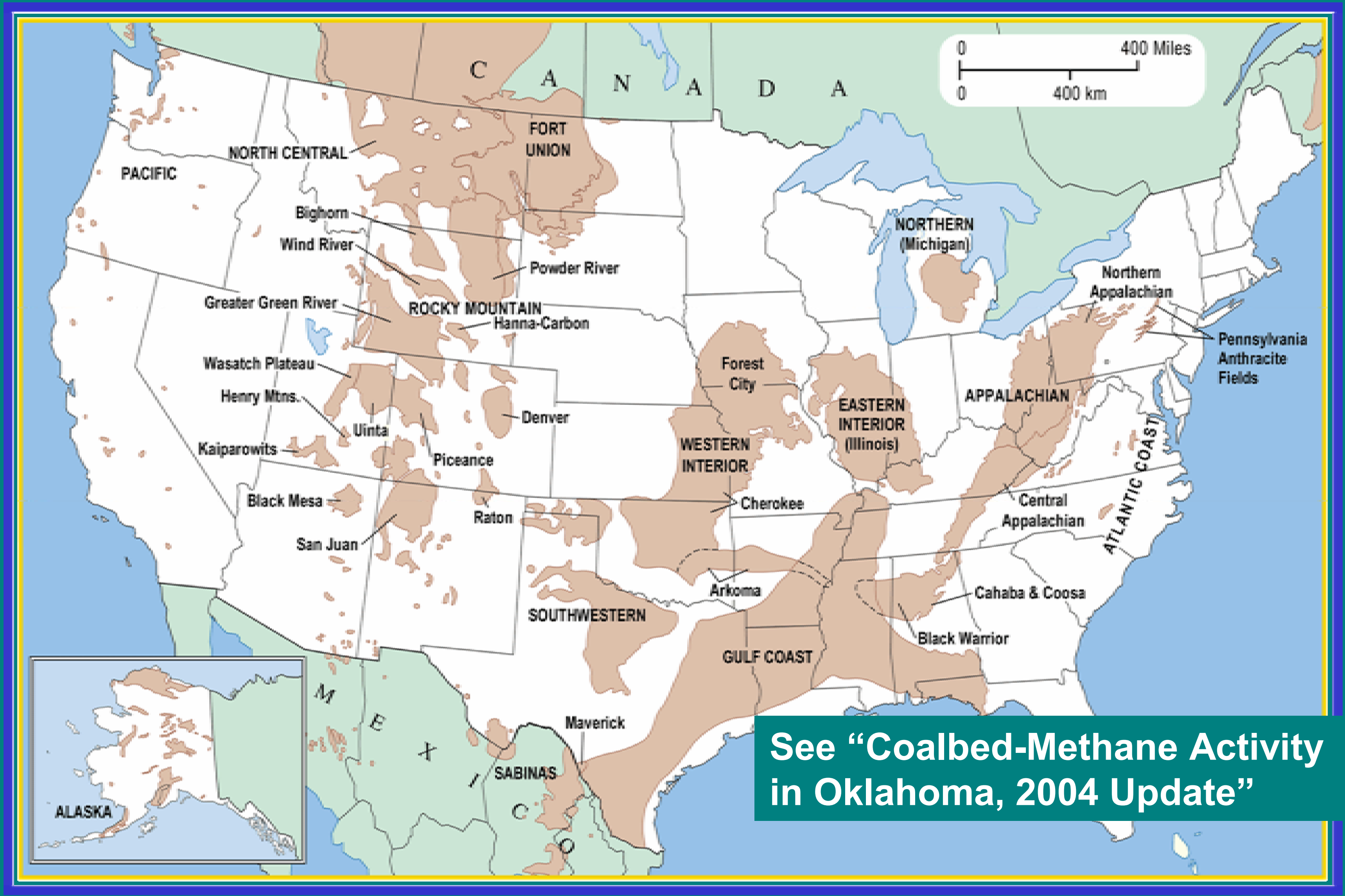
Non-conventional (or unconventional) fuels that were eligible for tax credits under the Internal Revenue Service Code Section 29 from 1980–2002

- 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

o gas from biomass (including wood)
o steam from solid agricultural by-products
o 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

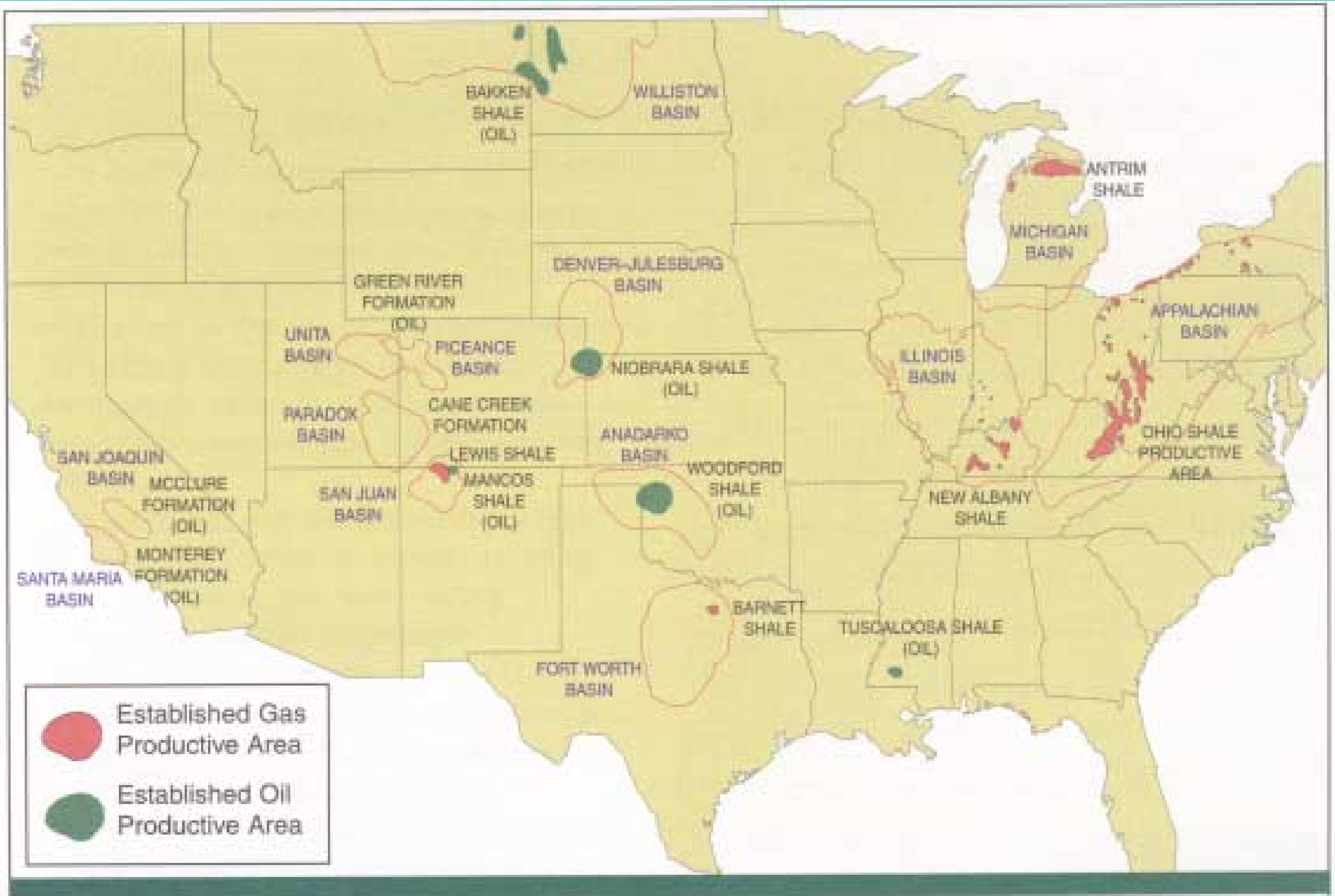


Figure 1: Distribution of Fractured Shale Reservoirs

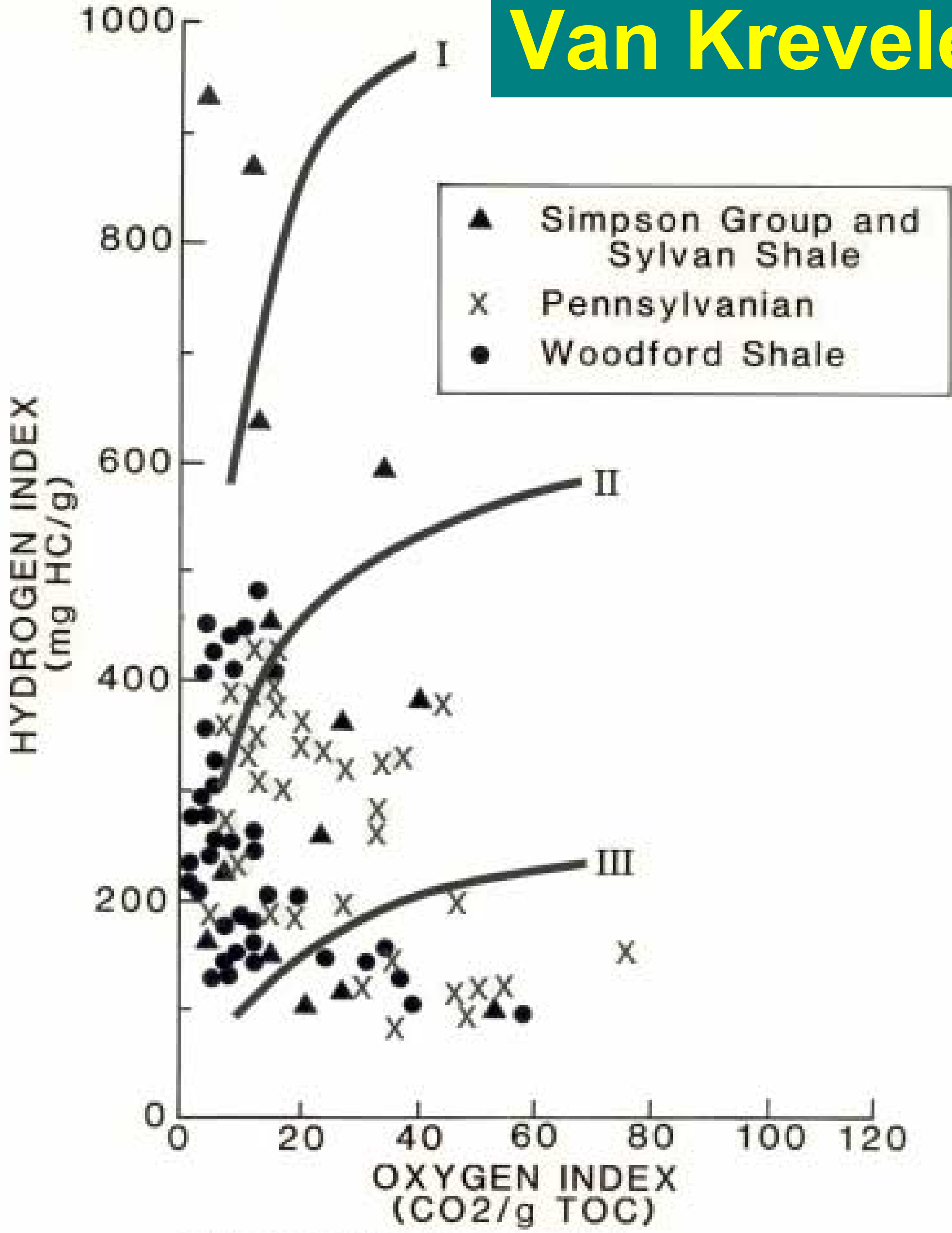
Hill and Nelson, 2000

Hydrocarbon Source Rocks of Oklahoma

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

Johnson and Cardott, 1992

Van Krevelen Diagram

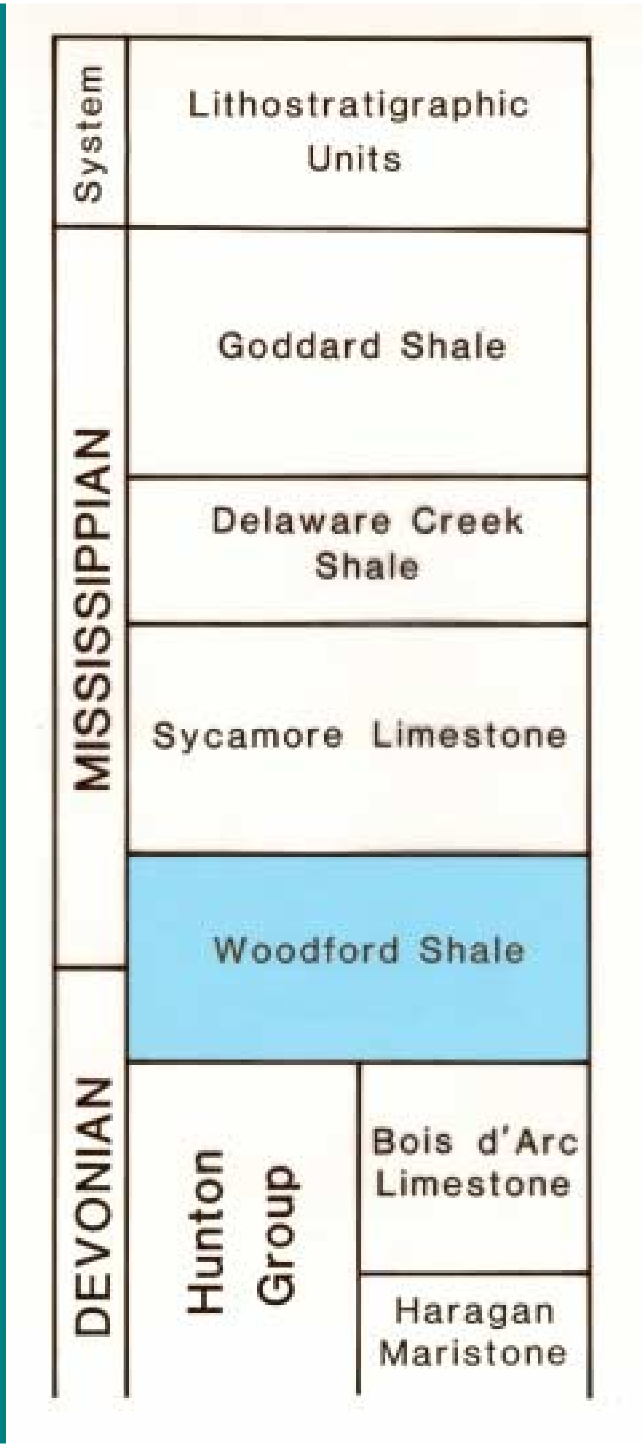


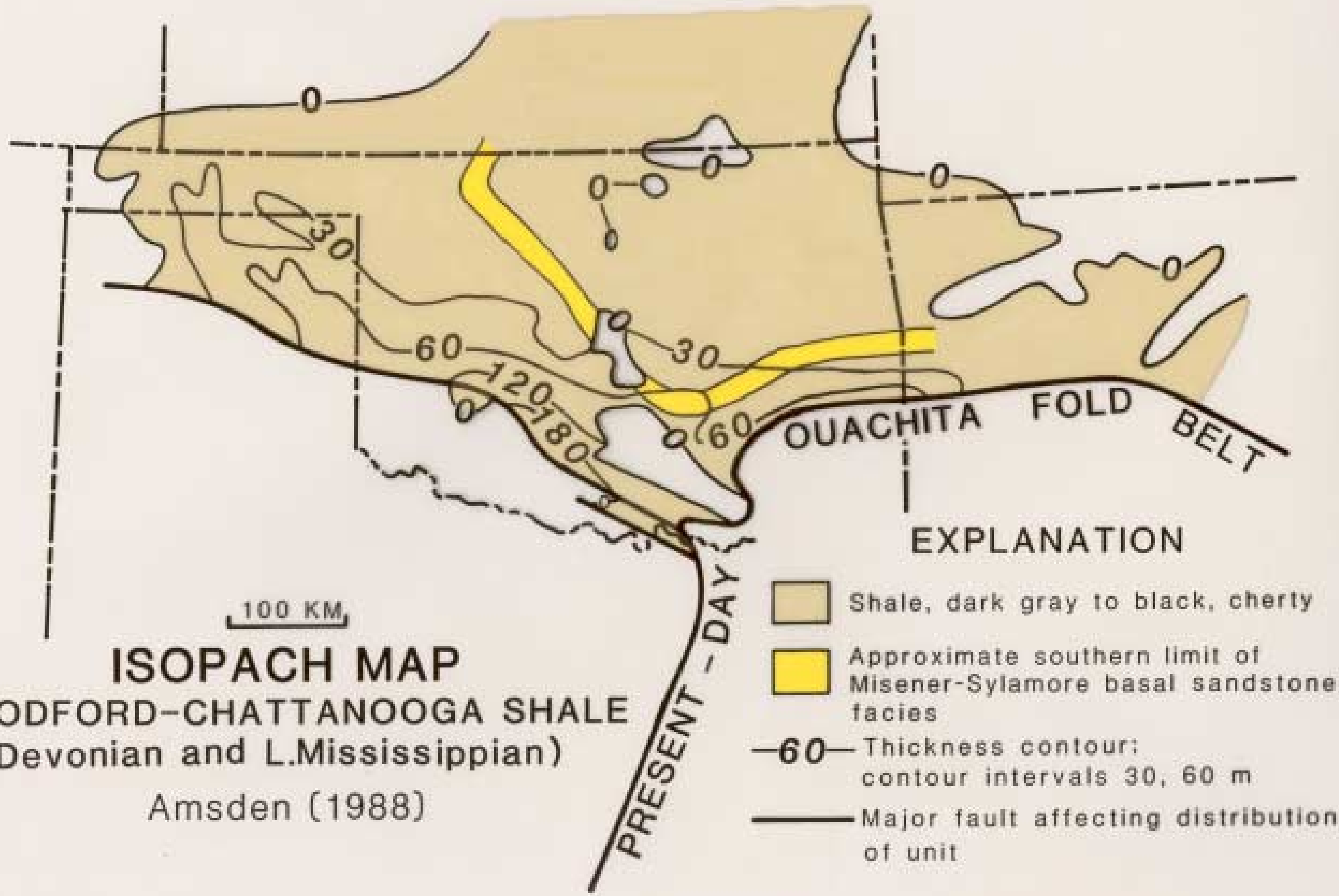
Burruss and Hatch, 1989

Potential Gas Shales of Oklahoma

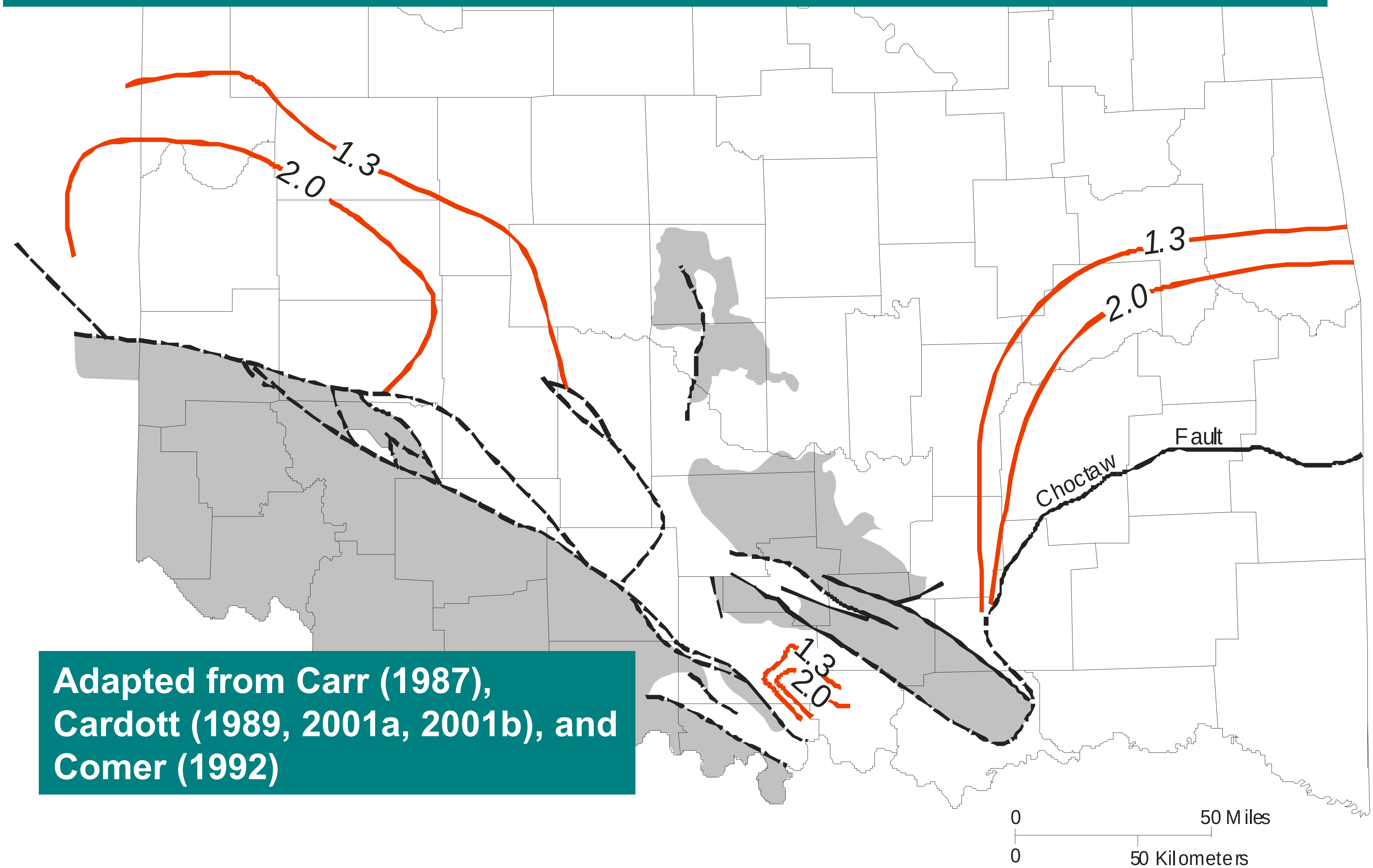
FORMATION	TOC (WT %)
Excello Shale (black shale lithofacies)	1-17
Caney Shale	2.02-5.4
Woodford Shale	<1-14

Woodford Shale Stratigraphy




0
0
0
0
0
30
60
30
120
180
0
60
OUACHITA FOLD BELT
PRESENT - DAY
100 KM
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
60 Thickness contour: contour intervals 30, 60 m
Major fault affecting distribution of unit

Map of Mature Woodford Shale

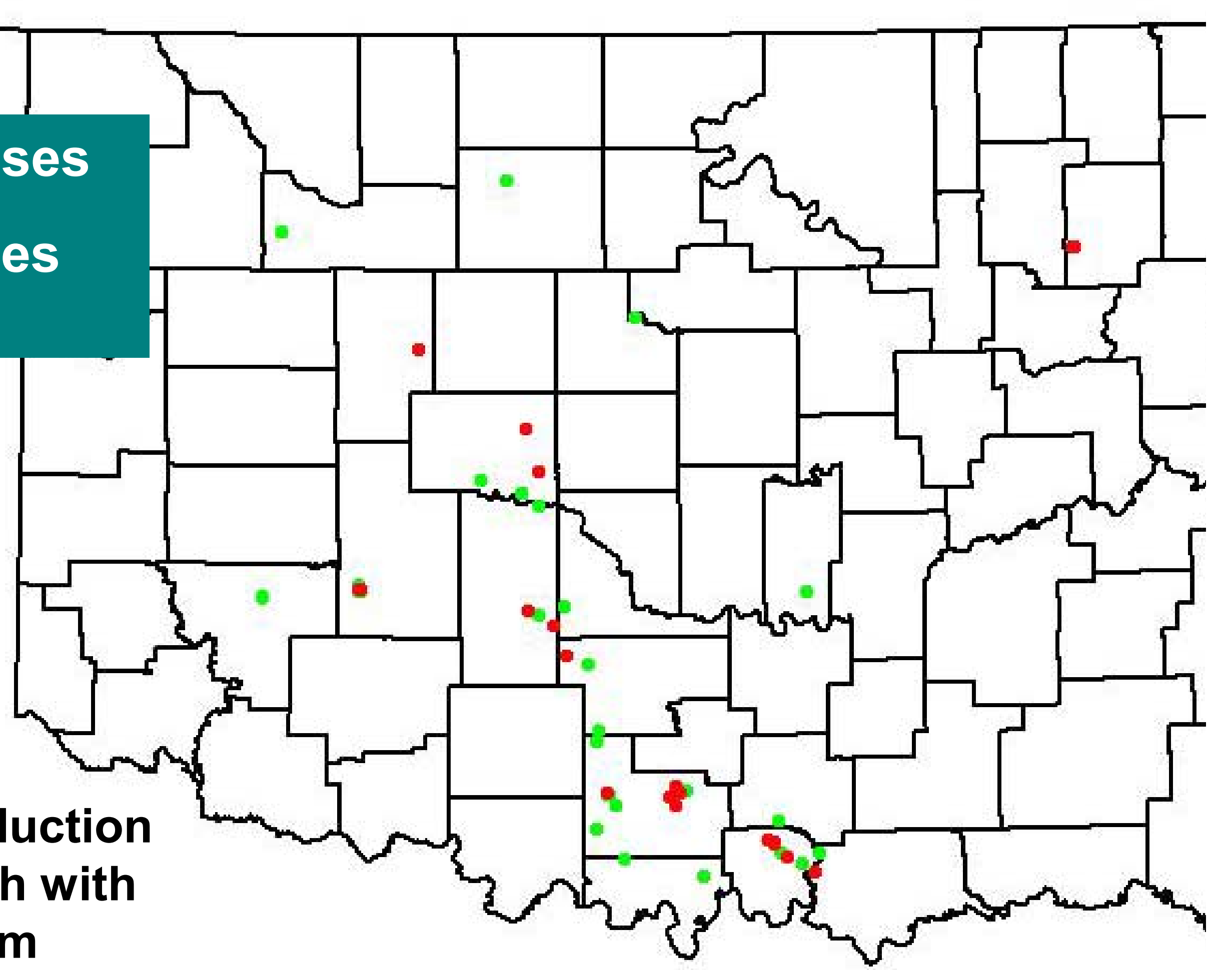


Adapted from Carr (1987), Cardott (1989, 2001a, 2001b), and Comer (1992)

Woodford-Only Oil & Gas Leases

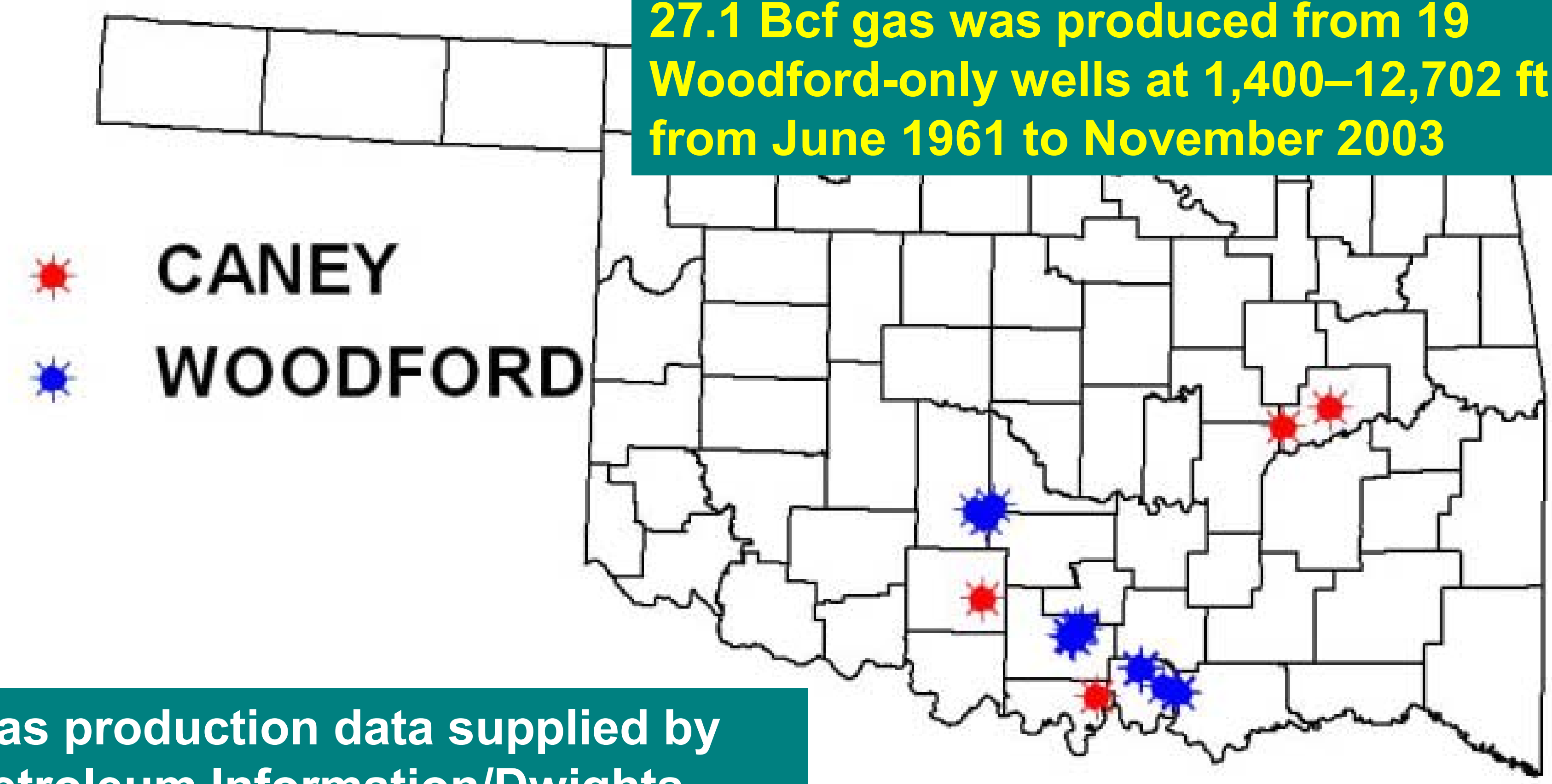
24 Woodford-only gas leases

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



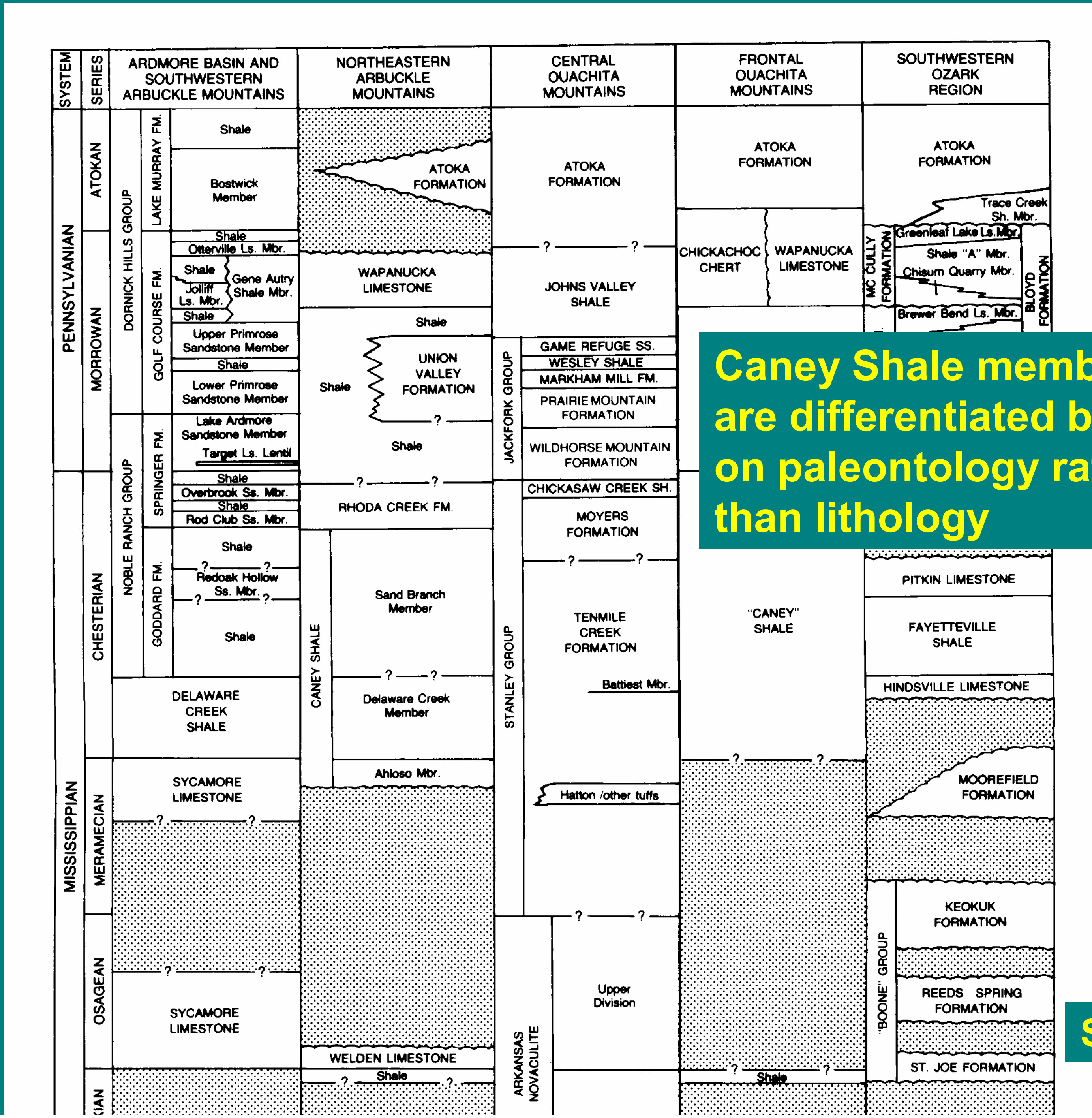
Map of oil and gas lease production was generated by Scott March with Geo Information Systems from Natural Resources Information System (NRIS) data files

Woodford Gas Wells



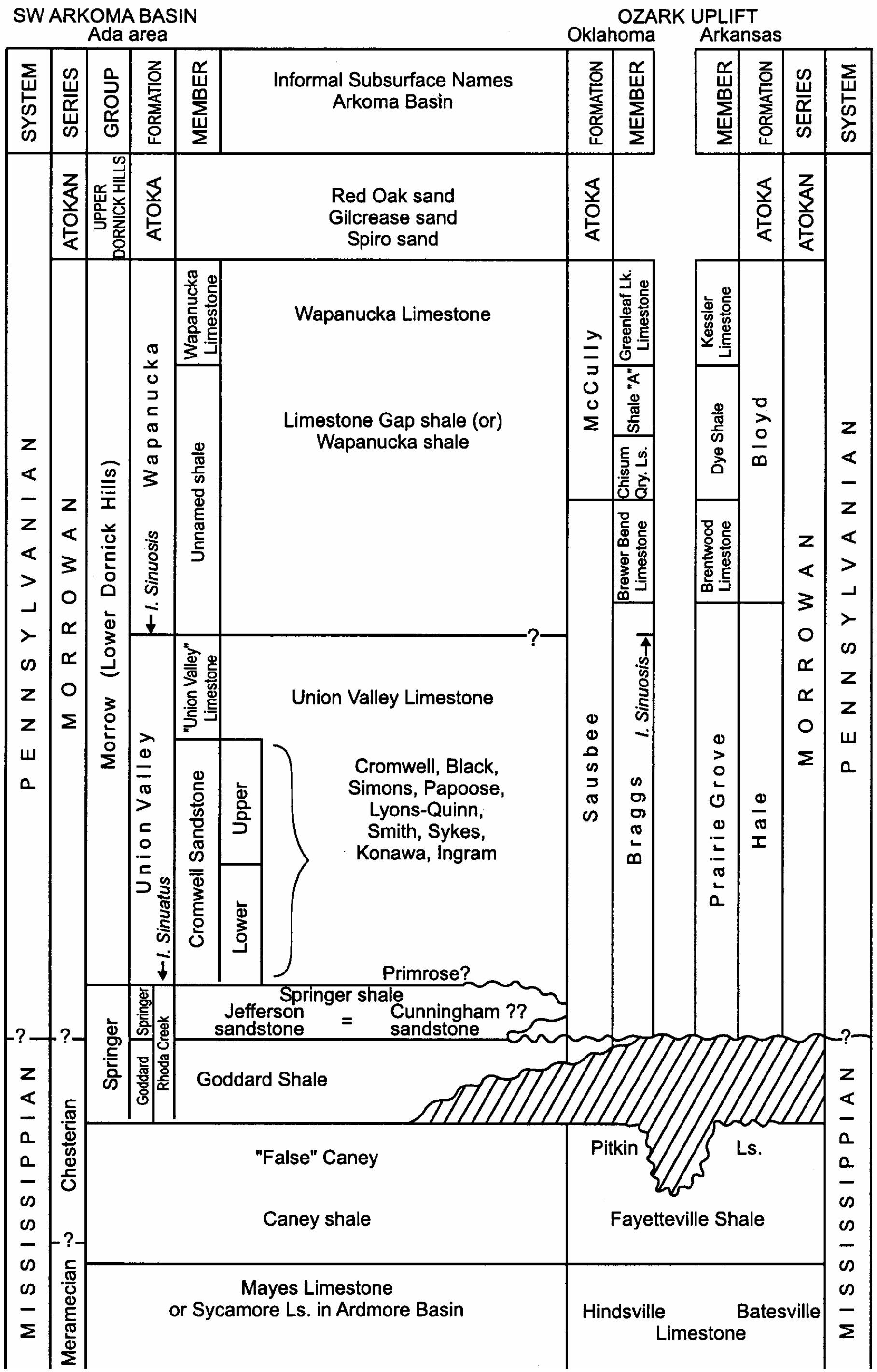
27.1 Bcf gas was produced from 19 Woodford-only wells at 1,400–12,702 ft from June 1961 to November 2003

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

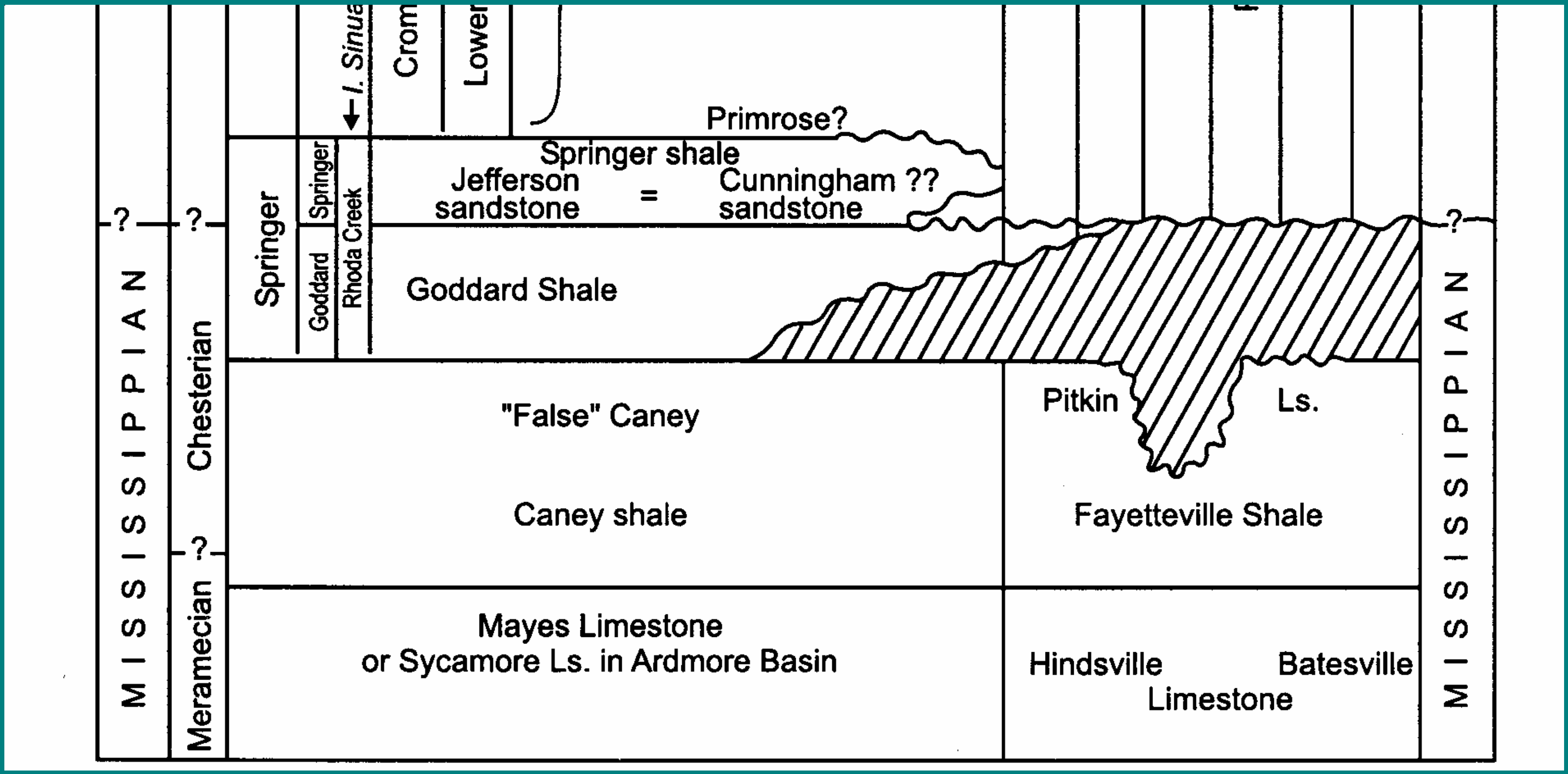
Sutherland, 1981



"False" Caney

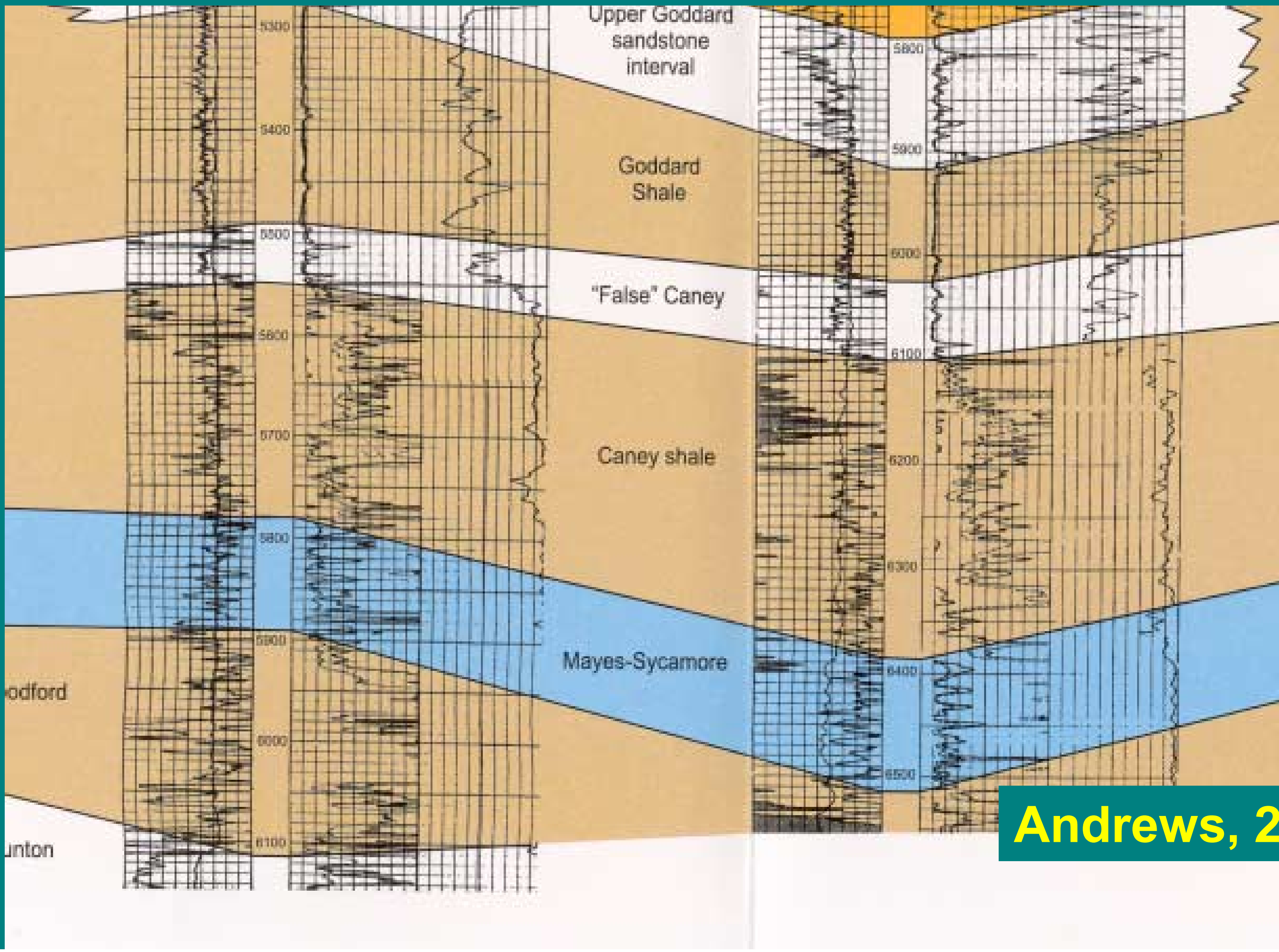
Andrews, 2003

“False” Caney



Andrews, 2003

“False” Caney

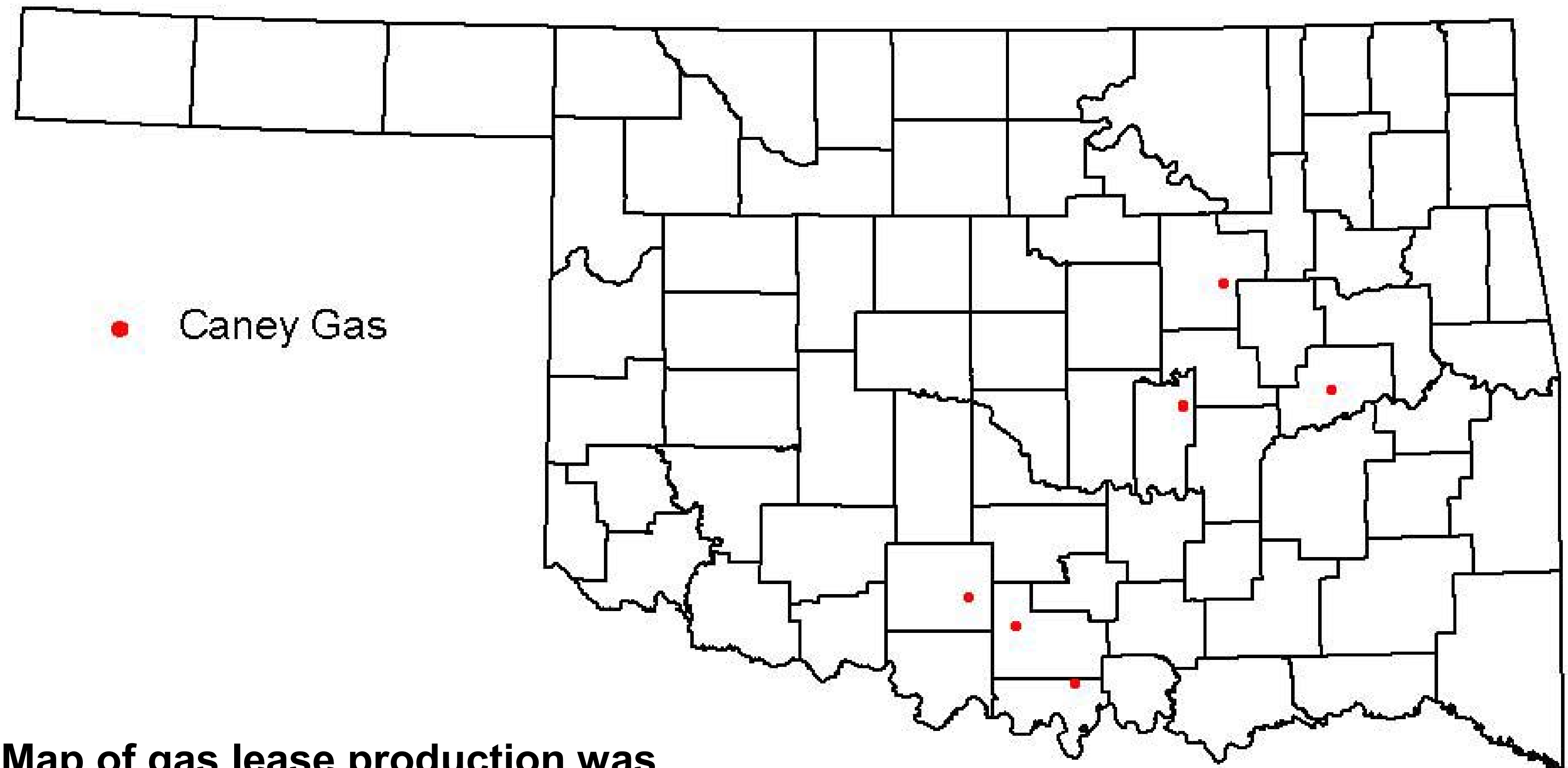


Andrews, 2003

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

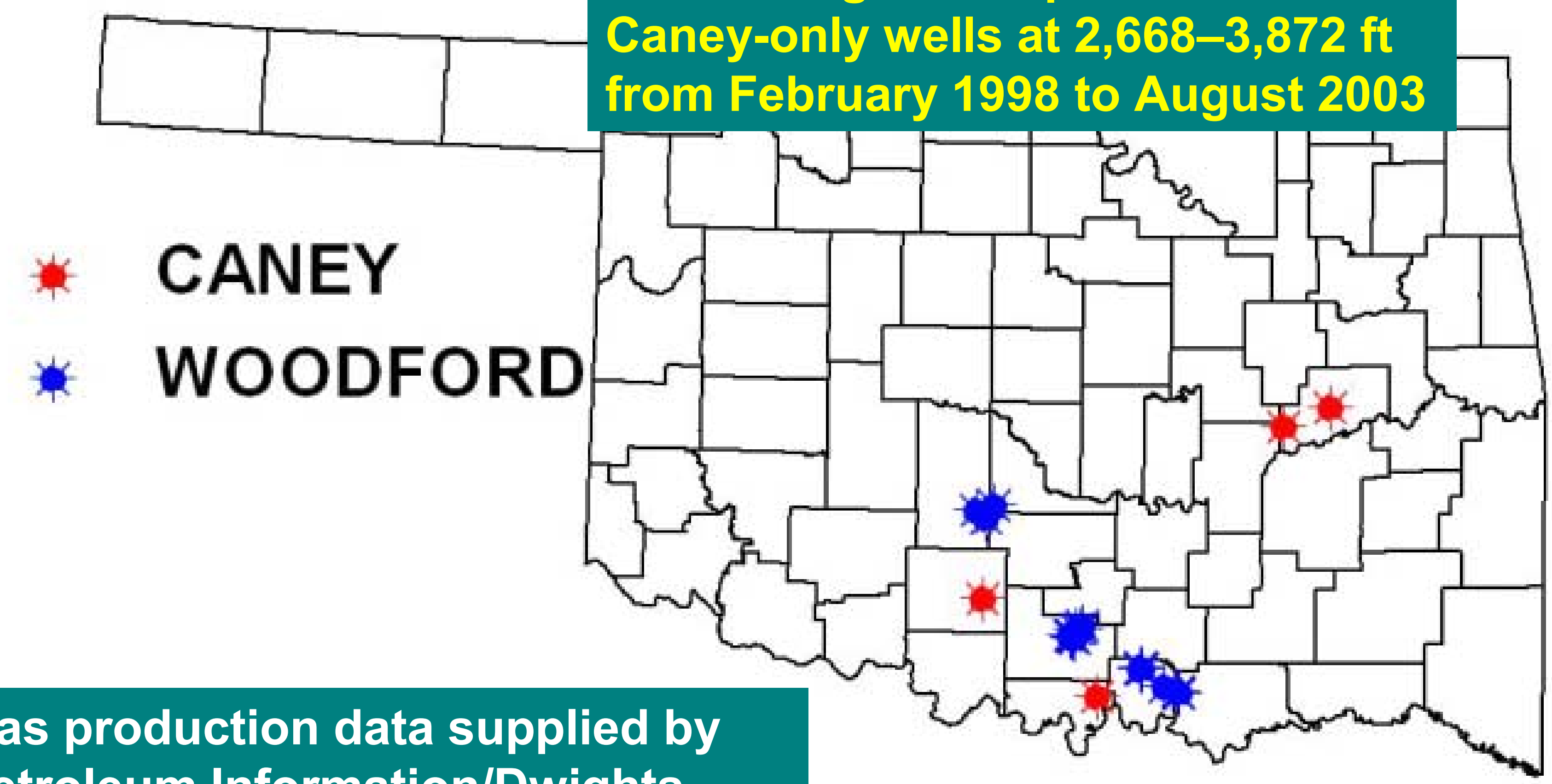


Map of gas lease production was generated by Geo Information Systems from Natural Resources Information System (NRIS) data files

7 gas-only leases, 1979-9/2003

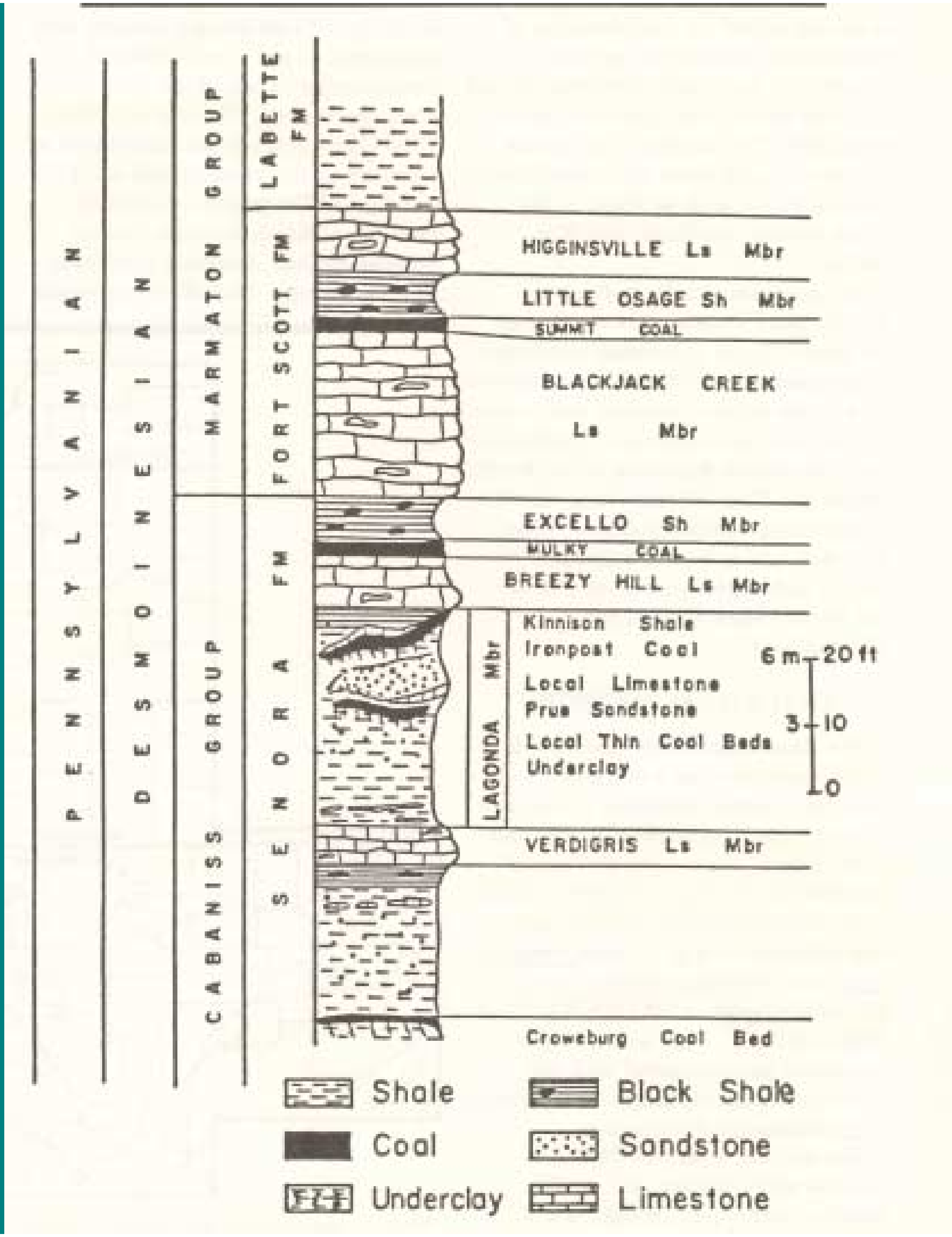
Caney Gas Wells

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

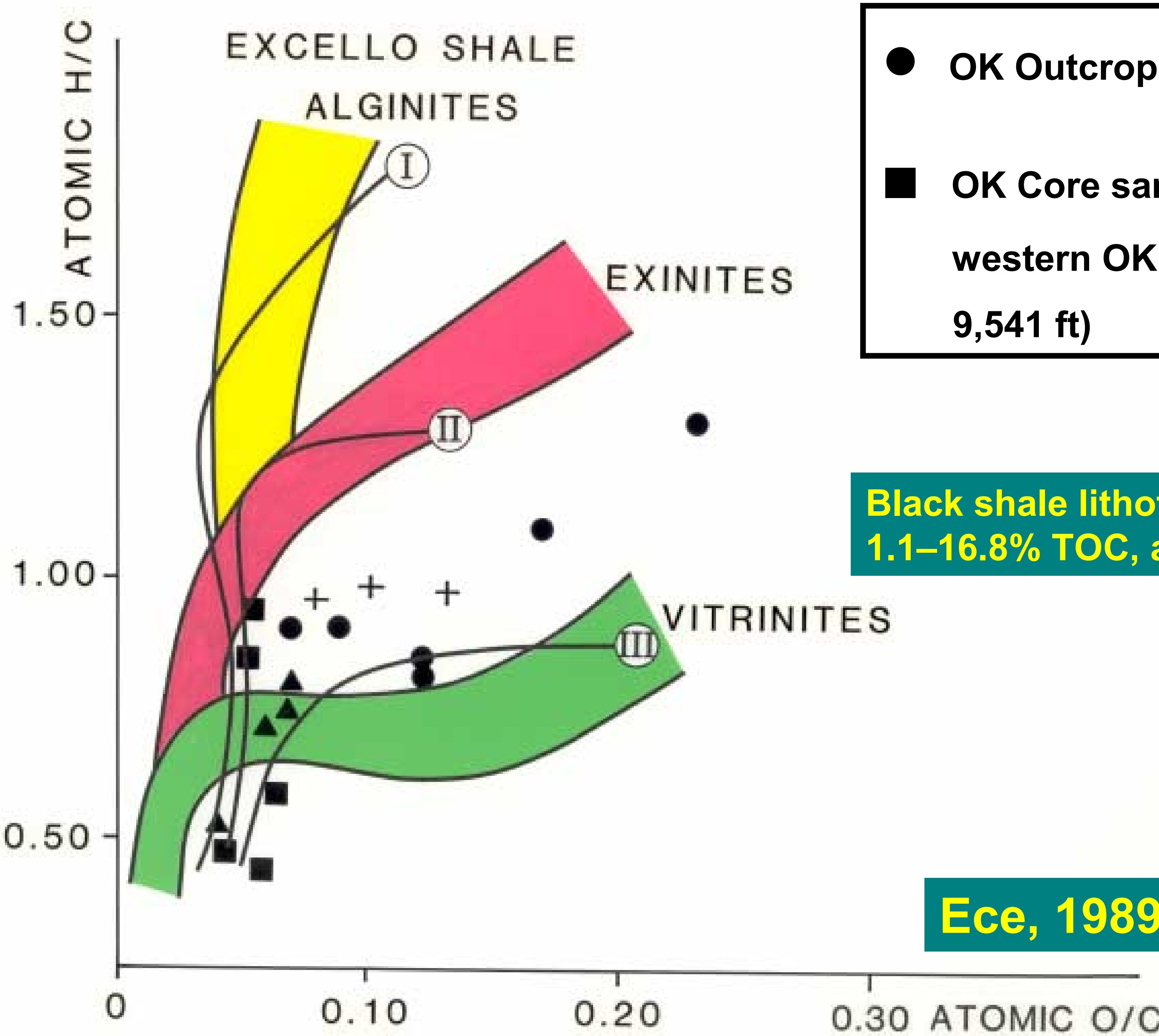


Gas production data supplied by Petroleum Information/Dwights LLC dba IHS Energy Group © 2004

Excello Shale Stratigraphy



Ece, 1989



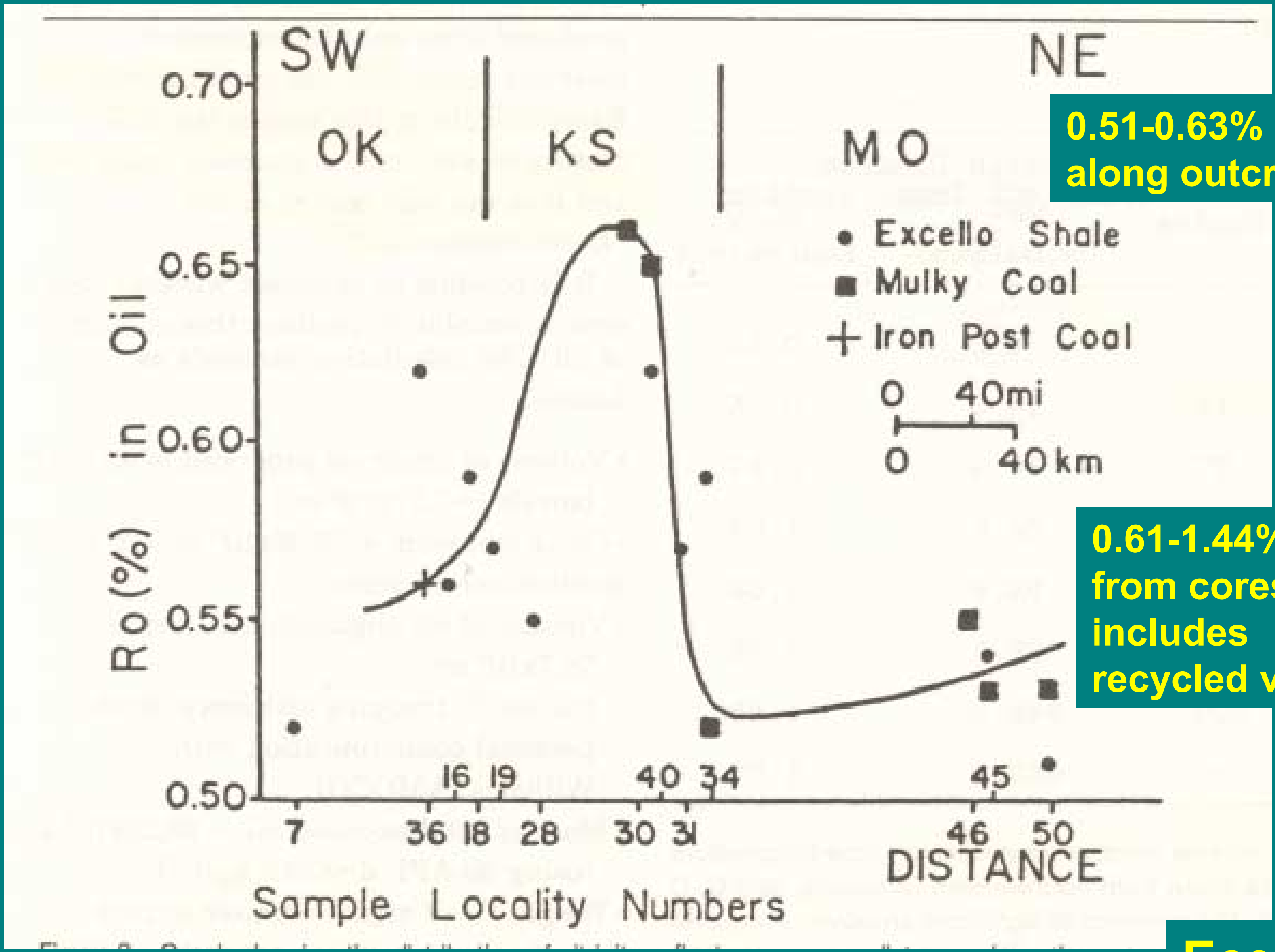
● OK Outcrop samples

■ 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

Oil Shales

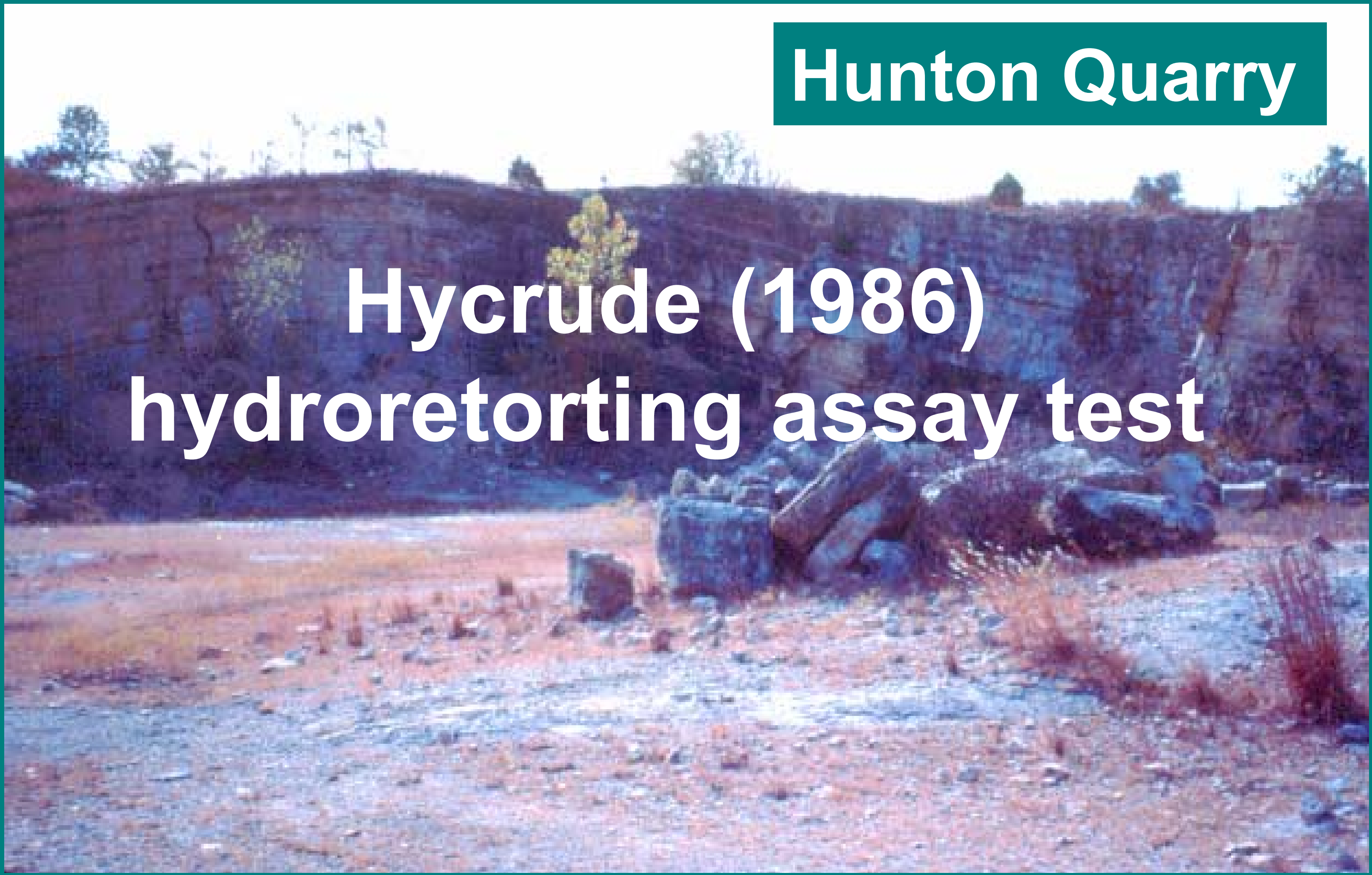
"any shallow rock yielding oil in commercial amount upon pyrolysis is considered to be an oil shale"

Tissot and Welte, 1984

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



Woodford Shale Pit

- Marginally mature
- Surface exposure
- Type II kerogen
- 9.5 wt% TOC

Hycrude (1986) hydroretorting assay test

- Hydroretorting is the heating (>540ºC) 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

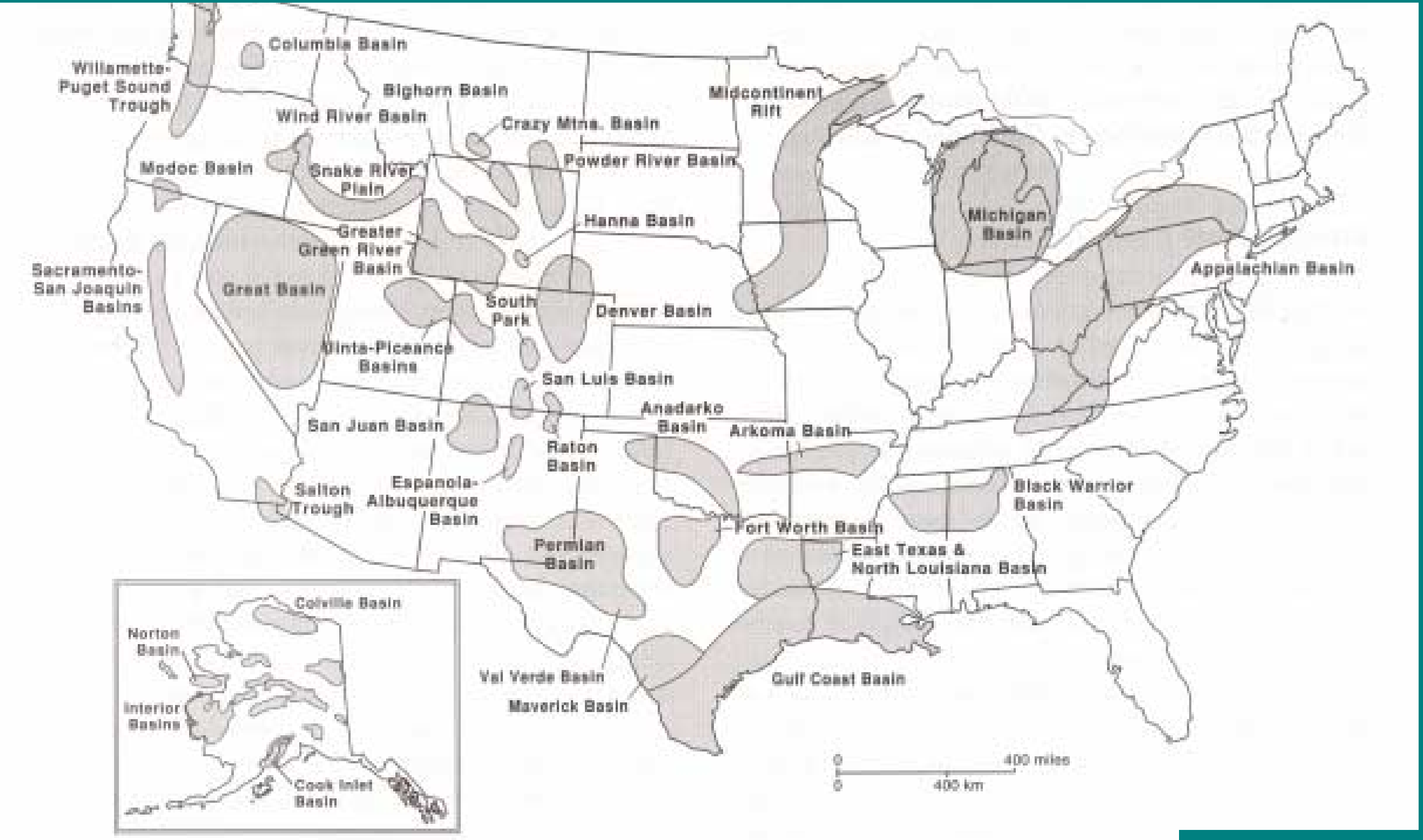


Figure 13. Map of the United States showing the geographic distribution of known and potential BCGAs.

Law, 2002

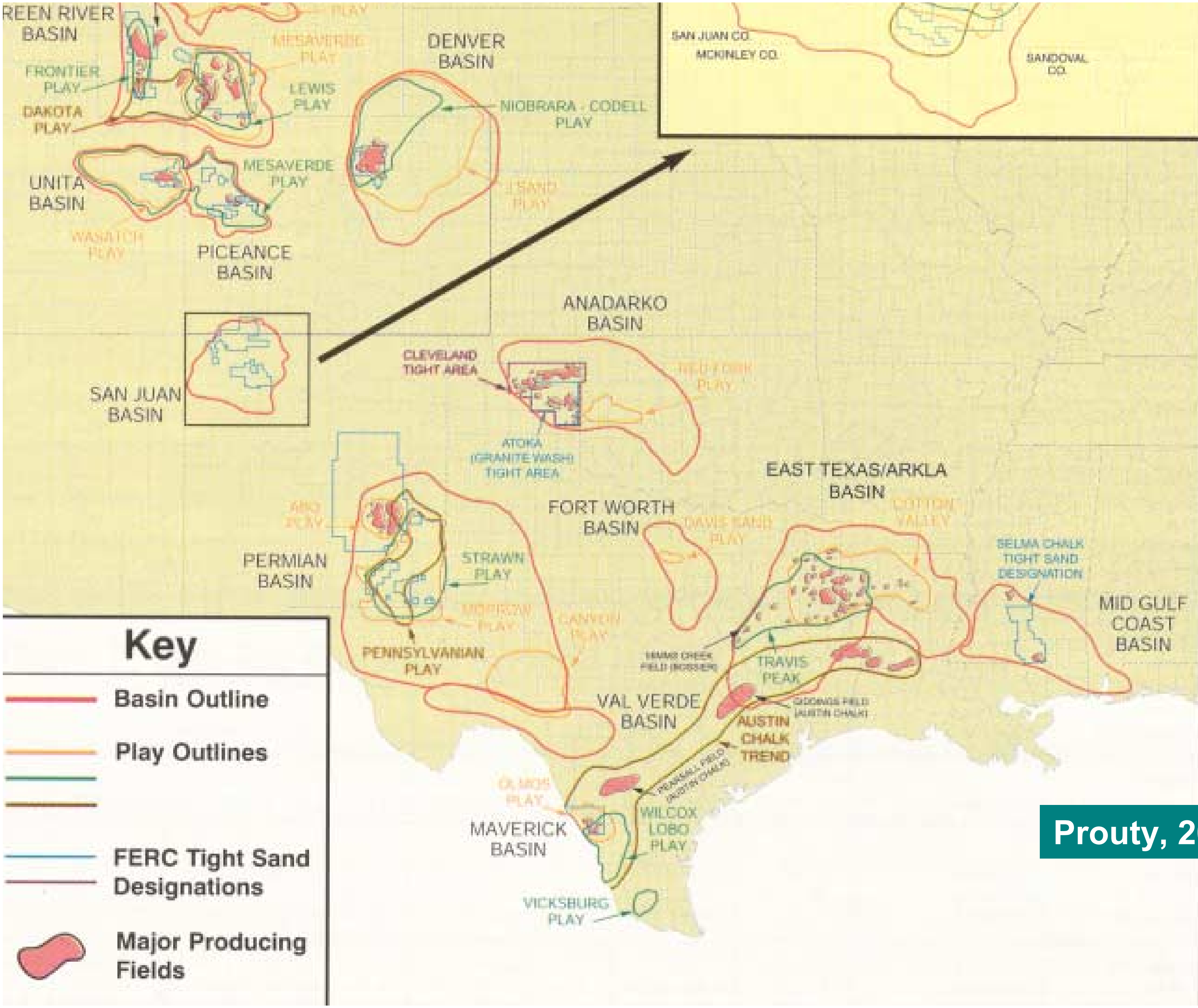
Tight Gas in Oklahoma

Anadarko Basin

- Red Fork
- Cleveland
- Granite Wash

Arkoma Basin

- Atoka



REEN RIVER BASIN
MESAVERDE PLAY
DENVER BASIN
FRONTIER PLAY
DAKOTA PLAY
LEWIS PLAY
NIOBRARA - CODELL PLAY
SAN JUAN CO.
MCKINLEY CO.
SANDOVAL CO.
UNITA BASIN
MESAVERDE PLAY
J SAND PLAY
WASATCH PLAY
PICEANCE BASIN
ANADARKO BASIN
SAN JUAN BASIN
CLEVELAND TIGHT AREA
RED FORK PLAY
ATOKA (GRANITE WASH) TIGHT AREA
EAST TEXAS/ARKLA BASIN
ABO PLAY
FORT WORTH BASIN
DAVIS SAND PLAY
COTTON VALLEY
PERMIAN BASIN
STRAWN PLAY
SELMA CHALK TIGHT SAND DESIGNATION
MID GULF COAST BASIN
MORROW PLAY
CANYON PLAY
PENNSYLVANIAN PLAY
TRAVIS PEAK
VAL VERDE BASIN
GIDDINGS FIELD (AUSTIN CHALK)
AUSTIN CHALK TREND
OLMOS PLAY
PEARSALL FIELD (AUSTIN CHALK)
WILCOX LOBO PLAY
MAVERICK BASIN
VICKSBURG PLAY
Key
Basin Outline
Play Outlines
FERC Tight Sand Designations
Major Producing Fields

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 (Tar) Sands

"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."

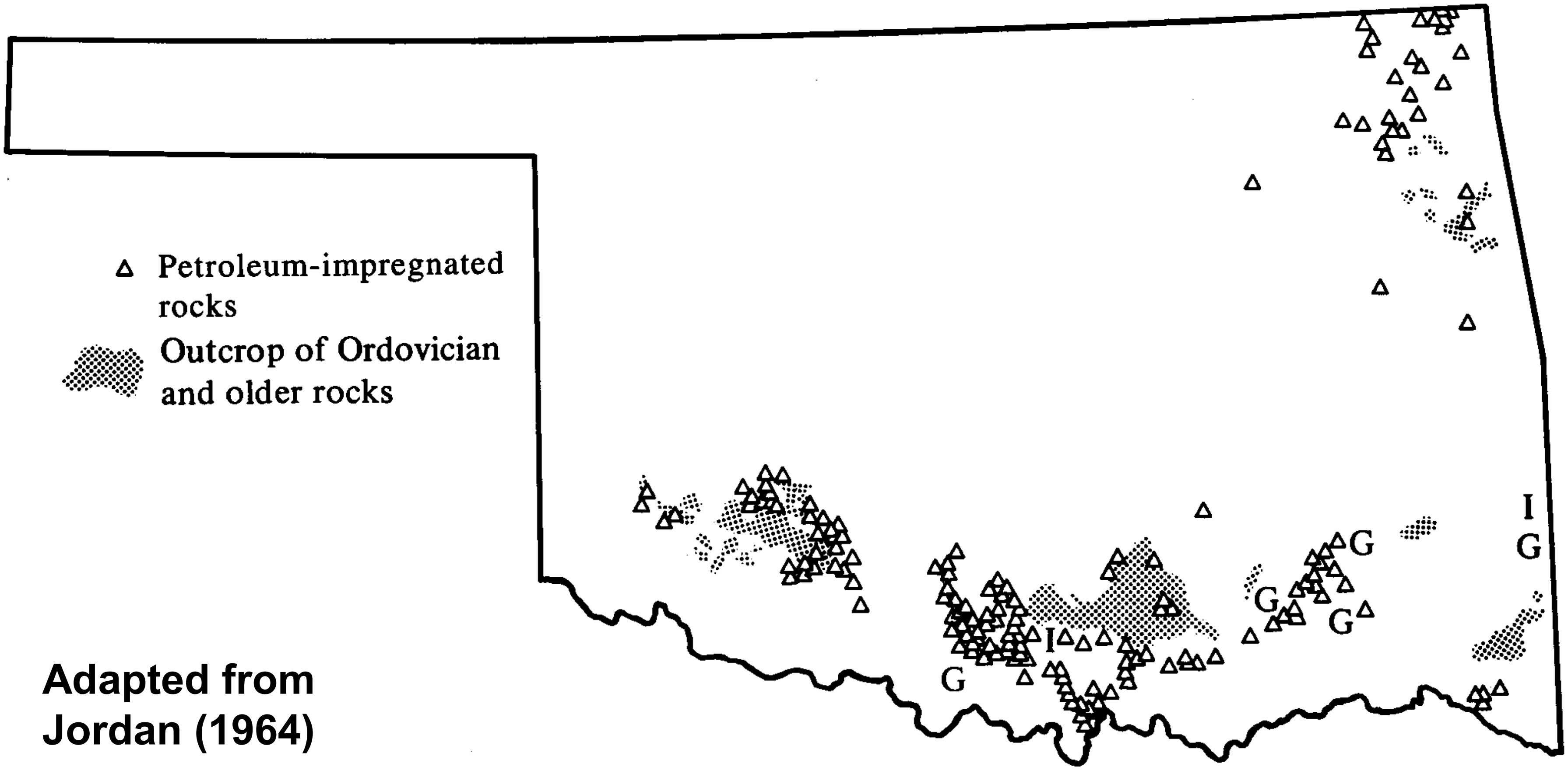
Rottenfusser, 2003

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

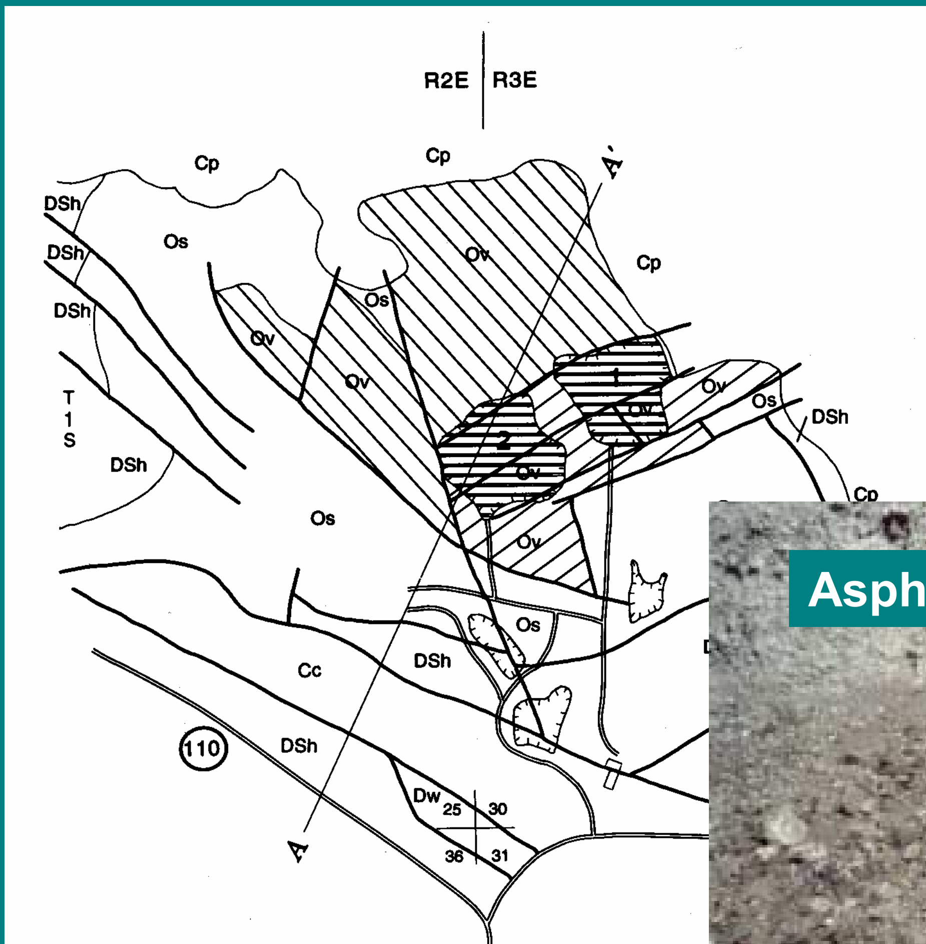


Adapted from Jordan (1964)

Dougherty Asphalt Quarry

In-Place Bitumen Resource of 3.6 million barrels

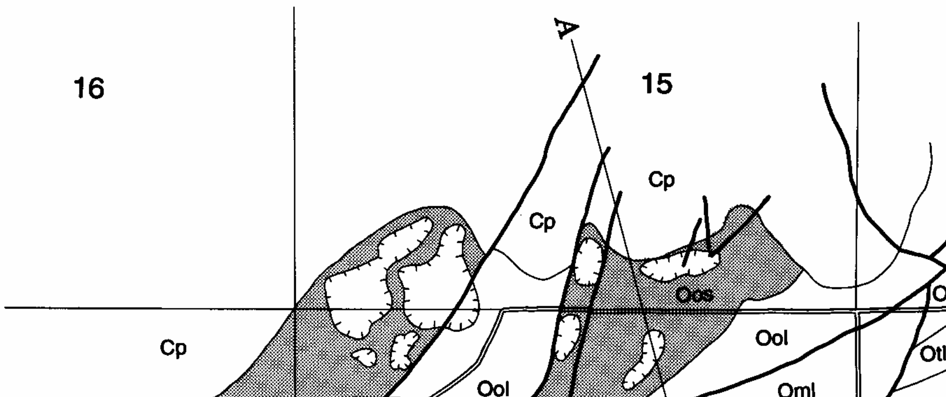
Production of bitumen-impregnated limestone > 1 million short tons from 1890 to 1960



Cardott and Chaplin (1993)

Asphalt-saturated Viola Group limestone

Sulfur Asphalt Quarry

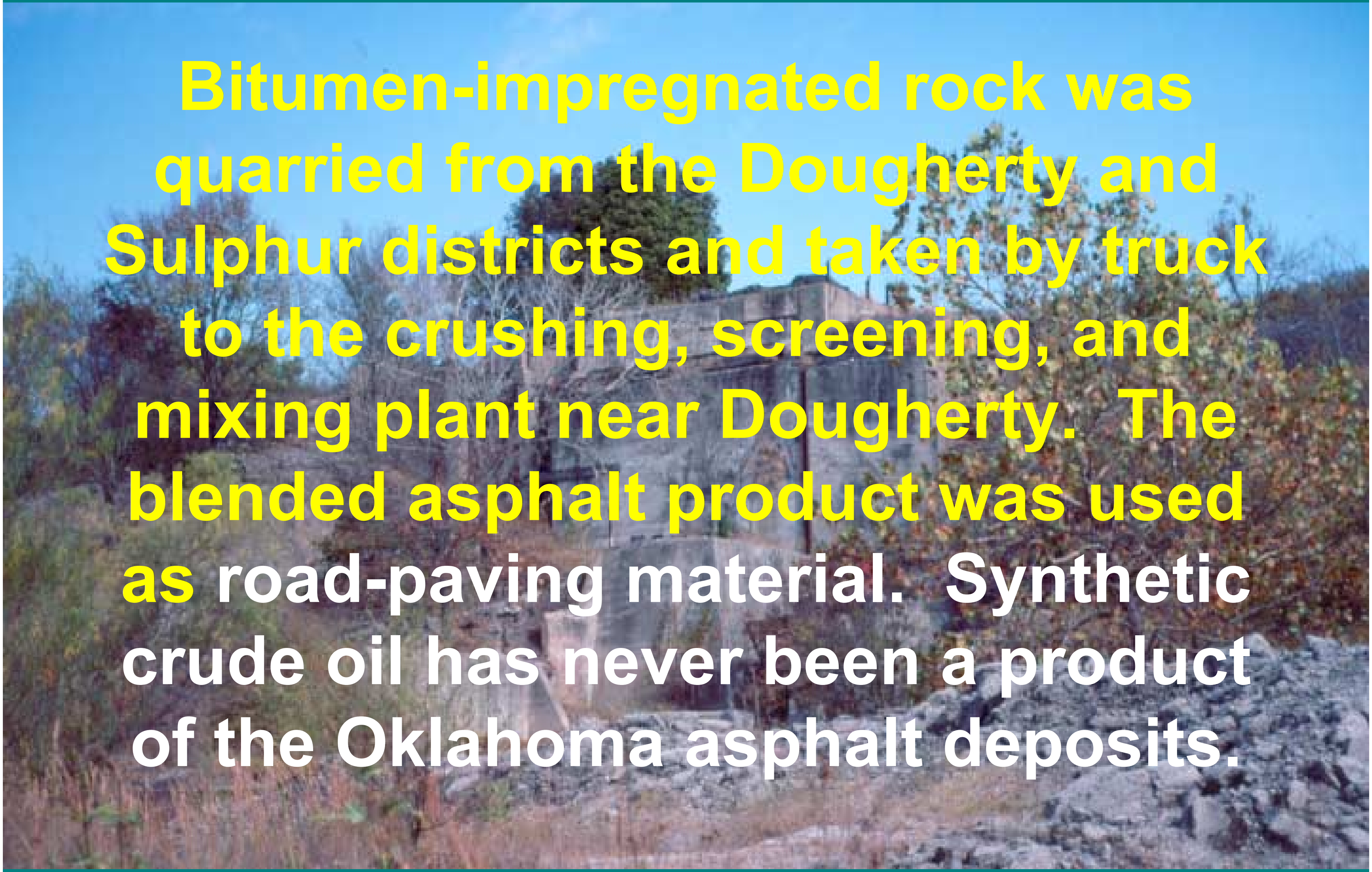


Cardott and Chaplin (1993)

In-Place Bitumen Resource of 46.4 million barrels

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

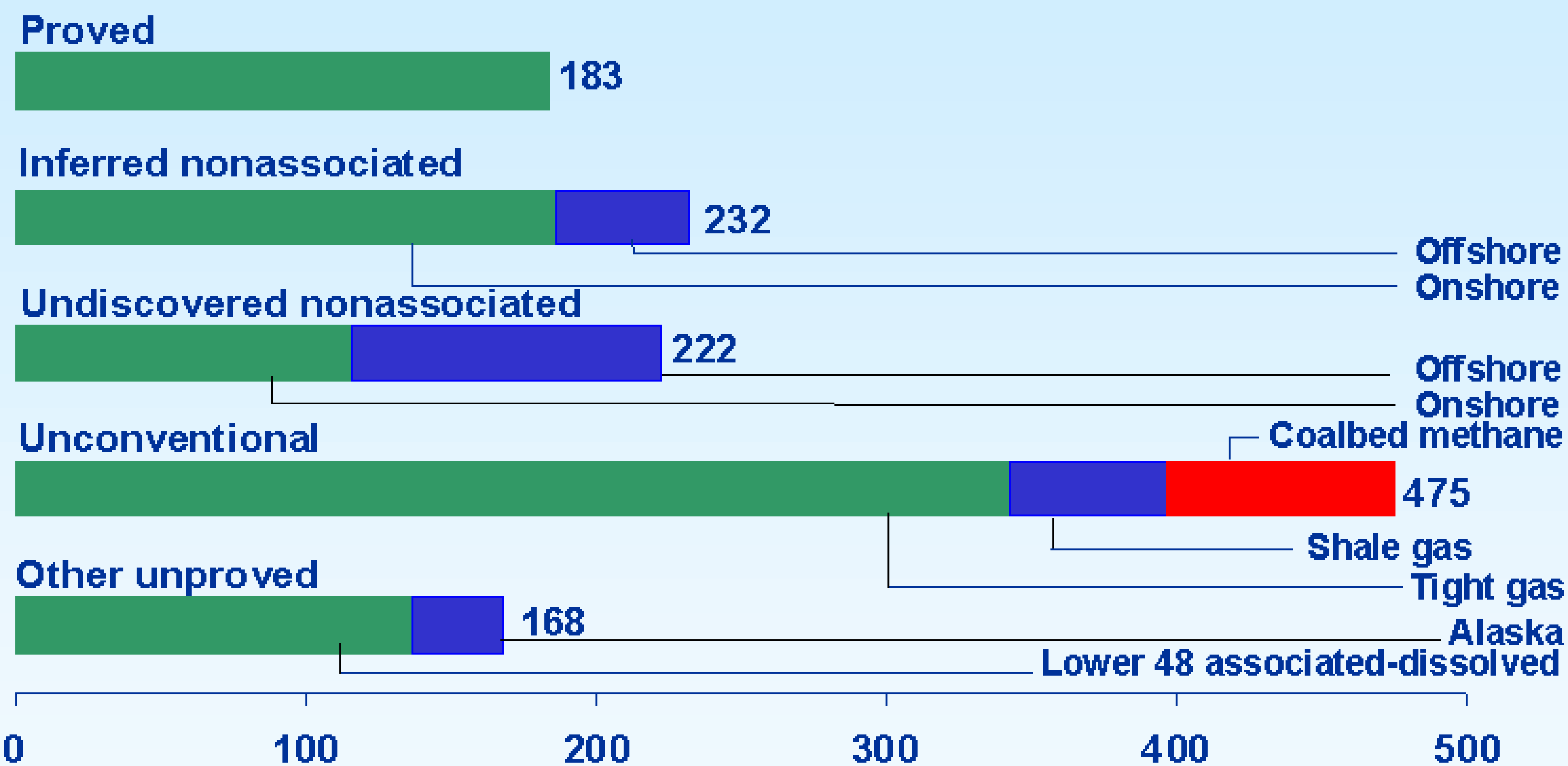
White silica veins in asphalt- saturated Oil Creek Formation sandstone



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)



Total: 1,279 trillion cubic feet