

National Assessment of Oil and Gas Fact Sheet

Assessment of Undiscovered Oil Resources in the Devonian-Mississippian Bakken Formation, Williston Basin Province, Montana and North Dakota, 2008

Using a geology-based assessment methodology, the U.S. Geological Survey estimated mean undiscovered volumes of 3.65 billion barrels of oil, 1.85 trillion cubic feet of associated/dissolved natural gas, and 148 million barrels of natural gas liquids in the Bakken Formation of the Williston Basin Province, Montana and North Dakota.

Introduction

The U.S. Geological Survey (USGS) completed an assessment of the undiscovered oil and associated gas resources of the Upper Devonian–Lower Mississippian Bakken Formation in the U.S. portion of the Williston Basin of Montana and North Dakota and within the Williston Basin Province (fig. 1). The assessment is based on geologic elements of a total petroleum system (TPS) that include (1) source-rock distribution, thickness, organic richness, maturation, petroleum generation, and migration; (2) reservoir-rock type (conventional or continuous), distribution, and quality; and (3) character of traps and time of formation with respect to petroleum generation and migration. Detailed framework studies in stratigraphy and structural geology and the modeling of petroleum geochemistry, combined with historical exploration and production analyses, were used to aid in the estimation of the undiscovered, technically recoverable oil and associated gas resources of the Bakken Formation in the United States. Using this framework, the USGS defined a Bakken-Lodgepole TPS (fig. 1) and seven assessment units (AU) within the TPS. For the Bakken Formation, the undiscovered oil and associated gas resources within six of these assessment units were quantitatively estimated (fig. 2, table 1). A conventional AU within the Lodgepole Formation was not assessed.

Bakken Formation and Bakken-Lodgepole Total Petroleum System

The Upper Devonian–Lower Mississippian Bakken Formation is a thin but widespread unit within the central and deeper portions of the Williston Basin in Montana, North Dakota, and the Canadian Provinces of Saskatchewan and Manitoba. The formation consists of three members: (1) lower shale member, (2) middle sandstone member, and (3) upper shale member. Each succeeding member is of greater geographic extent than the underlying member. Both the upper and lower shale members are organic-rich marine shale of fairly consistent lithology; they are the petroleum source rocks and part of the continuous reservoir for hydrocarbons produced from the Bakken Formation. The middle sandstone member varies in thickness, lithology, and petrophysical properties, and local development of matrix porosity enhances oil production in both continuous and conventional Bakken reservoirs. Within

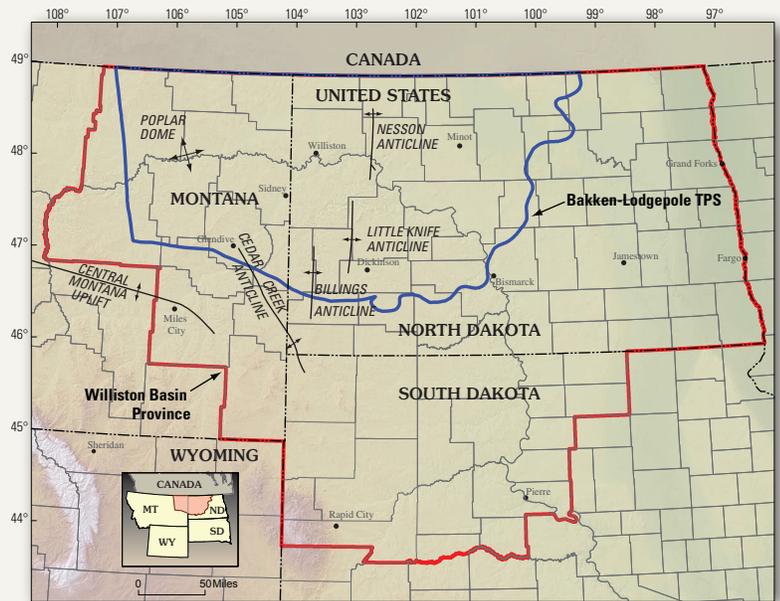


Figure 1. Map showing Williston Basin Province boundary (in red), Bakken-Lodgepole Total Petroleum System (TPS) (in blue), and major structural features in Montana, North Dakota, and South Dakota.

the Bakken-Lodgepole TPS, the upper and lower shale members of the Bakken Formation are also the source for oil produced from reservoirs of the Mississippian Lodgepole Formation.

Geologic Model and Assessment Units

The geologic model used to define AUs and to assess the Bakken Formation resources generally involves thermal maturity of the Bakken shale source rocks, petrophysical character of the middle sandstone member, and structural complexity of the basin. Most important to the Bakken-Lodgepole TPS and the continuous AUs within it are (1) the geographic extent of the Bakken Formation oil generation window (fig. 2), (2) the occurrence and distribution of vertical and horizontal fractures, and (3) the matrix porosity within the middle sandstone member. The area of the oil generation window for the Bakken continuous reservoir was determined by contouring both hydrogen index and well-log resistivity values of the upper shale member, which is youngest and of greatest areal extent.

The area of the oil generation window for the Bakken Formation was divided into five continuous AUs: (1) Elm Coulee–Billings Nose AU, (2) Central Basin–Poplar Dome AU, (3) Nesson–Little Knife Structural AU, (4) Eastern Expulsion Threshold AU, and (5) Northwest Expulsion Threshold AU. A sixth hypothetical conventional AU, a Middle Sandstone Member AU, was defined external to the area of oil generation.

Table 1. Bakken Formation, Williston Basin Province assessment results.

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. TPS, total petroleum system; AU, assessment unit]

	Total Petroleum System and Assessment Unit	Field Type	Total Undiscovered Resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Continuous Oil Resources	Bakken-Lodgepole TPS													
	Elm Coulee–Billings Nose AU	<i>Oil</i>	374	410	450	410	118	198	332	208	8	16	29	17
	Central Basin–Poplar Dome AU	<i>Oil</i>	394	482	589	485	134	233	403	246	10	18	35	20
	Nesson–Little Knife Structural AU	<i>Oil</i>	818	908	1,007	909	260	438	738	461	19	34	64	37
	Eastern Expulsion Threshold AU	<i>Oil</i>	864	971	1,091	973	278	469	791	493	20	37	68	39
	Northwest Expulsion Threshold AU	<i>Oil</i>	613	851	1,182	868	224	411	754	440	16	32	64	35
	Total Continuous Resources				3,645				1,848				148	
Conventional Oil Resources	Middle Sandstone Member AU	<i>Oil</i>	1	4	8	4	1	1	3	2	0	0	0	0
	Total Conventional Resources				4				2				0	
	Total Undiscovered Oil Resources				3,649				1,850				148	

Resource Summary

The USGS assessed undiscovered oil and associated gas resources in five continuous (unconventional) AUs and one conventional AU for the Bakken Formation (fig. 2; table 1). For continuous oil resources, the USGS estimated a total mean resource of 3.65 billion barrels of oil, which combines means of 410 million barrels in the Elm Coulee–Billings Nose AU, 485 million barrels in the Central Basin–Poplar Dome AU, 909 million barrels in the Nesson–Little Knife Structural AU, 973 million barrels in the Eastern Expulsion Threshold AU, and 868 million barrels in the Northwest Expulsion Threshold AU. A mean resource of 4 million barrels was estimated for the conventional Middle Sandstone Member AU.

The assessment of the Bakken Formation indicates that most of the undiscovered oil resides within a continuous composite reservoir that is distributed across the entire area of the oil generation window (fig. 2) and includes all members of the Bakken Formation. At the time of this assessment, only a limited number of wells have produced from the Bakken continuous reservoir in the Central Basin–Poplar Dome AU, the Eastern Expulsion Threshold AU, and the Northwest Expulsion Threshold AU. Therefore, there is significant geologic uncertainty in these estimates, which is reflected in the range of estimates for oil (table 1).

For Further Information

Supporting geologic studies of the total petroleum system and assessment units and the methodology used in the Bakken Formation, Williston Basin Province assessment are in progress. Assessment results are available at the USGS Central Energy Team website, <http://energy.cr.usgs.gov/oilgas/noga>.

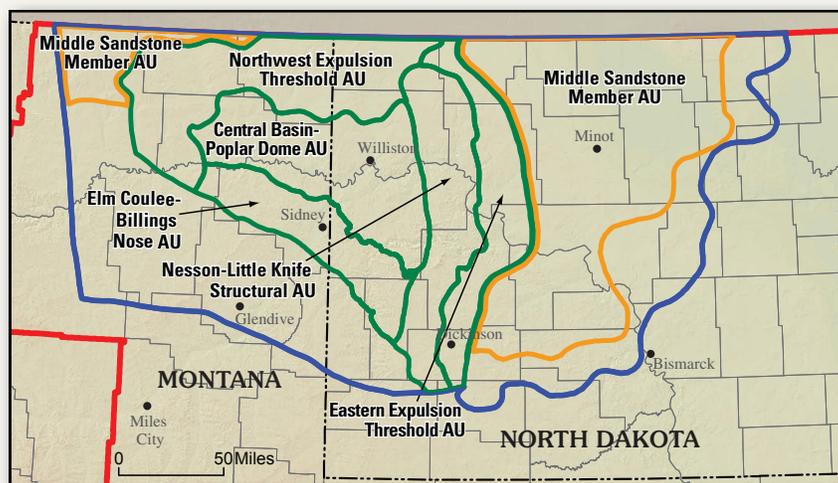


Figure 2. Map showing boundary of Bakken-Lodgepole Total Petroleum System (TPS) (in blue), five continuous assessment units (AU) (in green), and one conventional AU (in orange) defined for the assessment of undiscovered oil resources in the Upper Devonian–Lower Mississippian Bakken Formation in the U.S. portion of the TPS. The outermost green line defines the area of oil generation for the upper shale member of the formation.

Bakken Formation, Williston Basin Province Assessment Team

Richard M. Pollastro (Bakken Formation Task Leader; pollastro@usgs.gov), Troy A. Cook, Laura N. R. Roberts, Christopher J. Schenk, Michael D. Lewan, Lawrence O. Anna, Stephanie B. Gaswirth, Paul G. Lillis, Timothy R. Klett, and Ronald R. Charpentier.



Overview of USGS National Assessment of Oil and Gas Project

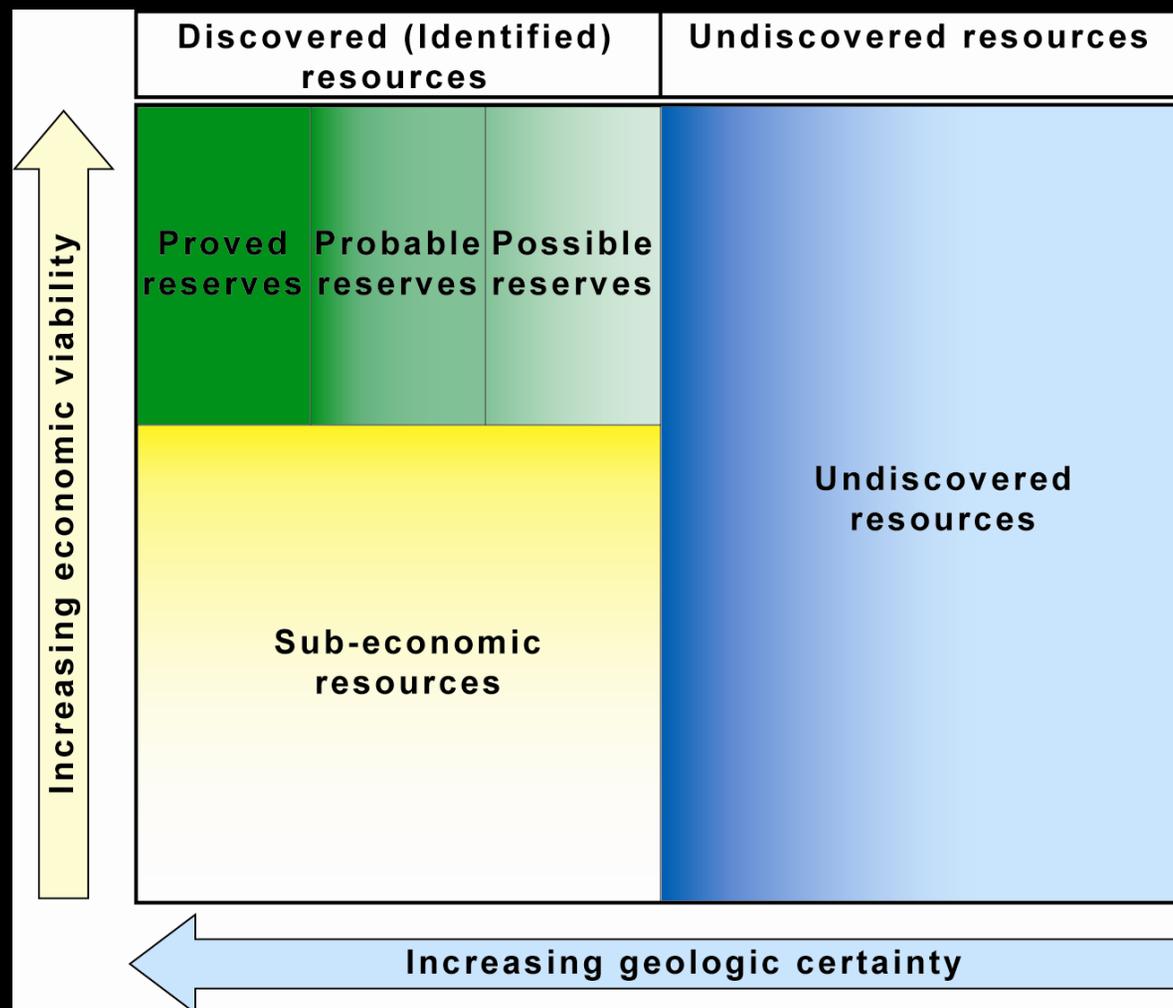
Bismarck, North Dakota
November 29, 2006

Goal of the National Assessment

- **Develop geologically based hypotheses concerning the quantities of oil and gas that have the potential to be added to proved reserves in the U.S.**

Resources vs. Reserves

USGS produces estimates of undiscovered, technically recoverable resources.



National Assessment Objectives

- **32 priority basins (~96% of resources)**
- **Petroleum Systems definition (fluids)**
- **Assessment Units (rocks)**
- **Conventional and Continuous resources**

Energy Policy and Conservation Act (EPCA) Amendments of 2000

Public Law 106–469, SEC. 604. SCIENTIFIC INVENTORY OF OIL AND GAS RESERVES.

(a) IN GENERAL.—The Secretary of the Interior, in consultation with the Secretaries of Agriculture and Energy, shall conduct an inventory of all onshore Federal lands. The inventory shall identify—

(1) the United States Geological Survey reserve estimates of the oil and gas resources underlying these lands; and
(2) the extent and nature of any restrictions or impediments to the development of such resources.

(b) REGULAR UPDATE.—Once completed, the USGS reserve estimates

and the surface availability data as provided in subsection **(a)(2)** shall be regularly updated and made publicly available.

Energy Policy Act of 2005

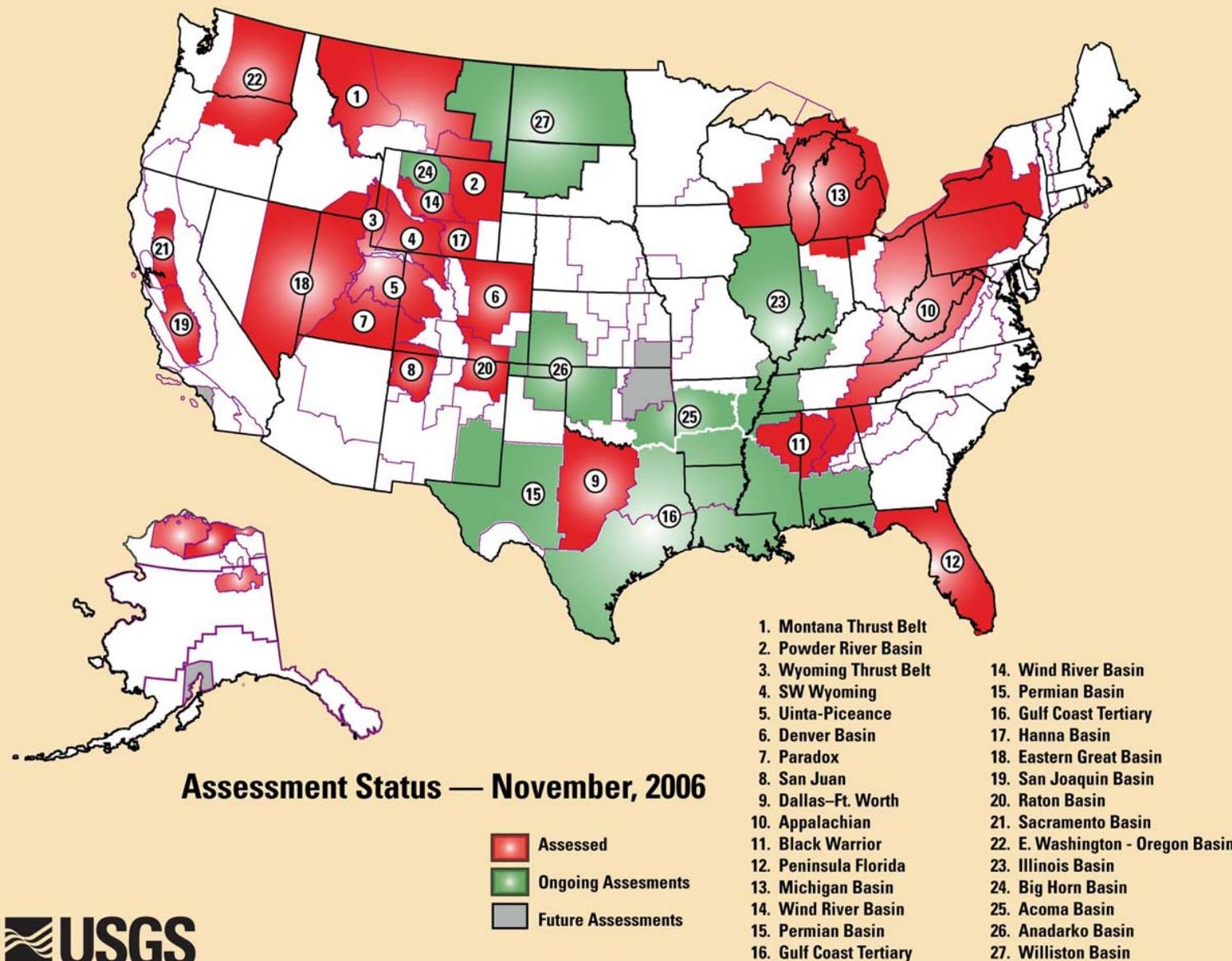
P.L. 109–58, SEC. 364.

**ESTIMATES OF OIL AND GAS RESOURCES
UNDERLYING ONSHORE FEDERAL LAND.**

(b) METHODOLOGY.—The Secretary of the Interior shall use the same assessment methodology across all geological provinces, areas, and regions in preparing and issuing national geological assessments to ensure accurate comparisons of geological resources.

Energy Policy and Conservation Act Amendments of 2000 (EPCA 2000)

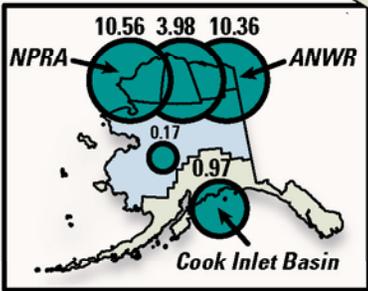
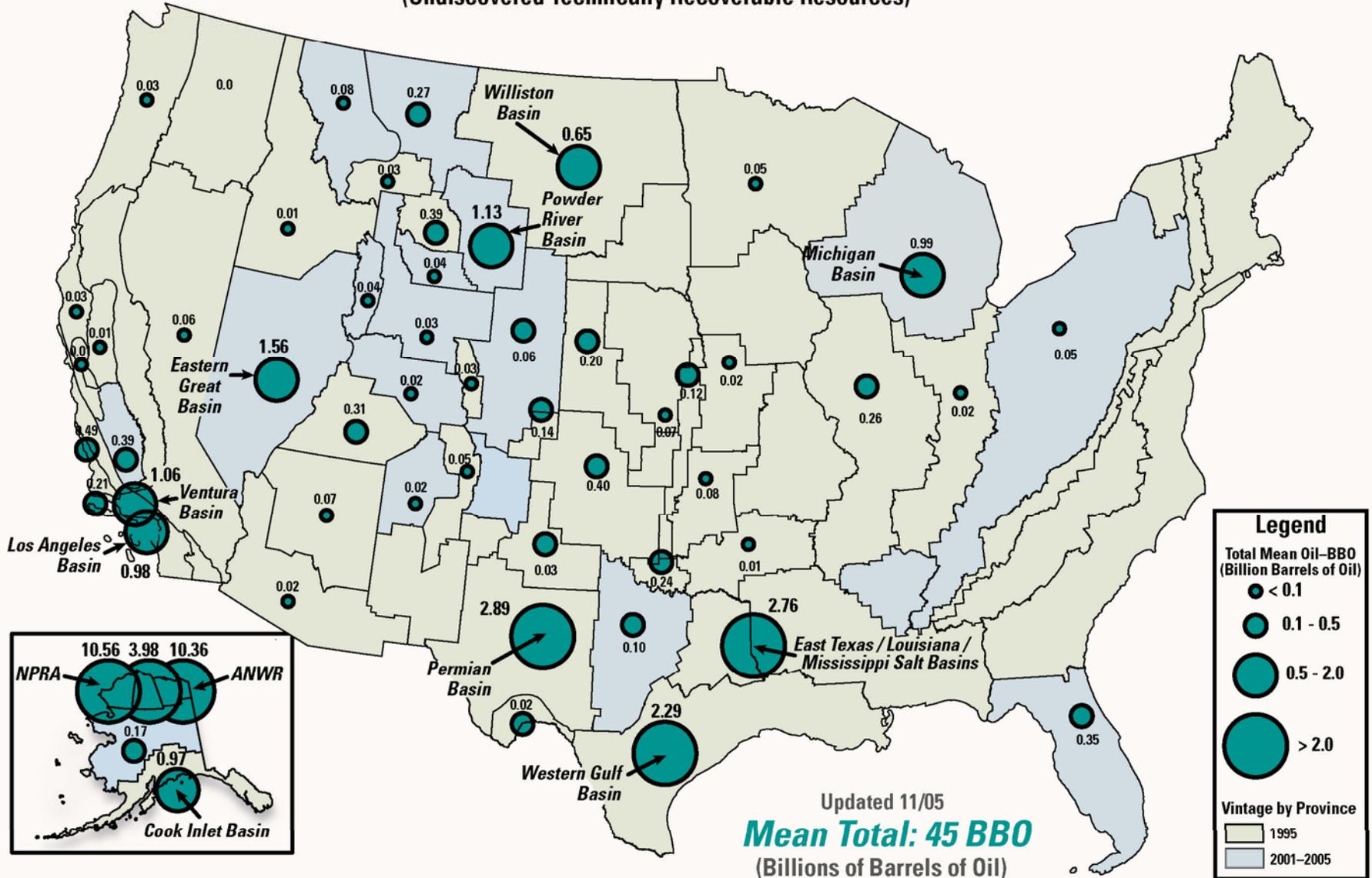
- USGS role; technically recoverable
- USGS, BLM, FS, FWS, DOE
- Assessments regardless of land status
- Assessments given to BLM for EPCA analysis
- Federal land basins are priority



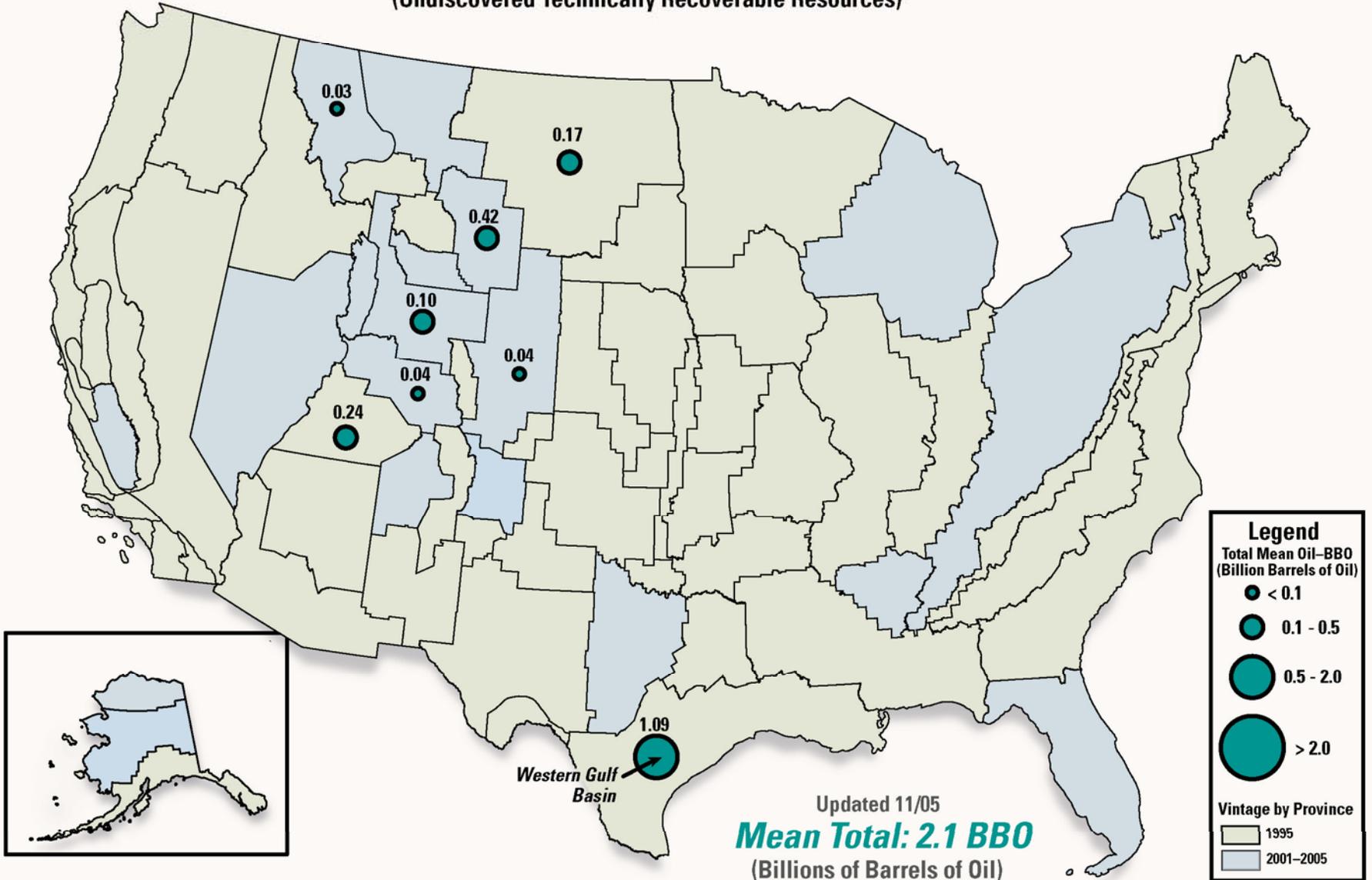
Remaining provinces will be completed in next three years

- **Gulf Coast**
- **Anadarko**
- **Arkoma**
- **Williston**
- **Cook Inlet**
- **Big Horn**
- **L.A. Basin**

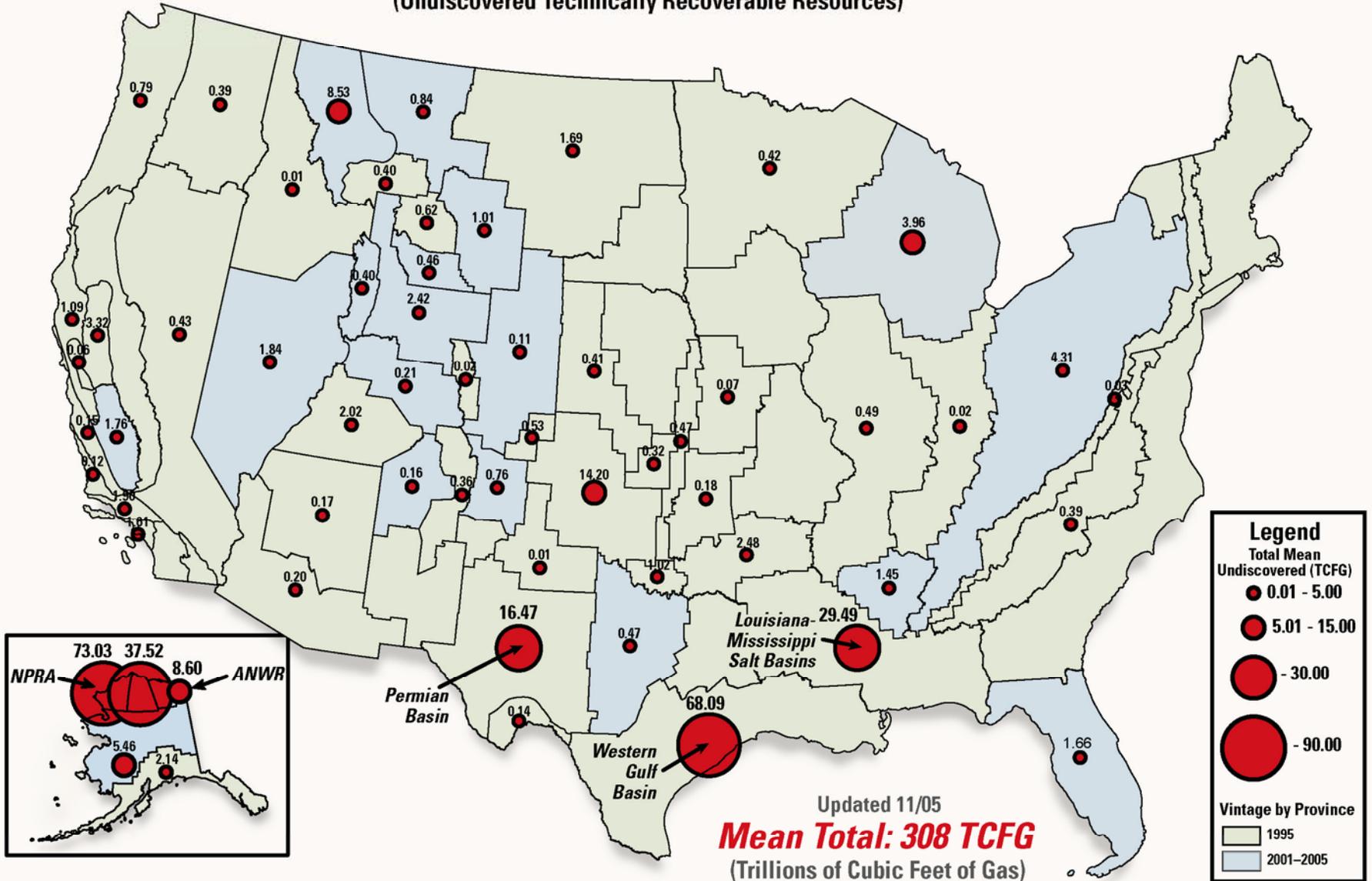
Mean Conventional Oil Resources (Undiscovered Technically Recoverable Resources)



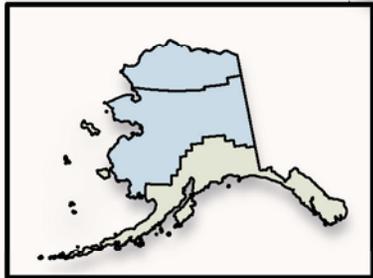
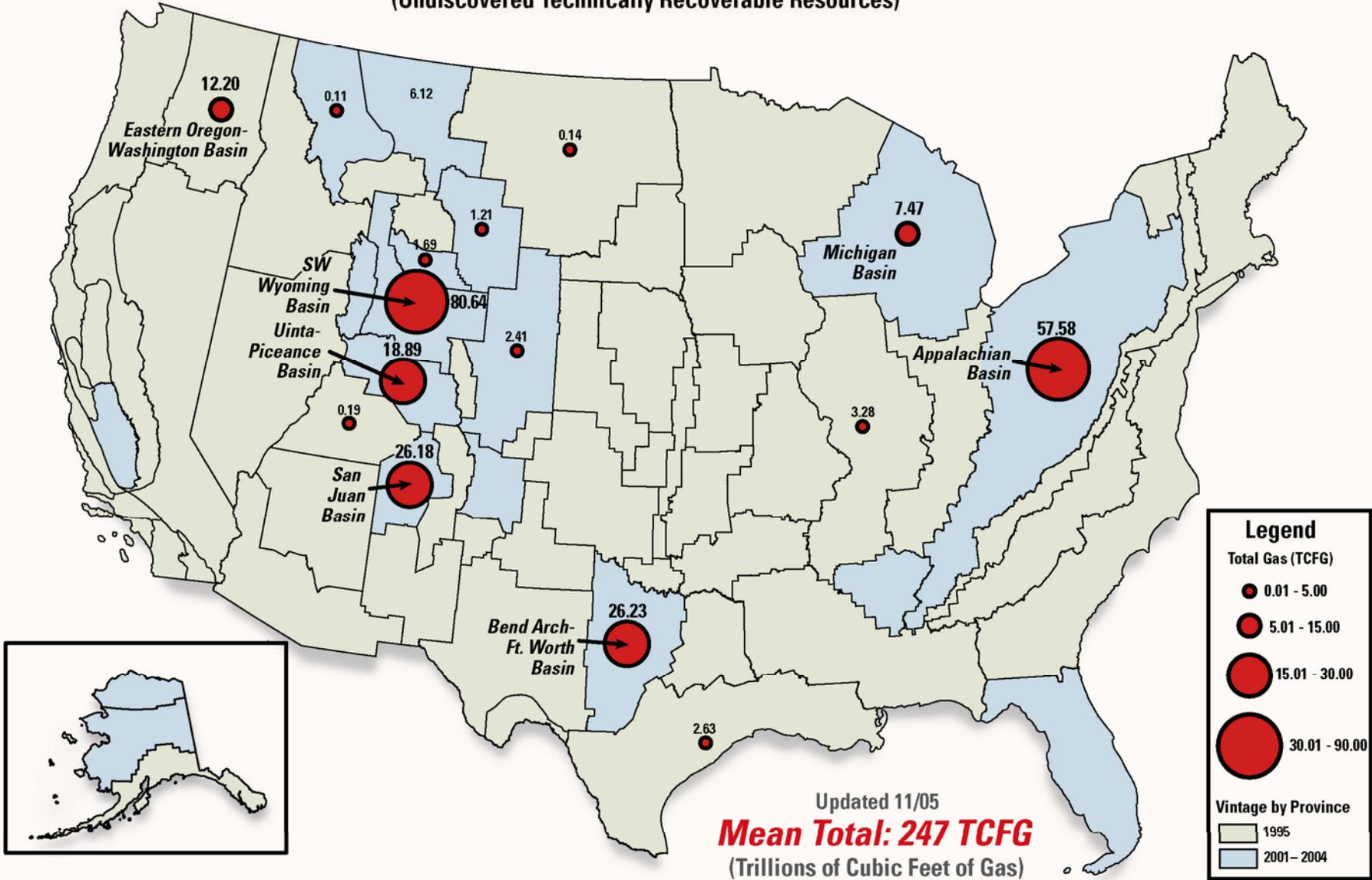
Mean Continuous Oil Resources (Undiscovered Technically Recoverable Resources)



Mean Undiscovered Conventional Gas Resources (Undiscovered Technically Recoverable Resources)



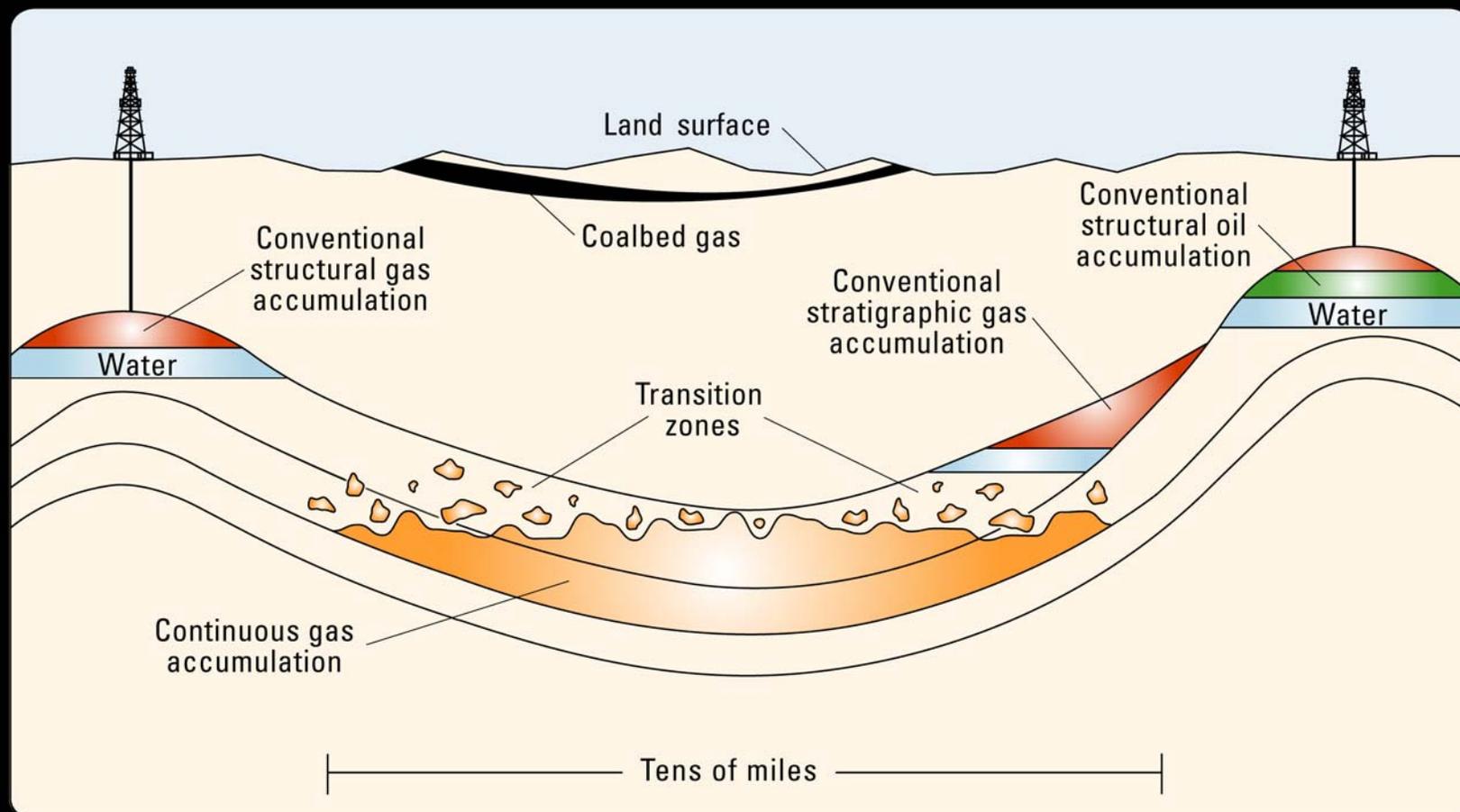
Mean Continuous Gas Resources (excluding coalbed methane) (Undiscovered Technically Recoverable Resources)



Assessment Methodology

- **Conventional resources**
- **Continuous resources (tight gas sands, gas shales, coalbed gas, continuous oil)**
- **Quantify geologic uncertainty**

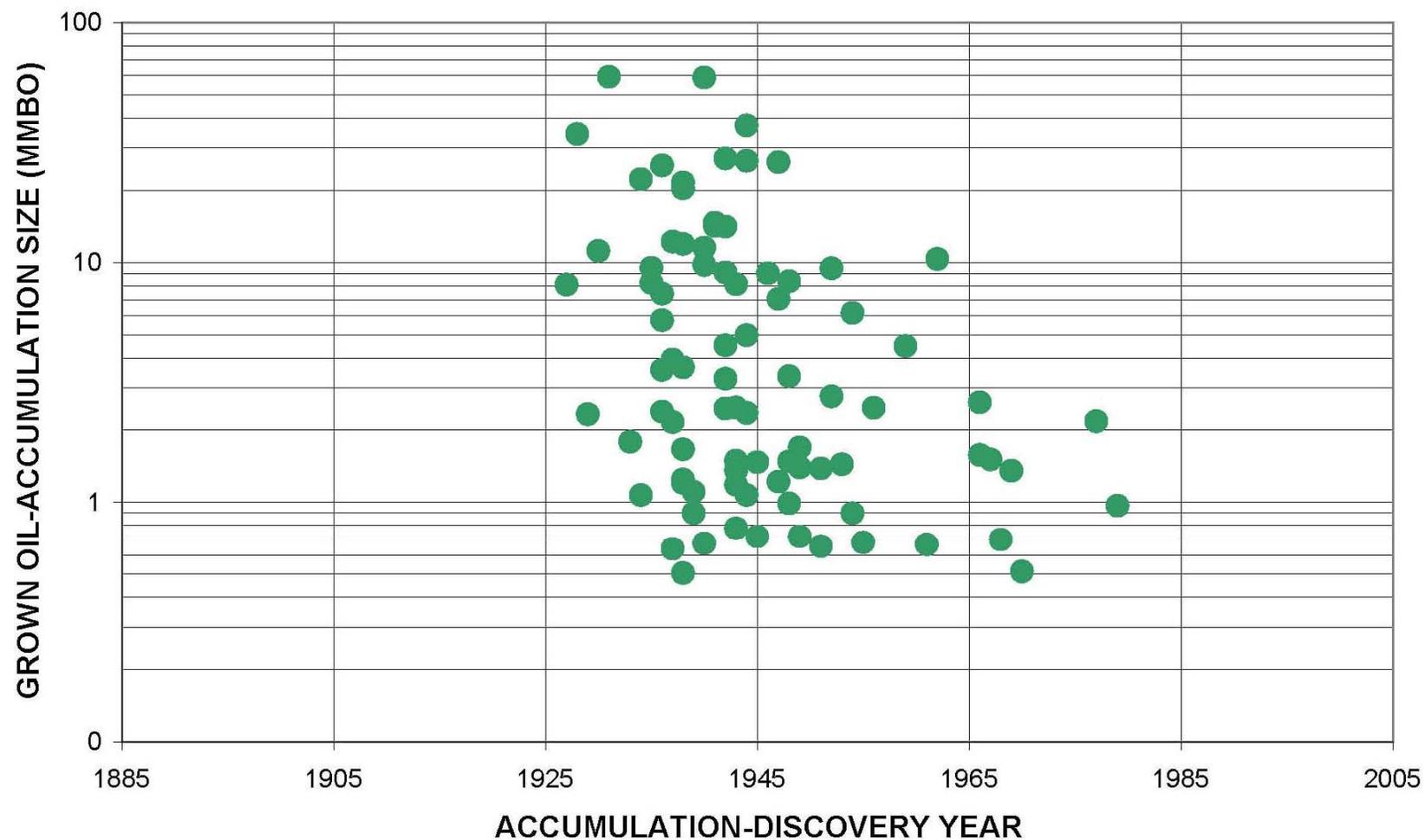
Conventional vs. Continuous Resources



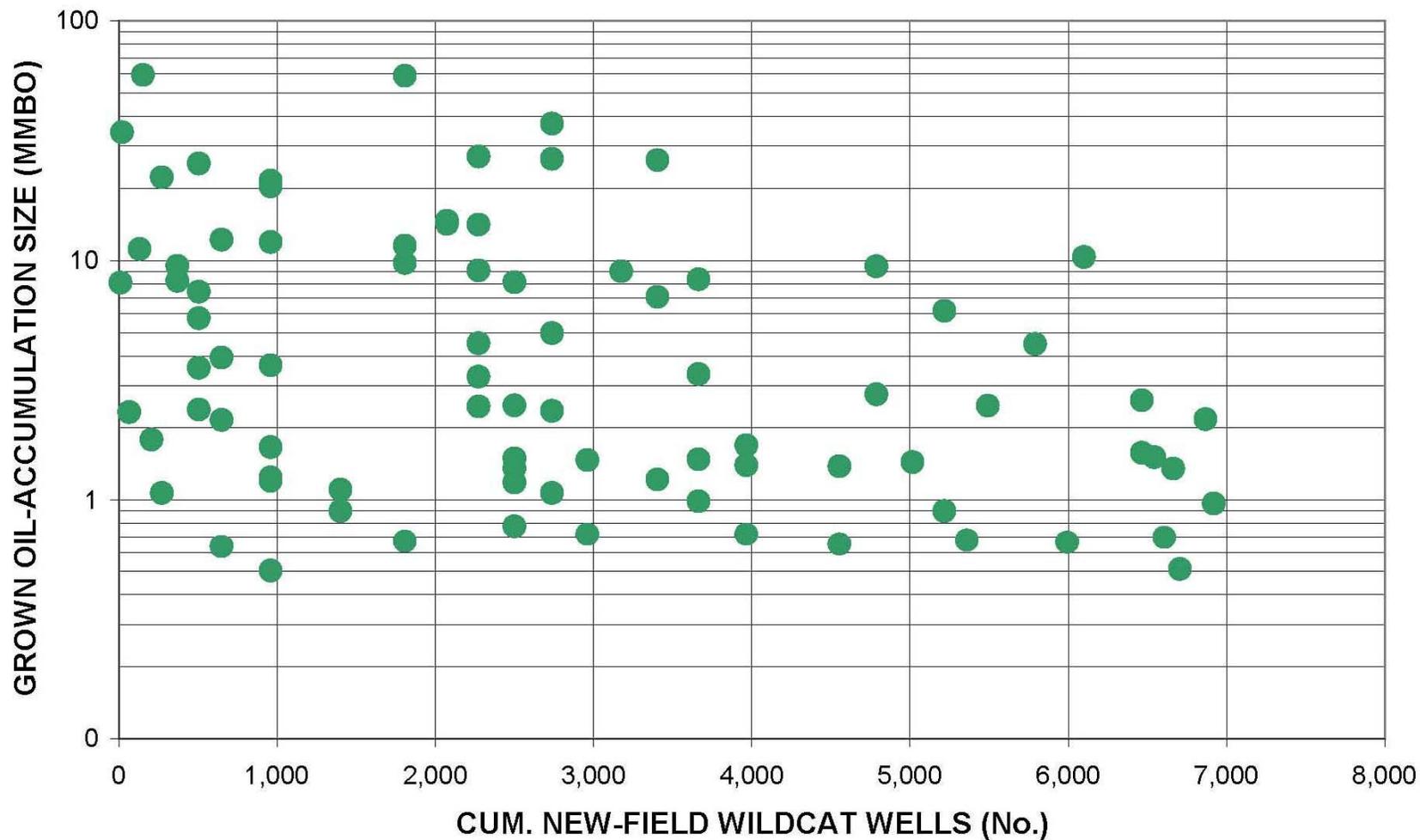
Conventional Methodology

- **Sizes and numbers of undiscovered fields**
- **Geologic analysis focuses upon new reservoirs and new concepts**

Middle Devonian Carbonates, Assessment Unit 50630304



Middle Devonian Carbonates, Assessment Unit 50630304



Continuous Methodology

- **Geology**
- **Engineering (Well-production performance; drainage areas)**
- **Every quantity is uncertain**

Continuous Methodology-(continued)

- **Geologic definition of assessment units**
- **Drainage areas of wells (cell sizes)**
- **Well production and performance**
- **EUR distribution**

Step 1. Geologic Definition of Assessment Unit

MINIMUM
50,000 Acres

MAXIMUM
75,000 Acres

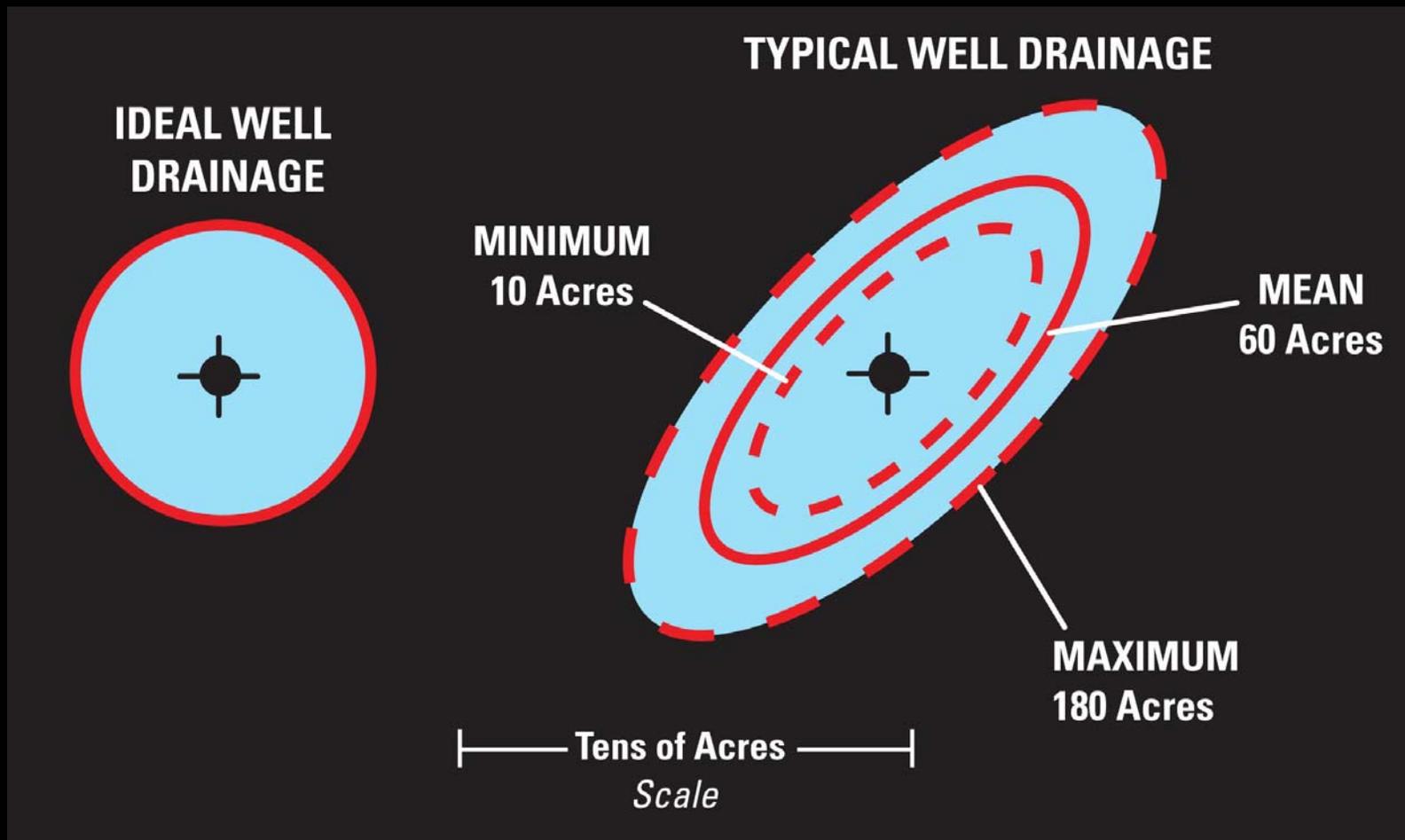
MEAN
60,000 Acres

— Tens of Miles —

Continuous Assessment Units

- May be divided based upon reservoir performance
- “Production sweet spots” – EUR distribution
- Outside of sweet spots – EUR distribution

Step 2. Drainage area estimation



Drainage Area Estimation

- Reservoir and fluid properties
- Fracturing and other stimulation techniques
- Technology of vertical vs. horizontal wells
- Single vs. multiple horizontal wells

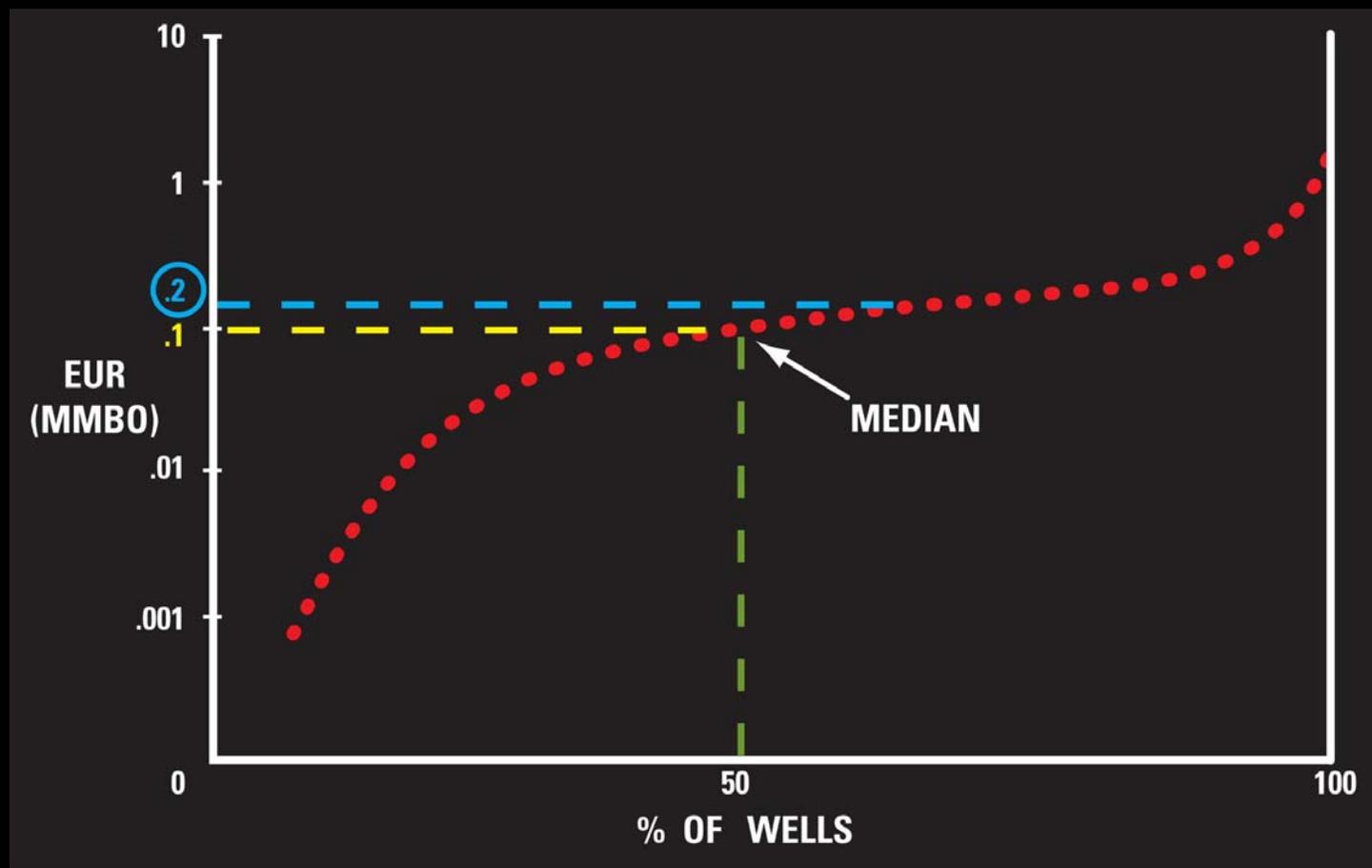
Step 3: Numbers of potential cells (mean)

- 60,000 acres (mean)
- 60 acres per cell (mean)
- $60,000 \text{ acres} / 60 \text{ acres per cell} = 1,000$ potential cells (mean)

Step 4: EUR distribution

- **EUR: estimated ultimate recovery per cell based on production data from wells within the assessment unit**

Step 4. EUR Distribution (Hypothetical)



EUR Distribution

- Using all available production data
- Integrates today's technology
- Used as a guide

Step 5: Calculation of Resources (Mean)

- 1,000 potential cells (mean)
- 200,000 barrels per cell (mean)
- $1,000 \times 200,000 = 200,000,000$, barrels
- Range: 50,000,000 – 500,000,000 barrels
(encompasses geologic uncertainty)

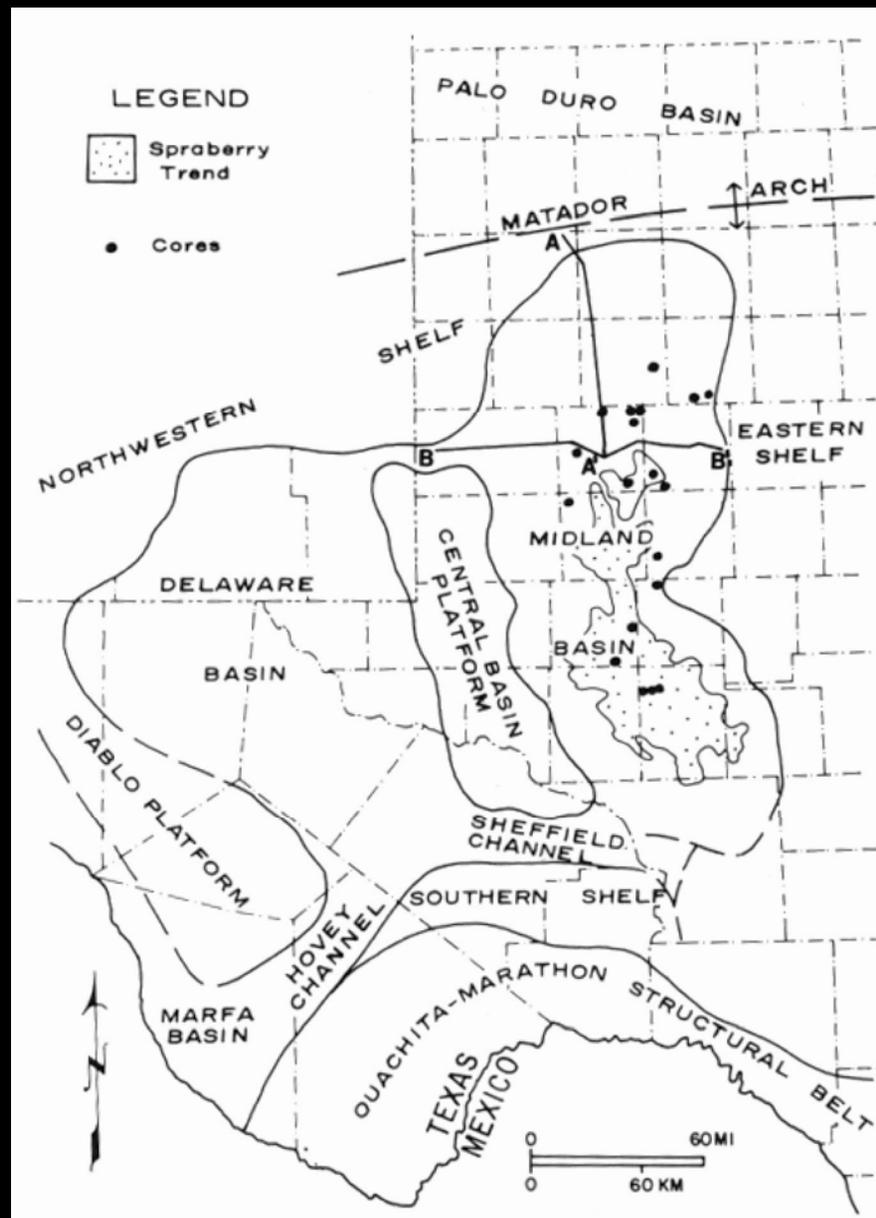
Continuous Assessment

- **Assessment based on geology, real production data, and petrophysical data**

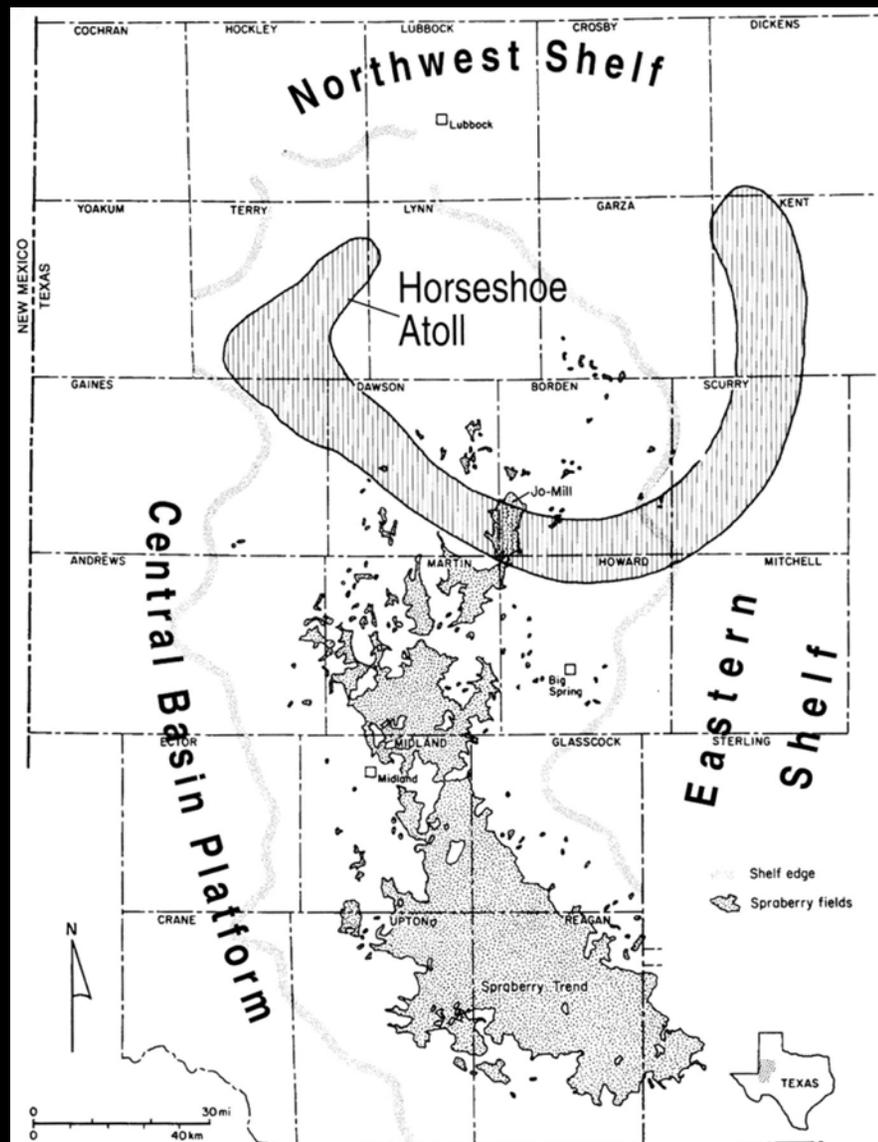
Spraberry Trend, West Texas

- Discovered in 1948
- “Largest uneconomic oil field in U.S.”
- 1954 – Began waterflooding
- Recoveries are extremely low
- Water breakthrough along fractures
- Patchy distribution of oil saturation
- 56 years of production
- ~ 1.3 BBO (cum. production + reserves)
- 20,000 to 30,000 wells

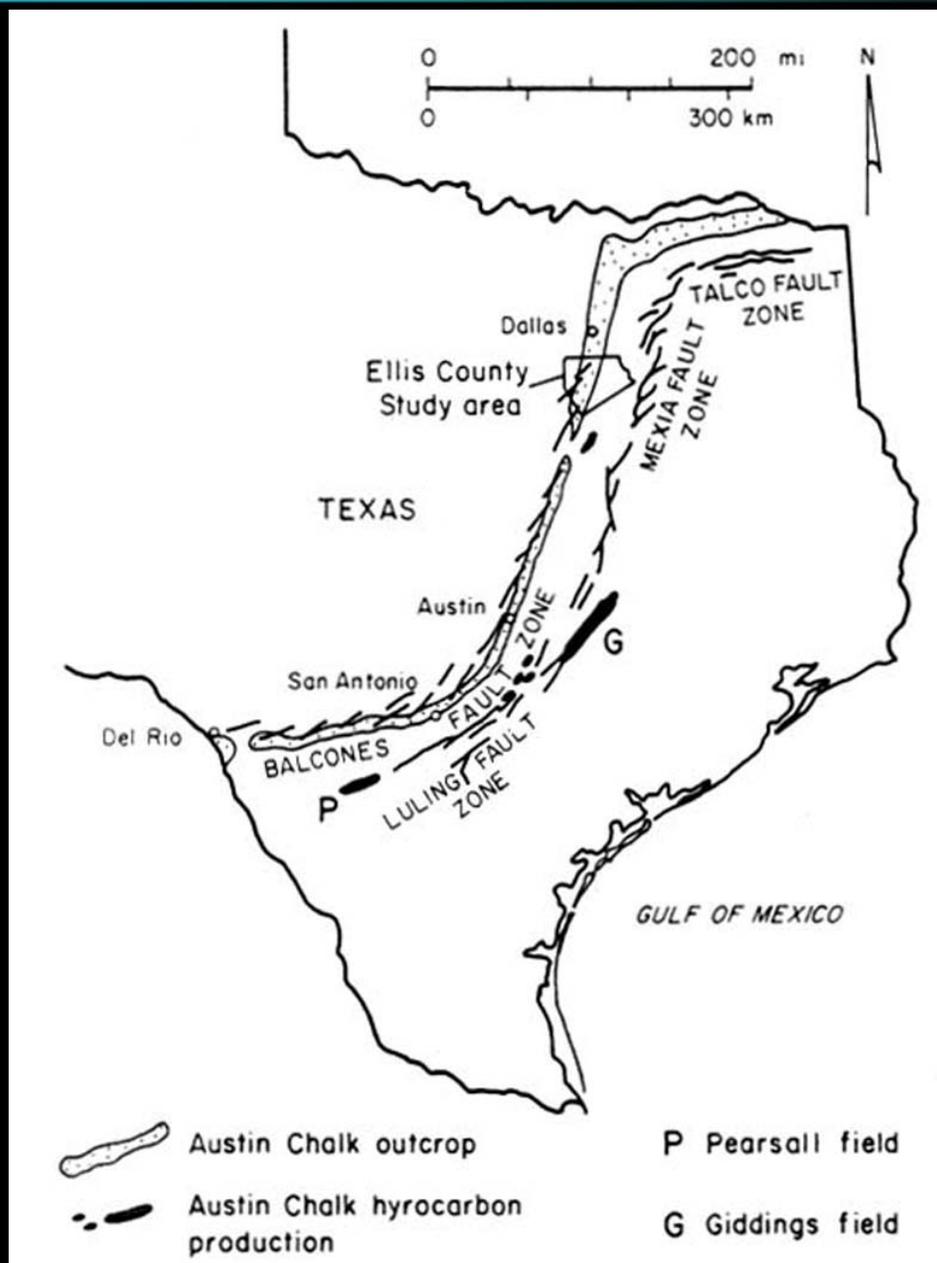
Midland Basin – Spraberry Fm.



Spraberry Production



Austin Chalk Trend, Texas



Austin Chalk Trend, Texas

- “Discovered” in 1970’s
- Trend crosses the state of Texas
- Fractured chalk
- Horizontal well technology
- ~ 650 MMBO (cum. production + reserves)
- Geologic sweet spots
- 1995 - ~ 1 BBO recoverable

Uinta-Piceance Basin

- 28-chapter CD
- Focus on continuous
- Federal lands



National Assessment of Oil and Gas Project:

Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado

*Compiled by USGS Uinta-Piceance
Assessment Team*

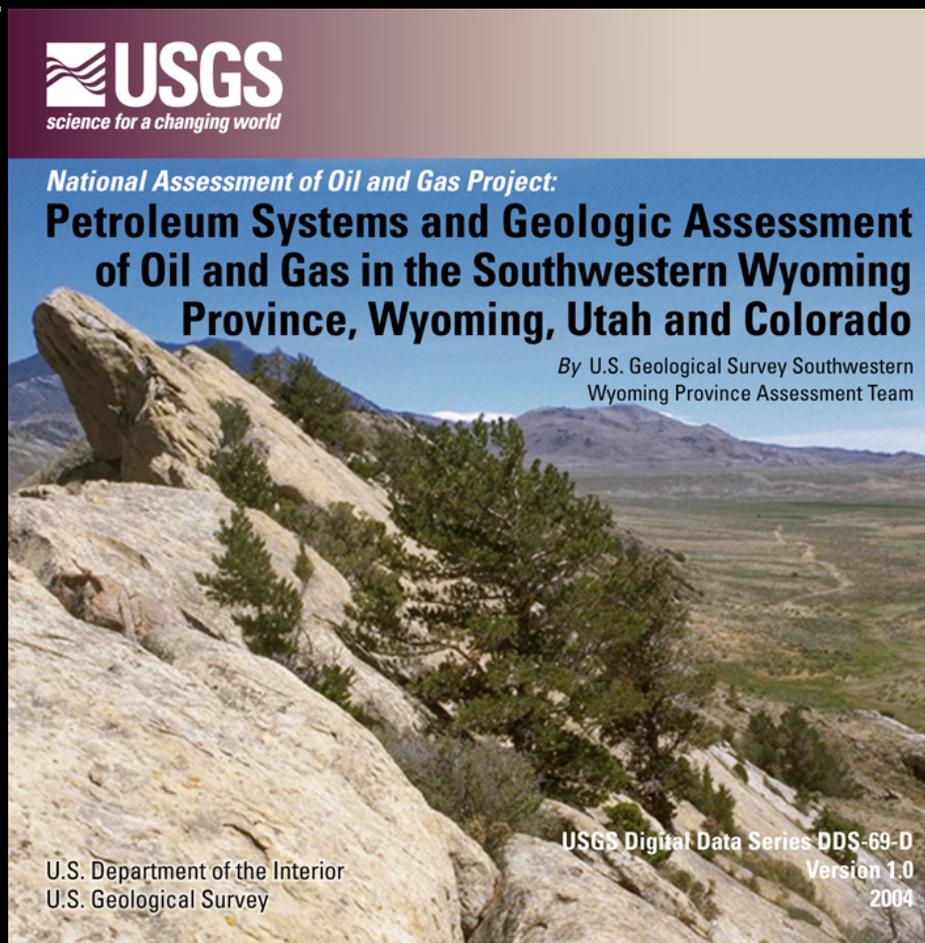


U.S. Department of the Interior
U.S. Geological Survey

USGS Digital Data Series DDS-69-B
Version 1.0
2003

Southwestern Wyoming Province

- 30-chapter CD-ROM
- “Persian Gulf” of gas; 85 TCFG
- Focal point of drilling restriction analysis by EPCA
- Tight gas sands



Summary

- **Project overview**
- **Methodology**
- **Geologically based assessments on schedule**
- **Assessments given to BLM for EPCA**
- **Technically recoverable only**
- **energy.cr.usgs.gov/oilgas/noga**