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Chapter 2

The Southwestern Wyoming Province —
Introduction to a Geologic Assessment of Undiscovered Oil and Gas Resources

By USGS Southwestern Wyoming Province Assessment Team

U.S. Geological Survey
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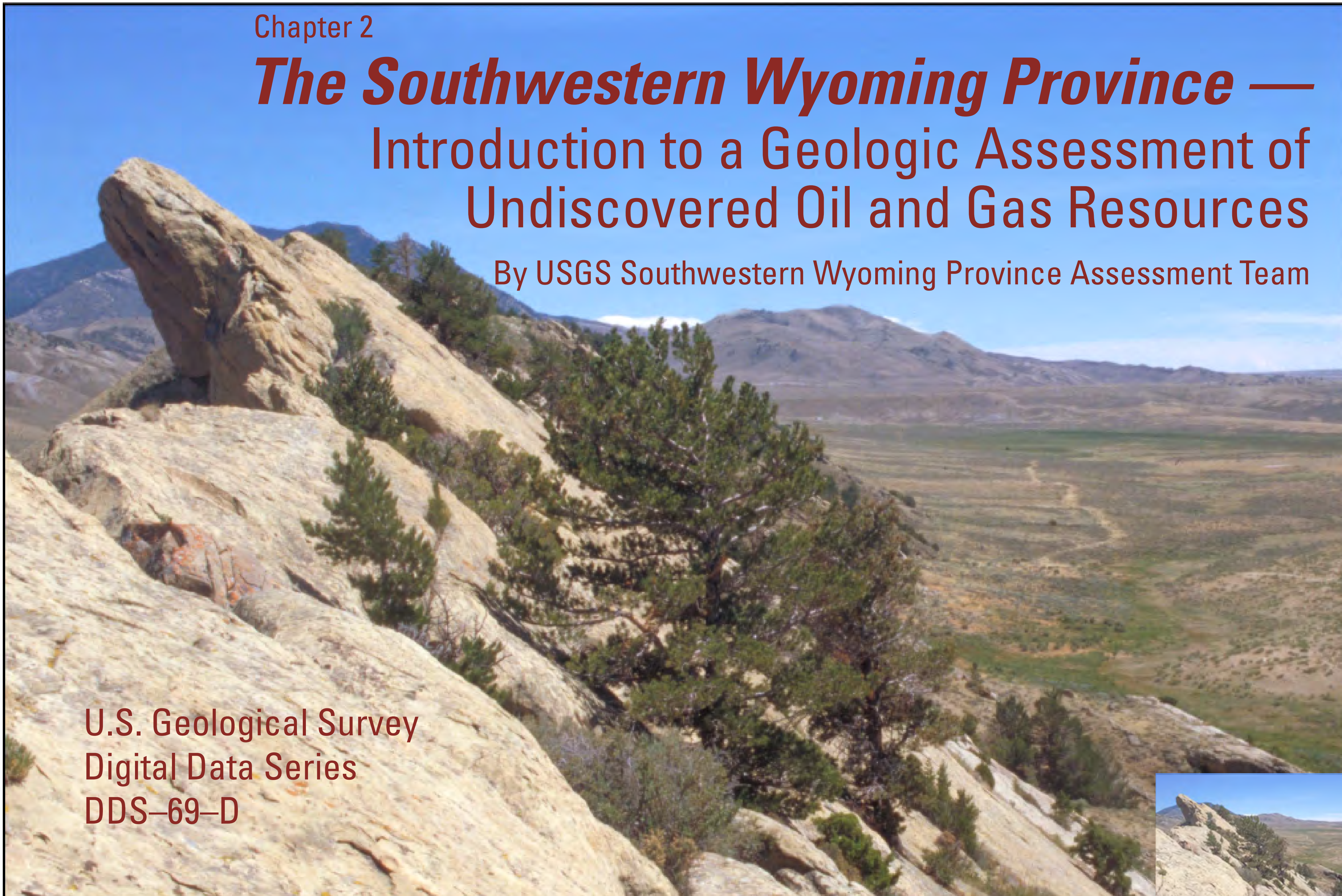

Sandstone, Frontier Formation, Muddy Gap, Wyoming. (Photograph by Chris Schenk)

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Volume Title Page

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Triassic and Jurassic strata in the Flaming Gorge area of Utah.

U.S. Geological Survey National Oil and Gas Assessment Project

Purpose

The purpose of the U.S. Geological Survey's (USGS) National Oil and Gas Assessment is to develop geologically based hypotheses regarding the potential for additions to oil and gas reserves in priority areas of the United States. The focus of the project is to determine the distribution, quantity, and availability of oil and natural gas resources, with an emphasis on quantifying undiscovered natural gas resources that may underlie Federal lands. The Southwestern Wyoming Province of Wyoming, Colorado, and Utah is a priority province for the National Oil and Gas Assessment because of the potential for significant natural gas resources. The approach, as in all priority provinces, was to establish the framework geology, define the total petroleum systems, define assessment units within the total petroleum systems, and assess the potential for additions to reserves in each assessment unit. This volume documents the framework geology and oil and gas assessment of nine total petroleum systems in the Southwestern Wyoming Province.

Figure 1. Southwestern Wyoming Province of southwestern Wyoming, northwestern Colorado, and northeastern Utah.

Location of Southwestern Wyoming Province

The Southwestern Wyoming Province is located in southwestern Wyoming, northwestern Colorado, and northeastern Utah, encompassing all or parts of (1) Moffat and Routt Counties in Colorado; (2) Carbon, Fremont, Lincoln, Sublette, Sweetwater, and Uinta Counties in Wyoming; and (3) Daggett and Summit Counties in Utah (fig. 1). The main population centers within the study area are Craig, Colorado, and Rock Springs, Wyoming. The main highways, I–80 and U.S. 40, generally traverse the area from east to west; U.S. 191 traverses the province from generally south to north. The Green River and its tributaries drain the area.

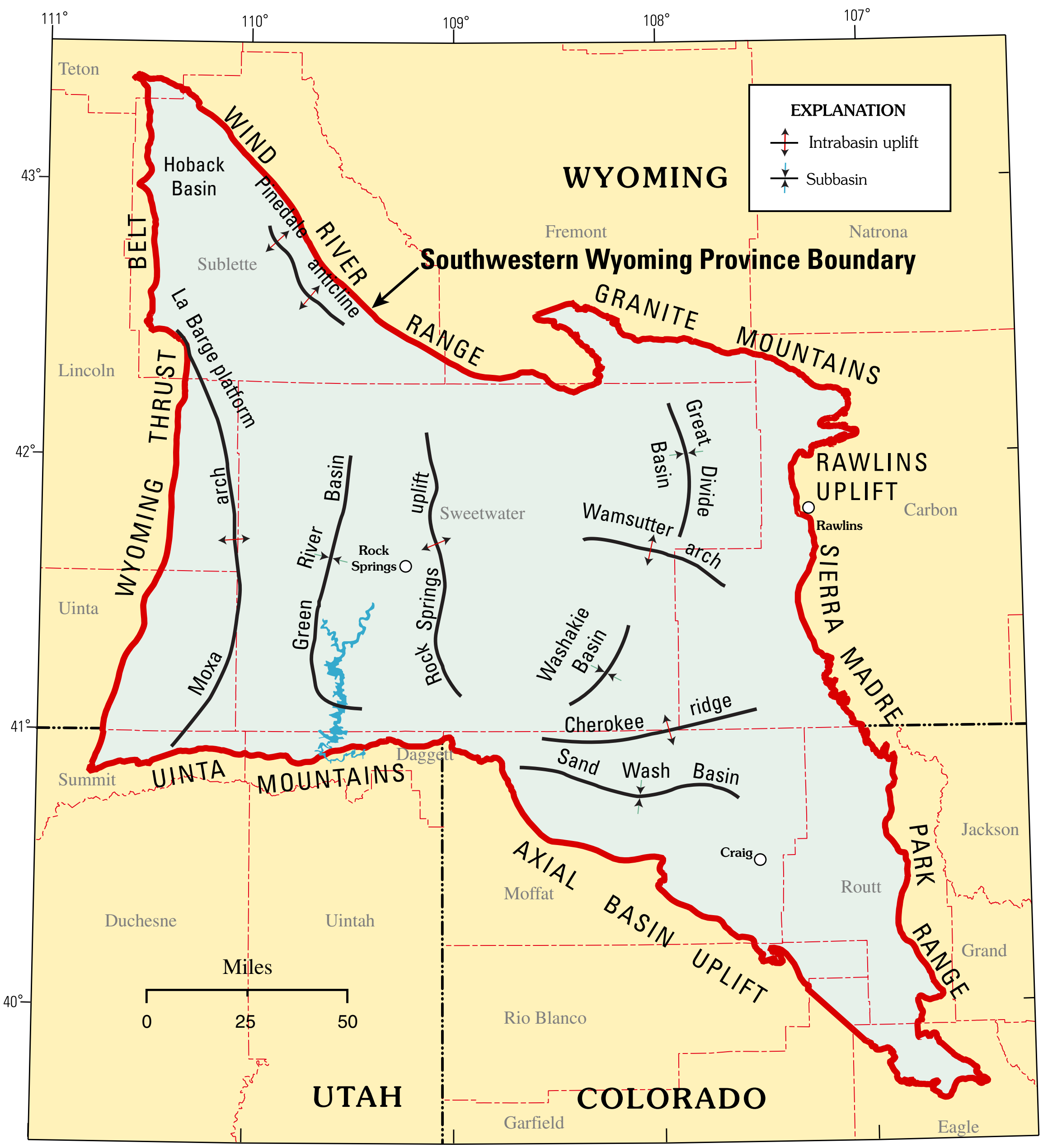
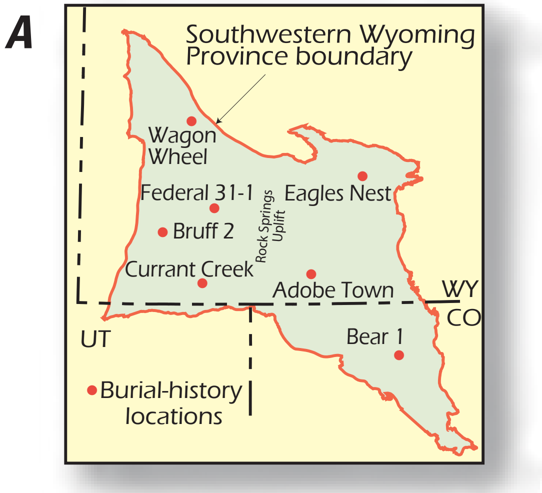


Figure 2. Major structural features in the Southwestern Wyoming Province.

Geologic Structure in the Southwestern Wyoming Province

In this assessment, the Southwestern Wyoming Province was defined to approximate the outline of the Greater Green River Basin (fig. 2). The Greater Green River Basin contains a number of subbasins including the Green River, Great Divide, Hoback, Sand Wash, and Washakie Basins. The province is bounded on the north by the Wind River Range and Granite Mountains; on the east by the Rawlins uplift, Sierra Madre, and Park Range; on the south by the Axial Basin uplift and Uinta Mountains; and on the west by the Wyoming and Utah portions of the Wyoming thrust belt. The province also contains the Rock Springs uplift and four major intrabasinal anticlines, the Cherokee ridge, Moxa arch (and La Barge platform), Pinedale anticline, and Wamsutter arch.



Burial History, Thermal Maturity, and Oil and Gas Generation History in the Southwestern Wyoming Province

Characterizing the level of thermal maturity and extent of petroleum generation of a potential source rock is critical in defining a total petroleum system and its associated assessment units, and in assessing the oil and gas resources of that system. The burial history, thermal maturity, and timing of petroleum generation were modeled at seven locations (fig. 3*A*) for eight key petroleum system source-rock horizons throughout the Southwestern Wyoming Province. The horizons are (1) the base of the Lower Permian Phosphoria Formation, (2) the base of the Upper Cretaceous Mowry Shale, (3) the base of the Upper Cretaceous Niobrara Formation, (4) the base of the Upper Cretaceous Baxter Shale (and equivalents), (5) the base of the upper part of the Upper Cretaceous Mesaverde Group, (6) the base of the Upper Cretaceous Lewis Shale, (7) the base of the Upper Cretaceous Lance Formation, and (8) the base of the Tertiary (Paleocene) Fort Union Formation (fig. 3*B*). See Chapter 3 by Roberts and others (this CD–ROM) for a discussion of the thermal maturation of petroleum source rocks.

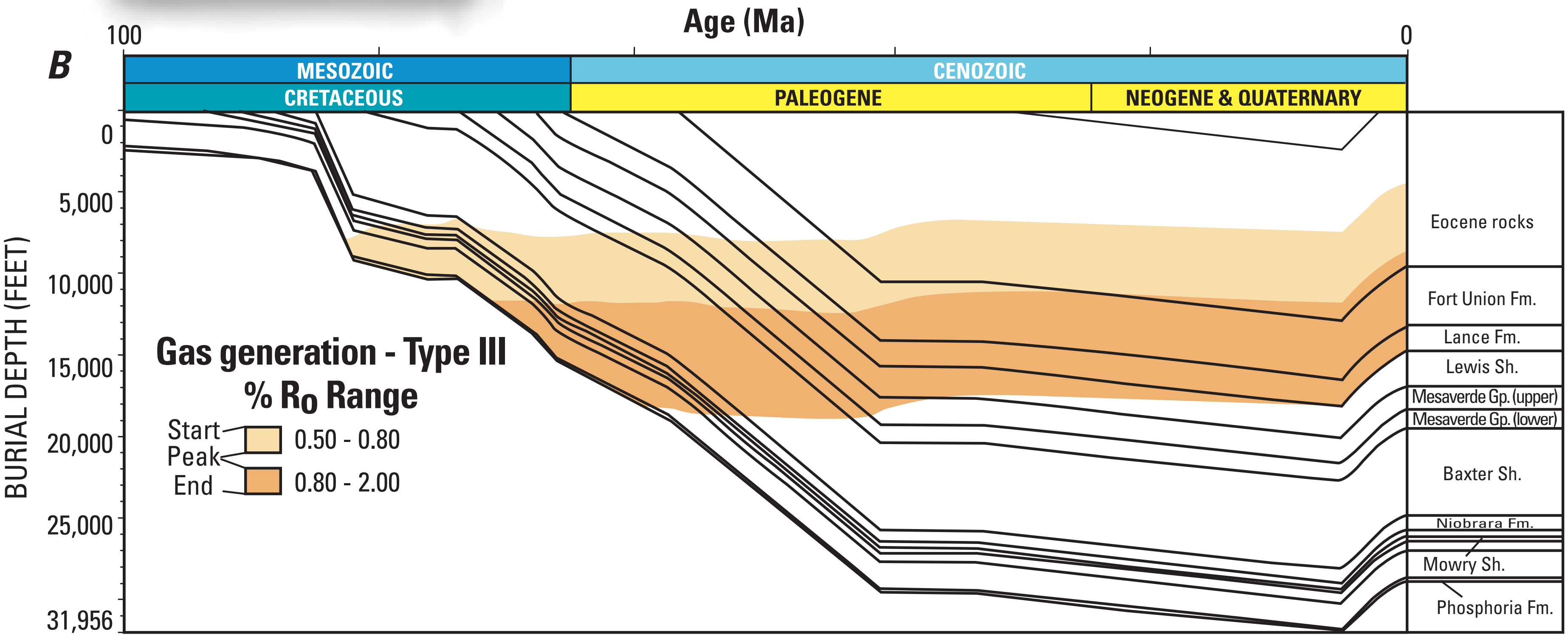


Figure 3. ***A***, locations of wells used in burial-history reconstructions. ***B***, an example of burial history for the Adobe Town well location showing petroleum generation windows for a Type-III kerogen.

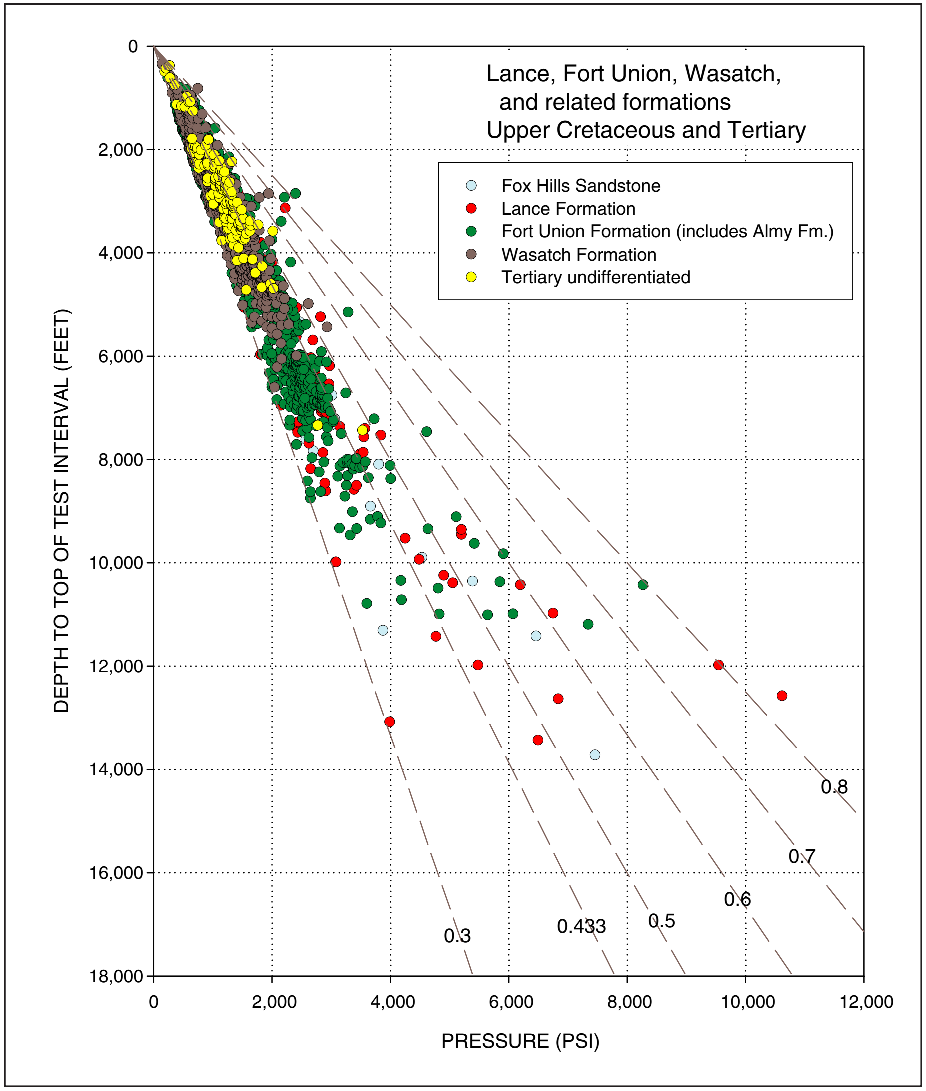


Figure 4. An example of pressure data from wells with drill-stem tests in the Upper Cretaceous Lance, and Tertiary Fort Union, Wasatch Formations, and related formations in the Southwestern Wyoming Province, Wyoming, Colorado, and Utah. Lines of constant pressure gradient give ratio of pressure to depth in pounds per square inch per foot (psi/ft).

Subsurface Pressure Data

Pressure and gas-flow rate data from the Southwestern Wyoming Province have been extracted from a commercial data base, edited, and organized into seven stratigraphic groups. As pressure increases with depth (fig. 4), most points plot between 0.3 psi/ft (the minimum retained value) and 0.433 psi/ft (the freshwater hydrostatic gradient). A large number of points also plot between 0.433 and 0.5 psi/ft, representing normally pressured to slightly overpressured conditions.

Pressure gradients exceeding 0.5 psi/ft, which represents significant overpressuring, tend to be more prevalent at depths greater than 9,000 ft as, for example, in the strata of the Lance, Fort Union, and Wasatch Formations. In addition to plots of pressure versus depth, maps of maximum pressure gradient (fig. 5) and maximum gas-flow rate, plots of completion date versus depth, and plots of gas-flow rate versus depth provide a broad perspective on development drilling in the province as a function of time, stratigraphic unit, and geographic location. (See Nelson and Kibler, Chapter 17, this CD–ROM.)

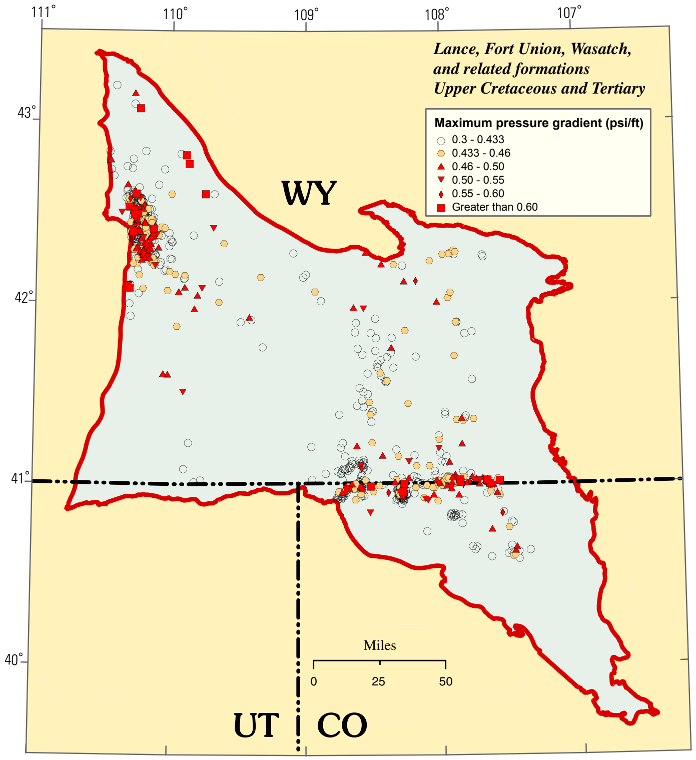


Figure 5. Drill-stem test data points.

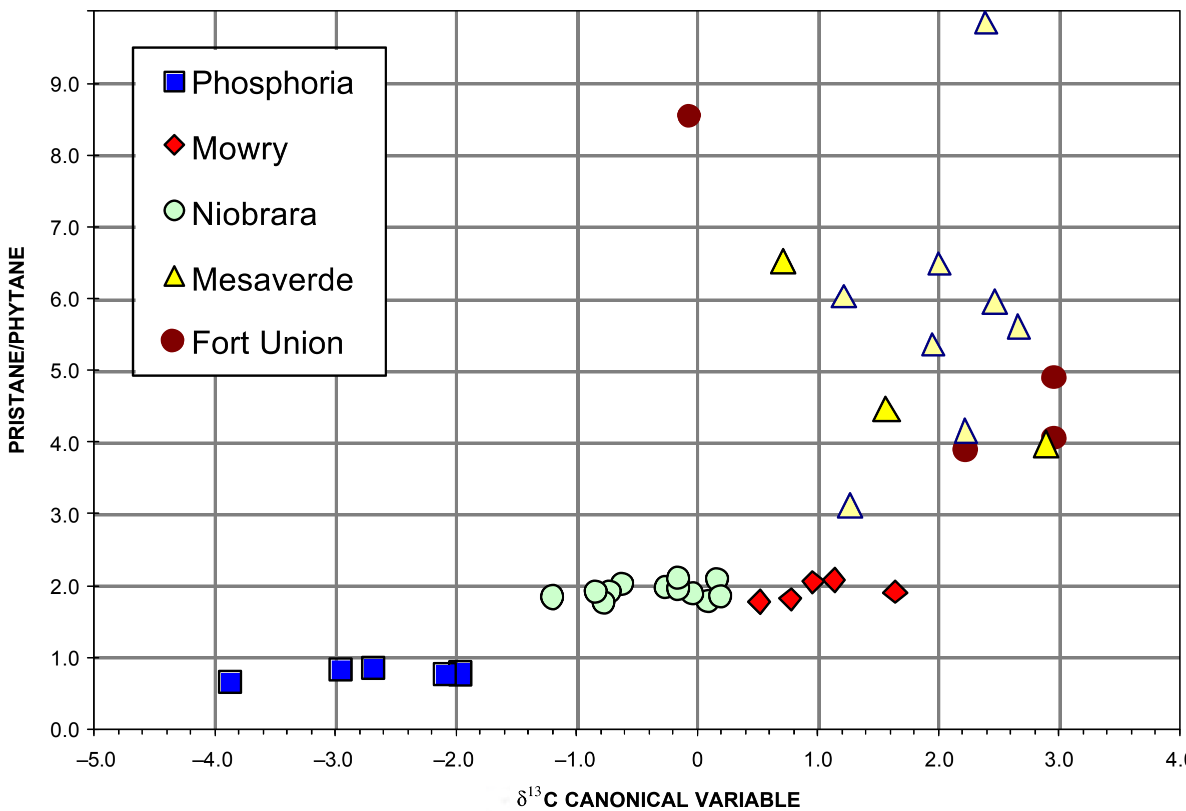


Figure 6. Graph of the canonical variable (CV equal to –2.53 ^{13}Csat + 2.22 ^{13}Caro –11.65) versus pristane/phytane of oils in the province.

Petroleum Geochemistry

As a part of the petroleum resource assessment of the Southwestern Wyoming Province by the USGS in 2002, oils were characterized geochemically and divided into genetic types that were named on the basis of their presumed source-rock units. Recognized petroleum systems based on these data include the Phosphoria, Mowry, Niobrara, Mesaverde (includes Almond), and Fort Union (includes Almy).

Oil data were compiled from a proprietary database (GeoMark Research), unpublished USGS data, and from published data (Sofer, 1984; Lillis and others, 2003). Pour point, API gravity, and sulfur-content data were also derived from the U.S. Department of Energy Crude Oil Analysis database version 2.0 (Sellers and others, 1996). Pristane/phytane values, stable carbon isotope values, and the related canonical variable (CV) devised by Sofer (1984), and sulfur content are the most useful geochemical parameters for the characterization of oil types. Figure 6 is a graph of the canonical variable (CV equal to –2.53 ^{13}Csat + 2.22 ^{13}Caro –11.65) versus pristane/phytane of oils in the province. Phosphoria oils generally have CV values less than –1.3, pristane/phytane values less than one, and sulfur content greater than 0.5 weight percent. Mowry and Niobrara oils have sulfur contents less than 0.5 weight percent and pristane/phytane values between 1.8 to 2.1 but can be distinguished based on CV values (fig. 6) and pour point (Mowry oil greater than 10°F, Niobrara less than 10°F). Mesaverde and Fort Union oils generally have pristane/phytane ratios greater than 3.0 and CV values greater than 0.5, indicating that the source-rock kerogen is dominantly nonmarine organic matter (Sofer, 1984; Hughes and others, 1995).

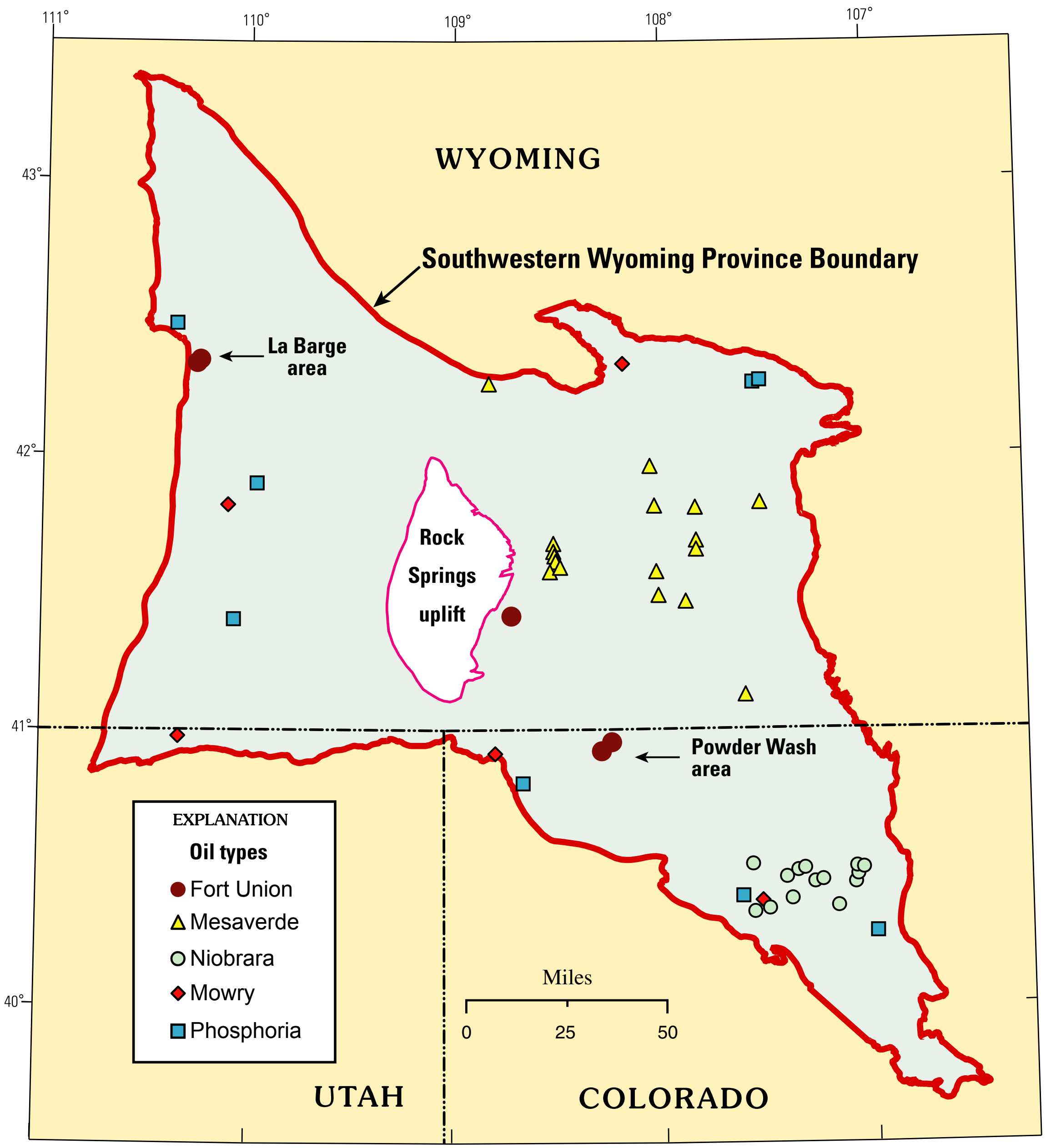


Figure 7. Distribution of oil samples throughout the Southwestern Wyoming Province.

Petroleum Geochemistry—(continued)

The Phosphoria and Mowry petroleum systems are widely distributed throughout the Southwestern Wyoming Province (fig. 7), and the Mesaverde system extends throughout the province except in the south-western part. The Niobrara system is limited to the eastern portion of the province. The Fort Union/Almy samples are restricted to three areas—La Barge area, the eastern flank of the Rock Springs uplift, and the Powder Wash area (fig. 7).

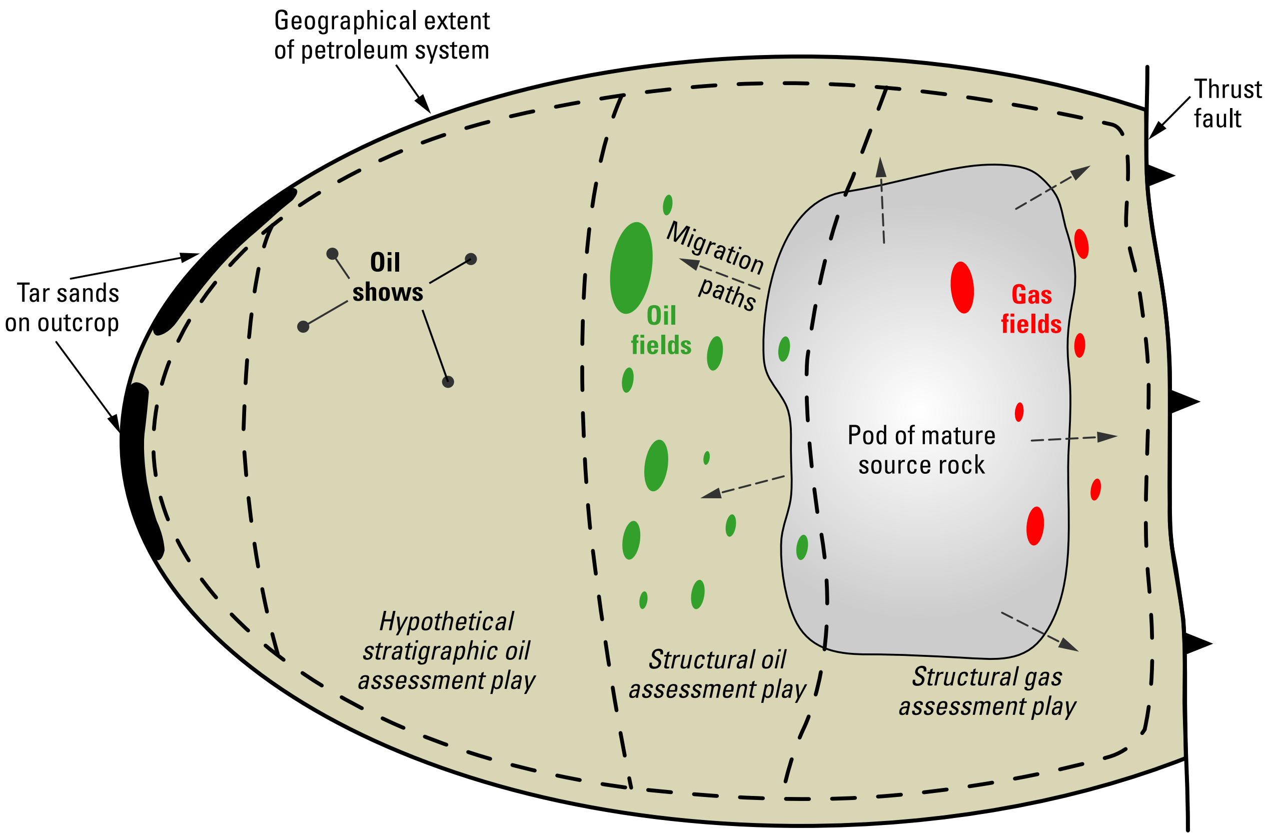


Figure 8. Schematic plan view of a total petroleum system, showing a pod of mature source rock, the distribution of known petroleum occurrences, and the boundaries of assessment units.

Total Petroleum System Concept

A total petroleum system (TPS) is a mappable entity encompassing genetically related petroleum that occurs in seeps, shows, and accumulations (discovered or undiscovered) that have been generated by a pod or by closely related pods of mature source rock (fig. 8). On this basis, we defined the various total petroleum systems in the Southwestern Wyoming Province. We also mapped the reservoirs, seals, and traps that contain or are projected to contain the petroleum within each TPS. The largest likely geographic extent of a TPS can then be mapped by integrating the areal distribution of known petroleum accumulations with potential migration fairways for oil and gas. Assessment units (AU) are defined within each TPS. An AU is defined as a mappable volume of rock within a TPS that encompasses accumulations (discovered and undiscovered) that share similar geologic characteristics and may be identified as conventional or continuous accumulations. (See fig. 27 for discussion of "conventional" and "continuous" hydrocarbon accumulations.)

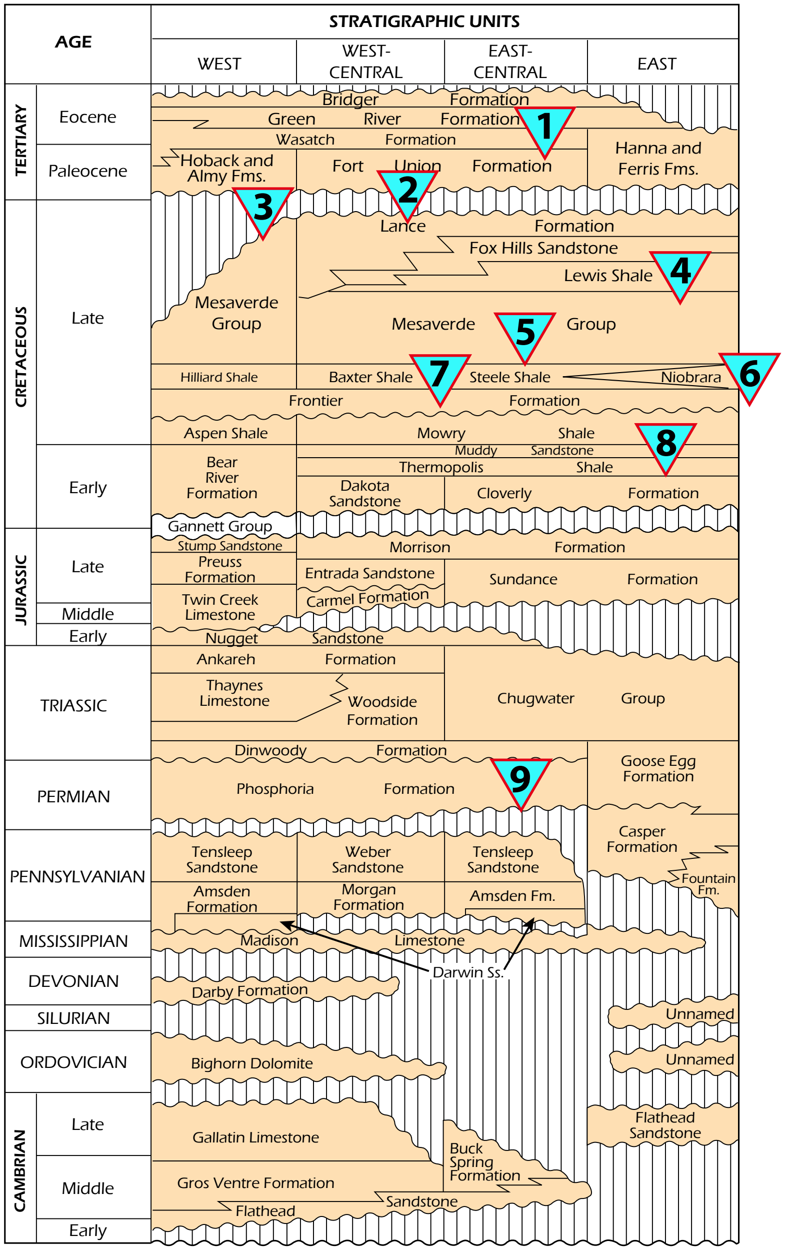


Figure 9. Generalized stratigraphic column of the Southwestern Wyoming Province.

Total Petroleum Systems in the Southwestern Wyoming Province

Nine petroleum systems named for their source rocks were determined for the Southwestern Wyoming Province. Some are composite systems because the exact source of the hydrocarbons or production information of some units were commingled and therefore could not be readily separated. The nine systems are listed below and highlighted by numbered markers on the columnar section (fig. 9).

1. Wasatch–Green River Composite TPS
2. Lance–Fort Union Composite TPS
3. Mesaverde–Lance–Fort Union Composite TPS
4. Lewis TPS
5. Mesaverde TPS
6. Niobrara TPS
7. Hilliard–Baxter-Mancos TPS
8. Mowry Composite TPS
9. Phosphoria TPS

Figure 10. Approximate location of oil and gas fields in the Green River Basin with reported sub-Cretaceous production (NRG Associates, 2001; IHS Energy Group, 2001).

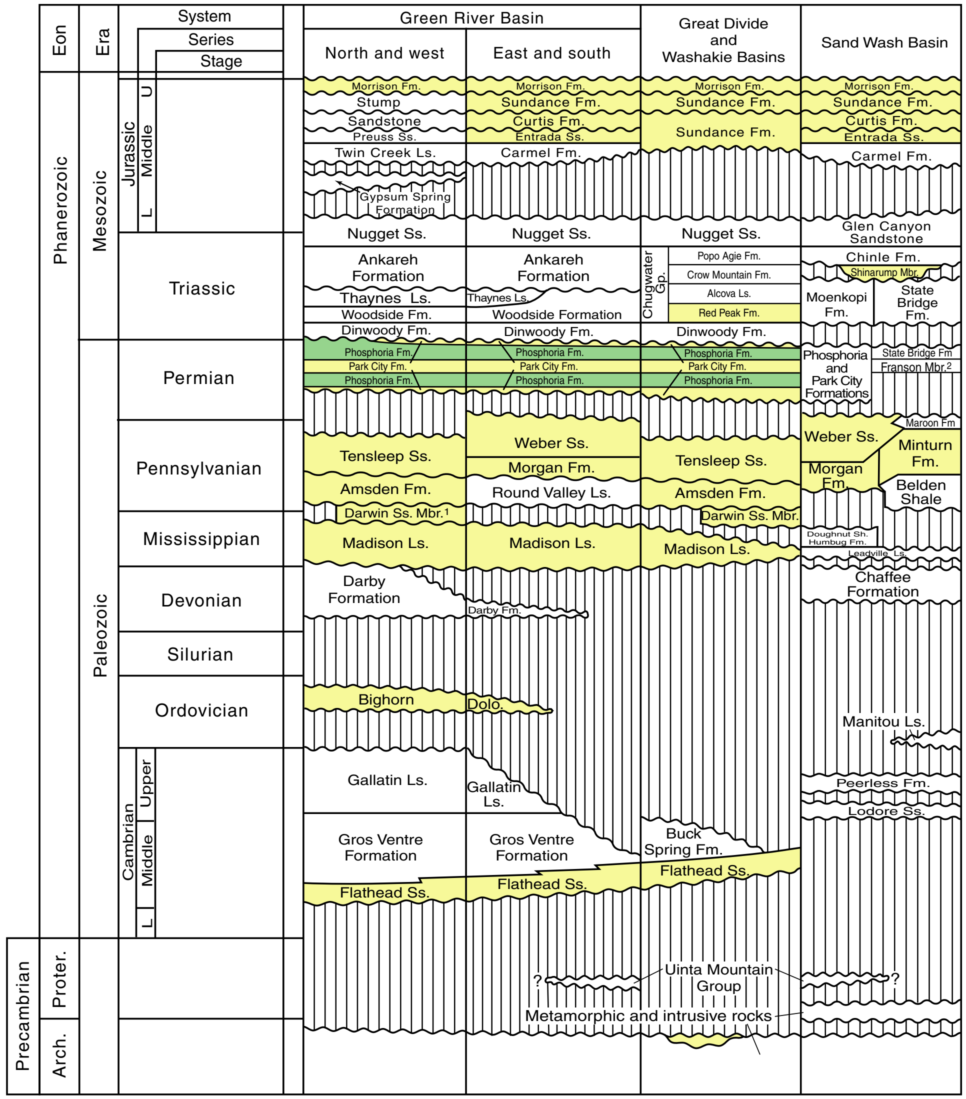
Phosphoria Total Petroleum System

Black marine shales of the Lower Permian Phosphoria Formation generated a substantial amount of hydrocarbons during the latter part of the Mesozoic Era that are now contained in a wide variety of lithostratigraphic units in the north-central Rocky Mountains (see for example, Claypool and others, 1978).

Sixty-eight oil and gas fields in the Green River Basin, containing some 700 wells, are reported to produce from one or more of the 18 formations of Cambrian through Jurassic age included in this TPS (fig. 10).

EXPLANATION

- Phosphoria TPS petroleum source rock
- Phosphoria TPS units with reported petroleum production



[1] of Amsden Formation [2] of Park City Formation

Figure 11. Generalized stratigraphic column showing distribution of reservoir rocks in Green River Basin containing oil and gas derived from Phosphoria Formation (modified from Ryder, 1988).

Southwestern Wyoming Stratigraphic Column

Eighteen units produce oil and gas thought to be sourced from the Phosphoria Formation. Of these, the most productive reservoirs are in the Tensleep Sandstone, Sundance Formation, Nugget Sandstone, Madison Limestone, and Morrison Formation. Of the 700 wells producing from this TPS, nearly 80 percent produce from these five formations.

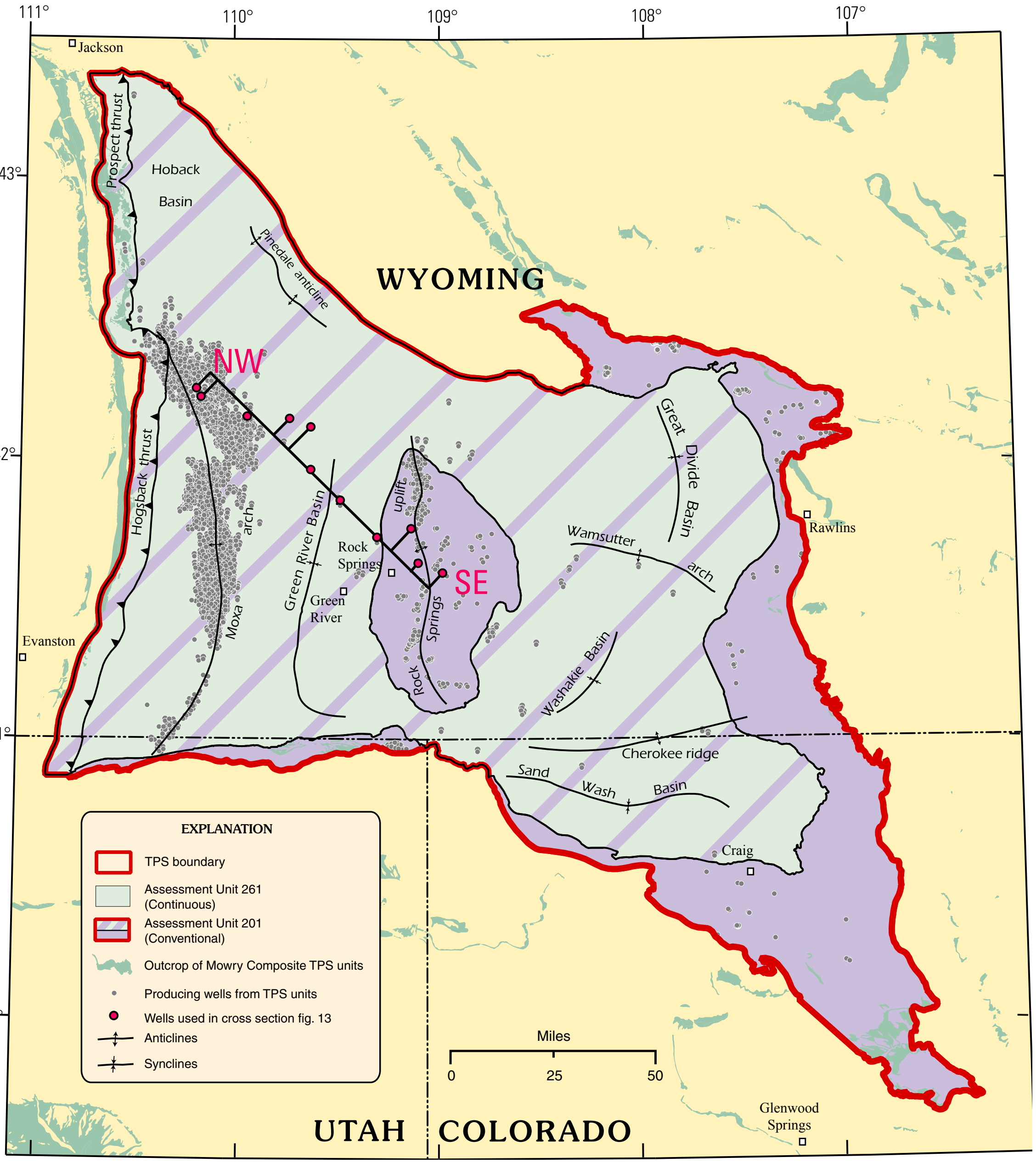


Figure 12. Geographic extent of the Mowry Composite Total Petroleum System in the Southwestern Wyoming Province. NW-SE cross section shown in figure 13.

Mowry Composite Total Petroleum System

A conventional oil and gas assessment unit (AU) and a continuous gas AU were defined for the Mowry Composite TPS. The Mowry Conventional Oil and Gas AU covers the entire province (fig. 12) and includes mainly intrabasinal and basin margin structures and stratigraphic traps, but also includes traps located stratigraphically below the basin-centered accumulations of the Mowry Continuous Gas AU. The continuous gas AU underlies an area of about 11.5 million acres where the approximate limit of gas saturation is defined by: (1) areas of overpressure, (2) bottom hole temperature greater than 200°F, (3) vitrinite reflectance greater than 0.8 percent, (4) low permeabilities, and (5) absence of gas/water contacts in the reservoirs. See Chapters 5 and 15 by Kirschbaum and Roberts (this CD–ROM) for geologic discussions of the Mowry Composite TPS.

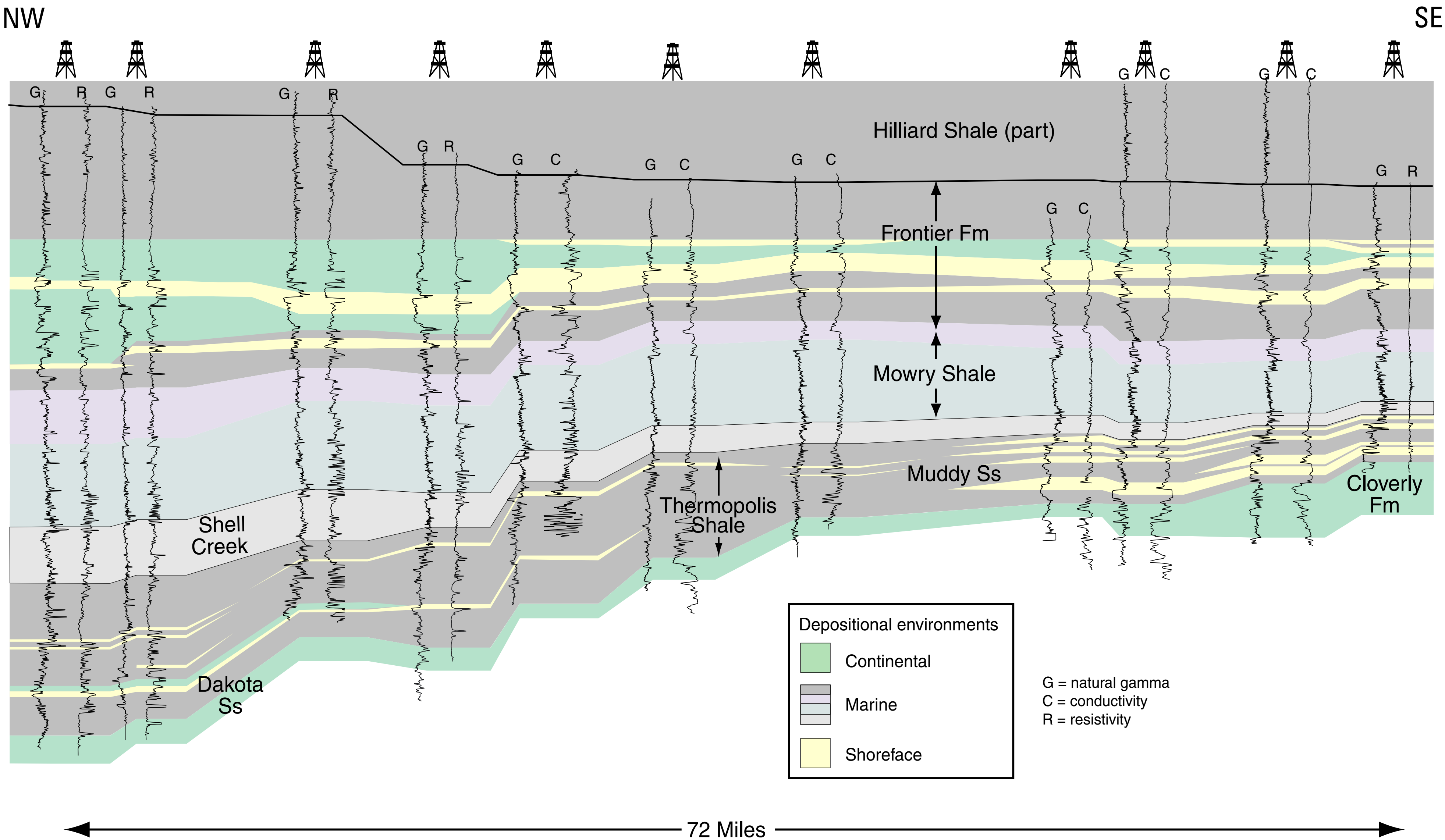


Figure 13. The Total Petroleum System is defined as a composite system because it contains hydrocarbons generated from multiple source rocks, including marine shale units of the Mowry and Thermopolis Shales and their equivalents, and coaly and lacustrine facies in the Bear River (not shown on cross section) and Frontier Formations and Dakota Sandstone. Oil and gas migrated into fluvial, tidal, deltaic, and shoreface sandstone reservoirs of the Bear River, Frontier, and Cloverly Formations and the Dakota and Muddy Sandstones. The hydrocarbons were trapped in structural, stratigraphic, and basin-centered accumulations. Seals include thick continuous marine shale sequences and in some cases terrestrial to estuarine mudstone units, diagenetic seals, and capillary-pressure seals. Location of cross section shown in figure 12.

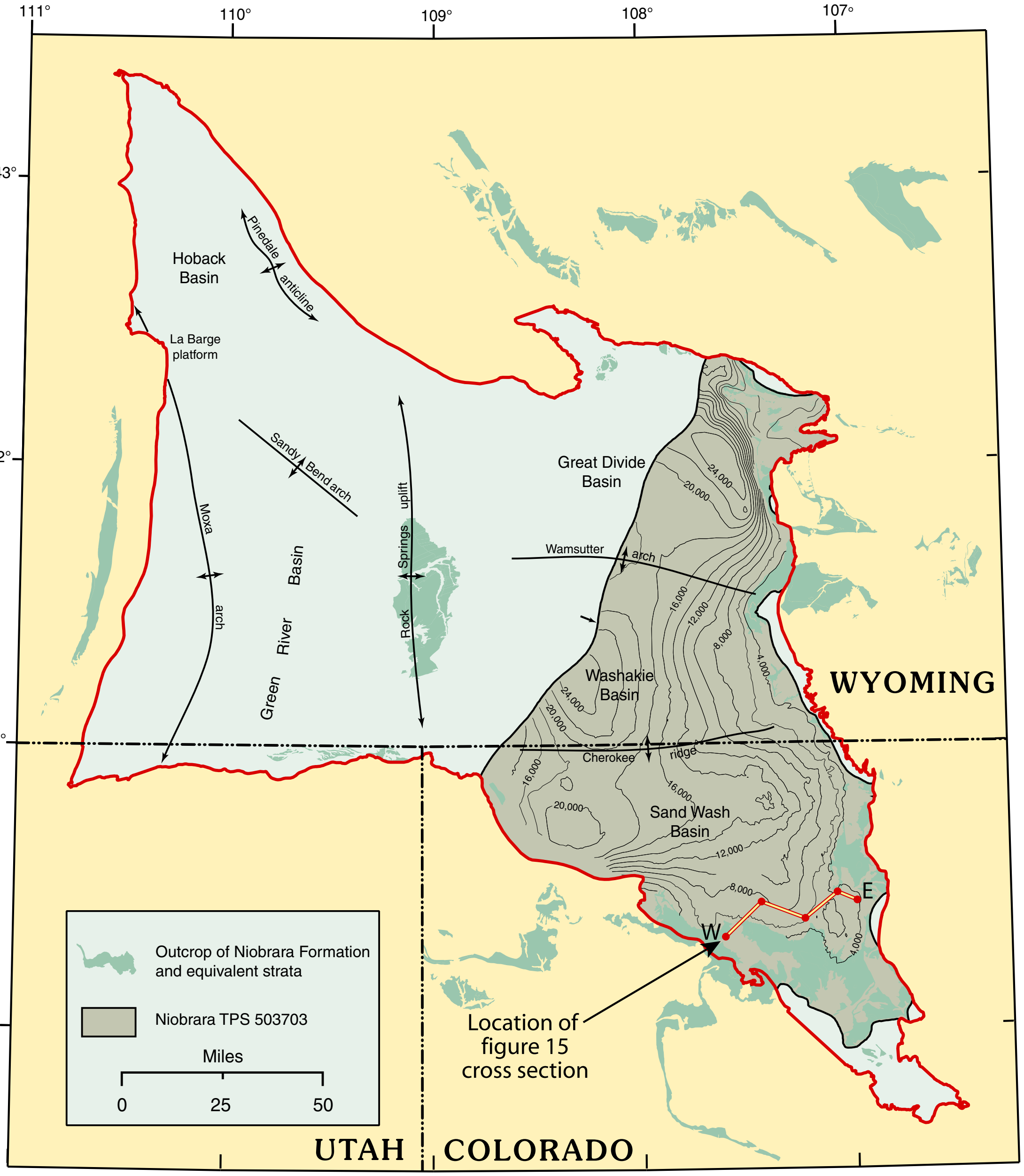


Figure 14. Geographic extent of the Niobrara Total Petroleum System in the Southwestern Wyoming Province.

Niobrara Total Petroleum System

This map shows the extent of the Niobrara TPS, major structural elements, and location of cross section (fig. 14). Contours represent the approximate depth in feet to the base of the Niobrara Formation (modified from Kirschbaum and Roberts, Chapter 5, this CD–ROM). Contour interval is 2,000 ft. The Niobrara TPS is a self-sourced system that produces oil and natural gas from fractured carbonate-rich reservoirs in the Upper Cretaceous Niobrara Formation and equivalent rocks. The Niobrara TPS encompasses parts of the Great Divide, Sand Wash, and Washakie Basins. See Chapter 6 by Finn and Johnson (this CD–ROM) for a geologic discussion of the Niobrara TPS.

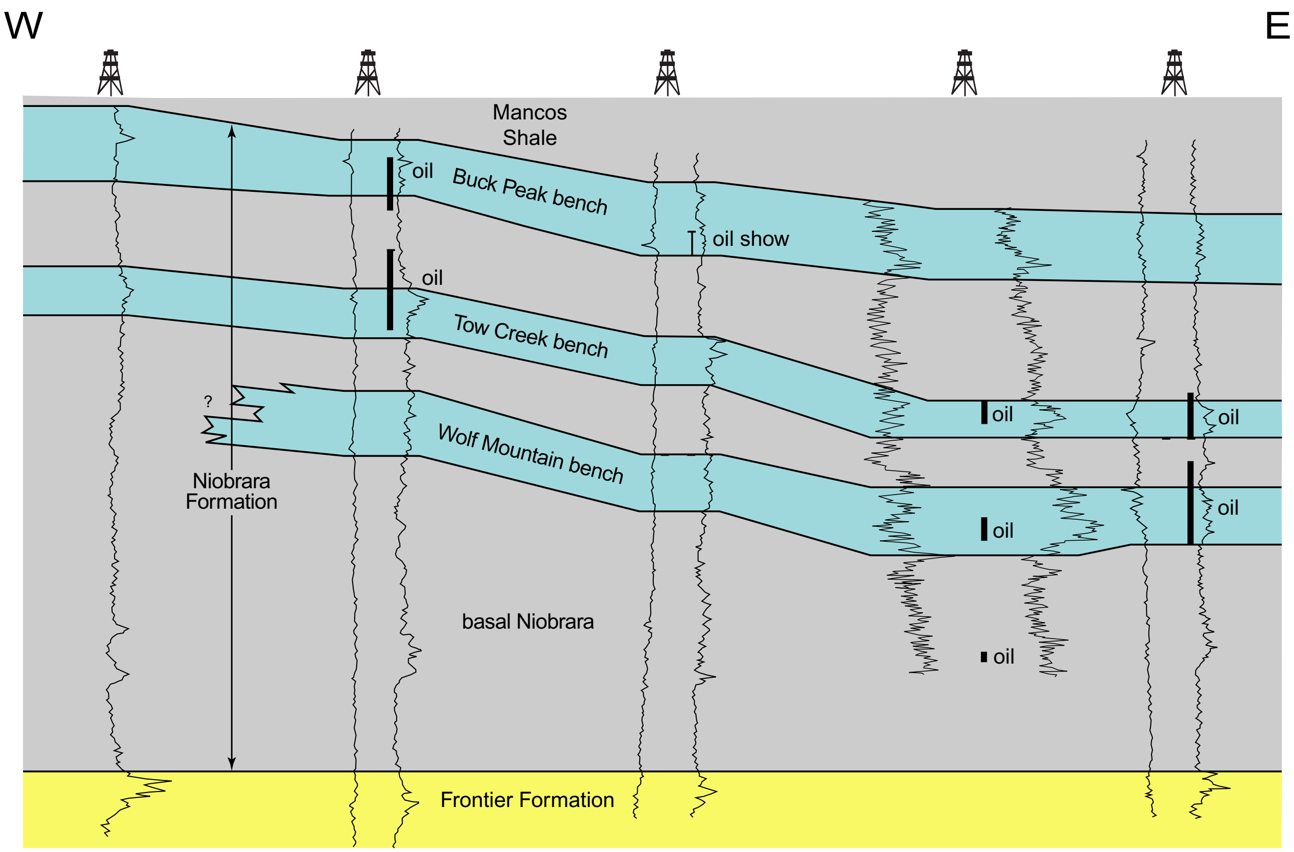


Figure 15. Generalized stratigraphic cross section of the Niobrara Total Petroleum System, modified from Haskett (1959).

Cross section of the Niobrara Formation in northwestern Colorado

In figure 15, marine sandstones are shown in yellow and clay-rich marine shale in gray; calcareous-rich zones that are more prone to fracturing are highlighted in light blue; and oil-producing zones are indicated by heavy vertical black bars.

The Niobrara TPS produces primarily oil from fractured, calcareous-rich shales, shaley limestones, and marls from the Upper Cretaceous Niobrara Formation and equivalent rocks in the eastern portions of the Greater Green River Basin. Location of cross section shown in figure 14.

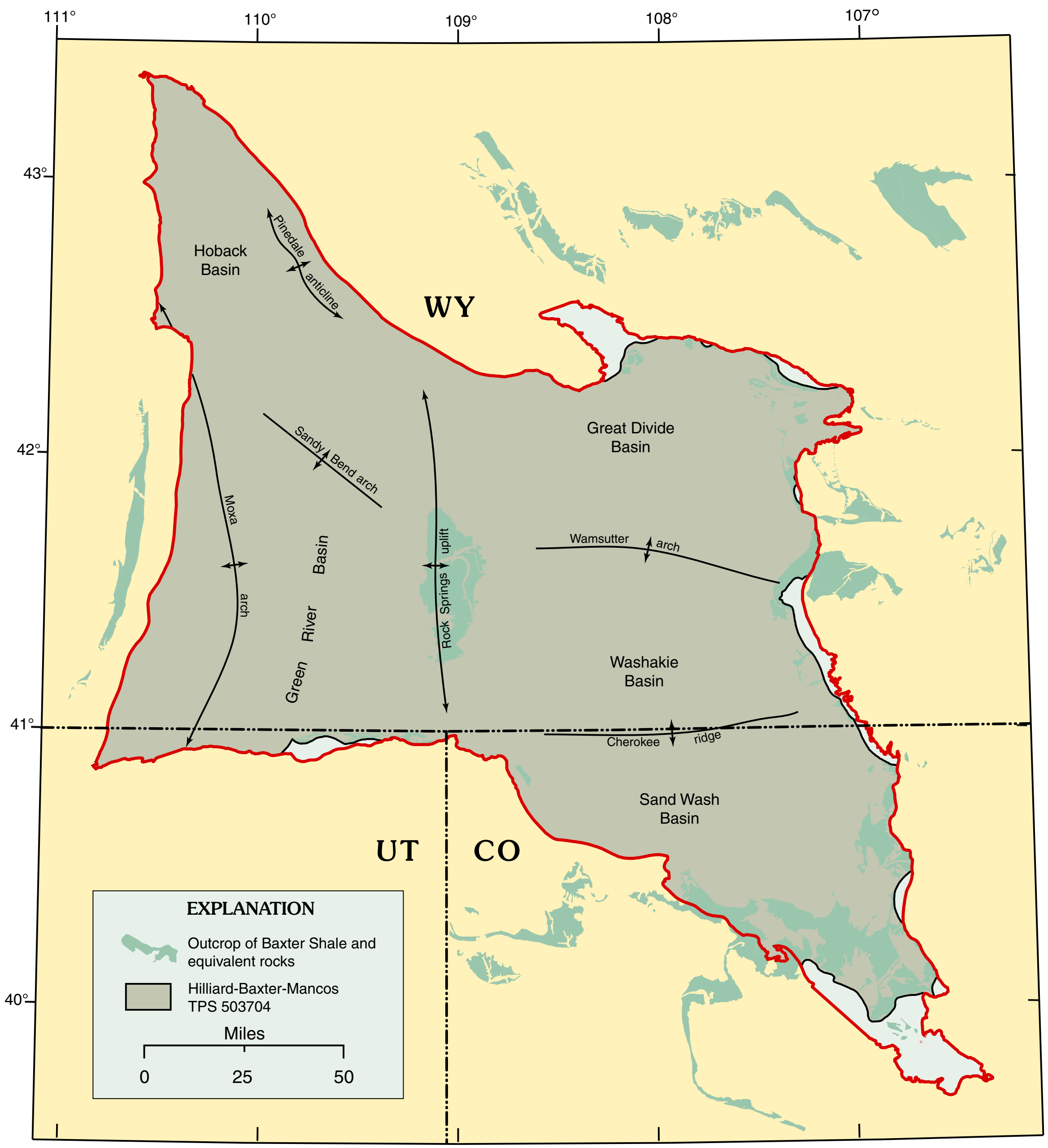


Figure 16. Geographic extent of the Hilliard-Baxter-Mancos Total Petroleum System in the Southwestern Wyoming Province.

Hilliard-Baxter-Mancos Total Petroleum System

The Hilliard-Baxter-Mancos TPS covers an area of 22,448 mi^2 and includes all of that part of the Southwestern Wyoming Province where this marine shale interval is present (fig. 16). The shales were deposited in offshore to nearshore environments during an extended period in which the Late Cretaceous shoreline was predominantly west of the TPS. The stratigraphic interval included in the TPS ranges in thickness from about 3,500 to 6,000 ft (see fig. 19). The thick organic-rich shales are potential source rocks, and thick nearshore to offshore silty and sandy strata are potential reservoir rocks. See Chapter 7 by Finn and Johnson (this CD–ROM) for a geologic discussion of the Hilliard-Baxter-Mancos TPS.

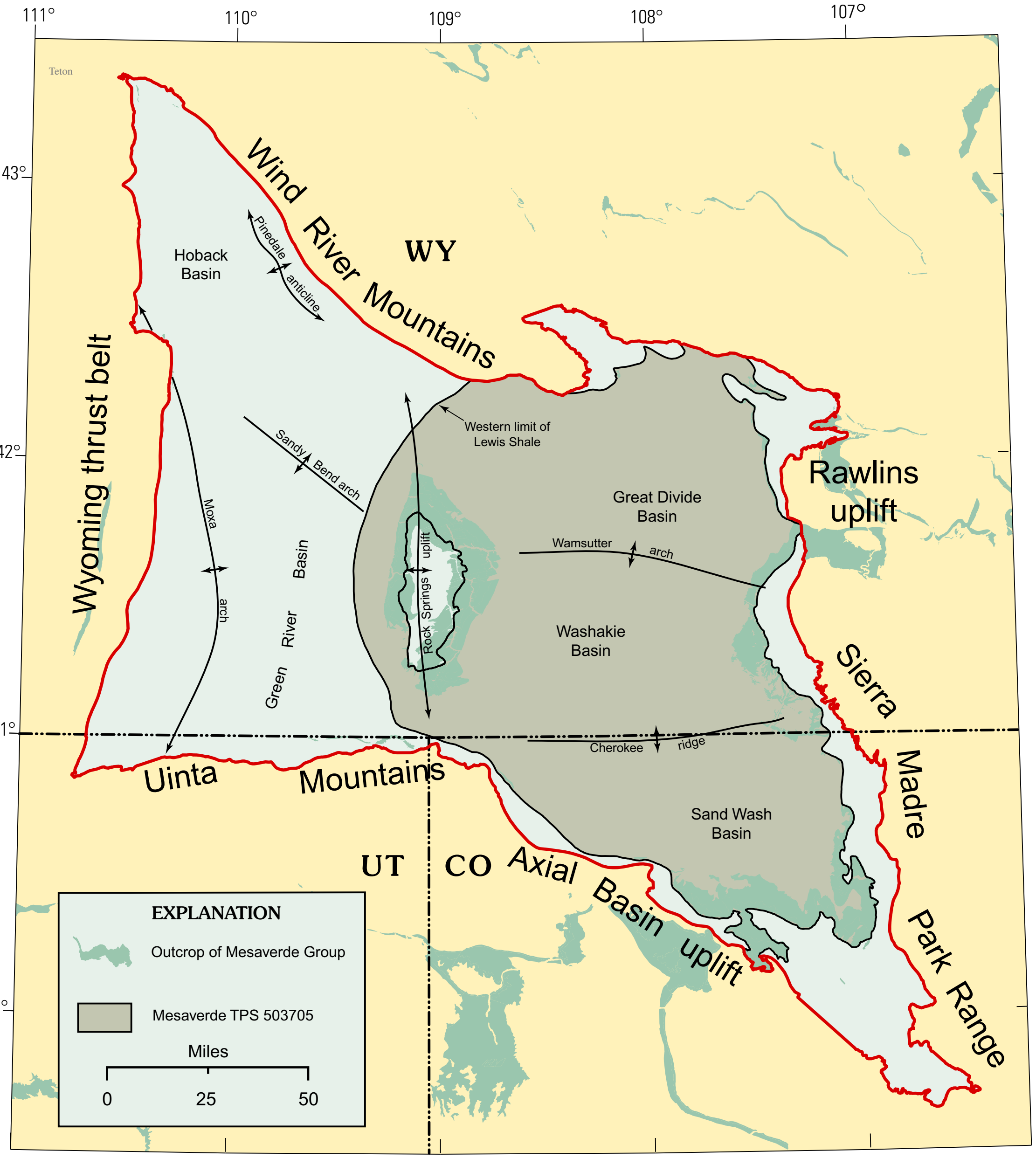


Figure 17. Geographic extent of the Mesaverde Total Petroleum System in the Southwestern Wyoming Province.

Mesaverde Total Petroleum System

The Mesaverde TPS in the Southwestern Wyoming Province produces hydrocarbons from sandstone and coal reservoirs in the Upper Cretaceous Mesaverde Group (fig. 17). Coals and terrigenous organic-rich shales within the Mesaverde Group are believed to be the primary source. The TPS includes most strata in the Mesaverde Group east of the pinch-out of the Lewis Shale. The TPS is subdivided into three continuous gas assessment units—the Almond Continuous Gas AU, the Rock Springs–Ericson Continuous Gas AU, and the Mesaverde Coalbed Gas AU—and one conventional assessment unit, the Mesaverde Conventional Oil and Gas AU. See Chapter 8 by Johnson, Finn, and Roberts (this CD–ROM) for a geologic discussion of the Mesaverde TPS.

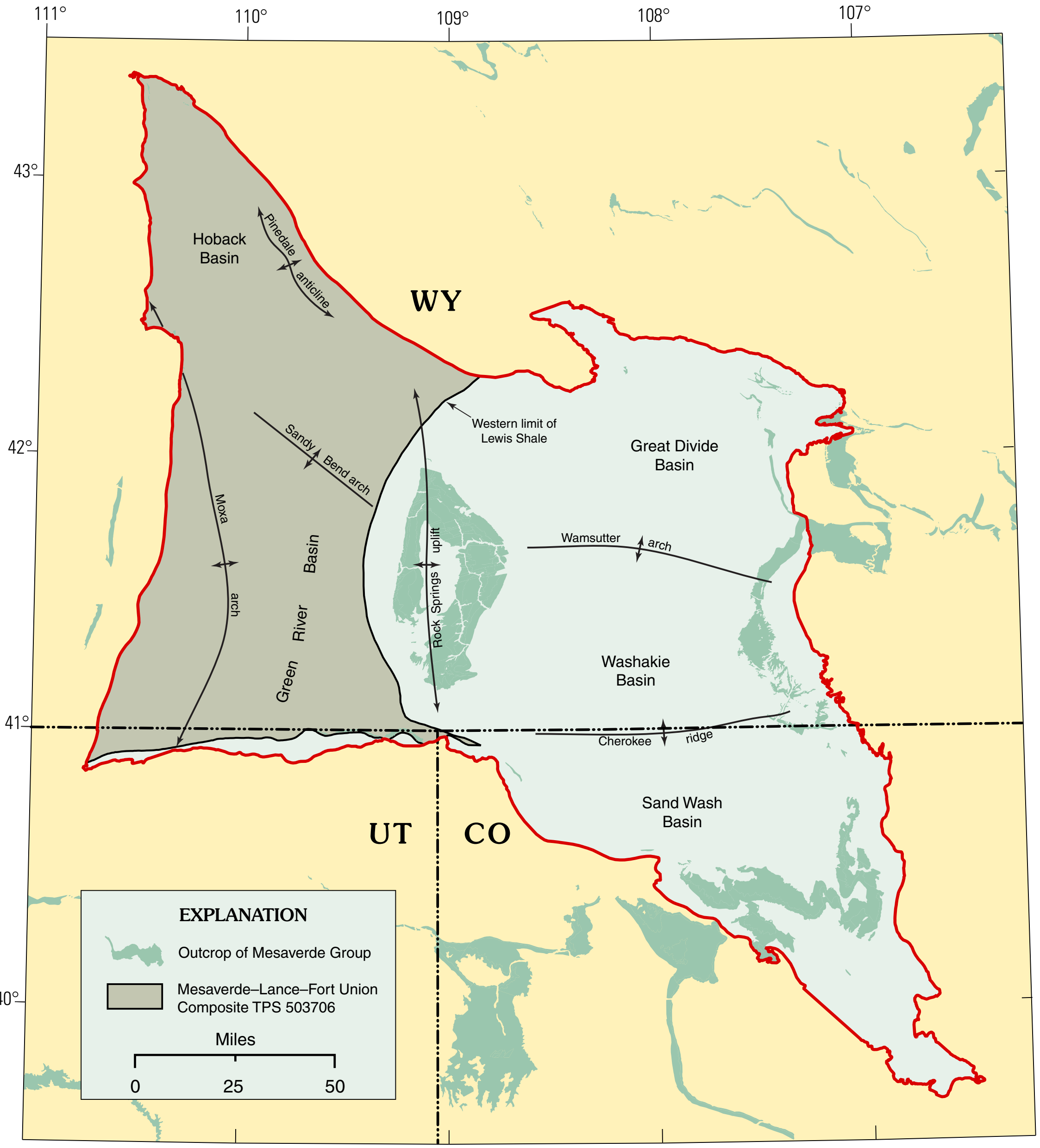


Figure 18. Geographic extent of the Mesaverde–Lance–Fort Union Composite Total Petroleum System in the Southwestern Wyoming Province.

Mesaverde–Lance–Fort Union Composite Total Petroleum System

The Mesaverde–Lance–Fort Union Composite TPS is a predominantly gas-prone system within the western part of the Southwestern Wyoming Province, west of the pinch-out of the Lewis Shale (fig. 19). The composite TPS is considered here as one system because all of the units were deposited in a terrestrial setting, contain similar gas-prone source rocks, and have no regional seal within the the entire stratigraphic succession to inhibit the vertical migration of gas. Coals and carbonaceous shales are presumed to be the primary source rocks. See Chapter 10 by Finn and others (this CD–ROM) for a geologic discussion of the Mesaverde–Lance–Fort Union Composite TPS.

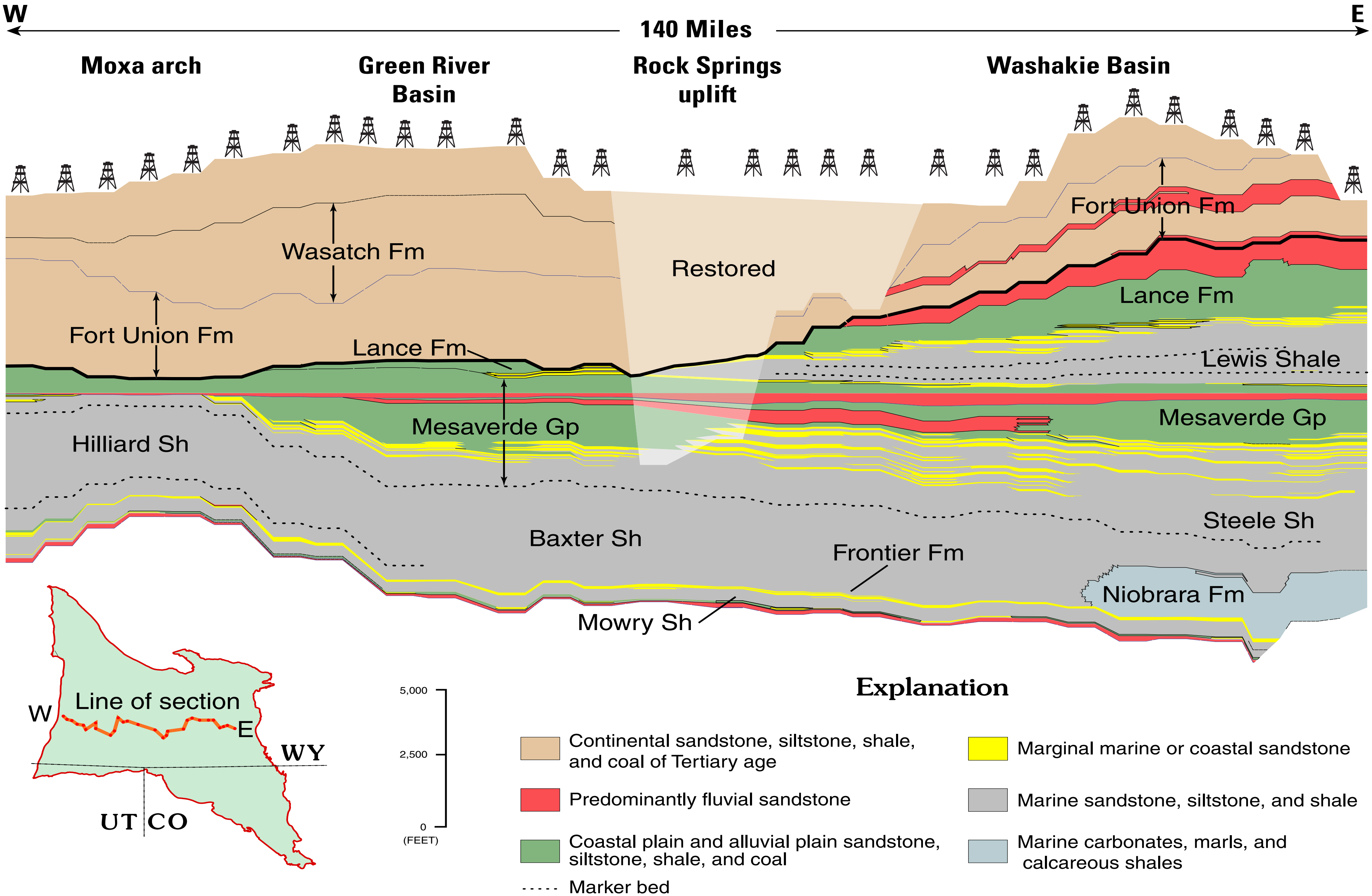


Figure 19. Generalized stratigraphic cross section of the Cretaceous and Tertiary rocks across the Greater Green River Basin. For detailed well-log cross section, see Finn and Johnson, Chapter 14 (this CD–ROM).

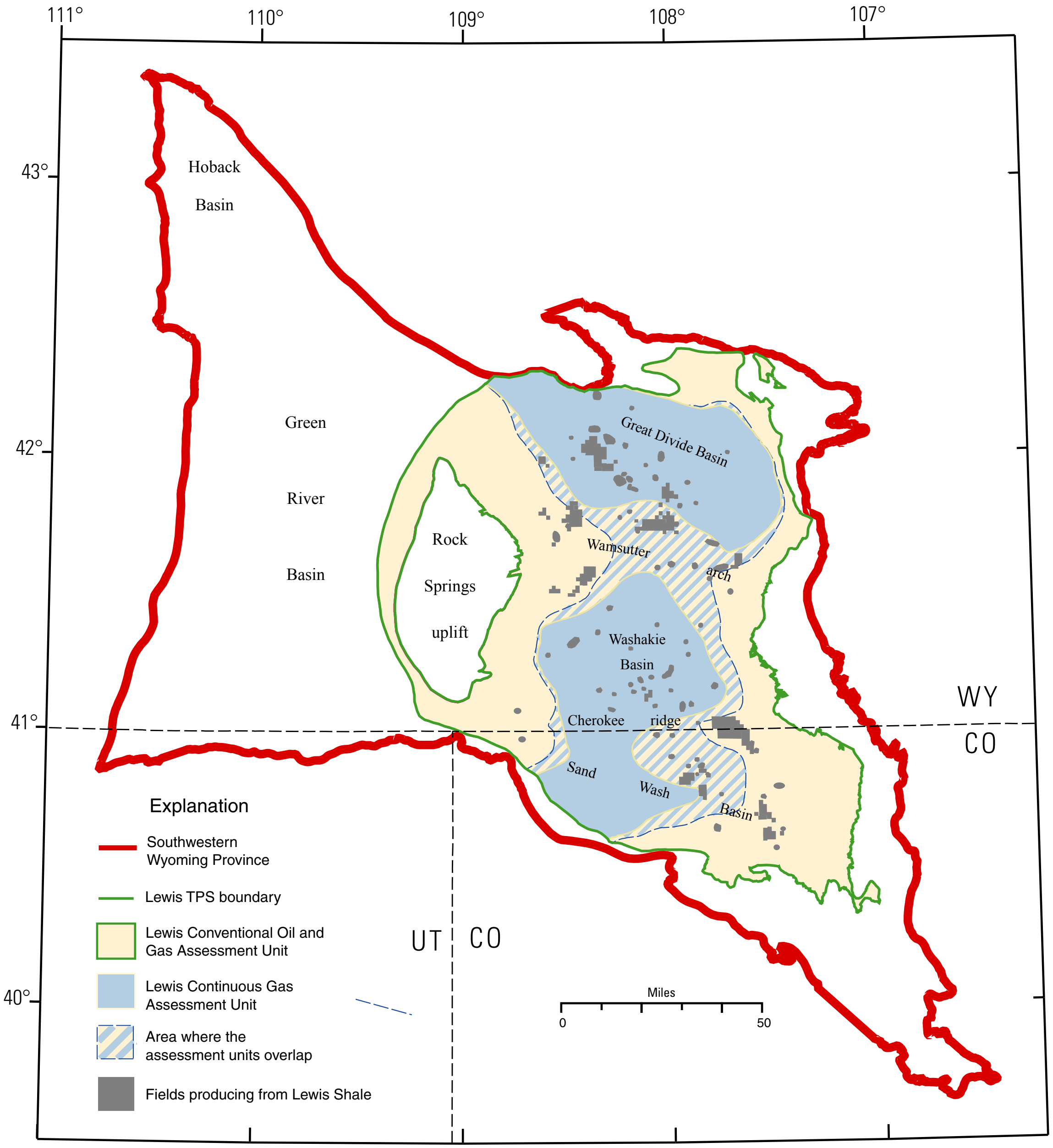


Figure 20. Geographic extent of the Lewis Total Petroleum System in the Southwestern Wyoming Province.

Lewis Total Petroleum System

Natural gas accumulations generated from marine mudrock in the Upper Cretaceous Lewis Shale define the limits of the Lewis TPS in the Southwestern Wyoming Province (fig. 20). Accumulations are confined to the Lewis Shale, which is distributed throughout the Great Divide, Sand Wash, and Washakie Basins. The TPS contains two assessment units: (1) the Lewis Continuous Gas AU, which includes the deeper basin areas characterized by an overpressured, gas-saturated, basin-centered accumulation (fig. 21); and (2) the Lewis Conventional Oil and Gas AU, which includes shallower basin areas where gas accumulations are within conventional-type traps. Principal reservoirs are sandstones deposited in laterally extensive turbidite systems (fig. 22). See Chapter 9 by Hettinger (this CD–ROM) for a geologic discussion of the Lewis TPS.

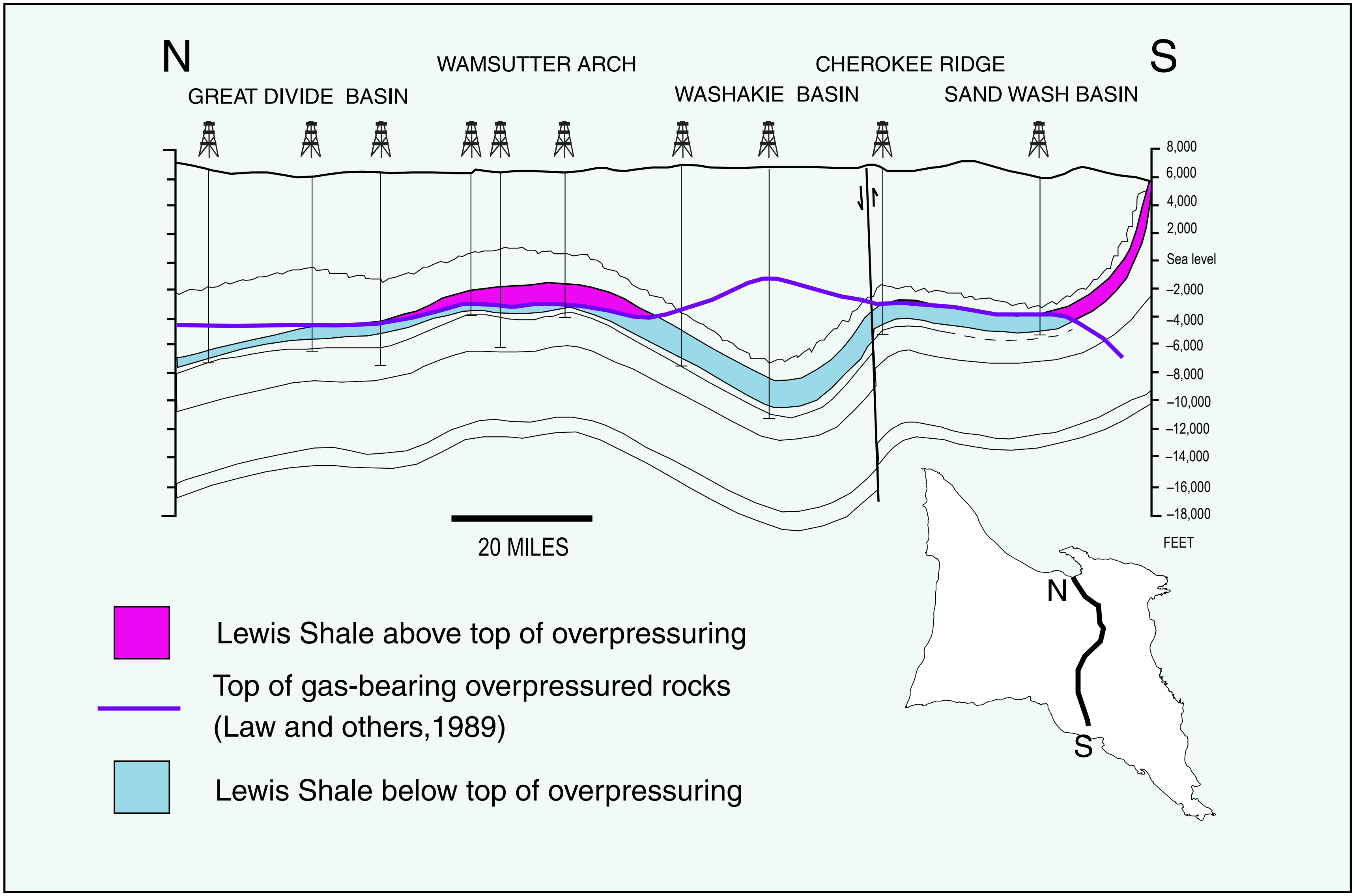


Figure 21. Relations of Lewis Shale to structure and to top of overpressured zone. Modified from Law and others (1989, their figure 8).

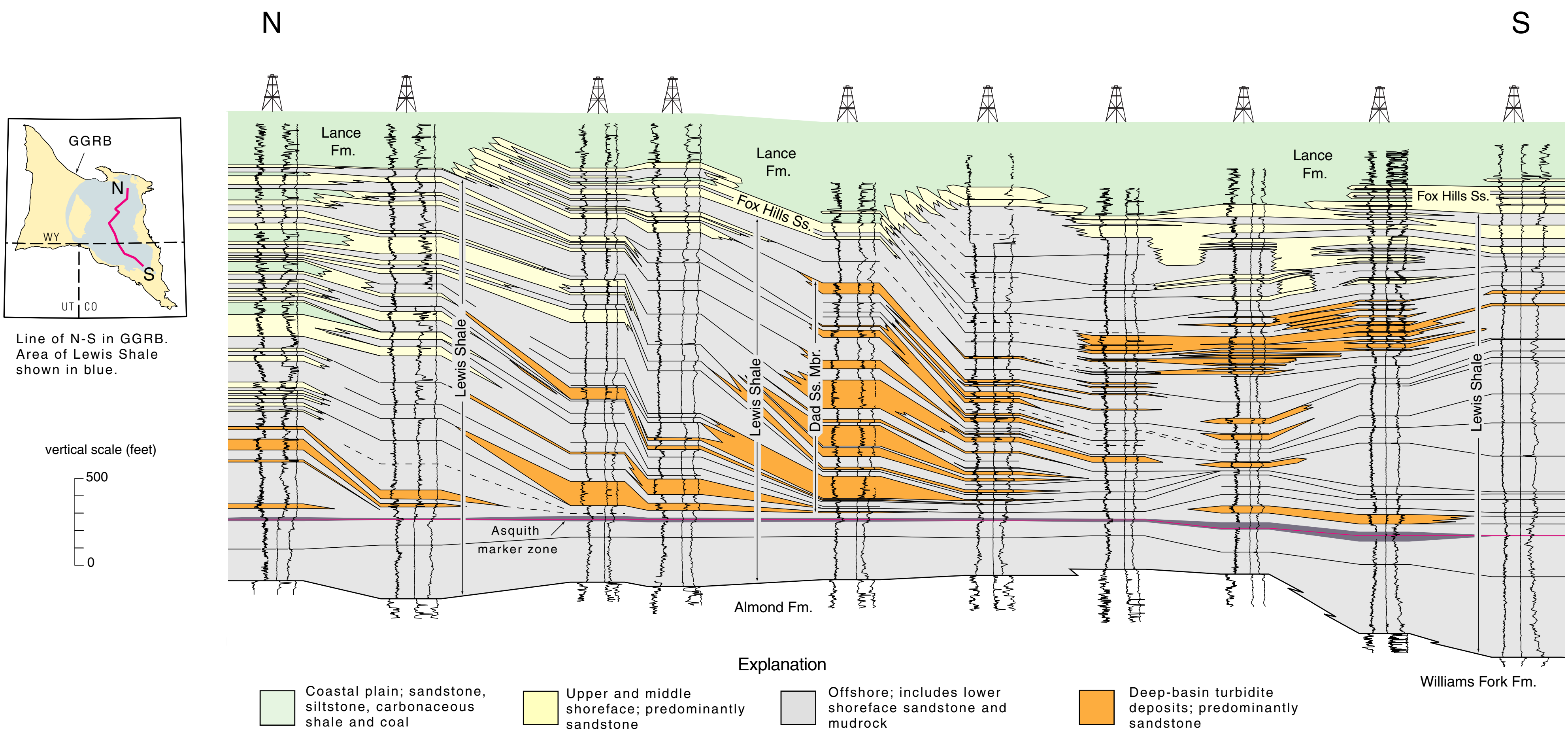
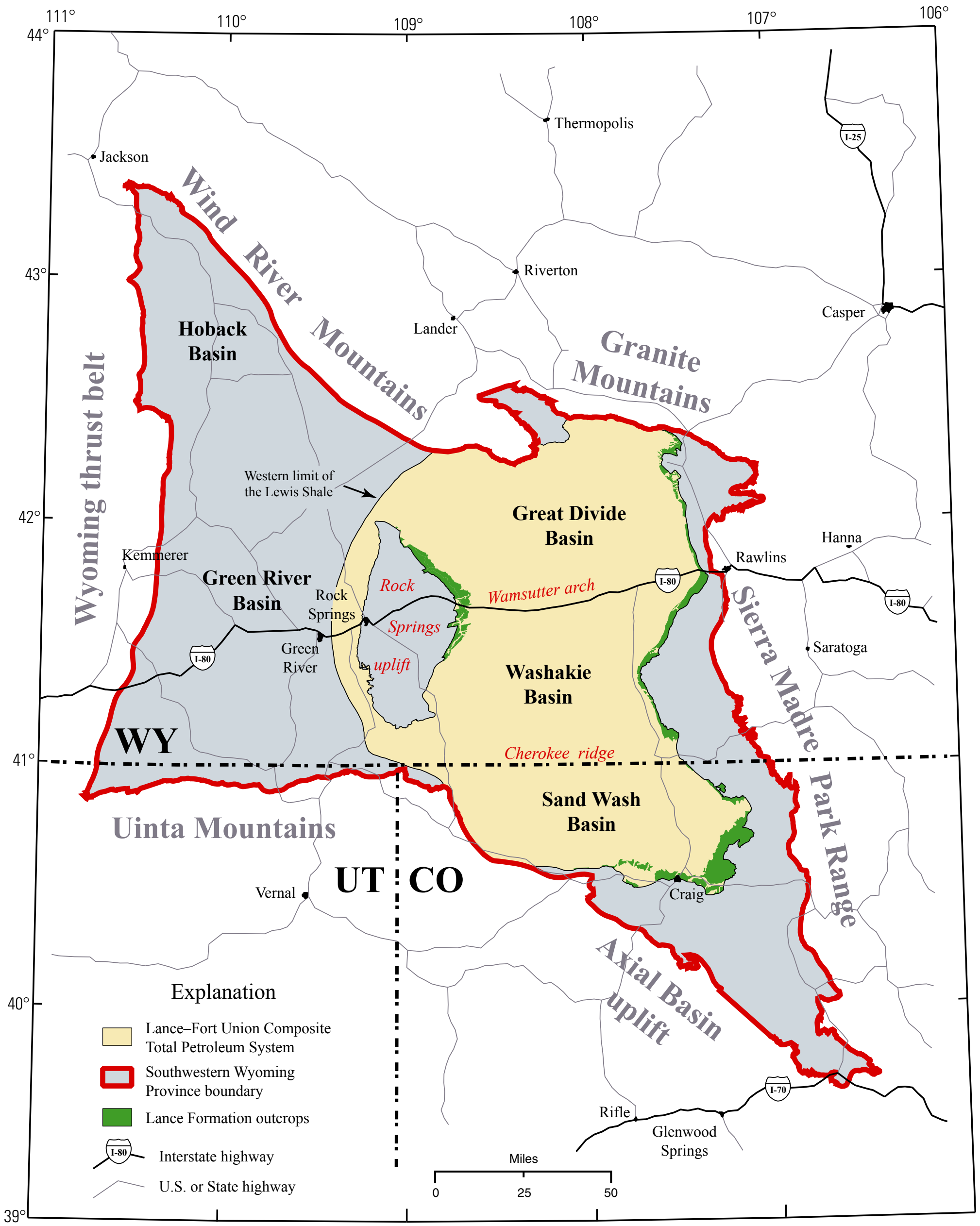


Figure 22. Stratigraphy and lithofacies of the Upper Cretaceous Lewis Shale in the eastern part of the Greater Green River Basin (GGRB), Colorado and Wyoming (Hettinger, Chapter 9, this CD–ROM).



Lance–Fort Union Composite Total Petroleum System

The Lance–Fort Union Composite TPS in the Southwestern Wyoming Province is a genetically related system of source rocks and hydrocarbon accumulations contained within the Upper Cretaceous Fox Hills Sandstone and the Lance Formation and the lower Tertiary Fort Union and Wasatch Formations. The petroleum system encompasses about 6,112,000 acres (9,550 mi^2) in Wyoming and Colorado and includes the Great Divide, Washakie, and Sand Wash structural basins and intervening Wamsutter and Cherokee ridge arches (fig. 23). See Chapter 11 by Roberts (this CD–ROM) for a geologic discussion of the Lance–Fort Union Composite TPS.

Figure 23. Geographic extent of the Lance–Fort Union Composite Total Petroleum System in the Southwestern Wyoming Province.

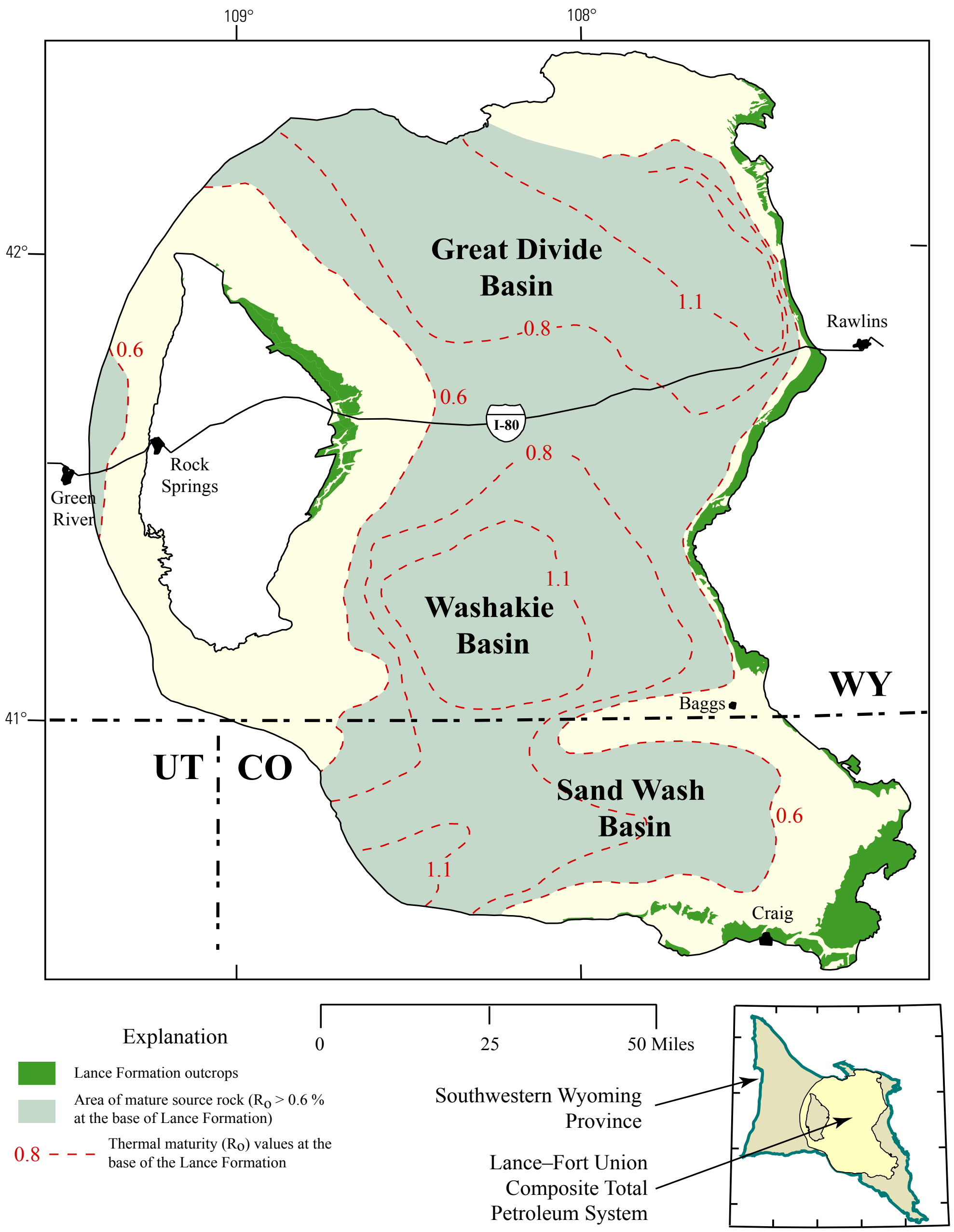


Figure 24. Lance–Fort Union Composite Total Petroleum System source rock thermal maturity (R_o) map.

Lance–Fort Union Formations Source Rock

Coalbeds and associated carbonaceous strata (shale, siltstone, and sandstone) within the Lance and Fort Union Formations are considered to be the primary source rocks for hydrocarbon generation within the Lance–Fort Union Composite TPS. These source rocks contain humic, Type-III organic matter and thus are considered to be gas-prone. The extent of mature source rocks is defined as that area in which thermal maturity (R_o) values at the base of the Lance Formation are estimated to be 0.6 percent or greater. This R_o value was used to define the primary "pod" of mature source rock within the TPS (fig. 24).

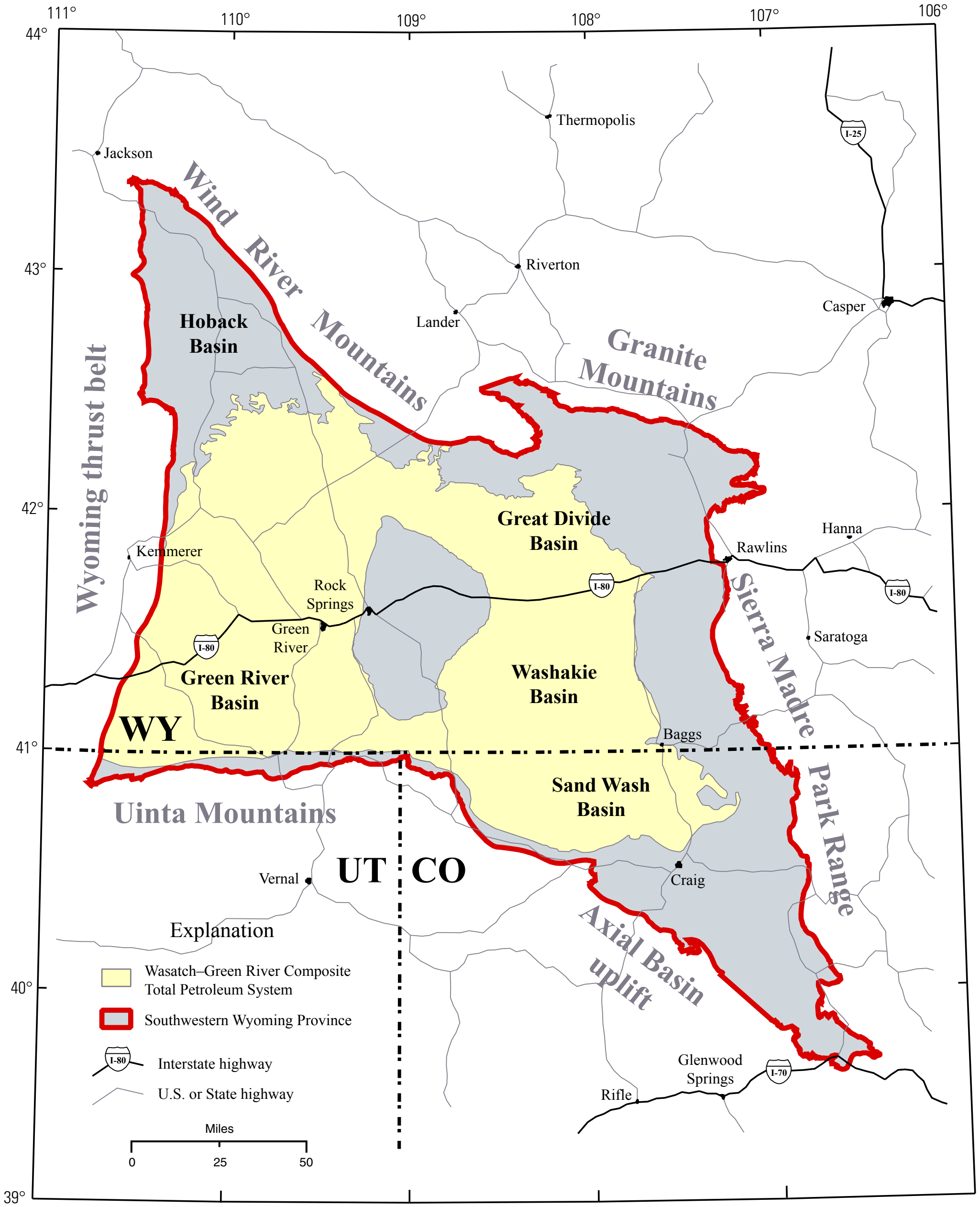
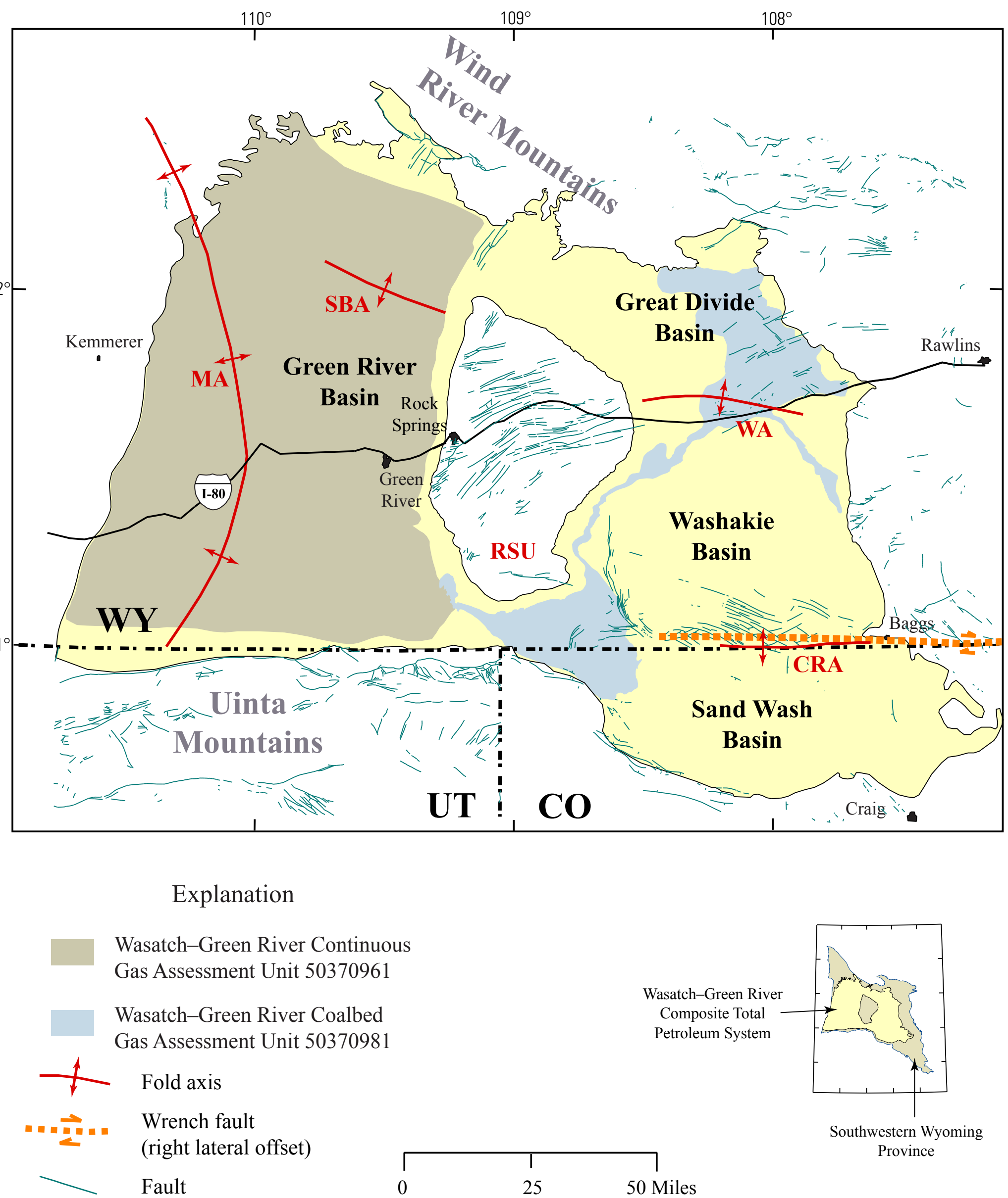


Figure 25. Wasatch–Green River Composite Total Petroleum System.

Wasatch–Green River Composite Total Petroleum System

Two hypothetical gas assessment units have been delineated within the Wasatch–Green River Composite TPS (fig. 25)—the Wasatch–Green River Continuous Gas AU and the Wasatch–Green River Coalbed Gas AU (fig. 26). Definition of the continuous gas AU is based on the extent of exploration activities and production tests of gas in the Wilkins Peak Member of the Green River Formation. This potential gas resource is considered to represent a self-sourced, biogenic shale-gas accumulation. The coalbed gas AU addresses the potential for gas accumulations in coals of the Wasatch and Green River Formations in western Washakie and central Great Divide Basins. Currently, there is no commercial production of gas from either assessment unit. See Chapter 12 by Roberts (this CD–ROM) for a geologic discussion of the Wasatch–Green River Composite TPS.



Wasatch–Green River Composite Total Petroleum System

The Wasatch–Green River Composite TPS in the Southwestern Wyoming Province includes source rocks and potential hydrocarbon accumulations within Tertiary (Eocene) strata in the Wasatch and Green River Formations. The petroleum system encompasses about 7,850,000 acres (12,265 mi^2) in Wyoming, Colorado, and Utah and includes areas within the Green River, Great Divide, Washakie, and Sand Wash structural basins (fig. 26). Two assessment units are defined in the TPS: (1) Wasatch–Green River Continuous Gas AU and (2) Wasatch–Green River Coalbed Gas AU.

Figure 26. Geographic extent of the Wasatch–Green River Total Petroleum System in the Southwestern Wyoming Province showing areas included with the Wasatch–Green River Continuous Gas and Coalbed Gas Assessment Units. Abbreviations: CRA, Cherokee ridge; MA, Moxa arch: RSU, Rock Springs uplift; SBA, Sandy Bend arch; WA, Wamsutter arch.

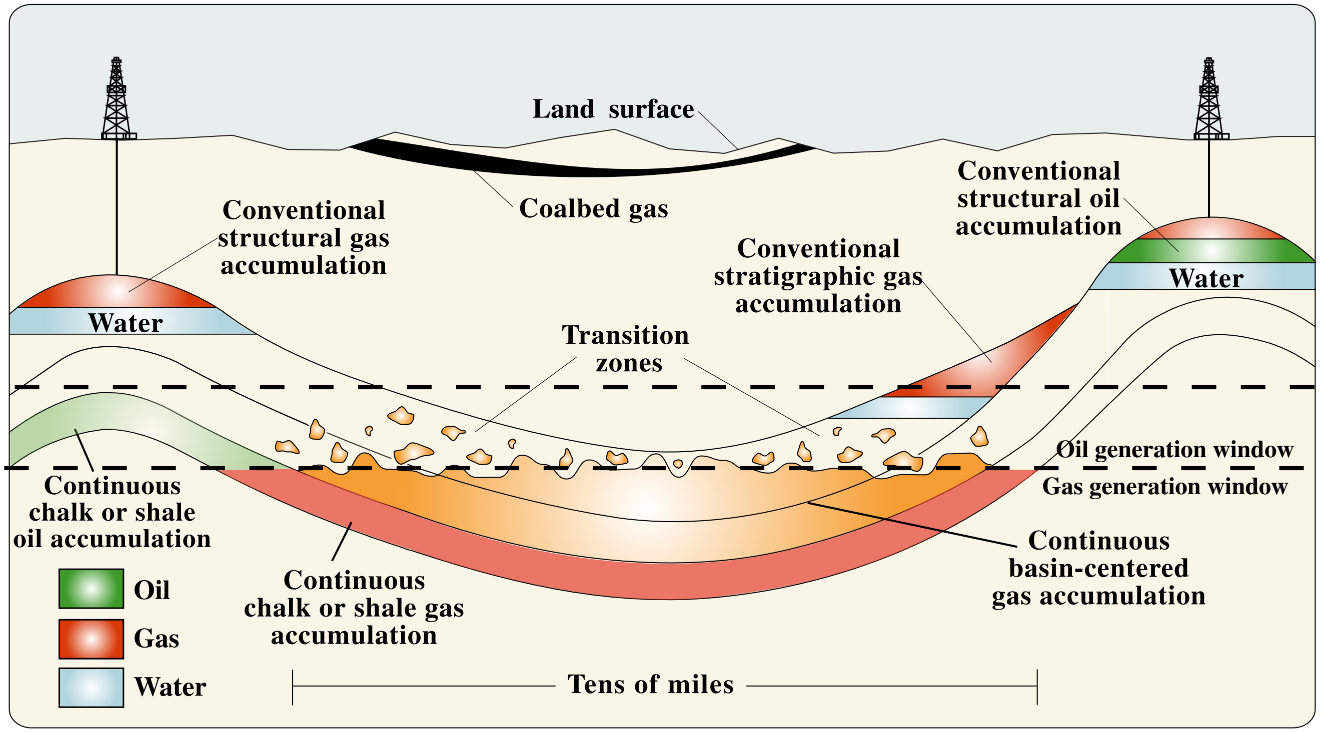


Figure 27. Categories of oil and natural gas accumulations (Pollastro and others, 2003).

Conventional and Continuous Hydrocarbon Accumulations

Hydrocarbon accumulations can be broadly defined into two categories: conventional and continuous (fig. 27). A conventional oil or gas accumulation is defined as a discrete accumulation with a well-defined hydrocarbon/water contact. Conventional accumulations commonly have high matrix permeabilities, obvious seals and traps, and high recovery factors. In contrast, continuous accumulations (also called unconventional) are regional in extent; commonly have low matrix permeabilities; do not have obvious seals, traps, or hydrocarbon/water contacts; are abnormally pressured; are in close proximity to source rocks; and have very low recovery factors. Continuous-type accumulations include basin-centered gas, tight gas, shale gas, shale oil, fractured-reservoir gas and oil, coalbed gas, and gas hydrates. The USGS assessed undiscovered conventional oil and gas accumulations and undiscovered continuous oil and gas accumulations in the Southwestern Wyoming Province.

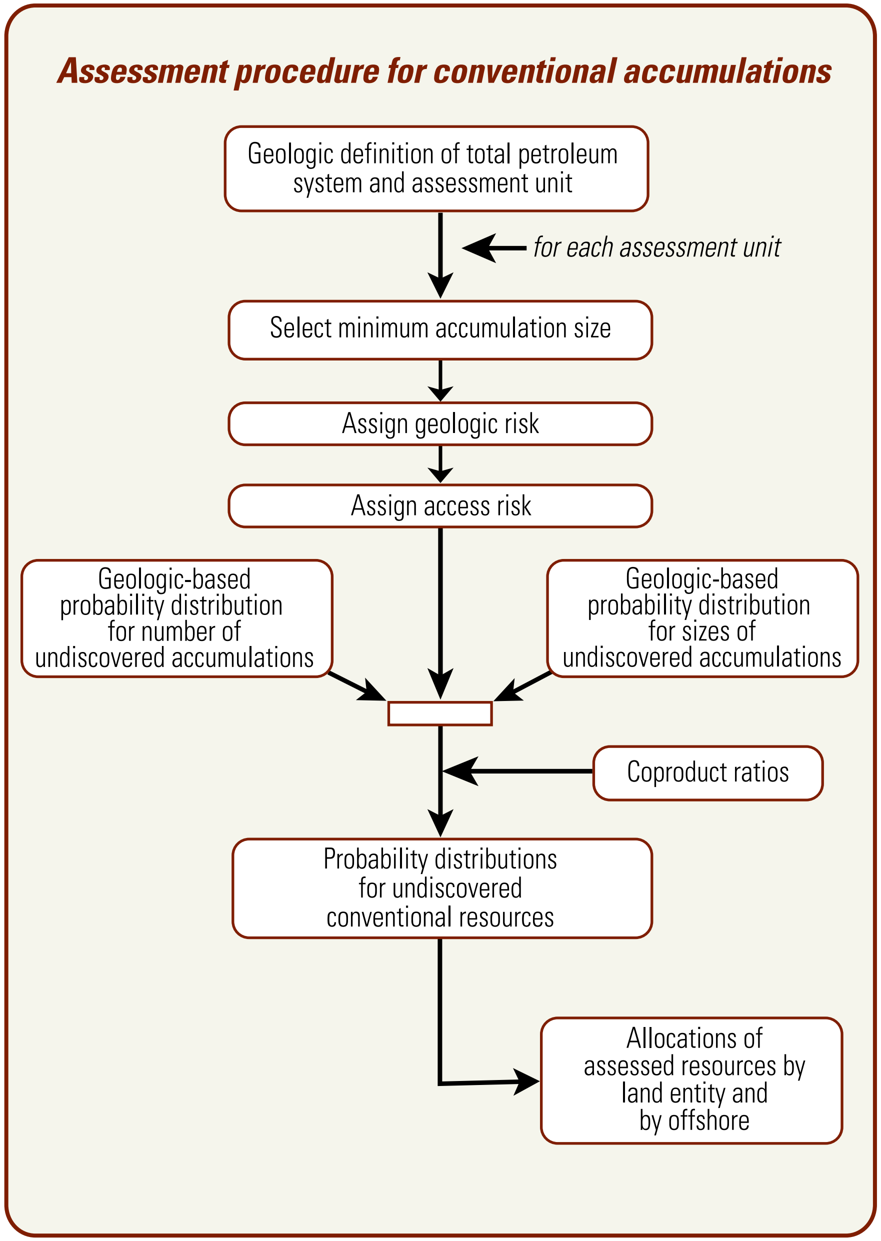


Figure 28. Major steps in the assessment of conventional hydrocarbon accumulations.

Conventional Accumulations—Assessment Methodology

The assessment of undiscovered conventional oil or gas accumulations depends entirely upon a geologic understanding of the framework geology and total petroleum system within which the undiscovered accumulations are interpreted to reside. The geologist must therefore have an understanding of hydrocarbon source-rock quality, maturation, timing of generation and hydrocarbon migration, and timing of structural development and trapping, as well as understanding either of the genesis of hydrocarbon accumulations that exist within an assessment unit or of the hydrocarbon accumulations in a geologic analog. An understanding of historical hydrocarbon accumulation types and sizes to construct a probability distribution for sizes and numbers of undiscovered accumulations (fig. 28) is also essential. These geologic-based probability distributions, combined with coproduct ratios, produce the probability distributions for undiscovered hydrocarbon resources that have the potential to be added to the reserve base of the United States over some specified time period. For details see Chapter 19 by Schmoker and Klett (this CD–ROM).

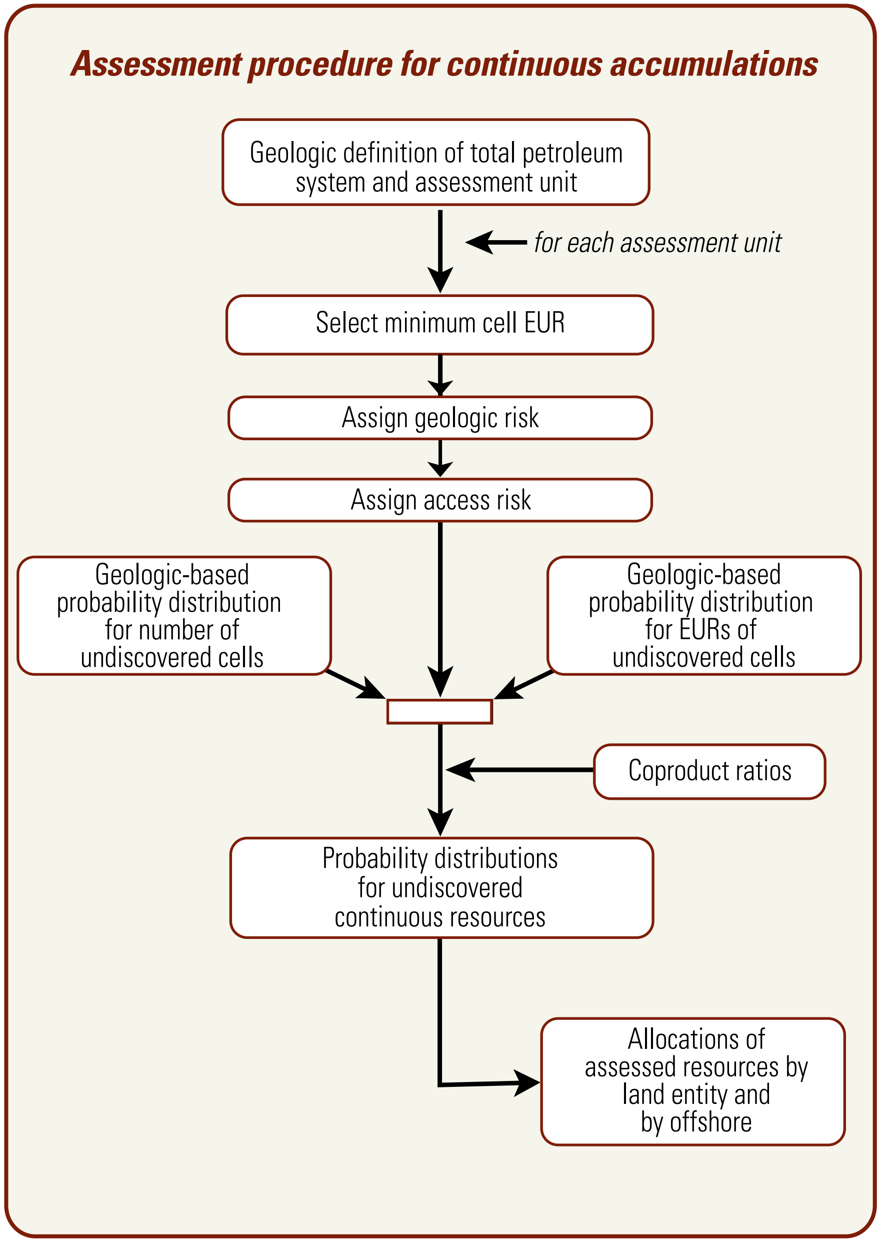


Figure 29. Major steps in the assessment of continuous hydrocarbon accumulations. EUR, estimated ultimate recovery.

Continuous Accumulations — Assessment Methodology

The assessment of undiscovered continuous accumulations, as with conventional accumulations, depends entirely upon a geologic understanding of the framework geology, total petroleum system, and engineering properties of the sequence that hosts the accumulation. In the United States, the locations of many continuous accumulations are known, but the goal of an assessment is to determine that part of the continuous accumulation that has the potential to be added to the reserve base of the United States over the next few decades. The methodology is as follows: the geologist develops a probability distribution of cell sizes in the continuous accumulation, a cell being the area drained by a well; the historical production data are used as a guide to develop a probability distribution of estimated ultimate recoveries (EUR) for cells. The probability distributions are combined with coproduct ratios to produce a probability distribution for undiscovered resources that have the potential to be added to the reserve base in the United States over the next few decades (fig. 29). Emphasis is given to the recognition of geologic "sweet spots" of production, as these areas are the most likely to be developed within continuous hydrocarbon accumulations. For details see Chapter 13 by Schmoker (this CD–ROM).

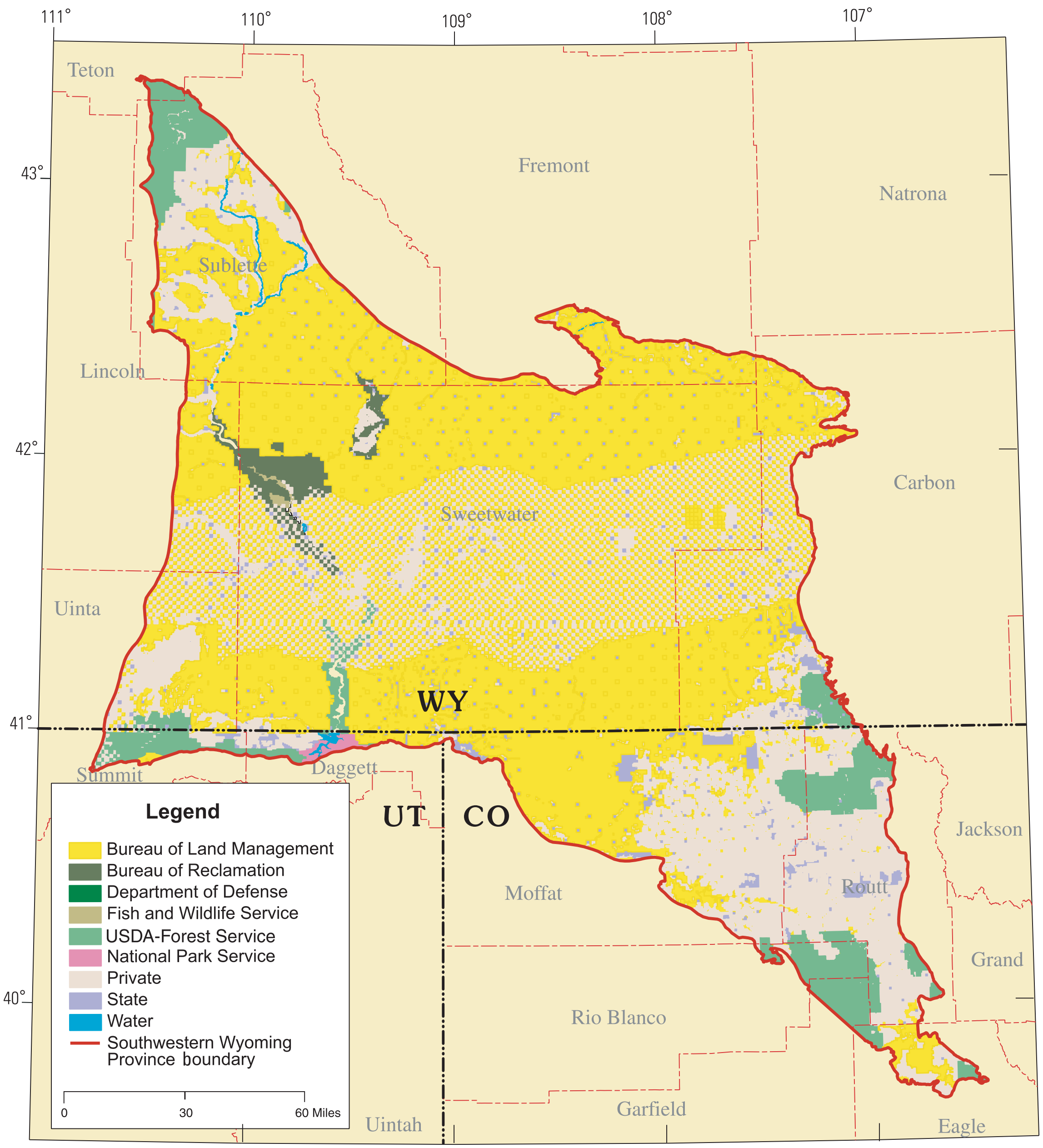


Figure 30. Distribution of Federal surface land ownership in the Southwestern Wyoming Province.

Federal Surface Ownership in the Southwestern Wyoming Province

In the Southwestern Wyoming Province study area, about 63 percent of the land surface is administered by the Federal Government, about 4.4 percent is administered by the States, and about 32.3 percent is held by private owners (fig. 30). Of the 63 percent of federally administered lands, the Bureau of Land Management is responsible for about 55 percent, the Forest Service about 6.5 percent, and the National Park Service less than 1 percent. National Forests include Medicine Bow–Routt and White River in Colorado; Wasatch-Cache and Ashley in Utah, and Bridger-Teton, Wasatch-Cache, Ashley, and Medicine Bow in Wyoming. National Recreation Areas include Flaming Gorge in Utah and Wyoming.

Table 1. Southwestern Wyoming Province assessment results—Conventional oil and gas resources.
[Assessment results of undiscovered oil and gas resources by assessment unit. Results shown are fully risked estimates. For gas fields, all liquids are included under the NGL (natural gas liquids) category. Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95-percent chance of at least the amount tabulated. Other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Gray shading indicates "not applicable."]

Total Petroleum Systems (TPS) and Assessment Units (AU)	Field type	*Total undiscovered resources* Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Phosphoria TPS													
Sub-Cretaceous Conventional Oil and Gas AU	***Oil***	3.80	12.70	43.60	16.60	6.70	24.00	85.90	32.20	0.20	0.80	3.20	1.20
	Gas					206.20	1,069.00	3,480.00	1,350.70	5.90	31.20	107.20	40.60
Mowry Composite TPS													
Mowry Conventional Oil and Gas AU	***Oil***	1.70	5.70	14.80	6.60	2.70	9.40	25.90	11.20	0.30	1.30	3.70	1.60
	Gas					85.80	196.30	301.40	195.10	1.60	3.80	6.70	3.90
Hilliard–Baxter–Mancos TPS													
Hilliard–Baxter–Mancos Conventional Oil and Gas AU	***Gas***					4.60	13.80	31.90	15.50	0.30	0.90	2.10	1.00
Mesaverde TPS													
Mesaverde Conventional Oil and Gas AU	***Oil***	0.90	2.10	4.00	2.30	7.40	17.30	34.80	18.80	0.30	0.60	1.40	0.70
	Gas					13.40	34.00	69.40	36.90	0.10	0.40	0.90	0.40
Mesaverde–Lance–Fort Union Composite TPS													
Mesaverde–Lance–Fort Union Conventional Oil and Gas AU	***Oil***	0.90	2.10	4.00	2.30	3.80	9.10	18.30	9.80	0.20	0.40	0.90	0.40
	Gas					101.40	297.70	558.80	310.40	4.20	13.00	26.90	14.00
Lewis TPS													
Lewis Conventional Oil and Gas AU	***Gas***					103.70	188.90	304.00	194.60	3.70	7.40	13.30	7.80
Lance–Fort Union Composite TPS													
Lance–Fort Union Conventional Oil and Gas AU	***Gas***					75.00	229.20	465.90	245.60	0.70	2.20	5.00	2.50
Total conventional resources		**7.30**	**22.60**	**66.40**	**27.80**	**610.70**	**2,088.70**	**5,376.30**	**2,420.80**	**17.50**	**62.00**	**171.30**	**74.10**

Table 2. Southwestern Wyoming Province assessment results—Continuous oil and gas resources.
[Assessment results of undiscovered oil and gas resources by assessment unit. Results shown are fully risked estimates. For gas fields, all liquids are included under the NGL (natural gas liquids) category. Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95-percent chance of at least the amount tabulated. Other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Gray shading indicates "not applicable." CBG is coalbed gas]

Total Petroleum Systems (TPS) and Assessment Units (AU)	Field type	Total undiscovered resources: Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Mowry Composite TPS													
Mowry Continuous Gas AU	*Gas*					6,745.90	8,461.90	10,614.40	8,542.80	110.90	165.80	247.90	170.90
Niobrara TPS													
Niobrara Continuous Oil AU	*Oil*	66.90	100.50	151.00	103.60	34.90	59.10	99.90	62.20	1.90	3.50	6.50	3.70
Niobrara Continuous Gas AU	*Gas*	Not quantitatively assessed											
Hilliard–Baxter–Mancos TPS													
Hilliard–Baxter–Mancos Continuous Gas AU	*Gas*					4,895.10	10,542.00	22,703.40	11,753.20	286.50	661.10	1,525.20	752.20
Mesaverde TPS													
Almond Continuous Gas AU	*Gas*					10,013.50	13,166.10	17,311.30	13,349.70	113.50	190.60	319.90	200.20
Rock Springs–Ericson Continuous Gas AU	*Gas*					8,768.90	11,962.80	16,320.00	12,178.00	89.20	140.70	221.70	146.10
Mesaverde Coalbed Gas AU	*CBG*					126.10	232.10	427.30	248.70	0.00	0.00	0.00	0.00
Mesaverde–Lance–Fort Union Composite TPS													
Mesaverde–Lance–Fort Union Continuous Gas AU	*Gas*					8,320.10	13,122.00	20,695.40	13,635.20	329.20	578.60	1,016.90	613.60
Mesaverde Coabed Gas AU	*CBG*					13.70	25.40	47.30	27.30	0.00	0.00	0.00	0.00
Fort Union Coalbed Gas AU	*CBG*					35.30	73.20	151.90	80.80	0.00	0.00	0.00	0.00
Lewis TPS													
Lewis Continuous Gas AU	*Gas*					8,764.90	13,132.80	19,677.40	13,535.70	305.00	514.70	868.70	541.40
Lance–Fort Union Composite TPS													
Lance–Fort Union Continuous Gas AU	*Gas*					4,450.60	7,255.80	11,829.10	7,583.30	39.40	71.10	128.40	75.80
Lance Coalbed Gas AU	*CBG*					78.20	152.00	295.50	165.00	0.00	0.00	0.00	0.00
Fort Union Coalbed Gas AU	*CBG*					513.90	891.20	1,545.40	942.50	0.00	0.00	0.00	0.00
Wasatch–Green River Composite TPS													
Wasatch–Green River Continuous Gas AU	*Gas*	Not quantitatively assessed											
Wasatch–Green River Coalbed Gas AU	*CBG*					27.80	58.40	122.60	64.70	0.00	0.00	0.00	0.00
Total continuous resources		**66.90**	**100.50**	**151.00**	**103.60**	**52,788.90**	**79,134.80**	**121,830.90**	**82,169.10**	**1,275.60**	**2,326.10**	**4,335.20**	**2,503.90**

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