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Volume Title Page

Chapter 2

The Uinta-Piceance Province —

Introduction to a geologic assessment of undiscovered oil and gas resources

By USGS Uinta-Piceance Assessment Team

U.S. Geological Survey
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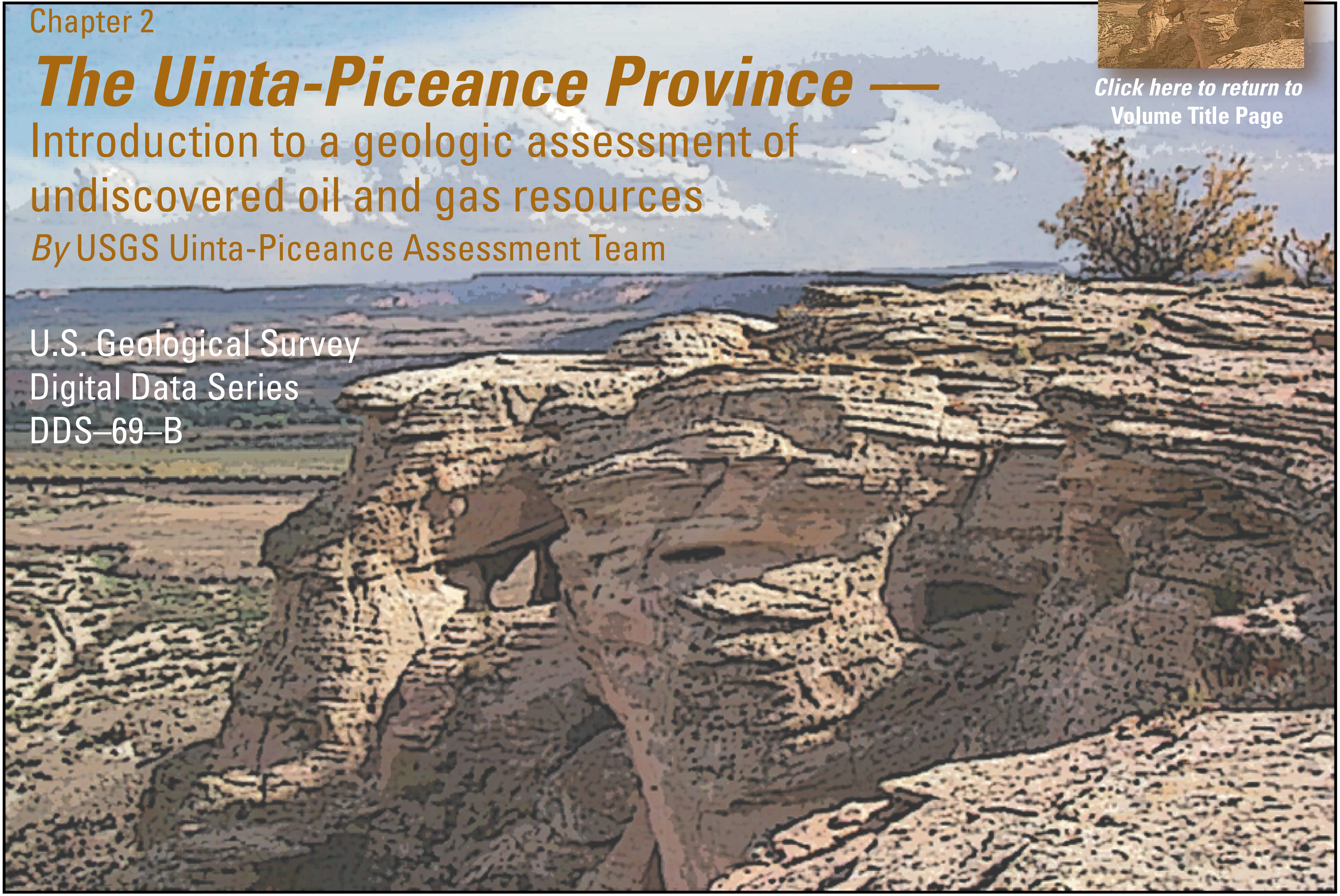

Upper Cretaceous Dakota Sandstone, Westwater Canyon, Utah. (Photograph by P. Lillis)

U.S. Department of the Interior
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Cliffs of the Jurassic Wingate Sandstone and the underlying Triassic Chinle Formation produce spectacular scenery in the Colorado National Monument near Grand Junction, Colo. (Photograph by P. Lillis)

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 National Assessment 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 Uinta-Piceance Province of Utah and Colorado is a priority province for the National Oil and Gas Assessment because of the potential for significant natural gas resources. The approach in the Uinta-Piceance Province, as in all priority provinces, was to establish the framework geology, define the major total petroleum systems, define assessment units within the major 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 five major total petroleum systems in the Uinta-Piceance Province.

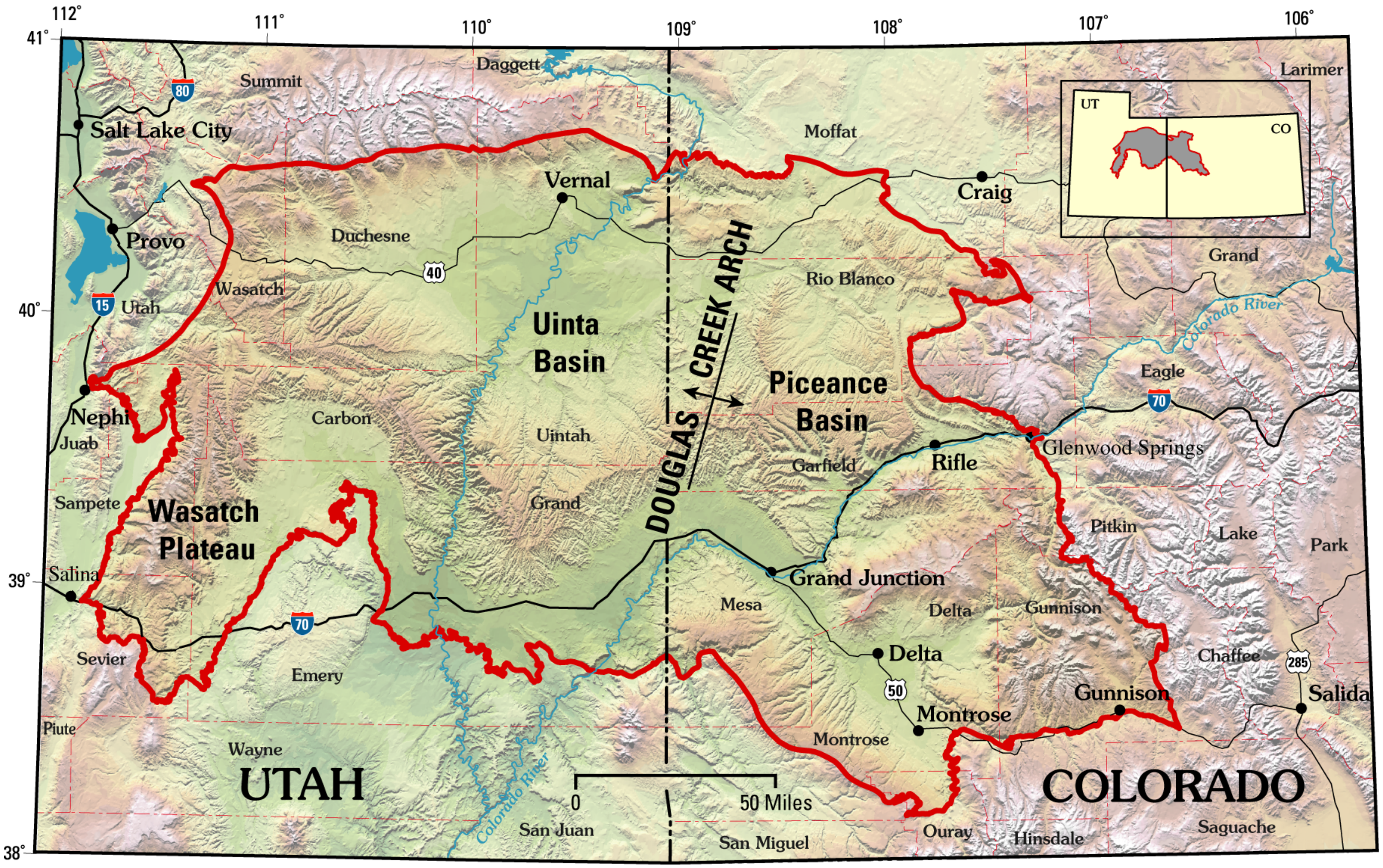


Figure 1. Digital elevation model showing the location and topography of the Uinta-Piceance Province (red line).

Location of Uinta-Piceance Province

The Uinta-Piceance Province is located in eastern Utah and western Colorado, encompassing all or parts of Delta, Garfield, Gunnison, Mesa, Moffat, Montrose, Ouray, Rio Blanco, and Routt Counties in Colorado and all or parts of Carbon, Duchesne, Emery, Grand, Sanpete, Sevier, Uintah, Utah, and Wasatch Counties in Utah (fig. 1). The main population centers within the study area are Grand Junction and Rifle, Colo.; and Price and Vernal, Utah. The main highways, I-70 and U.S. 40, generally traverse the area from east to west. The Green River and Colorado River and their tributaries drain the area. For this study the Uinta-Piceance Province includes the Wasatch Plateau. The province boundary was drawn to include the geologic structures generally considered to be in or bounding the Uinta Basin and Piceance Basin.

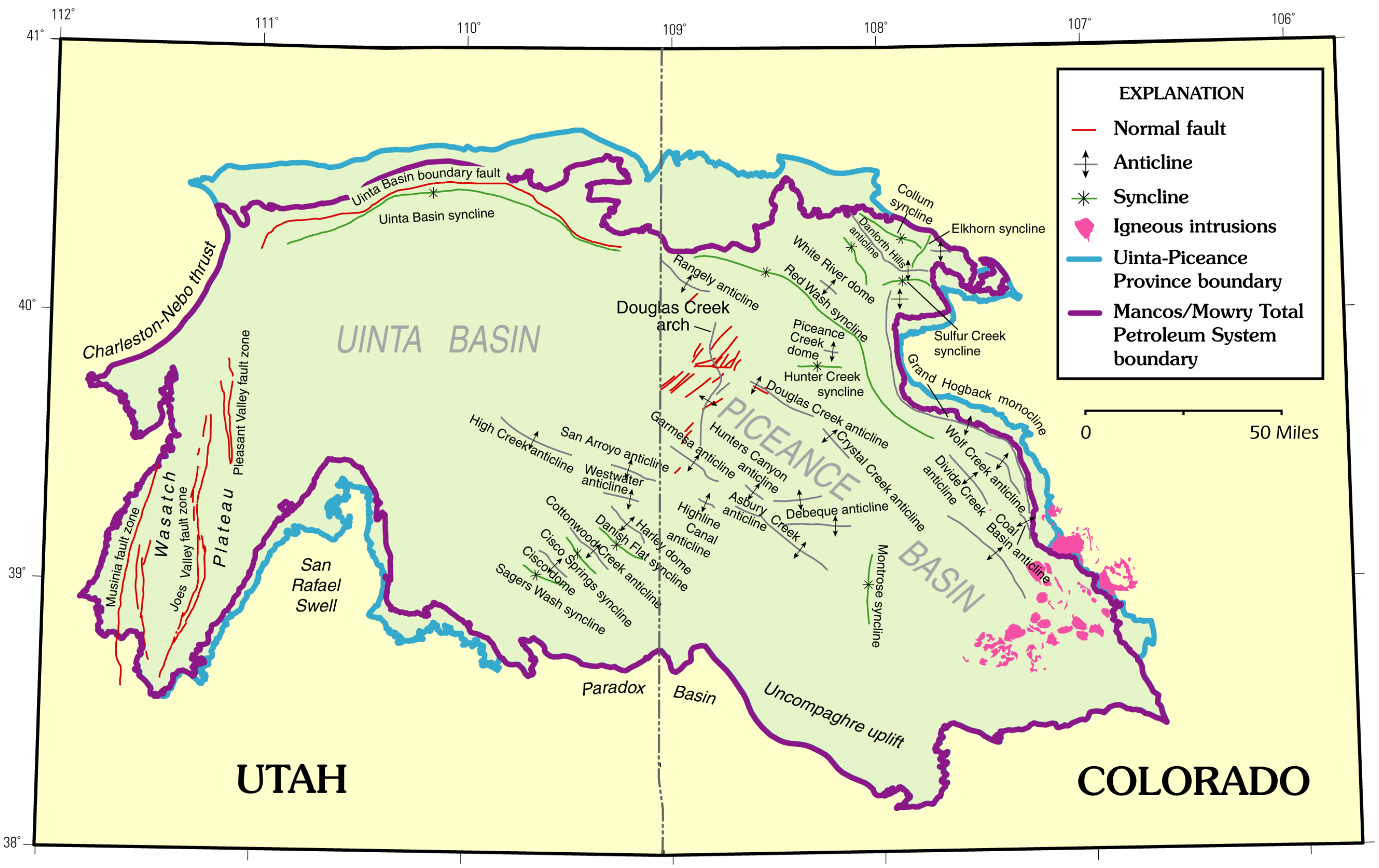


Figure 2. Major structural features and igneous intrusions in the Uinta-Piceance Province.

Geologic Structure in the Uinta-Piceance Province

The Uinta and Piceance Basins are Laramide structures separated by the Douglas Creek arch. The basins are mostly bounded by major faults, including the Charleston-Nebo thrust and the Uinta Basin boundary fault, or expressed at the surface by large monoclines such as the Grand Hogback (fig. 2). See Chapter 16 by Roberts (this CD-ROM).

Split Mountain anticline near Vernal, Utah.
(Photograph by M. K irschbaum)

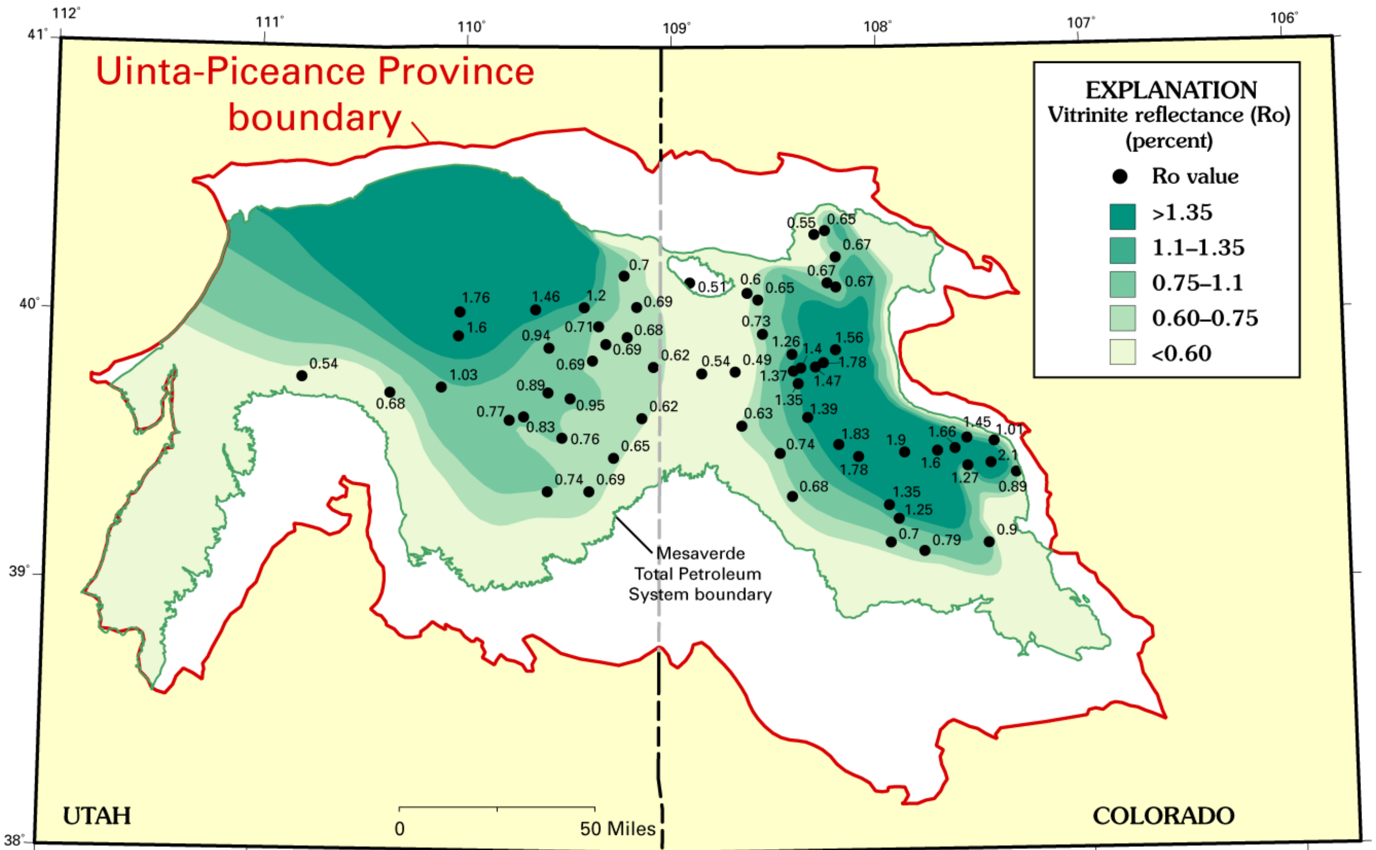


Figure 3. Vitrinite isoreflectance (Ro) trends at the base of the Cretaceous Mesaverde Formation or Group and the top of the Mancos Shale or Group (Nuccio and Roberts, Chapter 4, this CD-ROM).

Thermal Maturity and Oil and Gas Generation in the Uinta-Piceance Province

Characterizing the level of thermal maturity and hydrocarbon generation history of a potential hydrocarbon source rock is the critical first step in defining a total petroleum system. The burial history, thermal maturity, and timing of hydrocarbon generation for five source-rock horizons throughout the Uinta-Piceance Province were documented in this study (fig. 3). The source-rock intervals are: (1) the lower part of the Tertiary Green River Formation, (2) the lower part of the Cretaceous Mesaverde Group, (3) the coals in the Ferron Sandstone Member of the Mancos Shale, (4) the Mancos Shale and Mowry Shale, and (5) the lower part of the Permian Phosphoria Formation and other potential Pennsylvanian-Permian source rocks. See Chapter 4 by Nuccio and Roberts (this CD-ROM) for a discussion of the thermal maturation of hydrocarbon source rocks.

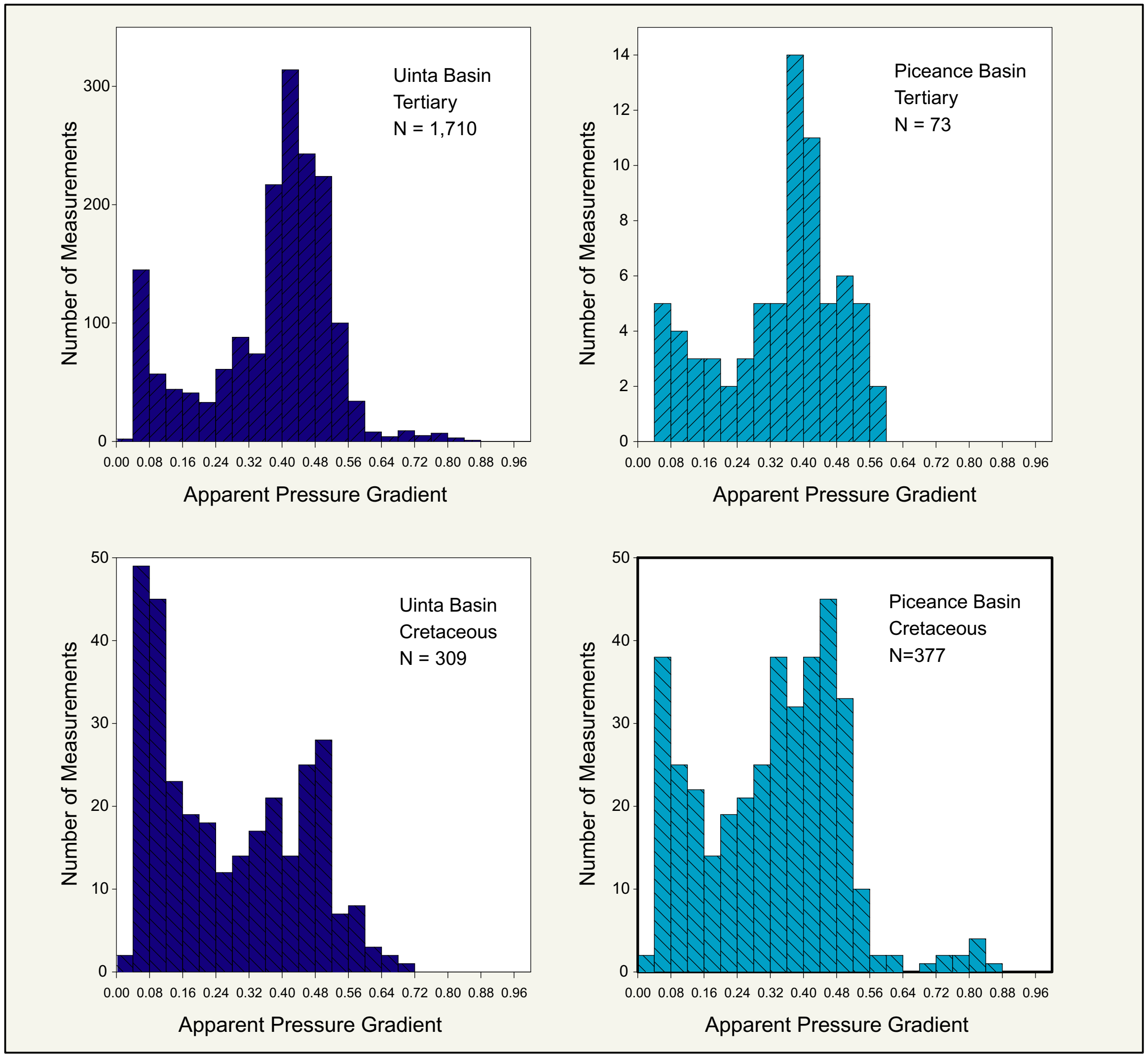


Figure 4. Histograms of subsurface pressure data from the Uinta Basin and the Piceance Basin.

Subsurface Pressure Data

Subsurface pressure data from oil and gas wells within the Uinta-Piceance Province have been compiled from shut-in pressures obtained from drill-stem tests for the purpose of determining the existence and distribution of abnormal subsurface pressures (fig. 4). The distribution of abnormal pressures is used to constrain the boundaries of continuous assessment units. Tests in wells completed prior to 1985 include 2,019 pressure measurements from the Uinta Basin and 450 pressure measurements from the Piceance Basin. Compilations of subsurface pressures show that overpressured strata are present throughout much of the deeper, northern and eastern areas of the Uinta Basin, particularly in the area of the Altamont-Bluebell field. Pressure data from tests in the Piceance Basin are not as diagnostic as in the Uinta Basin, due to lower spatial density of pressure tests and evidence that pressures measured in Cretaceous rocks of the Piceance Basin are not representative of actual formation pressure. See Chapter 14 by Nelson (this CD-ROM) for details of the subsurface pressure analysis.

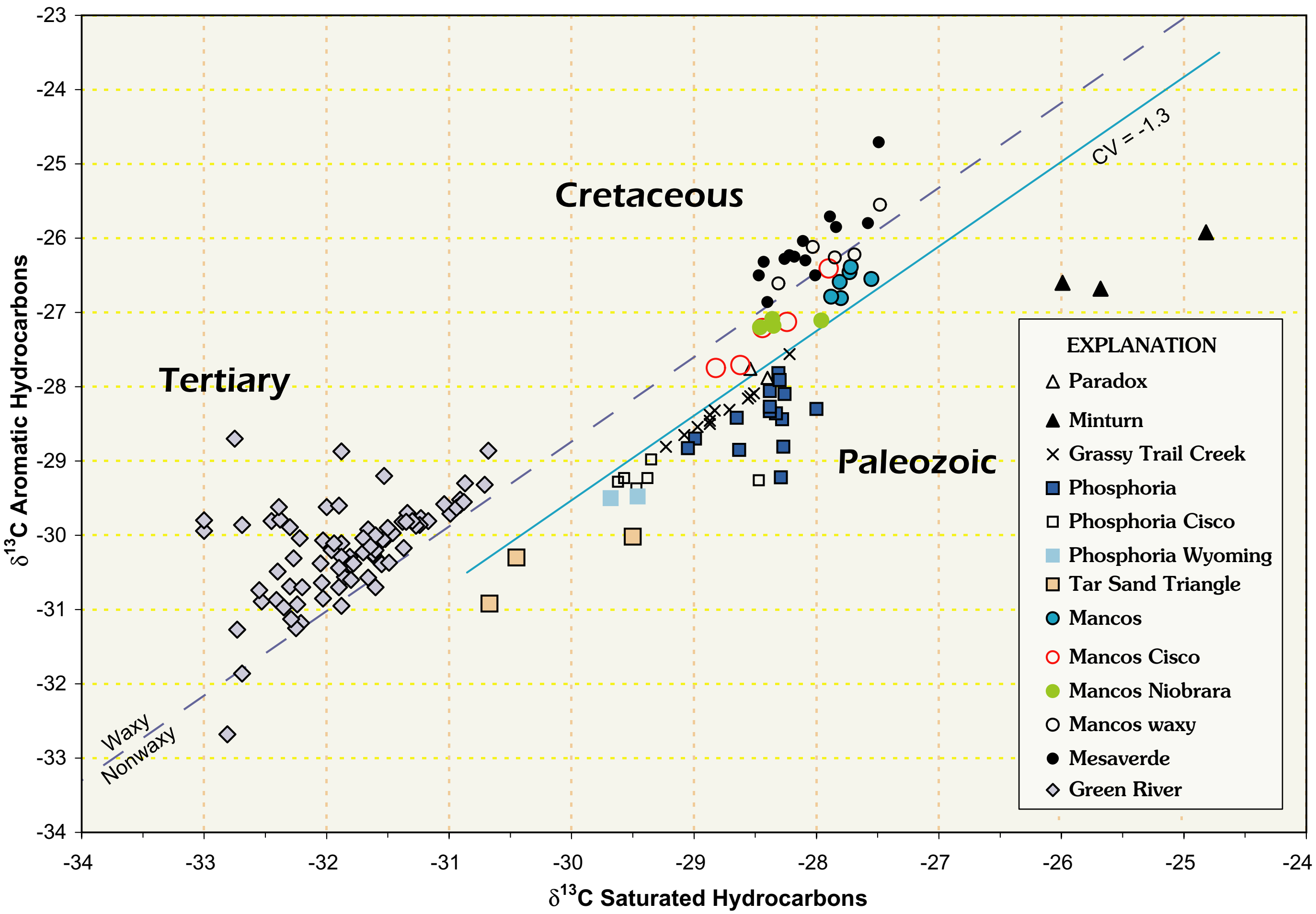


Figure 5. Stable carbon isotope values of oils, oil stains, and seeps from the Uinta-Piceance Province and adjacent areas. Dashed black line (canonical variable (CV) = 0.47) separates waxy (terrigenous source) from nonwaxy (marine source) oils (Sofer, 1984). Light-blue line (CV=-1.3) separates Cretaceous from Paleozoic oils (Lillis and others, Chapter 3, this CD-ROM).

Petroleum Geochemistry

Plots of various geochemical parameters are useful in defining genetic families of oil and gas in a province. In the Uinta-Piceance Province, sulfur content, stable carbon isotope values, and biomarker composition were most useful in the characterization of genetic oil types. Several oil types are recognized and, in some cases, an oil may be genetically related to hydrocarbon source rocks proposed in the literature. Based on stable carbon isotopes, identified oil types may be generally grouped into Tertiary, Cretaceous, and Paleozoic petroleum systems (fig. 5). The black-shale facies of the Green River Formation is the main petroleum system of Tertiary age whereas the Mahogany zone of the Green River Formation is a minor component. The Cretaceous Mancos Group and equivalent rocks are the main source of Cretaceous oil and a major contributor of gas in the basin, whereas the Upper Cretaceous Mesaverde is a lesser contributor of oil but a significant source for gas. Ferron Sandstone coals are known to be a source of coalbed methane. The most prominent source of oil from Paleozoic rocks is the Permian Phosphoria Formation. Several minor petroleum systems are suggested from the data, but these systems cannot be mapped at present because of an insufficient number or distribution of samples. Less information is available to determine genetic families of natural gas. See Chapter 3 by Lillis (this CD-ROM) for a discussion of the petroleum geochemistry as it applies to total petroleum systems.

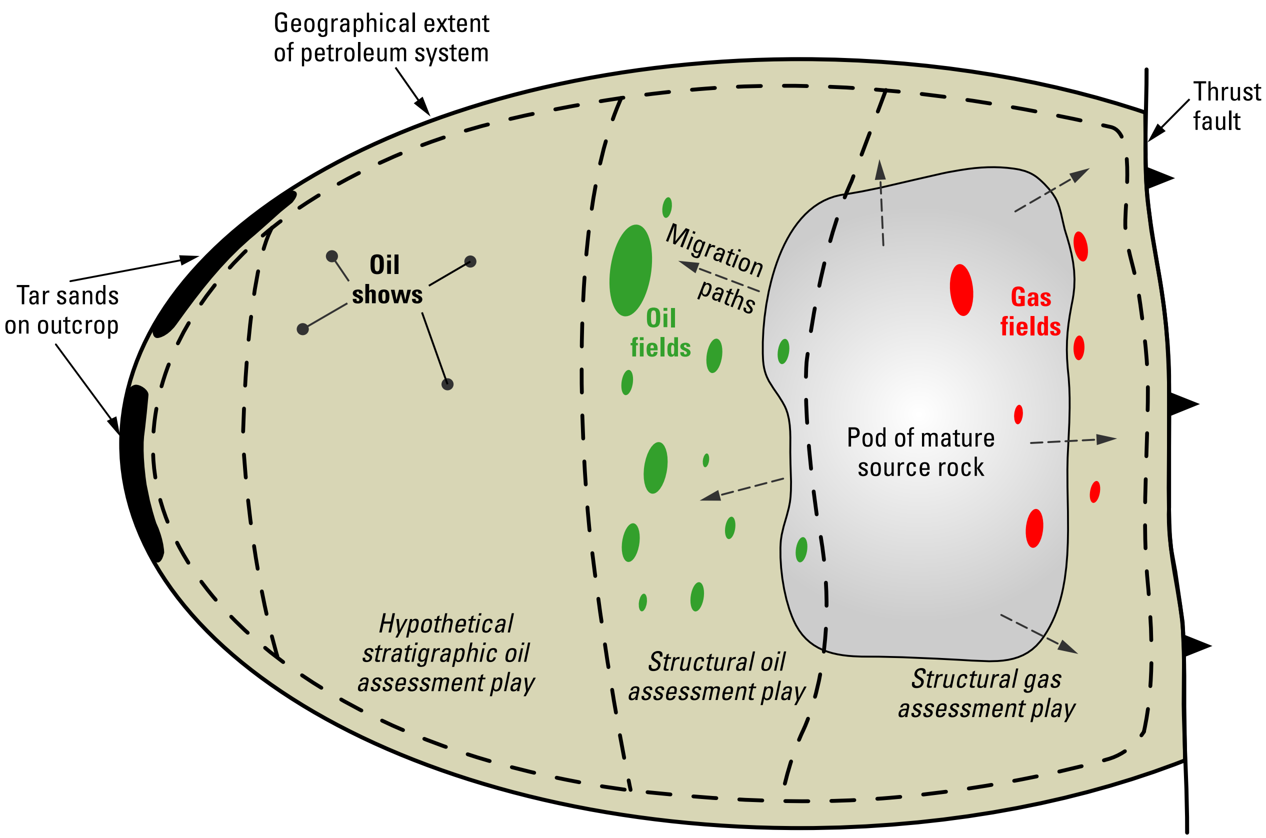
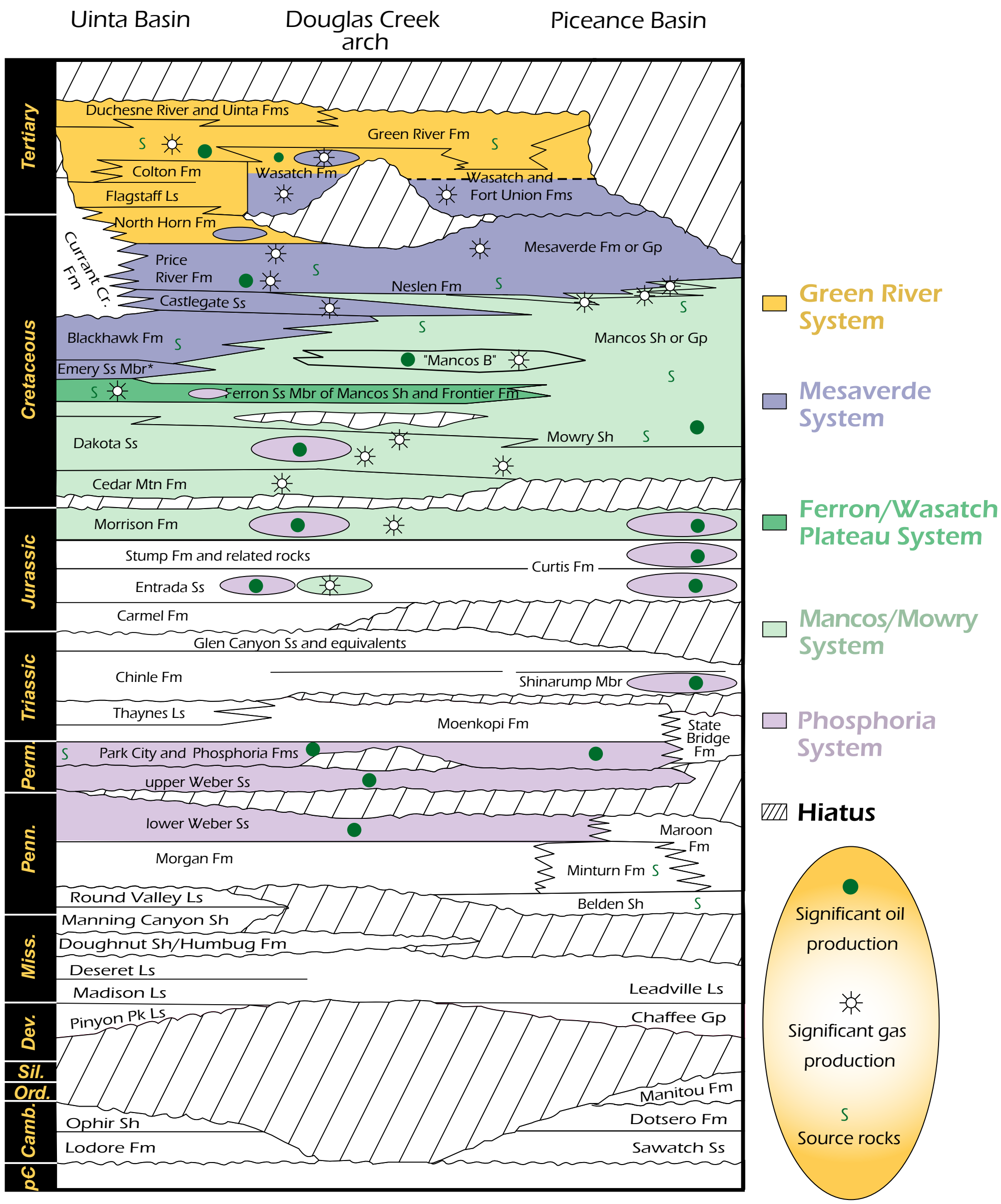


Figure 6. Schematic plan view of a total petroleum system, showing a pod of mature source rock, the distribution of known petroleum occurrences, and the boundaries of the assessment units.

Total Petroleum System Concept

Once the known petroleum occurrences are analyzed to define genetic families of oil and gas, we then defined total petroleum systems in the Uinta-Piceance Province. A total petroleum system 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. 6). Along with the pod(s) of mature source rock, we mapped the reservoirs, seals, and traps that contain or are projected to contain the petroleum within the total petroleum system. The largest likely geographic extent of the petroleum system can then be mapped by integrating the areal distribution of known petroleum accumulations with potential migration fairways for oil and gas. Assessment units are defined within each total petroleum system. An assessment unit is defined as a mappable volume of rock within a total petroleum system that encompasses accumulations (discovered and undiscovered) that share similar geologic traits. An assessment unit may be identified as conventional, if it contains conventional accumulations, or as continuous, if it contains continuous-type accumulations.



* Emery Sandstone Member of the Mancos Shale

Figure 7. Generalized stratigraphic column showing the reservoir rocks that contain significant amounts of oil and gas derived from the five major total petroleum systems contributing hydrocarbons to the Uinta-Piceance Province [modified from Sanborn (1977) and Spencer and Wilson (1988)].

Total Petroleum Systems in the Uinta-Piceance Province

The Uinta-Piceance Province contains five major total petroleum systems, in ascending stratigraphic order; the Phosphoria, the Mancos/Mowry, Ferron/Wasatch Plateau, Mesaverde, and Green River Total Petroleum Systems (fig. 7). The petroleum geology of each total petroleum system is discussed in detail in this report. Following the definition of total petroleum systems, assessment units were defined within each total petroleum system, and undiscovered petroleum resources were assessed within each assessment unit.

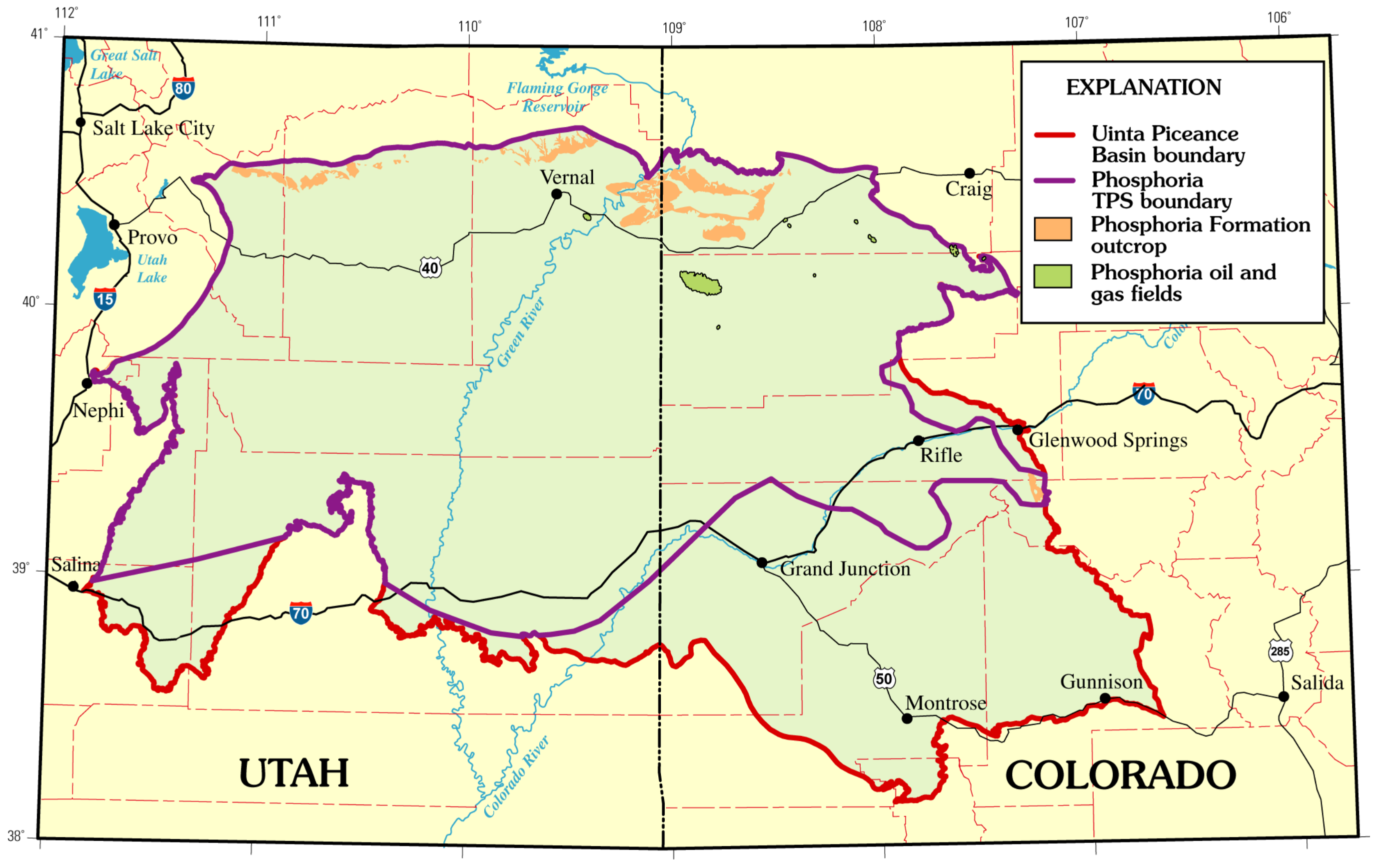


Figure 8. Geographic extent of the Phosphoria Total Petroleum System in the Uinta-Piceance Province (Johnson, Chapter 9, this CD-ROM).

Phosphoria Total Petroleum System

Hydrocarbon fluids generated from organic-rich mudstones of the Meade Peak Phosphatic Shale Member of the Permian Phosphoria Formation define the limits of the Phosphoria Total Petroleum System in the Uinta-Piceance Province (fig. 8).

Oil from the northern Piceance Basin that is chemically consistent with oil in western Wyoming known to have a Phosphoria source is contained in the Weber Sandstone at Rangely field, and Phosphoria oil has also been identified in the Shinarump Member of the Chinle Formation, Entrada Sandstone, Sundance Formation, and Morrison Formation at oil fields in the greater Danforth Hills area of Colorado. In addition, in the southern part of the Uinta Basin, Phosphoria oil mixed with oil from some other source (most likely Mesozoic in age) has been identified in the Entrada Sandstone, Morrison Formation, and Dakota Sandstone at oil fields in the greater Cisco area. Phosphoria-sourced oil is present in stratigraphic traps such as the Weber Sandstone–Maroon Formation facies transition at the Rangely oil field (fig. 9), and in structural traps such as the thrusted anticlines in the greater Danforth Hills area and the nonthrusted anticlines in the greater Cisco area. See Chapter 9 by Johnson (this CD-ROM) for a geologic discussion of the Phosphoria Total Petroleum System.

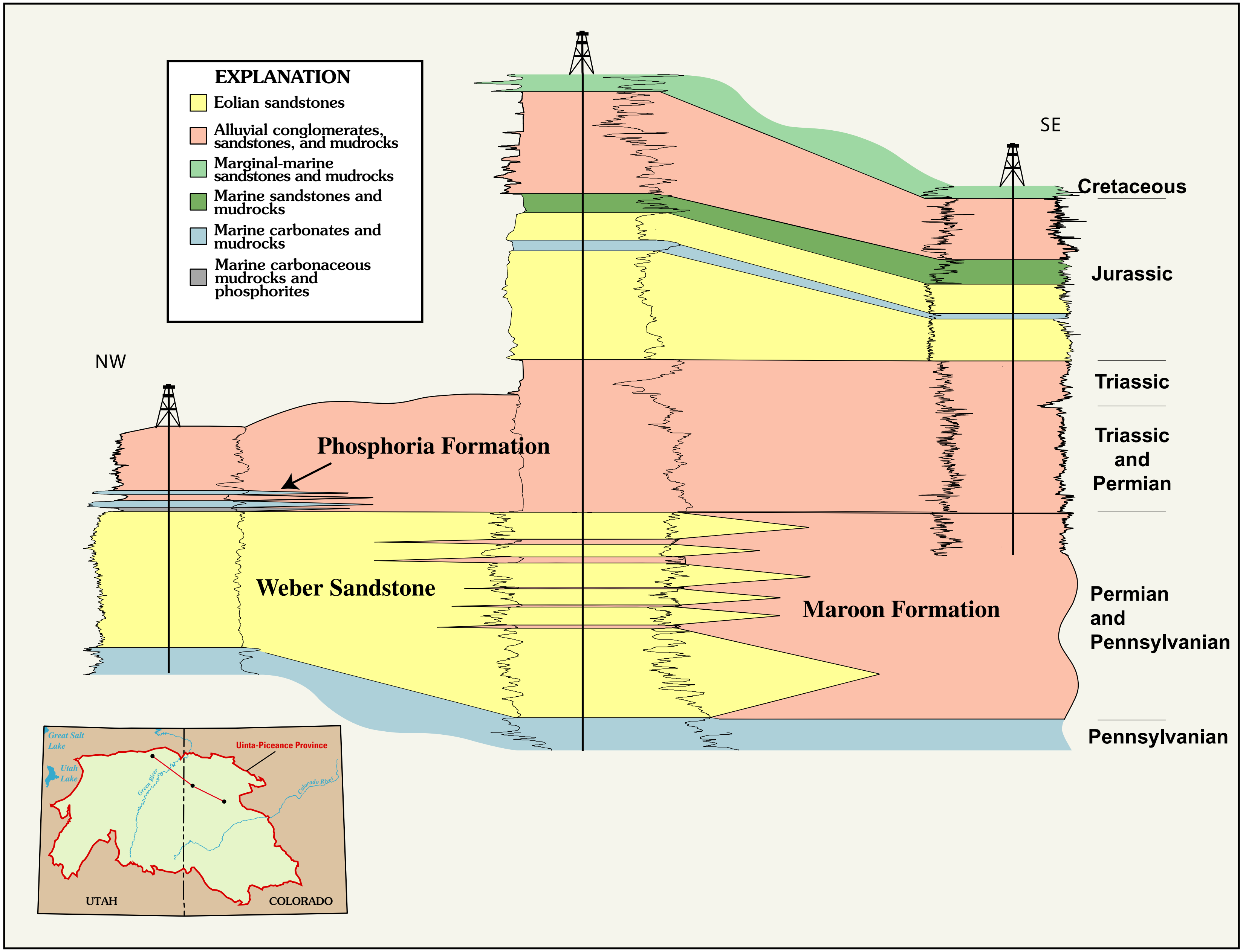


Figure 9. Generalized stratigraphic cross section of the Phosphoria Total Petroleum System in the Uinta-Piceance Province (Johnson, Chapter 9, this CD-ROM).

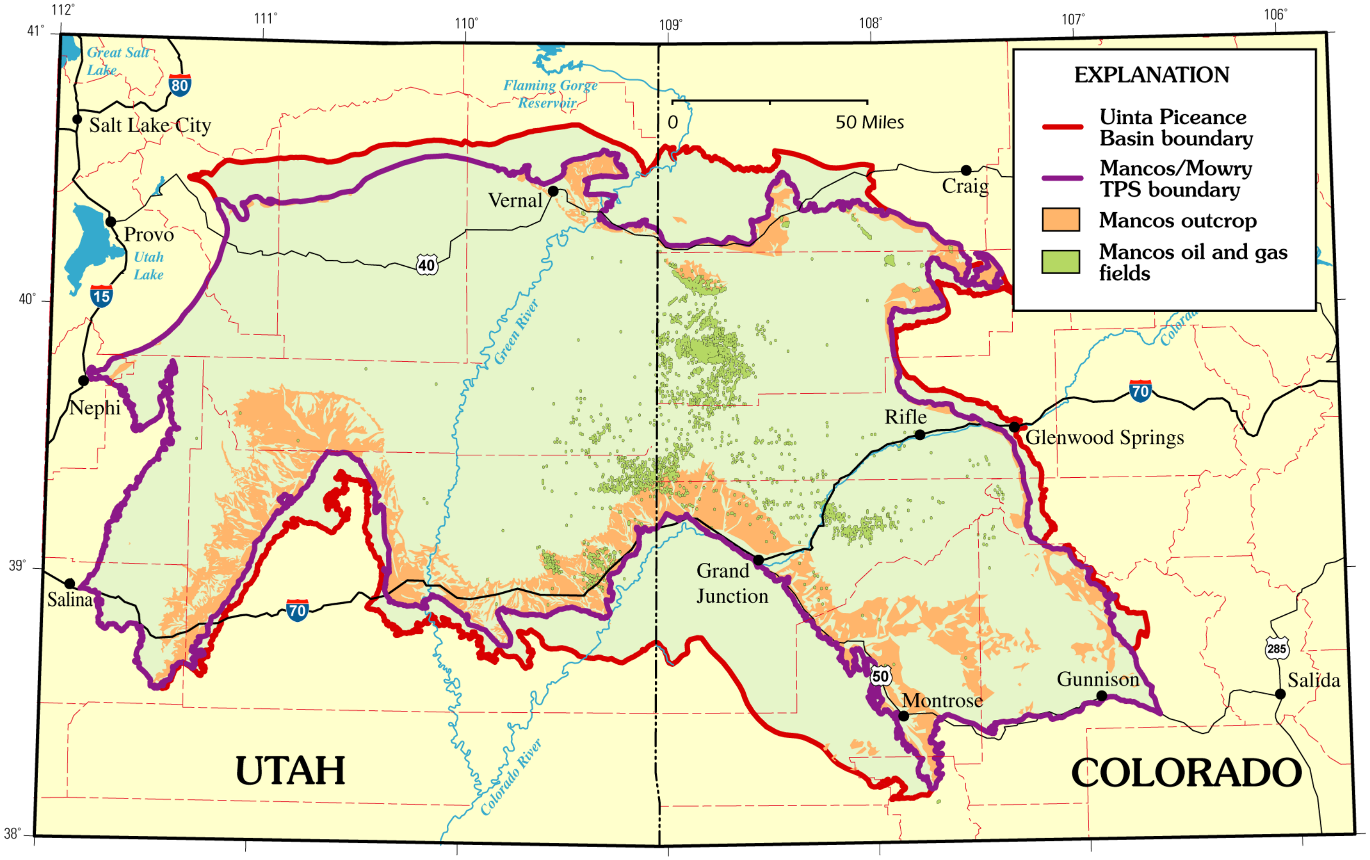


Figure 10. Geographic extent of the Mancos/Mowry Total Petroleum System in the Uinta-Piceance Province (Kirschbaum, Chapter 6, this CD-ROM).

Mancos/Mowry Total Petroleum System

Hydrocarbon fluids generated from the Mancos and Mowry define the limits of the Mancos/Mowry Total Petroleum System in the Uinta-Piceance Province (fig. 10). Gas from these source rocks migrated into adjacent fluvial, tidal, shoreface, and offshore sandstone reservoirs of the Morrison, Cedar Mountain, and Frontier Formations; the Prairie Canyon (Mancos B) Member of the Mancos Shale; the Dakota Sandstone; the Morapas Sandstone Member of the Mancos Shale; the Castlegate and Sego Sandstones; and the Corcoran, Cozzette, and Rollins Sandstone Members of the Mount Garfield and Iles Formations (fig. 11). See Chapter 6 by Kirschbaum (this CD-ROM) for a geologic discussion of the Mancos/Mowry Total Petroleum System.

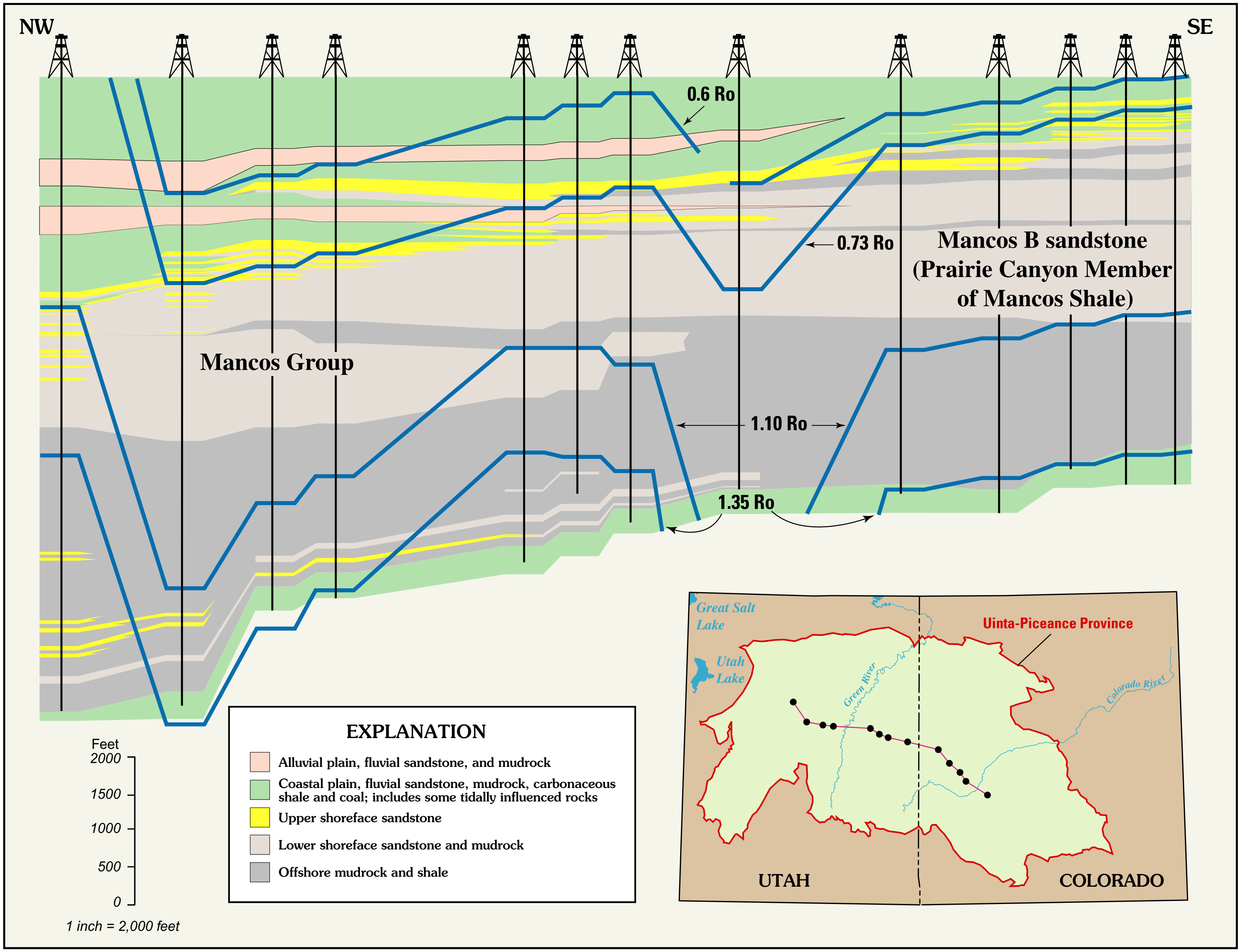


Figure 11. Generalized stratigraphic cross section of the Mancos/Mowry Total Petroleum System showing vitrinite reflectance lines (Ro) for the Uinta-Piceance Province (Kirschbaum, Chapter 6, this CD-ROM).

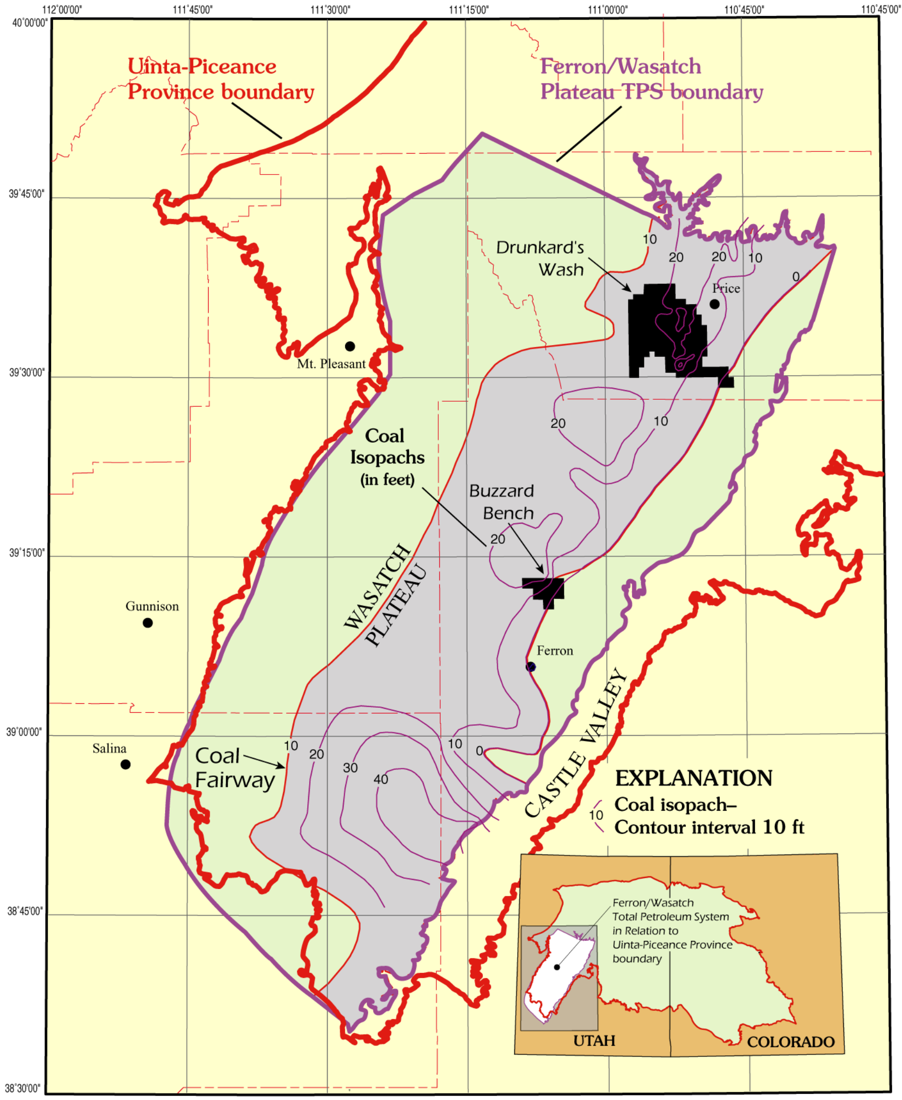


Figure 12. Geographic extent of the Ferron/Wasatch Plateau Total Petroleum System in the Uinta-Piceance Province (Henry and Finn, Chapter 8, this CD-ROM).

Ferron/Wasatch Plateau Total Petroleum System

Coals in the Cretaceous Ferron Sandstone Member of the Mancos Shale in the Wasatch Plateau are known to contain recoverable gas that was generated within coal beds. The Ferron/Wasatch Plateau Total Petroleum System was defined to encompass methane generated in coal beds of the Ferron (figs. 12, 13). See Chapter 8 by Henry and Finn (this CD-ROM) for a geologic discussion of the Ferron/Wasatch Plateau Total Petroleum System.

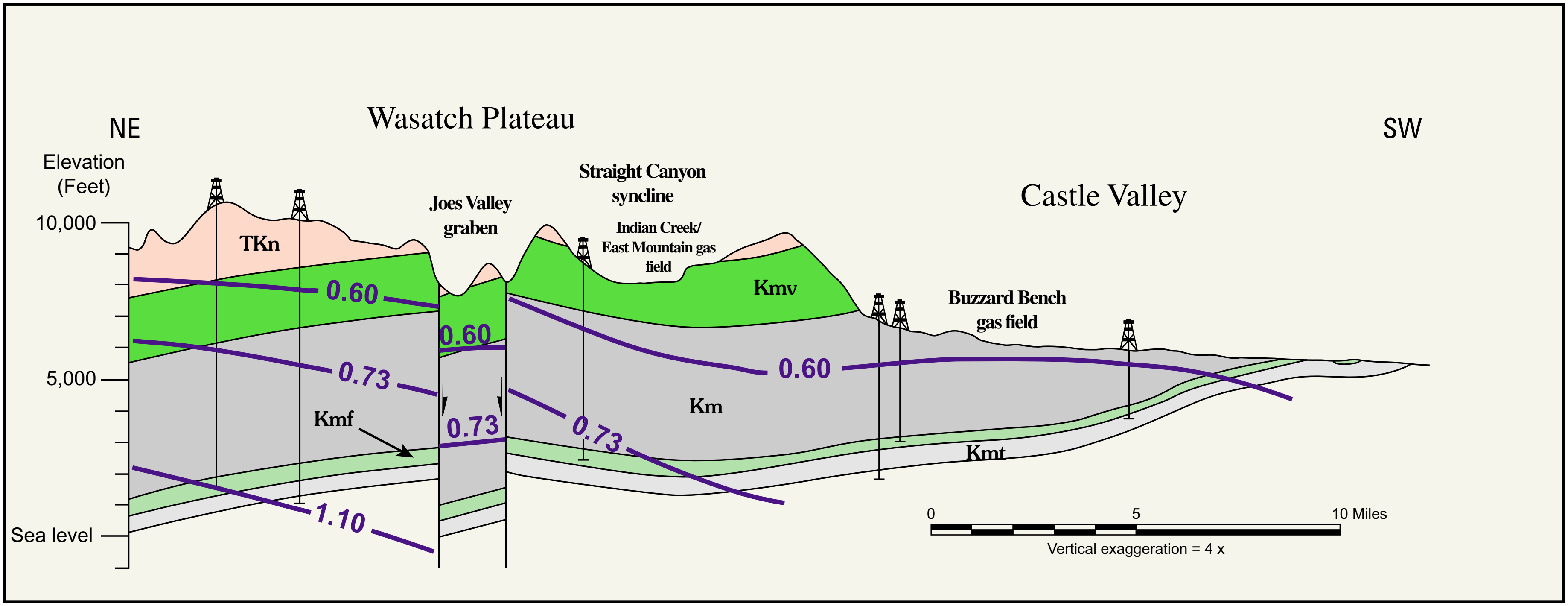


Figure 13. Generalized stratigraphic cross section of the Ferron/Wasatch Plateau Total Petroleum System showing vitrinite reflectance lines (Ro) (Henry and Finn, Chapter 8, this CD-ROM). Abbreviations: Kmt, Tununk Member of Mancos Shale; Kmf, Ferron Sandstone Member of Mancos Shale; Km, upper part of Mancos Shale; Kmv, Mesaverde Group; TKn, North Horn Formation.

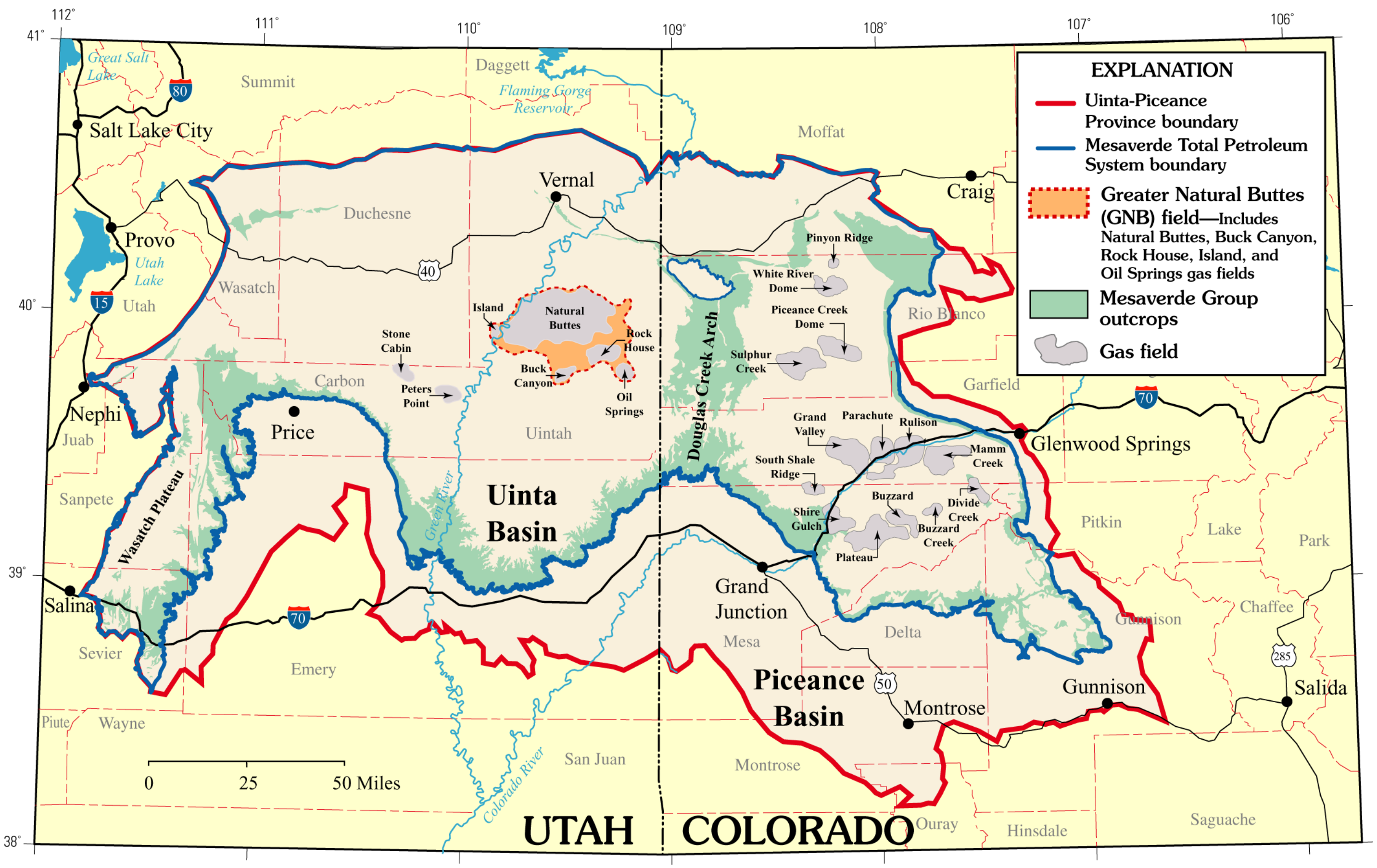


Figure 14. Geographic extent of the Mesaverde Total Petroleum System in the Uinta-Piceance Province (Johnson and Roberts, Chapter 7, this CD-ROM).

Mesaverde Total Petroleum System

Natural gas accumulations generated primarily from coal and carbonaceous shales in the Upper Cretaceous Mesaverde Formation or Group define the limits of the Mesaverde Total Petroleum System in the Uinta-Piceance Province (figs. 14, 15). Much of the gas expelled from Mesaverde coal and carbonaceous shale units migrated into low-permeability sandstone beds in the Mesaverde, resulting in basin-centered gas accumulations in both basins. See Chapter 7 by Johnson and Roberts (this CD-ROM) for a geologic discussion of the Mesaverde Total Petroleum System.

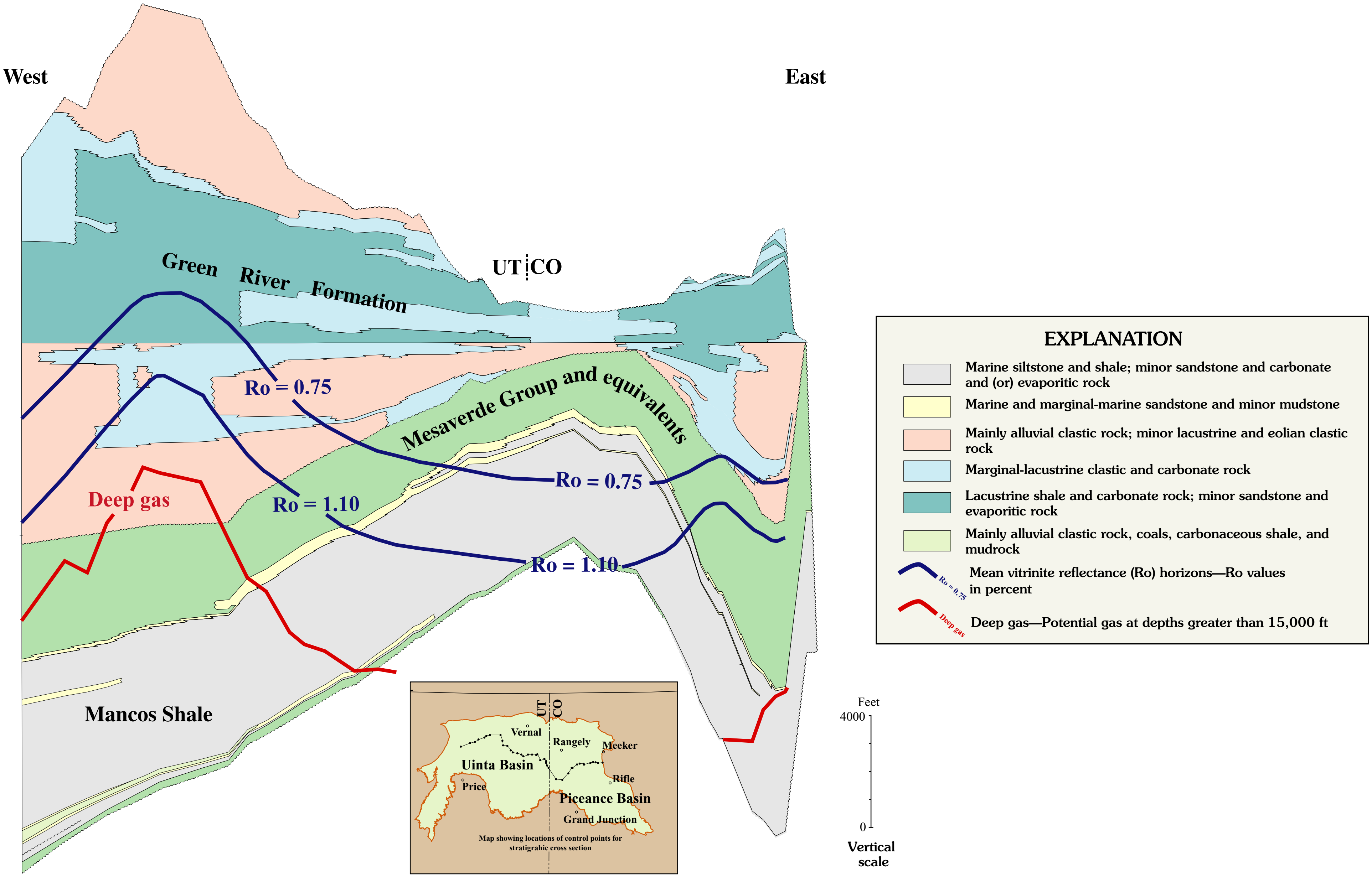


Figure 15. Generalized stratigraphic cross section of the Mesaverde Total Petroleum System showing vitrinite reflectance lines (Ro) (Johnson and Roberts, Chapter 7, this CD-ROM).

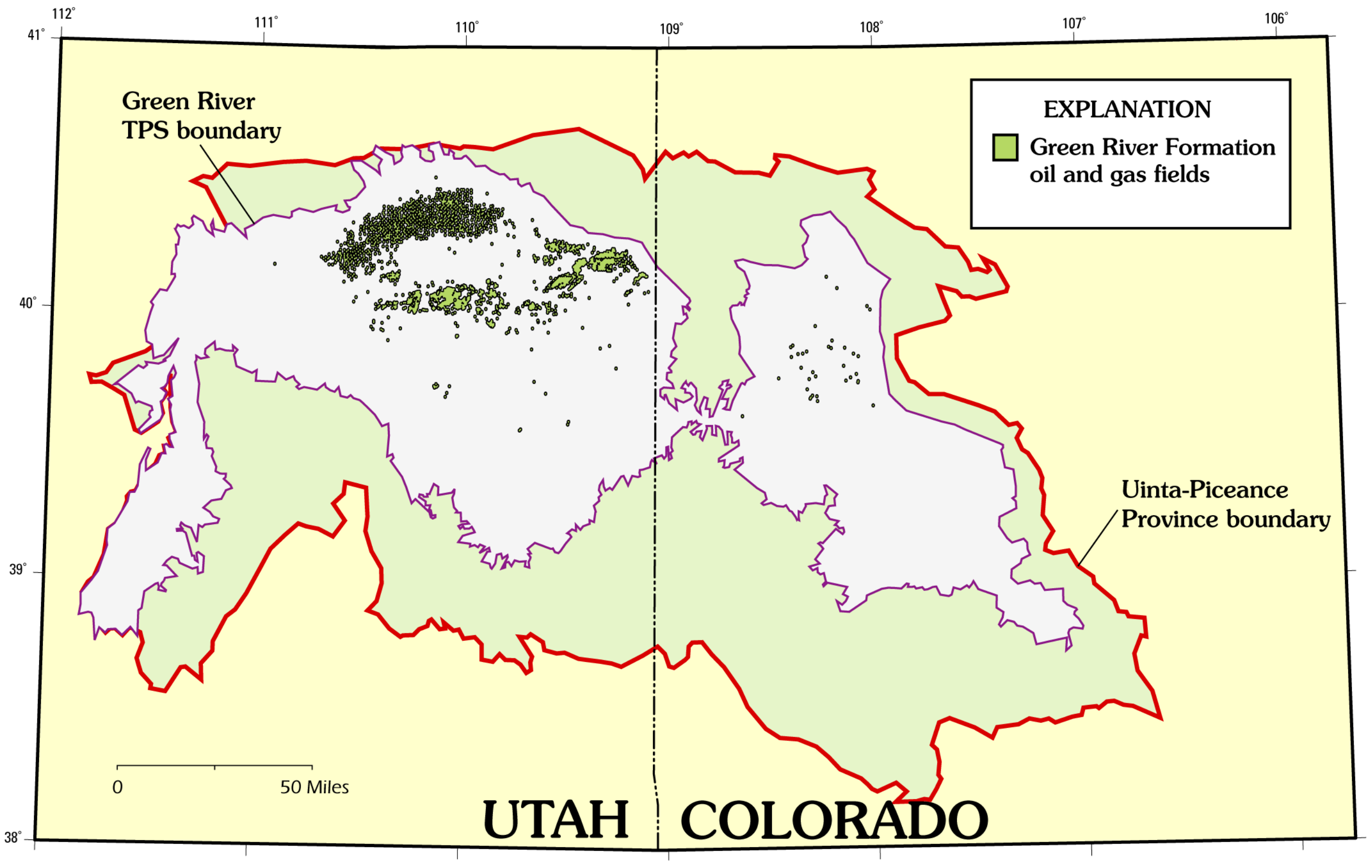


Figure 16. Geographic extent of the Green River Total Petroleum System in the Uinta-Piceance Province (Dubiel, Chapter 5, this CD-ROM).

Green River Total Petroleum System

Hydrocarbon fluids generated from organic-rich mudstones of the Tertiary Green River Formation define the limits of the Green River Total Petroleum System (fig. 16). Regionally, alluvial rocks stratigraphically trap oil in down-dip open-lacustrine and marginal-lacustrine reservoirs as a continuous overpressured oil accumulation (fig. 17). See Chapter 5 by Dubiel (this CD-ROM) for a geologic discussion of the Green River Total Petroleum System.

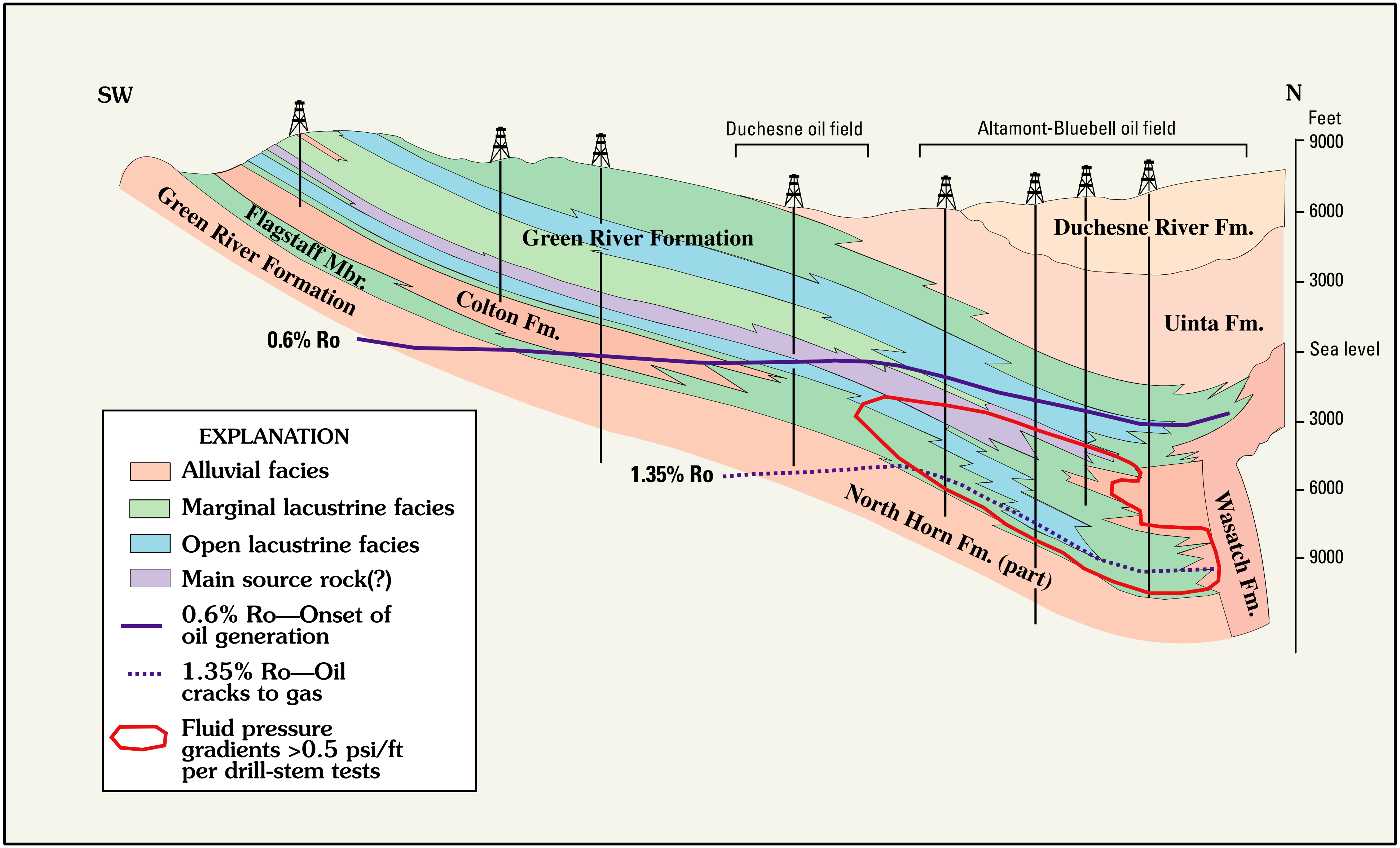


Figure 17. Generalized stratigraphic cross section of the Green River Total Petroleum System showing vitrinite reflectance lines (Ro) (modified from Fouch and others, 1992).

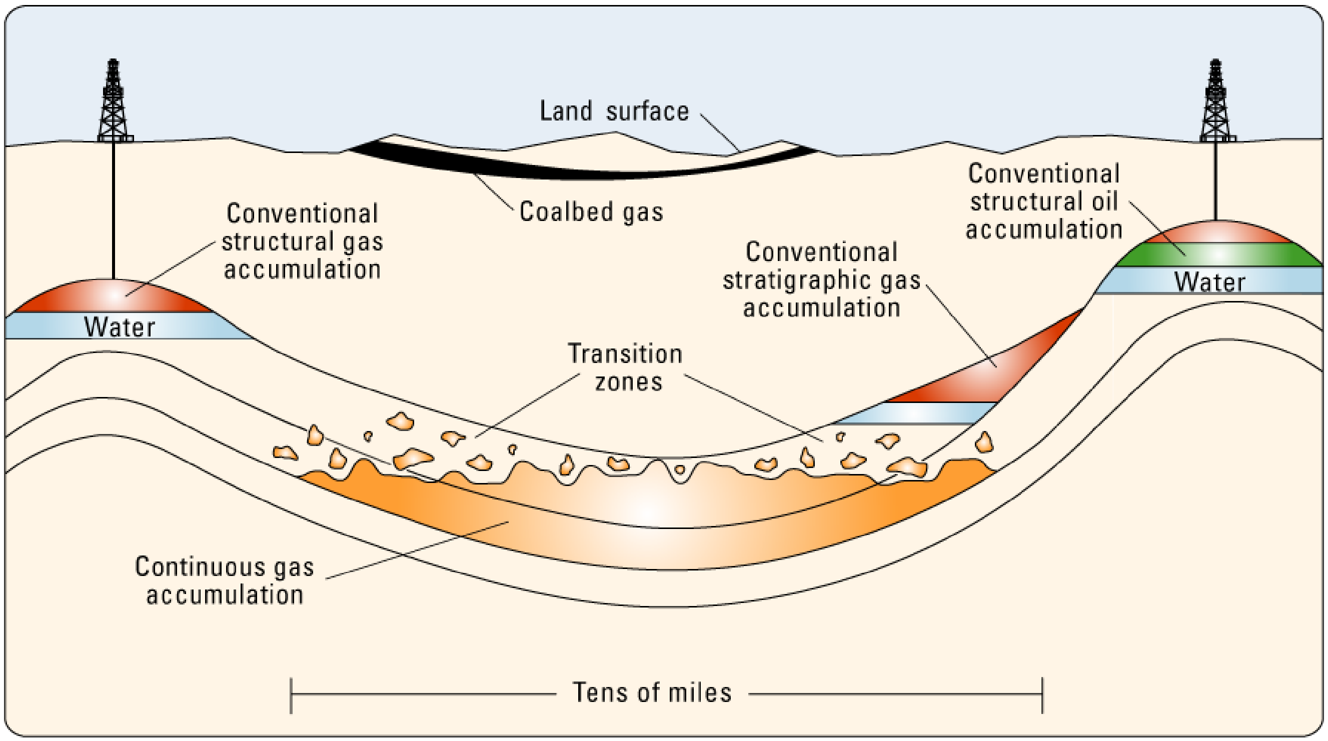


Figure 18. Categories of oil and natural gas occurrence (Schenk and Pollastro, 2002).

Conventional and Continuous Hydrocarbon Accumulations

Hydrocarbon accumulations can be broadly defined into two categories: conventional and continuous (fig. 18). 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 Uinta-Piceance Province.

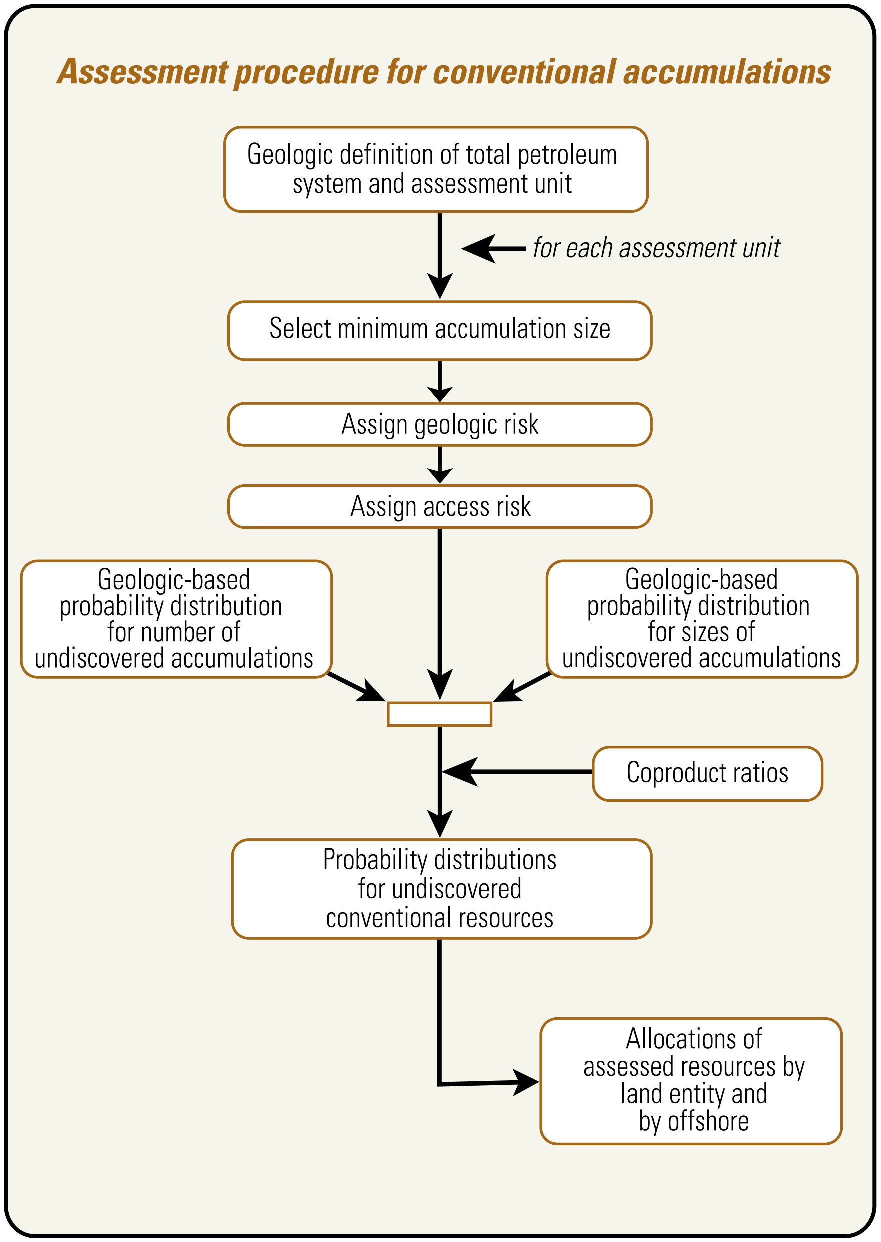


Figure 19. Major steps in the assessment of conventional hydrocarbon accumulations.

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 have an understanding of hydrocarbon source-rock quality, maturation, timing of generation and hydrocarbon migration, and timing of structures and trapping. This requires an understanding of the genesis of hydrocarbon accumulations that exist within an assessment unit, or an understanding of the hydrocarbon accumulations in a geologic analog. The geologist is asked to use all geologic knowledge and an understanding of historic hydrocarbon accumulation types and sizes to construct a probability distribution for sizes and numbers of undiscovered accumulations (fig. 19). 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.

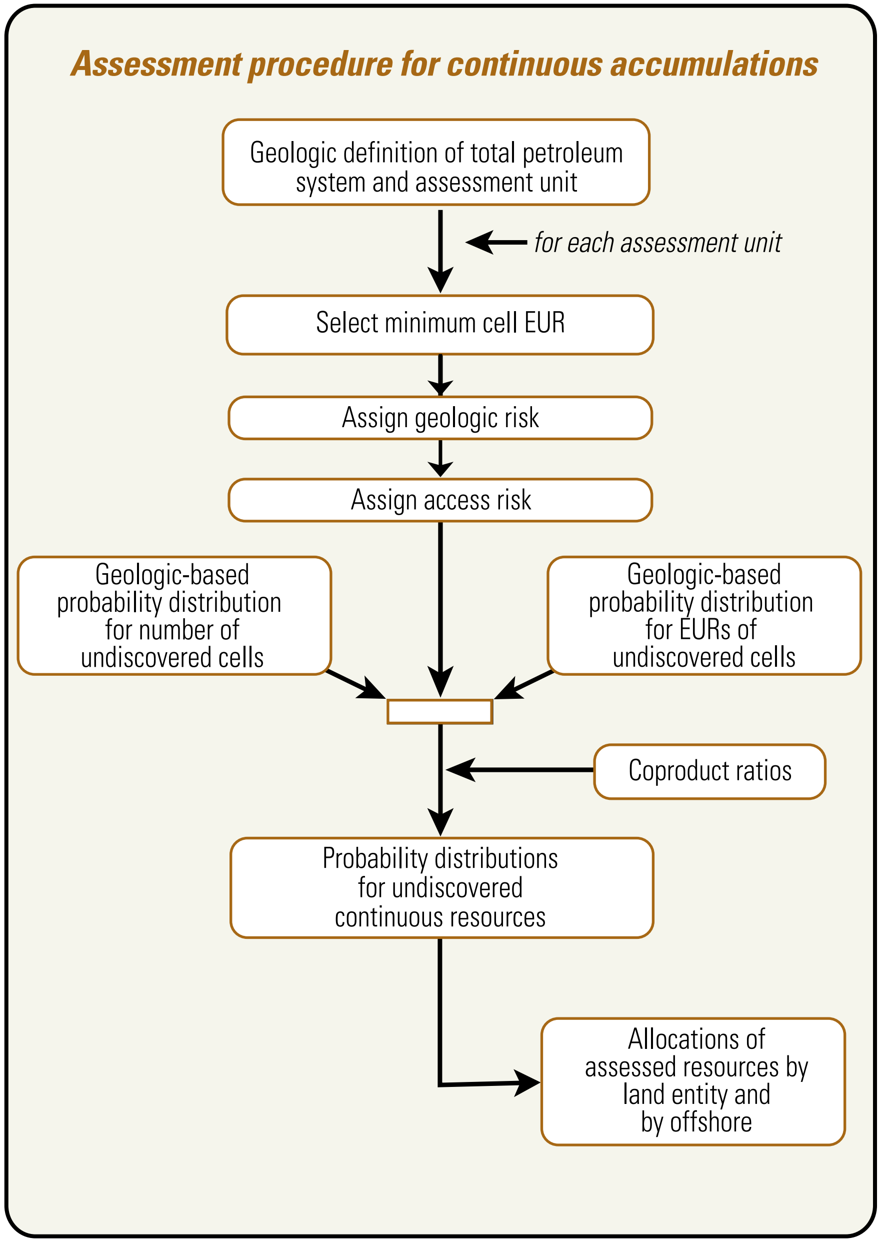


Figure 20. Major steps in the assessment of continuous hydrocarbon accumulations. EUR, estimated ultimate recovery.

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 historic production data are used as a guide to develop a probability distribution of estimated ultimate recoveries 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. 20). The geologist is asked to pay particular attention to the recognition of geologic “sweet spots” of production, as these areas are the most likely to be developed within continuous hydrocarbon accumulations.

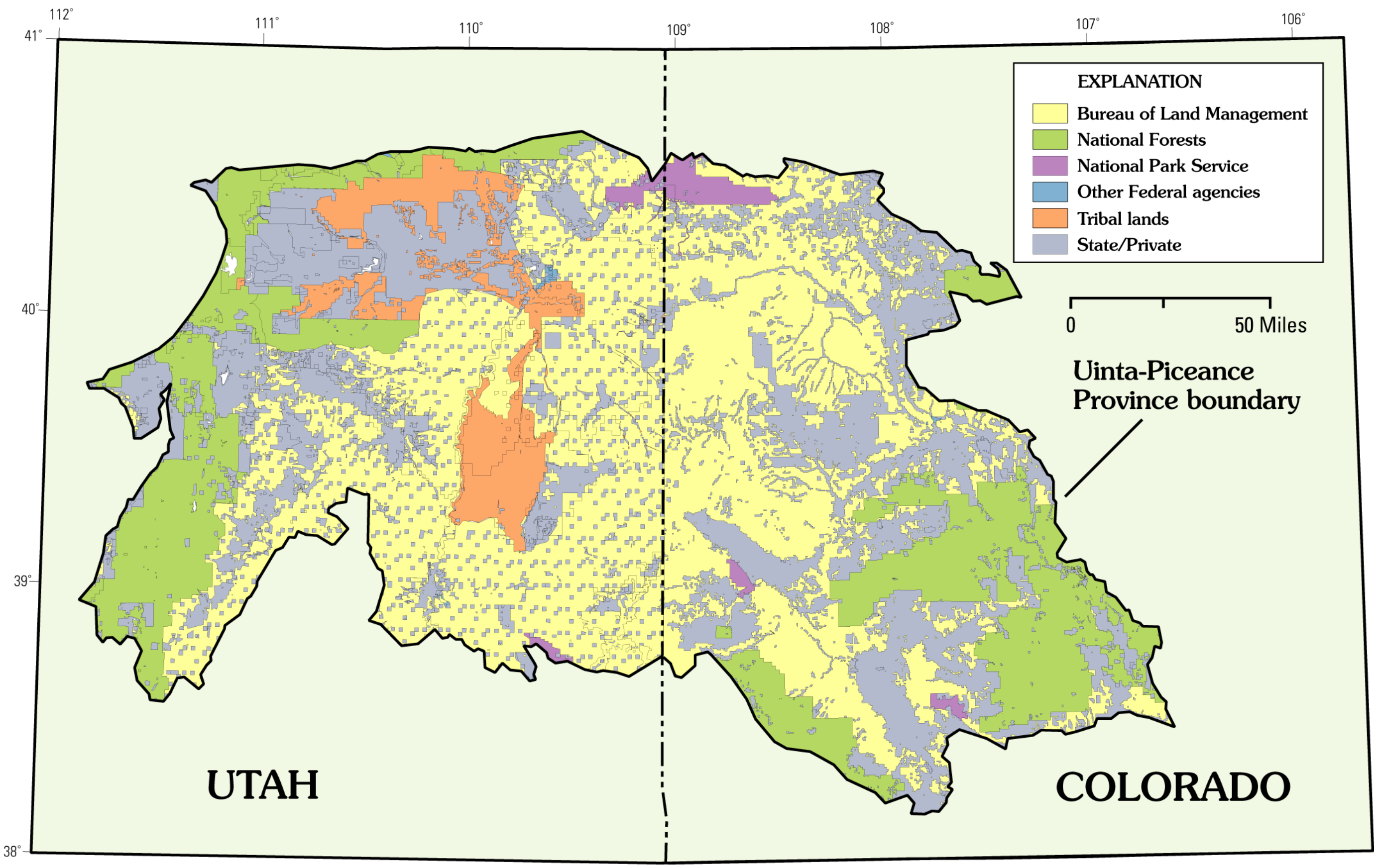


Figure 21. Distribution of Federal surface land ownership and Tribal lands in the Uinta-Piceance Province.

Federal Surface Ownership in the Uinta-Piceance Province

In the Uinta-Piceance study area, about 63 percent of the land surface is administered by the Federal Government, about 5 percent is Tribal land, about 6.5 percent is administered by the States, and about 25.5 percent is held by private owners (fig. 21). Of the 63 percent of Federally administered lands, the Bureau of Land Management is responsible for about 42 percent, the Forest Service about 20 percent, and the National Park Service about 1 percent. National Forests include Grand Mesa, Gunnison, Uncompahgre, Routt, and White River National Forests in Colorado; and Ashley, Fish Lake, Manti-La Sal, and Uinta National Forests in Utah. National Parks and Monuments include Black Canyon of the Gunnison National Monument, Colorado National Monument, Dinosaur National Monument, and part of Arches National Park. Tribal lands include the Uintah and Ouray lands of Utah.

Table 1. Uinta-Piceance Province Assessment Results—Conventional oil and gas resources.
[Assessment results of undiscovered oil and gas resources for the Uinta-Piceance Province 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 non-associated 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 & assessment units	Field type	Total undiscovered resources											
		Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Phosphoria													
Hanging Wall	Oil	1.75	4.13	8.37	4.47	0.47	1.21	2.67	1.34	0.03	0.07	0.17	0.08
	Gas					10.48	24.78	50.27	26.81	0.30	0.78	1.70	0.86
Paleozoic/Mesozoic	Oil	2.66	5.82	11.55	6.29	0.71	1.70	3.69	1.89	0.04	0.10	0.23	0.11
	Gas					15.82	43.74	94.30	48.04	0.47	1.36	3.21	1.54
Ferron/Wasatch Plateau													
Ferron Sandstone Gas	Gas					10.73	35.91	81.23	39.75	0.03	0.07	0.19	0.08
Mesaverde													
Mesaverde Sandstone Gas	Gas					17.91	58.95	140.12	66.41	0.13	0.46	1.18	0.53
Green River													
Uinta Green River Oil & Gas	Oil	2.74	8.52	20.52	9.63	7.59	24.83	63.73	28.88	0.42	1.45	3.98	1.73
Total Conventional Resources		**7.15**	**18.47**	**40.44**	**20.39**	**63.71**	**191.12**	**436.01**	**213.12**	**1.42**	**4.29**	**10.66**	**4.93**

Table 2. Uinta-Piceance Province Assessment Results—Continuous oil and gas resources.
[Assessment results of undiscovered oil and gas resources for the Uinta-Piceance Province 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 non-associated 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 & 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
Mancos/Mowry													
Piceance Basin	***Gas***					649.30	1,463.09	3,296.86	1,652.90	0.60	1.43	3.45	1.65
Uinta Basin	***Gas***					1,781.69	2,965.07	4,934.43	3,110.69	3.16	5.81	10.67	6.22
Uinta-Piceance Transitional and Migrated Gas	***Gas***					1,429.61	1,742.59	2,124.11	1,755.26	0.74	1.98	5.31	2.37
Ferron/Wasatch Plateau													
Deep (6,000 ft. +) Coal and Sandstone	***Gas***					0.00	52.04	136.43	59.10	0.00	0.00	0.00	0.00
Northern Coal Fairway/ Drunkards Wash AU	***CBG***					451.14	722.18	1,156.05	752.33	0.00	0.00	0.00	0.00
Central Coal Fairway/ Buzzards Bench	***CBG***					311.61	512.69	843.54	536.73	0.00	0.00	0.00	0.00
Southern Coal Fairway	***CBG***					78.16	145.81	255.49	152.59	0.00	0.00	0.00	0.00
Southern Coal Outcrop	***CBG***					0.00	9.95	30.71	10.56	0.00	0.00	0.00	0.00
Mesaverde													
Uinta Basin Continuous	***Gas***					4,134.18	7,018.47	11,915.02	7,391.36	5.52	10.31	19.27	11.09
Uinta Basin Transitional	***Gas***					889.42	1,431.73	2,304.72	1,492.97	1.18	2.10	3.76	2.24
Piceance Basin Continuous	***Gas***					1,902.23	2,956.15	4,594.01	3,064.27	5.00	8.69	15.09	9.19
Piceance Basin Transitional	***Gas***					161.74	284.47	500.33	301.73	0.29	0.56	1.07	0.60
Uinta Basin Blackhawk Coalbed Gas	***CBG***					181.97	433.84	1,034.28	498.78	0.00	0.00	0.00	0.00
Mesaverde Group Coalbed Gas	***CBG***					138.72	322.45	749.54	367.77	0.00	0.00	0.00	0.00
Green River													
Deep Uinta Overpressured Continuous Oil	***Oil***	24.83	37.57	56.84	38.78	35.72	60.74	103.29	63.99	2.23	4.17	7.79	4.48
Total Continuous Resources		**24.83**	**37.57**	**56.84**	**38.78**	**12,145.49**	**20,121.27**	**33,978.81**	**21,211.03**	**18.72**	**35.05**	**66.41**	**37.84**
Total Oil & Gas Resources		**31.99**	**56.04**	**97.28**	**59.17**	**12,209.20**	**20,312.39**	**34,414.82**	**21,424.15**	**20.14**	**39.34**	**77.07**	**42.77**

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