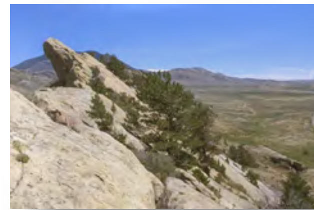
Chapter 7

The Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province



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Volume Title Page

By Thomas M. Finn and Ronald C. Johnson

Chapter 7 of
Petroleum Systems and Geologic Assessment of Oil and Gas in the Southwestern Wyoming Province, Wyoming, Colorado, and Utah
By USGS Southwestern Wyoming Province Assessment Team

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The Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province

By Thomas M. Finn and Ronald C. Johnson

Abstract

An assessment was made of the amount of gas in the Hilliard-Baxter-Mancos Total Petroleum System in the Southwestern Wyoming Province that has the potential for additions to reserves in the next 30 years. The Total Petroleum System was divided into two assessment units using variations in thermal maturity, the Hilliard-Baxter-Mancos Continuous Assessment Unit, and the Hilliard-Baxter-Mancos Conventional Assessment Unit. The Continuous Assessment Unit is estimated to contain a mean of 11.753 trillion cubic feet of gas and 752.2 million barrels of natural gas liquids, and the Conventional Assessment Unit is estimated to contain a mean of 15.5 billion cubic feet of gas and 1 million barrels of natural gas liquids that has the potential for additions to reserves in the next 30 years.

Introduction

The Hilliard-Baxter-Mancos Total Petroleum System (TPS), designated 503704, covers an area of 22,448 mi^2 and includes all of that part of the Southwestern Wyoming Province where any of this marine shale interval is preserved (fig. 1). The Hilliard-Baxter-Mancos interval was deposited in offshore to nearshore marine settings in the Rocky Mountain foreland basin during an extended period of time in the Late Cretaceous when the shoreline was predominantly west of the TPS. The stratigraphic interval included in the TPS ranges from about 3,500 to 6,000 ft thick and contains thick intervals of organic-rich marine shales that are potential source rocks and thick silty and sandy nearshore to offshore marine intervals that are potential reservoir rocks. This TPS has been sparsely explored, but some promising discoveries have been made.

The Hilliard-Baxter-Mancos TPS includes the Hilliard Shale in the Green River and Hoback Basins, the Baxter Shale and Blair Formation in the Rock Springs uplift area and western parts of the Great Divide and Washakie Basins, the Steele Shale and part of the Haystack Mountains Formation in the eastern part of the Great Divide and Washakie Basins, and the Mancos Shale in the Sand Wash Basin (figs. 2, 3, and 4). The Hilliard-Baxter-Mancos TPS overlies the Niobrara TPS (503703) in the Sand Wash Basin and eastern parts of the Washakie and Great Divide Basins (fig. 2–4). The Niobrara TPS consists of marine carbonates and calcareous marine shales of the Niobrara Formation that grade to the west into noncalcareous marine shales in the lower part of the Hilliard-Baxter-Mancos TPS. West of the pinch-out of the Niobrara Formation, the Hilliard-Baxter-Mancos TPS directly overlies the Mowry Composite TPS (503702).

The contact with the underlying Niobrara TPS is the top of the highest calcareous bed of the Niobrara Formation, and the contact with the Mowry TPS is the top of the highest sandstone in the Frontier Formation. Marine shale intervals in the lower part of the Hilliard-Baxter-Mancos TPS are thought to seal off the underlying Niobrara Composite TPS and Mowry TPS, but it is possible that hydrocarbons from these underlying total petroleum systems have migrated into at least the lower part of the Hilliard-Baxter-Mancos TPS. The contact between the Hilliard-Baxter-Mancos TPS and the overlying Mesaverde TPS and Mesaverde–Lance–Fort Union Composite TPS is generally placed at the base of the lowest coastal plain facies rocks, in the Rock Springs or Allen Ridge Formations. This places some marginal marine sandstone in the Rock Springs and Haystack Mountains Formations into the Hilliard-Baxter-Mancos TPS. Because coals and carbonaceous shales deposited in coastal plain environments are thought to be the main source of hydrocarbons in the overlying TPS, any gas found in these marginal marine sandstones below the lowest coaly source rocks is thought to be sourced by marine shales in the Hilliard-Baxter-Mancos TPS.

Acknowledgments

The authors wish to thank Rich Pollastro and Chris Schenk of the U.S. Geological Survey (USGS) National Oil and Gas Assessment team for discussions regarding the assessment of the Hilliard-Baxter-Mancos Total Petroleum System. We would also like to thank Troy Cook (USGS) for interpretations of production data and providing graphs of EURs; Phil Nelson and Joyce Kibler (USGS) for providing drill-stem test and pressure data; Laura Roberts (USGS) for providing key maps and for providing burial-history and petroleum-generation models; and

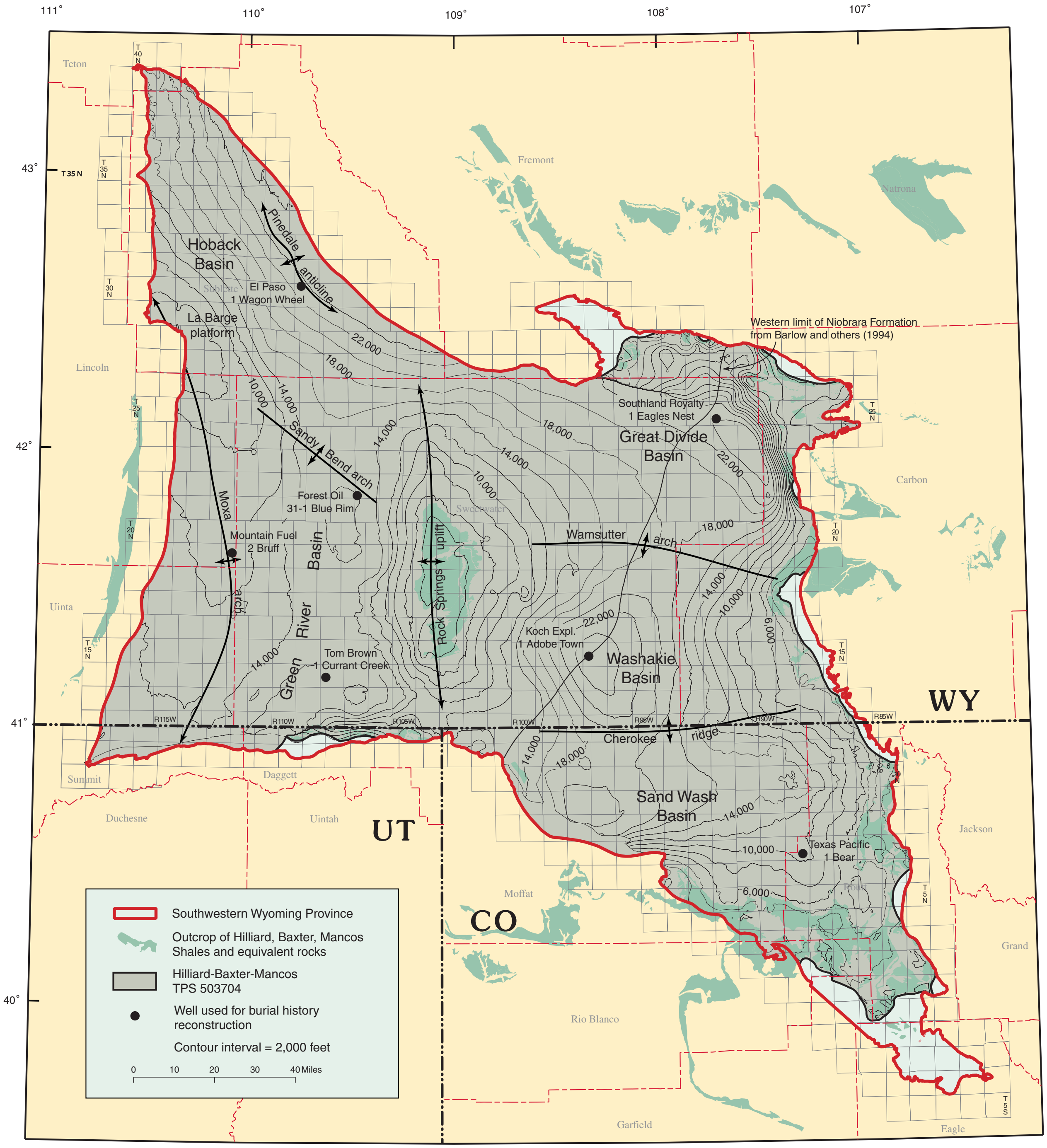


Figure 1. Distribution of outcrops of Hilliard, Baxter, and Mancos Shales and areal extent of the Hilliard-Baxter-Mancos Total Petroleum System in the Southwestern Wyoming Province. Contour lines show depth to the base of the Hilliard-Baxter-Mancos Total Petroleum System. Locations of wells for which vitrinite reflectance profiles were run are shown.

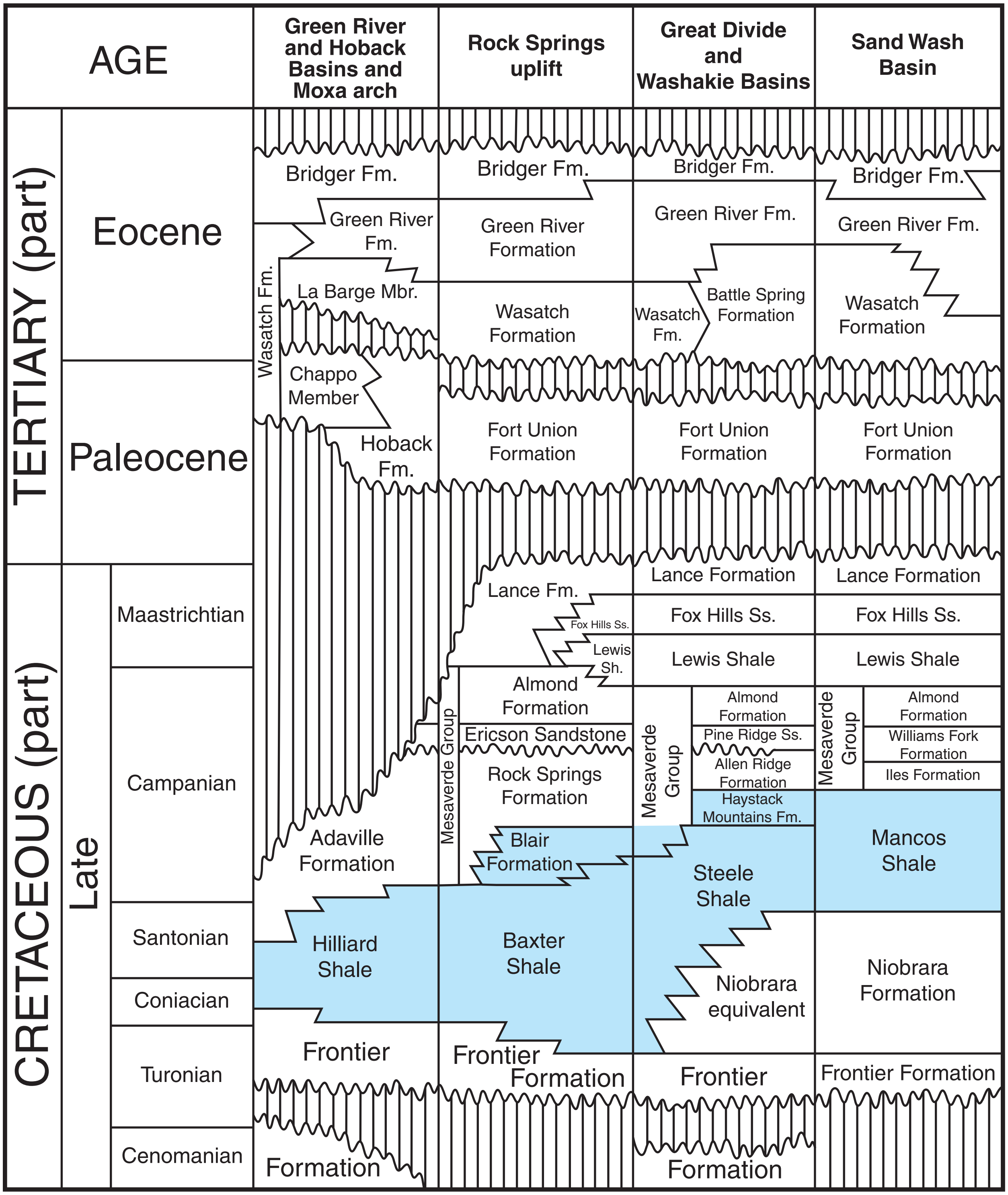


Figure 2. Generalized correlation chart of Upper Cretaceous and lower Tertiary stratigraphic units in the Southwestern Wyoming Province. Modified from Law and others (1989).

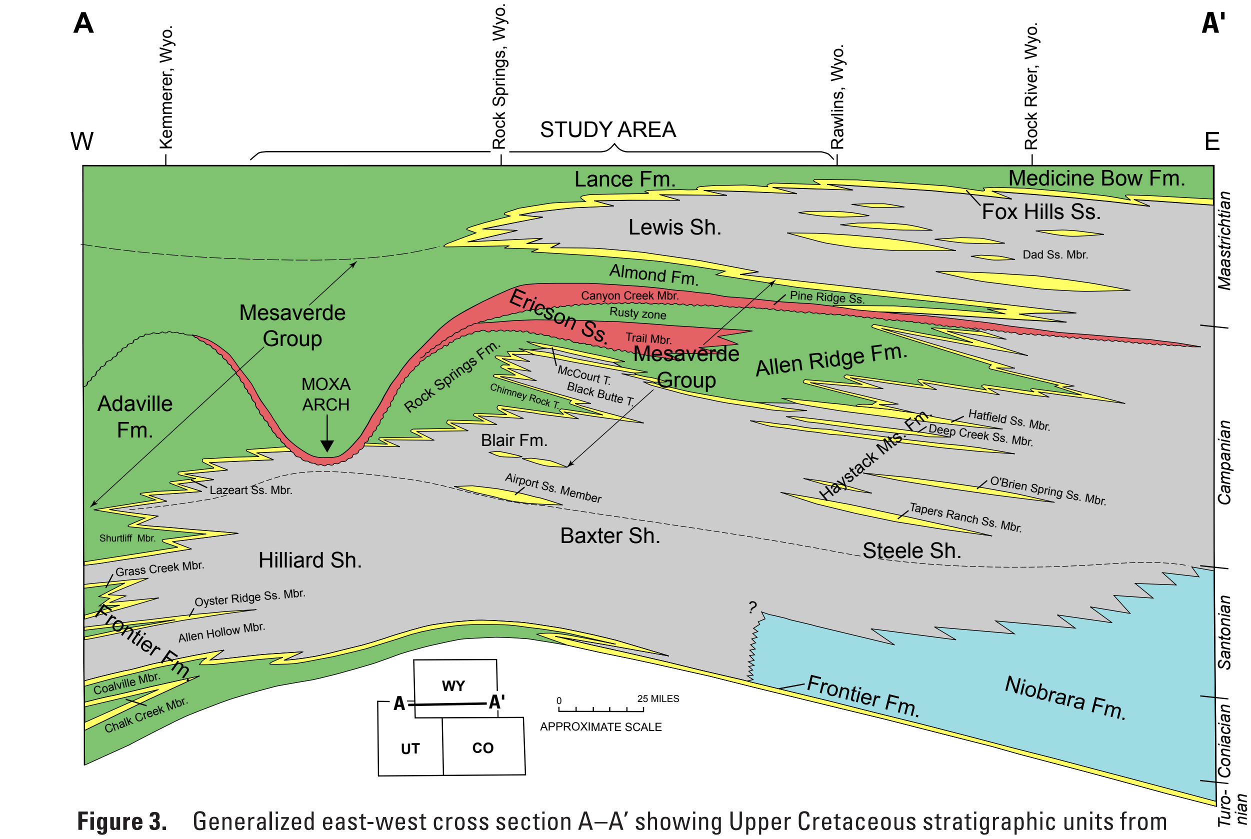


Figure 3. Generalized east-west cross section A–A′ showing Upper Cretaceous stratigraphic units from northeast Utah to southeast Wyoming. Approximate limits of Southwestern Wyoming Province shown in brackets. Modified from Roehler (1990, his fig. 7).

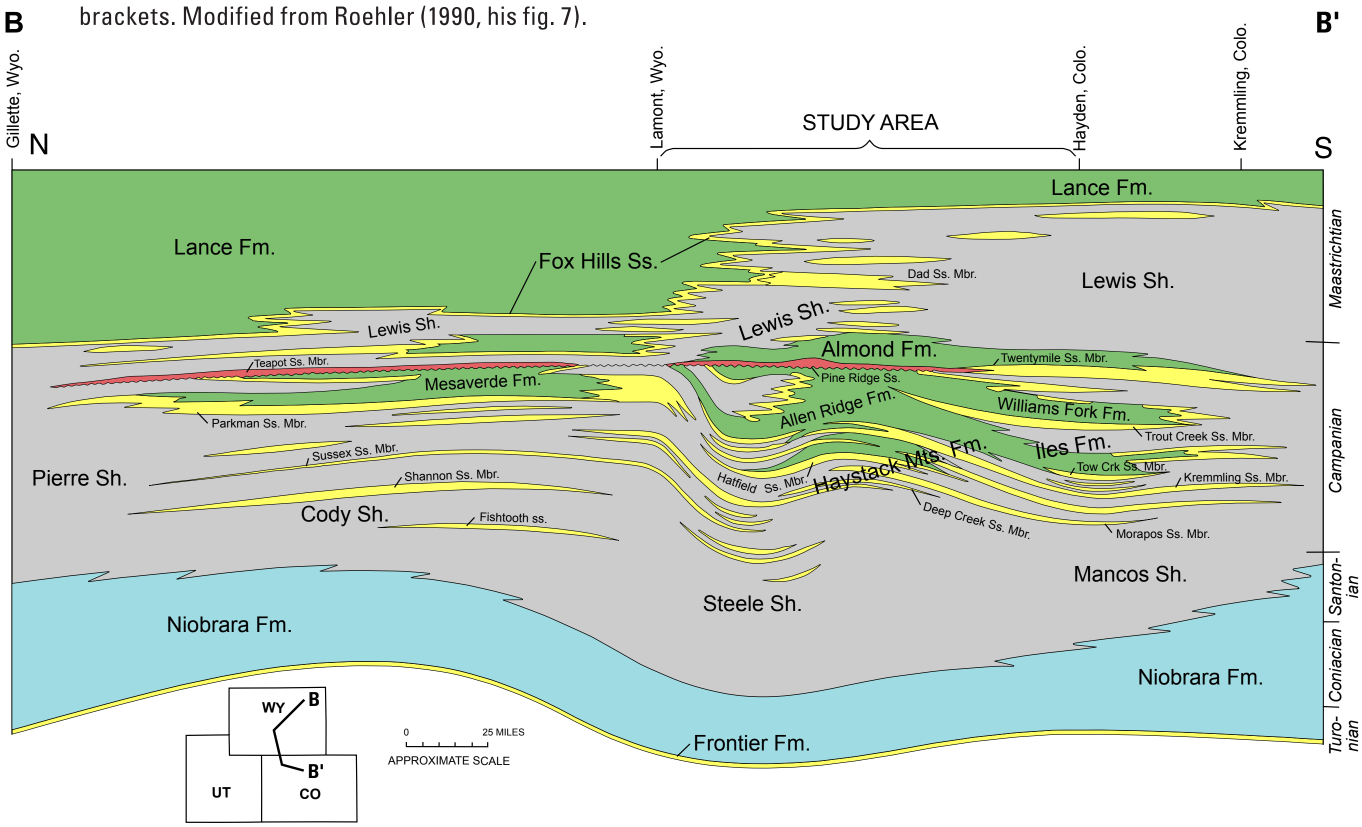


Figure 4. Generalized north-south cross section B–B′ showing Upper Cretaceous stratigraphic units from northeastern Wyoming to north-central Colorado. Approximate limits of Southwest Wyoming Province shown in braces. Modified from Roehler (1990, his fig. 9).

Paul Lillis and Mike Lewan (USGS) for providing geochemical data and numerous discussions regarding organic geochemistry and source rocks. The manuscript was reviewed by Mark Kirschbaum and Chris Schenk (USGS) who provided many helpful comments and suggestions.

Hydrocarbon Source Rocks

Source rocks for the Hilliard-Baxter-Mancos TPS are interpreted to be mixed Type-II and Type-III organic matter found in organic-rich intervals (as yet to be identified) in the thick marine shales. Law (1984) analyzed a few samples of marine shales from the Hilliard-Baxter-Mancos TPS and reported total organic carbon values of as high as 2.71 percent from a depth of 12,825 ft near the middle of the Baxter Shale in the Forrest Oil Blue Rim 31-1 Fed. well in sec. 31, T. 22 N., R. 106 W., which is considered a good source rock for hydrocarbons (Hunt, 1979). The well is along the Sandy Bend arch, a broad structural feature separating the Hoback Basin from the Green River Basin (fig. 1).

Source Rock Maturation

Locations of seven wells for which vitrinite reflectance profiles were obtained in the Greater Green River Basin are shown in figure 1. The profiles are included in Roberts and others (Chapter 3, this CD–ROM). Maps showing variations in levels of thermal maturity using vitrinite reflectance (R_o) at the base and top of the Hilliard-Baxter-Mancos TPS are shown in figures 5 and 6. The maps were constructed using the seven profiles and previously published data (see Roberts and others, Chapter 3, this CD–ROM). Thermal maturities at the base of the Hilliard-Baxter-Mancos TPS increase from less than 0.6 percent R_o in the shallow areas around the margins of the TPS to much greater than 1.3 percent in the deeper parts of the province (fig. 5), but data are too sparse to contour above the 1.3 percent level. Vitrinite reflectance levels at the top of the TPS vary from less than 0.6 percent around the margins of the TPS to more than 2.0 percent in the deep trough of the Great Divide and Hoback Basins and more than 2.2 percent in the deep trough of the Washakie Basin (figs. 1 and 6). Thermal maturities at the top of the TPS are lower in the Green River and Sand Wash Basins with maximum maturation levels slightly greater than 1.1 percent in the deep trough of the Green River Basin and 1.3 percent in the deep trough of the Sand Wash Basin (figs. 1 and 6).

Roberts and others (Chapter 3, this CD–ROM), using burial reconstructions for the seven wells for which vitrinite reflectance profiles were obtained, applied time-temperature modeling to estimate the timing of hydrocarbon generation by Type-III organic matter. Time-temperature modeling reconstructs the maturation of organic matter through time as a result of burial and heating. The model is calibrated using observed R_o levels in wells where the burial histories are well constrained. They (Roberts and others) used a kinetic model to reconstruct maturation of Type-II organic matter. Kinetic models predict timing and the amount of hydrocarbons generated by Type-II kerogen by using laboratory experiments such as hydrous pyrolysis.

Table 1 gives the years before present (BP) that the 0.6, 0.8, 1.1,1.35, and 2.00 R_o levels were reached in the seven wells using time-temperature modeling. An R_o of 0.6 percent is thought to approximately mark the onset of hydrocarbon generation (Waples, 1980), 0.8 percent is the level at which widespread overpressuring occurs in the Southwestern Wyoming Province (Law, 1984), 1.1 percent is about the level at which significant expulsion of hydrocarbons from coals begins (Levine, 1993), an R_o of 1.35 is about the level when oil begins to break down into gas (Dow, 1977), and an R_o of 2.0 percent is approximately the level where C_{2+} gases break down into methane (Dow, 1977).

Table 2 summarizes the results of the kinetic modeling of Roberts and others (this CD–ROM) and shows the onset, peak, and end of oil and gas generation by Type-II organic matter. The model predicts the onset of oil generation beginning at an R_o of from 0.64 to 0.69 percent, peaking at from R_o 0.92 to 0.93 percent and ending at from R_o 0.85 to 1.29 percent (table 2). Gas generation from the thermal cracking of oil begins at an R_o of from 1.63 to 1.74 percent, peaking at from 2.37 to 2.43 percent and ending at an R_o of from 2.84 to 2.98 percent (table 2). Thus a significant gap occurs between the end of oil generation and the onset of gas generation. In kinetic modeling of Type-II organic matter there is no direct correlation between hydrocarbon generation and changes in R_o; thus, the onset, peak, and end of oil and gas generation occur over a range of R_o values. The model indicates that significant gas generation from the cracking of oil has occurred in the Hilliard-Baxter-Mancos TPS in the deeper areas of the Great Divide, Washakie, and Hoback Basins and on the Sandy Bend arch between the Hoback and Green River Basins. Thermal maturities are not high enough in the Green River and Sand Wash Basins for cracking to have occurred.

Hydrocarbon Migration Summary

Migration of hydrocarbons out of organic-rich shales is poorly understood (Hunt, 1979) but probably begins shortly after the onset of hydrocarbon generation. Time-temperature modeling for Type-III organic matter indicates that the onset of hydrocarbon generation at the base of the Hilliard-Baxter-Mancos TPS ranged from 70 Ma or Late Cretaceous in the deep Washakie Basin to 56 Ma or early Eocene time in the deep Green River Basin (table 1). Laboratory pyrolysis experiments have shown that coals generate methane to thermal maturities of at least R_o 4.0 (Higgs, 1986), which is probably higher than the present-day thermal maturities for even the

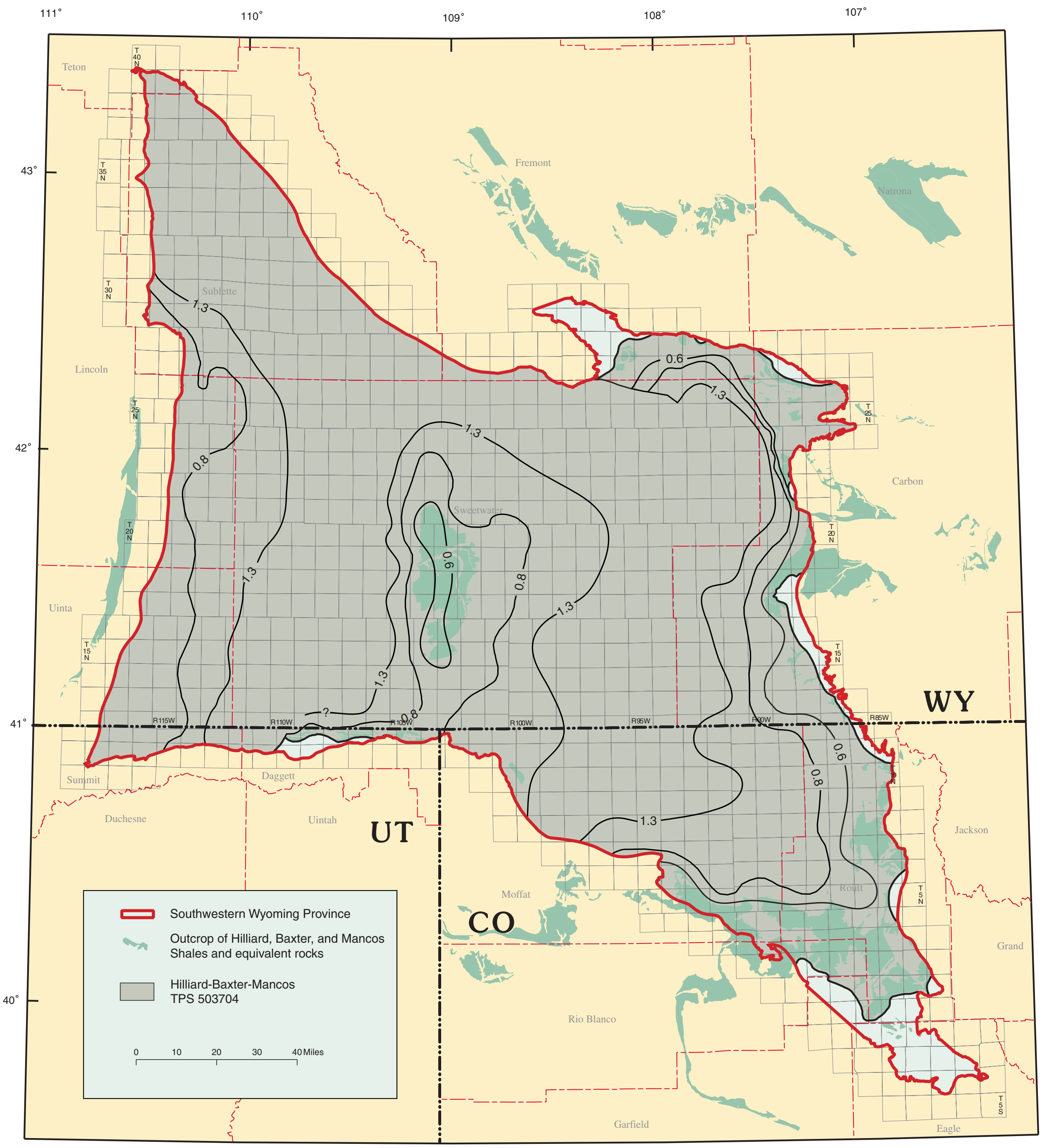


Figure 5. Variations in vitrinite reflectance at the base of the Hilliard-Baxter-Mancos Total Petroleum System.

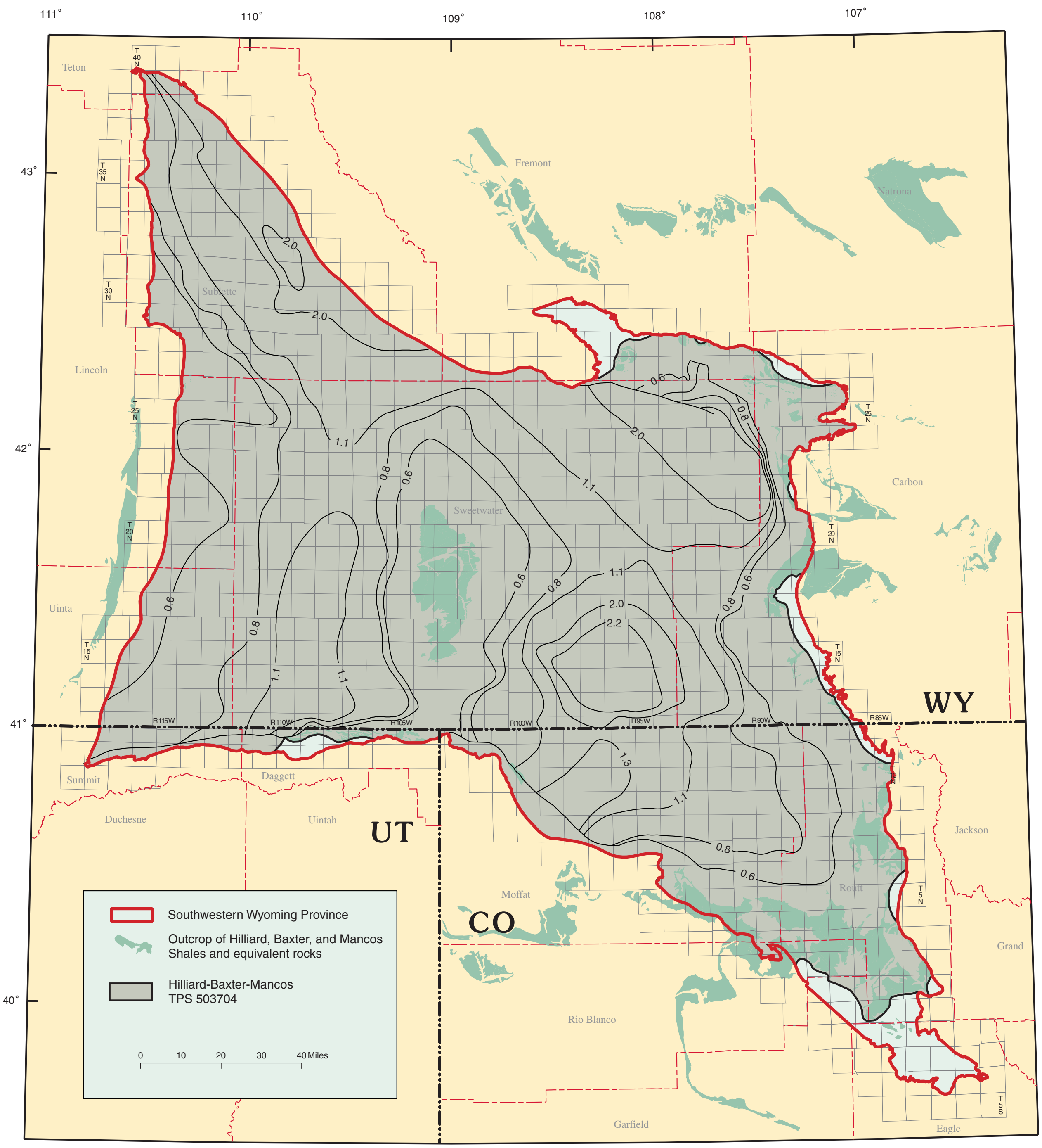


Figure 6. Variations in vitrinite reflectance at the top of the Hilliard-Baxter-Mancos Total Petroleum System.

Table 1. Millions of years before present that the vitrinite reflectance levels of 0.6, 0.8, 1.1, 1.35, and 2.0 were reached in key wells in the Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province. See figure 1 for locations of wells.

Selected Wells	Millions of years before present to reach the vitrinite reflectance levels shown below				
	0.60%	0.80%	1.10%	1.35%	2.00%
Adobe Town					
Top of Hilliard-Baxter-Mancos TPS	59	54	50	48	44
Top Niobrara Fm.	70	65	60	57	52
Eagles Nest					
Top of Hilliard-Baxter-Mancos TPS	64	59	54	50	32
Top Niobrara Fm.	66	63	59	56	48
Bear 1					
Top of Hilliard-Baxter-Mancos TPS	63	7			
Top Niobrara Fm.	69	65	42	5	NA
Blue Rim					
Top of Hilliard-Baxter-Mancos TPS	48	25	NA	NA	
Base of Baxter Sh.	62	55	46	40	NA
Mountain Fuel					
Top of Hilliard-Baxter-Mancos TPS	28	NA	NA	NA	NA
Base of Hilliard Sh.	48	38	NA	NA	NA
Tom Brown					
Top of Hilliard-Baxter-Mancos TPS	46	32	NA	NA	NA
Base of Hilliard Sh.	56	48	43	37	NA
Wagon Wheel					
Top of Hilliard-Baxter-Mancos TPS	64	58	54	50	NA
Base of Baxter Sh.	67	65	61	58	52

Table 2. Onset, peak, and end of oil and gas generation by Type-II organic matter in millions of years before present (Ma) and in percent R_o, for selected wells in the Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province using the kinetic model of Roberts and others (this CD–ROM).

	Oil generation						Gas generation					
Selected wells	Onset (Ma)	(%R_o)	Peak (Ma)	(%R_o)	End (Ma)	(%R_o)	Onset (Ma)	(%R_o)	Peak (Ma)	(%R_o)	End (Ma)	(%R_o)
Adobe Town												
Top of Hilliard-Baxter-Mancos Shs.	55	0.67	51	0.93	49	1.19	45	1.67	41	2.39	18	2.98
Base of Hilliard-Baxter-Mancos Shs.	67	0.69	62	0.92	58	1.18	53	1.69	49	2.37	47	2.84
Eagles Nest												
Top of Hilliard-Baxter-Mancos Shs.	61	0.64	54	0.93	48	1.29	39	1.63				
Base of Hilliard-Baxter-Mancos Shs.	66	0.69	61	0.92	58	1.15	50	1.74	40	2.43	11	2.89
Bear 1												
Top of Hilliard-Baxter-Mancos Shs.	44	0.69					No gas					
Base of Hilliard-Baxter-Mancos Shs.	68	0.68	54	0.92	14	1.17	No gas					
Mountain Fuel												
Top of Hilliard-Baxter-Mancos Shs.	40	0.68			0	0.85	No gas					
Base of Hilliard-Baxter-Mancos Shs.	46	0.69	29	0.92	0	1.11	No gas					
Tom Brown												
Top of Hilliard-Baxter-Mancos Shs.	42	0.65					No gas					
Base of Hilliard-Baxter-Mancos Shs.	52	0.69	45	0.92	42	1.14	No gas					
Blue Rim												
Top of Hilliard-Baxter-Mancos Shs.	41	0.66										
Base of Hilliard-Baxter-Mancos Shs.	58	0.69	50	0.92	44	1.14						
Wagon Wheel												
Top of Hilliard-Baxter-Mancos Shs.	61	0.65	54	0.92	48	1.28	9	1.7				
Base of Hilliard-Baxter-Mancos Shs.	66	0.68	63	0.92	60	1.14	54	1.74	44	2.43	12	2.87

deepest, most mature parts of the TPS. Thus, gas generation by Type-III organic matter is probably still going on today throughout much of the TPS, but rates of generation have decreased significantly during the past 10 million years due to regional uplift and resulting downcutting and cooling.

Kinetic modeling for Type-II organic matter suggests that the cracking of oil to gas at the base of the Hilliard-Baxter-Mancos TPS at the Wagon Wheel well on the Pinedale anticline began 54 Ma and ended about 12 Ma. At the Eagles Nest well in the trough of the Great Divide Basin, cracking began at the base of the TPS 50 Ma and ended 11 Ma. In the Adobe Town well in the deep trough of the Washakie Basin, cracking began 53 Ma at the base of the Hilliard-Baxter-Mancos TPS and ended 47 Ma. According to the modeling, cracking of oil to gas is still ongoing at the top of the TPS everywhere except the deep Washakie Basin. For the Sand Wash Basin, there are no data for the deep basin trough on which to do kinetic modeling. Again, the rate of hydrocarbon generation has decreased significantly throughout the TPS during the last 10 million years due to regional uplift and downcutting and, as a result, migration of hydrocarbons from source rocks to reservoir rocks has probably also slowed. Figure 7 is a total petroleum system events chart showing interpreted timing of elements and processes related to hydrocarbon generation and accumulation in the Hilliard-Baxter-Mancos TPS.

Hydrocarbon Reservoir Rocks

Reservoir rocks are sandstones and interbedded sandstone, siltstone, and shale deposited mainly in nearshore marine, marine shelf, marine slope, and deep basin-floor settings (Roehler, 1990) (figs. 2–4). In most cases, these reservoirs are encased in marine shale. Facies include distal lower shoreface or prodelta, offshore marine bars, submarine channels, and sheet sandstones winnowed from shelf and slope mudstones by current and wave action (Roehler, 1990, p. 23). Some marginal marine rocks, mainly in the Haystack Mountains Formation in the east part of the TPS, are included in this TPS (figs. 2–4). These rocks, which are included in this TPS because they are largely encased offshore marine rocks, include reservoir sandstones deposited in shoreface, tidally dominated delta front, and estuarine depositional settings (Mellere and Steel, 1995).

Sandstone reservoirs range in size from single sandstone

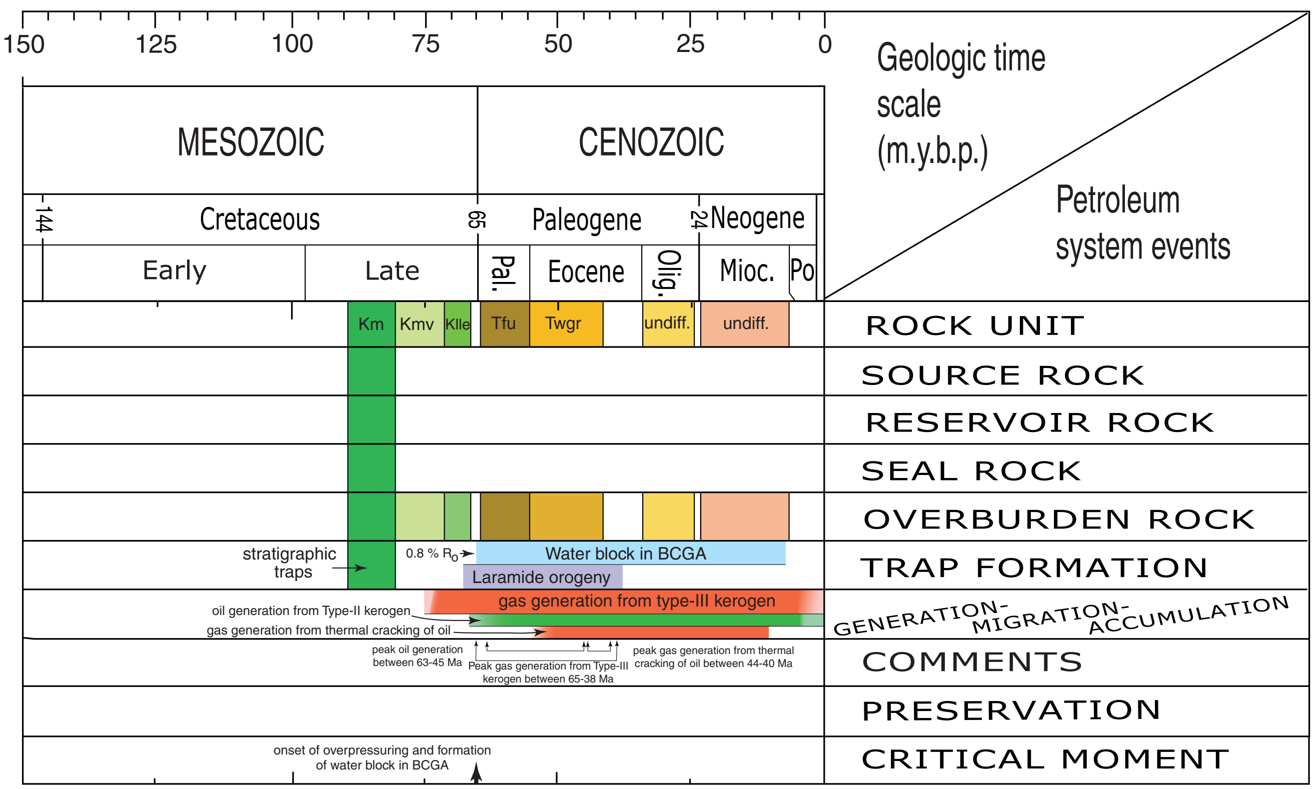


Figure 7. Total Petroleum System events chart showing interpreted timing of elements and processes related to hydrocarbon generation, accumulation, and migration in Hilliard-Baxter-Mancos Total Petroleum System (503704). Water block refers to hydrocarbon trapping by capillary seal. The timing of hydrocarbon generation is from Roberts and Lewan (this CD–ROM). Events chart modified from Magoon and Dow (1994). Km, Mancos Shale; Kmv, Mesaverde Group; Klle, Lewis Shale, Foxhills Sandstone, and Lance Formation; Tfu, Fort Union Formation; Twgr, Wasatch and Green River Formations; undiff., undifferentiated; Pal., Paleocene; Olig., Oligocene; Mioc., Miocene; Po, Pliocene; BCGA, basin-centered gas accumulation; R_o, vitrinite reflectance; m.y.b.p., millions of years before present .

bodies covering many square miles, with thicknesses ranging to 100 ft or more, to thin interbeds of sandstone and siltstone in thick mudstone, and shale intervals. The percent sandstone in these intervals varies markedly, and coarsening upwards cycles ranging from less than a foot to tens of feet thick are common.

Potential reservoir rocks are present throughout most of the area of the Hilliard-Baxter-Mancos TPS, but concentrations of reservoirs are present in the lower part of the Blair Formation near the Rock Springs uplift (Roehler, 1990, his plate 1, cross sections E–E′, F–F′, G–G′, and H–H′) and through a broad, northwest-trending zone of about 1,550 mi^2 (992,000 acres) in the Great Divide and Washakie Basins where the Haystack Mountains Formation is present (figs. 2–4). Here, shelf sandstones encased in marine shale are scattered through an interval as much as 2,000 ft thick (Roehler, 1990, his plate 1, cross section I–I′). A prominent sandstone, the Airport Sandstone Member, is in the upper part of the Baxter Formation along the east flank of the Rock Springs uplift (Roehler, 1990; Finn and Johnson, Chapter 14, this CD–ROM).

Hydrocarbon Traps and Seals

Conventional traps include anticlines and the stratigraphic pinch-out of sandstone into finer grained mudstone and shale. Seals are most commonly mudstone and shale, but seals can also form from the termination of sandstone bodies against faults. The overall trapping mechanism for continuous-type accumulations, such as the continuous gas accumulation that occurs in the more thermally mature (R_o greater than 0.80 percent) parts of the TPS, is thought to be a capillary seal or water block (Masters, 1979).

Assessment Unit Definition

The Hilliard-Baxter-Mancos TPS is divided into two assessment units: (1) the Hilliard-Baxter-Mancos Continuous Oil and Gas Assessment Unit (AU 50370461) (fig. 8) and (2) the Hilliard-Baxter-Mancos Conventional Gas Assessment Unit (AU 50370401) (fig. 9). Methodology for assessing continuous accumulations is described in Schmoker (Chapter 13, this CD–ROM), while methodology for conventional accumulations is described in Schmoker and Klett (Chapter 19, this CD–ROM). The Hilliard-Baxter-Mancos Continuous Gas Assessment Unit is defined as that area where the base of the interval has attained a thermal maturity as measured by vitrinite reflectance (R_o) of 0.8 percent or greater (fig. 5), whereas the Hilliard-Baxter-Mancos Conventional Assessment Unit is defined as that area where the top of the interval has attained a thermal maturity of less than R_o 0.8 percent (fig. 6). Defining these two assessment units in this fashion means that they overlap through a broad zone near the basin margins. The production characteristics of each field in this overlap area was examined to determine whether it was more appropriate to assign the field to the conventional or to the continuous assessment unit.

Assessment Results

Abbreviated results of the assessment of the Hilliard-Baxter-Mancos TPS were published in Kirschbaum and others (2002). The Hilliard-Baxter-Mancos Continuous Gas Assessment Unit (AU 50370461) covers about 10.5 million acres of the Southwestern Wyoming Province and it produces from five fields (fig. 8). Minimum, median, maximum areas for the assessment unit are 9,455,000, 10,506,000, and 11,557,000 acres (Appendix A). This uncertainty is due largely to uncertainties in position of the 0.8 percent R_o thermal maturity level. The assessment unit is largely untested with only 157 tested cells identified for this vast area for a median percentage of total assessment unit tested of 0.1 percent (Appendix A). Only wells that had drill-stem tests or completions in the Hilliard-Baxter-Mancos interval or that bottomed in the Hilliard-Baxter-Mancos interval were considered tests. Wells drilled to the underlying Frontier Formation are not included as Hilliard-Baxter-Mancos tests because there is no indication that the operators tested for gas in the overlying Hilliard-Baxter-Mancos interval. Of these 157 identified tests, only 12 had established production for a historical success ratio of 8 percent.

Minimum, median, and maximum area per cell of untested cells having potential for additions to reserves in the next 30 years are 20, 80, and 180 acres, respectively (Appendix A). Minimum, median, and maximum percentage of untested area that has potential for additions to reserves in the next 30 years are 2, 14, and 36, respectively.

The Hilliard-Baxter-Mancos Conventional Oil and Gas Assessment Unit (AU 50370401) covers the marginal areas of the Southwestern Wyoming Province (fig. 9) and includes one oil field and eight gas fields above the minimum of 0.5 million barrels of oil equivalent (MMBOE) grown. Median grown size of fields are 7.1 MMBOE for the first half and 10.5 MMBOE for the second half (Appendix B). There were too few fields to subdivide into thirds based on date of discovery. The first field discovered was Bunker Hill in 1937, and the most recent discovery was Craven Creek field in 1974. Thus it has been 28 years since the last field discovery in this conventional AU. All of the fields are on structures around the shallow margins of the basin, and it is likely that most structures have already been discovered. Because of these factors, the potential for future discoveries in this AU are not considered great. Estimates of minimum, median, and maximum number of gas accumulations that will be discovered in the next 30 years are 1, 2, and 4, respectively. Estimates of minimum, median, and maximum grown sizes of these fields are 3, 6, and 50 MMBOE, respectively (Appendix B).

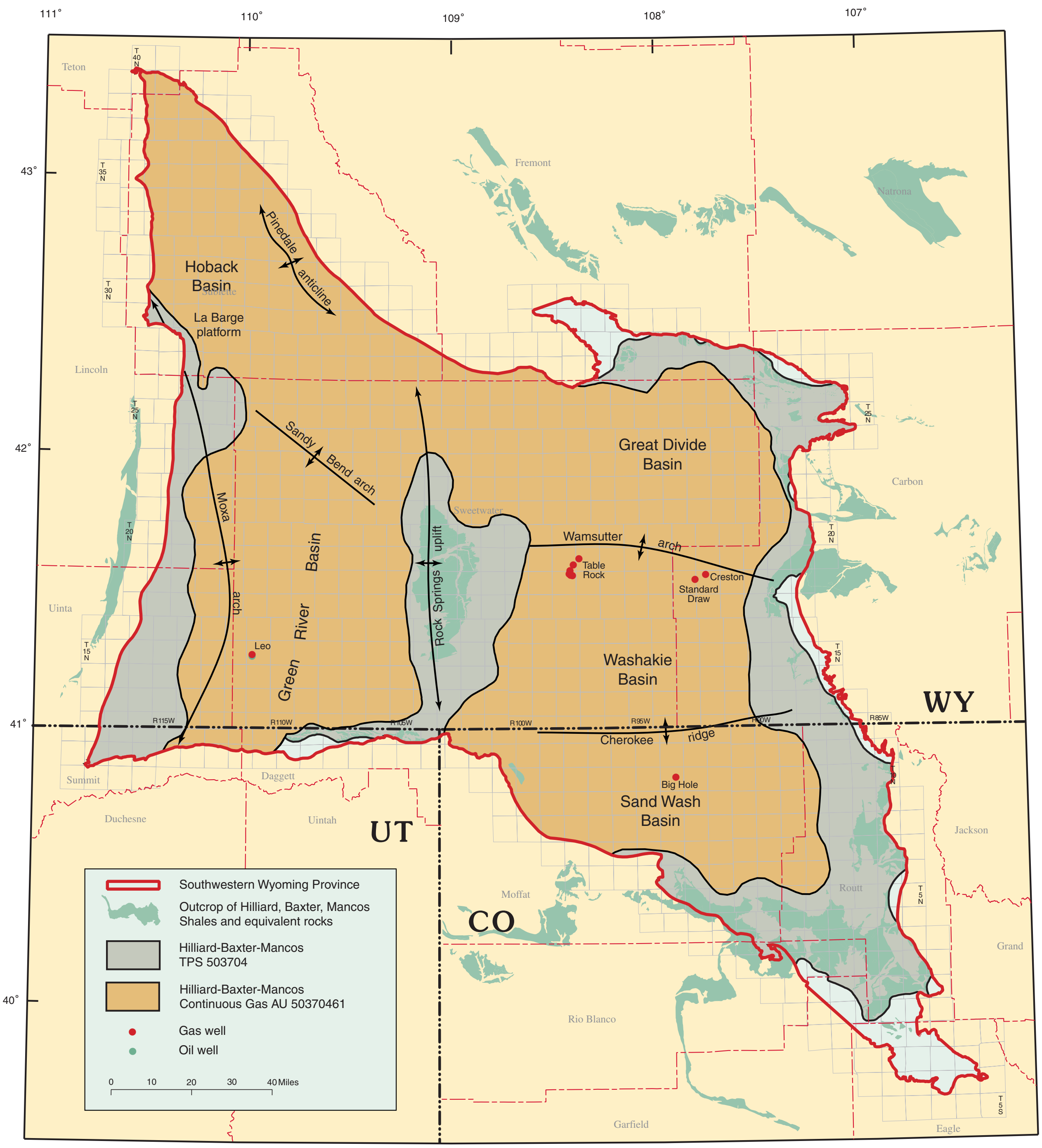


Figure 8. Continuous gas assessment unit in the Hilliard-Baxter-Mancos Total Petroleum System. The assessment unit is defined as that area where thermal maturities exceed a vitrinite reflectance of 0.8 percent at the base of the total petroleum system.

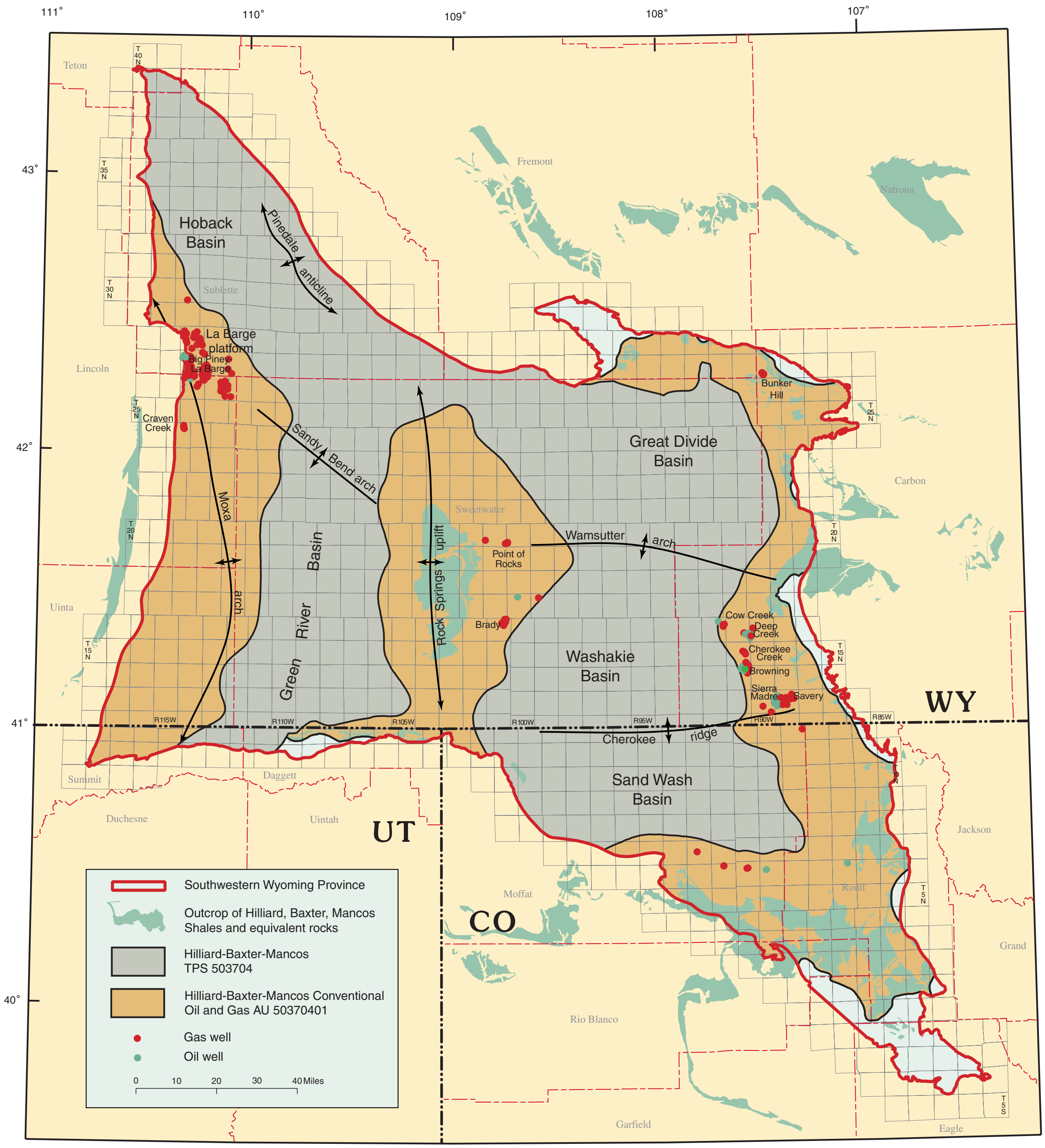


Figure 9. Conventional gas assessment unit in the Hilliard-Baxter-Mancos Total Petroleum System. The assessment unit is defined as that area where thermal maturities are less than a vitrinite reflectance of 0.8 at the base of the total petroleum system.

Summary of Results

Tabulated results of undiscovered oil, gas, and gas liquids in the Hilliard-Baxter-Mancos Total Petroleum System that have the potential for additions to reserves are listed in table 3. Mean estimate of the total gas is 11.77 TCF, and total gas liquids is 753.2 MMBNGL. Of the total gas, 11.753 TCF of gas and 752.2 MMBNGL is in the Hilliard-Baxter-Mancos Continuous Assessment Unit and 15.5 BCF of gas and 1 MMBNGL is in the Hilliard-Baxter-Mancos Conventional Assessment Unit.

Table 3. Tabulated assessment results of undiscovered oil, gas, and gas liquids in the Hilliard-Baxter-Mancos Total Petroleum System that have the potential for additions to reserves.

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Minimum, for conventional resources this is the minimum field size assessed (MMBO or BCFG); for continuous-type resources this is the minimum cell estimated ultimate recovery assessed. Prob., probability (including both geologic and accessibility probabilities) of at least one field (or, for continuous-type resources, cell) equal to or greater than the minimum. Results shown are fully risked estimates. For gas fields, all liquids are included under the natural gas liquids category. 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. 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
Hilliard-Baxter-Mancos TPS													
Hilliard-Baxter-Mancos Conventional Oil and Gas AU	*Gas*					4.60	13.10	31.90	15.50	0.30	0.90	2.10	1.00
Total conventional resources						**4.60**	**13.10**	**31.90**	**15.50**	**0.30**	**0.90**	**2.10**	**1.00**
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
Total continuous resources						**4,895.10**	**10,542.00**	**22,703.40**	**11,753.20**	**286.50**	**661.10**	**1,525.20**	**752.20**

References Cited

Barlow, J.S., Jr., Doelger, M.J., and McCutcheon, T.J., 1994, Accessibility to the Greater Green River Basin gas supply, southwestern Wyoming: Gas Research Institute GRI–94/01363, 185 p.

Dow, W.C., 1977, Kerogen studies and geological interpretations: Journal of Geochemical Exploration, v. 7, p. 79–99.

Higgs, M.D., 1986, Laboratory studies into the generation of natural gas from coals, *in* Brooks, J., Goff, J.C., and Van Hoorn, B., eds., Habitat of Paleozoic gas in northwest Europe: Geological Society Special Publication 23, p. 113–120.

Hunt, J.M., 1979, Petroleum geochemistry and geology: San Francisco, W.H. Freeman and Company, 617 p.

IHS Energy Group, 2001, [includes data current as of December, 2000] PI/Dwights Plus U.S. Production and Well Data: Englewood, Colo., database available from IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO 80112, U.S.A.

Kirschbaum, Mark, Finn, T.M., Hettinger, R.D., Johnson, E.A., Johnson, R.C., Kibler, Joyce, Lillis, P.G., Nelson, P.H., Roberts, L.N. R., Roberts, S.B., Cook, T.A., Crovelli, R.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2002, Assessment of undiscovered oil and gas resources of the Southwestern Wyoming Province, 2002: U.S. Geological Survey Fact Sheet FS–145–02.

Law, B.E., 1984, Relationships of source-rock, thermal maturity, and overpressuring to gas generation and occurrence in low-permeability Upper Cretaceous and lower Tertiary rocks, Greater Green River Basin, Wyoming, Colorado and Utah, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., eds., Hydrocarbon source rocks of the greater Rocky Mountain Region: Rocky Mountain Association of Geologists Guidebook, p. 469–490.

Law, B.E., Spencer, C.W., Charpentier, R.R., Crovelli, R A., Mast, R.F., Dolton, G.L., and Wandrey, C J., 1989, Estimates of gas resources in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah, *in* Eisert, J.L., ed., Gas resources of Wyoming: Wyoming Geological Association Fourteenth Field Conference Guidebook, p. 39–61.

Levine, J.R., 1993, Coalification—The evolution of coal as a source rock and reservoir rock for oil and gas, *in* Law, B.E., and Rice, D.D., eds., Hydrocarbons from coal: American Association of Petroleum Geologists Studies in Geology no. 38, p. 39–76.

Magoon, L.B., and Dow, W.G., 1994, The petroleum system, *in* Magoon, L.B., and Dow, W.G., eds., The petroleum system—From source to trap: American Association of Petroleum Geologists Memoir 60, p. 3–24.

Masters, J.A., 1979, Deep basin gas trap western Canada: American Association of Petroleum Geologists Bulletin, v. 63, no. 2, p. 151–181.

Mellere, D., and Steel, R.J., 1995, Facies architecture and sequentiality of nearshore and 'shelf' sandbodies—Haystack Mountains Formation, Wyoming, USA: Sedimentology, v. 42, p. 551–574.

NRG Associates, 2001, [includes data current as of 1999], The significant oil and gas fields of the United States: Colorado Springs, Colorado, NRG Associates, Inc.; database available from NRG Associates, Inc.; P.O. Box 1655, Colorado Springs, CO 80901, U.S.A.

Roehler, H.W., 1990, Stratigraphy of the Mesaverde Group in the central and eastern Greater Green River Basin, Wyoming, Colorado, and Utah: U.S. Geological Survey Professional Paper 1508, 52 p.

Waples, D.W., 1980, Time and temperature in petroleum formation—Application of Lopatin's method to petroleum exploration: American Association of Petroleum Geologists Bulletin, v. 64, p. 916–926.

Appendix A. Input parameters and calculations of potential additions to reserves for the Continuous Gas Assessment Unit (AU 50370461), Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province

FORSPAN **ASSESSMENT MODEL FOR CONTINUOUS ACCUMULATIONS--BASIC INPUT DATA FORM (NOGA, Version 7, 6-30-00)**

IDENTIFICATION INFORMATION

Assessment Geologist:…	R.C. Johnson and T.M. Finn	Date:	8/23/2002
Region:……………………	North America	Number:	5
Province:………………….	Southwestern Wyoming	Number:	5037
Total Petroleum System:.	Hilliard-Baxter-Mancos	Number:	503704
Assessment Unit:……….	Hilliard-Baxter-Mancos Continuous Gas	Number:	50370461
Based on Data as of:……	IHS Energy Group 2001, Wyoming Oil and Gas Conservation Commission		
Notes from Assessor…..			

CHARACTERISTICS OF ASSESSMENT UNIT

Assessment-Unit type: Oil (<20,000 cfg/bo) **or Gas** (>20,000 cfg/bo) Gas
What is the minimum total recovery per cell?… 0.02 (mmbo for oil A.U.; bcfg for gas A.U.)
Number of tested cells:………… 157
Number of tested cells with total recovery per cell > minimum: ……... 12
Established (>24 cells > min.) ____ Frontier (1-24 cells) X Hypothetical (no cells) ____
Median total recovery per cell (for cells > min.): (mmbo for oil A.U.; bcfg for gas A.U.)
1st third discovered ____ 2nd third ____ 3rd third ____

Assessment-Unit Probabilities:

Attribute	Probability of occurrence (0-1.0)
1. **CHARGE:** Adequate petroleum charge for an untested cell with total recovery > minimum ……	1.0
2. **ROCKS:** Adequate reservoirs, traps, seals for an untested cell with total recovery > minimum.	1.0
3. **TIMING:** Favorable geologic timing for an untested cell with total recovery > minimum………..	1.0

Assessment-Unit GEOLOGIC Probability (Product of 1, 2, and 3):……….........…… 1.0

4. **ACCESS:** Adequate location for necessary petroleum-related activities for an untested cell with total recovery > minimum ……………………………………………………………… 1.0

NO. OF UNTESTED CELLS WITH POTENTIAL FOR ADDITIONS TO RESERVES IN THE NEXT 30 YEARS

1. Total assessment-unit area (acres): (uncertainty of a fixed value)
minimum 9,455,000 median 10,506,000 maximum 11,557,000

2. Area per cell of untested cells having potential for additions to reserves in next 30 years (acres): (values are inherently variable)
calculated mean 85 minimum 20 median 80 maximum 180

3. Percentage of total assessment-unit area that is untested (%): (uncertainty of a fixed value)
minimum 99.8 median 99.9 maximum 100

4. Percentage of untested assessment-unit area that has potential for additions to reserves in next 30 years (%): (a necessary criterion is that total recovery per cell > minimum)
(uncertainty of a fixed value) minimum 2 median 14 maximum 36

Appendix A. Input parameters and calculations of potential additions to reserves for the Continuous Gas Assessment Unit (AU 50370461), Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province.—Continued

Assessment Unit (name, no.)
Hilliard-Baxter-Mancos Continuous Gas, Assessment Unit 50370461

TOTAL RECOVERY PER CELL

Total recovery per cell for untested cells having potential for additions to reserves in next 30 years:
(values are inherently variable)

	minimum	median	maximum
(mmbo for oil A.U.; bcfg for gas A.U.)	0.02	0.4	8

AVERAGE COPRODUCT RATIOS FOR UNTESTED CELLS, TO ASSESS COPRODUCTS
(uncertainty of fixed but unknown values)

Oil assessment unit:	minimum	median	maximum
Gas/oil ratio (cfg/bo)………………………...…….			
NGL/gas ratio (bngl/mmcfg)……………………..….			
Gas assessment unit:			
Liquids/gas ratio (bliq/mmcfg)….……………..…….	32	64	96

SELECTED ANCILLARY DATA FOR UNTESTED CELLS
(values are inherently variable)

Oil assessment unit:	minimum	median	maximum
API gravity of oil (degrees)…………….………….			
Sulfur content of oil (%)………………………...….			
Drilling depth (m) ……………...…………….……			
Depth (m) of water (if applicable)……………….			
Gas assessment unit:			
Inert-gas content (%)…………………………....…..	0.10	1.00	25.00
CO_2 content (%)……………………………….…..	0.10	0.40	0.90
Hydrogen-sulfide content (%)……………...…….	0.00	0.00	0.00
Drilling depth (m)………………………………….	2,100	2,700	4,600
Depth (m) of water (if applicable)……………….			

Success ratios:	calculated mean	minimum	median	maximum
Future success ratio (%)..	40	20	40	60

Historic success ratio, tested cells (%) 8

Appendix B. Input parameters and calculations of potential additions to reserves for the Conventional Gas Assessment Unit (AU 50370401), Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province.

SEVENTH APPROXIMATION
DATA FORM FOR CONVENTIONAL ASSESSMENT UNITS (NOGA, Version 5, 6-30-01)

IDENTIFICATION INFORMATION

Assessment Geologist	R.C. Johnson and T.M. Finn	Date:	8/26/2002
Region:………………	North America	Number:	5
Province:………………	Southwestern Wyoming	Number:	5037
Total Petroleum Syste	Hilliard-Baxter-Mancos	Number:	503704
Assessment Unit:……	Hilliard-Baxter-Mancos Conventional Oil and Gas	Number:	50370401
Based on Data as of:..	NRG 2001 (data current through 1999), IHS Energy Group, 2001, Wyoming Oil and Gas Conservation Commission		
Notes from Assessor..	NRG Reservoir Lower 48 growth function		

CHARACTERISTICS OF ASSESSMENT UNIT

Oil (<20,000 cfg/bo overall) **or** Gas (≥20,000 cfg/bo overall): Gas

What is the minimum accumulation size?…… 0.5 mmboe grown
(the smallest accumulation that has potential to be added to reserves in the next 30 years)

No. of discovered accumulations exceeding minimum siz   Oil: 1   Gas: 8
Established (>13 accums.) ____ Frontier (1-13 accums.) X Hypothetical (no accums.) ____

Median size (grown) of discovered oil accumulation (mmbo):
1st 3rd ____ 2nd 3rd ____ 3rd 3rd ____
Median size (grown) of discovered gas accumulations (bcfg):
1st 3rd 7.1 2nd 3rd 10.5 3rd 3rd ____

Assessment-Unit Probabilities:

Attribute	Probability of occurrence (0-1.0)
1. **CHARGE:** Adequate petroleum charge for an undiscovered accum. ≥ minimum size…..	1.0
2. **ROCKS:** Adequate reservoirs, traps, and seals for an undiscovered accum. ≥ minimum	1.0
3. **TIMING OF GEOLOGIC EVENTS:** Favorable timing for an undiscovered accum. ≥ mini	1.0

Assessment-Unit GEOLOGIC Probability (Product of 1, 2, and 3):………… 1.0

4. **ACCESSIBILITY:** Adequate location to allow exploration for an undiscovered accumulation ≥ minimum size………………………………………… 1.0

UNDISCOVERED ACCUMULATIONS

No. of Undiscovered Accumulations: How many undiscovered accums. exist that are ≥ min. size?:
(uncertainty of fixed but unknown values)

Oil Accumulations:…………………min. no. (>	0	median no. 0	max no. 0
Gas Accumulations:………………min. no. (>	1	median no. 2	max no. 4

Sizes of Undiscovered Accumulations: What are the sizes (**grown**) of the above accums?:
(variations in the sizes of undiscovered accumulations)

Oil in Oil Accumulations (mmbo):……min. size		median size	max. size
Gas in Gas Accumulations (bcfg):……min. size	3	median size 6	max. size 50

Appendix B. Input parameters and calculations of potential additions to reserves for the Conventional Gas Assessment Unit (AU 50370401), Hilliard-Baxter-Mancos Total Petroleum System, Southwestern Wyoming Province.—Continued

Assessment Unit (name, no.)
Hilliard-Baxter-Mancos Conventional Oil and Gas, Assessment Unit 50370401

AVERAGE RATIOS FOR UNDISCOVERED ACCUMS., TO ASSESS COPRODUCTS
(uncertainty of fixed but unknown values)

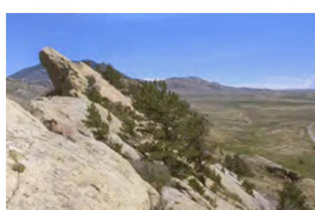
Oil Accumulations:	minimum	median	maximum
Gas/oil ratio (cfg/bo)			
NGL/gas ratio (bngl/mmcfg)			

Gas Accumulations:	minimum	median	maximum
Liquids/gas ratio (bliq/mmcfg)	32	64	96
Oil/gas ratio (bo/mmcfg)			

SELECTED ANCILLARY DATA FOR UNDISCOVERED ACCUMULATIONS
(variations in the properties of undiscovered accumulations)

Oil Accumulations:	minimum	median	maximum
API gravity (degrees)			
Sulfur content of oil (%)			
Drilling Depth (m)			
Depth (m) of water (if applicable)			

Gas Accumulations:	minimum	median	maximum
Inert gas content (%)	0.10	1.00	25.00
CO_2 content (%)	0.10	0.40	0.90
Hydrogen-sulfide content (%)	0.00	0.00	0.00
Drilling Depth (m)	300	1,500	2,400
Depth (m) of water (if applicable)			



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