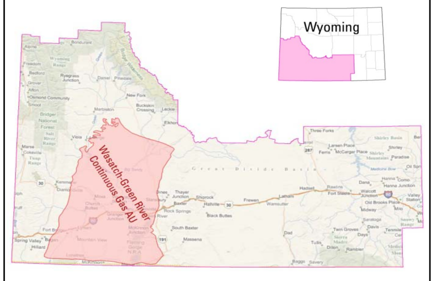
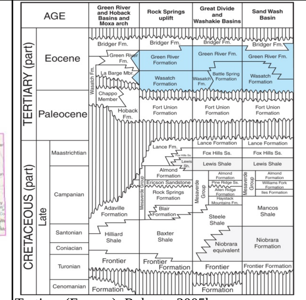
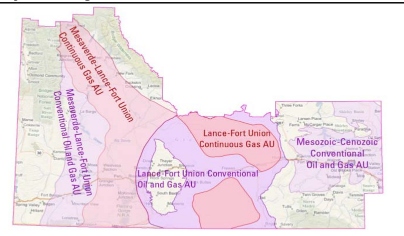
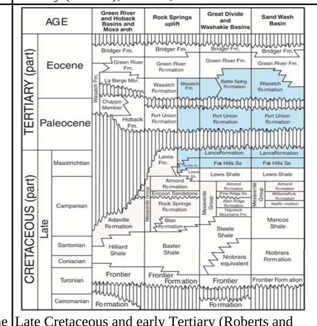
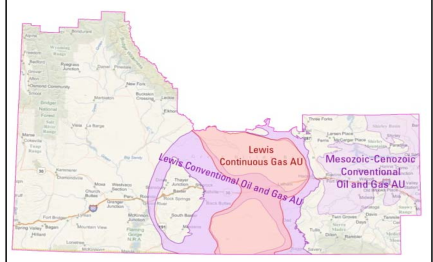
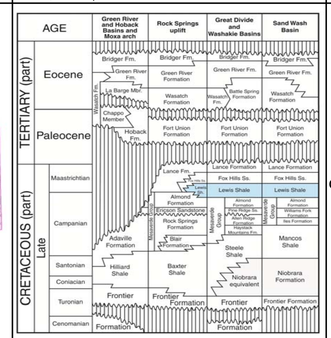
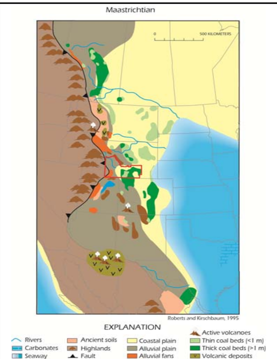
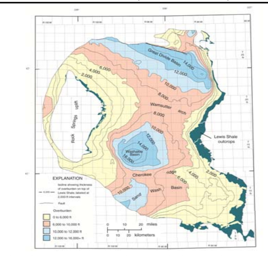
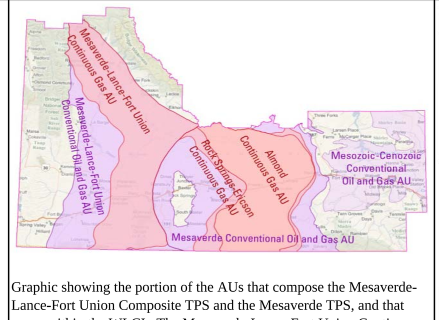
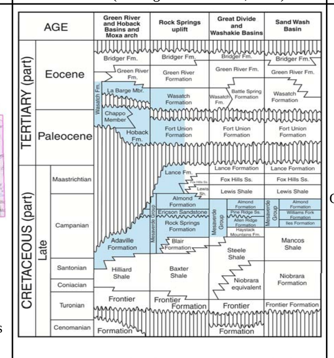
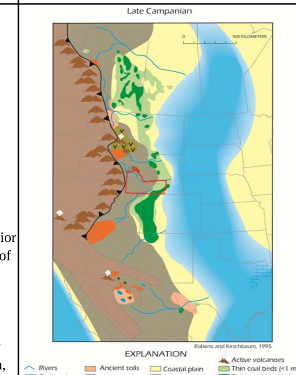
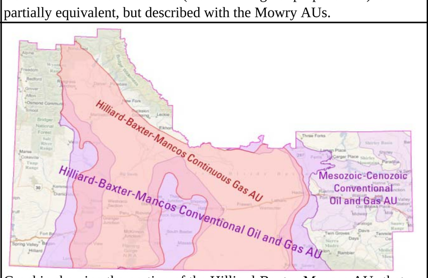
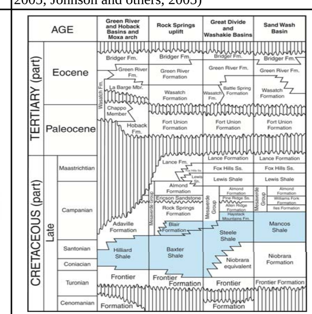
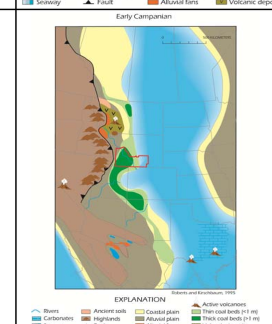
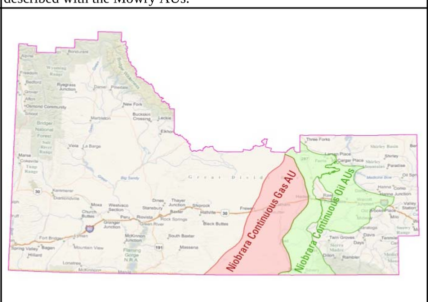
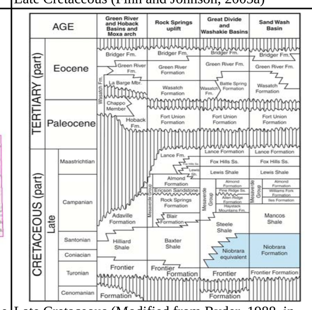
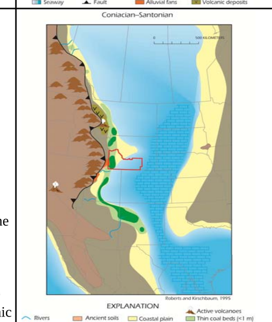
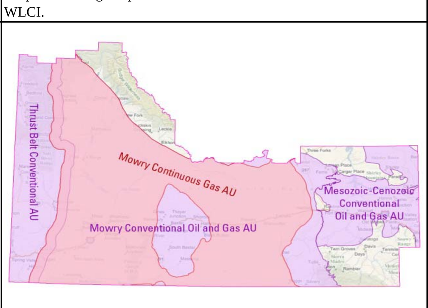
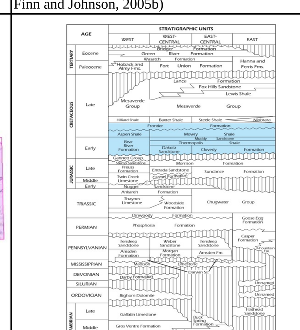
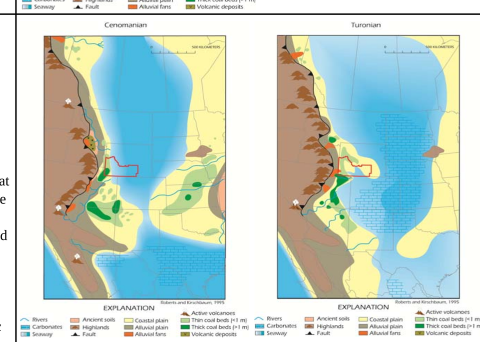
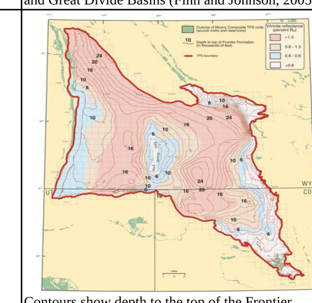
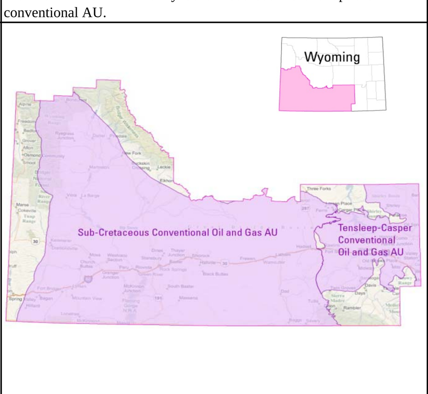
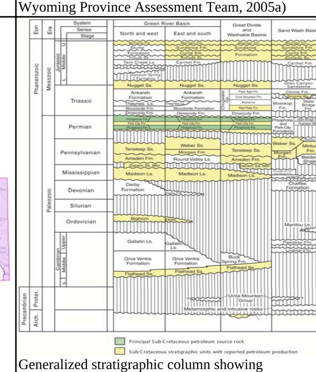
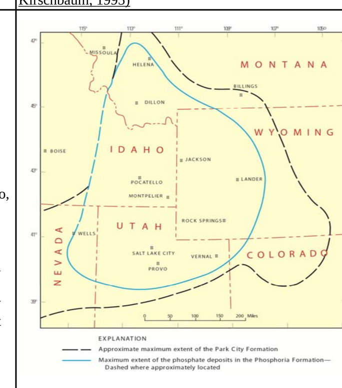
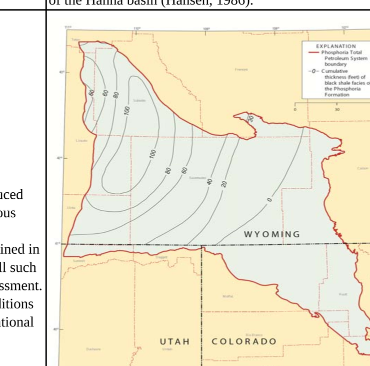
U.S. Department of the Interior
U.S. Geological Survey

Oil and Gas Assessment Unit (AU)		Age (stratigraphic interval highlighted in blue)	Basin	Depositional Environment	Paleogeography	Formation Depths	Source Rocks	Total Organic Carbon (TOC)	Thermal Maturity	Traps and Seals	Reservoir Lithology	Resources	Thickness
Wasatch–Green River Continuous Gas Assessment Unit (AU) (hypothetical) (Roberts, 2005b). The Wasatch–Green River Coalbed Gas AU is described separately in Part A of the Energy Map of Southwestern Wyoming (Biewick and Jones, 2012).	 Graphic showing the Wasatch–Green River Continuous Gas AU.	 Tertiary (Eocene); Roberts, 2005b	Greater Green River	The Wasatch and Green River Formations reflect the intertonguing of alluvial and lacustrine facies. Alluvial facies (for example, fluvial sandstone, flood-plain shale, and coal) are more predominant in the Wasatch Formation and lacustrine facies (for example, oil shale, evaporites, and carbonates) are more characteristic of the Green River Formation (Roberts, 2005b).	Map showing ancient landscapes of North America during the Paleogene Subperiod, Eocene Epoch (50 Ma) used with permission from Blakey, 2010.	Data from 28 wells drilled southwest of the town of Green River, Wyoming, primarily in T. 17 N., R. 107-108 W., indicate that tested intervals in the Wilkins Peak Member of the Green River Formation range in depth from 1,000 to 2,000 ft (Wyoming Oil and Gas Conservation Commission (WOGCC), 2002).	Potential source rocks in the Wasatch–Green River Continuous Gas AU are organic-rich lacustrine shale and mudstone in the Green River Formation. Lacustrine source rocks contain Type-I and mixed Type-I and Type-III kerogen in strata deposited in lake environments of varying water depths and salinities (Roberts, 2005b).	Total organic carbon (TOC) values for Wilkins Peak organic-rich lithologies range from 4.1 to 20.0 weight percent. Total organic carbon values are generally lowest in littoral and marginal lacustrine mudstone and highest in sublittoral mudstone and shale, indicating that highest organic enrichment took place when the lakes were deepest. Overall TOC values for Laney Member samples range from about 1.5 to 30 weight percent. Profundal lime mudstones enriched in Type-I kerogen (anoxic lakes) in the Laney Member have up to 30 weight percent TOC, whereas littoral shales have mixed Types-I and III kerogen and TOC values of about 7 weight percent. Total organic carbon values in the LaClede Bed in the lower part of the Laney Member (Roehler, 1992) are reported to be as high as 20 weight percent (Carroll and Bohacs, 2001, Grabowski and Bohacs, 1996).	Coalbeds and lacustrine units sampled from outcrops and shallow drill holes in the Composite TPS have measured thermal maturity (R_o) values generally ranging from 0.20 to 0.61 percent. In most areas of the Composite TPS, the low thermal maturity of these source rocks will limit the potential for thermogenic oil or gas accumulations. However, because of the widespread occurrence of these organic-rich source rocks, a potential exists for the generation and accumulation of biogenic (microbial) gas (Roberts, 2005b).	A common characteristic of biogenic gas accumulations is that source rocks also serve as primary reservoirs. Organic-rich, lacustrine shale in the Green River Formation could also be considered as a primary reservoir for biogenic shale-gas accumulation. Evaporites (for example, trona), which are interbedded with some oil-shale beds in certain areas of the Composite TPS, as well as impermeable, clay-rich units that are common in Green River rocks might form effective seals. Typically, traps in shale-gas systems are subtle, and gas-charged strata are anticipated to cover a large geographic area (Roberts, 2005b).	Although other lacustrine intervals in the Green River Formation in this area (Luman Tongue and Laney Member) might also have a similar potential for biogenic gas generation, the assessment unit was restricted to the Wilkins Peak Member, primarily because exploration and production test data (WOGCC, 2002) related solely to this interval. The Wilkins Peak Member is noted for an abundance of saline minerals and bedded trona deposits within a succession characterized primarily by sandstone, siltstone, mudstone, clay-shale, and oil shale; beds of marlstone, algal limestone, and clay pebble conglomerate are present locally (Bradley, 1964; Roehler, 1992).	Formulation of this assessment unit stemmed from exploration and production tests for gas in the Wilkins Peak Member of the Green River Formation; this potential resource was considered to represent a self-sourced, biogenic shale-gas accumulation. Because exploration for gas in the Wilkins Peak Member was in such an early stage, no quantitative assessment of undiscovered gas resources in the Wasatch–Green River Continuous Gas Assessment Unit was completed (Roberts, 2005b).	Estimates of the combined thickness of the Wasatch and Green River Formations in selected wells in the Green River Basin range from about 3,000 to 6,200 ft; in the deep Washakie Basin, the combined thickness is estimated to be about 8,050 ft (L.N.R. Roberts, USGS, oral commun., 2003). Because of facies variations and intertonguing relations, the thickness of individual units within both formations varies markedly throughout the province (Roberts, 2005b).
Continuous Gas and Conventional Oil and Gas AUs that compose the Lance–Fort Union Composite Total Petroleum System (TPS) (Roberts and others, 2005a). The Lance and the Fort Union Coalbed Gas AUs are described separately in Part A of the Energy Map of Southwestern Wyoming (Biewick and Jones, 2012).	 Graphic showing the portion of the AUs that compose the Lance-Fort Union Composite TPS within the WLCI. The Mesaverde-Lance-Fort Union AUs and Mesozoic-Cenozoic Conventional Oil and Gas AU (drawn more transparent) are partially equivalent, but described with the Mesaverde Group and the Mowry AUs, respectively).	 Late Cretaceous and early Tertiary (Roberts and others, 2005a)	Greater Green River	The stratigraphic interval from the Lewis Shale through the Lance Formation generally represents a transition from offshore marine environments (Lewis Shale) and shoreface or marginal-marine environments (Fox Hills Sandstone) to a coastal-plain and fluvial/alluvial depositional setting (Lance Formation) as the Western Interior Seaway retreated from the region during the latest Cretaceous (for example, see Roberts and Kirschbaum, 1995). The Fox Hills Sandstone is generally considered the uppermost regressive, shoreface sandstone succession deposited during final retreat of the seaway (Roberts, 2005a). The Fort Union Formation was described by Roberts (2005a), as fluvial and alluvial deposition coincident in part with Laramide structural development of the basins and uplifts that are present within and surrounding the Southwestern Wyoming Province. Coals were deposited in lower coastal-plain depositional settings (Finn and others, 2005). The Wasatch Formation was similarly deposited primarily in a fluvial/alluvial depositional setting during the latter stages of the Laramide orogeny (Roberts, 2005a).	Map showing ancient landscapes of North America during the Paleogene Subperiod, Paleocene Epoch (60 Ma) used with permission from Blakey, 2010.	Depths to the base of the Lance–Fort Union Composite TPS exceed 14,000 ft in the Washakie and Great Divide Basins (Roberts, 2005a).	Coal and carbonaceous shale 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 are composed of humic, Type-III organic matter, and are considered to be gas-prone (Roberts, 2005a).	Total organic carbon (TOC) in non-coal rocks with source-rock potential in Upper Cretaceous and Tertiary strata in the Southwestern Wyoming Province averages about 2.04 weight percent (Law, 1984), and TOC values from six non-coal samples in the Fox Hills Sandstone and Lance and Fort Union Formations range from 1.35 to 6.82 weight percent (Roberts, 2005a).	Source rocks in the basal part of the Lance Formation have reported thermal maturity (R_o) values ranging from less than 0.50 percent to more than 1.60 percent, based on direct measurements of R_o from Lance coal and carbonaceous shale beds, or extrapolated from vitrinite reflectance values for the top of the Lewis Shale. Measured R_o values for coal and carbonaceous shales near the base of the Fort Union Formation range from less than 0.50 percent to about 1.53 percent. Within the Composite TPS, the highest reported R_o values for the Lance and Fort Union Formations were measured at depths from about 12,000 to 13,000 feet in the deep, south-central part of the Washakie Basin (Roberts, 2005a).	Primary traps for hydrocarbon accumulation of thermogenic gas and oil in the Lance–Fort Union Composite TPS include structural, stratigraphic, or combined structural-stratigraphic traps associated with relatively shallow (less than 8,000 ft deep) conventional accumulations, and stratigraphic traps and the process of water block associated with deeper, basin-centered gas accumulations. Retention of gas in coalbed reservoirs may depend to some degree on "hydrologic" traps, whereby contained water and associated hydrostatic pressure within the coal prohibits desorption and leakage of coalbed gas; impermeable lithologies in contact with coal beds could also help to seal free gas within fractures and coal cleats (Roberts, 2005a).	The Fox Hills Sandstone is characterized by coarsening-upwards successions of shale and fine-grained sandstone (Hettinger and others, 1991); thin coal beds are present locally. Shoreface sandstone beds within the formation are potential reservoirs for hydrocarbon accumulation throughout the Composite TPS. The overlying Lance Formation includes hydrocarbon source rocks (especially coal) and potential hydrocarbon reservoirs in fluvial sandstones. A regional unconformity separates Upper Cretaceous and lower Tertiary strata within the Composite TPS, and is identified by a conglomeratic horizon in the uppermost part of the "unnamed Cretaceous-Tertiary sandstone unit" of Hettinger and others (1991), which separates the Lance and Fort Union Formations; the conglomerate is generally within 100–200 ft of the base of the Fort Union. The Fort Union contains potential source rocks (primarily coal) and fluvial sandstone reservoir rocks. The Wasatch and Battle Spring Formations contain fluvial and possibly marginal lacustrine rocks that are potential reservoirs for the accumulation of migrated hydrocarbon (Roberts, 2005a).	The Lance–Fort Union Composite TPS contains undiscovered gas resources in continuous accumulations (basin-centered gas and coalbed-gas resources) and gas and oil resources in shallow conventional accumulations. A mean of about 7.6 trillion cubic feet (TCF) is included in the Lance–Fort Union Continuous Gas Assessment Unit, and a mean estimate of about 0.25 TCF of undiscovered gas is included in the Lance–Fort Union Conventional Oil and Gas Assessment Unit. Undiscovered natural gas resources in the Lance–Fort Union Composite TPS represent about 10 percent of the mean estimated total of 84.6 TCF of gas in the Southwestern Wyoming Province (Roberts, 2005a).	The Fox Hills Sandstone is generally less than 200 ft thick in outcrops along the eastern Great Divide and Washakie Basins (Gill and others, 1970), and in the subsurface, locally exceeds 300 ft in thickness. The overlying Lance Formation varies in thickness from 1,000 to 2,000 ft in the Washakie Basin, to more than 5,000 ft in deeper parts of the Great Divide Basin. The combined thickness of the Fort Union Formation and the unnamed Cretaceous-Tertiary sandstone unit varies from about 1,300 ft or less in the southern Sand Wash Basin, to more than 4,500 ft in the central Washakie Basin and in deeper areas of the Great Divide Basin (Roberts, 2005a).
The Lewis TPS is interpreted to contain both continuous and conventional hydrocarbon accumulations. The continuous accumulation is the Lewis Continuous Gas AU and is located in deeper basin areas that are characterized by an overpressured, gas-saturated, basin-centered system. Conventional accumulations are in the Lewis Conventional Oil and Gas AU and are located in shallower basin areas where hydrocarbons have migrated from the overpressured zone and accumulated in conventional stratigraphic or structural traps (Hettinger and Roberts, 2005).	 Graphic showing the portion of the Lewis AUs that occur within the WLCI. The Mesozoic-Cenozoic Conventional Oil and Gas AU (drawn in a lighter purple shade) is partially equivalent, but described with the Mowry AUs.	 Late Cretaceous (Hettinger and Roberts, 2005)	Greater Green River	The Campanian and Maastrichtian Lewis Shale was deposited during the final transgressive-regressive phase of the Western Interior Seaway and during the early part of the Laramide orogeny (Perman, 1990). The Lewis TPS within the Southwestern Wyoming Province is a complex of marine strata that contains significant quantities of gas sourced from dominantly Type-III kerogen. The source rock, reservoir rock, and seals are distributed throughout most of the Maastrichtian part of the Lewis Shale, which was deposited from about 71 to 68 million years ago (Ma) in the eastern half of the Greater Green River Basin. The Lewis Shale is dominated by offshore marine strata. Previous investigations reveal that the sandstone reservoirs have a net thickness of as much as 600 feet. The sandstones were deposited in deltaic and turbidite systems, and some basin-floor sand lobes extend across as many as 30 townships (Hettinger and Roberts, 2005).	 Maastrichtian Paleogeography of the Late Cretaceous of the Western Interior (Roberts and Kirschbaum, 1995)	 In the deepest parts of the Washakie and Great Divide Basins, the base of the Lewis was drilled at depths of about 16,900 ft. Data compiled by the IHS Energy Group (2001) indicate that production depths range from about 2,400 to 17,200 ft (Hettinger and Roberts, 2005).	The source rock, reservoir rock, and seal rocks are distributed throughout most of the Maastrichtian part of the Lewis Shale. Gas-charged sandstones in the Lewis are generally considered to have been sourced by mudrock in the Lewis Shale (Law, 1996). Principal reservoirs are turbidite sandstones in the Dad Sandstone Member. Additional production has also been reported from the lower part of the Lewis (Hettinger and Roberts, 2005).	Values of total organic carbon (TOC) in the Lewis Shale have been measured from a limited number of core samples (Law, 1984; Pyles, 2000; Zainal, 2001). In the Great Divide Basin, core samples from the Amoco Production Company Champlin 276–D–1 well (sec. 13, T. 19 N., R. 92 W.) show that the Asquith marker zone has TOC values that range from 1.68 to 3.15 weight percent (Pyles, 2000). Law (1984) reported TOC values for additional mudrock intervals in Lewis Shale in the Great Divide and Sand Wash Basins; 15 core samples from 5 wells had TOC values that ranged from 0.55 to 2.86 weight percent and averaged 1.33 weight percent (Hettinger and Roberts, 2005).	Areas of thermal maturity in the Lewis TPS are depicted by isoreflectance contours at the base and top of the Lewis Shale in Hettinger and Roberts (2005). The isolines generally parallel the structural configuration of the basins and increase toward the basin centers, owing to greater burial depths and temperatures. R_o values range from less than 0.6 percent near the basin margins to as much as 1.1 percent in the Sand Wash Basin, 1.6 percent in the Great Divide Basin, and 2.0 percent in the Washakie Basin. Lewis Shale source rock is therefore considered to be thermally mature across large parts of the Lewis TPS (Hettinger and Roberts, 2005).	The basin-centered gas system extends across lithologic and stratigraphic boundaries and has no recognizable seal (Law and others, 1989). A water-block (capillary) trap, however, may form a seal that extends over the basin-centered accumulation (Masters, 1979; Law, 2002). Water-block traps develop as water is expelled from the low-permeability overpressured system and forced updip into overlying strata. Masters (1979) demonstrated that at 65-percent water saturation, rock is nearly impervious to gas flow in low-permeability strata. The proposed water trap in the Lewis TPS initiated at the time of peak gas generation (about 52 Ma, early Eocene) and expanded to its maximum size when the Lewis Shale attained its maximum burial, about 5 Ma (Hettinger and Roberts, 2005).	Field reports described in Cardinal and Stewart (1979) and Miller and others (1992) show Lewis Shale production is from very fine to fine-grained and some medium-grained sandstone, with pay thicknesses ranging from about 5 to 100 ft for individual fields. Hydraulic fracturing is commonly required for commercial production in reservoirs that have in-situ permeability less than 0.1 millidarcies (mD; Law and others, 1989).	Between 600 and 675 billion cubic feet of gas (BCFG) and minor amounts of oil have been produced since 1974. In area, about 18 to 69 percent of the Lewis Continuous Gas AU has potential for additions to reserves in the next 30 years. These areas are estimated to contain between about 8,765 and 19,667 BCFG, with a calculated mean of about 13,536 BCFG. Gas discoveries in the next 30 years are likely to be similar in size to historical discoveries, but success ratios are expected to be significantly higher owing to improved exploration strategies, improved completion techniques, and an improved understanding of the basin-centered system. In contrast, most of the significant hydrocarbon accumulations in the Lewis Conventional Oil and Gas Assessment Unit might have already been found. However, in the next 30 years, the conventional assessment unit has the potential to provide between about 104 and 304 BCFG, with a calculated mean of about 195 BCFG (Hettinger and Roberts, 2005).	The Lewis Shale is about 2,100 to 2,300 ft thick along the eastern margin of the Washakie and Great Divide Basins, and gradually thins to the north and west, toward its depositional pinch-out near the Rock Springs and Granite Mountains uplifts (Hettinger and Roberts, 2005).
Continuous Gas, and Conventional Oil and Gas AUs that compose the Mesaverde–Lance–Fort Union Composite Total Petroleum System (Finn and others, 2005) and the Mesaverde TPS (Johnson and others, 2005). Mesaverde coalbed gas AUs are described separately in Part A of the Energy Map of Southwestern Wyoming (Biewick and Jones, 2012).	 Graphic showing the portion of the AUs that compose the Mesaverde-Lance-Fort Union Composite TPS and the Mesaverde TPS, and that occur within the WLCI. The Mesaverde-Lance-Fort Union Continuous Gas AU overlaps the conventional AU. The Mesozoic-Cenozoic Conventional Oil and Gas AU (drawn in a lighter purple shade) is partially equivalent, but described with the Mowry AUs.	 Late Cretaceous and early Tertiary (Finn and others, 2005; Johnson and others, 2005)	Greater Green River	The Campanian-age Rock Springs, Allen Ridge, Iles, and Williams Fork Formations of the Mesaverde Group are a complex interval deposited in marginal marine and coastal-plain settings along the western margin of the Cretaceous Western Interior Seaway (Roehler, 1990). The fluvial Ericson Sandstone overlies the Rock Springs Formation and was deposited during maximum regression of the Cretaceous seaway in southwestern Wyoming prior to the Lewis transgression (Johnson and others, 2005). West of the pinchout of the Lewis Shale, the Mesaverde-Lance-Fort Union Composite is considered one TPS because all of the units were deposited in a nonmarine continental setting and contain similar gas-prone source rocks, and because there is no regional seal within the entire stratigraphic succession to inhibit the vertical migration of gas (Finn and others, 2005). In the Hanna, Laramie, and Shirley Basins Province, Mesaverde strata are primarily marine (Dyman and Condon, 2007).	 Late Campanian Paleogeography of the Late Cretaceous of the Western Interior (Roberts and Kirschbaum, 1995)	The depth to the top of the Mesaverde in the Greater Green River Basin ranges from 0 ft at the outcrop on the Rock Springs uplift and the eastern edge of the Southwestern Wyoming Province, to greater than 16,000 ft in the Washakie and Great Divide Basins. Evidence of expulsion of oil from Almond Formation coals occurs at depths of from 9,000 to 12,000 ft at R_o levels of 0.90 to 1.45 percent. Most production from the Almond Formation to date is from areas where reservoirs are at depths of less than 11,000 ft, and most major marine bar sandstones at these depths have been extensively explored and produced (Johnson and others, 2005). In the northern part of the Hanna Basin, Mesaverde coals are deep, and steep dips and faults are encountered in wells. The Mesaverde was not reached at 19,600 ft in the Anadarko Petroleum Durante 11–2 well (Dyman and Condon, 2007).	Coals and carbonaceous shales are presumed to be the primary source for gas and oil in both the Mesaverde TPS and the Composite TPS (Law, 1984); however, there is no effective seal between both TPS and the underlying Hillard-Baxter-Mancos TPS, and it is likely that some of the gas in these TPS systems originated from marine shale source rocks in the underlying Hilliard-Baxter-Mancos TPS (Finn and others, 2005). Mesaverde source rocks contain mainly Type-III organic matter which generates gas during maturation. Some Type-II organic matter, which generates both gas and oil, is also present because of the large oil fields producing from the Mesaverde TPS (Johnson and others, 2005). The Mesaverde Group gas-prone coal and carbonaceous shale are also potential source rocks in the Hanna, Laramie, and Shirley Basins Province.	Average TOC values for Mesaverde coals and carbonaceous shales range from 1.3 to 4.9 weight percent from Bierei's (1987) analyses.	Thermal maturities, based on R_o values, of the Mesaverde TPS are greater than 2.2 percent in the deepest part of the Washakie Basin and greater than 2.0 percent in the deepest part of the Great Divide Basin. Thermal maturities at both the top and base of the Mesaverde are about 0.6 percent along the margins of the basin (Johnson and others, 2005). Thermal maturities of the Rock Springs and equivalent Adaville Formations, the stratigraphically lowest unit in the Composite TPS, range from less than 0.6 percent along the Rock Springs uplift in the east and the Moxa arch in the west, to more than 2.0 percent along the deep trough of the Hoback Basin. Thermal maturities at the base of the Fort Union Formation and equivalent strata range from less than 0.6 percent along the Rock Springs uplift and Moxa arch to greater than 0.8 percent along the deep troughs of the Green River and Hoback Basins (Finn and others, 2005). Critical R_o levels include 0.5 percent, which is approximately where hydrocarbon generation begins (Waples, 1980), 0.8 percent, the approximate level where widespread overpressuring due to gas generation occurs in the Southwestern Wyoming Province (Law, 1984), 1.1 percent, the approximate level where significant expulsion of hydrocarbons from coals begins (Levine, 1993), and 1.35 percent, where oil begins to crack into gas (Dow, 1977).	The Lewis Shale overlies the Mesaverde Group, pinches out along the west flank of the Rock Springs uplift, and forms a regional seal separating the Mesaverde Total Petroleum System from the overlying Lewis Total Petroleum System. West of the pinch-out, there is no regional seal separating the Mesaverde Total Petroleum System from overlying continental rocks of Late Cretaceous and Paleocene age, and the Mesaverde Group is combined with the overlying Upper Cretaceous Lance and Paleocene Fort Union Formations to form the Mesaverde–Lance–Fort Union Composite Total Petroleum System (Johnson and others, 2005). The upper limit of the Composite TPS is placed at the base of the lowest regionally extensive lacustrine shale seal in the Wasatch or Green River Formation (Finn and others, 2005)	The Mesaverde TPS in the Southwestern Wyoming Province produces hydrocarbons from sandstone and coal reservoirs in the Upper Cretaceous Mesaverde Group. Reservoir rocks are fluvial sandstones, found throughout the Mesaverde Group, marginal marine sandstones in the Almond Formation and lower part of the Rock Springs Formation, and coalbeds throughout the Mesaverde Group (Johnson and others, 2005). In the Composite TPS, reservoir rocks are mainly fluvial sandstones, found throughout the Rock Springs, Adaville, Ericson, Lance, and Fort Union Formations and lower part of the Wasatch Formation, marginal marine sandstones in the Almond Formation and lower part of the Rock Springs and Adaville Formations, and coalbeds in the Rock Springs Formation, Almond Formation equivalent, and Fort Union Formation (Finn and others, 2005).	For the Mesaverde TPS, the mean estimate for undiscovered total oil is 2.30 million barrels of oil (MMBO), and the mean estimate of total gas liquids is 347.40 million barrels of natural gas liquids (MMBNGL). For gas, 13.35 TCFG is in the Almond Continuous Gas AU, 12.18 TCFG is in the Rock Springs–Ericson Continuous Gas AU, and 55.7 BCFG is in the Mesaverde Conventional Oil and Gas AU. All of the undiscovered oil is in the Mesaverde Conventional Oil and Gas Assessment Unit (Johnson and others, 2005). For the Mesaverde-Lance-Fort Union Composite TPS, the Continuous AU is estimated to contain a mean of 13.635 TCFG and 613.6 MMBNGL, and the Conventional AU is estimated to contain a mean of 2.3 MMBO, 320.2 BCFG and 14.4 MMBNGL that have the potential for additions to reserves in the next 30 years (Finn and others, 2005).	Coal and associated organic-rich shales are present in all stratigraphic units in the Mesaverde TPS; total coal thicknesses of more than 100 ft are present in the Rock Springs Formation northeast of the Rock Springs uplift (Tyler and others, 1995). The interval from the top of the Ericson Formation to the top of the Lance Formation is less than 1,000 ft thick in the Green River Basin and Moxa arch and is completely missing on the La Barge platform but thickens in the Hoback Basin toward the Wind River Range to over 5,000 ft (Finn and others, 2005). The Fort Union Formation averages about 2,000 ft thick in much of the Green River Basin and on the Moxa arch and thickens to more than 6,000 ft toward the trough of the Green River Basin just southwest of the Wind River Range (McDonald, 1972; Gries and others, 1992).
Hilliard-Baxter-Mancos Continuous Gas and Conventional Oil and Gas AUs (Finn and Johnson, 2005a).	 Graphic showing the portion of the Hilliard-Baxter-Mancos AUs that occur within the WLCI. The Mesozoic-Cenozoic Conventional Oil and Gas AU (drawn in a lighter purple shade) is partially equivalent, but described with the Mowry AUs.	 Late Cretaceous (Finn and Johnson, 2005a)	Greater Green River	The Hilliard-Baxter-Mancos Shale 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 (Finn and Johnson, 2005a).	 Early Campanian Paleogeography of the Late Cretaceous of the Western Interior (Roberts and Kirschbaum, 1995)	Depth to the base of the Hilliard-Baxter-Mancos Total Petroleum System are as great as 24,000 ft (Finn and Johnson, 2005a).	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 (Finn and Johnson, 2005a).	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 weight 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 (Finn and Johnson, 2005a).	Roberts and others (2005) applied time-temperature modeling to estimate the timing of hydrocarbon generation of Type-III organic matter. Time-temperature modeling reconstructs the maturation of organic matter through time as a result of burial and heating. 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 (Finn and Johnson, 2005a).	Conventional traps include anticlines and the stratigraphic pinch-out of sandstone into 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 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).	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). In most cases, these reservoirs are encased in marine shale. Sandstone reservoirs range in size from single sandstone 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 (Finn and Johnson, 2005a).	This TPS has been sparsely explored, but a few promising discoveries have been made. For the 2002 USGS assessment in the Southwestern Wyoming Province, the Hilliard-Baxter-Mancos Continuous Gas AU is estimated to contain a mean of 11.753 TCFG and 752.2 MMBNGL, and the Hilliard-Baxter-Mancos Conventional Oil and Gas AU is estimated to contain a mean of 15.5 BCFG and 1 MMBNGL that has the potential for additions to reserves in the next 30 years (Finn and Johnson, 2005a).	The stratigraphic interval included in the Hilliard-Baxter-Mancos TPS ranges from about 3,500 to 6,000 ft thick and contains thick intervals of marine shales that are potential source rocks and thick silty and sandy nearshore to offshore marine intervals that are potential reservoir rocks (Finn and Johnson, 2005a).
Niobrara Continuous AUs (Finn and Johnson, 2005b; Dyman and Condon, 2007).	 Graphic showing the portion of the Niobrara Continuous AUs within the WLCI.	 Late Cretaceous (Modified from Ryder, 1988, in Finn and Johnson, 2005b)	Greater Green River and Hanna	The Niobrara Formation and equivalents were deposited during a major Late Cretaceous marine transgressive cycle that created conditions favorable for the deposition of fine-grained marine carbonate rocks and the preservation of organic matter (Finn and Johnson, 2005b). Source rocks of appropriate organic carbon content and sufficient thermal maturity to generate hydrocarbons, primarily the Smoky Hill Shale Member of the Niobrara, were deposited in anoxic bottom conditions favorable for the preservation of organic matter (Dyman and Condon, 2007).	 Coniacian-Santonian Paleogeography of the Late Cretaceous of the Western Interior (Roberts and Kirschbaum, 1995)	In the Southwestern Wyoming Province (SWWP), producing intervals range in depth from 1,200 to nearly 10,000 ft (Finn and others, 2005). In the Hanna Basin, drilling depths to the top of the Niobrara range from 310 to 10,198 ft (Dyman and Condon, 2007). Little exploration has taken place within the Niobrara Continuous Gas AU because throughout most of the AU the Niobrara occurs at depths ranging from 12,000 to greater than 22,000 ft in the deep troughs of the Sand Wash, Washakie, and Great Divide Basins (Finn and Johnson, 2005a).	The Niobrara Total Petroleum System (TPS) is a self-sourced system that produces oil and natural gas from fractured carbonate rock reservoirs in the Upper Cretaceous Niobrara Formation and equivalent rocks of the Southwestern Wyoming Province (Finn and Johnson, 2005b). The Niobrara has been subdivided into a lower Fort Hays Limestone Member composed of limestone, shale, and minor sandstone and siltstone and an upper Smoky Hill Shale Member that is chalky and marly (Dyman and Condon, 2007). The best Niobrara source rocks are the Smoky Hill marls, which were deposited on an anoxic substrate in areas largely devoid of clastic sediments in the central part of the Western Interior Seaway (Longman and others, 1998; Landon and others, 2001; Finn and Johnson, 2005b).	Within the Western Interior Basin, Niobrara TOC ranges from 0.2 to 7.6 weight percent; the best values lie east of the Hanna, Laramie, and Shirley Basins Province in the area of Silo field in Laramie County, Wyoming, in the northern Denver Basin (Landon and others, 2001). Average TOC for the Hanna Basin is 2.14 weight percent, and the high percentage of chalk in the Niobrara indicates minor clastic dilution from western sources (Landon and others, 2001). TOC ranges from 0.85 to 2.75 weight percent in 28 samples from equivalent strata in the Southwestern Wyoming Province, the majority of which contain Type II oil-prone kerogen with some mixing from Type III gas-prone kerogen, especially in the western part of that province (Finn and Johnson, 2005b).	Thermal maturities range from less than 0.60 percent R_o along the eastern and southern flanks of the Greater Green River Basin to greater than 1.35 percent R_o in deeper parts of the basin (Finn and Johnson, 2005b). The continuous oil assessment unit is an established assessment unit located in the updip parts of the eastern and southern flanks of the basin where thermal maturities are less than 1.35 percent R_o and generally are considered to be within the oil window. The continuous gas assessment unit is hypothetical and is located in the deeper parts of the basin where thermal maturities are greater than 1.35 percent R_o (Finn and Johnson, 2005b). Bierei (1987) calculated that the Niobrara Formation reached a transformation ration (TR) value of 0.5 (50 percent) at 75 Ma and is currently overmature (TR at or near 100 percent) with respect to oil generation in the central Hanna Basin (Dymand and Condon, 2007).	Landon and others (2001) believe that given the fine-grained lithology, low matrix porosity and permeability of the Niobrara, and the integrity of the overlying and interbedded seals, hydrocarbons have not migrated far from where they were generated. A thick section (up to several thousand feet) of soft, noncalcareous Mancos or Steele Shale provides a good quality regional seal over the Niobrara Formation within the TPS (Finn and Johnson, 2005b, their plate 1). Hydrocarbon traps in the Niobrara TPS are considered unconventional in that they are defined by changing patterns in fracture development. Commonly, the fractured chalk facies is interbedded with less brittle shaly facies that form intraformational seals (Dyman and Condon, 2007).	In the Southwestern Wyoming Province, the Niobrara Formation and equivalent rocks consist of interbedded organic-rich shale, calcareous shale, and marl, with minor amounts of sandstone, siltstone, limestone, and chalk (Vincelette and Foster, 1992; Longman and others, 1998). In the Hanna Basin, the Niobrara is concretionary and contains ledge-forming coquina beds. Limestones and chalks in the Niobrara give off a strong petroliferous odor (Dyman and Condon, 2007).	For the 2005 USGS assessment in Hanna, Laramie, Shirley Basins Province, mean estimates of undiscovered resources for the Niobrara Continuous Oil AU were 38 MMBO and 19 BCFG (Dyman and others, 2005). The hypothetical Niobrara Biogenic Gas AU was defined on the basis of the potential that a biogenic gas resource exists in the Laramie and Shirley Basins. It was not, however, quantitatively assessed because of a lack of geologic and production data (Dyman and Condon, 2007). For the 2002 USGS assessment in the Southwestern Wyoming Province, the mean volume estimate of undiscovered oil resource for the Niobrara Continuous Oil Assessment Unit was 103.6 MMBO. The hypothetical Niobrara Continuous Gas Assessment Unit was not quantitatively assessed because of a lack of production data and (or) a suitable analog (Finn and Johnson, 2005b).	The Niobrara ranges in thickness from 900 to 1,800 feet and consists mainly of interbedded organic-rich shale, calcareous shale, and marl. Reservoir zones within the Niobrara average 50–200 ft thick in the Southwestern Wyoming Province (Finn and Johnson, 2005b). Mitchell (1961) identified about 1,200 ft of Niobrara (including the Sage Breaks Shale Member) in the Hanna Basin (Dyman and Condon, 2007).
Mowry Conventional Oil and Gas and Mowry Continuous Gas AUs (Kirschbaum and Roberts, 2005), Mesozoic-Cenozoic Conventional Oil and Gas and Hanna Basin Continuous Gas AUs (Dyman and Condon, 2007), and Thrust Belt Conventional AU (USGS Wyoming Thrust Belt Assessment Team, 2004).	 Graphic showing the portion of the AUs that compose the Mowry Composite TPS and the Mowry-Hanna Composite TPS, and that occur within the WLCI. The Mowry Continuous Gas AU overlaps the conventional AU.	 Cretaceous (Modified from USGS Southwestern Wyoming Province Assessment Team, 2005a)	Greater Green River and Hanna	The Mowry Shale is siliceous due to the presence of abundant radiolarians that favored the cool waters of the restricted boreal Mowry Sea (Davis, 1970). The silica was originally provided from volcanic sources near the Idaho batholith (Davis, 1970). This high-resistivity, organic-rich siliceous shale was deposited on an anoxic sea floor (Byers and Larson, 1979; Burtner and Warner, 1984). The anoxic condition of the Mowry Sea not only preserved the radiolarian tests, but preserved organic matter as well. The laminated mudrock grades upward and landward (westward) into bioturbated mudstone and sandstone, indicating more oxic conditions, shallower water, and proximity to the clastic source area (Burtner and Warner, 1984). The Mowry Shale was buried in a rapidly subsiding foreland basin due to tectonic loading associated with the more westward Meade-Crawford thrusts (Burtner and others, 1994).	 Paleogeography of the Late Cretaceous of the Western Interior (Roberts and Kirschbaum, 1995)	 Contours show depth to the top of the Frontier Formation in thousands of feet using a 2,000-foot contour interval. Ranges of thermal maturity values (in percent R_o) are at the top of the Frontier (Kirschbaum and Roberts, 2005).	The Mowry is considered a major source rock for petroleum in the northern Rocky Mountain region (Dyman and Condon, 2007). The Mowry Composite TPS is a composite system because there are multiple source rocks that could have generated petroleum mainly from Type-II and Type-III organic matter in marine shales of the Mowry and Thermopolis Shales and their equivalents, and from Type-III, with minor contributions of Type-I organic matter from terrestrial facies of the Bear River and Frontier Formations and Dakota Sandstone (Burtner and Warner, 1984; Burtner and others, 1994). The name Mowry is applied to the TPS because it is the most important source rock to the petroleum system (Burtner and Warner, 1984); as reported in Kirschbaum and Roberts, 2005. Within the Hanna, Laramie, and Shirley Basins Province, primary source rocks are shales and calcareous mudstones of the Cretaceous Thermopolis and Mowry Shales, Frontier, and Niobrara Formations, and Steele Shale (Dyman and Condon, 2007).	Total organic carbon (TOC) extracted from 19 samples of the Mowry Shale in the Green River Basin ranges between 1.2 and 2.5 weight percent, anomalously low according to Burtner and Warner (1984) who believe the anomaly is due to the expulsion of carbon dioxide and hydrocarbons from the source rock (Kirschbaum and Roberts, 2005). Mowry shales and mudstones have TOC contents ranging from 0.7 to 4.1 weight percent across the Western Interior of the United States. Within the Hanna, Laramie, and Shirley Basins Province, which lies near the geographic axis of the Mowry Sea, three Mowry samples collected in the Hanna Basin show TOC values ranging from 1.01 to 2.66 weight percent. Hydrogen to oxygen indices indicate a mixed Type II and Type III source (Dyman and Condon, 2007).	The source rocks of the Mowry Composite TPS are mature with respect to hydrocarbon generation throughout much of the province except around the basin margins and the Rock Springs uplift. Mature source rocks are also present in parts of the upper plates of the western Wyoming thrusts (Burtner and others, 1994), and maturities as high as 2.01 percent R_o have been recorded from the Bear River Formation in the northern thrust belt (Wallem and others, 1981).	Traps are stratigraphic, structural, and basin-centered, and seals are diagenetic, capillary, or lithologic, including marine, estuarine, and terrestrial shale. Production from conventional accumulations is from anticlines, fault-bounded closures, stratigraphic traps, or combinations of the three (Cardinal and Stewart, 1979; Miller and others, 1992). Major seals are provided by marine shale units of the Thermopolis, Mowry/Aspen, and Hilliard Shales (Kirschbaum and Roberts, 2005). Oil and gas migrated from source rocks into reservoirs through a system of faults and fractures that are pervasive throughout the Hanna Basin area. Structures may be faulted anticlines or triangle zones. Stratigraphic pinchouts and combination stratigraphic-structural traps are also common. Seals consist of interbedded shales and mudstones and diagenetic cements (Dyman and Condon, 2007).	Reservoirs in the Dakota and Muddy Sandstones and equivalent strata in the Bear River Formation consist of fluvial, estuarine, and nearshore marine sandstones. Cretaceous shales are thought to be the source of much of the petroleum found in reservoirs of the Dakota Sandstone and Frontier Formation (Warner, 1982; Burtner and Warner, 1984). The main reservoirs in the Frontier are shoreface/deltaic, estuarine, and fluvial sandstones at depths down to about 19,950 ft (IHS Energy Group, 2001); Kirschbaum and Roberts, 2005. In the Hanna Basin, the Mowry Shale is an organic-rich dark-gray to black siliceous marine shale with interbedded porcellanite and bentonite (Dyman and Condon, 2007).	The Mowry Conventional Oil and Gas Assessment Unit was estimated to contain a mean of 6.60 MMBO, 11.20 BCF of associated gas, and 1.60 MMB of associated natural gas liquids. Gas fields within the assessment unit were estimated at the mean to be 195.10 BCFG and 3.90 MMBNGL. The Mowry Continuous Gas Assessment Unit had a mean estimate of 8.54 TCFG and 170.9 MMBNGL (Kirschbaum and Roberts, 2005). The Thrust Belt Conventional AU was estimated to contain a mean of 557 BCFG, 39 MMBO, and 57.3 MMBNGL. Gas fields have not yet been discovered in the deep central Hanna Basin, and few deep wells have been drilled there. As a result, a deep (>20,000 ft) basin-center gas AU (Hanna Basin Continuous Gas AU) was defined in the Hanna Basin but was not assessed. Mean estimates of undiscovered resources for the Mesozoic-Cenozoic Conventional Oil and Gas AU are 36 MMBO, 207 BCFG, and 11 MMBNGL. The best areas for new discoveries will most likely be in undrilled and sparsely drilled structures in the Hanna Basin (Dyman and Condon, 2007).	The Mowry is a composite system because there are multiple source rocks present within a 1,000-ft stratigraphic interval, and the relative contribution of petroleum from individual sources could not be distinguished on the basis of data presently available (Kirschbaum and Roberts, 2005). In the Hanna, Laramie, and Shirley Basins Province, the Mesozoic-Cenozoic Conventional Oil and Gas AU boundary is based on the distribution of Sundance through Hanna Formations source and reservoir rocks (Dyman and Condon, 2007). Precambrian basement is about 30,000 to 40,000 ft deep in the eastern part of the Hanna basin (Hansen, 1986).
Sub-Cretaceous Conventional Oil and Gas AU (Johnson, 2005) and Tensleep-Casper Oil and Gas AU (Dyman and Condon, 2007).	 Graphic showing the portion of the AUs that compose the Phosphoria TPS in both the Southwestern Wyoming and the Hanna, Laramie, and Shirley Basins Provinces, and that occur within the WLCI.	 Generalized stratigraphic column showing distribution of reservoir rocks (yellow) containing oil and gas sourced by the Phosphoria Formation (green) (modified from Ryder, 1988); as reported in Johnson, 2005.	Greater Green River and Hanna	During the middle part of the Permian a large, relatively shallow, epicontinental embayment was present in what is now southeastern Idaho, southwestern Montana, western and central Wyoming, northwestern Colorado, northern Utah, and northeastern Nevada. This embayment, called the Sublett Basin (Maughan, 1979), was open to the Cordilleran sea on the west and bordered on the north, east, and south by various continental terrains on the North American craton. The central basin, called the Phosphoria Sea (as used by Sheldon, 1963), was bordered on three sides by a carbonate shelf. The Phosphoria Formation was deposited in the Phosphoria Sea and the Park City Formation was deposited on the carbonate shelf. As deposition in the Sublett Basin progressed, several eustatic sea-level changes resulted in marine transgressions and regressions, which caused an interfingering of Phosphoria members with Park City members. During the Early Triassic, argillaceous sediments of the Dinwoody Formation were deposited on top of and formed a seal on the Phosphoria, which later became fragmented by Laramide tectonism in the Late Cretaceous (Johnson, 2005).	 Diagram of the extent of Permian rocks in the region, first published by McKelvey, 1949 and subsequently by Swanson and others, 1953. It shows the maximum extent of the Sublett Basin (black dashed) and the maximum extent of the Phosphoria Sea (mostly solid blue line); as reported in Johnson, 2005.	Precambrian rocks in uplifts marginal to the Greater Green River Basin are present at elevations of more than 13,000 ft, and the top of Precambrian rocks in the subsurface of the basin can be as deep as 20,000 ft below sea level—thus more than 33,000 ft of structural relief is recognized (Keller and Thomaidis, 1971). The first eight reservoirs discovered were at depths between about 2,000 and 4,000 ft, and the last three reservoirs discovered were at depths between about 12,000 and 14,000 ft. The conclusion is that future discoveries will most likely be as deep or deeper than the historical trend (Johnson, 2005).	Source rocks in the Phosphoria Formation began generating oil in southeastern Idaho at the beginning of the Early Cretaceous, but in the Southwestern Wyoming Province oil generation did not commence until Late Cretaceous. Oil began migrating laterally away from the source rocks shortly after maturation, and regional carrier beds such as the Permian Park City Formation and Pennsylvanian Tensleep Sandstone distributed the oil throughout the central Rocky Mountain area. The oil-prone source rocks in the Phosphoria are contained in the Meade Peak and Retort Phosphatic Shale Members (Maughan, 1984). Although there are not samples from every stratigraphic unit, the spread of data is such that a Phosphoria source seems reasonable. While it is unlikely that all petroleum found in the 18 sub-Cretaceous stratigraphic units is derived from the Phosphoria, there is little geochemical evidence available to prove otherwise (Johnson, 2005). In the Hanna, Laramie, and Shirley Basins Province, the Phosphoria is thought to be a potential source rock for oil everywhere within the province where favorable structural development and facies are present in combined carrier and reservoir beds in the Casper Formation or Tensleep Sandstone (Dyman and Condon, 2007).	Over the years, at least nine stratigraphic units in and adjacent to the province have been mentioned as possible source rocks for these sub-Cretaceous petroleum accumulations. Although some of these units might have provided some petroleum, only the Phosphoria Formation contains enough total organic carbon (TOC) and lithic volume to be a major petroleum source rock. In the region of the former Sublett Basin, the Meade Peak and Retort Members combined have an average maximum TOC of about 10 weight percent, and in the organically richest beds, as much as 30 weight percent (Maughan, 1984). The average TOC in the Meade Peak is 2.4 weight percent based on the analyses of 285 samples collected from 40 localities; the average maximum TOC of 9 weight percent is from the area east of Pocatello, Idaho, near the Wyoming State line. The average TOC in the Retort is 4.9 weight percent (double the average of the Meade Peak) based on the analyses of 82 samples from 22 localities; the average maximum TOC of 10 weight percent is from the area of Dillon, Montana (Johnson, 2005).	The Phosphoria is inferred to have generated and expelled hydrocarbons as it reached burial depths greater than 6,560 ft. It continued to generate oil as it passed through the oil window until it reached a depth of about 16,400 ft in the Sublett Basin (Claypool and others, 1978). Below 16,400 ft, oil-to-gas cracking may have resulted in the generation of thermogenic gas (Dyman and Condon, 2007). Vitrinite reflectance data from organic-rich mudstones in the Meade Peak Member throughout the area of its deposition indicate that thermal maturity was high enough in that unit to generate economic quantities of oil in most of the Sublett Basin. However, the Retort Member is considered thermally immature in southwestern Montana owing to shallow burial depths (Johnson, 2003). The Retort is an oil shale at its type locality near Dillon, Montana, and has yielded oil upon distillation (McKelvey and others, 1959; Maughan, 1984). In this area the Retort is thermally immature, but where buried more deeply in west-central Wyoming, it is overmature. The depocenter for the Retort was in southwestern Montana. The depocenter for the Meade Peak was located in southeastern Idaho and northern Utah (Maughan, 1984).	Eighteen sub-Cretaceous units within this TPS, ranging from Precambrian crystalline rocks to the Upper Jurassic Morrison Formation, produce (or have produced) petroleum. The stratigraphic units are grouped vertically into five stratigraphic levels (Precambrian-Cambrian, Ordovician, Mississippian-Pennsylvanian, Permian, Triassic-Jurassic) each level containing one or more producing stratigraphic unit in the lower part and sealed by one or more low-permeability stratigraphic units in the upper part. All of the sub-Cretaceous oil and gas production in the Southwestern Wyoming Province comes from structural traps in the form of anticlines that developed during the Laramide orogeny between the Late Cretaceous and middle Eocene (Johnson, 2005). In the Hanna, Laramie, and Shirley Basins Province, hydrocarbon traps in the Phosphoria TPS are primarily structural or a combination of structural and stratigraphic traps. Stratigraphic traps, although less common, are formed by pinchouts of reservoir sandstones into finer grained mudrocks, by truncation beneath disconformities, and by bounding surfaces in eolian dune and sabkha facies (Dyman and Condon, 2007).	The oil-prone source rocks in the Phosphoria, the Meade Peak and Retort Phosphatic Shale Members, consist of organic claystone, muddy siltstone, phosphorite, and dolomitic calcilithite (Johnson, 2005). In the Southwestern Wyoming Province, the Phosphoria TPS contains 18 different reservoirs ranging in age from Precambrian crystalline rocks to the Jurassic Morrison Formation (Johnson, 2005). In contrast, the Tensleep Sandstone and Casper Formation are the primary reservoirs for Phosphoria oil in the Hanna, Laramie, and Shirley Basins Province. Reservoir properties of these formations vary greatly with geographic location and depositional environment (Dyman and Condon, 2007).	Most of the petroleum in the Southwestern Wyoming Province is produced from Cretaceous or younger reservoir rocks. However, 18 sub-Cretaceous lithostratigraphic units are reported (IHS Energy Group, 2001) to have produced petroleum. Based on the assumption that the petroleum contained in these sub-Cretaceous stratigraphic units have a common source rock, all such accumulations were grouped together for the purposes of resource assessment. The results of the assessment predicted mean estimates of potential additions to reserves over the next 30 years of petroleum in undiscovered conventional accumulations of 16.60 MMBO, 1.38 TCFG, and 41.80 MMBNGL; as reported in Johnson, 2005. In the Hanna, Laramie, and Shirley Basins Province, mean estimates of undiscovered resources for the Tensleep-Casper Conventional Oil and Gas AU are 20 MMBO, 72 BCFG, and 2 MMBNGL. The best areas for new discoveries are in undrilled and sparsely drilled structures in the Hanna Basin (Dyman and Condon, 2007).	 Isopach map of cumulative thickness (ft) of black shale facies of Phosphoria Formation in Phosphoria Total Petroleum System (modified after Sheldon, 1963).

Base derived from ESRI World Topo Map, accessed in 2011, at http://www.esri.com/software/arcgis/arcgisonline/maps/maps-and-map-layers

Oil and Gas Assessment Units in Southwestern Wyoming

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2014

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This report is available at:
http://dx.doi.org/10.3133/ds843

Publishing support provided by:
Denver Publishing Service Center
Manuscript approved for publication on April 28, 2014

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ISSN 2327-638X (online)
http://dx.doi.org/10.3133/ds843