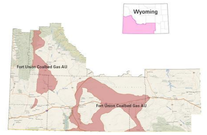
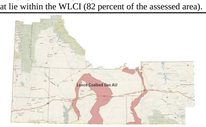
Coalbed Gas Assessment Unit		Age	Basin	Depositional Environment	Formation Depths	Gas Content	Geochemistry	Rank	Resources	Thickness	Water Issues
Mesaverde Coalbed Gas AUs (Johnson and others, 2005; Finn and others, 2005).	 Thumbnail graphic showing the portion of the Mesaverde Coalbed Gas AUs that lie within the WLCI (67 percent of the assessed area).	Late Cretaceous	Greater Green River	Coals were deposited in lower coastal plain depositional settings (Johnson and others, 2005; Finn and others, 2005).	For both the Mesaverde Coalbed Gas Assessment Unit (AU) (50370581) in the Mesaverde Total Petroleum System (TPS), and the hypothetical Mesaverde Coalbed Gas AU (50370681) in the Mesaverde-Lance-Fort Union Composite TPS, the AU areas define where significant coal is at depths of less than 6,000 ft (Johnson and others, 2005; Finn and others, 2005). For the Mesaverde TPS, the stratigraphically highest coals in the Mesaverde Group are in the Almond Formation (Johnson and others, 2005). In the Mesaverde-Lance-Fort Union Composite TPS, the AU defines coals in the Rock Springs Formation. Commercial production rarely extends to depths greater than 6,000 ft (Finn and others, 2005).	Coals in the Mesaverde Coalbed Gas AU (50370581) in the Mesaverde TPS, contain as much as 540 standard cubic feet per ton (scf/ton; Tyler and others, 1995).	Glass and Jones (1991) reported that as-received analyses of coalbeds in the Green River Coal Field indicate moisture values averaging 20.5 percent, ash averaging 8.8 percent, total sulfur averages of 0.5 percent, and average heating content of 9,480 Btu/lb.	Almond Formation coals are subbituminous (Glass, 1977). See also, plate 2, Green River Coal Field.	The 2002 assessment of the U.S. Geological Survey (USGS) estimated a mean volume of about 248.7 billion cubic feet (BCF) of undiscovered, technically recoverable natural gas in the Mesaverde Coalbed Gas AU east of the pinchout of the Lewis Shale (Johnson and others, 2005). The hypothetical Mesaverde Coalbed Gas AU to the west was given a mean estimate of 27.3 BCFG that has potential for additions to reserves over the next 30 years (Finn and others, 2005).	Glass (1977) reported that in the Rock Springs area, Mesaverde coals are in the 500-ft-thick Almond Formation, which marks the top of the Mesaverde sequence, and in the 1,400-ft-thick Rock Springs Formation near the base of the Mesaverde Group. Rock Springs coals reportedly range from 10 to 14 ft thick, but 4 to 6 ft coals are more common. Almond coals seldom exceed 8 ft in thickness, but are more numerous. On the east side of the Green River Region, Mesaverde Group coals average less than 4 ft thick, but locally reach 16 ft. See also, plate 2, Green River Coal Field.	Coalbed natural gas (CBNG) production requires extraction of large volumes of water from target formations. This may alter local aquifers and large hydrologic systems. Previously in Wyoming, scientifically defined baseline data of CBNG targeted aquifers was outpaced by CBNG production. Being a newer CBNG play, springs, streams, and CBNG wells across the Atlantic Rim were sampled to quantify regional hydrogeology before full scale CBNG production. To characterize each water sample, field measurements, chemical analysis, and C and Sr isotopic analysis were used. The extent to which isotopic data allow predictive modeling of lifespan of production can be assessed with ongoing, periodic resampling and isotopic analysis of Atlantic Rim co-produced waters (McLaughlin and others, 2009).
Fort Union Coalbed Gas AUs (Finn and others, 2005; Roberts, 2005a)	 Thumbnail graphic showing the portion of the Fort Union Coalbed Gas AUs that lie within the WLCI (82 percent of the assessed area).	Paleocene		Roberts (2005a) described the Fort Union Formation as fluvial and alluvial deposition coincident in large 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 hypothetical Fort Union Coalbed Gas AU (AU50370682) encompasses nearly 1.2 million acres in four separate areas around the margins of the Mesaverde-Lance-Fort Union Composite TPS where significant coal is present in the Fort Union Formation at depths of 6,000 ft or less (Finn and others, 2005). In the Lance-Fort Union Composite TPS, the Fort Union Coalbed Gas AU (AU50370882) is also hypothetical and includes areas where coalbeds in the basal 1,000 ft of the Fort Union Formation are interpreted to be at depths of less than 6,000 ft (Roberts, 2005a).	Tyler and others (1995) reported that gas has been documented in Fort Union Formation coalbeds in the Lance–Fort Union Composite TPS, with measured gas contents generally less than 100 scf/ton (Tyler and others, 1995).	Roberts (2005a) reported that as-received analyses of the upper and lower Cherokee coalbeds in the Cherokee coal zone near the top of the Fort Union Formation indicate moisture ranging from 15 to 25 percent, ash yields ranging from 10 to 25 percent, total sulfur ranging from 0.5 to 5.0 percent, and heating content ranging from 5,000 to 9,000 Btu/lb (Glass, 1981, after Smith and others, 1972). See also plate 2, Green River Coal Field.	Finn and others (2005) reported ranks of Fort Union coals within the Mesaverde-Lance-Fort Union Composite TPS are mostly subbituminous to high-volatile C bituminous (Tyler and others, 1995). The apparent rank of Fort Union coal within the Lance-Fort Union Composite TPS is subbituminous (Roberts, 2005a).	The 2002 assessment of the USGS estimated the hypothetical Fort Union Coalbed Gas AU to the west was given an estimate of 80.8 BCFG that has potential for additions to reserves over the next 30 years (Finn and others, 2005). To the east, within the Lance-Fort Union Composite TPS, the USGS estimated a mean volume of 942.5 BCF of undiscovered, technically recoverable natural gas in the Fort Union Coalbed Gas AU (Roberts, 2005a).	Tyler and others (1995) reported individual coal thicknesses of as much as 40 ft within the area now included in the Fort Union Coalbed Gas AU in the Mesaverde-Lance-Fort Union Composite TPS. Finn and others (2005) stated that total coal thicknesses within the AU generally average 10 to 60 ft in the Mesaverde-Lance-Fort Union Composite TPS. In the Lance-Fort Union Composite TPS, Roberts (2005a) described Fort Union coalbed thickness within the AU ranging from less than 1 ft to as much as 50 ft, and continuous coalbeds or zones are present within 1,000–1,200 ft above the base of the formation (lower coal-bearing unit; Tyler and others, 1995). Cumulative coal thickness in this lower interval exceeds 80 ft in areas of the AU along Cherokee Ridge and the Wamsutter Arch and may exceed 100 ft locally (Tyler and McMurry, 1993; Tyler and others, 1995; as reported in Roberts, 2005a).	
Lance Coalbed Gas AU (hypothetical); Roberts, 2005a.	 Thumbnail graphic showing the portion of the Lance Coalbed Gas AU that lies within the WLCI (65 percent of the assessed area).	Late Cretaceous		As the Western Interior Seaway retreated from the region during the latest Cretaceous, coal-forming environments were in coastal plain and fluvial/alluvial depositional settings (Roberts, 2005a).	The Lance Coalbed Gas AU includes areas where coalbeds in the basal 300–500 ft of the Lance Formation are interpreted to be at depths of 6,000 ft or less (Roberts, 2005a).	Roberts (2005a) assumed that, because coalbeds in the Lance and Fort Union Formations are of similar rank (subbituminous), gas contents might also be similar. See Fort Union Coalbed Gas AUs.	Roberts (2005a) reported that coalbeds in this area typically have ash averaging about 5 percent, total sulfur contents averaging about 0.7 percent, and average moisture contents of about 20 percent (Keystone Coal Industry Manual, 1999).	Roberts (2005a) reported the apparent rank of Lance Formation coal on the southeast flank of the Rock Springs uplift is subbituminous B (Keystone Coal Industry Manual, 1999).	The hypothetical Lance Coalbed Gas AU, was estimated by the USGS at a mean volume of 165 BCF of undiscovered, technically recoverable natural gas (Roberts, 2005a).	Cumulative coal thickness in the Lance typically is less than 30–40 ft, with minimum values of less than 10 ft and a maximum reported total coal thickness of 85 ft; reported thicknesses for individual coalbeds within the AU range from less than 1 ft to as much as 13 ft (Law, 1996; as reported in Roberts, 2005a).	
Wasatch–Green River Coalbed Gas AU (hypothetical); Roberts, 2005b.	 Thumbnail graphic showing the portion of the Wasatch–Green River Coalbed Gas AU that lies within the WLCI (87 percent of the assessed area).	Paleocene and Eocene		The Wasatch Formation was deposited primarily in a fluvial/alluvial depositional setting during the latter stages of the Laramide Orogeny (Roberts, 2005b).	The Wasatch–Green River Coalbed Gas AU includes areas where coalbeds in the main body of the Wasatch Formation, and Red Desert and Niland Tongues of the Wasatch Formation, and the Luman Tongue of the Green River Formation are present in outcrops and in the shallow (less than 2,500 ft) subsurface (Roberts, 2005b).	Coalbed gas wells producing from subbituminous coal in the Fort Union Formation in the Powder River Basin (PRB) in northeastern Wyoming were used as analogs, because no coalbed gas production or test data specific to the Wasatch and Green River Formations were available. For Fort Union Formation coal in the PRB, reported gas contents vary from 6 to more than 75 scf/ton and are commonly in the range of 20 to 40 scf/ton (for example, see Stricker and others, 2000; Boreck and Weaver, 1984). It was assumed by Roberts (2005b) that because coalbeds in the Wasatch and Green River Formations are of similar rank (subbituminous C to high-volatile C bituminous), gas contents might also be similar.	Roberts (2005b) reported that analyses (as-received) of samples from thicker Eocene coalbeds in the Great Divide Basin indicate an average moisture content of about 21 percent, an average ash of about 16 percent, an average total sulfur content of 2.5 percent, and an average heat content of about 7,900 Btu/lb (Glass, 1981, after Smith and others, 1972). The Vermillion Creek coalbed has an apparent rank of high-volatile C bituminous (Hatch, 1987), although inconsistent agglomerating characteristics in certain coal samples indicate the coal could also be considered as subbituminous (for example, see Ellis, 1987). As-received moisture values typically range from about 11 to 15 percent, and average, as-received values for ash and total sulfur content are 18.2 and 5.6 percent, respectively; heat content (moist, mineral-matter-free basis) averages 11,556 Btu/lb (Ellis, 1987; Hatch, 1987).	Apparent coal rank varies from subbituminous C to B (Pipiringos, 1961; Masursky, 1962; as reported in Roberts, 2005b).	Roberts (2005b) reported that the potential for significant coalbed gas production from the Wasatch and Green River Formations in the near future appears limited. The fact that many of the coalbeds are in close proximity to outcrops could result in gas leakage, and the thin, discontinuous nature of these coalbeds could restrict reservoir (and gas) volume. The hypothetical Wasatch–Green River Coalbed Gas AU, was assessed in 2002 when the USGS estimated a mean volume of 64.7 BCF of undiscovered, technically recoverable natural gas.	Most coals average about 7 ft thick however, several beds are as thick as 20 ft, and lenticular coalbeds are locally as thick as 42 ft (Roberts, 2005b).	Wells must undergo dewatering before gas flows.
Frontier-Adaville-Evanston Coalbed Gas AU (hypothetical); Kirschbaum and others, 2004.	 Thumbnail graphic showing the portion of the Frontier-Adaville-Evanston Coalbed Gas AU that lies within the WLCI (80 percent of the assessed area).	Cretaceous and Tertiary (Kirschbaum and others, 2004)	Fossil Basin (Love and Christiansen, 1985)	Supporting geologic studies of Total Petroleum Systems and Assessment Units and a report on the methodology used in the Wyoming Thrust Belt Province assessment are in progress. Assessment results are available at the USGS Central Energy Team website: http://energy.cr.usgs.gov/oilgas/noga/					In 2003, the hypothetical Frontier-Adaville-Evanston Coalbed Gas AU, was assessed by the USGS to contain an estimated mean volume of 361 BCF of undiscovered, technically recoverable natural gas (Kirschbaum and others, 2004).		
Medicine Bow–Ferris–Hanna Coalbed Gas AU—Not quantitatively assessed (Dyman and others, 2006)		Cretaceous and Tertiary (Dyman and Condon, 2007)	Hanna and Carbon Basins (Dyman and Condon, 2007)	Coal-rich source rocks, such as the Almond Formation of the Mesaverde Group, and the Medicine Bow, Ferris, and Hanna Formations, of sufficient thickness for generating biogenic and minor amounts of thermal gas, were deposited in coastal and nonmarine environments (Dyman and Condon, 2007).	Dyman and Condon (2007) reported that Glass and Roberts (1980) recognized that the most numerous coalbeds are in the upper 12,000 ft of the Hanna Formation and in the upper part of the Ferris Formation in the northern part of the Hanna Basin. Medicine Bow coals are generally restricted to the lower part of the formation (Merewether, 1971, 1972, 1973; Glass and Roberts, 1980; as reported in Dyman and Condon, 2007).	Drilling is still in its early stages, and gas production is limited. Data are insufficient to identify areas where coalbed gas-generating potential exists (Dyman and Condon, 2007).	Hanna Formation coals in the Hanna coal field north of Hanna, Wyoming, are high-volatile C bituminous, according to Glass and Roberts (1980, 1984). Ferris Formation coals in the Seminoe Road Mining District west of Hanna are subbituminous A and are suspected to be high-volatile C bituminous underlying the Hanna Formation at Hanna (Dyman and Condon, 2007).	The Medicine Bow-Ferris-Hanna Coalbed Gas AU was not quantitatively assessed because of a lack of geologic and production data. Current production for producing cells is less than the minimum recovery per cell required for assessment (Dyman and Condon, 2007).	Individual coals in the Hanna Formation are thicker, on average, than those of the Ferris Formation; cumulative coal thicknesses range from 30 - 375 ft and 125 - 305 ft, respectively (Glass and Roberts, 1980). Between the Hanna Basin and the Carbon Basin (a synclinal area between the Hanna and Laramie Basins), coals in the Hanna Formation are locally offset by faulting and are therefore difficult to correlate. Medicine Bow coals are not as laterally persistent as those of the Hanna and Ferris Formations (Merewether, 1971, 1972, 1973; Glass and Roberts, 1980; as reported in Dyman and Condon, 2007).	
Mesaverde Coalbed Gas AU—Not quantitatively assessed (Dyman and others, 2006)		Cretaceous (Dyman and Condon, 2007)			Steep dips and faults are encountered in wells, and Mesaverde coals are deep. In the Anadarko Petroleum Durante 11–2 well, the Mesaverde was not reached at 19,600 ft. Thermal gas would be expected from gas-prone coaly source rocks at such extreme depths (Dyman and Condon, 2007).			In the central Hanna Basin, Medicine Bow and Almond coals are expected to be high-volatile A or B bituminous coals (Dyman and Condon, 2007).	The Mesaverde Coalbed Gas AU was not quantitatively assessed because of a lack of geologic and production data. Current production for producing cells is less than the minimum recovery per cell required for assessment (Dyman and Condon, 2007).	Seven laterally persistent coal beds greater than 5 ft thick have been described for the deeper Almond coals, and cumulative coal thickness ranges from 10 - 40 ft. Mesaverde coals are deep, and steep dips and faults are encountered in wells in the northern part of the Hanna Basin (Dyman and Condon, 2007).	

Definitions

Total Petroleum System (TPS) – the essential elements (source rock, reservoir rock, seal rock, and overburden rock) and processes (generation, migration, accumulation, and trap formation) as well as all genetically related petroleum that occurs in seeps, shows, and accumulations, both discovered and undiscovered, whose provenance is a pod or closely related pods of active source rock. The TPS is a naturally occurring hydrocarbon-fluid system in the lithosphere that can be mapped, and includes the essential elements and processes needed for oil and gas accumulations to exist (Magoon and Schmoker, 2000).

Assessment Unit (AU) – a volume of rock within the TPS that encompasses fields, discovered and undiscovered, sufficiently homogeneous in terms of geology, exploration strategy and risk characteristics to constitute a single population of field characteristics with respect to criteria used for resource assessment. AUs are considered established if they contain more than 13 discovered fields, frontier if they contain 1−13 discovered fields and hypothetical if they contain no discovered fields (Magoon and Schmoker, 2000).

Wyoming Landscape Conservation Initiative (WLCI) – a multi-partner, long-term, science-based program to assess, monitor, and enhance aquatic and terrestrial habitats at a landscape scale in southwest Wyoming, while facilitating responsible development through local collaboration and partnerships (http://www.wlci.gov/).

Coalbed Gas Assessment Units in Southwestern Wyoming

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