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SCIENTIFIC INVESTIGATIONS MAP 3053
SHEET 1 OF 3
Version 1.0

# GEOLOGIC MAP OF UPPER CRETACEOUS AND TERTIARY STRATA AND COAL STRATIGRAPHY OF THE PALEOCENE FORT UNION FORMATION, RAWLINS–LITTLE SNAKE RIVER AREA, SOUTH-CENTRAL WYOMING

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## DESCRIPTION OF MAP UNITS

### SURFICIAL DEPOSITS

Eolian sand dunes (Holocene and (or) Pleistocene)—Unconsolidated deposits of wind-blown sand. Eolian deposits are widespread throughout the study area but only selected areas were mapped. Largest area is about 10 mi long and 3 mi wide in The Sand Hills (fig. 1). Dunes west of Highway 789 (fig. 1) were mapped from aerial photographs, and units may locally include bedrock

Playa lake deposits (Holocene and (or) Pleistocene)—Unconsolidated, light-gray to red clay and silt. White alkali salts are on some playa surfaces. Locally includes colluvium and alluvial fans

Alluvium (Holocene and (or) Pleistocene)—Unconsolidated clay, silt, sand, and gravel. Locally includes small playa deposits, alluvial fans, and slope wash. Alluvium mapped only along the Little Snake River and a few named creeks. Deposits in minor tributaries and drainages not mapped

Gravel (Holocene and (or) Pleistocene)—Undifferentiated and generally unconsolidated sand and gravel deposited 40–380 ft above modern drainages. Gravel deposits mapped only where they obscure extensive areas of bedrock near Creston Junction and along the Little Snake River (fig. 1). Many other gravel deposits in the study area were not mapped. Deposits near Creston Junction contain pebbles of granite, quartzite, chert, and jasper and were interpreted as pediment deposits by Sanders (1974, 1975). Gravel along the Little Snake River consists of sand, pebbles, cobbles, and boulders deposited on terraces. Boulders are as much as 1 ft in diameter and composed of quartzite, intermediate intrusive igneous rock, and basalt. Pebbles and cobbles are composed of quartzite, mafic igneous rock, and chert. Some deposits are partially covered by colluvium

Landslide deposits (Holocene and (or) Pleistocene)—Mixed debris of soil and clasts of bedrock; mainly in areas of steep topography where bedrock is dominated by clayey lithologies

### SEDIMENTARY ROCKS

Browns Park Formation (Miocene and Oligocene)—Consists of an upper sandstone member that generally overlies, but locally intertongues with, a basal conglomerate member; formation lies unconformably on older rocks. Upper sandstone member consists of white to yellowish-gray to yellowish-orange, very fine grained to medium-grained tuffaceous sandstone. Sandstone member also contains a few thin beds of tuffaceous, light-gray, ripple-laminated, lacustrine limestone in areas east of the study area and north of Browns Hill (fig. 1). Basal conglomerate is yellow orange, and contains gravel in a sandstone matrix as well as beds of fine- to coarse-grained sandstone, and limestone. Gravel generally consists of pebbles and cobbles, but granules and boulders are present locally. Clasts are generally composed of chert, quartzite, gneiss, schist, amphibolite, and granite; noticeably absent are basalt clasts that are common in Quaternary deposits along the Little Snake River. Deposits in Poison Basin (fig. 1) are a host rock for uranium mineralization (Cronoble, 1969a; Lewis, 1977).

The Browns Park Formation is generally considered a widespread deposit that filled intermontane basins of northern Colorado and southern Wyoming (Buffler, 2003). Basal conglomerate was probably laid down as alluvial fans derived from the ancestral Sierra Madre and Park Range (fig. 1), and the overlying fine-grained interval was deposited primarily in eolian, fluvial, and flood-plain environments (Buffler, 2003). The Browns Park is as much as 1,600 ft thick 11 mi east of the study area at Battle Mountain in T. 12 N., R. 88 W. (fig. 1) (Buffler, 2003). As much as 700 ft is present just east of the study area in the Browns Hill–Savery Creek area (fig. 1), where detailed descriptions were provided by Naftz and Barclay (1991).

In the study area, thick remnants of Browns Park Formation are preserved in Poison Basin and in a northwest-trending graben near the town of Dixon (fig. 1). In Poison Basin, the formation is as much as 300 ft thick and the basal conglomerate is 0–75 ft thick (Cronoble, 1969a; Lewis, 1977). An estimated 600 ft of strata are preserved in the graben near Dixon. About 420 ft were penetrated in the Dixon-C well (fig. 1), located near the center of the graben in sec. 33, T. 13 N., R. 90 W.; the basal conglomerate is about 40 ft thick in the depth interval 385–425 ft (Barclay and Shoaff, 1978). Isolated remnants of Browns Park also cap Wild Horse Butte, Allen Hill, Deep Creek Rim, Muddy Mountain, Doty Mountain (fig. 1), and an unnamed ridge in sec. 22, T. 17 N., R. 90 W.; these remnants range from 5 to 180 ft thick

Green River Formation (Eocene)

Laney Member—Includes the Hartt Cabin and LaClede Beds of the Laney Member, as well as strata equivalent to the Godiva Rim Member of the Green River Formation (Roehler, 1989); these units are collectively mapped as the Laney Member in this report. The upper contact of the unit is not exposed in the study area. The lower contact is conformable. Approximately 1,050 ft of the Laney Member (including strata equivalent to the Godiva Rim Member) are estimated to be preserved in outcrops at North Flat Top (fig. 1).

Roehler (1973, 1989) described the Hartt Cabin Bed 2 mi west of the study area at West Flat Top Mountain (fig. 1) as consisting of 625 ft of interbedded drab-brown sandstone, siltstone, mudstone, shale, oil shale, tuff, limestone, and dolomite deposited in a freshwater lacustrine environment. The Hartt Cabin Bed intertongues with the underlying LaClede Bed. The latter, about 225–240 ft thick, is tan to brown oil shale with some interbeds of gray and tan siltstone and minor algal and ostracodal limestone deposited in a brackish-water and freshwater lacustrine environment (Roehler, 1989). The LaClede Bed conformably overlies 150–195 ft of gray, green, and tan mudstone, dolomitic limestone, algal limestone, oil shale, and sandstone that were described and considered by Roehler (1989) to represent the Godiva Rim Member of the Green River Formation; he interpreted these strata as brackish-water lacustrine, mudflat, and flood-plain deposits

Tipton Tongue—Includes strata equivalent to the Wilkins Peak Member of the Green River Formation, the Rife Bed of the Tipton Shale Member of the Green River Formation, and the Scheggs Bed of the Tipton Tongue of the Green River Formation (Roehler, 1989). These rocks are collectively mapped as the Tipton Tongue of the Green River Formation in this report. The unit is about 150–430 ft thick in outcrops north of Little Robbers Gulch and generally 100–150 ft thick in outcrops south of Little Robbers Gulch (fig. 1). The tongue pinches out near the southwestern corner of the study area in sec. 33, T. 13 N., R. 93 W. (Bradley, 1964).

Wilkins Peak Member equivalent strata (1) extend from near Wamsutter south to Little Robbers Gulch, (2) consist of 30–200 ft of shale, oil shale, siltstone, and algal limestone deposited in saltwater and mudflat environments, and (3) conformably overlie the Rife Bed (Roehler, 1989).

The Rife Bed consists of tan, brown, or black oil shale deposited in a saltwater lacustrine environment; it is about 230 ft thick near Wamsutter and pinches out to the south near Robbers Gulch (Roehler, 1989). The unit conformably overlies the Scheggs Bed.

The Scheggs Bed extends along the entire outcrop of the Tipton Tongue and Tipton Shale Member as described by Roehler (1989). North of the Dad arch (fig. 1), this bed forms slopes, is about 70–120 ft thick in outcrop, and consists of tan, brown, or black oil shale (Roehler (1989). South of the arch, it forms cliffs, is generally 100–150 ft thick, and consists of brown oil shale, gray or yellowish-brown sandstone, and minor gray mudstone, siltstone, and shale; sandstones are 40–90 ft thick, fine to coarse grained, massive, trough crossbedded, and ripple laminated, and contain scattered chert pebbles, shell and bone fragments, algal heads, and root casts (Hettinger and Honey, 2005; Roehler, 1988, 1989). The Scheggs Bed was interpreted as a freshwater lacustrine, mudflat, and deltaic deposit by Roehler (1989)

Luman Tongue—Tan, brown, or black oil shale deposited in a freshwater lacustrine environment (Roehler, 1989). Forms gentle slopes. The Luman intertongues with the underlying main body of the Wasatch Formation. It is about 320 ft thick in outcrops near Wamsutter and pinches out just north of the Dad arch (Roehler, 1989; Love and Christiansen, 1985)

Wasatch Formation (Eocene)

Cathedral Bluffs Tongue—Reddish-brown and lavender mudstone, gray shale, and greenish-gray and white, very fine grained to fine-grained, micaceous, and locally crossbedded sandstone. Typically forms broad gentle slopes. As mapped north of Robbers Gulch, the basal part may locally include strata equivalent to the Wilkins Peak Member of the Green River Formation as described by Roehler (1989). The Cathedral Bluffs Tongue was interpreted to be a flood-plain deposit by Roehler (1989). The Cathedral Bluffs intertongues with the underlying Tipton Tongue of the Green River Formation. The Cathedral Bluffs is 1,360 ft thick in the depth interval 530–1,890 ft in the Mattie No. 1 drill hole in sec. 14, T. 14 N., R. 93 W. (fig. 1) (Honey and Hettinger, 2004), about 1,450 ft thick in outcrops in T. 18 N., R. 94 W. (Roehler, 1989), and about 900 ft thick in outcrops in T. 19 N., R. 95 W. (6 mi west of Wamsutter) (Pipiringos, 1961)

Niland Tongue—Near the Dad arch, the Niland consists of thinly interbedded gray or tan sandstone and variegated mudstone; it grades northward into gray or green mudstone interbedded with brown or dark-gray carbonaceous shale and gray or tan sandstone (Roehler, 1989). Near Wamsutter, it consists of a 30-ft-thick, parallel-bedded, gray or tan sandstone overlain by a 5-ft-thick bed of coal (Roehler, 1989). The tongue is conformable and intertongues with the underlying Luman Tongue of the Green River Formation. It is about 40 ft thick in outcrops in Tps. 18 and 19 N., Rs. 93 and 94 W. (Roehler, 1989). The Niland was interpreted as a flood-plain and paludal deposit by Roehler (1989)

Main body—Predominantly mudstone with some interbedded light-gray and grayish-brown, fine-grained sandstone and lenticular, coarse-grained, conglomeratic sandstone. Considered a flood-plain deposit by Roehler (1989). South of the Dad arch, the main body forms steep badland topography and lithologies are varicolored (light gray, red, maroon, and green). North of the Dad arch, the main body forms gentle slopes, and mudstone is grayish white and less varicolored. Near the town of Wamsutter, the lower part of the main body contains several beds of subbituminous coal 1–30 ft thick (Masursky, 1962; Dames and Moore, 1978f).

The main body of the Wasatch Formation lies unconformably on Paleocene strata (Hettinger and others, 1991). The basal part is generally coarse grained. In outcrops from Interstate 80 south to the Continental Divide (fig. 1) this basal unit is characterized by coarse-grained arkosic sandstone that Sanders (1975) considered equivalent to the Paleocene-Eocene Battle Spring Formation in the Great Divide Basin. Farther south at Pine Butte (fig. 1), the basal unit is about 30 ft thick and characterized by a multistoried, trough-crossbedded bituminous sandstone that contains feldspar granules, flat siltstone clasts as much as 2 in. across, and carbonaceous shale and mudstone clasts as much as 1 ft across (Hettinger and Honey, 2006). From the Dad arch south to near the Little Snake River, the basal unit is 1–12 ft thick and consists of conglomerate and conglomeratic sandstone containing pebbles as much as 2.5 in. in diameter of chert, quartzite, quartz, limestone, and porphyritic igneous rock (Honey and Hettinger, 2004). Near the Little Snake River in the southernmost part of the study area, the basal conglomerate is absent and the base of the main body of the Wasatch is placed beneath the lowest variegated mudstone.

The main body is about 2,100 ft thick where exposed in the Peach Orchard Flat quadrangle (Honey and Hettinger, 2004) and about 1,220 ft thick in outcrops in the Blue Gap quadrangle (Hettinger and Honey, 2005). Farther north, the main body is 1,010 ft thick in the depth interval 850–1,860 ft at the U.P.R.R. No. 17-1 drill hole in sec. 17, T. 17 N., R. 93 W. (fig. 1) (Hettinger and others, 1991)

Fort Union Formation (Paleocene)—Includes the upper middle and upper Paleocene Overland Member, the lower Paleocene Blue Gap Member, and the lower Paleocene China Butte Member as defined by Honey and Hettinger (2004). Deposited in fluvial channel, flood-plain, lacustrine(?), and paludal environments. Descriptions are from a report by Honey and Hettinger (2004) except where noted

Overland Member—Includes (in descending order) the Cherokee coal zone, a middle fine-grained unit, and a basal sandstone; the Overland Member appears to lie unconformably on the Blue Gap and China Butte Members. The Overland thins from north to south across the study area due to erosion along the unconformity at the base of the overlying Wasatch Formation. Outcrop thicknesses are at least 2,271 ft in T. 20 N., R. 90 W.; 925 ft in secs. 33 and 34, T. 16 N., R. 91 W.; and about 425 ft from sec. 21, T. 14 N., R. 91 W. southward to the Colorado-Wyoming State line.

Cherokee coal zone (labeled Tfoc on geologic map)—Consists of gray-brown argillaceous siltstone, brown micaceous sandstone, shale, and coal (Sanders, 1975). Drill holes just west of the outcrop belt show the coal zone to be about 450 ft thick near Interstate 80 (Hettinger and others, 1991); it thins southward, and pinches out on outcrop where Coal Bank Wash crosses Highway 789 (fig. 1). The coal zone extends farther south and west in the subsurface and was drilled at the Federal DS 14-1 drill hole (depth interval 1,730–1,940 ft) in sec. 4, T. 17 N., R. 93 W. and at the U.P.R.R. No. 17-1 drill hole (at 2,100 ft) in sec. 17, T. 17 N., R. 93 W. (fig. 1) (Hettinger and others, 1991; Hettinger and Kirschbaum, 1991). Coal beds, 1–40 ft thick, include (in descending order) the High Point (HP), upper Cherokee (Chu), Cherokee (Ch), lower Cherokee (Chl), Cow Butte (CB), and Horse Butte (HB) (sheet 1)

Fine-grained middle unit—Weathers to badlands topography and consists of light-gray, massive, fine-grained sandstone, sandy siltstone, mudrock (mudrock includes claystone, mudstone, and their fissile counterparts), with subordinate amounts of crossbedded sandstone, and sandy ironstone. Crayfish burrows are locally common (Hasiotis and Honey, 2000). On outcrop, thicknesses are about 1,100 ft in T. 20 N., R. 90 W., 870 ft near the Dad arch, and 200 ft near the Colorado-Wyoming State line. Correlations by Hettinger and others (1991) showed that the unit is only 200–400 ft thick in the subsurface north of the Dad arch; thinning in that area is due to intertonguing with the basal sandstone

Basal sandstone—Consists of light-gray, coarse-grained sandstone with lenses of quartz and feldspar granules and chert pebbles as large as 1 in. in diameter. Clasts are largest from a few miles north of the Little Snake River to just south of the Dad arch and are progressively finer northward to Interstate 80. Exposures are sparse north of the Dad arch. Drill-hole data (Hettinger and others, 1991) show the basal sandstone to be about 1,050 ft thick in the subsurface north of the Dad arch. It is less than 100 ft thick in outcrops south of the Dad arch

Blue Gap Member—Olive- to brownish-gray claystone and mudstone with thin beds of fine-grained sandstone, siltstone, ironstone, and carbonaceous shale; rootlets and plant fragments are common. Member is poorly exposed. It lies conformably over, and intertongues with, the China Butte Member. The Blue Gap Member is about 570 ft thick near the Colorado-Wyoming State line where it was drilled between depths of 1,000 and 1,570 ft at the No. 1 Montgomery well in sec. 18, T. 12 N., R. 90 W. (fig. 1). The member thins northward and pinches out just north of the Dad arch

China Butte Member—Sandstone, siltstone, mudrock (mudrock includes claystone, mudstone, and their fissile counterparts), carbonaceous shale, and coal; the basal part contains conglomerate and conglomeratic sandstone. Plant fragments are common. Burnt coal has produced red clinker, locally. Forms valleys and ridges of low relief. Lithologies are typically in fining-upward units of thick multistoried sandstone, mudrock, and coal. Sandstone is light to yellowish gray, fine to coarse grained, trough crossbedded, and as much as 220 ft thick. Mudrock is gray or light to medium brown, and as much as 80 ft thick. Coal beds are 1–40 ft thick. The basal part of the member is characterized by light-gray to white, medium- to coarse-grained, trough-crossbedded, multistoried sandstone as much as 220 ft thick. The base of the member is characterized by a widespread conglomerate and (or) conglomeratic sandstone containing pebbles as much as 2 in. in diameter of chert, quartzite, quartz, and porphyritic felsic igneous rock. The conglomerate overlies a regional unconformity that separates the China Butte Member from the underlying Red Rim Member of the Lance Formation. In outcrop, the China Butte Member is about 735 ft thick near Baggs and 1,060 ft thick near the Dad arch. It is 2,160 ft thick where it was drilled between the depths of 1,975 and 4,135 ft in the Federal 3-2A drill hole in sec. 2, T. 20 N., R. 91 W. (fig. 1).

Coal zones mapped on sheet 1 include, from youngest to oldest, the Chicken Springs (CS), Fillmore Ranch (FR), Fillmore Creek (FC), Muddy Creek (MC), Separation Creek (SC), lower Separation Creek (SCl), Riner (R), lower Riner (Rl), Wild Cow (WC), Olson Draw (OD), Hadsell Draw (HD), Fivemile Point (5M), combined Olson Draw and Fivemile Point (O&5), Red Rim (RR), Daley Ranch (DR), Continental Divide (CD), and unnamed or uncorrelated coal beds (C). Some mapped coal zones represent several closely spaced zones or beds shown on the correlation chart (sheet 3). The lines on the geologic map represent the base of the most persistent bed. As mapped, the Fillmore Ranch coal zone also includes the equivalent Fillmore Ranch coal zone. Similarly, the Muddy Creek coal zone includes the Muddy Creek 1, 2, 3, and 4 coal beds, as well as the upper Muddy Creek coal zone, lower Muddy Creek coal zone, Muddy Creek coal bed, and Muddy Creek lower coal bed. The Olson Draw coal zone includes the upper, middle, and lower Olson Draw coal zones and the Olson Draw coal zone equivalent; the Red Rim coal zone also includes the Red Rim (lower) and equivalent Red Rim coal zone

Lance Formation (Upper Cretaceous)—Includes the late, but not latest, Maastrichtian Red Rim Member and the Maastrichtian lower member as described by Honey and Hettinger (2004). Descriptions are based on their work except where noted

Red Rim Member—Superposed and laterally continuous, trough-crossbedded, multistoried sandstones in units as much as 200 ft thick. Sandstone units are split by 20- to 100-ft-thick lenses of mudrock (mudrock includes claystone, mudstone, and their fissile counterparts). Exposures form conspicuous reddish-orange cliffs along Red Rim, a prominent ridge that extends from Interstate 80 southward to Separation Creek (fig. 1). Exposures south of Red Rim form discontinuous cliffs that are light gray to light yellowish gray. The member displays an overall coarsening-upward grain size. The lower part is fine to medium grained and generally contains no chert pebbles, whereas the upper part is medium to coarse grained and contains abundant chert pebbles as much as 0.5 in. in diameter (Hettinger and Honey, 2005, 2006). Interpreted primarily as an amalgamated fluvial channel deposit. The Red Rim Member probably intertongues with the lower member of the Lance Formation. In outcrops, the Red Rim Member is about 370 ft thick near the town of Baggs and about 685 ft thick near the Dad arch. It is about 900 ft thick (depth interval 2,800–3,700 ft) at the No. 1 Red Rim well (fig. 1) in sec. 19, T. 20 N., R. 90 W.

Lower member—An overall coarsening-upward succession. The upper part is dominated by 10- to 200-ft-thick units of fine-grained, light-gray, trough-crossbedded sandstone separated by 10- to 70-ft-thick units of dark- to medium-gray and brown mudrock (mudrock includes claystone, mudstone, and their fissile counterparts) and is interpreted to have been deposited in fluvial channel and flood-plain environments. The lower part consists of dark- to medium-gray and brown mudrock with minor amounts of very fine grained to fine-grained, ripple-laminated sandstone in lenticular beds less than 5 ft thick, and lenticular units of trough-crossbedded sandstone as much as 50 ft thick. The basal 50 ft of the member contains several lenticular coal beds that are about 1–10 ft thick. The lower part is interpreted to have been deposited in coastal plain, paludal, and brackish-water environments. The lower member of the Lance Formation is conformable and intertongues with shoreface deposits of the underlying Fox Hills Sandstone; the formation contact is placed at the top of the uppermost shoreface sandstone. The lower member is 1,675 ft thick in outcrops of the Peach Orchard Flat 7.5-minute quadrangle. Subsurface correlations made several miles west of the outcrop belt by Hettinger and others (1991, their Lance Formation) show the lower member is about 2,950 ft thick near Interstate 80, about 1,300 ft thick near the Dad arch, and about 1,300 ft thick near the Colorado-Wyoming State line

Fox Hills Sandstone, upper part of Lewis Shale, and Dad Sandstone Member of Lewis Shale, undivided (Upper Cretaceous)—Nearshore and marine Maastrichtian strata deposited during the Baculites clinolobatus and Baculites grandis biozones (Gill and others, 1970). The Fox Hills intertongues, and is gradational with, the upper part of the Lewis Shale, which in turn intertongues with the underlying Dad Sandstone Member (fig. 5). The Dad Sandstone also intertongues with the lower part of the Lewis Shale. Laterally continuous clinoforms extend from the Fox Hills Sandstone through the Dad Sandstone Member (Perman, 1990; Pyles and Slatt, 2000). Thicknesses of the Fox Hills Sandstone and members of the Lewis Shale are highly variable owing to intertonguing relations. The Fox Hills–Dad interval has a combined thickness of about 1,980 ft in the depth interval 7,040–9,020 ft 3 mi south of Wamsutter at the Tierney Unit 2 well (sec. 15, T. 19 N., R. 94 W.); 1,635 ft (depth interval 3,800–5,435 ft) 6 mi south of the Dad arch in the Blue Bell No. 3-3 well (sec. 3, T. 15 N., R. 92 W.); and 960 ft (depth interval 5,140–6,100 ft ) 8 mi north of the Colorado-Wyoming State line in the Muddy Creek Unit 1 well (sec. 8, T. 13 N., R. 91 W.) (fig. 1). Cross sections by Bader (1990a, b) show that the Lewis Shale is not subdivided in T. 12 N., R. 91 W., near the town of Baggs owing to the absence of the Dad Sandstone Member.

The Fox Hills Sandstone consists of coarsening-upward successions of shale and sandstone; shales are 5–150 ft thick and sandstones are 5–100 ft thick. Sandstone is grayish orange to yellowish gray, concretionary, very fine grained to medium grained, massive, trough crossbedded, and ripple laminated. Exposures locally form cliffs. Oyster shells and Ophiomorpha are common. Shale is gray and silty, and contains thin beds of fine-grained sandstone. The formation was deposited predominantly in shallow-water marine, barrier bar, and shoreface environments (Gill and others, 1970). It is about 80–300 ft thick in outcrops south of the Continental Divide (Hettinger and Honey, 2005, 2006; Gill and others, 1970). North of the Continental Divide, the Lance, Fox Hills, and upper part of the Lewis Shale intertongue in a 450-ft-thick interval (G.M. Edson and J.M. Back, unpublished mapping; Hettinger and others, 1991, their interbedded marine and nonmarine zone of the Fox Hills Sandstone); it contains the 8-ft-thick Nebraska coal bed (N) on sheet 1. In the subsurface, the Fox Hills Sandstone is 400 ft thick (depth interval 7,040–7,440 ft) in the Tierney Unit 2 well, 145 ft thick (depth interval 3,800–3,945 ft) in the Blue Bell No. 3-3 well, and 240 ft thick (depth interval 5,140–5,380 ft) in the Muddy Creek Unit 1 well.

The upper part of the Lewis Shale is poorly exposed, forming valleys. It was described by Witton (1999) in the Blue Gap 7.5-minute quadrangle as olive-gray, silty shale with some 1- to 3-ft-thick beds of yellowish-gray, silty, very fine grained sandstone. Sandstone beds are massive to parallel laminated, exhibit slump features, and have flat, nonscoured bases. Witton (1999) interpreted the sandstones as turbidite deposits that accumulated on the upper slope. The upper part of the Lewis Shale is about 330 ft thick where it is exposed in the Peach Orchard Flat 7.5-minute quadrangle (Gill and others, 1970; p. 39). In the subsurface, the upper part of the Lewis Shale is 1,170 ft thick (depth interval 7,440–8,610 ft) in the Tierney Unit 2 well, 700 ft thick (depth interval 3,945–4,645 ft) in the Blue Bell No. 3-3 well, and 555 ft thick (depth interval 5,380–5,935 ft) in the Muddy Creek Unit 1 well.

The Dad Sandstone Member forms small rounded hills and cuestas in covered valleys and consists of thick, pale-yellowish-gray, light-brown, and locally concretionary sandstones encased in olive-gray mudstone. The member contains as much as 400–600 ft of net sandstone in the study area and sandstone-dominated intervals are as much as 250 ft thick (Law and others, 1989, their fig. 14; Hettinger and Honey, 2006). Sandstone architecture is shown by Perman (1990), Pyles and Slatt (2000), and Hettinger and Roberts (2005; their plate 1). Witton (1999) described the sandstones as both channel-form and sheet-like. The channel-fill sandstones are lenticular and massive to parallel laminated, exhibit soft sediment deformation, and have basal lags that fill scoured surfaces (Witton, 1999). The sheet-like sandstones are laterally continuous, flat-based, massive, parallel laminated, and convoluted (Witton, 1999). The Dad Sandstone Member was deposited in a deep basin turbidite system (Perman, 1990; Pyles and Slatt, 2000; Witton, 1999). The member is as much as 1,300 ft thick in the subsurface along the western boundary of the Mexican Flat NW 7.5-minute quadrangle (Perman, 1990). It is about 410 ft thick (depth interval 8,610–9,020 ft) in the Tierney Unit 2 well, 785 ft thick (depth interval 4,650–5,435 ft) in the Blue Bell No. 3-3 well, 165 ft thick (depth interval 5,935–6,100 ft) in the Muddy Creek Unit 1 well, and it pinches out along the Cherokee ridge (fig. 1) near the town of Baggs (Bader, 1990a, b)

Lower part of the Lewis Shale (Upper Cretaceous)—Dark-gray, sandy marine shale that is poorly exposed and forms valleys. These upper Campanian and lower Maastrichtian rocks were deposited during the Baculites baculus and Baculites eliasi biozones (Gill and others, 1970). The lower part of the Lewis Shale intertongues, and is conformable with, the underlying Upper Cretaceous Almond Formation of the Mesaverde Group (fig. 5). Limestone concretions within 20–50 ft of the contact contain Baculites eliasi. The lower part of the Lewis Shale is about 430 ft thick (depth interval 9,020–9,450 ft) in the Tierney Unit 2 well, 1,035 ft thick (depth interval 5,435–6,470 ft) in the Blue Bell No. 3-3 well, and 1,605 ft thick (depth interval 6,100 ft–7,705 ft) in the Muddy Creek Unit 1 well. Thickening of the lower member south of the Dad arch is due to thinning of the overlying Dad Sandstone Member

Mesaverde Group, undivided (Upper Cretaceous)—Includes (in descending order) Campanian strata of the Almond Formation, Pine Ridge Sandstone, Allen Ridge Formation, and Haystack Mountains Formation (Gill and others, 1970). Cross sections by Roehler and Hansen (1989a, b) show the Mesaverde Group is about 2,700–2,900 ft thick in the subsurface of the study area. Descriptions are based on Barclay (1980a, b), Naftz and Barclay (1991), and Barclay, C.S.V. (this report), except where noted.

The Almond Formation is 450–550 ft thick and comprises intertonguing marine, restricted marine, and nonmarine deposits. It is divided informally into lower and upper members. The upper member is characterized by repetitive coarsening-upward units of gray shale and sandstone that are locally capped by mudrock (mudrock includes claystone, mudstone, and their fissile counterparts) and thin beds of coal. Sandstone is fine grained (Gill and others, 1970), ripple laminated, and crossbedded or massive, and contains Ophiomorpha. Coarsening-upward units are interpreted as shoreface deposits that probably formed barrier islands or mainland beaches. Coal beds developed from peat swamps that formed adjacent to the mainland beaches or in sediment-filled lagoons. The lower member is characterized by coarsening-upward units that consist, in ascending order, of brown carbonaceous mudstone, wavy- to flaser-bedded sandstone, and crossbedded to massive very fine grained to fine-grained sandstone, and are generally capped by mudrock and beds of coal as much as 16 ft thick. Sandstone and interlaminated sandstone and mudstone commonly contain burrows associated with brackish-water deposits. Root traces are common in strata underlying beds of coal. Coarsening-upward units in the lower member are tentatively interpreted as splays in brackish-water interdistributary bays located in lower delta-plain settings. The lower member also contains fining-upward units of trough-crossbedded sandstone interpreted as deposits that filled active distributary channels. Coal in the lower member developed from peat that accumulated where splay deposits filled bays and water was shallow enough to allow the growth of vegetation.

The Pine Ridge Sandstone is a continental fluvial deposit consisting primarily of trough-crossbedded sandstone and minor amounts of carbonaceous siltstone, mudstone, and coal. Coal seams are discontinuous and only a few inches thick. The Pine Ridge is probably unconformable on the Allen Ridge Formation in most places in southern Wyoming (Gill and others, 1970). It is believed to be about 40–100 ft thick in outcrops of the study area, but its contacts with adjacent formations are not well known.

The Allen Ridge Formation is 1,200–1,400 ft thick and is informally divided into an upper marginal marine member and a lower nonmarine member. The upper marginal-marine member is 140–220 ft thick and typically consists of thick bioturbated organic-rich brown shaly mudstone, ripple-laminated very fine grained sandstone, and coal. Coal beds are generally 1–7 ft thick. Thick sandstone beds in the upper part of the upper member commonly have ripple-laminated, subparallel crossbed sets that dip more steeply than enclosing beds of mudstone, and are believed to be point-bar deposits of meandering streams. Thin beds of sandstone and mudstone near the base of the upper member commonly contain burrows and are interpreted as brackish-water-bay fill. The lower nonmarine member is 1,000–1,200 ft thick and comprises continental deposits of sandstone, siltstone, mudrock (mudrock includes claystone, mudstone, and their fissile counterparts), carbonaceous shale, and coal. Sandstone is yellowish orange to yellowish gray, very fine grained to medium grained, ripple laminated, and (or) trough crossbedded. Units of sandstone are typically in fining-upward lenticular units as much as 40 ft thick, have bases in erosional contact with underlying strata, and are interpreted as active channel-fill deposits. Siltstone is yellowish orange, clayey, massive to laminated, and flat bedded. Mudrock is grayish brown to olive gray. Siltstone and mudrock are interpreted as flood-plain deposits containing limnic coals. Coal beds are generally 1–2 ft thick and lenticular. The Allen Ridge conformably overlies the Haystack Mountains Formation.

The Haystack Mountains Formation was deposited in marine and marginal-marine environments during an overall eastwardly retreat of the Cretaceous Western Interior Sea. The formation is 750–950 ft thick but only the uppermost 100 ft are exposed in the study area between Muddy Creek and Horse Gulch (fig. 1) in T. 17 N., R. 90 W. The formation consists of thick alternating units of laterally extensive sandstone and shale beds that respectively form prominent cliffs and intervening slopes east of the study area along Atlantic Rim to Savery Creek canyon (fig. 1). Sandstones are very fine grained to medium grained, weather grayish orange and light yellowish gray, coarsen upward, include some thinner intervals of gray shale, display hummocky, flat, swaley, and trough crossbeds, contain Ophiomorpha and Thalassinoides, and are interpreted as progradational shoreface and foreshore deposits of wave-dominated shorelines. Shales consist of gray, clayey silt-shale with some layers of scattered carbonate concretions that commonly contain marine fossils. The shale units are interpreted as offshore marine deposits. One or two coal beds, 1–3 ft thick, overlie the Hatfield Sandstone Member near the middle of the formation east of the study area. The coal beds developed from peat that accumulated in freshwater to brackish-water swamps landward of the shoreline. Shale near the top of the Haystack Mountains Formation contains Baculites perplexus, and the zone of Baculites obtusus lies near the top of the underlying Steele Shale (Gill and others, 1970)

NOTES ON GEOLOGY AND COAL DEPOSITS

INTRODUCTION

This report presents the geology of some Upper Cretaceous and Tertiary strata, and the stratigraphy of Paleocene coal beds in the eastern part of the Greater Green River Basin in Wyoming and northernmost Colorado (fig. 1). The area generally lies within the Little Snake River coalfield that was discussed by Ball (1909) and Ball and Stebinger (1910). Herein, the mapped area is referred to as the Rawlins–Little Snake River area or simply as the study area.

The geologic map of the Rawlins–Little Snake River area (sheet 1) is a compilation of published maps by various investigators and of previously unpublished data from the authors of this report and others. Sources of geologic mapping are shown in figure 2. Geology is plotted on parts of the 1:100,000-scale (metric) topographic maps of the Baggs and Rawlins 30 x 60-minute quadrangles. A structure contour and overburden map constructed on selected Paleocene coal-bearing horizons is shown on sheet 2, and the stratigraphy of Paleocene coal beds is shown on sheet 3. The study area covers about 1,250 mi2 and includes all or parts of twenty seven 7.5-minute quadrangles (fig. 3) in Carbon and Sweetwater Counties, Wyoming, and Moffat and Routt Counties, Colorado (fig. 1). Its southern boundary extends about 20 mi from east to west and is located about 1,000 ft south of the Colorado-Wyoming State line near the towns of Baggs and Dixon (fig. 1). Its northern boundary is located about 55 mi north of the State line and extends about 40 mi east to west along Interstate 80 between the towns of Wamsutter and Rawlins, Wyoming (fig. 1).

GEOLOGIC SETTING

The Greater Green River Basin is bounded by the Wind River and Granite Mountains uplifts to the north; the Rawlins, Sierra Madre, and Park Range uplifts to the east; the Axial arch to the south; and the Wyoming thrust belt to the west (fig. 1). The study area is located in the eastern part of the Greater Green River Basin—that part of the basin located east of the Rock Springs uplift (fig. 1). The eastern part of the Greater Green River Basin is partitioned into the Sand Wash, Washakie, and Great Divide Basins by the northwest-southeast-trending Wamsutter arch and the east-west-trending Cherokee ridge (fig. 1). The study area extends from the southern part of the Great Divide Basin, across the eastern part of the Washakie Basin, and into the northern part of the Sand Wash Basin. The location of major surface and subsurface geologic structures in the study area are shown on figure 4 and are briefly described below.

Strata generally dip 2°–15° westward on the west flank of the Sierra Madre uplift and are gently folded across the east-west-trending Dad arch, Wamsutter arch, and Cherokee ridge (fig. 4). The Wamsutter arch is poorly defined at the surface but forms a distinct fold in the subsurface as shown by Lickus and Law (1988). Strata are more steeply inclined (about 15°–35°) along a west-dipping monocline (fig. 4). In map view this monocline wraps around the axis of the Dad arch, indicating the formation of the monocline preceded the folding of the arch. In the northeastern part of the study area, beds are inclined vertically and overturned along the west flank of the Rawlins uplift. Some structural features mapped along the Cherokee ridge may not extend very far into the subsurface. For example, the anticline mapped at the surface across the southern row of sections in T. 13 N., R. 92 W. (sheet 1) was considered by Cronoble (1969a) to be superficial and related to faulting or decollement planes in the underlying mudstone of the Wasatch Formation. Surface faults are generally oriented northeast to southwest and northwest to southeast, and are interpreted as extensional structures. Scissors faults, just south of the axis of the Dad arch (fig. 4), bound a series of blocks that are rotated down to the west and up to the east (Hettinger and Honey, 2005). Faults on the northern limb of the Dad arch and south of Doty Mountain (fig. 4) are down to the north, and reverse drag on the downthrown sides has tilted the strata southward toward the faults, indicating a possible listric origin (Hettinger and Honey, 2006). The northwest-southeast-trending graben near the town of Dixon (fig. 4) contains a thick remnant of Browns Park Formation that was folded and faulted downward several hundred feet relative to adjacent deposits of Browns Park that cap nearby buttes and ridges. Similarly, the thick remnant of Browns Park Formation in Poison Basin was also likely displaced downward.

Major subsurface structural features include an east-west-oriented fault system along the Cherokee arch and a series of blind thrust faults underlying the eastern part of the study area (fig. 4), neither of which is observed at the surface. The north limb of the Cherokee ridge is faulted and displaced down to the north. The fault system extends at least 42 mi west of the town of Baggs (Bader, 1987) and has been studied by Cronoble (1969a, b), Lewis (1977), Bader (1987, 1990a, b), and Parker and Bortz (2001). The faults were interpreted as a right-lateral wrench-fault system by Bader (1987) and, conversely, as a left-lateral shear fault zone by Parker and Bortz (2001). In this report, the structure contours shown along the Cherokee ridge (sheet 2) are based on all available drill-hole data in the area and have been influenced by interpretations of those previous investigations.

Positions of blind thrust faults shown in figure 4 represent approximate locations where the fault traces intersect the Upper Cretaceous Mowry Shale (Doelger and others, 1999, their fig. 1-23) about 11,000–13,000 ft below the surface of the study area. The close association between the positions of the monocline and the underlying blind thrust faults indicates that the monocline is likely a surface expression of the blind thrusts. Similarly, the close association between positions of the graben near Dixon and the subsurface structure along Cherokee ridge implies a structural relation as well.

## STRATIGRAPHY

Strata discussed in this report are principally bedrock. Detailed lithologic descriptions and thicknesses are provided in the “Description of Map Units” on sheet 1. Quaternary deposits are widespread throughout the region, but were mapped only along major drainages and where they obscure large areas of underlying bedrock. Bedrock includes (in ascending order) marine and nonmarine deposits of the Upper Cretaceous Mesaverde Group, marine deposits of the Upper Cretaceous Lewis Shale, nearshore and shoreface deposits of the Upper Cretaceous Fox Hills Sandstone, and continental deposits of the Upper Cretaceous Lance Formation, Paleocene Fort Union Formation, and Eocene Wasatch and Green River Formations. Generalized thickness trends and stratigraphic relations of these formations are shown in figure 5. Fluvial and eolian deposits of the Miocene-Oligocene Browns Park Formation are the youngest bedrock in the study area.

The Mesaverde Group is stratigraphically the lowest unit exposed in the study area. It consists (in ascending order) of the Haystack Mountains Formation, Allen Ridge Formation, Pine Ridge Sandstone, and Almond Formation (Gill and others, 1970). The Pine Ridge is thought to pinch out east of the study area (Barclay and Shoaff, 1978; Barclay, 1979a; Naftz and Barclay, 1991) in T. 14 N., R. 89 W., and is probably absent south of that location. Where the Pine Ridge is absent, the upper member of the Allen Ridge can not be distinguished from the overlying Almond Formation (Barclay, 1980a, b). In those areas where the Pine Ridge is absent, strata equivalent to the upper member of the Allen Ridge, Pine Ridge, and Almond are about 820–930 ft thick and referred to as the upper part of the Mesaverde Group (Naftz and Barclay, 1991). Just south and east of the study area, the Mesaverde Group is represented by the Upper Cretaceous Iles and Williams Fork Formations; intertonguing relations are described by Roehler and Hansen (1989b). Coal beds in the Mesaverde Group are described below.

The Lewis Shale is divided into a lower part, the Dad Sandstone Member, and an upper part (Gill and others, 1970). In this report, the lower part of the Lewis Shale was mapped separately, and the Dad Sandstone, upper part of the Lewis Shale, and Fox Hills Sandstone were mapped together. The Fox Hills Sandstone contains a few thin discontinuous beds of coal, including the 8-ft-thick bed at the Nebraska mine (fig. 1) in sec. 6, T. 20 N., R. 88 W. (Ball and Stebinger, 1910); the bed, mapped on sheet 1 as N, is informally referred to here as the Nebraska coal bed.

The Lance and Fort Union Formations were divided into members by Honey and Hettinger (2004). The Lance Formation was divided into a lower member and the upper Red Rim Member. Several thin and discontinuous coal beds about 1–10 ft thick are near the base of the lower member. The Fort Union Formation was divided (in ascending order) into the China Butte, Blue Gap, and Overland Members. Numerous thick beds of coal are in the China Butte Member as well as in the Cherokee coal zone in the upper part of the Overland Member. The coal beds are mapped on sheets 1 and 3 and discussed below.

Eocene strata are divided (in ascending order) into the main body of the Wasatch Formation, the Luman Tongue of the Green River Formation, the Niland Tongue of the Wasatch Formation, the Tipton Tongue of the Green River Formation, the Cathedral

Bluffs Tongue of the Wasatch Formation, and the Laney Member of the Green River Formation. These Eocene deposits were described in detail by Bradley (1964). The main body of the Wasatch Formation has been referred to previously as the Wasatch Formation (Bradley, 1964), the Red Desert Tongue of the Wasatch Formation (Pipiringos, 1961), and the main body of the Wasatch Formation (Masursky, 1962; Love and Christiansen, 1985). Coal beds 1–30 ft thick are in the main body of the Wasatch Formation near the towns of Wamsutter and Creston Junction (fig. 1) (Masursky, 1962; Dames and Moore, 1978f). They are part of an extensive coal zone that is distributed throughout the main body of the Wasatch Formation north of Interstate 80 in the Great Divide Basin where it was mapped by Pipiringos (1961) and Masursky (1962).

The Tipton Tongue and Laney Member of the Green River Formation were subdivided in the study area by Roehler (1973, 1989). The Tipton Tongue was subdivided into the Scheggs Bed of the Tipton Tongue and the Rife Bed of the Tipton Shale Member by Roehler (1989); he also considered the upper part of the tongue, north of Little Robbers Gulch (fig. 1), to be equivalent to the Wilkins Peak Member of the Green River Formation. The Scheggs Bed, Rife Bed, and equivalent strata of the Wilkins Peak were mapped together as the Tipton Tongue of the Green River Formation in this report. The Laney Member was subdivided into the LaClede and Hartt Cabin Beds by Roehler (1973, 1989) and strata in the lower part of the Laney was thought by Roehler (1989) to represent the Godiva Rim Member of the Green River Formation. In this report, the LaClede Bed, Hartt Cabin Beds, and Godiva Rim equivalent strata were mapped together as the Laney Member of the Green River Formation.

## COAL IN THE MESAVERDE GROUP

Each of the formations in the Mesaverde Group contains at least one coal bed that is more than 1 ft thick, except the Pine Ridge Sandstone, which contains only discontinuous coal seams a few inches thick in most places.

The Haystack Mountains Formation contains one or two coal beds, 1–3 ft thick, that overlie the Hatfield Sandstone Member near the middle of the formation east of the northern part of the study area. Data on coal quality are not available, but heating value is probably similar to that of other Mesaverde coals.

The Allen Ridge Formation contains lenticular coal beds, generally 1–2 ft thick, in most of the lower nonmarine member. Southeast of the study area, the basal part of the formation contains as many as three coal beds that are 2–4 ft thick. As-received analysis of a sample from a 2.8-ft-thick coal bed collected near the base of the Allen Ridge 16 mi northeast of Dixon shows 6.94 percent ash, 2.25 percent sulfur, and a heating value of 11,218 Btu/lb (Ball and Stebinger, 1910; their sample 6644). Coal beds in the upper member are generally 1–7 ft thick and more numerous, but generally grade laterally and vertically to carbonaceous shale over short distances. An as-received analysis of a sample from a 4.5-ft-thick coal bed in the upper member of the Allen Ridge at the abandoned Dillon mine (fig. 1) near Rawlins shows 8.44 percent ash, 0.49 percent sulphur, and a heating value of 11,009 Btu/lb (Ball, 1909).

Coal is present throughout the Almond Formation (Barclay, 1979a, b; 1980a, b; Barclay and Shoaff, 1977, 1978; Barclay and Zimmermann, 1976). Along most of the eastern side of the study area, where the formation is underlain by the Pine Ridge Sandstone, the thickest and most numerous beds of coal are in the lower 200–300 ft. There, beds are 1–16 ft thick, with 4–8 of them at least 5 ft thick. However, near Rawlins, Almond coals are much thinner and less numerous than in the rest of the study area. Southeast of the study area, where the Pine Ridge is absent, the upper part of the Mesaverde Group contains coal beds that are 1–22 ft thick; as many as 15 are at least 4 ft thick and 6 are at least 5 ft thick. Published analyses of coal in the Almond Formation show it generally to be of subbituminous rank but ranging up to bituminous where it is deeply buried (Ball and Stebinger, 1910; Hatch and Barclay, 1979). The average of six analyses (as-received basis) of six coal samples from four abandoned mines in T. 12 N., Rs. 88–89 W., show 6.61 percent ash, 0.58 percent sulfur, and a heating value of 10,359 Btu/lb (Ball and Stebinger, 1910).

## COAL IN THE CHINA BUTTE MEMBER OF THE FORT UNION FORMATION

Important deposits of coal are distributed throughout the China Butte Member. The interval of coal-bearing rocks is about 1,500 ft thick near Creston Junction, gradually thins southward to about 550 ft near the Colorado-Wyoming State Line, and is only about 80 ft thick near the town of Baggs. Outcrops of the coal beds are shown on sheet 1. The coal-bearing strata extend throughout the subsurface of the study area west of the outcrop belt. Structural relief on the uppermost coal bed ranges from 7,300 ft at the surface in the northwestern part of the study area to about 100 ft above sea level in the subsurface of the southwestern part (sheet 2). Overburden on the uppermost coal bed is as much as about 6,400 ft along the southwestern boundary of the study area (sheet 2). The uppermost coal is in the Baggs, Fillmore Ranch, and Chicken Springs coal zones (fig. 6), which are in a stratigraphic interval that varies by less than 150 ft in thickness. In areas where the uppermost coal is absent, the structure contour and overburden maps were constructed on its projected stratigraphic position.

Nomenclature, lateral continuity, and maximum coal bed thickness are summarized for each coal zone in table 1. Detailed coal correlations are shown on sheet 3 and portrayed schematically in figure 5. Several zones contain thick and laterally extensive beds of coal. For example, the Fillmore Ranch and Red Rim coal zones each extend about 40 mi along outcrops and contain beds that are more than 30 ft thick. Most of the coal zones were originally named by Edson (1979) and Honey and Hettinger (1989a). Exceptions are the Baggs, Fivemile Point, Hadsell Draw, and Wild Cow coal zones. The Baggs coal zone was named for a coal bed identified in the subsurface in the southern part of the Baggs and Poison Basin 7.5-minute quadrangles and the Fivemile Point coal zone was named for exposures in the Peach Orchard Flat and Baggs 7.5-minute quadrangles (Honey and Robinson Roberts, 1989). The Hadsell Draw coal zone is herein introduced for exposures in the Rawlins Peak SW 7.5-minute quadrangle. The Wild Cow coal zone was mapped in the Blue Gap and Doty Mountain 7.5-minute quadrangles (Hettinger and Honey, 2005, 2006). The terms Red Rim equivalent, Olson Draw equivalent, and Fillmore Ranch equivalent coal zones are used to indicate beds that are laterally equivalent to the Red Rim, Olson Draw, and Fillmore Ranch coal zones, respectively. The Red Rim equivalent and Olson Draw equivalent coal zones were mapped by Honey and Robinson Roberts (1989) and Honey and Hettinger (2004). The Fillmore Ranch equivalent coal zone is applied in this report to an unnamed coal bed mapped in the Riner 7.5-minute quadrangle by Honey (1990). Some coal zone names have been applied inconsistently by Dames and Moore (1978b, c, e; 1979a–f, h, i) owing to errors in coal bed correlations. Revised correlations were provided by Honey and Hettinger (1989a) for the Seaverson Reservoir and Fillmore Ranch 7.5-minute quadrangles.

Ash yield, sulfur content, heating values, and rank of coal in the China Butte Member were reported on an as-received basis by Dames and Moore (1978b, c, e; 1979a, c, h) and are summarized in table 2. Ash yields range from 4.8 to 14.63 percent, sulfur content ranges from 0.15 to 1.31 percent, heating values range from 7,319 to 9,786 Btu/lb, and apparent rank varies from subbituminous B to subbituminous C. Additional chemical analyses from coal and associated shale are reported in Hatch and Affolter (1980).

## COAL IN THE OVERLAND MEMBER OF THE FORT UNION FORMATION

The Overland Member also contains important deposits of coal in the Cherokee coal zone. The coal zone is exposed in the northern part of the study area near Creston Junction, and in the subsurface it extends westward across the southern part of the Great Divide Basin (Hettinger and Kirschbaum, 1991). Coal outcrops are shown on the geologic map (sheet 1). The Cherokee coal zone is about 450 ft thick near Creston Junction. It thins to the south and pinches out near Coal Bank Wash in sec. 4, T. 18 N., R. 92 W. (fig. 1). Detailed coal correlations are shown on sheet 3 and shown schematically in figure 5. Coal bed mapping and nomenclature are based on Sanders (1974, 1975), Edson (1979), Dames and Moore (1978d, f; 1979a, b), and J.M. Back (U.S. Geological Survey, unpublished coal resource study of the Creston Junction 7.5-minute quadrangle, 1976). The name, maximum thickness, and lateral continuity of each coal bed are summarized in table 3. Coal beds extend about 2–14 mi on outcrop and the thickest bed is about 41 ft thick. Clastic intervals between the coal beds are highly variable and individual coal beds vary in thickness by as much as 50 percent over distances of 1,000 ft (Sanders, 1975).

Ash yield, sulfur contents, heating values, and apparent rank of coal beds in the Cherokee coal zone were reported on an as-received basis by Sanders (1974, 1975) and are summarized in table 4. Ash yields range from 9.60 to 35.28 percent, sulfur content ranges from 1.03 to 5.74 percent, heating values range from 6,098 to 9,122 Btu/lb, and apparent rank varies from lignite to subbituminous C.

## SOURCES OF DATA

Geology shown on sheet 1 is largely a product of field mapping and drilling for coal conducted by the U.S. Geological Survey during the 1970s to assess coal resources in the Rawlins–Little Snake River area. Principal investigators were J.M. Back, C.S.V. Barclay, G.M. Edson, R.D. Hettinger, J.G. Honey, and R.B. Sanders. Specific areas of mapping are shown in figure 2. Field investigations were mostly confined to coal-bearing strata exposed east of Highway 789 (fig. 1). Mapping was done on 1:62,500-scale topographic base maps of the Baggs, Bridger Pass, Doty Mountain, and Rawlins Peak 15-minute quadrangles and 1:24,000-scale topographic base maps of the Creston Junction, Duck Lake, Fillmore Ranch, Mexican Flats, Riner, and Seaverson Reservoir 7.5-minute quadrangles (fig. 3). The 15-minute quadrangles were subsequently recompiled and released as 7.5-minute quadrangles shown in figure 3.

Although preliminary geologic mapping from these investigations was released on the Geologic map of Wyoming by Love and Christiansen (1985) and preliminary coal bed mapping was released in coal assessment reports by the Dames and Moore Company (1978a–g; 1979a–k), most of the detailed mapping remained unpublished at that time. Initial publications included geologic maps of the Riner and Creston Junction 7.5-minute quadrangles (Sanders, 1974, 1975), Seaverson Reservoir 7.5-minute quadrangle (Edson, 1979), and the Baggs area (Honey and Robinson Roberts, 1989). Additional geologic maps were made just east of the study area in the Tullis 7.5-minute quadrangle (Barclay, 1976) and Browns Hill–Savery Creek area (Naftz and Barclay, 1991, their plate 1) (fig. 1). Coal drilling in the Fort Union Formation was reported by Edson and Curtiss (1976) and Hettinger and Brown (1979), and measured surface sections were reported by Honey (1984). Coal drilling in the Almond Formation was described by Barclay (1979a, b; 1980a, b), Barclay and Shoaff (1977, 1978), and Barclay and Zimmermann (1976).

In subsequent studies, formal nomenclature was established for coal beds in the Fillmore Ranch and Seaverson Reservoir 7.5-minute quadrangles (Honey and Hettinger, 1989a) and coal beds were mapped in the Riner 7.5-minute quadrangle (Honey, 1990). The stratigraphic framework of Upper Cretaceous and Tertiary rocks was demonstrated by Honey and Hettinger (1989b), Hettinger and others (1991), and Hettinger and Kirschbaum (1991). These studies resulted in more closely defined stratigraphic contacts and in formally named members for the Fort Union and Lance Formations by Honey and Hettinger (2004). The units were mapped across the Peach Orchard Flat, Blue Gap, and Doty Mountain 7.5-minute quadrangles by Honey and Hettinger (2004) and Hettinger and Honey (2005, 2006), and then extended across the rest of the study area for the present map compilation. Coal bed outcrops and correlations shown in this report are based on the sources of data listed above and include some revisions to work published prior to 1989.

Most of the geology mapped west of Highway 789 is modified from the various sources listed in figure 2. Mapping in the structurally complex Poison Basin area (fig. 1) is generalized and modified from mapping by Bradley (1964), Cronoble (1969a), Lewis (1977), and Love and Christiansen (1985). The outcrop of Oligocene(?) Bishop Conglomerate mapped by Bradley (1964) and Olson (1959) on North Flat Top (fig. 1) was excluded because we observed only widely scattered and isolated pebbles of chert at that location. Bedrock mapped north of Red Wash (fig. 1) was modified from Bradley (1964) and Love and Christiansen (1985), based on photogeologic mapping using 1:36,000-scale color aerial photographs. Tongues of the Wasatch Formation were recognized on the aerial photographs by red, white, gray, and yellow bedding and distinguished from the light- to dark-brown beds of the Green River Formation. Contacts were traced southward from the town of Wamsutter, where they were mapped by Pipiringos (1961), to the vicinity of Red Wash where they were mapped by Hettinger and Honey (2005). As mapped, exposures of the Cathedral Bluffs and Tipton Tongues closely match mapping by Bradley (1964), and exposures of the Niland and Luman Tongues closely match mapping by Love and Christiansen (1985). Surficial units north of Red Wash were also mapped using color aerial photography; the mapping was guided by the work of Hallberg and others (1998).

## METHODS

Procedures used to construct maps and correlation charts on sheets 1, 2, and 3 are described here.

Geologic map (sheet 1)—Geologic contacts were selected and transferred onto 1:24,000-scale topographic base maps of each 7.5-minute quadrangle. Sources of data are referenced in figure 2. The resulting maps were reduced in scale and transferred onto topographic bases of the Baggs and Rawlins 30 x 60-minute quadrangles. Line work was digitized using ArcMap 9.1.

Structure contour and overburden map (sheet 2)—The structure contour and overburden map represents the elevation and depth of the uppermost coal bed in the China Butte Member of the Fort Union Formation. Elevations were determined from geophysical well logs and outcrops mapped at a scale of 1:24,000. Drill-hole locations and kelly bushing elevations were obtained from the Wyoming Oil and Gas Conservation Commission (2005). Overburden isolines represent the thickness of the interval between the structure-contoured surface and the Earth's surface from each 7.5-minute quadrangle. Structure elevations and overburden thickness were contoured manually at a scale of 1:24,000 and transferred onto the 1:100,000-scale topographic base of the Baggs and Rawlins 30 x 60-minute quadrangles. Line work was digitized using ArcMap 9.1.

Coal correlation (sheet 3)—Coal bed correlations shown on sheet 3 were constructed from stratigraphic sections measured in the field, interpretations of geophysical logs from numerous coal test holes, and correlations made from outcrops and photogeologic mapping by the authors, with contributions from J.M. Back and G.M. Edson (see below).

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