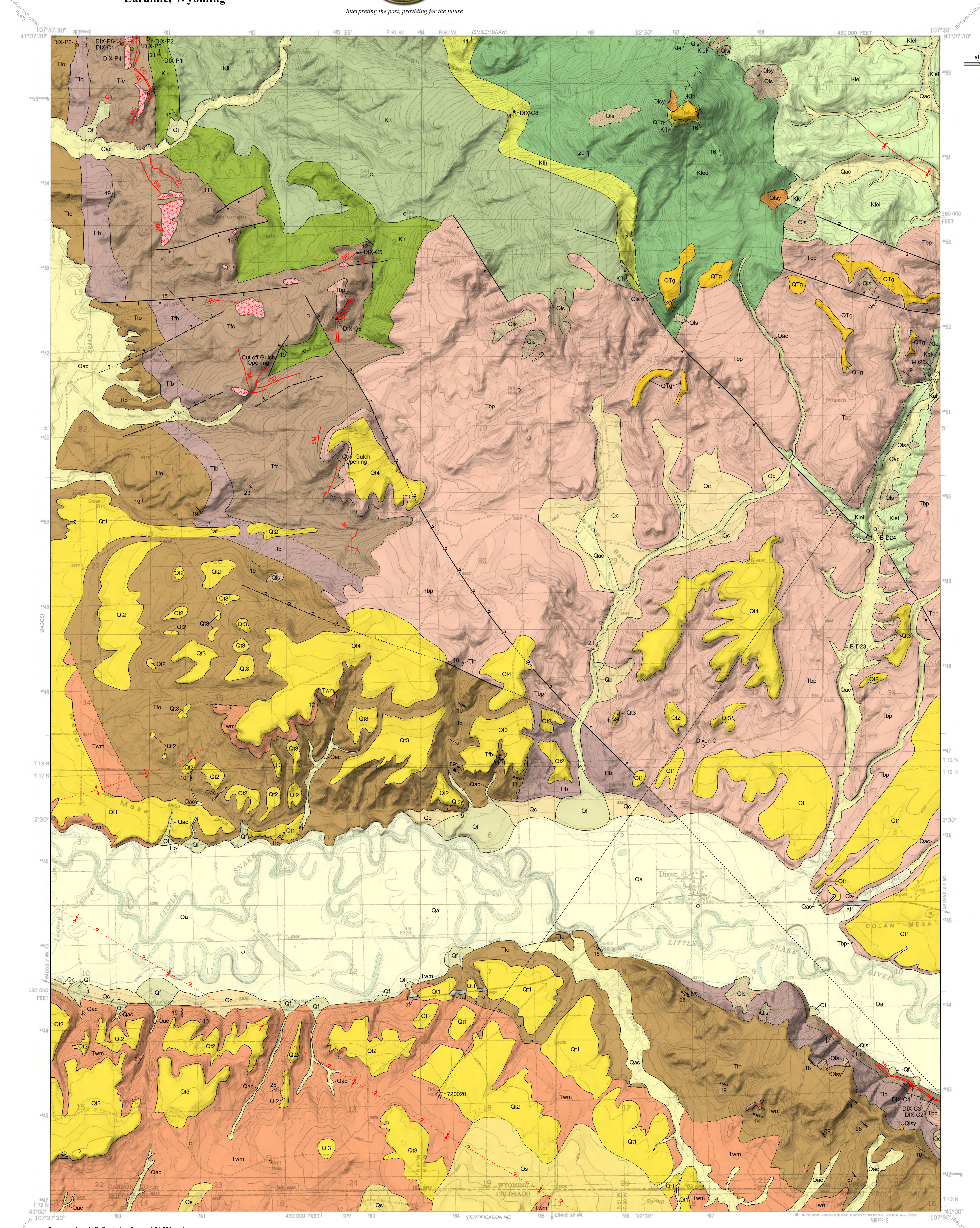
WYOMING STATE GEOLOGICAL SURVEY
Thomas A. Drean, Director and State Geologist
Laramie, Wyoming

Interpreting the past, providing for the future

OPEN FILE REPORT 2016-5
Dixon 1:24,000-scale
Bedrock Geologic Map



Base map from U.S. Geological Survey 1:24,000-scale topographic map of the Dixon, Wyoming-Colorado Quadrangle, 1982

Base hillshade derived from a U.S. Geological Survey tile of the National Elevation Dataset (NED), 10-meter Digital Elevation Model (DEM), 2013: azimuth 315º, sun angle 45º, vertical exaggeration 2.7

Projection: Universal Transverse Mercator (UTM), zone 13
North American Datum of 1927 (NAD 27)
1,000-meter grid ticks: UTM, zone 13
10,000-foot grid ticks: Wyoming State Plane Coordinate System, east central zone

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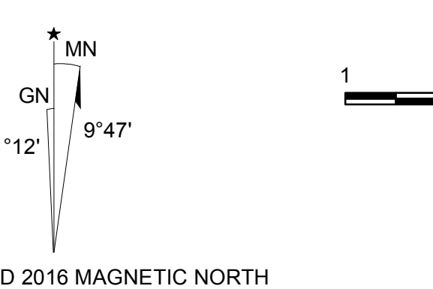
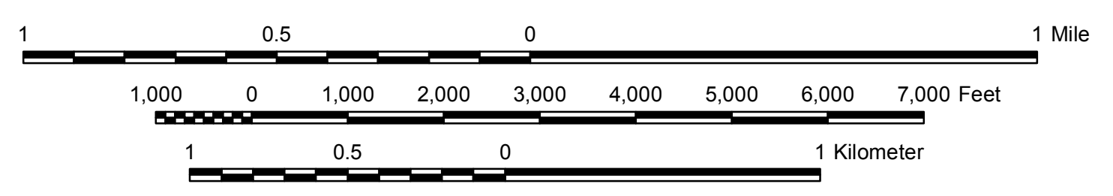
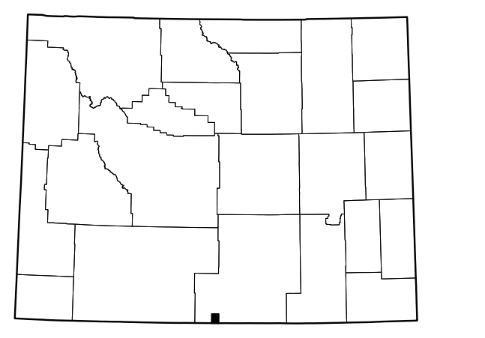


UTM GRID AND 2016 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24,000



CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929



WYOMING QUADRANGLE LOCATION

Digital cartography by Lynsey J. Spaeth and Christopher J. Carroll

Map edited by Suzanne C. Luhr

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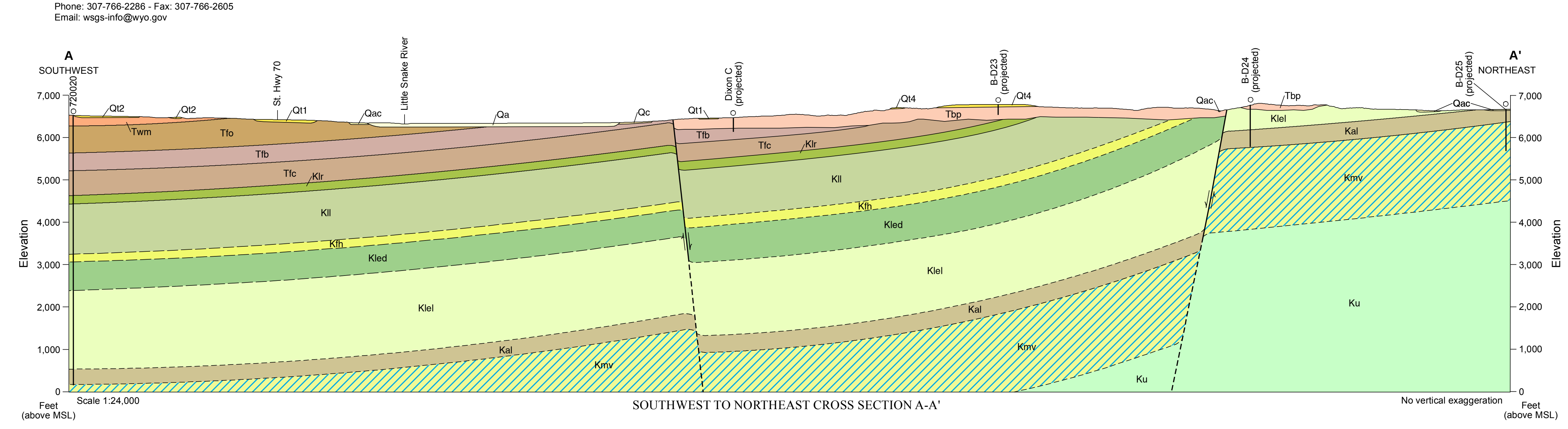


SOUTHWEST TO NORTHEAST CROSS SECTION A-A'

PRELIMINARY GEOLOGIC MAP OF THE DIXON QUADRANGLE, CARBON COUNTY, WYOMING, AND MOFFAT COUNTY, COLORADO

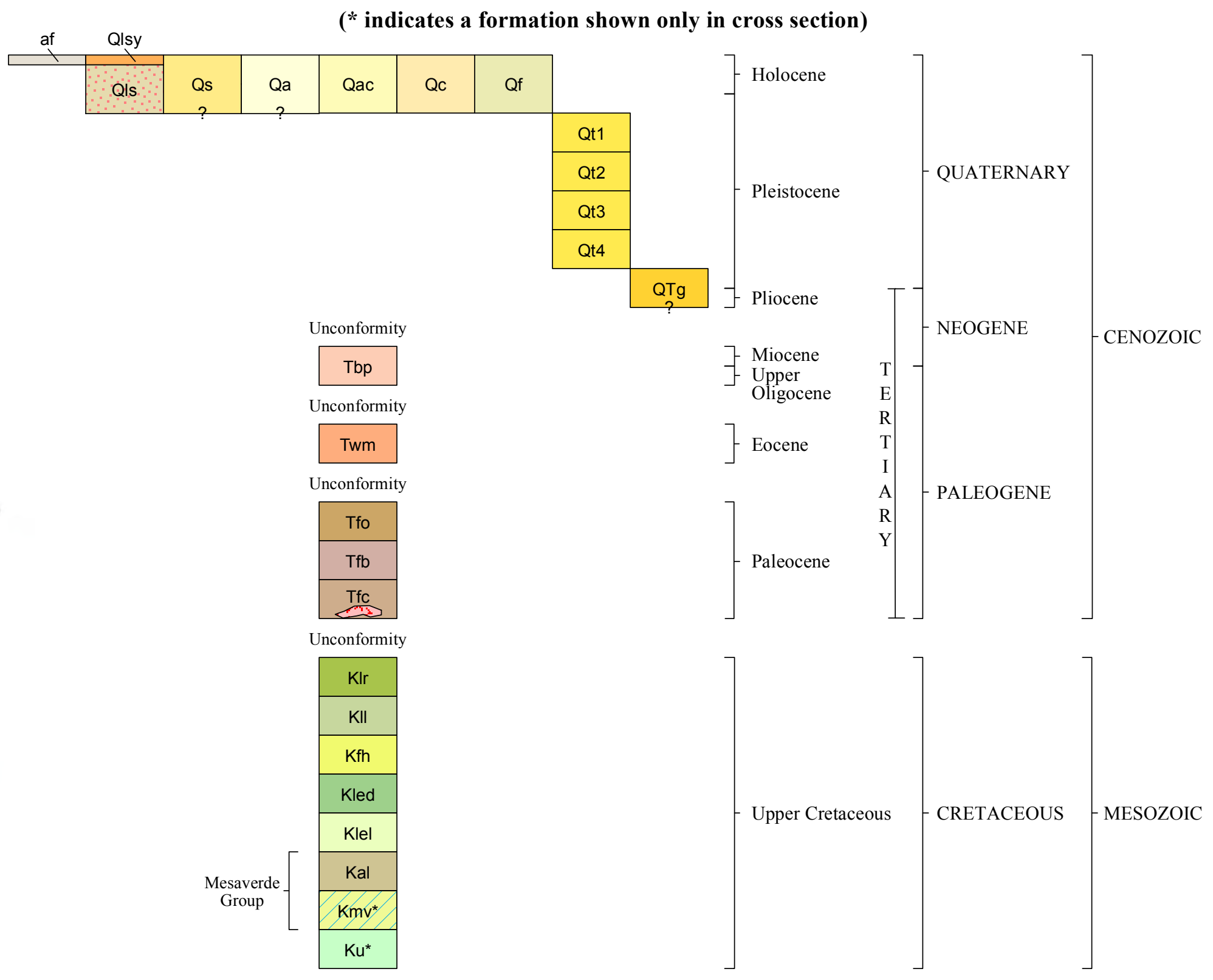
by

Christopher J. Carroll, Lynsey J. Spaeth, and Jacob D. Carnes

2016

EXPLANATION

CORRELATION OF MAP UNITS
(* indicates a formation shown only in cross section)



DESCRIPTION OF MAP UNITS
(* indicates a formation shown only in cross section)

Cenozoic

af **Artificial fill (latest Holocene)**—Clay, silt, sand, gravel, cobbles, and boulders derived from surrounding Quaternary deposits and bedrock; used in highway grades, small embankment dams, and stock ponds. Mapped where greater than 1.5 m (5 ft) thick

Qlsy **Recent landslide deposits (Holocene)**—Unconsolidated material comprised of angular rock debris and fine-grained matrix that has moved via landslide processes within the last ten years. Unit is 5–12 m (16–39 ft) thick

Qls **Landslide deposits (Holocene and Pleistocene)**—Unconsolidated mixed debris of angular rocks and finer grained matrix; mainly in areas of steep topography and north-facing slopes usually contained within shale bedrock. Unit is up to 20 m (66 ft) thick

Qs **Eolian sand (Holocene and Upper Pleistocene [?])**—Unconsolidated deposits of windblown sand. Covers Quaternary terrace deposits and the Eocene Wasatch Formation in the southern portion of the quadrangle. Mapped where the unit is approximately greater than 1.5 m (5 ft) thick

Qa **Alluvium (Holocene and Pleistocene [?])—**Unconsolidated clay, silt, gravel, and cobbles along the floodplain of the main stem Little Snake River valley. Material is derived from sedimentary, igneous, and metamorphic geologic units upstream from Dixon and contains clasts of quartz, quartzite, granite, basalt, and amphibolite. Unit is up to 6.4 m (21 ft) thick

Qac **Alluvium and colluvium, undifferentiated (Holocene and Pleistocene)**—Unconsolidated to poorly consolidated clay, silt, sand, and gravel deposited at the base of slopes and along intermittent streams; includes slope wash, small talus slopes, and small alluvial fans that merge with alluvium. Material is locally derived from geologic units and often capped by a thin veneer of clay-rich soil. Along Willow Creek the unit contains a large percentage of volcanic gravel. Approximately 1–9 m (3.3–30 ft) thick

Qc **Colluvium (Holocene and Pleistocene)—**Undivided slope wash and slump deposits at or near the base of steep slopes. Comprised of sand, silt, clay matrix, boulders, cobbles, and pebbles locally deposited by gravity processes. Unit is up to 10 m (33 ft) thick

Qf **Alluvial fan deposits (Holocene and Pleistocene)**—Sand, silt, and clay interbedded with minor gravel from local deposits. Fans associated with Qac coalesce and are sometimes a composite of sheet wash and stream alluvium. Tributary stream fans interfinger with Qa deposits. Maximum thickness is 10–20 m (33–65 ft)

Qt1
Qt2
Qt3
Qt4

Terrace gravels (Pleistocene)—Light- to dark-brown, orangish-brown, yellowish-gray, gray, and black, unconsolidated to locally cemented silt, sand, gravel, cobbles, and boulders. Locally derived from parent bedrock in the headwaters of the Little Snake River. Clasts average 8 cm (3 in) in diameter, but can be over 30 cm (1 ft) in diameter, and consist of quartzite, Precambrian igneous rocks, amphibolite, sandstone, and Tertiary volcanic rocks. Clast-supported gravel is 1–5 m (3.3–16 ft) thick and is overlain by sand and silt 0.5–2 m (1.6–6.6 ft) thick. Older terrace gravels Qt3 and Qt4 are steeper, more dissected, and have relatively older soils and thicker sand and silt layers than the younger terrace gravels. Unit covers a large part of Dixon quadrangle. Cobbles typically erode onto terrace edge bedrock below. Terrace height ranges measured on Dixon quadrangle:

Qt1	9.4–29 m (31–95 ft) above present Little Snake River level
Qt2	42–78 m (137–255 ft) above present Little Snake River level
Qt3	79–110 m (260–356 ft) above present Little Snake River level
Qt4	120–140 m (410–444 ft) above present Little Snake River level

QTg **Older gravels (Pleistocene and Pliocene [?])**—Unconsolidated silt, sand, gravel, cobbles, and boulders of igneous and metamorphic origin from ancient headwaters of the Little Snake River. Cobbles are mostly light- to dark-brown quartzite, with common red chert, some granitic and other igneous rocks. The matrix is comprised of moderately well sorted, subrounded clasts of pebbles and sand. Unit is highly dissected and may be pediment gravel. Mapped on gravel surfaces greater than 150 m (490 ft) above present Little Snake River level. Unit caps the top of Muddy Mountain, 472 m (1,550 ft) above the river valley

Tbp **Browns Park Formation (Miocene and Upper Oligocene)**—Comprised of a sandstone unit and a basal conglomerate. The fine-grained sandstone is yellowish brown, light brown, or orangish brown and thinly bedded with fine laminations 0.25–0.63 cm (0.1–0.25 in) thick. Low angle trough cross-bedding is preserved and can be up to 1.5 m (5 ft) thick. Sandstone member is up to 488 m (1,600 ft) thick as measured on Battle Mountain 21 km (13 mi) east of Dixon (Buffler, 2003). Only the basal 300 m (1,000 ft) are present on Dixon quadrangle, as measured in seismic boreholes.

Basal conglomerate is poorly sorted, loose to well indurated, and cross-bedded. It contains a characteristic ferruginous yellowish-orange matrix with chert, sandstone, amphibolite, quartzite, and felsic and mafic igneous pebbles, mainly of Precambrian origin (Scott and others, 2011; Buffler, 2003). Unit unconformably covers older formations. Basal conglomerate ranges from 15–91 m (49–300 ft) thick. Age determination estimated by Rosenberg and others (2014)

Twm **Wasatch Formation, main body (Eocene)**—Comprised of mudstone with some interbedded white to light-gray, medium- to coarse-grained arkosic sandstone and siltstone and a basal conglomerate only observed just off the northwest corner of the quadrangle. Formation is not well exposed, only outcropping on hillslopes beneath Quaternary terraces. The middle portion is comprised of light-gray, reddish- brown, maroon, and green mottled mudstone with poor to moderately sorted very fine grained to medium-grained sandstone. Unit contains angular quartz and lithic clasts, and is moderately well cemented. Basal conglomerate contains poorly sorted, well-lithified, and rounded to subrounded clasts of chert, quartzite, quartz, and igneous cobbles up to 6.3–10 cm (2.5–4 in) in diameter. Conglomerate ranges from 1.5–3.7 m (5–12 ft) thick (Honey and Hettinger, 2004). Only the basal 340 m (1,100 ft) of the formation are reported from subsurface wells in the southwest corner of the map area (Dames & Moore, 1979a)

Fort Union Formation (Paleocene)

Tfo **Overland Member**—White to orangish-brown sandstone with interbedded medium-dark gray claystone, with lesser red and purple mudstones. The upper-middle and middle sections of the unit are comprised of light- to medium-gray, grayish-white, to orangish-tan sandstones, mudstones, and siltstones. The sandstones are interbedded with shale and brown carbonaceous shales 0.3–0.6 m (1–2 ft) thick. Sandstones are fine to coarse grained, moderately to poorly sorted, well cemented, and contain ferruginous concretions up to 0.3 m (1 ft) in diameter. The basal part of the Overland Member consists of thick, buff-white sandstone that weathers light gray to pale orange, has ironstone beds, is well sorted and fine to medium grained, is 18–30 m (60–100 ft) thick with bedding up to 0.6 m (2 ft) thick that slightly interfingers with the underlying Blue Gap Member. At the type section on Peach Orchard Flat the entire Overland Member is 130 m (425 ft) thick (Honey and Hettinger, 2004), but thins to approximately 110 m (350 ft) thick on the Wyoming-Colorado border

Tfb **Blue Gap Member**—Gray to olive-brown shale and claystone interbedded with olive to brownish-gray mudstone, and lesser amounts of thin silty sandstone. Clayey units are noncalcareous, weather blocky, fissile, or popcorn texture and contain beds of carbonaceous material including rooty and woody plant fragments (Honey and Hettinger, 2004). Light-gray to yellowish-brown, very fine to fine-grained, thin bedded sandstones, approximately 0.3 m (1 ft) thick, are trough cross-bedded with truncated bases containing claystone clasts. Thickness ranges from 24–49 m (80–160 ft) but Hettinger and others (2008) reported it is up to 170 m (570 ft) thick at the Colorado-Wyoming stateline (Hettinger and Honey, 2005)

Tfc **China Butte Member**—Unit comprised of sandstone, shale, coal, and carbonaceous shale. Sandstone is fine to medium grained, moderately well-sorted, subangular, and white to gray with lenticular bedding that weathers white to light brown with rounded ledging. The upper part contains more numerous resistant sandstone lenses interbedded with coal, carbonaceous shale, and shale. The lower 250 m (820 ft) section is a thick coal-bearing zone generally containing alternating beds of black coal and brown to dark-brown carbonaceous shale over 1.5–9 m (5–30 ft) thick. The lowermost 91–180 m (300–600 ft) contain repeated sequences of fining upward zones comprised of thick-bedded to massive, medium- to coarse-grained sandstone overlain by sandstone, siltstone, shale, and subbituminous coal beds up to 12 m (40 ft) thick (Hettinger and others, 2008). Clinker is mapped where coal beds have burned, baked, and fused overlying rock strata. The basal China Butte Member is characterized by a 1.2 m-thick (3.9 ft-thick) pebble conglomerate and sandstone in a very dark, coarse-grained, iron-oxide-cemented matrix containing clasts of gray and black chert. The China Butte Member is approximately 450 m (1,500 ft) thick in the northwest part of the map area, thinning toward the south.

On the northwest part of the Dixon quadrangle China Butte coal exposures correlate to the Muddy Creek (**MC)**, Fivemile Point (**5M**), and Olson Draw (**OD**) coal zones of Hettinger and others (2008) and Edson (1979). The Fivemile Point coal is reportedly 5.2 m (17 ft) thick and the Olson Draw coal is 5.5 m (18 ft) thick in a well at sec. 11, T. 13 N., R. 91 W., (Dames & Moore, 1979a). Additionally, two uppermost China Butte coals outcrop in the southeastern corner of the quadrangle; they are not laterally continuous but possibly correlate to Chicken Springs or Fillmore Ranch coal zones of Edson (1979). In stratigraphic order from youngest to oldest:

C	Unnamed or uncorrelated coal zone
MC	Muddy Creek coal zone
5M	Fivemile Point coal zone
OD	Olson Draw coal zone

Mesozoic

Lance Formation (Upper Cretaceous)

Klr **Red Rim Member**—White sandstone, weathers light gray to yellowish brown, tabular cross-bedded, medium to coarse grained, with occasional thin-bedded pebble conglomerates and clay rip-up clasts. Member is silica cemented, moderately to well sorted, and contains subangular quartz grains. Uppermost 15 m (49 ft) contains brown iron-stained sandstone. Beds of poorly sorted, subangular, coarse-grained sandstone to pebble conglomerate are 61 m (200 ft) below the top of the unit. Sandstone contains red, black, yellow, gray, and translucent subangular chert clasts, with salt and pepper texture, distinctive honeycomb weathering, and ferruginous concretions up to 1 m (3.3 ft) in diameter. Pebble conglomerate beds have associated mud rip-ups, carbonaceous clasts, woody material, and chert pebbles. The middle of the member is characterized by massive to faintly bedded sandstone fins with more than 15 m (49 ft) of relief; some fins have preserved slump structures. The Red Rim Member is 120 m (380 ft) thick on Peach Orchard Flat quadrangle (Honey and Hettinger, 2004), and approximately 110 m (370 ft) thick near Baggs (Hettinger and others, 2008)

Kll **Lower Member**—Alternating layers of interbedded dark-brown shale and fine-grained, well-sorted, well-rounded rusty brown sandstone. Shale beds are approximately 0.63 cm (0.25 in) thick, friable with minor carbonaceous material. Potassium feldspar and black lithic grains are commonly observed in sandstones. Uncommon sandstone beds average 1 m (3.3 ft) thick but range 0.3–3 m (1.3–10 ft). Coal and carbonaceous shale are at the base, which is gradational and conformable with the underlying Fox Hills Sandstone. Minor shell fragments are common throughout the basal 21 m (70 ft) of the unit. A carbonaceous shale and thin coal zone at base of unit is gradational with underlying formation. Thickness of the lower member ranges approximately 390–420 m (1,300–1,400 ft) in the subsurface on Blue Gap quadrangle (Hettinger and Honey, 2005), and reportedly is much thicker on the north end of the map area

Kfh **Fox Hills Sandstone (Upper Cretaceous)**—Yellowish-brown to light-gray and buff-colored, friable to semi-friable very fine to fine-grained sandy siltstone to sandstone; some claystone and carbonaceous shale and coal. Forms tabular or blocky outcrops with a white-yellow soil zone. Sandstone is massive to faintly bedded, well sorted, with calcareous cement. Tabular to trough cross-bedding is common with beds ranging from 0.63 cm (0.25 in) up to 0.3 m (1 ft) thick with occasional *Ophiomorpha* trace fossils. Basal sandstones are interbedded with shale and coal and minor amounts of claystone containing carbonaceous woody material. Basal marine shale coquina member present on upper slope of Muddy Mountain. Unit is approximately 50–55 m (165–180 ft) thick

Lewis Shale (Upper Cretaceous)

Kled **Lewis Shale, upper part, and Dad Sandstone Member**—Poorly exposed gray to dark-gray shale that weathers light gray to bluish gray interbedded with pale yellowish-gray to brown, moderately rounded, very fine grained sandstone bodies that weather rusty brown and orange to light brown. Dad Sandstone grades into light-gray orangish-brown sandstone, is fine to medium grained, well sorted, with subrounded grains; dominantly ripple cross-bedded, with some concretions, and minor iron oxidization. Forms four or five sandstone and shale sequences on Muddy Mountain. Unit is approximately 150 m (500 ft) thick

Klel **Lewis Shale, lower part**—Light-gray to dark bluish-gray shale with lesser thin pale-yellowish-gray, very fine grained sandstone. Shale is fissile with white calcite crystals on bedding planes and fractures. Orange to light-brown tonsteins 5–13 cm (2–5 in) thick are common in the base of the unit along Cottonwood Creek. Contact with underlying Almond Formation is gradational, 250–490 m (820–1,600 ft) thick

Mesaverde Group (Upper Cretaceous)

Kal **Almond Formation**—White to orangish-tan very fine grained sandstone interbedded with mudstone, carbonaceous shale, and coal. Sandstone beds range from 0.6–5 cm (0.25–2 in) thick and thin as they grade into mudstone and shale of the Lewis Formation. Only the upper 10 m (33 ft) of the Almond Formation crop out in the map area in Cottonwood Creek at the Dixon/Savery quadrangle border. One vitreous coal bed in the uppermost Almond Formation in Cottonwood Creek is 0.6 m (2 ft) thick. Total thickness of the unit on Savery quadrangle is about 240 m (790 ft) (Barclay and Shoaff, 1978)

Kmv* **Mesaverde Group, lower units, undivided**—Comprised of, from youngest to oldest: Pine Ridge Sandstone, Allen Ridge Formation, and Haystack Mountain Formation. Only shown in cross section

Ku* **Older Cretaceous units, undivided**—Only shown in cross section

MAP SYMBOLS

Definitions:
Certain—Known location <25 m (82 ft)
Approximate—Estimated location 25-100 m (82-330 ft)
Inferred—Estimated location >100 m (330 ft)

—?— — – –	**Formation contact**—Continuous where certain; long dash where approximate; short dash where inferred; dotted where concealed; queried where identity or existence uncertain
—┬— – - ?·	**Fault**—Continuous where certain; long dash where approximate; short dash where inferred; dotted where concealed; queried where identity or existence uncertain; bar and ball on downthrown block
····↕····	**Anticline**—Dotted where concealed
—+—··?··	**Syncline**—Continuous where certain; dotted where concealed; queried where identity or existence uncertain
—MC– – –	**Coal bed or coal zone**—Continuous where certain; long dash where approximate. Abbreviations: Muddy Creek coal zone (MC); Fivemile Point coal zone (5M); Olson Draw coal zone (OD); Unnamed or uncorrelated coal zone (C)
A —— A'	**Line of cross section**
	Outcrop of clinker
21	**Strike and dip of inclined bedding**
19	**Strike and dip of inclined bedding in cross-bedded rocks**
87	**Strike and dip of joint**
	Strike of vertical joint
● DIX-P1	**Palynology sample location**—Showing sample name
● DIX-C1	**Coal quality sample location—**Showing sample name
720020 ○	**Oil, gas, or coal exploration well**—Showing abridged API number or drill hole name if projected to the cross section
Coal Gulch Opening ⚒	**Abandoned coal mine**—Showing name

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by

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Open File Report 2016-5
Laramie, Wyoming
2016

Prepared in cooperation with and research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G15AC00514. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

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INTRODUCTION

The Dixon 1:24,000-scale quadrangle is located in south-central Wyoming on the eastern margin of the Washakie Basin (fig. 1), a sub-basin of the Greater Green River Basin, and on the western margin of the Sierra Madre Mountains. The area was reconnaissance mapped by the King Survey in 1871-72 (Ball and Stebinger, 1909). This area lies in the southern part of the Little Snake River coal field, and was originally mapped in detail by Ball (1908) at 1:250,000 scale.

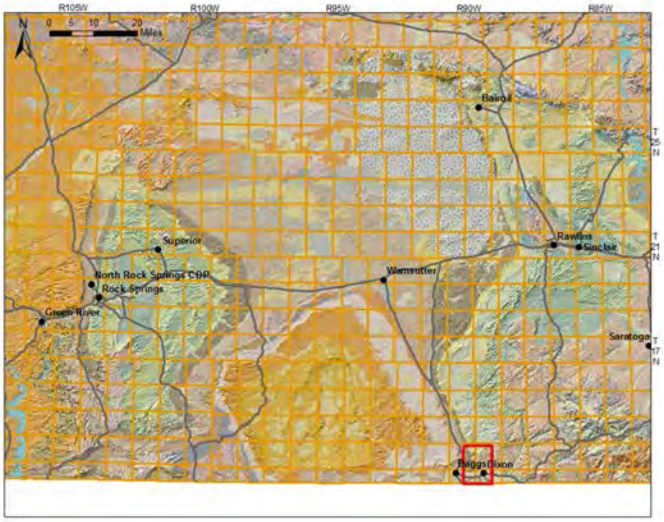

Figure 1. Location map showing study area in south-central Wyoming. Northern thick red box highlights the Dixon quadrangle. Geologic map base from Love and Christiansen (1985).

In the 1950's and 1960's several geologists mapped the area for mineral exploration. The western part of the Dixon quadrangle was mapped as part of a University of Wyoming master's thesis of the Baggs area at the scale of 1:28,000 by Good (1960). This led to Buffler's map (1967) of the Elkhead Mountains. In the 1970s, the US Geological Survey reconnaissance mapped geology of the uranium district in Cottonwood Canyon (Haacke and others, in press). In the late 1970s, Dames & Moore Co. engineering consultants were contracted by the U.S. Geological Survey to assist in compiling coal geologic information in the area. They calculated coal resources for several quadrangles, including the Baggs 15-minute quadrangle (Dames & Moore Co., 1979a), and the Savery quadrangle (Dames & Moore Co., 1979b). The SE¼ of the Baggs 15-minute map was later remapped and renamed the Dixon 7.5-minute quadrangle (Haacke and others, in press). It was compiled to include coal bed occurrences and calculations of known coal resources. The Wyoming State Geologic Survey (WSGS) published a surficial geologic map of the Baggs area, scaled at 1:100,000 (Case and Hallberg, 2006). The most comprehensive geologic map of the area was compiled by the U.S. Geological Survey (USGS) at a 1:100,000-scale for the Rawlins-Little Snake River area (Hettinger and others, 2008), which borrowed from an abundance of 1:24,000-scale mapping. Most recently the WSGS published a 1:100,000-scale (30' x 60' quadrangle) map of Baggs (Scott and others, 2011), which constitutes the best detailed geology to date. Additional maps in the region include a 1:250,000-scale bedrock map of the Craig, Colorado area (Tweto, 1972), surficial geologic map of the Craig 1:100,000-scale area (Madole, 1982), and the USGS mapped Peach Orchard Flat quadrangle at 1:24,000-scale (Honey and Hettinger, 2004) adjacent northwest from Dixon quadrangle.

Mapping was conducted through on-the-ground examination and measurement of rock units, aerial imagery interpretation, and compilation of previous maps and written reports. Field work encompassed more than 33 days for three geologists between September 2015 and July 2016. Mapping was completed in cooperation with the U.S. Geological Survey 2015 StateMap grant award G15AS00514.

We wish to acknowledge and thank the landowners and caretakers for access to their private lands. This project would not have been possible without their generosity.

LOCATION

The Dixon 7.5-minute quadrangle is in southwestern Carbon County, Wyoming and northeastern Moffat County, Colorado. It is located in parts of Townships 12 and 13 N., Ranges 90 and 91 W. The town of Dixon, Wyoming (pop. 97) is in the southeast part of the quadrangle, and the western edge of the quadrangle is 3.2 km (2 mi) east of Baggs. Wyoming State Highway 70 is an east-west highway that transects the southern part of the map. The western part of the map area is accessible via Wyoming State Highway 789, and the northeast part is accessible on Cottonwood Creek Road north of Dixon. Most parts of the quadrangle are accessible by unimproved Bureau of Land Management (BLM) gravel roads.

The Dixon quadrangle lies on the eastern edge of the Greater Green River Basin of Wyoming and Colorado, a 32,000 km^2 (12,400 mi^2) area containing numerous sub-basins. The Washakie Basin comprises 80 townships north of the Colorado border (Bradley, 1945). It is a Laramide structural basin bounded on the east by the Sierra Madre Mountains, on the south by faulted uplifts on the Cherokee Ridge arch, on the west by the Rock Springs uplift, and on the north by the Wamsutter arch. It is an intermontane desert basin that lies west of the Continental Divide, and is mostly dry with the exception of the Little Snake River that flows southwest toward the Yampa River in Colorado. Cretaceous rocks of the Washakie Basin are exposed along the Atlantic Rim in the Dixon quadrangle, marking the boundary between the Washakie Basin and the Sierra Madre Mountains.

Surface ownership consists of mixed-use private and public land. The public land is controlled by the BLM and the State of Wyoming. Private landholders are mostly agricultural along the Little Snake River or ranching nearby. Permission was obtained from land owners prior to entering private lands.

GEOLOGIC SETTING

Upper Cretaceous through Eocene strata exposed within the study area record the retreat of the Western Interior Seaway and a transition to continental syndepositional sedimentation. During deposition of the oldest mapped unit, the Upper Cretaceous Almond Formation, through deposition of the Upper Cretaceous Fox Hills Sandstone and parts of the lower member of the Lance Formation, the study area was in the foreland basin of the Sevier Orogenic belt, on the western margin of the resultant Western Interior Seaway. Sea level transgression began during Almond Formation time at the end of the Mesaverde Group deposition. It was during this time that the Lewis Shale seaway was at its deepest. The transition from the Lewis Shale through the Lance Formation records the sea level regression. This regression was capped by the fluvial Red Rim Sandstone, which has an unconformable base, suggesting a regional drop in sea level.

The Laramide orogeny commenced during the Latest Cretaceous, most notably within the study area during deposition of the Red Rim Member of the Lance Formation. This period of mountain building, responsible for much of the present geometry of the Washakie Basin and the basin-margin uplifts, also resulted in basin subsidence. The Late Cretaceous to late Paleocene was a time of continued deposition, and the Greater Green River Basin was connected to other basins farther east such as the Hanna, Carbon, and Laramie Basins (Lillegraven, 2015). During the transition from Cretaceous to the Paleogene (Tertiary), the Western Interior

Seaway retreated to the northeast, and the subsiding Great Divide and Washakie Basins began accumulating Paleocene sediments of the coal-bearing Fort Union Formation. Subsidence continued into the Eocene and was likely tapering off during deposition of the Wasatch Formation, a fluvial to paludal basin-filling material deposited prior to Eocene Lake Gosiute. Intrabasinal faults common in the map area along the northwest-southeast trending basin margin may suggest basement block fault movements adjacent to the Sierra Madre uplift.

Post-Eocene time was a period of erosion and subsequent deposition of coarse-clastic fluvial sedimentation, called the Browns Park Formation, onto an unconformable surface. This unit covered much of the eastern part of the map area with more than 305 m (1,000 ft) of sand, cobbles, and boulders. The age of the Browns Park Formation is bracketed from 24.8 Ma to 8.2 Ma (Luft, 1985; Buffler, 2003). The basal conglomerate unit was deposited on an uneven surface. This unit represents alluvial fans being shed westward from the Park and Sierra Madre Ranges toward the Sand Wash Basin (Buffler, 2003). The ancestral Little Snake River valley was filled with sediments of the Browns Park Formation. On the Dixon quadrangle it was deposited unconformably onto westward inclined Cretaceous and Paleocene rocks. The thicker upper Browns Park Formation unit is composed of sandstone of both eolian and alluvial origin (Buffler, 2003) with a suggested transport direction toward the north-northeast (Buffler, 1967, 2003). Basalt flows from the nearby Elkhead Mountains covered and preserved the Browns Park sediments just east of the Dixon quadrangle. A recent Ar^{40}/Ar^{39} age date of 11.46 +-0.04 Ma on a basalt flow overlying the Browns Park Formation on Battle Mountain 16 km (10 mi) east of the Dixon quadrangle brackets the youngest age for the Browns Park Formation locally (Rosenberg and others, 2014). Post-Browns Park faulting has considerably steepened the dips along the Cherokee Ridge arch. The region had extensional faulting in the late Miocene (Buffler, 1967), and in the Dixon area it was post-11.46 Ma, and post-basalt flow faulting was generally less than a few hundred meters (Rosenberg, 2014). Deep incision of the Browns Park Formation resulted along the Little Snake River region. Regional uplift and erosion during the Neogene removed thousands of meters of sediments and resulted in high elevations and rock exposures displayed in the map area today. These outcrops were then eroded, reworked, and deposited as silt, sand, and gravel in the form of alluvium, colluvium, sand dunes, loess, pediment gravels, and terrace gravels during the Quaternary.

STRUCTURE

The Greater Green River Basin is a large Laramide basin encompassing a series of sub-basins in Wyoming and Colorado. The Washakie Basin is the southern sub-basin in the Wyoming part of the Greater Green River Basin. It is a flat-lying sedimentary sequence with steeply dipping Cretaceous and Paleocene rocks along the margin. The interior of the Washakie Basin is hilly and filled with flat-lying Eocene Green River Formation that forms steep mesas. Within the study area, these basin-margin strata dip to the west and southwest. The Cretaceous and Paleocene rocks trend north-northwest to south-southeast, with moderate changes in strike, suggestive of large-scale faulting. A northwest-southeast graben mapped north of the town of Dixon is bounded by two long fault systems filled with a thick section of Browns Park Formation. Drill holes B-D23 and Dixon-C on the map cross-section A-A' show the extent of the Browns Park Formation within the west-northwest trending graben (Barclay and Shoaff, 1978). This structure is probably related to movement of faulting related to the Cherokee Ridge arch, which was created by fault movement along Precambrian basement suture zones (Coalson, 2014). It is estimated Neogene faulting in the Dixon area may have throws on the order of 370 m (1,200 ft). Two synclines and a regional anticline transect the Dixon quadrangle from northwest-southeast, including a large syncline mapped in the subsurface forming a hinge line between the north-south Atlantic Rim and the west-east Cherokee Ridge arch.

The most prominent structural feature in the region is the uplift of the Sierra Madre Mountains and Park Range east of the Dixon quadrangle (Ball and Stebinger, 1909). This structurally complex mountain range, with Precambrian rock exposed in the center and surrounded by hogbacks of Paleozoic and Mesozoic strata, is bounded on the west by a series of thrust faults just northeast of the study area. Dips in the map area are uniformly similar exhibiting a 12- to 24° structural dip to the southwest. Steeper dips were measured along faults that offset Cretaceous and Paleocene strata. Minor folding during Lance time formed ancestral structural highs (Cronoble, 1969). Associated with this folding of Cretaceous sediments adjacent to the Sierra Madres was a time of erosion between Red Rim Sandstone and Fort Union Formation deposition. Active movement ceased after deposition of the basal conglomerate of the China Butte Member (Honey and Hettinger, 2004) as succeeding coal mire swamps were laid down. This quiet time extended into Eocene Wasatch deposition. Uplift, associated with folding and high-angle to vertical faulting (Cronoble, 1969) occurred after this time regionally, and the Cherokee Ridge arch was formed.

Several faults were identified by Barclay (1979a) and mapped in this study along the eastern side of the Dixon quadrangle. The southeastern part of the study area hosts a large Neogene fault oriented southeast-northwest that places the China Butte Member of the Fort Union Formation against the Browns Park Formation. The main fault trends approximately 320° and two antithetic faults (not mapped) may parallel the Chalk Bluff area. The main fault may be part of a larger regional thrust fault deeper in the subsurface. Folding probably occurred during the late Paleocene or early Eocene (Dames & Moore Co., 1979a). This late Cenozoic extensional faulting with displacement across graben-bounding faults may be on the order of 300–600 m (1,000–2,000 ft) of offset (Buffler, 1967).

Fractures

Sandstone joints and coal cleat measurements from the Wasatch, Fort Union, Lance, Fox Hills Sandstone, Dad Sandstone, Lower Lewis Shale, and Almond Formations all show fracture orientations that reflect a complex history of Laramide and post-Laramide structural events. These fractures form large, prominent open-mode joints in sandstone and shale, expressed as planar surfaces with very small apertures and spacing ranges from 0.2-2 m (0.7-6.6 ft). These fractures are usually open-mode, through-going type. Most of the fractures open but some are filled with iron stained surfaces and occasional calcite filling.

Fractures measured at 12 stations on the map area indicate a main J1 fracture orientation of 321° azimuth, dipping 87° northeast; a J2 subsequent set of 53° azimuth, dipping 86° northwest; and a minor J3 set with orientation of 3° azimuth north-northeast, dipping 83°east. Fracture development was greatest in the Overland Member of the Fort Union Formation and the Fox Hills Sandstone. These measurements indicate local extension features vary from unit to unit, based on differing rock properties. However, the majority of J1 fractures measured from the Wasatch Formation through the Almond Formation are through-going and represent regional fracture patterns in the area. The J3 set was not prominent and mostly truncated by the younger fractures.

Coal cleat measurements at three localities indicate a regional trend on the Dixon quadrangle. For coal in the China Butte Member, Fox Hills Sandstone, and top of the Almond Formation the main cleat orientation averages 36° azimuth, dipping 83° southeast. Orthogonal butt cleats average 307° azimuth dipping 81° northeast. A majority of the coal cleat had significant sulfur filling the cleat network.

ECONOMICS

Exploration and exploitation of oil, natural gas, and uranium resources along the Cherokee Ridge arch, west of the map area highlight an economic interest in the energy-producing resources of the Wasatch and Fort Union Formations, Lewis Shale, Dad Sandstone, and Mesaverde Group. Coal and coalbed methane resources have been explored on the Dixon quadrangle. The U.S. Geological Survey mapped the extent of Paleocene and Cretaceous coals along the Atlantic Rim from Dixon northward to U.S. Interstate 80 (Hettinger and others, 2008).

Petroleum

The WSGS Interactive Oil and Gas Map of Wyoming (2016) shows 11 wells in the Dixon field on Dutch Joe Creek (Savery quadrangle) producing from the Almond Formation. This field is currently abandoned, last producing in 1994. GRMR Oil and Gas has recently (2016) applied for drilling several wells in the field with a Niobrara Formation objective (Wyoming Oil and Gas Conservation Commission, (WOGCC), 2016). One of these wells, the Big House Federal 28-3, is located on the Dixon quadrangle at sec. 13, T. 13 N., R. 90 W. The Sierra Madre field in the northeast corner of the Dixon quadrangle in Cottonwood Canyon consists of 41 active wells: 34 oil wells, 6 gas wells, and 1 water injection well. The producing reservoirs are the Haystack Mountains, Shannon, Niobrara, and Nugget Sandstone.

Historical petroleum development from nearby structures targeted Cretaceous geologic formations in this area. The earliest petroleum discovery in the area was the South Baggs-West Side Canal gas field in 1947. Located mostly west of Baggs, there are 60 commercial wells producing from the Williams Fork (Mesaverde), Lewis, Fox Hills, Lance, and Fort Union Formations. Cumulative production through 1969 was initially in-excess of 24.2 MMcf natural gas (Cronoble, 1969). The West Side Canal field, on the eastern part of the structure, had a discovery well called the Kirby Royalties #2 Maggie Baggs Govt 05006 near Baggs, drilled in July 1964 (Coalson, 2014). As of 2013, cumulative production is 93k BO, 232 BCF Gas, 945k BW from stratigraphic traps. Most of the gas wells in West Side Canal field produce from lithic turbidite sandstones within the Lewis Shale. Cumulative gas production is less than1 MMCF from the Fort Union Formation coals near West Side Canal field. In general, the eastern Cherokee Ridge arch is considered too shallow to have reached peak gas generation (Coalson, 2014). The play along the arch is structurally controlled by a series of NW-SE and WSW-ENE trending fault systems, so the reservoirs along the arch are a combination of structural and stratigraphic traps. The gas source is probably the organic non-marine coals and carbonaceous shales of the Williams Fork (Almond equivalent), Lance, and Fort Union Formations (Cronoble, 1969), and the Wasatch Formation (DeBruin, 2006). Marine shales of the Lewis and Fox Hills also supply gas to the system.

The eastern part of the West Side Canal field is located within 1½ km (1 mile) of the study area, in the southwest corner of the Dixon quadrangle, T. 12 N., R. 91 W. It is a dome-like feature off the east end of the Cherokee Ridge arch (Abrassart, 1992). The eastern part of the field on Dixon quadrangle is currently abandoned, with production from 1978-2015 totaling 170.5MMcf natural gas and 2,983 Bbl. of oil (WOGCC, 2015). The field consists of 23 permanently abandoned wells that produced from the Cloverly/Dakota and Fort Union formations (WOGCC, 2016). Oil and gas has also been produced in the region from the Pennsylvanian Tensleep Formation (Scott and others, 2011).

The Paleocene and Cretaceous strata of the Greater Green River Basin are of exploration interest to numerous petroleum companies. More than 5,000 wells have been drilled in the nearby Washakie Basin. Natural gas in low-permeability sandstone reservoirs and coalbed methane gas are targets in these formations in the Washakie Basin (McDonald, 1975; Carroll and others, 2015a; Lynds and others, 2015). Fluvial sandstones in the China Butte Member of the Fort Union Formation are a current target for petroleum in the deeper part of the Washakie Basin (Bircher, 2014). Sampson Resources Endurance and Barricade's active play is 45 km (28 mi) west northwest of the Dixon quadrangle at T. 15 N., R. 95 W. and T. 14 N., R. 96 W.

Coalbed methane has been developed from the Mesaverde Group about 14.5 km (9 mi) north of the Dixon quadrangle (Quillinan and others, 2009). More than 85 percent of the coal gas resources are found in the Mesaverde Group with its deeper burial depths and higher coal rank (Scott and others, 1995). The Cow Creek Field produces from the lower Mesaverde shoreface sandstones and from the Frontier, Dakota, and Nugget sandstones. It is part of the Atlantic Rim Natural Gas Development Area, overseen by the BLM. The BLM plan calls for development of about 2,000 gas and petroleum condensate wells: 1,800 coalbed methane and 200 traditional oil and gas (Scott and others, 2011). Within the next 50 years the BLM anticipates nearly 1.35 billion cubic ft (bcf) of natural gas will be produced (2016 BLM Rawlins website). The northern part of the Dixon quadrangle is located within the Atlantic Rim Project Area, specifically north of Township 12 N, on BLM land. The northeast corner of the map area around Muddy Mountain and Cottonwood Creek is within the Wyoming sage grouse core study area (WOGCC data, 2016). To date, no coalbed methane or natural gas wells have produced in the Dixon study area.

Coal

Subsurface coal-bearing formations in the Dixon quadrangle include the Fort Union, Lance, Almond, and Allen Ridge formations. Subbituminous coal found in the China Butte Member of the Fort Union Formation is considered of minable thickness. The Dixon quadrangle lies at the southern boundary of the Little Snake River coal field. Various studies have been done on the coal resources in the area including a coal resource occurrence study of the Dixon area (Dames & Moore Co., 1979a) and in the Fort Union Formation along the Little Snake River coal field (Hettinger and others, 2008). Subsurface geologic data for coal exploration was provided by the U.S. Geological Survey drilling and reconnaissance mapping. Dames & Moore Co. compiled coal information for the Baggs 15-minute quadrangle, including subsurface and coal resource evaluations, but did not include original mapping. Coal bed names were adopted on the Dixon quadrangle and extrapolated northward after coal correlations on sheet 3 of Hettinger and others (2008).

Figure 2. Coal sampling within the China Butte Member of the Fort Union Formation.

There are 16 coal stratigraphic data points in the U.S. Geological Survey's National Coal Resource Data System (NCRDS) from the Dixon quadrangle (Palmer and others, 2015; NCRDS, 2016). These points show Mesaverde, Lance, and Fort Union coals in both the outcrop and the subsurface and were used to locate coal beds in the map area. Uppermost Mesaverde Group Almond Formation coals were encountered in outcrop at NE¼ sec. 22, T. 13 N., R. 90 W. along the boundary with Savery quadrangle. There is a 2 m (7 ft) thick uncorrelated Almond coal in the creek bed of Cottonwood Creek. Coal exploration drill hole 11 encountered this 3 m (9 ft) thick coalbed in the nearby subsurface at 122 m (401 ft) deep (A1 (3) coal) (Dames & Moore Co., 1979b). Three and one third meters (12 ft) beneath that bed is the 2 m (7 ft) thick A1(2) coal bed. The

A1(1) coal bed is 30 m (100 ft) below that bed and is the thickest coal in the section at 3m (10 ft) thick (Dames & Moore Co., 1979b).

The subsurface coal beds correlate to coals in a petroleum well on Dolan Mesa at sec. 27, T. 13 N., R. 90 W. (Resources Investment Corp Sierra Madre 1-27). This well shows 10 coal beds from 253.4 to 380.2 m (831.5–1,247.5 ft). It was drilled on the downthrown side of a normal fault crossing Cottonwood Creek. The thickest Almond coal in that well is 4.6 m (15 ft) thick, called the Almond A1(1) coal at a depth of 341 m (1,120 ft). Coal exploration drill hole 12 shows two other significant and minable thickness coals: the 3 m (10 ft) thick A1(4) and the 3.4 m (11 ft) thick A1(3) coals at 282 and 297 m (925 and 975 ft) deep respectively (Dames & Moore Co., 1979b).

Coal quality sampling of nine coal beds in the Dixon quadrangle (fig. 2) shows variations in quality between the Fort Union Formation, the Fox Hills Sandstone, and the Almond Formation coals. Fort Union coals are characterized as moderate sulfur, high ash, lignite to sub-bituminous coal (Appendix 2). The average ash content of outcrop sampling is 22.7 percent (as-received), heating value 5,574 Btu (low value due to weathered coal), 0.84 percent sulfur, and 0.063 mg/kg mercury. Moisture (20.9 percent), volatile matter (29.7 percent), and fixed carbon (33.8 percent) all were very low values for subbituminous coal for the area. The coal outcrops sampled were not well exposed, and represent mostly weathered coal.

In the southwest corner of the Dixon quadrangle five coal exploration holes penetrated the Fort Union coals and are included as part of the NCRDS stratigraphic database. According to that data, the Olson Draw coal is 537 m (1,761 ft) deep and 11.6 m (38 ft) thick. This is the thickest, most minable underground coal in the region. There are no permitted coal projects in the Dixon area today.

According to Dames & Moore Co. (1979a), there are 21 individual coal beds in the Fort Union Formation that are of mineable thickness. Coal resources were calculated using surface and subsurface coal thicknesses and a density factor of 1,770 short tons of coal per acre-foot (13,018 metric tons per hectare-meter) for subbituminous coal. Only those coal beds thicker than 1.5 m (5 ft) and less than 914 m (3,000 ft) deep are included in the calculations. Coal reserve base tonnages total 206.46 million metric tonnes (227.59 million short tons) on federal lands on the quadrangle (Dames & Moore Co., 1979a). There is no economic determination of recoverability at this time.

There are reportedly 2.095 million metric tonnes (2.31 million short tons) of coal available for surface mining on the Dixon quadrangle. The one federal lease area with high coal-development potential is in the northwest part of Dixon quadrangle in secs. 3, 10, 11, 13, 14, 23, and 24, T. 13 N., R. 91 W. Measured sections in this area (Hicox Draw and Coal Mine Draw) indicate Fort Union Formation FU(5) coal at 5.5 m (18 ft) thick, FU(6) coal at 3.7 m (12 ft) thick, and FU(19) coal at 4.3 m (14 ft) thick (Dames & Moore Co., 1979a). Two historic coal mines are in secs. 23 and 24, T. 13 N., R. 91 W: named the Cut-off Gulch and Coal Gulch Openings, shown on the map plate. These prospect pits were sampled in 1907 by M. Ball (1908). The Cut-off Gulch Opening had a coal bed 6.3 ft thick with an estimated rank of subbituminous C.

Uranium

Uranium deposits within sandstone beds were discovered in 1953 near Baggs and mined until 1981. More than 350 tons of uranium ore were mined with grades averaging 0.17 percent. The US Geological Survey estimates 205,882 tons of ore remain in reserve (Wilson, 2015). There were open pits and some underground workings in the Poison Basin district. The pay zone is within the top 20 m (66 ft) of the Miocene Browns

Park Formation because the basal Browns Park Formation is mostly cobbles and gravel and uranium is concentrated within the less porous sandstone and limestone bedding. Uranium exploration is active near Ketchum Buttes, 20.9 km (13 mi) northeast of the Dixon quadrangle, and at Poison Basin 9.6 km (6 mi) west of Baggs (Scott and others, 2011).

Several uranium prospect pits are present in the Browns Park Formation on the east side of the Dixon quadrangle along Cottonwood Creek. The Crescent Uranium Group has several small prospects on private land in this area. According to Robert Gregory (personal commun., 2016) of the WSGS this prospective uranium area was originally identified by radiometric survey. High radioactivity up to 50 times background was reported in a conglomerate in the lower Browns Park Formation. One sample reported greater than 0.10 percent U_3O_8. Samples of a white tuffaceous sandstone and light gray sandy limestone contained 125 and 178 ppm U_3O_8 at sec. 32, T. 13 N., R. 90 W. called the Snipper Claim (R. Gregory, personal commun., 2016).

Industrial Minerals

Alluvial sand and gravel

Quaternary floodplain alluvium associated with the Little Snake River contains plentiful sand and gravel resources. The Qa unit contains clasts ranging in size from silt to gravel, with abundant cobbles and boulders. These units are locally interbedded with clay. Harris (2004) located three known pits or quarries for sand, gravel, or unspecified aggregate in the map area. Those Qac deposits have clasts of softer material derived from local bedrock along Muddy Creek and Cottonwood Creek, are very clay-rich and are not as suitable for sand resources. The Wyoming Department of Transportation (WYDOT) has a maintenance shop in Baggs operates two sand and gravel pits in the Dixon area along County Road 702.

Terrace sand and gravel

Younger terraces (Qt1-2) associated with the Pleistocene Little Snake River contain plentiful sand and gravel resources. These units contain clasts that range in size from silt to gravel, cobbles, and boulders. The larger clasts of these units consist of dense metamorphic and igneous rocks derived from exposures in the headwaters of the Little Snake River. Units commonly covered with 1-5 m (3-15 ft) of silty material. The WYDOT maintenance shop in Baggs purchases gravel from an active operation located southwest of Baggs, 3.2 km (2 mi) west of the Dixon quadrangle (fig. 3). Gravel thicknesses there are up to 4.9 m (16 ft) and are interbedded with fluvial sands and clays. Their operation is in Qt2 terrace gravel. Harris (2004) defines terrace sand and gravel as Quaternary/Tertiary terrace gravels. These correlate to the map units Qt1 and Qt2 deposits on the Dixon quadrangle.

Figure 3. Qt2 correlated gravel pit excavation near Baggs, Wyoming.

Windblown sand

Windblown sand includes both active (unstabilized) and stabilized sand dunes and deposits (Harris, 2004). These correlate to the eolian sand deposits mapped by Madole (1982) in the Craig ½° x 1° quadrangle. Windblown sand may be a potential source of sand for hydraulic fracturing used in the petroleum industry, as a foundation material for the construction industry, or for local and county maintenance.

Older sand and gravel

Older sand and gravel consists of poorly consolidated to unconsolidated gravels and conglomerates (Harris, 2004). Within the study area, this is identified in higher level terraces more than 79 m (260 ft) above the Little Snake River floodplain. These correlate to the map units Qt3, Qt4, and QTg deposits on the Dixon quadrangle. Higher level Qt3, Qt4, and QTg deposits are coarser grained skewed toward cobble and boulder-sized clasts, and are generally farther from gravel projects in the area.

DESCRIPTION OF MAP UNITS

Cenozoic Deposits and Sedimentary Rocks

Quaternary

MAN—MADE DEPOSITS

Artificial fill (af)

Artificial fill consists of clay, silt, sand, gravel, cobbles, and boulders derived from surrounding Quaternary deposits and bedrock. Artificial fill is used in highway grades, and to a lesser extent, in small earth embankment dams and stock ponds, where it is less than 10 m (33 ft) thick. Fill material is only mapped where it is greater than 1.5 m (5 ft) thick. Embankment materials for Wyoming State Highway 70 bridge abutments over the Little Snake River and small side drainage areas are mapped. Mine dumps where sediment and rock fragments have been re-worked or excavated are also mapped as artificial fill.

ALLUVIAL DEPOSITS

Alluvium (Qa)

Alluvium in the map area consists of unconsolidated clay, silt, sand, gravel, and cobbles, mainly along the perennial mainstem river course and floodplain deposits of the Little Snake River valley. The top 1.5 m (5 ft) of topsoil is usually a silty clayey loam that becomes increasingly more sandy to 3 m (10 ft) deep before cobbles are encountered in the subsurface (Wyoming State Engineer's Office, water well permit records, 2016). The mainstem alluvial material is derived from local geologic units and parent material upstream from Dixon, including sedimentary, igneous, and metamorphic clasts. Clasts are predominantly quartzite (up to 60 percent), with basic igneous rocks and amphibolite (Madole, 1982). The main stem of the Little Snake River begins in northern Colorado, flows west along the Wyoming/Colorado border, and back into Colorado southwest of Baggs, Wyoming. All fluvial material is derived from the headwaters of the Little Snake River and drains southwestward into the Yampa River, 96.6 km (60 mi) at Dinosaur National Monument. The alluvium of the Little Snake River includes all Holocene deposition and Late Quaternary deposits along the lowest floodplain surface within the valley. Unit includes meandering stream features such as abandoned oxbows and point bars of the Little Snake River. Thickness is measured at 5.5–6.4 m (18–21 ft) in the town of Dixon (Dixon-A and Dixon-B wells of Barclay and Shoaff, 1978), but unit generally is less than 5 m (16 ft) thick and may be subject to flooding.

Alluvium and colluvium, undivided (Qac)

Co-mingled rocks derived from alluvial and colluvial processes are mapped at the base of slopes and along some intermittent streams. They consist of unconsolidated to poorly consolidated clay, silt, sand, and gravel.

The alluvium and colluvium are derived from local geologic units and are often capped by a thin veneer of clay-rich soil. Slopewash or sheetwash, small talus slopes, and small alluvial fans, where not mapped separately, are also included as part of alluvium and colluvium. The Qac unit along Cottonwood Creek ranges up to 9 m (29.5 ft) in thickness (wells B-D23, B-D24, and B-D25 of Barclay and Shoaff, 1978; Barclay, 1979b). The Qac unit along Willow Creek on the south side of the quadrangle also contains a large percentage of volcanic gravel locally derived from the Elkhead Mountains of Colorado. Unit correlates with Qal and Qac units on Peach Orchard Flat quadrangle (Honey and Hettinger, 2004), consisting of mostly alluvium along the Muddy Creek floodplain. Tributary alluvium is generally 1–9 m (3.3–30 ft) thick (Madole, 1982).

Unit includes Holocene deposition along Muddy Creek on northwestern part of map area and correlates to unit Qal on Peach Orchard Flat quadrangle (Honey and Hettinger, 2004). The unit is predominantly derived from Miocene, Eocene, Paleocene, and Cretaceous bedrock in the headwaters region consisting of clay, silt, sand, and gravel deposited in the active channel of Muddy Creek.

Colluvium (Qc)

Unit is composed of sand, silt, clay, and minor amounts of pebbles derived by gravity on valley-side slopes of bedrock. Usually have concave-upward profiles from stream valleys to bedrock ridges. Correlates to sheetwash alluvium of Madole (1982) along the Little Snake River valley, is incised by modern Qac at the toe, and grades laterally on the upper reaches with bedrock. Unit is consistently more gravelly in areas with Browns Park Formation bedrock and finer-grained where the bedrock is the Wasatch Formation. Generally up to 10 m (33 ft) thick, but only mapped where greater than 1.5 m (5 ft).

Alluvial fan deposits (Qf)

Holocene deposits of sand, silt, and clay interbedded with minor gravel derived from local tributary valleys. Fans associated with Qac coalesce and are sometimes a composite of sheetwash and stream alluvium (Madole, 1982). Alluvial fans of tributary streams of the Little Snake River interfinger with alluvium (Qa) deposits at depth, but usually form a geomorphic fan feature covering alluvium. Maximum thickness is 10–20 m (33–65 ft) thick (Madole, 1982).

Youngest terrace gravels (Qt1)

The youngest terrace gravels are adjacent to the sides of the Little Snake River valley and consist of light- to dark-brown, orangish-brown, yellowish-gray, gray, and black, unconsolidated subangular to subrounded pebble gravel derived from local bedrock parent material in the headwaters of the Little Snake River. Gravel in the unit is clast-supported, 2–6 m (6.5–19.7 ft) thick, and overlain by sand and silt 0.5–1.5 m (1.6–4.9 ft) thick along the Little Snake River (Madole, 1982). Unit on Weber Mesa is mixed with colluvium from nearby hills of Twm and Tfo parent material. Clasts along the Little Snake River are up to 8 cm (3 in) in diameter, consisting of quartzite, Precambrian igneous rocks and amphibolite, and lesser granitic rocks, sandstone, and Tertiary volcanic rocks. Four distinct Qt1 surfaces dip 1° gently toward the river, and are 9.4–29 m (31–95 ft) above the floodplain level of the Little Snake River valley and up to 18 m (60 ft) thick (Dixon-C well of Barclay and Shoaff, 1978). Qt1 correlates to three terrace levels near Baggs at 12 m, 21 m, and 43 m (39 ft, 68 ft, and 141 ft) as measured by Madole (1982). Qt1 deposits on Dixon quadrangle also correlate to Qt terrace deposits mapped on Peach Orchard Flat quadrangle (Honey and Hettinger, 2004). The unit sometimes has up to 1 m (3 ft) of eolian sand cover. Madole (1982) suggests that the soil development, secondary calcite ($CaCO_3$,) and the degree of clast weathering make these deposits probably less than 150,000 years old. The closest quaternary glaciations (Battle Creek glaciation of Mears, Jr., 2001) upstream are 28 miles northeast of the quadrangle in the Bridger Peak area of the Sierra Madre Mountains.

Younger terrace gravels (Qt2)

The second youngest terrace gravels, similar to those described in Qt1, are also derived from exposed parent material in the headwaters of the Little Snake River valley. Unit consists mainly of quartzite and quartz clasts with other granitic and amphibolite metamorphic clasts, and includes basalt clasts from Neogene flows from the Elkhead Mountains. Clasts are up to 8 cm (3 in) in diameter. Unit sometimes has up to 1 m (3 ft) of eolian sand and silt cover. The unit forms terrace slopes 42–78 m (137–255 ft) above the Little Snake River valley level and are approximately up to 3.6 m (12 ft) thick. Deposit is dissected more than unit Qt1, with terraces that dip 1-2° toward the river valley. Unit similar in clast-supported lithologies and thickness to the younger terrace gravels of Madole (1982), which measured three inset terrace levels near Baggs at 75 m, 90 m, and 130 m (246 ft, 295 ft, and 427 ft) above the Little Snake River. Carbonate content of soils is greater than the younger terrace gravels (Qt1), and was estimated to range from 0.3 Ma to 0.6 Ma (Madole, 1982). This terrace gravel is the source for active gravel quarries in the area.

Figure 4. Older gravel terraces (QTg) as viewed looking northeast from Eversole Basin, including the top of Muddy Mountain

Older terrace gravels (Qt3 and Qt4)

Unit caps low-lying hills above the Little Snake River valley. These higher-level gravels are located north of Carbon County Road 702 and south of Wyoming State Highway 70. Qt3 and Qt4 deposits are located on inclined erosional surfaces overlying truncated bedrock locally 79-140 m (260–444 ft) above the level of the Little Snake River. The highest Qt3 surface was measured in the southwest corner of the map area at 110 m (356 ft) above the Little Snake River, and the highest Qt4 deposit is approximately 140 m (444 ft) above the river on the north side of the valley. Deposits of Qt3 consist of unconsolidated to locally cemented silt, sand, gravel, cobbles, and boulders of igneous and metamorphic origin from the headwaters of the Little Snake River. Unit is composed of pebbly, sandy matrix, with moderately well-sorted, sub-rounded clasts. Cobbles are mostly quartzite, light- to dark-brown, red chert is common, and some granitic and lesser amounts of basaltic volcanic clasts are present. Boulders up to 0.5 m (1.5 ft) diameter, averaging 7.6–12.7 cm (3–5 in) are also preserved on Qt3 and Qt4. Qt3 terrace gravels are 12 to 24 m (40–80 ft) thick, as measured at the highest point of gravel south of the Little Snake River, with surfaces sloping more than 3° toward the river valley. The 0.6 Ma Pearlette type O ash, now known as the Lava Creek B ash, occurs on the 130 m (427 ft) terrace east of Wyoming State Highway 789 near the Colorado-Wyoming state line (Madole, 1982). Unit is deeply dissected, much more than unit Qt2. Gravel measured at 3 m (10 ft) thick was observed on terrace gravel surfaces west of Burbank Draw. Qt3 and Qt4 terraces are more incised than younger terrace gravels, and include deflated geomorphic ‘bench’ deposits of Case and Hallberg (2006), and caps mesas previously mapped as Browns Park Formation.

Older gravels (QTg) High-level gravels of possibly ancestral Little Snake River origin or pediments consisting of pebble to cobble gravels, angular to subangular clasts up to 20 cm (8 in) diameter, consisting of igneous, quartz (red, white, and opaque), greenish metamorphic, and rare brown sandstone clasts. Basalt clasts are rare. Unit covering Muddy Mountain is 3.3 m (10 ft) thick and flat-lying, deeply incised in weathering appearance and soil development (fig. 4). Cenozoic incision along the Little Snake River is estimated at 550 m (1800 ft) over the past 9 Ma (Rosenberg and others, 2014). Remnant river gravel on Muddy Mountain at 472 m (1550 ft) above the Little Snake River is a possibility. Older gravels are only on terrace slopes more than 150 m (490 ft) above the Little Snake River.

EOLIAN DEPOSITS

Eolian Sand (Qes)

Windblown sand and silt, light yellowish-brown to reddish-brown, fine- to medium-grained sand and silt. Grains are sub-angular to sub-rounded. Sand dunes are 1–4 m (3–13 ft) thick. Unit partly covers quaternary terraces (Qt1, Qt2, and Qt3) and the Wasatch Formation in the southern part of the quadrangle. Unit displays a strong southwesterly wind component (Madole, 1982). Wind-blown eolian sand mantles stream-like terrace deposits along the Little Snake River, but are only mapped where greater than 1.5 m (5 ft) thick. Unit is preserved west of the Overland Member outcrop that probably comprises most of the local parent material for the sand. Charcoal from a hearth was excavated and sampled from eolian dune sand on the southwestern part of the Dixon quadrangle (sample GaK-7605 of Madole, 1982). This charcoal has a carbon-14 age of 490+-130 yrs. BP (before 1982). Additionally, a paleosol buried 46 cm (18 in) deep in an eolian sand unit on Thornburg Gulch quadrangle, north bank of the Little Snake River, one mile west of Baggs, WY (sample GaK-6868 of Madole, 1982) has a radiocarbon age of 3,060 ± 100 yrs. BP (as of 1982). Loess within eolian deposits of Morgan and others (2014) for the Craig quadrangle in Colorado, 42 km (26 mi) south of Dixon quadrangle, show an OSL age date of 28.4 Ka. Eolian sand deposits form drifts that are thickest on northeast-facing slopes.

MASS WASTING DEPOSITS

Recent Landslides (Qlsy)

This unit refers to ground movement via landslide processes of unconsolidated material approximately within the last 10 years. A landslide occurred in 2015 above Carbon County Road 702 (fig. 5). This landslide, located in NW¼ sec. 6, T. 12 N., R. 90 W. is approximately 8,100 m^2 (2 acres) in size. Source of the landslide is probably man-made from upslope development. Bedrock in the headscarp is the Overland Member of the Fort Union Formation capped by Quaternary terrace gravel (Qt2). Other small recent landslides are on shale slopes around Muddy Mountain and Chalk Bluff. Unit is approximately 5-12 m (16-39 ft) thick.

Figure 5. Recent landslide along Carbon County Road 702.

Landslide deposits (Qls)

Unit is a heterogeneous mixture of angular rock debris within a fine-grained matrix. Landslides originally mapped by Case and Hallberg (2006) were used to identify Qls on Dixon quadrangle, and modified for mapping at 1:24,000 scale. Landslide deposits include earthflows, debris flows, and other mass-wasting land movement more dissected than recent landslides. Primarily occurs on steep slopes of shale bedrock such as Lewis Shale and lower Lance Formation. Unit found mainly on steeper slopes around Muddy Mountain. Unit is approximately up to 20 m (66 ft) thick.

BEDROCK UNITS

Upper Oligocene to upper Miocene

Browns Park Formation (Tbp)

The Browns Park Formation consists of two members: a basal conglomerate member and an overlying sandstone member (Buffler, 1967; 2003). The sandstone member is up to 480 m (1,600 ft) thick as measured on Battle Mountain 16 km (10 miles) to the east (Scott and others, 2011). The basal conglomerate ranges up to 91 m (300 ft) thick and overlies an unconformity that truncates all older rocks, but may interfinger with the overlying

Figure 6. Sandstone unit of the Browns Park Formation, Eversole Basin.

sandstone member. The conglomerate member is loosely consolidated, cross-bedded and sandy, with a ferruginous yellow-orange matrix with quartz pebbles (Scott and others, 2011). The clasts are mainly of Precambrian origin derived from the Park and Sierra Madre Ranges, deposited in coalescing alluvial fans (Buffler, 2003). Coarse-grained facies are interpreted as dune fields, while a finer-grained facies is interpreted as loess. This material rests unconformably in the Washakie Basin on the Oligocene Gilbert Peak erosion surface (Hansen, 1986).

Prevailing westerly winds in mid- to late-Neogene time brought ash into the Browns Park Formation and other units in the Rocky Mountain Region from distant sources in numerous volcanically active areas in the western United States (Luft, 1985; Luft and Thoen, 1981). Basalt flows covered the surface of the Browns Park Formation, locally preserving a thick section of the formation. An 11.45 Ma age for basalt flows at Battle Mountain overlying the Browns Park Formation is a minimum age for the unit, as it is locally constrained by late Miocene basaltic magmatism in the northwestern end of the Elkhead Mountains of Colorado (Rosenberg and others, 2014). Stratigraphic dips of the Browns Park Formation are generally 10° northeast in the map area. The upper sandstone unit is prone to landslides.

Sandstone unit of the Browns Park Formation

The upper unit consists of yellowish-gray to light yellowish-orange, tan to olive, fine-grained sandstone; moderately well sorted, poorly to loosely indurated and thin bedded (fig. 6) In the map area most of the unit is covered with loose cobbles and boulders of the Quaternary terraces and sandstone exposures of the Browns Park Formation are rare. Only the lower 300 m (1,000 ft) of the Sandstone unit are present on the Dixon map area, as the upper 182 m (600 ft) from Battle Mountain (Scott and others, 2011) of the unit are eroded.

Basal conglomerate of the Browns Park Formation

Conglomerate clasts are of chert and mafic volcanic origin. The poorly-indurated, cobble-gravel unit of the Browns Park Formation unconformably overlies older bedrock in the area. The unit is exposed in the canyons north of Carbon County Road 702 where it lies directly above the Overland Sandstone, and in the hillslopes north of Eversole Basin. The contact underlying the basal conglomerate unconformably overlies Eocene through upper Cretaceous rocks on the Dixon quadrangle, suggesting that upper Cretaceous rocks were uplifted by the Sierra Madre Mountains before deposition of the Browns Park Formation in the Miocene. Basal conglomerate reported from uranium prospects and seismic boreholes 15-91 m (49-300 ft). Unit was not mapped separately.

Eocene

Main Body of the Wasatch Formation, (Twm)

The basal member (Main Body) of the Wasatch Formation is the only part of the formation exposed in the map area. Unit forms rolling hill topography on the western side of the Dixon quadrangle and is mostly covered by Quaternary units.

Formation consists of fluvial sandstones and interbedded shales. Lacustrine beds of the Green River Formation deposited in the shallow and periodically restricted Lake Gosiute are found nearby in Baggs quadrangle, but not on the Dixon quadrangle. In the southwest corner of the map area the upper parts of the Main Body of the Wasatch Formation consist of medium- to coarse-grained arkosic sandstone and siltstone. The middle part of the Main Body is varicolored (light gray, reddish-brown, maroon, and green) mottled mudstone with very fine-grained to medium-grained sandstone with poor to moderate sorting and angular clasts with a distinct lack of coal-bearing strata.

At the base of the formation is a basal conglomerate exposed in the northwest corner of the map area near Peach Orchard Draw quadrangle (fig. 7). This conglomerate lies immediately above an unconformable contact with the Overland Sandstone Member of the Fort Union Formation. This conglomerate was also observed as a 1.5 m (5 ft) thick ridge-former on Peach Orchard Flat quadrangle northwest of the map area, and has been measured at 3.7 m (12 ft) thick with chert, quartzite, quartz, and igneous cobbles up to 6.4 cm (2.5 in) in diameter (Honey and Hettinger, 2004). Clasts are poorly sorted, well lithified, rounded to subrounded grains in particle size up to 10 cm (4 in) in diameter, and probably becomes finer grained basinward to the west. The Wasatch Formation mapped on Weber Mesa was adopted from Good (1960).

Figure 7. Conglomerate and coarse-grained sandstones from the basal member of the Wasatch Formation, northwest corner of Dixon quadrangle.

In the southern part of Peach Orchard Flat quadrangle near the Dixon map area, the total thickness of the Main Member of the Wasatch Formation is reportedly 640 m (2,100 ft) thick (Honey and Hettinger, 2004); only the basal 340 m (1,100 ft) of the Main Member was present from subsurface petroleum geophysical logs (Dames & Moore Co., 1979a) in the southwest part of Dixon quadrangle.

Fort Union Formation, Paleocene (Tfo, Tfb, Tfc)

Honey and Hettinger (2004) formally defined and subdivided the Fort Union Formation into the Overland Member (youngest), Blue Gap Member, and the China Butte Member (oldest) on the Peach Orchard Flat quadrangle. The China Butte Member is the only coal-bearing unit on the Dixon quadrangle. Barclay and Shoaff (1978) and Beaumont (1979) described the formation as interbedded sandstone, siltstone, and mudstone, carbonaceous shale, and coal. Coal bed correlations on the map area were modified from Hettinger and others (2008) and Dames & Moore Co. (1979a). Carroll and others (in press) further extended these coal correlations into the adjacent Washakie Basin, which were also mapped within the study area. In T. 14 N., R. 91 W., Swain (1957) reported 466 to 533 m (1,530–1,750 ft) for the complete Fort Union section. From subsurface geophysical logs in the southwestern part of the map area the Fort Union Formation averages 405 m (1,330 ft) thick (Dames & Moore Co., 1979a). Drill holes API 4900720020 and API 4900720124 indicate 490 m (1,600 ft) of section for the entire Fort Union Formation. Carbonaceous shales of the Fort Union Formation were encountered at 5.9 m (19.5 ft) deep beneath the alluvium in the town of Dixon (Wyoming State Engineer's Office, 2016; Dixon A and B wells).

The Fort Union Formation represents a fluvial, but low-lying coastal plain depositional environment of Laramide basin fill, and is stratigraphically equivalent to other Paleocene units throughout Wyoming.

Overland Member (Tfo): The top of the formation, just below the contact with the Wasatch Formation, is orange-brown sandstone with interbedded medium-dark gray claystone and locally red and purple mottled mudstones (Honey and Hettinger, 2004). The upper contact is sharp and unconformable with the Wasatch Formation. The upper middle and middle section of the unit is a cliff-forming, light- to medium-gray to buff-white or grayish-white sandstone unit with lesser mudstone and siltstone. Some reddish-stained ironstone nodules are pisolitic and abundant on the whitish sandstone outcrops. The sandstones are interbedded with shale and carbonaceous shale. Sandstones are fine- to coarse-grained, moderately to poorly sorted, well indurated, and contain ferruginous concretions up to 0.3 m (1 ft) in diameter. Pollen sample D4446 from Hettinger, Honey, and Nichols (1991) was collected at SW¼ NW¼ sec. 15, T. 12 N., R. 90 W. and assigned late Paleocene age (zone P6 of Nichols and Ott, 1978).

Figure 8. Hoodoos formed on Chalk Bluff from

The middle of the member is interbedded sandstone with lesser amounts of siltstone and shale. The sandstone is white to light gray, weathers light brown, and is well indurated and blocky with bedding 15-91 cm (0.5-3 ft) thick. Some massive beds up to 3.7 m (12 ft) thick were also observed. Sandstone cementation is calcareous, and clasts are fine- to medium-grained, well-sorted, and forms hoodoos (fig. 8) in channel sandstones overlying massive sandstone sections. Iron-stone units up to 1 ft thick are common throughout, and claystone bedding up to 20 ft thick occurs within unit. Crayfish burrows are rare (Hasiotis and Honey, 2000).

The lower or basal part of the Overland Member consists of thick, buff-white sandstone that weathers light gray to pale orange, is well sorted, fine- to medium-grained, with 10 percent black biotite grains and 90 percent quartz, and well-indurated. Unit is massive with faint bedding, is bioturbated in part, has surface fractures filled with calcite, and is interbedded with lesser beds of gray claystone. The basal part of the Overland Member is an 18-30 m (60–100 ft) thick sandstone unit of stacked, conglomeratic channel sandstones that Honey and Hettinger (2004) interpreted as the lower part of a valley-fill succession. The cliff-forming unit forms the cap rock and dip-slope profile of the Chalk Bluff in secs. 8, 9, 15, 16, and 17, at T. 12 N., R. 90 W. This section is defined as middle Paleocene in age (pollen zones P3 or P4 of Nichols and Ott, 1978), as pollen sample D4447 identified by R.H. Tschudy, was collected at this location (Hettinger and others, 1991). The sample, collected at the Blue Gap/basal Overland sandstone contact, is the only P4 age pollen in the Fort Union Formation in the Little Snake River coal field.

The basal Overland Member sandstones are buff-white, weathering brownish-orange, coarse-grained, with bedding up to 0.6 m (2 ft) thick that slightly interfingers with the underlying Blue Gap Member. These basal sands correlate to the basal sandstone unit as defined by Lynds and Carroll, (2015), Hettinger and others (2008) and Honey and Hettinger (2004). The basal sandstone member is approximately 46 m (150 ft) thick in the subsurface of the Dixon area (D. Lichtner, personal commun., 2016; Hettinger and others, 1991). The basal contact is sharp but conformable with the underlying Blue Gap Member as observed in the Chalk Bluff section along the Little Snake River, where the Overland Member is 110 m (350 ft) thick. (fig. 9).

Figure 9. Sharp contact between the overlying Overland sandy member and the Blue Gap shale member of the Fort Union Formation, Chalk Bluff.

Blue Gap Member (Tfb): Slope-forming unit consists of gray to olive-brown shale and claystone interbedded with olive to brownish-gray mudstone, with lesser amounts of thin silty sandstone (fig. 10). Clayey units contain beds of carbonaceous material (rooty and woody plant fragments), are non-calcareous, and weather blocky or fissile (Honey and Hettinger, 2004). The Blue Gap Member was named by Honey and Hettinger (2004) for exposures on the Dixon map area at NE¼ sec. 15 and SE¼ sec. 10, T. 13 N., R. 91 W. Ironstones common in the Overland Member are not present in the Blue Gap Member. Sandstones are light gray to yellowish-brown, very fine- to fine-grained, and thinly bedded. Some trough cross-bedded sandstones were reported by Honey and Hettinger (2004) with truncated bases containing claystone clasts. Base of the Blue Gap Member is about 30 m (100 ft) above the highest coal bed in the China Butte Member (Honey and Hettinger, 2004). On the Blue Gap quadrangle Hettinger and Honey (2005) measured the Blue Gap Member between 24 m and 49 m (80–160 ft) thick; but has been reported up to 170 m (570 ft) thick at the Colorado-Wyoming state line (Hettinger and others, 2008).

Figure 10. Type section of the Blue Gap Member of the Fort Union Formation (looking north).

China Butte Member (Tfc): First identified by Honey and Hettinger (2004) on nearby Peach Orchard Flat quadrangle the China Butte Member of the Fort Union Formation consists of sandstone, shale, coal, and carbonaceous shale. The sandstone is fine- to medium-grained, moderately well-sorted, subangular, and white to gray lenticular sandstone that weathers white to light brown. Sandstones are interbedded with shale, carbonaceous shale, and lesser subbituminous coal in the upper part

230 m (750 ft). The lower 250 m (820 ft) section is a thick coal-bearing zone that correlates for 60 miles along the eastern margin of the Washakie Basin (Hettinger and others, 2008) to north of U.S. Interstate I-80 (Lynds and Carroll, 2015; Lynds and others, 2015). In the southeast corner of the Dixon quadrangle two coal beds in the upper part of the China Butte generally contain alternating beds of subbituminous black coal and brown to dark-brown carbonaceous shale over a 1.1–2.3 m (3.5–7.5 ft) thick zone. The thickest coal bed has a roof rock of sandstone and a floor rock of shale and dark ironstone. The two coal beds mapped are possibly Chicken Springs or Fillmore Ranch equivalent (Edson, 1979). Dames and Moore (1979a) correlated these coals to FU (17) coal, which is one of the highest coal beds in the China Butte Member, and may be part of the local Baggs coal group of Hettinger, Honey, and Nichols (1991).

On the northwest part of the Dixon quadrangle China Butte coal beds correlate to the Muddy Creek, Fivemile Point, and Olson Draw coal zones of Hettinger and others (2008) and Edson (1979). Most outcrop coal correlations from the southeast part of the Peach Orchard Flat map (Honey and Hettinger, 2004) were carried into the Dixon quadrangle: these are the Fillmore Ranch, Olson Draw, and Red Rim coal beds. Subsurface drill hole data for a well 1.6 km (1 mi) west of the northwest corner of the map area at sec. 4, T. 13 N. R. 91W. there are four coal beds, in descending order: Muddy Creek 3.9 m (12.8 ft), Fivemile Point 0.6 m (2 ft), Olson Draw 2.2 m (7.3 ft), and Lower Olson Draw 0.67 m (2.2 ft) (data from Carroll and others, in press); however only the identifiable coal beds were mapped on Dixon quadrangle.

In the southern part of the map area Hettinger, Honey, and Nichols (1991) correlates the lower coal zone of the China Butte Formation coals as the Baggs, Fivemile Point, Olson Draw coal beds, and three additional unnamed coal beds from Dames & Moore Co. (1979a). Drill hole 4900720020 is 3 miles west of the outcrop at sec. 18, T. 12 N., R. 90 W., and the thicknesses of the coal beds were re-correlated and measured from geophysical logs as 0.42 m (1.4 ft, Fivemile Point), 1.6 m (5.3 ft Olson Draw), and 1.8 m (5.9 ft Lower Olson Draw. Additionally, two basal China Butte coals outcrop in the southeastern corner of the quadrangle, are not laterally continuous, and do not correlate to any coal beds in the subsurface. The China Butte Member unconformably overlies the Lance Formation, and the lowermost 91 m to 183 m (300-600 ft) contain thick-bedded to massive, medium- to coarse-grained sandstone overlain by an interbedded sequence of sandstone, siltstone, shale, and coal beds up to 12 m (40 ft) thick (Dames & Moore Co., 1979a).

Beaumont (1979) suggested that the sandstone belt trends northward in a paleocurrent direction and lithologies tend to succeed one another in a consistent order of irregular surface, sandstone, siltstone, shale, carbonaceous shale, and coal. Overall the unit fines upwards, and within the coal zones a repeated sequence is observed with a rootlet zone at the bottom, carbonaceous debris, coal, sedimentary structures on sandstone, marking this as consistent within a fluvial system (Beaumont, 1979).

The base of the China Butte Member is only found in the northwest part of the Dixon map area. It is mostly dark gray shale with lesser beds of sandstone, coal, and carbonaceous shale. Lowermost section above the unconformable contact with the Red Rim Sandstone is a dark gray to black sandy shale zone. China Butte member is approximately 450 m (1500 ft) thick in the northwest part of the Dixon quadrangle.

Mesozoic Sedimentary Rocks

Cretaceous

Lance Formation (Klr, Kll)

The Lance Formation was subdivided by Honey and Hettinger (2004) into the upper Red Rim Member and the lower (unnamed) member. Overall, the Lance Formation averages 280 m (920 ft) thick in subsurface wells on the map area (Hettinger and others, 2008).

Red Rim Member (Klr): Also called the Unnamed Cretaceous sandstone unit (Hettinger and Kirschbaum, 1991), the Unnamed Cretaceous and Tertiary sandstone unit (Hettinger and Kirschbaum, 1991; Hettinger and others, 1991), and the Massive K/T Sandstone (Tyler and others, 1995), this prominent thick white to light brown weathered sandstone outcrops in the northwest part of the Dixon quadrangle as a distinctly massive to weakly bedded sandstone with fins overlain by 15 m (50 ft) of brown iron-stained sandstone. Iron nodules are abundant on the northwest corner of the map area (fig. 11); they are white and weather light brown, 5.1–12.7 cm (2–5 in) in diameter, some up to 0.9 m (3 ft). Unit displays rounded ledging, sandstone is well sorted, medium- to fine-grained with silica cement and approximately 10-15 percent of the grains are mafics with faint bedding preserved. Black to brown chert gravel clasts are uncommon to rare. Some coarse-grained bedding with drab olive green weathering is common in upper section. The Cretaceous-Paleogene boundary is somewhere near the regional unconformable contact with the China Butte Member of the Fort Union Formation. It is considered fluvial and its system is much higher energy than the China Butte Member of the Fort Union Formation. The Red Rim Member is 120 m (380 ft) thick on Peach Orchard Flat quadrangle (Honey and Hettinger, 2004), and approximately 110 m (370 ft) thick near Baggs (Hettinger and others, 2008). Appendix 1 contains a summary of palynological work conducted in this area.

Figure 11. Outcrops of the Red Rim Member of the Lance Formation with distinctive concretionary iron nodules.

Lower Member (Kll): Only exposed in the northern part of the map area the Lower Member of the Lance Formation interfingers with the Red Rim Member. The upper part consists of light gray, fine-grained sandstone separated by 3-12 m (10-40 ft) thick units of claystone and mudstone as observed in Hicox Draw. The unit has trough-crossbedding and is interpreted as fluvial channel and flood-plain deposits (Hettinger and others, 2008). The lower part consists of poorly exposed shale and claystone forming valleys on the map area. Sandstones are more numerous to the north (Carroll and others, 2015) for both sections of the Lower Member of the Lance Formation. Interpreted as low-energy fluvial coastal plain and brackish-water (Hettinger and others, 2008) to marginal marine environments (Carroll and others, 2015; Gill and others, 1970). Carbonaceous shale and coal near the base of the formation is gradational and conformable with the underlying Fox Hills Sandstone. Three coal beds identified from geophysical logs in a well in SW¼ NW¼ sec. 18, T. 12 N., R. 90 W. are measured at 0.6–1.8 m (2–6 ft) thick (Dames & Moore Co., 1979), reportedly within a coquina section in the basal 21m (70 ft) of the unit on Blue Gap quadrangle (Hettinger and Honey, 2005). Thickness of the lower member ranges approximately 390–420 m (1,300–1,400 ft) in the subsurface on Blue Gap quadrangle (Hettinger and Honey, 2005), and reportedly is much thicker on the north end of the Dixon quadrangle than along the Colorado-Wyoming state line where it is approximately 400 m (1,300 ft) thick (Hettinger and others, 2008).

Fox Hills Sandstone (Kfh)

The Fox Hills Sandstone is a yellowish-brown to light gray to buff-colored, very fine-grained sandstone with interbedded siltstone and claystone and carbonaceous shale beds. Bedding is massive to thickly bedded, blocky to ledge-forming, friable to semi-friable sandstone, well sorted and calcite cemented. Tabular bedding is common with low-angle wispy trough crossbedding with organics in the base. *Ophiomorpha* trace fossils are uncommon. A 0.76 m (2.5 ft) coal bed on Smiley Draw quadrangle, 0.4 km (0.25 mi) north of the map area in sec. 6, T. 13 N., R. 90 W. was sampled for this project (sample DCC-168c of Appendix 2) and is a high-sulfur subbituminous coal bed. This coal was correlated onto Dixon quadrangle at sec. 7, T. 13 N., R. 90 W, and is 9.1 m (30 ft) below the 3.6 m (12 ft) thick 'Nebraska coal bed' of Hettinger and others (2008), but was mostly carbonaceous shale and lignite.

Figure 12. Coquina layer in the Fox Hills Sandstone found on Muddy Mountain.

The Fox Hills Sandstone interfingers with both the lower member of the Lance Formation and the upper Lewis Shale. It consists of approximately five individual marginal-marine to coastal shoreface sandstones over an estimated 150 m (492 ft) thick zone deposited as shoreface sands in the retreating Western Interior Seaway (Finn and Johnson, 2005). The formation is 73m (240 ft) thick near Baggs, WY (Hettinger and others, 2008), and was measured in the study area as approximately 50–55 m (165–180 ft) thick. On the southeast ridgeline 30 m (100 ft) below the top of Muddy Mountain there is a 3-4.6 m (10-15 ft) thick coquina fossil zone of clams (fig. 12). These clams and other fossil hash (mollusks?) (Hartman and others, 2015) have been described as a 'clam bank' within the shallower parts of the Lewis Seaway (J. Hartman, written commun. 2016). The fossil zone trends for 30 m (100 ft) horizontally.

Lewis Shale (Kled, Klel)

This mostly valley-forming section was deposited as marine sediments during the final major regression of the Late Cretaceous Epicontinental Sea. The Lewis Shale is considered the seaway sediments, with the overlying Fox Hills Sandstone representing the transitional continental shoreface. Age has been estimated as Maastrichtian, approximately 71 to 69 Mas (Perman, 1987) in this region. The formation is composed of shale and sandstone units interfingering with the overlying Fox Hills Sandstone at the top, and shale units interfingering with the Almond Formation at the base. Three main facies are identified: nearshore, shelf, and basin marine depositional environments (Perman, 1987) that were deposited during a southern-moving progradational sequence. Most of the formation is marine shale, but several upward-coarsening sequences of siltstone and sandstone are interpreted as a prograding sequence of shelf to nearshore deposits.

Figure 13. Soft sediment deformation preserved in the Dad Sandstone from the north side of Muddy Mountain.

Lewis Shale upper part and Dad Sandstone (Kled); and Lewis Shale, lower part (Klel): The Lewis Shale is typically subdivided into three parts, but only two parts were observed on the Dixon quadrangle: a combined interbedded upper shale and Dad Sandstone beds, and the lower shale.

Dad Sandstone Member (Kled): The Dad Sandstone Member of the Lewis Shale consists of shallow marine sandstone interbedded with marine shale. The sandstone is light gray, weathers orange-brown, fine- to medium grained, well sorted, salt and pepper lithic minerals, subrounded, thin to thick bedded and distinctly calcareous cement. Sandstones are dominantly ripple cross-bedded, with soft sediment dewatering features (fig. 13), contains uncommon iron concretions up to 0.9 m (3 ft), and excellent orthogonal fractures.

The contact with the lower Lewis Shale is gradational. Dad Sandstone beds are well exposed on the flanks of Muddy Mountain where four sandy sequences crop out as 9.1-15.2 m (30-50 ft) thick sandstones within a 150 m (500 ft) interval of overall shale and sandstone. The Dad Sandstone is considered part of a deep basin turbidite system, possibly a down-dip tongue of the Fox Hills Sandstone (Perman, 1987; Pyles and Slatt, 2000). The Dad Sandstone thins south of the Dad Arch.

Figure 14. Good exposure of lower Lewis Shale in Cottonwood Creek.

Lower Lewis Shale (Klel): The lower part of the Lewis Shale is poorly exposed gray to dark-gray shale that weathers light gray to bluish-gray. This marine shale is occasionally interbedded with pale yellowish-gray to brown, moderately rounded, very fine-grained sandstone bodies that weather rusty-brown and orange to light brown. The shale is fissile, contains trace amounts of coarser detritus and displays thin bedding, which is typically less than 2.5 cm (1 in) thick. The lower part of the Lewis Shale is dark gray shale with orange to light brown tonsteins, well exposed only in Cottonwood Creek (fig. 14), and forms valleys in the northeast corner of the map area. The basal contact is conformable and gradational and mapped above the laterally persistent sandstones of the Almond Formation. The lower part of the Lewis Shale is 250 m (820 ft) thick on Dixon quadrangle, and the overall Lewis Shale, including the Dad Sandstone Member, has a maximum thickness of 722 m (2,370 ft) thick in the study area (Dames & Moore Co., 1979a). The lower part of the Lewis Shale thickens from 125 m (410 ft) 9.7 km (6 miles) south of the Dad Arch 32 km (20 mi) north of the study area, to approximately 490 m (1,600 ft) thick near Baggs (Hettinger and others, 2008). The lower Lewis Shale and the interfingering Almond Formation are a source of petroleum in the Washakie Basin.

Mesaverde Group

Almond Formation (Kal)

Figure 15. Distinctive A1 coal bed of the Almond Formation exposed in NW¼ sec. 22, T. 13 N., R. 90 W.

The Almond Formation is the uppermost unit of the Mesaverde Group in Wyoming. It contains pale yellowish-gray, orange, and ochre red, very fine to fine-grained sandstone interbedded with gray to dark-gray shale, carbonaceous shale, and coal. Sandstone and shale zones are several meters thick and weather in a distinctive striped pattern (fig. 15). Only the top 6–12 m (20–40 ft) of the formation are exposed on the Dixon quadrangle; it is approximately 241 m (790 ft) thick on the neighboring Savery quadrangle (Barclay and Shoaff, 1978). In the subsurface, discontinuous coals are present in the lower part of the formation with beds up to 1.5 m (5 ft) thick, associated with carbonaceous zones containing abundant woody fragments (Haacke and others, in press).

The Almond Formation represents a coastal plain environment deposited from 72.36 Ma to 70.4 Ma (Luo and Nummedal, 2010). It interfingers with the Lewis Shale locally as a result of westward marine transgression. The Almond Formation was deposited during a period of overall transgression, but contains numerous transgressive-regressive cycles, intraformational unconformities, and flooding surfaces (Martinsen and others, 1995). This formation represents a series of high-frequency, back-stepping sequences associated with the transgression between the Almond and Pine Ridge time interval. The Almond Formation is approximately 180 m (590 ft) thick. The Almond Formation coal beds correlate to the Upper Coal Group of the Williams Fork Formation in Moffat County, Colorado.

Lower Mesaverde Group, Undivided (Kmv)

Displayed only on the cross-section, this unit is composed of the Mesaverde Group below the Almond Formation. The Pine Ridge Sandstone, Allen Ridge Formation and Haystack Mountains Formation (Roehler and Hansen, 1978; Roehler, 1990) are only present in the subsurface of the Dixon quadrangle.

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APPENDIX 1: PALYNOLOGY

Previous Investigations

The U.S. Geological Survey conducted extensive pollen and fossil studies from Cretaceous and Paleocene rocks along the rim of the Little Snake Coal Field (Hettinger and others, 1991; Honey and Hettinger, 2004). They collected several samples near the Cretaceous-Paleogene (K-Pg; formerly Cretaceous-Tertiary or K/T) boundary. Palynology results from that work indicate the upper part of the Lance Formation is bracketed between Maastrichtian to early Paleocene in age, and contains the K-Pg boundary zone. The authors suggest that the K-Pg boundary is located within the upper part of the Red Rim Sandstone locally. The authors found predominately late Maastrichtian palynomorphs in the lower part of the Red Rim Member, while the upper Red Rim Member contained several samples with early Paleocene palynomorph assemblages. Within the overlying China Butte Member of the Fort Union Formation (their "Fort Union Formation"), they found palynomorph assemblages characteristic of early Paleocene. Their China Butte Member samples were collected from the lower part of the section, near the Red Rim coal zone. They also sampled the Overland Member (their "Unnamed upper Paleocene unit") and found middle to late Paleocene palynomorph assemblages.

WSGS sampling on Rawlins Peak SW quadrangle (Carroll and others, 2015) suggests that the latest Maastrichtian pollen species *Wodehouseia* assemblage was not present there and that the K-Pg boundary is at the unconformity boundary between the Red Rim Sandstone of the Lance Formation and the China Butte Member of the Fort Union Formation. On the Dixon quadrangle, both the China Butte and Red Rim units have thinned from the north, so the contact remains as an unconformable boundary and the K-Pg boundary is likely on that boundary.

The nomenclature of Nichols and Ott (1978) indicates that Lance and Fort Union Formation polymorphs of the Atlantic Rim and Rawlins uplift span the range of P6 (youngest) to P2 (oldest). However, Lillegraven (2015) suggests that this system is controlled more by paleoenvironmental constraints than discrete parts of geologic time. Thus, pollen assemblages collected in this area represent only a relative range of geologic time. Two US Geological Survey samples (D6473 and D6474) collected on Peach Orchard Flat quadrangle indicate Late Cretaceous (probably Maastrichtian) age (Honey and Hettinger (2004)).

Correspondingly, several authors also identified vertebrate fossils south of the study area. Rigby (1980) found early Paleocene (Torrejonian) mammal fossils in the Swain Quarry of the upper China Butte Member of the Fort Union Formation. McComas (2014) discovered a new genus and species of earliest Paleocene Arctocyonid on Coal Gulch quadrangle. The fossils suggest that the lowest part of the China Butte Member (below the Red Rim and Daley Ranch coal zones) is early Puercan in age. These are correlative to zone P2 of Nichols and Ott (1978) and the Continental Divide coal zone of Hettinger and others (2008). In the upper Wasatch Formation, at the Dad fossil vertebrate locality, Gazin (1962) found early Eocene (late Wasatchian) fossils.

Methods

Coal and carbonaceous shale samples were collected from the China Butte-Blue Gap and Overland Members of the Fort Union Formation, and the Red Rim Member of the Lance Formation in the study area. Coal roof or floor rock, usually carbonaceous shale, were targeted for sampling, in hope of selecting the best palynomorphs because pollen in coal beds are usually too bioturbated for recovery. Six samples were sent to Biostratigraphy.com (Garland, Texas) for processing and analysis. In addition to age, the palynology samples were used to determine paleoenvironment based on the taxa identified, and thermal maturity based on spore color. Samples are detailed in table 1; sample locations are identified on the maps.

Results

Age

Table 1 shows the range of possible ages for each sample. Two samples were collected from the K/Pg boundary near the Red Rim and China Butte contact (DIX-P1 and P2). The former sample is Late Maastrichtian to earliest Paleocene, while the latter sample is not bracketed precisely. This suggests the Red Rim Member of the Lance Formation represents latest Cretaceous rocks and was very near the K/Pg boundary. *Wodehouseia* does not occur in any of the WSGS study area samples, implying a significantly moderate gap in time at the K/Pg boundary.

The next two samples, DIX-P3 and DIX-P4 are representative of the overlying basal China Butte Member of the Fort Union Formation. Samples were collected in the basal coals that correlate to the biozone described by McComas (2014). The pollen assemblages for these two samples were not precise other than to indicate that the K/Pg boundary was recent to deposition of these rocks of earliest Paleocene. This study was not able to identify the exact K-Pg boundary but observed that it is stratigraphically lower than sample DIX-P3 in the section. Sample DIX-P5 was collected from carbonaceous shales overlying a coal bed higher in the China Butte section than DIX-P3 and DIX-P4 (fourth coal from the base of the China Butte Member). The sample was mostly bioturbated with low recovery. The few pollen assemblages indicate early Paleocene. Pollen samples from the Maastrichtian found in these samples are probably reworked.

Sample DIX-P6 was collected at the Blue Gap and Overland Member contact of the Fort Union Formation. The palynological recovery was low (Zippi, 2016). This sample pollen assemblage implies an age of early Paleocene, which is older than what previous collectors observed. Overland Member pollen samples collected by the U.S. Geological Survey (Hettinger and others, 1991) on Chalk Bluff indicate late to middle Paleocene age. Pollen sample D4447 at NW¼ SW¼ sec. 15, T. 12 N., R. 90 W. is considered middle Paleocene and correlated to zone P3 or P4 of Nichols and Ott (1978). This was collected at the base of the Overland Member just above the Blue Gap Member. Stratigraphically higher palynology sample D4446 at SW¼ NW¼ sec. 15, T. 12 N., R. 90 W has a pollen assemblage indicative of late Paleocene, or zone P5 of Nichols and Ott (1978).

Paleoenvironment

The paleoenvironment results suggested by Zippi (2016) generally agree with the interpretations of Hettinger and others (2008) and Roehler (1990). The samples were collected across a profile from the Lance Red Rim Sandstone to the Fort Union Overland Member, spanning the Paleogene/Cretaceous boundary. Biostratigraphy.com interpreted all paleoenvironments as fluvial floodplain to fluvial lacustrine for the coal zone samples. Sample DIX-3 had an angiosperm palynoflora and high proportion of algal cysts to suggest fluvial-lacustrine floodplain environment (Zippi, 2016). The Red Rim Member represents an alluvial-plain landscape that later changes into a coal-mired fluvial-lacustrine environment of the lower part of the China Butte Member of the Fort Union Formation. The Overland Sandstone and Blue Gap shale members overlie the China Butte member and are interpreted as more fluvial floodplain.

Table 1. Results for palynology analyses showing sample name, unit sampled, palynology age, paleoenvironment, thermal maturity (as estimated percent Ro, vitrinite reflectance), and sample location (latitude and longitude in GCS NAD27). Blank spaces for age and vitrinite reflectance indicate the palynomorph count was too low to make a determination.

Sample ID	Unit, rock type	Age (this report)	Prev. Age Estimate for these formations (Hettinger and others, 1991)	Paleoenvironment	est. %Ro	Latitude	Longitude
DIX-P1	Klr, claystone	Late Maastrichtian-Earliest Paleocene	Maastrichtian	Fluvial, floodplain	0.26	41.123099	-107.610435
DIX-P2	Tfc/Klr contact, claystone	Late Maastrichtian-Recent	Late Maastrichtian-Earliest Paleocene	Fluvial, floodplain	0.26	41.124738	-107.612048
DIX-P3	Tfc lower coal zone, claystone	Late Maastrichtian-Earliest Paleocene	- -	Fluvial-lacustrine floodplain	0.26	41.124911	-107.61363
DIX-P4	Tfc upper coal zone, fine sand	Late Maastrichtian-Earliest Paleocene	- -	Fluvial, floodplain	0.26	41.123698	-107.61431
DIX-P5	Tfc above coal zones, coal	Late Maastrichtian-Early Paleocene	- -	Fluvial, floodplain	0.87	41.124227	-107.615663
DIX-P6	Tfo/Tfb contact, claystone/shale	Early Paleocene	- -Middle to Late Paleocene	Fluvial, floodplain	0.26	41.124066	-107.622012

APPENDIX 2: COAL QUALITY

Nine coal samples were analyzed by Wyoming Analytical Laboratories Inc., Laramie, Wyoming for proximate and ultimate analyses, moisture, and mercury (table B1). Results are displayed on an as-received, moisture-free, and moisture- and ash-free basis. Heat values are much lower than expected because they were collected from weathered outcrop material. From the US Geological Survey's COALQUAL database, the apparent rank for these samples is much lower than the average coal present in Carbon County, Wyoming, (Palmer and others, 2016), and can be considered 'impure subbituminous coal'. Most of the samples are in-seam coal, with much parting on the outcrops. The average mercury in coal sampled is 0.063 mg/kg, or 63 ppb. These samples were also entered into the U.S. Geological Survey's National Coal Resource Data System (NCRDS) (U.S. Geological Survey, 2016) and the WSGS Wyoming Database of Geology (WyoDOG) database during this mapping project.

Table 2. Coal quality sample results collected from the study area. Sample locations are given as latitude and longitude in GCS NAD27.

				Moisture Content	**Ash Content**			**Volatile Matter**		
Sample ID	**Sample Description**	**Latitude**	**Longitude**	**Total As Rec. %**	**As Determined %**	**As Received %**	**Dry %**	**As Received %**	**Dry %**	**MAF %**
DIX-C1(DLS 16-14)	Tfc, 5-Mile Point coal	41.124911	-107.61363	24.18	63.92	54.64	72.06	13.21	17.42	62.35
DIX-C2 (DCC-87)	Tfc, Muddy Creek coal	41.012062	-107.501734	33.28	19.78	16.29	24.41	26.99	40.46	53.53
DIX-C3 (DLS 16-59)	Tfc, Fillmore Ranch coal	41.012095	-107.502162	36.98	26.38	19.13	30.36	22.59	35.84	51.46
DIX-C4 (DLS 16-62)	Tfc, Muddy Creek coal	41.013367	-107.50451	35.9	13	10.35	16.14	28.38	44.27	52.79
DCC-124c	Kal, A(1) coal (Savery Quad)	41.090648	-107.499579	9.89	8	8	8.88	33.58	37.27	40.9
DCC-150c	Tfc, Olson Draw coal	41.101983	-107.582529	11.99	38.2	38.2	43.4	34.34	39.02	68.94
DCC-151c	Tfc, 5-Mi Pt coal	41.095005	-107.585466	13.7	10.33	10.33	11.97	38.46	44.57	50.63
DCC-168c	Kfh, thick coal (Smiley Draw quad)	41.137839	-107.580002	11.6	7.86	7.86	8.89	37.09	41.96	46.05
DCC-179c	Kfh, Highest unit Coal	41.117043	-107.560523	10.77	39.26	39.26	44	32.18	36.06	64.4
Average				**20.92**	**25.19**	**22.67**	**28.9**	**29.65**	**37.43**	**54.56**

Table B1. continued

Fixed Carbon	**Sulfur Content**	**Heating Values (BTU)**	**Carbon**

	As Received	Dry	MAF	As Received	Dry	MAF	As Received	Dry	MAF	As Received	Dry	MAF
Sample ID	%	%	%	%	%	%	%	%	%	%	%	%
DIX-C1(DLS 16-14)	7.98	10.52	37.65	0.1	0.13	0.46	1,487	1,962	7,022	12.45	16.43	58.8
DIX-C2 (DCC-87)	23.44	35.13	46.47	0.14	0.21	0.28	4,986	7,473	9,887	32.69	49	64.83
DIX-C3 (DLS 16-59)	21.3	33.8	48.54	0.04	0.07	0.1	4,179	6,631	9,522	28.03	44.47	63.86
DIX-C4 (DLS 16-62)	25.38	39.59	47.21	0.46	0.71	0.85	5,181	8,083	9,639	35.65	55.62	66.33
DCC-124c	48.53	53.86	59.1	0.66	0.73	0.81	9,935	11,025	7,022	61.37	68.11	74.74
DCC-150c	15.47	17.58	31.06	0.29	0.33	0.59	4,084	4,640	8,199	31.74	36.06	63.72
DCC-151c	37.51	44.46	49.37	0.2	0.23	0.26	7,389	8,562	9,726	52	60.25	68.45
DCC-168c	43.45	49.15	53.95	3.31	3.74	4.11	8,934	10,106	11,093	55.61	62.91	69.05
DCC-179c	17.79	19.94	35.6	1.26	1.41	2.52	3,998	4,481	8,001	31.14	34.9	62.32
Average	**26.76**	**33.78**	**45.44**	**0.72**	**0.84**	**1.11**	**5,574**	**6,995**	**8,901**	**37.85**	**47.53**	**65.79**

Table B1. continued

	Hydrogen			Nitrogen			Oxygen			Mercury
	As Received	**Dry**	**MAF**	**As Received**	**Dry**	**MAF**	**As Received**	**Dry**	**MAF**	
Sample ID	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**mg/kg**
DIX-C1(DLS 16-14)	0.91	1.2	4.3	0.03	0.03	0.12	7.69	10.15	36.32	0.058
DIX-C2 (DCC-87)	2.06	3.08	4.08	0.46	0.69	0.91	15.08	22.6	29.9	0.064
DIX-C3 (DLS 16-59)	1.4	2.22	3.19	0.4	0.63	0.91	14.02	22.24	31.94	0.070
DIX-C4 (DLS 16-62)	1.44	2.25	2.68	0.52	0.81	0.96	15.69	24.47	29.18	0.056
DCC-124c	4.13	4.59	5.03	1.39	1.54	1.69	4.7	16.2	5.73	0.041
DCC-150c	2.42	2.75	4.86	0.47	0.53	0.94	2.9	16.82	5.82	0.064
DCC-151c	2.65	3.08	3.5	0.75	0.87	0.99	6.67	23.6	8.78	0.066
DCC-168c	3.87	4.38	4.81	1.35	1.53	1.68	4.8	18.55	5.96	0.055
DCC-179c	1.75	1.97	3.51	0.71	0.80	1.42	4.34	16.93	8.68	0.089
Average	**2.29**	**2.84**	**4**	**0.68**	**0.83**	**1.07**	**8.43**	**19.06**	**18.03**	**0.063**