Geology of the Shotgun Butte Area Fremont County, Wyoming

GEOLOGICAL SURVEY BULLETIN 1157

Prepared in cooperation with the Geological Survey of Wyoming and the Department of Geology of the University of Wyoming as part of the program of the Department of the Interior for development of the Missouri River basin

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By W. R. KEEFER *and* M. L. TROYER

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

GEOLOGY OF THE SHOTGUN BUTTE AREA, FREMONT COUNTY, WYOMING

By W. R. Keefer and M. L. Troyer

ABSTRACT

The Shotgun Butte area includes approximately 300 square miles in the northern part of the Wind River Basin, Fremont County, Wyo. The area lies wholly within the Wind River Indian Reservation, and includes all or parts of the Harris Bridge, Pavillion Butte, Shotgun Butte, Eagle Point, Jenkins Mountain, Bargee, Sheep Ridge, and Kates Basin 7½-minute quadrangles. The northern boundary lies along the south flank of the Owl Creek Mountains.

Sedimentary rocks exposed in the Shotgun Butte area range in age from Triassic to Recent and have an aggregate thickness of more than 18,000 feet. The area contains some of the most complete exposures of Upper Cretaceous, Paleocene, and lower Eocene rocks in central Wyoming. These rocks locally are more than 15,000 feet thick.

Rocks of Paleozoic age that underlie the Shotgun Butte area are well exposed along the flanks of the nearby Owl Creek Mountains. The Paleozoic rocks, which unconformably overlie Precambrian rocks in the core of the mountains, include the Flathead Sandstone, Gros Ventre, and Gallatin Formations of Cambrian age, Bighorn Dolomite of Ordovician age, Darby Formation of Devonian age, Madison Limestone of Mississippian age, Amsden Formation and Tensleep Sandstone of Pennsylvanian age, and the Phosphoria Formation of Permian age. The Paleozoic strata have a total thickness of about 2,600 feet.

Rocks of Triassic and Jurassic age crop out in fault blocks along the northeast edge of the Shotgun Butte area. These rocks include the Dinwoody and Chugwater Formations, and the Nugget Sandstone and Gypsum Spring and Sundance Formations, respectively. The Sundance Formation is overlain by the Morrison and Cloverly Formations, undifferentiated, of Late Jurassic and Early Cretaceous age. The Morrison and Cloverly Formations were mapped as a single unit, although locally a conspicuous conglomerate about 160 feet above the base may mark the contact in this area. Overlying the Cloverly Formation are the Thermopolis and Mowry Shales, also of Early Cretaceous age. The Muddy Sandstone Member of the Thermopolis Shale locally forms a conspicuous ledge within the black shale sequence.

The Frontier Formation is the lowermost unit of Late Cretaceous age in the Shotgun Butte area. This formation is 890 feet thick and consists of alternating shale and sandstone. Abundant marine fossils of early Niobrara age occur in its upper part. The overlying Cody Shale, 3,725 to 4,145 feet thick, is predominantly shale in the lower half and interbedded sandstone and shale in the upper half. Marine fossils indicate an age ranging from early Niobrara (Colorado Group) into Eagle (Montana Group). The Mesaverde Formation consists of prominent

sandstone units at the base and top, and interbedded sandstone, siltstone, shale, carbonaceous shale, and coal in the middle. The basal sandstone, as much as 250 feet thick, represents a beach deposit and is gradational with the underlying marine sandstone beds of the Cody Shale. The upper sandstone, termed the white sandstone member, is 225 to 435 feet thick and forms the most conspicuous unit of Late Cretaceous age in the region. The Mesaverde Formation is almost wholly nonmarine and is uniformly 2, 000 feet thick throughout the Shotgun Butte area. The next younger formation is the Meeteetse Formation, which consists of nonresistant sandstone, siltstone, shale, carbonaceous shale, and coal in its lower part, and massive cliff-forming lenticular sandstone in its upper part. The formation ranges in thickness from 659 to 1,335 feet. The Lance Formation, which forms the uppermost unit of Cretaceous age in the area, is largely sandstone and conglomerate in the lower part and soft claystone and shale in the upper part. It has a maximum thickness of 1,140 feet in the vicinity of Shotgun Butte, but thins to wedge edges to the north and south. The Lance Formation overlies the Meeteetse Formation with apparent conformity in the vicinity of Shotgun Butte, but southward toward Little Dome anticline a conspicuous unconformity is present.

The Fort Union Formation of Paleocene age is 1,710 to 3,925 feet thick and can be divided into a lower unnamed member and the overlying Shotgun Member. The lower member is predominantly sandstone and conglomerate deposited under fluviatile conditions. The Shotgun Member is a uniformly even bedded series of drab-colored claystone, shale, and siltstone containing shark remains; the composition of the member suggests that deposition was in and adjacent to a large body of water. Plant and vertebrate fossils were collected from several beds in the Fort Union Formation and indicate that nearly all Paleocene time is represented.

Lower Eocene rocks are represented by the Indian Meadows and Wind River Formations, which are mostly variegated red and gray claystone and shale interbedded with massive sandstone and conglomerate. Ancient landslide masses of limestone and dolomite of Paleozoic age comprise part of the Indian Meadows Formation in the vicinity of Twin Buttes. The Indian Meadows Formation contains fossils of earliest Eocene age and the Wind River contains fossils of late early Eocene age (Lost Cabin). In the vicinity of Shotgun Butte the Indian Meadows Formation overlies the Fort Union Formation with apparent conformity, but in other places the two formations have an angular discordance of as much as 90°. The Wind River Formation overlies older units with angular unconformity. Tertiary rocks younger than early Eocene are not present in the Shotgun Butte area. Quaternary deposits, mainly alluvium and terrace and pediment gravels, are widespread.

The Shotgun Butte area lies along the northern margin of the Wind River structural basin, and includes a narrow segment of the Owl Creek Mountains. A series of northwest-trending anticlines and synclines plunge sharply southeastward into the structurally deeper parts of the basin. Several extensive faults are also present. Structural features along the basin margin and in the Owl Creek Mountains have a northwesterly trend that diverges markedly from the more westerly trend of the range itself. The more westerly alined structures are younger than the northwest-trending ones. The forces causing the deformation changed from predominantly lateral during the early stages of orogeny to nearly vertical during the later stages in the mountains proper.

The sedimentary and structural history of the area during Late Cretaceous and early Tertiary times may be divided into several distinct stages: (a) a major advance and retreat of the Late Cretaceous sea, (b) a long period of nonmarine deposition during latest Cretaceous and early Paleocene time, (c) a reinvasion of the sea or the development of a widespread fresh-water lake in middle and late Paleocene time, and (d) the major phases of the Laramide orogeny and associated events. Deformation began in Late Cretaceous time and culminated at the end of Paleocene time with the pronounced uplift of the nearby Owl Creek Mountains. Thick conformable sedimentary sequences accumulated in the trough area surrounding Shotgun Butte, but along the margins of the trough, sedimentation was intermittent and many interformational unconformities, and possibly intraformational unconformities as well, were formed. Some folding took place in late early Eocene time, and normal faulting occurred in post-early Eocene time.

Except for one gas well on Little Dome anticline, no commercial quantities of petroleum have been discovered in the Shotgun Butte area. Lenticular coal beds, in places attaining several feet in thickness, are present in the lower part of the Mesaverde Formation and the middle part of the Meeteetse Formation. The coal is subbituminous in grade; the combined estimate of reserves for several small districts within the area is about 8 million tons.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Shotgun Butte area includes approximately 300 square miles in the northern part of the Wind River Basin, west-central Wyoming (fig. 1). The area lies wholly within the Wind River Indian Reservation. The southeastern part is included in the U.S. Bureau of

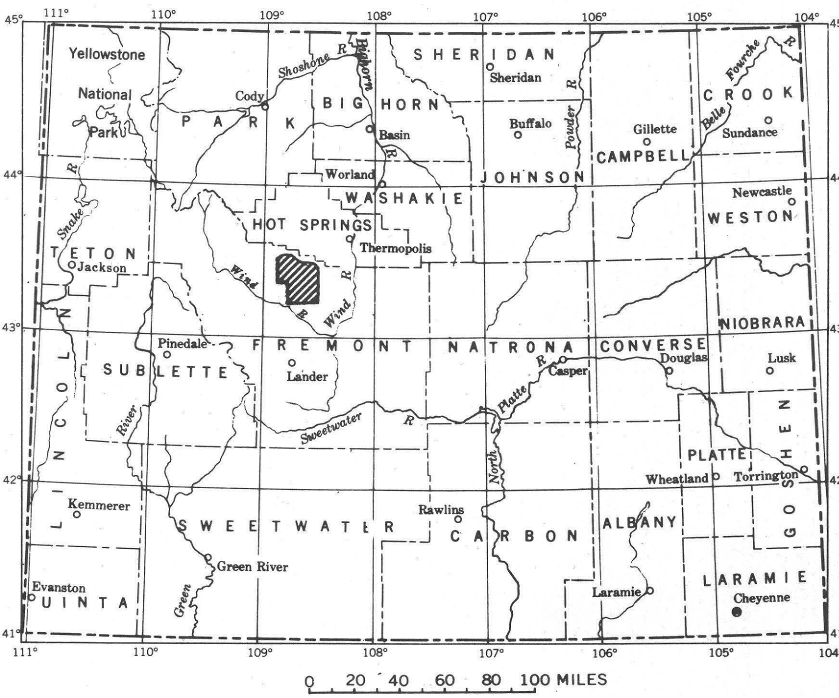

FIGURE 1.—Index map of Wyoming showing location of Shotgun Butte area.

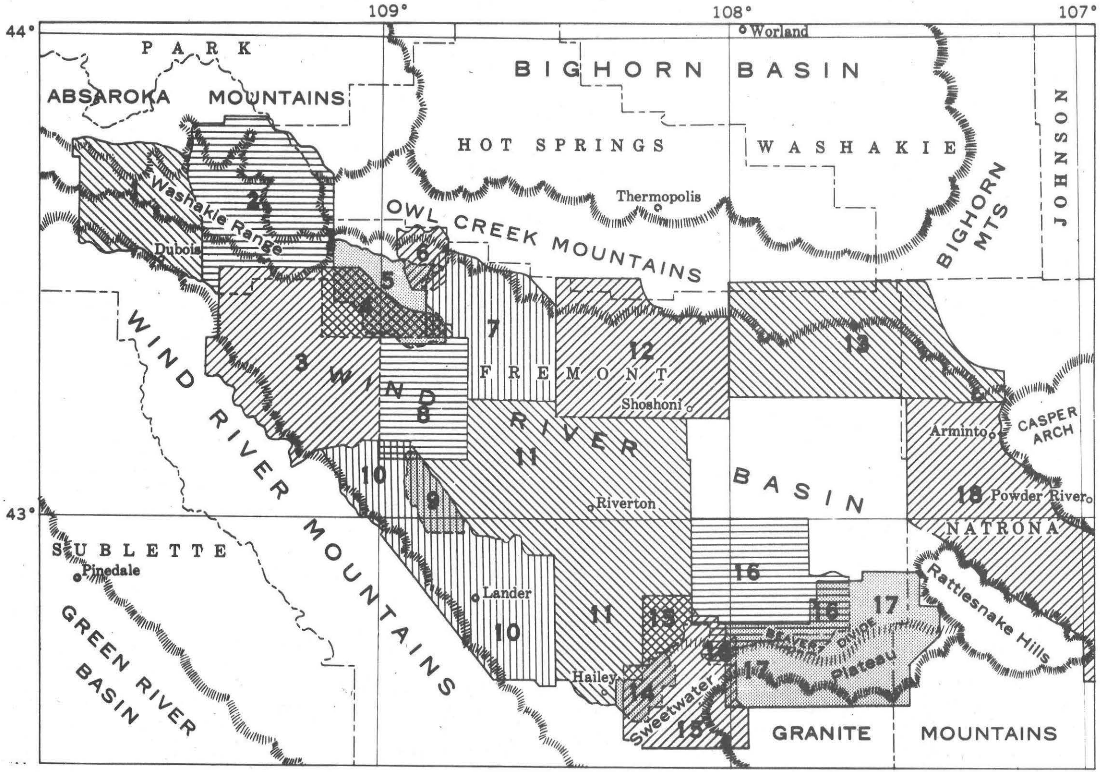

FIGURE 2.—Index map showing major physiographic features and areas of geologic mapping by the U.S. Geological Survey in the Wind River Basin.

Reclamation Riverton Irrigation Project. All the Harris Bridge, Pavillion Butte, Shotgun Butte, and Eagle Point 7½-minute quadrangles and parts of the Jenkins Mountain, Bargee, Sheep Ridge, and Kates Basin 7½-minute quadrangles are in the mapped area. The northern boundary is the south flank of the Owl Creek Mountains; the other three sides adjoin areas previously mapped by the U.S. Geological Survey as indicated on figure 2.

PURPOSE OF THE INVESTIGATION

Geologic investigations in the Shotgun Butte area were undertaken by the U.S. Geological Survey as a part of the program of the Department of the Interior for the development of the Missouri River basin. The report is one of a series of studies on the oil and gas possibilities and coal resources of the Wind River Basin (fig. 2).

Specially emphasized during the present investigation were detailed stratigraphic studies of the rather complete sequence of Upper Cretaceous and lower Tertiary strata that form most of the sedimentary rocks exposed in the mapped area. Elsewhere in the northern and central parts of the basin, exposures of these rocks are limited and data concerning them are incomplete. Because many wells drilled for oil and gas in the region penetrate all or parts of the Upper Cretaceous and lower Tertiary rocks, stratigraphic and structural data obtained in the Shotgun Butte area will aid subsurface correlations and evaluation of oil and gas possibilities of the region.

PREVIOUS INVESTIGATIONS AND PUBLICATIONS

Early geologic work in the Shotgun Butte area was done by Comstock (1875) in 1873 and Eldridge (1894) in 1893 as part of their reconnaissance investigations of a large part of northwestern Wyoming. Much of the area was also included by Darton (1906) in his studies of the Owl Creek Mountains. Woodruff and Winchester (1912) examined coal fields in the Wind River Basin and measured many coal sections in the Shotgun Butte area; descriptions of many

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References for areas of geologic mapping shown on figure 2 are:

1. Keefer (1957)
2. Love (1939)
3. Mapping by J. F. Murphy
4. Murphy and others (1956)
5. Andrews (1944)
6. Williams and Sharkey (1946)
7. Area of this report
8. Murphy and Roberts (1954)
9. Sharkey and others (1946)
10. Thompson and others (1950)
11. Thompson and White (1954)
12. Tourtelot and Thompson (1948)
13. Tourtelot (1953)
14. Van Houten (1950)
15. Van Houten (1954)
16. Thompson and White (1952)
17. Van Houten and Weitz (1956)
18. Rich (1962)

of these sections are incorporated in the present report. Condit (1916) made a stratigraphic study of the rocks of Permian and Triassic age along the north edge of the mapped area.

Some mapped areas in adjacent regions are shown on figure 2. In addition to these maps, there are several other reports primarily concerned with the stratigraphy of Mesozoic rocks in the Wind River Basin. Love and others (1947, p. 17–26) have given a detailed section of the upper Paleozoic and lower Mesozoic rocks along East Fork Sheep Creek in the north-central part of the Shotgun Butte area.

METHODS OF INVESTIGATION

This report is based on field investigations done during the summers of 1949, 1950, and 1951. The geology was mapped on aerial photographs at a scale of 1:24,000. The data were later transferred to U.S. Geological Survey topographic maps (scale 1:24,000), which provided control for structure contouring and the preparation of cross sections. Stratigraphic sections were measured by planetable methods; detailed measurements of beds were made with 100-foot tape and Brunton compass.

ACKNOWLEDGMENTS

The writers were assisted in the field by R. J. Burnside during the summer of 1950 and by S. W. Welch during the summer of 1951. R. J. Koogle helped measure the Twin Buttes section in June 1959. Fossil determinations by J. B. Reeside, Jr., W. A. Cobban, R. W. Brown, and M. J. Hough, of the U.S. Geological Survey, who visited the area at various times during the field seasons, assisted greatly in the stratigraphic studies of the Upper Cretaceous and early Tertiary rocks. E. B. Leopold, U.S. Geological Survey, studied the spore and pollen assemblages and made possible a more precise determination of the Cretaceous-Paleocene boundary in this area. C. L. Gazin, of the U.S. National Museum, identified many of the vertebrate fossils from the Paleocene and lower Eocene rocks. The writers benefited greatly from many discussions with Prof. Paul O. McGrew, Department of Geology, University of Wyoming, about the stratigraphy and paleontology of Tertiary rocks throughout Wyoming. The geology of Little Dome anticline and the adjoining area to the south was mapped and described by Murphy and others (1956). Their mapping on Little Dome anticline, in the southwestern part of the Eagle Point quadrangle, is used in this report. Grateful acknowledgment is given to Mr. and Mrs. William Bradford, on whose ranch the writers camped during the field seasons and who were otherwise helpful in many ways. The report was prepared with the cooperation of the

Geological Survey of Wyoming and the Department of Geology, University of Wyoming.

GEOGRAPHY

CLIMATE AND VEGETATION

The climate of the Shotgun Butte area is arid to semiarid. Pavillion, just south of the southern boundary of the area, has an average annual rainfall of 9.18 inches. More than 50 percent of the precipitation occurs during the months of April, May, June, and July. Precipitation in the Owl Creek Mountains along the northern boundary of the area is probably somewhat greater, as shown by the stands of pine trees and the profuse growth of grass and flowers, but no data are available for this region.

Vegetation is sparse in the nonirrigated parts of the Shotgun Butte area. The valleys support some grass, sagebrush, and cactus, and a few willows and cottonwoods grow along the stream channels. The western slopes of the hills are commonly very steep and sparsely vegetated; the eastern slopes have a scanty sagebrush cover and a few scrub pine trees. The pine trees are generally concentrated along outcrop belts of massive porous sandstone, such as that in the Frontier Formation, the white sandstone member of the Mesaverde Formation, and the lower part of the Fort Union Formation. The nonirrigated parts of the area are mostly used as winter grazing lands for cattle and sheep. Summer grazing is limited, for the most part, to grassland areas in the Owl Creek Mountains.

Irrigation in the Fivemile and Muddy Creek valleys in the southeastern part of the area has made possible the cultivation of grains, alfalfa, and other crops in these areas. Water from streams in the northern part of the area is used for the irrigation of hay meadows at several localities along the south flank of the Owl Creek Mountains.

At Pavillion, the length of the growing season (that is, the number of days between the last date in the spring and the earliest date in the fall having temperatures of 28°F or below) from 1940 to 1950 averaged 142 days. The last killing frost (28°F or below) in the spring generally occurs about the middle of May, and the earliest killing frost in the fall usually occurs between September 15 and October 15. The average annual temperature for the years 1924 to 1950 was 44.8°F.

SURFACE FEATURES

In Muddy Creek valley, near the southeast edge of the mapped area, the elevation is about 5,150 feet. The elevation increases both to the north and northwest; the highest point in the area, in the northwest corner along the Owl Creek Mountains, is about 7,000 feet. The steep south flank of the range rises abruptly along the northern boundary of the area.

The topography of the western and northern parts of the mapped area is very irregular because of the alternating succession of resistant and nonresistant beds. The dominant topographic feature in the northwest-central part of the area is Shotgun Butte, which rises more than 500 feet above the surrounding area. Basinward the terrain is characterized by badlands interspersed with broad flats. Prominent flat-topped mesas and divides include Muddy Ridge which forms the drainage divide between Muddy and Fivemile Creeks, Sand Mesa on the north side of Muddy Creek, and Cottonwood Flat in the east-central part of the area. Several smaller but conspicuous flat-topped divides extend basinward from the south flank of the Owl Creek Mountains. Badland topography, formed by the gullying of soft sandstone and shale, is most extensive near the east and southeast edges of the area. Terrain in the northeast corner is also deeply dissected and is dominated by Twin Buttes, which rise 500 to 600 feet above the general landscape and lie approximately half a mile south of the Owl Creek Mountain front. Because of sparse vegetation, the poorly cemented sedimentary rocks in this region erode rapidly during flash floods.

DRAINAGE AND WATER SUPPLY

The Shotgun Butte area is drained by Fivemile and Muddy Creeks, which flow southeastward into Boysen Reservoir approximately 4 miles west of the town of Shoshoni. During most of the year the streams have a very small flow, but in the spring and after heavy summer rains flash floods are common. At flood stage both streams carry large amounts of silt eroded from the relatively soft strata in which their channels are formed. Irrigation waste water augments the flow in the lower reaches of the two drainage systems during periods of irrigation. Several minor perennial streams, heading in the Owl Creek Mountains, enter Muddy Creek from the north, but most of the tributary streams are intermittent. The growth of cottonwoods and willows along streambeds that are normally dry indicates that much water may flow underground through the gravel of the stream channels.

Most of the ranches in the foothills along the south flank of the Owl Creek Mountains obtain water for domestic use from local springs along the mountain front. Some of the surface water is also fit for domestic use.

Extensive studies of ground water in the Riverton Irrigation Project, including a few wells in the southeast corner of the mapped area just north of Pavillion, have been made by Morris and others (1959).

Most of the wells produce water from lenticular sandstone beds of the Wind River Formation; these beds are the best source of water for domestic use in the area. The water level in the deeper wells fluctuates very little during the year. Shallow wells produce water from the loosely consolidated upper part of the Wind River Formation and from alluvial deposits.

During the present investigation no information was obtained on water supply for domestic use at ranches upstream from the Riverton Irrigation Project on Fivemile and Muddy Creeks. However, alluvial deposits and the sandstones in the Wind River Formation should also yield water in these areas.

Water for livestock in nonirrigated tracts is obtained mainly from many small reservoirs along minor streams. In the Owl Creek Mountains, plentiful water of good quality is generally available for summer grazing. Along the south flank of the range, small permanent streams supply water for stock.

SETTLEMENT AND ACCESSIBILITY

The region is sparsely settled. A few ranches are located along the south flank of the Owl Creek Mountains and along major streams within the basin proper. Since 1949 many small farms have been established in irrigable tracts along Muddy and Fivemile Creek valleys in the southeast part of the area. Pavillion, the nearest town, is just south of the area and had a population of 190 according to the 1960 census. Larger towns near the area include Riverton, Shoshoni, and Lander, which are, respectively, 17 miles southeast, 24 miles east, and 30 miles south of the area.

The area is accessible by three graded roads. One joins U.S. Highway 26 via the Missouri Valley Road, approximately 7 miles west of Shoshoni; another leads northward through the area from Pavillion; the third branches to the north-northeast from the oiled road to Maverick Springs oil field at a stock-loading pen 11 miles north-northeast of the junction of the Maverick Springs Road and U.S. 26.

STRATIGRAPHY

GENERAL FEATURES

The Shotgun Butte area contains one of the most complete sequences of Upper Cretaceous, Paleocene, and lower Eocene rocks in central Wyoming; most of the area is underlain by these strata. Rocks of Late Cretaceous and Paleocene age form wide outcrop belts in the western and northern parts, and Eocene rocks crop out over much of the remaining region. Detailed descriptions of several sections of this heretofore little-known sequence were made during the present investigations.

The Thermopolis Shale of Early Cretaceous age crops out in the northern part of the mapped area (pl. 1). Except for a few exposures of Triassic and Jurassic rocks in the northeast corner, strata older than the Thermopolis Shale are present only in the subsurface of the area that was mapped. The older strata are well exposed, however, in the adjoining area to the north along the steep south flank of the Owl Creek Mountains.

A detailed stratigraphic section of the rocks between the Tensleep Sandstone (Pennsylvanian) and Cody Shale (Upper Cretaceous), measured previously along East Fork Sheep Creek in the north-central part of the area, secs. 2, 3, 10, 11, 14, and 15, T. 6 N., R. 3 E., has been published by Love and others (1947, p. 18–26). The Cities Service Tribal 1 well (well 12, table 2), SW¼ NE¼ SW¼ sec. 9, T. 5 N., R. 1 E., was drilled to a depth of 10,905 feet and penetrated a complete stratigraphic sequence between the lower part of the Meeteetse Formation (Upper Cretaceous) and the Tensleep Sandstone; samples from this well were studied by the writers. The Tensleep Sandstone and older Paleozoic rocks have been described by Tourtelot and Thompson (1948) from exposures in the Wind River Canyon, approximately 15 miles east of the Shotgun Butte area. A subsurface section between the Dinwoody Formation (Triassic) and the Bighorn Dolomite (Ordovician) in the Maverick Spring oil field, a few miles to the west, has been described by Olson (1948, p. 178–179). A few wells on Little Dome anticline have been drilled to the Tensleep Sandstone.

A generalized composite stratigraphic section is given in table 1, and detailed measured sections are shown graphically on plate 2. Lithologic descriptions are given on pages 60 to 118. In the stratigraphic discussions following, descriptions of the lower Paleozoic rocks are taken from Tourtelot and Thompson (1948), and descriptions of the sequence that lies between the Tensleep Sandstone and the Cody Shale are adapted from Love and others (1947, p. 18–26) without further citation.

ROCKS NOT EXPOSED

Rocks older than Triassic do not crop out in the Shotgun Butte area; however, they are present and locally well exposed along the steep south flank of the Owl Creek Mountains and probably underlie all the area mapped. The older sequence includes rocks of Precambrian, Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, and Permian ages. Precambrian and Paleozoic rocks crop out in the

TABLE 1.—*Generalized section of sedimentary rocks exposed in the Shotgun Butte area*

Age		Formation	Thickness (feet)	Character of rocks
Tertiary	Eocene	Wind River Formation	0–1,000	Variegated red, purple, gray, and white claystone, shale, sandstone, and conglomerate contains Precambrian and; Paleozoic rock fragments.
Tertiary	Eocene	Indian Meadows Formation	0–725	Variegated red, purple, lavender, tan, and gray claystone containing some sandstone and siltstone, and brown to red massive conglomerate; conglomerate in lower part contains Mesozoic rock fragments, in upper part Paleozoic rock fragments.
Tertiary	Paleocene	Fort Union Formation	1,710–3,925	Shotgun Member at top (1,190–2,830 ft): gray, olive-drab, and brown, locally red and purple, claystone, siltstone, and shale; thin beds of brown carbonaceous shale and sandstone. Lower part (520–1,200 ft): interbedded white, gray, buff, and brown sandstone, conglomerate, shale, and siltstone; conglomerate contains pebbles and cobbles of chert, quartzite, petrified wood, and siliceous shale.
Cretaceous	Late	Lance Formation	0–1,140	Gray bentonitic claystone, siltstone, and shale in upper part; gray, white, and buff sandstone and conglomerate with fragments of chert, quartzite, and siliceous shale in lower part.
Cretaceous	Late	Meeteetse Formation	660–1,335	Variable sequence of gray, black, yellow, and brown sandstone, siltstone, shale, carbonaceous shale, claystone, and coal; upper 150–300 ft contains massive lenticular sandstone beds as much as 120 ft thick; lower part soft and forms conspicuous valleys.
Cretaceous	Late	Mesaverde Formation	1,950–2,000	Interbedded sandstone, shale, siltstone, carbonaceous shale, and coal. White sandstone member at top is 225–435 ft thick; basal massive sandstone is 0–250 ft thick.
Cretaceous	Late	Cody Shale	3,725–4,145	Sandy member: chiefly gray to buff thin-bedded and platy sandstone and siltstone and minor amounts of black shale. Shaly member: predominantly gray to black, soft, finely fissile shale containing some bentonite.
Cretaceous	Late	Frontier Formation	890	Interbedded gray and tan sandstone and gray to black shale; some thin tuff beds, chert pebbles at top.
Cretaceous	Early	Mowry Shale	560	Black fissile shale in lower 165 ft; remainder is gray hard siliceous shale; many thin bentonite beds.
Cretaceous	Early	Thermopolis Shale	210	Muddy Sandstone Member at top (0–75 ft): gray, buff, and brown sandstone; some shale. Lower part: gray to black fissile shale; some shaly and silty sandstone partings.
Cretaceous -?-	Early -?-	Morrison and Cloverly Formations, undifferentiated	560	Rusty beds at top (150 ft): gray, brown, and olive-drab sandstone, siltstone, and shale. Middle part (250 ft): red and purple claystone and siltstone; white conglomerate and sandstone at base. Basal part (160 ft): white soft friable sandstone (may represent Morrison Formation).
Jurassic	Late	"Upper Sundance"	190	Green to gray sandstone and siltstone, highly glauconitic; some red, brown, and gray limestone.
Jurassic	Late	"Lower Sundance"	105	Gray, white, and red sandstone, gray shale, and gray to white oolitic limestone.
Jurassic	Middle	Gypsum Spring Formation	175–230	Light-gray to white dolomite, limestone, and gypsum and red siltstone.
Jurassic	Early	Nugget Sandstone	8–45	Dark-red sandstone with large frosted sand grains.
Triassic		Chugwater Formation	1,215	Popo Agie Member (210 ft): red, purple, and yellow sandstone, shale, and siltstone. Crow Mountain Sandstone Member (90 ft): brownish-red and gray sandstone; some frosted grains. Alcova Limestone Member (5 ft): gray limestone and violet-red laminae. Red Peak Member (910 ft): red slabby to thin-bedded sandstone, shale, and siltstone.
Triassic	Early	Dinwoody Formation	70	Tan, yellow, and gray sandstone, shale, and siltstone; some limestone and dolomite.

overriding blocks of reverse faults in the northeast corner of the area, but detailed mapping of these blocks was not attempted.

Precambrian rocks underlie extensive areas along the crest of the Owl Creek Mountains, but few data have been published concerning them. Small exposures along the north edge of the mapped area indicate that the Precambrian is a crystalline complex consisting largely of coarse-grained granite and granite gneiss cut by prominent dark-colored mafic dikes. Many of these dikes are several feet in width; locally they may be so numerous as to constitute nearly 50 percent of the bedrock.

The Cambrian rocks are about 1,110 feet thick in the Wind River Canyon and include the Flathead Sandstone at the base, the Gros Ventre Formation in the middle, and the Gallatin Formation at the top. These formations are 255, 400, and 455 feet thick, respectively. The Flathead Sandstone consists of fine- to medium-grained soft to quartzitic sandstone that is conglomeratic near the base, the Gros Ventre Formation is mostly shale with lesser amounts of sandstone and limestone, and the Gallatin Formation consists predominantly of limestone and calcareous shale.

The Bighorn Dolomite of Ordovician age is 140 feet thick in the Wind River Canyon. The formation is probably somewhat thicker in the subsurface of the Shotgun Butte area, inasmuch as it is 200 to 300 feet thick in the northwestern part of the Wind River Basin (Thomas, 1948, p. 83; Keefer, 1957, p. 166–167). The formation is usually characterized by tan massive dolomite that forms conspicuous cliffs in many places in the Owl Creek Mountains.

Rocks of Devonian age, represented in the northwestern part of the Wind River Basin by the Darby Formation, are not present in the Wind River Canyon. However, Thomas (1948, p. 85) reported the Darby to be 90 feet thick in the vicinity of Merritt Pass, just north of the northwest corner of the Shotgun Butte area, and it is 70 feet thick in wells in the Maverick Spring oil field, approximately 5 miles west of the area (Olson, 1948, p. 180). The formation in this field consists mainly of dully varicolored sandy and silty dolomite and limestone. Although subsurface data are lacking for the Shotgun Butte area, the Darby probably decreases eastward to a wedge edge near the eastern boundary.

The Madison Limestone of Mississippian age is 465 feet thick in the Wind River Canyon. Westward the thickness increases to 690 feet in the Maverick Spring oil field (Olson, 1948, p. 180). The formation consists mainly of massive to thin-bedded gray limestone that is commonly dolomitic and cherty. The Madison Limestone forms massive cliffs in many places in the Owl Creek Mountains.

Rocks of Pennsylvanian age are represented by the Amsden Formation and the overlying Tensleep Sandstone. The Amsden Formation is about 240 feet thick in the Wind River Canyon area. The lower 80 to 100 feet of the formation is the Darwin Sandstone Member, a conspicuous white, brown, tan, and buff crossbedded to thin-bedded sandstone that is locally hard and quartzitic. This basal unit is commonly overlain by about 20 feet of red siltstone and shale. The remainder of the Amsden Formation consists of white, gray, and tan, partly limy dolomite, and a minor amount of siltstone. In the subsurface at the Maverick Spring oil field the formation is 295 feet thick. The overlying Tensleep Sandstone forms steep resistant ridges along the south flank of the Owl Creek Mountains and, in places, constitutes the outermost conspicuous dip slopes along the mountain front. The Tensleep Sandstone is 365 feet thick in the Wind River Canyon and about 295 feet thick in the Maverick Spring oil field (Olson, 1948, p. 180). The formation is white, buff, tan, and gray crossbedded sandstone that is locally quartzitic and contains some chert lenses and beds of gray hard limestone and dolomite.

The Phosphoria Formation of Permian age is the uppermost unit of the Paleozoic sequence in the region. In the section (stratigraphic section 5) measured at East Fork Sheep Creek, just north of the mapped area, the formation is 242 feet thick and consists of interbedded gray and white limestone, chert, shale, and dolomitic limestone. Some of the limestone beds are hard and crystalline; others are soft, clayey, and in part glauconitic and fossiliferous. Chert occurs in irregular beds as much as 2 inches thick and in irregular nodular masses.

ROCKS EXPOSED

TRIASSIC SYSTEM

TRIASSIC ROCKS, UNDIFFERENTIATED

Triassic rocks are represented in the region by the Dinwoody and Chugwater Formations, but because they are present in only a few exposures along the northeast edge of the area, these two formations were not mapped separately.

The Dinwoody Formation consists of interbedded tan, yellow, and gray slabby sandstone, shale, and siltstone, and a minor amount of limestone and dolomite. It is 70 feet thick along East Fork Sheep Creek, but thickens to about 120 feet in the Cities Service Shotgun Bench well, SE¼ sec. 9, T. 5 N., R. 1 E., and at Maverick Spring (Love and others, 1945a).

The overlying Chugwater Formation includes thick prominent red beds that form a conspicuous outcrop belt along the south margin of the Owl Creek Mountains. Throughout much of the northwestern part of the Wind River Basin the formation consists of the Red Peak Member at the base, the Alcova Limestone and Crow Mountain Sandstone Member in the middle, and the Popo Agie Member at the top. The upper and lower members are present throughout this region, but the Alcova Limestone and Crow Mountain Sandstone Members locally are thin or absent (Love and others, 1945a).

Along East Fork Sheep Creek the Chugwater Formation is 1,217 feet thick and contains the four members. The Red Peak Member comprises the lower 909 feet of the formation and is characterized by slabby to thin-bedded red sandstone, shale, and siltstone. The lower 40 feet of beds is light ocher in color and slightly limy but is less resistant than the slabby strata of the underlying Dinwoody Formation. The Red Peak Member is faulted in places along East Fork Sheep Creek and the thickness given above may not be accurate.

The Alcova Limestone Member, overlying the Red Peak, consists of a single 4-foot limestone bed with violet-red laminae. The limestone is hard and locally forms a prominent ledge. The Alcova is present just north of the northwestern part of the mapped area, in the vicinity of Madden anticline.

The Crow Mountain Sandstone Member is 88 feet thick and consists of light brownish-red to gray fine- to medium-grained sandstone that is crossbedded in part, and contains large frosted sand grains. It is very similar to the Nugget Sandstone. The Crow Mountain has become an important oil producer in several fields in this region, and it contains commercial quantities of gas in Little Dome anticline (well 5, table 2).

The Popo Agie Member comprises the topmost 216 feet of the Chugwater Formation at East Fork Sheep Creek (stratigraphic section 5). The member consists largely of red and purple sandstone, shale, and siltstone, and thin beds and irregular lenses of limestone-pellet conglomerate. The upper 7 feet of the member is mustard-yellow siltstone. The distinctive yellow and purple colors, in addition to the limestone-pellet conglomerate, are characteristic of Popo Agie strata throughout the western part of the Wind River Basin.

The Dinwoody Formation is considered to be Early Triassic in age (Newell and Kummel, 1942, p. 942–945). The age of the various members of the Chugwater Formation was discussed by Colbert (1957, p. 89–93) who concluded from fossil vertebrate evidence that the formation represents much of Triassic time, the Red Peak Member being Early to Middle Triassic, the Alcova Limestone Member Middle or Late Triassic, and the Popo Agie Member Late Triassic in age. Reeside and others (1957) considered the Alcova Limestone Member to be Late Triassic in age, and they believed that none of the Chugwater Formation is Middle Triassic in age.

JURASSIC SYSTEM

NUGGET SANDSTONE

The Nugget Sandstone overlies the Popo Agie Member of the Chugwater Formation. The formation is dark-red, in part bluish-gray, sandstone that contains large frosted sand grains in a finer grained matrix. The formation is 44 feet thick along East Fork Sheep Creek but thins to about 8 feet just north of the northwest corner of the area in the vicinity of Madden anticline. It is about 35 feet thick in the Cities Service Shotgun Bench well. The thinning of the formation is probably due to an erosional unconformity at the top.

The Nugget Sandstone is generally considered to be Early Jurassic in age, but regional correlations by Love (1957) and Reeside and others (1957) suggest that it may be partly or entirely of Late Triassic age.

GYPSUM SPRING AND SUNDANCE FORMATIONS, UNDIFFERENTIATED

The Gypsum Spring and Sundance Formations are exposed in fault blocks along the northeast edge of the Shotgun Butte area, but, because they are brecciated in the fault zones and generally are poorly exposed, these rocks were mapped as a single unit. The two formations are well exposed directly north of the mapped area in a belt extending from East Fork Sheep Creek westward to the vicinity of Bargee.

The Gypsum Spring Formation of Middle Jurassic age consists of interbedded light-gray to white dolomite and limestone, red siltstone, and gypsum. Gypsum is most conspicuous in the lower 50 feet, and at some places along the outcrop belt it forms prominent white cliffs. The formation is 175 feet thick at East Fork Sheep Creek but thickens southwestward to about 230 feet in the subsurface in the Cities Service Shotgun Bench well. There gypsum near the base is about 70 feet thick. The Gypsum Spring Formation is conspicuously exposed along the north side of a reverse fault that extends from the SE¼ sec. 20 to the SW¼ sec. 34, T. 6 N., R. 3 E.

The Sundance Formation in the Wind River Basin has been divided into the "lower Sundance" and "upper Sundance" (Love and others, 1945c). The lower unit in the Shotgun Butte and adjoining areas consists of nonglauconitic grayish-green to gray shale, gray, white, and red sandstone, and gray to white oolitic limestone; the upper unit consists largely of highly glauconitic green to gray, fine- to medium-grained sandstone and siltstone and a minor amount of red, brown, and gray limestone. At East Fork Sheep Creek the "lower Sundance" is 105 feet thick and the "upper Sundance" is 192 feet thick (stratigraphic section 5). Both sequences contain abundant Late Jurassic fossils at several localities in the basin.

JURASSIC AND CRETACEOUS SYSTEMS

MORRISON AND CLOVERLY FORMATIONS, UNDIFFERENTIATED

Throughout much of the Wind River Basin, rocks assigned to the Morrison and Cloverly Formations have been mapped as a single unit because no consistent regional basis for subdivision has yet been found. However, a major lithologic break that occurs from 100 to 200 feet above the base of the unit in the northern part of the Wind River Basin may mark the contact between the two formations (Love and others, 1945b). This break (fig. 3) is regionally marked

FIGURE 3.—Conglomerate in lower part of Morrison and Cloverly Formations undifferentiated; base of conglomerate may mark contact between the two formations in this area. Center of sec. 12, T. 6 N., R. 1 E.

by a change from lenticular dull earthy, silty sandstone and dully variegated silty claystone below to sparkly, clean porous and conglomeratic sandstone and brightly variegated claystone above. Nonmarine Jurassic fossils have been found below the break, but nonmarine Cretaceous fossils have been found in beds above the break.

A nearly complete section of the Morrison and Cloverly Formations, undifferentiated, is exposed along the crest of Little Dome anticline, and the formations crop out along the north margin of the area next to the outcrop belt of the Thermopolis Shale. In the measured section (5) along East Fork Sheep Creek the total thickness of the sequence is 561 feet.

The basal 162 feet consists of white medium- to fine-grained, moderately soft friable lenticular sandstone that forms conspicuous rounded smooth cliffs. Laterally the sandstone grades into dully variegated claystone.

The rest of the Morrison and Cloverly sequence at East Fork Sheep Creek can be divided into three more or less distinctive lithologic units that generally are found in the same stratigraphic order throughout the Wind River Basin. The lower 27 feet is a cliff-forming conglomerate and sandstone unit. The conglomerate consists of fairly well sorted rounded chert fragments ranging in size from coarse sand to pebbles 1 inch in diameter. The interbedded sandstone is white, crossbedded, soft, porous, and sparkly due to abundant quartz crystal facets. Both conglomerate and sandstone seem to have been deposited in channels cut into underlying rocks. The base of this unit may mark the contact between the Morrison and the overlying Cloverly Formation as defined elsewhere in central Wyoming (Love and others, 1945b). The overlying 220 feet consists mainly of variegated red and purple claystone and siltstone interbedded with a minor amount of white fine- to medium-grained sandstone. The sequence forms conspicuous, brightly colored slopes. The topmost 152 feet of the Morrison and Cloverly sequence is the rusty beds of the Cloverly Formation. It is characterized by gray, brown, and olive-drab rusty-weathering sandstone and siltstone and a minor amount of dark shale.

The contact between the rusty beds and the overlying Thermopolis Shale is marked by a change from chiefly gray sandstone and shale below to chiefly black fissile shale above.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

THERMOPOLIS SHALE

In central Wyoming, the Thermopolis Shale consists of a lower black shale member, the Muddy Sandstone Member, and an upper black shale member (Thompson and others, 1949). The upper black shale member grades into the overlying siliceous Mowry Shale, and the contact between the two formations is difficult to distinguish, both in surface and subsurface sections. For this reason the upper black shale member is generally mapped with the lower part of the Mowry Shale. In the Shotgun Butte area, the Thermopolis Shale is restricted thereby to the lower two members, and the contact between the Thermopolis and Mowry Shales is placed at the top of the Muddy Sandstone Member.

The Thermopolis Shale crops out along the north edge of the mapped area and around the core of Little Dome anticline. The lower black shale member is 163 feet thick along East Fork Sheep Creek and consists chiefly of dark-gray to black flaky shale containing a few thin silty layers and some shaly sandstone partings. Bentonite layers are present 30 to 60 feet above the base, and scattered limonitic concretions are present throughout. The member is generally poorly exposed but commonly forms conspicuous dark-colored slopes.

In the north-central part of the area the Muddy Sandstone Member ranges in thickness from 50 to 75 feet, but lenses out west of the center of sec. 18, T. 6 N., R. 2 E.; it stands out conspicuously on shale slopes formed by the underlying and overlying formations. At East Fork Sheep Creek the Muddy Sandstone Member is gray, buff, and pinkish-brown sandstone interbedded with some black fissile shale. The sandstone is fine to medium grained, shaly, and thin bedded, and some contains much carbonaceous material. A 1-foot thick bed of bentonite is present in a black shale 33 feet above the base.

The Thermopolis Shale is considered to be Early Cretaceous in age (Cobban and Reeside, 1951, p. 1892). The contact between the Thermopolis and Mowry Shales is well marked in the Shotgun Butte area where the Muddy Sandstone Member is conspicuous. Elsewhere the contact is difficult to identify, but is generally marked by a thin, poorly exposed sandy zone that represents a shaly facies of the Muddy Sandstone Member.

MOWRY SHALE

The Mowry Shale is the uppermost formation of Early Cretaceous age in the Shotgun Butte area. It forms light- to dark-gray banded slopes in the northern part of the area and around Little Dome anticline. The formation is 560 feet thick along East Fork Sheep Creek and consists predominantly of dark-gray to black shale. The lower 165 feet of shale is similar to the underlying Thermopolis Shale; the rest is siliceous and hard and weathers bluish gray to light gray. Many bentonite beds, including one 6 feet thick, are present in the formation. A hard quartzitic sandstone occurs about 50 feet below the top and commonly caps a conspicuous ridge. Fish scales are scattered throughout the formation.

The contact between the Mowry Shale and the overlying Frontier Formation is sharp and is marked by a change from dark-gray hard siliceous shale that weathers bluish gray below to dark olive-gray silty, sandy, and, in part, limy shale above.

UPPER CRETACEOUS SERIES

FRONTIER FORMATION

In the Wind River Basin the Frontier Formation is a resistant sequence of sandstone and shale overlain by the Cody Shale and underlain by the Mowry Shale. It is an important oil- and gas-producing formation in many fields in Wyoming. A detailed surface and subsurface study of the formation in the basin has been made by Thompson and others (1949).

The Frontier Formation crops out on hogbacks and ridges in the northern part of the Shotgun Butte area and around Little Dome anticline. It consists for the most part of alternating gray to black shale, gray fine- to medium-grained, massive- to thin-bedded sandstone, and a few thin beds of tuff and bentonite. Chert pebbles as much as one-fourth inch in diameter are present in the upper 30 feet. The formation is 889 feet thick at East Fork Sheep Creek. Abundant marine fossils of early Niobrara age occur in the upper part. The contact between the Frontier Formation and the overlying Cody Shale is generally well marked by a lithologic and topographic change from ledgy sandstone below to soft, weathered shale above.

CODY SHALE

The Cody Shale, which was named and described by Lupton (1916, p. 171) from the town of Cody in the western part of the Bighorn Basin, is a marine sequence consisting mostly of shale in the lower half and interbedded sandstone and shale in the upper half. On this basis the formation can be divided into a lower shaly member and an upper sandy member throughout much of central Wyoming.

In contrast to the ledge- and ridge-forming formations that overlie and underlie it, the Cody Shale is easily weathered and eroded, and commonly forms broad flat soil-covered valleys, although at a few places, such as on the high bluff southeast of Eagle Point in the west-central part of the area, the upper sandy member is sufficiently resistant to form cliffs. The shale units are best exposed along the edges of high terraces that trend southward from the Owl Creek Mountain front where the gravel cover has protected the underlying soft shale from extensive erosion.

The thickness of the Cody Shale varies considerably; in areas of steep folding and faulting, as on the steep flanks of anticlines, the formation is conspicuously thinner than in areas where relatively little deformation has occurred. Much of this thinning probably resulted from the squeezing of the plastic shales into areas of less pressure. Some of the thinning may also have been the result of reverse faulting, although no faults were observed in the thick, weathered shale units. Sections of the Cody Shale were measured on the northeast flank of Maverick Spring anticline and along East Fork Sheep Creek (fig. 4; stratigraphic sections 3, 5); the thicknesses were 4,145 feet and 3,726 feet, respectively.

The lower shaly member is 1,547 feet thick at the East Fork Sheep Creek locality and is characterized by gray to black soft finely fissile shale, the upper part of which becomes progressively more silty and sandy. Some of the shale is bentonitic and plastic. Except for beds that are more silty and hence harder than others, the succession of shales is interrupted only by a 5-foot thick bed of highly glauconitic and conglomeratic sandstone that occurs 990 feet above the base of the formation. This sandstone is a conspicuous ledge-forming bed that contains black chert pebbles as much as an inch in diameter. A glauconitic sandstone bed approximately 1510 feet above the base of the Cody Shale at the Maverick Spring locality (stratigraphic section 3) is similar except that it contains no chert pebbles. Poor exposures prevent the tracing and correlating of these sandstone beds between widely separated outcrops, but at least locally they are excellent datum beds, useful for determining the structure of the thick, otherwise nondescript bodies of shale.

The upper sandy member of the Cody Shale has an average thickness of approximately 2,150 feet and consists of gray to buff calcareous sandstone and siltstone interbedded with minor amounts of gray to black fissile shale. The sandstone is soft and friable at some places and very hard and compact in others. Viewed from a distance, the individual sandstone beds at some places appear to be thick and massive, but in detail they are thin bedded and platy, except for some beds near the top of the sandy member that become thicker and more massive and are similar to sandstone in the lower part of the overlying Mesaverde Formation.

The Cody Shale is abundantly fossiliferous, as shown by the numerous collections obtained from the East Fork Sheep Creek section (pl. 2; stratigraphic section 5). Most of the fossils occur in gray to brown claystone or marlstone concretions in the shale beds and in friable irregular sandstone masses, as much as 3 feet in diameter, in the sandstone beds. The fossils in the sandstone are not as well preserved as those found in the concretions in the shale. Microfossils also occur in the Cody Shale, and collections from the East Fork Sheep Creek section have been studied.[1] The age of the formation

[1] White, R., 1961, Foraminifera from two sections of Cody shale, central Wyoming: Wyoming Univ. unpublished Master's thesis.

ranges from early Niobrara (Colorado) into Eagle (Montana), and all the intermediate zones are represented. The Cody Shale may be correlated with equivalent rocks in other areas by the guide fossils indicated below (W. A. Cobban *in* Yenne and Pipiringos, 1954):

Equivalent rock	*Guide fossil*
Eagle	*Scaphites* of *hippocrepsis* and *aquilaensis* groups.
Telegraph Creek	*Demoscaphites bassleri* Reeside.
Niobrara:	
Upper	*Clioscaphites vermiformis* (Meek and Hayden); *Scaphites binneyi* Reeside, at a somewhat lower level.
Middle	*Inoceramus stantoni* Sokolow; *Inoceramus*, coiled species; *Scaphites ventricosus* Meek and Hayden.
Lower	*Inoceramus deformis* Meek and Hayden; *Scaphites preventricosus* Cobban.

The contact between the Cody Shale and the Mesaverde Formation in the Wind River Basin divides sedimentary rocks deposited in an offshore environment (Cody Shale) from those deposited in near-shore, brackish-water, swampy, and fluviatile environments (Mesaverde Formation). Regional relations indicate that the Late Cretaceous sea in which the Cody was deposited retreated from west to east across central Wyoming so that the top of the Cody gets younger eastward (Keefer and Rich, 1957, p. 76). The upper part of the Cody Shale in the southeastern part of the basin is therefore younger than that in the Shotgun Butte area. Because of the oscillatory nature of the shoreline of the regressing sea, the two types of sedimentary rocks commonly interfinger and the contact is arbitrarily determined in some places. In general, however, the contact is marked by a rather abrupt change from thin-bedded sandstone interbedded with shale below to crossbedded and massive honeycombed sandstone above. At West Dry Creek (stratigraphic section 6) about 80 feet of interbedded sandstone, shale, and siltstone closely resembling strata in the upper part of the Cody Shale occurs 110 feet above what is considered there to be the base of the Mesaverde Formation.

MESAVERDE FORMATION

The term Mesaverde Formation (or Group) was first used by Holmes (1877, p. 244) for a group of rocks in the Upper Cretaceous Series in Montezuma County, southwestern Colorado; it has since been applied over wide areas in Wyoming to littoral marine and nonmarine strata deposited during the initial retreat of the Late Cretaceous sea from the region. The unit varies greatly from one place to another—in age, in lithology, and in stratigraphic relations to overlying and underlying beds. In the southeastern part of the Wind River Basin, for example, the Mesaverde Formation contains thick tongues of marine strata representing minor readvances of the sea, and in places it is overlain by marine shale of the Lewis Shale (Keefer and Rich, 1957). In the Shotgun Butte area, on the other hand, the change from marine to nonmarine beds is relatively abrupt and almost all the formation is nonmarine. Because the regression of the sea was from west to east across the region, the base of the Mesaverde becomes progressively younger eastward.

The Mesaverde Formation in the Shotgun Butte area is a sequence of interbedded sandstone, siltstone, shale, carbonaceous shale, and coal. Its thickness is remarkably uniform, ranging from 1,950 to 2,000 feet, but the thicknesses of individual units vary considerably. At most places the formation can be divided into three more or less distinctive units—a basal sandstone, a middle variable sequence of thin-bedded sandstone and shale, and an upper sandstone that has been referred to as the white sandstone member (Troyer and Keefer, 1955).

The basal unit, a beach deposit, ranges in thickness from 0 to as much as 250 feet. In some places it consists of only one sandstone bed; in other places it consists of two or more sandstone beds separated by thin beds of shale, siltstone, or carbonaceous shale (figure 4). The

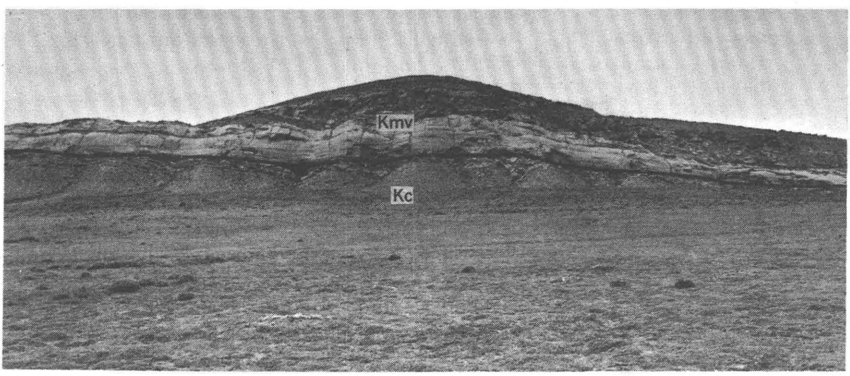

FIGURE 4.—Basal sandstone of Mesaverde Formation (Kmv); Kc, Cody Shale. Center of sec. 14, T. 6 N., R. 1 E.

sandstone is characteristically buff, very fine to medium grained, calcareous, porous, friable, massive to crossbedded, lenticular, and cliff forming. In some places the lowermost beds contain lenses and fragments of gray clay and shale that may be reworked from the Cody Shale. Small limonite concretions are abundant. Outcrops of the buff massive sandstone commonly are honeycombed with small pits formed by wind abrasion. The pits originally were filled with soft shaly sandstone more friable than the surrounding sandstone. Overlying the buff massive sandstone directly, or separated from it by a few feet of siltstone or shale, is generally a 25- to 35-foot-thick bed of white to light-gray flaggy to massive sandstone that crops out as a persistent white band through a large part of the Shotgun Butte area.

The middle and thickest unit of the Mesaverde Formation is a variable sequence of interbedded sandstone, siltstone, shale, carbonaceous shale, and coal. Individual beds are lenticular for the most part, and commonly are not more than a few feet thick. Colors are predominantly gray, brown, and buff. The sandstone is very fine to fine grained, massive to thin bedded, and friable to well cemented. Concretionlike masses of brown-weathering, irregularly bedded sandstone as much as 30 feet in diameter are abundant at some places in the unit. The sandstone in these masses contains a higher percentage of calcareous and ferruginous cement than the host rock, and so is less easily eroded than the surrounding sandstone. The masses are very conspicuous on weathered outcrops. A few coal beds are present, mostly in the lower third of the middle unit. Most of the coal beds are lenses rarely more than 2 feet thick, although locally they may attain thicknesses of several feet.

The white sandstone member at the top of the Mesaverde Formation forms cliffs or prominent ledges, commonly covered with pines, and is the most conspicuous unit of Late Cretaceous age in the area (fig. 5). The member ranges in thickness from about 225 feet at West Dry Creek (stratigraphic section 6) to 435 feet at the Armstrong mine (fig. 4), and consists of white to light-gray, very fine- to coarse-grained,

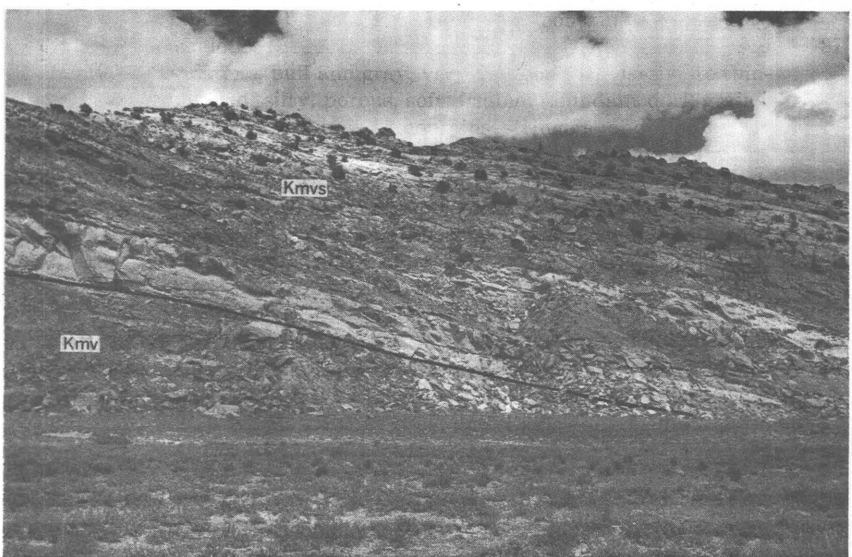

FIGURE 5.—White sandstone member (Kmvs) of Mesaverde Formation (Kmv), SE¼ sec. 18, T. 6 N., R. 1 E.

massively crossbedded sandstone. The sandstone is moderately porous and friable. A grain-size analysis of a sample collected by J. F. Murphy (oral communication, 1957) from the southeast end of Little Dome anticline, just south of the Eagle Point quadrangle, shows the sandstone to be well sorted, the greatest size fraction (45 percent) falling in the very fine grained range. A heavy mineral analysis of a sample of the white sandstone shows that, of the total heavy fraction (0.02 percent of total sample), 88 percent is composed of opaque minerals, 9 percent is garnet, 2 percent is zircon, and 1 percent is made up of other minerals. One of the most characteristic features of the white sandstone member is the crisscross pattern of veinlets that stand out on weathered surfaces. These veinlets are 1/16 to 1/2 inch thick, stand in relief of as much as 2 inches, and are composed of sandstone that is harder and more quartzitic than the surrounding rock. Thin beds of gray shale and claystone, brown carbonaceous shale, and dark-brown to black ironstone are minor constituents of the white sandstone member; large concretion-like masses of brown ferruginous sandstone are also present. The ironstone beds contain much hematite that occurs mostly as a coating on quartz grains, but some is in the form of specularite.

Fossils are few in the Mesaverde Formation; only fragmentary plant remains and brackish-water mollusks, including *Corbula* sp., were found. Elsewhere in the Wind River Basin, marine fossils common to the Eagle Sandstone, possibly to the Claggett Shale, and to the Parkman Sandstone to the north occur in the formation (Yenne and Pipiringos, 1954; Keefer and Rich, 1957). Regional relations suggest that most, if not all, of the Mesaverde Formation in the Shotgun Butte area is Eagle in age.

The top of the Mesaverde at most places is mapped at the top of the conspicuous pine-covered dip slope formed by the white sandstone member. Lithologically, however, the contact is less distinct because lenticular white sandstone beds, similar to those in the white sandstone member of the Mesaverde Formation, commonly occur also in the lower part of the overlying Meeteetse Formation.

MEETEETSE FORMATION

The Meeteetse Formation was named and described by Hewett (1914, p. 102) from exposures near the town of Meeteetse in the southwestern part of the Bighorn Basin, 45 miles north of the Shotgun Butte area. In general appearance and lithology the Meeteetse differs considerably from the underlying Mesaverde Formation and the overlying Lance and Fort Union Formations. The strata are nonresistant, particularly in the lower part, and the formation forms conspicuous strike valleys that extend for several miles and contain only a few outcropping beds. Excellent exposures, on the other hand, are usually present toward the headwaters of the intermittent streams that occupy the valleys and where erosion is active (figs. 6, 14).

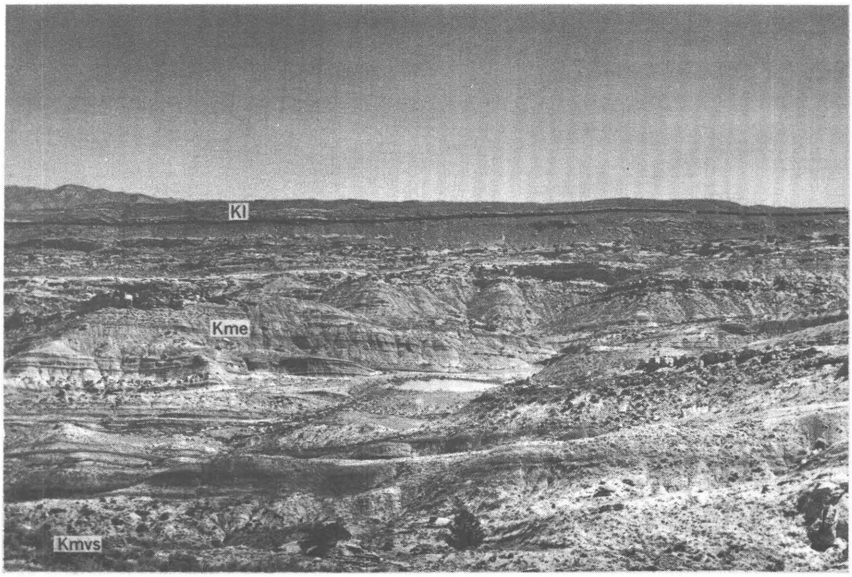

FIGURE 6.—Exposure of Lance (Kl) and Meeteetse (Kme) Formations; note massive lenticular sandstone beds in upper part of Meeteetse; Kmvs, white sandstone member of Mesaverde Formation. North end of Shotgun Bench, S½ sec. 31, T. 6 N., R. 1 E.

The Meeteetse Formation in the Shotgun Butte area is 659 to 1,335 feet thick, and can be divided into a lower banded unit of alternating lithologies and an upper massive lenticular sandstone unit.

The lower part of the Meeteetse Formation is an interbedded sequence of sandstone, siltstone, shale, carbonaceous shale, and coal ranging in thickness from 650 to 1,080 feet. It is best exposed at the north end of Shotgun Bench in sec. 31, T. 6 N., R. 1 E. (fig. 6), and at a few localities in the vicinity of Twin Buttes. Where well exposed the strata present a distinctive gray-, black-, yellow-, and brown-banded appearance that is unlike that of any other Upper Cretaceous sequence in the region. The sandstone in the lower unit is mostly gray and buff, thin bedded to massive, fine to medium grained, soft, porous, friable, and in part bentonitic; it weathers to smooth, rounded hills. A distinguishing feature is the spherical cannonball-like concretions, as much as 3 feet in diameter, that weather out profusely on the slopes. The sandstone in the concretions is coarse grained, contains fairly abundant grains of brownish-red biotite, and is noticeably more calcareous than the surrounding sandstone. Near the base of the formation are sporadic, large brown ferruginous sandstone masses similar to those in the underlying Mesaverde Formation.

Easily eroded shale, siltstone, and claystone comprise the rest of the lower part of the Meeteetse. Some beds are bentonitic and weather distinctly tan or yellowish gray. Coal beds are present throughout the unit and several are of minable thickness. The thickest coal beds are near the top of the sequence in the vicinity of Welton mine (pl. 3), sec. 20, T. 6 N., R. 1 E.

The upper part of the Meeteetse Formation is a massive lenticular sandstone unit (fig. 6) that ranges in thickness from 0 to about 300 feet. Individual sandstone beds are locally as much as 120 feet thick. The sandstone is buff and gray, fine to coarse grained, massive, moderately porous and friable, and contains sporadic concretionlike masses of brown ferruginous sandstone as much as 10 to 15 feet in diameter. A few thin beds of gray shale are interbedded with the sandstone, but no coal beds were seen.

The Meeteetse Formation is Late Cretaceous in age as shown by spore and pollen samples collected from the Welton mine-Shotgun Butte section (E. B. Leopold, written communication, 1960), and by fragmentary plant remains, including *Sequoia reichenbachi*, from several localities. Fragments of large dinosaur bones were observed in the upper massive sandstone unit near Welton mine and at one locality north of Shotgun Butte in the northwest corner of sec. 23, T. 6 N., R. 1 E.

In earlier reports on the Shotgun Butte area (Troyer and Keefer, 1955; Keefer and Troyer, 1956), the upper massive sandstone unit of the Meeteetse Formation was believed to constitute the uppermost unit of Cretaceous age in the region and hence to be equivalent to the Lance Formation. Subsequent studies of spore and pollen assemblages by E. B. Leopold, however, have shown that the next overlying strata (units 162 through 183, stratigraphic section 4), heretofore assigned to the Paleocene Fort Union Formation, are also of Late Cretaceous age. These younger Cretaceous strata, therefore, are accordingly now designated as the Lance Formation.

The Meeteetse Formation is overlain by the Lance Formation in the prominent belt of outcrops that extends from sec. 8, T. 6 N., R. 1 E., southward toward Little Dome anticline. In the Shotgun Butte syncline and adjoining areas the two formations are apparently conformable, but farther south the Lance Formation bevels across successively older beds and hence near the locality of the Armstrong mine the upper unit of the Meeteetse Formation is only a few feet thick. The upper unit is also absent in the vicinity of Twin Buttes and in the area east of sec. 25, T. 6 N., R. 1 E., where the Fort Union

Formation of Paleocene age rests directly on the lower part of the Meeteetse Formation.

LANCE FORMATION

The name Lance, or Lance(?) as used by Yenne and Pipiringos (1954), is generally applied to a unit of latest Cretaceous age in the Wind River Basin. Hewett (1926, p. 26) also applied the name Lance to the strata lying between the Meeteetse and Fort Union Formations in the southern part of the Bighorn Basin, about 25 miles north of the Shotgun Butte area. It is not known, however, whether the rocks referred to the formation in this basin are everywhere the same age. Their stratigraphic relations with the youngest rocks of Cretaceous age in adjacent basins are not fully understood. Rocks of approximately the same age in nearby areas include the Harebell Formation in Jackson Hole (Love, 1956, p. 1900–1904) and the Medicine Bow Formation in the Hanna Basin.

The Lance Formation in the Shotgun Butte area crops out in a narrow belt that extends southward from the trough line of Shotgun Butte syncline to the vicinity of Little Dome anticline. Elsewhere the Fort Union seems to rest directly on the Meeteetse Formation, and the Lance Formation, if present, was not recognized.

The Lance Formation is as much as 1,140 feet thick and is characterized by a basal sandstone and conglomerate overlain by claystone and shale. At the Welton mine-Shotgun Butte locality (stratigraphic section 4) the basal part is about 390 feet thick and consists of white to light-gray and buff medium-to coarse-grained massive to thinly crossbedded sandstone that contains thin beds and irregular lenses of conglomerate. The conglomerate contains granule-sized fragments and scattered pebbles of chert and siliceous shale or porcelanite. Some thin beds of gray shale occur in the sandstone. A heavy mineral analysis of a sample of sandstone from the basal unit shows that of the heavy fraction (0.02 percent of total sample) 76 percent is opaque minerals, 15 percent zircon, 5 percent garnet, 1 percent rutile, 1 percent amphibole, and 2 percent other minerals.

The upper 750 feet of the Lance Formation in the Welton mine-Shotgun Butte section (stratigraphic section 4) is predominantly claystone and shale that is mostly gray to black, but in part maroon and purple. Many of these beds are bentonitic, and characteristically weather into smooth rounded hills and slopes strewn with large selenite crystals. Weathered outcrops are commonly bluish gray. Gray to buff and brown fine- to coarse-grained sandstone is present in minor amounts at most places, and locally sandstone occurs in beds as much as 80 feet thick. A few conglomerate beds, similar to those in the lower part of the Lance Formation, are also present.

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In the measured section at Armstrong mine, (stratigraphic section 1) the Lance Formation is only 200 feet thick. At this locality the basal part is a 124-foot-thick sandstone and conglomerate sequence containing in the lower 50 feet well-rounded to subrounded pebbles and cobbles as much as 6 inches in diameter of chert, quartzite, and siliceous shale or porcelanite. The upper 76 feet of the formation is interbedded gray and locally reddish-gray siltstone and claystone.

Carbonaceous shale and thin partings of black coal are present near the top of the Lance Formation in the Welton mine-Shotgun Butte section, but no coal was seen elsewhere in the formation.

Detailed mapping and comparison of beds or groups of beds indicate that a thin pebble conglomerate (unit 170, stratigraphic section 4), occurring 545 feet above the base of the Lance Formation and 155 feet above the base of the claystone and shale sequence in the Welton mine-Shotgun Butte section, thickens rapidly southward and correlates with part of the 124-foot-thick basal sandstone and conglomerate in the Armstrong mine section (pls. 1, 2).

The thinning of the Lance from north to south is probably due to nondeposition and erosion within the formation, but it is not known which process was dominant.

In the vicinity of Welton mine, the Lance Formation is overlain by the Fort Union Formation with apparent conformity. To the north and south, however, the two formations are separated by an erosional unconformity, and in these areas the contact is marked by a change from predominantly gray and dark-gray bentonitic claystone, shale, and siltstone in the Lance below to white and gray sandstone and conglomerate in the Fort Union above. Conglomerates in the two formations are similar.

STRATIGRAPHIC EFFECTS OF EARLY LARAMIDE FOLDING

Detailed stratigraphic studies of the Meeteetse, Lance, and Fort Union Formations show the early development of local Laramide folds in the Shotgun Butte area. The stratigraphic and structural relations of these formations can be studied in the wide belt of outcrops that extends for 10 miles from secs. 8 and 9, T. 6 N., R. 1 E., southward to the northeast flank of the Little Dome anticline in sec. 27, T. 5 N., R. 1 E. Stratigraphic sections were measured in the Welton mine-Shotgun Butte area near the north end of this line of outcrop, at Shotgun Bench section near the center, and near the Armstrong mine at the south end; additional measurements were made directly from the topographic base maps (fig. 7).

The relations shown in figure 8 indicate that several folds began to form during deposition of the Meeteetse Formation and that moderate deformation was generally continuous through latest

Cretaceous and Paleocene time. During this time, thick conformable sequence of sediments accumulated in the trough areas, and thin disconformable sequences were laid down across the crests of the rising anticlines.

At some places the upwarps and downwarps that began to form in Late Cretaceous time continued to develop along the same structural trends throughout the later and major phases of the Laramide orogeny (in early Eocene time). The present sites of the Little Dome anticline and the Shotgun Butte syncline, for example, coincide closely with the features ancestral to them. The Merriam anticline and the Shotgun Bench syncline, on the other hand, were probably the sites of a trough and an upfold, respectively, during Late Cretaceous and Paleocene time. As shown on pages 49–51, structural data indicate that neither the Merriam anticline nor the Shotgun Bench syncline was formed until late early Eocene time. Thinning of Upper Cretaceous and Paleocene sedimentary rocks toward the present site of Shotgun Bench syncline (fig. 8) was probably caused by the initial folding of the Maverick Spring anticline, which lies directly northwest of the Little Dome anticline in the southwestern part of T. 6 N. and the northwestern part of T. 5 N., R. 1 W. The thickening of strata toward the present site of the Merriam anticline may be a reflection of the ancestral syncline between Maverick Spring and Little Dome anticlines.

TERTIARY SYSTEM

PALEOCENE SERIES

FORT UNION FORMATION

The Shotgun Butte area contains one of the thickest and most complete sections of Paleocene rocks exposed in central Wyoming. These rocks are assigned to the Fort Union Formation, which is the term used to designate all Paleocene strata in the Wind River Basin. Regionally the formation can be divided into two general sequences: a lower part of interbedded sandstone, conglomerate, shale and carbonaceous shale deposited in a fluviatile environment, and an upper part of very fine grained clastic strata deposited in and adjacent to an extensive body of water (Keefer, 1961). The upper part, in turn, contains two distinct rock types deposited contemporaneously in the marginal and offshore areas, respectively, of the Paleocene lake or sea. The marginal unit, consisting chiefly of drab colored shale, siltstone, claystone, and sandstone, has been named the Shotgun Member from exposures in the Shotgun Butte area. The offshore unit, consisting of homogeneous dark-brown to black silty micaceous shale, has been named the Waltman Shale Member from outcrops near the town of Waltman along the east margin of the

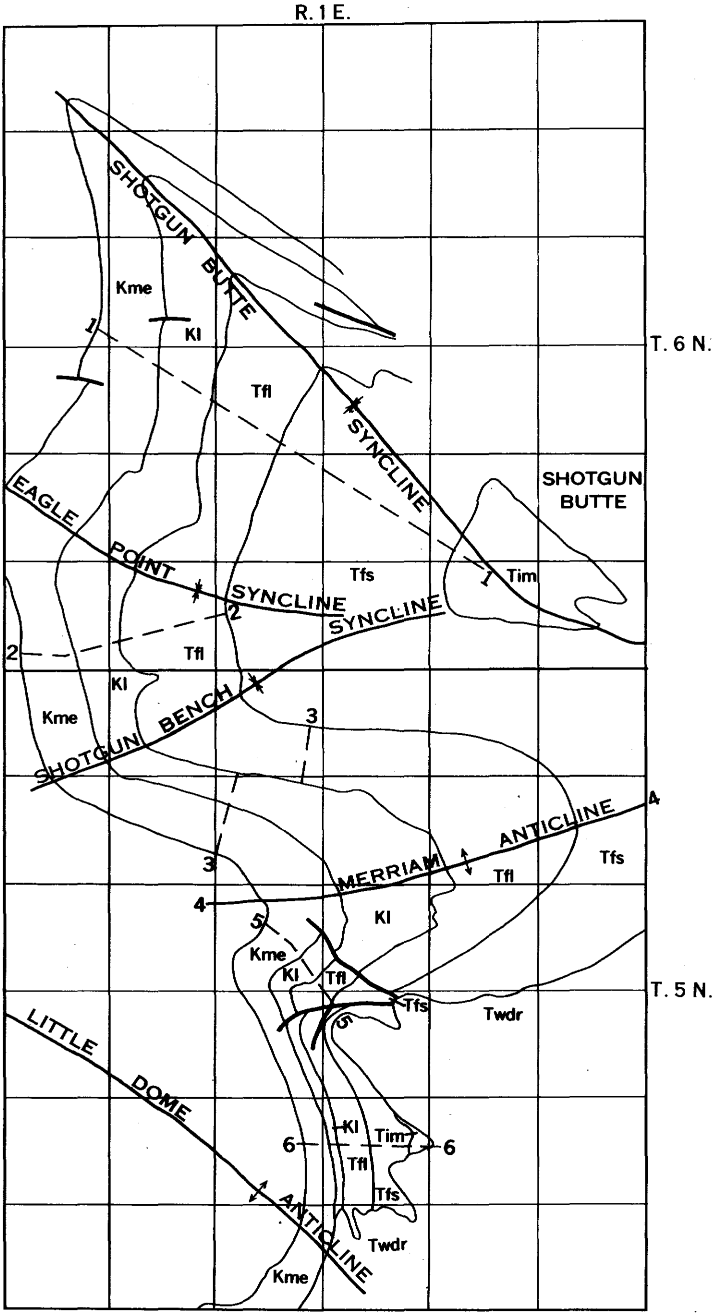

FIGURE 7.—Geologic map of area between Shotgun Butte syncline and Little Dome anticline, showing locations of measured sections presented on figure 8. (See fig. 8 for explanation.)

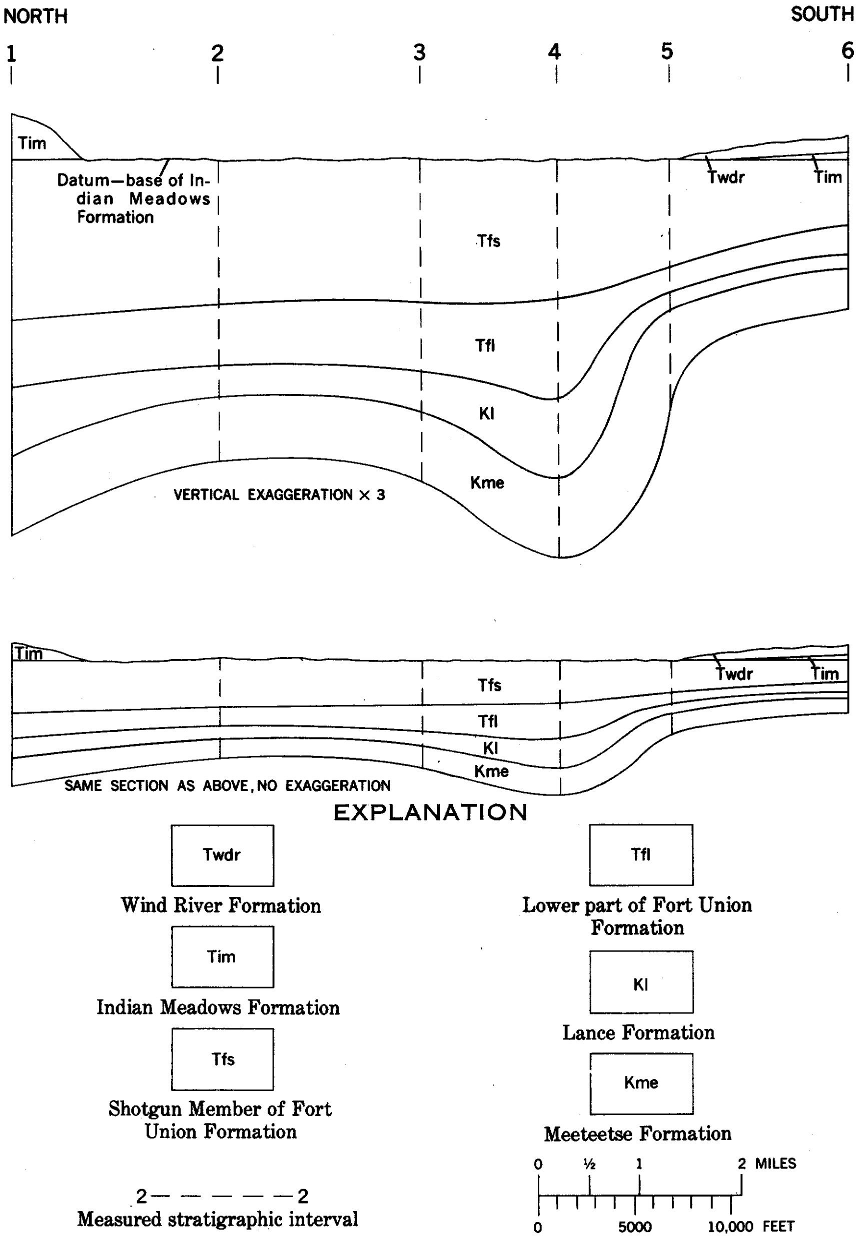

FIGURE 8.—Stratigraphic relations of Meeteetse, Lance, and Fort Union Formations in vicinity of Shotgun Butte and Little Dome anticline. (Location of sections shown on fig. 7.)

Wind River Basin, approximately 80 miles east of the Shotgun Butte area. The Waltman Shale Member thins progressively westward and wedges out a few miles east of the Shotgun Butte area (fig. 9).

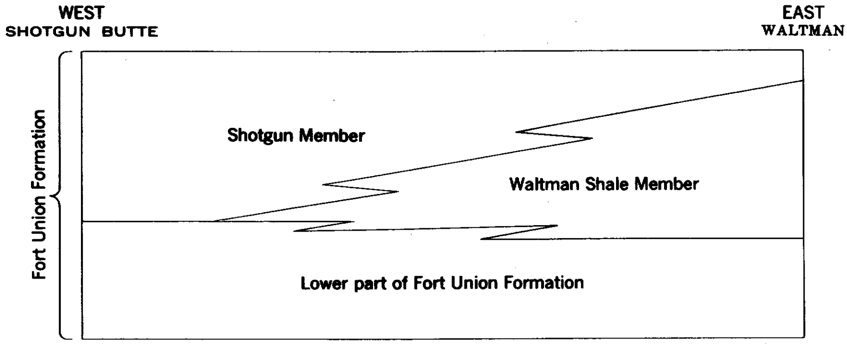

FIGURE 9.—Sketch showing general relations of various members of Fort Union Formation from west to east along north margin of Wind River basin. Modified from Keefer (1961.)

The lower part of the Fort Union Formation in the Shotgun Butte area ranges in thickness from 520 to about 1,200 feet. This unit is comprised predominantly of sandstone and conglomerate. The sandstone is white, gray, buff, and brown, fine to coarse grained, and thinly crossbedded to massive. Many thin ironstone beds occur in the sandstone, and these commonly contain many fossil leaf impressions on bedding surfaces. A little gray shale and brown carbonaceous shale are also present. The conglomerate beds are more numerous toward the top of the unit, and are lenticular. Rock fragments in the conglomerate are well-rounded to subrounded pebbles and cobbles, as much as 2 inches in diameter, of chert, quartzite, porcelanite, siliceous shale, petrified wood, and quartz. No limestone or granite fragments were observed. Much granule conglomerate occurs in the sandstone beds as thin lenses following the crossbedding.

The overlying Shotgun Member of the Fort Union Formation is 1,190 to 2,830 feet thick. It forms a wide belt of outcrops surrounding Shotgun Butte and extending southward toward Little Dome anticline. The lower part is also present and well exposed in the vicinity of Twin Buttes. Stratigraphic section 4, at Shotgun Butte, has been designated as the type section (Keefer, 1961, p. 1311–1313) because of the considerably greater thickness of strata involved; however, detailed descriptions of the member at that locality were not obtained because many intervals are poorly exposed.

The Shotgun Member, in contrast to the lower part of the Fort Union Formation, is a remarkably even bedded sequence of soft, easily eroded claystone, siltstone, shale, and sandstone (fig. 11).

Colors are mostly gray, olive drab, buff, brown, and tan, but a few zones, particularly at Twin Buttes (stratigraphic section 7), are pale red and purple. Several thin brown carbonaceous shale beds form conspicuous dark-brown bands on the normally light colored slopes. The sandstone is predominantly fine grained, soft, and porous. Some hard thin beds of calcareous brown-weathering siltstone and sandstone locally form ledges in otherwise deeply weathered and dissected outcrops. In the Armstrong mine section (stratigraphic section 1) the upper 217 feet of the Shotgun Member is entirely sandstone and contains lenses of granules and pebbles of chert, quartzite, and siliceous shale or porcelanite similar to the conglomerate in the lower part of the Fort Union Formation.

The contact between the Shotgun Member and the lower part of the Fort Union Formation is conformable and is marked by a sharp lithologic and topographic change from resistant sandstone and conglomerate below to soft, very fine grained strata above. The contact of the Shotgun Member and the overlying Indian Meadows Formation can be observed in only a few places. The two sequences seem to be conformable at Shotgun Butte, but in other parts of the area there is an unconformity of considerable angular discordance and erosional relief (fig. 10). The contact is generally marked by a conspicuous change from drab-colored strata below to red strata above.

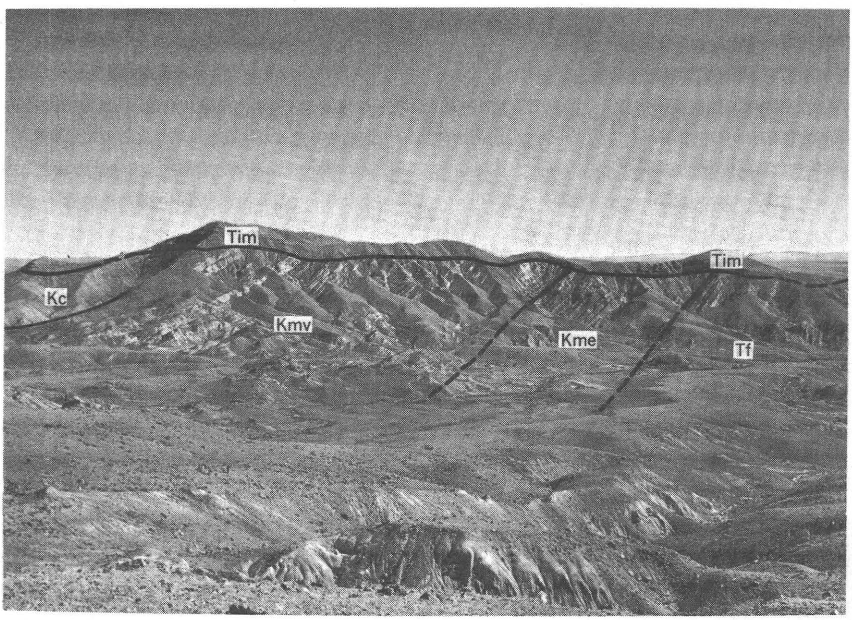

FIGURE 10.—Unconformable relation of Indian Meadows Formation (Tim) to overturned sequence of Cody Shale (Kc), Mesaverde (Kmv), Meeteetse (Kme), and Fort Union (Tf) Formations in easternmost part of Twin Buttes, S½ sec. 33, T. 6 N., R. 3 E., and N½ sec. 4, T. 5 N., R. 3 E.

Fossils, both plant and vertebrate, were collected from several zones within the Fort Union Formation. These fossils indicate that nearly all of Paleocene time is represented. Plant remains about 20 feet above the base in the Welton mine-Shotgun Butte section were identified as being transitional forms between the Cretaceous and the Paleocene (R. W. Brown, oral communication, 1950). Additional collections of leaves from the lower member of the formation at several different localities are of Paleocene age, but do not indicate what part of Paleocene time is represented.

A large and varied vertebrate fauna was collected from a channel-like sandstone in the lower part of the Shotgun Member in the vicinity of Twin Buttes. (See unit 32, stratigraphic section 7.) These fossils consist almost entirely of isolated teeth and jaw fragments of mammals, crocodiles, and sharks. The mammalian fauna has not been studied in detail, but C. L. Gazin has tentatively identified the forms listed below; the assemblage is considered to be of Torrejonian or early Tiffanian age (middle or early late Paleocene):

Multituberculata:
- *Ptilodus* cf. *P. montanus* Douglass
- *Mimetodon* cf. *M. douglassi* (Simpson)
- *Ectypodus*? cf. *E. silberlingi* Simpson
- Cf. *Anconodon gidleyi* (Simpson)
- Cf. *Eucosmodon* sp.
- *Catopalis* cf. *C. fissidens* Cope

Marsupialia: cf. *Peradectes* sp.

Insectivora:
- *Gelastops* sp.
- Cf. *Diacodon* sp.
- Pantolestid, possibly *Aphoronorus* sp.
- *Pentacodon* sp.

Chiroptera?, possibly *Zanycteris* sp.

Primates: Plesiadapid cf. *Pronothodectes* sp.

Creodonta:
- *Claenodon* cf. *C. ferox* (Cope)
- *Tricentes* near *T. subtrigonus* (Cope)

Condylarthra:
- *Periptychus* cf. *P. carinidens* Cope
- *Anisonchus* near *A. sectorius* (Cope)
- *Promioclaenus* sp.
- Cf. *Litomylus* sp.
- *Gidleyina* sp.

Pantodonta: *Pantolambda* cf. *P. cavirictus* Cope

Two types of sharks were identified by D. H. Dunkle (written communication, 1959): (a) several specimens of small conical teeth belong either to a species of sand shark or mackerel shark, and (b) a single large tooth pertains either to the mackerel shark *Corax pristodontus* or to the tiger shark *Galeocerdo*. According to Dunkle, both types of sharks range in age from Late Cretaceous to Recent and are of cosmopolitan distribution in marine sediments laid down under deep and coastal waters. The marine-type shark remains in the strata of the Shotgun Member and other features in equivalent strata of the Waltman Shale Member farther east, such as glauconite formed in place, suggest that the body of water that occupied the Wind River Basin during middle and late Paleocene time had a close association with an open sea (Keefer, 1961, p. 1322–1323).

Both plant and vertebrate fossils, the latter including *Phenacodus* sp. and *Plesiadapis* cf. *P. cookei*, were obtained from the upper part of the Shotgun Member on the west side of Shotgun Butte. These fossils are considered to be of late Paleocene or earliest Eocene age.

EOCENE SERIES

INDIAN MEADOWS FORMATION

The name Indian Meadows was applied by Love (1939, p. 38) to rocks of earliest Eocene age in the northwestern part of the Wind River Basin. The type section is along the North Fork River, approximately 30 miles west of the Shotgun Butte area. Outcrops of the Indian Meadows Formation are few in the Shotgun Butte area. The formation ranges in thickness from a wedge edge to as much as 725 feet; over a large part of the area it is covered by the Wind River Formation.

The Indian Meadows Formation is thickest and best exposed at Shotgun Butte. There it consists of variegated red, purple, lavender, tan, gray, and greenish-gray claystone interbedded with buff and gray sandstone and brown to red massive conglomerate. Conglomerate in the lower part of the sequence contains predominantly rock fragments of Mesozoic age similar to those in the Fort Union Formation. The conglomerate in the upper 180 feet is much coarser and contains fragments of Paleozoic limestone, dolomite, quartzite, chert, and flat-pebble conglomerate. Boulders as much as 15 feet in diameter, of Precambrian granite and of mafic dike rock, are present on top of Shotgun Butte, but none was observed in place in the uppermost conglomerate bed and it was not definitely determined whether rock fragments of Precambrian age occur in the Indian Meadows Formation at this locality, or whether they may be residual gravel from younger strata that have been removed by erosion. In general, however, the absence of rock fragments of Precambrian age in the Indian Meadows Formation and their abundance in the overlying Wind River Formation provide a valuable criterion for distinguishing the two formations in places where there are no fossils and no mappable unconformity.

In the vicinity of Twin Buttes and some other places, the Indian Meadows Formation consists of thin conglomerate units that cap many hills and slopes. The unconformable relations between the Indian Meadows and older rocks is best seen in the vicinity of Twin Buttes (fig. 10).

Some of the most unusual features associated with the Indian Meadows Formation are the anomalous masses of Paleozoic rocks resting on drab shale and siltstone beds of the Shotgun Member of the Fort Union Formation in secs. 31 and 32, T. 6 N., R. 3 E., approximately 2 miles south of the nearest outcrop of source rocks in the Owl Creek Mountains (fig. 11). These masses are composed chiefly of blocks of Bighorn Dolomite and Madison Limestone that have been extremely brecciated and subsequently recemented (fig. 12). Except for the brecciation, the appearance of the rock is like that of the normal Bighorn and Madison in the mountains to the north. The fact that the masses at some places are underlain by a few feet of red clay, together with other field relations, suggests that they were once incorporated in the Indian Meadows Formation. Similar features in the vicinity of the type section of the Indian Meadows Formation approximately 30 miles to the west were described by Love (1939, p. 60–62).

The writers at one time considered the masses segments of a low-angle fault block (Troyer and Keefer, 1955), which rode out over a

FIGURE 11.—Masses of Bighorn Dolomite and Madison Limestone in remnant of ancient landslide in Indian Meadows Formation (Timl); Tfs, Shotgun Member of Fort Union Formation. Near center of section line between secs. 31 and 32, T. 6 N., R. 3 E.

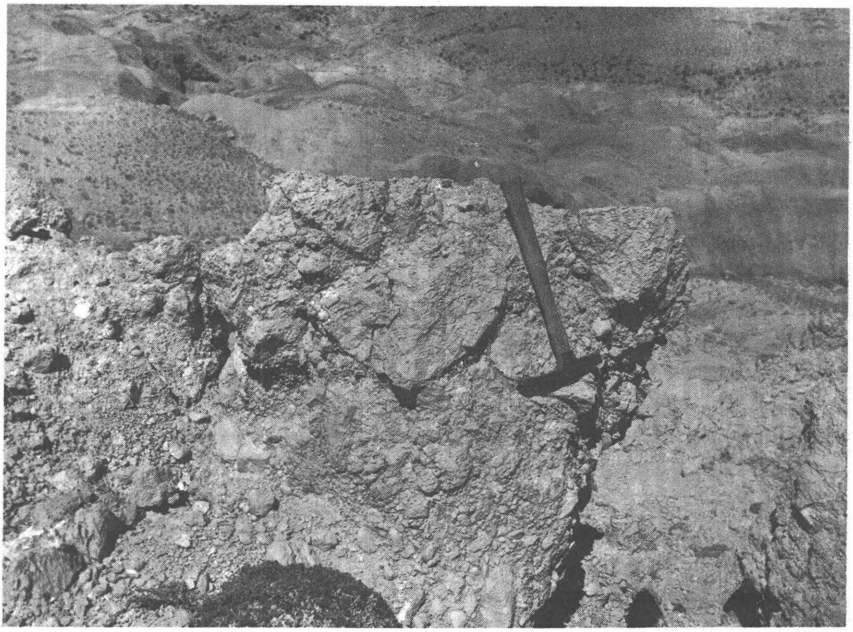

FIGURE 12.—Brecciated Bighorn Dolomite and Madison Limestone in landslide remnant in Indian Meadows Formation. View is closeup of ridge shown in figure 11.

basin surface dipping southward slightly. Subsequent field investigations, however, have shown that the Cottonwood Creek fault, which underlies the nearest source for the Bighorn and Madison strata, is a high-angle fault having dips that range from 32° to 72° N. within the area mapped. It seems, therefore, that these anomalous masses could not have been emplaced by direct tectonic movement, but are the products of large landslides that slid into place during a period of rapid uplift of the adjacent mountain range. The largest component of movement along the Cottonwood Creek fault was upward; hence during Indian Meadows time the mountain face was probably even more precipitous than it is now. Shale of Cambrian age would have provided a ready glide plane for the slides in the mountains, and soft shale in the Upper Cretaceous and Paleocene sequence would have lubricated the slides as they moved onto the basin floor. Although only one large and three small remnants of one of these ancient slides have been preserved from erosion, their original extent was probably large.

Vertebrate fossils of early Eocene age are present in the Indian Meadows Formation (pl. 2). The following collection was obtained from the northwest corner of Shotgun Butte in the center of NW¼SE¼ sec. 26, T. 6 N., R. 1 E.: *Phenacodus primaevus*, *Ectocion* cf. *E. ralstonensis*, *Ectocion* cf. *E. osbornianum*, and *Hyracotherium* sp. C. L.

Gazin, who identified the fossils (written communication, 1951), considers them to be early Wasatchian in age, equivalent to the Gray Bull faunal zone.

WIND RIVER FORMATION

All of the lower Eocene rocks in the Wind River Basin, with the exception of the Indian Meadows Formation, are included in the Wind River Formation. It is the youngest and most widespread formation in the Shotgun Butte area and forms conspicuous, brightly colored badlands over much of the southern half of the region. In areas to the east, Tourtelot (1948, p. 114–119) has separated the formation into the Lysite and Lost Cabin Members. Such subdivision was not attempted in the Shotgun Butte area. Fossils typical of the Lost Cabin Member have been found, but none have been identified that are restricted to the Lysite Member.

The Wind River Formation is undeformed in most places, but in a few places it is folded and faulted and reflects to some degree the structure of the underlying rocks. The formation overlies all older rocks with angular unconformity.

The Wind River Formation was not measured in detail in the Shotgun Butte area because generally it is poorly exposed and because it varies considerably in thickness and lithology in short distances. The thickness ranges from 0 to nearly 1,000 feet in exposures; in the Gulf Oil Co. Mae Rhodes 1 well (well 12, table 2), SW¼ sec. 3, T. 3 N., R. 2 E., along the south margin of the area, the thickness may be as much as 4,500 feet. The formation is mostly bright red, purple, gray, and white claystone, shale, sandstone, and conglomerate. Beds of conglomerate are generally at the base and throughout the sequence. These contain rounded cobbles of Paleozoic and Precambrian rocks ranging from ¼ to 2 inches in diameter. Much of this rock was locally derived, but a conglomerate bed exposed in a gravel pit in the center of sec. 15, T. 4 N., R. 1 E., contains mostly rounded Precambrian quartzite cobbles that probably were reworked from conglomerate in Cretaceous or Paleocene rocks to the west and whose original source was probably in southern Montana. The abundance of rock fragments of Precambrian age in the Wind River Formation is in sharp contrast to the absence of these rock types in conglomerates in the underlying Indian Meadows Formation. Many individual beds in the Wind River Formation are lenticular and probably fill ancient channels.

Abundant vertebrate fossils of early Eocene age, mostly Lost Cabin (late early Eocene) forms, are present in the Wind River Formation (pl. 2). One of the largest collections was obtained in secs. 26 and 35, T. 5 N., R. 1 E., along the north side of the bluff that extends northwest from Muddy Ridge. The following species were identified by C. L. Gazin: *Ectocion* sp., *Phenacodus* sp., *Hyracotherium* cf. *H. boreale*, *Pelycodus*? sp., *Hyopsodus* large species, *Hyopsodus* cf. *H. mentalis*, *Cynodontomys* sp., and *Crocodilus* sp. Seton (1931; written communication to J. D. Love, 1934) reported *Heptodon brownorum* and *Lambdotherium popoagicum* from the same locality. The assemblage is of Lost Cabin age.

QUATERNARY SYSTEM

LANDSLIDE DEBRIS

A large landslide mass, in secs. 1, 2, 11 and 12, T. 6 N., R. E., forms a conspicuous lobe extending southward from the mountain front. The mass is composed of consolidated blocks and loose rubble of Bighorn Dolomite (Ordovician) and Gallatin Limestone (Cambrian) and is underlain by rocks of Cretaceous age that crop out in a few places in gullies and on hillsides where the slide debris has been eroded. The upper (north) end of the slide mass coincides closely with the projected trace of the Cottonwood Creek fault. Southward-dipping Cambrian and Ordovician rocks crop out on the north side of the fault and presumably the debris was derived from these outcrops, although there is no landslide scar to indicate the exact area from which the slide came. Possibly at the time the slide occurred the mountain flank was steeper than it is at present, and the topography has since been so altered by erosion that the scar has now been obliterated. The age of the sliding could not be definitely determined, but the amount of weathering and erosion which has subsequently taken place suggests that it occurred sometime during the Pleistocene.

A small mass of Precambrian rocks extending southward from the main trace of the Cottonwood Creek fault in the center of sec. 20, T. 6 N., R. 3 E., is also probably composed of landslide debris. The Cottonwood Creek fault has a high-angle northward-dipping fault plane along which Precambrian rocks are in contact with rocks of the Tensleep, Phosphoria, and younger formations. Around the landslide mass, Precambrian rocks rest on Triassic and Jurassic strata and the Cody Shale with a nearly horizontal contact. The flat contact suggests that this lobe of Precambrian rocks was not brought to the surface by the Cottonwood Creek fault.

Both of the landslide masses described above were originally interpreted as part of the overriding block of the Cottonwood Creek fault in a preliminary report on the Shotgun Butte area (Troyer and Keefer, 1955).

TERRACE AND PEDIMENT GRAVEL

Deposits of gravel and sand underlie several terrace and pediment surfaces throughout the Shotgun Butte area. The gravel is composed principally of angular fragments of Precambrian igneous and metamorphic rocks, sandstone, limestone, and dolomite of Paleozoic and Mesozoic age, and basalt and andesite of Tertiary age, all derived locally from the mountains to the north and northwest. Angular wind-faceted and polished fragments of black dense dike rock of Precambrian age are conspicuous in the gravel.

Winnowing by wind and water has caused a residual concentration of the larger, more resistant fragments on the surfaces and adjacent slopes. The largest individual rock fragments are estimated to be about 2 feet in diameter, and the average length seems to range from about 5 inches in the deposits near the mountain to about 2 inches in deposits 2 to 3 miles south of the mountain front. The thickness of the gravel beds ranges from a thin veneer to several feet; the average thickness is probably less than 3 feet.

SLOPE WASH

Coarse colluvial material has accumulated on several steep slopes along the Owl Creek Mountains in the northeast corner of the Shotgun Butte area. The material consists mainly of a loose rubble of Precambrian and Paleozoic rocks derived from the adjacent mountain slopes. The deposits grade basinward into terrace and pediment gravel in some places, and the contact between the two types of deposits is marked by the abrupt change in slope.

ALLUVIUM

Considerable quantities of alluvium, consisting of a mixture of sand and silt and a minor amount of gravel, have accumulated in the valleys of Muddy and Fivemile Creeks and along most of the tributary streams. The most extensive deposits are in valleys underlain by the Cody Shale, Meeteetse Formation, Shotgun Member of the Fort Union Formation, and Wind River Formation. In the southern half of the area, the drainage divide between Fivemile and Muddy Creeks is Muddy Ridge, a high prominent mesa capped by a veneer of coarse gravel and underlain by soft, easily eroded strata of the Wind River Formation. Erosion along the edges of the mesa and washing of the sediment valleyward by many small streams during heavy rainstorms have formed broad alluvial-covered flats adjacent to the stream channels.

STRUCTURE

GENERAL FEATURES

The Shotgun Butte area lies along the north margin of the Wind River structural basin, and includes a narrow segment of the south flank of a large anticlinal uplift that makes up the Owl Creek Mountains (fig. 13). This uplift, separating the Wind River Basin on the south from the Bighorn Basin to the north, extends 80 miles across central Wyoming from the south end of the Bighorn Mountains west to the southeast edge of the Absaroka Mountains. Rocks on the south flank of the range are steeply dipping to overturned, and have overridden the north margin of the Wind River Basin along an extensive system of reverse faults (Fanshawe, 1939; Tourtelot and Thompson, 1948; Tourtelot, 1953). Abundant surface and subsurface information indicates that the structural relief between the trough line of the basin and the south front of the Owl Creek Mountains is several thousand feet in distances of only a few miles. Many of the features necessary for interpretation of the structural relations of the mountain to the basin provinces, however, are covered by undeformed or moderately deformed strata of the Wind River Formation. The Shotgun Butte area is of particular interest because it is one of the few areas where enough of the Wind River Formation has been stripped away from the mountain flank to expose the folds and faults in the older rocks at the basin margin (fig. 14). Uplift at least of that part of the range adjacent to the Shotgun Butte area obviously was nearly vertical along high-angle reverse faults.

The structure of the mapped area is dominated by a series of northwest-trending anticlines and synclines that plunge sharply basinward (southeastward). Faults are associated with many of the folds and are most numerous in the northeastern part of the area. The axes of the folds and the traces of the major faults along the basin margin are parallel to the trend of most of the individual structural features within the adjacent Owl Creek Mountains, which are, in turn, oblique to the more westerly trend of the range itself. Only two folds, the Merriam anticline and the associated syncline to the north, have easterly and northeasterly trends in this area.

Anticlines in the area include the Little Dome, Maverick Spring, Blacktail, Madden, West Sheep Creek, East Sheep Creek, Shotgun Butte, and Merriam (pl. 1). The largest syncline, and the dominant structural feature in the mapped area, is the Shotgun Butte syncline, which underlies Shotgun Butte (pl. 1). It is an extension of one of the major troughs of the Wind River Basin.

Deformation in the Shotgun Butte area was most intense around the southwest margin of Jenkins Mountain, in the northeastern part

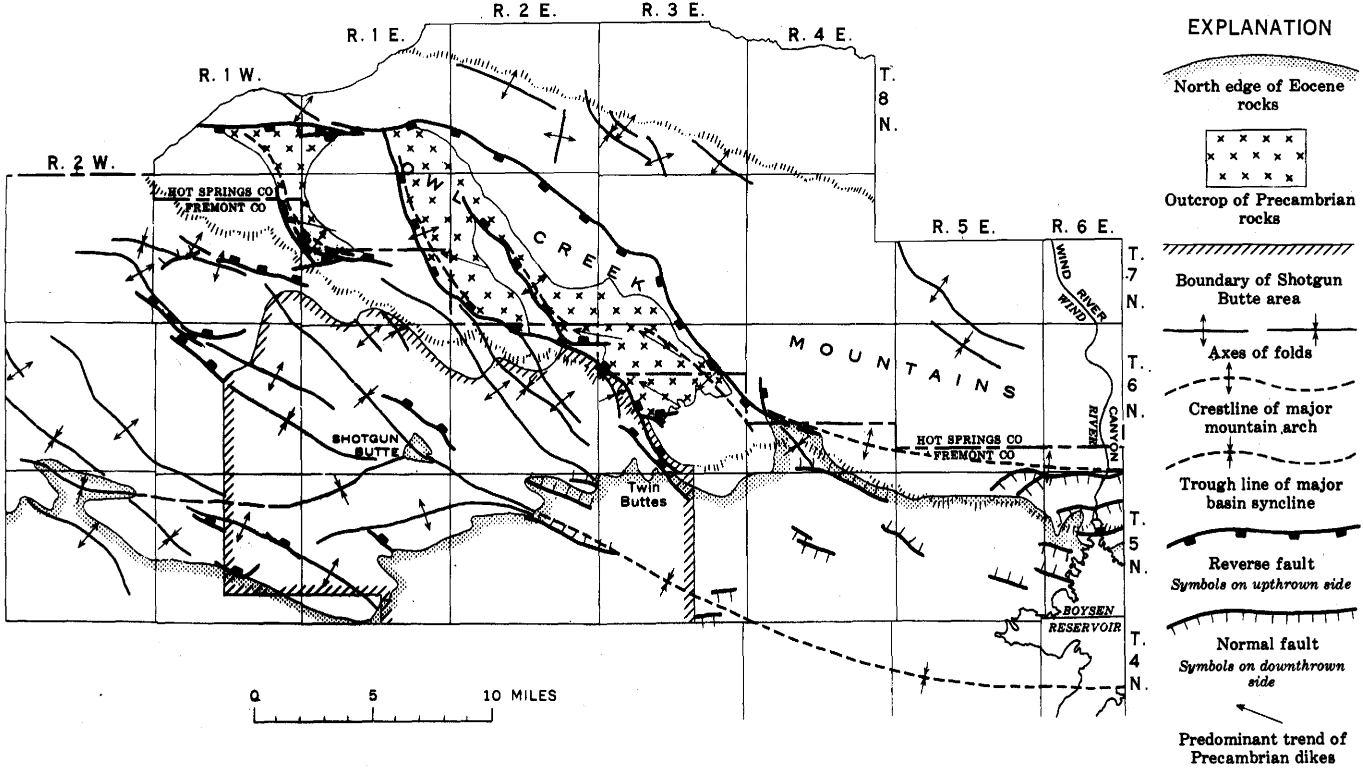

FIGURE 13.—Tectonic map of north-central Wind River Basin and adjacent parts of Owl Creek Mountains.

of the area, where there are many reverse faults and where the rocks are overturned at many places. The main fault is the Cottonwood Creek fault, which extends from Jenkins Mountain northwestward beyond the edge of the area and forms one of the major transverse faults across the Owl Creek Mountains in this region.

The southern half of the Shotgun Butte area is covered by nearly flat lying strata of the Wind River Formation, which in most places do not reflect the structure of the underlying rocks. The formation is, however, folded and cut by normal faults at some localities.

FOLDS

Little Dome anticline.—The Little Dome anticline was mapped and described in detail by Murphy and others (1956); data on that part of the fold lying west of the Wind River meridian were adapted from their map. The feature, in gross aspect, is a striking example of an anticlinal dome, outlined by outcrops of all formations from the Morrison and Cloverly sequence at the center of the dome to the Cody Shale along the flanks.

Except at its southeast end, the Little Dome anticline is strongly asymmetric; its steep side is to the southwest. Dips in the Frontier Formation and younger beds along the southwest side are very steep to overturned; dips on the opposite flank average around 50°. The asymmetry is reversed at the southeast end of the fold, where the dips are generally less to the south than to the north (cross section *B–B′*, pl. 1). Several faults are present along the crest of the anticline and on both limbs, and Murphy and others (1956) have shown that the fold is broken by faults at depth. The Little Dome anticline is reflected in beds as young as early Eocene. These younger strata are folded varying degrees around the south and southeast margins, but angular unconformities between the Fort Union and Wind River Formations and older rocks indicate much less post-Paleocene than pre-Paleocene movement.

Maverick Spring anticline.—Only the extreme east end of the Maverick Spring anticline extends into the Shotgun Butte area. The fold is shown by the outcrop pattern of the Cody Shale and younger formations east of Hurley Draw. The small segment of a road in the E½ sec. 4, T. 5 N., R. 1 E., lies approximately on the contact between the Frontier Formation and Cody Shale, and the anticline extends northwestward from this point for a distance of about 10 miles (Andrews, 1944). The anticline is breached to the Chugwater Formation.

Blacktail anticline.—The Blacktail anticline, which was mapped and described in detail by Williams and Sharkey (1946), extends into the Shotgun Butte area in the northeastern part of T. 6 N., R. 1

W. Its axis is parallel to the channel of Muddy Creek and can be traced southeastward to the vicinity of Merriam triangulation station, where the fold is very shallow. Near its southeast end, the fold dips 15°–20° on either flank and is nearly symmetrical, but to the northwest there is conspicuous steepening and thrust faulting along the southwest flank (Williams and Sharkey, 1946). The anticline plunges to the southeast.

Madden, West Sheep Creek, and East Sheep Creek anticlines.—The Madden, West Sheep Creek, and East Sheep Creek anticlines occur in order from west to east along the north margin of the Shotgun Butte area, and are parts of sharp folds in the older Paleozoic and Mesozoic rocks that crop out farther up on the mountain flank. These anticlines plunge steeply southeastward into the basin, oblique to the main east-west trend of the adjacent mountain front. Rocks as young as the Fort Union Formation are folded on the flanks of the West Sheep Creek anticline, but the other two folds only slightly affect beds younger than the Cody Shale. All three are asymmetrical and have nearly vertical to overturned southwest limbs. A reverse fault is present along the southwest side of the West Sheep Creek anticline (cross section *B′–B″*, pl. 1). The Madden anticline has probably been thrust southwestward, also, along faults in the Cody Shale, inasmuch as the outcrop belt of the Cody Shale is locally at least 2,000 feet narrower than the normal thickness of the formation. (section *A–A′*, pl. 1).

Shotgun Butte anticline.—The Shotgun Butte anticline is a long narrow, slightly curved fold that extends from the NW¼ sec. 22, T. 6 N., R. 1 E., southeastward to sec. 5, T. 5 N., R. 2 E., where it disappears beneath Quaternary deposits. The Fort Union Formation is exposed throughout the length of the anticline, except at Shotgun Butte where the Indian Meadows Formation is present. The fold plunges southeast except for a slight dome, which has perhaps as much as 200 feet of closure in surface strata, in the center of sec. 36, T. 6 N., R. 1 E. At this locality the horizontal distance between the trough lines of the two flanking synclines is only about 1,600 feet. Dips of 50° to nearly vertical are common along the southwest flank. Along the northeast flank, dips range from 12° to 55°. The fold is near the structurally lowest part of the synclinal area at Shotgun Butte, and it may die out with depth (cross section *B′–B″*, pl. 1).

Merriam anticline.—The Merriam anticline is a large anticlinal nose that extends from the northeast flank of Little Dome in sec. 18, T. 5 N., R. 1 E., eastward for about 8 miles. The fold plunges generally northeastward about 10° to 20° and is nearly symmetrical. Maximum dips are generally about 20° This trend contrasts to the northwesterly trend of most of the other folds in the region. Both the Indian Meadows and Wind River Formations are folded along the south flank of the anticline.

Shotgun Butte syncline.—The Shotgun Butte syncline is the dominant structural feature in the region. It can be traced from the vicinity of the Bargee School building southeastward through Shotgun Butte for about 12 miles, and it continues to the southeast beneath lower Eocene rocks as a main branch of the major trough of the Wind River Basin. Structural relief on the top of Precambrian rocks between the bottom of the trough and the top of the adjacent mountain arch is in excess of 21,000 feet in a horizontal distance of 5 to 6 miles across the north-central part of the Shotgun Butte area, and, because the syncline plunges southeast, the total structural relief increases appreciably southeastward. Stratigraphic studies show that this trough was the site of the deposition of a thick sequence of sedimentary beds during latest Cretaceous, Paleocene, and earliest Eocene times (pl 2; fig. 7). The formations represented in this sequence thin to the south and to the northeast owing to reduced deposition and (or) erosion along the margins of the trough.

The Shotgun Butte syncline is sharply defined in the Fort Union and older formations northwest of the butte; at the butte the downfolding is slightly reflected in the Indian Meadows Formation (fig. 15). The northeast limb of the syncline is vertical to overturned, and at places is cut by reverse faults.

Shotgun Bench and Eagle Point synclines.—The Shotgun Bench and Eagle Point synclines strike obliquely eastward into the trough line of the Shotgun Butte syncline and extend beyond the west edge of the mapped area; both are symmetrical. The Shotgun Bench syncline separates the Little Dome and Maverick Spring anticlines and can be traced westward from Shotgun Butte for a total distance of about 16 miles (Murphy and others, 1956). Williams and Sharkey (1946) mapped the westward extension of Eagle Point syncline; they interpreted rather sharp dip reversals in the Cody Shale as evidence of thrust faulting along the trough line.

FAULTS

Cottonwood Creek fault.—The Cottonwood Creek fault, along the northeast edge of the Shotgun Butte area, is one of the major transverse faults across the Owl Creek Mountains. It can be traced from the SE¼ sec. 23, T. 6 N., R. 3 E., northwestward for approximately 15 miles. The fault is a high-angle reverse fault that dips northeast from 32° to 72° in the area mapped. Precambrian rocks compose the overriding northeast block, and, at some localities, are placed in contact with strata as young as the Cody Shale. The maximum stratigraphic displacement is more than 7,500 feet.

Jenkins Mountain area.—At the southwest margin of Jenkins Mountain, many faults are present in a structurally complicated area about 2 miles wide and 4 miles long. The northeasternmost of these is a thrust fault that can be traced in intermittent exposures from the south edge of the small landslide mass in the center of sec. 20 southeastward for about 3 miles to the SE¼ sec. 34, T. 6 N., R. 3 E. The northwest end of the fault is apparently overridden by the Cottonwood Creek fault, but the relations of the two faults there are obscured by the landslide debris. Along this thrust fault, Triassic and Jurassic rocks on the north, or upthrown, block are in contact with rocks of the Mowry, Frontier, or Cody Formations.

Another fault extends from the NE¼ sec. 30, T. 6 N., R. 3 E., southeastward to the east edge of the area in the NE¼ sec. 10, T. 5 N., R. 3 E. The offset along this fault is variable. In T. 6 N., R. 3 E., the fault is a reverse fault and for most of its length the upthrown side is on the northeast. Near its northwest end, however, the stratigraphic relations indicate a scissors movement, the point of rotation being about 100 yards northwest of the section line between secs. 29 and 30. Northwest of this point the fault plane dips to the south and the south block is upthrown (fig. 14). The Cody Shale and the Mesaverde, Meeteetse, and Fort Union Formations are surface rocks cut by this segment of the fault. From the center of the S½ sec. 33, T. 6 N., R. 3 E., to the east edge of the area, the Wind River Forma-

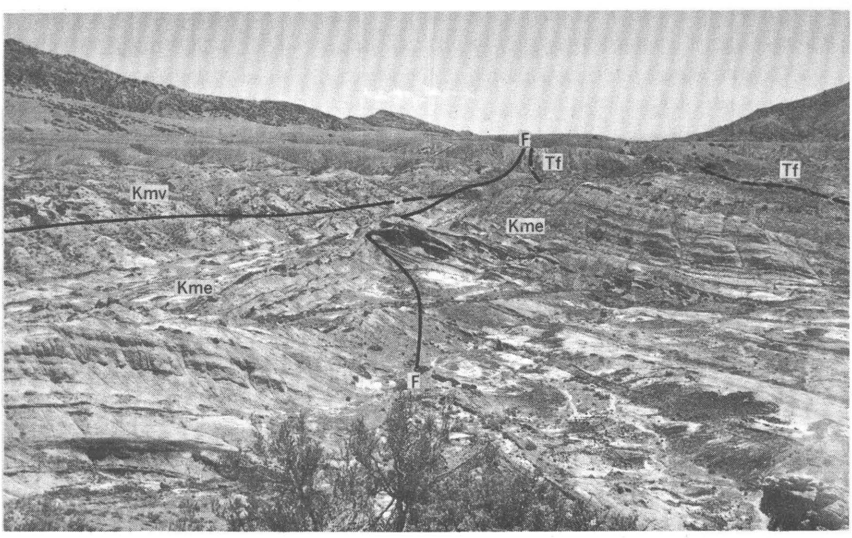

FIGURE 14.—Fault (F) in secs. 29 and 30, T. 6 N., R. 3 E. In segment in foreground right side is upthrown; in segment in background left side is upthrown. Kmv, Mesaverde Formation; Kme, Meeteetse Formation; Tf, Fort Union Formation. Note pediment surface in left background.

tion, on the northeast side of the fault, has been dropped down against the Cody Shale on the southwest side. Apparently in pre-Wind River time the north side was thrown up, but after the deposition of the Wind River Formation the movement was in the opposite direction, and the north block subsided as much as 50 feet or more along the old fault zone.

A branch of this fault extends from the NE¼ sec. 32, T. 6 N., R. 3 E., through the E½ sec. 5, T. 5 N., R. 3 E. At some places the Mesaverde Formation is faulted against the Fort Union Formation. Several smaller faults and overturned folds are also present in the vicinity.

Shotgun Butte area.—A reverse fault, about a mile north of Shotgun Butte, extends from the SW¼ sec. 15, T. 6 N., R. 1 E., southeastward into the NW¼ sec. 31, T. 6 N., R. 2 E., where it is covered by alluvium. The Fort Union and Meeteetse Formations are involved, and the maximum stratigraphic displacement is about 2,000 feet as shown in cross section *B′–B″* (pl. 1). The north block is upthrown, but the net slip is not known because the surface trace of the fault is parallel to the bedding planes of the strata throughout most of its exposure. Abundant fracturing involving small offsets of beds has occurred in sec. 15 north of the northwest end of this fault.

Little Dome anticline area.—Several faults are exposed in the vicinity of the Little Dome anticline. The largest is a northwest-trending reverse fault on the southwest flank of the fold; this fault brings the white sandstone member of the Mesaverde Formation on the north side against steeply dipping beds of the Wind River Formation on the south side for at least a mile. Reverse faults may also be present in the Cody Shale at Maverick Spring Draw although none were seen.

Other faults.—Several northwest-trending normal faults dropped down on the north are present mostly in the Wind River Formation in the NE¼ T. 5 N., R. 2 E. In the NW¼ sec. 3, T. 5 N., R. 2 E., the terrace gravel also appears to be faulted, for there is an abrupt change of about 20 feet in the level of the terrace surface along the trend of one of the faults. Some of these faults originally may have been reverse faults, upthrown on the north, but, in post-early Eocene time, movements were reversed and normal faults developed along the same trends.

SUMMARY OF LATE CRETACEOUS AND EARLY TERTIARY HISTORY

The sedimentary and structural history of the Shotgun Butte area during Late Cretaceous and early Tertiary times may be divided into several more or less distinct stages: (a) major transgression and regression of the Late Cretaceous sea, (b) prolonged nonmarine deposition and moderate deformation, (c) reinvasion of a sea or the development of a widespread fresh-water lake in middle and late Paleocene time, and (d) the major phases of the Laramide orogeny.

The first of these stages is represented by the thick sequence of marine shale and sandstone in the upper part of the Frontier Formation and the Cody Shale. The sea expanded westward into the Jackson Hole region of western Wyoming, but by middle Niobrara time it began to retreat eastward across central Wyoming, as shown by the middle Niobrara age of the uppermost marine strata in Jackson Hole (Love and others, 1951). In the Shotgun Butte area, however, the sea persisted until Eagle time. Deposition continued as the environment changed from marine to nonmarine. More than 2,000 feet of interbedded sand and mud, now represented by the upper half of the Cody Shale, was deposited in the nearshore environment. The basal sandstone of the Mesaverde Formation was then laid down as the final regressive deposit.

Extensive lagoons, deltas, swamps, and coastal plains, drained by sluggish meandering streams, developed after the withdrawal of the epicontinental sea from the region and persisted for a long time. More than 3,000 feet of fine-grained clastic sedimentary and carbonaceous material, now represented by the Mesaverde and Meeteetse Formations, was deposited. During Meeteetse time, however, there was a gradual change from widespread swamps to broad and extensive flood plains, as is suggested by the general increase in sandstone content and by the decrease in carbonaceous material in the younger rocks.

The variation in thickness of the Meeteetse Formation indicates that the Shotgun Butte syncline and the adjacent Maverick Spring and Little Dome anticlines to the south began to form during this stage of Late Cretaceous time (fig. 15). Gentle arching of the Owl Creek Mountains to the north and the Washakie Mountains to the west (fig. 2) probably commenced at the same time and continued into latest Cretaceous and early Paleocene time, as is recorded by the conglomerate and the locally derived Mesozoic rock fragments in the Lance Formation and lower part of the Fort Union Formation.

The trough area continued to sink throughout latest Cretaceous and early Paleocene time, and 2,000 feet or more of fluviatile sedimentary rocks accumulated. During middle and late Paleocene time a sea or a fresh-water lake advanced westward across the central and northern parts of the Wind River Basin, nearly to the east edge of the Shotgun Butte area (Keefer, 1961). Nearly 3,000 feet of clay and silt was deposited in marginal and shore environments related to this extensive body of water. During this period, the adjacent highlands were low, although the ancestral Owl Creek Mountains remained a barrier between the Wind River and Bighorn Basins during

STRUCTURE FEATURE OR AREA	TIME, SHOWING FORMATION DEPOSITED								TYPE OF DEFORMATION
	LATE CRETACEOUS		PALEOCENE		EARLY EOCENE				
	Meeteetse	Lance	Fort Union	Post-Fort Union, Pre-Indian Meadows	Indian Meadows	Post-Indian Meadows, Pre-Wind River	Wind River	Post-Wind River	
Main Owl Creek Mountain arch	— — —	— — —	— — —	———	— —?	?— —?			Moderate folding followed by pronounced faulting and uplift; slight tilting in post-Indian Meadows pre-Wind River time
Cottonwood Creek fault			—	———	— —				Mainly vertical uplift during post-Fort Union pre-Indian Meadows time
Vicinity of Twin Buttes			— —	———	— —	?— —?			Pronounced folding and faulting during post-Fort Union Pre-Indian Meadows time; slight tilting following Indian Meadows deposition
Vicinity of Shotgun Butte	— — —	— — —	— — —	— — —	— — —	———	—?		Continuous downwarping until end of Indian Meadows time, followed by strong folding
Merriam anticline							?—	———	Folding began in late Wind River time or post-Wind River time
Little Dome anticline	— — —	— — —	— — —	———	—? ?—	———	—? ?—	———	Nearly continuous arching throughout the period
Major Wind River Basin trough east of Shotgun Butte	— — —	— — —	— — —	— — —	— — —	— — —	— — —	— — —	Nearly continuous downwarping throughout the period

FIGURE 15.—Time of deformation in and adjacent to Shotgun Butte area.

most or all of Paleocene time. In the western part of the Bighorn Basin, 2,000 feet or more above the base of the Fort Union Formation, Hewett (1926, p. 30–34) has described quartzite cobbles derived from Precambrian rocks. These cobbles were carried in presumably by streams flowing from regions to the west and northwest. No such pebbles are present in the Fort Union Formation in the Shotgun Butte area; their absence indicates that the drainage systems of the two basins, at least in their western parts, were not connected during Paleocene time.

The most intense folding and faulting in the Shotgun Butte area began with Eocene time; it caused a retreat of the late Paleocene lake or sea and gave rise to the coarse conglomerate in the Indian Meadows Formation. At Twin Buttes, in the northeastern part of the area, there is a discordance greater than 90° between the Indian Meadows Formation and the Fort Union and older formations (fig. 10). During this time, the Owl Creek Mountains area was vigorously uplifted and carved into mountains.

Uplift took place in two distinct stages, and this fact may explain the divergence in trend between the northwest alinement of individual structural features and the more westerly trend of the range as a whole. During the first stage the region was subjected to lateral compressive forces operating in a southwest direction, and strong asymmetric folding and thrust-faulting toward the southwest resulted. By the close of this first stage the pronounced northwest structural "grain" was established; the folds along the north edge of the Shotgun Butte area are probably parts of larger folds that at one time extended across what is now the main Owl Creek Mountain arch. During the second stage of deformation, which proceeded during the deposition of the coarse conglomerate beds of the Indian Meadows Formation, movements were nearly vertical along high-angle reverse faults, and the various horstlike segments of the main mountain mass were differentially uplifted with respect to one another, and also were elevated several thousand feet with respect to the adjacent basin areas. The major reverse fault zones are sinuous in outline; segments are alternately parallel to the northwest trend of the faults and folds that had been established earlier and to a second major system of fault zones that trend more westerly and cut aross the older structural features (fig. 14). This second fault system is, in turn, almost parallel to the predominant strike of the mafic dikes in the Precambrian crystalline core of the Owl Creek Mountains. Such a relation suggests that the resulting structural pattern of the region was at least partly influenced by preexisting lines of weakness in the basement complex.

The Indian Meadows Formation was intensely folded along the northeast side of Shotgun Butte, but elsewhere it was only slightly deformed at the end of Indian Meadows time (fig. 15). Angular discordance between the Indian Meadows and Wind River Formations may be observed at several localities, but more conspicuous is the erosional unconformity between the two units, particularly in the vicinity of Twin Buttes. There the topographic relief at the beginning of Wind River time must have been in excess of 500 feet, and the fine-grained strata of the Wind River Formation were deposited in valleys and smaller depressions between the more prominent buttes. In the rest of the area, however, the relief of the surface over which the Wind River Formation was deposited was probably much smaller.

By Wind River time the Owl Creek Mountains had been eroded to the Precambrian core in some places, and the range was more subdued than in earliest Eocene time. Flood-plain and stream-channel deposits accumulated over wide areas along the mountain front and in the basin. Thick channel sandstone beds are most conspicuous in the Wind River Formation in the southern part of the area, south of Muddy Ridge, and in the same area quartzite cobbles derived from Precambrian rocks indicate that the main streams of the region flowed eastward and southeastward from at least as far west as the Togwotee Pass area along the east edge of Jackson Hole. The latter area is approximately 60 miles west of the Shotgun Butte area and is the nearest known source for the quartzite cobble debris.

The final compressional phase of the Laramide orogeny in the Shotgun Butte area occurred after the deposition of the Wind River Formation. This formation is thrust faulted along the south flank of the Little Dome anticline (fig. 15) and has been folded around both the Little Dome and Merriam anticlines. The latter anticline and the adjacent syncline to the north are east- and northeast-trending folds that are part of a system of structural features that were formed late in early Eocene time (Lost Cabin age) and significantly modified the older northwest-trending folds in the region (Murphy and others, 1956).

The sedimentary and structural history of the Shotgun Butte area following the late early Eocene (Lost Cabin age) is not known in detail. In other places around the margins of the Wind River Basin, thick middle and upper Eocene, Oligocene, and possibly younger Tertiary rocks have been described (Love, 1939; Tourtelot, 1953; Van Houten, 1957). Presumably such rocks, and particularly thick deposits of pyroclastic material from the Absaroka region to the west, once covered the Shotgun Butte area, but they have since been removed by erosion. The normal faults in the Wind River Formation in the northeastern part of the area are believed to be the youngest structural features, but dating is not possible from the available information. Evidence from farther to the east along the south edge of the Owl Creek Mountains indicates that the normal faulting occurred there either during or after latest Eocene time (Tourtelot, 1953). In the Beaver Divide area in the southern part of the basin, some normal faulting is post-Miocene (Van Houten, 1957, p. 86).

In the NW¼ sec. 3, T. 5 N., R. 2 E., there is an abrupt change of about 20 feet in the level of a prominent terrace surface directly along the line of projection of one of the normal faults. This change may indicate that some faulting has taken place in the Shotgun Butte area as late as Recent time.

GEOMORPHOLOGY

Broad, nearly flat surfaces, underlain by thin veneers of coarse gravel, are conspicuous throughout much of the Shotgun Butte area. The surfaces have been extremely dissected, and the remnants are elongated parallel to the present main drainage system, which is northwest-southeast in the basin and north-south along the mountain front. Many of the surfaces abut against the mountain front and are pediments (fig. 14), but they merge imperceptibly with stream terraces basinward, so no differentiation between terraces and pediments was made during the present study. Three conspicuous surfaces, Muddy Ridge, Cottonwood Flat, and Sand Mesa (fig. 16), and several subsidiary surfaces may be distinguished. Each represents a stage in the Pleistocene or Recent erosional history of the region. In the classification proposed by Morris and others (1959, p. 27–31) for terraces in the Riverton Irrigation Project, the Muddy Ridge surface corresponds to Terrace T_8 and the Cottonwood Flat and Sand Mesa surfaces correspond to Terrace T_3.

Muddy Ridge, which forms the drainage divide between Fivemile and Muddy Creeks, is the highest terrace level in the area. It stands 350 to 450 feet above Muddy Creek (fig. 16*B*) and approximately 300 feet above Fivemile Creek. Shotgun Bench, in the northwest corner of T. 5 N., R. 1 E., and the top of Shotgun Butte, which is covered by coarse boulders, may also be parts of this high surface. Muddy Ridge is a mountainward extension of one of the higher and more conspicuous terrace levels farther south and southwest adjacent to the channel of the Wind River (Morris and others, 1959, pl. 1).

Sand Mesa and Cottonwood Flat are local terraces along Muddy and Cottonwood Creeks, respectively. These two streams empty into the Boysen Reservoir approximately 15 miles east of the Shotgun Butte area. Cottonwood Creek enters the main Wind River drainage at an altitude lower than Muddy Creek, and the channel of Cottonwood Creek is somewhat lower than the channel of Muddy Creek in the Shotgun Butte area, even though Cottonwood Creek lies nearer the mountain front. As shown on figure 16*A* the Cottonwood Flat

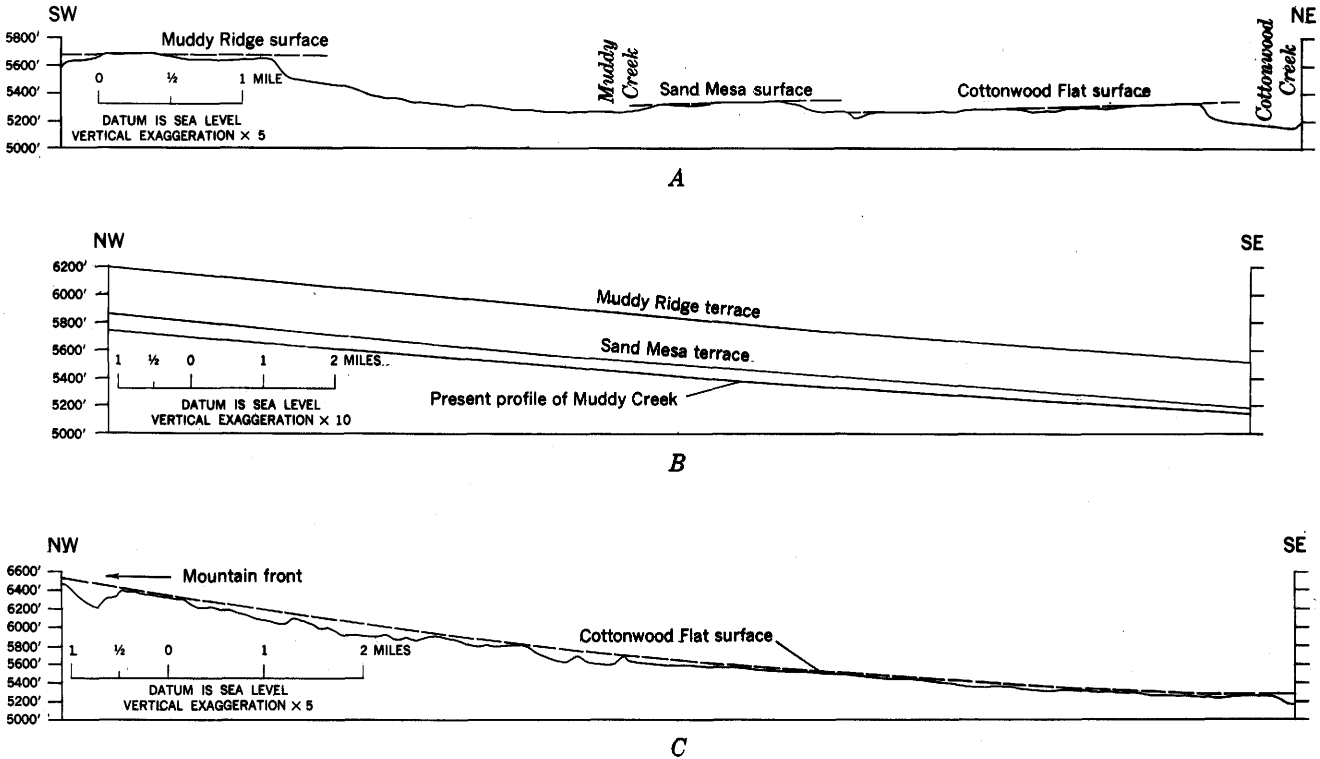

FIGURE 16.—Terrace and stream profiles in Shotgun Butte area.

surface is, in general, also lower in altitude than the Sand Mesa surface in sections transverse to the long profile of Muddy Creek. This difference may indicate that Sand Mesa is slightly older but, on the other hand, the two terraces could have formed almost simultaneously. A continuous smooth curve can be drawn connecting the main part of Cottonwood Flat with the several isolated remnants of surfaces toward the headwaters of the stream (fig. 16*C*). The profile rises with increasing gradient toward the mountain front.

During the formation of the Muddy Ridge surface the area must have been a vast planed surface, veneered with coarse gravel and through which a few isolated hills and ridges protruded. Later the streams were rejuvenated, the older surface was deeply incised, and terrace and pediment surfaces formed at successively lower levels.

ECONOMIC GEOLOGY

OIL AND GAS

Gas was discovered on the Little Dome anticline in 1958, but no other commercial quantities of oil or gas have been discovered in the Shotgun Butte area (table 2). Aside from drilling at Little Dome, only two other wells have been drilled, the Gulf Oil Co. Mae Rhodes 1 (NW¼NW¼ sec. 3, T. 3 N., R. 2 E.) and the Cities Service Tribal 1 (SW¼NE¼SW¼ sec. 9, T. 5 N., R. 1 E.). The Gulf well (well 13, table 2), located on the basis of seismic data, was drilled to a depth of 11,000 feet and apparently bottomed in the Mesaverde Formation. Shows of gas were reported at two intervals, one at the depths 6,258 to 6,298 feet and the other at the depths 8,985 to 9,100 feet. Subsurface correlations of the Upper Cretaceous and lower Tertiary sequence are very difficult to make, but well cuttings examined by the writers suggest that the upper show of gas was in the Fort Union Formation and that the lower show was in the Mesaverde Formation. The Cities Service well is on the Merriam anticline (well 12, table 2) and was drilled to a depth of 10,908 feet and bottomed in the Tensleep sandstone (section *B–B′–B″*, pl. 1). No shows were reported.

Prior to 1958, seven unsuccessful tests had been drilled for oil and gas on the Little Dome anticline (wells 3, 4, 6, 7, 8, 9, 11, table 2). In July 1958, gas was discovered in the Petroleum, Inc., Tribal 1 well (well 5, table 2), NE¼NW¼NE¼ sec. 15, T. 5 N., R. 1 W. Initial production listed by Petroleum Information, Denver, Colo.. was 5,010,000 cubic feet of gas per day from the depths 1,306 to 1,502 feet in the Crow Mountain Sandstone Member of the Chugwater Formation. A second well drilled about 1 mile east of the discovery well (well 10, table 2) also penetrated the Crow Mountain Sandstone Member, but only minor shows of gas were found.

TABLE 2.—*Wells drilled for oil and gas in and adjacent to Shotgun Butte area*

Well (pl. 1)	Location (Wind River meridian)			Name	Completion date	Surface rock unit	Oldest rock unit reached	Total depth (feet)	Oil and gas shows; initial production	Status (July 1, 1960)
	Sec.	Township	Range							
1	C NE ¼NW¼ 30	7 N.	1 E.	Carter Oil Shoshone Madden 1.	May 1948	Chugwater	Madison	1,270	None	Abandoned; flowing water.
2	C NW¼ SW¼ 3	6 N.	1 W.	British-American Tidewater Oil Arapahoe 2.	June 5, 1960	Cody	Tensleep	4,451	None	Plugged and abandoned.
3	SW¼ SE¼ SW¼ 10	5 N.	1 W.	Carter Oil 1 W	June 7, 1918	Cloverly	(?)	500	None	Do.
4	NW¼ NW¼ NE¼ 15	5 N.	1 W.	Carter Oil 1	May 12, 1919	do	Chugwater	2,093	Show gas and oil; Chugwater.	Do.
5	NE¼ NW¼ NE¼ 15	5 N.	1 W.	Petroleum, Inc., Tribal 1	July 9, 1958	do	do	1,605	5,010,000 cu ft; Chugwater.	Gas shut in.
6	SW¼ SE¼ SE¼ 10	5 N.	1 W.	Superior Oil Little Dome 1.	Apr. 27, 1944	Thermopolis	Tensleep	4,111	Show oil; Phosphoria	Plugged and abandoned.
7	NW¼ SE¼ SE¼ 10	5 N.	1 W.	Superior Oil Little Dome 2.	Sept. 1, 1944	Mowry	Chugwater	4,150	None	Do.
8	NE¼ NE¼ NE¼ 15	5 N.	1 W.	Pacific Western Tribal 1	Sept. 9, 1949	Cloverly	Phosphoria	3,708	None	Do.
9	SW¼ NE¼ NE¼ 15	5 N.	1 W.	Superior Oil 1	Mar. 2, 1927	do	Chugwater	4,365	Show gas; Nugget and Chugwater.	Do.
10	C SW¼ NE¼ 14	5 N.	1 W.	Petroleum, Inc., Tribal 2	Oct. 30, 1959	Mowry	do	2,025	Show gas; Chugwater	Do.
11	SW¼ SE¼ NE¼ 23	5 N.	1 W.	Atlantic Refining "B" 1 Gov't.	Nov. 25, 1952	Cody	Tensleep	8,138	Show gas; Dinwoody and Phosphoria.	Do.
12	SW¼ NE¼ SW¼ 9	5 N.	1 E.	Cities Service Tribal 1	Dec. 17, 1955	Meeteetse	do	10,905	None	Do.
13	C NW¼ NW¼ 3	3 N.	2 E.	Gulf Oil Mae Rhodes 1	Jan. 1, 1954	Wind River	Mesaverde (?)	11,000	Show gas; Fort Union and Mesaverde.	Do.

Two test wells have also been drilled on the Blacktail anticline just west of the mapped area, one in C SW¼SE¼ sec. 4, T. 6 N., R. 1 W., and the other (well 2, table 2) in C NW¼SW¼ sec. 3, T. 6 N., R. 1 W. The first was drilled to a depth of 5,605 feet and bottomed in Triassic rocks, and the second was drilled to a depth of 4,451 feet in the Tensleep Sandstone. No shows were reported.

A dry hole, in C NE¼NW¼ sec. 30, T. 7 N., R. 1 E. (well 1, table 2), was drilled on the Madden anticline just north of the northwest corner of the area. This well bottomed at a depth of 1,270 feet in the upper part of the Madison Limestone, and potential oil- and gas-producing formations were found to be water bearing.

In 1960, gas was discovered in the Shell Oil Co. 14–12 well, SW¼SW¼ sec. 12, T. 3 N., R. 2 E., about 0.3 mile south of the Harris Bridge quadrangle. Initial production listed by Petroleum Information, Denver, Colo., was 1,945,000 cubic feet from the depths 3,838 to 3,858 feet, apparently in the upper part of the Fort Union Formation.

Several oil- and gas-producing fields are adjacent to the Shotgun Butte area on the southwest. These are the Pilot Butte, Steamboat Butte, Maverick Spring, Circle Ridge, Sheldon Dome, Northwest Sheldon Dome, and Rolff Lake fields (Murphy and Roberts, 1954; Murphy and others, 1956). All these fields are closed anticlinal domes, and several formations contain petroleum, including the Madison Limestone, Darwin Sandstone Member of the Amsden Formation, Tensleep Sandstone, Phosphoria Formation, Crow Mountain Sandstone Member of the Chugwater Formation, Nugget Sandstone, Cloverly Formation, Muddy Sandstone Member of the Thermopolis Shale, Frontier Formation, and Cody Shale.

All the formations mentioned above extend into the Shotgun Butte area and would provide reservoir rocks for petroleum if suitable traps were present. The upper half of the Cody Shale and the younger formations are predominantly sandstone, much of which is moderately porous, permeable, and suitable as reservoir rock, but there has been little testing of these rocks because nearly all the producing anticlines in the region are breached to strata older than the Cody Shale.

Because of excessive depths to known producing strata in the structurally deeper parts of the Wind River Basin, much interest has centered since the middle 1950's in the possibilities of production from the Cody Shale and younger Cretaceous and early Tertiary rocks. Commercial quantities of petroleum have been found in the Cody Shale in the Beaver Creek, Raderville, and Castle Gardens fields in the southern part of the basin, and also in the Pilot Butte field in the northwestern part. Production in the first three fields is from sandstone in the upper part of the formation, and production from the Pilot Butte field is from fractured shale beds (J. F. Murphy, oral communication, 1957). Small amounts of oil were produced from the Cody Shale in the Alkali Butte field in the south-central part of the basin during the 1920's (Espach and Nichols, 1941, p. 6). In the West Poison Spider field along the east margin of the basin, oil was discovered in the basal sandstone of the Mesaverde Formation and in sandstone in the upper part of the Cody Shale. Commercial quantities of oil and gas have also been found in uppermost Cretaceous (Lance Formation), Paleocene, and lower Eocene rocks in several fields in the central and eastern parts of the Wind River Basin, particularly in the Lysite-Lost Cabin-Waltman area, 50 to 80 miles east of the Shotgun Butte area.

With the exception of Little Dome and Shotgun Butte anticlines, nearly all the major anticlines in the Shotgun Butte area plunge sharply to the east and southeast and have no closure. Basinward these folds are covered by the unconformably overlapping Wind River Formation, which does not reflect the structure of the underlying rocks at most places, and information on the configuration of the folds can be obtained only from seismic reflectivity and drill data.

The Shotgun Butte anticline has about 200 feet of closure in surface exposures. However, this fold is probably not a favorable drilling prospect because of its narrow width, steep flanks, and possible decrease in closure with depth. Possibly the Merriam anticline has fault closure near its west end, but the northeast-dipping thrust fault commencing in sec. 22, T. 5 N., R. 1 E., and extending into sec. 16 cannot be traced with certainty across the entire structure. The fault was not detected in an electric log and sample study of the Cities Service Tribal 1 well, but it may be northeast of the well.

The Little Dome anticline has a probable closure of 1,300 to 1,500 feet on the Nugget Sandstone (Murphy and others, 1956) and is an excellent structural trap for the accumulation of oil and gas. Earlier unsuccessful tests almost surround the Petroleum, Inc., Tribal 1 well (well 5, table 2) near the crest of the anticline, and, if they were drilled and tested properly, suggest that the gas accumulation is very localized. Other wells will help determine the size of the pool.

Zapp (1956) has described tilted water tables and their influence on the accumulation of petroleum in some of the oil and gas fields in the Bighorn Basin to the north. Murphy and others (1956), on the other hand, found no appreciable tilting of the oil-water interfaces in the Circle Ridge and Maverick Spring fields. However, some of the eastward- and southward-plunging anticlines in the Shotgun Butte area probably flatten at depth, and favorable hydrodynamic conditions may have produced effective oil and gas traps locally.

Stratigraphic relations in the Upper Cretaceous and lower Tertiary sequence seem to be favorable for stratigraphic traps. Particularly around the Little Dome anticline there are angular unconformities at several horizons. Oil and gas could migrate updip along the flanks of the folds and be trapped beneath the unconformities. Lenticular sandstone-beds that pinch out updip along the anticlinal folds may also contain oil.

Very little is yet known about the variations of porosity and permeability in the sandstone units of the various Upper Cretaceous and lower Tertiary formations. Porous sandstone beds, for example, are present in the Cody Shale in some places, but in other places these beds are considerably more silty and shaly. Conditions are thus favorable for porosity traps. The sandstone beds in the Mesaverde and younger formations are commonly porous and permeable, but variations may be significant enough to produce suitable traps.

In many places in the Wind River Basin the Waltman Shale Member of the Fort Union Formation has a high organic content and yields liquid hydrocarbons on distillation (Keefer, 1961, p. 1319). This unit is believed to be the source for much of the oil and gas that has been found in the Paleocene and lower Eocene rocks in the basin. The interfingering of sandstone and shale around the margin of the ancient body of water in which the Waltman Shale Member was deposited therefore provides favorable stratigraphic conditions for entrapment. One of the areas of interfingering apparently lies close to the east edge of the Shotgun Butte area, but as yet no test wells have been drilled.

COAL

Woodruff and Winchester (1912, p. 26–30), in the course of their investigations on the coal fields of the Wind River region, measured the thickness of coal beds at 62 localities within the Shotgun Butte area, and this information was supplemented by observations at several additional localities by the present writers during this study (pl 3). Localities of coal sections and the outcrops of locally mappable zones of coalbeds are shown on plate 1; localities of sections listed by Woodruff and Winchester (1912) were not all checked in the field during the present study, so localities shown for many of their sections are approximate. All the coal examined is in the Mesaverde and Meeteetse Formations. No detailed appraisal of the coal reserves of the entire area was made, although sufficient information was obtained to compute reserves for certain districts (table 3). The coal is subbituminous.

The coal beds in the Shotgun Butte area are lenticular, and most outcrops of coal 2½ feet or more in thickness are commonly not more than 200 to 300 yards long. The thickest coal beds, however, are

TABLE 3.—*Coal reserves in Shotgun Butte area, Fremont County, Wyo.*

[In thousands of short tons, rounded; calculations based on 1,770 tons per acre-foot of coal]

Locality	Acres	Measured and indicated reserves				Total
		Overburden (feet)	In beds 2½–5 feet thick	In beds 5–10 feet thick	In beds more than 10 feet thick	
T. 7 N., Rs. 1 E. and 1 W.:						
Bargee district	45.0	0–1,090	363			363
T. 6 N., R. 1 E.:						
Welton mine district	129.3	0–1,000	170	1,055	595	1,820
South Welton mine district	304.8	0–1,000	1,290	1,000	105	2,395
T. 6 N., R. 2 E.:						
LeClair mine district	356.2	0–2,000	2,360			2,360
Clifford Ranch district	29.4	0–1,000	172			172
East Sheep Creek district	22.0	0–500	126			126
T. 6 N., R. 3 E.:						
Cottonwood Creek district	53.3	0–1,000	343			343
T. 5 N., R. 1 W.:						
Williams mine district	82.6	0–1,500	673			673

generally confined to persistent carbonaceous zones that may be traced for considerably greater distances, as for example the zone near the base of the Mesaverde Formation, just above the basal sandstone, and the zone directly beneath the massive lenticular sandstone units near the top of the Meeteetse Formation. Because these carbonaceous units may contain several thin coal beds separated by shale partings or may contain one or two relatively clean coal beds of greater thickness, it is difficult to calculate and classify the coal reserves in them without a large number of measurements along each coal zone. Computations of reserves for the smaller districts listed in table 3 assume that a coal bed extends underground at least half as far as it does along the outcrop. The area assumed to be underlain by coal, therefore, is a semicircle with a radius equal to one-half the length of the outcrop. The coal beds in the area of the LeClair coal mine (pl. 3) were the only ones that seemed to be sufficiently uniform in thickness to warrant assumption that the zone extends as far as half a mile downdip from the outcrop. All reserves as calculated in table 3 are therefore in the "measured and indicated" class as defined by Berryhill and others (1950).

For more than 20 years previous to 1951, coal had been mined at the Barquin mine, which is only a few hundred feet south of the Eagle Point quadrangle in the SW¼ sec. 29, T. 5 N., R. 1 E. (Troyer and Keefer, 1955). It is estimated that approximately 6,000 tons were produced before this mine was closed because of a reported lack of local market. The coal was mined from a 56-inch-thick coal bed (section 1T, pl. 3) approximately 100 feet above the base of the Mesaverde Formation.

The Welton mine, sec. 20, T. 6 N., R. 1 E., more recently known as the Arrowhead mine, was operated for 4 or 5 years prior to 1936 and again for a few months in late 1951. It is estimated that not much more than a thousand tons has been mined. A slope 7 feet high extends for about 250 feet at an incline of 22° down the dip in coal. At the base of the slope, drifts have been dug along the coal bed, one about 50 feet to the north and another about 30 feet to the south. The clean coal is more than 7 feet thick (section 44T, pl. 3) in nearby exposures; caving of the adit prevented inspection of the seam in the mine.

Many other small inactive mines and prospects are in the area, but none of these was examined except to obtain measurements of the beds that were being mined or prospected. Only a few tons of coal for local use was produced at most of these localities.

No samples of coal were collected for analysis during the present study, but analyses from three different localities within the area are given by Woodruff and Winchester (1912, p. 22) as shown in table 4.

The lack of local markets and the absence of satisfactory transportation facilities limit the possibilities for large-scale development of the coal resources. Underground mining would be required in nearly all districts because of the relatively steep dip of the coal. In the Cottonwood Creek district, for example, the coal beds are overturned at the surface. Dips in other areas of coal outcrop generally exceed 20°, and small-scale faulting and fracturing is also common in many places.

TABLE 4.—*Analyses, in percent, of coal in the Shotgun Butte area*

[After Woodruff and Winchester (1912, p. 22). Analyses made after samples had been dried until the weights had become constant]

Locality (pl. 3)	Moisture	Volatile material	Fixed carbon	Ash	Heat value	
					Calories	Btu
43-W, lower part	5.9	31.9	53.2	9.0	6,120	11,070
12-W, lower 18 inches	8.3	33.8	43.9	14.0	5,280	9,500
21-W	6.1	43.1	45.0	5.8	5,065	9,120

STRATIGRAPHIC SECTIONS

Locations of sections are shown on inset map, plate 2; lithologies and thicknesses of Upper Cretaceous and lower Tertiary rocks are shown on plate 2.

1. *Armstrong mine section, secs. 26, 27, 28, and 36, T. 5 N., R. 1 E.*

Top of exposures.

	Feet
Wind River Formation: Detailed lithologic descriptions not obtained. Interval consists chiefly of variegated red, purple, gray, and white claystone, shale, sandstone, and conglomerate; conglomerate contains fragments of Precambrian rocks	1,018
Total Wind River Formation	1,018

1. *Armstrong mine section, secs. 26, 27, 28, and 36, T. 5 N., R. 1 E.*—Continued

Conglomerate above contact between Wind River and Indian Meadows Formations contact contain fragments of Precambrian rocks; those below contact contain no Precambrian rock fragments.

Indian Meadows Formation:

	Feet
91. Conglomerate, massive; boulders and cobbles of quartzite, limestone, dolomite, siliceous shale, chert, and petrified wood, as much as 4 ft in diameter	10
90. Siltstone, variegated red, purple, and gray; 50 feet above base is white conglomeratic sandstone containing pebbles of chert, quartzite, and siliceous shale or porcelanite; no carbonate pebbles; 4 ft buff conglomeratic sandstone near top	139
Total Indian Meadows Formation	149

Contact between Indian Meadows Formation and Shotgun Member of Fort Union Formation placed at base of lowermost variegated beds.

Fort Union Formation:

Shotgun Member:

89. Sandstone, white and light-gray, fine- to medium-grained, porous; abundant dark grains and some red grains; contains lenses of granule and pebble conglomerate of quartzite, siliceous shale or porcelanite, and chert fragments	197
88. Sandstone, light-gray, fine- to medium-grained, massively crossbedded, slightly limy, porous; abundant dark grains and some red grains, contains lenses of granule and pebble conglomerate with fragments as much as 2 in. in diameter of quartzite, chert, and siliceous shale or porcelanite	20
87. Siltstone, light-gray; poorly exposed in part	51
86. Sandstone, brown, fine-to medium-grained, massive, highly ferruginous, slightly limy	6
85. Siltstone, gray, poorly exposed	32
84. Sandstone, light-gray and buff, fine- to medium-grained, massive, porous, friable; abundant dark grains; lenses of granule and pebble conglomerate in basal part contain quartzite, chert, and siliceous shale or porcelanite fragments	23
83. Siltstone, gray; bentonitic near base, shaly near top; contains thin beds of brown carbonaceous shale, hard limy, ferruginous, very fine grained brown-weathering gray sandstone, and softer, very fine grained gray sandstone; some brown and gray marlstone near top	280
82. Sandstone, gray and buff, fine- to medium-grained, thin-bedded; one thin bed of hard limy brown-weathering sandstone; some gray siltstone and shale near base	16
81. Siltstone and shale, gray; some thin beds of sandstone	24
80. Shale, brown, carbonaceous	2
79. Shale, gray	3
78. Siltstone, gray; bentonitic in part; some thin nodular beds of dark reddish-brown ironstone near middle and some beds of boulderlike masses of hard gray siltstone near top	54

1. *Armstrong mine section, secs. 26, 27, 28, and 36, T. 5 N., R. 1 E.*—Continued

Fort Union Formation—Continued

Shotgun Member—Continued

		Feet
77.	Sandstone, gray and light-buff, fine- to coarse-grained, thin bedded to massive, porous; abundant dark grains; contains concretionlike masses of hard limy brown-weathering sandstone with some granule-size fragments	32
76.	Shale and claystone, gray and buff; bentonitic(?) in part; some thin beds of brown carbonaceous shale	41
75.	Shale, gray; silty in part	12
74.	Shale, brown, carbonaceous	1
73.	Shale, gray, clayey	5
72.	Siltstone, gray	5
71.	Sandstone, gray and light-buff, very fine grained, silty; abundant dark grains	6
70.	Siltstone, gray, shaly	1
69.	Shale, gray and brown, carbonaceous, clayey; clayey beds contain abundant plant fragments	3
68.	Claystone, gray; silty in part	8
67.	Sandstone, buff, very fine grained, thin-bedded, porous, slightly friable; abundant dark grains and some red grains; contains some thin beds of shaly gray siltstone	22
66.	Siltstone, buff; minor amount of gray shale	8
65.	Shale, gray, brown and black; bentonitic in part, carbonaceous and coaly in part	23
64.	Sandstone, gray and brown, fine grained, thin-bedded	8
63.	Shale, gray and brown; carbonaceous in part	20
62.	Siltstone, gray and buff, shaly	24
61.	Sandstone, light-gray, fine- to medium-grained, flaggy; abundant dark grains, sporadic red grains and white opaque grains; some concretionlike masses of hard thin-bedded ferruginous sandstone	18
60.	Shale, gray, brown, and black; bentonitic and plastic in part, silty near top; some beds are carbonaceous and coaly	56
59.	Siltstone and shale, gray; abundant carbonaceous fragments	18
58.	Siltstone, gray and brown; carbonaceous in part; abundant plant fragments	7
57.	Shale, brown, carbonaceous	9
56.	Sandstone, light-buff, fine grained, massive, slightly porous; dark grains; contains some concretionlike masses of hard limy ferruginous brown-weathering sandstone	11
55.	Shale, gray; silty in lower part	8
54.	Sandstone, gray and brown, fine grained; upper 1 ft is hard limy ferruginous quartzitic	2
53.	Claystone, gray and buff, slightly bentonitic and plastic	24
52.	Sandstone, light-buff, fine- to medium-grained; thin-bedded to beds as much as 4 ft thick; slightly limy and limonitic; dark grains; contains some concretionlike masses of hard limy, thinly crossbedded ferruginous sandstone	39
51.	Claystone and siltstone, gray and buff	28

1. *Armstrong mine section, secs. 26, 27, 28, and 36, T. 5 N., R. 1 E.*—Continued

	Feet
Fort Union Formation—Continued	
Shotgun Member—Continued	
50. Sandstone, light grayish-buff, very fine grained, thin-bedded, silty, slightly limy; abundant dark grains and some red grains; upper part poorly exposed	20
49. Siltstone, gray to dark-gray	25
Total Shotgun Member	1,192
Lower part:	
48. Sandstone, gray and buff, fine- to coarse-grained, massive to thin-bedded; abundant dark grains, some red grains; some concretionlike masses of hard platy limy brown sandstone and some lenses of granule and pebble conglomerate that contain fragments of quartzite, chert, and siliceous shale or porcelanite	33
47. Conglomerate, brown; rounded pebbles of quartzite, siliceous shale or porcelanite, and chert; matrix is buff sandstone; some thin lenses of fine-grained buff sandstone	9
46. Largely covered interval; probably underlain mostly by gray and buff sandstone and siltstone	76
45. Sandstone and conglomerate, interbedded; sandstone is buff, fine grained, massive, slightly limonitic; conglomerate is brown and contains subrounded pebbles as much as 1 in. in diameter of chert, quartzite, and siliceous shale or porcelanite	17
44. Siltstone, gray; minor amount of fine-grained buff and gray sandstone. Unit is poorly exposed	80
43. Conglomerate, brown, massive; rounded pebbles and cobbles as much as 6 in. in diameter of quartzite, chert, and siliceous shale or porcelanite; matrix is ferruginous buff sandstone which constitutes approximately 10 percent of the conglomerate. Unit forms massive outcrop and conspicuous dip slope	20
42. Siltstone, gray; some thin beds of gray, very fine grained thin-bedded sandstone	76
41. Largely covered interval; isolated outcrops and lateral exposures indicate unit is underlain mostly by buff and gray sandstone that contains lenses of pebble conglomerate and thin beds of hard reddish-brown ironstone	95
40. Sandstone, gray and light-buff, fine-grained, thin-bedded, flaggy; many thin beds of hard reddish-brown ferruginous sandstone and ironstone	66
39. Sandstone, gray and light-buff, fine- to coarse-grained, thin-bedded, flaggy, slightly limy, porous; abundant dark grains, sporadic red grains, and conspicuous white opaque grains of siliceous shale(?); some thin beds of gray siltstone; in upper 10 ft many lenses of granule-to-cobble conglomerate that contains rounded fragments of chert, quartzite, and siliceous shale or porcelanite	48
Total lower part	520
Total Fort Union Formation	1,712

1. *Armstrong mine section, secs. 26, 27, 28, and 36, T. 5 N., R. 1 E.*—Continued

Lance Formation:

		Feet
38.	Claystone, gray, shaly; bentonitic at top; minor amount of gray siltstone and very fine grained sandstone at base	10
37.	Siltstone, brown, thin-bedded, hard ferruginous	1
36.	Siltstone, gray, thin-bedded	3
35.	Claystone, gray, shaly	15
34.	Claystone, gray; bentonitic in part; contains some thin beds of gray and buff fine-grained sandstone and hard ferruginous sandstone	23
33.	Claystone, red and gray; forms distinctive band in slope	6
32.	Siltstone, gray	11
31.	Sandstone, gray; weathers reddish brown; very fine grained, hematitic	2
30.	Shale, gray, silty near top	5
29.	Sandstone, grayish-buff, very fine grained, thin-bedded, silty, porous; dark grains	7
28.	Sandstone, gray and buff, fine-grained, thin-bedded, flaggy; some thin lenses of conglomerate. Upper part of unit poorly exposed	67
27.	Sandstone and conglomerate interbedded. Sandstone is gray and buff, fine grained, massive; abundant dark grains and some red grains; contains sporadic carbonaceous fragments near base; conglomerate is lenticular and is most abundant in upper part. Unit contains well-rounded to subrounded fragments of chert, quartzite, and siliceous shale or porcelanite ranging in size from granules to cobbles as much as 6 in. in diameter. Lower 30 ft forms massive conspicuous cliff	50
	Total Lance Formation	200

Contact between Lance Formation and Meeteetse Formation is sharp in some places and appears to be an erosional disconformity, but in other places it is more or less gradational from sandstone below to conglomerate above.

Meeteetse Formation:

26.	Sandstone, buff; interfingers with thin carbonaceous and coaly beds laterally	6
25.	Siltstone, brown, thin-bedded, ferruginous, clayey; many carbonaceous fragments	2
24.	Shale, brown carbonaceous; some black coal partings	3
23.	Sandstone, buff, very fine grained, thin-bedded, silty	1
22.	Shale, brown, carbonaceous; some black coal partings	4
21.	Sandstone, buff, very fine grained, thin-bedded, silty; abundant dark grains	4
20.	Siltstone, gray: some thin beds of brown carbonaceous shale	4
19.	Siltstone and sandstone, gray and buff	1
18.	Coal, black, lignitic; brown carbonaceous shale at top	6
17.	Shale, gray and brown; carbonaceous for most part	4
16.	Siltstone, gray	1
15.	Siltstone and claystone, gray and buff; some sandstone at top	11
14.	Sandstone, buff, very fine grained, thin-bedded, silty, poorly sorted, porous, slightly friable	4
13.	Siltstone, gray, clayey	2

1. *Armstrong mine section, secs. 26, 27, 28, and 36, T. 5 N., R. 1 E.*—Continued

	Feet
Meeteetse Formation—Continued	
12. Shale, brown, carbonaceous	4
11. Siltstone, gray, clayey	5
10. Siltstone or sandstone, buff, very fine grained, thin-bedded; some thin beds of gray claystone	14
9. Shale, gray	1
8. Shale, brown, carbonaceous	1
7. Claystone, gray, silty	3
6. Sandstone, very fine grained, massive, silty	14
5. Siltstone and claystone, gray	4
4. Coal, black; clayey in part. A shaft has been driven down dip for at least 100 ft	2
3. Claystone, gray	5
2. Claystone, gray and brown; carbonaceous in part; minor amount of sandstone	14
1. Sandstone, buff, very fine to fine-grained, massive-to-thin-bedded, slightly limy, friable; abundant dark grains; some bright-red grains; sporadic pebbles of siliceous shale as much as 1 in. in diameter; some thin beds of shaly siltstone. Laterally, units 1 through 26 interfinger with massive lenticular sandstones as much as 50 ft thick that contain large concretion-like masses of brown-weathering sandstone. Units 1 through 26 were measured on steep slope that is capped by unit 27	33
Total measured part of Meeteetse Formation	153

Base of measured section. Total Meeteetse interval in this section is 659 ft, and total Mesaverde interval is 1,953 ft as measured by planetable traverse from base of unit 1 westward to top of Cody Shale.

2. *Shotgun Bench section, sec. 31, T. 6N., R. 1 E.*

Lance Formation.

	Feet
Meeteetse Formation:	
56. Claystone, gray; minor amount of gray sandstone; some carbonaceous shale partings near top	28
55. Sandstone, buff, very fine grained, massive to thin-bedded, silty, ledgy, limonitic; abundant dark grains, sporadic red grains; some thin lenses of gray claystone and shale, and some layers of gray claystone pellets; 1.5 ft of carbonaceous shale 10 ft below top	26
54. Claystone, gray and brown	13
53. Sandstone, buff, brown, in part greenish-gray; fine- to coarse-grained, massive, soft, friable, tuffaceous; abundant angular to subrounded dark and red grains and sporadic green grains; some coarse grains of mica and granule-sized grains of chert	58
52. Sandstone, buff, fine- to medium-grained, massive, soft, friable, porous, limonitic; abundant dark grains, sporadic red grains, and mica grains; some thin lenses of ironstone concretions that average half an in. in diameter, and brown sandstone concretions as much as 10 feet in diameter. Sandstone in the concretions contains much limonite and is very limy. Unit forms cliff	81

2. *Shotgun Bench section, sec. 31, T. 6 N., R. 1 E.*—Continued

		Feet
Meeteetse Formation—Continued		
51.	Shale, brown, carbonaceous; some thin beds of gray claystone; 1.3 ft of black coal 3 ft below top	11
50.	Sandstone, buff, fine- to medium-grained, thin-bedded; massive in part, soft, porous, limonitic; abundant dark grains and sporadic red grains; minor amount of gray shale and brown carbonaceous shale in lower half	22
49.	Sandstone, light-buff, fine- to medium-grained, massive, porous, friable, limonitic; abundant dark and red grains; brown sandstone concretions as much as 6 ft in diameter; forms massive cliff	41
48.	Shale, brown, carbonaceous; thin bed of black coal at top	4
47.	Sandstone, buff and light-gray, fine-grained, massive to thin-bedded; soft at top; silty in part, limonitic in part; some dark grains; basal 5 ft contains lenses of gray shale and rounded flat cobbles of claystone as much as 1 ft long; bottom part of unit forms conspicuous ledge	27
46.	Shale, brown, carbonaceous; some thin black coal partings	6
45.	Sandstone, buff, very fine grained, massive, soft, porous; silty in part, limy; abundant dark grains; sporadic red grains	8
44.	Shale and claystone, gray, bentonitic in part; interbedded with minor amount of gray sandstone, brown carbonaceous shale, and black coal; at top, 2 ft of brown carbonaceous shale with black coal partings	62
43.	Sandstone, gray and buff; weathers buff; fine grained, thin bedded, soft, limy; abundant dark grains; sporadic gray, brown-weathering sandstone concretions, and some thin partings of gray shale. Laterally unit becomes much harder and forms conspicuous ledge	57
42	Sandstone, gray and buff, fine- to medium-grained, massive to thin-bedded, soft, porous; abundant dark grains; contains "cannonball" concretions of hard gray brown-weathering sandstone and a minor amount of gray and grayish-green shale and brown carbonaceous shale	55
41.	Coal, black, impure	2
40.	Shale and claystone, gray and brown, bentonitic; minor amount of soft gray thin-bedded sandstone	58
39.	Coal, black; impure in part; some brown carbonaceous shale partings	2
38.	Shale and claystone, gray and brown; interbedded with minor amount of soft gray thin-bedded sandstone	27
37.	Shale, brown, carbonaceous; thin coal partings at top and base; thin bed of gray bentonitic claystone in middle	5
36.	Claystone, gray; interbedded with minor amount of gray shale, gray fine-grained sandstone, and brown carbonaceous shale	31
35.	Shale and claystone, gray; interbedded with soft gray thin-bedded sandstone; 2 ft hard, gray thinly crossbedded brown-weathering sandstone at top	14
34.	Coal, black, impure; some thin partings of brown carbonaceous shale and lignite	4

2. *Shotgun Bench section, sec. 31, T. 6 N., R. 1 E.*—Continued

Meeteetse Formation—Continued

		Feet
33.	Sandstone, gray, weathers light buff; fine grained, thin bedded, soft, silty, porous; dark grains; flat, rounded brown-weathering sandstone concretions as much as 10 ft in diameter; sandstone in concretions is well cemented	11
32.	Shale, brown, carbonaceous; some thin beds of black coal	8
31.	Shale and claystone, gray and brown	22
30.	Shale, claystone, siltstone, and carbonaceous shale interbedded, gray, buff, and reddish brown; weathers gray and yellow; in part bentonitic	14
29.	Shale and claystone, gray, bentonitic; shale is flaky; minor amount of gray fine-grained sandstone and brown carbonaceous shale; individual beds are lenticular; upper 36 ft contains beds as much as 1 ft thick of gray limy brown-weathering siltstone or silty marlstone	81
28.	Sandstone, light-gray and buff, medium- to coarse-grained, thin-bedded; abundant black, red, and green grains; contains "cannonball" concretions of hard gray brown-weathering sandstone	23
27.	Shale and claystone, gray, bentonitic in part; shale is clayey, flakey; minor amount of gray fine-grained sandstone containing plant stems; some brown carbonaceous shale; individual beds are lenticular	37
26.	Claystone, black, hard, shaly; forms conspicuous black band in hill	2
25.	Sandstone, gray and buff, medium-grained, soft, clayey; minor amount of gray claystone; many fragments of wood; black carbonaceous claystone at top	12
24.	Sandstone, light-gray, medium-grained, massive, soft, porous; abundant coarse dark grains; contains "cannonball" concretions of hard gray brown-weathering coarse-grained sandstone	16
23.	Sandstone, gray and buff, medium-grained, soft, clayey; minor amount of gray claystone; 1 ft of gray and brown carbonaceous shale at base	11
22.	Sandstone, light-gray, medium-grained, massive, very soft, porous; abundant coarse dark grains; contains "cannonball" concretions of hard gray brown-weathering coarse-grained sandstone	15
21.	Claystone, dark-gray, thin-bedded, hard; carbonaceous in part	3
20.	Claystone, dark-gray, thin-bedded, hard; carbonaceous in part	5
19.	Shale, brown, carbonaceous; minor amount of gray, very fine grained, silty sandstone	5
18.	Coal, black, impure; some brown carbonaceous shale partings	3
17.	Shale, black, flaky, bentonitic; many thin carbonaceous shale partings	6
16.	Sandstone, light-gray, medium- to coarse-grained, massively crossbedded. Abundant concretions as much as 3 ft in diameter of coarse-grained sandstone that contains brownish-red grains of mica. Unit weathers to "elephant-back" topography	16
15.	Shale, brown, carbonaceous	1
14.	Sandstone, gray, fine-grained; many thin partings of brown carbonaceous shale	5

2. *Shotgun Bench section, sec. 31, T. 6 N., R. 1 E.*—Continued

		Feet
Meeteetse Formation—Continued.		
13.	Shale and claystone, gray; some thin partings of brown carbonaceous shale and gray sandstone	9
12.	Sandstone, gray and buff, fine-grained, thin-bedded and irregularly bedded, hard to soft, porous; limonitic in part; dark grains and some red grains	6
11.	Claystone, gray, splintery, bentonitic; minor amount of gray sandstone and brown carbonaceous shale with many plant fragments	14
10.	Sandstone, white and light-gray; weathers light gray and buff; fine grained, massive, blocky; thin bedded in part, flaggy at top; hard, porous; mostly a clean quartz sandstone; some dark, red, and green grains; grains are subangular to subrounded. Unit is lenticular and locally forms a cliff	14
9.	Sandstone, light-gray; buff in part; weathers white and buff; coarse grained, thin bedded, very soft, porous, friable; abundant dark grains, and sporadic red grains; forms a slope	17
8.	Shale, gray and brown; carbonaceous in part; contains thin beds of black coal as much as 1 ft thick. Thin dark-brown to black marlstone 10 ft above base, some thin gray fine-grained sandstone beds in middle, and 6 in. of black coal at top. Carbonaceous shale contains many plant fragments	45
7.	Coal, black, impure	1
6.	Shale, dark-gray to black; silty in part; some brown carbonaceous shale partings in upper half	5
5.	Sandstone, gray and buff, fine-grained, thin-bedded, very soft; limonitic and limy in part; minute partings of carbonaceous shale contain plant fragments. Unit contains masses of harder sandstone that weather out in concretions	17
4.	Sandstone, gray and buff, fine-grained, very thin bedded; interbedded with brown carbonaceous shale that contains many plant fragments; 6 in. of gray shale at top	4
3.	Shale, dark-gray and brown; upper 2.5 ft is carbonaceous and has thin black coal partings and many plant fragments	5
2.	Sandstone, light-gray, medium- to coarse-grained, thin-bedded, very soft, friable, porous, slightly limonitic; some dark grains; contains large concretions of hard white and brown fine- to medium-grained, thinly crossbedded limy sandstone that weathers out on pedestals of the softer sandstone. The degree of hardness of the sandstone is dependent on the amount of calcareous cement present. Some thin brown carbonaceous shale partings	24
1.	Shale, gray and brown; carbonaceous at top; 6 in. of hard gray and brown sandstone 2 ft above base that contains carbonaceous shale partings	4
	Total Meeteetse Formation	1,103
Mesaverde Formation.		
Base of measured section.		

3. *Maverick Spring section, secs. 22, 27, 28, T. 6 N., R. 1 W.*

Mesaverde Formation.
Cody Shale:
Sandy member:

		Feet
28.	Sandstone, buff, fine-grained, irregularly bedded, cross-bedded in part, limy, limonitic; abundant dark grains; 4 in. of gray fissile shale at top and at 4 ft below top	11
27.	Shale, gray, silty; contains a minor amount of gray sandstone becoming more abundant at top	80
26.	Sandstone, gray and reddish; weathers reddish brown; very fine grained; in beds as much as 2 ft thick; silty, limy, blocky; contains spherical ironstone concretions; ripple marks at top; some gray silty shale beds as much as 2 ft thick. Unit is largely covered by talus from overlying cliffs	115
25.	Sandstone, buff, fine-grained, massive, limy; abundant dark grains; contains ironstone concretions as much as 1 in. in diameter	9
24.	Shale, bluish-gray, limy, silty, sandy; some sandstone layers as much as 2 in. thick	9
23.	Sandstone, gray, buff, and reddish; weathers buff and brown; very fine grained, massive to thin bedded, silty, limonitic; blocky in part; contains some gray shale beds from 1 to 2 ft thick. Individual beds of sandstone thicken and thin laterally. Unit forms a conspicuous cliff	50
22.	Sandstone, gray; weathers buff; fine grained, thin bedded, limy, silty, limonitic, blocky; abundant dark grains, sparse red grains; contains some beds of gray silty shale as much as 2 ft thick	29
21.	Talus-covered slope. Many outcrops of gray very fine grained thin bedded limy silty sandstone; interbedded in part with gray shale	66
20.	Shale, dark-gray, very silty, slightly limy; contains a minor amount of gray fine-grained sandstone that increases in amount near top. Unit is poorly exposed	110
19.	Sandstone, gray; weathers buff and brown; very fine grained, thin bedded, silty, limy, blocky; abundant dark grains, sparse red grains; minor amount of dark-gray silty shale	95
18.	Shale, dark-gray, finely fissile, slightly limy, silty; thin beds of fine-grained sandstone in upper one-third. Unit forms topographic saddle	48
17.	Shale, dark-gray, finely fissile. Top 4 in. is tan-weathering, very shaly bluish-gray limestone, that weathers into flat pebbles	21
16.	Sandstone, gray; weathers buff and gray; very fine grained, platy, wavy bedded in part, silty, limy, limonitic; abundant dark grains and sporadic small clay pellets; abundant thin shale partings	79
15.	Sandstone, gray; yellowish in part; weathers buff; very fine grained, thin bedded, wavy-bedded in part, dirty; occasional dark and red grains	15

3. *Maverick Spring section, secs. 22, 27, 28, T. 6 N., R. 1 W.*—Continued

		Feet
Cody Shale—Continued		
Sandy member—Continued		
14.	Claystone, bluish-gray, limy, concretionary; appears to be a boulder bed from a distance; forms a distinctive bed in vertical cliff	2
13.	Sandstone, gray, very fine grained, thin-bedded; some thin gray shale partings. Units 13 through 28 form a high consipcuous cliff	48
12.	Covered interval	79
11.	Sandstone, gray to buff; weathers gray and dark brown; limy; contains claystone pellets ⅛ to ½ in. thick and ½ to 1 in. long	18
10.	Covered interval; apparently underlain by soft tan and gray sandstone	106
9.	Sandstone, gray; in part yellowish; weathers buff and tan; very fine grained, thin-bedded, silty, sugary, limy, limonitic; dark grains and sporadic bright-red grains	45
8.	Sandstone, gray and buff, very fine grained, thin-bedded, limy; dark and red grains; forms poor outcrops	70
7.	Covered interval; apparently underlain by sandstone	26
6.	Sandstone, gray; weathers gray and brown; very fine grained, thin bedded, silty, platy, limy, soft, limonitic; abundant dark grains	249
	USGS Mesozoic locality 21752 (SW¼NE¼SW¼ sec. 22, T. 6 N., R. 1 W.) 90 feet above base; age, Telegraph Creek equivalents: *Inoceramus* cf. *I. barabini* Morton *Ostrea* cf. *O. congesta* Conrad *Anomia* cf. *A. subquadrata* Stanton *Baculites thomi* Reeside *Desmoscaphites bassleri* Reeside	
5.	Covered interval	693
4.	Sandstone, gray and buff, fine-grained, thin-bedded, dirty; salt-and-pepper appearance; many thin sandy shale partings	41
Approximate contact between sandy and shaly members of Cody Shale.		
Shaly member:		
3.	Covered interval. Unit forms a valley with no outcrops	513
2.	Sandstone, grayish-green, fine- to medium-grained, thin-bedded, glauconitic, limy; salt-and-pepper appearance; abundant dark grains	10
	USGS Mesozoic locality 21751 (NE¼NE¼NE¼ sec. 28, T. 6 N., R. 1 W.); age, late Niobrara equivalents: *Nuculana* sp. *Inoceramus* n. sp. *Crassatella andrewsi* (Henderson) cf. *C. wyomingensis* (Sidwell) *Ringicula* sp. *Baculites asper* Morton *codyensis* Reeside *Clioscaphites novimexicanus* (Reeside) *Linuparus* sp.	

3. *Maverick Spring section, secs. 22, 27, 28, T. 6 N., R. 1 W.*—Continued

Cody Shale—Continued

Shaly member—Continued

	Feet
1. Covered interval; sporadic outcrops of gray shale	1, 508
Total Cody Shale	4, 145

Frontier Formation.

Base of measured section.

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*

Top of Shotgun Butte and top of exposures.

Indian Meadows Formation:

	Feet
222. Conglomerate, brown and reddish, massive; consists of rounded to subrounded boulders and cobbles of limestone, dolomite, quartzite, chert, and flat-pebble conglomerate derived from rocks of Paleozoic age; size of fragments increases upward. Unit contains some lenses of red claystone and siltstone	180
221. Claystone and siltstone, brown, gray and red; sporadic nodules of white tuff(?)	21
220. Conglomerate, light-brown, massive; rounded to subrounded cobbles and boulders of siliceous shale, limestone, quartzite, sandstone, and chert; maximum size 1-ft in diameter; average size 1 to 2 in. in diameter. Size of fragments increases upward and there is a greater proportion of carbonate rocks in upper than in lower conglomerate beds; matrix is gray fine-grained sandstone; some lenses of red claystone. Unit is poorly exposed in part owing to rubble cover from overlying beds	65
219. Claystone, red; probably some thin lenses of conglomerate; poorly exposed owing to rubble cover from overlying beds	29
218. Conglomerate, light-brown, massive; consists of rounded to subrounded cobbles and boulders, which average 1 to 2 in. in diameter but are as much as 1 ft in diameter, of siliceous shale, limestone, quartzite, chert, and sandstone; matrix is slightly limy fine-grained sandstone; some sandstone lenses near top of unit	17
217. Claystone, brown, gray, and red; plastic when wet; minor amount of siltstone	34
216. Sandstone, gray, fine-grained, massive, hard, limy; abundant dark grains, some red grains; minor amount of siltstone	14
215. Conglomerate, brown, massive; consists of rounded boulders, cobbles, and pebbles which average 1 to 2 in. in diameter and have a maximum diameter of 2 ft, of quartzite, siliceous shale with fish scales (fragments of Mowry Shale not weathered as in lower conglomerates), limestone, dolomitic limestone, petrified wood, and sandstone; matrix is gray and brown, slightly limy silty fine-grained sandstone; some thin lenses of sandstone in upper part	34

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

	Feet
Indian Meadows Formation—Continued	
214. Claystone and siltstone, variegated red, gray, dark greenish-gray, and tan; plastic when wet; some thin beds of gray sandstone. Upper 56 ft forms badland topography with typical varicolored banded slopes	130
213. Sandstone, gray, soft, argillaceous	20
212. Conglomerate, massive, lenticular; consists of rounded and subrounded pebbles, cobbles, and boulders, which average ½ to 1 in. in diameter but are as much as 1 ft in diameter, of siliceous shale, black chert, quartzite, jasper, and petrified wood; no limy fragments observed; matrix is light-brown limy sandstone. Unit appears to be a large channel deposit	21
211. Claystone and siltstone, red; some red siltstone concretions as much as 2 in. in diameter	50
210. Claystone, greenish-gray, gray, red, and purple; plastic when wet	28
209. Sandstone, gray and brown, fine- to medium-grained, massive, porous, lenticular; abundant dark grains and sporadic pink, red, and orange grains	10
208. Claystone, variegated red, purple, lavender, tan, gray, and greenish-gray; plastic in part; contains a few thin beds of irregularly bedded brown-weathering fine-grained gray sandstone in basal 9 ft	50
207. Sandstone, gray and buff, fine- to medium-grained, massive, lenticular; soft and friable in part; contains lenses of coarse-grained to granule-sized fragments of siliceous shale of porcelanite and chert; maximum diameter is ½-in. Laterally sandstone interfingers with variegated claystone or siltstone	24
Total Indian Meadows Formation	727

Contact between Indian Meadows Formation and Shotgun Member of Fort Union Formation appears to be gradational. Unit 207 marks the base of the variegated sequence; the underlying beds are drab in color.

Offset along contact 0.6 mile northwest to northwest side of Shotgun Butte, NW¼SE¼SW¼ sec. 26, T. 6 N., R. 1 E.

Fort Union Formation:	
Shotgun Member:	
206. Part of interval covered; exposed portions not detailed	2, 830
Total Shotgun Member of Fort Union Formation	2, 830
Lower part:	
205. Conglomerate, brown; consists of well-rounded to subrounded and subangular pebbles, which average ¼ to ½ in. in diameter but are as much as 2 in. in diameter, of chert, quartzite, and porcelamite or siliceous shale; contains many granule-sized fragments and many highly polished pebbles; matrix is brown ferruginous coarse-grained sandstone; sparse lenticular beds of white sandstone present	23

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

Fort Union Formation—Continued

Lower part—Continued

		Feet
204.	Sandstone, white and light-gray, massive; lenses of conglomerate as in unit 202; upper 17 ft contains sporadic brown and gray hard sandstone concretionary masses as much as 12 ft in diameter	52
203.	Claystone and shale, gray; 6 in. of ironstone 12 ft above the base	17
202.	Conglomerate and sandstone, lenticular. Conglomerate is brown and contains well-rounded pebbles of chert, quartzite, petrified wood, quartz, and porcelanite or siliceous shale; fragments range in size from a fine-pebble and granule-sized conglomerate to cobbles as much as 6 in. in diameter, the average diameter being ½ to 1 in. Matrix is gray and dark-brown, very fine grained sandstone, which constitutes approximately 25 percent of the conglomerate. Sandstone is white and light gray fine grained, massively crossbedded, in part limonitic; it is mostly clean quartz sandstone with abundant dark grains and some red grains. Unit forms a conspicuous dip slope over much of the area	73
201.	Sandstone, buff, thinly crossbedded, slightly limy, porous, limonitic; some dark and red grains; 16 feet above base are concretionlike masses of hard gray brown-weathering fine-grained limy sandstone as much as 30 ft in width; some lenses of granule and pebble conglomerate in upper 50 ft, and a thin shale bed 25 ft below top	66
200.	Sandstone, buff, medium-grained, massively crossbedded, slightly limy, porous, limonitic; some dark and red grains; contains thin lenses of granule and pebble conglomerate that have rock fragments of quartz, chert, and porcelanite or siliceous shale 1/64 to 1 in. in diameter; these lenses follow the crossbedding	10
199.	Shale, dark-gray, finely fissile; 4 ft of buff thin-bedded sandstone 20 ft above base	59
198.	Sandstone, buff; weathers buff and brown; fine grained to medium grained, massive to thin bedded and irregularly bedded, in part soft and friable, porous, limonitic; abundant dark grains, some red grains; sporadic large brown thin-bedded sandstone concretions 22 ft above base; some thin gray shale beds	63
197.	Shale, gray and buff, silty; minor amount of gray and brown sandstone and ironstone; units 197 through 199 form topographic saddle	29
196.	Sandstone, gray; weathers buff in part; fine grained, massive, limonitic; abundant dark grains; hard gray brown-weathering sandstone at top; some thin ironstone partings in lower 3 ft	14
195.	Shale, gray, silty; minor amount of gray sandstone	24

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

Fort Union Formation—Continued

Lower part—Continued

		Feet
194.	Sandstone, gray; weathers brown; very fine grained, platy, very limy, quartzitic	3
193.	Sandstone, buff, fine-grained, thinly cross bedded, limonitic, porous; dark and red grains; sparse thin partings of gray siltstone	20
192.	Sandstone, light-gray, white, and brown, thinly cross-bedded	11
191.	Sandstone, gray; weathers brown; fine grained, thin-bedded and irregularly bedded; massive at top; hard at base to soft at top, limy; some lenses of granule conglomerate in top 1 ft	6
190.	Covered interval; lateral exposures indicate that it is underlain mostly by soft brown, white, and gray sandstone	7
189.	Ironstone, dark reddish-brown; abundant leaves	3
	Fossil collection (SW¼ sec. 23, T. 6 N., R. 1 E.); age, Paleocene (Fort Union equivalents): *Aralia notata* Lesquereau *Platanus raynoldsi* Newberry *Cercidiphyllum arcticum* (Heer) Brown *Persea* sp.	
188.	Sandstone, white, massive, hard brown sandstone, and ironstone, interbedded; unit poorly exposed, and was measured along top of ridge where sparse outcrops are present; some shale may be present. Top of unit is marked by Merriam triangulation station	188
187.	Sandstone, light-gray; buff and brown in part, medium-grained, massive to thin-bedded and irregularly bedded; porous and friable in part, limy and limonitic in part; abundant dark grains, sporadic red grains. Minor amount of gray claystone and shale in lower 10 ft and from 60 to 80 ft above base; at top is hard dark reddish-brown sandstone that contains much specularite; 5.5 ft below top is ironstone that contains leaves identified by R. W. Brown as being Paleocene in age	137
186.	Shale and claystone, gray; interbedded with sandstone that is, buff, medium grained, massive to thin bedded and irregularly bedded, porous, and in part soft; sporadic brown sandstone concretions as much as 6 ft in diameter are present in the sandstone. Approximately 60 percent of unit is shale and claystone, and 40 percent is sandstone	68

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

	Feet
Fort Union Formation—Continued	
Lower part—Continued	
185. Sandstone, buff; weathers brown and buff; medium grained, massive to thin bedded and irregularly bedded, porous; soft in part, limonitic; some dark grains; contains sporadic brown wavy-bedded sandstone concretions as much as 20 ft in diameter in upper part. Unit contains a minor amount of gray shale and claystone and a few thin beds of dark-brown ironstone	120
184. Sandstone, light-gray and buff; weathers white and buff; fine to medium grained, massive to thin bedded and irregularly bedded, porous, soft to hard; abundant dark grains, some red grains; some thin irregular beds of brown ironstone that contain plant fragments; thin beds of brown carbonaceous shale and gray shale as much as 2 ft thick; 12 ft of gray shale 22.5 ft above base; 3 ft of ironstone 19.5 ft above base which contains leaves identified by R. W. Brown as appearing to be transitional forms between the Cretaceous and Paleocene	103
Total lower part of Fort Union Formation	1,096
Total Fort Union Formation	3,926
Lance Formation:	
183. Claystone and shale, gray; includes minor amount of brown carbonaceous shale that contains thin partings of black coal in upper two-thirds of unit; contains abundant plant fragments. Sporadic ironstone concretions as much as 1 ft in diameter present. Thin hard brown ironstone bed at base. Unit contains spore and pollen assemblage identified by E. B. Leopold as Cretaceous in age	68
182. Sandstone, gray and buff; weathers buff and brown; fine grained, thin bedded and irregularly bedded, dirty; sporadic large brown sandstone concretions at top; minor amount of gray claystone and shale	27
181. Shale and claystone, gray to black; shale is finely fissile; minor amount of gray medium- to coarse-grained sandstone and brown ironstone. Sandstone 40 ft above base contains brown sandstone concretions as much as 3 ft in diameter	93
180. Sandstone, buff, medium- to coarse-grained, some layers gritty, massive to irregularly bedded, soft, friable, porous; limonitic in part; abundant dark grains; interbedded with shale and claystone. Unit is approximately 60 percent sandstone and 40 percent shale and claystone	30
179. Claystone, gray and purplish; minor amount of buff fine grained sandstone, in part in the form of rounded and botryoidal-shaped concretions as much as 6 in. in diameter; 6 in. green claystone bed in middle. Unit forms badland topography	36

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

		Feet
Lance Formation—Continued		
178.	Claystone, gray; sandy in part, bentonitic in part; selenite crystals present on weathered surface; fragments of turtle bones; some thin ironstone beds; forms "elephant-back" topography; contains spore and pollen assemblage identified by E. B. Leopold as Cretaceous in age	56
177.	Claystone, gray and purplish-gray; bentonitic in part; some thin beds of brown ironstone. Unit is poorly exposed	9
176.	Sandstone, gray and brown, fine- to medium-grained, thin-bedded and irregularly bedded, hard; limonitic in part; limy; abundant dark grains	12
175.	Shale and claystone, gray	24
174.	Sandstone, buff; weathers buff and brown; fine to coarse grained, massive to thin bedded and irregularly bedded; limonitic in part, limy, soft, porous; abundant dark grains, sporadic brown wavy-bedded fine-grained limonitic sandstone concretions, one bone fragment observed; one thin bed of granule conglomerate 21 ft above base; some thin lenses of dark-gray shale and claystone. Unit forms conspicuous outcrop at base of hill	80
173.	Claystone and shale, gray and brown; claystone is bentonitic and plastic in part	48
172.	Shale, gray, bentonitic; interbedded with an equal amount of buff thinly crossbedded fine-grained sandstone that contains brown sandstone concretions; 1 ft dark-brown to black ironstone at top	34
171.	Shale, gray; minor amount of buff sandstone; poorly exposed	68
170.	Shale, gray, and buff medium to coarse-grained, thinly crossbedded limonitic sandstone; unit lenticular; abundant dark grains, sporadic red grains; some granule layers, most abundant in upper 59 ft. Sporadic large brown thin-bedded sandstone concretions in the sandstone. Ten ft below top is 1.5 ft of conglomerate that contains granule- (1 to 2 mm) and pebble-sized (as much as ½-in. in diameter) rock fragments of chert, quartzite, hard sandstone, porcelanite, and siliceous shale; matrix is mostly ironstone which contains much hematite, in part in the form of specularite	86
169.	Shale, gray; maroon in part, poorly exposed; may contain some thin beds of sandstone	15
168.	Sandstone, light-gray and buff, medium-grained, thinly crossbedded, in part limonitic; slightly limy; abundant dark grains, sporadic bright-red grains	10
167.	Shale and claystone, dark-gray and maroon; many sandy and silty layers in lower two-thirds; some brown hard ironstone beds in upper one-third	53
166.	Sandstone, light-gray and buff, coarse-grained, massive to thinly crossbedded, porous, friable; limonitic in part; abundant dark and red grains. Contains some granule-sized grains that are probably porcelanite or siliceous shale	15

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E*—Continued

		Feet
Lance Formation—Continued		
165.	Shale, dark-gray; 8-in. brown to black ironstone bed in middle; poorly exposed	18
164.	Sandstone, light-gray and brown, medium to coarse-grained; some lenses of conglomerate that consists mostly of granule-sized subrounded to subangular fragments of chert and some pebble-sized (as much as half an inch in diameter) fragments of porcelanite or siliceous shale. Unit weathers to a dark-brown shiny surface	20
163.	Sandstone, brown; light-gray in part, medium-grained, thinly crossbedded, limonitic, soft, porous; abundant dark grains; some 3-ft beds of white massive sandstone; sporadic brown sandstone concretions. At top are two lenses of conglomerate separated by white sandstone; the conglomerate contains granule-sized fragments of chert and porcelanite or siliceous shale and is loosely cemented with a matrix of limonite and coarse-grained sandstone. Some thin shale partings in lower part of unit	57
162.	Sandstone, white, light-gray, and buff, medium- to coarse-grained, massive; thinly crossbedded in part, porous, slightly friable, slightly limy; abundant dark grains, sporadic red grains; many conglomeratic layers from 130 ft above base to top of unit that are composed of granule-sized rock fragments of chert and white porcelanite or siliceous shale; 1 ft of brown carbonaceous shale 140 ft above base; some thin beds of gray shale and siltstone in lower part; some 3-in. beds of hard brown ironstone throughout unit; upper 130 ft contains sporadic brown, irregularly bedded sandstone concretions. Unit forms conspicuous outcrop	281
	Total Lance Formation	1, 140

Contact between Lance Formation and Meeteetse Formation is placed at the base of the conspicuous white conglomeratic sandstone constituting unit 162; southward the sandstone is gradually replaced by a massive pebble and cobble conglomerate. The sandstone beds in units 159 through 161 are not continuous, and elsewhere in the area coal beds, which are placed in the Meeteetse Formation, are present at the top of unit 161.

Offset 1.14 miles north along contact to SW¼SW¼NE¼, sec. 17, T. 6 N., R. 1 E.

Meeteetse Formation:		
161.	Sandstone, gray and buff; weathers buff; fine to medium grained, thinly crossbedded; silty in part, limonitic; abundant dark grains; contains lenses of gray shale, in part carbonaceous, as much as 10 ft thick, 8 in. brown ironstone at top	88
160.	Sandstone, buff, fine- to coarse-grained, massive; crossbedded at top, limonitic, limy, porous; abundant dark grains, sporadic red grains; locally contains lenses of conglomerate which have gray claystone balls, and brown ironstone concretions as much as 6 in. in diameter in a coarse-grained	

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

Meeteetse Formation—Continued

		Feet
160.	Sandstone, etc.—Continued sandstone matrix; many large vertebrate bone fragments present locally; sporadic brown sandstone concretions that are in part botryoidal-shaped and in part round; plant fragments present. Unit locally forms massive cliffs	51
159.	Sandstone, white, light-gray, and buff; weathers gray and buff; medium to coarse grained, massive, thin bedded in part, slightly limy, limonitic; abundant dark grains, sporadic red and green grains: sporadic brown irregularly bedded sandstone concretions as much as 6 ft in diameter; upper 25 ft contains thin gray shale partings; some hard dark-brown ironstone beds. Ironstone 1.2 ft below top contains large vertebrate bone fragments and turtle bone fragments as does the sandstone above it; the largest bone observed was 1.8 ft long and 11 in. in maximum diameter	117
158.	Coal, black, impure	2
157.	Shale, gray and brown, carbonaceous in upper part	8
156.	Sandstone, gray and buff; weathers buff; very fine grained, massive, silty; contains thin beds of brown thin-bedded fine-grained sandstone which in part weathers out in the form of concretions	9
155.	Shale, gray and brown; carbonaceous in part; minor amount of hard gray marlstone; marlstone bed 18.5 ft above base contains abundant ripple marks	25
154.	Coal, black, impure	2
153.	Shale and claystone, gray, carbonaceous	.5
152.	Coal, black, impure	1
151.	Claystone, gray	.5
150.	Coal, black, very impure; many thin shale partings	7
149.	Shale, gray and brown; carbonaceous in part; minor amount of gray fine-grained sandstone	14
148.	Sandstone and siltstone, gray, buff, and brown; weathers buff and brown; very fine grained, thin bedded, limy	5
147.	Sandstone, gray; weathers brown; fine grained, thinly cross-bedded and irregularly bedded, hard, limy, quartzitic	2
146.	Interbedded sandstone, shale, carbonaceous shale, and coal	19

Offset 3,500 ft south along coal at base of unit 146 to shaft of abandoned Welton coal mine. At this locality unit 146 is 16.5 ft thick and is detailed as follows:

Claystone and shale, dark-gray and brown, carbonaceous	2.2
Coal, black	2.0
Claystone, gray	5
Coal, black; minor claystone partings; measured on top of coal-mine shaft	4.
Coal, black; appears to be quite pure; little or no clay in most places; measured inside the coal-mine shaft and is the bed that was being mined	7.2

The following units were measured immediately west of the coal mine:

145.	Shale, brown, carbonaceous	2

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

		Feet
Meeteetse Formation—Continued		
144.	Shale, gray, clayey	3
143.	Sandstone, gray; weathers brown; very fine grained, thin bedded and irregularly bedded; silty, hard, limy; dark grains	3
142.	Shale, gray and brown, carbonaceous; some thin sandstone beds near top	16
141.	Sandstone, buff, fine-grained, thin-bedded and irregularly bedded, limy, limonitic	4
140.	Shale, gray, clayey	2
139.	Coal, black, impure	2
138.	Sandstone, light-gray, very fine grained, thin-bedded, soft, silty	8
137.	Sandstone, gray; weathers brown; fine-grained, thinly cross-bedded, slightly quartzitic, limy, hard; weathers out in masses resembling large concretions	4
136.	Shale, gray and brown, carbonaceous	5
135.	Sandstone, brown, fine-grained, thin-bedded, limonitic	9
134.	Shale, gray and brown, carbonaceous; 1 ft of black impure coal 14 ft above base	25
133.	Sandstone, gray and brown, very fine-grained, thin-bedded, limonitic, hard; dark grains	2
132.	Shale, gray; carbonaceous in part; gray siltstone near top	8
131.	Sandstone, gray and brown, very fine grained, thin-bedded; hard at base, soft at top	6
130.	Shale, dark-gray; carbonaceous in part; some sandy layers in upper part	9
129.	Coal, black, impure; 6 in. of brown carbonaceous shale at top	5
128.	Sandstone, buff, very fine grained, thin-bedded, silty; minor amount of brown carbonaceous shale; 1.5 ft of black coal 4 ft below top	12
127.	Shale, gray and brown; carbonaceous in part; interbedded with buff claystone in upper 4.5 ft	7
126.	Sandstone, buff, very fine grained, thin-bedded, silty; contains hard dark-gray fine grained sandstone balls as much as 3 in. in diameter	3
125.	Sandstone, dark-gray and reddish-brown, very fine grained; in beds ½ to 1 in. thick; limy, hard	2
124.	Shale, gray; minor amount of buff sandstone at top and base	22
123.	Sandstone, dark-gray and reddish-brown, very fine grained, evenly bedded, limy, hard; ripple marks at base	2
122.	Sandstone, shale, and carbonaceous shale, interbedded; gray and brown	11
121.	Sandstone, buff, fine- to medium-grained, massive, dirty, limonitic, limy; abundant dark grains, some red grains	5
120.	Claystone, siltstone, and sandstone; claystone is reddish buff; sandstone is gray, very fine grained, thin bedded	14
119.	Sandstone, gray; weathers buff; very fine grained, massively crossbedded; thin bedded in part, silty, dirty, limy; dark and red grains	10

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

	Feet
Meeteetse Formation—Continued	
118. Claystone, gray, shaly; carbonaceous in part	7
117. Sandstone, gray; weathers buff; very fine grained, in beds 6 in. thick. Brown limonitic sandstone layers give unit a banded appearance	2
116. Shale, gray and brown; carbonaceous in part	14
115. Sandstone, gray and greenish; weathers buff and greenish; medium- to coarse-grained, massively crossbedded, clean, limy; abundant dark and red grains. Units 115 through 145 form a series of strike ridges and valleys on east side of covered valley	40
114. Covered interval; sporadic outcrops of sandstone present. This unit forms a prominent topographic valley throughout most of the area	634
113. Partially covered interval; apparently underlain by gray and buff sandstone; some brown sandstone concretions have weathered out on the surface	25
112. Shale, dark-gray to black; carbonaceous in part	4
111. Sandstone, gray to buff, fine-grained, thin-bedded; silty in part, limonitic in part, limy; dark grains	3
110. Covered interval	13
109. Sandstone, gray to buff, fine-grained, thin-bedded; many large brown sandstone concretions	31
108. Shale, gray	4
107. Covered interval; probably underlain by gray shale	6
Total Meeteetse Formation	1, 335

Contact between Meeteetse Formation and white sandstone member of Mesaverde Formation marked by a sharp topographic and lithologic break from soft sandstone and shale above to hard massive white sandstone below.

Mesaverde Formation:	
White sandstone member:	
106. Sandstone, white and light-gray; buff in part; weathers white and gray; medium-grained; coarse grained in part, massively crossbedded, limy, slightly limonitic, porous; abundant dark grains, sporadic red grains; contains brown sandstone concretions as much as 12 ft in diameter. The sandstone in the concretions is fine to medium grained, thinly cross laminated, very limonitic, limy, and hard; the concretions appear in a definite zone near the base and are sporadic in the rest of the unit. Lenticular brown sandstone and ironstone layers present; lenticular gray and brown carbonaceous shale partings in upper part; hard sandstone veinlets present as in unit 99 but not conspicuous throughout unit. Unit forms conspicuous ridge	105
105. Shale, gray and brown; carbonaceous in part	7

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

Mesaverde Formation—Continued

White sandstone member—Continued

		Feet
104.	Ironstone, dark reddish-brown; contains much hematite which in part is in the form of specularite; hematite present mostly as a coating on quartz grains; sporadic spherical concretions	1
103.	Shale, gray, dark-gray, and brown; carbonaceous in part; plant remains	8
102.	Sandstone, white and light-gray, fine- to coarse-grained; lower part thin-bedded, upper part massive; sandstone veinlets as in unit 99, but not as conspicuous. The dip slope of the unit is covered by sandstone balls averaging 1 in. in diameter	36
101.	Sandstone, white and light-gray, fine- to medium-grained; thinly crossbedded in lower two-thirds, massively crossbedded in upper one-third. Unit is nearly pure quartz sandstone; contains some dark, red, and pink grains. Hard sandstone veinlets stand out conspicuously on weathered surface as in unit 99	47
100.	Shale and siltstone, gray; some sandy layers	11
99.	Sandstone, light-gray; weathers white; fine to coarse grained, massively crossbedded; dirty and silty in part; dark and red grains; gray clay pellets and claystone partings abundant near base; abundant plant remains at base. Hard white quartzitic sandstone veinlets, 1/16- to 1/8-in. thick and as much as 2 inches high; stand out conspicuously on weathered surface; they are present in two definite orientations, one with a strike of N. 70° W. and a dip of 55° S., and the other with a strike of N. 60° E. and a vertical dip. The veinlets form a criss-cross pattern on the surface of the rock	57
98.	Sandstone, gray, very fine grained; in beds from 1/2-in. to 2 ft thick; silty	5
97.	Claystone, gray, hard; plant remains	2
96.	Sandstone, gray, very fine grained, silty	2
95.	Shale, gray; silty and sandy near top	4
94.	Sandstone, light-gray; weathers white; very fine grained, thin bedded, silty. Upper 1 ft is limonitic and contains rounded gray sandstone concretions	7
93.	Shale, gray, silty	1
92.	Sandstone, light-gray and buff, very fine grained, massive, silty; some limonitic layers; dark grains	7
91.	Claystone, gray; limonite on bedding planes; plant remains	3
90.	Sandstone, buff to brown, very fine grained, thinly cross-bedded, silty, dirty; some thin gray shale partings	3
89.	Ironstone, dark-brown to black	1
88.	Shale, dark-gray, silty	8

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

	Feet
Mesaverde Formation—Continued	
White sandstone member—Continued	
87. Sandstone, light-gray to white, fine- to medium-grained, massively crossbedded. Unit is nearly pure quartz sandstone; contains some dark and red grains. At base, coarse-grained sandstone bed containing gray claystone pellets as much as 1 in. in diameter	21
Total white sandstone member	336
Lower part of Mesaverde Formation:	
86. Sandstone, buff, very fine grained, thin-bedded, silty, limonitic; sporadic dark grains; gray clay shale partings in middle	29
85. Sandstone, buff; weathers buff and brown; very fine grained, irregularly bedded, silty, limy; abundant dark grains	15
84. Shale; alternating gray, brown, and reddish beds; carbonaceous and sandy layers in upper part	17
83. Sandstone, buff; weathers buff and brown; fine grained, massive to thin bedded, limonitic, limy; sporadic dark grains	6
82. Shale, gray and brown; carbonaceous in part; minor amount of gray sandstone that becomes abundant near the top	45
81. Sandstone, light-gray, weathers buff and gray; medium grained, massive, porous; abundant dark grains, sporadic bright-red grains	5
80. Shale, gray and greenish-gray; carbonaceous at top	8
79. Sandstone, buff and reddish; weathers reddish brown; fine grained, massive to thin bedded, silty, limonitic; abundant dark grains	2
78. Siltstone, gray at base grading upward to gray and brown; carbonaceous and sandy layers in upper half	23
77. Sandstone, gray and buff; weathers buff and brown; fine grained, massive to thin bedded, limy, limonitic; abundant dark grains; sporadic ironstone concretions as much as 6 in. in diameter	6
76. Shale, gray; carbonaceous in upper half; minor amount of gray silty sandstone in upper half	53
75. Sandstone, buff, fine grained, massive, limy, limonitic; abundant dark grains, sporadic red grains; some limonitic pellets as much as half an in. in diameter; minor amount of gray shale, carbonaceous in part	26
74. Sandstone and shale, interbedded. Sandstone is buff, light gray, and brown, fine to medium grained, massive to thin bedded, limonitic, in part silty; contains dark grains. Shale is gray and brown, in part carbonaceous. Individual beds thicken and thin in short distances laterally	273
73. Shale, gray; carbonaceous in part	5
72. Sandstone, buff and brown, very fine grained, massive to thin-bedded, silty, limy; interbedded with 2- to 3-ft beds of gray siltstone and shale	33

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

Lower part of Mesaverde Formation—Continued

		Feet
71.	Shale, black, carbonaceous; interbedded with minor amount of dark-gray to black claystone; 1-ft of black coal 3 ft below top; plant remains	8
70.	Sandstone, light-gray to buff, very fine grained, limy; interbedded with gray shale that is carbonaceous in part; some thin beds of brown ironstone present	35
69.	Sandstone, light-gray, buff, and brown, fine grained, thinly crossbedded. Buff sandstone has much limonite and is limy; gray sandstone is porous and nonlimy; a thin bed of gray clay shale near top	24
68.	Sandstone, buff, fine- to medium-grained, massive, limy, very limonitic; abundant dark grains; locally forms massive cliff	32
67.	Covered interval. Apparently underlain by partly carbonaceous gray shale and by fine-grained thin bedded sandstone	60
66.	Sandstone, light-gray and buff, fine grained, massive; crossbedded in part, thin bedded at top, limy; abundant dark grains, sporadic red grains; ironstone concretions as much as 1 in. in diameter	24
65.	Sandstone and shale, interbedded. Sandstone is gray and buff, fine grained, thin bedded, limy, limonitic; shale is gray, carbonaceous in part; some thin beds of hard gray brown-weathering marlstone	107
64.	Shale, dark-gray	5
63.	Sandstone, gray to buff, fine-grained, massive; thin-bedded in part, very limonitic; sporadic bright-red and dark grains; some ironstone concretions as much as 4 in. in diameter	45
62.	Sandstone, buff and brown, fine-grained, silty, limy, very limonitic	2
61.	Shale, gray and brown; carbonaceous in part; some thin sandy layers	6
60.	Siltsone, brown, hard, limy, and gray shale; some minor beds of sandstone	6
59.	Shale, gray and brown; carbonaceous at top	5
58.	Sandstone, buff to brown, very fine grained, thin-bedded, silty, flaggy, hard, limy, very limonitic; dark grains; ironstone concretions as much as 1 in. in diameter	5
57.	Shale, gray	5
56.	Sandstone, light-gray and buff, very fine grained, thin-bedded; limy and limonitic in part	2
55.	Shale, dark-gray and brown; carbonaceous in part; plant remains	11
54.	Sandstone, buff, fine-grained, massive to thin-bedded; flaggy at top, very limonitic	6
53.	Shale, gray to black; minor amount of sandstone, claystone, and ironstone. Unit is poorly exposed	34
52.	Sandstone, buff; white at top, fine- to medium-grained, massive, soft, porous, limy, limonitic; forms conspicuous cliff	26

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

Lower part of Mesaverde Formation—Continued

		Feet
51.	Sandstone, light-buff to brown, very fine grained, thin-bedded, very limonitic in part; 1-ft of brown carbonaceous shale at top	17
50.	Shale, bluish-gray; carbonaceous in part; some minor beds of gray and buff fine-grained sandstone	16
49.	Sandstone, buff, very fine grained, silty; poorly exposed	4
48.	Sandstone, white and light-buff, fine- to medium-grained, massive; silty and dirty in part; abundant dark grains. Buff sandstone is limonitic and limy. Unit contains ironstone concretions as much as 3 in. in diameter; weathers with large pits on surface; forms conspicuous cliff	45
47.	Siltstone and sandstone, gray and buff, very thin bedded; shaly in part	3
46.	Shale, gray; weathers brown	7
45.	Shale, dark-gray, carbonaceous; some minor coal partings	6
44.	Siltstone and sandstone, gray and brown, very fine grained, thin-bedded	6
43.	Sandstone, brown, very fine grained, very limonitic; abundant large black grains that may be fragments of carbonaceous material	2
42.	Shale, gray; grades upward into siltstone and sandstone at top of unit	6
41.	Shale, gray and dark-brown; clayey at base, carbonaceous at top; plant remains	7
40.	Lignite, black and brown, soft	4
39.	Siltstone, sandstone, and shale, gray to dark-gray; sandstone is fine grained; some plant remains	7
38.	Lignite, black and brown	1
37.	Shale, gray, clayey	6
36.	Sandstone, gray and buff, very fine grained, silty; some claystone and ironstone	1
35.	Siltstone, gray and brown; weathers brown	2
34.	Sandstone, gray, very fine grained; abundant dark grains	2
33.	Siltstone, gray, limy	1
32.	Shale, gray, clayey	6
31.	Sandstone, gray and buff, very fine grained, silty, limy	3
30.	Sandstone, gray and brown; weathers brown; very fine grained, thin bedded and wavy bedded, hard, quartzitic	2
29.	Shale, gray; some thin beds of hard limy claystone that weathers reddish brown	5
28.	Sandstone, gray to brown; weathers brown; very fine grained, thin bedded and wavy bedded, hard, quartzitic	3
27.	Shale, bluish-gray; carbonaceous at top	5
26.	Sandstone, buff and gray, very fine grained, thin-bedded	6
25.	Shale, gray, dark-brown, and black; carbonaceous at top; minor amount of buff sandstone	9
24.	Sandstone, gray, fine- to medium-grained; abundant dark grains	2
23.	Shale, gray, black, and brown; carbonaceous in part; minor amount of sandstone	11

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

		Feet
Lower part of Mesaverde Formation—Continued		
22.	Sandstone, buff, very fine grained, thin-bedded, limy, very limonitic	4
21.	Shale, gray and brown; minor amount of sandstone. Unit is poorly exposed	9
20.	Sandstone, buff and white, fine- to medium-grained, massive; thin bedded in part, crossbedded in part, silty in part, limonitic; abundant dark grains, sporadic red grains; sporadic ironstone concretions as much as 2 in. in diameter; some thin lenses of gray shale. White sandstone occurs in distinct beds 32 ft and 66 ft above base	82
19.	Shale, brown, gray, and black; carbonaceous in part; minor amount of sandstone; some black impure coal beds as much as 1 ft thick near top	23
18.	Sandstone, gray; weathers brown; very fine grained, thin bedded, platy	2
17.	Shale, gray and brown; clayey in part, carbonaceous at top	2
16.	Sandstone, light-gray, fine-grained; abundant dark grains; wood fragments	2
15.	Shale, gray, brown, and black, carbonaceous; sandy near top	4
14.	Sandstone, gray and buff; weathers buff; fine- to medium-grained, massive; silty in part, limonitic, limy; abundant dark grains; some thin shale partings in lower part; forms conspicuous ledge	42
13.	Shale, claystone, coal, and lignite, interbedded. Shale has carbonaceous partings and minor amount of sandstone	8
12.	Sandstone, gray and buff, very fine grained, thin-bedded, limy, silty; minor amount of shale and coal; 22 ft above base is 2.7 ft of brown lignite that contains plant fragments	38
11.	Shale, gray, silty; minor amount of buff sandstone and brown lignite. Brackish water mollusks identified as *Corbula* sp. were found in approximately this same bed 1,000 ft to the south	5
10.	Sandstone, gray and buff; weathers brown and buff; fine-grained, thin-bedded, limy; some thin shale partings, and some thin hard layers of sandstone	8
9.	Claystone, dark-gray; 4 in. of black coal at base	1
8.	Sandstone, bluish-gray; weathers white; fine grained	4
7.	Shale, black and brown, carbonaceous; thin partings of coal	3
6.	Sandstone, bluish-gray; weathers white; fine grained	2
5.	Shale, brown, black, and bluish-gray, carbonaceous; minor amount of coal and thin-bedded sandstone	16
4.	Sandstone, bluish-gray, very fine grained; in beds from ½-in. to 1 ft thick	3
3.	Shale, brown, carbonaceous, gypsiferous; plant remains	3
2.	Sandstone, white and light-gray, fine- to medium-grained, massive; abundant dark grains, sporadic red and green grains; thin beds of brown carbonaceous shale 12 ft above base. This unit is nearly always present at this position and, although it thickens and thins laterally, it is conspicuous throughout most of the area	25

4. *Welton mine-Shotgun Butte section, sec. 13, T. 6 N., R. 1 W., secs. 17, 18, 20, 21, 22, 26, 27, and 35, T. 6 N., R. 1 E.*—Continued

	Feet
Lower part of Mesaverde Formation—Continued	
1. Sandstone, buff, in part greenish; fine to medium grained, massive; crossbedded in part, limy, limonitic, porous, friable; abundant dark grains, sporadic red grains; ironstone concretions that average 1 in. in diameter. Basal sandstone contains gray clay pellets as much as half an in. in diameter. Six feet above base is lenticular gray shale bed which is in part formed by fragments of clay and shale cemented together by sandstone; this bed may be a reworked deposit of Cody Shale. Near the base of unit are other small lenses of shale and sandstone containing shale and clay fragments as much as 1 in. long. Caverns as much as 10 ft in diameter are present on the weathered surface of the sandstone; these caverns apparently were filled with soft shaly sandstone that has been scooped out by wind action	147
Total lower part of Mesaverde Formation	1,622
Total Mesaverde Formation	1,958

Contact between Mesaverde Formation and sandy facies of Cody Shale marked by massive pitted sandstone above and by blocky thin-bedded sandstone and shale below. The thickness of unit 1 is variable and was observed to range from a minimum of 6 ft to a maximum of 150 ft in a distance of 3 miles. A zone of shale and clay fragments, reworked from the Cody Shale, is usually present at the base of unit 1.

Cody Shale.

Base of measured section.

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*

Top of measured section.

	Feet
Mesaverde Formation:	
204. Coal, black, impure; some carbonaceous shale	1
203. Sandstone or siltsone, gray; weathers light gray to white; very fine grained	2
202. Shale, dark reddish-brown and gray; weathers into small fragments; slightly carbonaceous	6
201. Shale, gray, in part silty; contains thin lenses of reddish-brown claystone in lower half	8
200. Sandstone, brown to reddish, very fine grained, thinly crossbedded, limy, limonitic	4
199. Covered interval	78
198. Sandstone, gray to buff; weathers brown; fine-grained, massive to thin-bedded; flaggy in part, silty, slightly limy, limonitic, friable, porous; abundant dark grains, sporadic red grains	3
197. Largely covered interval; outcrop of white sandstone 52 ft above base	116

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Mesaverde Formation—Continued	
196. Sandstone, grayish-buff, very fine grained; thin irregular bedding; limy, hard, quartzitic; abundant dark grains, sporadic red grains	*Feet* 4
Total measured part of Mesaverde Formation	222
Cody Shale:	
Sandy member:	
195. Largely covered interval; sporadic outcrops of gray sandstone	154
194. Sandstone, gray to buff, very fine grained, platy, soft, friable, porous; contains many thin lenses of gray shale and some thin beds of hard brown-weathering gray limy limonitic sandstone that form small ledges in the softer sandstone	93
193. Sandstone, gray to buff, very fine grained, massive to thick-bedded, soft, friable, slightly limy; dark grains; contains some thin zones of gray shale lenses and pockets; many spherical limonite concretions as much as 1½ in. in diameter. Unit forms cliff	29
192. Sandstone, gray to buff, very fine grained, thin-bedded to massive, silty, argillaceous, soft, friable, porous; interbedded with an equal amount of thin beds of gray shale; some beds of hard brown sandstone present; contains *Inoceramus* sp. at top	21
191. Covered interval. Lateral exposures indicate unit is mostly underlain by soft gray sandstone containing some gray shale	87
190. Sandstone, buff and gray, very fine grained, massive to thin-bedded, silty, porous, soft, friable; abundant dark grains, sporadic red grains; contains stringers and pockets of gray shale, some thin beds of hard platy blocky brown-weathering sandstone, and limonitic concretions as much as 2 in. in diameter. Some of the more massive sandstone resembles that of the Mesaverde Formation	23
189. Siltstone, gray and buff, sandy; many thin beds of black shale and some thin beds of hard limy, very fine grained sandstone	82
188. Shale, black, gray, and buff, fissile; contains thin beds of siltstone and sandstone in upper 20 ft	39

USGS Mesozoic locality 23112 (E½NE¼SE¼ sec. 23, T. 6 N., R. 2 E.) at base; age, Eagle equivalents:

Inoceramus aff. *I. sagensis* Owen
Ostrea sp.
Baculites haresi Reeside
Scaphites aquilaensis Reeside
hippocrepis (DeKay)
n. sp.
Haresiceras placentiforme Reeside

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Cody Shale—Continued

Sandy member—Continued *Feet*

187. Cone-in-cone interval, tan, very limy 1
186. Shale, black, finely fissile; some 1- to 2-in. beds of black claystone 50
USGS Mesozoic locality 23111 (E½NE¼SE¼ sec. 23, T. 6 N., R. 2 E.) in basal 1 ft; age, Eagle equivalents:
Inoceramus aff. *I. sagensis* Owen
Scaphites sp.
Baculites haresi Reeside
185. Covered interval 362
184. Largely covered interval. Isolated exposures and potholes indicate it is underlain mostly by gray silty sandstone or sandy siltstone with many gray shale partings 103
183. Siltstone, gray to buff, sandy; argillaceous in part, shaly in part; some beds of very fine grained sandstone and many thin beds of buff and gray fissile shale 160
182. Sandstone, gray and buff, very fine grained, silty, hard, blocky, platy; abundant dark grains and some limonite grains; forms ledge 6
181. Sandstone, gray and buff, very fine grained, thin-bedded, platy, silty, limy; limonitic in part; abundant dark grains; many thin partings of gray and buff fissile shale; top 2 ft contains thin layers of yellow-weathering claystone that form distinctive outcrop 172
USGS Mesozoic localities 23110 and 23430 (NW¼SE¼ NE¼ sec. 23, T. 6 N., R. 2 E.) 100 ft below top; age, Telegraph Creek equivalents
Inoceramus sp.
Ostrea sp.
Baculites sp.
"*Puzosia*" *manosensis* Reeside?
Scaphites leei Reeside
Desmoscaphites bassleri Reeside
Uintacrinus sp.
Marsupites sp.
180. Sandstone, bluish-gray; weathers buff; hard blocky, silty, limy; dark grains 2
179. Sandstone, buff, very fine grained, silty, limy; abundant dark grains; some thin partings of buff fissile shale 22
178. Siltstone and shale, gray to black; contains many thin beds of hard limy bluish-gray siltstone 43
177. Siltstone or very fine grained sandstone, gray; hard in part; some thin beds of black bentonitic shale 64
176. Covered interval; probably underlain by fine-grained sandstone and shale 47
175. Siltstone, gray, soft, deeply weathered, sandy; many thin partings of black bentonitic shale and thin beds of gray, very fine grained sandstone. Some of sandstone appears tuffaceous(?) 73
174. Covered interval; probably underlain by siltstone and shale 24

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Cody Shale—Continued

Sandy member—Continued

	Feet
173. Siltstone and shale, gray, buff, and black; shale is bentonitic in part; unit deeply weathered for most part; some thin beds of gray hard, very fine grained sandstone	184
USGS Mesozoic locality 23109 (center N½NE¼ sec. 23, T. 6 N., R. 2 E.) in claystone concretions 22 to 48 ft above base; age, late Niobrara equivalents:	
Nuculana sp.	
Ostrea congesta Conrad	
Veniella goniophora Meek	
Xenophora sp.	
Baculites asper Morton	
codyensis Reeside	
Scaphites n. sp.	
172. Sandstone, gray; weathers gray and buff; very fine grained, thin bedded, limy, very fossiliferous	2
USGS Mesozoic locality 23106 (center N½NE¼ sec. 23, T. 6 N., R. 2 E.); age, late Niobrara equivalents:	
Inoceramus (*Haploscapha*) *grandis* Conrad	
Ostrea congesta Conrad	
Veniella goniophora Meek	
Clioscaphites vermiformis (Meek and Hayden)	
Scaphites n. sp.	
Baculites codyensis Reeside	
171. Siltstone, gray and buff; interbedded with minor amount of gray and black shale; some gray limy silty concretions in upper half. Unit is deeply weathered	56
170. Shale, gray and black, bentonitic in part; minor amount of siltstone; large *Inoceramus* prisms near top. Unit is poorly exposed	56
169. Siltstone and shale, gray to black; shale is bentonitic in part; siltstone is sandy in part, soft; contains some large *Inoceramus* prisms and oysters. Some thin beds of hard limy siltstone and gray limy claystone concretions. Unit is poorly exposed in part	123
168. Covered interval; probably underlain by black and gray shale containing some thin beds of siltstone	42
167. Siltstone, gray, thin-bedded, limy; abundant dark grains; interbedded in about equal amounts with gray shale. Unit is poorly exposed in part	59
Total sandy member	2, 179

Approximate contact between sandy and shaly members of Cody Shale.

Shaly member:

166. Shale, gray; silty in part, bentonitic in part: contains some limy claystone concretions as much as 2 ft in diameter; some selenite crystals on weathered surface. Unit is deeply weathered	69

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Cody Shale—Continued

Shaly member—Continued

	Feet
165. Shale, black; bentonitic in part; gray siltstone bed near base; contains oyster fragments. Unit is poorly exposed in part	60
164. Largely covered interval. Lateral exposures indicate unit is mostly underlain by black shale containing some bentonitic beds. Some sandy and silty layers near top	269
USGS Mesozoic locality 23108 (SE¼SE¼SW¼ sec. 14, T. 6 N., R. 2 E.) in brown claystone concretions in basal 38 feet; age, late middle Niobrara equivalents: *Turritella* n. sp.; *Baculites codyensis* Reeside; *Scaphites depressus* var. *stantoni* Reeside	
163. Shale, black, fissile; highly bentonitic for most part	43
162. Shale, black, fissile: slightly bentonitic near base; some thin beds of gray siltstone near base	112
USGS Mesozoic locality 23103 (SE¼SE¼SW¼ sec. 14, T. 6 N., R. 2 E.) in brown claystone concretions near top; age, late middle Niobrara equivalents: *Inoceramus* n. sp.; *Gryphaea* sp.; *Pholodomya papyracea* Meek and Hayden; *Dentalium pauperculum* Meek and Hayden; *Polinices* sp.; *Turritella* n. sp.; *Cylichna* sp.; *Scaphites depressus* Reeside; *depressus* var. *stantoni* Reeside; *Baculites asper* Morton; *codyensis* Reeside	
161. Sandstone, grayish-green, fine-grained, highly glauconitic, conglomeratic; salt-and-pepper appearance; abundant dark grains; sporadic red grains and gray clay pellets; grains are angular. Unit contains black and light-colored chert pebbles as much as 1 in. in diameter; 6 in. of brownish-red claystone at top. Sandstone appears reddish in part owing to coating on quartz grains. Unit forms outcrop that can be traced for some distance laterally	5
160. Shale, black; brownish in part; slightly bentonitic in part; silty near base	100
USGS Mesozoic locality 23107 (center SE¼ SW¼ sec. 14, T. 6 N., R. 2 E.) in gray limy claystone concretions; age, late middle Niobrara equivalents: *Membranipora* sp.; *Inoceramus stantoni* Sokolow; *Baculites asper* Morton; *codyensis* Reeside	

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Cody Shale—Continned
Shaly member—Continued

	Feet
159. Largely covered interval. Potholes and lateral exposures indicate unit is mostly underlain by gray and black fissile, slightly bentonitic shale	82

USGS Mesozoic locality 23101 (center SE¼ SW¼ sec. 14. T. 6 N., R. 2 E.) 35 feet above base in gray claystone concretions; age, late middle Niobrara equivalents:
Inoceramus stantoni Sokolow
Gryphaea sp.
Caryocorbula n. sp.
Anisomyon n. sp. aff. *A. frontierensis* Sidwell
Turritella n. sp.
Oligoptycha n. sp.
Cylichna sp.
Baculites codyensis Reeside
Phlycticrioceras oregonense Reeside

158. Shale, black; bentonitic in part	26

USGS Mesozoic locality 23100 (center SE¼ SW¼ sec. 14, T. 6 N., R. 2 E.) in gray limy claystone concretions in lower half; age, late middle Niobrara equivalents:
Nucula sp.
cf. *N. corsicana* Stephenson
Inoceramus stantoni Sokolow
sp.
Exogyra sp.
Anomia sp.
Volsella sp.
Crassatella wyomingensis (Sidwell)
Cardium n. sp.
Brevicardium n. sp.
Caryocorbula n. sp.
Dentalium pauperculum Meek and Hayden
Gyrodes cf. *G. ednae* Sidwell
Turritella sp.
Drepanochilus sp.
Urceolabrum sp.
Cylichna sp.
Eutrephoceras sp.
Scaphites ventricosus Meek and Hayden var. *depressus* Reeside
Phlycticrioceras oregonense Reeside
Baculites asper Morton
codyensis Reeside
?n. sp.
Texanites shoshonensis (Meek)
shoshonensis var. *crasus* Reeside
shoshonensis n. var.

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Cody Shale—Continued

Shaly member—Continued — *Feet*

157. Shale, black; bentonitic in part — 58

USGS Mesozoic localities 23098 and 23099 (SW¼ NE¼ SW¼ sec. 14, T. 6 N., R. 2 E.) in gray claystone concretions in basal 4 ft and at top; age, late middle Niobrara equivalents:

Nuculana sp.
Inoceramus stantoni Sokolow
Exogyra sp.
Dentalium pauperculum Meek and Hayden
Gyrodes sp.
Turritella sp.
Polinices sp.
Acteon? sp.
Scaphites vermiformis Meek and Hayden var. *binneyi* Reeside
Baculites codyensis Reeside

156. Shale, dark-gray, in part brown; finely fissile, bentonitic in part, silty in part; 4 ft below top is 1 ft of impure bentonite; some gray limy claystone concretions 30 ft above base; 65 ft above base some thin beds of reddish-brown claystone containing *Scaphites* sp — 86

155. Covered interval. Lateral exposures indicate unit is underlain by black and gray shale — 70

154. Shale, dark-gray to black; brownish in part. Upper part contains thin beds of hard brownish-red limy claystone — 17

153. Shale, dark-gray to black; brownish in part; weathers in brown and gray bands; finely-fissile; slightly bentonitic in part near base. Basal 1 ft contains abundant *Inoceramus* prisms — 28

USGS Mesozoic locality 23095 (SW¼NE¼SW¼ sec. 14, T. 6 N., R. 2 E.) in gray claystone concretions in top 1 ft; age, late middle Niobrara equivalents:

Inoceramus n. sp.
Inoceramus (*Haploscapha*) *grandis* Conrad
Ostrea n. sp.
Veniella aff. *V. goniophora* Meek
Turritella sp.
Acteon? n. sp.
Oligoptycha sp.
Actinocamax sp.
Baculites asper Morton
?n. sp.
Scaphites binneyi Reeside
n. sp.

152. Shale, dark-gray, fissile; many beds of gray and brown limy claystone concretions; cone-in-cone structure in some of the claystone beds. *Baculites* fragments near top — 80

151. Shale, dark-gray and black; brownish in part, finely-fissile; bentonitic in part; some thin beds of brown and gray limy

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E*—Continued

	Feet
Cody Shale—Continued	
Shaly member—Continued	
151. Shale, etc.—Continued siltstone; contains many *Inoceramus* prisms on weathered slopes	326
150. Bentonite, white and cream-colored, impure	1
149. Shale, dark-gray and black; brownish in part; weathers in brown and silver-gray bands; finely fissile; bentonitic in part; sporadic gray limy claystone concretions 75 ft above base; many *Inoceramus* prisms on weathered slopes; hexagonal biotite flakes in shale near base	115
Total shaly member	1, 547
Total Cody Shale	3, 726

Remainder of measured section adapted from Love and others (1947, p. 18–26).

Frontier Formation:

148. Sandstone, gray, fine- to medium-grained, clayey, limy, soft. Upper 30 ft is coarse-grained and contains many chert pebbles as much as one-fourth inch in diameter	115

USGS Mesozoic locality; 19532 and 23438 (S½SW¼NW¼ sec. 14, T. 6 N., R. 2 E.) in brown limy concretions; age, early Niobrara equivalents:

Serpula sp.
Crinoid ossicles, possibly *Uintacrinus*
Membranipora sp.
"*Arca*" n. sp.
Inoceramus deformis Meek
Oxytoma aff. *O. nebrascensis* (Evans and Shumard)
Pteria gastrodes Meek
Ostrea congesta Conrad
n. sp.
Camptonectes platessa White
Lithophagus sp. *A*.
? sp. *B*.
Modiolus? sp.
Pholadomya coloradoensis Stanton
Laternula n. sp.
Psilomya elongata (Stanton)
? n. sp.
Crassatellites n. sp.
Crassatella wyomingensis (Sidwell)
Cardium pauperculum Meek
Tapes? *cyprimeriformis* Stanton
Tellina modesta Meek
Legumen aff. *L. planulatum* Conrad
Cymbophora utahensis (Meek)
Martesia aff. *M. cuneata* Meek and Hayden
Polynices? sp.
Gyrodes depressa Meek
conradi Meek

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Frontier Formation—Continued

148. Sandstone, etc.—Continued
Anchura n. sp.?
Turritella whitei Stanton
Drepanochilus n. sp.
Seminola? n. sp.
Pyropsis sp.
Epitonium? n. sp.
Paladmete? n. sp.
Turris? n. sp.
Volutoderma plicatula Dall
dalli (Stanton)
Anisomyon frontierensis Sidwell
Eutrephoceras sp.
Baculites cf. *B. besairei* Collignon
Scaphites ventricosus Meek and Hayden
Placenticeras planum Hyatt
Placenticeras guadalupe (Roemer)
Cone and twigs of an *araucarian* conifer, commonly identified as *Sequoia reichenbachi* Geinitz

		Feet
147.	Shale, dark-gray; silty and sandy in part	256
146.	Sandstone, yellowish-gray, chiefly fine grained; shaly; many laminae of black shale along bedding planes. Upper 50 ft thin-bedded and harder. Unit forms inconspicuous ledge	126
145.	Shale, dark-gray, silty; bentonitic throughout	33
144.	Sandstone, light-gray, fine- to medium-grained, noncalcareous; stained yellowish brown; much dark-gray interstitial clay	4
143.	Shale, dark-gray to black, silty; 10 ft of very sandy shale 5 ft above base	90
142.	Sandstone, yellowish-gray, fine- to medium-grained; many dark-colored mineral grains	10
141.	Shale, dark-gray, silty; bentonitic in upper part	50
140.	Sandstone, gray, locally iron-stained, fine-grained, noncalcareous, thin-bedded	3
139.	Shale, light to dark-gray, bentonitic	43
138.	Shale, gray; silty and sandy in part, siliceous	15
137.	Tuff, creamy-yellow to white, soft; massive and waxy in lower half, harder and bedded near top. Capped by 0.4 ft of hard thin-bedded white tuff	7
136.	Shale, black, flaky, soft	4
135.	Sandstone, yellowish-tan to gray, fine- to medium-grained; many dark-colored mineral grains; contains much interstitial, gray clay. Unit is siliceous, carbonaceous, and nodular; forms ledge	6
134.	Sandstone, light-gray to olive-brown, thin-bedded; weathers gray to rusty brown; fine to medium grained; noncalcareous to slightly calcareous; many chert grains; contains irregular masses of interstitial clay; lower 30 ft forms prominent slabby ledge and upper 10 ft forms conspicuous smooth outcrop	106

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Frontier Formation—Continued	
133. Shale, dark olive-gray, silty and sandy; basal contact sharp; limy and harder near top	21
Total Frontier Formation	889

The following section was measured half a mile to the northeast, in the SW¼ sec. 11, T. 6 N., R. 2 E. Offset was made on contact between the two formations.

Mowry Shale and upper black shale member of Thermopolis Shale:	
132. Shale, dark-gray; weathers bluish gray; silty, hard,, brittle, siliceous. Fish scales up to within 3 ft of top; scattered sand grains; 3 ft of bentonite 36 ft above base; lower 25 ft poorly exposed	47
131. Sandstone, light bluish-gray; weathers brownish gray; fine- to medium-grained; many chert grains; contains much interstitial clay. Unit is hard and quartzitic, and it caps ridge	3
130. Shale, dark-gray; weathers light-gray; hard, siliceous; fish scales throughout except in basal 5 ft; some black soft shale in lower 50 ft, 3 ft of bentonitic shale 21 ft above base, 6 ft of bentonite 45 ft above base, 3 ft of bentonite 114 ft above base, 1 ft of bentonite 130 ft above base and 3 ft of bentonite 340 ft above base	343
Possible contact between Mowry Shale and upper black shale member of Thermopolis Shale.	
129. Shale, dark-gray to black, flaky; some silty layers; scattered limonite concretions; 1 ft of bentonite 69 ft above base and 3 ft of bentonite 78 ft above base; alternating beds of bentonite and shale, each about 1 ft thick, from 135 to 147 ft above base; 1 ft of bentonite 166 ft above base	167
Total interval between top of Mowry Shale and top of Muddy Sandstone Member of Thermopolis Shale (contact between Mowry and Thermopolis Shales probably some distance above this point)	560

Contact between upper black shale member and Muddy Sandstone Member of Thermopolis Shale.	
Thermopolis Shale:	
Muddy Sandstone Member:	
128. Sandstone, gray to pinkish-brown; weathers light-gray; stained with limonite; fine to medium grained; many chert grains; very shaly, thin bedded; forms a ledge	6
127. Shale, dark-gray to black, flaky; silty and sandy; some layers of very shaly fine grained sandstone near base and 6 in. of very shaly medium-grained sandstone 5 ft above base; more sandy near top; 1 ft of bentonite 6 ft above base	15
126. Sandstone, pinkish-brown, very fine grained, shaly, massive, hard; caps ridge; contains scattered lignite fragments	2

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Thermopolis Shale—Continued

Muddy Sandstone Member—Continued

	Feet
125. Sandstone, light-gray, mottled black; very carbonaceous, almost a sandy coal; very shaly	1
124. Sandstone, buff to pinkish-brown; weathers light yellowish gray; limonitic, medium grained, noncalcareous, argillaceous; many chert grains; laminae of carbonaceous material in lower 2 ft; thin bedded; forms rounded ledge	17
123. Sandstone and shale, in alternating beds. Sandstone is dark gray, shaly, fine grained; shale is black, fissile	7
Total Muddy Sandstone Member	48

Lower black shale member:

122. Shale, dark-gray to black; chiefly flaky but contains thin silty layers and sparse shaly sandstone partings; scattered limonitic concretions; bentonitic layers 30 to 60 ft above base; poorly exposed	163
Total lower black shale member	163
Total Thermopolis Shale	211

Morrison and Cloverly Formations, undifferentiated:

121. Shale and sandstone, light-gray to dark-gray; weathers olive brown. Sandy shale alternates with thin layers of platy, very fine grained, very shaly drab sandstone. Unit is soft and forms slope; hard sandstone ledge 1 ft thick 15 ft below top and another hard ledge 1 ft thick at top	68
120. Sandstone, light-tan, stained rusty brown to nearly black; fine to medium grained; many well-rounded grains; well bedded, crossbedded in part; soft, friable; forms prominent ledge	14
119. Shale, light-gray, sandy and silty, soft; some ironstone concretions	9
118. Sandstone, light-gray; weathers light rusty brown; very fine grained, noncalcareous, hard, irregularly bedded; forms inconspicuous ledge	2
117. Sandstone, olive-brown, gray in lower part, fine grained, shaly, soft	15
116. Sandstone, grayish-tan, fine-grained; shaly, particularly in lower half; noncalcareous, hard; forms ledge	2
115. Partly covered interval. Poor exposures of shale; lower part gray but stained brick red, upper part dark gray to black; sandy; several layers of soft shaly sandstone in lower half	9
114. Sandstone, light yellowish-brown; stained rusty-brown; fine grained, moderately clean, slightly limy, well bedded, hard; locally forms prominent ledge	9
113. Siltstone, gray, slabby; upper part interbedded with fine-grained thin-bedded sandstone weathering rusty brown to black; upper 4 ft all sandstone	12

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

		Feet
Morrison and Cloverly Formations, undifferentiated—Continued		
112.	Sandstone, gray to yellowish-gray; weathers olive and buff; fine grained; lower part weathers into small olive-colored angular fragments; upper part forms small rusty ledge	12
111.	Siltstone and silty claystone, reddish at base, gray and buff in upper part; soft, blocky	22
110.	Sandstone, white; weathers yellowish buff; medium grained; subangular to rounded grains; some black mineral grains; two beds of olive-green sandstone in upper part. Unit is porous and crossbedded. Some beds form ledges	11
109.	Claystone, variegated. Lower 45 ft is purplish and is overlain by 10 ft of hard gray siltstone and claystone, then by 6 ft of medium-grained white sandstone with limy layers, and then by 20 ft of purplish silstone and claystone becoming nearly black at top. Bone fragments, chalcedony nodules, and dark-purplish ironstone concretions weather out on slope. Polished chert pebbles present. Unit is poorly exposed	81
108.	Sandstone white; weathers gray and brown; medium to fine grained, porous; very limy at top and contains sandy limy concretions; sparse polished chert pebbles	10
107.	Siltstone and claystone, variegated, chiefly purple and and red; some greenish-gray layers; 1 ft of soft, very limy red sandstone 9 ft above base	30
106.	Claystone, gray, yellow stained, soft, blocky; forms conspicuous unit	1
104.	Claystone and siltstone, brilliant-red, interbedded with dull-red and yellow zones; some layers of red sandstone and quartzite; bright-red claystone and siltstone at top	35
104.	Covered interval on valley floor. Probably underlain by purple and gray claystone and siltstone	30
103.	Conglomerate and sandstone. Conglomerate consists of rounded chert fragments ranging in size from coarse sand to pebbles 1 in. in diameter; fairly well sorted. Sandstone is white, crossbedded; has rounded to subangular grains; soft, porous; sparkles with abundant quartz crystal facets; some irregular limonitic staining. Both conglomerate and sandstone are apparently channel deposits cut into underlying rocks. Unit forms cliff	27
A distinct lithologic change at this point marks possible contact between Cloverly and Morrison Formations. There are no quartz crystal sandstone and conglomerate beds below. The underlying sandstone grades laterally into dully variegated claystone.		
102.	Sandstone, white, medium- to fine-grained; forms conspicuous rounded smooth cliff. The unit is remarkably homogeneous, moderately soft, and porous, and has some limonite-stained zones. At 70 and 125 ft above base of cliff are lenses of gray compact limy sandstone weathering light brown. The upper 32 ft is soft, very argillaceous, and pale greenish white; it contains hard sandstone balls as much as 1 ft in diameter, that have small round ironstone centers	162
	Total Morrison and Cloverly Formations, undifferentiated	561

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

Contact between Morrison and Cloverly Formations, undifferentiated and "upper Sundance" appears gradational, possibly because of extensive reworking of sandstone of the "upper Sundance" at the time of deposition of the remarkably thick sandstone in the basal part of the overlying sequence.

Sundance Formation:

"Upper Sundance":

		Feet
101.	Sandstone, gray to green, medium- to fine-grained, thin-bedded; contains pale-green glauconite in rounded grains near base and fine rounded grains of bright and pale-green glauconite near middle; several thin beds of hard, very limy greenish-gray sandstone containing lenses of green shale near base	15
100.	Limestone, gray, greenish, and brick-red, very sandy; contains finely disseminated bright-green glauconite; forms conspicuous dip slopes	1
99.	Sandstone, light grayish-green, medium- to fine-grained, soft and friable; contains abundant, finely disseminated bright-green glauconite	1
98.	Siltstone, dark-red to brick-red	2
97.	Limestone, red, very hard; weathers into rounded blocks; forms small ledge	1
96.	Siltstone, dark grayish-green at base, purplish in middle, light-green at top; flaky; fractures into small pieces	1
95.	Sandstone, light-green; medium-grained, even textured, soft, friable, thin bedded; rounded grains; contains abundant grains of bright-green glauconite; crossbedded in part	19
94.	Sandstone, greenish-gray; weathers yellow; many black grains and rounded bright-green glauconite grains; friable, medium grained, soft; hard ledge at top	8
93.	Sandstone, yellowish-green, medium-grained; contains rounded orange and black mineral grains and abundant glauconite; moderately soft; massive to thick bedded; 4.5 ft above base is 1 ft of gray sandy fine-grained glauconitic limestone. Forms conspicuous cliff	19
92.	Sandstone, gray; weathers yellow; medium-grained; contains rounded grains of black mineral and bright-green glauconite	7
91.	Sandstone, grayish-green; weathers buff; medium-grained, soft, friable; contains one thin bed of sandy limestone	3
90.	Covered interval; probably underlain by glauconitic soft gray sandstone	13
89.	Limestone, gray; weathers light brown; very sandy, fossiliferous; many black grains and abundant glauconite; forms ledge	2
88.	Sandstone, gray; weathers yellowish to buff; very limy, glauconitic, fossiliferous; contains rounded sand grains and many dark mineral grains; central part forms prominent cliff	18

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Sundance Formation—Continued	
"Upper Sundance"—Continued	
87. Limestone, brown, with gray and orange flecks; weathers tan; coarsely crystalline, very hard and compact, fossiliferous; contains small black mineral grains and glauconite	1
86. Covered interval; apparently underlain by yellowish-green to gray soft friable medium-grained glauconitic sandstone	8
85. Limestone, gray; weathers rusty; hard, irregularly bedded, fossiliferous	3
Offset half mile northeast along strike to SE¼SW¼ sec. 2, T. 6 N., R. 2 E.	
84. Siltstone and sandstone, dark-green to black; glauconitic; contains gypsum crystals; thin fossiliferous limestones near base, well-defined glauconitic sandstone near top	28
83. Limestone, gray; weathers reddish buff; crystalline, glauconitic; forms ledge	1
82. Sandstone and siltstone, dark-green, highly glauconitic, fossiliferous; thin beds of fossil coquina, "Belemnites" in place at base; sporadic pebbles and large sand grains at base	40
81. Siltstone and shale, dark-green to gray, glauconitic	1
Total "upper Sundance"	192
"Lower Sundance":	
80. Shale, olive-green to gray, soft; gypsum crystals at top	5
79. Sandstone, gray, fine- to medium-grained, nonglauconitic; interbedded with olive-green shale	1
78. Shale, olive-green, soft; contains gypsum crystals and lenses of dark green fine-grained hard sandstone	7
77. Sandstone, white to gray, fine-grained, thin-bedded; some gray shale partings; forms ledges	12
76. Limestone, brownish-gray, sandy; composed chiefly of oolites	1
75. Sandstone, gray, fine-grained, thin-bedded; gray shale partings	4
74. Limestone, dark-gray; weathers light gray; sandy; composed chiefly of small gray oolites	1
73. Sandstone, gray to white, fine-grained, thin bedded; interbedded with gray shale; forms ledges	14
72. Shale, gray, silty; a few thin beds of grayish-white fine-grained sandstone. Unit is poorly exposed	13
71. Sandstone, brownish-gray; weathers buff; contains abundant calcareous oolites and sparse large rounded frosted sand grains; forms ledges	9
70. Limestone, white; weathers buff; sandy, oolitic	3
69. Sandstone, light-gray, thin-bedded, fine-grained; abundant calcareous oolites	2
68. Limestone, grayish-white, fine-grained, sandy	1

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Sundance Formation—Continued	
"Lower Sundance"—Continued	
67. Sandstone, gray; weathers brown to yellowish; fine-grained; small rounded red grains scattered among clear quartz grains of the same size; thin greenish sandy shale parting at top	5
66. Limestone, gray; interbedded with grayish-brown sandstone and greenish-gray shale; some red oolites and large rounded sand grains	6
65. Shale, grayish-green, silty, soft; a lens of salmon-colored siliceous materials 2 in. thick	5
64. Sandstone, shale, and limestone, interbedded. Sandstone is gray to greenish and reddish, limy, very fine grained, oolitic; shale is dark greenish gray, sandy; limestone is brownish gray, oolitic, sandy	7
63. Sandstone and siltstone, dark-red and brown, very fine grained, moderately soft. One mile southwest the following fossils were collected from this bed (USGS loc. 19358): *Trigonia quadrangularis* Whitfield, *Pleuromya* sp., *Cardinia* sp	9
Total "lower Sundance"	105
Gypsum Spring Formation:	
62. Dolomite, light-gray to white, earthy, dense to porous, irregularly bedded	9
61. Siltstone, brick-red near base, purplish-red near top, soft; contains thin beds of grayish-green siltstone	30
60. Dolomite, gray, chalky, porous, silty	3
59. Siltstone, lavender, limy, soft	4
58. Dolomite and dolomitic siltstone, gray, lavender, buff, and salmon-red, well-bedded to poorly bedded, moderately hard; forms ledges	11
57. Limestone, light-gray, fine-grained, sublithographic, poorly bedded	3
56. Siltstone, dark-red, slightly mottled with green	1
55. Dolomite, white, chalky, mottled with lavender; fine-grained, hard, homogeneous	2
54. Siltstone, dark-red, slightly mottled with green	5
53. Dolomite, white, chalky, mottled with lavender; fine-grained, hard, homogeneous	1
52. Siltstone, dark-red, slightly mottled with green	5
51. Dolomite, gray and red; weathers reddish buff; homogeneous, crystalline, limy, slabby	2
50. Limestone, gray, porous to dense, sublithographic to crystalline	3
49. Dolomite, white, chalky, homogeneous, hard	1
48 Siltstone, dark-red, hard	1
47. Limestone, light-gray, poorly bedded, sublithographic; interbedded with reddish and greenish silty shale	3
46. Dolomite, white, chalky, limy, porous, poorly bedded	2
45. Siltstone, dark-red to brick-red; some green mottling	32
44. Gypsum, white, crystalline	1

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Gypsum Spring Formation—Continued	
43. Siltstone, dark-red, mottled with black spots	1
42. Gypsum, white; interbedded with thin red shale laminae; forms cliff	45
41. Siltstone, dark-red; interbedded with fine-grained red sandstone. Unit is poorly exposed	10
Total Gypsum Spring Formation	175
Because of poor exposures, contact between Gypsum Spring Formation and Nugget Sandstone is only approximate.	
Nugget Sandstone:	
40. Sandstone and siltstone, dark-red; some small angular fragments of white to yellow siltstone. Unit is poorly exposed	8
39. Sandstone, dark-red, fine-grained; many small rounded grains, a few large frosted grains; many small angular fragments of white to yellow siltstone	1
38. Sandstone, bluish-gray; stained yellowish-brown; large rounded frosted quartz grains in matrix of smaller rounded grains	1
37. Sandstone, dark-red; some bluish-gray sandstone beds; large rounded frosted quartz grains in finer grained matrix	30
36. Sandstone, dark-red, shaly; large rounded frosted quartz grains in finer grained matrix; some small black grains. Angular fragments of yellow siltstone from underlying rocks reworked into basal part of sandstone	4
Total Nugget Sandstone	44
Chugwater Formation:	
Popo Agie Member:	
35. Siltstone, mustard-yellow; sporadic large rounded sand grains in lower part	7
Offset 1¼ miles southwest to the center of sec. 10, T. 6 N., R. 2 E. Nowhere in this area is the entire Popo Agie section exposed, nor are there key beds on which to offset; therefore, the thickness of the interval between the top of the Popo Agie Member and Alcova Limestone Member of the Chugwater Formation is an approximation.	
34. Covered interval; probably underlain chiefly by red siltstone, red and purple shale, and fine-grained red sandstone	37
33. Shale, grayish-purple to maroon, silty, limy; many ferruginous limestone nodules; gypsum nodules in lower half; 6 in. of limestone pellet conglomerate 2 ft below top	68
32. Sandstone, light orange-red, fine-grained, limy, soft; 2 ft of white sandstone forms ledge at base	20
31. Shale, grayish-purple, very limy; many small limestone nodules; 6-in. bed of nodular limestone 5 ft above base	14
30 Sandstone and shale; purplish-gray limy silty shale alternates with gray to purplish massive to thin-bedded fine-grained limy sandstone	36

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Chugwater Formation—Continued	
Popo Agie Member—Continued	
29. Sandstone and conglomerate; sandstone is light orange red, fine grained, limy, and interbedded with irregular lenses of purplish-gray limestone pellet conglomerate; conglomerate most abundant near top and bottom of unit	31
Total Popo Agie Member	216
Crow Mountain Sandstone Member:	
28. Sandstone, light brownish-red to gray, fine-grained; chiefly clean but with a few soft shaly beds. Lower half forms cliff	52
27. Sandstone, light brownish-red, fine- to medium-grained; some larger well-rounded frosted grains in a finer grained matrix; irregular thin bedding; conspicuous cross-lamination in part; lithologically identical to Nugget Sandstone; small angular fragments of underlying Alcova Limestone Member in lower 1 ft. Unit forms massive smooth cliff	36
Total Crow Mountain Sandstone Member	88
Alcova Limestone Member:	
26. Limestone, gray; some violet-red laminae and surface stains; finely crystalline to sublithographic; irregular contorted lamination; hard; forms prominent ledge	4
Red Peak Member:	
25. Sandstone, light yellowish-brown irregularly layered with pastel pink and violet; fine to medium grained, limy, soft	8
24. Sandstone and shale, light brownish-red. Sandstone is very fine grained and slabby: shale is silty and soft	5
23. Sandstone, light brownish-red, fine-grained, limy, moderately clean; silty in lower half; silty and shaly in upper half. Lower half forms two prominent ledges	52
22. Sandstone, light brownish-red, slabby; contains 2 ft of bluish-violet waxy shale and thin-bedded dolomitic siltstone 62 ft above base. Upper half of unit is chiefly silty shale interbedded with soft shaly sandstone	151
Fault.	
21. Estimated interval of section cut out by fault based on measurements half a mile to northeast	273
20. Sandstone and shale. Sandstone is light brownish red, soft, shaly, thin bedded, ripple marked; shale is brownish maroon, silty. Unit contains some thin beds of greenish-gray limy sandstone. Three prominent ledges of sandstone: one 15 ft thick at top of unit, one 30 ft thick 50 ft below top, and one 10 ft thick 100 ft below top	155

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Chugwater Formation—Continued	
Red Peak Member—Continued	
19. Sandstone, light brownish-red, fine-grained, shaly, limy, thin-bedded; many beds ripple marked. Beds 2 to 10 ft thick alternate with beds 1 to 5 ft thick of more clayey and finer grained sandstone and maroon shale. Lower two-thirds forms prominent cliff	101
18. Sandstone, siltstone, and shale. Sandstone is brownish red, fine grained, clayey; soft in lower half; grades upward into sequence of brownish-red shaly sandstone and shale interbedded in about equal amounts; limy. Unit contains two 4-ft-thick beds of greenish-gray sandstone, one 41 ft below top, the other 20 ft below top	123
17. Siltstone, light-ocher; slightly limy or dolomitic; blocky in upper part, thin bedded in lower part; soft; color change at top is sharp and even. Unit is poorly exposed in part	41
Total Red Peak Member	909
Total Chugwater Formation	1, 217
Dinwoody Formation:	
16. Limestone, dolomitic limestone, and dolomite. Unit consists chiefly of finely crystalline sandy limestone and thin beds of sublithographic dolomite. A 6-in. bed of porous brownish-violet crystalline limestone near middle, and some grayish-green silty shale beds in upper part. Sequence is thin bedded, slabby, ripple marked	13
15. Siltstone, greenish-gray; weathers tan; shaly, very slightly limy or dolomitic, slabby; harder near top; intertongues with overlying unit	8
14. Dolomite and dolomitic limestone, gray to tan; some greenish layers near top; fine-grained, sandy, very thin bedded and slabby; forms ledge	2
13. Limestone, white to gray, soft, chalky; thin lenses of dolomite; layers of grayish-violet crystalline sandy limestone near base	5
12. Breccia, consisting of fragments of laminated white chalky dolomite in a matrix of very limy fine-grained sandstone; some spongy masses of limestone. In places the dolomite is contorted without being brecciated. Thin partings of silty grayish-green shale near top	1
11. Sandstone and shaly dolomite, light-tan; weathers brown; some green layers; thin bedded; shale blocky and soft	5
10. Sandstone, light-tan to greenish-gray, very fine grained, clayey, noncalcareous, thin bedded; ripple marks conspicuous in some beds; forms slabby ledge	6
9. Partly covered interval; sporadic outcrops of tan thin-bedded platy soft dolomitic shale and siltstone; at base is 6 in. of fine-grained sandstone that contrasts sharply with underlying	

5. *East Sheep Creek section, secs. 2, 3, 10, 11, 14, 15, 23, and 24, T. 6 N., R. 2 E.*—Continued

	Feet
Dinwoody Formation—Continued	
9. Partly covered interval, etc.—Continued crystalline limestone and dolomite; basal contact is sharp and uneven	30
Total Dinwoody Formation	70
Contact between Dinwoody and Phosphoria Formations. The underlying beds were measured about one-fourth mile farther north. Offset was made on the dolomitic limestone directly below the contact. Because of structural complications and possible slight facies changes, there may be a discrepancy in correlation of as much as 20 ft.	
Phosphoria Formation:	
8. Limestone and dolomitic limestone in upper 1 ft, violet gray, crystalline, porous, hard; weathers to a rough surface. Lower 14 ft of interval is covered	15
7. Limestone, gray, medium crystalline, hard; dolomitic in part; local abundance of white to gray chert, especially in upper part, and much pyrite; unit is massive to well bedded and weathers to a rough surface; softer layers clayey and glauconitic; fossiliferous throughout but fossils more abundant in softer layers	33
6. Chert and limestone in proportion of 7:3. Chert is gray, in irregular nodules as much as 2 in. thick, has thinner branches roughly alined in layers in a matrix of grayish-violet crystalline limestone; some round nodules of white granular chert 1 in. in diameter. Unit is hard and massive; forms prominent cliff	25
5. Covered interval, probably underlain by soft clayey limestone and dolomite and gray shale	137
4. Chert, white to brownish-gray, granular; hard; irregular beds as much as 2 in. thick; a few thin beds of limestone; some crystalline quartz in upper 1 ft	4
3. Limestone, white, soft, granular; some hard irregular nodules of brownish-gray crystalline limestone	2
2. Covered interval; sporadic outcrops of light-gray to white hard dolomite or dolomitic limestone, some soft very shaly tan dolomite or dolomitic shale, and some white granular chert nodules as much as half an inch in diameter	23
1. Sandstone, light-gray to creamy-tan, fine-grained, soft. Limestone and dolomite content increases progressively from bottom to top	3
Total Phosphoria Formation	242
Tensleep Sandstone: Sandstone, gray; weathers buff to brown; fine- to medium-grained; many well-rounded grains; hard and quartzitic on weathered surface but softer on fresh surface; porous; limy in part	220
Base of measured section.	

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*

Top of exposures.

Fort Union Formation:

Shotgun Member:

		Feet
170.	Siltstone and claystone, gray; minor amount of gray and buff sandstone and thin beds of brown carbonaceous shale	164
	Total measured part of Shotgun Member	164

Lower part:

169.	Sandstone, buff, massive	30
168.	Sandstone, white and light-gray, fine- to coarse-grained, massive to thinly crossbedded, conglomeratic; abundant dark grains, some red grains; lenses of pebble and granule conglomerate with fragments of quartzite, siliceous shale or porcelanite, and chert; sporadic concretionlike masses of brown-weathering thin-bedded sandstone as much as 6 ft in diameter	10
167.	Largely covered interval; probably underlain mostly by gray siltstone	22
166.	Sandstone, light-gray and buff, fine- to medium-grained, massive, porous; abundant dark grains, sporadic red grains; conspicuous white angular grains of siliceous shale or porcelanite; some beds of concretionlike masses of hard limy wavy-bedded brown-weathering fine-grained sandstone; some thin lenses of bentonitic siltstone and claystone near top	55
165.	Siltstone, gray; minor amount of gray and buff sandstone	27
164.	Siltstone and claystone, gray and buff; shaly for most part; some thin beds of buff and gray sandstone	36
163.	Covered interval. Lateral exposures indicate unit is mostly underlain by gray siltstone, some gray fine-grained sandstone, and buff very fine grained silty ferruginous sandstone	29
162.	Siltstone, gray; shaly in part; minor amount of gray and white fine-grained sandstone	12
161.	Siltstone, gray, shaly in part; 2.5 ft of carbonaceous brown shale 45 ft above base and several 1- to 2-ft beds of buff and light-gray massive fine-grained sandstone in upper 20 ft; some thin beds of ironstone	76

Fossil collection (SE¼ sec. 25, T. 6 N., R. 2 E.); age, Paleocene:

Platanus raynoldsi
Aralia notata
Rhamnus cleburni
Sassafras sp.
"Problematic" root stock

160. Sandstone, light-gray, fine-grained, massively crossbedded, poorly sorted, porous, friable; abundant dark grains, sporadic red grains; conspicuous coarse grains of white siliceous shale or porcelanite. Some thin beds of hard brown to black ferruginous sandstone or ironstone that

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

		Feet
Fort Union Formation—Continued		
Lower part—Continued		
160.	Sandstone, etc.—Continued contain plant impressions; some thin beds of gray shale and siltstone. Fossil leaves at top were identified by R. W. Brown as Paleocene in age	82
159.	Siltstone, gray and buff	13
158.	Largely covered interval; probably underlain mostly by light-gray, very fine grained massive sandstone	21
157.	Sandstone, light-gray, very fine grained; coarse grained in part, silty, crossbedded; massive in part, porous, slightly friable; dark and red grains; contains carbonaceous fragments; some thin beds of hard brown-weathering ferruginous sandstone and ironstone and beds of silty gray claystone. Individual beds in unit are lenticular. Fossil leaves at top were identified by R. W. Brown as Paleocene in age	121
156.	Claystone, gray; silty in part, carbonaceous in part, bentonitic; minor amount of gray sandstone	19
155.	Sandstone, white and light-gray, very fine grained, massive to thinly crossbedded; flaggy in part, silty in part, porous, friable; abundant dark grains. At top is 1 ft of hard brown-weathering fine-grained sandstone that contains much hematite. Unit forms cliff	30
154.	Shale, gray; silty in part; 4 ft of red shale in middle of unit forms distinctive band in gray shale slope	27
153.	Sandstone, white, light-gray, and buff, fine- to medium-grained, massively crossbedded, poorly sorted, friable, porous; limonitic in part; abundant dark grains, sporadic red and pink grains. Unit thickens and thins laterally	16
	Total lower part	626
	Total measured part of Fort Union Formation	790

Contact between Fort Union Formation and Meeteetse Formation. No Lance equivalents recognized.

Meeteetse Formation:		
152.	Shale, gray and brown; carbonaceous in part; minor amount of gray fine-grained sandstone; at top, 1 ft of brown and black coaly shale that contains more coal laterally along outcrop	62
151.	Sandstone, buff and gray, fine to medium-grained, massive, poorly sorted, soft, friable, porous; abundant dark grains; some gray shale and brown carbonaceous shale; abundant large concretionlike masses 2 to 10 ft in diameter of hard wavy-bedded brown ferruginous limy sandstone that weathers out on the slopes. Unit forms conspicuous outcrop and can be recognized over long distances laterally	76
150.	Shale, gray, bentonitic; interbedded with soft sandstone; some thin beds of brown carbonaceous shale	32
149.	Sandstone and siltstone, yellow and gray, soft; weathers into a powder with no induration	6
148.	Shale, brown, carbonaceous; some black coal partings	2

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

Meeteetse Formation—Continued

		Feet
147.	Sandstone, yellow, soft; interbedded with gray bentonitic shale; some thin beds of hard limy siltstone	17
146.	Shale, brown, carbonaceous; some black coal partings	3
145.	Sandstone and claystone, gray and buff	2
144.	Shale, brown, carbonaceous, hard; some black coal partings	2
143.	Claystone, grayish-blue; silty in part	1
142.	Shale, brown and gray, carbonaceous; bentonitic in part; some black coal partings	3
141.	Sandstone, yellow, soft, silty, bentonitic	5
140.	Shale and coal beds:	

	Ft	in.
Shale, brown, carbonaceous; black and bentonitic in part; some soft yellowish sandstone	2	8
Coal, black, impure	1	10
Shale, brown, carbonaceous	--	6

		Feet
139.	Sandstone, yellow and buff, very fine grained, soft, silty; many carbonaceous fragments; some carbonaceous layers near base	7
138.	Sandstone and shale interbedded, gray, bentonitic; carbonaceous in part; sandstone is soft; some thin beds of hard brown-weathering thin-bedded silty limy sandstone	30
137.	Shale, brown and black; coaly in part	2
136.	Sandstone, shale and siltstone, gray and buff; sandstone is soft; shale is bentonitic	7
135.	Shale, gray and black, bentonitic; plastic when wet	4
134.	Sandstone, gray and buff, fine-grained, soft, friable, silty; abundant dark grains	14
133.	Shale, gray, silty in part; thin beds of brown carbonaceous claystone at top	8
132.	Shale, brown, carbonaceous, silty	1
131.	Shale, gray and black, fissile; bentonitic in part	3
130.	Shale, brown, carbonaceous, silty	1
129.	Sandstone, white and light-gray, fine-grained, soft, friable; some dark and pink grains; bentonitic or tuffaceous in part. Some beds are hard and silty, and contain carbonaceous fragments	18
128.	Shale, gray, black, and brown; bentonitic in part. Lower two-thirds contains some thin gray sandstone beds; upper one-third is carbonaceous	8
127.	Coal, black and brown, lignitic	2
126.	Siltstone and shale, gray to black, bentonitic; plastic when wet; many gray claystone layers that contain numerous plant remains; some thin beds of soft gray sandstone	36
125.	Sandstone, gray and buff, fine- to medium-grained, massive, soft, friable, porous; contains abundant dark grains and sporadic biotite(?) flakes	18
124.	Siltstone, gray, sandy, carbonaceous; interbedded with thin beds of brown carbonaceous shale and soft gray sandstone. Gray claystone concretionary bed 10 ft above base weathers dark red	17
123.	Siltstone, gray, shaly in part; some thin beds of gray shale and very fine grained soft gray sandstone. Contains many plant fragments	22

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

		Feet
Meeteetse Formation—Continued		
122.	Shale, claystone, and siltstone, brown, carbonaceous. Many plant fragments. Some beds of claystone at top are gray and hard	10
121.	Sandstone and siltstone, gray, soft	3
120.	Shale, gray and brown, carbonaceous; silty in part	8
119.	Sandstone, gray and buff, very fine grained, silty, soft; some thin beds of gray shale. Upper 2 ft of unit is hard and platy, and contains abundant ripple marks	32
118.	Shale, brown, carbonaceous	2
117.	Sandstone, white and light-gray, very fine- to fine-grained, massive, very soft; some buff limonitic streaks; abundant dark grains, sporadic red grains; contains plant remains; thin bed of carbonaceous brown shale near base	43
116.	Shale, brown, carbonaceous	2
115.	Sandstone, white and light-buff, very fine grained, poorly sorted, soft, tuffaceous. Contains many "cannonball" concretions of sandstone that are white and cream colored, brown weathering, fine to medium grained, limy, and tuffaceous; abundant dark grains; sporadic biotite(?) flakes	47
114.	Shale and siltstone, brown, carbonaceous	4
113.	Sandstone, buff, very soft, deeply weathered	4
112.	Sandstone, white and buff, fine-grained, thinly crossbedded, tuffaceous	2
111.	Shale and siltstone, gray; brown and carbonaceous in part; upper 2 ft is black and coaly	40
110.	Sandstone, light-gray, fine-grained; some buff limonitic streaks; massive, porous; sporadic red grains; many sandstone veinlets on weathered surface. Unit thickens and thins in short distances laterally	4
109.	Shale, gray and brown, carbonaceous	5
108.	Sandstone, buff, fine- to medium-grained, poorly sorted, soft, friable, porous, limy	8
107.	Shale and siltstone, gray and brown; carbonaceous for most part	43
	Total Meeteetse Formation	671
Mesaverde Formation:		
White sandstone member:		
106.	Sandstone, white to light-gray, fine- to medium-grained, massive to thin-bedded; crossbedded in part, flaggy in part; abundant dark grains, some red and pink grains, and abundant white opaque grains; contains many large, irregularly bedded concretionlike masses of hard brown-weathering quartzitic limy, very fine grained ferruginous sandstone, and many thin beds and concretions of hard dark-brown ironstone; many small limonite concretions; some brown carbonaceous shale lenses in upper part. Top of unit forms conspicuous dip slope	79
105.	Siltstone, brown, carbonaceous; shaly in part; many plant fragments	10

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

		Feet
Mesaverde Formation—Continued		
White sandstone member—Continued		
104.	Sandstone, white to light-gray, some buff limonitic streaks; fine- to medium-grained; some coarse grains; massive; crossbedded in part, friable, porous; abundant dark grains, some red and pink grains, and abundant white opaque grains. Many limonite and limonitic sandstone concretions as much as 3 in. in diameter at base; sporadic large, irregularly bedded concretionlike masses of hard reddish-brown quartzitic limy ferruginous, very fine grained sandstone in upper part	47
103.	Shale, gray; silty in part; carbonaceous at top	9
102.	Sandstone, white to light-gray, very fine- to fine-grained, thin-bedded, flaggy; abundant dark grains and many red and pink grains	18
101.	Shale and siltstone, gray and light-gray; many thin beds of brown carbonaceous shale, dark-brown to black ironstone, and white sandstone	22
100.	Sandstone, white and light-gray, very fine- to fine-grained, massive to massively crossbedded, porous, slightly friable; abundant dark grains, many red and pink grains, sporadic limonite grains; many sandstone veinlets that stand out conspicuously on weathered surface	40
	Total white sandstone member	225
Lower part of Mesaverde Formation:		
99.	Shale, gray and dark-gray; some thin beds of soft gray siltstone near base	20
98.	Sandstone, dark-gray; weathers reddish-brown; very fine grained, thin bedded, platy, hard, limy, quartzitic; contains many limonite concretions as much as 1½ in. in diameter	6
97.	Sandstone, white to light-gray, very fine grained, soft, porous; abundant dark grains; 6 in. of dark-brown to black ironstone at top	27
96.	Covered interval; probably underlain by shale and siltstone	12
95.	Shale and siltstone, gray; some carbonaceous fragments; some thin beds of hard limy ferruginous very fine grained sandstone. Unit is poorly exposed	32
94.	Sandstone, buff, very fine grained, massive to thin-bedded; flaggy in part, friable, limonitic, limy; dark grains; contains masses of hard limy ferruginous sandstone as much as 30 ft in diameter	14
93.	Shale, gray and brown; carbonaceous for most part; some thin beds of gray soft siltstone in lower part	31
92.	Shale, brown and gray; carbonaceous for most part, silty in part; black and coaly in part; some thin beds of brown and buff ferruginous siltstone or very fine grained sandstone in upper part	34
91.	Siltstone, gray; contains some masses of hard quartzitic sandstone that weathers to a rough and irregular surface. Unit is poorly exposed	31

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

Lower part of Mesaverde Formation—Continued

		Feet
90.	Sandstone, gray and light buff, very fine grained, massive to thin-bedded, limy, slightly limonitic, friable, porous; in part hard and quartzitic; contains many impressions of large plant stems. Base is irregular and appears to be a channel deposit	28
89.	Shale, brown, carbonaceous; silty in part; contains many plant fragments	9
88.	Shale, gray, silty in part	6
87.	Claystone and siltstone, gray; weathers brownish-red in part; limy; contains many carbonaceous fragments	4
86.	Shale, gray; silty in part	2
85.	Siltstone, gray and buff; plant fragments	2
84.	Shale, brown, carbonaceous; plant fragments	17
83.	Shale, gray and brown; carbonaceous at top; interbedded with minor amount of sandstone and siltstone; contains many concretionlike masses of hard brown-weathering limy quartzitic ferruginous sandstone, and some brownish-orange-weathering limy claystone concretions; many plant remains near top	108
82.	Sandstone, buff, very fine grained, thin-bedded, limonitic, limy; soft and friable in upper 6 ft; minor amount of gray fissile silty shale in middle of unit; 17 ft above base is 1-ft bed of hard brown-weathering gray siltstone and claystone	23
81.	Claystone, gray; weathers brown and brownish-orange; hard, limy; hackly fracture	2
80.	Siltstone and shale, gray; sandy in upper half	29
79.	Shale, gray; silty in part, brown and carbonaceous in part; some thin beds of hard gray siltstone and gray, very fine grained silty sandstone; concretionlike masses of hard gray limy brown-weathering sandstone at top	33
78.	Sandstone, light-gray with buff limonitic streaks; very fine grained, massive, porous, friable; abundant dark grains, sporadic red grains; at base some concretionlike masses of hard sandstone as much as 4 ft in diameter	12
77.	Siltstone and claystone, gray; weathers reddish brown and brownish orange; hard, limy	3
76.	Siltstone and shale, gray, brown; carbonaceous in part; 1 ft of brown to black coaly shale at top	26
75.	Claystone and siltstone, gray; weathers reddish brown and brownish orange; hard, limy	3
74.	Siltstone and sandstone interbedded. Siltstone is gray; shaly in part. Sandstone is gray, very fine grained; sporadic dark grains. Unit contains limonite concretions as much as 6 in. in diameter, and beds and concretionlike masses of hard sandstone. Many thin coaly beds in middle of unit	40
73.	Shale, gray; brown and carbonaceous in part; silty in part near top; 1-ft bed of brownish-orange-weathering, limy gray claystone near base	40
72.	Siltstone and sandstone, gray and buff, soft; sandstone is very fine grained; thin beds of carbonaceous shale 14 ft and 32 ft above base; the bed 32 ft above base is coaly; many thin gray shale beds near top; concretionlike masses of hard sandstone at top	43

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

	Feet
Lower part of Mesaverde Formation—Continued	
71. Siltstone, buff; bed of concretionlike masses of hard brown-weathering limy quartzitic sandstone that contains abundant limonite concretions as much as half an inch in diameter	10
70. Shale, gray, fissile	2
69. Siltstone, buff	21
68. Shale, gray and brown, carbonaceous; coaly in part	4
67. Siltstone, sandstone, and shale, gray. Sandstone is very fine grained, thin bedded; some thin beds of hard brown-weathering sandstone	24
66. Shale, gray and brown, carbonaceous	9
65. Siltstone and sandstone, gray, bluish-gray, and buff. Siltstone is shaly and silty, carbonaceous in part; sandstone is very fine grained, soft in part; many irregular concretionlike masses of hard brown-weathering quartzitic gray sandstone	122
64. Shale, gray and brown; carbonaceous in part, bentonitic(?) in part; a few thin beds of coal and gray, very fine grained sandstone	24
63. Siltstone and sandstone, gray to white, very fine grained; some concretionlike masses of hard brown-weathering sandstone	24
62. Siltstone, light-gray, shaly, very carbonaceous; 8 in. of brownish-orange weathering limy gray claystone at top	9
61. Sandstone, buff, very fine grained, silty, massive to thin-bedded; flaggy in part, limy, limonitic; some dark grains; sporadic limonite concretions as much as 2 in. in diameter, and sporadic concretionlike masses of hard brown ferruginous sandstone. Unit is lenticular	8
60. Shale and siltstone, gray; sandy in upper part; some thin beds of brown carbonaceous shale and black coal partings in middle	20
59. Sandstone, grayish-buff, very fine grained, massive to thin-bedded; flaggy in part, limy; dark grains, limonitic grains, and white opaque grains; sporadic masses of hard limy brown-weathering sandstone; some thin beds of gray siltstone and shale and brown carbonaceous shale near top and base; 6 ft of lenticular hard flaggy brown sandstone at top	54
58. Claystone, gray; weathers brownish orange; limy; hackly fracture in part; weathers into fragments averaging 1 in. square	1
57. Shale, gray and brown; carbonaceous in part; some thin black coal beds	15
56. Sandstone or siltstone, gray, very fine grained, massive to thick-bedded, slightly limy; dark grains; 3 ft of brown carbonaceous shale in middle	27
55. Sandstone, gray; weathers brown in lower part; very fine grained, soft to hard; shaly in upper part; poorly exposed in part	11
54. Claystone, gray; weathers brownish orange; very limy; forms distinctive bed in slope and can be traced for some distance laterally	2
53. Shale, gray and brown; carbonaceous in part; lower half poorly exposed	23
52. Shale, gray, silty; carbonaceous in part; upper 9 ft contains thin beds of orange-weathering gray claystone, gray sandstone, and hard brown sandstone	28

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

Lower part of Mesaverde Formation—Continued

		Feet
51.	Sandstone, buff, very fine grained, massive, hard, limy, limonitic; contains small limonite balls on weathered surface. Unit is lenticular	15
50.	Sandstone, light-buff, fine-grained, massive, soft, friable, porous; abundant dark grains, some red grains; contains sporadic limonite concretions as much as 3 in. in diameter, and thin beds and concretionlike masses of hard flaggy brown-weathering sandstone; many thin beds of brown carbonaceous shale and gray shale in upper 25 ft; upper part poorly exposed. Unit is lenticular	80
49.	Shale, gray and brown, carbonaceous; coaly in upper part	16
48.	Sandstone, buff, very fine grained, thin-bedded, flaggy, limonitic; abundant dark grains; contains masses of hard brown-weathering sandstone. Unit is lenticular	9
47.	Coal, black, impure; minor amount of brown, carbonaceous shale	1
46.	Sandstone, gray; weathers brown in part; hard to soft; many carbonaceous fragments in lower part	15
45.	Largely covered; probably underlain mostly by gray shale and brown carbonaceous shale	11
44.	Siltstone and sandstone interbedded; gray and buff, soft	12
43.	Sandstone, buff and reddish-brown, very fine grained, thin-bedded, flaggy, hard, limy; quartzitic in part, shaly in lower part	15
42.	Covered interval; probably underlain by shale	13
41.	Sandstone, buff, very fine grained, thin-bedded, limonitic, silty, slightly limy; abundant dark grains and limonite grains	6
40.	Shale, gray and brown, fissile; carbonaceous near top	9
39.	Siltstone, buff, thin-bedded, soft; contains some thin beds of hard limy quartzitic flaggy, very fine grained reddish-brown sandstone; abundant leaves in middle of unit	23
38.	Sandstone, gray, flaggy; top part is hard and weathers reddish brown	6
37.	Coal, black; carbonaceous shale at base	2
36.	Shale, gray, silty; sandy near base; some thin beds of gray sandstone in middle	37
35.	Sandstone, gray to buff, very fine grained, thin-bedded, flaggy, silty; concretionlike masses of hard brown-weathering sandstone at top	8
34.	Shale, gray and brown, carbonaceous; many black coal partings	6
33.	Sandstone, gray, very fine grained	1
32.	Shale, gray, fissile; sandy in upper half	9
31.	Sandstone, gray and buff, very fine-grained, massive; flaggy in part; abundant dark grains; some concretionlike masses of hard quartzitic limy brown-weathering sandstone	24
30.	Shale, siltstone, sandstone, and carbonaceous shale interbedded. Shale is gray; siltstone is reddish brown, hard, limy; sandstone is white and light gray, flaggy; carbonaceous shale is brown and contains a few thin beds of black impure coal	29

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R. 2 E.*—Continued

Lower part of Mesaverde Formation—Continued

		Feet
29.	Sandstone, buff and gray, very fine-grained, massive; flaggy in part; abundant dark grains, some red grains; many limonite concretions as much as 6 in. in diameter; abundant large pits on weathered surface	19
28.	Shale, gray and brown; carbonaceous in part; thin coal bed 6 ft below top	15
27.	Sandstone, buff and gray, very fine grained, thin-bedded, silty; minor amount of gray shale	5
26.	Shale, gray; 6 in. of black coal in middle	6
25.	Sandstone, gray and buff, very fine grained, thin-bedded, silty; minor amount of gray shale	10
24.	Sandstone or siltstone, gray and buff, very fine grained, thin-bedded, hard, limy	2
23.	Shale, gray; minor amount of gray sandstone	7
22.	Sandstone, gray and buff, very fine grained, thin-bedded, hard, limy	3
21.	Shale, gray and brown; carbonaceous in lower 5 ft	7
20.	Sandstone or siltstone, gray and buff, very fine grained, thin-bedded, hard, limy; upper 2 ft soft and shaly	5
19.	Shale, gray	6
18.	Shale, brown, carbonaceous	2
17.	Shale, gray	4
16.	Shale, brown, carbonaceous	4
15.	Shale, gray	18
14.	Sandstone, buff and gray, fine- to medium-grained, massive, soft, friable, porous; abundant dark grains and sporadic red grains; minor amount of gray shale; thin bed of wavy-bedded hard brown-weathering sandstone at top	15
13.	Sandstone, buff, fine-grained, massive, slightly limy, limonitic, porous; friable in part; abundant dark grains and limonitic grains; contains small pits on weathered surface. Unit forms massive outcrop	44
12.	Sandstone, gray, very fine grained, thin-bedded	67
11.	Siltstone and shale interbedded; gray; siltstone is sandy, thin bedded; some thin beds of platy hard limy gray siltstone that form small ledges. Units 11 and 12 resemble beds in upper part of sandy member of Cody Shale	13
10.	Coal, black, impure, tarry	1
9.	Shale, brown, carbonaceous	1
8.	Sandstone, white to light-gray, fine-grained; in beds 3 in. to 1 ft thick, flaggy, porous, friable; abundant dark grains, sporadic pink grains; some thin lenses of brown carbonaceous shale; a thin bed of hard brown-weathering sandstone in middle of unit; weathered surface has intersecting joints filled with brown limonitic material. This is a conspicuous unit that can be recognized widely throughout the area	34
7.	Shale, brown, carbonaceous	2
6.	Sandstone, gray and buff, fine-grained, massive	2
5.	Siltstone, tan to orange, thin-bedded	3

6. *West Dry Creek section, secs. 24 and 25, T. 6 N., R 2 E.*—Continued

	Feet
Lower part of Mesaverde Formation—Continued	
4. Sandstone, gray and buff, very fine grained, massively cross-bedded, silty, limy; limonitic in part; contains large pits on weathered surface. Lower 15 ft forms massive outcrop; upper part is soft and shaly and forms a saddle	64
Total lower part of Mesaverde Formation	1, 781
Total Mesaverde Formation	2, 006
Contact between Mesaverde Formation and sandy member of Cody Shale.	
Cody Shale:	
Sandy member:	
3. Shale, gray, clayey, fissile; minor amount of siltstone	4
2. Sandstone, gray, very fine grained; interbedded with gray shale and siltstone; upper part poorly exposed	51
1. Sandstone, gray to buff, very fine grained, massive to thick-bedded, silty, limy; abundant dark grains; contains many thin beds and concretionlike masses of hard brown weathering sandstone in upper part. Sandstone is "honeycombed" to some extent and resembles sandstone in the Mesaverde	47

USGS Mesozoic Locality 23113 (SE¼SE¼NW¼ sec. 24, T. 6 N., R. 2 E.) 10 feet below top; age, Eagle equivalents:

Membranipora sp.
Serpula sp.
Nucula n. sp.
Inoceramus lundbreckensis McLearn
Pteria linguaeformis (Evans and Shumard)
Pecten (*Syncyclonema*) *hallii* Gabb
Legumen cf. *L. ellipticum* Conrad
Tellina equilateralis Meek and Hayden
Geltena? sp.
Eutrephoceras alcesense Reeside
Baculites aquilaensis Reeside
  aquilaensis var. *obesus* Reeside
  aquilaensis var. *separatus* Reeside
  haresi Reeside
Scaphites hippocrepis (DeKay) var. *crassus* Reeside
Placenticeras planum Hyatt
  syrtale (Morton)

Base of measured section.

7. *Twin Buttes section, secs. 30 and 31, T. 6 N., R. 3 E.*

Top of exposures.	
Indian Meadows Formation:	
65. Claystone, brick-red, silty; contains large masses of Bighorn Dolomite and Madison Limestone which originated as an ancient landslide; contains some yellow conglomeratic sandstone	20
Total thickness of exposed part of Indian Meadows Formation	20

7. Twin Buttes section, secs. 30 and 31, T. 6 N., R. 3 E.—Continued

Contact between Indian Meadows Formation and Shotgun Member of Fort Union Formation is sharp and irregular.

Fort Union Formation:

Shotgun Member:

		Feet
64.	Claystone and shale, gray; 3-ft bed of brown carbonaceous shale and claystone in middle	64
63.	Siltstone, gray; weathers brown; hard, limy, ledgy; forms marker bed near top of slope	1
62.	Claystone and siltstone, gray and buff banded; contains a few thin beds of brown carbonaceous shale	131
61.	Shale, purple and brown, carbonaceous; contains abundant gypsum crystals and yellow jarosite; forms distinctive band in slope	4
60.	Claystone, gray and yellowish-brown banded; minor amount of gray siltstone; locally contains lenses of hard limy ferruginous very fine grained sandstone and siltstone that weather brown; 1 ft of hard carbonaceous claystone 25 ft below top	105
59.	Claystone, gray, hard, silty, locally forms marker bed	1
58.	Claystone and siltstone, gray and brown banded; 15 ft below top are two 1- to 3-ft beds of carbonaceous shale and claystone that contain abundant leaves and stems	91
57.	Claystone, brown, waxy; some gray and olive-drab claystone and siltstone	5
56.	Shale, gray and brown; carbonaceous in part, sandy in part; sandy beds locally are hard and ledgy	7
55.	Claystone and siltstone, gray and olive-drab; sandy in part; deeply weathered	45
54.	Covered interval. Lateral exposures indicate most of unit is underlain by drab-colored and, in part, variegated red and purple claystone and siltstone	191
53.	Claystone, gray and olive-drab; sandy in part; weathers gray and brown	42
52.	Claystone, siltstone, and sandstone interbedded; gray and olive drab, soft; carbonaceous in part; 5 ft below top is 1 ft of brown carbonaceous shale and sandstone; outcrop is deeply weathered	60
51.	Siltstone, gray to brown; weathers brown; limy, hard	1
50.	Siltstone and claystone, gray and olive-drab	34
49.	Siltstone, gray; weathers dark brown; thin-bedded and soft to massive and hard, limy; concretionary in part	2
48.	Claystone, siltstone, and sandstone interbedded; gray, olive drab, and brown banded, soft; sandstone is very fine grained. Unit contains a few ledgy hard limy brown sandstone beds 1 to 2 ft thick and some 1- to 2-ft lenses of brown carbonaceous shale; outcrop is deeply weathered	68
47.	Claystone, brown; forms conspicuous band in slope	2
46.	Sandstone, buff and yellow, very soft, clayey	7
45.	Claystone, gray and tan-banded; sandy in part	18
44.	Sandstone, yellow and tan, fine-grained, very soft; carbonaceous in lower 2 ft	10

7. Twin Buttes section, secs. 30 and 31, T. 6 N., R. 3 E.—Continued

Fort Union Formation—Continued		
Shotgun Member—Continued		*Feet*
43.	Claystone, gray, silty in part	12
42.	Sandstone, gray and buff laminated, fine-grained, soft; contains an abundance of carbonaceous material	5
41.	Claystone, gray and greenish-gray	19
40.	Sandstone, gray to white, fine-grained, clayey, ledgy, lenticular	2
39.	Claystone, siltstone, and sandstone interbedded; gray, buff, and yellowish brown, soft; outcrop is deeply weathered	22
38.	Sandstone, gray to light-tan, very fine grained, soft porous	8
37.	Claystone, gray; contains some sandy layers	12
36.	Sandstone, white to light-gray, very fine grained, lenticular	1
35.	Claystone, gray, purple, and red; in part hard and blocky; contains a minor amount of siltstone	49
34.	Shale and siltstone, gray and buff; outcrop deeply weathered	10
33.	Sandstone, buff, fine-grained; contains many grains and fragments of coal and carbonaceous material	15
32.	Sandstone, brown and tan, fine-grained, highly crossbedded; contains stringers of carbonaceous material. Lower 2 ft contains an abundance of fossil leaves and mammal, shark, and crocodile teeth. Fossil bed can be traced for 200 to 300 yards along strike and contains bone fragments throughout	4
	Fossil mammals tentatively identified by C. L. Gazin are listed below; age, Torrejonian or early Tiffanian: *Ptilodus* cf. *P. montanus* Douglas *Mimetodon* cf. *M. douglassi* (Simpson) *Ectypodus*? cf. *E. silberlingi* Simpson Cf. *Anconodon gidleyi* (Simpson) Cf. *Eucosmodon* sp. *Catopalis* cf. *C. fissidens* Cope Cf. *Peradectes* sp. *Gelastops* sp. Cf. *Diacodon* sp. Pantolestid, possibly *Aphronorus* sp. *Pentacodon* sp. Possibly *Zanycteris* sp. Plesiadapid cf. *Pronothodectes* sp. *Claenodon* cf. *C. ferox* (Cope) *Tricentes*, near *T. subtrigonus* (Cope) *Periptychus* cf. *P. carinidens* Cope *Anisonchus*, near *A. sectorius* (Cope) *Promioclaenus* sp. Cf. *Litomylus* sp. *Gidleyina* sp. *Pantolambda* cf. *P. cavirictus* Cope	
31.	Shale and siltstone, gray	4
30.	Sandstone, buff, very soft	2
29.	Siltstone and shale, gray and olive-drab	11
28.	Claystone, variegated gray and purple	8
27.	Sandstone, gray; weathers brown; limy, hard, flaggy	1

7. Twin Buttes section, secs. 30 and 31, T. 6 N., R. 3 E.—Continued

Fort Union Formation—Continued		
Shotgun Member—Continued		*Feet*
26.	Shale and claystone, gray, silty	5
25.	Sandstone, white to gray, fine-grained, silty, porous, ledgy	2
24.	Claystone, gray	6
23.	Claystone, gray, red, and purple; silty in part. Unit forms lowermost variegated beds in Shotgun Member of Fort Union Formation	16
22.	Claystone and siltstone, gray, locally hard	9
21.	Sandstone, gray and tan, fine- to medium-grained, lenticular, locally hard and ledgy	4
20.	Claystone, gray, hard, blocky	13
19.	Shale, gray, soft	4
18.	Sandstone, gray, soft; outcrop is deeply weathered	4
17.	Sandstone, gray and buff; some yellowish staining on bedding planes; fine grained, soft, porous; contains abundant dark grains, some red grains; abundant carbonaceous material	4
16.	Shale, gray and olive-drab, fissile; in part blocky; at top is carbonaceous and has thin coaly partings	18
15.	Sandstone, gray, fine- to medium-grained, thin-bedded, soft; clayey and silty in part; contains many carbonaceous layers	3
14.	Shale, olive-drab, gray, and red; carbonaceous in part. Outcrop is deeply weathered	27
13.	Shale, gray, clayey; contains 1 ft of white sandstone in middle	13
12.	Covered interval. Lateral exposures indicate unit is underlain by soft deeply weathered gray claystone and shale	16
11.	Sandstone, gray, thin-bedded	3
10.	Sandstone and shale, gray and brown, carbonaceous; individual beds are lenticular	2
9.	Shale, gray, clayey	5
8.	Sandstone, gray and buff, fine- to medium-grained, thin-bedded and slabby, soft, porous; abundant carbonaceous material	5
7.	Shale, gray, very clayey, bentonitic(?); contains some dark-brown ferruginous claystone concretions. Outcrop is deeply weathered	12
6.	Sandstone, gray, soft; upper half is ferruginous, hard, limy, slabby, brown weathering, ledge forming	4
5.	Shale, gray, very clayey	5
4.	Sandstone, gray and buff, fine-grained, thin-bedded and slabby, porous, lenticular	3
3.	Sandstone and shale, brown, carbonaceous	1
2.	Shale, gray, finely fissile	7
	Total thickness of Shotgun Member of Fort Union Formation	1, 265

7. Twin Buttes section, secs. 30 and 31, T. 6 N., R. 3 E.—Continued

Contact between Shotgun Member and lower part of Fort Union Formation is marked by a pronounced change in lithology from predominantly drab colored soft, deeply weathered shale, claystone, sandstone, and siltstone above to resistant ledge-forming sandstone interbedded with shale below.

Lower part of Fort Union Formation (in part):

	Feet
1. Sandstone, white to buff, fine- to medium-grained, crossbedded and massive, porous; abundant dark grains; locally sandstone is pitted and forms honey-combed appearance	20

Base of measured section.

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INDEX

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