Geology of the Crazy Woman Creek Area Johnson County Wyoming

By RICHARD K. HOSE

A CONTRIBUTION TO ECONOMIC GEOLOGY

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A CONTRIBUTION TO ECONOMIC GEOLOGY

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By Richard K. Hose

ABSTRACT

The Crazy Woman Creek area comprises about 576 square miles along the west-central margin of the Powder River Basin and the east-central flank of the Bighorn Mountains in Johnson County, Wyo. Pre-Cambrian granitic rocks form the high rugged core of the Bighorn Mountains. Resistant units of the Paleozoic sequence support the high essentially north-trending scarp along the east flank of the Bighorn Mountains; the softer rocks of the Permian red shale and gypsum sequence and younger units underlie the Powder River Basin.

Rocks of every system except the Silurian and Devonian are present in the Crazy Woman Creek area. Paleozoic rocks are as much as 2,550 feet thick and are dominantly of marine origin. Mesozoic rocks attain a maximum thickness of about 9,350 feet and are of marine, brackish water, and nonmarine origin; marine rocks are the most common. The Cenozoic rocks, which have an aggregate thickness of more than 5,000 feet, are wholly of continental origin.

The oldest sedimentary unit, the Flathead sandstone of Middle Cambrian age, is about 250 feet thick. It is overlain by the Gros Ventre formation and Gallatin limestone undivided, aggregating 550 feet in thickness and ranging in age from Late Cambrian to Early Ordovician. The next younger unit is the Bighorn dolomite, which ranges in thickness from about 150 to over 350 feet and in age from Middle to Late Ordovician. The 550-foot Madison limestone of early Mississippian age unconformably overlies the Bighorn dolomite. It is succeeded by the Amsden formation of Mississippian(?) and Pennsylvanian age. The Tensleep sandstone of early Pennsylvanian (Des Moines) age overlies the Amsden formation and is about 350 feet thick. The Tensleep sandstone is overlain by the Permian red shale and gypsum sequence, which is about 250 feet thick.

The oldest Mesozoic unit is the nonmarine Chugwater formation of Triassic age. This formation ranges from 750 to more than 800 feet in thickness and consists dominantly of red siltstone, sandstone, and shale. The Chugwater formation is unconformably overlain by the Gypsum Spring formation of Middle Jurassic age, which ranges in thickness from about 120 feet to a wedge edge 6 miles south of the mapped area. Unconformably overlying the Gypsum Spring formation is the Sundance formation of Late Jurassic age, which is approximately 285 feet thick and consists of sandstone, shale, and minor amounts of oolitic limestone. The nonmarine Morrison formation of Late Jurassic age,

about 185 feet thick, overlies the Sundance formation, and consists dominantly of varicolored claystones and thin beds of siltstone and sandstone. This unit is overlain by the Cloverly formation, which is of Early Cretaceous age and ranges in thickness from 135 to 165 feet. The Skull Creek shale of Early Cretaceous age, which overlies the Cloverly formation, is about 165 feet thick. The Newcastle sandstone of Early Cretaceous age, next above the Skull Creek shale, is about 40 feet thick. The Mowry shale of Early Cretaceous age overlies the Newcastle sandstone and is about 500 feet thick.

The Frontier formation of Late Cretaceous age, which overlies the Mowry shale, is about 480 feet thick and consists dominantly of interlaminated dark-gray shale and light-gray sandstone, capped by a resistant conglomeratic sandstone. The next younger unit, the Cody shale of Late Cretaceous age, is about 3,670 feet thick; 925 feet below the top is the 200–foot Shannon sandstone member. The Parkman sandstone of Late Cretaceous age overlies the Cody shale and is 720 feet thick. The next younger unit, the Bearpaw shale of Late Cretaceous age, is 200 feet thick and consists of drab-colored silt shale.

The Lance formation of Late Cretaceous age, which ranges in thickness from 1,950 to 2,200 feet, overlies the Bearpaw shale and consists of interbedded sandstone, siltstone, and shale.

The Fort Union formation of Paleocene age rests on the Lance formation and is about 3,900 feet thick. The Wasatch formation of early Eocene age rests apparently conformably on the Fort Union formation throughout most of the mapped area, but its mountainward basal equivalent, the Kingsbury conglomerate member of the Wasatch formation, unconformably overlies successively the Fort Union formation, the Lance formation, the Bearpaw shale, and the Parkman sandstone. The next higher mountainward member of the Wasatch formation, the Moncrief, rests unconformably on the Kingsbury conglomerate and older units just north of the Crazy Woman Creek area. The White River formation of early Oligocene age is restricted to small outliers on the subsummit uplands of the Bighorn Mountains and consists mainly of marlstone, conglomerate, and soft brown bentonitic clay. Quaternary deposits, dominantly terrace gravels, alluvium and landslide debris, are widespread.

Structural activity during the time after the pre-Cambrian and before the Laramide orogeny began was limited to mild regional tilting, uparching, or uplift followed by erosion and subsequent depression. This mild tilting resulted in unconformities that are recognizable only by a study of the regional relationships of the formational units. These unconformities are present at the base of the Madison limestone, the Permian red shale and gypsum sequence, at the base of the Gypsum Spring formation, and at the base of the Sundance formation.

Laramide orogeny in the Bighorn Mountains began during Fort Union time. Before the end of Fort Union time the central portion of the Bighorn Mountains had been elevated and eroded in part to the pre-Cambrian. A record of uplift at the end of Fort Union time is preserved in the angular unconformity at the base of the Kingsbury conglomerate member of the Wasatch formation. After Kingsbury time another uplift occurred which tilted the Kingsbury conglomerate member of the Wasatch formation as much as 60 degrees. The Moncrief member of the Wasatch formation, which overlies the Kingsbury conglomerate member unconformably was not affected by folding. However thrust faults have moved older rocks up and over the Moncrief member.

Strata in the Crazy Woman Creek area generally dip eastward, and except for the almost flat-lying Wasatch formation crop out as relatively narrow north-trending bands. Structural relief resulting from this eastward dip is as much as 18,000 feet. The mapped area contains 5 major anticlinal folds and one structural terrace. Faults with a few exceptions are confined to the competent Paleozoic strata.

Oil and gas have been produced in the Billy Creek anticline, but to date not elsewhere in the area. A small manganese deposit and a deposit of allanite are present at the northern end of the Horn. Bentonite beds are common in the Mowry shale and the Frontier formation. Subbituminous coal beds from 2.5 to 15 feet thick underlie three townships, and total measured, indicated, and inferred coal reserves are more than one billion tons.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Crazy Woman Creek area lies south of the town of Buffalo in Johnson County, Wyo., and includes 16 townships, approximately 576 square miles. The location of the area mapped is shown on the index maps (fig. 13 and pl. 7). The western boundary extends southward along the western edge of R. 83 W. along the east flank of the Bighorn Mountains to the vicinity of the Horn, a prominent structural and physiographic feature of the Bighorn Mountains. The southern boundary extends eastward along the southern edge of T. 46 N. well out into the Powder River Basin. The eastern boundary lies along the eastern edge of R. 80 W. and the northern boundary along the northern edge of T. 49 N.

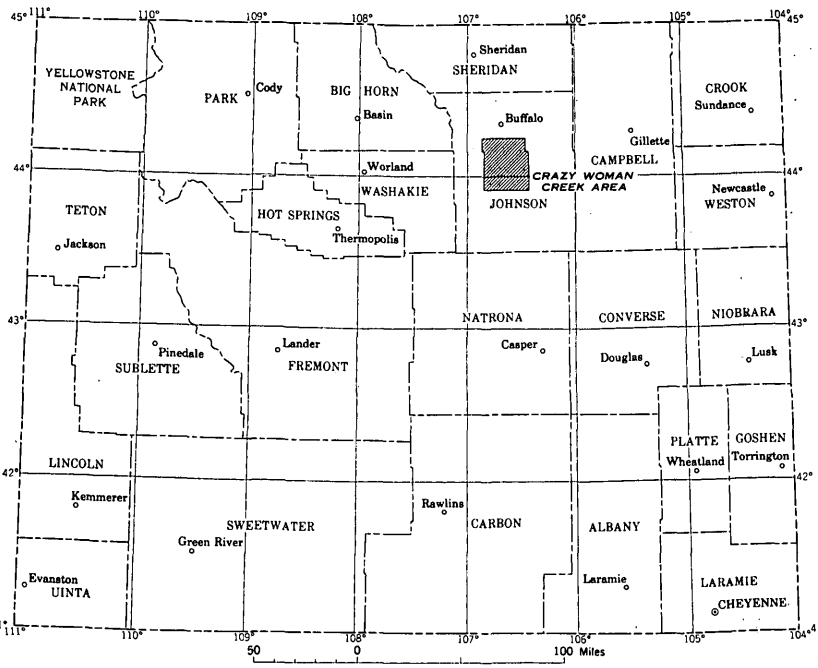

FIGURE 13.—Index map of Wyoming showing location of the Crazy Woman Creek area.

PURPOSE AND SCOPE OF REPORT

The present study is one of oil, gas, and coal investigations made by the U. S. Geological Survey as a part of a program of the Department of the Interior for the development of the Missouri River basin. Basic geologic data for use in oil and gas exploration and coal reserve evaluation include determinations of thickness, lateral variation, and relative age of stratigraphic units; present structural configuration and tectonic history of the area; extent, thickness, and attitude of numerous coal beds; and distribution, thickness, and types of terrace deposits. These data contribute to an appraisal of regional geologic problems and hence to a better regional evaluation of oil and gas possibilities.

FIELD WORK AND MAP COMPILATION

This report is based on field work done during the field seasons of 1950 and 1951 and 2 weeks in 1952. Field data were compiled on aerial photographs at a scale of 1 : 31,680. Data were transferred to a polyconic projection upon which was superimposed a land grid. The land grid was plotted from data provided by the U. S. Bureau of Land Management. The only surveys in approximately 7 townships were made in 1882; few of the section corners were recovered. The remaining 9 townships were resurveyed at least in part in 1927, 1947, and 1948, and all quarter and section corners are marked with brass caps. Geologic mapping in the westernmost tier of townships was transferred to preliminary topographic maps which were prepared for the U. S. Bureau of Reclamation by Fairchild Aerial Surveys, Inc., and then transferred to the base map. Four first-order U. S. Geological Survey and U. S. Coast and Geodetic Survey triangulation stations are located in the area. A subordinate triangulation net was established with planetable and alidade. Altitudes for structure contouring were established with an aneroid barometer. Stratigraphic sections of major units were measured with planetable and alidade; smaller units were measured with compass and tape.

ACKNOWLEDGMENTS

During the 1950 field season the writer was assisted by Theodore Scott, who mapped a substantial portion of the Paleozoic and Quaternary rocks. In 1951, M. J. Bergin and R. S. Sears assisted in mapping Tertiary beds. Bergin also mapped some of the Paleozoic rocks of the Horn area and Quaternary rocks in the eastern part of the area. W. J. Mapel collaborated with the writer in measuring several stratigraphic sections of Mesozoic rocks along the west margin of the Powder River Basin. All phases of the investigation were supervised

by J. D. Love, whose cooperation and suggestions greatly facilitated the preparation of this report.

Identification of fossil collections and determination of their ages was done by paleontologists of the Geological Survey. Trilobites from the Cambrian and a brachiopod from the Lower Ordovician were identified by A. R. Palmer. Palmer and Josiah Bridge jointly identified dendroid graptolites from the Gallatin and Gros Ventre formations, undivided. Mollusks and a sponge from the lower part of the Bighorn dolomite were identified by Josiah Bridge and corals by Edwin Kirk. Faunas from the upper part of the Bighorn dolomite were identified by Jean Berdan and Josiah Bridge. Collections from the Madison limestone and Amsden formation were studied by Helen Duncan and J. S. Williams. R. W. Imlay identified mollusks from the Gypsum Spring and Sundance formations and Edwin Kirk a crinoid from the basal part of the Sundance formation. All Cretaceous fossils were identified by W. A. Cobban and J. B. Reeside, Jr. Eocene fresh-water mollusks were identified by T.-C. Yen and Eocene vertebrates by M. J. Hough. C. L. Gazin of the U. S. National Museum identified *Hyposodus simplex*.

A. H. Makela described thin sections of crystalline rocks. Three analyses of manganese-bearing rock were made by Dr. H. G. Fisk, of the National Resources Research Institute. The report was prepared with the cooperation of the Geological Survey of Wyoming and the Department of Geology, University of Wyoming.

PREVIOUS INVESTIGATIONS

During 1859 and 1860 a reconnaissance of a large area of northern Wyoming, Montana, and the western parts of North and South Dakota was carried out under the direction of Capt. W. F. Raynolds. F. V. Hayden (1869) who accompanied Raynolds, compiled a generalized geologic map of the region of which the Crazy Woman Creek area is a small part. In 1904 Darton defined the stratigraphic units of the Bighorn Mountains. Later (1906) Darton revised some of his preliminary units and published a map and comprehensive report on the entire Bighorn Mountains and a peripheral belt in which major physiographic, structural, and stratigraphic units were outlined. Gale and Wegemann (1910) made a reconnaissance examination of Tertiary coals in this and adjoining areas. In 1912 Wegemann studied the Sussex coalfield, the northern part of which extends into the Crazy Woman Creek area. Wegemann (1913) also studied coals in the Barber coalfield, which adjoins the Crazy Woman Creek area on the northeast. Wilson (1938) mapped the Tensleep fault, which trends essentially east across the Bighorn Mountains from Tensleep, Wyo., to the northern part of the Horn. Demorest (1941) mapped Paleozoic and Triassic units along the east flank of the Bighorn Mountains from Clear Creek south to the Horn. Sharp (1948) made a detailed study of the Moncrief member of the Wasatch formation along the east flank of the Bighorn Mountains. Richardson [1] mapped an area which included a portion of the Horn. Detailed geologic mapping was done by Mapel in 1949 and 1950 in the Lake DeSmet area to the north; this is also a part of the Geological Survey's oil, gas, and coal investigations program.

GEOGRAPHY

SURFACE FEATURES

The Crazy Woman Creek area covers parts of two major topographic provinces: the east flank of the Bighorn Mountains and the western margin of the Powder River Basin. The Bighorn Mountains rise abruptly from about 5,900 feet to more than 8,200 feet above sea level in a distance of 2 to 3 miles. Altitudes in the basin range from about 4,200 feet in the eastern part of the mapped area to about 5,900 feet above sea level along the base of the Bighorn Mountain front, over a distance of about 19 miles. The east flank of Bighorn Mountains is composed of a sequence of resistant Paleozoic rocks overlying the pre-Cambrian core of the range. The top of the Tensleep sandstone can be regarded as the boundary between the mountains and the basin. The Powder River Basin has been etched out of more easily eroded sedimentary rocks ranging in age from Permian through Mesozoic to Eocene. Kingsbury Ridge, which is composed of the resistant Kingsbury conglomerate member of the Wasatch formation, forms a divide in the northernmost part of the area between the Clear Creek drainage 6 miles north of the mapped area and the Crazy Woman Creek drainage. Resistant units in the upper part of the Fort Union formation and the lower part of the Wasatch formation form a discontinuous north-trending ridge about 3 to 6 miles east of U. S. Highway 87.

Piedmont interstream surfaces with relief of as much as 500 feet are characteristic of the entire Bighorn Mountain front (fig. 14). Basinward, however, these older surfaces have been eroded, leaving only remnants.

Streams head high in the Bighorn Mountains and flow eastward through steep youthful canyons cut in the resistant rocks which form the east flank of the range (fig. 15). As the streams leave the mountain canyons, they flow with progressively decreasing gradient into the Powder River Basin where they occupy valleys flanked by more mature topography.

[1] Richardson, A. L., 1950, Geology of the Mayoworth region, Johnson County, Wyo.: Unpublished Master of Arts thesis in files of Univ. of Wyoming library.

FIGURE 14.—View of east flank of the Bighorn Mountains showing prominent piedmont surfaces.

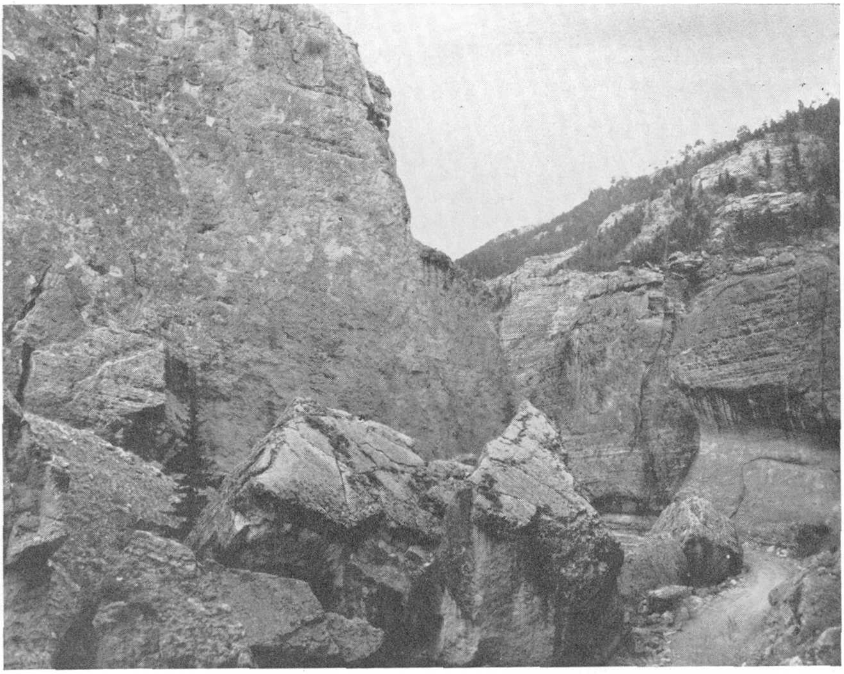

FIGURE 15.—Canyon of the North Fork Crazy Woman Creek cut through massive dolomitic part of the Bighorn dolomite.

WATER SUPPLY AND DRAINAGE

Major streams are the North, Middle, and South Forks Crazy Woman Creek in the north, central, and southern parts of the area; Muddy and Billy Creeks south of the North Fork Crazy Woman Creek; and Beaver Creek between the Middle and South Forks Crazy Woman Creek. All streams flow into the forks of Crazy Woman Creek or the main drainage which is designated Crazy Woman Creek east of the juncture of the Middle Fork with the North Fork. The use of irrigation waters taken from Billy Creek, Beaver Creek, and the South Fork Crazy Woman Creek is so extensive during the summer months that these streams become intermittent in their lower courses.

Stream gradients in the last mile of flow through the mountains range from a minimum of 250 feet per mile for the North Fork Crazy Woman Creek to a maximum of 1,100 feet per mile for the South Fork Crazy Woman Creek. This gradient difference may be partly due to the fact that the North Fork Crazy Woman Creek has the greatest discharge in the area, whereas the South Fork Crazy Woman Creek has one of the lowest. The first mile of flow in the basin is on gradients ranging from 210 feet per mile for Muddy Creek to as much as 540 feet per mile for the South Fork Crazy Woman Creek. Gradients for the second mile of flow in the basin range from 100 feet per mile for the Middle Fork Crazy Woman Creek to 190 feet per mile for the South Fork Crazy Woman Creek. Gradients past the two-mile mark decrease and more closely approach uniformity, until a relatively gentle gradient of approximately 11 feet per mile is reached for Crazy Woman Creek between the bridge in sec. 31, T. 48 N., R. 81 W., and the northeast edge of the mapped area.

Altitudes at which the streams leave the resistant rocks of the Bighorn Mountains and enter the relatively nonresistant rocks of the Powder River Basin are as follows: North Fork Crazy Woman Creek, 5,900 feet above sea level; Muddy Creek, 5,600 feet above sea level; Billy Creek, 5,720 feet above sea level; Middle Fork Crazy Woman Creek, 5,450 feet above sea level; Beaver Creek, 5,900 feet above sea level; and South Fork Crazy Woman Creek, 5,900 feet above sea level. The difference in altitude at which the streams leave the mountain province coupled with their various gradients is significant in the consideration of a classification and correlation of terrace levels.

Table 1 shows a maximum mean discharge in June 1949 of 117 cfs and a minimum mean discharge of 4.08 cfs in February 1949 for the North Fork Crazy Woman Creek. Table 1 also shows a maximum mean discharge of 114 cfs during June 1949, and a minimum mean discharge of 7.35 cfs in February 1949 for the Middle Fork Crazy Woman Creek. Most of the discharge of the forks and tributaries of Crazy Woman Creek is diverted for irrigation of the flat bottom lands during

TABLE 1.—*Discharge of the North and Middle Forks Crazy Woman Creek, October 1948 to September 1949*

[Gaging station: North Fork, sec. 27, T. 49 N., R. 83 W.; Middle Fork, sec. 11, T. 47, N., R. 83 W.]

	North Fork				Middle Fork			
	Cubic feet per second	Maximum	Minimum	Mean	Cubic feet per second	Maximum	Minimum	Mean
October	274.1	11.0	7.5	8.84	307.4	14	8.2	9.92
November	193.8	7.8	5.5	6.46	265.6	10	7.0	8.85
December	168.7	5.9	4.9	5.44	257.4	9.7	7.0	8.30
January	138.4	4.9	3.5	4.46	249.5	8.9	7.2	8.05
February	114.2	4.5	3.8	4.08	205.7	8.5	6.5	7.35
March	134.9	4.9	3.9	4.35	260.3	10	7.2	8.40
April	590.2	54	4.3	19.7	691.0	51	7.0	23.0
May	1,652	86	24	53.3	1,389	63	31	44.8
June	3,514	349	46	117	3,405	357	43	114
July	898	67	14	29	817	47	12	26.4
August	377.6	26	8.0	12.2	320.5	16	8.2	10.3
September	315.8	24	7.6	10.5	342.7	23	8.2	11.4

TABLE 2.—*Average annual and monthly precipitation and temperature in the Crazy Woman Creek area*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Precipitation [1]													
Sheridan Field Station	0.50	0.65	1.18	2.22	2.91	3.29	1.48	0.87	1.51	1.03	0.90	0.57	17.11
Buffalo	.46	.54	1.15	1.36	2.95	2.99	1.19	1.11	1.53	1.12	.79	.55	15.74
Lower Crazy Woman Creek	.59	.41	1.00	1.37	1.82	4.56	1.24	.57	1.51	.83	.73	.39	15.02
Kaycee	.41	.32	.75	1.52	2.23	2.67	.92	.63	.93	.98	.56	.38	12.61
Temperature [2]													
Sheridan Field Station	20.3	20.6	31.2	44.3	54.1	61.4	72.2	69.8	59.2	47.9	31.4	25.3	44.7
Buffalo	23.8	24.4	30.3	41.9	50.5	57.8	68.2	66.2	57.4	45.1	34.1	27.9	44.0
Lower Crazy Woman Creek	19.2	20.8	31.6	44.1	52.9	59.8	69.8	68.6	57.6	46.4	30.0	21.5	43.5
Kaycee	22.8	25.2	31.0	43.8	51.4	59.0	69.2	67.8	56.2	46 4	32.0	24.6	44.2

[1] Same number of years average as for temperature except for record at Kaycee which is an average of 6 years.
[2] Sheridan Field Station average of 14 years, Buffalo average of 8 years, Lower Crazy Woman Creek average of 5 years, Kaycee average of 8 years.

the summer months. No statistics are available on discharge of smaller streams or Crazy Woman Creek; hence total discharge and amount of irrigation waters used cannot be determined.

Water supply in the mapped area is augmented by many pumping wells and earthwork dams across intermittent streams. Many of the larger dams contain water the year round, but some of the smaller ones contain water only intermittently.

CLIMATE AND VEGETATION

The climate of the Crazy Woman Creek area is semiarid. Average annual precipitation as recorded by U. S. Weather Bureau stations (table 2) ranges from an average annual rainfall of 12.61 inches at Kaycee to 17.11 inches at the Sheridan Field Station. On lower Crazy Woman Creek the average annual temperature for a 5-year period was 43.5° F; the lowest monthly average temperature over a 5-year period was 19.2° F in January, and the maximum monthly average temperature was 69.8° F for July.

Vegetation in the basin area consists mainly of sagebrush, pricklypear, rabbitbrush, and a number of grasses. Trees are confined to stream bottoms or irrigated areas. Arable lands are mainly restricted to irrigated flat valleys, but in recent years many acres of relatively flat nonirrigated dry farmlands have been profitably planted with wheat. The flanks and subsummit uplands of the Bighorn Mountains are heavily forested; areas of various types of conifers in the uplands are interspersed with large open grassy parks.

ACCESSIBILITY AND SETTLEMENT

U. S. Highway 87 extends north through the middle of the area and passes through Buffalo, the county seat of Johnson County, 7 miles north of the northern boundary. Although U. S. Highway 87 is the only paved road in the area, there are several graded all-weather roads that form a network, making the larger portions of the mapped area easily accessible. Numerous small trails and ungraded roads, many of which are not shown on the geologic map, give almost complete accessibility by motor vehicle; an exception is the steep eastern flank of the Bighorn Mountains.

No towns are present within the mapped area, and settlement is almost wholly confined to the vicinity of streams.

STRATIGRAPHY

GENERAL FEATURES

Rocks ranging in age from Cambrian through Cretaceous were mapped, and stratigraphic sections were measured in detail; Paleocene and younger rocks, although not measured, were mapped and described. Paleozoic rocks aggregate a maximum thickness of about 2,550 feet; the dominant rock types are carbonates and sandstone. In the Paleozoic sequence, rocks of Silurian and Devonian age are absent. Mesozoic rocks attain a maximum thickness of about 9,350 feet; the dominant rock type is shale or claystone. Thickness of Cenozoic rocks ranges from 4,000 to 5,000 feet.

Paleozoic rocks are dominantly of marine origin, whereas the Mesozoic sequence includes units of nonmarine, marine, and brackish-water origin; Cenozoic rocks are wholly of continental origin. Paleozoic and Mesozoic rocks are confined mostly to the western part of the mapped area, and, except in areas of local structural anomalies, dip eastward and trend essentially north-south. Cenozoic rocks occupy the eastern half of the mapped area and dip gently eastward or are flat lying. A generalized graphic section of rocks cropping out in the Crazy Woman Creek area is shown in plate 8.

LOCATION OF MEASURED SECTIONS

Except for the Gallatin limestone and Gros Ventre shale, undivided, and the Permian red shale and gypsum sequence, the section of Paleozoic rocks was measured along the North Fork Crazy Woman Creek through secs. 27 and 28, T. 49; N., R. 83 W. The Gallatin limestone and Gros Ventre formation, undivided, were measured in secs. 8 and 9, T. 47 N., R. 83 W. The Permian red shale and gypsum sequence was measured in sec. 35, T. 48 N., R. 83 W. The Gypsum Spring and Sundance formations were measured in secs. 2 and 11, T. 48 N., R. 83 W. The Morrison and Cloverly formations, Skull Creek shale, Newcastle sandstone and Mowry shale were measured in secs. 25, 35, and 36, T. 49 N., R. 83 W. Except for the Frontier and Lance formations, younger Cretaceous rocks were measured in secs. 12 and 13, T. 49 N., R. 83 W. The Frontier formation was measured in sec. 1, T. 48 N., R. 83 W., and the Lance formation in sec. 29, T. 49 N., R. 83 W.

PRE-CAMBRIAN ROCKS

Pre-Cambrian rocks in the Crazy Woman Creek area have not been studied in detail. They consist mainly of foliated granite which has been locally intruded by diabase and pyroxenite dikes and irregularly shaped pegmatite masses. The granite is pinkish gray to gray, fine to coarse grained and contains plagioclase in places altered to sericite, quartz, microcline, biotite, and minor amounts of accessory minerals. Enclosed in pre-Cambrian granite in the southern half of sec. 31, T. 47 N., R. 83 W. is a small deposit which contains calcite, diopside, garnet, soda amphibole, epidote, oligoclase, and allanite.

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PALEOZOIC ROCKS

FLATHEAD SANDSTONE

The Flathead sandstone unconformably overlies the foliated pre-Cambrian granite and is overlain by the Gallatin limestone and Gros Ventre formation, undivided. Darton (1904, 1906) considered the unit a part of his Deadwood formation. The term Flathead sandstone was first used in this region by Wilson (1938), who applied it to outcrops of the formation along the Tensleep Fault west of the southern part of the Crazy Woman Creek area. In 1941 Demorest extended the usage to the east flank of the Bighorn Mountains.

The formation consists of about 260 feet of tan to light-brown, medium- to coarse-grained quartz sandstone. The quartz grains are relatively equant and rounded throughout, and many are secondarily enlarged; accessory minerals are rare. The basal 2 to 5 feet are conglomeratic, containing well-rounded quartz pebbles as much as 1.5 inches long. Bedding ranges from regular to cross laminated. The Flathead sandstone forms a rounded ridge commonly covered by pine trees or grass. The upper few feet of the Flathead sandstone contains abundant inarticulate brachiopods and sparse "*Elrathia*" sp.; the latter fossil indicates a Middle Cambrian age for at least the upper part of the Flathead sandstone of the mapped area.

GALLATIN LIMESTONE AND GROS VENTRE FORMATION, UNDIVIDED

The Gallatin limestone and Gros Ventre formation are not distinguishable in this area although elements of both are present. They overlie the Flathead sandstone. The sequence crops out high along the flanks of the Bighorn Mountains and generally dips eastward. Three distinct lithologic units are present. The lower 136 feet consists of a very friable nonresistant medium- to coarse-grained glauconitic sandstone. The average length of the intermediate intercept of quartz grains in a disaggregated sample mounted in balsam is 0.3 millimeter as compared with the average of 0.4 millimeter for the long intercept. The quartz grains range from rounded to subangular and the glauconite is polylobate. About 30 percent of the rock is glauconite and the remainder is quartz. The upper part of the sequence is partly hematitic; colors range from a drab brownish green to dusky red. The glauconitic sandstone and overlying unit form soft slopes; except where exposures are good, the two units cannot be separated. The sandstone is overlain by about 370 feet of interbedded soft grayish-green shale, light-gray limestone, thin sandstones, and beds of flat-pebble conglomerate. The slopes formed by these units are usually covered by talus and vegetation. The topmost unit, which occupies the stratigraphic position of the Gallatin limestone of other areas, is about 50 feet thick and consists of resistant grayish-red slabby silty limestone and a few thin beds of flat-pebble conglomerate. The limestone contains about 35 percent of irregularly shaped angular silt and very fine sand sized grains; the remainder is calcite in rhombs ranging from 0.1 millimeter in length down to cryptocrystalline interstitial filling. Minor amounts of glauconite are present. Some very small brachiopod shells are visible in thin section.

The contact between the Flathead sandstone and the Gallatin limestone and Gros Ventre formation, undivided, is marked by a sharp change from resistant nonglauconitic quartz sandstone below to friable glauconitic sandstone above. Darton (1904, 1906) included the units which are herein defined as the Flathead sandstone and the Gallatin limestone and Gros Ventre formation, undivided, in his Deadwood formation. Demorest (1941) used the term Flathead sandstone and referred to the overlying shale and limestone section as the Deadwood formation. The glauconitic sandstone and the grayish-green shale sequence strongly resemble the Gros Ventre of areas to the west, and the grayish-red limestone occupies the stratigraphic position of the Gallatin limestone. Because the limestone is too thin to be mapped as a separate unit in the areas of steep dips and vertical faces where it commonly crops out, it is included with the Gros Ventre formation. Trilobite assemblages that characterize the Dresbach and Trempeleau ages of the Late Cambrian are found in the glauconitic sandstone and grayish-green shale. Fossils representing a Franconian age have not been found, but this is probably due to generally heavy cover on the softer parts of the Gallatin limestone and Gros Ventre formation, undivided. Although no fossils were found in the grayish-red limestone within the mapped area, Denson (personal communication, 1951) reported a Canadian fauna to be present in the unit about 32 miles to the northwest.

BIGHORN DOLOMITE

The Bighorn dolomite overlies the Gallatin limestone and Gros Ventre formation, undivided, and is unconformably overlain by the Madison limestone. The formation crops out in prominent cliffs along both flanks of the Bighorn Mountains north of the Horn. The Bighorn dolomite consists of three major units.

The basal 65-foot unit of the formation is a very light gray to brick-red very fine grained to coarse grained almost pure quartz sandstone; accessory minerals are rare. Of this sandstone unit the lower 48 feet is dominantly very light gray and very fine grained. Grains vary in cross section from equidimensional to somewhat elongated and from rounded to subround. Some zones show hematitic staining. The next higher 12 feet of sandstone includes two major grain sizes, those

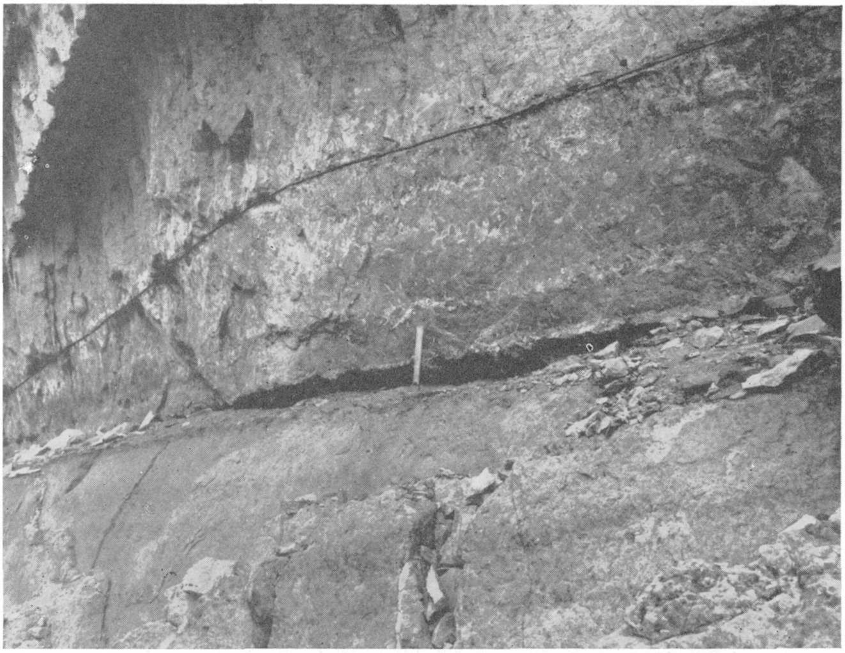

FIGURE 16.—Contact between the dolomitic and sandstone units of the Bighorn dolomite on the North Fork Crazy Woman Creek. Bone fragments zone about 8 inches below hammer; handle rests on unit 10.

ranging from 0.5 to 1.0 millimeter in diameter and those ranging in long intercept from 0.2 to 0.5 millimeter. Grains of the coarser fraction consist of almost perfect spheres; grains of the finer fraction show less perfect sphericity although they are quite rounded. A great number of the larger grains contain very fine hairlike needles of rutile(?). This 12-foot bed (fig. 16) contains abundant small bone fragments of primitive jawless fishes. The upper 3.5 feet is fine to medium-grained well-indurated quartz sandstone which contains mollusks, *Receptaculities oweni* Hall, and conodonts. At the surface this 65-foot sandstone unit is moderately friable, but, in the few subsurface sections where it has been drilled, it is characteristically very dense, hard, and impermeable.

Overlying the basal 65-foot sandstone unit of the Bighorn dolomite is about 250 feet of tan very dense massive dolomite which forms steep resistant cliffs (fig. 15). The weathered surface of the dolomite is, in places, pitted and marked by a reticulate network of siliceous veinlets. The lower 3 feet of the unit contains very fine sand grains. Thin sections of samples of the massive dolomite show a random orientation of dolomite rhombs ranging in maximum length from 0.02 to 0.04 millimeter. Some larger anhedral crystals of dolomite have the smaller rhombs included in them.

Overlying the 250-foot massive dolomite along the North Fork Crazy Woman Creek is a white-weathering slabby argillaceous dolomite about 40 feet thick. This dolomite is characterized by an abundance of ostracodes covering bedding surfaces. In a covered interval between the North Fork Crazy Woman Creek and Billy Creek the unit wedges out, but north of the North Fork Crazy Woman Creek it thickens and persists.

The Bighorn dolomite is truncated by the Madison limestone and thins from about 350 feet along the North Fork Crazy Woman Creek to about 150 feet at the southern end of the Horn. Darton (1906) shows the Bighorn dolomite completely cut out 18 miles southwest of the Horn by the unconformity at the base of the Madison limestone. The contact between the grayish-red limestone of the Gallatin limestone and Gros Ventre formation, undivided, and the Bighorn dolomite is sharp. Beds directly above the contact are light-gray sandstone, whereas those below are grayish-red limestone.

The basal sandstone unit of the Bighorn dolomite has at different times been correlated with the Harding sandstone of Colorado and with the Lander sandstone member of the Bighorn dolomite of the western Wind River Basin. The correlation of these two units is not certain, however, for the Lander sandstone until recently has been regarded as Upper Ordovician (Miller, 1932) and the Harding sandstone as Middle Ordovician. Flower (1952b), in light of more recent knowledge, indicates that the Lander sandstone member may be as old as late Trenton, and he has reaffirmed the Middle Ordovician age of the Harding sandstone as stated by Kirk (1930). According to Flower (1952a) the cephalopods of the Harding sandstone most resemble those of Black River and Trenton species; hence it is apparent that the Lander is younger than the Harding. Amsden and Miller (1942), who have studied the conodonts of the basal sandstone of the Bighorn dolomite of the Crazy Woman Creek area, have discovered two distinct faunal zones in that unit. The younger is restricted to unit 10 (the upper 3.5 feet of the lower 65-foot sandstone) of the Bighorn dolomite of this report (p. 112) and the older to the underlying sandstone. According to Amsden and Miller, conodonts from the lower zone are similar to those found in the Harding sandstone of Colorado, as well as in the Platteville limestone of Minnesota. Unit 10, the upper zone, yielded a conodont fauna similar to that found in the gray shales and siltstones of the Whitewood limestone of the Black Hills, South Dakota. The shale and siltstone sequence of the Whitewood is regarded by Furnish (and others, 1936) as Middle(?) Ordovician. Amsden and Miller regard the lower faunal zone of the clastic portion of the Bighorn dolomite as Middle Ordovician, as well as unit 10, but state that the fauna of unit 10 may be Upper Ordovician. Because the

Harding and Lander sandstones now appear as two distinct chronological entities within the Middle Ordovician, and as two distinct faunal zones are present in the basal sandstone of the Bighorn dolomite, it is possible that chronologic elements of both the Lander and Harding sandstones are present in the clastic portion of the Bighorn dolomite. According to Josiah Bridge, collections of *Maclurites manitobensis* Whiteaves and *Endoceras landerense* Foerste from a bed equivalent to unit 10 just 12 miles north of the mapped area indicate a Middle Ordovician age for that unit. Fossils from the upper part of the massive dolomite, the middle unit of the Bighorn dolomite, and from the upper white slabby dolomite indicate a Late Ordovician age for these parts of the Bighorn dolomite.

MADISON LIMESTONE

The Madison limestone unconformably overlies the Bighorn dolomite and crops out in resistant cliffs along the flanks of the Bighorn Mountains (fig. 17). The unit has been penetrated in deep test wells in both the Billy Creek and the Steel Creek anticlines. The Madison limestone is about 550 feet thick and consists of four major alternating units of limy dolomite, which range in color from light tan to gray, and limestone. The lower 3 feet of the formation is slightly sandy

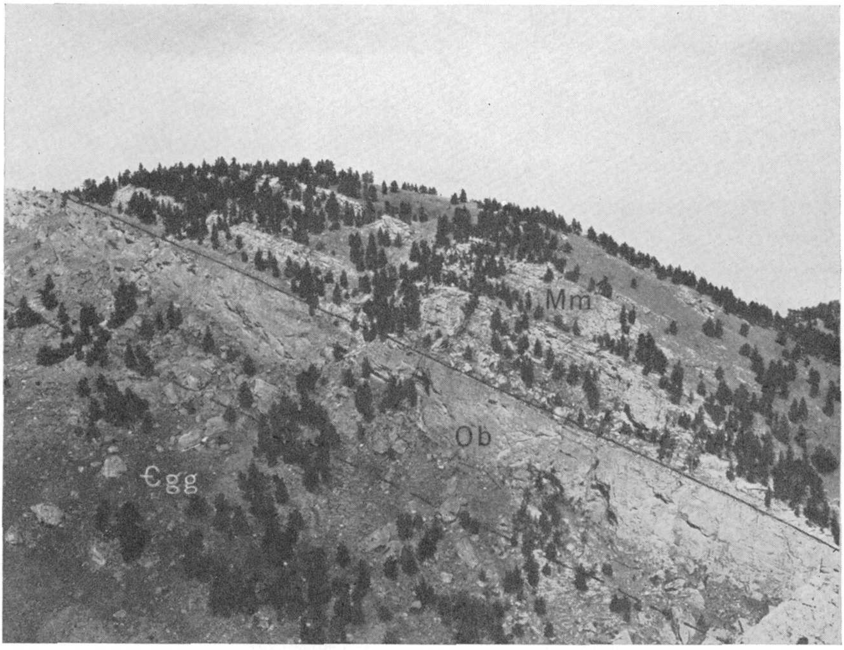

FIGURE 17.—View of the east flank of the Horn at the South Fork Crazy Woman Creek. The Bighorn dolomite (Ob) and Madison Limestone (Mm) form the resistant cliffs. The Gallatin limestone and Gros Ventre formation, undivided (€gg), form the slope.

and locally conglomeratic. The sequence ranges from thin bedded to massive. Some of the beds are bioclastic, but most are finely crystalline limestone or dolomite. The entire formation is fossiliferous but sparsely so in the lower 100 feet. The most common fossils are spiriferoid brachiopods and solitary tetracorals; the former are abundant in the middle part.

The contact between the Bighorn dolomite and the Madison limestone is characterized by a topographic break; the Madison limestone cliffs are set back from the Bighorn dolomite. The basal part of the Madison limestone is a gray somewhat sandy dolomitic limestone; the underlying Bighorn dolomite is a tan dense dolomite or white slabby dolomite north of Billy Creek. The Madison limestone contains an early Mississippian fauna; collections from Rock Creek, 12 miles north of the mapped area, identified by Helen Duncan on April 12, 1952, indicate that the upper part may be late Mississippian.

AMSDEN FORMATION

The Amsden formation overlies the Madison limestone and is present along the flanks of the Bighorn Mountains. A complete section was penetrated in test holes in both the Billy Creek and Steel Creek anticlines. The Amsden formation is about 250 feet thick; it consists of soft brick-red fine-grained silty sandstone in the basal 100 feet, thin-bedded light-gray dolomites, dolomite breccia, and soft red claystone in the middle 75 to 100 feet, and yellow to tan massive dolomite interspersed with a network of light-brown siliceous veinlets in the upper 50 to 75 feet. The contact between the Madison limestone and the Amsden formation is marked by a sharp change from dense gray limestone below to thin lenticular sandstones, slabby tan dolomite, and reddish-brown siltstones above. Collections from the lower part of the Amsden formation at Rock Creek, 13 miles north of the mapped area, contained *Diphyphyllum* sp., *Syringopora* sp. (identified by Helen Duncan on April 16, 1952) and some productid brachiopods. Corals found in the lower part of the Amsden formation range from late Mississippian to early Pennsylvanian; no forms diagnostic of either system were found. No fossils were found in the upper part of the Amsden formation of the mapped area.

TENSLEEP SANDSTONE

The Tensleep sandstone overlies the Amsden formation and forms the resistant steep dip slopes along the flanks of the Bighorn Mountains. The contact of the Tensleep with the overlying Permian red shale and gypsum sequence marks the topographic boundary between the Bighorn Mountains and the Powder River Basin. The formation has long been a producer of oil in fields along the western and southern margins of the basin.

The Tensleep sandstone in the mapped area is about 350 feet thick. Mapel (personal communication, 1952) reports a thickness of 275 feet in the Lake De Smet area. Richards and Rogers (1951) report a range in thickness from a wedge edge to 100 feet for the Tensleep sandstone in the Hardin area, Montana, 55 miles north of the Crazy Woman Creek area. The formation is dominantly a light-tan to gray, or sometimes grayish-red, fine-grained massive to crossbedded sandstone. Dolomite beds are common in the lower part of the formation; they are thinner and scarcer in the upper part. In places thin lenticular beds of light-gray to brown chert yield abundant foraminifers. The apparently conformable contact between the Amsden formation and the Tensleep sandstone is placed at the top of the upper thick limy dolomite. Beds above the contact are dominantly sandstone. Love (personal communication, 1952) collected fusulines from the upper part of the Tensleep sandstone along the western margin of the Bighorn Mountains, which were identified by L. G. Henbest as characteristic of the Des Moines (early Pennsylvanian) epoch.

PERMIAN RED SHALE AND GYPSUM SEQUENCE

The Permian red shale and gypsum sequence overlies the Tensleep sandstone; it crops out along the eastern margin of the Bighorn Mountains and generally dips eastward. The sequence is about 250 feet thick. The lower 50 feet consists of soft dark reddish-brown silty claystone, with local conglomeratic lenses in the basal 6 feet composed of reworked Tensleep sandstone in a reddish-brown claystone matrix. This unit is overlain by 50 feet of red siltstone which contains at the top and base 5 and 8 feet, respectively, of thin-bedded yellowish-gray dolomitic and argillaceous limestone that is similar to the Minnekahta limestone of areas to the east and southeast. The upper 150 feet consists of interbedded gypsum and red siltstone, which is capped by a porous brecciated and lenticular limestone from 3 to 5 feet thick. In places the gypsum is leached out at the surface. Except for the limestones, the unit forms a slope.

The contact with the Tensleep sandstone is sharp; beds above the contact are soft red claystone and shale which contrast strongly with the light-colored sandstones below. The basal 50-foot red silty claystone unit is very similar to the Opeche shale of eastern Wyoming and seems to be correlative with that formation. The limestone of the middle red siltstone and limestone unit bears a strong resemblance to the Minnekahta limestone of eastern Wyoming and occupies the same stratigraphic position. Darton (1904) included the dolomitic limestone in his Chugwater formation but suggested that it was equivalent to the Minnekahta limestone. Although no fossils have been found in the dolomitic limestones of the mapped area, brachiopods, pelecypods, and bryozoans similar to those in the Phosphoria formation of Permian age, 70 miles to the southwest, were collected by Love (personal communication, 1952) 3 miles northwest of Mayoworth from a tan dolomite which directly overlies the Tensleep sandstone. The upper 150-foot gypsum and red siltstone unit is tentatively correlated with a similar sequence in the upper part of the Phosphoria formation on the southwestern flank of the Bighorn Mountains and with the Permian(?) shale and gypsum sequence of the Hartville region in eastern Wyoming. The gypsiferous sequence may be in part equivalent to the Dinwoody formation of Early Triassic age of the southwestern Bighorn Basin.

MESOZOIC ROCKS

CHUGWATER FORMATION

The Chugwater formation overlies the Permian red shale and gypsum sequence and is unconformably overlain by the Gypsum Spring formation. The formation crops out as a prominent red unit along the western margin of the Powder River Basin and has been penetrated in numerous test holes in that region. It ranges in thickness from 750 to more than 800 feet and in most places can be separated into three units. The lowermost 700 feet, called the Red Peak member of the Chugwater formation in central Wyoming (Love, Johnson, and others, 1945), consists of a soft sequence of interbedded moderate reddish-brown siltstone, shale, and silty fine-grained sandstone; the sandstone is more abundant in the upper half. The unit weathers to soft reddish slopes. Overlying this unit in places is a lenticular slabby dense resistant light-gray dolomitic limestone, which has a maximum thickness of 5 feet in the mapped area and which contains purple clay laminae along bedding surfaces. This limestone is correlated with the Alcova limestone member of the Chugwater formation of central Wyoming. It can be traced on the surface in prominent hogbacks along the southeast edge of the Bighorn Mountains to the Powder River lineament and correlated in subsurface sections into central Wyoming. The topmost unit of the Chugwater formation is a salmon-pink fine-grained massive sandstone ranging in thickness from 45 to more than 100 feet. The sandstone in many places contains scattered spherical frosted quartz grains as much as 0.5 millimeter in diameter embedded in the fine-grained matrix. In the Red Fork Powder River area this sandstone has been called the Crow Mountain sandstone member of the Chugwater formation by Carlson (1949) on the basis of correlation with the type Crow Mountain sandstone member of Love in central Wyoming (Love, 1939). The threefold division of the Chugwater formation is feasible only where the Alcova limestone member is present. Where the limestone is absent, it is difficult to separate the sandstone beds of the

Red Peak member from those of the Crow Mountain sandstone member as defined by Love (1948).

The contact between the Permian red shale and gypsum sequence and the Chugwater formation is characterized by a change from red siltstone and white gypsum below to reddish-brown siltstone and silt shale above.

The lower part of the Chugwater formation, the Red Peak member of central Wyoming, thins from about 700 feet in the Crazy Woman Creek area to 480 feet in the Texas Co.'s Forbes test well 1, 11 miles southwest of Sheridan, Wyo. In view of this substantial northward thinning along the western margin of the Powder River Basin when compared with the relatively constant thickness for the unit in central Wyoming, it is likely that the Alcova limestone member rests unconformably on the lower Chugwater unit. The so-called Crow Mountain sandstone member ranges in thickness from 45 to more than 100 feet within the Crazy Woman Creek and thins to less than 25 feet on Little Goose Creek 14 miles south of Sheridan. The difference in thickness of the sandstone as well as the complete absence of younger Chugwater strata, such as are present in the Wind River Basin, is evidence for an unconformity at the base of the Gypsum Spring formation (fig. 19). Love, Johnson, and others, (1945) have suggested that the thinning of the Nugget sandstone and the upper part of the Chugwater formation in central Wyoming may be the result of uplift followed by erosion preceding Gypsum Spring time. Except for the Alcova limestone member, the Chugwater formation is nonmarine in origin and fossils are rare. Those fossils found indicate a Triassic age for the Chugwater formation.

GYPSUM SPRING FORMATION

The Gypsum Spring formation unconformably overlies the Chugwater formation and is unconformably overlain by the Sundance formation. The Gypsum Spring formation thins southward from 120 feet at Elgin Creek to a wedge edge 6 miles south of the mapped area; it persists northward along the western margin of the Powder River Basin into Montana where it attains a maximum thickness of 190 feet in the vicinity of Lodgegrass Creek (Hose and Mapel, unpublished data). Because of the southward thinning of the Gypsum Spring formation, with the oldest beds extending the farthest south, the following description applies to the northernmost measured sections of the mapped area.

The lower part of the formation contains as much as 50 feet of probably limy gypsum with interbedded reddish-brown siltstone and shale, but generally the gypsum is leached out, leaving in its stead a thinner section of limestone breccia and reddish-brown siltstone or shale. Overlying the gypsiferous unit are from 20 to 40 feet of moderate reddish-brown claystone. The remaining 70 feet consists of alternating zones of light-gray argillaceous limestone and moderate reddish-brown claystone; a 5-foot limestone zone is at the base, succeeded by a 15-foot claystone unit and a 10-foot limestone unit, with a 20-foot claystone unit at the top.

The unconformable contact between the Chugwater formation and the overlying Gypsum Spring formation is comparatively sharp. The beds below the contact are reddish-brown sandstone whereas those above consist of gypsum, limestone breccia, or fine-grained siltstone.

Southward from Elgin Creek the Sundance formation overlies progressively older units of the Gypsum Spring formation; at the southern edge of the mapped area the Sundance formation rests on a thin portion of the lower gypsiferous unit (figs. 18 and 19). This relationship indicates post-Gypsum Spring and pre-Sundance upwarping and erosion in the southern part of the Powder River Basin.

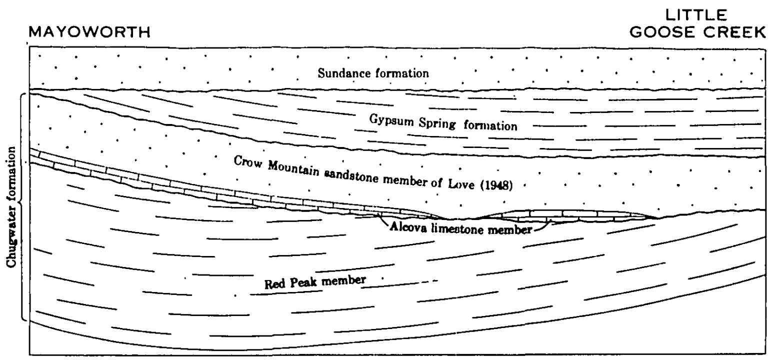

FIGURE 18.—Diagrammatic cross section showing unconformable relationship of Gypsum Spring formation to older and younger units along the western margin of the Powder River Basin.

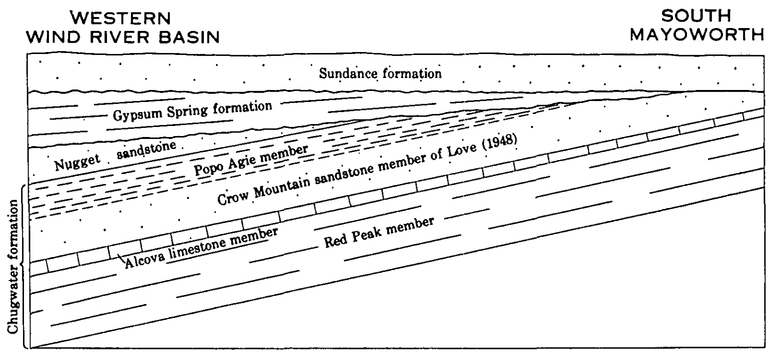

FIGURE 19.—Diagrammatic cross section showing relationship of Gypsum Spring formation to older and younger units from the western Wind River Basin to 3 miles south of Mayoworth.

The thinning of the Gypsum Spring formation from the western part of the Wind River Basin eastward has also been attributed to mild regional upwarping and subsequent erosion (Love, Tourtelot, and others, 1945). Fossils from the Gypsum Spring formation of the mapped area are limited to nondiagnostic pelecypods. Imlay (personal communication, 1951), on the basis of collections from a more typically marine facies of the formation in the western part of the Bighorn Basin and on the relationship of the formation to younger marine units in western Wyoming, considers the Gypsum Spring formation to be early Middle Jurassic (Lower Bajocian) in age.

SUNDANCE FORMATION

The Sundance formation unconformably overlies the Gypsum Spring formation in the Crazy Woman Creek area (fig. 18) and is overlain by the Morrison formation. The formation crops out along the western part of the Powder River Basin and has been penetrated in numerous test holes in the region. The Sundance formation is approximately 287 feet thick. The lower 112 feet consists of three stratigraphic units of which the lower and upper are resistant sandstones: the lower 30 feet is light-gray to light-tan fine-grained regularly bedded very calcareous and somewhat resistant sandstone with some shale beds in the lower part; overlying the basal sandstone is approximately 25 feet of soft calcareous grayish-olive shale. The next higher 57 feet is yellowish-gray fine-grained calcareous slightly glauconitic crossbedded resistant sandstone. The remaining 175 feet consists dominantly of olive-gray silty calcareous shales with a few thin soft sandstone layers. The upper 10 feet of this 175-foot unit consists of slabby shaly calcareous slightly glauconitic brown-weathering sandstone.

In the southern part of the mapped area the lowermost unit of the Sundance formation is a lenticular glauconitic, oolitic, and locally conglomeratic limestone. Several thin sections of specimens from the oolite bed show a flood of rounded quartz grains. Many of these grains serve as nuclei for the oolites. The oolites are spherical to ovoid in shape, ranging in diameter from 0.1 to 0.3 millimeter. The oolites range from radial with no concentric bands to a series of concentric bands in which the crystalline calcite is radial. Interstitial filling is cryptocrystalline calcite. The basal oolite bed attains a thickness of approximately 15 feet about 7 miles south of the mapped area and rests on the Crow Mountain sandstone member of the Chugwater formation. The lower fine-grained sandstone in the mapped area grades into an arenaceous oolitic limestone with abundant rounded quartz and rare zircon grains, 7 miles south of the mapped area.

The upper slabby sandstone of the Sundance formation is channeled, and the channels are filled by the basal sandstone of the Morrison formation. The contact between the Gypsum Spring formation and the Sundance formation is unconformable and is marked by soft red shale and argillaceous limestone beds below the contact and sandstone or dense oolitic limestone beds above. The basal sandstone of the mapped area yielded *Isocrinus* sp., and a zone 20 feet above the base of the 175-foot shale sequence contained abundant *Pachyteuthis densus* (Meek and Hayden). Neither of these fossils is particularly useful in accurately dating beds, but ammonites from the basal sandstone of the Sundance formation of adjacent areas and in the Black Hills (Imlay 1947) indicate a Late Jurassic age for the Sundance formation.

MORRISON FORMATION

The Morrison formation overlies the Sundance formation and is overlain by the Cloverly formation. The outcrop of the Morrison formation trends essentially north-south and dips generally eastward. The formation has remarkable uniformity of thickness, about 185 feet, in both surface and subsurface sections along the western part of the Powder River Basin. The formation is dominantly sandstone in the lower part and claystone in the upper part. The lower part contains many beds of yellowish-gray siltstone and fine-grained sandstone interbedded with varicolored shales and claystones. In the upper part there is much less sandstone and siltstone and more red, green, and black claystone. The upper 30 feet throughout the mapped area is very dark gray carbonaceous shale; the lower 112 feet of the formation is calcareous. Fifty-five feet above the base is a lenticular very light gray marlstone bed about 1 foot thick which contains abundant nonmarine ostracodes and chara fructification. Disaggregated grains of the basal sandstone of the Morrison formation show an average long intercept of 0.24 millimeter and an average intermediate intercept of 0.13 millimeter. The grains range from angular to subangular and are dominantly quartz, although some feldspar is present; accessory minerals are minor. The matrix of the sandstone falls into the clay to silt size, and the cement is calcite.

Except for the thin slabby beds of glauconitic sandstone of the Sundance formation, strata below the contact with the Morrison formation are dominantly shale; beds directly above the contact are massive light-gray lenticular sandstones. The Morrison formation contains an abundant fresh-water invertebrate fauna of Late Jurassic age near Mayoworth, about 7 miles south of the Crazy Woman Creek area (Love, Thompson, and others, 1945). Dinosaur bones are also common.

CLOVERLY FORMATION

The Cloverly formation overlies the Morrison formation. Throughout the mapped area the Cloverly formation consists of a well-developed basal sandstone which ranges in thickness from 15 to 45 feet, overlain by about 120 feet of grayish-black shale interlaminated with olive-gray siltstone. The basal sandstone is coarser grained than the sandstones in the Morrison; from a disaggregated sample approximately 45 percent was retained on a 60 mesh screen, 45 percent retained on a 115 mesh screen, and 10 percent retained on a 250 mesh screen. The sandstone is composed of almost pure quartz; grains are relatively equant and rounded to subangular. Many of the grains have been secondarily enlarged and have developed crystal facets. The basal sandstone forms a resistant ridge largely covered with pine trees. The grayish-black shale and siltstone sequence contains several zones of flat ellipsoidal ironstone concretions, as well as a zone of radial concretions of the phosphatic mineral dahllite, 110 feet above the base of the formation. The grayish-black shale and siltstone sequence is capped by a 5.5-foot bed of calcareous thin-bedded brownish-gray siltstone, which forms a persistent ridge throughout the mapped area.

The upper boundary of the Cloverly formation in the mapped area conforms to the definition of the Cloverly formation in adjacent regions. In central Wyoming the formation consists of three major units: a basal sandstone which is locally conglomeratic, an intermediate varicolored claystone, and the so-called "rusty beds," a series of resistant slabby siltstone and sandstone beds. This threefold breakdown strongly resembles the Black Hills sequence where the Lakota sandstone is at the base and is overlain by the Fuson shale and the Fall River sandstone. Except for minor facies variations the two sequences are probably equivalent. The correlation of the Cloverly formation of the Crazy Woman Creek area with that of central Wyoming and with the Lakota sandstone, Fuson shale, and Fall River sandstone of the Black Hills is difficult because of the atypical facies of the sequence in the mapped area.

In the Crazy Woman Creek area the intermediate varicolored sequence is absent and the rusty bed sequence is poorly developed. The equivalents of those units are grayish-black shales and siltstones. The lower part of the overlying Skull Creek shale also contains grayish-black shale and siltstone, as well as a resistant and persistent ridge which is almost identical with that in the upper part of the Cloverly formation. A study of electric logs from the Mush Creek oilfield on the southwest flank of the Black Hills to the Crazy Woman Creek area across the Powder River Basin (pl. 9) shows the development of a zone of siltstone in the lower part of the Skull Creek shale as indicated by the increase in resistivity curves of subsurface section 8. This siltstone zone of the Skull Creek shale persists along the western margin of the basin into the Crazy Woman Creek area; it is for this reason that the upper resistant siltstone and grayish-black shale of the sequence between the basal sandstone of the Cloverly formation and the Newcastle sandstone is included with the Skull Creek shale rather than with the Cloverly formation.

It should be noted in subsurface sections 12 through 15 (pl. 9) that the upper zone of the Cloverly formation is dominantly shale, and in the region of Sheridan, Wyo., the problem of selecting the top of the Cloverly formation would be difficult.

One mile south of the mapped area the Cloverly formation contains a 20-foot remnant of the intermediate varicolored claystone unit, which is overlain by grayish-black shale and siltstone. The lithologic change northward into the grayish-black shales is apparently gradational, as indicated by the constant thickness of the formation above the basal sandstone in subsurface section 17, at a point 9 miles south of the mapped area and subsurface section 16 on the Middle Fork Crazy Woman Creek. The basal sandstone has a thickness of 12 feet in subsurface section 17 and 55 feet in subsurface section 16.

The contact between the Morrison formation and the Cloverly formation is sharp. The upper part of the Morrison formation consists of dark and dully varicolored claystones and shales, and the lowermost Cloverly strata are light-yellowish-gray sandstone. The assignment of the Cloverly formation to the Lower Cretaceous has been discussed by Love, Thompson, and others (1945).

SKULL CREEK SHALE

The Skull Creek shale overlies the Cloverly formation and varies in thickness from 125 feet in subsurface section 17 (pl. 9), 9 miles south of the mapped area, to 165 feet in subsurface section 16, on the Middle Fork Crazy Woman Creek; it is 165 feet thick on the surface at Muddy Creek. The lower 87 feet is characterized by many laminae and beds of gray siltstone alternating with grayish-black shales, a sequence very much like that in the upper part of the underlying Cloverly formation. This silty zone in the Skull Creek shale first appears in subsurface section 8, sec. 28, T. 53 N., R. 68 W., and persists westward across the Powder River Basin into the Crazy Woman Creek area. The lower 87-foot unit is capped by a resistant ridge-forming siltstone bed about 2.5 feet thick, which can be traced throughout the mapped area. The upper 79 feet consists of grayish-black soft flaky clay shale.

The contact between the Cloverly formation and the Skull Creek shale is placed at the top of the first resistant siltstone ledge above the 15- to 45-foot basal sandstone of the Cloverly formation. Beds directly above the contact are grayish-black shales that form a slope, but beds below the contact are more resistant and contain siltstone laminae.

The Skull Creek shale correlates with that part of the Thermopolis shale which underlies the Muddy sandstone member in central Wyoming. The Skull Creek shale is considered to be Early Cretaceous in age (Cobban, 1951).

NEWCASTLE SANDSTONE

The Newcastle sandstone which overlies the Skull Creek shale was named by Hancock (1920) from excellent exposures about a half mile east of Newcastle, Wyo., on the southwestern edge of the Black Hills. In the southern part of the Powder River Basin and elsewhere the unit has been called the Muddy sandstone or the Muddy sandstone member of the Thermopolis shale. The formation is in general one of the most persistent and widespread sandstones in Wyoming; locally, however, it grades into shale and becomes impermeable, as shown in subsurface sections 5 and 6 and in part 7 (pl. 9). The gradation of the sandstone into shale in an appropriate structural setting, as in the Mush Creek oilfield, is responsible for oil accumulation.

In the mapped area the Newcastle sandstone is about 40 feet thick and consists of light-gray medium-grained sandstone which contains abundant black and red grains. The unit forms a persistent, in many places pine-covered, ridge throughout the mapped area.

The contact between the Skull Creek shale and the Newcastle sandstone is sharp. Beds above the contact are light-colored sandstone which contrast with the grayish-black shales below. The Newcastle sandstone and its correlatives had been regarded for many years as the basal sandstone of the Upper Cretaceous, but Crowley (1951) found foraminifers in the intercalated shales of the Newcastle sandstone in the Mush Creek oilfield which he believed to be of Early Cretaceous age. Subsequently Cobban and Reeside (1951) ascribed to the Early Cretaceous ammonites from the overlying Mowry shale and thus corroborated the Early Cretaceous age of the Newcastle sandstone.

MOWRY SHALE

The Mowry shale overlies the Newcastle sandstone and, like the Newcastle, extends over most of Wyoming. In the Crazy Woman Creek area the Mowry shale is about 500 feet thick and consists of two major units which grade into each other. The lower unit, which is about 150 feet thick, is soft grayish-black shale with several thin beds of bentonite. This unit is nonsiliceous in the lower part but slightly siliceous in the upper part; any contact between it and the overlying unit would be unreliable. The upper unit of 350 feet consists of light-gray brittle laminated siliceous shale, with several yellowish bentonite beds and a few thin sandstones. The siliceous shale crops out as a resistant rounded ridge characteristically marked by a growth of pine trees.

The lower 150-foot unit occupies the same stratigraphic position and is in part the lithogenetic equivalent of the upper part of the Thermopolis shale as defined by Lupton (1916) in the southern part of the Bighorn Basin. It is also equivalent to the nonsiliceous portion of the Mowry shale of the Black Hills, which at one time was mapped as a distinct unit, the Nefsy shale member of the Graneros shale. Rubey (1930, p. 4) considered the Nefsy shale member a poor unit to map and included it in his Mowry siliceous shale member of the Graneros shale. The upper limit of the nonsiliceous portion of the Mowry shale in the mapped area also has a poor upper boundary to map and is included with the Mowry shale.

The contact between the Newcastle sandstone and the overlying Mowry shale is sharp: the beds above the contact are soft grayish-black shales which contrast with the light-gray sandstone below. The Mowry shale contains abundant fish scales throughout. A collection of ammonites from the upper part of the siliceous shale in the southern half of the mapped area contained *Metengonoceras* sp. and *Neogastroplites wyomingensis* (Reeside and Weymouth). This faunule indicates an Early Cretaceous age for the Mowry shale (pl. 10).

FRONTIER FORMATION

The Frontier formation, which is about 480 feet thick, overlies the Mowry shale. The lower 80 feet consists of somewhat bentonitic dark-gray shale and siltstone, with four bentonite beds ranging in thickness from 1 to 6 feet; it is characterized by flat ellipsoidal ferruginous and calcareous siltstone concretions and is similar to the lower part of the Belle Fourche shale of the Black Hills region. The remaining 400 feet of the Frontier formation consists mainly of interlaminated light-gray sandstone and dark-gray shale, with a few conglomeratic sandstone beds and a 4-foot bentonite bed.

The upper 35 feet of this 400-foot unit consists mainly of fine-grained sandstone with a few shale laminae and is capped by a black chert pebble conglomerate which ranges in thickness from 2 to 10 feet. The 35-foot sandstone unit increases in resistance to weathering and becomes coarser grained about 4 miles south of the mapped area. Disaggregated samples of the unit in that area show an average ratio of long to intermediate intercept of 1.4; the intermediate intercept ranges from 0.2 to 0.5 millimeter in length, and the grains range from angular to subrounded. About 20 percent of the grains are feldspar; the remainder is quartz, many grains of which are coated with a limonitic stain. Four miles south of the mapped area the upper 35-foot sandstone is conglomeratic and contains well-rounded ellipsoidal pebbles and cobbles of andesite, as well as abundant black-weathering chert pebbles. The conglomeratic sandstone forms a resistant ridge which is recognizable over the entire area, but the underlying strata usually form soft slopes.

The top 2- to 10-foot conglomeratic sandstone of the Frontier formation of the mapped area is not equivalent lithogenetically or chronologically to the top sandstone of the Frontier formation (First Wall Creek sand of drillers) of the Tisdale anticline, 19 miles to the south. There the top sandstone is either late Turner or early Sage Breaks in age, and the Frontier formation is much thicker than in the Crazy Woman Creek area where the top sandstone of the Frontier formation is of Greenhorn age.

Several of the faunal zones of Colorado age as outlined by Cobban (1951) in the Black Hills region are represented in the Crazy Woman Creek area (fig. 20). A zone 250 to 350 feet above the base of the Frontier formation contains *Acanthoceras? amphibolum* Morrow, which is correlative with the middle faunal zone of the Belle Fourche

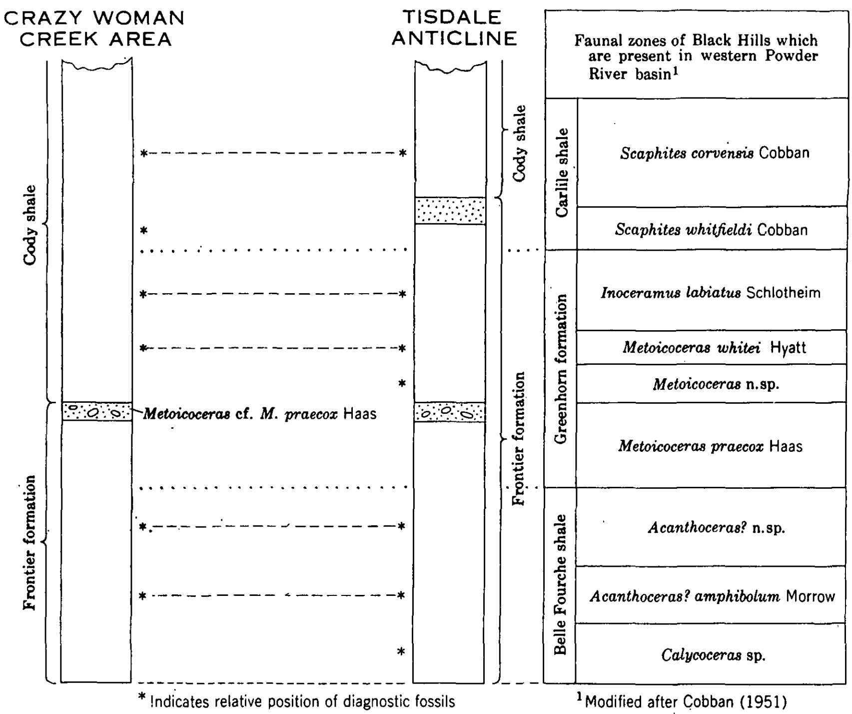

FIGURE 20.—Diagram (not to scale) showing the occurrence of faunal zones of the Black Hills region in the Frontier formation of the Crazy Woman Creek area and Tisdale anticline.

shale in the Black Hills. *Acanthoceras?* n. sp. was found 400 feet above the base of the Frontier formation and correlates with the upper zone of the Belle Fourche shale. The topmost conglomerate ledge contains *Metoicoceras* cf. *M. praecox* Haas which resembles *M. praecox* Haas, the diagnostic form of the lowest faunal zone of the Greenhorn formation, which overlies the Belle Fourche shale in the Black Hills. *Metoicoceras* cf. *M. praecox* Haas is slightly more advanced than *M. praecox* Haas and is probably slightly younger (Cobban, personal communication, 1952). The lowermost Belle Fourche faunal zone, characterized by *Calycoceras* n. sp., was not found in the mapped area but is present on the northeast flank of the Tisdale anticline 19 miles south of the Crazy Woman Creek area. The part of the Frontier formation of Belle Fourche age is much more sandy than its Black Hills equivalent, and the uppermost sandstone of the Frontier formation, which is lowermost Greenhorn in age, contrasts sharply with the marls, limestones, and shales in the lower part of that unit in the Black Hills.

The contact between the Mowry shale and the overlying Frontier formation is arbitrarily placed at the base of the first bentonite bed above the siliceous shale. Beds above the contact are nonsiliceous, in contrast with siliceous beds below.

CODY SHALE

The Cody shale overlies the Frontier formation. At Elgin Creek the shale is about 3,670 feet thick and is about the same thickness in the North Fork Powder River well. However, equivalent rocks in the Amerada Petroleum Co.'s deep test at Smith Cut, 3 miles south of the mapped area, are about 3,100 feet thick. The amount of thinning within the mapped area is not known, but it is probable that the Cody shale in the Billy Creek and Steel Creek anticlines is considerably thinner than at Elgin Creek. Almost the entire sequence is soft and forms slopes. Strata whose age equivalents range from lower Greenhorn through Claggett are included in the Cody shale.

The lower 320 feet is equivalent in age to the Greenhorn formation and consists domintantly of dark-gray shale. The basal 35 feet of this sequence contains some soft conglomeratic sandstones interbedded with shale; the upper 40 feet consists of light-gray fine- to medium-grained soft calcareous sandstone. Shale just below this sandstone is also calcareous. *Metoicoceras* n. sp., characteristic of the lower part of the Greenhorn formation of the Black Hills, was not found in the Cody shale of the Crazy Woman Creek area but was found in the Frontier formation of the northeast flank of the Tisdale anticline, 19 miles south of the mapped area. Fossils of the *Metoicoceras whitei* Hyatt zone of the upper middle part of the Greenhorn formation were found about 100 feet above the base of the Cody shale, and the *Inocer-*

amus labiatus Schlotheim zone characteristic of the uppermost Greenhorn was found at the top of that part of the Cody shale that is of Greenhorn age.

Overlying the 40-foot sandstone at the top of the sequence of rocks of Greenhorn age is 45 feet of interlaminated shale and fine-grained sandstone which contains the *Scaphites whitfieldi* Cobban zone, characteristic of the middle part of the Turner sandy member of the Carlile shale. The lower Carlile faunal zones typical of the unnamed member of the Carlile shale beneath the Turner sandy member in the Black Hills appear to be absent in the Crazy Woman Creek area. These two zones are also absent in the Bighorn and Wind River Basins to the west and southwest.

Overlying the sequence of middle Turner age in the mapped area is approximately 115 feet of dark-gray silty shale, the lower 20 feet of which contains several beds of ironstone concretions and the upper 95 feet of which contains septarian concretions. The 95-foot unit contains an abundant fauna, including *Scaphites corvensis* Cobban, which is diagnostic of the Sage Breaks member of the Carlile shale of the Black Hills (pl. 10).

In the vicinity of the Tisdale anticline the First Wall Creek sand of drillers, which forms the top unit of the Frontier formation of that area, occurs above a sequence which resembles the lithology of the *Scaphites whitfieldi* Cobban zone and below shales containing a Sage Breaks fauna. It is probable that this sandstone, which wedges out north of the Tisdale anticline and about 4 to 5 miles south of the Crazy Woman Creek area, is equivalent to the upper part of the Turner or the lower part of the Sage Breaks members of the Carlile shale. In summary, the upper part of the Frontier formation of the Tisdale anticline includes beds of Greenhorn and Turner age, whereas in the Crazy Woman Creek area these beds are included in the Cody shale.

The next higher 200 feet of section is poorly exposed and consists largely of dark-gray shales. About 160 feet above the base of the unit is a persistent siltstone concretion zone weathering light rusty brown, in which the concretions are as much as 10 feet in diameter. This zone contains an abundant fauna characteristic of the lower part of the Niobrara; the 2 most abundant forms are *Inoceramus deformis* Meek and *Scaphites preventricosus* Cobban (pl. 10). This concretionary zone has been mapped throughout the area and is well developed along U. S. Highway 87, at a point 20 miles south of the mapped area.

The overlying 750 feet is dominantly soft gray chalky shale, which is usually poorly exposed; it is lithologically unfavorable for the preservation of fossils. The only fossils found in the unit in the mapped area are *Ostrea congesta* Conrad encrusting thick-shelled *Inoceramus* sp. A similar unit in a similar stratigraphic position in the Black Hills also contains this fauna. Abundant specimens of flattened mollusks were found in the unit 20 miles south of the Crazy Woman Creek area, half a mile east of U. S. Highway 87, along the south bank of the South Fork Powder River. This fauna includes one scaphite questionably identified as *S. depressus* Reeside, a form diagnostic of the middle part of the Niobrara. The remaining calcareous shale sequence is poorly exposed; no other Niobrara faunal zones were found.

The next higher 1,100 feet of section consists essentially of interlaminated dark-gray shale and light-gray fine-grained sandstone with many zones of siltstone and many beds containing light-gray septarian concretions. No fossils were found in the lower 300 feet of the sequence, but it may be equivalent to the Telegraph Creek. From 300 feet above the base to the top of the unit the sequence contains many varieties of both *Scaphites hippocrepis* (De Kay) and *Scaphites aquilaensis* Reeside. These forms are characteristic of the Eagle sandstone of Montana.

The next younger unit of the Cody shale is the Shannon sandstone member, which is about 200 feet thick. This unit consists dominantly of pale-olive very fine to fine-grained glauconitic sandstone with many thin partings of dark-gray shale. A disaggregated discrete sample of the Shannon sandstone member has relatively equant and angular grains ranging in intermediate intercept from 0.1 to 0.2 millimeter. The sample shows a significant percentage of transparent and cloudy feldspar, but it is dominantly clear quartz. Polylobate glauconite is very abundant; minor constituents are biotite, muscovite, chlorite, black chert, and dark-gray opaque grains. Locally this unit contains rusty brown-weathering fossiliferous siltstone concretions as much as 4 feet in diameter. The concretions contain *Baculites aquilaensis* Reeside, which is also characteristic of the Eagle sandstone of Montana. Locally, also the Shannon sandstone member forms resistant hogbacks, but in places the sequence is soft and is mapped only with difficulty.

Overlying the Shannon sandstone member of the Cody shale is a soft grayish-black shale which is approximately 900 to 950 feet thick. The lower 80 feet of this unit contains zones of small ellipsoidal dark reddish-brown concretions and resembles the upper part of the Gammon ferruginous member of the Pierre shale of the Black Hills. This upper sequence corresponds in stratigraphic position to the Claggett shale of Montana.

Shale in surface sections of the Cody shale is calcareous only in rocks believed to be Greenhorn or Niobrara in age. The contact between the Frontier formation and the Cody shale is marked by a change from resistant conglomeratic sandstone below to nonresistant shale with some sandstone above.

PARKMAN SANDSTONE

The Parkman sandstone, which overlies the Cody shale, forms a prominent ridge extending from the southern margin of the Powder River Basin northward through the mapped area into Montana. In the Crazy Woman Creek area the Parkman sandstone attains a maximum thickness of 720 feet. The unit is dominantly a yellowish-gray sandstone, the lower half of which contains large moderate-brown ellipsoidal concretions.

Sandstone in the lower part is fine- to medium-grained, angular to subangular, and has a ratio of long to intermediate intercept of 1.5. The grains are composed dominantly of quartz with many inclusions; most of the grains are translucent to opaque and are coated with limonitic material. A few zones of dark-gray shale are interbedded with the sandstone.

A 25-foot moderate-brown carbonaceous shale is present near the top, and the formation is capped by an 8-foot white to very light gray crossbedded sandstone. This sandstone is fine- to medium-grained, angular to subangular, and with a long to intermediate intercept ratio of 1.5. The grains are dominantly of quartz with 5 to 10 percent feldspar. The sandstone is argillaceous and contains minor amounts of biotite. In reflected light most of the grains appear cloudy and light colored.

The Parkman sandstone of the mapped area is referred to as the Mesaverde formation 15 miles south of the mapped area. There the Mesaverde formation is divided into three units: the Parkman sandstone member at the base, an unnamed member just above the middle, and the Teapot sandstone member at the top. The white to very light gray 8-foot sandstone at the top of the Parkman sandstone in the Crazy Woman Creek area is probably equivalent to the Teapot sandstone member of the Mesaverde formation, but the lower members of the Mesaverde formation cannot be recognized as distinct units in the mapped area.

The contact between the Cody shale and the Parkman sandstone is sharp. Beds below the contact are soft grayish-black shale, and beds above are yellowish-gray sandstone. A remnant of sandstone of about the same age as the Parkman is in the Pierre shale of southeastern Montana. The formation is absent along the western margin of the Black Hills; it probably thins eastward from the mapped area and grades into the dark-gray shales of the Pierre shale. North of the Wyoming-Montana State boundary the Parkman sandstone is called the Judith River formation (Andrews and others, 1944).

BEARPAW SHALE

The Bearpaw shale, which overlies the Parkman sandstone, is about 200 feet thick and consists mainly of dark-greenish-gray shale with light-gray siltstone laminae. The unit is soft and is commonly covered with slopewash at most places. The upper 15 feet grades from silty shale near the base to shaly sandstone 2 to 3 feet thick at the top. The upper 6 inches of the Bearpaw shale consists of grayish-yellow bentonite. *Baculites compressus* Say and *Acanthoscaphites nodosus* (Owen) were found in the upper part of the formation and are diagnostic of part of the Bearpaw shale of Montana (pl. 10). Formerly the sequence in the Crazy Woman Creek area had been included in the Piney formation of Darton (1906). The contact between the Parkman sandstone and the Bearpaw shale is characterized by white sandstone below and olive-gray shales above.

LANCE FORMATION

The Lance formation, which overlies the Bearpaw shale, is poorly exposed throughout most of the mapped area. It ranges in thickness from 1,950 to 2,200 feet. The lower 100 feet consists of drab-brown thin-bedded fine-grained shaly sandstone with many partings of dark-gray shale. The next higher 500 feet of strata is a series of lenticular yellowish-gray crossbedded sandstone beds—some of which are as much as 70 feet thick—interbedded with dark-gray shales. A discrete sample of the lenticular sandstone of the Lance formation is fine to medium grained. The grains range in length of intermediate intercept from 0.15 to 0.35 millimeter and have a ratio of long to intermediate intercept of 1.3. The grains are dominantly quartz with minor feldspar; most of them have a cloudy appearance in reflected light. The rock contains abundant dark-gray to black translucent to opaque grains and minor amounts of biotite and chlorite. Grains range from subrounded to angular. The remainder of the Lance formation consists of interbedded light- to yellowish-gray soft sandstones and dark-gray shales. Beds of carbonaceous shale are present throughout the upper half of the unit.

The contact between the Bearpaw shale and the Lance formation is arbitrarily placed at the top of the 6-inch bentonite bed. Beds directly above the contact are similar to beds below but grade upward into a thin-bedded shaly sandstone unit which is different from the shales of the Bearpaw.

The lower 600 feet of the formation, which contains dinosaur bones, is of Late Cretaceous age. No fossils have been found in the upper part of the Lance formation within the mapped area, and the assignment of the entire Lance formation to the Upper Cretaceous is one of convenience. The lower 100 feet of the Lance formation may, in part, be equivalent to the Fox Hills sandstone, a well-developed resistant marine sandstone unit of Late Cretaceous age, which is recognized about 20 miles south of the Crazy Woman Creek area.

CENOZOIC ROCKS

FORT UNION FORMATION

The Fort Union formation overlies the Lance formation with apparent conformity. The Fort Union formation is overlain unconformably in the Kingsbury Ridge area by the Kingsbury conglomerate member of the Wasatch formation, but farther south it is overlain with apparent conformity by the shales and sandstones of the finer grained facies of the Wasatch formation.

In the vicinity of Billy triangulation station the Fort Union formation is approximately 3,950 feet thick. Here the lower 500 feet contains many beds of moderate-brown ferruginous resistant sandstone ledges interbedded with siltstone and shale. The next higher 1,900 feet of strata consists dominantly of very light gray siltstone and gray shaly sandstone with some thin reddish-brown resistant ferruginous sandstone ledges. A discrete sample of sandstone from this zone contains grains ranging in intermediate intercept from 0.2 to 0.5 millimeter and has a ratio of long to intermediate intercept of 1.2. Grains are angular to subangular. The rock contains moderate amounts of somewhat weathered feldspar but is dominantly quartz. In reflected light about one-fourth of the grains are cloudy. Light-colored mica is present in moderate amounts, and black opaque grains are abundant.

The remainder of the sequence contains many thick zones of carbonaceous shale interbedded with siltstone and includes many lenticular beds of conglomerate which are very similar to those in the Kingsbury conglomerate member of the Wasatch formation. The conglomerates contain mostly quartzitic sandstone pebbles, minor amounts of dolomite and limestone pebbles, and rare pebbles of pre-Cambrian igneous rocks apparently derived from the Bighorn Mountains. These lenses of conglomerate do not extend south of Crazy Woman Creek in the mapped area, nor do they extend farther north than 1 mile north of Billy triangulation station. However, along Rock Creek, 13 miles north of the mapped area, conglomerates of this type again appear in the upper part of the Fort Union formation; they also are present 12 miles south of the mapped area. Pebbles and cobbles in the upper part of the Fort Union formation 12 miles south of the mapped area consist dominantly of quartzite and highly siliceous metasediments, which contrast sharply in type with those found to the north. Just south of Crazy Woman Creek the upper part of the Fort Union formation contains 8 coal beds and many carbonaceous shales. The coal beds attain maximum thickness between 1 and 5 miles south of Crazy Woman Creek; southward they grade into thin zones of carbonaceous shale. No coals are in the Fort Union formation north of Crazy Woman Creek. The carbonaceous shales can be traced southward to where they pinch out about 2 to 5 miles north of the southern boundary of the mapped area.

The contact between the Lance and Fort Union formations is arbitrarily placed at the base of a series of slabby resistant ferruginous sandstone ledges. Beds just above the contact are resistant and form persistent rounded ridges; beds below the contact are soft sandstones and shale which form slopes. No angular unconformity was noted within or at the base of the Fort Union formation. In the Rock Creek area, however, Mapel (personal communication, 1952) reports an angular unconformity at the base of the conglomeratic sequence within the Fort Union formation. R. W. Brown (personal communication, 1952) collected Paleocene plants from the Fort Union formation of the mapped area.

WASATCH FORMATION

The Wasatch formation is exposed in the eastern part of the Crazy Woman Creek area. From Kingsbury Ridge northward to a point a few miles south of Sheridan, Wyo., the Wasatch formation is divisible into two distinct members—the Kingsbury conglomerate member below and the Moncrief member above—which are separated by an angular unconformity of as much as 45 degrees. The discordance between the two members diminishes sharply basinward and separation becomes difficult, both structurally and lithologically. The lower unit was called the Kingsbury conglomerate by Darton (1906), but in this report it will be treated as a member of the Wasatch formation following Love and Weitz's (1951) consideration of the unit and, more specifically, as the coarse basal mountainward facies of the Wasatch formation. The upper member has been called the Moncrief gravel by Sharp (1948) but was later called the Moncrief member of the Wasatch formation (Love and Weitz, 1951).

The Kingsbury conglomerate member of the Wasatch formation unconformably overlaps the Fort Union formation (pl. 6, cross section *A–A′*), and north of the mapped area it successively overlaps the Lance formation, the Bearpaw shale, and the Parkman sandstone. Four miles north of the mapped area the Kingsbury conglomerate member is unconformably overlain by the Moncrief member of the Wasatch formation. Southward and eastward from Kingsbury Ridge the Kingsbury conglomerate member thins and grades imperceptibly into the finer basal, basinward part of the Wasatch formation; the Moncrief member grades imperceptibly into the finer facies of the upper part of the formation. In the vicinity of Kingsbury Ridge the Kingsbury conglomerate member ranges in thickness from 400 to 600 feet. The unit contains a series of interbedded poorly indurated conglomerates, medium- to coarse-grained sandstones, siltstones, and silty shales (fig. 21). Typically the conglomerate has a

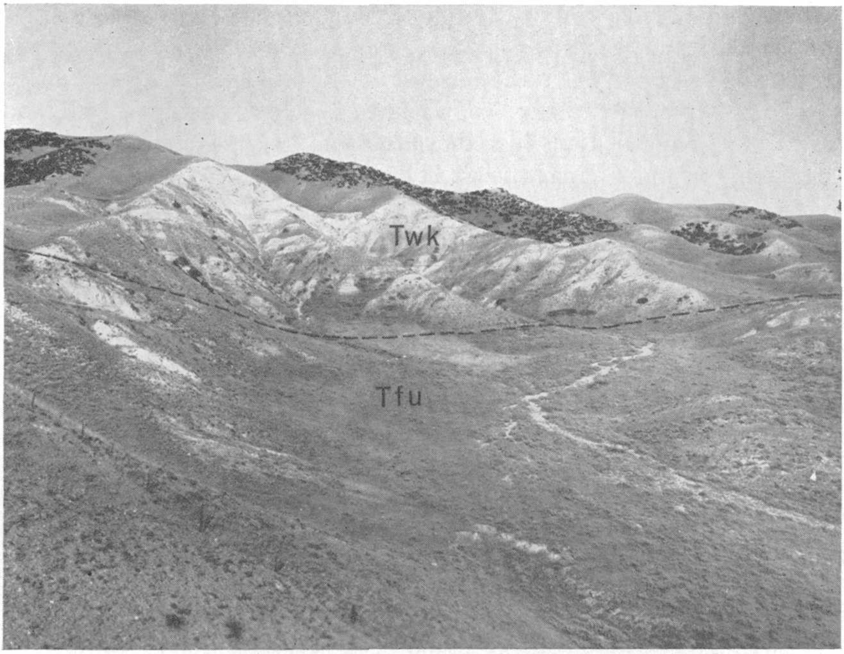

FIGURE 21.—Southwest face of Kingsbury Ridge showing approximate contact between the Kingsbury conglomerate member of the Wasatch formation (Twk) and the Fort Union formation (Tfu).

medium- to coarse-grained matrix with moderate amounts of black, pink, and green accessory grains. The well-rounded pebbles and cobbles consist of limestone, dolomite, quartzite, chert, and rarely of deeply weathered pre-Cambrian igneous rocks. Many collections of fresh-water invertebrates indicate an Eocene age for the Kingsbury conglomerate member. The assemblage identified by T.-C. Yen is as follows: *Pisidium* sp., *Hydrobia? eulimoides* Meek, *Goniobasis* cf. *G. tenera* (Hall), *Viviparus* cf. *V. retusus* Meek and Hayden, *Physa* cf. *P. longiuscula* Meek and Hayden, *Macrocyclus* sp., *Discus* cf. *D. ralstonensis* (Cockerell).

Two miles north of Kingsbury Ridge the flat-lying Moncrief member of the Wasatch formation rests unconformably on the Kingsbury conglomerate member. The Moncrief member in that area is about 1,200 feet thick (Sharp 1948). The lower third of the Moncrief member consists of interbedded greenish siltstone, silty sandstone, grits, and thin beds of conglomerate; it grades upward into coarse boulder beds, in which the boulders are dominantly deeply weathered pre-Cambrian igneous rock. A typical sandstone of the lower part of the Moncrief member is dominantly medium- to coarse-grained, but some of the grains are in the fine and granule sizes. The larger grains are relatively equidimensional and well rounded; the smaller grains are less equidimensional and subangular to subrounded. The sandstone includes minor amounts of greenish biotite and hornblende as well as moderate amounts of translucent to opaque altered feldspars. Some lithic fragments are likewise present. The top of the northern part of Kingsbury Ridge is characterized by boulders as large as 5 feet in diameter. Some of these boulders are derived from Paleozoic rocks; Sharp (1948) suggests that this material was deposited in late Cenozoic time as a result of erosion of Bald Ridge and the Bighorn Mountains and is not a part of the Kingsbury conglomerate member. The part of the Wasatch formation which overlies the Kingsbury conglomerate member in the region east and southeast of Kingsbury Ridge comprises the finer clastic basinward facies of the Moncrief member.

South of the southernmost limit of the Kingsbury conglomerate member the Wasatch formation includes equivalents of both the Kingsbury conglomerate member and the Moncrief member. The Wasatch formation, where it contains equivalents of both of these members, attains a thickness of about 500 feet in the mapped area. The basal portion of the Wasatch formation, in part the Kingsbury conglomerate member equivalent, is best developed south of Crazy Woman Creek, where its maximum thickness is about 150 feet. The sequence consists of red and dark-green soft claystones with lenticular calcareous medium- to coarse-grained sandstone lenses. The larger grains of these lenticular sandstones are equant and well rounded, but grains of the smaller fraction are somewhat elongate and angular. Although it is dominantly a quartzose sandstone, moderate amounts of orthoclase, microcline, and rocks fragments are present. Some of the quartz grains are discolored by hematite, which imparts a red color in reflected light. Black translucent to opaque grains are abundant. The calcite cement is in part poikilitic. The basal part is of various thicknesses and southward is less brightly colored. The zone persists as far southeast as Sussex, Wyo., 15 miles from the mapped area.

The upper part of the Wasatch formation, the lateral equivalent of the Moncrief member, consists of soft argillaceous sandstones, siltstones, shales, many carbonaceous shales, and 6 major coal beds, one of which is as much as 7 feet thick. Associated with the coals in places is a red slaglike rock which has been called clinker. There are two different rock types included in clinker. One is formed from burned coal and resembles clinker found in a coal-burning stove; the other is formed by fusion and oxidation of the enclosing sediments as a result of burning of coal. The coals can be traced northeast along Crazy Woman Creek for many miles, but they thin southward and are absent at the southern boundary of the mapped area. The coal and carbonaceous shale portion of the Wasatch formation grades, in the southern part of the mapped area, into a sequence of coarse-grained tan sandstone and drab-greenish-gray siltstone. The sandy facies of the formation contains many lenses of ferruginous material, which locally imparts a red color to the unit. These sandstones, about 5 miles south of the mapped area, are conglomeratic and contain pebbles of quartzite and chert. The contact between the Fort Union formation and the Wasatch formation is marked by a lithologic change from coals or carbonaceous shales below to soft red and green claystones with intercalated sandstone lenses above. In places where the Kingsbury conglomerate member of the Wasatch formation truncates the Fort Union formation, the contact is characterized by coarse conglomerate above and nonconglomeratic beds below.

The red claystones of the basal portion of the Wasatch formation yielded a few mammal teeth of early Eocene age. Fossils found from 200 to 400 feet above the redbed sequence of the Wasatch formation of the Sussex region are more abundant and indicate a very early Eocene age (Gray Bull of Granger, 1914) for that part of the Wasatch formation. The fossils found in the Sussex region are as follows: Multituberculata, *Ectypodus* cf. *tardus;* Insectivora, *Cynodontomys* sp.; Primates, *Pelycodus* sp., *Tetonius* sp., *Phenacolemur* sp.; Creodonta, *Sinopa*, *Pachyaena;* Carnivora, *Viverravus;* Condylarthra, *Hyopsodus* sp., *Ectocion* sp., *Haplomylus* sp., *Phenacodus* sp.; Perissodactyla, *Hyracotherium;* Artiodactyla, *Diacodexis.*

The upper 50 feet of the Wasatch formation in the southeastern part of the Crazy Woman Creek area contains *Hyopsodus simplex*, a form characteristic of the lower Eocene (Gray Bull of Granger). Brown (1948) found *Coryphodon* sp. and *Hyracotherium* (*Eohippus*) sp. in a zone slightly higher than the Kingsbury conglomerate member of the Wasatch formation. This form is present throughout lower Eocene strata.

WHITE RIVER FORMATION

On the subsummit uplands of the Bighorn Mountains there are a number of almost flat-lying deposits of similar sedimentary rocks. Osterwald (1949) called these rocks in the Tongue River area the White River (?) formation, basing the assignment on vertebrates of Oligocene age collected from these deposits (Osterwald, personal communication, 1951). Because of the similarities of the deposits in the Crazy Woman Creek area to the material in the Tongue River area as well as in other parts of Wyoming, they are herein referred to as the White River formation. The strata are almost flat lying and unconformably overlap the pre-Cambrian and Paleozoic strata. The White River formation fills pre-Oligocene valleys of high relief and usually forms flat grassy parks. The formation is best exposed 1 mile

FIGURE 22.—Conglomerate of the White River formation on Canyon Fork Powder River 10 miles west of the Crazy Woman Creek area.

west of the mapped area along the North Fork Crazy Woman Creek, where it attains a maximum thickness of 200 to 300 feet. Here the sequence consists of light-brown bentonitic claystones interbedded with conglomerates cemented by calcium carbonate and very light gray tuffaceous marlstones. The conglomerates in the northern part of the area contain angular fragments of igneous rocks ranging in diameter from ½ to 7 inches (fig. 22); at the north end of the Horn the conglomerate contains some fragments derived from Paleozoic rocks. Thin sections of the finer part of this conglomerate show irregularly shaped grains of feldspar, quartz, blue-green hornblende and biotite, all of which are usually surrounded by thin bands of radial calcite; these are embedded in a finely crystalline nonoriented calcite matrix. Many microscopic calcite-lined vugs are present and fractures in grains of feldspar, hornblende, and rock fragments are filled with calcite oriented at right angles to the fracture. The matrix is argillaceous; the very fine insoluble residue is a light-brown clay of the same type as the interbedded claystones.

QUATERNARY ROCKS

Three types of surficial deposits of Quaternary age were mapped in the Crazy Woman Creek area: landslide debris, terrace gravels, and alluvium. Landslide debris is present in places in the basin area but is of such limited extent that mapping is impracticable. Landslide debris in the steep canyons cut in the pre-Cambrian terrane consists of angular fragments and blocks of granite; in other places in the mountain area it consists of slumped rocks from the Gros Ventre formation and the Gallatin limestone, as well as large blocks derived from the more resistant Bighorn dolomite and Madison limestone. Landslide debris in both the mountain and basin areas includes homogeneous bodies of material emplaced as discrete but broken units as well as individual blocks.

Gravels cap many terrace levels. On older terraces gravel deposits range in thickness from 5 feet in the eastern part of the mapped area to as much as 20 feet close to the mountain front. These gravels consist of pebbles, cobbles, and boulders mainly derived from the pre-Cambrian crystalline rocks of the Bighorn Mountains, with minor amount of limestone and dolomites derived from Paleozoic rocks (fig. 23). The oldest terrace gravels are coarser grained in most places than the younger ones. The youngest terraces are covered chiefly with sand and silt but locally are capped by gravel. The finer portion of the gravels on all terraces ranges in size from clay through granule in almost equal proportions. The oldest terraces that abut against the Tensleep sandstone at the mountain front are covered with a veneer of angular blocks derived from the Tensleep sandstone.

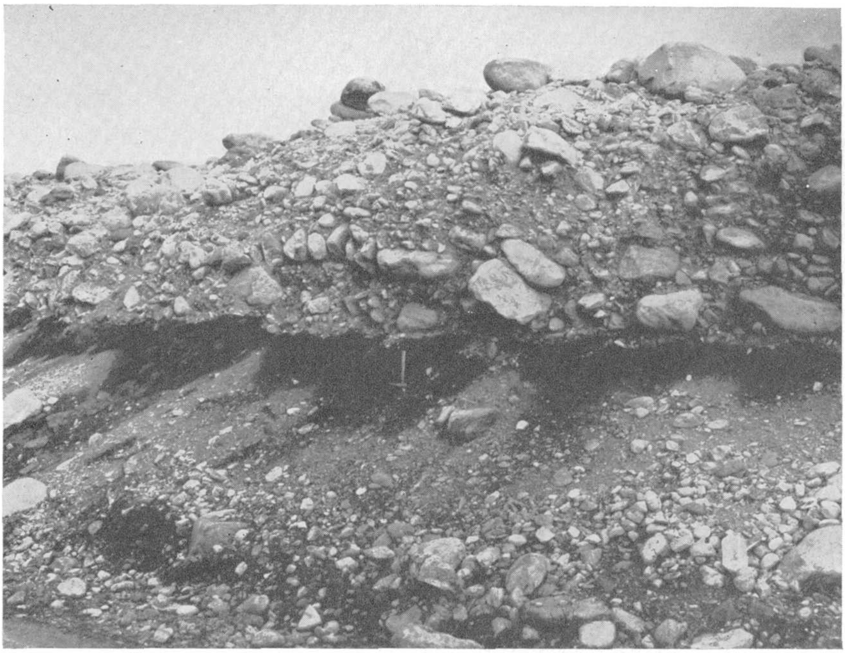

FIGURE 23.—Gravel of terrace level 2 (Qtg_2) on the North Fork Crazy Woman Creek. Gravel rests on eastward-dipping Cody shale.

The veneer thickens toward the mountain. The edges of terraces which abut against bedrock or against the "riser" of a higher terrace usually have cover of colluvial material sloping toward the streams. Terraces of the Crazy Woman Creek area are of many complexly related levels; they are classified only in the broadest sense. The following list shows ranges of terrace levels above adjacent streams using symbols appearing on the geologic map (pl. 6) : Qtg_5 is more than 300 feet above adjacent streams; Otg_4 ranges in height from 130 to 300 feet, Qtg_3 from 90 to 130 feet, Qtg_2 from 40 to 90 feet, and Qtg_1 from 5 to 40 feet. Deposits on levels below 5 feet are considered as alluvium.

Although alluvium is present along the beds of most streams, it was not feasible to show it in most places on the scale of mapping. The alluvium is a mixture of clay, silt, and sand, commonly containing much organic matter; it also contains pebbles and cobbles locally.

STRUCTURE

REGIONAL FEATURES

The Crazy Woman Creek area includes parts of both the Bighorn Mountain and the Powder River Basin structural provinces. The central part of the Bighorn Mountains as well as the adjoining Powder River Basin trend approximately N. 15° to 20° W. In the mountain province the folds are more intense than those in the basin. Anticlines of the mountain province have their steeper limb on the west, in contrast with those of the basin which have their steeper limb on the east. High-angle reverse faults predominate, but some thrust faults of minor displacement and normal faults are present. Except for four minor transverse faults, they are restricted to the mountain province. The foliated pre-Cambrian "granite" north of the Horn and west of the base of the Flathead sandstone trends almost at right angles to the axis of the range and dips from approximately 45 degrees northward to vertical. Except for local folds and faults the sedimentary rocks dip generally eastward, giving structural relief of more than 18,000 feet. The Tertiary strata of the eastern portion of the area dip gently eastward; the maximum dip at the base of the Wasatch formation is 13 degrees (fig. 17). An exception to the easterly dip was noted on the southeast bank of Crazy Woman Creek (pl. 6).

Darton (1906) discussed the structural geology of the Crazy Woman Creek area only generally. Chamberlin (1940), in discussing the mountain ranges around the Bighorn Basin, considered the Bighorn Mountains to be composed of three asymmetrical segments (fig. 25). Demorest (1941), in his study of the east flank of the Bighorn Mountains, followed the general outline suggested by Chamberlin. The north and south segments of the range have their steep limbs on the west side, and the central segment has its steep limb on the east. The central segment is outlined by the Tongue River on the north and by the Tensleep and Horn faults on the south. The Crazy Woman Creek area lies within the central segment.

Structure contours (pl. 6) with 1,000-foot intervals were drawn on the base of the Flathead sandstone as far east as the base of the Newcastle sandstone. Contours with the same interval were drawn on the base of the Newcastle sandstone for younger Cretaceous and Paleocene strata. Structure cross sections (pl. 6) were used as checks against computations of depth to datum surfaces from points where elevations and surface dips as well as thickness of stratigraphic units were known. In Tps. 48 and 49 N., R. 80 W., contours with 10-foot intervals were drawn on coal bed 6; this bed was selected because it had the longest outcrop and covered the greatest area.

FOLDS AND FAULTS

Pre-Cambrian granites of the Crazy Woman Creek area are intensely foliated. At the northern end of the Horn, including a few square miles just west of the mapped area, the granite forms an anticlinal fold with the axis plunging northwestward at about 50 degrees. The strike of foliation on the west flank is approximately N. 20° W.; the dip is about 60 degrees to the southwest. Foliation on the northeastern flank trends approximately N. 75° W. and dips approximately 65 degrees to the northeast. The foliation is unconformable with the attitude of beds of the Paleozoic sequence. Strike of foliation of the granite north of the Horn within and, in part, a few miles west of the mapped area, ranges from N. 35° E. to east-west and dip ranges from 35 degrees northward to vertical.

North of the North Fork Crazy Woman Creek within the mapped area, dips in the Paleozoic and Mesozoic rocks range from 30 degrees east to vertical and in some places beds are overturned and dip steeply westward. (See pl. 6, structure section *A–A′*.) In the northern part of the area there are three westward-dipping, generally northward-trending reverse faults. Along each fault the pre-Cambrian granite has been moved over the lower part of the Cambrian sequence. In the northernmost part of the mapped area a reverse fault trends about N. 25° E., oblique to the strike of bedding and then trends eastward and becomes a transverse fault.

South of the North Fork Crazy Woman Creek, dips of the strata are more gentle, and the width of outcrop of Paleozoic rocks ranges from 2 to 7 miles. The transition from gentle dips in the south to high dips in the Paleozoic rocks north (fig. 24) of the North Fork Crazy Woman Creek is marked by a reverse fault which trends obliquely

FIGURE 24.—View of the abrupt change from moderate to high dips in Paleozoic strata on the North Fork Crazy Woman Creek.

across the strike of the formations at its southern end and then curves eastward to become a transverse fault. Because of the greater intensity of deformation north of the fault when compared with the area to the south, it seems reasonable to assume that the resulting shearing stress was relieved by the fault. South of the North Fork Crazy Woman Creek structural configuration in the mountain area, although less intense, is somewhat more complex. This portion of the mapped area contains three southeastward-plunging asymmetric anticlines with steep and faulted west limbs. The steep limb of anticlines on the mountainward side of basins is quite common, particularly in the Bighorn Basin (Pierce and others, 1947). This characteristic direction of asymmetry may be explained by what Thom (1936, p. 210) has called "basin mechanics."

The northernmost anticline, the West Billy Creek anticline of Demorest (1941), is approximately 7 to 8 miles long. The northern end of this fold is in part overturned and thrust westward. The thrust (low-angle reverse fault) has minor westward displacement and is truncated at its northern end by a transverse fault. North and east of the thrust fault is a reverse (high-angle) fault, with the eastern block upthrown, which trends about N. 20° E. at its southern end and about N. 70° E. at its northern end. It is probable that this fault antedates the transverse fault at the north end of the anticline and was at one time continuous with the thrust fault. Southward the thrust fault passes into a reverse fault and disappears in the Amsden formation. The fault along the southwestern side of the anticline is a reverse fault with the east block upthrown. (See pl. 6, structure section *B—B'*.) The anticline loses its identity about 1 mile south of the Middle Fork Crazy Woman Creek.

The Beaver Creek anticline of Demorest (1941), just south of the Middle Fork Crazy Woman Creek, is also asymmetrical with its southwest side marked by a reverse fault in which the eastern block is upthrown. The Beaver Creek anticline is about 3 miles long and is breached to the pre-Cambrian basement at its northern end.

The Horn, a large southeastward-plunging anticlinal fold breached to the pre-Cambrian rocks, lies in the southwestern part of the mapped area. The fold is bounded on the southwest by the Horn fault, a reverse fault with more than 4,000 feet of throw in its central portion; the eastern block is upthrown. Paralleling this fault about a quarter of a mile to the southwest is a low-angle thrust fault, the overriding (northeast) block of which has moved relatively southwestward and has placed Chugwater strata in contact with the Sundance formation. In gross aspect the area lying between the two faults is an overturned syncline modified by transverse faulting. (See pl. 6, structure section *C—C'*.) Within the mapped area the Horn anticline is terminated at the north by a transverse fault which may be a branch of the Tensleep fault to the west (Wilson, 1938).

In the part of the mapped area that lies within the Powder River Basin, the structure is less complex than in the mountains. The major features include two closed anticlinal folds and one structural terrace. The Billy Creek anticline (pl. 6, structure section *B—B'*) is asymmetrical, with dips on the east flank as much as 25 degrees and dips on the west flank as much as 10 degrees. The crest of the anticline trends about N. 20° W., but Bramlette (1949, p. 83) reports that the subsurface axis trends more northwesterly. Surface closure on the Billy Creek anticline is about 400 to 500 feet.

The Steel Creek anticline is also asymmetrical with its steeper limb on the east flank. (See pl. 6, structure section *C—C'*.) Dips on the east flank are as much as 30 degrees; on the west flank the maximum dip is 7 degrees. Surface closure on the Steel Creek anticline is about 300 feet.

About 2.5 miles south of Crazy Woman Creek, in sec. 22, T. 47 N., R. 81 W., and adjacent sections, there is a structural terrace. Along an east-west line through the terrace, beds in the upper part of the Fort Union formation dip eastward about 9 degrees. Beds in the lower part of the Wasatch formation are horizontal for about three-fourths of a mile and then assume an eastward dip of approximately

6 to 8 degrees. The southern end of the structural terrace is cut by a transverse fault. At the northern end of the structure, just south of Crazy Woman Creek, dips decrease from 9 degrees eastward in the upper part of the Fort Union formation to approximately 4 degrees eastward in the Wasatch formation 3 miles northeast of the structural terrace. South of the fault marking the southern edge of the structural terrace are three more transverse faults, in echelon, which cut both the upper part of the Fort Union formation and the lower part of the Wasatch formation.

STRUCTURAL HISTORY

In addition to both pre-Cambrian and Laramide orogenic movements, there were several periods of gentle regional uplift followed by erosion. The resulting unconformities, although angular, are so slight that their effect on present structure is negligible, and they can be detected only by regional studies. The first regional uplift of this type occurred after deposition of the Bighorn dolomite and before deposition of the Madison limestone. Evidence supporting this uplift is found in the truncated Bighorn dolomite and the complete absence of Silurian and Devonian strata. The unconformity at the base of the Madison limestone truncates the Bighorn dolomite; in the southern part of the Bighorn Mountains the Madison rests unconformably on the Gallatin limestone. It is possible that there were several later uplifts rather than one, but, as there is no record in the rocks, this cannot be determined. If the Tensleep sandstone of the mapped area is Des Moines in age, the lack of younger Pennsylvanian strata, such as those in the Hartville region in eastern Wyoming (Love and others, 1953) and at Casper Mountain along the southern margin of the Powder River Basin (Thomas, 1948), suggests that one or more structural disturbances followed Des Moines time and preceded the deposition of the Permian red shale and gypsum sequence.

Meager evidence for uplift preceding the deposition of the Alcova limestone member of the Chugwater formation is found in the thinning of the pre-Alcova part of the Chugwater formation from 700 feet in the mapped area to about 480 feet in the Texas Co.'s Forbes test well 1 in the north in Sheridan County, Wyo. (figs. 18 and 19). The various thicknesses of the so-called Crow Mountain sandstone member of the Chugwater formation (Carlson, 1949) and the absence of the younger Popo Agie member of the Chugwater formation, which is so widespread in central Wyoming, indicate gentle regional uplift and erosion of these rocks in northeastern Wyoming before the deposition of the Gypsum Spring formation and following deposition of the Chugwater formation. The truncation of the Gypsum Spring formation by the unconformity at the base of the Sundance formation in central Wyoming as well as in the mapped area indicates regional uplift followed by erosion preceding deposition of the Sundance (figs. 18 and 19).

Laramide tectonic activity in the Bighorn Mountains began during the time of deposition of the Fort Union formation. In the northern part of the Crazy Woman Creek area and at Rock Creek, 13 miles north of the mapped area, the upper part of the Fort Union formation contains pebbles derived from Paleozoic rocks, indicating that uplift was followed by erosion of the Bighorn Mountains at least to the Bighorn dolomite and in part of the pre-Cambrian. Deformation was more intense in the central part of the Bighorn Mountains and was probably confined to the central segment of Demorest (fig. 25). This probability is supported by the fact that well-developed conglomerates in the Fort Union formation are confined to a belt directly east of the central segment. Folding, following deposition of the Fort Union formation, resulted in as much as a 45-degree discordance between the Kingsbury conglomerate member of the Wasatch formation and the Fort Union formation in the vicinity of Kingsbury Ridge. Folding after the deposition of the Kingsbury conglomerate member of the Wasatch formation resulted in local dips in the unit as much as 45 degrees; the Kingsbury conglomerate member is unconformably overlain by the flat-lying Moncrief member of the Wasatch formation. Sharp (1948) has described thrust faulting that followed the deposition of the Moncrief member. This thrusting was not accompanied by even local folding of Wasatch strata in that part of the Powder River Basin which lies opposite the zone of thrusting along the east front of the Bighorn Mountains. In the Crazy Woman Creek area, however, beds which are equivalent to the lower part of the Moncrief member of the Wasatch formation dip as much as 9 degrees eastward; this suggests that the forces which produced post-Moncrief thrusting from Kingsbury Ridge north to Moncrief Ridge produced mild folding south of Kingsbury Ridge. The Fort Union formation is conformable with older units and is the youngest unit to be strongly folded regionally. It is therefore believed that at least the outlines of the major folds discussed above were formed after deposition of the Fort Union and preceding the deposition of the Kingsbury.

ECONOMIC GEOLOGY

OIL AND GAS POTENTIALITIES

The discovery well for the Billy Creek gasfield was drilled in 1923 and gas was found in the Frontier formation. Since that time, 7 more producing wells have been drilled to the Frontier formation; in 1937 a well was drilled to the basal sandstone of the Bighorn dolomite. The well penetrated neither gas nor oil in commercial quantities. Cumulative production to 1947, according to Bramlette (1949,

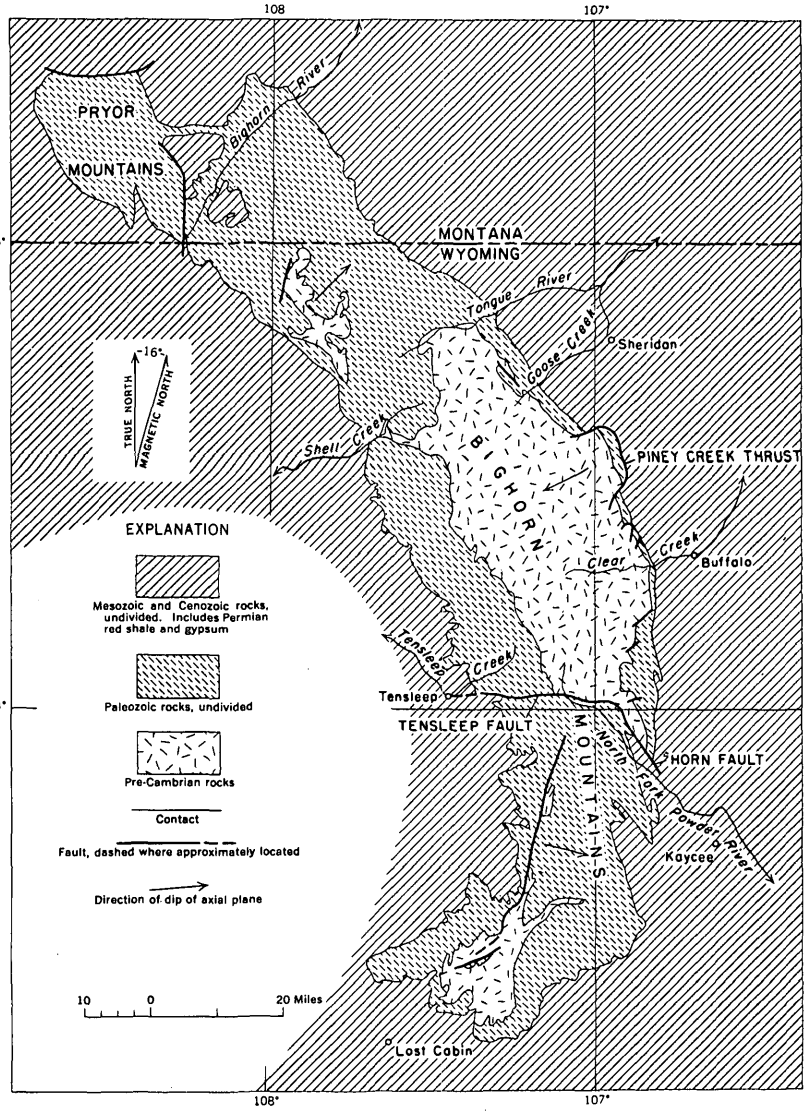

FIGURE 25.—Geologic map of the Bighorn Mountains showing three major structural segments.

p. 83), was 3,218,858 thousand cubic feet of gas. This production so depleted the field that it is now used as a storage reservoir for the gas coming from the Big Sand Draw field in Fremont County for use by the towns of Buffalo and Sheridan. Owing to the recent discovery of oil in the Tensleep sandstone in Stanolind's North Fork Powder River field 24 miles to the south of the Billy Creek anticline, further testing of this sandstone in the vicinity of the Billy Creek anticline may be worth while.

Three dry test holes have been drilled on the Steel Creek anticline thus far. A recent test well that penetrated the Amsden formation and reached the Madison limestone showed slight oil staining in the Permian red shale and gypsum sequence, but the Tensleep sandstone was barren.

The most promising untested structure within the mapped area is the structural terrace south of Crazy Woman Creek. Although there is no closure at the surface, geophysical data suggest that there is closure at depth. In the Sussex-Meadow Creek oilfield 20 miles south of the mapped area there is oil in the Parkman sandstone, the Sussex and Shannon sandstone members of the Cody shale, the Frontier formation, the Newcastle sandstone, the Cloverly formation, and the Tensleep sandstone. On the structural terrace it is estimated that a test hole 13,500 feet deep would penetrate all these zones except the Sussex, which probably has graded into shale or wedged out in this area. A well drilled 52 miles north of the mapped area by J. Ray McDermott & Co. at Ash Creek in Sheridan County, Wyo., recently pumped 180 barrels per day of 36 gravity oil from what has been called the Shannon sandstone member of the Cody shale (Petroleum Information, 1952).

Stratigraphic data at the present are insufficient for predicting stratigraphic traps within the Crazy Woman Creek area. A few regional generalizations can be made, however, that may be useful in the search for oil accumulated in such traps.

The Parkman sandstone, which is overlain and underlain by marine shales, thins eastward so that it is unrecognizable on the east side of the Powder River Basin. The axis of the basin is located only a few miles east of the Bighorn Mountains and the thinning and wedging out would occur updip east of the axis. The topmost sandstone of the Frontier formation, which is equivalent to the Carlile in age at Tisdale anticline and which is probably the First Wall Creek sand, of drillers, that yields oil in the Sussex-Meadow Creek oilfield, thins northward and grades into shale a few miles south of the Crazy Woman Creek area. When more subsurface data are available, it may be possible to determine more precisely the area of "pinch-out." The grading into shale of the Sussex sandstone member of the Cody shale (Wilson, 1951) in areas to the south suggests the possibility of oil accumulation in favorable places, but more subsurface data are needed before the most promising areas can be defined.

The so-called Crow Mountain sandstone member of the Chugwater formation (Carlson, 1949) is truncated by the Gypsum Spring formation, or, where that unit is absent, by the Sundance formation in the area east of the axis of the Powder River Basin. This truncation may have resulted in a trap favorable for the accumulation of oil at the wedge edge. Oil is produced from a unit occupying the same stratigraphic position as this sandstone at Hamilton dome in the Bighorn Basin; the sandstone is oil stained at the surface at Lodgegrass Creek, on the west side of the Powder River Basin in Montana. Furthermore the sandstone is oil saturated in many surface and subsurface sections in central Wyoming (Love, Johnson, and others, 1945).

COAL

GENERAL FEATURES

Coal beds of commercial thickness are present in T. 47 N., R. 81 W., and Tps. 48 and 49 N., R. 80 W. Coal in T. 47 N., R. 81 W., is present both in the upper part of the Fort Union formation and in the Wasatch formation; in the other two townships only the Wasatch formation is exposed. Coal beds of the Fort Union formation are limited to a north-south trending zone about 4 miles long; north and south of this zone the coal beds grade into carbonaceous shales. In the same township the coal beds of the Wasatch formation also grade southward into carbonaceous shales. The northward gradation into carbonaceous shales is obscured by the terrace and alluvial deposits along Crazy Woman Creek. The coal seams in the Wasatch persist northeastward into Tps. 48 and 49 N., R. 80 W., along Crazy Woman Creek to the north edge of the mapped area, where they can be correlated with the coals of the Lake De Smet area.

The coals of the Crazy Woman Creek area are usually black, shiny, and brittle and, upon exposure to air, slack and break down to small angular fragments. Some of the coal is dull and woody in appearance. Partings of carbonaceous shale and coaly shale are common, as are petrified stumps and logs. Many of the thicker beds have been locally burned to clinker. Because mining of these coals has been on a very small scale, and because operations have virtually ceased in recent years, no samples have been collected for analysis. Analyses of samples collected in the Lake De Smet area by Mapel (personal communication, 1952) indicate that the coal from the Wasatch formation is subbituminous. Coal of the Fort Union formation is likewise subbituminous (Wegemann, 1912).

Reserves of coal were computed for two classes: measured and indicated, and inferred. Reserves were computed only for beds which exceed the 2.5-foot commercial minimum thickness for their grade. Size of areas underlain by coal were determined by polar planimeter; a weight of 1,700 short tons per acre-foot has been assumed for subbituminous coal. Total reserves of all classes in the Crazy Woman Creek area exceed one billion short tons.

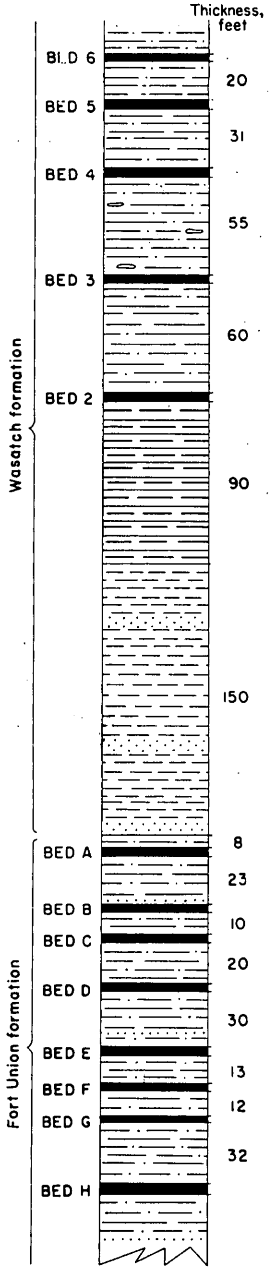

FIGURE 26.—Generalized section showing average interval between coal beds of T. 47 N., R 81 W.

COAL IN T. 47 N., R. 81 W.

Within the upper 200 feet of the Fort Union formation 8 coal beds are present. These are shown in figure 26 and are lettered in descending order from *A* to *H*. All except bed *F* exceed, at least locally, 2.5 feet in thickness. The combination of heavy cover and burning of coal beds at the surface restricted a detailed study of the various thicknesses of the coal and nature and number of partings in many of the beds. The various thicknesses for all beds is given in plate 11. Localities of measured coal sections have been plotted on the geologic map (pl. 6). Average interval between coal beds of the Fort Union and Wasatch formations is given in figure 26. Beds in the upper part of the Fort Union formation dip as much as 14 degrees eastward. Total reserves of coal of all classes for the Fort Union formation aggregate 82.4 million short tons. Table 3 shows various classes of reserves for all beds except the *F* bed.

Five coal beds have been mapped in the Wasatch formation of this township. They are numbered in ascending order from 2 to 6 (fig. 26); all of these, except coal bed 6, locally exceed the 2.5-foot commercial minimum thickness. A 90-foot zone of carbonaceous shale and thin coal beds is present above the basal red and green claystone of the Wasatch formation and below coal bed 2. The carbonaceous shale and coal zone grades into shales and siltstones both north and south from the NE¼ of sec. 28, where it is best developed; the zone of maximum development of carbonaceous shales and thin coals is only about a mile long. It is possible that a part of the zone is equivalent to coal bed 1 of the north-easternmost township of the mapped area. South of secs. 28 and 27, coal beds numbered 2 through 6 thin and grade into siltstone and shale. Plate 11 shows the various thicknesses of the coal beds and nature and thickness of partings. Reserves of all classes of Wasatch coals are given in table 3.

COAL IN T. 48 N., R. 80 W.

Coal beds numbered 3 to 6 crop out along both sides of Crazy Woman Creek; the outcrops are generally restricted to areas close to the creek. Coal bed 6 probably extends into the adjoining township on the west, but does not crop out; older coal beds do not crop out any farther west than the east half of sec. 30. Within this township coal bed 6 attains a maximum aggregate thickness of 3 feet 5 inches; reserves have been computed for that part of the bed that exceeds 2.5 feet. Coal bed 5 attains a maximum aggregate thickness of 8 feet 4 inches at locality 5–17 and minimum aggregate thickness of 4 feet 7 inches at locality 5–16. Coal bed 4, because of its lower position in the section, is more limited in outcrop than younger beds; south of sec. 10 the bed is below stream level. The bed ranges in aggregate thickness

TABLE 3.—*Coal reserves in T. 47 N., R. 81 W.*

[In millions of short tons]

Bed	Acres	Weighted average thickness (feet)	Overburden (feet)	Measured and indicated reserves. Beds have thickness of—				Inferred reserves. Beds have thickness of—				Total measured indicated and inferred reserves
				2½–5 (feet)	5–10 (feet)	More than 10 (feet)	Total (feet)	2½–5 (feet)	5–10 (feet)	more than 10 (feet)	Total (feet)	
5	184	3.3	0–150	1.1			1.1					1.1
5	304	7.2	0–150		3.9		3.9					3.9
5	4,745	5.2	0–150		44.0		44.0					44.0
5	525	4.8	0–150					4.4			4.4	4.4
4	4,818	3.6	0–200	21.7			21.7	8.9			8.9	30.6
3	280	5.1	0–250		2.5		2.5					2.5
3	2,265	4.5	0–250	18.0			18.0					18.0
3	1,560	4.0	0–250					11.0			11.0	11.0
2	262	3.1	0–250	1.4			1.4					1.4
2	371	4.3	0–250	2.8			2.8					2.8
A	345	2.7	0–400	.6			.6					.6
A	493	3.2	0–400	.9			.9					.9
B	238	4.0	0–400	1.7			1.7					1.7
B	1,932	3.5	0–400	3.4			3.4					3.4
C	260	10.4	0–400			4.8	4.8					4.8
C	2,993	6.0	0–400		31.8		31.8					31.8
D	1,527	2.6	0–400	6.9			6.9					6.9
E	2,764	5.4	0–500		26.3		26.3					26.3
G	264	4.9	0–500	2.3			2.3					2.3
H	634	3.3	0–500	3.7			3.7					3.7
												202.1

from 4 feet 7 inches to 5 feet 2 inches. Reserves for all coals and for all classes are given in table 4 and measured sections on plate 12. Average interval between coal beds in T. 48 N. and T. 49 N., R. 80 W., is given in figure 27.

COAL IN T. 49 N., R. 80 W.

Two more coal beds crop out in this township than in T. 48 N., R. 80 W. These beds are numbered 1 and 2, in ascending order. Coal beds numbered 2 through 6 correlate with beds of the same numbers in T. 47 N., R. 81 W. Coal bed 1 crops out in 3 localities, but exposures are so poor elsewhere that the bed cannot be mapped. It ranges in aggregate thickness from 2 feet 10 inches at locality 1–1 to 7 feet 4 inches at locality 1–3. Coal bed 3 has an average aggregate thickness of about 3 feet, but at localities 3–1, 3–2, 3–3, and 3–5 it is less than 2.5 feet. Coal bed 4 ranges in thickness from 2 feet 4 inches at locality 4–8 to 5 feet 8 inches at locality 4–7. Coal bed 5 ranges in thickness from 3 feet 6 inches to as much as 7 feet 2 inches. Coal bed 6 is of commercial thickness at only 5 of the numbered localities (pl. 6). Reserves for all coals and for all classes are given in table 5 and measured sections on plate 13.

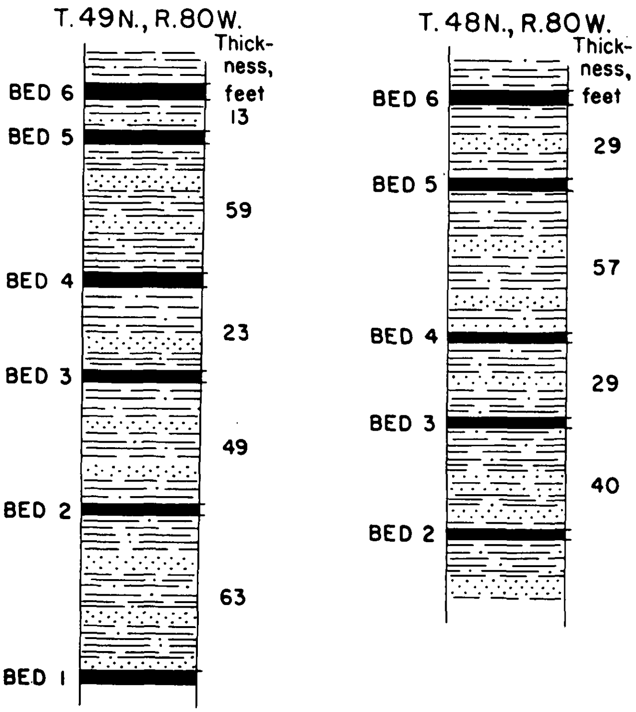

FIGURE 27.—Generalized sections showing average interval between coal beds in the Wasatch formation in Tps. 48 and 49 N., R. 80 W.

TABLE 4.—*Coal reserves in T. 48 N., R. 80 W.*

[In millions of short tons]

Bed	Acres	Weighted average thickness (feet)	Over-burden (feet)	Measured and indicated reserves. Beds have thickness of—				Inferred reserves. Beds have thickness of—				Total measured indicated and inferred reserves
				2½–5 (feet)	5–10 (feet)	More than 10 (feet)	Total (feet)	2½–5 (feet)	5–10 (feet)	More than 10 (feet)	Total (feet)	
6	38560	2.7	0–150	29.5			29.5					29.5
5	35,394	6.2	0–150		62.6		62.6					62.6
5	1,053	4.7	0–150	1.9			1.9					1.9
5	10,116	6.2	0–150		111.0		111.0					111.0
5	981	4.7	0–150	8.1			8.1					8.1
5	2,638	6.2	0–150						28.9		28.9	28.9
5	1,960	4.7	0–150					3.4			3.4	3.4
4	99	3.4	0–200	.6			.6					.6
4	1,450	5.1	0–200		13.1		13.1					13.1
4	9,592	4.3	0–200					73.0			73.0	73.0
3	6,790	4.0	0–300	7.1			7.1	41.2			41.2	48.3
												436.3

TABLE 5.—*Coal reserves in T. 49 N., R. 80 W.*

[In millions of short tons]

Bed	Acres	Weighted average thickness (feet)	Overburden (feet)	Measured and indicated reserves. Beds have thickness of—				Inferred reserves. Beds have thickness of—				Total measured indicated and inferred reserves
				2½–5 (feet)	5–10 (feet)	More than 10 (feet)	Total (feet)	2½–5 (feet)	5–10 (feet)	More than 10 (feet)	Total (feet)	
6	656	2.8	0–150	3.2			3.2					3.2
5	214	3.8	0–100	1.4			1.4					1.4
5	342	6.7	0–100		4.1		4.1					4.1
5	731	5.5	0–100		7.1		7.1					7.1
5	11,188	4.8	0–150	74.8			74.8	20.2			20.2	95.0
4	801	3.8	0–200	5.4			5.4					5.4
4	2,398	4.3	0–200	18.2			18.2					18.2
4	1,049	4.5	0–200	8.3			8.3					8.3
4	1,387	3.1	0–200	7.6			7.6					7.6
4	251	3.0	0–200	1.3			1.3					1.3
4	2,470	4.9	0–200	21.4			21.4					21.4
4	1,445	3.9	0–200	9.9			9.9					9.9
4	3,005	2.8	0–200	14.9			14.9					14.9
4	2,928	3.5	0–200					18.1			18.1	18.1
3	289	2.6	0–200	1.3			1.3					1.3
3	6,986	3.1	0–200	38.2			38.2					38.2
3	6,091	3.2	0–200	34.5			34.5					34.5
3	285	3.0	0–200	1.5			1.5					1.5
3	5,238	2.7	0–200					25.0			25.0	25.0
2	478	2.9	0–200	2.4			2.4					2.4
2	992	3.7	0–200	6.5			6.5					6.5
2	2,104	3.5	0–200	13.0			13.0					13.0
2	2,881	3.7	0–200	18.8			18.8					18.8
2	2,984	3.5	0–200	18.5			18.5					18.5
2	1,129	3.0	0–200	6.0			6.0					6.0
2	10,126	3.3	0–200					59.1			59.1	59.1
1	124	2.7	0–250	.6			.6					.6
1	80	7.0	0–250		1.0		1.0					1.0
1	920	2.7	0–250	4.3			4.3					4.3
1	1,963	3.2	0–250	11.1			11.1					11.1
1	2,027	7.0	0–250		25.1		25.1					25.1
												483.1

Coal beds numbered 5 and 6 seem to correlate with the Healy bed of the Lake De Smet area to the north, but, owing to the increasing interval between the beds south of the northern edge of the mapped area, it was more practical to map the beds separately. Coal bed 4 corresponds to the Timar bed of Mapel. Bed 3 correlates with Mapel's lower Cameron bed. Coal bed 2 correlates with the Dry Creek bed of Mapel and bed 1 probably with the Ucross bed of Mapel.

MANGANESE

Manganese is present in two deposits, one in the NW¼ sec. 32 and the other in the N½ sec. 30, T 47 N., R. 83 W. The deposits are of two major types. In one type pyrolusite has impregnated the Flathead sandstone; the mineralized masses are lenticular and are apparently parallel to the bedding. In the other type the ore has been localized as dense black nodules in the brown clay of the White River formation or as stringers in the porous weathered pre-Cambrian granites near the contact with the White River formation. The largest body of impregnated sandstone is in the NW¼ sec. 32. Here the lens is from 30 to 50 feet thick and about 150 feet long. Analyses of representative samples of this ore provided by H. G. Fisk, of the Wyoming Natural Resources Research Institute, show 8.9 percent MnO_2. The deposit in the NW¼ sec. 32 is in part overlain by the White River formation, and the clays just above the contact contain limited amounts of the nodular pyrolusite. In sec. 30 pyrolusite occurs dominantly as nodules in the clay in the White River or as stringers in the weathered pre-Cambrian granite, although small lenses of the pyrolusite occur in the Flathead sandstone. A sample of the nodular pyrolusite in the brown clays retained on a 10-mesh screen assayed 50.3 percent MnO_2; the average MnO_2 content for the entire sample is 33.8 percent. These analyses were also provided by H. G. Fisk.

Owing to the occurrence of pyrolusite nodules in the White River formation, it is apparent that the mineralization is post-White River. The manner in which the mineral was emplaced is not so apparent; the mineralization seems to be related to the contact of the White River formation with older units, and the pyrolusite may have been precipitated out from ground water along a permeable contact zone.

ALLANITE

Allanite, a complex silicate of calcium, aluminum, and iron containing a large proportion of rare earths, is found in a small deposit in foliated granite along the north line of sec. 6, T. 46 N., R. 83 W. The assemblage of associated minerals, calcite, diopside, garnet, soda, amphibole, epidote, and oligoclase suggests a contact metamorphic origin.

The igneous body which may have given rise to this mineral suite was not observed although the granite terrane of the Horn includes many small pegmatite bodies. The epidote is banded parallel to the country rock; the allanite occurs as irregular masses feathering into the epidote and wall rock.

The mineralized body is concordant with foliation in the granitic country rock, which strikes about N. 70° W., and dips about 65 degrees northeast. The determination of the exact size of the deposit would require inclined core drilling, for cover is heavy. Studies with a geiger counter indicate that the lens-shaped body containing allanite is about 100 feet long and as much as 7 feet wide. Table 6 presents results of a quantitive spectroscopic analysis.

BENTONITE

Bentonite beds, ranging in thickness from a few inches to as much as 6 feet, were observed in both the Frontier formation and the Mowry shale (see sections p. 99–103); thin beds were also observed in other Cretaceous formations. The minimum dip of bentonite beds at the surface is 15 degrees eastward.

CONSTRUCTION MATERIALS

Gravels capping terraces range in thickness from more than 20 feet close to the mountain front to less than 5 feet in the eastern part of the mapped area. The pebbles and cobbles of these deposits are derived mainly from pre-Cambrian igneous and metamorphic rocks of the Bighorn Mountains, with minor amounts of limestone and dolomite. The pebbles, cobbles, and boulders are well rounded; the boulders reach a maximum diameter of about 5 feet. The matrix ranges in size from clay through grit. The terrace gravels are used extensively in the construction of unpaved roads throughout the mapped area. Where streams flow through conglomeratic formations, such as the Kingsbury conglomerate member of the Wasatch formation, stream beds contain much gravel and sand.

TABLE 6.—*Spectroscopic analysis of allanite*

[Analysis by Charles Annell, U. S. Geological Survey]

Sample no.	Over 10 percent	1–10 percent	0.1–1.0 percent	0.01–0.1 percent	0.001–0.01 percent	0.0001–0.001 percent
1	Al Ce Si	Fe La Ca Zr Mg Nd	Pr Sr Pb Ti Sm	Gd Ba Mn Co V Y	Ga Sc	
2		Mg Si Zr	Ca Al	Co Mn Pb La V Sr	Ba Ga Sc	
3		Ti	Al Mg Si Zr	Co Mn V Pb	Ga Ba Sr	Sc.

STRATIGRAPHIC SECTIONS OF MESOZOIC AND PALEOZOIC ROCKS

	Feet
Upper Cretaceous:	
Lance formation: Measured in sec. 29, T. 49 N., R. 82 W.	
12. Sandstone and shale, interbedded; sandstone is very light gray and pale grayish yellow, fine grained, friable, thin- to thick-bedded, crossbedded; shale is dark gray and dark olive gray; a few thin beds of dark-yellowish-brown carbonaceous shale. In the upper two-thirds of the unit are several massive bedded sandstone lenses as much as 20 ft thick, which grade into thin-bedded sandstone and shale within 100 yd	1,330
11. Sandstone, very light gray (weathering to grayish yellow), medium- to fine-grained, friable, thick-bedded, crossbedded, cavernous; unit is lenticular, forms a cliff	70
10. Sandstone, very light gray (weathering to grayish-yellow), medium- to fine-grained, medium- to thick-bedded, crossbedded; contains a few thin beds and partings of dark-gray shale and dark-brown carbonaceous shale and scattered calcareous sandstone concretions weathering moderate yellowish brown	285
9. Shale, moderate-brown, silty, carbonaceous; contains thin lenses of light-gray fine-grained sandstone. Top of unit channeled by overlying unit	8
8. Sandstone, very light gray, very fine to fine-grained, thin- to medium-bedded; a few thin partings of moderate-brown carbonaceous shale and scattered yellowish-brown sandstone concretions that are about 1 to 3 in. across	62
7. Concealed	46
6. Sandstone, very light gray (weathering to yellowish gray), fine-grained, thinly and evenly bedded, locally crossbedded; contains beds of platy calcareous sandstone concretions at intervals of 3 to 6 ft apart and a few partings of dark-gray shale	25
5. Concealed	26
4. Sandstone, yellowish-gray to very light gray, fine-grained, friable, thin-bedded, crossbedded; a few beds are calcareous and slabby; contains laminae of dark-gray shale and particles of carbonized wood	25
3. Concealed	31
2. Sandstone, very light gray, very fine grained, thin-bedded; contains many thin partings of dark-gray shale	20
1. Mostly concealed. Appears to be mainly interbedded dark-greenish-gray shale and light-gray fine-grained sandstone	42
Total Lance formation	1,970

Contact between the Lance formation and the Bearpaw shale. The beds above this horizon are predominantly sandstone; the beds below are predominantly shale.

Upper Cretaceous—Continued *Feet*

Bearpaw shale: Measured in sec. 13, T. 49 N., R. 83 W.

3. Bentonite, grayish-yellow ---------- 0.5
2. Shale, dark-greenish-gray, silty, becoming more silty and slightly sandy near the top. Top 2 to 3 ft is very fine grained sandstone that contains many partings of dark-greenish-gray shale and forms a weak ledge ---------- 15

   USGS Mesozoic locality 22831; from sandstone at top of unit:

   Nucula sp.
   Nuculana cf. *N. corsicana* Stephenson
   Pteria (*Oxytoma*) *nebrascana* (Evans and Shumard)
   Ostrea sp.
   Baculites compressus Say
   Acanthoscaphites nodosus (Owen) var. *quadrangularis* (Meek and Hayden)
   nodusus (Owen) var. *brevis* (Meek)
1. Shale, dark-greenish-gray; laminae of light-gray siltstone near the top. Unit is partly covered ---------- 183

Total Bearpaw shale ---------- 198

Contact between the Bearpaw shale and the Parkman sandstone. The beds below this horizon are predominantly sandstone.

Parkman sandstone: Measured in sec. 13, T. 49 N., R. 83 W.

7. Sandstone, white, fine-grained, poorly cemented, crossbedded ---------- 8
6. Shale, pale-brown and moderate-brown, carbonaceous, silty ---------- 25
5. Sandstone, very light gray, fine- to medium-grained, many black, pink, and green grains, friable, medium-bedded, crossbedded; contains a few moderate-brown siltstone concretions and a few laminae of moderate-brown carbonaceous shale ---------- 130
4. Shale and sandstone, interbedded; shale is dark greenish gray, silty, slightly carbonaceous; sandstone is very light gray, very fine grained; unit is thin bedded ---------- 45
3. Sandstone and shale, interbedded; sandstone is very light gray, very fine to fine grained, locally calcareous and slabby, in beds as thick as 2 ft, crossbedded; shale is dark greenish gray, sandy, slightly carbonaceous ---------- 85
2. Sandstone, very light gray (weathering to grayish yellow), fine- to medium-grained, calcareous, alternating thick, medium, and thin beds, crossbedded; contains moderate-brown calcareous sandstone concretions as much as 4 ft long. 215 ft above the base is a lenticular bed 2 ft thick of moderate-brown carbonaceous siltstone. Forms rounded ridges and knolls ---------- 283

   USGS Mesozoic locality 22826; 30 ft above base of unit:

   Pinna sp.
   Inoceramus sp.
   Ethmocardium whitei Dall
   Gyrodes sp.
   Baculites sp.

Upper Cretaceous—Continued

Parkman sandstone—Continued — *Feet*

1. Sandstone and shale, interbedded, becoming more shaly near the base; sandstone is very light gray, fine grained, thin bedded, locally calcareous and slabby, crossbedded, contains a few moderate-brown sandstone concretions; shale is dark gray, locally slightly carbonaceous — 145

Total Parkman sandstone — 721

Contact between the Parkman sandstone and the Cody shale. The beds above this horizon are transitional between clay shale and sandstone. The contact is placed at the base of the lowest bed of sandstone.

Cody shale: Measured in secs. 13 and 14, T. 49 N., R. 83 W.

42. Clay shale, grayish-black; contains several beds of dark-gray septarian limestone concretions — 293

    USGS Mesozoic locality 22833; concretions 98 ft below top of unit:

    Inoceramus cf. *I. barabini* Morton

    Baculites aff. *B. haresi* Reeside

41. Shale, dark-gray; interlaminated light-gray siltstone and very light gray fine-grained sandstone near the base; bed 1 ft thick of grayish-green bentonite 78 ft from base; unit partly covered — 513

40. Shale, dark-gray to grayish-black; a few laminae and thin beds of light-gray fine-grained sandstone; at top of unit a bed about 3 in. thick of fine-grained sandstone that contains highly polished pebbles as much as 1 in. long of black, green, and gray chert; unit contains 4 or 5 beds of ellipsoidal dark-gray silty limestone concretions as much as 1 ft long, which weather dark reddish brown — 65

    USGS Mesozoic locality 22832 and 22824; from concretions:

    Nuculana sp.

    Geltena cf. G. *gracilis* (Meek and Hayden)

    Inoceramus barabini Morton

    Baculites haresi Reeside

39. Bentonite, pale-greenish-gray — 1½

38. Shale and sandstone, interbedded; shale is dark gray; sandstone is light gray, fine grained; unit contains 2 beds of ellipsoidal dark-gray silty limestone concretions that weather dark reddish brown — 12

37. Shale, dark-gray, sandy — 42

Total "upper shale member" of Cody shale (beds 42–37) — 927

36. Sandstone and shale, interbedded; sandstone is very light gray, weathering yellowish gray, fine to medium grained, a few grains of glauconite, slightly calcareous, very thin bedded, more sandstone near base of unit; shale is dark gray, sandy; unit contains several beds of moderate-yellowish-brown

	Feet
Upper Cretaceous—Continued	
Cody shale—Continued	
36. Sandstone and shale, interbedded—Continued calcareous sandstone concretions	76
USGS Mesozoic locality 22803; concretions in top 10 ft of unit:	
Perissonota sp.	
Pecten (Syncyclonema) halli Gabb	
Baculites haresi Reeside	
aquilaensis Reeside	
Placenticeras planum Hyatt	
35. Sandstone, pale-olive, very fine grained, abundant glauconite locally, many thin partings of dark-gray shale, slightly calcareous; top 15 ft is fine- to medium-grained sandstone that contains sparse glauconite; beds of widely spaced moderate-yellowish-brown calcareous sandstone concretions about 25 and 75 ft above base of unit; contact with the underlying unit is gradational	139
USGS Mesozoic locality 22823; sandstone concretions 75 ft above base of unit:	
Pteria linguaeformis (Evans and Shumard)	
Anomia n. sp.	
Lucina aff. *L. subundata* Hall and Meek	
Volutoderma? sp.	
Baculites haresi Reeside	
Total Shannon sandstone member of Cody shale (beds 36 and 35). (In part equivalent to Eagle sandstone)	215
34. Siltstone and shale, interlaminated; siltstone is very light gray; shale is dark gray; several beds of ellipsoidal rusty-weathering ironstone concretions that are as much as 6 in. long	126
USGS Mesozoic locality 23148; float about 75 ft below top of unit:	
Pecten (Syncyclonema) hallii Gabb	
Turitella n. sp.	
Eutrephoceras alcesense Reeside	
Baculites haresi Reeside	
Scaphites hippocrepis (DeKay)	
Placenticeras sp.	
33. Shale and siltstone, interbedded and interlaminated; shale is dark gray to grayish black; siltstone is light yellowish gray; crushed fossil fragments in the shale in upper half of unit	57
32. Clay shale, dark-gray to grayish-black; a few very thin stringers of light-yellowish-gray siltstone; contains 3 or 4 beds of ellipsoidal rusty-weathering ironstone concretions; at top of unit is a bed of dark-yellowish-brown calcareous siltstone concretions that weather moderate brown	28
31. Bentonite, grayish-yellow; contains small moderate-yellow cone-in-cone chips	1

Upper Cretaceous—Continued

Cody shale—Continued *Feet*

30. Shale, dark-gray to grayish-black; top half of unit contains many laminae of light-gray siltstone; 2 ft below top of unit is a bed of closely spaced dark-gray calcareous siltstone concretions as much as 2 ft long and 1 ft thick; 5 ft below top of unit is a bed of dark-gray white-weathering septerian limestone concretions ---------- 39
29. Shale, dark-gray, silty; about 15 ft, 25 ft, and 35 ft above the base of the unit are beds of dark-gray white-weathering limestone concretions from 6 to 18 in. across; at base of unit is a bed of closely spaced light-gray calcareous siltstone concretions about 6 in. thick and 2 ft long. A 1-ft grayish bentonite bed is present at top ---------- 52

    USGS Mesozoic locality 22830; concretions 35 ft above base of unit:
    - *Ostrea* sp.
    - *Cyprimeria* sp.
    - *Xylophagella*, sp.
    - *Oligoptycha?* n. sp.
    - *Baculites aquilaensis* Reeside
    - *Scaphites hippocrepis* (DeKay) cf. *S. aquilaensis* Reeside

    USGS Mesozoic locality 22828; concretions 25 ft above base of unit:
    - *Scaphites hippocrepis* (DeKay)
    - *Placenticeras meeki* Boehm
    - *Baculites aquilaesis* var. *separatus* Reeside

    USGS Mesozois locality 22829; concretions 15 ft above base of unit:
    - *Inoceramus* sp.
    - *Pteria* cf. *B. linguaeformis* (Evans and Shumard)
    - *Anomia* sp.
    - *Baculites haresi* Reeside
    - *aquilaensis* var. *obesus* Reeside

28. Shale, dark-gray, silty ---------- 48
27. Bentonite, yellowish-gray; contains dark-greenish-gray concretions about 12 in. across at widely spaced intervals ---------- 1
26. Shale and sandstone, interlaminated; shale is dark gray; sandstone is very light gray, fine grained; several beds of dark-gray septarian limestone concretions 1 to 6 in. across, which weather yellowish gray and contain fucoidal markings on their exterior surface; 5 ft below the top of the unit is a prominent bed of moderate-brown calcareous siltstone concretions which are as much as 10 ft in diameter ---------- 30

    USGS Mesozoic locality 22821; from limestone concretions:
    - *Baculites aquilaensis* Reeside
    - *haresi* Reeside
    - *Scaphites hippocrepis* (DeKay)

    USGS Mesozoic locality 22834; float from this unit:
    - *Fasciolaria* aff. *F. cheyennensis* (Meek and Hayden)

Upper Cretaceous—Continued

Cody shale—Continued — Feet

25. Shale and sandstone, interlaminated; shale is dark gray; sandstone is very light gray, fine grained; a bed of dark-gray septarian limestone concretions weathering light brown, about 30 ft above base — 123
24. Bentonite, yellowish-gray, 1 ft thick; underlain by a bed 6 in. thick of calcareous sandstone that forms a weak ledge — 1½
23. Sandstone and shale, interbedded and interlaminated; shale is dark gray; sandstone is very light gray, fine grained, occurs locally in lenses as much as 1½ ft thick, which contain tabular dark-gray limestone concretions weathering light brown — 565

    USGS Mesozoic locality 22822; from tabular limestone concretions 242 ft below top of unit:

    Nucula sp.
    Nuculana n. sp.
    Breviarca n. sp.
    Inoceramus sp.
    Ostrea sp.
    Geltena cf. *G. gracilis* (Meek and Hayden)
    Lucina aff. *L. subundata* (Hall and Meek)
    "*Corbula*" n. sp.
    Dentalium pauperculum (Meek and Hayden)
    Polinices sp.
    Actaeon? sp.
    Cylichna sp.
    Scaphites aquilaensis Reeside
      aquilaensis var. *nanus* Reeside
      aquilaensis var. *costatus* Reeside
      levis Reeside
      hippocrepis (DeKay)
      hippocrepis var. *crassus* Reeside
    Haresiceras placentiforme Reeside
      placentiforme var. *parvum* Reeside
    Baculites aquilaensis Reeside
      aquilaensis var. *separatus* Reeside
      aquilaensis var. *obesus* Reeside
      haresi Reeside
      asper Morton?

22. Shale, grayish-black, noncalcareous. Unit is poorly exposed — 40
21. Shale, dark-gray to grayish-black (weathering to light gray to brown), very calcareous. Unit is partly covered — 300
20. Shale, dark-gray to grayish-black, alternately calcareous and noncalcareous. Unit is poorly exposed — 190
19. Shale, dark-gray, very calcareous; a few stringers of bentonite less than 1 in. thick; contains a few poorly preserved *Inoceramus* and *Ostrea congesta*. Unit is partly covered — 182
18. Bentonite, very light gray — 1
17. Shale, grayish-black, noncalcareous. Unit is partly covered — 73
16. Shale, dark-gray, noncalcareous; a bed of medium-gray septarian limestone concretions at top of unit — 40

Upper Cretaceous—Continued

Cody shale—Continued — *Feet*

15. Mostly concealed. Appears to be mainly dark-gray shale; at top of unit is a prominent bed of dark-yellowish-orange septarian silty limestone concretions as much as 10 ft in diameter; beds of similar concretions crop out less prominently near the middle and at base of unit — 160

USGS Mesozoic localities 23151 and 22827; concretions at top of unit:

Serpula sp.
Inoceramus deformis Meek
aff. *I. erectus* Meek
n. sp.
Pholadomya papyracea Meek and Hayden
Cardium sp.
"*Tellina*" sp.
Parmicorbula n. sp.
Creonella? n. sp.
Polinices cf. *P. concinna* (Hall and Meek)
Gyrodes conradi Meek
aff. *G. depressa* Meek
Xenophora simpsoni Stanton
Turitella whitei Stanton
Hercorhynchus n. sp.
Bellifusus? n. sp.
Anchura? sp.
Actaeon? n. sp. aff. *A. propinquus* Stanton
Baculites mariasensis Cobban
Scaphites preventricosus Cobban

USGS Mesozoic locality 23152; concretions at base of unit:

Inoceramus n. sp.
Anchura? n. sp.

14. Mostly concealed. Appears to be mainly dark-gray silt shale; several beds of dark-gray septarian concretions (weathering to light gray) with veins of dark-orange calcite — 92

USGS Mesozoic locality 22816; concretions 58 ft from base of unit:

Inoceramus n. sp.
Baculites cf. *B. besairiei* Collignon
Prionocyclus n. sp.
Scaphites corvensis Cobban

USGS Mesozoic locality 22817; concretions in this unit at Dry Muddy Creek, NE¼ sec. 1, T. 48 N., R. 83 W.

Inoceramus n. sp.
Gyrodes depressa Meek
Aporrhais sp.
Eutrephoceras n. sp.
Scaphites corvensis Cobban
Baculites cf. *B. besairiei* Collignon
Prionocyclus n. sp.
Proplacenticeras pseudoplacenta (Hyatt)

13. Silt shale, dark-gray (weathering to dusky yellowish brown), noncalcareous; several beds of dark-gray ironstone concretions, weathering to rusty — 20

Upper Cretaceous—Continued
Cody shale—Continued *Feet*

12. Shale and sandstone, interbedded and interlaminated; shale is dark gray, noncalcareous; sandstone is white to light gray, fine grained, in lenticular beds as much as 1 in. thick; locally plate-shaped dark-gray limestone concretions occur in the sandstone beds; contact with the underlying unit is very sharp ---------- 44

USGS Mesozoic locality 22813; concretionary sandstone lens 27 ft above base of unit:
Inoceramus dimidius White
perplexus Whitfield
Polinices sp.
Scaphites whitfieldi Cobban
Prionocyclus wyomingensis Meek

11. Sandstone, light- to dark-gray (weathering to light gray), fine- to medium-grained, friable, calcareous; bottom part of unit contains many thin partings of dark-gray shale; 9 ft above base of unit is a bed of medium-gray sandy limestone concretions that weather light gray ---------- 41

USGS Mesozoic locality 22819; concretions 9 ft above base of unit:
Serpula sp.
Inoceramus labiatus (Schlotheim)
Ostrea sp.
Cerithium n. sp.
Mammites aff. *M. nodosoides* (Schlotheim) var. *spinosa* Basse
Watinoceras cf. *W. coloradoense* (Henderson)
Puzosia aff. *P. planulate* (Sowerby)

10. Shale and sandstone, interlaminated, bentonitic in bottom 3 ft; shale is dark gray; sandstone is light gray, fine grained; slightly calcareous ---------- 20

9. Bentonite ---------- 2

8. Shale, dark-gray (weathering to moderate yellowish brown), sandy slightly calcareous ---------- 11

7. Shale, dark-gray (weathering to dark bluish gray), calcareous, fossiliferous ---------- 61

USGS Mesozoic locality 22811; near base of unit:
Inoceramus labiatus (Schlotheim)
Borissjakoceras sp.

6. Silt shale, dark-gray noncalcareous; scattered dark-gray septarian limestone concretions near top of unit.

USGS Mesozoic locality 22815; concretions in this unit about 2 miles south of Dry Muddy Creek SE¼NE¼SW¼ sec. 12, T. 48 N., R. 83 W ---------- 22
Pteria sp.
Inoceramus aff. *I. fragilis* Hall and Meek
Scaphites delicatulus Warren
Sciponoceras gracile (Schumard)
Allocrioceras pariense (White)
Borissjakoceras cf. *B. reesidei* Morrow

Upper Cretaceous—Continued	
Cody shale—Continued	*Feet*
5. Mostly concealed. Appears to be mainly dark-gray noncalcareous shale	45
4. Mostly concealed. Appears to be mainly dark-gray shale; unit contains several beds of dark-gray septarian limestone concretions with veins of bright-yellow calcite; black chert pebbles weathering out from the top of the unit; 1-foot-thick bed of bentonite at top	51
USGS Mesozoic locality 22808 and 23149; limestone concretions in this unit:	
Pteria n. sp.	
Inoceramus cf. *I. fragilis* Hall and Meek	
Dentalium pauperculum Meek and Hayden	
Anchura? sp.	
Oligoptycha sp.	
Metoicoceras n. sp.	
Dunveganoceras cf. *D. conditum* Haas	
3. Bentonite, grayish-orange	1
2. Mostly concealed. About 5 ft of dark-gray silty shale exposed near middle of unit	27
1. Sandstone and shale, interbedded and interlaminated; shale is dark gray (weathering to grayish brown); sandstone is light gray to white, fine to medium grained, a few slabby calcareous sandstone beds as much as 1 in. thick, which contain coarse grains of black chert; a 3-inch-thick bed of sandstone at top of unit contains rounded and polished black chert granules and pebbles as much as 1½ in. long	36
Total Cody shale	3, 672. 0

The contact between the Frontier formation and the Cody shale is characterized by soft shales and sandstones above and by resistant conglomeratic sandstone directly below.

Frontier formation: Measured in sec. 1, T. 48 N., R. 83 W.	
26. Siltstone, tan and light-gray, calcareous, contains well-formed cone-in-cone structure and lenses 6 to 8 in. thick of friable coarse-grained light-gray sandstone that contain granules and pebbles of black chert as much as three-fourths of an inch long; forms weak ledge	2½
USGS Mesozoic localities 22809 and 23154:	
Inoceramus prefragilis Stephenson	
Gyrodes aff. *G. conradi* Meek	
Metoicoceras n. sp.	
cf. *M. praecox* Haas	
Mantelliceras cf. *M. canitaurinum* Haas	
25. Sandstone, light-gray to white, fine-grained, occurs in beds less than one-half inch thick, which are separated by partings and very thin beds of dark-gray shale; a few thin beds of siltstone with incipient cone-in-cone structure; weathers to yellowish-gray slopes	33

Upper Cretaceous—Continued

Frontier formation—Continued *Feet*

24. Shale with interlaminated sandstone; shale is dark gray; sandstone is light gray, fine grained, and occurs in lenticular beds as much as 1½ in. thick; beds of dark-gray septarian limestone concretions with septa of bright-yellow calcite occur 3 ft and 12 ft above base of unit; widely spaced dark-gray septarian silty limestone concretions that weather moderate brown occur 20 ft above base of unit ---------- 65

    USGS Mesozoic locality 22801; bed of sandstone 43 ft above base of unit:

    Acanthoceras? n. sp.

    USGS Mesozoic locality 22807; concretions 12 ft above base of unit:

    Acanthoceras? n. sp.

23. Bentonite, pale-olive-green ---------- 4
22. Sandstone and shale, interbedded and interlaminated; shale is dark gray; sandstone is light gray, fine grained ---------- 15
21. Shale, dark-gray; contains a few laminae of light-gray fine-grained sandstone ---------- 6
20. Sandstone and shale, interbedded and interlaminated; sandstone is light gray, fine grained; shale is dark gray; a bed of widely spaced dark-gray brown-weathering septariate limestone concretions as much as 10 ft in diameter at top of unit ---------- 39

    USGS Mesozoic locality 22804; concretions at top of unit:

    Nuculana sp.
    Inoceramus prefragilis Stephenson
    Ostrea sp.
    Psilomya n. sp. aff. *P. concentrica* (Stanton)
    Corbulamella n. sp.
    Dentalium pauperculum Meek and Hayden
    Polinices aff. *P. concinna* (Hall and Meek)
    Gyrodes aff. *G. conradi* Meek
    Borissjakoceras reesidei Morrow
    n. sp.
    Acanthoceras? amphibolum Morrow

    USGS Mesozoic locality 22806; 14 ft above base of unit:

    Ostrea sp.
    Acanthoceras? amphibolum Morrow

19. Shale and sandstone, interbedded and interlaminated; shale is dark gray; sandstone is very light gray, fine to medium grained, crossbedded, occurs mostly in beds less than 4 in. thick, a few lenticular beds as much as 8 in. thick; a bed of bentonite 6 in. thick 40 ft above base of unit ---------- 43
18. Sandstone, yellowish-gray (weathers to dark yellowish orange); contains sparse black chert granules and pebbles as much as one-fourth inch long in a medium-grained matrix, many red and green grains, crossbedded, calcareous; forms a ledge ---------- 1

	Feet
Upper Cretaceous—Continued	
Frontier formation—Continued	
17. Shale and sandstone, interbedded and interlaminated, predominantly sandstone in upper part and predominantly shale in lower part; shale is dark gray; sandstone is very light gray, fine to medium grained, crossbedded in beds and lenses as much as 4 in. thick	16
USGS Mesozoic locality 22805; 2 ft above base of unit: *Acanthoceras? amphibolum* Morrow	
16. Sandstone, very light gray (weathering to grayish orange), fine-grained, friable, noncalcareous; contains a few laminae of dark-gray shale	2
15. Silt shale and sandstone, interlaminated; shale is dark gray; sandstone is light gray, fine grained	15
14. Silt shale and siltstone, interlaminated, dark gray; 6-inch-thick lens of fine-grained light-gray sandstone in top 1 ft of unit	15
13. Sandstone and shale, interbedded and interlaminated; shale is dark gray to grayish black; sandstone is light gray to white, weathering light gray and light brown, very fine grained to silty, crossbedded, in lenticular beds that are mostly less than 1 in. thick; near top of unit are two or three lenticular beds of sandstone as much as 1 ft thick	142
12. Shale, dark-gray (weathering to dark yellowish brown), slightly silty	11
11 Shale, light-olive-gray, very silty, lower 2 ft bentonitic	5
10. Bentonite, light greenish gray in lower half and light olive gray in upper half; near base of unit is a light-brown layer 3 in. thick, which is present for at least 1 mile in either direction along the strike of the beds	5
9. Shaly siltstone, dark-yellowish-brown; contains dark-gray calcareous siltstone concretions that are 2 to 3 ft long and about 9 in. thick; at base of unit is a lenticular bed of brown-weathering sandstone 1 ft thick	12½
8. Shale, dark-gray, silty, flaky	1
7. Shale and siltstone, light-olive-gray, more silty in upper half of unit, bentonitic; contains manganiferous-stained plate-shaped limy siltstone concretions	6
6. Bentonite, pale-olive-gray	1
5. Siltstone, dark-gray to grayish-brown, bentonitic becoming more bentonitic toward top of unit, poorly consolidated; a few platy dark-gray calcareous siltstone concretions as much as 4 ft long	15
4. Shale, medium-dark-gray, bentonitic	4
3. Bentonite, light-olive-gray	2
2. Shale, dark-gray to grayish-black (weathering to dark yellowish brown), minor silty partings	13
1. Bentonite, pale-olive-green to gray; 2-foot-thick zone of light-gray bentonitic shale near middle of unit	6
Total Frontier formation	481.0

Contact between the Frontier formation and the Mowry shale. The base of the Frontier formation is placed arbitrarily at the base of a persistent bed of bentonite that occurs at approximately the change from dark gray-weathering silt shales above to light-gray-weathering siliceous shales below.

	Feet
Lower Cretaceous:	
Mowry shale: Measured in sec. 25, T. 49 N., R. 83 W.	
25. Siltstone and claystone, gray, slightly brittle, weathers rusty brown along joint surfaces	5½
24. Shale, gray to light-gray, siliceous, laminae and thin beds of fine-grained sandstone	27
23. Sandstone, tan to gray, fine-grained (weathering to light gray), contains laminae of siltstone and dark-gray shale	11
22. Shale, brownish-gray, silty becoming sandy in top 1 ft and grading into overlying unit	6
21. Bentonite and bentonitic shale; bentonite is dirty greenish yellow; shale is grayish brown	3½
20. Shale, gray, somewhat siliceous	12
19. Sandstone, gray (weathering to light gray), medium-grained, noncalcareous	2
18. Sandstone and siltstone, gray, thin-bedded; a few laminae of gray shale in the lower portion; the unit is capped by a bed of 1.3 ft thick of very light gray fine-grained sandstone	7
17. Shale, gray, siliceous, a few laminae of fine-grained gray sandstone	6
16. Shale with interlaminated fine-grained sandstone, gray, weathering brown, soft	21
15. Shale, light-gray, siliceous; contains abundant fish scales	22½
14. Bentonite, tan	½
13. Shale, gray, siliceous	5
12. Bentonite, greenish-yellow	3
11. Scale, light-gray, siliceous, brittle, contains abundant fish scales	216
USGS Mesozoic locality 23581; in the SW¼ sec. 25, T. 46 N., R. 83 W.: *Inoceramus* sp., *Metengonoceras* sp. *Neogastroplites wyomingensis* (Reeside and Weymouth)	
10. Shale, dark-gray (weathering to medium gray), slightly silty, brittle; a bed of bentonite 1.3 ft thick occurs 37 ft above base of unit; two beds of bentonite, less than one-half foot thick, occur in the basal 32 ft; at top of unit is a zone of cone-in-cone concretions that are as much as 4 ft long	62
9. Bentonite, pale-greenish-yellow, silty	1½
8. Shale, grayish-black; brownish-gray calcareous concretions at base of unit	8
7. Shale, grayish-black, plastic	10
6. Shale, grayish-black, a few sandy streaks	32
5. Bentonite, moderate-greenish-yellow	1½
4. Shale, grayish-black, bentonitic, soft	1½
3. Sandstone and shale; sandstone is gray, fine grained; shale is black	1½

Lower Cretaceous—Continued

Mowry shale—Continued	*Feet*
2. Shale, grayish-black, bentonitic; dark-brown silty concretions that contain a few poorly preserved *Inoceramus* impressions occur about 1 ft from the base of the unit	30
1. Sandstone and shale; sandstone is brownish black, weathering to light brownish gray; shale is brownish black; a bed 1 ft thick of steel-gray bentonitic shale 2 ft from top of unit	7
Total Mowry shale	503.0

Contact between the Mowry shale and the Newcastle sandstone. The Newcastle sandstone forms a broad white outcrop that contrasts both in color and lithology with the soft dark shale of the overlying Mowry shale. The contact is gradational within about 7 ft.

Newcastle sandstone: Measured in sec. 25, T. 49 N., R. 83 W.	
4. Sandstone, light-gray to light-tan, medium-grained, abundant black grains; the middle 6 ft is fine grained and poorly consolidated; the top 1 ft forms a weak ledge	22
3. Sandstone, light-tan to light-gray (weathering to rusty orange), medium-grained, abundant black and red accessory grains; forms a ledge	5
2. Sandstone, light-gray, medium-grained, abundant black and yellowish-green accessory grains, poorly cemented	4
1. Sandstone, light-tan to light-gray, fine-grained, very shaly, poorly cemented	11
Total Newcastle sandstone	42

Contact between the Newcastle sandstone and the Skull Creek shale. The contact is placed at the base of a zone about 10 ft thick, which is gradational between the medium-grained sandstone of the Newcastle and underlying black clay shale.

Skull Creek shale: Measured in sec. 25, T. 49 N., R. 83 W.	
5. Clay shale, grayish-black, flaky, soft	64
4. Shale, grayish-black; and interlaminated light-gray siltstone; unit becomes more silty towards base	15
3. Siltstone, tan to light-gray, calcareous, thin-bedded, contains a few plant fragments: forms a weak ledge	2.5
2. Clay shale and silt shale, olive-gray to dark-gray, noncalcareous; a few laminae of light-gray to tan siltstone; two beds of siltstone—one 8 in. thick 56 ft above base of unit, and the other 2 ft thick 40 ft above base of unit—locally form weak ledges	61
1. Concealed. Zones of iron-stained siltstone concretions 5 and 10 ft above base of unit	22
Total Skull Creek shale	164.5

The contact between the Cloverly formation and the Skull Creek shale is characterized by grayish-black shales that form a slope above and shales that contain siltstone laminae and that are more resistant below.

	Feet
Lower Cretaceous—Continued	
Cloverly formation: Measured in sec. 25, T. 49 N., R. 83 W.	
14. Siltstone, brownish-gray, calcareous, thin-bedded, slabby	5½
13. Shale and siltstone interbedded in beds 4 to 6 in. thick; dark gray and light gray, weathering from drab tan to brown; contains abundant dahllite concretions	23
12. Shale, dark-gray; top 8 ft is clay shale and remainder is silt shale; at 12 and 17 ft above the base are zones of iron-stained siltstone concretions 6 in. thick	32
11. Clay shale, grayish olive in upper half, dark gray in lower half; unit capped by a bed of pebbly ferruginous sandstone 2 in. thick	12
10. Shale, grayish-black (weathering to drab brown), noncalcareous; at top and near middle of unit are beds 2 ft thick of thin-bedded brown calcareous siltstone; a few 4- to 6-in. beds of siltstone in upper part of unit	31
9. Sandstone, brownish-black, conglomeratic, a few pebbles as much as one-fourth inch long	½
8. Shale, olive-gray (weathering to ochre), plastic	6½
7. Shale, brownish-black, silty, carbonaceous	2
6. Shale, light-yellowish-gray, silty	5
5. Sandstone, light-yellowish-gray; medium grained with subrounded grains, well sorted; unit is lenticular	2
4. Clay shale, brownish-black, carbonaceous	9
3. Mostly concealed. Appears to be mainly gray silty sandstone	17
2. Sandstone, very light gray, fine-grained, calcareous, clean, thin-bedded, crossbedded	8
1. Sandstone, light-yellowish-gray (weathering from light yellowish brown to white); composed almost entirely of medium to coarse grains of quartz, fairly well sorted, crossbedded. This and the overlying unit support a growth of cedars and scrubby pines and form a prominent and persistent ridge that can be traced for several miles in either direction along the strike of the beds in this vicinity	3
Total Cloverly formation	156.5

Contact between the Cloverly formation and the Morrison formation. Beds above the contact in the lower part of the Cloverly formation are predominately sandstone; beds below the contact are varicolored claystones.

Jurassic:	
Morrison formation: Measured in secs. 35 and 36, T. 49 N., R. 83 W.	
25. Claystone, grading upwards from brownish black to light gray in upper 1 ft, soft	5.8
24. Claystone, gray, silty	2.3
23. Shale and claystone, brownish-black; may be carbonaceous; bentonitic 2-ft zone 3 ft above base	29.0
22. Claystone, grayish red in lower half and pale olive green in upper half; a 5-ft bentonitic zone 22 ft above base, grades into overlying unit	39.2
21. Sandstone, light-yellowish-gray, fine-grained, calcareous; accessory grains minor; forms a weak ledge	.5

Jurassic—Continued	
Morrison formation—Continued	*Feet*
20. Claystone, alternating grayish red and pale olive, soft	5.1
19. Sandstone, light-yellowish-gray (weathering to brown), very fine grained, crossbedded to slabby	7.0
18. Claystone, dark-greenish-gray, silty, calcareous, soft	3.1
17. Sandstone, light-yellowish-gray (weathering to brown); fine grained containing sparse red and green minerals	.7
16. Claystone, dark-greenish-gray, silty, calcareous, soft	3.1
15. Sandstone, yellowish-gray, fine-grained, soft, lenticular	1.9
14. Siltstone, yellowish-gray, sandy, calcareous, soft	2.1
13. Sandstone, yellowish-gray (weathering to brown), very fine grained thin-bedded to massive, calcareous, lenticular	.7
12. Claystone, dark-greenish-gray to pale-olive, silty in part, calcareous, soft; contains a 6-in. argillaceous limestone about 10 ft above base. Chara fructifications and ostracodes are abundant in the limestone	27.1
11. Siltstone and sandstone, dark-greenish-gray (weathering to yellow gray), very thin bedded, calcareous, soft	10.6
10. Siltstone, dark-reddish-brown, clayey, calcareous	4.0
9. Sandstone, yellowish-gray, very fine grained, silty, calcareous, thin-bedded, soft	1.8
8. Claystone, dusky-red, silty, calcareous, soft	5.6
7. Siltstone, dusky-red (weathering to brick red); fractures into small cuboidal fragments, calcareous	3.0
6. Claystone, dark-greenish-gray, calcareous, soft	1.2
5. Sandstone, yellowish-gray, fine-grained, thin-bedded; forms a ragged ledge, lenticular	2.0
4. Claystone, dark-greenish-gray, silty in middle 1 ft, calcareous	5.2
3. Sandstone, yellowish-gray, fine-grained, calcareous, lenticular	.9
2. Claystone, dusky-yellow-green, silty, calcareous, soft	2.9
1. Sandstone, yellowish-gray, fine grained, crossbedded, calcareous; this unit is lenticular and ranges from a featheredge to over 6 ft in thickness; channels through underlying Sundance beds	2.0
Total Morrison formation	184.7
Contact between the Morrison formation and the Sundance formation. Beds above the contact are predominantly sandstone; beds below the contact are thin glauconitic shaly sandstones and marine shales.	
Sundance formation: Measured in sec. 2, T. 48 N., R. 83 W.	
24. Sandstone, brown, medium- to fine-grained; resistant to weathering. This unit is completely removed a few feet along outcrop and replaced by the basal lenticular sandstone of the Morrison formation	.8
23. Sandstone, tan, fine-grained, shaly, soft	3.4
22. Sandstone, brown to red, fine-grained, calcareous, shaly, soft	3.4
21. Sandstone, weathers brown, medium- to fine-grained, glauconitic, calcareous, 6-in. olive-gray shale 8 ft from top	5.6
20. Shale, olive-gray, silty, calcareous; 3 ft from top is a 6-in. ledge of oyster coquina	47.3
19. Sandstone, gray (weathering to tan), fine-grained, slabby, very calcareous; forms a ledge	1.4

Jurassic—Continued

Sundance formation—Continued

	Feet
18. Shale, olive-gray, silty, calcareous, a few thin sandy zones throughout. *Pachyteuthis densus* are abundant in lower 20 ft	113.8
17. Oolitic limestone, yellowish-gray (weathering to brown), sparsely fossiliferous, lenticular; absent 300 ft north	2.3
16. Sandstone, yellowish-gray, fine-grained, well-sorted, calcareous; contains red and green accessory grains; regular to crossbedded; forms topmost prominent cliff in lower Sundance formation	16.5
15. Sandstone, yellowish-tan, fine-grained, calcareous, poorly indurated; contains red and green accessory minerals	25.1
14. Shale, grayish-olive, silty, calcareous, soft	1.6
13. Sandstone, tan, very fine grained, silty, calcareous	11.5
12. Sandstone and shale; tan sandstone is fine grained and silty and unit appears to grade upward into unit 14	2.4
11. Shale, grayish-olive, calcareous, soft	5.6
10. Sandstone, light-tan, fine-grained, silty, crossbedded, calcareous	1.3
9. Shale, grayish-olive, calcareous, soft	.9
8. Sandstone, light-tan, very fine grained, silty, calcareous, soft	.9
7. Shale, grayish-olive, calcareous, with a 6-in. sandstone ledge 3 ft above base	13.8
6. Sandstone, pale-olive, very fine grained, shaly, calcareous, soft	5.5
5. Sandstone, light-gray to light-tan, fine-grained, well-sized; in thin regular beds from 2 to 8 in. thick; very calcareous, somewhat friable; minor red accessory minerals	12.0
4. Sandstone, light-tan, fine-grained, crossbedded, calcareous, glauconitic?	5.0
3. Shale, greenish-gray, sandy, calcareous, soft	3.0
2. Sandstone, light-tan, very fine grained, shaly, soft	1.7
1. Sandstone, light-tan, fine-grained, crossbedded, calcareous; rounded chert pebbles as much as 1.5 in. long in the upper 6 in.; contains *Isocrinus* sp	2.6
Total Sundance formation	287.4

Contact between the Sundance formation and the Gypsum Spring formation. Beds above the contact are conglomertic sandstones; beds below are argillaceous light-colored limestones and reddish-colored claystones.

Gypsum Spring formation: Measured in sec. 11, T. 48 N., R. 83 W.

13. Limestone, light-greenish-gray, argillaceous, soft	1.0
12. Claystone, grading upwards from dark reddish brown to light greenish yellow in top 6 in.; calcareous, soft	3.4
11. Limestone, light-tan to light-gray, argillaceous, irregularly bedded in lower half and concretionary in upper half; forms a minor ledge	2.0
10. Claystone, dark-reddish-brown with pale-yellowish-green bands and laminae in lower 5 ft; silty, calcareous	15.6
9. Siltstone and limestone, interbedded in about 7.3 ratio, moderate reddish brown and light gray, weathers to a rounded ochre-colored ledge	4.5

Jurassic—Continued	
Gypsum Spring formation—Continued	*Feet*
8. Limestone, light-gray, argillaceous; contains a parting 4 to 6 in. thick of pale-green claystone near middle; forms a ledge	3.0
7. Claystone, grading upwards from dark to moderate reddish brown mottled ochre to pale greenish yellow in top 8 in.; silty, calcareous, soft	7.1
6. Limestone, pale-greenish-yellow, argillaceous; forms a minor ledge	.6
5. Claystone, pale-greenish-yellow, calcareous, soft	1.0
4. Claystone, grading upwards from dark to moderate reddish brown to grayish red in top 8 ft; silty, slightly calcareous, soft	35.2
3. Limestone breccia, light-brown, porous, contains angular red fragments of claystone and a few thin beds of light-brown siltstone	15.6
2. Siltstone, light-brown, sandy, soft	12.0
1. Gypsum, white, weathering to gray	5.0
Total Gypsum Spring formation	106.0

The contact between the Chugwater formation and the Gypsum Spring formation is characterized by salmon-pink sandstones below and gypsum, limestone breccia, or fine-grained siltstone above.

Triassic:	
Chugwater formation: Measured in secs. 34 and 35, T. 49 N., R. 83 W.	
4. Sandstone, light-brown, weathering to salmon-pink, the top 1 ft banded pink and red, very fine grained, calcareous, crossbedded, massive; contains irregularly shaped lenses and pods of gypsum that are probably secondary	24.0
3. Sandstone, light-brown (weathering to salmon pink), very fine grained, silty, slightly calcareous, crossbedded, massive	27.6
2. Limestone, light-gray, dolomitic, thin-bedded, slabby, dense, resistant, lenticular; contains laminae of purple clay along bedding surfaces	0–5
1. Interbedded moderate reddish-brown siltstone, shale and silty fine-grained sandstone; weathers to slopes	700–750
Total Chugwater formation	750–870

Contact between the Permian red shale and gypsum sequence and the Chugwater formation. Beds above the contact are silty shales, siltstones, and shaly sandstones; beds below the contact are predominantly gypsiferous.

Permian:	
Red shale and gypsum sequence: Measured in sec. 35, T. 48 N., R. 83 W.	
20. Limestone, pink, porous, soft, brecciated, not continuous along outcrop	5.2
19. Gypsum, white with 2-ft bed of red siltstone in the middle	10.6
18. Partly covered, probably gypsiferous siltstone with a few beds of gypsum	29.7
17. Gypsum, white to pink, soft, with a few thin layers of silt	15.9

Permian—Continued	
Red shale and gypsum sequence—Continued	*Feet*
16. Siltstone, moderate-reddish-brown, gypsiferous, soft	15.9
15. Gypsum, white with pink laminae	1.0
14. Shale, grading upwards from moderate reddish brown to grayish red in the upper half. There are two thin pale-green chert nodule zones in the middle about 1 to 1.5 in. thick	3.9
13. Gypsum, white, soft, three 1-ft partings of moderate-reddish-brown silt in the upper half. The gypsum generally modified by red and gray laminae along bedding. Outcrop appears affected by slumping	40.0
12. Siltstone and gypsum; siltstone, moderate-reddish-brown, soft; gypsum, white, soft	2.0
11. Gypsum, white, soft	1.5
10. Partly covered, potholes indicate reddish gypsiferous siltstone	9.0
9. Gypsum, white with some minor red mottling	7.2
8. Partly covered, potholes indicate reddish gypsiferous siltstone	8.1
7. Limestone, yellowish-gray, porous, soft	1.9
6. Dolomite, light-tan, calcareous, thin-bedded, and modified by many darker laminae parallel to bedding	2.2
5. Limestone, yellowish-gray, soft, porous, thin-bedded	1.0
4. Siltstone, moderate reddish-brown, soft, platy to massive	37.0
3. Limestone, yellowish-gray, dolomitic, argillaceous and silty, beds thin and undulating and modified by closely spaced dark laminae; in the middle is 1.5 ft of thin-bedded calcareous grayish-red siltstone	7.9
2. Claystone, dark- to moderate-reddish-brown, slightly calcerous, soft	49.1
1. Claystone, pale-olive-green, silty, slightly calcareous, soft	1.8
Total Permian red shale and gypsum sequence	250.9
Contact between the Tensleep sandstone and the Permian red shale and gypsum sequence. Contact is sharp between the light-colored sandstone of the Tensleep and the dark-reddish-brown shale of the Permian red shale and gypsum sequence.	
Carboniferous:	
Tensleep sandstone: Measured in sec. 27, T. 49 N., R. 83 W.	
27. Sandstone, salmon-pink to very light tan, fine- to medium-grained, crossbedded	88.0
26. Covered	5.0
25. Sandstone, same as underlying unit but forms a separate cliff	33.0
24. Sandstone with same lithology as unit 23 but stands out as a separate cliff	43.0
23. Sandstone, salmon-pink, fine-grained, crossbedded, a prominent cliff former; at top is a zone containing poor molds of crinoid stems	46.5
22. Sandstone, tan to salmon-pink, fine-grained; in ledges 10 to 14 in. thick	22.4
21. Covered, possibly same as the underlying unit 20	4.5
20. Sandstone, gray to red, fine-grained; lower 3 ft massive, remainder thin bedded	10.1

	Feet
Carboniferous—Continued	
Tensleep sandstone—Continued	
19. Covered, probably sandstone as indicated by 6-in. exposure at base and at top	4.5
18. Siltstone, grayish-red to buff, sandy soft	1.2
17. Sandstone, pink, white and tan, in 4- to 8-in. beds; in ledges; has some thin silt zones; sandstone is very clean	4.5
16. Sandstone, salmon-pink (weathering to light reddish brown), fine-grained, massive	3.0
15. Sandstone, reddish-tan to pink, crossbedded in the upper half, massive below	13.5
14. Sandstone, light-gray (weathering from tan to gray), fine-grained, massive, forms a rounded ledge	12.0
13. Dolomite, light-tan and gray, limy, argillaceous; at top is an irregular lens of chert-bearing foraminifers	2.6
12. Sandstone, very light tan (weathering to gray), fine-grained, clean, massive, somewhat crossbedded; contains a zone of siliceous nodules 4 ft from top	8.4
11. Dolomite, pinkish-gray; contains irregular sparkly salmon-pink fine-grained sandstone lenses	3.6
10. Limestone, gray (weathering to light gray), silty, massive	1.6
9. Sandstone, tan (weathering to gray), fine-grained, calcareous, massive	5.9
8. Dolomite, tan, limy; appears to vary in thickness	.8
7. Sandstone, light-gray, fine-grained, massive, clean; top appears to be channeled	3.8
6. Dolomite, pink, limy; contact with overlying unit is wavy	2.0
5. Sandstone, light-gray (weathering to gray), fine-grained, massive; a 5-ft more resistant zone caps the unit	15.0
4. Dolomite, light-pink, limy, sandy	1.1
3. Sandstone, light-gray, fine-grained	6.4
2. Dolomite, light-pinkish-gray	4.3
1. Sandstone, light-gray, fine-grained, calcareous; massive in beds about 2.5 ft thick; forms minor ledge	8.6
Total Tensleep sandstone	355.3
Contact between the Amsden formation and the Tensleep sandstone. The contact is based on the presence of sandstone in the basal portion of the Tensleep sandstone and dolomites and chert in the upper part of the Amsden formation.	
Amsden formation: Measured in sec. 27, T. 49 N., R. 83 W.	
14. Dolomite, very light gray, argillaceous	2.8
13. Dolomite, pinkish-tan (weathering from red to tan); forms a minor ledge; silica lenses and nodules are parallel to bedding	7.8
12. Dolomite, weathers very light tan, limy, fractures irregularly	8.2
11. Dolomite, tan, calcareous; in three resistant ledges: lower ledge weathers to a pockety surface, modified by many closely spaced fractures and contains a network of chert; middle ledge is massive; at base of upper ledge is 3 ft of grayish-red silty claystone overlain by 1.5 ft of pinkish-gray dolomite. The remainder of the upper ledge is massive with top 1 to 2 ft a hackly light-gray chert	41.5

Carboniferous—Continued	
Amsden formation—Continued	*Feet*
10. Covered, lower portion probably contains redbeds, with a few limestone, dolomite, and sandstone ledges	57.0
9. Breccia, weathers gray; dolomite and silica fragments in a dolomitic matrix	3.4
8. Dolomite, tan, slightly argillaceous, resistant; at top is a disconformity	4.0
7. Limestone, brown to reddish-tan, dolomitic; contains abundant irregularly shaped inclusions of silica	6.0
6. Covered	11.0
5. Claystone, moderate-reddish-brown, silty with irregular light-colored fine-grained sandstone stringers	9.5
4. Covered, closely spaced "potholes" indicate a soft fine-grained reddish-brown sandstone in part yellowish-gray	85.5
3. Dolomite, light-tan, argillaceous, calcareous; has many pink to buff zones; fractured irregularly	9.0
2. Limestone, tan (weathering to gray), dense to crystalline; forms a minor ledge	1.6
1. Sandstone, reddish-tan (weathering to brown), fine-grained, calcareous, lenticular and contorted; contains limestone fragments near the base as much as 6 in. long	2.3
Total Amsden formation	247.6
Contact between the Madison limestone and the Amsden formation. Beds above the contact are in part red and sandy. Beds below the contact are gray limestones and limy dolomites.	
Madison limestone: Measured in sec. 28, T. 49 N., R. 83 W.	
21. Limestone tan (weathering to gray), beds 2 to 4 ft thick	9.6
20. Limestone, light-tan, thin-bedded, less resistant than adjacent units; contains flat chert inclusions along bedding; disconformity at top	3.5
19. Limestone, light-tan to white (weathering to tan), massive; erosional unconformity at top	48.6
18. Limestone breccia weathers to an irregular surface, perhaps caused by solution	27.4
17. Breccia, weathers to a rusty tan; dolomite, fragments in a dolomite matrix; disconformity at top	7.0
16. Dolomite, light-gray, containing secondary calcite inclusions	6.0
15. Limestone breccia, weathering from pink to white	4.0
14. Dolomite-limestone, light-tan (weathering to a brownish tan), thin and irregularly bedded, slightly limy at the base becoming limestone at the top	43.0
13. Dolomite, light-tan (weathering to a brownish tan), massive; resistant forming a prominent cliff; modified by many closely spaced fractures at a high angle to bedding	61.4
12. Covered	28.0
11. Limestone, yellowish-gray (weathering to gray), dolomitic, resistant, massive; contains a few thin zones of chert along bedding	31.5
10. Limestone, yellowish-gray; lower part massive, remainder thin- to medium-bedded with a 2-ft zone of clastic? cross-bedded limestone about 20 ft from top	76.0

Carboniferous—Continued	
Madison limestone—Continued	*Feet*
9. Limestone, gray with a reddish tint in places, oolitic, resistant, abundantly fossiliferous	5.6
Unit contains:	
Schuchertella? sp.	
Camarotoechia? sp.	
Spirifer centronatus Winchell	
Punctospirifer sp.	
Composita cf. *C. humilis*	
8. Limestone, gray (weathering tan), dense, massive, resistant; contains a 3-in. zone of reworked dolomite in a limestone matrix at the base; erosional unconformity at base	2.2
7. Dolomite, light-gray (weathering light tan), limy, argillaceous, dense; resistant in places; has thin closely spaced bedding laminae of grayish-red material. Contains *Spirifer centronatus* Winchell	3.0
6. Covered, probably a thin-bedded limestone or dolomite	26.8
5. Dolomite, tan to light-tan, limy; massive in the lower one-fourth and upper half, the remainder thin bedded	88.7
4. Covered, probably similar to unit 35 but is thin bedded and softer	12.0
3. Limestone, light-gray with grayish-red mottling, weathering from tan to pink, dolomitic, resistant	9.2
2. Limestone, greenish-gray, resistant, dense; in beds from 2 in. to 1 ft thick	5.9
1. Dolomite, tan, massive, dense	3.6
Total Madison limestone	540.5
Contact between the Bighorn dolomite and the Madison limestone. Beds above the contact are predominantly limestone and bear a Mississippian fauna. Beds below the contact are massive dense dolomite.	
Ordovician:	
Bighorn dolomite: Measured in sec. 28, T. 49 N., R. 83 W.	
15. Dolomite, white to very light gray, argillaceous, slabby; contains abundant ostracodes on bedding surfaces	40.0
Float from this unit contained:	
Rhinidictya sp.	
Streptelasma sp.	
Tropidodiscus sp.	
Raphistoma sp.	
Isotelus sp.	
Odontopleura ap.	
Bythocypris cf. *B. cylindrica* (Hall) *Beyrichia* sp.	
Laccoprimitia sp.	
Chevroleperditia sp.	
14. Dolomite, tan, massive, crystalline; contains irregular chert nodules along the bedding; somewhat less resistant than unit 12	57.0
Unit contains:	
Streptelasma sp.	
Calapoecia sp.	
Halysites sp.	
Paleofavosites sp.	

	Feet
Ordovician—Continued	
Bighorn dolomite—Continued	
13. Covered	2.0
12. Dolomite, light-tan; in the lower 10 ft there are irregular streaks that are rust colored and contain a dark mineral, the remainder seems to be a mixture of porous and very dense dolomite that may account for its pitted appearance; there are scattered irregular inclusions of chert. The entire unit is somewhat fossiliferous, but the fossils are difficult to get out	188.0
The basal 7 ft contains *Lepidocyclus* cf. *L. perlamellosa* (*Rhynchotrema* of authors).	
11. Transition zone—dolomitic sandstone in lower half and sandy dolomite in upper half, light tan, abundant dark grains; seems to be made up of thin undulating lenses; very faint traces of brachiopods and solitary tetracorals	3.9
Contact between the basal sandstone of the Bighorn dolomite and the dolomitic facies. Included in the dolomitic facies is a 3.9-ft transition zone of sandy dolomite. Beds above the contact are predominantly dolomite.	
10. Sandstone, light-gray with dark-maroon mottling	3.5
The upper 2 to 4 in. is a mildly undulatory bedded ferruginous zone containing *Receptaculities*, Orthocerid(?) cephalopods? and *Maclurites* sp. An equivalent zone at Rock Creek 12 miles north of the mapped area contained:	
Receptaculites oweni Hall	
Maclurites manitobensis Whiteaves	
Endoceras landerense Foerste	
9. Sandstone, silty greenish-gray, soft	.6
8. Sandstone, very light reddish gray (weathering to brick red), medium- to coarse-grained; numerous red grains; massive; contains many "bone" fragments	12.2
7. Covered	5.0
6. Sandstone, light-tan with streaks of dark gray, medium-grained	4.6
5. Sandstone, very light gray, very fine grained, very soft	1.8
4. Shale, very light gray, soft, containing one thin band of reddish-gray shale	2.0
3. Sandstone, very light gray (weathering to light tan), fine- to medium-grained, friable, massive, modified by a few inconspicuous bedding surfaces. The whole unit is marked by discontinuous grayish-red laminae spaced irregularly about one-eighth to one-fourth inch apart. In the lower 5 ft are pinkish lenses arranged at right angles to the bedding, crossbedded in part	33
2. Sandstone, alternating pale-greenish-gray and pale red, fine-grained, thin-bedded	.6
1. Sandstone, pale-pinkish-gray, very fine grained, calcareous, somewhat soft	.8
Total Bighorn dolomite	355.0

Contact between the Gallatin limestone and Gros Ventre formation, undivided and the basal sandstone of the Bighorn dolomite is sharp.

	Feet
Cambrian:	
Gallatin limestone and Gros Ventre formation, undivided: Measured in secs. 8 and 9, T. 47 N., R. 83 W.	
8. Limestone, pinkish-gray (weathering to salmon pink) silty, thin-bedded; contorted in part; conglomeratic (flat-pebble type); contains grayish-red silt laminae along bedding; fucoids present throughout	48.0
7. Covered. Lithology in this zone to the north is very similar to the underlying unit	306.0
A well-exposed section along U. S. Highway 16 at a point 5½ miles north of the mapped area contained the following: *Dikelocephalus* sp.; *Illaenurus* cf. *I. calvini* Walter; *Corbinia* sp.; *Koldinioidea?* sp.; *Dendrograptus hallianus* (Prout) (?); *edwardsi* Ruedemann?; sp.	
6. Siltstone, silt shale, limy sandstone; grayish green, very slabby; sandstone is light tan, fine to medium grained and glauconitic, inarticulate brachiopods and poorly preserved trilobites throughout, unit forms a slope	61.0
5. Sandstone, dusky red with streaks of olive green, medium-grained, crossbedded; beds range from 6 in. to 4 ft, glauconitic and hematitic; contact with overlying unit is sharp	18.0
4. Sandstone, dusky-yellow-green, medium-grained, very glauconitic, a few shale laminae, friable	43.0
3. Sandstone: shale in about a 2:3 ratio; sandstone is yellowish gray weathering to brown, medium grained, thin bedded and glauconitic; shale is grayish green, silty, glauconitic, poorly preserved trilobite fragments in the lower 2 ft	54.1
Contains: *Arapahoia convexa* Lochman; *nichartensis* Lochman; *aspinosa* Lochman; *Cedaria nixonia* Lochman; *Dicellomus occidentalis* Bell; *Tricrepicephalus* sp.; *Uncaspis* sp.	
2. Sandstone, green, medium- to course-grained, glauconitic, friable, appearance very similar to gunpowder, many grayish-green silt shale laminae and a thin bed of olive-gray plastic clay near top, the upper 5 ft becomes shaly and slabby Contains *Bolaspidella* sp., *Syspacheilus* cf. S. *dunoirensis* (Miller)	13.6
1. Sandstone, dark-greenish-brown (weathers to a reddish brown) in beds up to 1.5 ft, crossbedded, very glauconitic, very poorly preserved trilobites	7.3
Total Gallatin limestone and Gros Ventre formation, undivided	551.0

Cambrian—Continued

Contact between the Flathead sandstone and the Gallatin limestone and Gros Ventre formation, undivided, is characterized by nonglauconitic resistant sandstone below and glauconitic friable sandstone above.

Flathead sandstone: Measured in section 28, T. 49 N., R. 83 W.

	Feet
7. Sandstone, gray in the lower half and top 10 ft, the remainder reddish gray; in other places this unit is light tan, medium grained, well rounded and spherical, friable. In the upper 6 in. are abundant inarticulate brachiopods. "*Elrathia*" sp. was collected from this zone 12 miles north of the mapped area	23.5
6. Sandstone, predominantly tan but unit has a few buff and red beds, medium to coarse grained, some massive beds as much as 6 ft thick	42.5
5. Sandstone, buff, medium- to coarse-grained; grains are well rounded and spherical; beds are about 1 to 2 ft thick, unit forms a slope. In the upper 20 ft are several 2-in. ferruginous zones parallel to the bedding	48.5
4. Mostly covered, probably similar to unit 3	28.0
3. Sandstone, tan (weathering to reddish tan), medium- to coarse-grained, soft, clean; upper 30 ft partly covered	58.0
2. Sandstone, reddish-brown, medium to coarse-grained, crossbedded, friable	11.5
1. Partly covered, small holes indicate a brownish-red sandstone, medium- to coarse-grained, crossbedded and soft. In other places the basal 10 to 15 ft are conglomeratic with rounded quartz pebbles as much as one-half inch in diameter	45
Total Flathead sandstone	258.0

Contact between the pre-Cambrian and Cambrian Flathead sandstone. Contact is sharp, and the surface upon which the Flathead sandstone lies is flat.

Foliated pre-Cambrian granite.

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